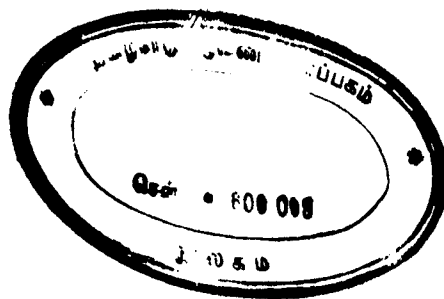


Public Works, Roads and Transport
Congress and Exhibition,
1933. (74)

FINAL REPORT.

*(Reported by Thomas Hill & Co.,
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*The Congress Organising Committee do not accept any responsibility for the
views expressed either in the Papers submitted to the Congress
or in the course of the discussions thereon.)*



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PUBLIC WORKS, ROADS AND TRANSPORT CONGRESS AND EXHIBITION, 1933.

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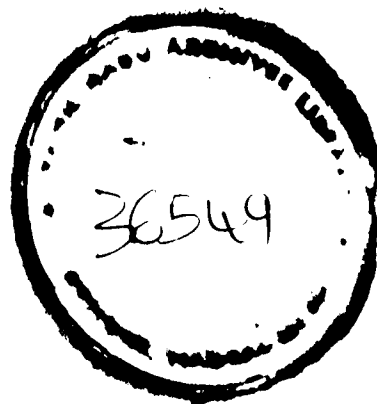
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INTRODUCTION.

HAVING regard to the increasing responsibilities of local authorities, and the large sum which is annually expended on services under their control (amounting in 1930-31 to £322,943,730 including loan charges) it is obviously of the highest importance that members and officials of local government bodies should be given opportunities for furthering their knowledge of the problems with which they have to deal, and also that the general public should be educated to a fuller appreciation of the many services which contribute so much to their well-being, and for which they are called upon to pay.

One of the most valuable factors in securing increased efficiency and economy in local administration is the Public Works, Roads and Transport Congress and Exhibition, which is organised by a Joint Committee representing the principal associations of local authorities and their officers, and is held in London in November in alternate years. The Organising Committee seeks to attain the above objects:—

- (a) By devoting such funds as may be forthcoming to furthering the existing facilities for students (including post graduate) to obtain the best scientific training ;
- (b) By providing suitable opportunities for members and officials to meet together at reasonable intervals to discuss difficult problems and recent developments, and to obtain from each other information as to methods which have proved effective in their respective areas ;
- (c) By providing an opportunity for members and officials to inspect the latest types of materials and machinery manufactured and designed to meet the special requirements of the local authorities ; and
- (d) By bringing to the notice of the general public (as it is suggested can best be done by Congresses and Exhibitions of this character) the work which is being carried out on their behalf.

PAPERS.

The Papers presented for discussion at the sessions of the 1933 Congress were more numerous and generally of an even higher standard of usefulness than on previous occasions, many of them embodying the results of research work of incalculable value.

These Papers were circulated beforehand and taken as read at the meetings. They are reprinted in full in the following pages, together with a report of the discussions. (Remarks of a formal character have been omitted).

BRITISH BRIDGES.

An interesting feature of the 1933 Congress was an exhibition of photographs of 443 British bridges. As a companion to, and a permanent record of, this display,

the Congress Committee published a book containing particulars of all the bridges included in the exhibition, and reproductions of more than 300 of the photographs. The book, which is entitled "British Bridges" and is published at a price of 10s. 6d, forms a brief survey of the most notable structures, ancient and modern, now existing in Great Britain, having regard not only to their importance in the general scheme of road communications but also to their aesthetic value, historic interest, and the different types of construction they represent.

EXHIBITION.

The figures relating to the Exhibition are gratifying as indicating the importance to which those who transact business with local authorities attach to this means of contact with their clients. Some 230 firms acquired 92,554 square feet of space for the purpose of displaying the latest and most ingenious forms and types of materials, plant and machinery designed to meet the special needs of the public services. Exclusive of exhibitors and members of their staffs, nearly 22,000 persons visited the Exhibition.

The following figures as to appointments of delegates indicate the wide interest taken in the 1933 Congress and Exhibition:

	NUMBER OF AUTHORITIES.	OFFICIAL DELEGATES.
County Councils (England and Wales)	51	88
Metropolitan Boroughs	21	36
County Boroughs and Boroughs (England and Wales)	177	330
Urban District Councils	189	275
Rural District Councils	112	158
County Councils (Scotland)	16	22
Scottish Burghs	14	29
Irish Authorities	16	23
	596	961
Miscellaneous Delegates		24
	596	985

In addition, representatives of His Majesty's Overseas Dominions and of several foreign countries were present, while bodies such as the British Waterworks Association, the Institution of Gas Engineers, the Institution of Municipal and County Engineers, the Incorporated Municipal Electrical Association, the Association of Managers of Sewage Disposal Works, the County Land Agents' Association, the Municipal Tramways and Transport Association, and many others, applied for facilities for some hundreds of their members to visit the Congress and Exhibition.

DELEGATES.

The following is a list of the Local Authorities and other bodies which appointed delegates to attend the Congress:—

County Councils (England and Wales) (51).

Anglesey, Bedfordshire, Berkshire, Breconshire, Buckinghamshire, Caernarvonshire, Cambridgeshire, Carmarthenshire, Cheshire, Cornwall, Cumberland, Denbighshire, Derbyshire, Devon, Dorset, Durham, Essex, Flintshire, Gloucestershire, Hampshire, Herefordshire, Huntingdonshire, Isle of Ely, Kent, Lancashire, Leicestershire, Lincs (Holland), Lincs (Kesteven), London, Middlesex, Monmouthshire, Northamptonshire, Northumberland, Notts, Oxfordshire, Pembrokeshire, Radnorshire, Salop, Soke of Peterborough, Somerset, Staffordshire, Suffolk (East), Surrey, Sussex (East), Warwickshire, Westmorland, Wiltshire, Worcestershire, Yorks (East Riding), Yorks (North Riding) and Yorks (West Riding).

County Councils (Scotland) (16).

Aberdeen, Argyll, Ayr, Berwickshire, Dunbartonshire, East Lothian, Kirkcudbright, Lanarkshire, Midlothian, Moray, Nairnshire, Perth, Renfrew, Roxburghshire, Stirling, and Wigtown.

Metropolitan Borough Councils (21).

Battersea, Deptford, Finsbury, Fulham, Greenwich, Hackney, Hammersmith, Hampstead, Holborn, Islington, Kensington, Lambeth, Lewisham, Paddington, St. Marylebone, Shoreditch, Southwark, Stoke Newington, Wandsworth, Westminster, and Woolwich.

County Borough and Borough Councils (177).

Abergavenny, Aberystwyth, Acton, Ashton-under-Lyne, Aylesbury, Bangor, Barking, Barnes, Basingstoke, Bath, Batley, Bedford, Beverley, Bexhill, Bilston, Birkenhead, Birmingham, Blackburn, Blackpool, Bolton, Bootle, Bournemouth, Bradford, Brentford and Chiswick, Bridlington, Brighouse, Brighton, Bristol, Bromley, Burnley, Burton-upon-Trent, Bury, Buxton, Canterbury, Cardiff, Carlisle, Carmarthen, Chatham, Cheltenham, Chester, Chesterfield, Chichester, Chorley, Colchester, Colne (Lancs), Coventry, Darlington, Dartmouth, Darwen, Derby, Dewizes, Dewsbury, Doncaster, Dorchester, Ealing, Eastbourne, East Ham, Eccles, Exeter, Falmouth, Finchley, Gillingham, Glastonbury, Glossop, Gloucester, Goole, Gravesend, Great Yarmouth, Grimsby, Guildford, Halifax, Harrogate, Hartlepool, Harwich, Hastings, Hereford, Hertford, Hove, Huddersfield, Hull, Hyde, Ilford, Ilkeston, Ipswich, Jarrow, Keighley, Kidderminster, Kingston-upon-Thames, Lancaster, Leamington Spa, Leeds, Leicester, Leyton, Lincoln, London, Lowestoft,

Ludlow, Luton, Lymington, Maidstone, Maldon, Manchester, Margate, Marlborough, Middlesbrough, Middleton (Lancs), Morecambe and Heysham, Neath, Nelson, Newbury, Newcastle-under-Ly, 10, Newcastle-upon-Tyne, Newport (Isle of Wight), Newport (Mon.), Northampton, Norwich, Nottingham, Nuneaton, Oldham, Oxford, Portsmouth, Preston, Rawtenstall, Reading, Redcar, Reigate, Rugby, Richmond (Surrey), Rochdale, Rotherham, Rye, St. Albans, St. Helens, Scarborough, Sheffield, Shrewsbury, Smethwick, Southampton, Southend-on-Sea, Southgate, Southport, Stafford, Stalybridge, Stockport, Stourbridge, Stratford-upon-Avon, Stretford, Sunderland, Sutton Coldfield, Swansea, Swindon, Tamworth, Taunton, Tewkesbury, Tiverton, Todmorden, Torquay, Tunbridge Wells, Tynemouth, Wakefield, Wallasey, Walsall, Walthamstow, Warrington, Wells, West Bromwich, West Ham, West Hartlepool, Whitehaven, Widnes, Willesden, Wimbeldon, Wolverhampton, Wood Green, Worcester, Worthing and Wrexham.

Scottish Burgh Councils (14).

Aberdeen, Ayr, Coatbridge, Dundee, Dunfermline, Edinburgh, Glasgow, Hamilton, Kilmarnock, Milngavie, Paisley, Rothesay, Rutherglen and Stirling.

Urban District Councils (189).

Abercarn, Aberdare, Abergele and Pensarn, Abram, Adwick-le-Street, Alderley Edge, Alsager, Alvaston and Boulton, Amblecote, Ashby-de-la-Zouch, Ashford (Kent), Atherton, Audenshaw, Baunstead, Barnoldswick, Barry, Beaconsfield, Beddington and Wallington, Bedlingtonshire, Bedwellty, Bedworth, Belper, Bexley, Billingham, Bingley, Bishop Auckland, Brentwood, Brownhills (Staffs), Buckley, Budleigh Salterton, Burton Latimer, Bushey, Cannock, Castleford, Caterham and Warlingham, Cheadle and Gatley, Chertsey, Chesham, Cheshunt, Chingford, Chislehurst, Chorleywood, Clacton, Cleethorpes, Coalville, Coulsdon and Purley, Crayford, Cromer, Cudworth, Dagenham, Darton, Droylsden, Earsdon, Eastleigh, Ebbw Vale, Edmonton, Egham, Ellesmere Port and Whitby, Enfield, Epsom, Erith, Eston, Fareham, Farnborough, Farnworth, Felixstowe, Formby, Friern Barnet, Frimley and Camberley, Frome, Gainsborough, Gellygaer, Glynecorwg, Gosforth, Grays Thurrock, Great Crosby, Hale, Hampton, Harrow-on-the-Hill, Haslemere, Havant and Waterloo, Hayes and Harlington, Hazel Grove and Bramhall, Hemsworth, Holmfirth, Honley, Horncastle, Horwich, Houghton-le-Spring, Hucknall, Ilkley, Irlam, Kettering, Kidsgrove, Kingsbury, Leek, Leyland, Litherland, Llanfrechfa Upper, Llantarnam, Loftus, Loughbenton, Long Eaton, Maesteg, Malden and Coombe, Malvern, Mangotsfield, Melton Mowbray, Minehead, Mirfield, Mitcham, Newmarket, North Walsham, Northwich, Padilham, Paignton, Panteg, Penge, Penmaenmawr, Penrith, Pontypridd, Porthcawl, Portland, Portslade-by-Sea, Prestwich, Radcliffe, Ramsbottom, Redditch, Rhondda, Rhyl, Rickmansworth, Ripley (Derbyshire), Rishton, Romford, Royston, Royton, Ruislip-Northwood, Sealby, Seunthorpe and Frodingham, Seaham Harbour, Seaton Delaval, Selby, Shepton Mallet, Sheringham, Shipley, Shoreham-by-Sea, Silsden, Skegness, Skelton and Brotton, Skipton, Solihull, Southall-Norwood, Southwram, Soyland, Spenborough, Stanley, Surbiton, Sutton and Cheam, Swadlincote, Swanscombe,

Swinton and Pendlebury, Tanfield, Teddington, Thornton Cleveleys, Thurnscoe, Thurmaston, Tipton, Tottenham, Tredegar, Trowbridge, Turton, Urmston, Uxbridge, Walton-le-Dale, Wanstead, Washington, Waterloo-with-Seaforth, Wath-upon-Deane, Wednesfield, Wellingborough, Wellington (Somerset), Welwyn Garden City, Wembley, Westhoughton, Whitefield, Wilmslow, Winsford, Wolverton and Worsley.

Rural District Councils (112).

Alnwick, Alton, Andover, Ashby-de-la-Zouch, Atcham, Axbridge, Axminster, Barnet, Basford, Bathavon, Beverley, Blackwell, Bowland, Burnley, Campden, Cannock, Cardiff, Chailey, Chard, Cheltenham, Chester-le-Street, Chipping Sodbury, Chorley, Clutton, Darlington, Dartford, Droitwich, Dulverton, Durham, Easington, East Grinstead, East Retford, Evesham, Frome, Godstone, Goole, Grimsby, Guildford, Hailsham, Halifax, Hambledon, Hendon, Henstead, Hollingbourne, Holywell, Honiton, Houghton-le-Spring, Howden, Hungerford, Isle of Thanet, Kettering, Kidderminster, Knaresborough, Lancaster, Langport, Lexden and Winstree, Lichfield, Louth, Lydney, Maidstone, Midhurst, Morpeth, Newton Abbot, Northampton, North Kesteven, Northwich, Orsett, Patrington, Pontardawe, Pontefract, Pontypool, Romney Marsh, Rotherham, Rugby, St. Mellons, Sedgfield, Seisdon, Selby, Settle, Sevenoaks, Sheppey, Shepton Mallet, Skipton, Skirlaugh, South Mimms, Spalding, Strood, Stroud, Taunton, Tenterden, Tewkesbury, Thornbury, Tiverton, Todmorden, Tonbridge, Truro, Ulverston, Upton-on-Severn, Warmley, Warrington, Wells, Welton, Welwyn, West Ashford, West Lancashire, Whiston, Wigan, Winchester, Winslow, Wortley, Wrexham and Yeovil.

Irish Local Authorities (16).

Antrim, Armagh, Clare, Down, Dublin, Fermanagh, Londonderry, Meath, Tipperary (N.R.), Tyrone, and Westmeath County Councils: Belfast, Dublin, and Londonderry Borough Councils: Strabane Urban District Council; Belfast and Castlereagh Rural District Council.

Miscellaneous (24).

Twenty-four miscellaneous delegates also attended the Congress and Exhibition.

In addition to the above a large number of Societies interested in the matters discussed at the Congress were represented thereat, whilst delegates from the various British Dominions and many foreign countries also attended.

CONGRESS PROGRAMME.

Monday, November 13th, at 3.0 p.m.

Conference under the auspices of the Institution of Sanitary Engineers on—"The Re-sewerage of Guildford." (Paper by Mr. J. W. HIPWOOD, M.Inst.C.E., M.Inst.M.Cy.E., M.R.San.I., Borough Surveyor of Guildford). Chairman: Mr. H. C. ADAMS, M.Inst.C.E., M.I.Mech.E., F.R.San.I. (President of the Institution).

Conference on—"Town Building: L.C.C. Cottage Estates (Post-War)." (Paper by Mr. H. BERRIDGE, C.I.E., O.B.E., M.Inst.C.E., M.Inst.Mech.E., late Assistant to Administrator, L.C.C. Housing Development Schemes). Chairman: Sir ARTHUR B. LOWRY, C.B., Deputy Secretary, Ministry of Health. (NOTE—This Paper was awarded a Special Prize in the Open Competition organised by the Congress Committee).

Tuesday, November 14th, at 11.0 a.m. and 3.0 p.m.

Conferences under the auspices of the Society of Chemical Industry on—(a) "Laboratory Tests and their Correlation with full scale Road Experiments." (Paper by Mr. R. G. C. BATSON, M.Inst.C.E., M.I.Mech.E.). (b) "Some factors involved in the Mechanical Testing of Bituminous Mixtures." (Paper by Mr. W. G. ADAM, B.A., M.I.Chem.E., F.I.C., and Mr. D. G. MURDOCH, B.Sc., A.I.C., A.M.I.Chem.E.). (c) "The Mechanical Testing of Bituminous Road Mixtures." (Paper by Mr. PREVOST HUBBARD, Chemical Engineer, The Asphalte Institute, New York). Chairman: Major F. C. COOK, D.S.O., M.C., M.Inst.C.E., Deputy Chief Engineer, Ministry of Transport. (d) "The Mechanical Testing of Asphalt." (Paper by Mr. D. M. WILSON, D.Sc., A.I.C.). (e) "Mechanical Tests and the Modern Highway." (Paper by Mr. D. C. BROOME, M.I.P.T., and Mr. A. R. THOMAS, M.I.P.T.). (f) "Mechanical Testing of Bituminous Road Materials." (Paper by Prof. Dr. ING. E. NEUMANN, Stuttgart, Germany). Chairman: Professor G. T. MORGAN, O.B.E., D.Sc., F.R.S. (Past President of the Society; Director of Chemical Research, Department of Scientific and Industrial Research).

Tuesday, November 14th, at 11.0 a.m.

Conferences under the auspices of the Institution of Gas Engineers on—(a) "Dry Purification: Some new methods for its Control." (Paper by Mr. W. A. CURRIE, Jr., A.M.Inst.Gas E., Technical Assistant, Glasgow Corporation Gas Department). (b) "Qualities of Tars for Use on Roads." (Paper by Mr. W. E. CONE, Technical Adviser, British Road Tar Association). Chairman: Mr. F. P. TARRATT, M.Inst.C.E., M.Inst.Gas E. (President of the Institution). (NOTE—Mr. CURRIE's Paper was awarded a Special Prize in the Open Competition organised by the Congress Committee).

Tuesday, November 14th, at 3.0 p.m.

Conference under the joint auspices of the Association of Public Lighting Engineers and the Institution of Gas Engineers on—"The Lighting of Arterial Roads by Gas." (Paper by Mr. A. M. BELL, A.M.Inst.GasE., Public Lighting Superintendent, Tottenham and District Gas Co.). Chairman: Mr. E. M. SEVERN (President of the Association of Public Lighting Engineers).

Wednesday, November 15th, at 11.0 a.m.

Conference under the auspices of the Institution of Municipal and County Engineers on—"Specifications in the light of tradition, experience and research." (Paper by Mr. B. PRICE DAVIES, F.S.I., M.Inst.M. & Cy.E., M.R.San.I., L.R.I.B.A., City Engineer, Bangor). Chairman: Major L. ROSEVEARE, O.B.E., M.Inst.C.E., Borough Engineer, Eastbourne (President of the Institution). (NOTE—This Paper was awarded the First Prize in the Open Competition organised by the Congress Committee).

Conferences under the auspices of the County Land Agents Association on—(a) "Allotments and Small Holdings." (Paper by the late Mr. F. H. OSMOND-SMITH, F.S.I., formerly County Land Agent for Glamorgan). (b) "Rats and Musk Rats." (Paper by Mr. M. A. C. HINTON, Deputy Keeper of Zoology, Natural History Museum). Chairman: Sir CHARLES J. HOWELL THOMAS, K.C.B., C.M.G., Permanent Secretary, Ministry of Agriculture and Fisheries. (NOTE—Paper (a) above was awarded a Special Prize in the Open Competition organised by the Congress Committee, and it was submitted, in consequence of the regretted death of Mr. OSMOND-SMITH, by Major C. R. HARDING, F.S.I., F.L.A.S., the County Land Agent of Surrey).

Wednesday, November 15th, at 2.30 p.m.

Special Session, when the President of the Congress and Exhibition, the Rt. Hon. Sir HILTON YOUNG, G.B.E., D.S.O., D.S.C., M.P., Minister of Health, presented the prizes to the successful competitors in the Papers Competition organised by the Congress Committee and addressed the delegates.

Wednesday, November 15th, at 3.0 p.m.

Conferences under the auspices of the Institution of Municipal and County Engineers on—(a) "The Development of Road Bridges in Great Britain." (Paper by Mr. C. H. BRESSEY, C.B., C.B.E., F.S.I., Chief Engineer, Roads Department, Ministry of Transport). (b) "The Design of Superstructures for Small Bridges." (Paper by Mr. HADDON C. ADAMS, M.A., Assoc.M.Inst.C.E., Assistant Engineer, Roads Department (Bridge Section), Ministry of Transport). Chairman: Sir HENRY P. MAYBURY, G.B.E., K.C.M.G., C.B. (President of the Institution of Civil Engineers and Chairman of the Congress Organising Committee). (NOTE—A special exhibition of bridge photographs was arranged in connection with this Session).

Thursday, November 16th, at 11.0 a.m. and 2.45 p.m.

Conferences under the auspices of the British Waterworks Association on—
 (a) "Pooling of Supplies by interconnection of Water Undertakings and their trunk mains through Rural Areas." (Paper by Mr. ALAN E. L. CHORLTON, C.B.E., M.Inst.C.E., M.I.Mech.E., M.P.). (b) "Water Pollution Research." (Paper by Dr. A. PARKER, D.Sc., M.I.Chem.E., F.I.C., Secretary and Assistant Director of Research, Water Pollution Research Board, Department of Scientific and Industrial Research). (c) "The Financial Management of Municipal Trading Departments." (Paper by Mr. SYDNEY LARKIN, F.S.A.A., F.I.M.T.A., City Treasurer, Coventry). (d) "Fire Fighting Apparatus." (Paper by Commander A. N. G. FIREBRACE, R.N. (Retd.), Senior Divisional Officer, London Fire Brigade.) (e) "The Legal Aspect of Water Supply for Fire Protection Purposes." (Paper by Mr. JOHN HALL, Clerk and Solicitor to the Fylde Water Board). Chairman: Mr. G. M. ROBERTSON, J.P. (President of the Association).

Thursday, November 16th, at 11.0 a.m.

Conferences under the auspices of the Institution of Municipal and County Engineers on—(a) "Office Efficiency in a Highways Department." (Paper by Mr. E. TASKER, A.M.Inst.C.E., Chief Engineering Assistant, Gloucestershire County Council). (b) "Control over Highway Expenditure." (Paper by Mr. P. TAIT, Finance and Statistics Department, Ministry of Transport). Chairman: Mr. C. H. BRESSEY, C.B., C.B.E., F.S.I., Chief Engineer, Roads Department, Ministry of Transport. (NOTE—Mr. TASKER's Paper was awarded the Second Prize in the Open Competition organised by the Congress Committee).

Thursday, November 16th, at 3.0 p.m.

Conference under the auspices of the Institution of Municipal and County Engineers on—"Some considerations affecting the economical reconstruction of Rural Roads." (Paper by Mr. D. G. R. TIDDY, F.S.I., M.Inst.M. & Cy.E., District Highway Surveyor, Somerset County Council). Chairman: Major L. ROSEVEARE, O.B.E., M.Inst.C.E., Borough Engineer, Eastbourne (President of the Institution). (NOTE—This Paper was awarded the Fourth Prize in the Open Competition organised by the Congress Committee).

Friday, November 17th, at 11.0 a.m.

Conferences under the auspices of the Institute of Sewage Purification on—
 (a) "Recent developments in methods of Sewage Works Analysis." (Paper by Mr. J. T. THOMPSON, M.Sc., F.I.C., Chemist and Works Manager, Knostrop Sewage Works, Leeds). (b) "The Disposal of Surplus Activated Sludge." (Paper by Mr. H. D. BELL, F.I.C., F.C.S., Manager and Chemist, Barnsley Sewage Disposal Works). Chairman: Mr. J. HAWORTH, M.B.E., F.I.C., Sewage Disposal Works Manager and Chemist, Sheffield (President of the Institute). (NOTE—Both these Papers were awarded Special Prizes in the Open Competition organised by the Congress Committee).

Conference under the auspices of the Institution of Municipal and County Engineers on—"The Design and Construction of Municipal Aerodromes." (Paper by Mr. T. L. ROBERTS, Assistant Engineer, Anglesey County Council). Chairman: Mr. E. A. SANDFORD FAWCETT, C.B., M.Inst.C.E. (Late Chief Engineering Inspector, Ministry of Health, and Vice-Chairman of the Congress Committee). (NOTE—This Paper was awarded a Special Prize in the Open Competition organised by the Congress Committee).

Friday, November 17th, at 3.0 p.m.

Conferences under the auspices of the Institute of Sewage Purification on—
 (a) "Present day conceptions of Sewerage and Sewage Treatment." (Paper by Mr. GRANVILLE BERRY, Engineering Assistant, Royal Borough of Kensington). (b) "The logical design of separate sludge digestion plant and its effect upon other phases of sewage treatment." (Paper by Mr. A. S. LOWE, B.Sc., A.M.Inst.C.E., A.M.I.Mech.E.). Chairman: Dr. H. T. CALVERT, M.B.E., D.Sc., Ph.D., F.I.C., Chemical Inspector, Ministry of Health. (NOTE—Mr. BERRY's Paper was awarded the Third Prize and Mr. LOWE's Paper a Special Prize in the Open Competition organised by the Congress Committee).

Conferences under the auspices of the Institution of Municipal and County Engineers on—(a) "Private Street Works." (Paper by Mr. A. O. MITCHELL, Private Street Works Assistant, West Sussex County Council). (b) "Vibration in Roads and Buildings." (Paper by Mr. C. H. BRADBURY, A.M.Inst.C.E.). Chairman: Major L. ROSEVEARE, O.B.E., M.Inst.C.E. (President of the Institution). (NOTE—Both these Papers were awarded Special Prizes in the Open Competition organised by the Congress Committee).

Saturday, November 18th, at 11.0 a.m.

Conference under the auspices of the Institution of Municipal and County Engineers on—"Vehicle Design in relation to Public Cleansing." (Paper by Mr. J. E. SWINDLEHURST, M.A., A.M.Inst.C.E., Borough Engineer, Hampstead). Chairman: Major L. ROSEVEARE, O.B.E., M.Inst.C.E. (President of the Institution).

SPECIAL SESSION.

Prize Distribution and Address by The Rt. Hon. SIR HILTON YOUNG,
G.B.E., D.S.O., D.S.C., M.P., Minister of Health.

SIR HENRY P. MAYBURY, G.B.E., K.C.M.G., C.B. (*Chairman of the Congress Organising Committee*), in the Chair.

Wednesday, November 15th, 1933.

THE CHAIRMAN (SIR HENRY P. MAYBURY) having welcomed the Minister of Health (Sir Hilton Young), said: It will be remembered that our last Congress and Exhibition synchronised with the trouble in 1931, when it was necessary to impose strict economy, and it was therefore not to be wondered at that our Exhibition and Congress suffered somewhat in attendances. I am glad to say that with the recovery of the industrial position of the Nation the attendances at the Congress, and certainly the Exhibition, show a very marked improvement. The very wide interests of local government are exemplified in that great hall, where in keeping with the mechanical age in which we are living, all forms of machinery are to be found for the performance of work of every kind, and the exhibitors will be glad to show to the engineers who will visit their stands how very efficient those implements are.

There were 39 Papers submitted for the competition. That again is a record, notwithstanding the fact that the Organising Committee passed a resolution which excluded the officers of Government Departments from competing on this occasion. It is very gratifying to the Organising Committee that we have even so a record number of Papers submitted.

Speaking for my colleague, Mr. Sandford Fawcett and myself, 39 Papers were ample for our purpose. It took I do not know how long to examine them, and I was glad to take advantage of Mr. Sandford Fawcett's diligence and his energy, and accept his findings.

You have around the hall a very fine exhibition of photographs of bridges which is not only instructive but I hope also interesting. You will see at any rate what to avoid if not what to emulate. Most of those photographs are reproduced in the volume that has been published by the Organising Committee.

Sir Henry then announced the following awards:

First Prize (Gold Medal and 100 guineas): Mr. B. Price Davies.

Second Prize (Silver Medal and 50 guineas): Mr. E. Tasker.

Third Prize (Bronze Medal and 20 guineas): Mr. G. Berry.

Fourth Prize (10 guineas): Mr. D. G. R. Tiddy.

Special Prizes (five guineas each): Messrs. H. D. Bell, H. Berridge, C. H. Bradbury, W. A. Currie, A. S. Lowe, A. O. Mitchell, T. L. Roberts, J. T. Thompson, and the late F. H. Osmond-Smith.

THE RT. HON. SIR HILTON YOUNG (*Minister of Health*), having distributed the prizes, said: It is indeed a matter of great interest to me to be here this afternoon as President, under our Patron His Majesty the King, of the Public Works, Roads and Transport Congress and Exhibition.

My first words must be words of congratulation and gratification at the renewed success of this annual occasion, and all its varied interests, all its high potentialities for service for the public need. I think that special appreciation should be given to the varied vigour of this organisation. A week or two ago I had put into my hands that beautiful volume relating to old and new bridges in this country. Sir Henry, that is a permanent addition both to the historical and aesthetic interest of our national possessions, and it must I think be a matter of pride to all associated with the Congress to have this permanent record of the varied interests which are here represented. Sir, it is gratifying to learn of the great vigour which is displayed by the exhibition side on this occasion—(Hear, hear); and we are all well aware—those of us who are

practical workers in the vineyard amongst local authorities and at the centre—we are all well aware of the very great service rendered to those concerned in the practical work of Local Government by this opportunity of seeing the newest and the best machinery, material and equipment which is available for our service by the invention and the enterprise of the commercial community.

Then, it is particularly gratifying to see the great vigour which attends this prize competition of the Congress; and let me add in public what I already have had the pleasure of saying in private, that I offer my warm congratulations to the winners of the prizes. I have already been informed, Sir Henry, by you and by your fellow judge, of the very high quality which is shown by the Papers submitted for the competition this year. I think one circumstance is particularly gratifying; that those who may be successful in gaining awards pass on to greater success as they renew their efforts in the coming years. That I think shows that the competition is serving the useful purpose which it is designed to serve, of encouraging the active minds that are engaged in this work, of encouraging them to put together the records of their analyses and to put the benefit of what they have done with their own brains at the disposal of those who are engaged on such work as this.

I was certainly astonished, on looking through the list of the Papers, at the immense variety of the subjects which are dealt with therein, and I was also struck—if I may record this personal impression—by this circumstance: that the list of subjects is one which might well be selected to represent a list of the kind of subjects which the industry needs and which will benefit by the work of research. There was so much that was new; there was so much that required thought, and particularly there were so many new problems suggested, of which one was conscious that for their solution there was needed a deliberate effort of conscious thought—and not only of thought in the abstract, but of the collection and the recording of the essential facts in order that the right solution of the problem might be found.

I would also comment upon another important and good feature of the work which we thus see recorded. It is this: the realisation of the necessity for collecting facts and data before forming theories. Our work with which we are concerned to-day is practical work. It is not purely theoretical; it is concerned with practical problems, and for the solution of those problems the first necessity is a close grip of the facts of the case and a careful preparation of the groundwork, in order that the structure of the administration may be built upon firm foundations.

How vast are the interests which such an organisation as this seeks to further! Let me select but one for illustration, one that I think will strike a responsive chord in your memories—the question of national highways. I look upon one figure and find that in the course of the last 10 years the amount expended out of grants and loans upon our national highways—not allowing for the supplementary amounts which must have been spent on the basis of private acts—is no less than 134 million pounds. What an enormous national effort this represents! If there were any waste owing to lack of educated thought, lack of design, lack of good planning in such an expenditure, how great would be the waste! Remembering that we are controlling forces of such magnitude, a task of such magnitude, requiring expenditure of such magnitude, it is a primary duty on all of those who are concerned therein, by their thought, by their research, and by careful labour, to avoid the wastage of public funds. (Hear, hear).

Now, Sir, there are several subjects which have been engaging your consideration, which I have no doubt will continue to engage the close attention of you, the assembled experts in these matters, and which I find from my point of view, as Minister of Health, of particular interest. Amongst those to-day there is one of such surpassing interest that I would select it for special mention and attention. That subject is building science in relation to the activities of local government. There is no more constant pre-occupation of the energies of the nation in local government at the present time than the due use of the financial and other forces available from the time to time in the provision for the national needs of the housing accommodation which the nation requires. (Hear, hear). In no region of administrative activity are we more closely tied down to conditions of cost in relation to that standard of accommodation which, according to modern ideas, is suitable for the housing of the nation's workers. We are constantly engaged in the resolution from day to day, with changed circumstances, of this problem of how to provide the accommodation required for the lower-paid wage earners at the minimum cost, at a cost which will make it possible, in accordance with the conditions of the time.

Now, Sir, of course the cost of raw materials is a comparatively intractable problem. Probably no research, no taking of thought by experts, will much affect that; it depends upon world wide factors of demand and supply. But the formation of the raw materials into the right type of house, how that can be done with the minimum expenditure of labour and materials in order to produce the desired results—that is a problem which is quite tractable, and which will amply repay the constant thought of all those whose practical knowledge, whose opportunities of acquiring that knowledge, enable them to serve the public ends in that regard.

On these general grounds I venture to invite the constant attention and the strenuous attention of all those of you who have these matchless opportunities to the solution, and the resolution from day to day, of that problem in the design of the perfect economical small house to let. (Hear, hear).

Sir, there are other matters of course hardly secondary in importance to that, as subjects for your attention and consideration. When we look at them we find that they possess one common factor, a factor also of absorbing interest, an interest so absorbing that I am not surprised to find that it has occupied the attention of several of your competitors, and I think few of your competitors but have shed some light upon the matter. This common factor of all our problems I would describe as this: How to keep a due balance between the standardisation which is necessary for the sake of efficiency and economy on the one hand, and on the other the preservation of those individual characteristics in what we supply, in the services which we perform, which are no less an essential in order to adapt them to the requirements of particular areas and particular classes. Those two characteristics, both necessary in public life, are not in the least self-contradictory. The maximum of efficient standardisation is perfectly compatible with the maintenance of individuality in order to give due elasticity and variety from need to need and place to place. But their co-ordination requires constant thought. If we lose sight of the necessities of variety we produce a soulless uniformity, many of the products of which are very likely unsuitable owing to lack of conformity with actual local characteristics. If on the other hand we allow too free play to the forces of variety we sacrifice that essential economy which can only be attained by standardisation of those factors which can and ought to be standardised.

Forgive me for referring to these characteristics. To-day we meet to celebrate the work of those who are turning the powers of intelligence on to those problems which await our solution, and when we come together on such an occasion it is our function to exchange ideas.

My last word shall be this: to express on your behalf what I believe you all feel, a sense of the practical utility of such conferences as this. They provide a unique opportunity for a meeting together of the people who must meet together if their work has to be done to the highest degree of efficiency; the elected representatives, officials and experts, of local authorities, of members of the central Ministry (who are always so much interested in these aspects of your work), and last but by no means least, all representatives of other countries who come here to give us their ideas and to take ours. (Hear, hear).

For such purposes as these, Sir Henry, this Conference and this Exhibition serve indeed a useful purpose. It is a pleasure to record that this year they show signs of greater variety than before, and we are confident that that is but a sign of increasing activity and of increasing success in years to come.

SIR FREDERICK BERRYMAN, proposing a vote of thanks to the Minister of Health for acting as President, for his presence and for his interesting address, said: Allusion has already been made to the arduous and continuous demand upon the time of Ministers of the Crown in these days, and knowing that, as we do, our gratitude to him for his presence is all the greater. It is to us a great source of satisfaction to know, by his presence, and indeed from the concluding words of his address, how fully he and the Ministry realise the advantages of a Congress of this sort.

The Minister has already dealt with that; there is very little for me to add; perhaps only the point that in addition to the advantages that he has pointed out, the advantages that those of us who are present here to-day get from the discussion and the interchange of opinions in Session, the report of the Congress is published in great detail, and thus a means is provided of spreading the information that is available by reason of this Conference, to a yet larger circle.

There is a point that I believe is sometimes overlooked in Conferences of this sort, and that

is the great advantage that arises from the interchange of views and experiences in a friendly and unofficial way in the lobbies and elsewhere, amongst those who have common interests and common work. (Hear, hear).

I think it will be agreed that the Papers this year are of great merit, not only on account of the variety of practical subjects with which they deal, but also from the very large amount of research which was entailed in the preparation of those Papers.

As one of the workers in the vineyard of local government, and on behalf of others, I would like to express our most grateful and cordial appreciation of the attitude of the Ministry to-day in its readiness to allow its representatives to meet us in a friendly and unofficial way to talk over our difficulties, to listen, with marvellously well-concealed signs of weariness, to our grievances, and, perhaps most important of all, to take us into their counsel when new and important proposals are on the table, before those proposals receive statutory confirmation.

MR. HUMPHRIES (*City Engineer, Birmingham*), seconding the vote of thanks, said: Thinking superficially one might question whether the Chair at the Transport Congress is quite the place for a Minister of Health, but on consideration it is seen to be an extremely proper situation for him. For example, he is naturally interested in great transport questions in connection with town planning, which is one of his great Departments, because after all, road and transport questions form the skeleton, as it were, of all town planning and unless they are properly designed the skeleton cannot be clothed with the innumerable things required, including amenities which can only follow after the road systems are planned. Then again, we may be sure that the Minister recognises what a vital thing transport is in connection with the great housing schemes. Nowadays, when our towns are growing so rapidly and when the central industrial areas are crowded out, we are compelled to house our people in far-flung suburbs, some great distances from the industrial and town areas, so that the matter of the transport of the people to and from work is of much greater importance than hitherto. Therefore the Minister is much interested in the question of the laying out of main arterial roads to enable convenient, cheap and rapid transport for people to be provided or, in other words, a quick transport at a cost which working-people can afford to pay. It is, of course, evident that although the amount of rent working-people have to pay is a great thing to-day, yet the question of the cost of transport is a very vital matter and of almost equal importance for it does not appear to be a great deal of good to send a man a long way out, giving him a house of reasonably cheap rent, if he has to pay a great deal of money to transport his family and himself to and from work or town. It does seem to me that we who are building the houses now can say that, from the housing side, we have succeeded in providing houses at reasonably cheap rents and it would seem that we should turn to the transport people and say—"Now it is up to you to provide cheap transport." Where people of necessity have to be sent unreasonable distances out, it would seem essential that some method of meeting the difficulty of the cost of travelling should be devised.

The Minister spoke of the necessity of providing houses which could be let at cheap rents, and I can assure him that there is hardly a man in this country who has to do with the building of houses who does not spend a great deal of time racking his brains to find something that will be practically as good as the buildings he is erecting and yet which can be built at such a cost as will reduce the rent to the working classes; indeed there are very few of them who cannot be found in their leisure moments sketching plans with that end in view, for I am sure that everybody concerned is anxious to follow Sir Hilton's advice.

We all admire the splendid way in which the Minister has tackled this great slum question which I have no doubt is taking up most of his time at present, and I expect we seldom think of him nowadays without thinking of slums in connection with him. I venture to say that until Sir Hilton Young told the nation about the slums, although many of us, of course, knew a good deal about them, I do not think the nation at large really knew what the slums were and we all wish him the greatest of success in his campaign.

The resolution was carried by acclamation.

THE RT. HON. SIR HILTON YOUNG, returning thanks, said: Mr. Humphries reminded me of a letter I received the other day from a lady in Sunderland. She said: "Dear Minister of Health, Thank God you are slum-minded." I do not think that was the happiest way to put it, but I knew what she meant.

CONFERENCE

Under the auspices of the Institution of Sanitary Engineers.

MONDAY, 13th NOVEMBER, at 3.0 p.m.

MR. H. C. ADAMS, M.Inst.C.E. (*President of the Institution*), in the Chair.

The following Paper was taken as read :—

The Re-sewerage of Guildford.

BY

J. W. HIPWOOD, M.Inst.C.E., M.Inst.M. & Cy. E., M.R.San.I.,
Borough Surveyor and Water Engineer, Guildford.

INTRODUCTORY.

In selecting this subject for his paper to this Congress, the Author is of opinion that a present day example of the common sense application of sanitary engineering principles to problems pertaining to districts rapidly developing on well governed line from Victorian to modern conditions may be not only of guidance to the junior members of the profession, but of some interest to senior members who have been entrusted by other authorities with the solution of similar schemes. No sensational methods have been adopted, but the aim of the author throughout has been, first thoroughly to investigate every existing condition, then to envisage every reasonable future sanitary need of the areas affected, and lastly, to set about the accomplishment of the task thereby involved with the greatest possible expedition, the least possible disturbance to traffic, businesses and the public in general, and with the minima of capital expenditure, running costs and maintenance, consistent with the observance of good design and sound engineering.

PART I.—THE PROBLEM.

GENERAL FEATURES AND EXISTING SEWERS.

Drainage Area.—The map reproduced herewith shows the entire Guildford drainage area. It falls to the north along the central valley of the River Wey, is bounded on the east and west by natural ridge lines and terminates at the southern or higher end of the valley with the land already drained to the Hambledon Sewage Disposal Works.

The topography of the area, consisting essentially of the valley of the River Wey falling northwards through the middle of it, with tributary valleys running east and west therefrom, and the Sewage Disposal Works at the northern or lower end, makes the design of the drainage system reasonably simple.

The only topographical difficulties occur in connection with the two most northerly, or lower, drainage areas on the east and west of the main valley. These cannot drain direct to a central sewer and must be brought to the works by separate outfall sewers.

The natural features of the ground therefore called for a main outfall sewer along the valley of the River Wey, intercepting the tributary valleys en route, with two further intercepting sewers, one to drain the north west area, and one to drain the north east areas back to the Disposal Works.

It was clearly not financially sound to construct such a comprehensive scheme until the flows from the areas warranted the large capital outlays; the map shows the various stages of the growth of the drainage system as it was originally designed and extended from time to time to keep pace with the development of the drainage area.

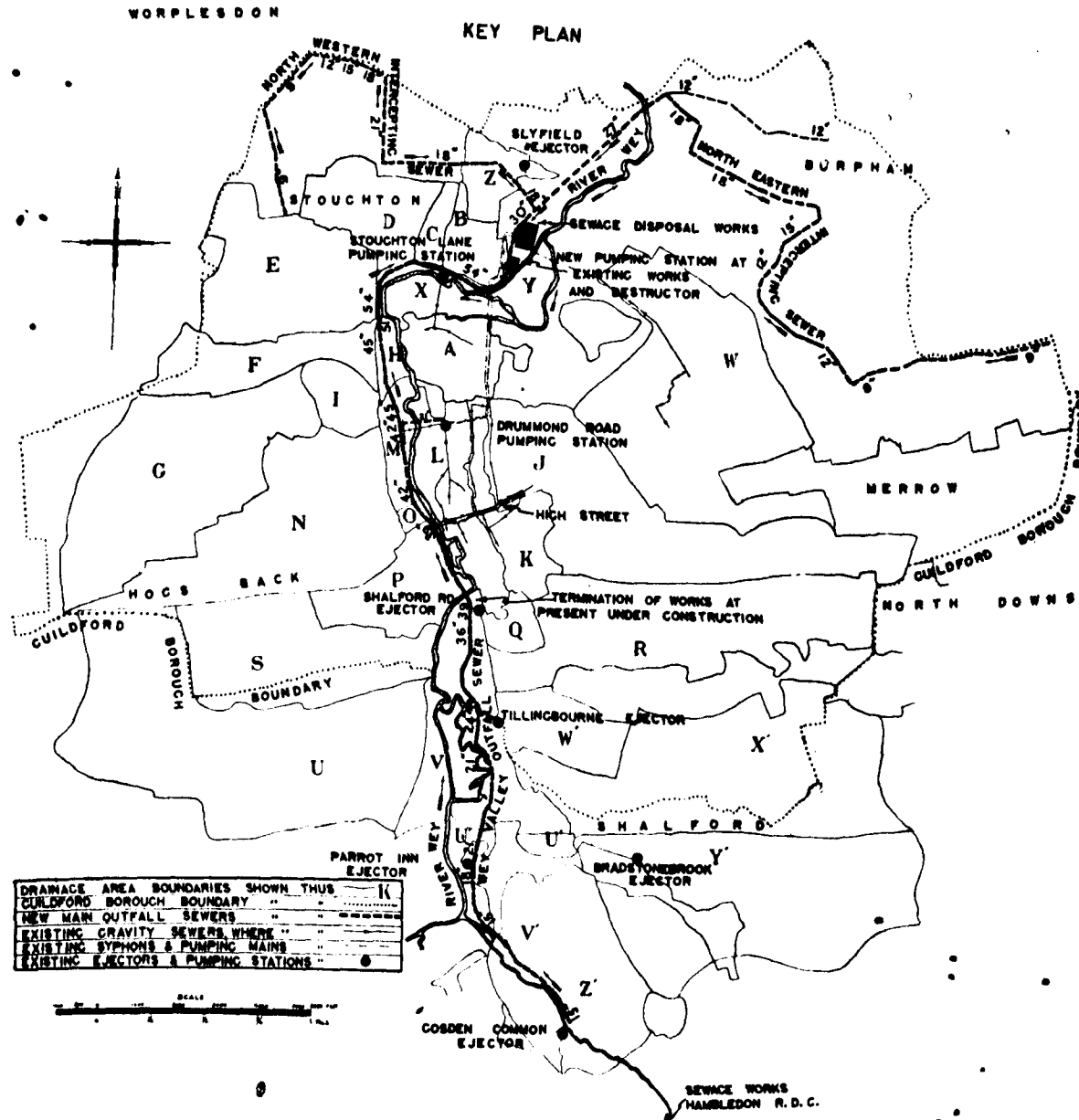
The first recognised drainage scheme for Guildford, prepared by Mr. G. Nicholson Lailey in 1889, consisted of the area L known as the "low level area" which drained to a pumping station at Drummond Road and was thence lifted through a 10 in. rising main into the "high level area" consisting of area K and part of area J.

The combined flows from these high level and low level areas, then gravitated through a 15 in. syphon under the River Wey to the beds at the Sewage Disposal Works.

This original scheme with additional pumping plant and the duplication of the 15 in. syphon to the work still forms—until the completion of the present scheme—the nucleus of the present drainage of the town, the remainder of the system with a few exceptions being simple tacked on to the original scheme.

The exceptions are the area B, C, D, E, F, which drain to Stoughton Lane Pumping Station, the area A, which drains under the river to the same point, and the area W which syphons under the river direct to the beds at the Sewage Disposal Works.

The Stoughton Lane Pumping Station lifts to a separate Sewage Disposal Works at Woodlands, and is really a complete sewerage and Sewage Disposal system of the old R.D.C. taken over under the 1904 borough extension. It has, however, been incorporated in the present scheme.



The areas J, M, O, P, and N, simply grew on to the 1889 scheme and gave rise to no difficulties.

The extensions to the south, however, presented more difficulty. The time was not ripe for a main outfall scheme, the cost of construction being out of all proportion to the flow to be dealt with. It was therefore then decided to construct shallow sewers and to make use of a number of ejector stations operated by compressed air.

Accordingly, in 1908, the ejector system shown on the plan was constructed and simultaneously a refuse destructor and air compressing station were constructed at the Sewage Disposal Works to provide compressed air to operate the ejectors.

The destructor consisted of four Manlove Alliott cells and two Babcock & Wilcox water tube boilers, having a maximum duty of 35 tons of refuse per 24 hours per pair of cells.

The system as then completed served the natural drainage area quite satisfactorily, and was undoubtedly right for that period of development.

The original 1889 sewers could not however be expected to deal indefinitely with this greatly increased area, particularly in view of post-war development, and flooding in the original low level area began and increased. This was partially and temporarily relieved by the installation of further pumps at Drummond Road Pumping Station, but the accelerated discharge of sewage from the low to the high level area, to some extent transferred the problem to the high level area, occasioning flooding in the high level zones also.

At the same time owing to the rapid growth of Stoughton a similar state of things was occurring in the Stoughton Lane Pumping Station district, areas B, C, D and E. This system, constructed in 1902, became badly surcharged, although additional plant at this pumping station, together with a further rising main to Bellfields Sewage Disposal Works, constructed in 1927, enabled the system, although badly surcharged to function for a further brief period of years without serious flooding.

The drainage system of the area with a maximum pipe diameter of 12 in. had now reached a point when no further relief measures were possible and a complete reconstruction had to be undertaken. In 1929 work was commenced on the preparation of the present scheme which will now be described in detail, and which on completion will provide one complete unified system consisting essentially of a main intercepting sewer in the Valley of the River Wey, extending throughout the Guildford drainage area, and intercepting all the contributory valleys *en route*. All the existing sewers are retained and used as collecting sewers for the new main outfall sewer, and where these existing sewers are not large enough for the ultimate flow, duplicate sewers have been provided. The traffic problem has been duly considered, and the work designed and carried out to ensure the minimum disturbance of road surface.

PART II.—DESIGN.

PRESENT SCHEME—PRELIMINARY CONSIDERATIONS.

Natural drainage routes.—As shown earlier, the topographical features of the Guildford drainage area falling from south to north with ridge lines on the east and west falling to the central valley of the River Wey, indicated that ultimately the drainage system must follow the natural drainage course of the River Wey with a main outfall sewer to the Sewage Disposal Works at the lower, or northern end of the valley, with two smaller intercepting sewers to drain the north-west and north-east flanks back to the works.

Existing Sewage Works and Refuse Destructor.—The position of the existing destructor which it was economical to retain at the Sewage Disposal Works with the consequent supply of steam available for pumping completes the chain of argument for a system gravitating to a central pumping station, the lifting being done on the spot where the power is generated, thereby saving the loss on conversion and transmission. These are therefore the lines on which the author has developed the scheme.

Two important questions, which were inter-related, arose from the purely financial side (a) what in the circumstances was the economic period to design for, and (b) how far up the valley should the outfall sewer at present extend.

(a) *Economic period to design for.*—A further consideration of the natural features of this gap through the North Downs shows that the possible limits of deviation of the route along the main valley are confined within a very narrow range, and further that if the sewer was made deep enough readily to pick up the tributary valleys of the upper zones, it would be approximately twenty feet deep by the time it crossed under the High Street some two miles upstream from the Sewage Disposal Works.

This was the first point at which traffic would be appreciably affected by construction and a tunnelling depth at this point was very desirable in view of the traffic difficulties in this congested part of the town.

It was apparent therefore that (i) within certain narrow limits there was only one possible route for the sewer and (ii) that for roughly two miles it had to be constructed at a depth greater than twenty feet in heading; the necessary corollary being that any future duplication must take place along the same route and at approximately the same depth.

Further, when we consider the rate of growth within the Borough, we find that for the past ten years it has been at the average rate of 2.07 per cent. per annum. At this rate the ultimate population allowed under the Town Planning Regulations would be reached in 57 years.

On these facts, the author based his conclusions that the present scheme should be adequate for the *ultimate* run off from the natural drainage area when the area is fully developed under the Town Planning Character and Density Zonings. This has accordingly been adopted as the basis of the calculations.

(b) *Extent of present scheme.*—Having settled the question of the period to be designed for—(the actual run off is discussed later under "calculations") it was

possible to prepare a complete scheme, leaving the question of the actual length to be constructed at present until detailed estimates had been prepared. It then became simply a question of relieving the present flooding in the town, and then deciding which was the more costly (i) the capital charge of constructing the length of sewer to the next ejector, or (ii) the additional cost of supplying compressed air—including the loss in transmission from a distant air compressing station and operating the ejector) over the cost of lifting at the central pumping station.

The length to be constructed at present stops just outside the town at a point which will effectively relieve all flooding, but from which a further extension to the Tillingbourne ejector can be made as soon as it is shown that the flow is such that the additional cost of power for operating the Tillingbourne ejector exceeds the amortization of the capital cost of this length of sewer.

I believe this time to be not far distant, but it is a point which will be capable of demonstration when the new works have been running for a period.

General Description of scheme.—The present scheme then consists of a main outfall sewer varying from 4 ft. 6 ins. to 15 ins. in diameter constructed along the valley of the Wey and extending from the Sewage Disposal Works up the valley to the boundary of the area drained by the local authority higher up the valley. It is deep enough to intercept all the tributary valleys and large enough to carry off the ultimate run off from the whole natural drainage area. The scheme has been designed in its entirety, but only approximately the lower half section is being constructed at present, the upper half remaining on the present ejector system, the ejectors continuing to be supplied with compressed air from the air compressing station at the Sewage Disposal Works. As the increasing flow in the upper lengths makes the extension of the outfall sewer economic, it is extensible as already designed.

The main outfall sewer is some thirty feet deep at the Sewage Disposal Works, a pumping station has therefore been provided to lift the sewage from the main outfall sewer, and also from the north-west and north-east intercepting sewers to the adjacent Sewage Disposal Works.

Preparation of scheme.—At the commencement of the preparation of the scheme no records of the existing sewers were available; a great amount of investigation had therefore to be made prior to plotting complete records of all sewers in their respective drainage areas. The ultimate run off from each area was then calculated and the capacity of the existing tributary sewers discharging to the outfall sewer checked, and where these main tributary sewers were found to be inadequate, supplementary sewers were designed capable of dealing with the balance of the ultimate flow.

In the case of the undeveloped areas the drainage area was plotted, the ultimate run off calculated, and the future main tributary sewer designed.

So from the constituent drainage areas the ultimate run off and the point and depth of connection to the main outfall sewer were obtained, the actual design of the main outfall sewer then becoming quite a straight forward matter.

In view of the fact that there would be a reasonable flow at all times in the sewer

It was decided to adopt the circular rather than the egg shaped section. It was also decided to use brick instead of concrete tubes when the diameter increased to 4 ft. 6 in. on account of ease of handling such material in heading.

Calculations for Wey Valley Main Outfall Sewer

The run off from each separate drainage area, based on the ultimate density under the Town Planning Regulations as previously discussed, was obtained in the following manner:

Determination of number of houses to be provided for

This was determined as under

(1) In fully built up areas by counting the actual number of houses and properties existing

(2) In partially developed areas

(a) In areas at present excluded from Town Planning, by assuming similar densities and types of properties as exist

(b) For areas Town Planned, at the Town Planning densities.

Kun off per l'ut home

The average water supply in recent years has been 37 gallons per head per day, made up as under:

Domestic 30 gallons per head per day

Trade 7 gallons per head per day

Total **37**

Gaugings were taken during absolute dry weather flow conditions and the quantities were as under

Gravitated 498,700 gallons per day

Pumped	971.057	"	"	"
--------	---------	---	---	---

Total 1,470,357 gallons per day.

or for an estimated population in the drainage area of 30,000, the D.W.F. 37.7
gallons per head per day

For the purposes of calculation the lower figure of 37 gallons per head per day was adopted

Provision to be made for infiltration and storm water.

Under the present bylaws separate storm water sewers are provided and no storm water from new properties is permitted to enter the soil sewers.

This also applies to the adjacent local authorities. In the case of older properties however the backs of houses are in many cases connected to the soil

BOROUGH OF GUILDFORD.

Calculations for Wey Valley Main Outfall Sewer. Refer to Plan No. 760.

CAPACITIES AND VELOCITIES ARE TAKEN FROM ALEXANDER'S HYDRAULIC DIAGRAMS BASED ON CRIMP & BRUGES' FORMULA $V = 124 R^{.67} S^{.50}$.

Area Lettered	Area in Acres	"Equivalent" Number of Houses under Town Planning from this Area Density Regulations	Quantity in cu feet per min from this Area 1 cu foot per min per House	Point of Connection to Main Sewer Numbered	Total Run Off to this point of Concentration Cu feet min	Manhole No. at point of Connection (see Contract Drawings)	Chainage of Manhole	Length in feet, Manhole to Manhole.	Invert Level at Manhole.	Fall in feet, Manhole to Manhole.	Gradient.	Diameter of Sewer provided.	Velocity in Sewer, feet per second.	Capacity provided in Sewer, cu. feet min.	Total Run Off Cu. feet min.	REMARKS.
							170		70.34							Inlet to Storage Chamber at Pumping Station.
B	54	570	95	1	4,734	2	715	545	71.12	0.78	1:700	54 ins.	5	4,800	4,734	Capacity, etc., refers to length from Connection No. 1 to Works.
X	51.8	1,020	170	1												
C	44.7	504	94	2	4,460	9	2,120	1,405	72.86	1.76	1:800	54 ins.	4.70	4,500	4,469	Capacity, etc., refers to length from Connection No. 2 to Connection No. 1.
A	99.3	654	109	2												
D	132.7	1,338	223	3	4,266	12	2,868	748	73.76	0.88	1:850	54 ins.	4.50	4,300	4,267	Capacity, etc., refers to length Connection No. 3 to Connection No. 2.
E	265.5	2,232	372	4	4,043	20	4,810	1,942	75.80	2.04	1:950	54 ins.	4.25	4,100	4,043	Capacity, etc., refers to length Connection No. 4 to Connection No. 3.
						20	4,810		76.05			51 ins.				Diameter changes from 54 ins. to 51 ins. Soffits kept level.
F	137.4	1,086	181	5	3,671	21	4,936	124	76.20	0.15	1:850	51 ins.	4.5	3,680	3,672	Capacity, etc., refers to length from Connection No. 5 to Connection No. 4.
						21	4,936		76.70			45 ins.				Diameter changes from 51 ins. to 45 ins. Soffits kept level.
G	438.3	4,140	690	5												
H	24.0	384	64	5												
I	56.0	684	114	6	2,736	25	6,343	1,407	78.58	1.88	1:750	45 ins.	4.25	2,900	2,736	Capacity, etc., refers to length from Connection No. 6 to Connection No. 5.
L	122.6	1,740	200	7	2,622	28	7,640	1,297	79.98	1.40	1:925	45 ins.	3.85	2,630	2,622	Capacity, etc., refers to length from Connection No. 7 to Connection No. 6.
M	40	210	35	7												
					2,622	28	7,640		80.23			42 ins.				Diameter changes from 45 ins. to 42 ins. Soffits kept level.
N	388.3	2,592	432	8	2,297	34	9,476	1,836	82.52	2.29	1:800	42 ins.	4.0	2,300	2,297	Capacity, etc., refers to length from Connection No. 8 to Connection No. 7.
O	8.1	66	11	8												
					2,297	34	9,476		82.77			39 ins.				Diameter changes from 42 ins. to 39 ins. Soffits kept level.
P	132.8	570	95	9	1,854	39	10,085	609	83.49	0.72	1:850	39 ins.	3.75	1,860	1,854	Capacity, etc., refers to length Connection No. 9 to Connection No. 8.
Q	34.4	126	21	10	1,759	49	12,368	2,283	86.03	2.54	1:900	39 ins.	3.50	1,800	1,759	Capacity, etc., refers to length Connection No. 10 to Connection No. 9.
						49	12,368		86.28			36 ins.				Diameter changes from 39 ins. to 36 ins. Soffits kept level.
R	402.0	756	126	10												
S	207.0	972	162	11	1,612	50	12,703	335	86.80	0.52	1:650	36 ins.	4.0	1,650	1,612	Capacity, etc., refers to length Connection No. 11 to Connection No. 10.
T	69.5	144	24	11												
W	192.5	1,212	202	12	1,426	58	15,239	2,536	89.62	2.82	1:900	36 ins.	3.35	1,430	1,426	Capacity, etc., refers to length Connection No. 12 to Connection No. 11.
X	526.6	1,170	195	12												
Y	191.1	2,340	309	12												
																Diameter changes from 36 ins. to 24 ins. Soffits kept level.
END OF PRESENT WORKS AT CONNECTION No. 12. THE FOLLOWING REFERS TO FUTURE EXTENSION FOR WHICH PROVISION IS MADE ABOVE.																
							15,779	840	24 ins. 91.70	1.08	1:500	24 ins.	3.25	650	639	Capacity, etc., refers to length Connection No. 13 to Connection No. 12.
U	673.6	1,494	249	13	639		15,779		21 ins. 91.95			21 ins.				Diameter changes from 24 ins. to 21 ins. Soffits kept level.
				13												
V	78.8	156	26	13			19,220	3,450	21 ins. 96.88	4.93	1:700	21 ins.	2.65	380	364	Capacity, etc., refers to length Connection No. 14 to Connection No. 13.
U	33.6	360	60	14			19,220		18 ins. 97.13			18 ins.				Diameter changes from 21 ins. to 18 ins. Soffits kept level.
				14												
				15			20,300	1,071	18 ins. 99.27	2.14	1:500	18 ins.	2.75	305	304	Capacity, etc., refers to length Connection No. 15 to Connection No. 14.
V	115.0	918	153	15			20,300		15 ins. 99.52			15 ins.				Diameter changes from 18 ins. to 15 ins. Soffits kept level.
				15												
				15A			22,550	2,250	15 ins. 101.02	4.50	1:500	15 ins.	2.5	180	151	Capacity, etc., refers to length from 15A to 15.
				16			24,035	1,485	109.02	5.00	1:297	15 ins.	3.25	240	151	Capacity, etc., refers to length Connection No. 16 to 15A.
Z	190.0	906	151													

IT HAS NOW BEEN
DECIDED NOT TO
INCLUDE THIS
LENGTH IN THE
1931 PROPOSALS
• WHICH WILL
• THEREFORE TER-
• MINATE AT CON-
• NECTION No. 10.

sewers. Gaugings and records of pumping were taken during wet weather and the maximum run off was found to be :—

(Highest recorded in 4 years) Pumped 3,770,571 gallons per day.
(approx.) Gravitated 1,496,100 „ „ „

Total 5,266,671

Ratio $\frac{\text{Maximum flow}}{\text{Dry Weather flow}} = \frac{5,266,671}{1,470,357} = 3.58$

Hence averaged over 24 hours maximum flow = 3.58 times dry weather flow.

In view of the present byelaws it is likely that flows from partially developed areas will be less than this, but in order to provide for all contingencies it has been considered advisable to provide for four times D.W.F.

Rate of Run off per unit house.

From the above on a basis of 5 persons per house we have :—

D.W.F. = 37 gallons per head per day.

D.W.F. per unit house = $5 \times 37 = 185$ gallons per day.

Half of this quantity flowing off in 6 hours

$= \frac{92.5}{6} = 15.4$ gallons per hour.

$= \frac{15.4}{6.25 \times 60} = \frac{1}{24}$ c. ft. per min. approximate.

Hence 4 D.W.F. = $\frac{1}{6}$ cu. ft. per min. per house.

Trade Wastes.

Existing laundries, Institutions, Breweries, etc., were allowed for on their actual water consumption where this is supplied from the mains, and on the amount drawn from private wells where these exist. As these form a relatively small portion of the flow they have for convenience of calculation been converted into an equivalent number of houses at $\frac{1}{6}$ cu. ft. per min. The relatively small undeveloped industrial areas have been treated in the same manner, hence column No. 3 of attached sheet "Equivalent number of houses under Town Planning Density Regulations."

Areas not draining to Outfall Sewer.

Certain areas shown on the plan do not drain to main outfall sewer, they have however been shown for the sake of completeness. They are as under :—

Area lettered.	Drains to.
Z	Filter beds at Slyfield.
Y	Direct to Pump Well (if ever developed).
W	Syphon direct to Disposal Works in separate sewers.
J	
K	

To face page 29. Calculations for Wey Valley Main, etc.

Area	Population	Equivalent Houses	Flow (gallons per day)	Flow (c. ft. per min.)
Z	1960	1960	725.6	1.404
Y	818	818	300	240
V	116.8	116.8	42.6	13
U	33.6	33.6	12.2	13
W	78.8	78.8	28.5	13
J	304	304	110.2	13
K	304	304	110.2	13
Total	3006	3006	1100.0	13

END OF PRESENT WORKS AT CONNECTION NO. 12

Detailed calculations for the total length of the Wey Valley main outfall sewer are shown on the sheet attached hereto. The sheet is self explanatory.

North Eastern and North Western sewers.—The proposed routes of the north eastern and north-western intercepting sewers together with the sizes of same are shown on the map. Both of these sewers gravitate to the pump well. These schemes are at present in course of preparation, and it is anticipated that sections of the work will be commenced at an early date.

PUMPING STATION AT SEWAGE DISPOSAL WORKS.

Syphoning and Pumping.—Although the natural drainage courses have been followed throughout the scheme, it has already been shown that the main outfall sewer is some thirty feet deep at the Sewage Disposal Works. This depth is sufficient to enable the north-eastern and north-western flank areas to be drained back to the pump well. It should be noted at this stage that the high level areas J, K and W, still gravitate through an inverted syphon direct to the beds at the works, the redundant 15 in. ejector main syphon being utilised as a duplicate syphon for the areas K and J and a further 15 in. duplicate syphon being constructed for the area W. These measures are adequate for the ultimate flow from the high level area, and ensure that full advantage is taken of the high land to save pumping costs where sewage can economically be syphoned under the river to the works.

It is interesting to note that the area W represents the limit to which this inverted syphon principle can be applied. For the flank area immediately east of area W, the amortization of the capital charge of constructing a syphon of a diameter sufficiently large to reduce the friction head to workable limits is greater than the cost of pumping.

Choice of Power.—The ultimate gravitation of all sewage to the works and the consequent lifting at a central pumping station instead of at a number of isolated points, alters the whole aspect of the problem of sewage lifting. It will no longer be necessary to transmit power over a length of from four to five miles, and we are free to select the cheapest form of power available. The steam plant at the refuse destructor works operating the present air compressors is augmented by a 325 brake horse power motor driven air compressor in wet weather. A steam boiler test was carried out over a period of six days and it was found that an average rate of steaming of 3,500 lbs. of steam per hour at 100 lbs. pressure could be maintained by the judicious use of coal and refuse. The quantity of refuse burnt during the test being 116 tons 17 cwts, and the quantity of coal 13 tons 15 cwts.

It was therefore decided that as the ejectors became displaced by the gravity sewer, the steam thus rendered available should be diverted to the new pumping station, which should be operated primarily by steam driven centrifugal pumps with electrically driven stand-by pumps. The main factors in favour of the use of electricity as a stand-by plant were:—(i) that it is instantly available, and (ii) it is supplied by a thoroughly modern undertaking belonging to the Council and (iii) as a standby plant it was the cheapest form of power available. This statement should perhaps be amplified further. It is true that crude oil engines would have given a lower fuel cost, but the capital charges on Diesel or semi-Diesel engines are so much

greater than the capital charges for an electric motor, that when, as in the present case, the plant is used as a standby at infrequent intervals, the overall cost is greatly in favour of the cheaper plant even though its power cost may be considerably higher.

One other factor had to be considered in selecting the motive power. The existing air compressing plant erected 1908-1910 is still in good condition, and although it will continue to be used in a greatly reduced measure until the ejectors have been entirely superseded, it will eventually be scrapped. The possibilities of the use of compressed air were explored, but as would be expected from the inherent loss in conversion of energy from steam to compressed air, it was easily demonstrated that, when the power could be used without transmission it would be far cheaper to write off the existing plant when it is no longer required for the existing ejectors, than to perpetuate a costly method of power in order to use existing machinery.

General considerations affecting design of pumping station.—The site of the station was fixed by the existing refuse destructor and steam plant, and the depth of the sump by the outfall sewer. This depth was such that the pumps had to be put down a pump well, the suction length being too great to operate from the surface. It was therefore decided to carry the pump well down to such a depth that the pumps should be self priming.

In view of the cost of carrying out extensions at this depth, the pump well has been designed to accommodate sufficient pumps to deal with the ultimate flow.

Rate of flow to be designed for.—Commencing with the highest flow recorded during the past four years, adding 10 per cent. thereto to allow for a five years' growth at 2 per cent. per annum, and allowing for peak loads by assuming that half this quantity will run off in six hours, we get a peak load of 350,000 gallons per hour.

The minimum night flow was found as a result of gaugings to be 18,000 gallons per hour.

Pump duties and storage capacity.—The factors determining the capacity and number of pumps to be used were (1) maximum and minimum flow of sewage, (2) cost of providing storage capacity (3) type of power employed.

It will be at once apparent that for given maximum and minimum flows the pump capacities will depend on the storage capacity provided. If the storage capacity is such that the peak flows can be stored, and a fairly uniform rate of pumping maintained throughout the 24 hours then the capacity of the pumps can be much less than would be required if they had to deal with peak flows.

A further variable factor to be considered in this case was the variable supply of steam from the refuse destructor.

Apart from the variable calorific value of the refuse—which can be adjusted by coal firing) the day's refuse is normally burnt by 1.0 a.m. after which the fires are kept going until 8.0 a.m. by coal.

This period coincides with the minimum night flow. Since any pumping not done by steam from refuse destruction must be done by electricity, it was regarded as the essential of economic pumping that whenever steam was available, sewage and suitable machinery for pumping it should also be available.

practicable, and back wash pipes have been provided on all the pumps to clean the suction pipes, and also to provide a means of agitating the sludge in the sump should this be found necessary.

A five ton double girder travelling crane is provided, but no workshop has been included in this building as this has already been provided in the existing compressor buildings with which the station communicates.

The top of the sump is decked over with open type steel flooring thereby providing adequate ventilation to the sewer and storage chamber. It is also considered that a well lighted sump is less liable to become septic. A platform is provided above the soffit of the storage chamber from which the screens can be cleared by hand; the amended sump and screens as finally decided upon being an improvement on the draft suggestion.

A float recorder is provided, but the electric motors are not started automatically. A driver will always be in attendance and it was considered that an automatic device ultimately relieving the driver of the responsibility for the level of the sewage in the sump, would not help to produce the alertness necessary for jockeying variable sewage flows against variable steam supply, in order to achieve the maximum economy of pumping. The top of the pump well is open, the motors being surrounded with open type steel flooring.

The Venturi meter is of the water column type, the total pumping head being only some ten feet above the station floor level. This enables the difference in pressure across the Venturi throat to be measured in two 36 in. open ended pipes 10 ft. 6 in. in height—the travel of the float being 13.6 times greater than that obtained with a mercury column, with consequent greater accuracy of recording—especially on smaller flows.

PUMPING STATION CALCULATIONS.

The following abstracts from data and calculations are sufficient to indicate the lines on which these have been made:—

Present Flow An inspection of records for the past four years gives the maximum daily flow pumped and ejected to works as 3,770,571 gallons.

(a) *Maximum*

As a result of gauging during absolute dry weather conditions the night flow from 3.0 a.m. to 4.0 a.m. was found to be 18,000 gallons per hour.

(b) *Minimum*

Pumping Head	Invert level of incoming sewage	..	..	70.34	()
	Lowest invert level of sump	..	..	62.84	
• •	Top water level grit chamber	..	..	109.75	
	Static head	..	..	109.75	
				62.84	
				46.91 feet.	

Friction head in 750 ft. of 30 in. cast iron rising main—
 When delivering 350,000 galls. per hour $V=3.20$ friction head = 1.35 feet.
 When delivering 850,000 galls. per hour $V=8.00=7.5$ feet.
 Maximum total head for present pumps :—

Static	46.91
Friction	1.35
	48.26

Maximum total head when 500,000 galls. per hour future pump installed :—

Static	46.91
Friction	7.50
	54.41

but this is under the worst possible conditions when sump is right out, and future pumps which may be combined with present proposals are working at their maximum output. A maximum head of 50 ft. from all sources will be ample for pumps to be installed at present.

Duty of Pumps.

Pumps should be capable of dealing with a rate of flow equivalent to half the maximum daily flow in 6 hours.

$$\frac{3,770,571}{2 \times 6} = 314,214 \text{ gallons per hour.}$$

or allowing for a 5 years' growth at the rate of 2 per cent. per annum, in round figures 350,000 gallons per hour.

Steam required to lift 350,000 gallons per hour.

Duty of Pump. Gallons per Hour.	B.H.P. of Steam Engine.	Steam Consumption lbs. per hour.
50,000	28	600
100,000	52	925
200,000	72	1,650
Total 350,000	152	3,175

Steam available result of Boiler Test.

Average rate of steaming (coal and refuse) under normal working conditions 3,750 lbs. per hour.

Standby Plant.

As steam from refuse destruction cannot by reason of the variable calorific value of the refuse always be relied upon, and in view of the fact that steam plant has to be shut down for flue cleaning, etc., apart from the risk of break down of boiler or steam mains, it is necessary to provide electrically operated stand-by pumps, which will be capable of dealing with the maximum flow when no steam is available.

Works Pump

be considered unless
 rate or omissions, the

Don.

Name of
 Manufactu

ound
 Feed

E. Reader &
 Nottingham

Do.

34A

CONTRACT No. 1.

In order to facilitate comparison of tenders, contractors must complete the following schedule, and submit same with tender form. No tender will be considered unless the undermentioned details are fully set out. It is ~~not~~ intended to accept portions of the tender at the rates set out below; except possibly to sub-divide steam from electric plant these should however be substantially correct, as in the event of any extras or omissions, the prices stated must be considered as a reasonable basis of agreement. See also Clause 35 of Specification.

[illegible]

CONDENSERS.													BEVEL GEARS.									
Description and Type of Condenser.	Name of Manufacturer	Number and Description of Circulating Pumps.	Name of Manufacturer of Steam Drive Circulating Pumps.	Steam Consumption of Circulating Pumps Engines lbs. per hour.	Name of Manufacturer of Steam Engines.	Number and Description of Valves provided.	Name of Manufacturer of Valves.	Temperature of Water to Hot Well.	Duty of Condensers.		Inches of Vacuum.	Name of Manufacturer and Description of Gauges.	Quotation.			Description of Gears.	Name of Manufacturers.	Total Weight carried by supports per set, including Bevel Gears, Plummer Block, Coupling, etc.	Quotation.			
									Lbs. of Steam per hour.	Cooling Water galls. per hour.			£	s.	d.				£	s.	d.	
Horizontal Single Wet Vacuum Pump 8 - 12 - 12 with attached cone regulating Jet Condenser	Worthington, Simpson, Ltd.	None required				One brass fitted 4 in. Gate Valve on injection inlet One 1 in. Steamed Stop Valve One 1½ in. 3-way Plug Cock on Exhaust Drain Cocks One 6 in. Horizontal Automatic Relief Valve	Ally & McLellan Darsine and Worthington, Simpson	107°F.	3,500 max.	8,400	26 ft. (Bar 30 ins.)	J. Clayton. One 6 in. Vacuum Spring Control				Totally enclosed Spiral Bevels, oil bath Do. Do. but with forced lubrication	D. Brown & Sons Do. Do.	(1) 1,600 lbs. (2) 2,250 lbs. (3) 3,650 lbs.				
													£				£					

SHAFTING.				ELECTRIC MOTORS.										CONTROL GEAR.				
Description, Material, Method of Carrying Weight and Lubrication.	Type of Coupling.	Length.	Total H.P. Absorbed in Transmission Gears, Shafting, etc., per hour.	Quotation.	Duty of Pump.	Type of Motor.	Name of Manufacturer.	B.H.P. of Motor.	Volts.	Amperes at Full Load.	R.P.M.	Efficiency of Motor Load.	Total Weight carried by supports for each Motor, including Base, Bolts, etc.	Quotation.	Type and Description of Starter.	Name of Manufacturer.	Total Number of Meters supplied and Name of Manufacturer.	Quotation, including Wiring to Supply Terminals.
Kirkstall Puller Steel Polished Bar 35 40 tons square inch. Ball Thrust Bearings Grease lubrication from motor floor level	Cast Iron Flanged Type Solid and Pin and Rable Bush type flexible	As shown on Drawing 1931.8904	(1) 1 1/2 (2) 2 (3) 4 (4) 1 1/2 (5) 1 1/2	£ s. d.	100,000 galls. per hour	Dripproof Slip-ring	Lancashire Dynamo & Motor Co., Ltd.	48	400	68	960	4 1/2 3 1/2 1 2 91% 91% 89%	2,450 lbs.	£ s. d.	Floor Mounting Stator and Rotor Oil Immersed	Brookhurst Switchgear, Ltd.	Five Moving Iron Ammeters One do. Volt-meter	£ s. d.
					250,000 galls. per hour	Do.	Do.	95	400	125	575	91% 91% 89%	5,200 lbs.		Do.	Do.	Brookhurst	
£														£ Including Switchboard £				

[illegible]

These consist of :—

- 1 No. 42.5 B.H.P. motor and pump delivering 100,000 galls. per hour.
- 1 No. 86.0 B.H.P. motor and pump delivering 250,000 galls. per hour.

Machinery Schedule.—In order that a reasonable comparison of the machinery tenders should be readily obtained, the schedule of machinery and pipework herewith was embodied in the tender form.

The author is of the opinion that it sets out clearly the essentials of the plant—the details shown are those supplied by the successful contractors—the individual prices submitted have been left out.

In making the selection due allowance was made for steam consumption. The present value of the cost of additional steam required over and above a basic figure being capitalised over 15 years at 5 per cent. per annum and added to the amount of the tender as under :—

Comparative amount of tenders taking into account Present Value of additional expenditure on steam production over 15 years, Firm No. 1 (minimum) steam consumption, being taken as basic figure.

Name of Firm.	Amount of Tender.	Present value of cost of additional steam required (over and above Firm No. 1's steam consumption) capitalised over 15 years @ 5% p.a.	Comparative amount of tender allowing for present value of cost of additional steam.
Number 1	£4,088 0 0	(basic figure).	£4,088 0 0
Number 2	£4,223 0 0	£1,222	£5,445 0 0
Number 3	£4,263 19 0	£527	£4,790 19 0
Number 4	£4,288 5 0	£455	£4,743 5 0

The comparison shows that whilst the difference between the amounts of the tenders of firms numbered one and two is very small, the difference, after making allowance for the additional steam consumption of No. 2 is very considerable, and is of much more importance than the difference in first cost.

Testing.—As erection is not yet completed no tests have so far been carried out. The method of testing and the basis of guaranteed efficiencies are covered by the two clauses appended hereto extracted from the author's specification for the plant, as follows :—

“ Efficiency.

“ The contractor must state in his tender the guaranteed efficiencies of each separate set in the following manner :—

1. Steam Engine (or electric motor) efficiency.
2. Pump efficiency.
3. Overall efficiency of the set.
4. Steam consumption in pounds per B.H.P. hour at 100 lbs. pressure.

Figure 4. — PUMPING STATION : GENERAL LAY-OUT.

36C

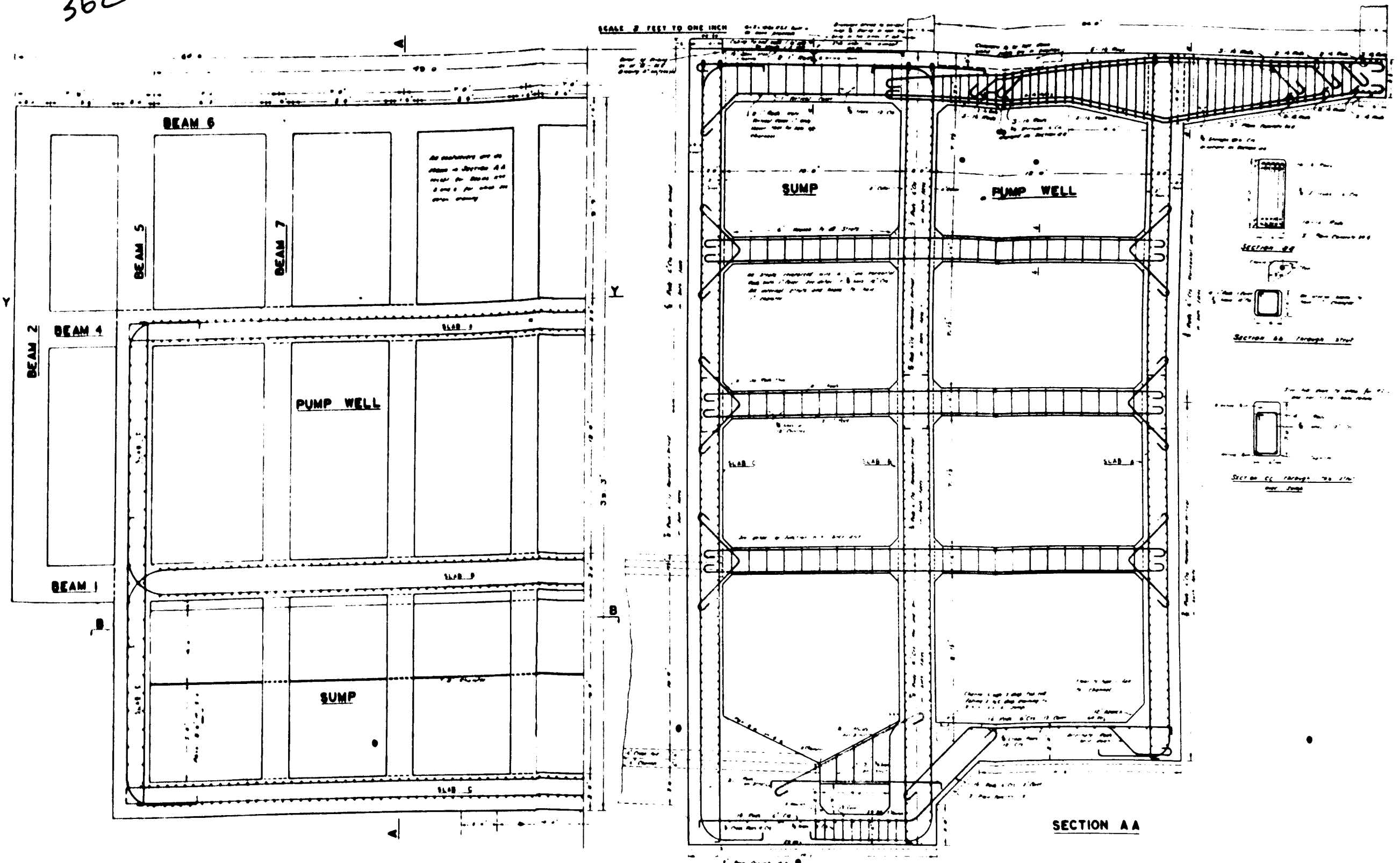


Figure 5. PUMPING STATION: REINFORCED CONCRETE WORK.

Stresses.

The structure has been designed generally for stresses not to exceed 16,000 lbs. per square inch, in steel, and 600 lbs. per square inch in concrete, and in no case does the stress in steel exceed 8 tons per square inch.

Method of Calculation.

The method on which the various parts of the structure have been designed is briefly set out, reference being made to drawing showing reinforced concrete work.

Slabs A and C.

Slabs are designed as rafts carrying a central load W , equal to the strut loading.

The B.M. is calculated on the formula $\frac{W(L-l)}{8}$

Similar rods are placed horizontally and vertically.

To allow for internal sewage loading of sump, and possible internal loading of pump well, the same steel is used in both faces. The steel has been calculated for the external loading, the horizontal external pressure being taken as $40(h+12)$ where h is the depth below ground level in feet. This loading is therefore adequate for the unbalanced amount of internal loading due to sewage pressure which is considered to approximate to $(65h-25h)=40h$, where $25h$ is the passive earth pressure which may reasonably be expected to occur.

Alternatively it may be held that before failure could occur due to internal loading an "active" pressure of earth would be developed to balance internal pressure.

Slabs are made 2 ft. 0 in. thick, the outer 8 in. being left clear of reinforcement for timbering.

Slab B.

External strut loading is transmitted from Slab A to Slab C. Slab B is therefore designed for sewage pressure loading only. Similar steel is used in both faces. Full depth of 24 in. is maintained to keep wall watertight, and to form suitable foundation for station wall.

Slabs D & E.

These are designed on external loading, the same steel being used in both faces, as for Slabs A and C. Slabs are made 24 in. thick, 8 in. being left for poling boards and walings. They are designed as slabs spanning horizontally from slab A to slab B, and from slab B to Slab C.

B.M. is taken at $\frac{WL}{8}$ for the longer span, and the same steel is used for both slabs, the difference of 2 ft. in the shorter span being neglected.

Floor of pump well and sump.

These are designed as slabs spanning between vertical walls M taken at $\frac{WL}{10}$ the load per foot being arrived at by assuming the total weight of the station to be uniformly distributed over the base.

Beam No. 2 (Drawing No. 5).

This beam carrying brick wall of station consists of a cantilever portion between beam 6 and beam 4, supported at beam 4, and held down by portion from beam 4 to beam 1. It is designed on the "steel beam theory" similar steel in top and bottom in order to keep depth shallow.

Beam No. 1.

Simple cantilever.

Beam No. 4.

Cantilever, designed on steel beam theory.

Beam No. 6.

Designed as spanning from cantilever to cantilever. Intermediate bays M taken at $\frac{WL}{12}$ and bays M $\frac{WL}{2}$

Engine Room Floor Slab.

Slab continuous over cantilever M taken at $\frac{WL}{12}$ for mid spans and $\frac{WL}{10}$ for end spans.

Cantilever.

Designed on steel beam principle, same steel top and bottom in order to keep depth shallow.

Struts.

Designed as doubly reinforced beams to allow for a two ton point load at centre of span plus the compressive stress due to end thrust.

Storage Chamber Junction.

Junction with sump section YY drawing No. 4. Beam under junction with sump takes half sump floor loading over this width. M taken at $\frac{WL}{12}$ designed as "steel beam."

Storage Chamber.

Arch Ring.—Pressure is considered as acting normal to surface, thrust line is therefore concentric with arch.

Floor.—Steel is provided in floor to resist the bending moment due to the eccentricity of the thrust.

Alternatively floor may be considered as a beam spanning between supports. Steel is sufficient to resist M taken at $\frac{WL}{10}$

Penstock manhole.

This has been designed for an external pressure of $40(h + 6.25)$ lbs. per sq. ft., with similar steel in both faces to allow for internal loading, as in the case of pump well and sump.

The shaft is designed as slab spanning horizontally from wall to wall, M being taken as $\frac{WL}{12}$

Floor as slab spanning between walls M at $\frac{WL}{10}$

TIMBERING OF EXCAVATION FOR PUMP WELL AND SUMP

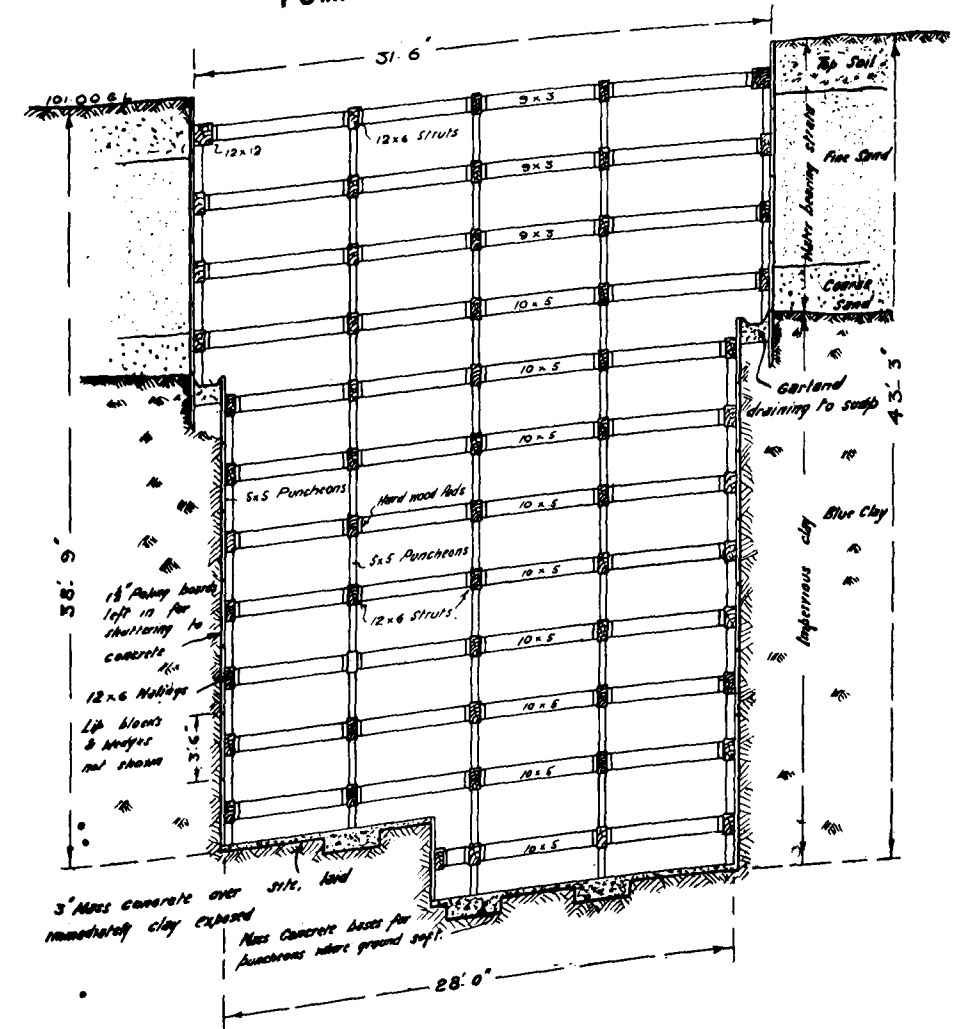


FIG. 6.

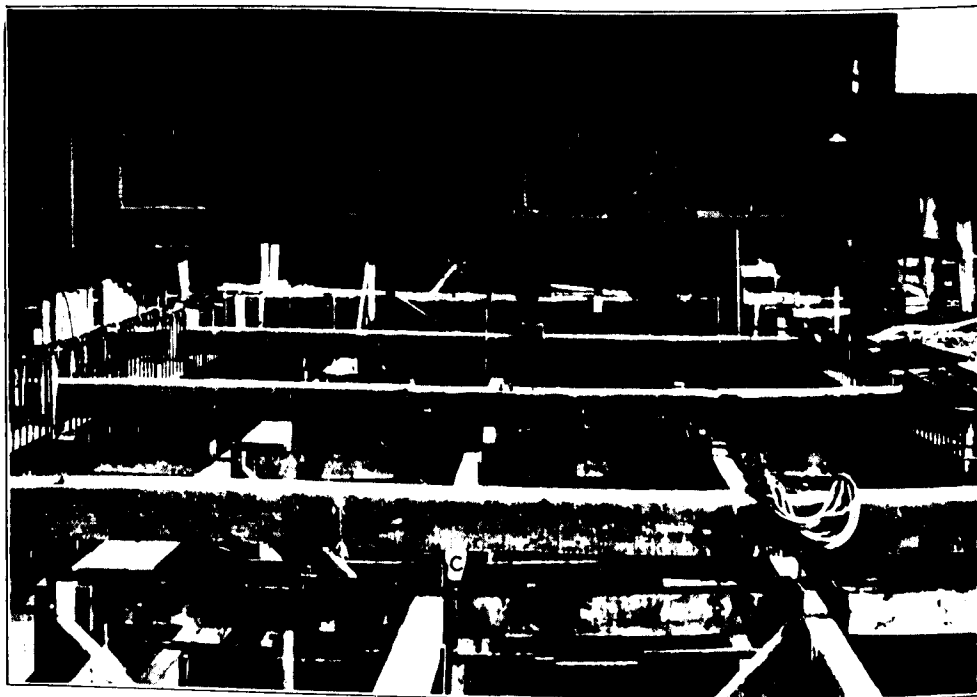


FIG. 7. General View of Excavation for Pump Well and Sump, showing existing Compressor House.

PART III. CONSTRUCTION.

PUMP WELL SUMP AND STORAGE CHAMBER.

Nature of soil and adjacent buildings. The subsoil consists of some 15 ft. of sand and ballast overlying the London blue clay. The clay is laminated and water is occasionally met between the laminations, it is softer than the London clay usually found in London, and does not stand so well.

The risk, and serious consequences, of a subsidence in carrying out this work, were considerably increased by the close proximity of the compressor house, the refuse destructor buildings, and the 80 ft. chimney shaft in connection therewith. Until the concrete walls had been completed to ground level, *i.e.*, during the whole period that the excavation was supported by timber, the verticality of the chimney shaft and the level of the timber were checked weekly. No movement occurred.

It was decided to leave the excavation for the storage chamber until concreting was well advanced in the main excavation, in order to reduce the length of time the main excavation should be supported by timber.

Timbering.—The essential features of the timbering of the excavation are shown on the accompanying sketch. The “garland” effectively intercepted the water in the ballast, the “garland” itself being drained to a sump adjacent, the main excavation thereby being kept dry.

The excavation was taken down in 3 ft. 6 in. frames, the sides being close boarded with 1½ in. boards, the walings were 12 in. by 6 in., the cross struts at 7 ft. 0 in. centres were 9 ft. by 3 in. to a depth of 10 ft. and 10 in. by 5 in. for the remainder of the depth.

The longitudinal struts were 12 in. by 6 in. and the puncheons 5 in. by 5 in. The walings of the lower three frames were also supported by 9 in. by 3 in. raking struts, thereby reducing the unsupported length of the waling to 3 ft. 6 in. As each frame was taken down, the timber was jacked up off the undisturbed soil, finally being supported from concrete blocks below floor level. The timber was prevented from rising by a series of two 6 by 3 channels carried from top to bottom as shown in the accompanying photograph which also shows the existing compressor house in the background.

Effect of earth pressure on standing timber.—As a result of the extreme care and the high standard of workmanship achieved by the contractors, Messrs. A. Streeter and Co., Ltd., of Godalming, there was never cause for anxiety for the safety of the adjacent building. The pressure designed for was 40h lbs. per sq. ft. where “h” represents the depth in feet below the surface, and on measuring the deflection on the timber, it was found that this pressure was very closely approximated to. The only movement of the timber was due to the crushing of the hard wood pads at the ends of the struts, bearing against the walings. This crushing was due to the hard wood pads not being properly seasoned. The timber was jacked tight against the soil before the struts and pads were inserted, and the crushing effect was produced over a period of some weeks.

To what extent this delayed action was due to the well known expansion of the London clay on exposure to atmosphere, and to what extent it can be attributed to “flow” in the clay causing the load to come on after a period, could well form the subject of a long discussion. The sides are large enough—53 ft. long by 44 ft. deep—to eliminate the “arching” effect found in narrow tunnels. Supporters of the “flow” theory must however consider that the 80 ft. chimney only some 40 ft. away is still undisturbed.

Stresses allowed in the timbering were:—

Stress on end grain, half ton per square inch.

Stress on side grain, soft wood, 300 lbs. per sq. in.

Stress on side grain, hard wood, 600 lbs. per sq. in.

Fixing Reinforcement.—In designing the steel, the face of the steel was kept 8 in. from the back face of the concrete, in order to allow the steel to be erected with the walings in position. The rods were kept exactly in their correct position by distance pieces cut out of ¼ in. iron strips, having semi-circular ends to receive the rods, and by wiring to keep them from spreading. On the vertical steel held rigidly in position, the horizontal rods were easily erected.

Shuttering.—The 1½ in. sheeting behind the walings was left in to form back shuttering, the front shuttering consisting of 1½ in. tongued and grooved square edged stuff, dressed both sides, and oiled before use. The shuttering for the mains walls was erected in the following manner. The 1½ in. shuttering was made up into an

PUMP WELL AND SUMP WALLS SHUTTERING FOR CONCRETE

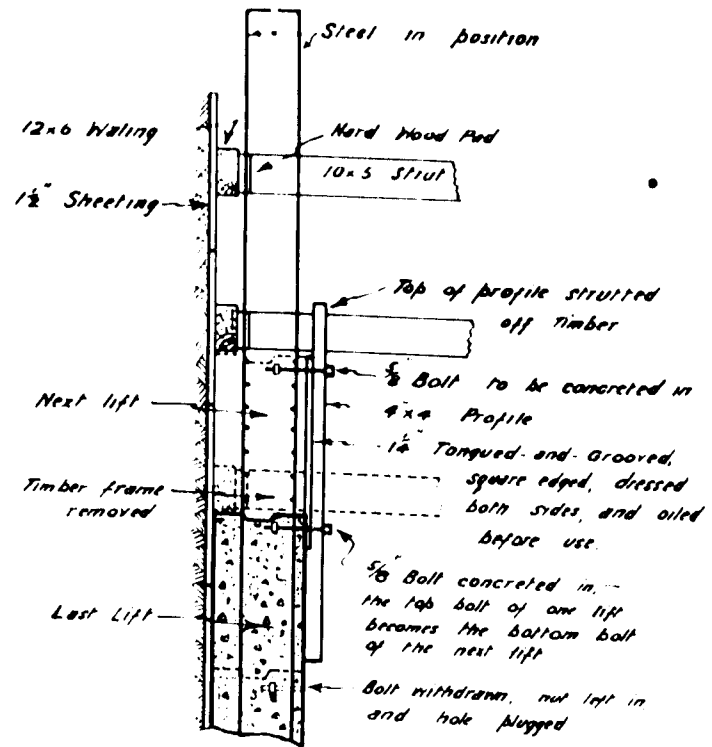


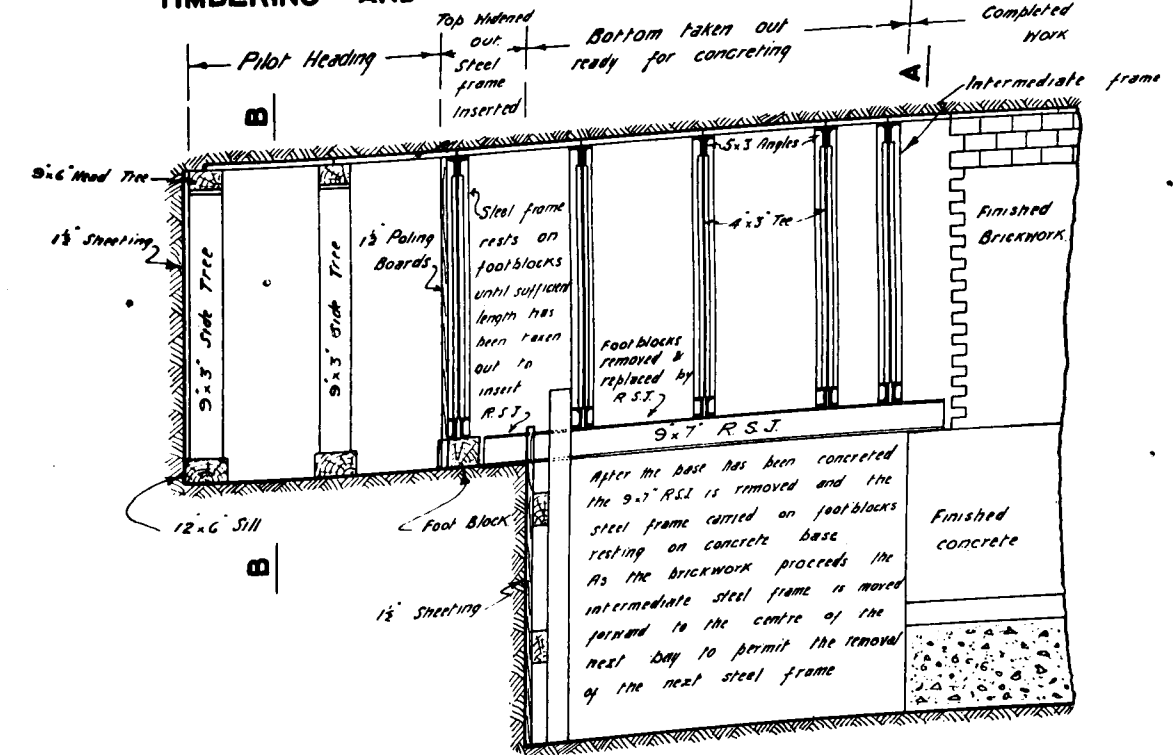
FIG. 8.

area 5 ft. 6 in. long by 3 ft. 6 in. deep, the boards being held together with three 1 1/4 in. battens. This was held in position by three 4 in. by 4 in. profiles, the profiles being secured by 5/8 in. bolts at the bottom and strutted off the timbering at the top.

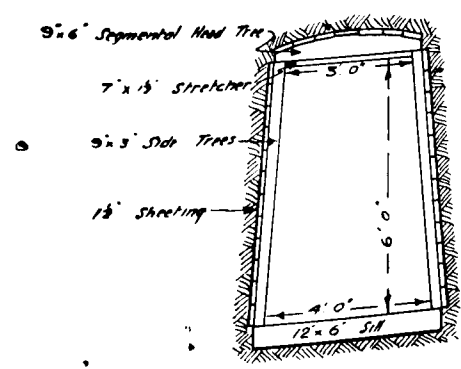
The method is shown clearly on the sketch. The top bolt is set 3 in. below the level to which it is proposed to concrete. The bolt is turned before the concrete sets to facilitate later removal. The shuttering is removed after 7 to 10 days and the top bolt of this lift becomes the bottom bolt of the next lift, the bottom bolt of this lift being unscrewed and withdrawn, the nut remaining in the wall and the hole being finally plugged.

The shuttering was kept wet during the hot weather and any board marks appearing on the face of the finished work were removed by carborundum. The shuttering for the centre walls was erected in this same manner except that in this case the bolt passed through the walls, the nuts being on the outside of the profiles. The bolts were turned in the concrete before the concrete set, and withdrawn on removal of shuttering.

TIMBERING AND CONSTRUCTION OF STORAGE CHAMBER

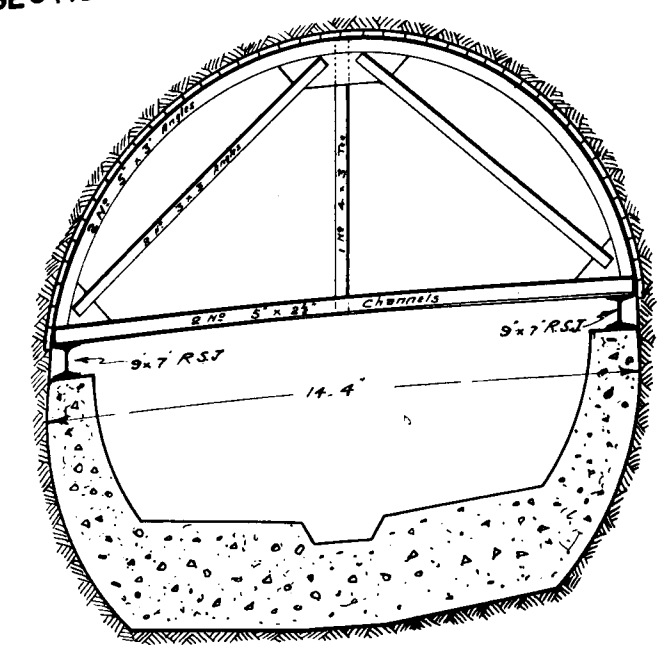


LONGITUDINAL SECTION



SECTION BB

PILOT HEADING



SECTION AA

FIG. 9.



FIG. 10. Storage Chamber showing Method of Supporting Timbering.

Concreting. Before concreting was commenced the existing work was thoroughly cleaned off by water and compressed air, and all concrete on standing steel was cleaned off. The concrete walls were brought up in 3 ft. 6 in. lifts to the underside of the walings, the four external walls and the partition wall being brought up together usually in one day's concreting.

Concreting was mixed at the surface in a half yard hatch type mixer, and lowered in buckets. No concrete wet enough to flow in chutes was used upon the works. To every man employed in placing concrete 2 men were employed ramming concrete around the reinforcement.

Thirty six hours were allowed to elapse before the timber frame immediately above the concrete was struck out. The walings were cut in short lengths in order to get them out from behind the vertical steel already in position.

Storage Chamber. After the concreting of the main walls of the pump well and sump was well advanced, the storage chamber, some 50 ft. in length, was driven from the sump to the penstock manhole shaft. This shaft, measuring 10 ft. 0 in. by 7 ft. 6 in. having been already excavated by the sewer contractors.

A 6 ft. 0 in. pilot heading, 4 ft. 0 in. at the bottom tapering to 3 ft. 0 in. in width at the top was first driven in short lengths, the pilot heading then being widened out to enable the steel frame to be inserted. These frames were at 3 ft. 0 in. centres, and were at first carried by footblocks resting on the earth. To enable the bottom



FIG. 11.—Storage Chamber showing method of supporting Centreing for Brick-work.

to be excavated the frames were then carried on 9 in. by 7 in. rolled steel joists, resting on the earth at the front end and on the finished concrete at the rear end as shown on sketch. The centres of the frames were supported on a further R.S.J. or jacked off the floor as found most convenient. When the bottom had been taken out the steel reinforcement was placed in the invert and the concrete carried up to the springing level of the brick arch.

After the concrete invert had stood for three days the steel joists were removed and the frames carried in wooden blocks resting on the concrete. The brickwork was brought forward to the intermediate steel frame shown on the sketch—thereby supporting the back end of the roof poling boards—the intermediate frame was then removed and placed in the centre of the next bay forward to allow the removal of the next frame.

The method of construction is shown clearly in the accompanying photographs and dimensioned sketch.

CONSTRUCTION OF 4 FT. 6 IN. BRICK SEWER.

Nature of soil.—The brick sewer was constructed entirely in the London clay. Throughout the sewer route the clay is overlaid by an alluvial deposit of sand and ballast, the thickness of clay above the sewer varying from 30 ft. to 1 ft., the variation in depth of clay marking the extent of the "travel" of the bed of the river in the past.

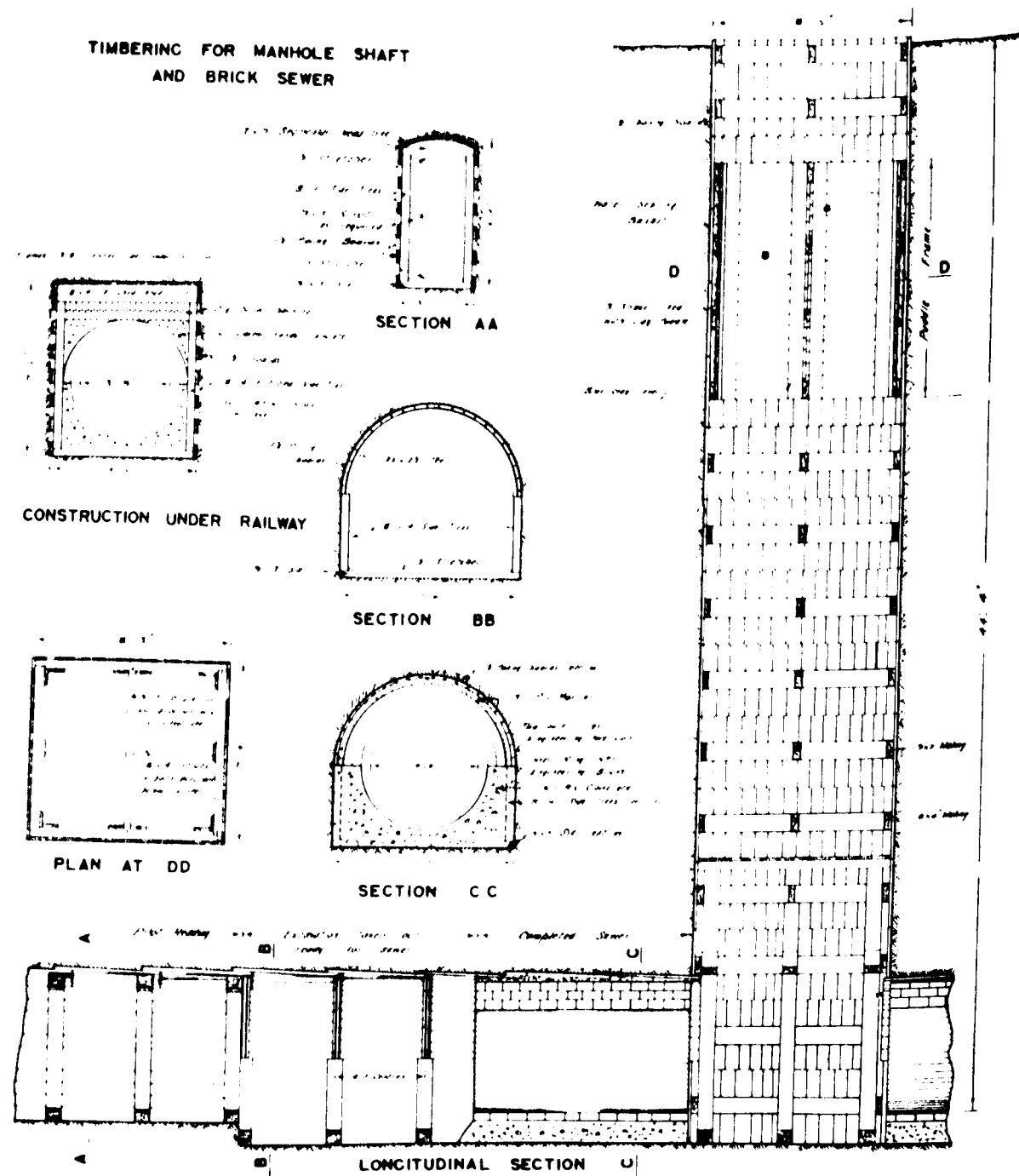


FIG. 12.

This varying thickness of clay cover added to the difficulties of construction, and will be referred to later.

The method of construction is illustrated on the drawings and photographs.

Manhole Shaft.—The timbering for a manhole shaft some 45 ft. deep is shown on the drawing.

The sides are close boarded throughout with $1\frac{1}{2}$ in. poling boards. The walings are 9 in. by 3 in. for the first 30 ft. of depth and 8 in. by 4 in. for the remainder.

Cross struts, 9 in. by 3 in. in one direction only, are used to a depth of 15 ft., at which level the blue clay is reached, after which 8 in. by 4 in. struts are used in both directions.

Water was found at a depth of five feet, and from this level to the top of the blue clay, at 15 ft. deep, a clay puddle frame was used to exclude the water in the ballast. The more general method was to construct the puddle frame outside the shaft, leaving the shaft opening the same throughout its depth, in this particular instance there was not sufficient room to do this.

Pilot Heading.—Tunnels were driven from both ends, the pilot heading being frequently completed throughout before the remainder of the excavation was taken out. In some cases, however, owing to the swelling of the clay with air exposure the pilot was only driven some 30 ft. ahead of the completed sewer.

The pilot heading, as illustrated on the drawing, was taken out some 6 ft. 0 in. high by 3 ft. 3 in. wide. Frames were set at 4 ft. 0 in. centres, the segmental head tree being 7 in. by 9 in., the side trees 8 in. by 4 in. the sill 9 in. by 3 in., $1\frac{1}{2}$ stretchers were spiked to the head tree and sill, and where side trees showed signs of bending 9 in. by 3 in. cross struts were inserted.

Poling boards were 4 ft. 6 in. long—giving a 6 in. overlap, 6 in. wide and $1\frac{1}{2}$ in. thick. The roof was close boarded and the sides were skeleton boarded.

Open and close timbering.—Much discussion has centred round the practice of timbering London Clay owing to the expansion of the clay on exposure to atmosphere. It has been argued that close boarding is preferable because it keeps the atmosphere from the face of the clay, thereby reducing expansion to a minimum. Where this practice has been followed a number of cases of crushing of timber have been reported. With the open timberings, loading due to surface expansion between the poling boards does not come on to the frame at all, the loading of the side trees being thereby considerably reduced. It was found in widening out the pilot heading, that the action of the atmosphere in no case penetrated beyond 9 in. It is considered therefore that the method adopted is to be preferred.

Main Excavation.—With the timbering of the pilot heading supporting the roof the main excavation was widened out to 7 ft. 6 in. as shown on the drawing. Frames were set at 4 ft. 0 in. centres, the sills being 9 in. by 3 in., stretchers $1\frac{1}{2}$ in. stuff, side trees up to springing level only—8 in. by 4 in.

Above springing level the top was supported by $2\frac{1}{2}$ in. by $2\frac{1}{2}$ in. tee iron bent to form a semi-circle. The boards forming the roof of the pilot tunnel remained undisturbed, being tightened with wedges on to the tee iron frame, the pilot framing was then removed, and the top half of the excavation close boarded, the boards being supported by the iron frame. Below springing level the sides were not sheeted, the concrete invert being placed immediately.

Concreting Invert. As indicated above this was carried out in short lengths as soon as the formation was got out. The length to be concreted therefore seldom exceeds two frames 8 ft. 0 in. semi-circular profiles were suspended at either end of the length to be concreted leaving $1\frac{1}{2}$ in. clear between the face of the profile and the finished concrete level. Three or four $1\frac{1}{2}$ in. by $2\frac{1}{2}$ in. battens were then placed against the bottom of the profiles extending for the full length to be concreted. This allowed easy access for the concrete at each side, the battens and concrete being brought up together to springing level. The 9 in. by 3 in. sills and 8 in. by 4 in. side trees were left concreted in, the minimum thickness of concrete over the sill being 6 in. and, in front of the side tree, $9\frac{1}{2}$ in.

Brick Arch. When the invert had been concreted the internal ring of brickwork was brought up to springing level, the centring for the brick arch was supported as shown in the photograph, and the three ring brick arch constructed in 3 ft. 0 in. lengths. The semi-circular iron rings were removed as the brickwork proceeded, the $1\frac{1}{2}$ poling boards in the roof being left in. The space between the

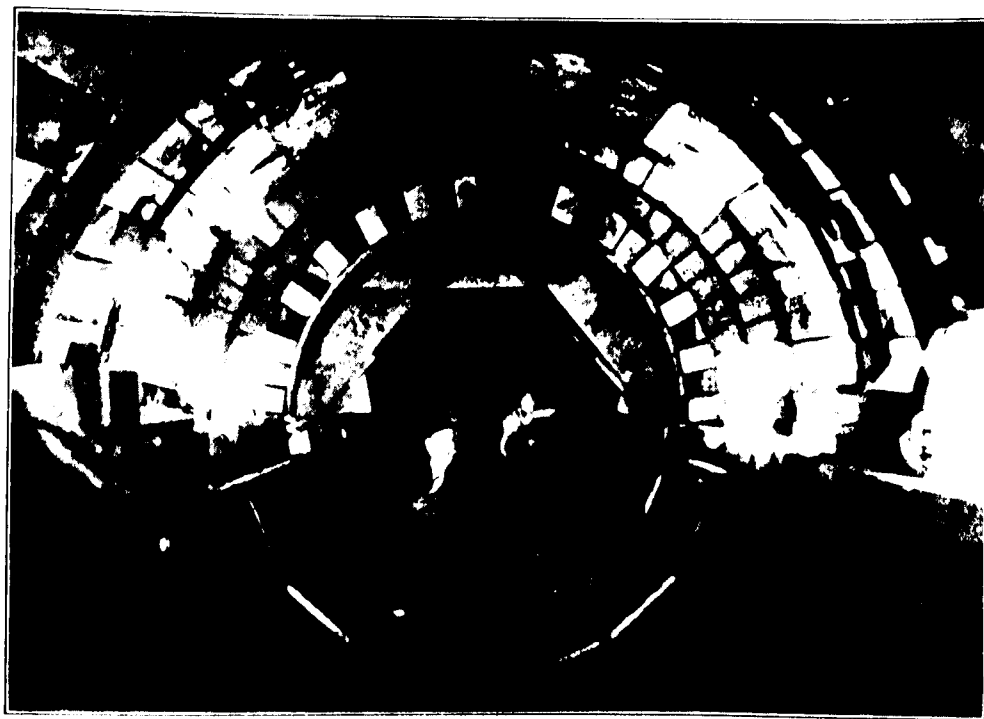


FIG. 13. - Construction of 4 ft. 6 in. Internal Diameter Brick Sewer.

poling boards and the brickwork was packed tight with 3 : 1 cement mortar and broken bricks.

Labour—Pumping—Progress.—All excavation was carried out by hand labour, pneumatic tools not being used on the work at all. The excavated material was run to the shaft by jubilee track and hoisted to the surface by hand winches. It was used to raise the level of some marshy ground, the property of the Corporation in Stoke Park, the finished surface being soiled and sown with grass seed.

As stated above the subsoil water in the old river bed gravels overlying the clay was excluded by puddle frames. The London clay is, however, in this area nearing the outcrop, it is laminated in places, the laminations being frequently water bearing. In addition a bed of clay-stones occurs intermittently at the level of the sewer, this too is water bearing.

The water was kept down by centrifugal pumps, driven by compressed air, delivering about 4,000 gallons per hour. One such pump at each shaft working at intervals was found to be sufficient to keep the works dry.

The rate of progress of the work including sinking shafts, all excavation, building manholes and brick sewer complete averaged about 50 lineal yards per month.

Subsidences.—Two small subsidences occurred during the progress of the works near the River Wey, and are interesting in that they illustrate different type of subsidence. They both occurred in ground where the London clay had been denuded by an earlier bed of the river, sand and shingle, now water bearing, having later been deposited in place of the denuded clay. The shifting river bed results in a subsoil in which it is difficult to predict what subsoil will actually be met, borehole results being applicable only to a very restricted area immediately around each borehole.

In the first instance sand and water were met in the top of the heading, and although the heading was close timbered the sand ran in between the cracks in the timber and filled the heading until its natural angle of repose was reached some 15 to 20 feet along the heading.

In the second case the heading had stood for some few days, the side trees resting on foot blocks. In this case there was a cover of approximately two feet of clay above the heading, between the heading and the water bearing sand.

During that week-end the pumps were allowed to stop, and the water rose in the heading, softening the clay upon which the footblocks rested. When the bearing value of the clay upon which the footblocks rested became less than the loading on them, the footblocks sank into the clay taking with them the side trees and roof timbers. This vertical displacement of the clay over the heading, permitted the superincumbent sand and water to break through into the heading.

In both cases it was necessary to sink a shaft from the surface completely to surround the damaged portion of the heading in order to clear the tunnel and make good.

Construction under Railway.—At the point of crossing under the Southern Railway line, the railway is carried on an embankment, sewer invert level being

some 23 ft. below natural ground level, and 47 ft. 6 in. below rail level. The subsoil is London clay. The method of construction is shown in the sketch. The Railway Company required the dry brick packing over the crown of the sewer. This was simply dry brickwork. The side trees and head trees were 8 in. by 4 in. being flitched with a $\frac{1}{2}$ in. by 4 in. mild steel plate. Sills were 9 in. by 3 in. Frames were 3 ft. 0 in. apart, the sides being skeleton boarded and the roof close boarded.

Protection against chemical action of sub-soil water.—In view of the well known deleterious effects of certain sub-soil waters occurring in clays, samples of subsoil water were analysed from time to time. The earlier samples contained comparatively small amounts of dissolved salts, but as the sewer progressed towards the clay outcrop increasing quantities of sulphates and magnesium salts were met with. Their occurrence was accompanied by the presence of gypsum crystals in the clay. It is difficult to say precisely at what point the soluble sulphate content becomes injurious to concrete. A weak solution may by continually bringing fresh supplies of injurious salts eventually prove harmful.

Ciment Fondu has proved to resist attacks better than ordinary Portland Cement, it being of course of the first importance to prevent penetration of the concrete by water. For this reason correct aggregate grading is essential in order to produce the densest possible concrete. Particular attention has been given to these points, and it is felt that the verdict of time may be confidently awaited.

ACTION FOR DAMAGES AGAINST CORPORATION.

Arising out of the construction of the brick sewer an action against the Corporation and their contractors to recover damages alleged to have been caused by the sewer works was brought by the owner and lessees of a laundry abutting a road in which the sewer was constructed.

The case was heard before Mr. Justice Swift in the King's Bench Division, the case for the defendants being stopped on the fifth day of the hearing after his Lordship had asked Plaintiff's Counsel to consider whether it was in the interest of his clients to continue the action. Mr. Edward John Silcock, M.Inst.C.E., consulting engineer of Westminster and Leeds was called to give expert evidence on behalf of the plaintiffs, and Mr. Godfrey Taylor, M.Inst.C.E. appeared in a similar capacity for the defendants.

Giving judgment his Lordship said that the house and laundry were standing on very dangerous ground, and on an insecure foundation. That was no answer to the claims made in the case. You could not assume from the fact that, directly after the defendants started their sewerage work, cracks appeared in this house and in the houses opposite that the two things were connected, although the coincidence was remarkable. But assuming that one did draw that inference, in order to succeed the plaintiffs had still to show that the damage was caused by negligence on the part of the contractors, that is, that the contractors did something which reasonable people in their position would not have done, or failed to do something which reasonable people in their position would have done. "It is not enough to prove that the defendants' sewer operations have done damage to the plaintiffs

house; it must be proved that defendants sewer operations were carried out negligently, improperly, and carelessly, and on this evidence I cannot come to this conclusion.

"The impression left upon my mind is that the operations which Messrs. Daniel T. Jackson Ltd. carried out were done with all proper care, all proper precautions, and if they did have the effect of letting down this house—but I am far from saying they did—at any rate it was not due to any negligence or impropriety on their part, and the only claim which the plaintiffs may have, and I am not saying they have a claim—is a claim for compensation under some statute which might give them some right, quite apart from proving negligence.

"In this case, before they can recover, they must prove that the defendants have been guilty of negligence, and in my view they have failed to prove that, and there must be judgment for the defendants."

Judgment for defendants was accordingly entered with costs.

CONCRETE TUBE SEWER.

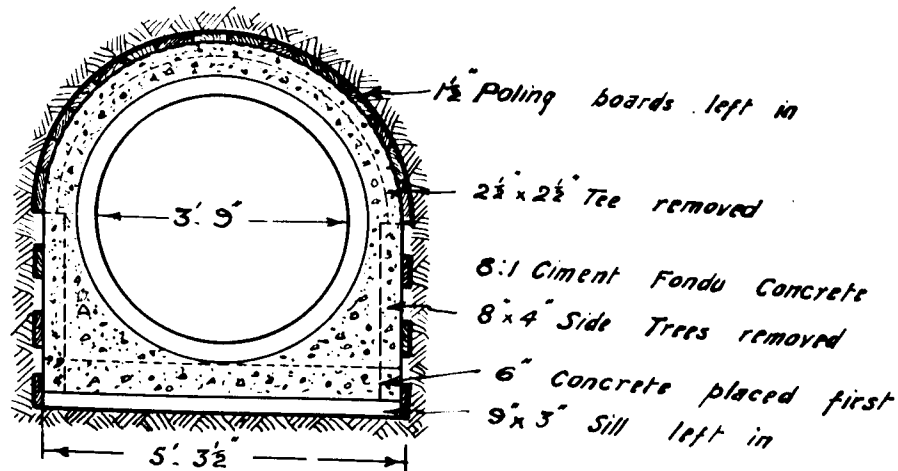
Construction in Clay Subsoil.—The size of the concrete tubes on that portion of the main outfall sewer now constructed varied from 45 in. to 39 in. internal diameter—the length being 4 ft. 0 in., a further section of 21 in. diameter concrete tube sewer being constructed to pick up the flow at present concentrating to Drummond Road Pumping Station. The subsoil was partly London Clay and partly chalk. Dealing first with the construction in London clay; the timbering of the manhole shaft was as previously described for the brick sewer. The clay in this section stood up better than previously and this allowed the tunnel to be driven from manhole to manhole without using a pilot heading. The method of construction is illustrated in the accompanying sketch and photograph. The frames at 3 ft. 6 in. centres consisted of 9 in. by 3 in. cills let into the clay, 8 in. by 4 in. side trees and $2\frac{1}{2}$ in. by $2\frac{1}{2}$ in. semi-circular tees, the roof being close boarded with $1\frac{1}{2}$ in. boards and the sides generally skeleton boarded.

Laying and Jointing.—In view of the chemical action of the subsoil water all concrete used in surrounding the tubes, and for making the joints were made with Ciment Fondu. The tubes being made with ordinary Portland Cement. It was considered that provided the concrete surround was protected from attack, no damage could be done to the tube. After the tunnel had been completed from manhole to manhole six inches of 8 : 1 Ciment Fondu concrete was placed on the bottom of the tunnel, the 9 in. by 3 in. cills being concreted in. The concrete was mixed at the surface, lowered in buckets and run to the site on jubilee track. Concrete tubes having ogee joints were then laid on the bed thus formed and surrounded with 6 inches of 8 : 1 Ciment Fondu concrete, the concrete being packed up tight to the underside of the roof poling boards which were left in. After the concrete had set, and before laying the next tube, the side trees and semi-circular tee iron at the leading end of the tube were removed.



FIG. 14. Concrete Tank Sewer in Clay.

CONCRETE TUBE SEWER



CONSTRUCTION IN CLAY

FIG. 15.

Construction Chalk—Water difficulties.—Driving south, the tunnel passes from the London clay overlying the chalk, into the chalk outcrop. This is part of the North Downs outcrop of the well-known chalk bed of the London Basin. The level of the sewer heading was below the saturation level of the chalk.

The chalk here encountered is mostly hard rock chalk with a number of water bearing fissures and stands fairly well in excavation.

From the commencement considerable difficulty was experienced in keeping the chalk waters sufficiently low to permit the work to be carried out. The quantity of water pumped from one shaft alone before the heading had been commenced varied from 80,000 to 100,000 gallons per hour. This was discharged by electrically operated centrifugal pumps mounted on a staging erected in the shaft. When, for any cause the pumps stopped for a short time, the water rose so rapidly that the men working in the heading had to hurry to the shafts.

Excavating and Timbering.—The timbering of the manhole shafts consisted simply of struts and walings, boards not being generally required.

Tunnels were driven from manhole shaft to manhole shaft without pilot headings at average spacing of 300 feet.

The excavation for the tunnels was taken out square at the top.

9 in. by 3 in. side trees resting on the chalk supporting 9 in. by 3 in. head trees were used, the roof being close boarded with 1 1/2 in. boards. The sides of the heading seldom needed boarding. The general shape of the invert and timbering is illustrated on the sketch and photograph.

Laying and Jointing.—The general method of concreting is illustrated on the drawing. The concrete in the invert was laid successfully by damming back the water from the downstream shaft. Two four inch land drains were constructed at the side of the concrete to carry the water off. Concrete tubes having ogee at the side of the concrete to carry the water off. Concrete tubes having ogee joints were laid on the bottom thus prepared, the greatest care being taken to exclude the water by means of dams until the joints had set. The heading was finally filled solid with 6:1 Portland cement concrete, all the timber being left in.

Test on ogee joints under external water pressure.—As the tunnel was driven further into the chalk the volume of water increased and although the ogee joints hitherto constructed showed no signs of leaking, it was decided to carry out a test on a joint constructed under normal tunnelling conditions and subjected to a 20 ft. head of water.

This test was carried out in conjunction with Messrs. Trollope & Colls at their works at Isleworth.

The object of the test was to determine whether ordinary ogee joints could be reliably laid in heading to keep out a head of 20 ft. of water.

As the test had to be carried out under the conditions existing in a heading the joint was untouched from the outside.



FIG. 16. Concrete Tank Sewer in Chalk.

CONSTRUCTION IN CHALK

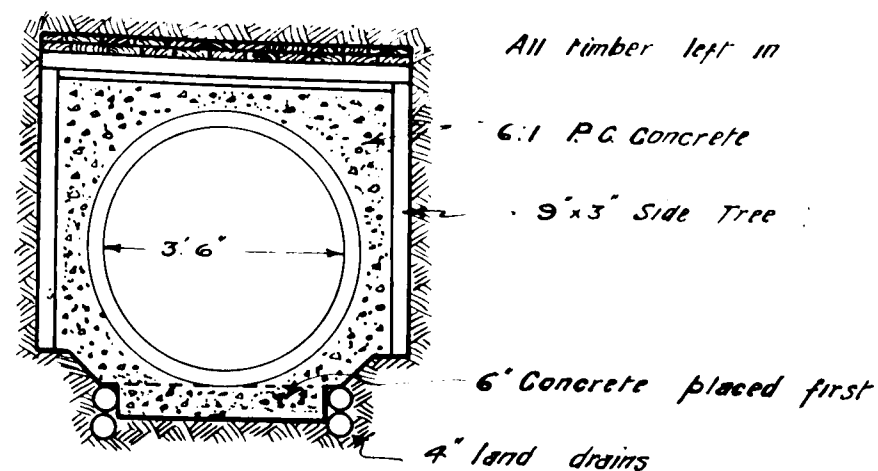


FIG. 17.

The pipes were jointed on the 28th February, 1933, in the following manner. The jointing material consisted of ordinary cement mortar (2 : 1) and was applied to the inside of the lower half of one pipe, and the outside of the upper half of the other pipe, and the pipes were then pressed home in the normal manner.

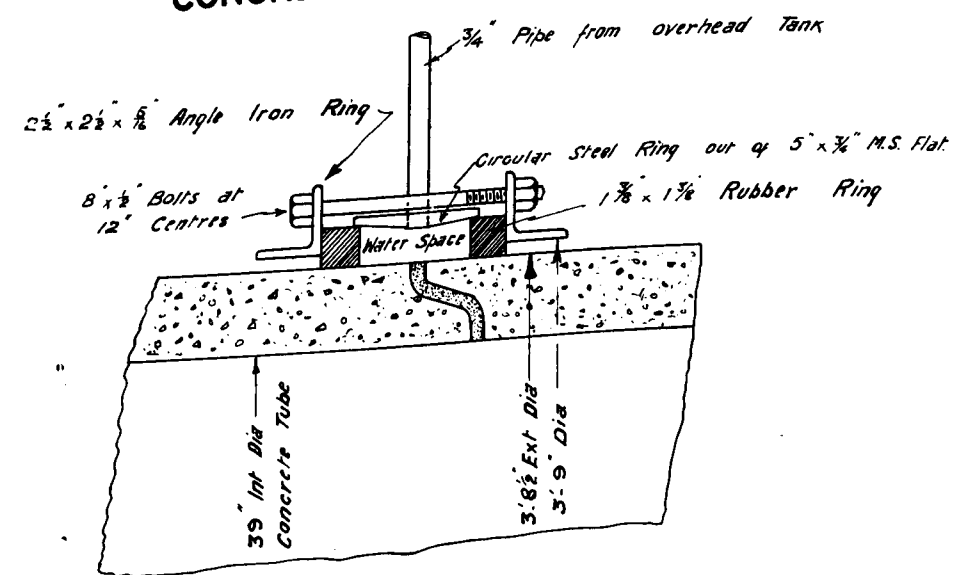
The water pressure was applied after 7 days in the following manner. Each pipe was fitted with a 2½ in. by 2½ in. steel angle ring fitting all round the outside of the pipe, these angles being connected with bolts and nuts which when tightened up caused the square section rubber rings to slide over the outside of the pipes, until, wedging under the circular steel band they made a watertight joint. Water was admitted to the annular space thus formed, surrounding the ogee joints by means of a ¾ in. diameter pipe from a tank fixed 20 ft. above the pipes.

On pressure being applied the joint showed slight weeping at three or four places. On being raked out and pointed from the inside by a representative of the Sika Francois Co. this weeping was practically stopped.

This was not a fair test of the Sika process because by chiselling out the mortar in the joint to apply the Sika, the pipes tended to be jarred apart and start fresh leaks. The test appears to indicate that under heading conditions, ogee joints are not likely to be satisfactory, although they could probably be made satisfactory, at least temporarily, by raking out the joints and pointing.

The author accordingly decided to accept no risk of infiltration and to use cast iron pipes, have turned and bored joints for this section of the work.

CONCRETE TUBE SEWER



EXTERNAL WATER PRESSURE TEST ON OCEE JOINTS

FIG. 18.

For the same reason, turned and bored cast iron manhole segments are being used from sewer level to above the normal underground water level.

CAST IRON PIPE SEWERS

General. In lengths where the quantity of water flowing from the chalk made the jointing of concrete tubes with cement joints impossible, 42 in. and 30 in. cast iron tubes 4 ft. 0 in. in length weighing 21 cwt. and 18 cwt. 3 qrs. respectively, with turned and bored spigot and socket joints were employed. The photograph gives a general impression of the work; the depth of water in the invert can be seen, being about 8 in. deep. The trolley in the foreground is used to run the pipes from the shaft.



FIG. 19. Cast Iron Pipe Sewer.

Side trees and head trees are 9 in. by 3 in. at 4 ft. 0 in. centres. The top is close boarded, but there is no sheeting at the sides. There are no foot blocks or cills.

Method of laying pipes. Bags containing approximately 1 cu. ft. of dry 6:1 P.C. concrete were first laid for a depth of approximately 6 in. to form the bed for the pipe, the line of the invert being fixed approximately by a length of tram rail carefully bedded in the chalk at either side of the heading. The spigot of the pipe was then placed in the socket of the last pipe laid, and the pipe packed up with bags of dry concrete to correct line and level. The method of drawing the spigot home into the socket is shown in the sketch. It consists essentially of a pair of hooks, hooked into

the recess between the end of the spigot and the socket of the joint, some five rings back; these hooks being connected by a steel hawser, swivel, and threaded spindle to a 6 in. by 3 in. channel placed across the horizontal diameter of the socket of the pipe to be drawn home. A hand wheel (clearly seen in the photograph) is then placed on the end of the threaded spindle passing through the channel. This wheel on being screwed up tightens against the channel and thereby draws the pipe home in the socket.

The closing gap between the advancing spigot and the shoulder of the socket is carefully measured as the pipe is drawn home and if it is not going forward square, packing pieces are placed to hold back the leading edge until the axis has been corrected.

Filling heading. When the pipe has been correctly drawn home into the socket, bagged concrete is packed tightly in the space between the pipe and the sides of the tunnel to a point just below the horizontal diameter of the pipe. The remainder of the space is filled solid with hand packed chalk. Actually the photograph shows it being placed with a shovel, but it is apparent from the vigorous ramming that is taking place that a dense filling is being obtained. The side trees, head trees, and close boarding in roof are left in.

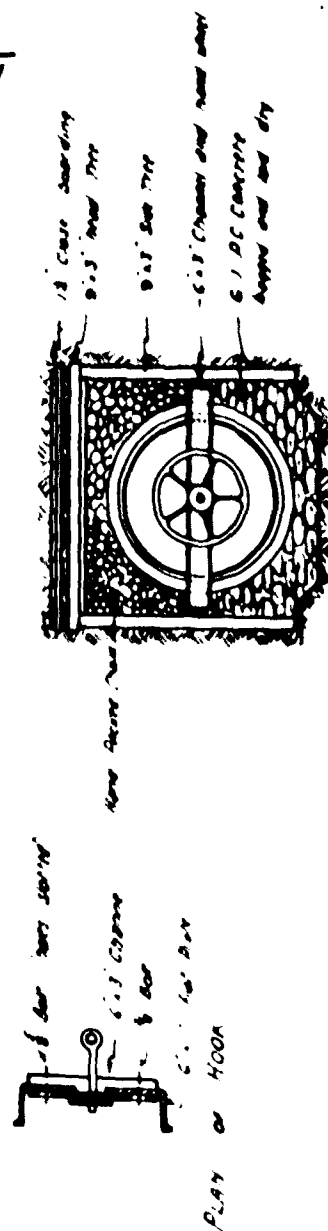
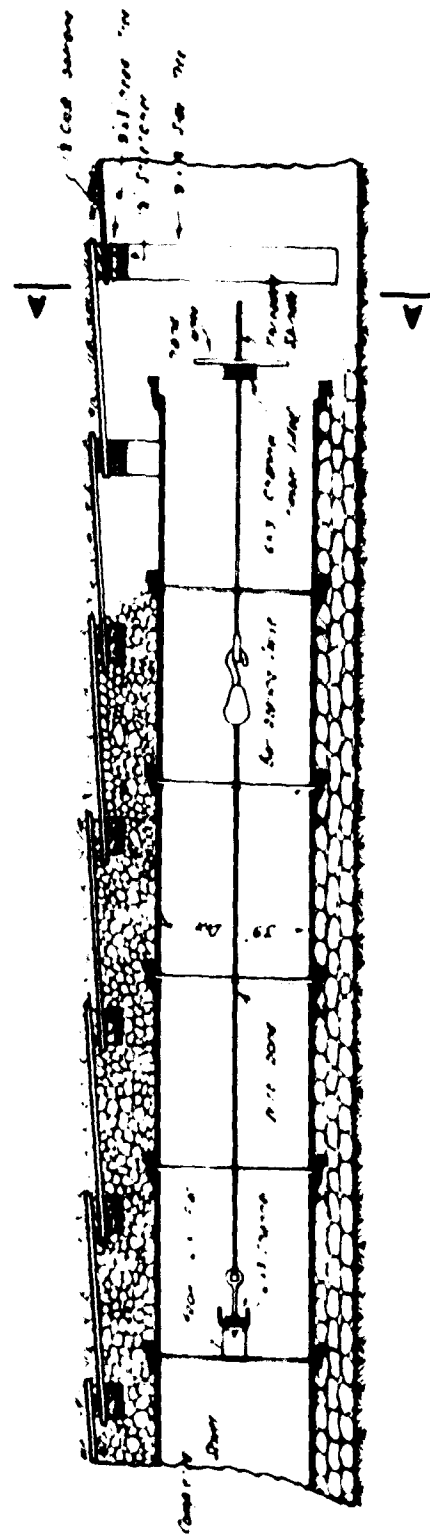
Construction under River Wey—Coffer Dam.—The crossing under the River Wey for the 21 in. diameter sewer from Drummond Road Pumping Station was carried out in cast iron, the pipes were Class C, 12 ft. long and have turned and bored spigot and socket joints.

The bed of the river at this point consists of clay and ballast, the total width is about 60 ft. The work was carried out in two sections, coffer dams being driven from each shore, and barge traffic on the river maintained throughout. The method of constructing the coffer dams was as follows:—

Six timber piles 9 in. by 9 in. were driven into the bed of the river as shown on sketch, 9 in. by 9 in. die square barks were then secured to the heads of the piles to act as guides for the 19 ft. 0 in. steel sheet piles which were driven some six feet into the river bed and to carry the gantry. The sheet piles were held in position against the guide rails and the river bed by 12 in. by 6 in. walings, and 12 in. by 6 in. struts as shown on sketch. The width between the sheet piles is approximately 6 ft. 0 in., the last 5 ft. 0 in. of the excavation being reduced to 2 ft. 9 in. wide by a further timber framing consisting of 9 in. by 4½ in. walings and struts, and 1½ in. runners. The pipes were bedded on and surrounded with 6 in. Cement Fondu concrete; and the excavated material refilled in the river, the bottom frame of timber (inside the sheet piling) being left in. The sheet piling was drawn by means of a 5 ton block and gantry mounted on the timber piling, the timber piling being removed by tackle rigged on a cantilever. The river banks were finally made good with clay.

Whilst driving the piles for the coffer dam, some twenty oak piles were encountered. They were grouped roughly in fours and varied in length from four to six feet, and in diameter from six to fifteen inches. Some of the smaller piles were cleft boughs, the points extending for a length of 2 ft. 6 in., they had no shoe

CAST IRON SEWER - TURNED AND BORED JOINTS METHOD OF DRAWING PIPES HOME



SECTION AA

FIG. 20

and had probably been fire hardened. They were quite black, and the heart wood was sound, although the external annular rings crumbled after exposure to the atmosphere.

They were found some four or five feet below the present river bed and might well have carried a small timber footbridge over a shallower stream. It is interesting to note that a map of Guildford dated 1607 shows The Priory adjacent to this site and the Royal Deer Park (dating back to at least 1267) on the side of the river, so that these piles may well have carried a footbridge giving access from The Priory to the Royal Park.

MANHOLES.

Manholes under 35 ft. in depth were made 2 ft. 3 in. internal diameter, and were constructed either with concrete tubes or with cast iron pipes. In the case of concrete tube manholes, the base was usually pre-cast, although in some cases it had to be constructed in situ.

The concrete tube shaft was surrounded with 6 inches of 6 : 1 Portland Cement or Ciment Fondu concrete, the remainder of the excavation being filled solid with excavated material, all timber being left in.

Where the quantity of water in the chalk prevented the use of concrete, 27 in. internal diameter Class B cast iron, spigot and socket pipes in 12 ft. 0 in. lengths were used. Where possible the joints were made with yarn and run lead, but where the water made this impossible, lead wool was substituted.

Where the depth from the ground level to the invert of the sewer exceeded 35 ft., manholes were constructed in engineering brickwork. The internal dimensions of the shaft were 2 ft. 3 in. by 2 ft. 3 in. and they were built in 9 in. work for the first 12 ft. of depth, 13½ in. work from 12 ft. to 30 ft. deep, and 18 in. work below 30 ft. deep.

Halfway down the shaft a landing with a hinged grating was provided, the size of the shaft being increased to 3 ft. 6 in. by 2 ft. 6 in. for a depth of 6 ft. 6 in. to accommodate same. In deep brick manholes wrought iron ladders replaced the galvanised step irons of the concrete tubes.

In all cases the timber was left in, and except in one or two exceptional cases the space surrounding the shaft was refilled with excavated material.

COSTS.

The author has intentionally avoided reference to costs as several of the works are still in the constructional stage. It is obvious that further mention is undesirable at the present stage beyond stating that the total estimated sum for the Wey Valley Resewerage Scheme and the new Pumping Station (but excluding the sewerage of the new areas added to the Borough) as submitted to and approved by the Ministry of Health was £126,000 and the total expenditures authorised by the Council for these works very closely aggregate to this figure.

CROSSING UNDER RIVER WEY DETAIL OF COFFER DAM

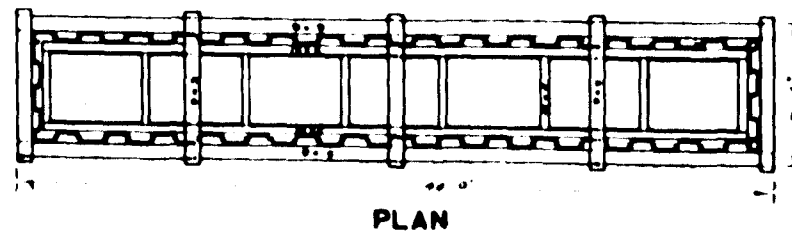
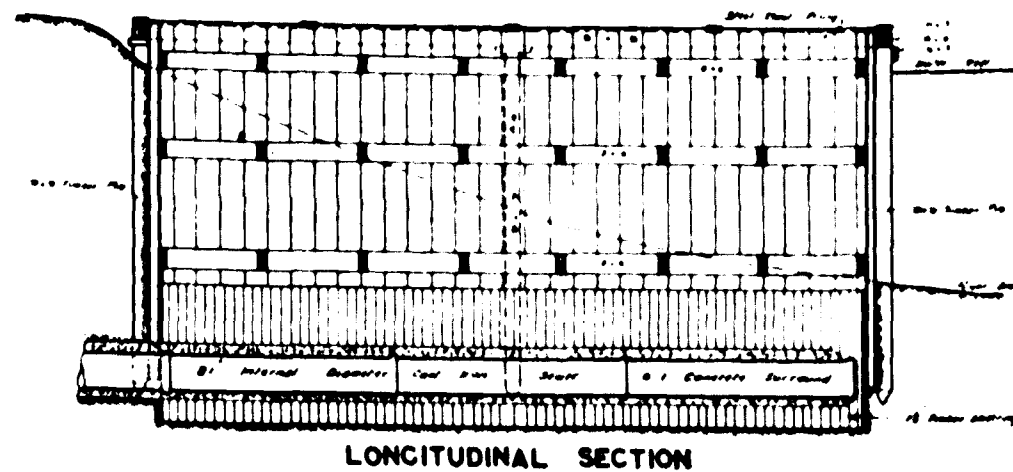
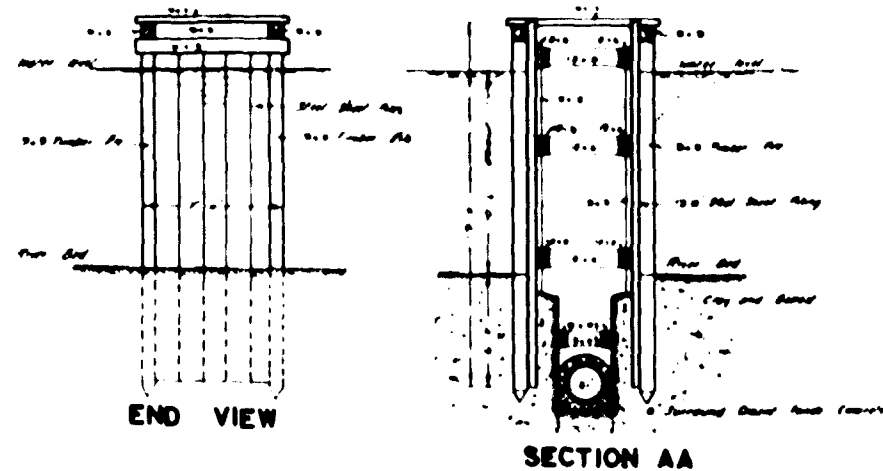


FIG. 21.

ACKNOWLEDGMENTS.

The Guildford Borough Council have been fortunate in the choice of firms selected to carry out the various sections of the schemes all of whom have given of their best throughout their contracts. The principal are as follows:—

Contracts for:—

Messrs. Daniel T. Jackson Ltd., of Barking.	A total length of 3,050 yards lineal of 54 in. and 51 in. brick sewer, and 45 in. and 21 in. concrete tube sewer.
Mr. A. E. Farr, 39 Victoria Street, Westminster.	A total length of 1,580 yards lineal of 42 in. and 39 in. cast iron and concrete tube sewer.
Messrs. A. Streeter & Co., Ltd., Godalming.	Excavation and reinforced concrete work for pumping station and well.
Mr. H. Ashenden, Guildford.	Superstructure of pumping station.
Messrs. Worthington Simpson Ltd. Newark-on-Trent.	Machinery and pipework for pumping station.

The duties of the collection of the author's data and the detailed development of the scheme have been safely entrusted to his Chief Engineering Assistant, Mr. C. E. Woodger, B.Sc., A.M.Inst.C.E., whose collaboration in the preparation of this Paper has been greatly appreciated. Mr. Woodger has been ably assisted by Mr. R. H. C. Woodham, A.M.Inst.C.E., whose services were specially secured by the Council for such duties together with the subsequent duties of Resident Engineer.

The valued specialised services of Dr. Oscar Faber, O.B.E., M.Inst.C.E., were requisitioned for the verification of the reinforced concrete pump well design and calculations and he has also been held jointly responsible with the author for the construction of the pump well.

DISCUSSION.

Mr. J. W. Hipwood, introducing his Paper said: I have put this paper forward in the hope that it may act as an example of the necessary sanitary developments appertaining to smaller towns, where these towns have changed from medieval or Victorian conditions to post-war conditions. Guildford is one of those jewels which lie on the threshold of the metropolis which is now being discovered, and it is because of its popularity among the better thinking class of the community that such problems as I describe arise.

There was a sewerage system inaugurated in 1896 for the older portion of the town where a combined system was not objected to, but we are now a town where the separate system is strictly enforced. In spite of that, however, there is a considerable amount of infiltration water which finds its way into the sewers and has to be dealt with; we find on measurement that our dry weather flow is perhaps 1½ million gallons a day, and that our maximum measured wet weather flow is 3.58 times that amount. That led to considerable discussion with the Inspector who took the inquiry, and he was satisfied that in the circumstances we should be allowed to lay our new system down on 4 times the measured dry weather flow, based on town planning densities for the areas which are to be absorbed and have recently been absorbed.

Our area has recently rather more than doubled, and we have taken the town planning densities and have calculated our ultimate run off on that basis. We have, of course, made allowance for the reservation and preservation of open spaces of ample magnitude. If you total up the number of houses which are provided for, as given in the paper, and multiply them by 4½ persons per house, you will see we allow eventually for a population of something like 150,000 people. That may be considered excessive, and probably it will be, but I do not think we shall be very far wrong in making the sewer of sufficient capacity for that. We are a cathedral city, though the cathedral has not yet been constructed, and it will naturally attract to itself a population which should, in the circumstances, be allowed for. It will not be possible, as members who know our town may have observed, to duplicate the

sewer economically. It may be asked why we make it of the ultimate capacity now, but the answer is that the cost of making the sewer a little larger is small in comparison with the cost of the tunnelling works which we had to carry out, so that it is infinitely worth while now to make the sewer sufficient for all time.

The next question was how far up the Wey and the Tillingbourne we should provide for taking the sewage from. There are adjacent local authorities who have their works situated at Bramley and at Godalming. Having considered the matter in all its aspects, the Ministry of Health are quite satisfied that by our concentrating all the flows from what is now known as Greater Guildford and the adjacent areas which we anticipate will eventually come into the borough at the next extension, we shall have completed all that can reasonably be expected in the way of centralisation of sewage disposal works.

You will realise that no reference is made in my paper to the sewage disposal works. These have recently been partly converted from the broad irrigation system to a sewage disposal plant which has been laid down under the guidance of Messrs. Dodd and Watson, and these works are at present of sufficient capacity for a population of 30,000 and are capable of indefinite extension. There is no specific reference, as I say, to the disposal works themselves. We have at our sewage disposal works a refuse destructor, and, having considered the question of refuse disposal in all its aspects, and with experience of salvage works and other types of disposal of refuse, we are of opinion that the best method is to continue using the refuse for steam raising purposes. We have at the present time for the more distant districts, as well as supplementary for the central portion of the town, a system of ejectors which are not so economical as the lifting of the sewage at one central station, as has been planned by the present scheme. We are now, by the construction of this long length of intercepting sewer, bringing everything on to the site, and are lifting direct, chiefly with the steam available from the disposal of house refuse, supplemented by coal, which we always have available. Our sewage works manager, who is present, has

most successfully coped with that problem at all times, so that no flooding normally occurs, and under the new conditions flooding will be entirely prevented. At the same time, he has had an extraordinarily difficult task before him in managing the distant stations, as they are in effect, all at one and the same time, particularly in flood periods. We are therefore proposing to instal units of steam plant, which will lift direct to the sewage works which have recently been constructed by Messrs. Dodd and Watson.

With regard to the design of the pumping station, those who are particularly interested in reinforced concrete work may find the information in the paper of considerable interest. I have endeavoured, with the help of my chief engineering assistant, to set out the development of the scheme from beginning to end, giving as far as possible the methods and the circumstances which have guided us in the designing and also in the execution of the work, which has been very ably carried out under the guidance of my resident engineer, Mr. Woodham, who is one of our Chairman's pupils and who has given my borough the utmost satisfaction by his work.

The contractors who have striven with these works have had a very difficult task to perform. Messrs. Daniel T. Jackson Ltd., of Barking, have had to struggle with the problem of London clay. Many of you, I expect, will be able to tell me a great deal more than I have experienced or know of works in London clay, but our experience has been rather exceptional in one or two respects, and particularly with regard to a claim made against the Council for the movement of a building which took place within the same year that our works were excited underground. I have briefly referred to that in the paper. It interested several of us for five days in the High Court before Mr. Justice Swift, and I give a summary of his conclusions, which I feel are of considerable interest to engineers as regards their actual liability with regard to adjacent properties.

Again, when we passed from the London clay to the Thanet sands and the Reading beds, we found that the atmospheric effect on the Reading beds was very different from that which obtained on the London clay.

London clay is influenced by the atmosphere in a very exceptional manner, which I believe is unique and not found in the case of any other subsoil or geological formation.

When we tunnelled into the chalk we again met with exceptional difficulties. We went through the upper chalk, of course, and met with the usual layers of flints, but, as we went forward and cut through the up-titled middle chalk, we found somewhat different conditions underground from those that we anticipated, and our contractor for that section of the work, Mr. A. E. Farr of Victoria Street, had very great difficulties to encounter. We are extremely obliged to him for the very capable, competent and plucky way in which he tackled all the problems which arose. I believe that at one period he was pumping from his tunnel as much as eight million gallons a day of the water coming through the fissures in that chalk. However, those difficulties have been overcome, and we are approaching the completion of the work.

It gave rise to an interesting comparison between the use of concrete tubes and cast iron pipes. I think I was wise in advising my Council that we could only be certain of avoiding infiltration by the use of cast iron pipes for the tunnel and manholes until we got right above the water level. By their use we spent some £15,000 more than we originally anticipated, but fortunately the tenders were lower than the first estimates, so that we are not likely to over-spend our total figure. We feel satisfied that on the completion of the present section of the work, which you will realise covers only half the distance provided for in the run-off, we shall have a scheme which will be well worthy of the future cathedral city of Surrey.

THE CHAIRMAN (Mr. Henry C. Adams), proposing a vote of thanks to Mr. Hipwood, said: I notice that the same rate of flow-off is taken from all the areas; that is, half the total flow passing off in six hours. That is a time-honoured rule which is sufficiently accurate for a main outfall sewer such as this one, but I very much doubt its sufficiency for small areas with populations of 500 and upwards. The sewers must be large enough to take the flow during the maximum hour, and the maximum six hours are not of very great moment.

The law case referred to, as I read it, lays it down that so long as one is not negligent one is not liable for any damage done to surrounding property. These legal cases, of course, are always involved, and it may be that the plaintiffs in this case took action under the wrong Act, or that there was something technically wrong with their claim; but it does not seem to me right that you can damage any sort of property and, as long as there is no negligence, the owner has to suffer.

Mr. A. P. I. COTTERELL (*London*): I notice that the author, like a good engineer, has accommodated his scheme to the natural characteristics of the place. He has had one or two advantages. I understand that Guildford has been blessed with a separate system, apart from one small portion which is so small that it does not very much affect the whole area. That has been a great advantage to him. He has also had a fairly homogeneous district of much the same character of inhabitants and industries throughout. He has also acted as a good engineer in making use of such facilities as he had at his disposal—the refuse destructor plant for steam raising, and also the electric energy owned by the Corporation.

I see he looks forward to a 57 years' development, and he has told us that that would involve a population of something like 150,000 persons. It is a big figure, but if it were at the rate of 2.07 per cent. per annum each year it would come to even more than that. I imagine he means 2.07 per cent. per annum on the present population of 30,000, because at a cumulative rate he would have something like 200,000 people to deal with, which is rather beyond what the main sewer, and probably the branch sewers, would be able to stand.

On this question of increase, we are told that we may expect by 1950, and some say by 1940, a stationary and possibly a declining population. It is fairly clear that if that comes to pass, it will affect certain parts of the country and not, perhaps, others. There will be some parts of the country which will go on increasing, and it may be that Guildford will be one of these. Its proximity to the London area, which seems to go on growing and growing, will help towards that. But apart from Guildford, there may be disappointments in store for

some who reckon that their districts will continue to grow, and who will find that not only are they stationary but that populations will move away to other and perhaps already enlarged districts. I note that the author has wisely planned for a pumping plant only five years ahead, and, if the cumulative rate of increase be taken, rather less than five years; but he has it in such a form that it is obvious he is ready to deal with a much larger flow as the necessity arises.

With regard to the ratio between the maximum and the dry weather flow of 3.58, I must regard that as satisfactory. I think it points, of course, to some amount of infiltration and some amount of rainwater from houses and yards, probably, getting into the sewers. We hear there is a small area where that does happen, but to have a ratio of only 3.58 in a town of this size is to my mind a satisfactory feature.

With regard to the pumping station and the pumping plant, it is quite right that Guildford should utilise a source of power at the refuse destructor works already in existence, and in my opinion the author has rightly advised his Corporation to do so; but, if it had not been that it was there already, it is quite a doubtful point whether it was worth while to use such a source of power. I have endeavoured to see what I could from the figures the author gives, though I should like to know a little more; but if I read his text values properly, then, taking the calorific value of the coal he uses at about 13,000 B.Th.U., he does not give the type of boiler or the calorific value of the coal; then the calorific value of the refuse with which the coal is mixed cannot be more than about 1,000 B.Th.U., a very low combustion figure and one that will possibly cause him trouble; because, being of a varying quality, his engineers must keep a constant eye on the steam-raising capacity of the plant in order that steam may be kept up. We know how difficult it is, even with ordinary coal, to maintain a high steaming rate and keep it steady, but when you have refuse to deal with it becomes a much more difficult problem, requiring much more care.

With regard to the use of electricity as a stand-by, I agree with the author that he has utilised a right source of power, but it is fortunate for him that the electric

installation belongs to the Corporation; I rather fancy that, if he had had an outside electricity company to deal with, they would have asked him for a fixed annual charge based on the kVA capacity, which he would have had to pay regularly, whether he used the electric power or not. If that had been the case it might have been well worth while to consider the use of stand-by oil engine plant rather than electricity.

I agree with the author's views about the use of compressed air and ejectors, and I also like the general design of the main pumping station. In passing, with regard to the use of every source of power, I am interested to learn that sewage works have recently been installed for a 39,000 population. I expect the author knows that he has an unused source of power there, and I hope some day he will make use of it; he has something like 40 h.p. which would be available by utilising the sewage gas, which would go a long way towards the required power for his pumping station. I should like to know a little more about the type of steam engine and boilers that he has there. I see that his steam consumption per B.H.P. works out for the proposed works to about 21 lbs., which seems to me to be rather a high figure. Perhaps he could give us further details about that.

I should like to ask for a little further explanation of the way in which the second of the subsidences referred to was tackled; from reading the last paragraph of that section I cannot follow how the damaged portion of the heading was made good.

The parts of the paper which dealt with the protection of the concrete against chemical action of the subsoil are also worth noting. I have had some little experience of the damage caused to ordinary Portland cement concrete by the subsoil water in the clay. It is difficult to tell how far the deleterious action will penetrate. I am inclined to think that with mass concrete only a small portion of the concrete of the outer face will be damaged to any serious extent, because by that time the remaining part of the concrete will be sufficiently set to resist the acid action of the water in the surrounding soil.

I passed through Guildford several times while these works were going on, and I noted what I thought was their very good

fortune in having a fine chalk subsoil to work through. The paper is illuminating in that it shows that one cannot judge from surface indications. I had little idea, when I was held up by the large obstructions necessarily placed in the streets, that they were passing through difficult water-bearing formations and were having to cope, even in the chalk, with flows of water which rendered sewer laying anything but easy.

ALDERMAN ROGERSON (*Worsley U.D.C.*): I am interested in what Mr. Hipwood has told us about the way the sewage system is dealt with in Guildford, and I should like to be supplied with a copy of their by-law which allows them to have the separate system. This question has been a source of very great trouble to my urban district, inasmuch as the builders are demanding the combined system from the Council, although there is every facility in the district for the use of the separate system. I should be interested to know what happened when Guildford sent their by-laws to the Minister of Health when they had made them, because he has informed the property owners or builders in our district that they may have the combined system if they care to have it. I should like to ask the author if we should be justified in telling the Minister of Health to mind his own business and let us mind ours.

We have a district with a slope straight from the bottom of the district to the top, a rise of about 80 yards between the bottom and the top, and there are plenty of shallow water-courses. If we took the over-water from the buildings in the district it would make it impossible, especially in case of a storm, to deal with our sewage at all, and I suggest that if we had the combined system it would tend to pollute the streams to a greater extent than occurs with the separate system. By the use of the separate system we can keep the storm water out of our sewage farms, and incidentally we have the broad irrigation system on all three of our farms and we find it quite satisfactory.

MR. G. T. COTTERELL (*London*): I notice that the author has been somewhat fortunate in the fact that on the calculated basis he finds that the full development will be complete at the rate of about two per cent. in 57 years. I agree with him that it is a

very wise precaution to have the sewer large enough to take that flow. I think, however, there is a little error in taking the flow that he has calculated at four times dry weather flow; I should assume it, on the basis that he gives, at eight times D.W.F. I notice, for instance, when he takes the figure of one-sixth of a cubic foot that is based on the D.W.F. being the peak flow, whereas the actual D.W.F. should be the average flow for the day. I am assuming from that that his maximum discharge of 3,770,571 gallons per day, as compared with his average rate of a little over a million gallons, is an average taken over the whole day, and that there may be times during that day when the peak flow is coming down; the maximum peak diurnal flow for a short period might be increased to once D.W.F. times more; in other words, instead of being a maximum flow of 3.58 it would be 4.58. On the other hand, probably he keeps to the rate of his pumps, and he is balanced to a very large extent on his peak flow by the storage capacity he has in the sewer and in the short length of storage chamber adjacent to the sump. However, even then I am inclined to feel that the figure of four times D.W.F. is not the right figure, but that it should be nearer eight times D.W.F.

However, I think that is a very wise position, because it enables him to provide for future developments which may take place in Guildford. Imagining that the future development of Guildford will reach its maximum in 57 years, it may be fully anticipated that, before that period has expired, further extensions of the borough may take place, perhaps in the direction of Godalming; and it may even be imagined that Godalming at some time might like to discharge its sewage through Guildford, and then the load on the Guildford sewer, if the authorities there could see their way to accommodate it, would be rather heavy if there was not a margin. It would be undesirable to have to construct two sewers, after facing all the difficulties which the author has had to encounter. Again, there is the advantage of ventilation through the sewer. If the sewer is not running full there are much greater facilities for proper and efficient ventilation through that sewer.

He has also designed his pumping plant

on the same basis, and I think he will find he has a margin of pumping plant that will provide for longer than five years. That again is an advantage, because I should imagine the calculations must have been made out two years ago, and when the works are completed and put into use it may be that half the period of five years will have gone by, so that it would be necessary to begin designing additional plant very soon. From that point of view the margin of additional capacity available is a great advantage.

The author mentions that the pumping plant will be carefully arranged so that there is no overload on the disposal works. He will correct me if I am wrong, but I think according to the figures the smallest units are 1.1 times D.W.F., the next size 2.2, and the next size 4.5. If either of those two units, the 1.1 and the 2.2, work together, or if the larger one, the 4.5, works it would mean that the sewage lifted would be going over the storm overflow at the disposal works. Presumably the disposal works are designed so that three times D.W.F. passes through the clarifying tanks. The effect might be that sewage, and not necessarily storm water, was passing on to the storm water tanks, unless there is careful management in the pumping, and therefore the pumping plant will have to operate more or less at short and frequent intervals, possibly continuously. I feel sure the author has that in mind.

In the section of the paper dealing with construction, the author refers to London clay and its effects, and he mentions the crushing of the hard wood pads at the ends of the struts, bearing against the walings. He refers to it again in connection with the tunnel headings, and he refers to the expansion of that clay. I am inclined to think it would more likely be the contraction of the clay, because as he pumps the water he must de-saturate that clay, and therefore the de-saturation would tend to cause a certain amount of contraction, but at the same time there might be a certain amount of lamination and something similar to flow might occur, and the clay would be more readily pressing or falling against the timber and creating that pressure. He refers to the fact that the chimney foundations were not affected 45 feet away, and that is

how he came to the conclusion that it would be expanding, but I would suggest that the angle of repose, or the actual effective angle, does not get back to that chimney; it is probably a very much steeper angle than 45°, and it is very unlikely that the chimney stack would be affected in the course of construction of the sump, and probably when the saturation of the clay was renewed after the works were completed that danger would be non-existent.

I notice the author has a screen in the sump with bars about 2½ in. apart. I know he anticipates the possibility of having to rake it, and I think it is quite likely that he will find it necessary to rake it. I would put it to him, therefore, that the arrangements there may cause a little difficulty in raking, and possibly compressed air might be used to clear the screens.

Mr. H. M. ENDERBY (Canterbury): In Part I of the paper the author refers to the flooding which occurred in several low-lying districts being pumped into the high level districts. I should like to ask him if he received any claims for compensation through the flooding which occurred in the high level districts; usually one got many claims from people who said, "You have pumped this water into our district; it is not a natural flood." I was going to ask him also about the storm water being kept out of the sewers in a separate system, but that question has already been asked. In Canterbury we allow no surface water to go into our drains, but I hope you will not ask me for a copy of our by-laws!

Referring to the calculations for the Wey Valley main outfall sewer in Part II of the paper, I cannot quite see how the author has got at his figure of 37 gallons per head per day for calculating the whole of the area. On the previous page it is mentioned that the domestic water supply is 30 gallons and the trade is 7 gallons, and then further down the page the actual pumping during dry weather flow has been taken as 37.7 gallons. In calculating the whole area which is to be provided for, the figure of 37 gallons per head per day has been taken for the number of houses in the area based on the town planning densities, and then I notice that the trade wastes have been added. It seems to me that this is an addition which should not have been made, and that the

7 gallons for trade wastes has already been included in the 37 gallons per head per day. It is always difficult to find a method by which one can estimate the flow or run-off from these large areas, because conditions vary in different districts.

On the next page, under "Syphoning and Pumping," mention is made of duplicate syphons being used, and I should like to ask the author if he has had any difficulty through the silting up of these syphons which are duplicated. I am assuming, of course, that these syphons are taken to a common chamber on each side. I have found, when using this method, that as soon as the slightest obstruction or deposit gets in one of the syphons it creates a greater resistance in that syphon, and the water flows very much more easily through the other one, with the result that the first gradually silts up.

Under "Pumping Station Calculations" I think there is an error in calculating the friction head in 750 ft. of 30 in. cast iron rising main. The paper says, "When delivering 850,000 gallons per hour $V=8.00$." I believe that figure should be about 7.77. I calculated it in the train, so that I may not be quite accurate, but I do not think the velocity will be 8.

Fig. 6 gives a very good diagram of the timbering, and I should like to ask the author if this diagram was supplied to the contractors before the work was commenced, or whether this is the method which was employed by the contractors.

Mr. H. C. H. SHENTON (London): A point which should be emphasised is the support which the author has given to the iron pipes. These iron pipes are very carefully supported with concrete and protected against lateral expansion. I have reason to know that iron pipes are sometimes put in without proper lateral support; and I have seen pipes larger than these at Guildford which have been cracked simply by the weight of the earth on them. I have also seen exactly the same thing happen with regard to concrete tubes. The author has been particularly careful about this, not only in putting concrete under the pipes, but in having it placed in bags where the water would be likely to affect the concrete.

With regard to the concrete pipes with ogee joints, I should like to support the view that these are unsuitable for use against

outside water pressure. I have had a very bad experience myself with the use of concrete pipes put in a very wet trench, where we tried to make the joints tight against water pressure. Every effort was made, but we failed to get them tight and had to take them out and put in iron pipes instead. The author has foreseen this trouble and taken the wise step of substituting iron pipes with spigot and socket joints for these concrete pipes with ogee joints when he found that the quantity of water encountered was absolutely excessive.

I notice in the drawing of the sections of the iron pipe sewer that there is a space between the end of the spigot and the end of the socket. This space, of course, is part of the design of the pipe in this particular case, but such pipes are frequently laid with the spigot pressed hard against the face of the socket at the end, and the result is that if there is a little inequality, if, as it were, they tend to form an arch, and a load comes on them, an immense stress is put on the pipe itself. There have been accidents through this cause, but I have seen plenty of pipes of large diameter laid in this way. The plan adopted by the author is certainly a wise one.

With regard to the excessive quantity of water encountered in the chalk tunnels, the author mentions 100,000 gallons per hour being pumped from one shaft, and this means nearly 2½ million gallons a day, or 1,666 gallons a minute. That is more than an ordinary 8 in. centrifugal pump with a 30 h.p. engine and one of the pumps employed on the works was of that capacity would lift. You can imagine, therefore, what an enormous quantity of water must have been encountered when there were several shafts and a long length of tunnel. To have grappled with a problem of this kind, which was presumably unexpected, certainly reflects enormous credit upon the engineer and the contractors.

Mr. HOWARD (Worsley F.D.C.): I should like to support the author's ratio of 3.58 of maximum flow to dry weather flow. The dry weather flow in our works is about 800,000 gallons, and we try to use the separate system if we can, but during the last 15 years, I do not think our separation overflow has come into operation; if so, only on very rare occasions. We have had no pollution

of the water courses, in consequence of being on the separate system. We have had one or two overflows at the storm sills, but that has been in consequence of cotton waste and other obstructions getting into our sewers. The figures the author gives tend to confirm the records at our works.

Mr. H. H. BARKER (Dagenham): I should like to ask what reasons have led the author to adopt five persons per house as the basis for calculation in arriving at the total run-off from each of the drainage areas. Am I to understand that the total number of equivalent individual houses at the present time, multiplied by five, would give a figure of approximately 30,000, which is the present population?

In Part II, where the author deals with trade wastes, I should like to know on what basis he converted the existing institutions, breweries, factories and so on into an equivalent number of houses discharging one-sixth of a cubic foot per minute each. Does he mean that for each business premises or factory, brewery, etc., he substituted one house having five members and discharging at the rate of one-sixth of a cubic foot per minute for the purposes of his calculations, having no regard to the size and number of persons employed in such institutions, factories and breweries?

Thirdly, I should like to ask if he could give an approximate idea of the probable cost of production of 1 B.H.P. hr. by the utilisation of steam produced from the destructor plant.

A little further on, reference is made to the fine secondary screens. I am by no means sure if the installation of a fine screen above the ground level is justified. To my mind, it is better for the fine screenings not to be intercepted, inasmuch as their disposal, by any of the usual methods never fails to elicit criticisms and complaints from those in the neighbourhood on the ground of the unfortunate odour which is always associated with them. I should also like to know what kind of screens have been installed for intercepting fine screenings, and whether they would be hand raked or mechanically raked.

The author states that the maximum run-off recorded in four years was found to be 3,770,571 gallons per day pumped and 1,496,100 gallons per day gravitated. I

should like to know whether the 1,496,100 gallons flowed on to the treatment works entirely by gravity.

In Part II, dealing with the reinforced concrete design of Slabs A and C, the author says the B.M. has been calculated on the formula $\frac{W(L-1)}{8}$. In the first place, I

should like to know whether the strut loading is the same as the resultant load due to earth and water pressure on the rectangular panel of slab which has the same area as that supported by four struts. Secondly, what does the small "1" in the formula stand for? I hope the author will be good enough to elucidate these points, and I should also like to ask if the design of slabs A, B and C is more economical by reason of the introduction of struts in between them. At Dagenham we have just ordinary slabs without any struts. I should like to know whether in the calculations for arriving at the loads on struts any elastic axial deformations of the struts due to loading has been taken into account.

The horizontal external earth pressure on Slabs A and C has been taken as 40 (h+12), where h is the depth in feet below ground level of the point where the pressure is concerned. From the expression it would appear that that super-imposed load on the ground adjacent to the walls, or in other words the surcharge, has been taken at somewhere about 1,400 to 1,440 lbs. per sq. ft., on the assumption that the earth weighs about 120 lbs. per ft. cube. I should like to know what was the actual allowance made and how to account for such a heavy loading.

Mention is made of the design of Beam No. 2 on the steel beam theory. Is it meant by this that part of the total compression is borne by concrete and the remainder by the compression steel rods? I am by no means sure that any actual economy is effected by reducing the depth of the beams, inasmuch as more steel has to be used under this theory than that required by the simple theory of reinforced concrete.

With regard to the timbering, I should like to ask the author as to the spacings of the 5 in. by 5 in. puncheons. I suppose they are at 7 ft. intervals.

I should like to know what kind of cement was used in the construction of the reinforced concrete work in the pumping station, and

with regard to the method of handling of concrete by buckets, it does not seem so efficient or economical as the use of cranes in conjunction with skips. No mention has been made of the kind of forms used for the brickwork ring forming the upper portion of the storage chamber, and if wooden semi-circular forms were employed, as it would appear from the photograph, what was their approximate spacing?

Mr. J. W. HIRWOOD, in reply, said: With regard to Mr. A. P. Cotterell's remarks, and dealing first with the question of the use of electricity, I agree that we are fortunate in Guildford in having our own installation which supplies the whole zone. The current is supplied to us at a very favourable rate; there is no question of making a profit out of the requirements of the Sanitary Committee and the Water Committee, which both draw the power they require from the central electricity station, which is in the capable hands of our borough electrical engineer and his committee.

So far as the calorific value of the coal is concerned, I had taken that at about 13,500 B.Th.U. per lb. It is stated in the paper that Babcock and Wilcox boilers are in use at the destructor, and we do in fact have a fairly high calorific value from our refuse; we get on an average 1.1 lbs. of steam per lb. of refuse, so that that is quite useful. The possibility of using sewage gas from the sludge digestion process was very carefully considered by my committee at the time the works were laid down, and Mr. Watson definitely advised that it might be used at the present time. However, my Council felt that the time had not quite arrived for that, having regard to the alternative sources of power available; but they may yet desire to use it at a later date. The question has not been overlooked. With regard to the steam consumption of 21 lbs. per B.H.P. to which he refers, that is the figure guaranteed by the makers and on which we are relying.

Regarding the construction of the brick sewer where it passed through the part of the tunnel which caved in, the difficulty was overcome by opening out a new shaft for the whole length of the collapsed portion. It was only a short length, and the contractor got over the difficulty in that way.

With regard to the influence of the salts

in the subsoil water, we constantly took analyses of the subsoil water, having heard of the difficulties which had been encountered in other districts. We were fortunate in hearing of these before we had done any of the constructional work. We took care, therefore, to send these samples for analysis and were guided by the reports of our laboratory; when we were advised to take the necessary precautions we of course took them. At one time we found the gypsum content reached 55 parts per 100,000, and the magnesium chloride as much as 25 parts. These were definitely deleterious to concrete, and we took the necessary precautions accordingly. We were advised that the density of the concrete was one of the most important factors, a porous concrete being very much more susceptible, and where the water containing these salts was flowing the influence was very much more dangerous than where still water was in contact with the material.

I am afraid I cannot give Alderman Rogerson very much information at the moment, but I should be pleased to send him a copy of our by-laws, and I think he will find them encouraging. I certainly should not wish to enter into any controversy with the Ministry of Health, but I would say that we have revised our by-laws within the last few years, and in their present form they are acceptable to the Ministry of Health and also acceptable to us with regard to the provision of surface water sewers on new properties.

I rather agree with Mr. G. T. Cotterell on the question of eight times dry weather flow from the point of view from which he put it. There is, of course, only one dry weather flow, and, if we have nearly four times dry weather flow allowed for, that shows that there is a balance of three further times available for dealing with the surface water or infiltration. If we take that as flowing off in six hours, it does amount to eight times the dry weather flow, and I do not see any flaw in that calculation. As a matter of fact, we have of course had to estimate what the size of the sewers should be on a definite basis, and I do feel that the basis which we have adopted, theoretical though it may be, is correct. One often has a sense of judgment that a certain size is right for a certain job, and in this case I feel, not only

on calculation but on my own judgment, which is not always based on calculation, that we are correct.

I do not think we are likely to take the sewage of any authority further up stream, although of course if the town did not develop at the densities which we have taken there would possibly be an opportunity for the adjacent authority to send sewage down to our works, although there seems no reason whatever why they should not continue to deal with it in their present effective way.

The question of the atmospheric effects on London clay is extremely fascinating. It is a subject upon which there may be a great difference, but we were very glad to find that the influence had not extended in our instance more than nine inches from the exposed face.

The screening of the sump is not $2\frac{1}{2}$ in. but 3 in., and we have considered the possibility that it might be necessary to use compressed air, which we have available in our existing station, for the clearing of the bars if we should meet with difficulty in raking. The bars on the hand operated screens which are in the detritus channels of the sewage disposal works are $1\frac{1}{2}$ in.

Mr. Enderby asked if we had had any claims from the high level districts when we pumped from the valley to the high level. Fortunately we have not had any claims to meet in that respect. We have been very fortunate in the way we have got through the very difficult time of transition for the last few years, largely owing to the very capable management of our sewage disposal manager, Mr. Fay, who gives most assiduous attention to all complaints, almost before they arise.

I am water engineer as well as being responsible for the sewage of the town, and I have careful records which I have kept every day and which are presented to my committees every month. 37 gallons per head per day is taken as the figure which is our average, 30 being domestic and seven trade. Where the explanation of the equivalent volume is given, of course, we do not simply take that as one unit, but we take the volume which we know or estimate closely to be that coming from the various trade sources and divide that by 185 (37 gallons per person, five persons per house) and reduce it in that manner.

We have had no difficulty from our duplicate syphons silting up; in fact, we have had no silting up at all, and have been fortunate in that respect. The figure $V=8$ is fairly close to Mr. Enderby's own figure of 7.7. We took it from a slide rule. With regard to the timbering which was used, in all contracts we agreed it in advance with the contractors. For example, my specification for the 54 in. brick sewer gave our actual requirements and exactly how the contract would be measured up. The contractor then had an opportunity of submitting, and was required to submit, exactly what type of timbering he proposed to use and the form he proposed to develop his tunnel work in, and that was agreed in advance. It gave me an opportunity of amending any point where there was a difference of opinion with the contractor, and it also gave those contractors who had had experience in this class of work an opportunity to adopt methods which, though not novel in themselves, were perhaps those for which they had a partiality, and so the work was carried out satisfactorily for all concerned.

I am very much obliged to Mr. Shenton for the kind remarks he made about the lateral support given to the iron pipes. I

am glad to say I see eye to eye with him in that matter, and I am glad he is also of opinion that it is really unwise to use concrete ogee joints for the concrete tubes under external pressure, particularly where the external pressure is considerable. It would of course lead to risk if the turned and bored joints on the iron pipes were driven hard home; we could not be quite so happy about the ultimate results as we are at present. With regard to the capacity of the pumps from the shaft where the large quantity is referred to as coming from one shaft, I believe we had two pumps in operation there.

Mr. Banerjee went too quickly through the detailed points he raised for me to be able to reply to them now, but I shall be very pleased to let him have the exact details. The 5 in. by 5 in. puncheons were seven feet apart. With regard to the use of buckets for handling the concrete, the space was so confined that this was advisable, and this was also a scheme on which my Council wanted to use labour from the distressed areas, and one of the points they had in mind was the employment of as much manual labour as possible.

CONFERENCE

Under the auspices of the Institution of Sanitary Engineers.

MONDAY, 13th NOVEMBER, at 3.0 p.m.

SIR ARTHUR B. LOWRY, C.B. (*Deputy Secretary, Ministry of Health*), in the Chair.

The following Paper was taken as read:

Town-Building : L.C.C. Cottage Estates (Post-War).

BY

HAROLD BERRIDGE, C.I.E., O.B.E., M.Inst.C.E.

(*Late Assistant to Administrator, Housing Development Schemes, London County Council.*)

(NOTE. - This Paper was submitted for the Open Competition arranged by the Congress Committee and was awarded a Special Prize of Five Guineas).

SUMMARY.

THE L.C.C. to cope in 1920 with its new responsibilities under the Housing Acts appointed an Administrator of Housing Development Schemes, purchased large areas in and outside its County Boundaries for Cottage Estates and adopted the "Value-Cost" form of Contract which enabled them to finance their operations directly. The system has been applied to the construction of 50,479 cottages, 139 miles of roads, 108 miles of soil sewers, and 118 miles of surface water sewers. The paper describes the organization and operation of this form of Contract, and gives some details of construction, and diagrams of progress.

Although much has been written on the subject of "Town-planning," there is very little on the subject of "Town-building," and the present paper describes methods adopted and the series of operations required to convert agricultural land into a township, as illustrated by the post-war development of cottage estates by the London County Council under the Housing Acts. A general description of these estates is given in *Housing, 1927 and 1928-1930*, published by the Council. Table I is a schedule of work and materials required in these undertakings.

TABLE I.

SCHEDULE OF HOUSES, ROADS AND SEWERS AND PRINCIPAL MATERIALS.

	Area, Acres.	Houses, Number.	Roads, Miles.	Soil Sewer, Miles.	S.W. Sewers, Miles.	Bricks, Millions.	Cement, Tons.	Lime, Tons.	Timber, Stan- dards.	Sand and Gravel, Cu. Yds.
Rushampton ..	147	1,212	3.1	2.8	3.2	24	7,000	4,000	2,000	42,000
White Hart Lane ..	138	1,167	3.5	2.8	3.0	10	10,000	3,000	1,750	43,000
Becontree ..	2,770	23,338 (a) 1,662 (b)	65.25	60.25	64.75	255	180,000	44,000	39,000	926,000
Bellingham ..	252	2,128	6.8	5.0	5.6	30	12,000	3,000	3,750	77,000
Downham ..	522	6,071	17.1	14.5	15.8	96	40,000	10,000	8,600	265,000
Watling ..	390	4,021	13.2	7.63*	8.61*	50½	21,000	6,650	6,000	163,000
Castelnau ..	52	644	2.0	1.5	1.7	3½	5,900	360	820	25,000
Wormholt ..	68	786	2.0	1.7	1.9	14½	4,650	1,600	1,000	29,000
St. Helier ..	825	5,293 (c) 4,207 (d)	26.3	12.50	13.38	91	32,000	8,100	8,750	164,000
	5,164	50,479	139.25	108.68	117.94	574	312,550	80,710	71,670	1,734,000

(a) Completed and under construction.

(b) Ordered.

(c) Completed and ordered.

(d) Not ordered.

* In addition to approximately 1 mile of soil sewer and 1 mile of S.W. sewer pre-existing.

It is evident from the magnitude of these figures and the high rate at which construction has proceeded (Fig. I) that special methods and organization have been brought to bear, and these are:—

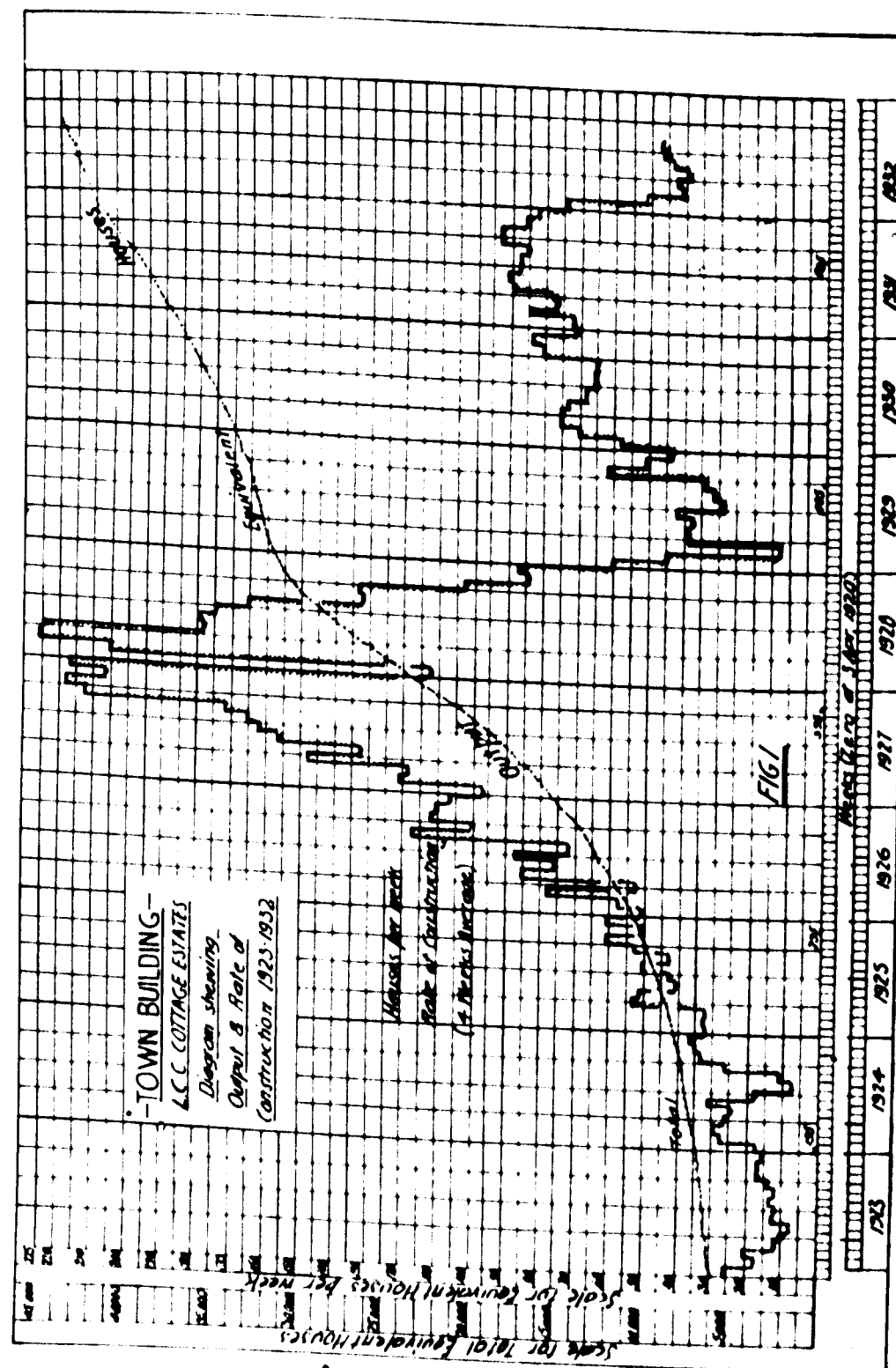
- The direct financial backing by the L.C.C. of building operations.
- The adoption for development of large areas 400 to 2,300 acres.
- The appointment of an Administrator Housing Development Schemes*.
- The adoption of the value-cost contract.
- The transport of building material on the estates by standard-gauge construction railways connected to main line sidings.

RELAXATION OF BYELAWS FOR NEW STREETS AND BUILDINGS.

Act of 1925, Pt. V.

The L.C.C., even in the County of London, has no power to relax existing bye-laws; and generally seeks to obtain the concurrence of Metropolitan Boroughs,

* Sir George W. Humphreys, K.B.E., M.Inst.C.E., Presidential Address to Royal Sanitary Institute Jubilee and London Congress, July, 1926.



and of Local Authorities outside the County, to such variations leading to economy in house and road construction as have been suggested by Government, such as :—

- (a) decrease of ceiling height from 8 ft. 6 ins. to 8 ft. 0 ins.
- (b) non-provision of secondary access.
- (c) "combined drainage" to blocks of cottages.
- (d) decreased width for side roads. (See Appendix III).

Generally speaking, concurrence has been obtained without appeal to the Ministry of Health; and broadly, Local Authorities have found the Housing Estates far superior in construction, appearance and amenities, to their original anticipations.

Of the estates, Downham, Bellingham, Wormholt and Roehampton are within the County, and Becontree, White Hart Lane, Watling, Castelnau and St. Helier are outside it. (Fig. 9).

Both Becontree and St. Helier lie each in the areas of three Local Authorities, and in questions affecting main roads, the Ministries of Health and Transport and the County Councils concerned, exterior to London, have also to be consulted; so that great complications have arisen in the adjustment of the technical, legal and financial aspects involved in these developments.

ACQUISITION OF LAND.

The Council acquires land either under the compulsory terms of the 1919 Town Planning Act, or by private negotiation. The Becontree Estate cost £210 per acre, and that at St. Helier £437*. Considerable delays in obtaining possession seem to be inevitable, and react on construction, as engineering surveys with permanent stations cannot be made without entering permanently on the properties. The best course would appear to be to take possession and re-let on short terms, having special regard to the Michaelmas quarter in the case of agricultural land. It is better to have a tenant on land than leave it unoccupied for the six months or so required to produce a layout and start construction.

NATURE OF SITES.

Becontree is a flat site with gravel subsoil, and is favourable for house construction, though drainage has presented considerable administrative difficulty. Downham, Watling and St. Helier are undulating sites with clay soil, and have watercourses and trees, in dealing with which considerable expense has been involved. Watercourses have had to be enlarged and cleaned, or culverted and diverted, and in many cases damp course levels of houses have been fixed at greater heights than otherwise necessary to avoid flooding.

Many of the large trees round London are elms of 200 or 300 years old and are obstructive to house and road construction. The timber has little value, and to remove a tree including the root costs £5 to £10.

* Minister of Health in Parliament reported in "The Builder," 22nd May, 1931.

APPOINTMENT OF ADMINISTRATOR HOUSING DEVELOPMENT SCHEMES.

It became evident in 1919* that a large amount of co-ordination of the work of different departments of the L.C.C. would be involved and that the usual procedure would have to be modified to meet, in the time available, the responsibilities newly thrust upon the Council by the Housing Acts.

The Council therefore, in May, 1920, appointed their Chief Engineer, Mr. (now Sir) George W. Humphreys, M.Inst.C.E., to be Administrator of Housing Development Schemes, and the works herein described have been carried out under his direction.

In addition to the negotiations with Government Departments and Local Authorities previously mentioned, a considerable number of agreements had to be entered into for Gas, Water and Electric Light Services. At St. Helier, for example, there were three Gas Companies, one Water Company, the Metropolitan Water Board, and two Electric Light Companies concerned, as well as the Postmaster-General, by whom rights of way were claimed for telephones and fire alarms.

"VALUE-COST" CONTRACT.

The urgency of the Housing problem immediately after the war demanded some method of putting construction in hand without delay, and the "value-cost" form of contract was devised by the Administrator† for the purpose. It has the advantages of enabling progress to be made so to speak in "echelon." As soon as a contract for the development of an estate was made, the area was divided into sections of, say 500 to 1,000 houses, and the Contractor put in hand at once arrangements for plant and purchase of materials. While these were in progress detailed surveys and plans were made for the first section; similarly, while the first section was in progress, plans were prepared for the second; and design and construction proceeded on parallel instead of on consecutive lines. The Council's and Contractor's staffs, though entirely separated in functions (see diagram Fig. 2) worked in adjacent offices on the Estates themselves, where the Administrator was represented by a Principal Resident Officer, responsible to him for the multifarious questions arising in the conduct of the work. The work was financed by the Council, which maintained control over expenditure by

- (a) current audit,
- (b) sanction to purchases and liabilities incurred,
- (c) inspection of works,
- (d) valuation of construction.

The Contractor's remuneration was by fee on a valued schedule of typical house and road work, and the fee varied inversely with the ratio of cost to valuation.‡

* See also Ministry of Health Periodical "Housing," 1st March, 1930.

† Sir G. W. Humphreys (*Loc. Cit.*).

‡ Mr. T. P. Frank, M.Inst.C.E., "American City," Sept., 1931, gives further details. Also "Housing," 1927, page 56. L.C.C. Published by P. S. King & Son, Ltd.

Much saving of time was effected in the early stages of development by adopting this form of contract, as apart from the General Conditions and specification, the only other information required was in the form of type drawings and Valuation Schedules for different classes of work.

The latter were in recent contracts simplified by using as a unit of housing work one "house" of any type likely to be required, though in any case provision was made for valuation of work not included in the original schedules.

GENERAL PROCESS OF DEVELOPMENT.

The first step in the development of a large estate was to divide it into sections on a small scale plan (say 1/2,500) and decide on the sequence of construction. This was of great importance when a standard gauge estate railway was used for transport of material; as, in the process of its withdrawal, finished construction must be left behind. When the first section was decided on, the Architect prepared a "cartoon" of it on 1 in. = 64 ft. scale, shewing in some detail roads, cottage blocks and types of accommodation by various colourings; and this layout, when approved, formed the basis of an accurate engineering survey carried out by the Administrator's staff on the estate. Centre lines of roads were calculated and important stations marked with iron pegs set in concrete. A grid of spot levels 200 ft. wide, 50 ft. apart longitudinally, was carried along each road. This survey was most important, as it was worked to by the engineering staff for road and sewer design and by the Architect's for house layout. Sizes and levels of existing soil and surface water sewers and watercourses, trees and fence lines, etc., were picked up, and any difficulties of drainage or road gradients could be definitely dealt with. Layouts are generally "tight," and any alteration in requirements in housing accommodation (and consequently in block dimensions) has a large consequential effect on drainage plans, etc. 10 ft. is generally left between blocks of cottages and 6 ft. between blocks and any adjoining boundary.

Concurrently with the house layout, longitudinal sections of proposed roads and sewers and house drainage drawings were drafted on the site, checked in the Chief Engineer's Department of the Council and sent to the Local Authority for approval, which it was generally found possible to anticipate by consultation with them during preparation of drawings. During this period, as the designs crystallised, the Contractor (having received from the Administrator an order to commence) was kept informed of the main features of the layout and had laid sidings, "overland route," purchased and laid out plant, temporary offices and other buildings, and made preliminary enquiries as to supplies of bricks, timber, sewer pipes, etc.

SERVICES.

In order to reduce delays on road work and avoid opening up finished surfaces, draft layouts on 1/2,500 scale were sent to the Postmaster-General for fire alarm and telephone cable, and to the Gas, Water and Electric Light Companies, at the earliest possible stage to enable them to put forward their proposals.

The sizes of mains were mostly 3 ins., 4 ins. and 6 ins., but ran up to 18 ins. for trunks, and the lengths laid at Watling were about: Gas, 18½ miles, water,

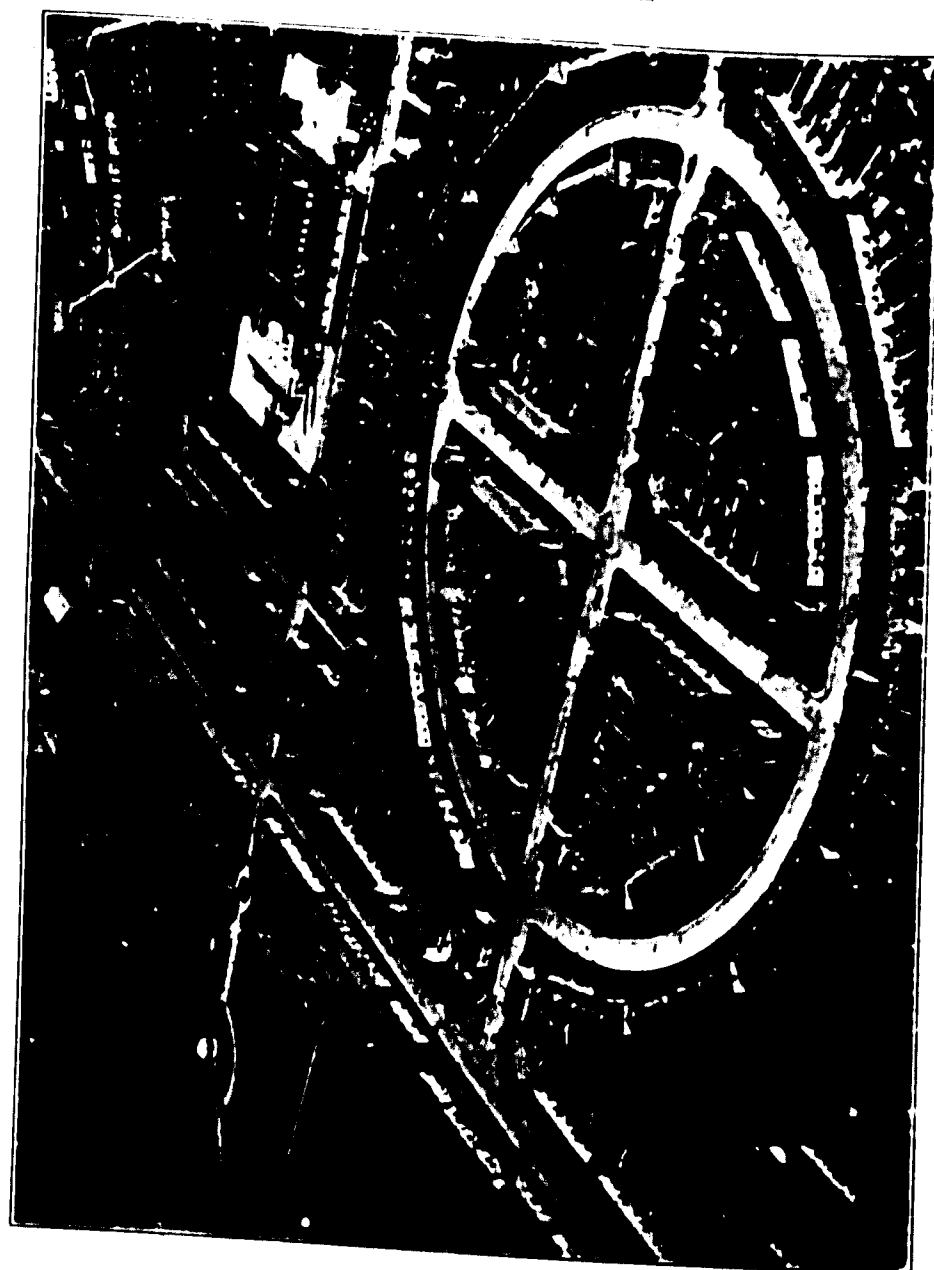
BECONTREE.

View of SECTION DAGENHAM
Nos 4 and 5, SEPTEMBER,
1931, looking North-east

VALENCE CIRCUS, ALDOMAR ROAD
and AYLMER, the last joins
VALENCE WOOD ROAD, which
runs parallel to VALENCE
PARK (top left)

VALENCE PARK on left

RAILWAY STATION, CHADWELL
HEATH (L.N.E.R.) 1 mile



PROVISION OF ESTATE RAILWAY.

Becontree, Watling, Downham and St. Helier have standard gauge sidings, the two former estates on the L.N.E.R., and the two latter on the S.R. Such sidings for estate traffic were capable of holding 150 to 200 wagons, and as many as 70 a day were handled in and out over considerable periods. Loco repair and running sheds and workshops and wagon weighbridges were provided. When the house layout was approved, the temporary railway was extended to the end of the furthest section with crossings laid in for spurs to different areas.

Where the estate railways crossed existing public roads, level crossings were constructed under licence from the highway authorities concerned, albeit after much opposition due to fears of obstruction to traffic, which proved, however, quite groundless. The construction trains are generally quite short, and by putting two able-bodied gatemens on, delays to road traffic seldom exceeded two minutes, and no complaint was ever received about them, although at St. Helier there were five, including one on the Brighton Road and one on the Sutton Bypass, see Fig. 29 (air view). A 60 ft. deck bridge to cross the Wandle was also required at St. Helier and two main lines are crossed by overbridges at Becontree, where also a jetty for unloading material was constructed on the Thames frontage.

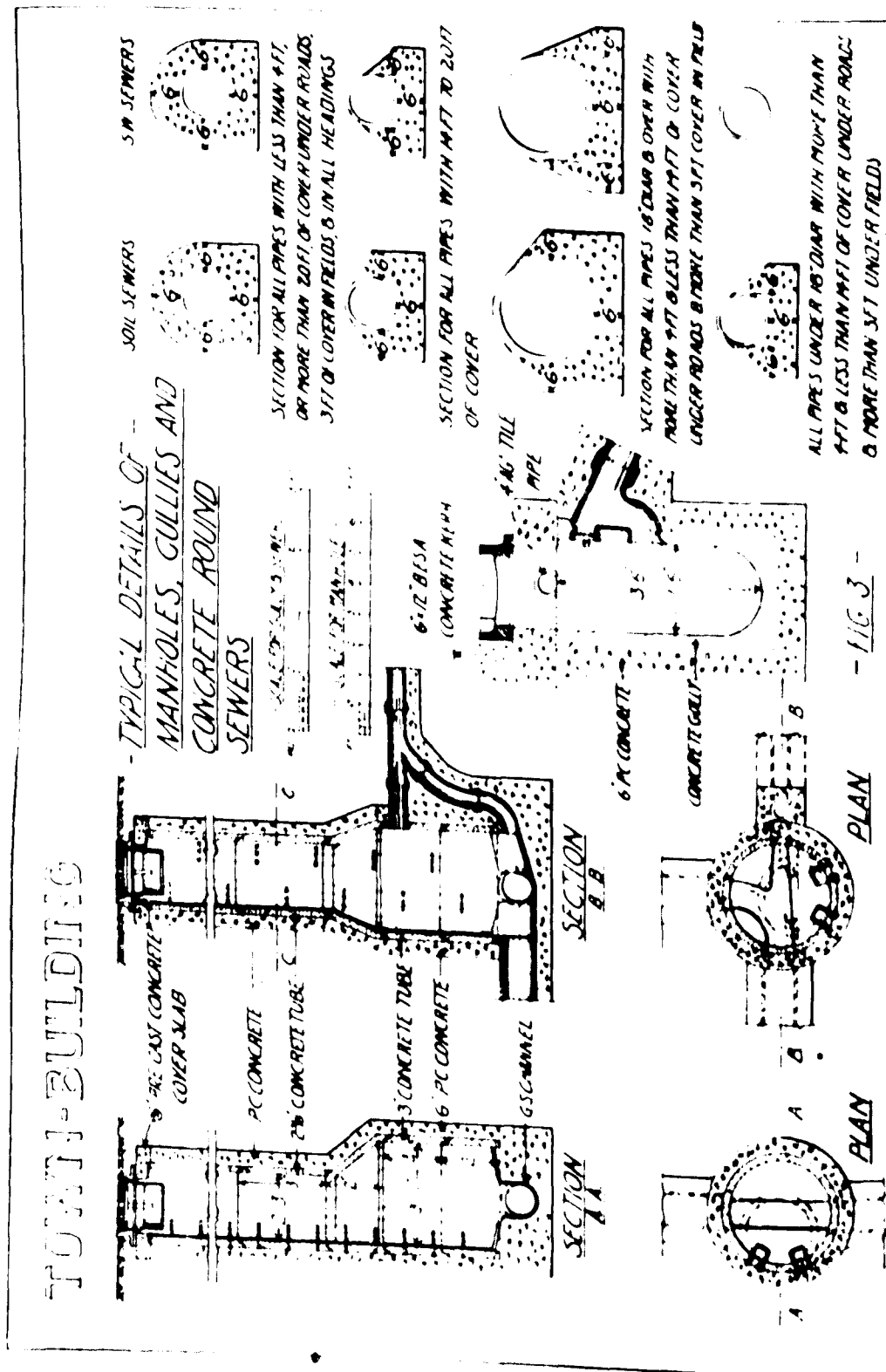
The advantage of using a standard gauge railway is that it enables the large quantity of heavy materials (say 120 tons per house) required, to be delivered at the sites of the houses independently of roads and sewer construction, and it certainly facilitates such supplies during the earlier stages of a development. It does, nevertheless, embarrass the later stages, as, however carefully laid out, it has to occupy a large number of house sites, roads, etc., which cannot be finished till it is withdrawn. It is also expensive, costing some £20 per house. It seems to the writer that in future a large estate siding from which material could be distributed on narrow gauge standardised light track operated by petrol locos, combined with road deliveries, will be adopted in preference.

COMMENCEMENT OF CONSTRUCTION.

As approval to road and sewer plans generally preceded that for housing layouts, work on the estates began by taking off the "top spit" from carriageways and side walks and wheeling and spreading it into future garden areas; sewer trenches were started, sometimes in dry weather at intermediate manholes as well as at outfalls to save time in extending the sewers up to the first batch of houses, which was generally remote from the outfalls. On clay soil it was found important to drain the ground during construction by putting the permanent surface water connections for gulleys and house drains as early as possible and leading temporary drainage to them from trenches, ponds and ditches.

SEWERS.

With few exceptions drainage was dealt with under the entirely separate system for soil and surface water.



The adoption of a partially separate system, which was permitted in a few cases, leads to considerable economy, as it enables the surface water at the back of a block to be led into the foul drain and so saves one row of drain pipes. In very flat sites it is even an advantage to do this to keep the foul drain flushed.

At Becontree and some of the smaller estates soil sewers were ventilated by ventilating columns, interceptors and fresh air inlets being fixed on drain inspection chambers next the fence line and soil vent pipes on the house drains.

At Downham, Watling and St. Helier, altogether some 15,000 houses at present, no interceptors were fitted, the sewer and drain pipes being ventilated through soil vent pipes extended from W.C.'s on houses at heads of drains and some times at intermediate ones.

This system has proved entirely satisfactory, and, besides being more economical than the "closed" system, avoids the difficulties encountered in siting and maintaining sewer ventilating columns.

As to soil and surface water manhole covers being open or closed, practice differed on every estate according to the requirements of the local authority; every possible combination being in use in one district or another. The only inference drawn by the writer is that with a properly designed and constructed sewer, the direction of ventilation is immaterial as long as it is adequate in volume.

Under "combined drainage" agreements with Local Authorities, the discharges from a number of cottages (up to about 12) were combined as shown (Fig. 8). Such agreements provide that the L.C.C. shall remain responsible for the repair and cleaning of the pipes up to their boundary.

SEWER CALCULATIONS.

The constants of calculations for sewers were as follows:—

Soil Sewers. 50 gallons per head per day and 5 persons per house; flow to be doubled for maximum.

i.e., Maximum flow $50 \times 2 \times 5$ galls. per day per house.

500 galls. = 80 c. ft. = 1,440 min.

0.055 c.f.m. per house.

Surface Water Sewers. Rainfall allowed— $\frac{1}{8}$ in. per hour reaching sewer
0.00052 c.f.m. per s. ft. of impermeable surface, such as roads, school grounds, etc.

For open spaces $\frac{1}{16}$ inch per hour reaching sewer.

Velocity of discharge, if possible, not to be less than $\frac{3}{4}$ ft. per sec.; or more than 10 ft. per sec. running half full.

For preliminary estimates the total flow was closely approximated by taking one-fifth of the estate area as roads, and 18 houses per acre.

Santo Crimp's tables were used, which require rather larger pipes than Kutter's.

The writer considers for the main sewers no size smaller than 9 in. should be used.

BECONTREE.

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Age Group	Percentage of Respondents
18-29	85%
30-49	80%
50-69	75%
70+	70%

100

10

100

10

Figure 1 consists of 12 small, vertically stacked micrographs. The top image shows a single cell. The subsequent images show the cell dividing and the formation of a blastocyst. The bottom images show a more complex structure, possibly a gastrula or a later stage embryo, with distinct layers and internal structures.



MANHOLE AND SEWER CONSTRUCTION.

Pipes were stoneware for soil and over 12 in. concrete with ogee joints for surface water. As regards surrounding with 8 to 1 concrete, the Ministry of Health letter 22nd March, 1920, was followed, see Appendix II and Fig. 3.

Manholes were formed with mass concrete inverts, the shafts being of precast rings and taper pieces surrounded with 6 in. 8 to 1 concrete. Step irons were malleable castings.

At St. Helier the progress of sewers was greatly expedited by a No. 4 paraffin engine Ruston excavator, which dug trenches within 6 ins. of finished levels and to widths adjustable by setting of bucket teeth.

This machine would easily cut 70-80 l. yds. of 2 ft. 6 in. wide trench 6 ft. deep in a day, and kept two gangs busy timbering and trimming behind it. It travelled round from one trench to another to keep it occupied. It was, however, difficult to operate with bad ground and for trenches over 8 ft. deep.

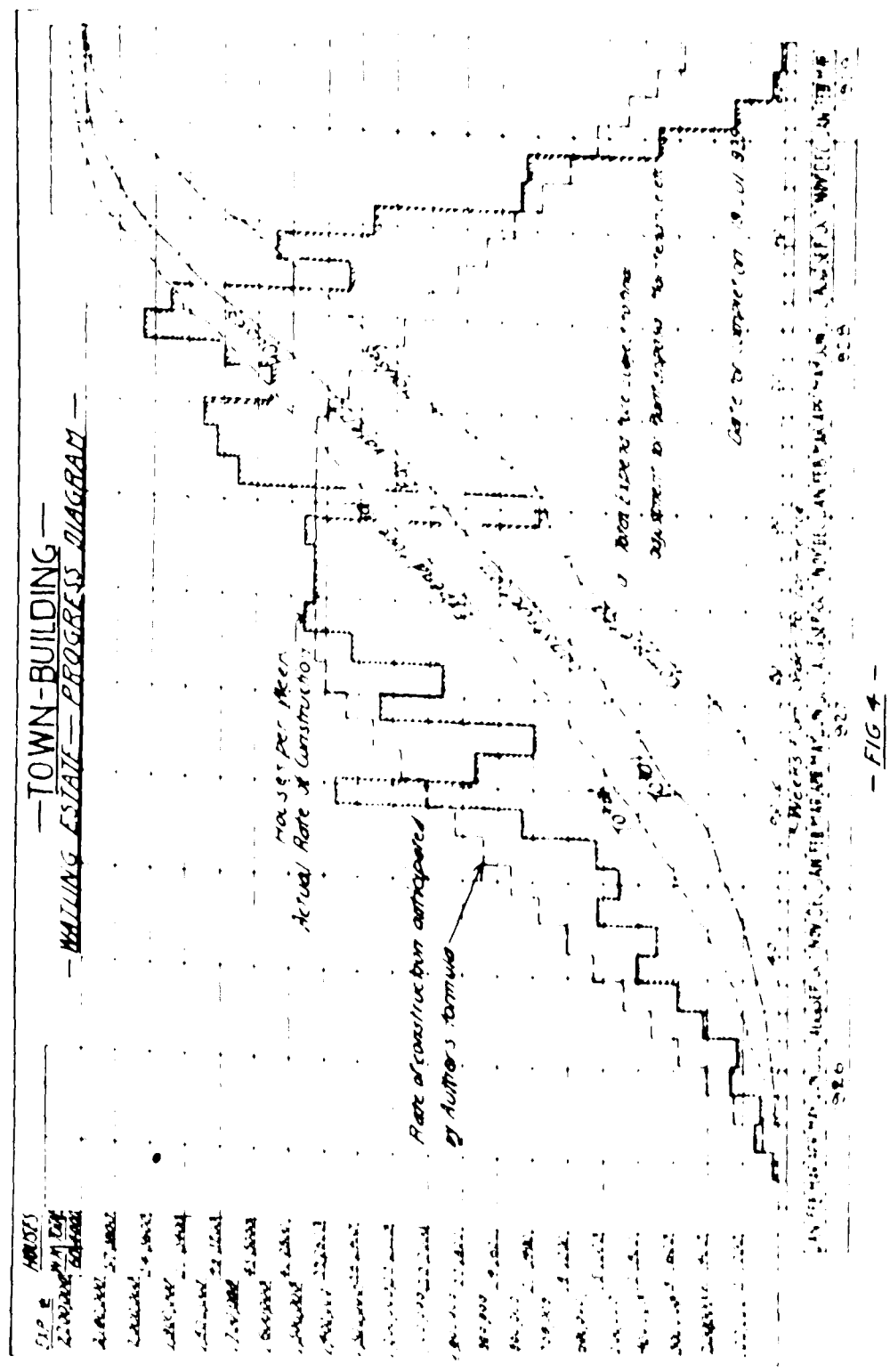
Mechanical excavation, however, produces large lumps, which demand mechanical ramming of refill. This was carried out with rammers on "board-drop" principle, operated by petrol engine, and with one driver and one navvy. In dry weather clay filling should be softened by hosing before refilling, otherwise it becomes too hard to consolidate and produces subsidence long after completion of road surfaces. Great diminution was observed in the amount of "surplus" from trenches when mechanical ramming was used.

Outfalls of S.W. sewers ran up to 36 in. diameter; one of this size at Castelnaud discharges into the Thames between High and Low Water mark being "threaded" under the 36 in. C.I. mains of the M.W.B., over the sewers of the local authority, and over a brick culvert of uncertain position connecting two reservoirs. This outfall has a duplicate tidal flap in a separate chamber, and the Port of London Authority required a concrete apron 1 ft. 6 in. thick to protect the foreshore out to low water mark.

Existing watercourses required careful consideration. In case of bridges or culverts the Stream Authority had to be consulted as to waterway allowed. See Fig. 5 for examples at Watling. Records of highest floods were ascertained and houses sited well above them, necessitating in many cases a considerable addition in height to sub-structures.

ROADS.

Typical sections of 50 ft. and 30 ft. roads are shown (Fig. 7) and these and similar sections have proved generally satisfactory. Recently 6 in. $\times$ 12 in. bevelled concrete kerb has been substituted for 12 in. $\times$ 6 in. and 6 in. $\times$ 10 in. granite, and answers well. The standard radius for corners was 20 ft. The provision of channel setts causes expense with doubtful benefit, except possibly on gradients of 1/20 and over. The road profiles were designed to balance cut and fill as far as possible,



but their position on plan relative to contours sometimes produced difficulties with the D.P.C. levels of houses.* Care must be taken well to consolidate filling of sewer trenches and the numerous cross cuts for services and house connections for drains. The gas service pipes were especially numerous and troublesome; and to avoid these cuts the writer considers gas mains should be duplicated, as it is not possible to combine the services to a block as it is in the case of water, electric light and drain connections. The large number of cuts and the amount of refilling make it impracticable, in the writer's opinion, to use concrete roads in housing estates on a clay soil, in the first instance. Doubtless, they can be used when the roads come to be re-made. It proved impossible also to anticipate the requirements for services and drains in the case of "Reserved" sites, and in many cases finished surfaces were cut into.

Service mains were laid in footpaths, the general arrangement being the water main at 3 ft. 6 in. depth next the kerb, the gas inside it rather higher, and the electric cables next the fence. The disposal of surplus excavation from these operations was a considerable item.

To effect drainage of road foundations, two 4 in. agricultural drain pipes were provided into all road gulleys below formation. This was specially important during construction, as the drainage from formation cannot reach the gulleys otherwise. The 6 in. and 3 in. layers of ashes or destructor clinker on carriageways and footpaths were well consolidated with 30 cwt. petrol rollers to keep the clay and footpaths were well consolidated with 30 cwt. petrol rollers to keep the clay on to the top of the hardcore by traffic, etc. Concrete hardcore was used for 50 ft. main road bottoming, and brick hardcore for 30 ft. side roads. Sleeper roads were used to protect brick hardcore against heavy traffic, otherwise it rutted badly over sewer trenches. Old macadam was used to bring hardcore surfaces to final section, flushed and consolidated with a 10 ton roller until all movement ceased. 3 in. and 2½ in. proprietary bituminous carpets were used under maintenance guarantees and have stood well in nearly all cases even when subjected to omnibus traffic. There is great variety in requirements as to manhole covers and gully gratings, which it seems might well be standardised.

PUBLIC FOOTPATHS.

The approval of an estate layout providing a network of roads with paved footways confers no legal right to deviate or obstruct an existing field track across the site of a cottage, even on to a new parallel road a few feet away. It has, accordingly, been found less troublesome in some cases to make the new layout conform with the old right of way to save the delay, which may be a year or two in obtaining the magistrates' consent, even to an unopposed application.

HOUSE CONSTRUCTION.

As soon as the Administrator passed the final layout and schedule of facings, roof pitches and coverings to the Contractor, the latter put in hand the ordering

* L.C.C. Manual "State Aided Housing Schemes," 1919. H.M.S.O. Appendix 1.

CASTELNAC.

[illegible]

of material, especially common and facing bricks, timber, cement, lime, sand and ballast. Face sheets in triplicate shewing comparative quotations for these supplies were submitted by the Contractor with his recommendations to the Administrator through the Principal Resident Officer with his remarks. These face sheets were examined at the Administrator's head office by a small specialised staff who dealt with such quotations entirely on an arithmetical basis and had no contacts with merchants. If and when sanctioned, the Administrator kept one copy, one was sent to the Comptroller, and one returned to the Contractor. For the supplies so approved, as well as for all other materials stores or plant, orders were given by the Contractor on numbered sheets and carbon copies were similarly supplied. A large staff was employed for checking all classes of material on delivery.

As soon as the Estate Railway was laid in and materials made available in sufficient quantity on the site, house construction commenced in earnest: General foremen were appointed at the rate of one to about every 200 houses on the layout and each would have about 250 men at work. The Administrator similarly increased his staff, and in addition, the Local Authorities had their own Inspectors who specially passed all soil sewers and house drains.

For the final layout the 1 in. 64 ft. plan was enlarged to 1 in. 32 ft. on which were shown dimensioned setting out of blocks and damp proof course levels to suit as closely as possible the spot-level grid. Every such D.P.C. level was set up and viewed on the ground before final adoption. On comparatively flat sites such as Becontree and Castelnau such levels presented little difficulty and involved comparatively little "stepping" of blocks, so that standard type drawings could be followed; but at Watling, Downham and St. Helier, the undulating nature of the ground necessitated a great amount of "stepping" to foundations, D.P.C.'s and roofs, and consequently special elevations had to be supplied for some 50 per cent. of the houses, involving a very large amount of architectural work, which had (like most on the estates) to be done against time.

The routine number of sets of drawings required is shewn in Appendix VI. The originals of layouts were very large and sub-divided into four to six "double elephant" sheets, so that the mere bulk of this work was formidable. In addition to cottage construction, blocks of shops with flats over increased largely the amount of work required, both design and construction being, naturally, entirely different from the "housing" work. At Watling and St. Helier the time from "order to commence" till commencement of construction was about four months, and to work up to an output of about twenty "equivalent" houses a week on each estate took about a year, during which time the organisations on the estate were gradually built up, so that inspection and execution of approved construction went on simultaneously with survey and design for further work.

HOUSES TYPE.

The percentage of each kind of house at Watling Estate is given in Table II. and some detail of their floor area and cubic contents in Appendix VII.

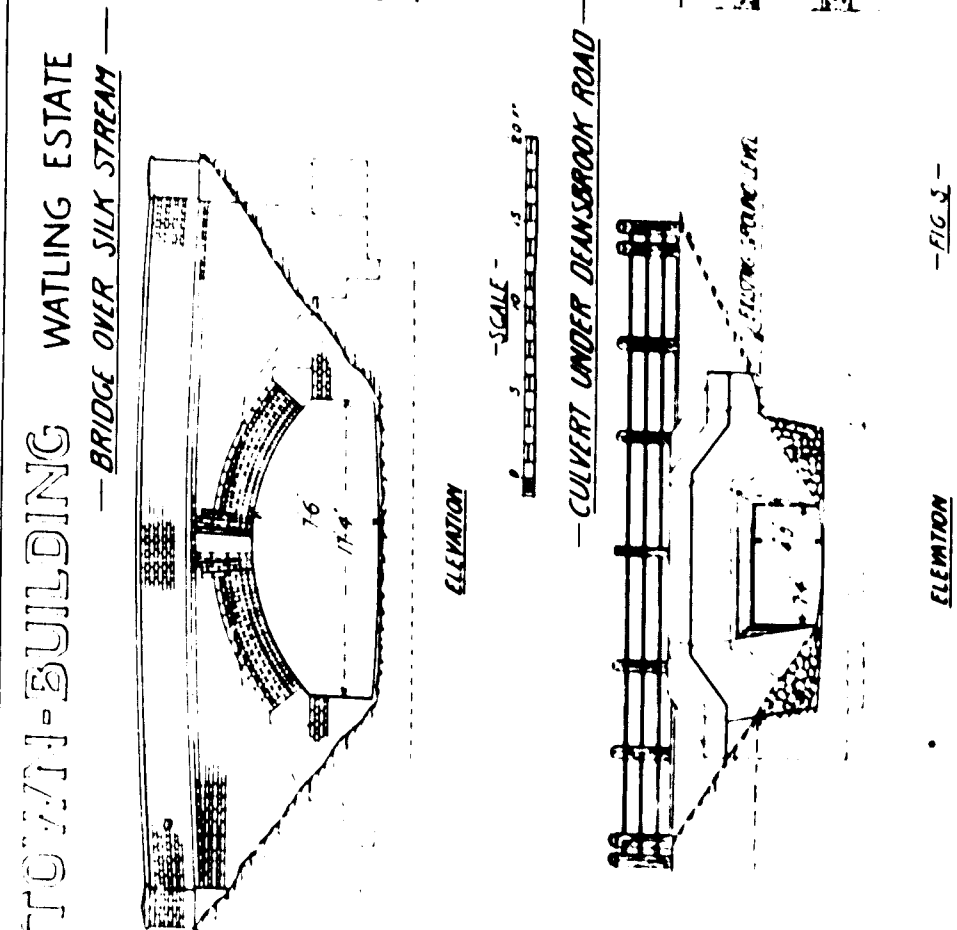


TABLE II.

	Percentage of Total.
5 Room Parlour	16.6
4 Room Parlour	22.2
4 Room Non-Parlour	23.2
3 Room	30.0
2 Room Flats	2.6
3 Room Flats	3.6
4 Room Flats	1.8
	100.0

The percentage and cubes on other estates are similar.

Cost.

This question need only be referred to in so far as stating that the valuations in the agreed schedule varied from 11d. to 13d. per cubic foot, and that the total cost of the works varied only slightly from the total calculated from the schedule. It should be borne in mind that valuation included not only drains, paths and fences, but work on greens and culs-de-sac, which amounted to a considerable item. Preliminary estimates excluding land given for "houses" (L.C.C. "Housing," 1928-30, page 4) are £550 at Becontree and St. Helier, and £600 elsewhere. These figures include roads and sewers, or say £60 per house.

ECONOMY IN CONSTRUCTION.

The most difficult task in these developments was to secure economy and at the same time secure good appearance and construction of the cottages. As regards design, standardization can only be carried to a certain point, but it was found possible largely to eliminate long sloping roofs, broken eaves lines, steep pitches and "steppings" of less than 1 foot, the incorporation of incompatible types of accommodation in the same block, the more costly facing bricks and tiles, and similar causes of expense.

With regard to manufactured articles, standardization was fairly successful as to joinery, but was difficult with respect to ironmongery, plumbing, fixtures, etc. Bulk purchases effected large economies, but not seldom suppliers' stocks were depleted, and alternative patterns had to be adopted to avoid delay.

FOUNDATIONS.

On clay, foundations were taken to 2 ft. 6 ins. for "intermediate," and 3 ft. 0 ins. for "end" houses below original surface of ground; and, where they crossed old ponds or ditches, reinforced with steel fabric or old rails. On bad ground the concrete was 2 ft. thick and reinforced with steel fabric, with 4 in. cover at top and bottom of foundations.

WATLING.

Sections A (bottom), C (top)
right, D (top), centre, May,
1928

BURST OAK STATION (L.E.R.
centre on WATLING AVENUE,
left to right)

SILK STREAM Road and Bridge
with open space at bottom

Tributary stream BURST OAK
to top right, flowing through
open space

HENSON School bottom centre

WOODROFF HALL right of
centre on WATLING AVENUE

ORANGE HILL Road, BURST
OAK Station to top centre

DEANSBROOK Road and
L.N.E.R. (Edgware to
Finchley) across top, Estate
Sedings on this line near MILL
HILL, Depot and Timber
Yard top right



SUBSTRUCTURES OF HOUSES.

As the result of experience on construction on wet sites on a clay bottom, the following precautions were taken:—

- (a) 4 in. agricultural open-jointed tile land drains with open gravel surround and connected to surface water drains laid at back and front of houses wherever damp-proof course was below level of back of footpath, or ground sloped toward back of house; 4 in. yard gullies also provided in bad situations.
- (b) Substructure built of hard bricks set in 4 to 1 P.C. mortar.
- (c) Joists and wall plates below floor level creosoted under pressure to 4 lbs. per c. ft. absorption, sawn ends brush coated with preservative.
- (d) Seven cast iron air gratings 9 in. x 3 in. each, with clear opening of 10½ sq. ins. (minimum provision to each house).
- (e) Raft concrete proportioned ½ hydrated lime, 1 P.C., 8 gravel; and rafts kept above finished ground level.
- (f) Floor boards brush coated with preservative and left loose till raft passed as dry and clean.
- (g) Special report made as to condition of air gratings and rafts at final inspection before handing over house for occupation.

COTTAGE WALLS.

The great majority of cottages were constructed with 11 in. cavity brick walls, which are superior to 9 in. solid construction, both as regards weather resisting properties and warmth. Care must be taken to keep wall ties and door and window heads free from mortar droppings. They are, however, not very strong owing to want of mechanical bond, and at St. Helier reinforcement was provided to brickwork in end houses of blocks fronting on sloping roads, and over common entrances and those at sides adjoining front walls.

DAMP COURSES.

These were two courses of slate laid in 1—3 P.C. mortar in external walls, and of bitumen-lead type in internal and sleeper walls. Vertical slate damp courses were provided in sub-structures of "stepped" blocks, both in external and party walls.

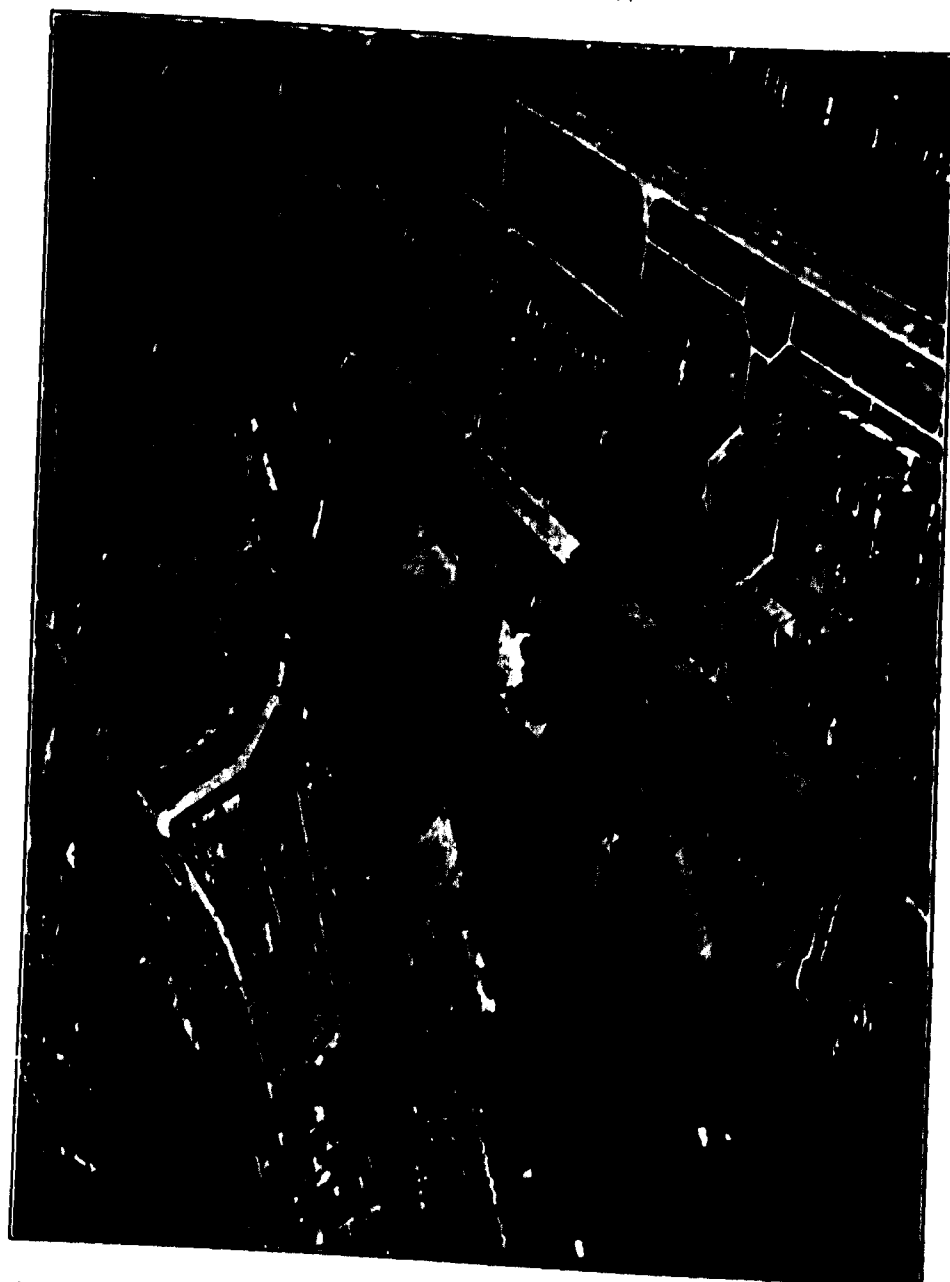
BRICKS.

Common bricks were generally Flettons, and it was found advisable to use 50 per cent. grooved in alternate courses where they had afterwards to be plastered. Facing bricks had to be of good colour and quality, and at the same time not too expensive. Lately, an assortment of two kinds of common bricks, and 2nd hard stocks gave the necessary variety in appearance and effected a considerable saving over the more expensive red facings previously used. The writer concurs with

ST. HELIER.

N.W. Corner Section 1 and
Section 3, June, 1931Surrey Education Committee
SCHOOL, centre

Section 3, with houses inhabited.

MORDEN STATION (L.E.R.) top
left

such alternatives served the purpose and produced satisfactory houses, it appears to be the case that no system now compares favourably in cost and general adaptability with the ordinary construction of bricks and mortar.*

CARCASSING TIMBER AND TIMBER YARDS.

To ensure uninterrupted progress, about a year's supply of timber had to be stacked, and sometimes amounted to 2,000 standards. British Columbian pine, recently adopted, requires six months seasoning in this country and the first arrivals were not well sawn, otherwise it is satisfactory. Recommendations for laying out a timber yard are:—

- (1) Area to be drained, levelled and covered with 4 in. of ashes.
- (2) Dunnage to be sound second-hand sleepers with $1\frac{1}{2}$ in. $\times$ 4 in. pressure creosoted bearing pieces on top, 1 ft. 0 in. above ground; 4 ft. gaps between ends of sleepers every 40 ft.
- (3) Scantlings and roof boarding to be "open sticked"; width of stacks 8 ft.; passages 2 ft. wide and three top layers laid overlapping and inclined at 1/20 to east to shed rain; stacks to be numbered.
- (4) Flooring to be under cover in open sided shed with tarpaulins hung on most exposed side.

Detail records should also be kept of source of supplies and location of use.

ROOF COVERINGS.

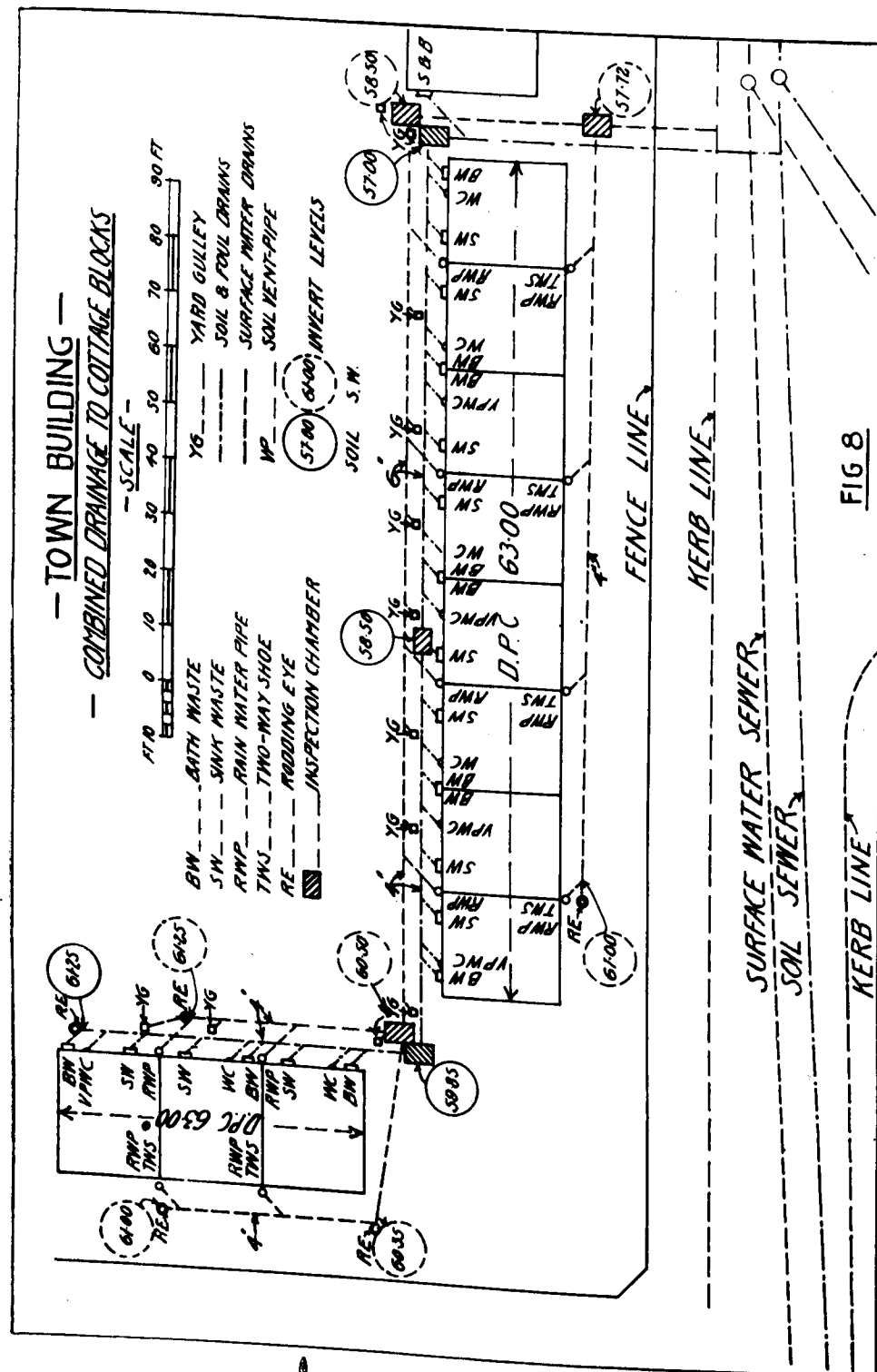
Roof coverings were either tiles of interlocking type laid on battens only at 35° pitch, the most economical type, or plain tiles on battens at $42\frac{1}{2}^\circ$ on cottages and shops (feature blocks). More recently slates have been adopted and all roofs boarded and battened to give protection both against frost, and tiles being dislodged by "suction" in gales. Large tiles do not look well on cottages, nor do slates go well with red facing bricks.

Where roofs are continuous over party walls, $\frac{3}{4}$ in. clearance between should be allowed for settlement, otherwise a "broken-backed" appearance will develop.

PLASTERING.

This item was carried out by sub-contract, both for internal work and external rough-casting where required. The trade is a difficult one and research has not so far thrown much light on its problems. It seems, however, certain that good ceilings cannot be made with two coat work and "ungauged" plaster. The writer thinks that the "London" practice of running lime direct into the coarse stuff and leaving it a month or six weeks is definitely wrong and the source of much trouble. He thinks that putty from stone or hydrated lime should be run first and used as required.

* Sir G. W. Humphreys (quoted above), also Standing Science Committee R.I.B.A. Journal, 28th Jan., 1928.



PAINTING AND DECORATING

Painting and decorating were carried out by sub-contract and a fruitful source of dispute both as to material and workmanship. A chemical analysis of paint takes two or three weeks so that this method is difficult to adopt as a check on actual materials used, and the writer, therefore, considers that the only safeguard is to use a standard brand whose makers will themselves defend its quality and reputation. Strict inspection of an agreed routine as to coats is the most that can be done as regards workmanship. It is impossible to distemper newly plastered walls in cold damp weather. Stizing (clearcole) may be slightly tinted to facilitate inspection.

PROGRESS AND OUTPUT.

Progress on a large estate has four periods : (a) preparation, say 3 or 4 months ; (b) increasing output, about 40 per cent. of total time ; (c) fairly regular output, about 20 per cent. of total time ; and (d) decreasing output, occupying the remaining 40 per cent. of total time.*

Road and sewer work progress depended largely on the supply of drawings, the number of sewer outfalls at which work could be commenced and the supply of hard core for roads, which was seasonal.

As regards house construction, with 12 houses per acre, and, say 2 men continuously at work per house, a general foreman with 250 men required some 10 acres to keep them employed.

With an output of 70 man-weeks per house, again it would take 35 weeks to build a house, which is about an average on several estates, so that one foreman will have an output of $\frac{250}{70} = 3.6$ houses per week. From these considerations it is evident that, with the cottage type of house where labour cannot be concentrated, a large area of ground is a necessity for a high total rate of progress to be obtained, and it follows from the first paragraph that the maximum rate of construction over period of regular output (c) must be $1\frac{2}{3}$ times that of the average, e.g., if 1,000 houses have to be built in 100 weeks the maximum output to complete on time must be not 10, but 16.66. These characteristics are exemplified in Fig. 4 shewing progress on Watling Estate, where the number of houses was 4,018 and the period of completion taken as 172 weeks after allowing for preparatory period.

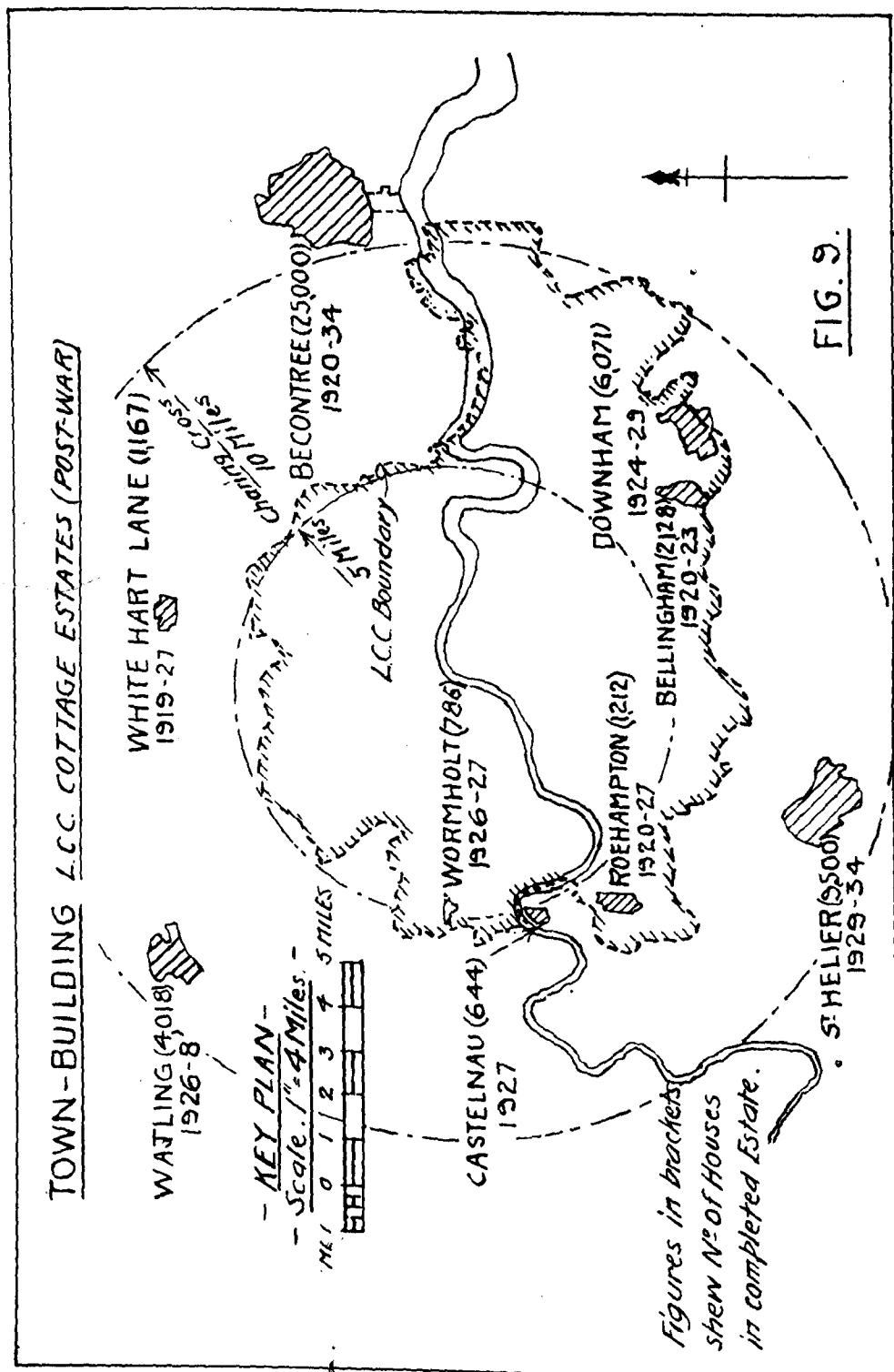
The writer's estimate of progress (shewn dotted on this diagram) was 68 weeks to work up to 40 houses a week, then 34 weeks at 40, and 68 weeks to decrease from 40 to nil, which gives :—

$$\frac{2(68 \times 40)}{2} = 2,720 \quad \text{(Increasing (b) period and decreasing (d) period).}$$

$$34 \times 40 = 1,360 \quad \text{Steady output.}$$

$$4,080$$

* See also B.R.B. Graphical Analysis of Cottage Building (Wainwright). H.M.S.O.



It will be seen that these figures were fairly well followed, except that in the summer of 1928 for various reasons progress was accelerated, construction being substantially complete four months ahead of the specified date.

To secure methodical progress the important points were:—

- (1) Possession of adequate areas for construction.
- (2) Early supply of drawings and schedules of facing bricks, roof coverings, etc., and
- (3) Adequate supplies of material.

The first two items were the Council's responsibility, and the last that of the Contractor, and all involved considerable forethought and co-ordination, any interruption producing serious consequential effects. There are sixty or seventy "operations" in house construction (see Appendix V.) which should follow in orderly sequence, and it is one of the disadvantages of alternative forms of construction (steel, wood, etc.), that they do not fit in with brickwork organization.

TAKING OVER HOUSES.

When the Principal Resident Officer was offered houses for acceptance by the Contractor, he first satisfied himself that houses, access and lighting would probably be ready by the given routine date (a Saturday three weeks in advance) and then notified:—

- (a) The Valuer for taking over and occupation.
- (b) The Architect for final inspection.
- (c) The Comptroller for rent audit.
- (d) The Local Authority for occupation, rating, and putting street lamps into lighting.
- (e) Service Companies for making final house connections and installation of slot meters, etc.

If the Architect's inspection was satisfactory, the handing over of keys on due date then took place.

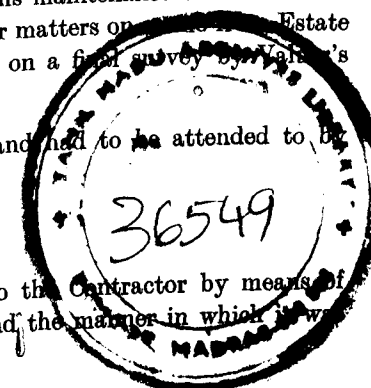
MAINTENANCE.

The Housing Contract provided for three months maintenance of houses after handing over, which was carried out as regards minor matters on the Estate Superintendents to Principal Resident Officer, and on a firm survey by the Department just before the three months expired.

This maintenance was a troublesome matter, and had to be attended to by staff specially detailed for the duty.

FINANCE AND AUDIT.

The expenses of construction were advanced to the Contractor by means of an "Estate Account" at the local branch Bank, and the manner in which it was



operated on by the Contractor was strictly laid down in regulations drawn up by the Comptroller and issued to the Contractor by the Administrator. The time book and wages sheets were combined in one book ; stocks of all materials in the stores were kept on cards and verified continuously, the usual methods of audit were applied to payments by cheque and cash, and invoices were, after checking and comparison with approvals, put up for payment under a face sheet endorsed by the Contractor's Agent, the Principal Resident Officer and the Comptroller's representative on the estate.

INSURANCE, LICENSES, INCOME TAX, ETC.

In addition to the statutory cards for Health and Unemployment Insurance, a third card was kept for Income Tax, and with 3,000 men on the pay roll these cards required a large amount of attention. Other insurances effected were fire, employer's liability, third party, engine and boiler, fidelity, cash in transit and plate glass (for shops). There was also the periodic renewal of licences for road vehicles, drivers, steam rollers, petrol stores and level crossings, which together with rates, wayleaves, leases, statutory and Council notices as to trades and wages, required unremitting work and considerable expense to keep in order.

TESTS.

Samples of all cement and concrete were systematically tested at the Chief Engineer's Department at County Hall ; paint was also analysed before approval, and samples periodically sent from painter's kettles. The Forest Products Research Board was consulted as to seasoning, etc., of British Columbian Pine, and stacks passed for use on their verification of moisture content.

VALUATION OF WORK.

As stated previously, the work was valued on completion in accordance with contract schedules for houses and road and sewer work.

In addition to making this final valuation, the Quantity Surveyor on the Administrator's staff "scored" and reported the housing progress every week in accordance with an adapted Ministry of Health scale (Appendix I.). This Surveyor also verified all payments under sub-contracts for measured work. As a general check on progress and results, an interim valuation was carried out once every six months on an appointed day, the Surveyor making a special survey of all construction, and the Comptroller simultaneously verifying balances of material and stocks on the estate. By collating figures of valued work and value of material and comparing them with total expenditure, it was possible to estimate the cost per house.

At the final valuation a reconciliation statement was prepared comparing quantities of materials purchased compared with those estimated from measurement.

CONCLUSION.

Although occasional notices have appeared in the press* with regard to different estates, the operations described have received as a whole comparatively little attention in spite of their importance, *e.g.*, Becontree has about the same population as Brighton†. At Watling and St. Helier the rate of expenditure was of the order of £1,000,000 per annum, and the total expenditure will probably be £27,000,000 when the present commitments are completed in about two years' time.

It will be noted that over the period March, 1927, to September, 1928, 13,417 equivalent houses were built, *i.e.*, construction proceeded at the average rate of 177 houses per week for some eighteen months, which is probably a record for a single housing authority.

As regards costs, it will be clear from the principles underlying the contracts that the L.C.C. have reaped the *whole* of the advantage which has in point of fact accrued from the fall in prices and wages since 1919. Moreover, considerable savings have resulted from the power under this form of contract to adapt construction to existing sources of supply.

It may also be pointed out that the Contractor's basic fee, which was 2½ per cent. from 1919 to 1929, has since the latter date been 1½ per cent. on the *valuation*, *not* the cost, and that these fees are only a fraction of the profit which would at any rate be provided for by contractors tendering on the firm price system.

It may, of course, be urged on the other hand that if prices had risen these savings would not have accrued, but this follows from the policy of the Council's accepting the financial risk, and the Council could at any period for this or for any other reason have terminated the contracts in this form, if they had desired to do so.

It may be doubted whether any other system could have produced similar results in the period 1919-32.

These points are recapitulated, as there are very general misunderstandings and misconceptions as to the position of the parties to the contract in this form.

* "The Builder," July 15th, 1927. (Becontree).

"Building," March, 1928. (London's Housing Problem).

"Sphere," 27th April, 1929. (Watling).

"Municipal Journal and Public Works Engineer," 25th July, 1930. (St. Helier).

† L.C.C. "Housing," page 75, 1927.

APPENDIX I.

ABRIDGED MINISTRY OF HEALTH SCORING FOR EQUIVALENT HOUSES.

(1) Commenced	5%
(2) Foundation concreted ; damp course laid ; brickwork 4 ft. up	10%
(3) Joists laid ; brickwork 5 ft. above first floor .. .	25%
(4) Wall plates laid ready for roof ; chimney stacks built ; roof framed and tiled or slates ; gas pipes fixed .. .	40%
(5) Floors laid ready for plastering ; plastering finished ; joinery fixed	60%
(6) Plumbing and water pipes completed and ready for painting	80%
(7) Drains laid, water mains laid ; painting completed ; iron-mongery fixed, fencing and paths complete .. .	90%
(8) Ready for occupation	100%

APPENDIX II.

EXTRACT FROM LETTER DATED 22ND MARCH, 1920, FROM MINISTRY OF HEALTH.

In connection with the development of sites for housing purposes, it is not considered necessary to use concrete for bedding on encasing salt glazed ware pipe sewers except in the following circumstances :—

- (a) Where the nature of the ground provides a bad foundation, the pipe to be bedded on concrete at least 6 in. thick, haunched up to the centre of the pipe.
- (b) Where the depth of cover above the pipe exceeds 14 ft. or is less than 4 ft. 0 in. in roads or 3 ft. 0 in. in fields or other places liable to be used by carts, etc., the pipes to be completely encased in concrete at least 6 in. thick.
- (c) Where the internal diameter of the pipe exceeds 15 ins. it may be strengthened with concrete where considered necessary.

ABSTRACT OF "RELAXATION OF LOCAL ACTS, REGULATIONS OR BYELAWS."
Notified by Ministry of Health letter to Merton and Morden U.D.C., 29th September, 1928.

Author's Abbreviations :—

- Type X means "Highway having a carriageway existing at the date of permission to develop."
- " Z " "Street of a minimum width of 42 ft. with a carriageway of a minimum width of 26 ft."
- N.C.R. " " Shall communicate with no other street other than a street not intended for use as a carriageway."

Type.	Descrip- tion of new Street.	Maxi- mum Length Feet.	Minimum Widths, Feet.			No. of Foot- ways.	Conditions as to provision of turning spaces, minimum size circle of 30 ft. diameter.	Conditions as to junctions with other streets.
			Street.	Carriage- way.	Foot- way.			
A	—	1,500	42	16	4 ft. 6 in.	2 (1 if houses one side only)	500 ft. apart in streets 500 ft. long or over	Shall communicate at each end with street
B	—	750	30	16	4 ft. 6 in.	1	" "	" "
C	Cul-de- sac. NCR	600 450	24 24	16 14	—	—	One to be provided at far end cul-de- sac	Shall communicate at one end with street
D	" *	200 500	16 14	8 10	—	—	" "	" "
E						None	" "	Of Type A, B, X or Z. Of Type A, B, X or Z. Note.—For this type, cross fall of carriageway may be all to one side at 1/4 in. per foot.

* Access to buildings on one side of street only forming three sides of a quadrangle or similarly to front on open space.

CONDITIONS APPLICABLE TO ALL ABOVE TYPES OF STREETS (A, B, C, D, E).

- (a) The street shall be one which in opinion of the Council is not likely to be required for through traffic, and in which no buildings other than dwelling-houses or such public buildings as the Council may approve are proposed to be erected.
- (b) Any portion of the street not constructed as a carriageway or footway shall be planted with grass, trees or shrubs, or treated in some other suitable manner to the reasonable satisfaction of the Council.
- (c) Any turning space which is required by the conditions set out in the Schedule, shall be of such dimensions that a circle with a diameter of 30 ft. could be inscribed in the carriageway of the street.

APPENDIX IV.

COTTAGE CONSTRUCTION.

Sequence of Operations.

Setting out and fixing sight rails.
 Surface excavation.
 Trench excavation, timbering as necessary.
 Concrete in foundations.
 Brickwork up to D.P.C. all walls.
 Concrete for raft.
 Damp course laid.
 Doors thresholds set, external frames erected.
 Block scaffold if necessary.
 Brickwork up to 4 ft.
 Scaffolding.
 Brickwork up to 1st floor level, including air bricks, setting door and window frames, setting lintels, forming fireplaces and flues, corbels, fixing-bricks.
 Set 1st floor joists.
 Raise scaffolding.
 Brickwork in all walls up to eaves, including window frames, and air bricks, form fireplaces, flues and arches and corbels, and close in cavity.
 Raise scaffold.
 Brickwork to chimney stacks, corbels, copings and flaunching up.
 Frame roofs, including wall plates, ridge, rafters, purlins and struts, ceiling joists and gutter brackets, prime fascia board. Fix tank in roof.
 Lead flashings to gutters and stacks.
 Board and batten, and tiling or slating, including ridges, hip tiles and pointing
 Dress down lead flashings, and fix eaves gutters and down pipes.
 External pointing, and clean down brickwork, and fill up putlog holes.
 Carcassing for gas, water and electric light.
 Fix soil pipes and branches and lead joints.
 Excavate and lay drains and build manholes.
 Test drains.
 Fill up trenches and dispose of surplus.
 Build sleeper and fender walls and fix sleeper plates, and ground floor joists, filling under hearths.
 Joiners first fixing: ground floor and 1st floor boards, partitions, window lining, door linings and stairs.

Build concrete slab partitions.

Glazing.

Plastering, inclusive, lathing and "grano" floors and hearths and curbs to gullies.

Joiners second fixing: Sashes and casements, skirtings, picture rails, hand-rails and balusters, wood mantels, shelves, doors and architraves and ironmongery.

Fix stoves and ranges.

Clean off wood and ironwork.

Plasterer: fixing wall tiles and make good after other trades.

Fix baths, W.C.'s, coppers, pump and water pipes.

Fix brick steps.

Paint and distempering.

Fix wood edging and concrete curbs to paths.

Form paths, retaining walls and additional steps.

Fix gates and fences.

Lay Tarmac to paths.

Stain woodwork.

Fix and connect gas and electric light meters.

APPENDIX V.

PLANT. PRINCIPAL ITEMS ON WATLING ESTATE.

<i>Locomotives.</i> Six wheel coupled, saddle tank type 12 in. cylinder, 1; 13 in. cylinder, 2; 14 in. cylinder, 1.			
<i>Wagons.</i> Ballast, 69; covered, 5; bogie, 2; tip, 12.			
<i>Temporary Standard Gauge Railway.</i> (56 lb. f.b. rails, 9 in. $\times$ 4½ in. sleepers).			
Sidings near main line, 4 "full" and 1 "empty" road, .. lin. yds.	Miles		3,039
Track on Estate	"		3
<i>Light Railway.</i> (2 ft. gauge, 14 lb. rails)	No.		66
<i>Tip Wagons</i> for do. 1 c. yd... .. .	"		3
<i>Mortar Mills.</i> 9 ft. pans	"		1
<i>Steam Engine.</i> Portable 16 N.H.P. driving mortar pans and saw	"		6
<i>Concrete Mixers.</i> 8½ 16 c. ft. capacity	"		4,000
<i>Scaffold Poles</i>	Stds.		45
" <i>Boards</i>	No.		16,000
" <i>Chains and Blocks</i>			

APPENDIX VI.

SCHEDULE OF AGREEMENTS, APPROVALS AND DRAWINGS REQUIRED ON ESTATE.

Item.		No. Sets of Drawings required.	Department of Origin.	Approval or Reference.
1	Land available	—	Valuer	Owners
2	Approval to scheme	—	"	Ministry of Health
3	Estimates reported to Committee	—	Administrator	Housing Committee
4	Expenditure authorised	—	"	L.C.C.
5	Lay-out approved	—	Architect	Housing Committee
6	Water supply agreement—mains	—	Administrator	Company
7	" " " service	—	"	"
8	Gas supply agreement—mains	—	"	"
9	" " " houses	—	"	"
10	"Electricity supply" agreement—mains	—	"	"
11	" " " houses	—	"	"
12	Street lighting	—	"	"
	Lay-out received	—	Architect	Local Authority and Company
14	Road plans received	—	Engineer	Administrator and Local Authority
15	Sewer " "	—	"	"
16	House " "	—	"	"
17	Schedule of types	—	Architect	Administrator
18	Approval of Plans—Roads and sewers	—	Administrator	Local Authority
19	" " Houses	—	"	"
20	Order to commence—Roads and sewers	—	"	"
21	" " Houses	—	"	"
22	Plans 1/2,500.. Properties acquired	1*	Valuer	—
23	" " " Cartoon lay-out	6	Architect	Housing Committee
24	" " " Available soil and surface water sewers	3*	Engineer	Administrator
25	" " " Gas mains	2*	Company and Principal Resident Officer	"
26	" " " Water mains	2*	"	"
27	" " " Electric mains	2*	"	"
28	" " " Electric distribution boxes	2	"	"
29	" " " Street lamps	3	Principal Resident Officer	Local Authority
30	" " " Sidings and service railway	8*	Contractors	Railway Company and Administrator
31	" " " Sequence of sections development	3*	Administrator	Housing Committee
32	" 1 in./64 ft. Diversion of footpaths	6*	Administrator or Principal Resident Officer	Magistrates
33	" " " Diversion of streams	11	"	Local Authority or Stream Authority
34	" " " Provisional centre line setting out of roads	4	Architect	—
35	" " " Centre line setting out of roads	5	Principal Resident Officer	—
36	" " " Roads and sewers	11	"	—
37	" " " Longitudinal sections of roads and sewers	11	"	—
38	" 1 in./32 ft. Lay-out plan of roads	1	"	—
39	" " " " blocks	13	Architect	—
40	" " " House connections (position on sewers)	7	Principal Resident Officer	—
41	" " " Cross sections and spot levels	2	"	—
42	" " " House drains	10	"	Local Authority

APPENDIX VI—Continued.

SCHEDULE OF AGREEMENTS, APPROVALS AND DRAWINGS REQUIRED ON ESTATE.

Item.		No. Sets of Drawings required.	Department of Origin.	Approval or Reference.
43	Plans 1 in./32 ft. Fencing, plan and paths	13	Architect	Local Authority
44	" " " Postal numbers and street names	15	"	"
45	" " " Gas service pipes	9	Company and Architect	—
46	" " " Water service pipes	8	Principal Resident Officer and Architect	—
47	" " " Electric light service	9	Engineer and Architect	—
48	" " " Land drains	7	Principal Resident Officer	—
49	Detail Drawings Road cross sections	11*	"	Administrator
50	" " " Manholes and gulleys	10*	"	"
51	" " " Bridges and culverts	10	"	"
52	" " " Houses, type elevations	14*	Architect	"
53	" " " 1/2 in. details	10*	"	"
54	" " " Types, doors and windows	10*	"	"
55	" " " Full size details	10*	"	"
56	" " " Special elevations for 50 per cent. of blocks (number for each block)	9	"	"

Note.—*These drawings one set only wanted.

Remainder shews number required for each section of 500-1,000 houses.

APPENDIX VII.

L.C.C. Watling Estate.

AREAS AND CUBE CONTENTS OF TYPICAL HOUSES.

Type.	Description.	Situation.	Floor Area, sq. ft.	Contents, c. ft. 35° pitch.	Contents, c. ft. 42½° pitch.
S.1	5-Room Parlour	End	874	11,602	12,359
S.1	" " " " " " ..	Inter... ..	828	10,630	11,323
S.2	4-Room Parlour	End	874	11,602	12,359
S.2	" " " " " " ..	Inter... ..	828	10,630	11,323
S.3	4-Room Non-Parlour	End	722	9,297	9,825
S.3	" " " " " " ..	Inter... ..	722	9,034	9,548
S.4	3-Room Non-Parlour	End	650	8,825	9,395
S.4	" " " " " " ..	Inter... ..	702	9,153	9,743
S.7	5-Room Parlour	End	867	11,118	11,607
S.10	4-Room Parlour (Special) ..	3 House, Cor- ner Block	2,608	—	11,316
S.11	4-Room Non-Parlour (Special) ..	Inter... ..	728	9,315	9,833
S.12	" " " " " " ..	End	834	10,732	11,216
S.13	" " " " " " ..	" " " " " " ..	879	—	11,525
S.14	4-Room Parlour	" " " " " " ..	772	10,083	10,755
S.14	" " " " " " ..	Inter... ..	772	9,866	10,311
S.5	2-Room Flats 4 Flats	Ground 1st Floor ..	Area excluding Passages.		End 14,733 Inter. 15,358
			End.	Inter.	
			504 494	531 550	
S.6	3 and 4 Room Flats 6 Flats	Ground 1st Floor 2nd Floor ..	998	1,081	—
			826	602	
			729	614	
			708	609	
S.15	2-Room Flats and 4-Room Parlour Houses 4 Dwellings	Ground, 1st Floor House	2,063	1,825	—
			Inter. 534		
			858		
					(47½° pitch) 33,076

DISCUSSION.

MR. HAROLD BERRIDGE, introducing his Paper, said: As you see, the operations cover the construction of fifty thousand houses, executed over a period of some thirteen years. I was not connected with the work personally the whole of that time, but I was in charge of about ten thousand houses for a period of about five years. If, therefore, I have not given quite such a birdseye view as might have been done by an officer who was higher up in the organisation, still I was very much in touch with details.

The paper describes the administrative machinery by which the London County Council constructed its cottage estates, and Fig. 1 shows that at one period during the Spring and Autumn of 1927 and the Spring of 1928 the Council actually turned out houses at the rate of 220 per week. If you take forty-four working hours per week, you will see that this means one house being turned out every twelve minutes of the working week, which is, of course, a very high rate of speed. To do this everybody had, of course, to get into line. It was a very complicated organisation.

You will see from Fig. 2 that the Headquarters Staff, which began with the Council itself and ended with the Assistant Administrator, was quartered in London, and that all the rest of the staff was on each Estate, so that when you had six Estates going it meant a very large number of people concerned and many different strings to keep in touch with.

You will also see that on each estate, apart from the Headquarters Staff, the Administrator was in touch with the other principal officers of the Council, being himself the Chief Engineer. He was in touch with his next in command, the Assistant Administrator, to whom the Principal Resident Officer on each estate reported. The position of the Principal Resident Officer was the position that I filled at Watling, at Castelnaud, and for part of the time at St. Helier.

The duties of the Principal Resident Officer were not simply and purely of a technical character. He had to keep in touch not only with the technical side, the engineering and the architectural side, but he had administrative duties such as the

appointment of the staff and the contractors' staff, and he had also to sign up every week for bills which amounted in some cases to £1,000,000 a year. This was a very heavy responsibility, and he was assisted by the Comptroller's Department, who kept in touch by current audit of the contractors' accounts.

You will see that the contract differs from the usual form of contract in so far as the Council financed the whole show as it went along, and the contractor did not carry any financial responsibility, apart from that of carrying out the work properly, and ordering materials in proper quantities.

There are one or two things I might bring forward which I find I missed out. I said that in some cases the outfalls of sewers ran up to thirty-six inches diameter. But in some places I am told they went up to nearly five feet. So that you see these jobs were very different from the ordinary building estate, where one has seldom to deal with sewers of more than a foot or so diameter.

The construction of houses on a clay soil is a very tricky business. You are torn between the two opposing considerations of not being too extravagant and going too deep, and yet at the same time going deep enough to prevent houses cracking when an extra dry year comes along, which frequently happens in the London area. So that this really was the crucial test of the work. In the first place it had to be a presentable sort of job to look at, the house had to be nice, and the architect provided the designs and the lay-out; and at the same time the other consideration was the cost; and these two conflicting considerations were very troublesome to deal with. The Council's Staff on the Estate had to work at high pressure the whole time to provide the contractors with drawings, both for engineering and for architectural work. My connection with the Council has now ceased, but I should like to say that the Council was very well served, all departments co-operating to produce this large amount of work and high rate of speed in accordance with requirements which were often conflicting.

In conclusion, I have the leave of the Congress to show you two small items which

I produced on my own account during the progress of the work. I have here a small machine which I invented for testing the mortar, which, as you know, is an essential constituent of good brickwork. The machine tests mortar at two days, four days and seven days, and you can soon tell whether you are getting proper proportions. The other item is a wall-tie which prevents mortar lodging on the tie itself and so producing a damp patch, which sometimes happens through water being carried from the outer to the inner skin.

I have not mentioned any of the principal officers by name, except the Administrator, but, of course, all departments of the Council and all the principal officers took a great deal of interest in the work—the Solicitor, the Architect, Mr. Topham Forrest, in the Chief Engineer's Department, Mr. D. C. Graham, who was in charge of the main drainage work, and the Administrative Department itself of which, for a good deal of the time, Colonel K. T. Lomas was in charge. Sir George Humphreys was, of course, the Administrator over the whole time of which I have spoken.

THE CHAIRMAN (Sir Arthur B. Lowry): I have had a good deal to do with various aspects of housing, but I could not add anything useful to a discussion on a Paper like this—a Paper on which I feel Mr. Berridge is to be very highly congratulated because it gives a very lifelike presentment of the staffwork that is necessary in the construction of what really amounts to a new town. I can quite imagine it being taken as a textbook by the people, more numerous, I suppose in the future than in the past, who will have to deal with the problems created by the displacement of population from the central part of so many towns in this country—problems which, I suppose, become larger and more difficult the greater the success of the slum clearance campaign.

Mr. A. SCOTT (Chief Architect, Ministry of Health): The Paper deals with a great achievement—the building, under one Authority, of 50,000 houses on undeveloped land, mainly within a period of ten years, a great work, of which Sir George Humphreys and his staff must be very proud.

First there is the organisation of the work under a Housing Administrator. This looks very like the system in vogue in India where,

under the Public Works Department, design is divorced from execution, and the architect is confined to his office.

It is true the organisation diagram shows that the Architect has direct access to the Housing Committee, and that he has a representative on the site, but he is made to look, to my mind, distressingly unimportant in the scheme of things.

The question of the type of contract adopted will, no doubt, lead to a good deal of discussion. Was the value-cost contract the best under the circumstances, and if at the commencement of operations it offered, as it no doubt did offer, special advantages over other forms was it desirable to continue it throughout the ten years period? It resembles our old friend of unhappy memory, the Ministry of Health Contract No. 3, except that the cost of financing is not borne by the contractor, and that some of the defects discovered in working the No. 3 form have been eliminated. It closely resembles building by direct labour. It has the flexibility of direct labour, but is free from some of its defects. The main difference, and it is of course a vital one, is that the remuneration of the director of operations, in this case the contractor, increases—within limits—in proportion to the amount by which he can get cost down below the agreed estimate, practically a salary with commission on savings. I will content myself with merely mentioning such subjects as the failure of alternative methods of construction to compete with traditional methods, the limits of standardisation, the field for research, reform in road planning construction, trees, in regard to which Mr. Berridge has taken a bold line, and relaxation of byelaws. Some of you may appreciate a state of affairs in which the London County Council has to apply for waivers.

If the development of regional planning should happily lead to decentralisation of industry and the planning of new self-contained communities, there is much here that will be of great assistance to those who will be responsible for the building of the new centres, and a great field of work will be open to men who, like Mr. Berridge, have had the good fortune to be closely associated with the carrying out of large-scale building operations.

CAPT. W. E. JAMES (Welwyn): I am one of those who, in a much smaller way than Mr. Berridge, has tried to build a town. My town, Welwyn Garden City, is planned for a population of fifty thousand, and in twelve years, which is about the time it has taken Mr. Berridge to build Becontree, we have built one-fifth of our town. Though on a smaller scale the problems are very much the same, except in one respect. Whereas Mr. Berridge had the immense advantage of the backing of a great public authority for his financial requirements, Welwyn Garden City has lived from hand to mouth, and until after 1921, when a clause inserted in the Housing Act of that year allowed approved Garden City undertakings to borrow from the Public Works Loan Board, we made very little progress. I may admit at once that we never reached the speed of producing a house every twelve minutes. We perhaps produced one every twelve hours during our peak periods.

I sympathise with Mr. Berridge very much in his reference to the preservation of trees. I sympathise because I wished, as he did, to preserve trees. But trees are found in such awkward positions, and at last I had to take a fairly firm line that it was not worth while to divert an important road for the sake of saving a tree or a hedgerow, because, after all, the roads are bound to outlive the trees. Generally speaking, however, in Welwyn we have preserved the old trees, with very few exceptions, and many of the old hedgerows.

It was not possible on that site to use the standard gauge railway as Mr. Berridge used it, but we did the next best thing. From our sidings, of which we had four, on the full gauge railway, we carried a light railway of two-foot gauge all round the whole Estate, and from that railway the town, in so far as it has been completed, was built. The roads came afterwards. At one time I had fourteen miles of light railway in use with branches running into the several gravel pits and brickworks. We still have what we call the "Inner Circle" of light railway from which, when a new road or district is to be developed, we throw out a spur and transport the whole of the materials for that district to the site, withdrawing the spur after the work has been completed and when the roads are ready. It has been

of extraordinary value on a site such as ours, particularly when, outlying areas being developed, one had to take materials across ploughed fields and over clay areas.

I was very pleased to notice that Mr. Berridge dispensed to a large extent with the interceptor trap. At Welwyn we have dispensed with it altogether. Our drainage system is open from the sewage works to the house vent shafts.

In regard to sewer calculations, although I proceeded from different premises, I arrived at a figure almost exactly the same as Mr. Berridge's of 0.055 cubic feet per minute per house. My figure agrees with his to the second place of decimals. I did find, however, from actual measurements that only 29.5 gallons per day per head of population reached the sewage works, although the water consumption was 37 to 39 gallons per head per day. That, I take it, is largely explained by the fact that everyone has a garden and waters it fairly plentifully.

In regard to rainfall, I allowed three-quarters of an inch per hour on impermeable surfaces, and nothing for any other surface, but I did slightly reduce the main drains, relying on the manholes themselves to provide accommodation for extraordinary and sudden flows.

I am not quite sure that I understand rightly the last reference to the tables from which Mr. Berridge calculated his sewers and surface water drains. I may have used, perhaps, a different constant, but I found that Kutter's formulae required a larger pipe than that of Crimp and Bruges.

It might be interesting for me to say one other thing, and that is that at Welwyn I instituted a rather mean method of procedure in regard to manholes and street gulleys, both of which I cast *in situ* in cement concrete from steel forms previously prepared and withdrawable. I see that Mr. Berridge used tubes in the case of manholes. Our experiment has been very successful and we have now used it throughout for ten years.

Mr. ISAAC BURNS (Hemsworth): If Mr. Berridge could build one house every 12 minutes, he must have had an enormous staff of ordinary workmen as well as officials. Where did he get his workmen from, and what efficiency had he amongst the workmen who were building the houses. In 1927-28

I presume there would be some difficulty in getting the number of builders you required. We had some difficulty in that respect in Yorkshire at that period. How many sites had you going on at the same time, or had you only one? How many Clerks of the Works had you? Were you overrun by officials?

Then you mentioned a thing that rather intrigues me. You mentioned a sewer of 5 ft. Was that five feet fall, or was it a 5 ft. sewer? I suppose it was a five feet fall.

MR. HAROLD BERRIDGE: 5 ft. diameter.

MR. ISAAC BURNS: Might I ask this: we have always been taught that you should fill your sewage pipes with sewage, that you should not have any spare room because of the gasses that would emanate, etc. I would like you to state whether you kept your sewage pipes full, or not. Then you referred to clay. Is clay a thing on which to build? What reference, has it to the health of the people, building on clay or building on sand?

I must introduce the subject of beauty. What variety of designs and colouring had you in the houses that you built? Those of us who are anticipating extending our boundaries and building in various parts of Yorkshire would like to see more variety of design and beauty. One has seen other parts of the world where houses are of various colours. What accommodation do you give these people, and what rents do you charge? What did your houses cost?

MR. HOLMES (Royston): The value of this Paper is very great to people like myself, and to Authorities like the one I represent, which is a very small one indeed, and which a year or two ago had the smallest rateable value per head of almost any district in England. We have different things to contend with in the North. We have hills and dales. In one particular section we have the wild nor'easters for nearly six months of the year sweeping right across from Stonecross Moor. We have had four or five Housing Schemes, and it may be of interest to know that the Authority I represent at present owns nearly one-half of the total number of houses, and these have all been built since 1921. We had difficulties under the Greenwood Act and

under the Wheatley Act with four different types of houses, and the chief feature of a Paper of this character is the assistance we can obtain from the information embodied in it and the various statistics that have been compiled.

I would like to know what has been the cost of attention to the houses, since their completion, in the shape of repairs, and that kind of thing. In an area like ours, in a mining community, we get a lot of subsidence. In some areas we get clay such as Mr. Berridge has referred to. You think you are building on a solid foundation, and probably in a dry season you find out there is some cracking of the houses, and some slight subsidence.

I should like to know whether after the construction of houses built at such a rapid rate and in such a manner there has been any necessity for immediate attention after the scheme was finished. I ask this question because I remember that in one scheme where we hurried our contractors to get it finished by a particular date in the interests of the subsidy, we found the result was that the houses wanted attention immediately after the building site was completed.

Apart from this, I would like the speaker to make a few observations as to how the site itself has continued since the completion of the building, because it is not necessarily a question of initial cost. There is the question of upkeep after the houses have been built.

MR. SHAW (Dunfermline): Mr. Berridge refers to the adoption of the "value-cost" contract. I am not quite clear on what basis the "value-cost" contract was based. As the building of the scheme extended over a period of ten years it occurs to me that if my idea of the contract system is correct the builder was getting a very great advantage should there be a fall in prices. It occurs to me that probably if the direct contract system had been adopted at a later date when the second and third developments had been started, the costs might have been very different from what they were at the finish.

I find according to the Paper that the ceiling height was decreased from 8 ft. 6 in. to 8 ft. Are we to take it that the 6 in. reduction in height applied to the ground floor as well as the first floor? In Scotland

we do not built below 8 ft. 6 in. for the ground floor.

I am very glad to see that the interceptor trap was omitted. I think it is an anachronism, and leads to a very great increase in the maintenance costs of the buildings. And I think a sweeter drainage system is obtained if the interceptor trap is omitted.

With regard to foundations, I was rather surprised to find it was necessary to go down 2 ft. 6 in. for "intermediate," and 3 ft. for "end" houses below the original surface of the ground. I would like to ask if the clay was found nearer the surface, or if there was an overlying depth of ground or earth which had been cultivated.

Referring to the precautions that were taken, the Paper says that joists and wall plates below floor level were creosoted under pressure of 4 lbs. per cubic ft. absorption, and sawn ends were brush-coated with preservative. I should like some information as to what preservative was used for the brush application.

Then with regard to damp courses, the Paper says there were two courses of slate laid in 1:3 P.C. mortar in external walls and of bitumen-lead type in internal and sleeper walls. I should like Mr. Berridge to give us his explanation as to why there was an alteration in the type of damp-proof course used in external and internal walls.

With regard to plastering, I see Mr. Berridge now recommends that putty from stone or hydrated lime should be run first and then used as required. In Scotland we do nothing else but run our lime into putty, and then mix it in the usual way with sand; but even then in many cases we have great difficulty in getting good plaster, and we have had a great deal of trouble through bad places. I believe there is a recommendation now that run lime should not be used for plastering, and that hydrated lime, or lime of gypsum, should be used, and that the ordinary run lime is not dependable. I had occasion to ask the Research Board for their guidance in this matter.

MR. W. ABBOTT (Cudworth): We are only a small Urban District Council, and like our friends in Royston our rateable value is a very low one, a penny rate only bringing in something in the region of £100. We have over 600 houses belonging to the township, and we are the largest ratepayers in the

district. In one particular scheme 310 houses were being built at one time, and you will realise that for a small district such as ours that was a very big task.

The question has been raised as to the cost of repairs. In our case it is probably due to colliery subsidences. You will realise that the cost of repairs from this cause alone, when it has to be borne by such a township as ours, is a very heavy burden.

The type of tenant is a very important factor. One tenant will take great care of the house he occupies, but another has no regard to the property. From this point of view, too, we have a very heavy burden to carry as a consequence of the wilful damage done to our property.

We were looking for a suitable piece of ground upon which to build houses for old people of 65 and upwards, but as soon as the owners of the land knew what was required, the price they put upon it was prohibitive. We wanted to build the houses as cheaply as we could so as to make it possible to let them at a low economic rent. Eventually, however, we were successful in getting a piece of land which had been an eyesore to the township for a considerable time. We got it at a cheap price because the owner knew that heavy costs would be incurred on account of street improvements, etc. We built 20 houses, and I say with pride that those houses are beyond comparison. They are fitted with two bedrooms and a bathroom upstairs, and a living room and big scullery, with every convenience inside. The tenants have not to go outside for anything in bad weather. Through the foresight of the Council we have been able to let these houses at the rate of 5s. 6d. a week, rent and rates included.

MR. HAROLD BERRIDGE (replying to the discussion): You have heard during the last half-hour or so, the kind of question which was presented to the Administrator and the Principal Resident Officer continuously over the period which I have covered. As I have said, the Administrator's duties were not only technical, but he had to consider as well the architectural, the legal, and the financial aspects of the scheme which the Council had ordered to be carried out.

With regard to the gentle prod which Mr. Scott administered, I do not want you to

think that the architect's part in this great scheme was in any way minimised or neglected.

While on this subject I will also deal with Mr. Burns's question about variety of design. This is a tremendous subject. At St. Helier we had finally, I think, 27 types of houses to deal with. You never quite knew when you finished one section what the next would be like. It was no guide at all to what you might get in the next one. I think anyone who goes round and looks at the Council's estates at Becontree, Watling, Downham, or St. Helier, will see that after the estates have matured, that is to say, after they have got past the first rawness of construction, the variety of design and the amenities of the estate generally are a long way ahead of anything that has been done in the country so far. Two or three years ago I went round a number of towns in the Midlands, and I say that the London County Council at any rate does not suffer by comparison. Of course, if you are going to keep within any reasonable cost at all you cannot go beyond the limit of twelve houses to the acre, or whatever is laid down by the Ministry of Health for the area in question.

Perhaps everybody does not realise that in building these estates the Council is merely in the position of an ordinary landlord. The Council has to go to the Local Authority and get its designs for houses and roads and sewers approved by the Authority in just the same way as if it was an ordinary owner building an estate. So that if there is any credit or discredit attached to the omission or insertion of interceptors it has very little to do with the Council. They merely have in many cases to conform to the local bye-laws and regulations. In those cases where the existing bye-laws have been departed from, they have only been departed from to the extent contemplated in the Housing Acts with which no doubt you are all familiar.

With regard to trees, I started off on this housing work with very great sympathy for the tree question. But after a little while one does find that trees and houses and roads do not go together. To start with, the estates in the London area, with one exception, are situated on clay soil. Becontree has gravel soil. I wrote a paper in

"Engineering" three or four years ago in which I showed that in every cubic yard of clay there are 60 gallons of water. Now a tree absorbs that amount of water and distributes it into the air in about a day; so that when you get a dry Summer a big tree like the elm, of which you have thousands on an estate, will dissipate into the air so many times 60 gallons of water, and the clay shrinks, and if the house happens to be within the radius of action of the tree it will produce a settlement. Nothing in the world can prevent it unless you are down below the saturation level, which is not always economical. In many cases it is cheaper to provide, by reinforcing the concrete foundation with steel fabric and expanded metal and old rails, against the possibility of settlement, and you will see if you read through the Paper that in many cases of end houses of blocks, and all houses where we had a bad place, such as crossing ditches or old ponds, the super-structure of the house was reinforced as well with "brick-tor" or "Exmet" fabric or similar material. That was the result of experience, and it has answered very well. We did have some houses crack, but when we had learned the lesson this did not happen. I think on the St. Helier estate we had very few indeed.

If you take a tree which has a height of 70 ft. or 80 ft. and weighs 15 to 20 tons, you have a dangerous structure, and in order to be safe you have to give that tree a very wide berth. The old rule used to be that a house should have a distance from a tree equal to its height. That means that you have to leave 50 ft. on each side of the tree, and you cannot build a house in that area of 100 ft. You have to crowd up the houses in some other part in order to leave that tree, which, as I state in the Paper, may crack the houses in the immediate environment, while it also fills the gutters with leaves, and in addition to that is the bugbear of the tenants who invariably kill any tree that they get in their back gardens.

I am afraid I cannot contest with Mr. James on the subject of Santo Crimp's tables. I had very largely to rely on the Engineering Department, and my idea was that Santo Crimp's tables did call for a larger pipe, but if I am wrong I stand corrected. Mr. James's idea of a standard gauge siding and a light railway for building

an estate is correct, and if he looks at my Paper he will see that I consider that should be done in the future. With regard to Mr. Burns's enquiry about manholes, we built them in clay. The London clay is fearful stuff to work in. When you get down 5 ft. or 6 ft. in the Winter you get the excavation standing on timber, and if you are going to mass concrete you cannot draw the timber, but you have to concrete it in. Personally I thought the pre-cast concrete rings, with the mass concrete surround, to be a very sound engineering job, and my opinion is that the pre-cast rings with concrete filling is much better than anything else you can do.

Mr. Burns asked about efficiency. Efficiency is rather a difficult term to define. I hunted up all sorts of authorities on the output of man-weeks per house. In the first place you have to define your house. Some people reckon a house from the foundation, including sub-structure, and other people only reckon the super-structure. It is obvious if you have a flat site like Becontree or Castelnau, you are not going to spend as much on sub-structures as you are on sites like Watling, Downham, and St. Helier, where you have slopes of 1 in 12, and you have to build very high sub-structures. So that I do not think anybody can really say in comparing two estates what the efficiency of the output is until they really know about it. I put in figures which give 44 man-weeks per house in some places, but at Watling, Castelnau and St. Helier, for the average house including the sub-structure, the drains, the footpaths and the construction of the greens, the figure would be about seventy man-weeks per house. That is to say, about seventy man-weeks per house would cover the house and everything connected with it. I think that is about as close as anybody can say.

During the time I was at Watling and St. Helier, we had very little difficulty in getting the number of workmen required. At Watling when we started there was a shortage of bricklayers and plasterers, and to cope with this the Council adopted steel and wooden houses. If you go to Watling now, you will see these houses in a variety of design, but I agree with most people who have had anything to do with them, that when all is said and done the brick house takes a lot of beating. Another trouble is

that with special forms of construction you cannot "step" them, and you have to go on using all the best sites to put in blocks of four so that they do not have to be stepped.

With regard to 5 ft. sewers, I should have said that these were surface water sewers. Naturally the surface water sewers were very much larger, and had to deal with flood water. In dealing with the separate sewage system you do not have to deal with flood water, but only with house sewage.

With regard to what Mr. Holmes said, I think I have already mentioned the reinforcements of the foundations.

As regards maintenance, I do not think there was anything out of the way in respect of maintenance. Of course, the crucial point of construction in this case is that the constructor is the landlord, and you have to be careful that what you hand over from one department to the other is up to the mark, otherwise you soon hear about it. We have had trouble in one or two places owing to unforeseen causes, but, generally speaking, out of the 50,000 houses built, I think after the first six months there has been very little complaint in any way.

Mr. Shaw mentioned the form of contract. There were several contracts covered by this form. The largest contractors were C. J. Wills, who carried out Becontree and Watling and they are still dealing with St. Helier. The latter is still in progress, being about half finished. Then there was Holland & Hannen and Cubitts who carried out Downham, Henry Boot & Sons who carried out Castelnau with their own type of construction, and Messrs. Lang & Son who did White Hart Lane, and Wilson Lovat who did Wormholt. Although the contract varied, the same form of contract was applied to these different estates, and each contractor worked under it and carried out his contract separately with the Council.

I will just briefly refer to this form of contract. The contract is based on the "bogey"; that is to say, all the work contemplated under the contract is set down in the Schedule and a value attached to it. You have houses of types A, B, C, D, E, F and G, and they are valued at so much for the super-structure. The sub-structure is valued in an itemised Schedule, and the roads and sewers are all itemised, and the

whole work valued in that way. The contractor is paid at a standard rate on the valuation, with this variation: that if the cost of the work as ascertained by the Comptroller of Accounts on the Council goes above the valuation he suffers a penalty, and if the cost of the work is less than the valuation he gets a bonus. But in all cases the contractor's remuneration is based on the valuation and not upon the cost. So that his constant effort is to keep the cost of the work down, and that benefits both himself and the Council. It is a very ingenious form of contract. Whether it should be now adopted under present conditions when costs of materials and rates of labour are more stable than they were when it was first got out, is a question for higher authorities than myself to say.

With regard to preservative, that on the timber in the hollow floors was ordinary creosote, and the ends were brushed with one of the proprietary preservatives. There are several of them, and we used to use them. Of course, in fitting floor joists you cannot always have the thing cut to the exact length; you have to have a raw end where the man puts the saw through the joist, and you have to put a brush on it.

As to the damp course, the inside of a house is generally much drier than the outside, the outside being always subject to splashing and that sort of thing. The only reason we adopted a bitumen-laid

damp course on the sleeper walls, and internal walls, was that it was a bit cheaper and was considered to be sufficiently effective in the drier situation.

I concur with what Mr. Shaw said, when he mentioned plastering and hydrated lime. I quite agree that hydrated lime, which is lime hydrated in accordance with its chemical requirements, that is to say, it is lime which is burned and then hydrated with the proper proportion of water to slake it, is infinitely preferable to the putty which is sometimes produced in a very haphazard sort of way. But I do not think anybody has yet been able to produce the specification guaranteed to produce satisfactory plastering under all conditions. It is an extremely difficult trade, and personally speaking I think the only thing to do is to make the man who carries it out responsible for it, for in that way he does take an interest in it.

I think I have dealt with Mr. Abbott's question about subsidence. The only thing to do on a clay or doubtful bottom if you think a house may be exposed to the risk of subsidence is to reinforce the foundation and the super-structure too.

With regard to the height of ceiling, the height of 8 ft. is applicable to both ground floor and upper storey. This is in accordance with the relaxation of the Bye-laws recommended by the Ministry of Health.

CONFERENCE

Under the auspices of the Society of Chemical Industry.

TUESDAY, 14th NOVEMBER, at 11.0 a.m.

MAJOR F. C. COOK, D.S.O., M.C., M.Inst.C.E. (*Deputy Chief Engineer, Ministry of Transport*),
in the Chair.

The four following Papers were taken as read:—

Laboratory Tests and their Correlation with Full Scale Road Experiments.*

BY

R. G. C. BATSON, A.K.C., M.Inst.C.E., M.I.Mech.E.

INTRODUCTION.

A ROAD may be considered as a structure which has to withstand (1) stresses due to externally applied forces; (2) internal stresses such as those due to changes of temperature. The problem of studying the external forces caused by vehicles traversing roads is relatively simple and a certain, at present rather meagre, amount of data is available. The problem of obtaining the value and distribution of the stresses in the road structure is more difficult. In the case of bituminous structures this difficulty is enhanced owing to (a) the fact that the material is plastic and the application of load causes flow with time, and, therefore, a redistribution of stress with time; (b) large changes in physical properties due to small changes in temperature; (c) alteration of the properties of the material with time. It is apparent that time and temperature are two of the most important factors to consider.

The object of the engineer is to provide a road which is durable, stable and safe. The position is analogous to the progress in the design of steel bridges which can be divided historically into two stages. Early construction was based on the results of experience with full size bridges. Parts were lightened or strengthened as the result of such experience. Spans were increased and the new designs based

on the experience with smaller spans. The finished bridges were tested both statically and dynamically with loads greater than those which would be applied during use in order to ensure that the structures were safe. Gradually, however, a technique was developed whereby, from the actual loads (both static and dynamic) to be applied, the value and type of the stresses in all parts of the structure could be calculated. A system of mechanical and physical tests of the materials to be used was also developed so that the dimensions of all parts of the bridge could be calculated. A factor of safety was allowed in the design on the actual strength of the material. This factor included a factor of ignorance to take account of errors in the various estimations involved. As knowledge of properties of material increased and more exact methods of stress estimation were evolved, the latter factor was reduced.

In order to ensure that the properties of the materials actually supplied agreed with those for which the calculations were made, specifications (including mechanical tests) were prepared.

Examinations of failures have probably done more than anything else in improving methods of design and reducing "factors of safety"; for example, a knowledge of the fatigue of materials was initiated by the failure of a structure.

There are thus three types of laboratory tests:—

- (1) To obtain the physical and mechanical properties of materials for design purposes.
- (2) Tests for use in specifications. These must be easily and rapidly applied.
- (3) Laboratory tests for the examination of failures. These form the basis for general research.

In the estimation of actual loads on structures use has been made of laboratory tests on scale models. The most important case of this kind is found in wind tunnel experiments on models of aeroplanes, airships, lattice towers, etc.

Considerable experience has been gained on full scale road construction, but in many cases the reasons leading to successes or failures are not understood, and in general, the fundamental factors involved in the materials and processes used in the industry are unknown.

No technique has been developed by means of which a foundation, surfacing, or surface dressing can be designed to ensure success under any stipulated set of conditions and at a minimum cost. Road design is, therefore, following historically the progress of bridge design, and is now passing from the first to the second stage of its development. Various laboratories have developed methods of test, and in the main, these have been applied to the control of materials used in construction, but until it has been definitely established that these tests measure the physical and mechanical properties which really matter, very little progress can be made.

The difficulties involved in correlating laboratory tests with road behaviour are great, thus:—

- (1) The results from small scale laboratory tests can be obtained in hours, but the behaviour of the road can only be estimated after years of usage.

- (2) Temperature and other weather conditions vary during the life of the road and cannot so far be reproduced in an accelerated form in the laboratory. The road is subjected to a large number of uncontrolled variables each of which may have an important bearing on its behaviour.
- (3) Unless laboratory tests are made on samples cut from the road it is difficult to ensure that the sample truly represents the material in the road as regards specification and amount of compaction. The specific gravity of the road carpet varies through its section (from top to bottom) due to consolidation by traffic. The consolidation produced by moving vehicles is not necessarily the same as that given by pressure in a laboratory press.
- (4) The chemical, physical and mechanical characteristics of the material may be different at the beginning of the life of the road from those towards the end of its life. There may be an ageing of the bitumen and alteration of its viscosity with time. Material may be brought on to the road by traffic and rolled in and the grading of the aggregate may be altered by the impact of the vehicles.

It is evident that if correlation be confined to full scale road work and small scale laboratory tests progress will be very slow. The alternative is to accelerate, if possible, road conditions on some type of Road Testing Machine, such as was installed at Teddington in 1912, and carry out small scale laboratory tests on samples cut from test roads (laid in this type of machine) at various stages of their economic life. Traffic intensity can be accelerated in the testing machine, but variations of weather conditions may be of more importance than traffic intensity and the difficulty of accelerating that kind of weather condition which is most harmful to the road still remains. Accelerated traffic intensity alone may produce results of doubtful value. The kind of weather condition which produces the maximum deterioration in one type of road may be innocuous to another type. Traffic figures are often given as so many tons per day. These figures may be misleading when making comparisons unless associated with the type of traffic and width of road. Traffic intensity is the load borne by the road per unit of width calculated on the actual width taking the traffic, thus with a 20 ft. road carrying 12,000 tons per day, the actual width of road bearing the traffic would be about 15 ft., and the traffic intensity 2,400 tons per yard width per day.

It is of interest to recall that the research programme of the Advisory Committee of the original Road Board, which was approved in January, 1911, included, as one of the items of research, the testing of bituminous materials. The tests included chemical, physical, mechanical and a road machine test. For the latter it was stated that the minimum diameter should be 30 ft. (greater if possible) and a number of loaded wheels "will be made to traverse the road, the path of each wheel being slightly different and the wear measured."

The Road Testing Machine at Teddington was the outcome of that decision. This machine consists of a circular track 30 ins. wide, having a mean diameter

of 34 ft. The endurance of the centre 24 ins. of this track is tested by the rolling on it of eight steel tyred wheels, 3 ins. wide and 39 ins. diameter. The wheels are at an angular distance of 45° from each other and each wheel is rotated by a separate electric motor mounted on a steel arm which revolves round the centre post. The radial distribution of the wheels is such that the whole width of 24 ins. is covered in one revolution of the arms, and in order to prevent as far as possible the formation of ruts in the tested surface each wheel is moved backwards and forwards radially by a cam mechanism through a distance of 1 in. The eight arms are all hinged to a rotating boss on the centre post, and at their outer ends are connected by spiral springs to eight corresponding cantilevers rigidly fixed to a second rotating boss connected with the former and immediately below it. The pressure of each wheel on the track can be adjusted to any desired value up to 25 cwt.

After the track is laid the machine is run slowly with a gradually increasing load in order to consolidate the material.

For the test the machine is run at a load of 470 lb. per inch of width of tyre and at a rate of about 2,200 tons per yard width of the road surface per hour. The test can be carried out either with the surface dry or flooded with water.

Arrangements have been made to transfer the Road Machine from Teddington to the Road Research Laboratory at Harmondsworth. During the transfer various modifications will be made to the machine and test track which experience has shown to be desirable. These modifications are:—

- (1) Track width. This will be increased from 2 ft. 6 in. to 6 ft. 0 in. so that the test road can be rolled by means of a petrol roller of commercial size. The central 2 ft. 0 in. of the track will be under test. The test road will be on the same level as the outer surround (i.e., on ground level) for convenience in rolling.
- (2) Arrangements to raise all the arms sufficiently high above the track to allow rolling to proceed normally.
- (3) Arrangements to raise all wheels clear of the track *while running*, so that the dead weight of the machine will not rest on stationary wheels on the track.
- (4) Provision of arrangements for
 - (a) increased torque for starting,
 - (b) running four motors braking and four pulling if required.
- (5) Arrangements to fit rubber tyred wheels in place of steel wheels if required.
- (6) Provision of higher loads and speeds.

CORRELATION OF TEST RESULTS WITH ROAD BEHAVIOUR.

The only published information in this country that the author has been able to find which definitely connects test results with road behaviour is in connection with sample roads tested in the road machine and laid to the same specification and by the same workmen as actual roads in the country. The results of these

tests are summarised in Tables 1, 2 and 3. It will be appreciated that, as the surfacings were laid in 1914, they do not all represent modern practice in bituminous road construction. Roads 1 to 4 inclusive represent one series and Roads 5 and 6 another. It will be noted that the results of the road machine tests link up with the actual behaviour on the road. All the surfacings failed by disintegration and not by pushing and a test with the surface continually wet was particularly severe on a surfacing which was not watertight. No attempt was made to keep a very close control of temperature, and the actual temperatures were considerably lower than those to which a surfacing is subjected in summer. Thus it is possible that, although Road 6 was better than Road 4 (458,000 against 125,000) under the conditions of test employed, a test at a higher temperature might not have given the same numerical comparison. The published description of the behaviour of Road 1 after test states:—

“The chief feature of the test was the rapid deterioration under wet conditions. A considerable quantity of water was absorbed by the surface and the road failed owing to the sand being washed out. This test road was an exact copy of some bituminous carpets which were laid in September, 1914. These carpets have shown exactly the same peculiarities, viz., the dry weather had but little effect, but the continuous wet weather of the past winter has washed the sand out, causing the road to be cut up by the traffic.”

The road was patched and then surface treated with tar, and this was probably one of the earliest examples of the surface dressing of asphalt carpets with tar.

As a result of tests on Roads 1 and 2 (which were almost identical in composition) a test was carried out on a road laid to the same specification as one in North London (Test Road No. 3) and which had stood up well in service, and finally, the specification for Road No. 4 was tested in the machine and used in the same locality as Test Road No. 1.

With respect to Test Roads Nos. 5 and 6, about three-quarters of a mile of road had been laid to the same specification as No. 5, but by the time this length had been laid the earlier portion was showing signs of disintegration and a road machine test was carried out. The report of this test states:—

“The causes of failure were possibly due to:—

- (a) an unsuitable mixture, i.e., insufficient filler.
- (b) the material being laid at too low a temperature (200°F. to 260°F.).
- (c) Insufficient consolidation.
- (d) Too small a percentage of bitumen (12 per cent.) for the class of sand used.”

A consideration of the question led to the specification for Test Road No. 6 and the author has been informed that this actual surfacing is still in use and giving good service.

In connection with the above full scale and road machine tests, certain small laboratory experiments were made on samples cut from the test roads (see Table 3), and the results of these may be of some interest. The voids determinations place

TABLE 1.
RESULTS OF ROAD MACHINE TESTS CORRELATED WITH ROAD BEHAVIOUR.

Road No.	1	2	3	4	5	6	7
Type of Surfacing.	Sand Carpets $1\frac{1}{2}$ in. to $1\frac{3}{4}$ in. thick on concrete.						$1\frac{1}{2}$ in. "travelled" asphalt on concrete.
Bitumen . . . %	13	13	13	13	11	14	12
Sand . . . %	78	78	72.5	67	85 (Sand and lime-stone dust)	78 (Sand and lime-stone dust)	55 ($\frac{3}{4}$ in. to $\frac{1}{2}$ in. Granite Chips)
Filler (Portland Cement) . . %	9	9	14.5	20 (Blue lias lime dust)	4	8	33 ($\frac{1}{8}$ in. Ground limestone and fine mineral matter)
Bitumen . . . % (actual)	9	9	12	12	12	14	12.3 to 13.3
Test result in tons per yard width. } Consolidation Dry . . . } Wet . . . }	20,000 414,000† 14,200	4,400 6,710	4,600 212,000	4,700 125,000	5,400 26,000	6,100 458,000	20,000 414,000† 136,000
Temperature of Test °F. . . .	58-64	60	63	68-72	73-78	67-71	58-68
Actual Road Behaviour . . .	Good in summer. Very poor in winter	Very poor	Good	Fairly good	Poor	Very good	Good

* The actual Chemical analysis is given in Table 2, and it will be noted that the actual bitumen content differs in some cases from that specified.

† After 414,000 tons per yard width the surface showed practically no deterioration and the test was continued with the surface wet.

TABLE 2.
ANALYSIS OF MATERIALS TAKEN FROM TEST ROADS.

Road No.	1	2	3	4	5	6	7
Bitumen (%)	9	9	12	12	12	14	12.3 to 13.3
Passing 200 (%)	8	7	13	17	4	12	
" 100 "	6	6	14	6	6	7	
" 80 "	4	4	12	3	9	6	
" 50 "	36	43	22	29	60	43	No Grading published.
" 40 "	22	23	7	22	7	11	
" 30 "	3	2	6	2	1	1	
Retained on 30 "	12	6	14	9	1	6	

TABLE 3.
SMALL SCALE LABORATORY TESTS CORRELATED WITH MEASURED DEFORMATION OF TEST ROAD.

Road No.	1	2	3	4	5	6
Specific Gravity as laid at conclusion of test	1.85	1.76	2.10	2.11	1.82	1.96
Upper half	—	—	2.14	2.16	1.96	2.10
Lower half	—	—	2.11	2.07	1.90	2.07
Full Section	2.05	1.78 to 1.85	2.13	2.13	1.94	2.08
Voids % as laid at conclusion of test	17.8	21.8	7.9	8.7	18.7	11.3
	8.9	20.8 to 17.8	7.0	7.8	13.4	5.9
Impact test—No. of blows to crack	—	6	13	7 to 19 (average 12)	10	11
Depth of indentation (ins.)	—	0.034	0.050	0.027 to 0.062	0.053	(9 to 13)
Temperature °F.	—	64	64	64	66	0.032 (0.022 to 0.036)
Absorption of water—Increase in weight % after three months' immersion	—	—	2.5	2.6	7.4	2.0
Average Deformation of Test Road* (% of original thickness).	16.1	7.9	1.2	0	8.0	2.0
During Initial Consolidation..	4.4	2.8	4.4	4.7	4.7	3.3
During Test ..	20.5	10.7	5.6	4.7	12.7	5.3
Total ..						

* Obtained from Profilometer observations (see Sixth Annual Report of the Road Board, 1916, p. 43).

the roads in the same approximate order as their life—lowest voids, longest life—and the specific gravity determination and absorption of water are also consistent in this respect.

The influence of consolidation upon the ultimate behaviour of the road was shown by a series of specific gravity determinations of pieces taken from Road No. 4 after the completion of the test. Although the value for the upper half of the surface was fairly uniform round the track with an average value of 2.16, that of the lower half varied considerably, the extreme values being 2.13 and 2.01 (with an average of 2.07). Analysing this further, the following variations were found:—

*Average Specific Gravity
of lower half of
surfacing.*

At bad hollows	..	..	..	..	2.02
At slight hollows	..	..	..	..	2.08
Road in "good" condition	..	..	..	..	2.10

For the impact test, samples 1½ in. diameter and 1 in. long were cut from the actual road surface and tested in a Page impact tester. In this tester a plunger (weight 1 Kg.) having a spherical end of 1 cm. radius rests on the test piece and a weight (2 Kg.) is allowed to drop on the plunger from a height of 1 cm. for the first blow. The height of fall increases by 1 cm. for each succeeding blow until failure occurs. Mr. Clifford Richardson has stated that the impact test "is valuable in revealing the difference in susceptibility to water action of different mixtures" and "the value of the test is assured from the results thus far obtained." The results recorded in Table No. 3 do not entirely bear out that statement.

The only other published series of mechanical tests linked up with actual road construction with which the author is familiar is that carried out by the Ministry of Transport in connection with the experimental sections on the Kingston By-Pass and published in "The Report for the year 1931 of the Technical Advisory Committee on Experimental Work." Unfortunately, no comparison is possible at present with actual road behaviour for the reason that all the sections are still giving good service. The results of the tests are summarised in Tables 4 and 4a. The tests carried out were:—

- Tension.
- Compression.
- Impact.
- Stability.
- Specific Gravity and Voids.

The types of test piece used and the methods employed were as follows:—

(a) *Tensile tests.*—These were made with test pieces of the shape used for cement briquettes, but with all the dimensions multiplied by three, thus the cross sectional area was 9 sq. ins. The test pieces were made in moulds by the roadside from the same mix as laid and were formed under a pressure of 3,000 lb. per sq. in. The tests were carried out at 65°F., and at a rate of extension between the testing machine jaws of 0.06 in. per minute.

TABLE 4.
RESULTS OF MECHANICAL TESTS ON THE EXPERIMENTAL SECTIONS OF THE KINGSTON BY-PASS.

Section.	Tensile Test at 65°F.			Impact Test. Blows to produce first crack at 65°F. (lb. to sq. in.).	Compression Test. Mean Strength at 65°F. (lb. to sq. in.).	Emmons and Anderton Stability Test at 140°F.	
	Mean Strength (lb. to sq. in.).	Mean Elongation in cm. on 15.3 cm. Length.				Max load lb.	Corresponding Penetration of die (in.).
1. Hot Asphalt 2 in. coat ..	150	0.08		32	950	2,300	1.2
2. Hot Asphalt 3 in. coat ..	90	0.05		23	780	6,200	1.7
3. Hot Asphalt 1½ in. wearing coat ..	80	0.05		28	930	2,900	0.5
4. " " 2½ in. binder coat ..	50	0.03		33	560	10,200	1.4
5. " " 2½ in. binder coat ..	150	0.25		18	950	7,500	0.5
6. " " 2½ in. binder coat ..	30	0.01	As binder of 4).	32	470	6,600	1.7
7. " " 3 in. coat ..	30	0.02		28	700	800	1.9
8. " " 3 in. coat ..	30	0.02		24	670	5,600	0.7
9. Cold Asphalt ½ in. wearing coat ..	10	0.01		17	800	3,400	1.1
10. " " 1½ in. binder coat ..	3	—		22	190	3,100	0.7
11. " " 2 in. coat ..	60	0.01		25	200	—	—
12. " " 2 in. coat ..	30	0.05		19	210	2,200	0.7
13. " " 2 in. coat ..	60	0.01		16	210	1,300	0.5
14. " " 2 in. coat ..	60	0.01		16	120	6,100	0.9
15. " " 2 in. coat ..	60	0.01		16	400	4,200	0.9

TABLE 4a.
RESULTS OF MECHANICAL TESTS ON THE EXPERIMENTAL SECTIONS OF THE KINGSTON
BY-PASS (Continued).

Section.	Specific Gravity.	Mean Specific Gravity of Test Specimens.	Specific Gravity of freshly laid road surfacing.	Voids in freshly laid road surfacing. %
	Voidless by calculation.			
1. Hot Asphalt 2 in. coat ..	2.40	2.37	2.34	2.7
2. Hot Asphalt 3 in. coat ..	2.44	2.44	2.41	1.2
3. Hot Asphalt 1½ in. wearing coat ..	2.38	2.26	2.26	5.9
4. " " 2½ in. binder coat ..	2.44	2.40	—	—
5. " " 2½ in. binder coat ..	2.21	1.97	1.53	30.8
6. " " 2½ in. binder coat ..	2.49	2.41	2.41	3.2
7. " " 2½ in. binder coat ..	2.30	2.30	2.30	Nil
8. " " 3 in. coat ..	2.47	(As binder of 4). 2.41	2.38	3.7
9. " " 3 in. coat ..	2.46	2.39	2.35	4.5
10. Cold Asphalt ½ in. coat ..	2.53	2.37	2.31	8.9
11. " " 1½ in. binder coat ..	2.56	2.46	2.46	3.9
12. " " 2 in. coat ..	2.32	2.26	2.14	7.6
13. " " 2 in. coat ..	—	2.25	—	—
14. " " 2 in. coat ..	—	2.36	—	—
15. " " 2 in. coat ..	—	2.38	—	—
16. " " 2 in. coat ..	—	2.38	2.34	—

(b) *Compression tests.*—These tests were made on cylinders 3 ins. diameter and 3 ins. high, moulded at a pressure of 3,000 lb. per sq. in. The tests were carried out at a temperature of 65°F., with a rate of compression of 0.13 in. per minute.

(c) *Impact tests.*—These tests were the same as those described above, except that the test piece was a cylinder 3 ins. diameter and 3 ins. high moulded at 3,000 lb. per sq. in., and the weight of the hammer was 5 Kg. instead of 2 Kg. The tests were carried out at 65°F., and the blows were struck every 10 seconds.

(d) *Stability tests.*—These tests were made at 140°F. by the Emmons and Anderton method. The sample, 8 ins. long by 2½ ins. wide by 6 ins. high, was moulded under a pressure of 3,000 lb. per sq. in., and then placed in a steel mould of the same internal dimensions. The bottom 3 ins. of each short side and the centre 4 ins. of the bottom of the mould were cut away, thus forming three openings. Pressure applied through a steel plate to the top of the test piece extruded the material through the openings. The top plate was made to move downwards at a constant speed of 0.06 ins. per inch and the maximum load taken by the material was recorded.

In addition to the tests described above, experiments were made on the surfaces of the sections to determine:—

- (1) Resilience or rebound.
- (2) The Relative Roughness.
- (3) Relative Slipperiness (Skidding).

The results of tests (1) and (2) are summarised in Table 5. The results of skidding tests are given in the Annual Reports of the Ministry of Transport Technical Advisory Committee (Page 11 and Fig. 1 in the report for 1931 and page 23 and Fig. 2 in the report for 1932). Although not strictly mechanical tests, they are not without interest.

(1) The resilience or rebound tests were made by allowing a hammer, weighing 1.8 Kg., and having a lower spherical striking end of 7.6 mm. diameter, to fall from a height of 100 cm. on to the surface, and noting the height of the rebound.

(2) The relative roughness was obtained by an integrating mechanism coupled between the front axle of a car and the cylinder block. The total vertical rise of the axle relative to the cylinder block in travelling over the section of road under test was recorded. The results are only comparative and the actual values depend on the car used. The results given in Table 5 were obtained at 30 m.p.h. with a 14 h.p. car and tyre pressure of 28 lb. per sq. in.

(3) The relative slipperiness was obtained by means of a special motor cycle and sidecar. Very little difference is obtained on surfaces at low speeds or under dry conditions.

Experiments (2) and (3) are primarily concerned with the usage of the road, and it has been found that the results obtained correlate with the actual performance of vehicles on the surface, but they can only be carried out on actual road surfaces. Small scale laboratory tests for slipperiness are urgently needed, but in any apparatus of this nature, "speed" is a primary consideration. Slow velocity determinations

TABLE 5.
RESULTS OF TESTS ON EXPERIMENTAL SECTIONS OF THE KINGSTON BY-PASS.

Section.	Roughometer. Comparative unevenness of surface.		Rebound of Hammer % of Height of fall.	
	1931.	1932.	86°F.	41°F.
1. Hot Asphalt 2 in. coat ..	60	60	8	19
2. Hot Asphalt 3 in. coat ..	80	90	6	13
3. Hot Asphalt 1½ in. wearing coat on a binder coat ..	90	90	—	—
4. Rock Asphalt 1½ in. wearing coat on 2½ in. binder coat ..	90	90	6	12
5. Mastic 1½ in. wearing coat on 2½ in. binder coat ..	70	80	9	22
6. Slag Tar-Concrete 3 in. coat ..	120	120	—	—
7. Granite Tar-Concrete 3 in. coat ..	170	160	4	9
8. Cold Asphalt ½ in. wearing coat on 1½ in. binder coat ..	100	100	5	7
9. Cold Asphalt 2 in. coat ..	90	100	4	8
10. Cold Asphalt ½ in. wearing coat on 1½ in. binder coat ..	90	100	9	13
11. Asphalticised Concrete 1½ in. coat ..	130	130	—	—

of coefficients of friction of rubber on various surfaces are occasionally published, but the only values which the author has seen in which such coefficients are low are those obtained on ice-coated surfaces.

CONCLUSIONS.

The published results of mechanical tests appear to indicate that no one test or combination of existing tests is likely to give a universally applicable criterion of the suitability of a bituminous mixture for road use—due regard must be given to the type of material considered. Because a material is comparatively weak mechanically at an arbitrary fixed temperature, it does not necessarily follow that it is unsuitable for road work, and conversely, high mechanical strength may not ensure long "road" life.

In the author's opinion, all mechanical tests of bituminous mixtures should be carried out under carefully controlled conditions as to rate of strain and over a range of temperature. The range of temperature should depend upon the property under consideration. For instance, when a surfacing material contracts under reduction of temperature tensile forces are applied. The behaviour of the material under such forces depends upon (1) the rate at which they are applied and the ability of the material to adjust itself by deformation; (2) the temperature of the surface and the temperature characteristics of the material. Unsuitable conditions may result in cracking. The interest in cracked pavements is confined to low temperatures and tensile tests should, therefore, be carried out over a range of temperature say from 6°F. to 65°F.

The material should be "stable" at summer temperatures so that any tests, which are designed to measure this property, whether of the extrusion type (Emmons and Anderton) compression tests or static indentation tests (by wheel sector or plunger) should cover a range of temperature up to, say, 140°F.

Toughness or impact tests probably give an indication of the liability of surfacing to disintegrate and as disintegration may be connected with water absorption and high voids, such tests should be carried out after soaking in water, as well as when dry, and with a temperature range of 40°F. to 100°F.

It should be emphasised that, apart from their use as controls of uniformity in laying bituminous surfaces, mechanical tests are useless and may be definitely misleading unless they are correlated with actual road behaviour. At the present time, although many tests have been used and suggested, this correlation is not available. Future progress in bituminous road construction will be exceedingly slow unless this information is obtained. It is needed by the research worker, the manufacturer and the user in this branch of road construction, and it is to the advantage of all concerned to co-operate in an endeavour to obtain that knowledge which will help to expedite road design from the first to the second stage in its development.

In conclusion, the author would like to thank the Director of Road Research (Dr. R. E. Stradling) for permission to write this paper, and his colleagues at the Road Research Laboratory for their assistance in its preparation.

Some Factors involved in the Mechanical Testing of Bituminous Mixtures.

BY

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THE work carried out in the recently equipped Technical Laboratory for the Mechanical Testing of Road Materials at the Products Works of the Gas Light and Coke Company has included a general investigation of the technique both of preparing test specimens from mixtures of mineral aggregate and a bituminous binder (viscous coal tar, soft pitch and asphaltic bitumen), and also of certain tests which could be applied to such mixtures. The aim has been to determine the conditions necessary to obtain consistent results, with a view to their subsequent interpretation from the strictly practical point of view of road service.

It was recognised at the outset that the merits of any test would have to be considered in relation to the class of material under investigation, and that several tests would be necessary to provide sufficient data to indicate the future excellence or otherwise of a material to be subjected to the whole range of traffic and weather conditions.

In the investigation of the mechanical properties of any material, those tests which combine simplicity and speed with the required degree of accuracy are of special value, and when any such test is applicable to a wide range of materials, it is worthy of the closest possible study. For example, the tensile and compressive strengths of solid materials have long been measured, and the testing machines and apparatus have been brought to a high standard of perfection; these properties can be readily measured for a large number of materials used in road construction, and the possibility of their useful interpretation should, therefore, be a matter for careful consideration.

When it is desired to carry out any mechanical test, the following factors have to be considered:—

- A. Shape and size of test specimen.
- B. Method of preparing test specimens in the laboratory.
- C. Conditions of the actual test.

A. SHAPE AND SIZE OF TEST SPECIMEN.

Test specimens are at present generally prepared as cylinders, cubes or rectangular slabs, or of figure 8 shape for the tensile test. When sufficient comparative data are available, it will be possible to determine which shape yields the most consistent results with a particular test. The question of shape is probably of greatest importance in the tensile test; the small tensile specimens used in the Beckton laboratory are prepared in moulds identical with those used by Dr. Herrmann at the Berlin Municipal Laboratory, Charlottenburg (see Fig. II), and have a more pronounced "waist" than the cement briquette prepared according to the British Standard Specification. The larger tensile specimens used are of the same shape as the standard cement briquette, but have three times the linear dimensions. Such specimens are in use at the Road Research Laboratory, Harmondsworth. It may here be mentioned that as far as possible the work at Beckton has been carried out with such apparatus and specimens as would allow results to be compared with those obtained at these two well established laboratories.

The size of specimen to be used for each test is of first importance, and is governed primarily by the nature of the test. Apart from this it may be taken that, in general, the larger the specimen the better, and that the size must be considered in relation to the size of the largest aggregate in the mixture. It has been suggested, for example, that the smallest dimension of the specimen should be not less than five times that of the largest aggregate in the mixture, but a vast amount of experimental work will be required before a definite ratio can be fixed. For a wide range of asphaltic materials and fine tar concrete, tests which have now been in use for some time can be carried out on comparatively small specimens, and the results obtained are consistent among themselves and give information capable of being applied to the control of production. It will readily be understood that the question of size is of great consequence in so far as materials which require considerable pressure for compaction are concerned, large specimens of such materials Beckton laboratory and referred to later in this paper has, however, indicated a possible means of obviating this (see "Methods of Compaction" (4)). Laboratory mechanical tests have also to be carried out on specimens taken from actual roads; for this purpose, slabs of material must be removed from the road and conveyed to the laboratory with the minimum of damage, and there cut to the required size and shape by means of a carborundum disc saw. It is also possible to cut cylinders of material from the road by means of specially designed portable core cutting machines. By either method the size and shape of specimen it is possible to cut without damage to the structure has yet to be determined for a large number of materials.

B. METHOD OF PREPARING TEST SPECIMENS IN THE LABORATORY.

The method adopted for the preparation of test specimens must within certain limits be governed by the method used in actual road practice for the particular material, and consists of two stages:—

- (i) Preparation of the material.
- (ii) Compaction of the prepared material.

(i) *Preparation of the Material.*

With the exception of natural rock asphalt, which in its powdered state may be applied to the road without any addition, the materials under consideration consist of mineral aggregate and a binder which must be brought together and adequately mixed.

For laboratory investigations, such mixtures may either be withdrawn from a large scale plant and conveyed to the laboratory as rapidly as possible in a closed and preferably heat insulated container, or may be prepared on a small scale in the laboratory itself, and in the latter case the closest attention to details is required.

Experience has been gained in the Beckton laboratory in the preparation of tar concrete mixtures consisting of closely graded aggregate ["coarse" (maximum size of aggregate $\frac{1}{2}$ in.— $\frac{3}{4}$ in.), and "fine" (maximum size of aggregate $\frac{1}{4}$ in.)] coated with a soft coal tar pitch. Mixtures are prepared by hand, careful attention being paid to the temperature and duration of mixing, both factors, as might be anticipated, having an effect on the results obtained on testing the compacted specimen. Sufficient of the mixture is prepared for one specimen only, the whole mix being placed in the mould; the amount necessary to give a specimen of the required depth in the direction of compression is found by trial. When, however, the size of the test specimen is extremely large in relation to the size of the largest particles of aggregate, it is obviously unnecessary to make separate mixtures for each mould.

If mechanical mixing is employed, it is necessary to ascertain in what respects, if any, the material obtained differs from that normally produced in the large scale plant. An estimate of any crushing of aggregate that may have taken place in a mixer can be obtained by sieve analysis after removal of the binder with a suitable solvent in a centrifugal machine or continuous extraction apparatus.

(ii) *Compaction of the prepared material.*

The prepared material at the correct temperature must be transferred to a mould for compaction by one of several available methods.

The moulds themselves, of which there are numerous patterns, are usually constructed of steel, and it is preferable that the inside and the plunger be very slightly greased. Although we have found that with some hot bituminous mixtures the temperature of the mould does not influence the density of the compacted specimen, it is probably generally desirable to use hot or warm moulds for those materials normally applied to the road in a heated condition; it has, in fact, been definitely claimed by other workers that the use of electrically heated moulds, the temperature of which can be maintained at a constant value during compaction, has given more uniform results than with moulds merely heated before use.

The method of compaction employed is of very considerable importance, and any comparison of such methods should have reference to certain important factors, viz. :—

- (a) Density of specimen obtained.
- (b) Variation in density throughout the specimen.
- (c) Crushing of aggregate taking place during compaction.

It is also necessary to know how these properties in a laboratory produced test specimen compare with those in specimens removed at intervals from actual roads constructed with the various materials.

Generally speaking, the problem is to obtain a specimen of a uniform density of the same order as that obtained in practice, and with no greater crushing of aggregate.

The following methods of compaction will now be considered :—

1. Tamping.
2. Ramming.
3. Compaction under gradually applied load.
4. Compaction by roller action.

1. *Tamping*.—This method consists in feeding the mixture at the appropriate temperature into the mould in portions, and compacting after each addition by means of a hand—or mechanically—operated tamper. One example of the method is contained in the recent description given by Hubbard and Field (Proc. Assn. Asphalt Paving Technologists 1932) of their adaptation of the stability test for mixtures containing coarse aggregate. The tamper described by Emmons and Anderton (Proc. Am. Soc. Testing Materials Pt. II., 1925) consists of an electromagnetically operated hammer fitted with a square ended tamper, and strikes about 1,500 blows per minute. The mould is gradually filled and compacted after each addition, and the contents finally levelled with a hot iron. It is claimed that this method gives high density specimens without fracturing the aggregate, and it is reasonable to assume that the density will be fairly uniform throughout. The use of a small area tamper permits a certain amount of kneading action, and will be referred to again later in connection with other methods of compaction. This method is certainly worthy of further investigation with a wide range of materials.

2. *Ramming*.—This was the first method used in the Beckton laboratory for the compaction of hot tar concrete mixtures, and consists in transferring the whole of the prepared mixture to the mould as evenly as possible with the aid of a steel spatula, placing the plunger in position, and allowing a ram to drop vertically on the latter a given number of times from a specified height. This method has received considerable attention in Germany, being embodied in D.I.N. specification 1995 (1929); a 12 Kg. ram is allowed to fall from a height of 25 cm., 10 or 20 times according to the type of material being compacted.

3. *Compaction under gradually applied load*.—The prepared mixture is transferred to the mould evenly with a steel spatula. This even distribution is essential to obtain uniform compaction. The plunger is placed in position, and the mould transferred to the bottom platen of a compression machine; pressure is then gradually applied until the desired load has been reached, and this maximum load may be maintained for any given period. It is important that the time taken for compaction be noted and adhered to when repeat tests are carried out. When working with mixtures of closely graded aggregate and binder, if the rate at which the plunger is forced into the mould is fixed, then the rate of increase of pressure will depend upon the percentage binder in the mixture; the greater the percentage binder, the more rapidly will the maximum compaction pressure be reached. The plungers used are, in general, of the same area as the mould opening less a very small clearance, and the method is simple. The main factor to be determined for each material is the maximum compaction pressure, and on this there is as yet no general agreement.

It has been claimed, although not universally accepted, that mechanical tests on bituminous road mixtures are not capable of useful interpretation from the point of view of predicting behaviour in actual practice unless carried out on test specimens of bulk density equal to that obtained on the road after a period of say one or two years under traffic. The densities of specimens of materials removed from roads can readily be determined, and when a particular mixture is compacted in the laboratory the pressure can be increased until the corresponding density has been attained, assuming that compression machinery of sufficiently great capacity is available. Taking the extreme case, it has been found necessary with rock asphalt to use pressures of the order of 10,000 lbs. per sq. inch to obtain the required compaction density, and to prepare a slab specimen of say 1 sq. ft. face in the laboratory for a wheel indentation test, for example, a compression machine of over 600 tons capacity would be required—a considerable item in the equipment of a testing laboratory. Even if the same bulk density is obtained, it does not necessarily follow that the laboratory specimen is similar in all respects to the road specimen.

The material delivered to the road has been spread to the correct contour and then consolidated either by hand rammers and ironed (compressed asphalt), or by rolling (steam rolled asphalt, tar concrete, tar macadam) or has been spread by means of wooden floats (mastic asphalt). Whatever the type of material, further consolidation—small in the case of mastics, which contain a high percentage of binder, but to a greater extent with other materials—takes place under the influence of the wheels of vehicular traffic.

Consolidation by steam roller or by traffic is characterised by a kneading action, under which the particles in the mixture are enabled to re-arrange themselves in dense formation far more readily than under a steady load applied only in a vertical direction. As already indicated, it has been found that the equivalent compaction of mixtures in the laboratory by the gradually applied load method requires very

high pressures, and it appears likely that with some materials far more crushing of aggregate takes place in the process than results from roller and traffic compaction.

The question of density variation in laboratory produced test specimens has been investigated by cutting up the specimens into sections and determining the density of the pieces. With all the mixtures investigated so far, the density is, as might be anticipated, greatest at the top, both with the ramming and steady pressure methods of compaction, although the variation with the latter method is less. The amount of crushing produced by these methods in the production of specimens of equal bulk density appears to be the same with the aggregate so far utilised.

The behaviour of bituminous mixtures under pressure in the confined space of a mould is dependent upon a number of factors, among which the following may be noted :—

1. Properties of the aggregate (shape, hardness and nature of surface).
2. Size of aggregate in relation to size of mould.
3. Shape of mould.
4. Grading of aggregate.
5. Physical properties of binder at the temperature of compaction.
6. Aggregate: binder ratio (thickness of film).
7. Voids in mixture at various degrees of compaction.

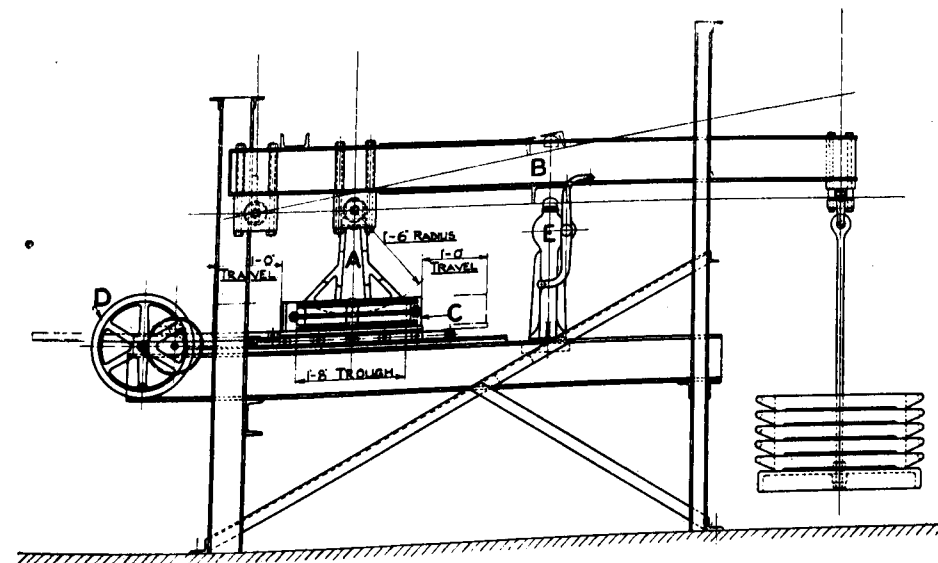
The difference in the distribution of applied pressure in compacting a cold bituminous macadam and a hot mastic—the behaviour of which approximates more to that of a viscous fluid rather than to that of a solid—is quite apparent in practice, and is a clear indication that the question of density variation in specimens compacted by various methods must be studied for each material.

It may also be said that the determination of variation in density and alteration in grading of aggregate by crushing in specimens of all classes of material cut from the actual road at intervals throughout its life constitutes an urgent task in this connection.

Many attempts have been made to overcome this difficulty of density variation and obtain a uniformly compacted specimen. With mixtures containing fine aggregate only, Hubbard has adopted a 1 in. high specimen in preference to a 2 in., and has obtained more even compaction. It has been proposed to use a plunger of one-third the area of the top surface of the specimen, gradually applying a load, releasing, and then moving the plunger to another position overlapping the first, and again applying pressure. The process is repeated until the whole surface has been subjected to pressure, and a final compression is given with a full area plunger. It is claimed that this method produces a compaction by kneading action, i.e., a compression immediately underneath the plunger and a flow in the adjacent material.

4. *Compaction by roller action* — Researches by

4. *Compaction by roller action.*—Recognition of the essential differences between compaction by direct pressure and by the action of steam roller and traffic led to the installation of a Roller Compression Machine in the Beckton laboratory, and the



ROLLER COMPRESSION MACHINE FOR ROAD MATERIALS.

FIG. I.

work so far carried out has indicated that it is likely to be a valuable method of preparing test specimens.

The machine was constructed to our requirements by Messrs. Saml. Denison and Son, Ltd., Leeds, and, as shown in Fig. I., consists of a wheel sector (A) mounted in roller bearings on a lever (B) pivoted at one end in roller bearings and carrying a scale pan at the other. With a leverage of 6 to 1, the load on the wheel sector roller may be varied between 30 cwt. and 6 tons by the addition of dead weights to the scale pan.

The mould (C) for containing the material to be compacted is 20 in. long by 9 in. wide by 5 in. deep, and consists of two angle walls and a base plate, all of which are bolted together for use. Between the base plate and bed of the machine is sandwiched a roller carriage, and the mould may be reciprocated under the wheel sector roller by means of a hand wheel (D) through a train of spur gearing operating a rack which is pin-jointed to the base plate. The free end of the beam has a considerable vertical freedom of travel, and a pointer attached at this end permits the distance of the roller from the bottom of the mould to be observed on a curved scale. To permit the necessary manipulation of the mould, a screw jack (E) is provided to raise the beam. The roller used in our experiments up to the present has been a sector of a 3 ft. diameter wheel and the same width as the inside of the mould less a clearance, but this can be replaced by one of different dimensions.

The method of operation is very simple, and consists merely in placing the material to be compacted in the slightly greased mould as evenly as possible, and

then lowering the beam until the roller—also slightly greased—makes contact in the mould. Rolling is now commenced by reciprocating the mould with the hand wheel; if a load greater than the minimum of 30 cwts. is required on the roller the requisite weights are added gradually to the scale pan, the mould being kept in motion. Rolling is continued until the desired degree of compaction is obtained with the particular load, and the lever then raised by means of the jack, so that the specimen may be removed.

The mould is previously warmed when hot material is to be compacted, but is used at the laboratory temperature with ordinary cold bituminous macadam. In the latter case a thin wood lining is placed into the mould before use to permit the removal of the compacted material without collapse.

Experiments carried out with tar concrete have shown:—

- (1) that specimen blocks can be obtained with a wheel sector load of, for example, 30 cwts. equal in density to those obtained by the gradually applied load method using a maximum pressure of 1 ton per square inch (equivalent to a total pressure of 180 tons on a specimen 20 in. by 9 in.).
- (2) that the density of the roller compressed blocks is more uniform.
- (3) that less crushing of aggregate takes place.

If work which it is hoped to carry out indicates that these results are equally true for a wide range of bituminous materials, then this method of compaction will certainly have very important claims for the consideration of those engaged in similar work and desiring to prepare large test specimens without the use of high capacity compression machines.

In concluding this brief survey of the methods of preparation of test specimens, it should be mentioned that care is required in the removal of the compacted material from the mould, in order to avoid damage, even if it has been allowed to cool to the laboratory temperature, or below, in the mould. With split moulds the specimen can usually be removed by hand with comparative ease, but with single piece moulds it is necessary to extrude the specimen slowly by means of pressure applied to a plunger.

Sufficient has been said to indicate that the question is one which must occupy considerable attention if the mechanical testing of bituminous materials is to be put on a sound basis.

C. CONDITIONS OF THE ACTUAL TESTS.

1. *Temperature of Specimen.*—The compacted specimen must be allowed to attain the temperature at which the test is to be carried out, over a period of time, and under conditions which call for some investigation.

The time taken for a specimen of any particular size and shape to attain a given temperature throughout its mass may be determined by preparing a duplicate in which narrow cavities extending to various points have been formed either during the moulding of the specimen or by subsequent drilling in the compacted specimen. Into these cavities thermometers may be embedded, and the rate of change of temperature observed. Although a minimum time which must elapse before carrying

out the test can be determined in this way, it appears likely that with some types of material mechanical tests carried out at intervals after this minimum time will continue to show variation for a period, and ultimately attain a value sufficiently constant for all practical purposes. The possibility of the existence of this stabilisation period requires to be investigated for all bituminous mixtures.

The question of the temperatures at which the specimens are to be tested is dependent to some extent on the nature of the test, but it is evident that the whole range of road temperatures should at least be covered jointly by the group of different tests adopted as the most informative for the particular material. Tests at temperatures between -10°C. and $+50^{\circ}\text{C.}$ should provide all the necessary information.

The maintenance of the specimen at a constant temperature before the test is readily ensured, if a refrigerator and an oven under thermostatic control are both available, but the method of ensuring constancy during the actual test must necessarily vary with the nature of the test. If it can be shown that no change in properties occurs when the compacted material is immersed in water, then the use of a thermostatically controlled water bath, containing a strong supporting platform, is suitable and convenient for those tests involving the application of a load to the surface of the specimen—compression, stability, and indentation tests for example. Where the immersion of the specimen in water is undesirable, or at temperatures below zero, or again, for tensile tests with a vertically supported specimen, the matter is by no means so simple, and some form of air jacket should be used when temperatures outside the range of that possible to maintain in the laboratory are necessary. In this connection the duration of the actual test is a point to be considered when designing apparatus for heat insulation.

2. *Method of applying load to Specimens.*—Bituminous mixtures fall into the category of plastic materials, which are characterised by the property of flowing to a great or small degree under an applied load and of remaining permanently deformed, and in this respect they differ from rigid bodies such as steel which rapidly reach an equilibrium under load at ordinary temperatures, no further movement taking place, and are capable of recovering their original shape. For this reason the method of applying a load, whether tensile or compressive, is of first importance in the testing of plastic materials.

The following methods of testing under dead load are available:—

(1) A load may be applied and maintained at a constant value; the resulting deformation will be instantaneous for rigid bodies and may be observed at any time, but with plastic bodies it will increase with time and must therefore be observed after a definite interval. This method of loading is used in certain deformation and indentation tests that are meeting with success in the testing of bituminous mixtures as providing an indication of the distortion likely to be caused at various temperatures by a heavy vehicle standing on the road.

(2) The applied load may be increased at a definite rate and the deformation observed at regular intervals and subsequently plotted in graphical form (or may be automatically recorded by a stress-strain recorder); if fracture or collapse occurs, the maximum load is noted.

The well known standard apparatus (Frühling—Michaelis) for testing cement briquettes in tension is arranged to operate on this principle, the gradually increasing load being applied by lead shot pouring into a canister suspended on the beam. Water from a constant level tank flowing into a receptacle at the end of the beam of such a machine can similarly be utilised for the gradual increase of the load by regular and adjustable amounts.

On large single-lever testing machines, the load may be regularly increased by moving the poise weight along the beam at a steady rate, and balance maintained by adjusting the rate of strain as required, both operations being carried out by controlling the pressure from separate variable displacement oil pumps.

(3) The specimen may be subjected to strain at a definite rate (i.e., controlled rate of deformation) and the load continuously increased as necessary to maintain the system in equilibrium. Here again the stress-strain data are observed at frequent intervals or automatically recorded. This principle is very commonly used for the routine testing of a wide range of materials. With the Denison Universal machine used in the Beckton laboratory it is possible to vary the rate of straining between the limits 0.05—2.4 inches per minute.

These three methods of applying a dead load have each been applied to the testing of bituminous mixtures. When any particular test involving the application of a variable load has become generally accepted as giving informative results of proved worth, it will obviously be necessary for the rate (or rates) of straining or loading to be standardised and rigidly adhered to by those desiring to obtain comparative results.

It must also be recognised that it is possible to apply a compressive load to a specimen either in, or perpendicular to, the direction of compaction. Quite apart from the obvious considerations of surface irregularity or lack of parallelism between the top and bottom faces, the factor is one which needs investigation.

Impact Testing.—Information may also be obtained by subjecting bituminous mixtures to loads applied suddenly, i.e., impact testing. There are several ways in which this may be done, and the work so far carried out appears to have been mainly with the Page repeated impact machine, which was originally devised for testing the toughness of road aggregates, and has since been adapted for testing bituminous mixtures. A 4.4 lb. hammer is allowed to fall upon a plunger, having a spherical end in contact with the specimen and supported in a vertical guide; the hammer falls 0.4 inch for the first blow, and this height is increased by 0.4 inch for each succeeding blow until the specimen fails. Modifications, chiefly in respect of the weight of the hammer, height of fall, and shape and dimensions of the end of the plunger have been proposed; the merits of these await the support of experimental results.

The influence of some of the factors which have been discussed is under investigation in the Beckton laboratory, and this work has been combined with a determination of the sensitiveness of certain tests to variation in the percentage

binder in mixtures of graded granite and soft pitch. The following is a brief account of three of these tests, and the results are quoted as being an indication of widely differing response (under the specified conditions) to change in composition.

The hot mixtures were compacted by a gradually applied load of 3,000 lbs. per sq. inch in a hydraulic compression machine, and conditioned in air for 48 hours before testing at 20°C.

1. *Tensile Test.*—The shape and size of the specimen are shown in Fig. II. (half actual size).

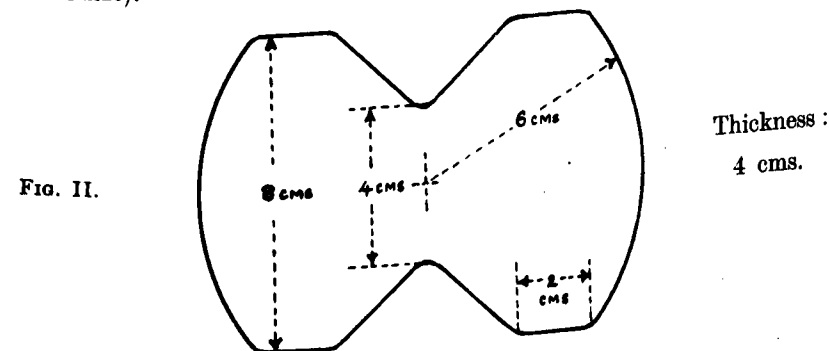


FIG. II.

Rate of straining : 0.18 inch per minute.

The breaking stress only has been plotted in Curve I.; this figure does not of course represent the total information obtainable from a tensile test.

2. *Compression Test.*—Shape and size of specimen : Cube, of 50 sq. cm. face area.

Rate of straining : 0.13 inch per minute.

Direction of compression at right angles to direction of compaction. The maximum stress is plotted in Curve II.

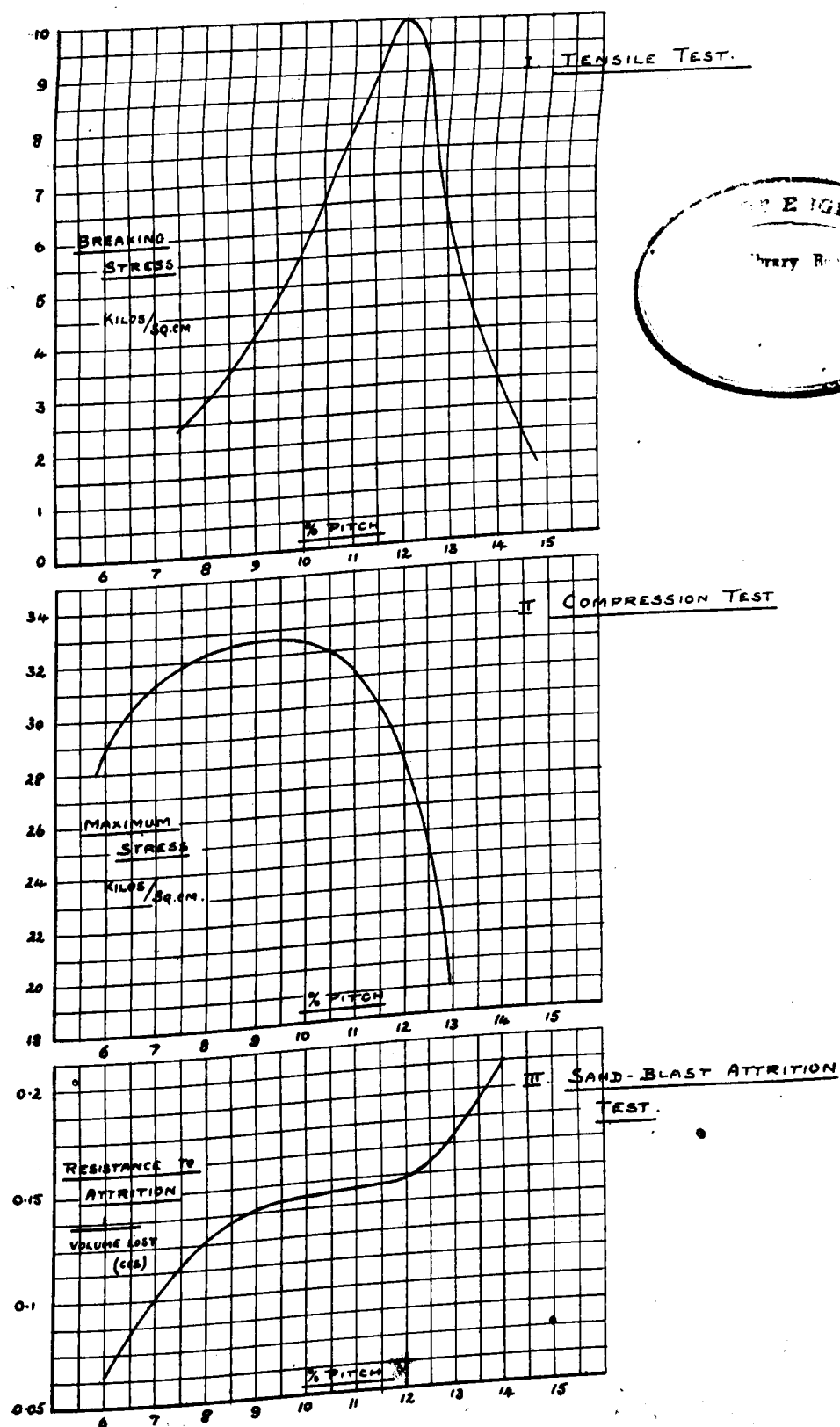
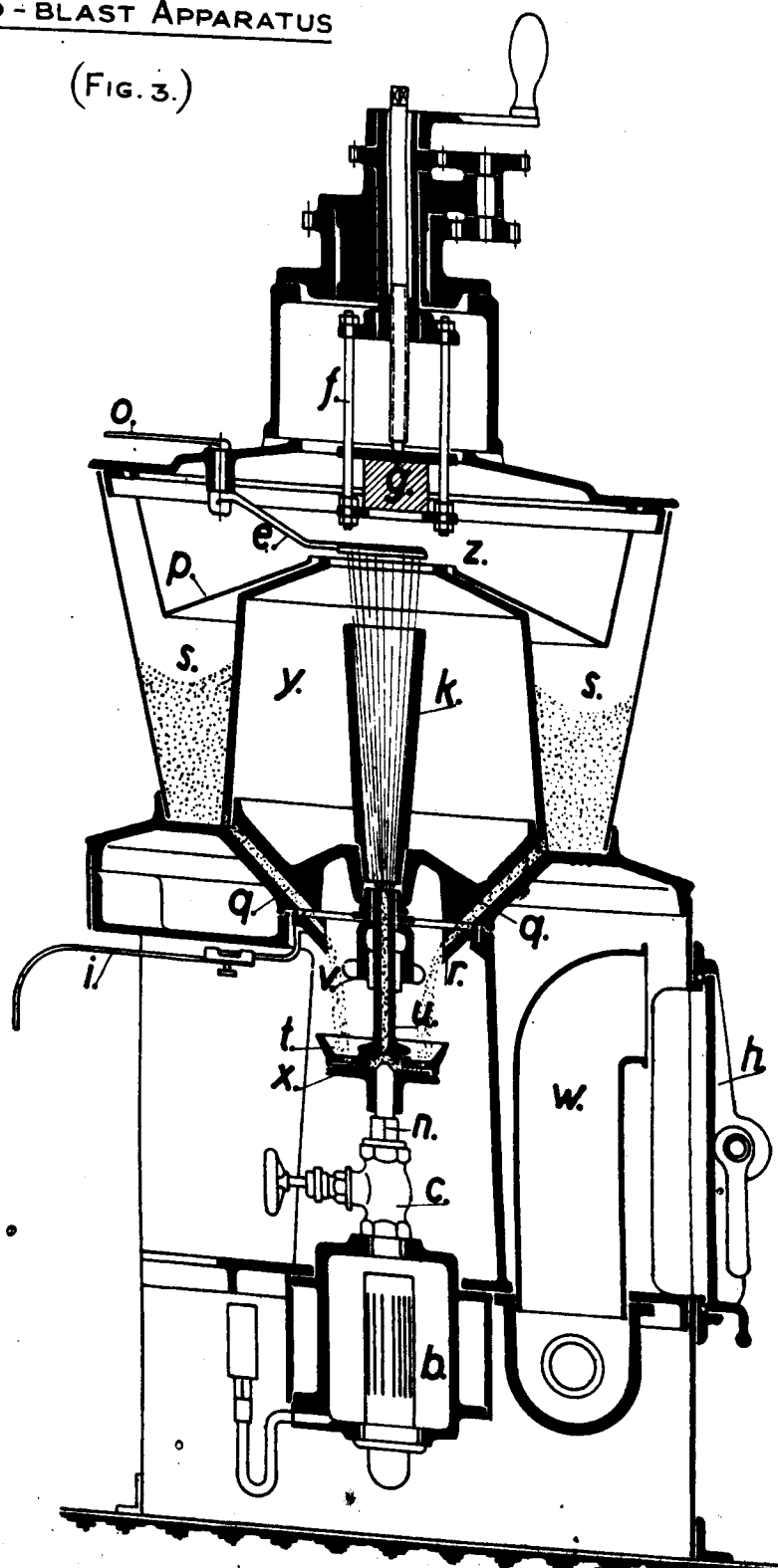
3. *Sand-blast Attrition Test.*—The apparatus installed in the Beckton laboratory is of the Gutmann-Ottensen type, and although the method of testing resistance to attrition by sand-blast is well known, a description of this particular unit may be of interest.

The construction of the apparatus is shown in Fig. III.; the compressed air used for the blast enters from a reservoir (not shown) through a pipe into trap *b*, and thence by a control valve *c* and nozzle *n* to the pipe *u*, constructed of chilled cast iron. The latter is screwed by means of a nut *v* and a rubber ring, and is easily replaceable.

The sand (Leighton Buzzard, 20-30 mesh; B.S.I. specification) falls from the box *s* through the small pipe *q* to the plate *t*, and passes through holes in the latter into the slot between *t* and the plate *x*, from whence it is sucked by the blast into the pipe *u*, and through the blast pipe *k*. The sand-blast impinges on the test specimen *g* held in the carrier *f*, and the air is sucked away from the compartment *y* by means of a small injector exhaust through the outlet pipe (not shown) to a large box outside the laboratory. The baffle pipe *w* serves to minimise clogging of the exhaust injector.

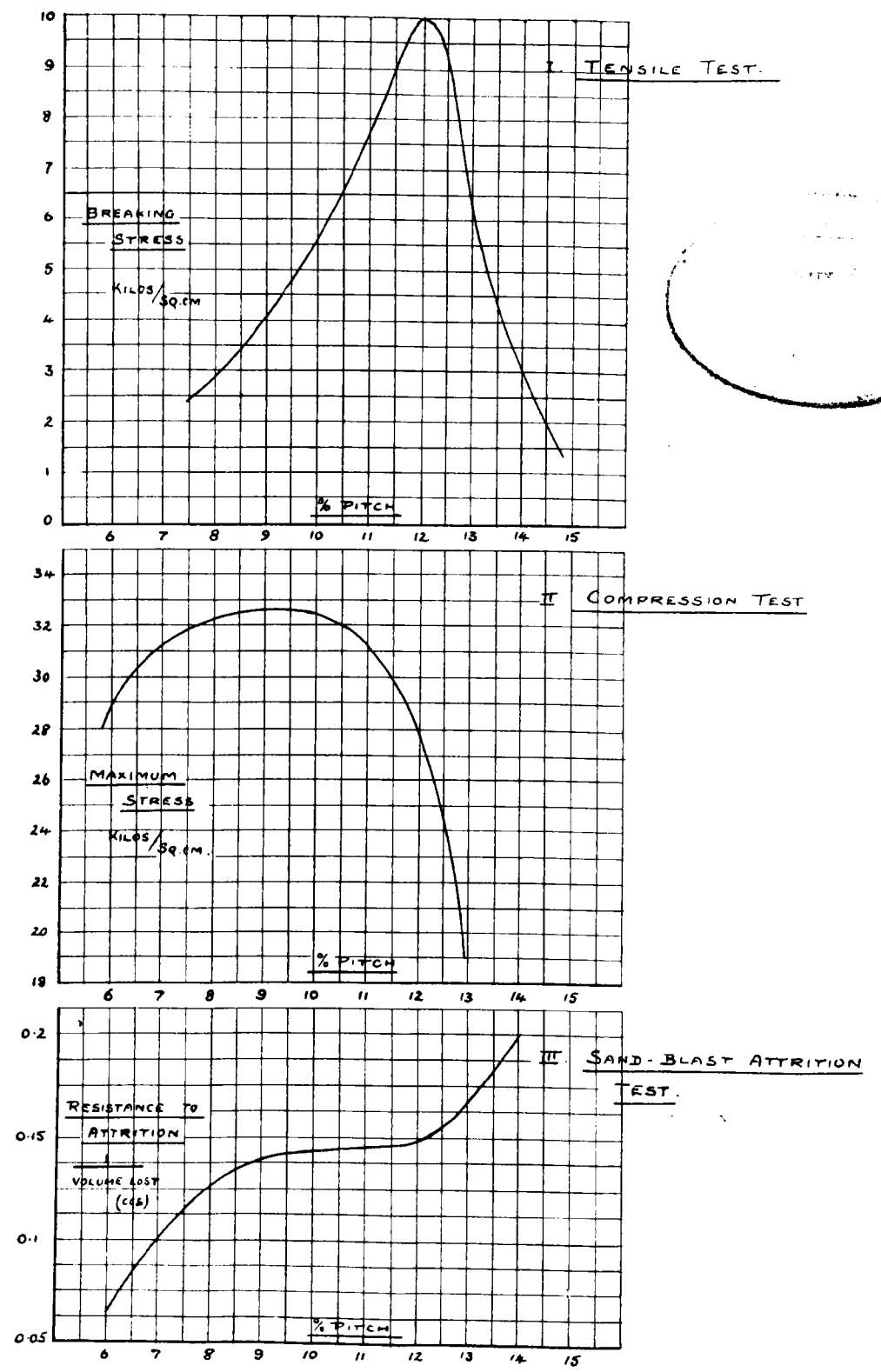
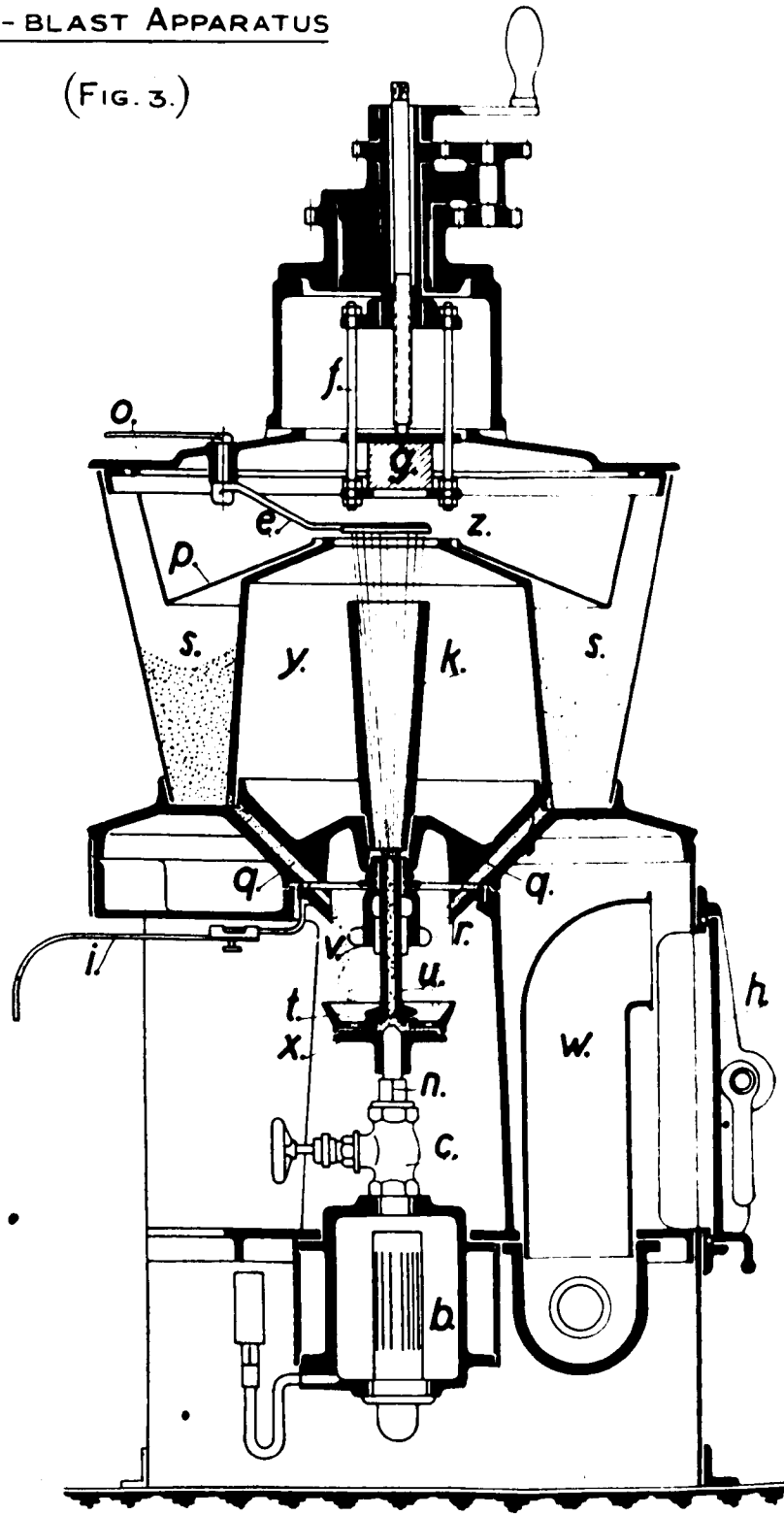
SAND-BLAST APPARATUS

(FIG. 3.)



SAND-BLAST APPARATUS

(FIG. 3.)



With the sliding stop *e* open, the sand blast impinges upon the test piece, the face of which presses against a steel template so as to expose a circular area 6 cms. diameter (= 28.27 sq. cms. area) to the jet. In order to obtain equal action over the whole of this exposed area, the test piece is placed eccentrically above the opening *z*, and is moved over the blast by means of planet wheel gear. The sand feed can be stopped or started instantly by means of the lever *i*, which operates the slide *r*.

The top part of the apparatus is easily accessible, as the cover and planet gear can be removed; the lower part is provided with a door *h* which permits the removal of used sand. A detachable case *p* is fitted in order to prevent used sand and detached particles from the specimen falling into the sand reservoir *s*.

Up to the present a blast pressure of 45 lbs. per sq. inch operating for 2 minutes has been employed. The speed of rotation of the specimen is approximately 30 r.p.m. about its own axis, and 20 r.p.m. about the axis of the machine. Each test utilises about 3 lbs. sand.

The specimen is weighed before and after test, and the loss in weight converted to loss in volume for record purposes.

It is important to note that the exposed face of the specimen is appreciably warmed during blasting; the extent of this has not yet been accurately determined for the various bituminous mixtures.

The volume lost by various materials under standard test conditions is given in the following table for comparison:—

					<i>1/2 Vol. Loss</i>
					<i>(for comparison</i>
					<i>with Curve III.).</i>
					<i>Volume Loss</i>
					<i>(cubic centimetres)</i>
Yellow stock brick	..	..	..	50.6	0.02
Wire-cut stock brick	..	..	..	35.9	0.028
Oak	{ With grain	..	..	2.4	0.417
	{ Across grain	..	..	4.1	0.244
Elm	{ With grain	..	..	3.1	0.323
	{ Across grain	..	..	2.0	0.5
Lead	..	..	..	0.2	5.0
Ebonite	..	..	..	0.08	12.5
Rubber (red sheet)	..	..	..	0.01	100.0

The test^o period of two minutes cannot be claimed to be equivalent to any particular duration of traffic of given intensity: it is probable that abrasion rather than attrition is responsible for the greater part of the loss of material from a bituminous road surface. The test is, however, capable of giving rather more information than was at first anticipated: excess or deficiency of binder, over-heating of the mixture and faulty grading of aggregate, for example, affect the volume of material removed by the blast, and the test specimen provides a "relief" picture which should prove of assistance to an experienced road constructor.

The results of these three tests, Tensile, Compression and Sand-blast attrition are shown graphically in Curves I.—III.

Points to be noted are:—

- 1. The different shapes of the curves, indicating different sensitiveness to the change in composition.
- 2. The different points at which maximum resistance is shown.
- 3. The halt in the rate of increase of resistance to attrition.

Other tests are now undergoing similar investigation.

In this paper, the authors have endeavoured to draw attention to some of the many factors involved in this comparatively new section of road research.

They are of the opinion that it would be premature to put forward definite recommendations as to technique at the present time in view of the considerable amount of investigation work in progress.

In conclusion, they desire to thank the Governor and Court of Directors of The Gas Light and Coke Company for permission to publish the paper, and to acknowledge assistance from members of the technical staff.

Mechanical Testing of Bituminous Road Mixtures.

BY

PREVOST HUBBARD

(Chemical Engineer, The Asphalt Institute, New York.)

INTRODUCTION.

THE mechanical testing of bituminous paving or road mixtures is of rather recent origin. These mixtures have such totally different characteristics from most construction materials that they are not susceptible to tests for compression, tension, cross bending and shear, as ordinarily made. This is due to the fact that they are semi-plastic. Moreover, their degree of plasticity often varies greatly with normal variations in atmospheric temperature conditions to which they are subjected. As their temperature is reduced they gradually approach a monolith in characteristics, and if any of the above-mentioned tests are made at a sufficiently low temperature typical end points will be obtained. At normal testing temperatures, however, a gradual distortion is developed without a critical end point, and small variations in rate of application of load greatly vary the degree of distortion produced under a given load.

That compressed bituminous paving mixtures possess high structural strength is demonstrated by their ability to successfully carry heavy and intensive traffic loads over a long period of time without failure, but if their structural strength is rated by the testing procedure used for monoliths, such as hydraulic cement concrete, brick and stone, a totally erroneous impression is created. Realization of

this fact has, during recent years, led a number of investigators to develop an entirely new test for determining the structural strength of these semi-plastic mixtures. While the problem has been attacked from a variety of angles, and different mechanical methods have been developed, practically all of these new tests are intended to determine the resistance of such mixtures to internal displacement under applied loads. The investigators who developed these tests all used them for the purpose of studying factors governing the design of bituminous paving mixtures, and it was soon evident from their published results that the same principles of design were being established. Choice of method for general use, therefore, gradually narrowed down to considerations affecting accuracy of results, and adaptability for testing a wide range of mixtures.

At the present time a method known as the stability test, devised by Hubbard and Field, is probably being more widely used than any other. This test has been fully described in publications of the Asphalt Institute, which are available upon application to any interested party. Another method known as the shear test, which was developed by the Chicago Paving Laboratory, has also been used to a considerable extent. Equipment for both the stability and shear tests is now being produced and sold by American manufacturers.

STABILITY TEST.

The stability test is an arbitrary measurement of the maximum load developed in forcing the mixture through a standard orifice. Test specimens consist of compressed cylinders of the mixture, which may be prepared in the laboratory, taken from plant output or cored directly from the finished pavement. Either of two sizes of specimens may be tested. For sheet asphalt and similar fine graded mixtures a 2-inch diameter cylinder is most conveniently used, while for coarser aggregate mixtures the diameter of the cylinder is 6 inches. In the testing apparatus the diameter of the orifice with relation to that of the test specimens has been adjusted so that the test results obtained with both are numerically equivalent. By this it is meant that if a given fine aggregate mixture is tested as a 2-inch cylinder the maximum load developed in forcing it through the orifice adopted for that size specimen is approximately the same as though it were tested as a 6-inch cylinder and forced through the larger orifice which has been selected for 6-inch specimens.

The stability test is usually run on specimens which have first been brought to a temperature of 140°F., approximately the most severe temperature attained by such mixtures under service conditions in temperate climates. For any given mixture resistance to internal displacement decreases as the temperature of the mixture is raised. Test results are, therefore, most informative when obtained at maximum service temperatures. In very hot climates the standard temperature of test should be raised to meet actual service conditions.

Studies have been made of a number of pavements under existing traffic conditions with relation to their resistance to displacement as measured by the stability test, and it has been found that a direct relation exists between the behaviour of the pavement and the test. Thus, it has been determined that under the intensive mixed traffic prevailing on Fifth Avenue, New York City, no appreciable rutting

or shoving had occurred where the mixture developed a stability of 2,000 pounds or more, but that when the stability fell below 1,200 pounds, displacement became quite pronounced. It is, therefore, possible to utilize the stability test as a specification requirement to meet known traffic and temperature conditions. So far, in American practice, this has only been done to a limited extent, but it is probable that the practice will spread as engineers secure additional correlative data and become more familiar with the test.

DESIGN OF BITUMINOUS PAVING MIXTURES.

The stability test has been of great service in establishing the fundamental principles of design of bituminous paving mixtures and in indicating the proportions in which a given set of constituents may be combined to best advantage. When so used, however, recognition of other desirable characteristics is essential. Among these are imperviousness to water absorption, particularly in fine aggregate mixtures, and durability. Imperviousness is directly related to the per cent. of voids in the compressed mixture, and durability to the film thickness of bituminous cement covering the particles of mineral aggregate. High stability may often be secured in porous mixtures showing a deficiency of bituminous cement. While such mixtures will for a while successfully resist displacement under traffic they may later fail because of water and frost action or by cracking and breaking up in cold weather, when, because of lack of bituminous cement, they become brittle and friable.

Practical application of the stability test to the proper proportioning of the various constituents should, therefore, generally be premised upon the following: (1) To produce a mixture of sufficiently high stability to prevent its displacement under traffic, but not unnecessarily high. (2) To keep the voids in the compressed mixture to a practical minimum. (3) To incorporate as much bituminous cement as possible without lowering the stability of the mixture to an undesirable extent.

With these factors in mind it is evident that the stability test should be accompanied by tests to determine voids in the compressed bituminous mixture and voids in the compressed mineral aggregate. With these auxiliary tests various combinations of the individual constituents may be intelligently studied.

VOIDS IN COMPRESSED BITUMINOUS MIXTURES.

Determination of voids in the compressed bituminous mixture first involves determination of the specific gravity of the compressed mixture by weighing it in air and water. In calculating voids, however, it is necessary to have previously determined the specific gravity of each constituent which may be done by well-known methods, and in addition to take into account the weight proportions in which they have been combined in the given mixture.

If W , W_1 and W_2 represent the percentage weights and G , G_1 and G_2 the specific gravities of coarse aggregate, fine aggregate and bituminous cement respectively

can be expected from the use of the particular aggregate. Aggregates entirely unsuitable for mixing have given swelling as great as three-quarters of an inch under the conditions of this test.

RESISTANCE TO CRACKING.

There is considerable need for the development of a test which will measure the resistance to cracking of compressed bituminous paving mixtures, particularly those coming under the classification of hot-mixes. Impact and compression tests at low temperatures have been studied to some extent but have so far not produced much information of practical value. Cracking of a pavement may be produced by a number of causes, one of which is inadequate base support when the mixture is cold and therefore more nearly resembles a monolith than at any other time. It may also be produced by the drag of the base or underlying support which by shrinkage develops cracks that are reproduced in the overlying mixture or shrinkage at low temperature of the mixture itself may be responsible. It would seem that the most informative type of test to which the bituminous mixture could be subjected would be one in which a specimen of the mixture, rigidly held at both ends, would be rapidly chilled to a standard low temperature and its behaviour noted. The difficulty in devising a satisfactory test of this nature lies in the difficulty of preparing and testing a sufficiently long specimen to duplicate results which might be expected to occur under normal service conditions. There are, however, probably other ways of ascertaining this characteristic which will be developed as the study of bituminous mixtures progresses.

CONCLUSIONS.

Many American highway and testing engineers are coming to the conclusion that too much attention has in the past been paid to developing tests for the constituents of bituminous mixtures and not enough to the mixtures themselves. The few tests that have already been devised for mixtures have indicated that many tests for evaluating the individual constituents have not been as important as they were previously believed to be. It is, therefore, probable that extensive future investigations will be devoted to the development of practical informative tests for mixtures as they are actually used.

The Critical Examination of Bituminous Road Materials.

BY

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IN a study of methods for the testing of road materials, it is necessary to differentiate between the examination of the component materials according to certain physical and chemical tests and the application of service tests, based on the factors which control road life, to the components or to the mixtures thereof in the form in which they are employed. Under the former heading we are concerned with the examination of the properties of the material by approved methods, whereby it is determined whether the material under test possesses those properties which, according to previous experience and standard specifications based thereon, are necessary that it may fulfil its function and yield a durable construction. From the latter group of tests founded on an imitation of the practical conditions to which the material or mixture must stand up to on the road, and designated service tests, an insight should be gained into the probable behaviour of the final construction. Such tests made in the laboratory serve not only to control current work, but they should also serve to enable improvements to be made in methods of road construction on the basis of laboratory results. In this case the service experiments fulfil a special role, and it is first necessary to ensure that the individual components conform to their respective standard specification.

In this paper, those service tests will be considered which, in Germany, have been introduced and approved as the result of laboratory researches for the examination of road paving mixtures containing bitumen or tar with a mineral aggregate with a view to developing methods of construction and of stimulating interest in the conditions of application on the road site.

1. *Resistance to Compression.*—This test has been very generally employed. It is made on cubical test pieces of 7.09 or 10 cm. edge, which are compressed in moulds by ramming (surface of face of cubes 50 and 100 sq. cm. respectively). This test, especially in conjunction with other tests, serves to give a figure for the cementing of the mineral particles by the binder and thereby enables conclusions to be drawn regarding the stability of the paving. An objection raised against this method is

that as it allows the mixture to expand outwards from the side faces, it does not correspond to road conditions, where the surfacing material is supported laterally. Further, as tar and bitumen are plastic masses, the figure obtained for the compression strength is dependent upon the speed of application of the load. This factor must therefore be fixed and uniformly applied if comparable results are to be obtained. The experience gained over many years in the Road Construction Research Laboratory at Stuttgart (Str. V. St.) nevertheless justifies the conclusion that the determination of resistance to compression has a definite significance if studied with due regard to the conditions of testing. In this laboratory the standard practice is to use the same hydraulic press and a constant rate of loading, this being determined by the design of the machine, so that the conditions necessary for comparability are met. The results from different research laboratories cannot be compared if there is a marked variation in the rate of loading. The Str. V. St., which has checked many results of other experimenters, has, however, often found unexpected agreement of the figures.

Moreover, if paving mixtures of varying composition are to be compared and judged by the resistance to compression test, we are concerned more with the comparative figures than with the absolute compression strength. We know quite well that the compression strengths measured on concrete test pieces are not the same as are to be expected in the structure. Rather may we say that this test serves to select from varying mixing conditions that which in each case may be expected to give in practice the best results, and at the same time it provides a means for controlling the actual process of construction. It is from this point of view that we must value the compression testing of tar and bitumen paving mixtures.

In an examination of the compression strength properties of bituminous mixtures it must be remembered that fundamentally the strength is dependent firstly on the cohesive properties of the binder, and secondly on the resistance of the aggregate mixture, the influence of the cohesive properties of the binder very frequently outweighing that of the stability of the mineral aggregate. In consequence of the lower cohesive properties of tar in comparison with those of bitumen, the compression resistances of briquettes made with tar as a binder are lower than the corresponding figures for bitumen mixtures made under the same compounding conditions. The stability of the mineral aggregate likewise influences the resistance properties of the test briquettes. The denser the mineral mixture, the better the stone particles can wedge and dove-tail into one another, and the mineral aggregate being less liable to displacement the better will be the resulting mechanical properties. •

Further, as it is possible to demonstrate that correctly proportioned mixtures which have been found to have a given compression strength prove satisfactory in practice, this test may be considered informative.

The influence of weathering on the paving is imitated in the laboratory by submitting the test briquette to 28 days immersion in water and then to a freezing

test in which the change from frost to thaw is performed 25 times. The water absorption and the swelling after the soaking are measured and the resistance to compression is determined on the samples after submission to the soaking and again after the freezing treatments and the values compared with that obtained on the original sample.

Bearing in mind the peculiarities of the binder, care must be taken not to assume that relatively high compression strengths are necessarily indicative of correct composition. High compression strengths are attained if, in agreement with the earlier statements, the binder is so dispersed in a correctly designed mineral aggregate that its cohesive properties are correctly utilized and if the mixture has been correctly prepared. High values are also obtained, however, if the binder is too hard or if it has been overheated during melting and rendered brittle. High values for the compression test may therefore be misleading if, at the same time, the tar or bitumen is not tested to show that it has retained its original plasticity. This point is covered in the German Standard Specification 1995/96, section 5*. A characteristic of tar and asphalt pavings is that between the extremes of temperature to which they are subjected (-20 and $+50^{\circ}\text{C}.$), they remain in a plastic condition. This condition so functions that the road surfacing continues to consolidate under traffic after laying, a factor which may have considerable bearing on its stability. Too high a compression strength for the mixture should therefore not be demanded.

As the plasticity of the binder increases with increasing temperatures, and as this influences the compression strength of the mixture, the test must be carried out at a fixed temperature if the values are to be comparable. The German standard temperature is $22^{\circ}\text{C}.$ It may be taken that a compression strength at this temperature of not less than 30 kg/sq. cm. indicates a satisfactory composition. The determination of the value at $22^{\circ}\text{C}.$ is however not sufficient in that it does not show how the material will behave under the effect of heat or cold. It is therefore necessary to further prove whether the binder during melting or the subsequent treatment has not lost its cohesive properties.

An essential step in the examination of bitumen or tar consists in assessing their properties at low and high temperatures, for which purpose the brittle point by the Fraass test, the Kraemer-Sarnow softening point, the Ring and Ball melting point and the drop point test are determined. The greater the temperature range over which the binder remains in a plastic condition, the more serviceable it is. The same principle should be applied to the paving mixture, the compression strength at high and low temperatures being measured. At high temperatures—the Str. V. St. employs $50^{\circ}\text{C}.$ for bitumen and $40^{\circ}\text{C}.$ for tar—the values naturally decrease. From the interval between the compression strength at $22^{\circ}\text{C}.$ and $50^{\circ}\text{C}.$ (or $40^{\circ}\text{C}.$), one can conclude whether the binder in the carpet has the necessary temperature

*The properties of the binders tar and bitumen are laid down in the German Standard Specification 1995/96—bitumen Section 1, tar Section 2, and for mixtures of bitumen with mineral aggregates (asphalt concrete, sand asphalt, etc.) in Section 5.

stability. This second test at 50°C. (or 40°C.) should therefore always be carried out. A paving is only serviceable if it still possesses at these higher temperatures a compression strength of not less than 10 kg./sq. cm.

The values at 22°C. and 50°C. fix two points of the plastic state of the mixture and not only allow the resistance the carpet will offer to traffic forces to be assessed, but also show whether it will consolidate satisfactorily, tending neither to develop waviness in summer, nor cracks in winter.

A special example will serve to show how this test enables conclusions to be drawn regarding the serviceability of a road surfacing material. The object of the experiment was to prove whether tar concrete can be improved by the choice of a suitable limestone filler and by the addition of 15 per cent. bitumen. Such a deduction can be made from a comparison of the compression strength values in the following table :—

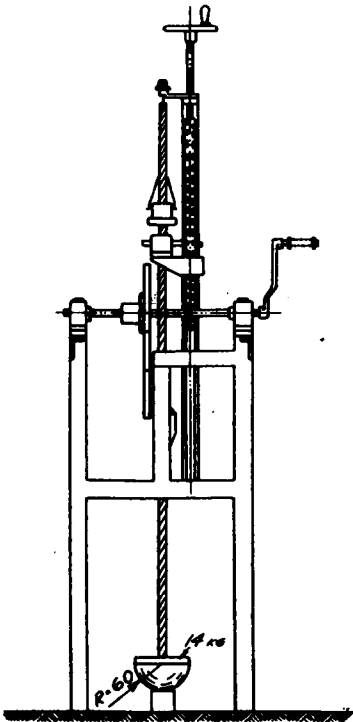
*Compression Strengths of Test Specimens of Tar Concrete.
(7.09 cm. cubical briquettes).*

	<i>Mineral Aggregate with Filler.</i>					
	<i>Limestone Filler.</i>		<i>Basalt Flour.</i>		<i>Powdered Blast Furnace Slag.</i>	
	At 20°	At 40°	At 20°	At 40°	At 20°	At 40°
	kg./cm².	kg./cm².	kg./cm².	kg./cm².	kg./cm².	kg./cm².
1. Tar 65/35	28	5	21	3	17	1
2. Special Tar	45	12	33	4	23	2
3. Tar 65/35 plus 15 per cent. Bitumen	46	14	36	6	27	2

No useful purpose is served by determining compression strengths at lower temperatures. Under these conditions another test based on the behaviour of the material at low temperatures as well as on the nature of the traffic conditions must be employed.

2. *Impact Resistance.*—With a plastic mass the energy of a striking body is converted to deformation. If the plastic mass changes to a rigid state, for instance through being cooled, the impact forces can either be reflected or may lead to fracture of the mass. Since traffic particularly affects the road surface by its impact action, the danger that bituminous mixtures may become so brittle at low temperatures that they break down through inability to withstand the shock, must be taken into account. This disintegration occurs the more readily since at low temperatures the mass endeavours to contract (influence of the temperature co-efficient of expansion) and is in a state of considerable internal strain. In such a case a very light blow can

overcome the strength and disintegrate the carpet. Therefore for low temperature work the impact test should replace the determination of the resistance to compression. The former test is carried out in the following manner. The cubical briquettes are cooled to zero or lower temperature, and then submitted to an impact test on a machine specially designed for this purpose. This consists of a steel hammer weighing 14 kg., and having a hemispherical face of 12 cm. diameter which strikes the centre of the test piece. The height of fall is 15 cm. (Fig. 1.). A cement block



*FIG. 1
FALLING HAMMER FOR IMPACT TEST
(STUTTGART CITY ENGINEERING DEPT)*

serves as a base. The briquettes are maintained for 10 hours at the test temperature, and are then rapidly submitted to a series of blows until fracture takes place.

The resistance to impact decreases with falling temperatures and at low temperatures increases with increasing size of the mineral aggregate particles. The explanation is that the coarser particles absorb the impact energy and their resistance must be overcome until they break. With fine grained mixtures the binder alone must absorb the energy. If, as a result of the lowering of temperature, the cementing action is changed or eliminated, the mass develops cracks. Mixtures which remain plastic at low temperatures withstand heavy stresses, those which become brittle quickly

fracture. This has been the experience with mastic asphalts under extreme cold, their destruction being traced to the traffic load.

The Central Institute for Asphalt and Bitumen Research, Berlin, has evolved a method in which the plasticity of the binder in the cold ($\pm 0^{\circ}\text{C}$.) is determined by allowing a test piece to fall from a height. Plastic binders, or mixtures thereof with mineral aggregates, cooled to 0°C . attain a great height of fall before they shatter or crack. For the test, the pure binder or the bituminous mixture is formed by kneading into a ball of 50 gms. weight, submitted for 2 hours to cooling in a freezing mixture at 0°C . or to the required experimental temperature, and is then held by tongs similarly cooled and allowed to drop on to a horizontal steel plate (1 cm. thick) from increasing heights. The height of fall at which the ball develops cracks or breaks in half is taken as the resistance to impact. Up to 2 metres, the height of fall is increased by 10 cm. steps, and thereafter by 50 cm. steps. Experiments have shown that bitumen alone breaks at a drop height of 1 metre, while mixtures of bitumen and limestone filler give higher values and a still further increase to 22 metres can be attained by the addition of 60 : 40 parts by weight of levigated asbestos powder. This method therefore offers the possibility of determining the capabilities of tar and bitumen mixtures to withstand sudden stresses.

3. *Stability*.—In America the stability test, carried through at 60°C ., has been introduced to replace the compression test. This method is also a test of plasticity. Experiments at the Str. V. St. have shown that the stability test figures run parallel with those of the compression test (see Fig. 2). The test has not been adopted in Germany. The author employs it when the compression test alone yields no definite conclusions. In England the view is taken that of the mechanical methods for testing paving mixtures containing tar and bitumen, this as a service test most closely approaches the conditions of road surface destruction as the result of deformation under the action of traffic.* It has been suggested that the stability test should replace the compression test at 50°C . This, however, could only hold for sand asphalts, for the Hubbard test developed for sand asphalts is the only available test free from objection. For asphaltic concretes the Emmons & Anderton stability test can be employed, but the author does not consider it particularly suitable for the object in view.

4. *Tensile Strength*.—The road carpet is submitted under traffic to compressive and shoving forces and by temperature changes to tensile forces, which may lead to formation of cracks at low temperatures. As mastic asphalt is particularly liable to cracking, a method has been developed for the determination of its tensile strength and elongation capacity. For this purpose test pieces of the shapes shown in Figs. 3 and 4 are employed. These are placed in the testing machine and the shackles drawn apart until the sample fractures, the temperature of the test being 22°C . The type of test piece shown in Fig. 4 is the most practical, since with this form the elongation can be more accurately followed. The tensile strength at the breaking point

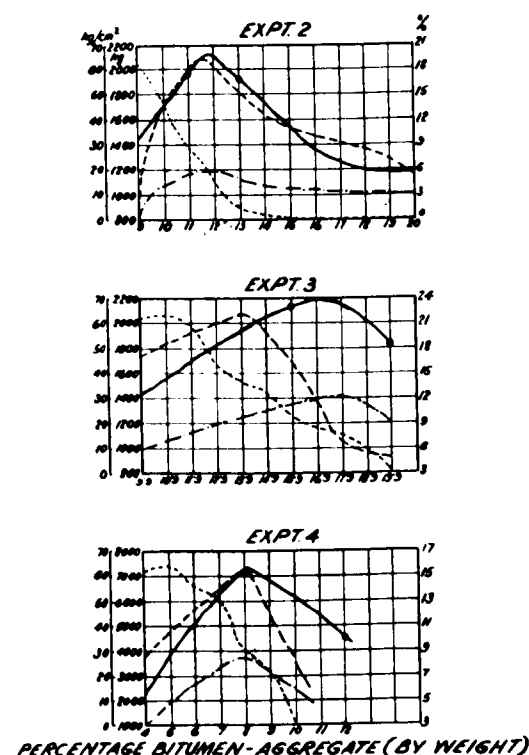


FIG. 2
COMPRESSION STRENGTH, STABILITY, AND VOIDS IN RELATION
TO AMOUNT OF BITUMEN MIXED WITH AGGREGATE

COMPOSITION OF AGGREGATE MIXTURES: PARTS BY WEIGHT :-

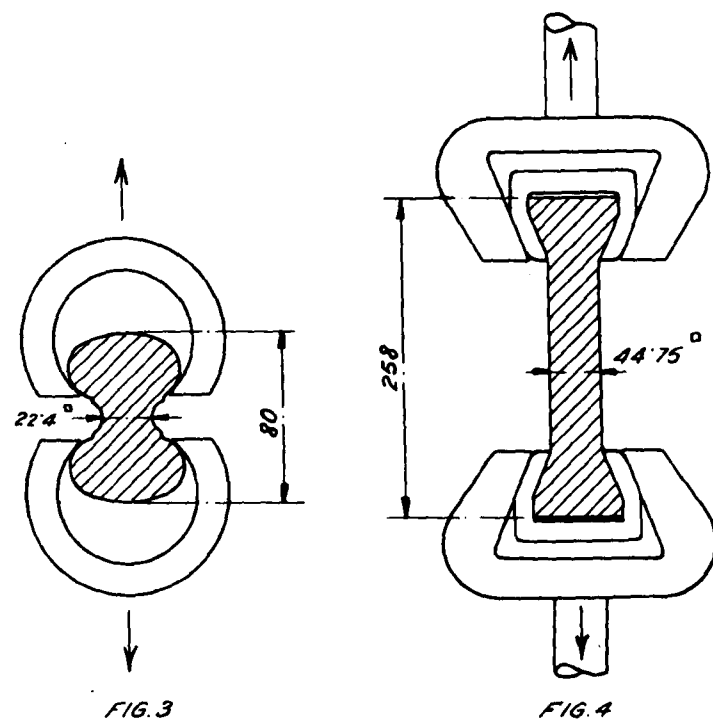
EXPT. 2 FILLER 30; SAND K_1 35; SAND K_2 35.

EXPT. 3 FILLER 40; SAND K_1 30; SAND K_2 30.

EXPT. 4 FILLER 22.8; SAND K_1 12.2; SAND K_2 9;
SAND K_3 23.5; SAND K_4 32.5.

— PRESSURE AT $+20^{\circ}\text{C}$ } IN KG./SQ. CM.
- - - " " $+50^{\circ}\text{C}$ } L.H. 1ST COLUMN
- - - - - % VOIDS. R.H. COLUMN
- - - - - RESISTANCE TO DEFORMATION AT $+50^{\circ}\text{C}$
IN KG. L.H. 2ND COLUMN

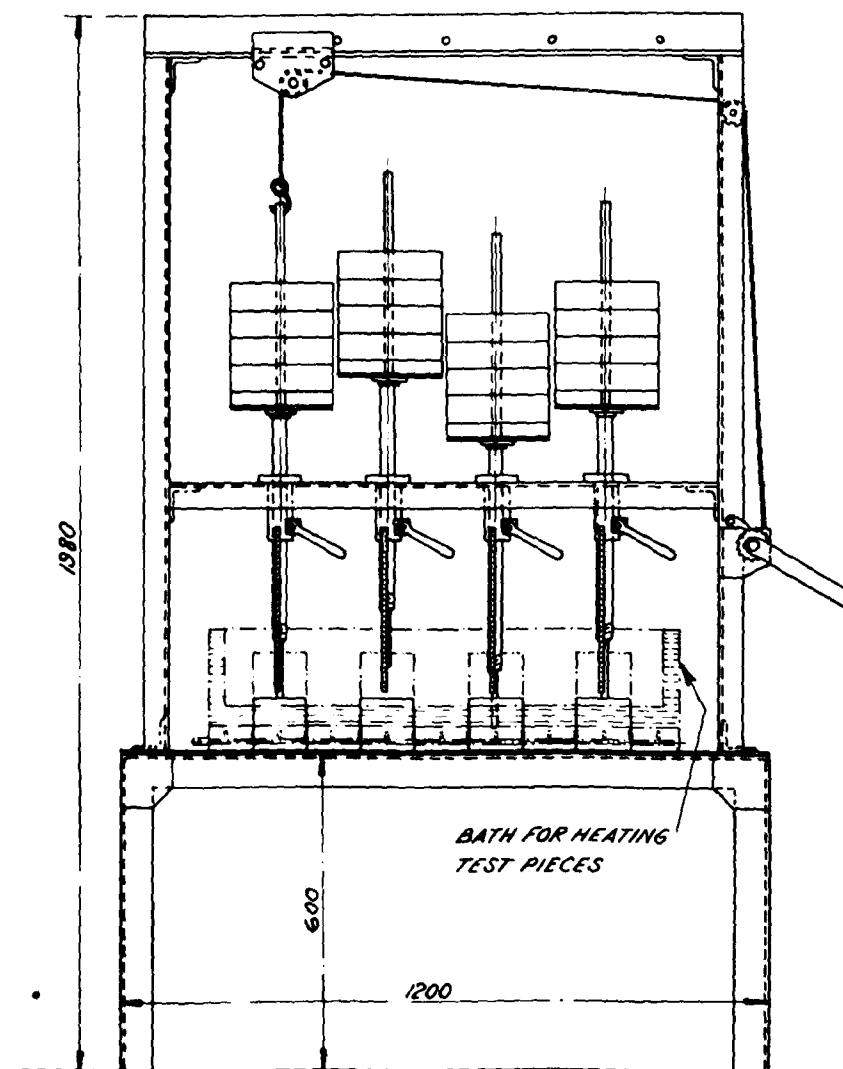
*Experimental Work on Roads Report for the Year 1931.



TENSILE TEST PIECES

and the degree of elongation during the application of the tensile force are measured. The remarks made under the compression test again apply, for high tensile strength of itself is not a guarantee against cracking since high tensile tests are obtained with brittle bitumens. The main consideration is satisfactory elongation, and hence the tensile test is also performed at 0°C . The relationship of the tensile strength to the elongation is a measure of the ductility of the mastic asphalt which can be plotted in the form of a curve.

5. *Resistance to Impression*—(Plunger pressure).—The well-known A.S.T.M. penetration test, normally applied to binders such as bitumen and viscous tars, can be developed as a service test for paving mixtures containing these in admixture with stone. It has been applied at Stuttgart both to samples prepared in the laboratory and to samples drawn from the finished road surface. The testing machine consists of a plunger of 1 sq. cm. cross sectional area which applies a load of 52.5 kg. to the briquette face or to the road sample surface. The depth of the indentation after 5 hours application of the load at 22°C . is measured and should not exceed 10 mm. This experiment may be considered a service test since it corresponds to the actual road conditions. The plunger exerts a similar action to that of a horse-hoof or a small iron shod cart-wheel. If the road sample withstands the plunger pressure in

FIG. 5
PENETRATION APPARATUS

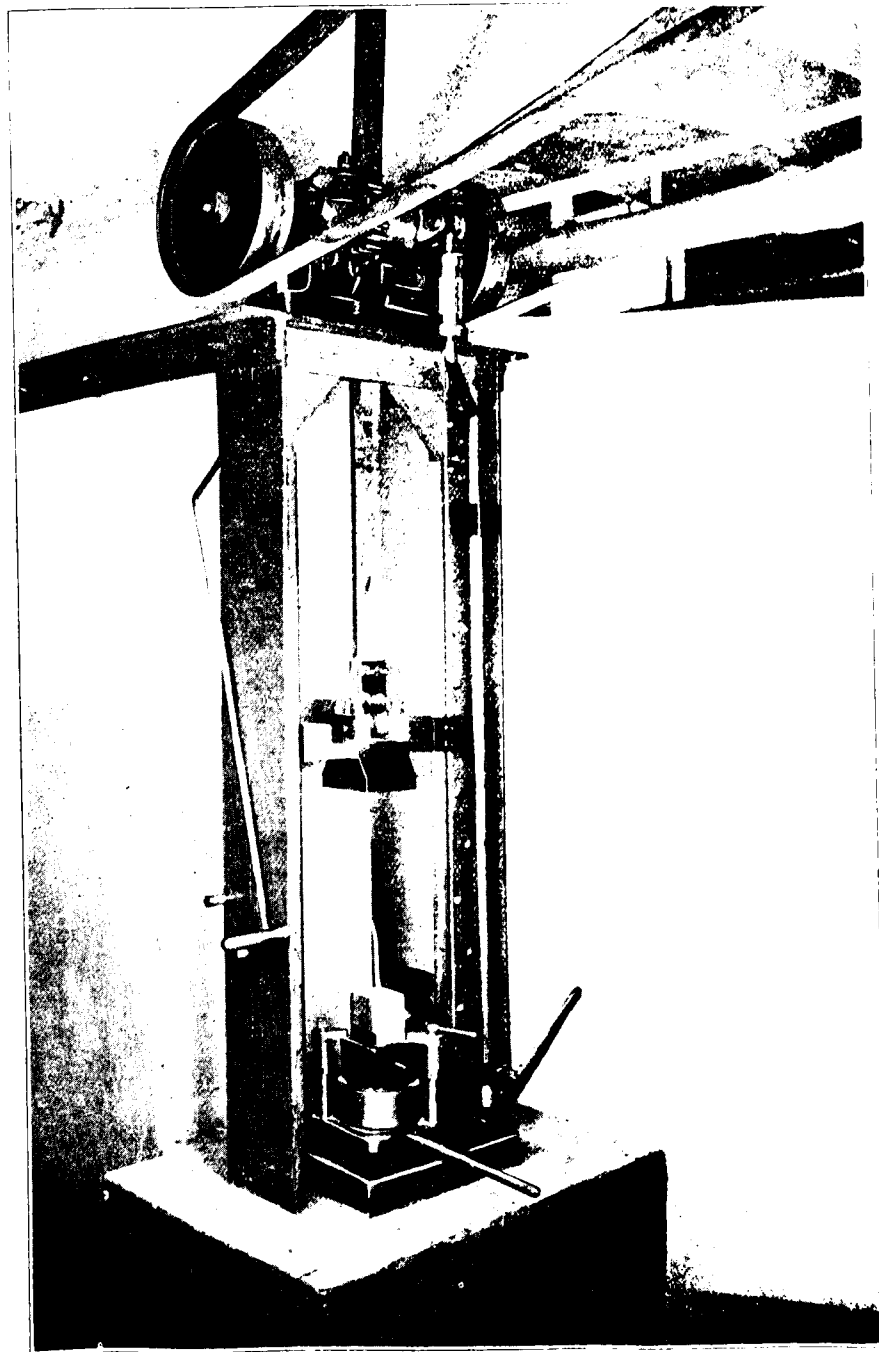


FIG. 6. - Drophammer

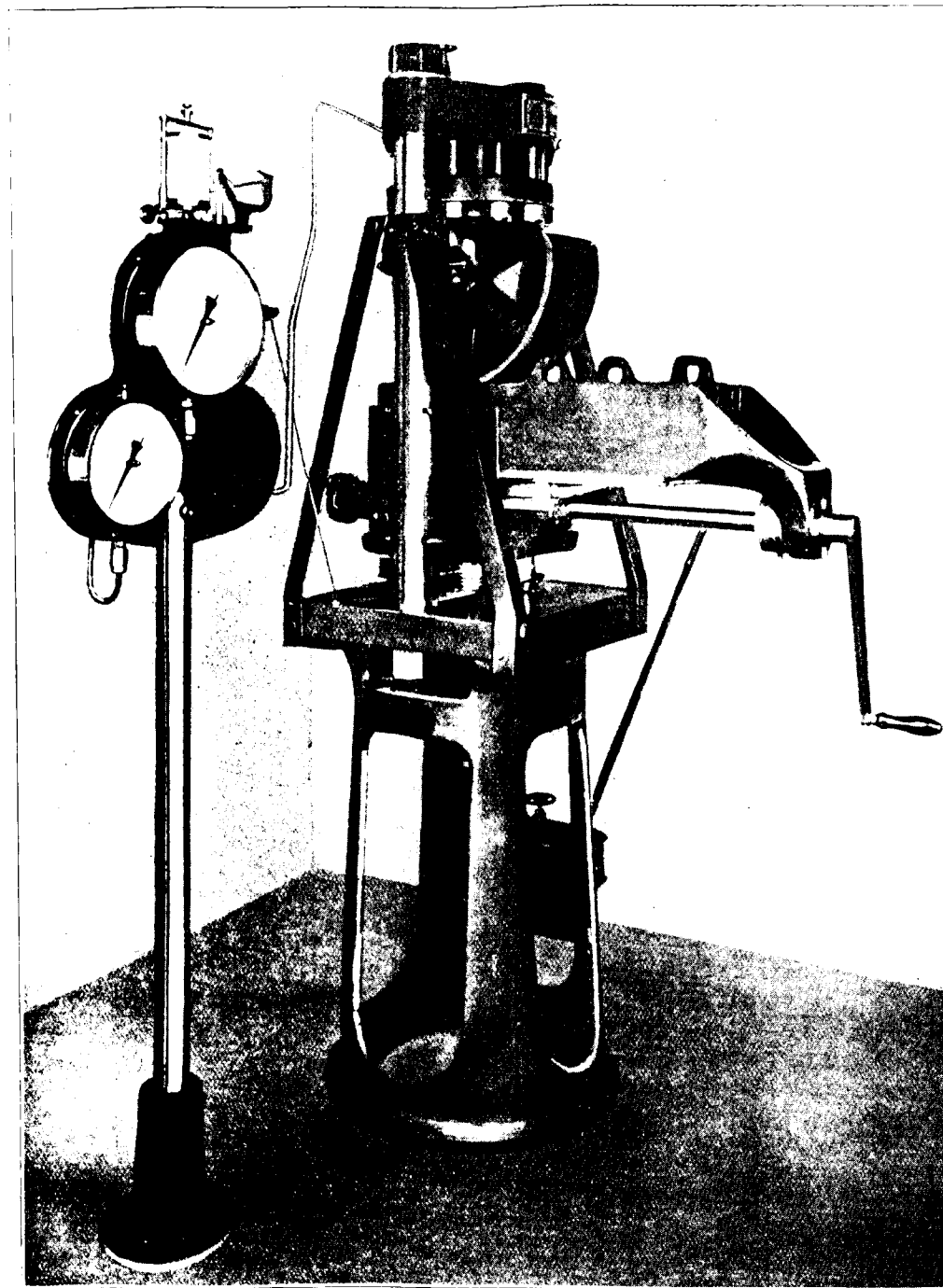


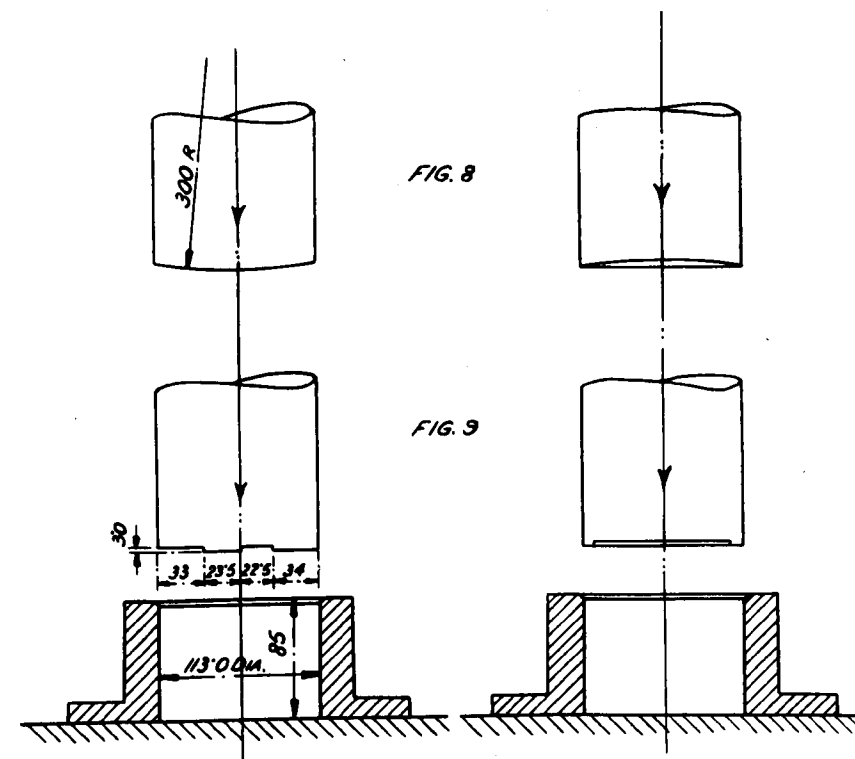
FIG. 7. - Roller Press.

the laboratory, it can be taken that as a road carpet it will withstand the pressure of such single loads without receiving destructive impressions. The special form of apparatus constructed at Stuttgart is shown in Fig. 5. This test gives unreliable results if the plunger rests on an area containing one or more large mineral particles for the pressure is then dispersed over a larger area. The indentation will be deeper if the plunger is set on an area containing only fine mineral particles and excess bitumen. Hence the cross sectional area of the plunger and the load employed must be adjusted to correspond to the grading of the mineral aggregate. The Str. V. St. apparatus permits of this. Since asphalt and tar pavings receive impressions easiest at high temperatures, this test should be made at the highest temperature to which the paving is likely to be submitted—in Germany about 50°C.

6. *Compressibility*.—Road carpets containing tar or bitumen as binder are consolidated during laying by tamping and rolling. Further consolidation takes place under the action of traffic. The test pieces, which have served for the compression, tension and deformation tests (cf. Nos. 1, 3 and 4), must be submitted to similar conditions in the laboratory. In Germany, various types of apparatus are used, e.g., hydraulic presses, drop hammers, etc. The Str. V. St. employs a drop hammer of 12 kg. weight (Fig. 6). The briquette is formed in a resistant iron mould with 25 blows from a height of 25 cms.

Recent researches have shown that the compressibility of the paving mixture is related to its soundness and durability. A well known example of this fact is given by mastic asphalt.

On the road carpet, in which the mineral particles are coated with binder, the action of traffic, however, exerts a kneading action which leads to a quite different density. Various methods have been proposed in order to imitate this kneading action. The Str. V. St. uses a roller press (Fig. 7), intended to imitate the action of the road roller. The Bureau of Public Roads (U.S.A.)—Public Roads, Vol. 10, No. 2—has constructed a similar apparatus for this purpose, and a unit has been installed in the Highways Engineering Department of the Darmstadt Technical College. In order to study the factors affecting compressibility and construction density, the Str. V. St. has installed a further type of apparatus. It consists of a hollow steel cylinder of 100 sq. cm. cross sectional area and fitted with a plunger. The working face of the plunger is not flat but is so formed that a pushing action on the mineral particles takes place on the application of pressure. In one design the plunger face has two grooves (Fig. 8). The plunger is placed on the paving mixture contained in the cylinder and pressure is applied. The mixture is of the same thickness as is normally employed in road work. The plunger is then turned through an angle of 90° and again loaded. This procedure is continued until no further consolidation takes place. The applied forces correspond roughly to those applied by the usual type of road roller. The experiments have been made on mineral aggregates with and without the addition of the binder. A second type of plunger is in the form of a section cut from a wheel of 60 cm. diameter (Fig. 9). This type also exerts a kneading action for the plunger only applies a vertical pressure at its centre, and the compressed mass can move sideways. Using these two units numerous experiments on rounded and broken mineral aggregates have been undertaken,



APPARATUS FOR MEASUREMENT OF COMPRESSIBILITY

with the object of determining the density attained by varying types of mineral aggregate and the alteration in grading taking place during compression. It has been shown that pressure applied through a plane surface has a different action from that of pressure accompanied by a kneading action as obtained in these experiments. Pressure accompanied by kneading action leads to higher densities and to less degradation of particle size than direct simple pressure, and more nearly corresponds to the actual road conditions.

The author thanks Mr. F. M. Potter for translating this Paper into English.

DISCUSSION ON PAPERS BY MESSRS. R. G. C. BATSON, W. G. ADAM AND D. G. MURDOCH, PREVOST HUBBARD, AND PROF. NEUMANN.

THE CHAIRMAN (MAJOR F. C. COOK): I am sure you would wish in the first place that we should extend a very hearty welcome to Professor Neumann who has come to England for the purpose of this meeting, and who has been good enough to furnish a Paper.

Mechanical testing of bituminous materials has hitherto been regarded chiefly as a matter of laboratory interest, but the desirability of having such tests available has long been apparent to road engineers, although it is only recently that the subject has reached that point where the whole question has become one of interest to others than research workers. Some three years ago the British Standards Institution approached the Ministry of Transport concerning the possibility of devising Standard Specifications involving mechanical tests of bituminous road materials. In consequence a meeting was held between representatives of the British Standards Institution and the then Technical Advisory Committee of the Ministry of Transport, as a result of which it was decided to set up a Joint Committee for consideration of the whole subject. This Committee was got together, but it soon became apparent that at that stage the questions involved were so detailed that they were likely to be more profitably dealt with by laboratory workers already engaged in the pursuit of the subject. A technical panel was therefore formed comprising laboratory workers concerned with asphalt, bitumen, and tar, and representatives of the British Standards Institution, the Ministry of Transport and the Road Research Station at Harmondsworth. The Terms of Reference to this Technical Committee were: "To collect and co-ordinate information regarding methods of test at present in use in this country and abroad, and to make recommendations as to the form of tests for determining durability, stability and anti-skid properties." I should like to take this opportunity on behalf of the Ministry of Transport and of the Road Research Board, of which I have the honour to be Chairman, to thank those gentlemen who have given their co-operation in this section.

The Papers afford sufficient indication of the complexity of the problem, and forbid any hope that its solution will be found easy. I do not doubt that in due time the labours of that Committee will be brought to a successful issue, but there is one particular in which it can be claimed that success has been already achieved, for I think this is the first time that road engineers, manufacturers and research workers have been brought together in this way and have agreed freely to interchange their views, to exchange laboratory facilities, and to put their experiences into the common pool. Those of us who are engineers recognise the laboratory difficulties which have to be surmounted in devising tests applicable to materials which are characteristically plastic, and which are of value not only individually but when used in combination relative to results which may be obtained in practice. Tests, however interesting in the laboratory, are useless unless they can be relied upon to give an indication of the behaviour of the material under all conditions of traffic and climate to which they are subjected in the road. It was on this account that the Ministry of Transport have arranged with the County Surveyors of Lancashire and Middlesex to lay down test sections of various bituminous materials on certain roads from which samples will be taken very freely with a view to determining the characteristics under traffic of that material in relation to the mechanical tests which may be applied. This obviously is a lengthy process, which is perhaps characteristic of all research, but it is the only one likely to ensure success. Doubtless the Committee to which I have referred have considered to what extent such a process can be shortened by making use of the information which must already be in existence in the laboratories of the various industries concerned, and if this is found practicable I am quite sure that the degree of co-operation which has been already reached will ensure that such facilities shall be placed freely at the Committee's disposal.

It cannot be too strongly urged that the whole question of mechanical testing is of definite interest to other than research

workers. It has great possibilities of practical application to all who are interested in road construction and maintenance. For this reason I hope that the discussion this morning will not be confined to one school of thought, and that not only those who are directly engaged in research but that road engineers who are responsible for the use of materials, and those who are engaged in the industry, will take part in our discussion and give us the benefit of their experience. I am quite sure of this; that anything which leads to the improvement or better use of the material is to the benefit of the industry engaged in its production, as well as of those who are responsible for its use.

MR. R. G. C. BATSON, introducing his Paper, said: During the last few years it has been realised that a bituminous road structure consists of aggregate as well as binder, and that the aggregate plays just as important a part in the behaviour of the resulting structure as the binder. Also that tests on the binder alone would not of necessity ensure a good and lasting road. The need for mechanical testing is emphasized by the Papers you have to discuss, and this need is probably shown by this being one of the rare occasions on which the tar interests and the asphalt interests have combined in desiring a common end.

The Papers emphasize four important properties of bituminous construction. The first one is the susceptibility of such materials to the small changes in temperature. The susceptibilities are so great that a few degrees makes a tremendous difference in the results which are obtained from the mechanical tests. The second important property is the effect of the rate of strain or the rate of loading—a rate of loading from say an impact to a continuous load. We all know the difference in the properties of pitch, for instance, under extreme rates of loading, where in the case of impact it breaks with a brittle fracture, and under prolonged loading it will draw out almost to a thread.

The third important property or variable is the type or method of consolidation, and the fourth is the property of bitumens in that they age with time.

In mechanical testing there are four main objects in view: (1) To control the design and uniformity of the material as laid upon the

road, (2) to enable those properties to be given in specifications, (3) to enable tests to be carried out on the finished product as laid upon the road to ensure that it conforms to the specification and will give a satisfactory life, and (4) for research and investigatory purposes, as in my opinion it is only by investigating failures that you are able to discover causes.

I should like to look at the problem for a minute or so through the road engineer's glasses, and I am sure that if I look at it through the wrong glasses the road engineer will correct me. As I see it, the road engineer wishes to have so much information that he can draw up a specification giving actual test clauses allied to the requirements of traffic, temperature, etc., with which he has to deal. Having drawn up his specification he then wants to put the contract out to tender, and from his test clauses to be sure that all the tenders are on the same basis as regards the life, behaviour and maintenance of his road. Finally, having got his road down, he would like to be able to carry out tests on that road to ensure that the road as laid is in accordance with the specification. He wants to carry out those tests at various places on the surface without cutting out samples from it. The last requirement is, in my view, the most difficult, because in carrying out such tests on a site it is extremely difficult to separate one variable from another. It is extremely difficult to separate the behaviour of the surface from the behaviour of the foundation, or in two-coat work to separate the behaviour of the surface course from the behaviour of the binder course.

Various mechanical tests have been proposed which can be applied to bituminous mixtures, and the majority of these tests are of an arbitrary character. They include a definite condition of bedding of the sample, and definite conditions as regards dimensions of test piece and side constraint, and most of them are allied to the particular purpose for which the test is carried out. They are also, of course, subject to definite rates of loading and also definite temperatures. It seems to me that at the present juncture when the whole subject is more or less in its infancy we should do well to consider just what type of mechanical test we require. Do we require mechanical tests which can be

applied to the structure as a whole under arbitrary fixed conditions, or do we require mechanical tests which will give us definite properties of the mixture, or of each unit in the construction such as the properties of the surfacing course, the properties of the binder course, the properties of the foundation, and so on?

It also seems to me that in order to make progress we are bound in the long run to develop tests of the second character, although the former tests will undoubtedly be a very great advantage. Therefore, I would put to you the following questions which I hope during the course of the discussion some of you will answer. Are mechanical tests required, and if so, for what purpose? If they are required, what properties are the most important? Should the tests give the properties of the road as a whole, or of the individual components separately? And finally, how can correlation with road behaviour be obtained?

Major Cook has mentioned that the Ministry are helping by laying down sections of roads from which test samples can be taken. I suggest that that is probably the best manner of obtaining correlation, although there may be other methods.

MR. W. G. ADAM, introducing his Paper, said: Progress in the mechanical testing of bituminous road materials has now reached such a stage—as shown by papers presented to this Conference—that agreement in the fundamental technique of the actual tests is highly desirable. This Paper is intended to draw attention to some of the more important factors involved in the hope that their recognition will ensure prompt efforts on the part of all testing laboratories to secure uniformity in technique. In this way further progress will be more rapid, as the results obtained by different workers will be capable of direct comparison, and a reliable estimate of the reproducibility of the various tests will be possible.

The factors have been divided into three main groups in the Paper: (A) shape and size of test specimens, (B) method of preparing test specimens, and (C) conditions of the actual test. As regards (A), the question of size of the test specimen in relation to the size of the largest aggregate in the mixture is one on which many may wish to express views. That the ratio should be as

great as possible is generally conceded, but the problem of compacting large specimens in the laboratory is a very important one in connection with the capacity of the necessary machinery. The technique of cutting and removing test specimens from the road without damage to the specimen is under examination and requires further work with certain classes of material. Completely satisfactory methods must be devised before we can claim the assistance of road engineers in the matter of supplying such samples from roads of known constitution and history.

As regards (B), the preparation of laboratory specimens calls for great attention to all details, and both the method and degree of compaction has been discussed in considerable detail in the light of the work carried out at Beckton—mainly upon roads of tar concrete—during the comparatively short period in which systematic work has been possible in the newly equipped laboratory.

Certain important factors are: (1) The density of the specimens obtained, (2) variation in density throughout the specimen, and (3) the crushing of the aggregate during compaction, and it is obviously necessary to know how these properties in a laboratory-produced test specimen compare with those removed at intervals from actual roads constructed with the various materials.

Among the various methods of compaction discussed, that of the roller compression machine is of particular interest as it most nearly approaches practical consolidation by steam roller. From preliminary work it would appear that this machine promises to be an extremely useful unit in the testing laboratory. It is worthy of note here that this machine is not our original idea. I believe it was originally proposed in America, and Professor Neumann has also referred to it in his Paper.

As regards (C), a discussion of the conditions of the actual tests follows. The method of applying the load is especially important with bituminous mixtures—which are plastic materials. Reference to the other papers presented will reveal a need for early standardisation.

As examples of the differing sensitiveness to variation in per cent. binder of various tests, some results obtained with tar concrete

specimens subjected to the tensile, compression and sand blast attrition tests are quoted.

While our ultimate aim is the development of our many grades of tar for the various types of road construction, we have, and are continuing to offer the results of our work to the common pool of information on mechanical testing of bituminous road materials.

With regard to the other papers read, I refer to Mr. Batson's Paper where he has discussed the why and wherefore of laboratory mechanical tests. In connection with the difficulty of correlation of rapid laboratory tests with the slowly disclosed actual road behaviour, the accelerated results obtained with the road machine will be awaited with great interest. Can Mr. Batson give us an estimate of the initial and running cost of the modified machine? Perhaps Dr. Neumann when he speaks will be able to give us some information on that point.

Mr. Batson comments on the obvious lack of published correlation data, and, therefore, the data given in the Papers to be presented and discussed later are particularly welcome.

PROF. DR. ING E. NEUMANN (*Stuttgart, Germany*), introducing his Paper, said: When I saw the papers presented to this Congress I was very much surprised to see how much progress you had made in the laboratory testing of bituminous and tar materials. I was for many years an engineer in Germany, and I am now Professor at Stuttgart University. I am not only connected with technical and theoretical work, but I also come into contact with road engineers because it is my duty to control the road surfaces laid by contractors for the State and for various county and local authorities. In this way I am always in close touch with practical work, and it is my endeavour not only to do something to help theoretical progress but to do something for practice also.

I would like to draw attention to one special point dealing with the opinion of German engineers with regard to the composition of the mixture. I know there is an English standard for mixture for road surfaces, but we really like to control our roads in the sense of controlling the aggregates. It seems to me that this is very

important from the point of view of the road construction.

Mr. Adam mentioned the machine that has been constructed at the University of Stuttgart. I must confess that the idea came from Teddington. German engineers came over here to study the question, they saw your machine at Teddington, and we then made up our minds in Germany to construct a similar machine. We have been able to improve upon your machine in some respects as a consequence of the experience gained in the testing of road surfaces. This machine is now used for research work on rubber tyres, but we combine this research work with the testing of road surfaces. Weather is, however, an important factor with regard to roads, and I would like to draw your attention to the fact that we have constructed another machine at Karlsruhe which is entirely out of doors. The one at Stuttgart is under a roof, but the one at Karlsruhe is exposed to all the varying conditions of weather Summer and Winter. I think this will be of great help to us in our research work.

DR. STRADLING (*Director of Road Research*): I speak on this subject with great diffidence because my experience is so small. This sort of work has not been my special line up to now, so that I have to approach this subject this morning from the point of view of work in which I am to some extent experienced.

From the building side there are quite a number of points which I think are of great importance in relation to roads when we come to consider the question of mechanical testing. We are rather in the same position as we were a few years ago in the testing of building materials. Mechanical testing both in England and elsewhere developed from the use of metals, and so many of our mechanical tests are devised for handling metals where temperature and moisture play very little part during the period of the test. In building materials and road materials, however, we have the complicating factors of temperature and moisture.

Mr. Batson speaks of traffic on the roads, and uses terminology which I understand is perfectly general—so many tons per day on the road. My experience of bituminous mixture is merely with its use on roofs, and here I know definitely that a certain amount of traffic is advantageous, and in

conversations I have had with experienced road engineers they tell me the same thing is typical of roads. So that when we come to consider traffic on roads I think one has to realise that some of that traffic at any rate is desirable if you are going to keep your road surface in a good state.

When we are handling small samples in the laboratory we miss one very serious factor which occurs in practice. The same thing applies equally to concrete work and to bituminous materials. When there is a change in temperature, or a change in moisture in the case of concrete, we produce internal strain, and when we are dealing with low temperatures of bituminous mixtures I imagine we must be producing quite considerable internal strain. At any rate, there is no doubt this happens in the case of roofs, and I fail to see why the same thing should not happen on roads. When this happens it seems quite clear that the effect of impact and so on must be much more severe if the material is under a strain. The small samples in the laboratory are relatively free from strain compared with the large specimens on the road, and therefore it seems to me here again is a complicating factor which we have to get over.

I should like to compliment the Authors of the Papers on the emphasis they have laid upon the compacting of samples. It has seemed to me very definitely that the attempt to compact a sample in a laboratory by direct compression with a plunger in a mould, the plunger being only just a fraction of an inch smaller than the mould itself, cannot give any reasonable compaction, and that one must of necessity get a difference in compaction from the top to the bottom, or from the top to the middle if there are two plungers. This seems to me to arise from a kind of arching effect.

I should like to draw the attention of those who are interested in this matter to the work of Professor C. F. Jenkin. Professor Jenkin started at Oxford, and then continued at the Building Service Station on the question of sand pressures, and he showed the tremendous effect of arching whenever you come to compact anything like sand or aggregate generally. An account of that work has been published, one paper to the Royal Society, and the other to the Institute of Civil Engineers. There is no doubt to my

mind that the key to the situation with regard to preparation of specimens in the laboratory, and possibly on the road too, is contained in this work of Professor Jenkin, where he indicates how serious this arching effect is. You can build up pressures in moulds sufficient to smash your aggregate long before you start appreciably to compact it.

Mr. Adam's work at Beckton in forming specimens in rolling action must, in my opinion, give a much better and sounder way of forming a specimen of more or less constant density. This is undoubtedly a step in the right direction. The interesting point, however, that emerges from Mr. Adam's paper is that when you come to apply some of these quite arbitrary tests to your mixtures you find, as shown towards the end of the Paper, that the optimum condition for certain properties does not occur in all the tests at the same constitution, and I think this again shows how necessary it is that these mechanical tests should be correlated with practical experience. In fact, until we can achieve that correlation these tests can be more misleading than guiding. On the building side it has been my unhappy experience to see sections of industry misguided by arbitrary testing. Standard specifications have been produced in certain sections of building industry, and the slavish following of some of the arbitrary mechanical tests has been so misleading that it is now necessary to retrace our steps somewhat and try to discover what are the real factors that affect practice.

May I say on behalf of the Department I serve how much we appreciate the very close co-operation which has been given to us already in our work, and the very open manner in which the various sections of contractors, engineers and so on, have given us of their experience. It is perfectly clear that if any progress at all is to be made in this subject, it is just by the kind of co-operation represented by this Congress.

DR. SPIELMANN: Mr. Batson, if I understood him aright, raised the fundamental point as to whether one would get the maximum advantage by testing the properties of the road surfacings or of the road as a whole, or of the components of those surfacings. I submit that if we are to get the maximum advantage out of this campaign that we have started, it is of the highest

importance to do all three. As regards components, we know our way about pretty well, and we shall know it a bit more when the British Standards Institution has examined the tests on road aggregates which they are about to start upon. Road surfacings are treated broadly in the papers that we are here to consider. But the properties of the road as a whole are, I think, barely touched upon anywhere, and I think this should be elaborated as quickly as possible in order to fit in with the other work that we are engaged on. It will be a very difficult matter because questions of subsoil come in, but I think it is not impossible to get a test at any rate of the resilience of the road. I have one in mind where you will be able to gather the resilience of the road the deeper you investigate it from the outside.

Mr. Batson has referred to the road machine which Dr. Neumann has also so interestingly augmented. It has been known that several of these road machines have been in use in Germany for some time, and it is very interesting to know that they are so well regarded and improved upon.

The Paper by Mr. Adam and Mr. Murdoch gives an extremely lucid and valuable description of exactly what the troubles are in the preliminaries of mechanical testing, and I think this Paper will be referred to many times by anybody who is engaged in this work.

The Paper of Mr. Prevost Hubbard is also very stimulating. We get the latest ideas of his exclusion apparatus for stability, but what seemed to me very important was the reference he makes to the necessity for investigating the attack of water on asphalt mixtures. It is established that the surface tensions of the system bitumen-water-mineral aggregate are of such dimensions that there is a tendency for water to get in between the bitumen and the stone if it is given an opportunity of doing so. The answer of the asphalt contractors immediately is that asphalt is always so good that water is never given an opportunity to get in, but at any rate there is the scientific possibility, and I think this ought to be very carefully investigated and numerical results obtained so that we may know exactly where we are.

I venture with some trepidation to question the point Dr. Stradling makes about the

arching of sand. I think I know Professor Jenkin's work. It is of course absolutely true and correct when you are dealing with dry sand, but when the sand particles are more or less lubricated by bitumen and tar I think the arching effect is minimised. In fact we almost know it is, because compression in the laboratory gives that specific gravity which is obtained on the road under conditions which do not tend to arching through ramming in a confined space. There is sufficient play with asphalt roads and tar roads for the particles of aggregate to take their places, and arching would thereby be minimised.

May I respectfully but very strongly urge that if and when anybody undertakes mechanical testing and carries it out in a laboratory, they attach recording mechanism to the machine that is making the test, because there will thereby be obtained a permanent trace on a piece of paper of what is happening to the sample during the test, whereas otherwise we only get a numerical result of what has happened, so to speak, after the test. We get only a final total result, but no information as to how the sample piece is stretching, or how it is compacting, or how it is collapsing, and so on. I suggest that very valuable information might be obtained through such a process.

PROFESSOR CLEMENTS: The subject of the testing of materials is, I think, being approached in the proper cautious manner. Mr. Batson raises the question of the correlation of measured tests with road conditions. I venture to suggest that that does not go quite far enough back. What indeed we really want to know is what are the conditions that are obtaining in the material subject to road action during its life, so that from that we can begin to work forward. May I give you an illustration. A test which is referred to in nearly all the Papers is the compression test, and relevant to that is the very valuable and very informative stability test of Mr. Hubbard. It is, I think, quite clear that no one really knows—though an analysis has been made and will, I hope, shortly be published—what is taking place in the case of the stability test. What is it? What are you testing? Is the material a viscous fluid or a plastic solid? What is taking place within that mould during the period of the test? This, I submit, is one of the

points, and indeed the nature of the information, that is most wanted in any form of analysis leading up to the establishment of tests as tests.

In the case of the sample test commonly accepted by engineers for certain materials of construction such as steel, concrete and so forth, you have two direct issues—tensile test and compression test—and sometimes a combination of the two in the form of the shear test. At least the forces exerted there are fairly well known, and the conditions are clearly indicated, and from that point onwards the question of the establishment or formulation of a test is a relatively simple matter, and receives the general approval of engineers and architects. In the case of the much more complex conditions where in fact you have something akin to a state of unstable equilibrium disturbed by loading, disturbed by temperature, disturbed by weather, and disturbed by time, where all these things are functioning together in different degrees of intensity, I think you have a condition of the unknown which is closely akin to that of the boy putting his hand into a bran pie and hoping something interesting will come out.

Therefore I think my contribution to this discussion would take the form of emphasising the need of further and more fundamental research work into the question of what is happening. I am confirmed in this by the fact that very recently some research work done in my own laboratories has proceeded upon lines which tend to indicate that there is a definite comparability between shear value and the stability test, both as to the shear value of the aggregate itself which can be tested, and of the compound mixture which can also be tested, which would rather indicate that that, for example, is one of the principal forces which have to be taken into account in considering the ultimate life value, that is to say, the stability value, of this compounded mixture. I visualise such a test being applicable to all pavements, whether of the coarse or of the fine type, where asphalts are the relatively fine compounds, and tar macadam or tar concrete are the relatively large and coarser mixtures.

I am much interested in the point raised by Mr. Hubbard, who I understand is not here this morning. I had hoped he would have thrown a little light upon some in-

formation which he brings in towards the conclusion of his Paper. I gather from that the impression that American engineers have reached the conclusion that too much work has been done upon the testing and examination of the component materials, and too little work has been done upon the testing of mixtures as compounds. Upon that point I do feel a little at variance with Mr. Hubbard. I think that not sufficient work has yet been done upon these fundamentals of the properties of materials, and that the behaviour of those materials not only relative to the mixture but relative to the material itself—its physical qualities—is by no means yet determined.

There are points running through all the papers which suggest a certain common line of thought. There is a reference to the compression test as an index of the quality of material as such. I am a little surprised and much interested to see that Professor Neumann regards the compression test as an important index of the stability value of the material, and I gather from his Paper that the German engineers and scientists prefer to adopt the compression test as a better guide, or at least a guide of equal value with the stability test.

The compression test of a cube of material standing by itself under load deprived of the support of adjacent cubes upon either side, suggests to me a complete dissociation from road conditions, and therefore I do not think that could be regarded as an adequate and representative value of the behaviour of the material in response to that test.

This is particularly so in relation to the point raised by Dr. Stradling. He refers to the arching effect of sand. I can corroborate his opinion from some other research work recently carried out. In the case of moulds filled with sand and bitumen mixtures the arching effect was most pronounced. The density, if the mould was sufficiently long, was found to be so slight at the base end of the mould as to be practically free from compaction at all, whereas the upper surface had reached its assigned density. In short, it was the confirmation of a phenomenon perfectly familiar in road engineering practice, namely, that the wearing surface, the upper layer of the road, receives its consolidation most quickly, and the lower layer attains its consolidation, and indeed a

much lesser consolidation, only after a long lapse of time. Therefore in discussing the question of the relativity of the material in the road in relation to mechanical tests it must, I think, be clearly borne in mind, and is indeed capable of confirmation from many sources, that the material throughout its depth has indeed got a variable density arising from its varying degree of compaction.

I should like to conclude with a reference to the question of mechanical tests as such. Mr. Batson invites replies to the question which he has formulated, namely: What is it the road engineer wants to know? What is the test? That is a very difficult question, and one, I submit, that cannot be replied to in the form of an equally short direct answer. What he wants to know, of course, is how long his road is going to last as an efficient wearing surface and traffic carrying unit, and therefore the difficulty arises that it has to be translated back, as Mr. Batson says, in a very clear exposition in the course of his Paper, into the question of its tonnage capacity. That is where, I think, lies the real difficulty in all mechanical testing, whether any means, arbitrary or otherwise, can be devised to formulate something which is going to prove by tests acceptable to engineers such an extremely difficult and abstract things as the ultimate life value of materials so complex as those used for modern road surfaces.

MAJOR TURNER (*Engineer-in-Charge of the Experimental Branch of the Ministry of Transport*): I would like to offer some general observations on the way in which the road engineers are likely to consider this question of mechanical testing.

The thing that always strikes me is the very great difficulty that attaches to the problem. Mr. Batson refers to the analogy with the steel bridge. A little consideration of that point will, I think, indicate some of the very serious difficulties that have to be met. A tar or a bituminous road surface is subject to external stresses brought to bear on it by passing traffic, and Mr. Batson says that concerning this there is a rather meagre amount of information available. One might go on to say that there is a similarly meagre amount of information available at times concerning the support given to that material by the foundation underneath it. That is only the beginning of the trouble. Steel

at least is an elastic material, and mechanical tests are peculiarly applicable to steel, and ever since our school days we have had some sort of idea of what happens to steel when it is under mechanical test. But we shall have to try to get an entirely new conception of what is happening to materials under test if we are to interpret the results of mechanical tests on plastic materials such as tar and bitumen. Steel, too, is to a large extent for the purpose of mechanical tests homogeneous, but tar and bituminous road surfaces are very far from that. You have a mixture of one material, tar or bitumen, with other materials of a totally dissimilar kind—mineral aggregate—and it may very well be that tests which are applicable to one form of surface, having say a binder of high melting point and comparatively small aggregate, would be found quite inapplicable to a material which has a comparatively low melting point and an aggregate comparatively large in size; and that the tests that are applicable to one or the other of these are themselves not applicable to the cold asphalt surface.

There is an associated difficulty in that a road surface as such does not exist until it is laid and consolidated, and even then it is constantly changing, or so we believe at all events, throughout the whole of its life. So that one can only admire the courage of research workers who, despite all these difficulties, are investigating this question of mechanical tests.

It has been pointed out that the matter is one of interest to research workers, manufacturers, and road engineers, and somewhat challengingly, the road engineer has been called upon to express his point of view. I could not pretend to speak for all road engineers by any means, but it seems to me a road engineer might fairly say he would like to know what combination of available materials is likely to give the best surface he can afford, and he would like to know, when that surface has been laid, whether its characteristics meet his needs in certain respects. A road engineer might fairly say he wanted a road with a low tractive resistance, a good non-skid surface, not liable to deformation, durable (i.e., not likely to disintegrate), resilient, and possibly he might add quiet. How far do the tests

that are discussed by the Authors offer information on these points?

There seems to have been a tendency to apply, perhaps a little indiscriminately, to bituminous road materials tests which have hitherto been commonly accepted for elastic materials in the hope, more or less, that something will turn up. It is suggested that these materials should be tested in tension, compression and bending. It is very doubtful indeed whether the results of such tests can be interpreted by us unless we are helped to almost a new conception of what takes place in the materials—a different conception from that which we have had regarding what takes place, for instance, in steel under test.

Mechanical tests applied to plastic materials tend very largely to become tests to the flow of the material under one form or another of loading. It remains to be shown whether very different information is likely to be obtained from one particular form of loading rather than from another. A rigid body such as a piece of steel arrives very quickly at its ultimate state of strain under any given stress. A tar or bituminous road surface, on the other hand, continues to adjust itself for quite a considerable time after the application of the load. A load which is not effective if applied for only a few minutes may give a serious deformation if kept on for an hour. Most of us, I think, have seen examples of bituminous road surfaces which are apparently quite unaffected by the passage of a very considerable amount of heavy traffic, and yet a comparatively light vehicle standing for half-an-hour or so outside one of the wayside refreshment booths will give quite an appreciable deformation of the road surface. Temperature greatly affects the viscosity of the binder, and therefore affects the deformation of the road material. So that, as I think has been brought out by the Papers, the temperature at which the test is made, the rate of loading and, perhaps one might add, the length of time for which any particular load is applied, will probably have a very important bearing on the results obtained. It may well be, as Dr. Spielmann suggested, that the important results in a mechanical test may be less the actual final strength obtained, but rather the relation between the

load applied and the rate at which the material deforms.

An appreciable amount of work has been done on mechanical testing at the Experimental Station, Harmondsworth, and it might be of interest if I were to summarise the results obtained there prior to it becoming part of the Road Research Organisation, under Dr. Stradling. The results indicate that no one physical test is likely to afford a criterion of the suitability of the material for road use. The tensile strength, for instance, of a number of materials, all of which are giving good results on the road, has been found to vary within extremely wide limits. As another example, two materials of the same type and largely of the same composition were found to give very nearly the same compression strength in the laboratory, and yet under normal traffic conditions the one which gave the rather better result under test gave a markedly poorer result on the road. The position summed up in March of this year was as follows: In the light of existing evidence it had to be said that a bituminous material was not necessarily unsuitable because it was mechanically weak, still less could it be said that it was satisfactory because it gave satisfactory results under mechanical tests.

DR. B. H. KNIGHT: In conjunction with Sir Robert Hadfield I have recently carried out work on the testing of aggregates, and the impact test as ordinarily used has come in the course of that work under a certain amount of suspicion. In Mr. Batson's Paper it is stated that the standard impact test has been diverged from, and that a different procedure has been adopted in carrying out that test. What I would like to ask Mr. Batson is if it has been considered whether that test could be improved as used at the present time by cutting the specimens in different directions in the mixture.

Dr. Stradling spoke about the effect of sand arching, and structural peculiarities of that kind. We found the same thing in testing aggregates, and we found that structural differences do affect these tests, and that the height of the test piece is a controlling factor. If you take it short enough, you get ridiculous results, and if you take it long enough you can get correspond-

ingly ridiculous results. What you have to do is to find out the height which suits the conditions. I offer this as a suggestion to Mr. Batson.

In the Paper of Mr. Adam and Mr. Murdoch I notice that they describe the sand blast test for abrasion. I think they meant it to be an abrasion test, because they make a remark about abrasion or attrition. I am not quite sure whether they mean the same thing or not. Perhaps they would like to explain what they mean by abrasion or attrition.

Under the old Dorry test used in the States we got some very conflicting results, and I would like to ask the Authors of the Paper whether they were dissatisfied with the Dorry test, and if so whether they think the test they have is a better one, and the reasons why. The test they have seems to be a far more scientific test to my mind than the old Dorry test that has been used up to the present.

MR. W. J. A. BUTTERFIELD: I think many of the tests described, especially those in Mr. Hubbard's Paper, are primarily applicable to standing loads on a highway. They apply chiefly to the conditions in city streets, where traffic is pulled up by traffic signals, and stands for some time. That is an entirely different problem from the open highway.

I think the road machine as described by Mr. Batson, which was formerly at the National Physical Laboratory, is well adapted for testing the wear and tear under running conditions, but there is one fundamental point to which I would like to draw attention. Mr. Batson says that arrangements have been made to fit rubber tyred wheels in place of steel wheels if required. I think there is no question that the steel-shod wheel should now be dropped in all tests for road materials. It is as unreasonable to test a road surface with a steel tyre as it would be to test the engine and transmission of a motor-car by running the car on steel tyres at 50 miles an hour. One certainly wants to use the rubber tyre in testing a road surface.

As to this machine itself, I think it is admirable for research stations, but works such as the Beckton and East Greenwich Tar Works, and those of the large asphalt firms, might be glad of a modification of it

which could be put in at less expense, and would I think give the working conditions quite as well. Some five years ago Mr. Dryland, then County Surveyor of Middlesex, in collaboration with the speaker and Mr. A. R. Peart, arranged for some special tests on a circular track on which the road material under test (in that case, "Tarvia") was laid, and on that track, which was 12 ft. wide, and with an outside diameter of 53 ft., he used a motor lorry steered by a radial arm so that it could not leave the track. It was anchored to the centre of the circle. The lorry could be started and run at whatever speed was desired on the track. It had the advantage of having two rolling wheels and two driven wheels, and thus gave all the conditions of practical road work. The track was a wider one than Mr. Batson's, and therefore more costly, but if it were simply used for testing the wearing qualities of road surfacings it would be possible to lay two different materials and let the outer wheels test one material, and the inner wheels test another, so that both could be tested at the same time.

I think some arrangement might, through the ingenious machine of Mr. Adam and Mr. Murdoch, be used to test small samples in a tray. The machine they describe in Fig. 1 could be fitted with a wheel with inflated tyre, which could be rotated at whatever speed was desired, say equivalent to 40 or 50 miles an hour, and if the tray were then arranged to be brought up momentarily in contact with the tread of that wheel and dropped again, by an eccentric gear, it should be possible to test a slab of material, in a tray such as theirs, under almost ideal working conditions.

As regards what has been said about compression of test samples, as a very old amateur firework maker I might say that I realised years ago that it was hopeless to try to compress uniformly any dry powdered material at any great depth. The tamping method of compression in successive thin layers is the right one undoubtedly to get even compression right through the material.

The following contribution to the discussion was sent in by MR. W. H. BUDGETT (*Ministry of Transport, Edinburgh*): The stability test devised by Mr. Hubbard offers a field of investigation which suggests much practical value.

It is interesting to note, however, from Table 4 in Mr. Batson's Paper that the maximum load by the Emmons & Anderton's stability test shows a more favourable result in the binder coats than with the wearing coat which suggests that advantages are to be derived from the use of the larger aggregates. Resistance to impact also appears to be greater with the larger aggregates under certain conditions (see Professor Neumann's Paper).

From these two tests the conclusion might be drawn that the finer aggregates are unnecessary, but Mr. Hubbard draws our attention to the need for imperviousness to water absorption and later refers to voids.

The laboratory therefore confirms a view held by many engineers that the larger aggregates should be brought as near to the surface as possible, covered by a fine coat used for its sealing and not its wearing qualities. This has led on many occasions to the use of a badly balanced aggregate containing too many voids, and a consequent frequent resort to dressing in an effort to waterproof a surface coat imperfectly constructed.

In course of time, the road is overloaded with tar and the views of the Author as to the effect on the stability of the surface would be interesting.

Mr. Hubbard suggests the desirability of incorporating as much bituminous cement as possible without lowering the stability of the mixture to an undesirable extent. In the opinion of many, slippery conditions have often arisen through the use of too much binder and I believe it to be now the practice of the trade to reduce the quantity so far as is possible consistent with efficiency.

For this reason the road may not be so stable, and have less life, but the great loss of human life on the road demands greater attention to the roughness of the surface even at the expense of reduced life of the surface.

MR. R. G. C. BATSON (replying to the Discussion): Taking the observations of Mr. Butterfield first, I quite agree that to test the surface conditions of roads the pneumatic tyre is necessary. But we have to bear in mind that one of the objects of the laboratory road machine is to obtain rapid results. It is no good exactly simulating

road conditions if you want to obtain rapid results. Otherwise the method is useless.

As I see it, there are two problems. One is the test of the road surfacing as surfacing (i.e., test of the structure of the road), and the other is the test of the actual surface of the road, which is quite a different matter. I quite agree that for testing the surface of the road, or surface dressings, or for skidding characteristics, rubber tyres are essential, but for testing the actual structure it is doubtful whether the test would be sufficiently rapid to give results in a reasonable time if pneumatic tyres were used. It might be possible, and it is worth trying, but there is considerable doubt about it.

With regard to Dr. Knight's remarks I am afraid I lost his main point as regards the impact test. He stated that the test as described in the Paper was different from the ordinary Page test. The only difference I can see is that in the impact test on bituminous carpets described in my Paper the size of the test piece and the weight of the hammer were larger.

As regards his other point, as to the results of impact tests on stones being different according to the direction of the grain, I can confirm that. In some stones you do get lower results in one direction of the grain than in the other.

I was rather surprised to hear Major Turner's pessimistic contribution to the discussion. He said that in his opinion most of the tests upon bituminous materials—I do not know that he used these actual words, but this is what I gathered was the substance of his opinion—were simply types of flow tests under various forms of loading. I think I could almost entirely agree with him as regards certain types of tests, but does not one find with all types of plastic materials that such tests are more or less based on flow?

Major Turner mentioned that he considered steel was different from bituminous materials as regards its properties, but if you take steel to a high enough temperature you get flow in just the same way as you do with bituminous materials, and the only test of steel at high temperatures with which I am familiar is the flow test in which various rates of flow are measured.

Dr. Spielmann suggested that in all testing

machines recording mechanism should be adopted. This is an ideal, and is an ideal which a good many workers are trying to work up to. In fact my colleague Dr. Lonsdale is at present looking into the construction of a machine in which everything is recorded autographically.

MR. W. G. ADAM: Dr. Knight asked about the Dorry test, and whether the sand blast test was an abrasion or an attrition test. The Dorry test is an abrasion test, and consists of taking a piece of road material, loading it with a definite weight and keeping it while loaded pressed against a revolving steel plate fed with sand. There are various modifications of this test. The loss of weight of the specimen after a definite period is taken. The sand blast test is, in my opinion, more of an attrition test, the loss of weight being brought about by the bombardment of the material by the small grains of sand. We admit freely that we do not know in what way there is a linking up of the sand blast test and actual road conditions.

Mr. Butterfield made a suggestion with regard to the fixing of a wheel on the consolidating machine which we have at Beckton. I think it is a very good suggestion, and

possibly later on we shall be able to try it out.

PROF. DR. ING. E. NEUMANN: Professor Clements and Dr. Stradling have criticised the compression test, or the test of resistance against compression. They are right, I must confess that this test does not have regard to the stresses in the road. But we do not use it to imitate the stresses in the road. We have another object. The contractors sometimes come to me and ask for the best mixture of aggregate and bitumen or tar. I have explained previously that we like to make the mixture of tar or bitumen in accordance with the road materials, and in this way we obtain good results from the behaviour of the roads. We can exercise control as to whether the contractor has made his road mixture correct or not. We control it by taking road material into the laboratory and testing it there, and to carry out the experiment within a short time we have used the compression test. This is a simple test but we should be very glad to have a better. Mr. Hubbard's test is better, but we have found that it is easier to make a compression test, and that is the reason we have adopted it. I endorse the opinion of Professor Clements and Dr. Stradling, and I shall be happy to learn their experience with the new tests in due course.

CONFERENCE

Under the auspices of the Society of Chemical Industry.

TUESDAY, 14th NOVEMBER, at 3.0 p.m.

PROF. G. T. MORGAN, O.B.E., D.Sc., F.R.S., in the Chair.

The following two Papers were taken as read :—

The Mechanical Testing of Asphalt.

BY

D. M. WILSON, M.C., B.Sc., A.I.C.

INTRODUCTION.

UNTIL recently the only guide to the properties of an asphalt mixture, apart from rough and ready tests such as that for the Pat Stain, has been a study of the properties of the constituents themselves. Tests could be made on the bitumen and on the mineral aggregate, but no means were available for studying the properties of the materials resulting from mixing bitumen with the aggregate.

Tests on the constituents have been found to be of limited value, and many efforts have been made to express the characteristics of the finished materials by the results obtained by means of tests. The problem is one of amazing complexity; there are so many variables and the properties of the bitumen itself may be changed considerably if care is not exercised in the manufacture of the asphalt.

The mechanical tests which will be described, although they do not actually reproduce conditions existing under traffic, aim at determining certain properties of the mixtures, the results being expressed in simple figures which make it possible to distinguish between materials that have given satisfactory service on a road and others which have been less satisfactory.

As no single test can be devised to give all the information required about an asphalt mixture a testing scheme has been drawn up to comprise a range of tests,

the results of which are interpreted by a study of the way in which the different mixtures have behaved under traffic. Samples cut from roads have been examined in the laboratory in order to see in what respect they show differences. Thus, by carefully co-ordinating the practical results on the road with laboratory observations, certain common factors can be discerned and the laboratory tests can, with confidence, be employed to guide the large scale operations and help the "practical man" to make a good job.

• Asphalt mixtures may range from the fine-grained compressed asphalt to the large aggregate single coat and tests which can be applied to compressed asphalt are not necessarily applicable to single coat steam-rolled asphalt; specific methods of testing are required for each class.

Many suggestions for testing asphalt mechanically have been published from time to time, but no test on a road material can be considered to be of any real value unless it expresses in simple figures a marked difference between samples which have behaved differently on a road.

A number of the tests that have been used in actual practice will be described, together with a short discussion of the value of each test. Finally, information will be given as to methods of recording and correlating the results obtained.

PREPARATION OF TEST PIECES.

When dealing with materials which have been under traffic it is often possible to cut a test piece from the sample by means of a carborundum saw and grind it to the shape required with carborundum wheel. Where this is not possible a laboratory sample can be moulded in steel moulds, of appropriate shape, at a temperature not exceeding 130°C., using sufficient pressure to produce a test piece of the same specific gravity as that to which the material had become compressed on the road.

When mixtures are to be examined which have not been laid on the road and consolidated by traffic it is advisable that the test pieces should be fully compacted. In the case of mastic asphalt a pressure of 3,000 lbs. per square inch is sufficient, but carpet samples should be moulded under a load of 12,000 lbs. per square inch. This load is much higher than that employed by other workers on the subject, but it has been found to be necessary in order to reach final compaction in the case of all the practical mixtures that might be made. In fact, some steam-rolled asphalt materials cannot be moulded to the specific gravity they eventually attain on the road unless this high pressure be employed.

The necessity of using a load of 12,000 lbs. per square inch was discovered by compacting a number of cylinders, each 2 in. in diameter, containing the same solid volume of mineral aggregate (viz., 75 cc.) under different loads, and measuring the height of each cylinder when under load. The curves in Fig. I. show that compaction increases with each increase of pressure until 12,000 lbs. per square inch is reached, when the curves become practically horizontal.

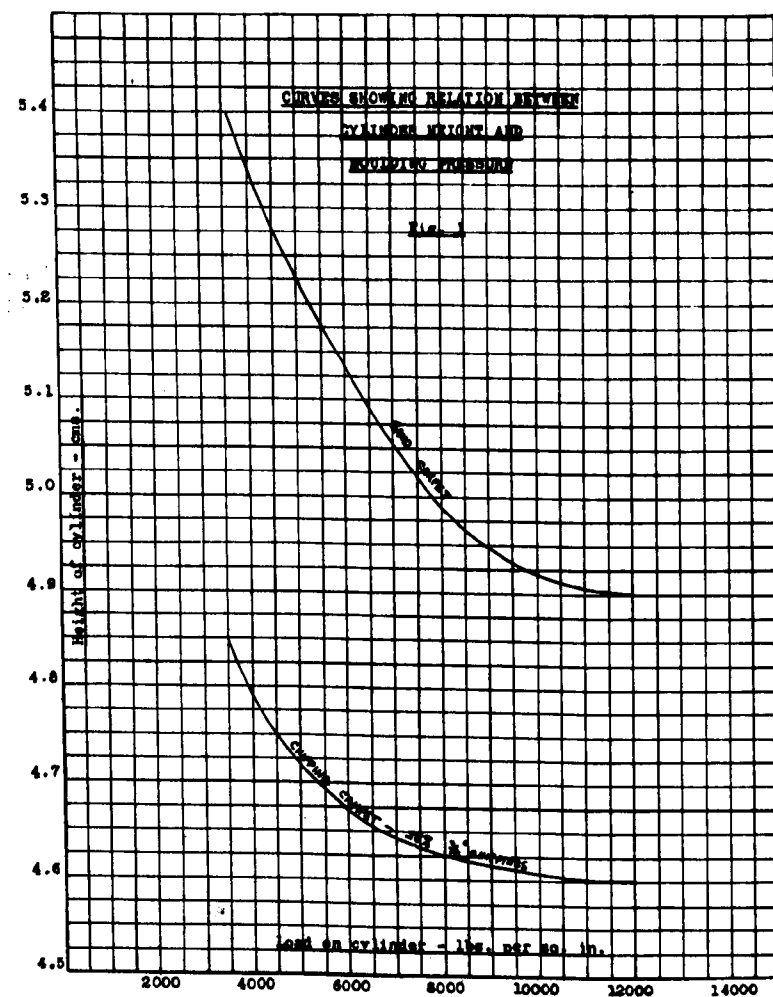


FIG. I.

To ascertain to what extent the aggregate had become crushed by the load, the bitumen was dissolved out of each cylinder and the mineral aggregate graded. The following figures show the gradings both for the original uncompressed mixtures and for the mixtures after compression at different loads :—

SAND CARPET.

Sieves I.M.M.			Uncom- pressed.	Compressed under load of :—				
				4,000	6,000	8,000	10,000	12,000
			(lbs. per sq. in.)					
Passing	200 mesh	..	11.6	12.1	14.3	14.0	13.8	15.0
„	100 „	..	32.8	31.9	31.3	31.6	32.6	33.8
• „	70 „	..	22.0	21.6	20.8	20.0	21.6	19.6
„	50 „	..	26.4	27.2	26.4	27.2	25.2	24.8
„	30 „	..	7.0	7.0	7.0	7.0	6.6	6.6
„	20 „	..	0.2	0.2	0.2	0.2	0.2	0.2
			100.0	100.0	100.0	100.0	100.0	100.0

CHIPPING CARPET, 25 PER CENT. THREE-QUARTER INCH CHIPPINGS.

Sieves I.M.M.			Uncom-pressed.	Compressed under load of :—				
				4,000	6,000	8,000	10,000	12,000
			(lbs. per sq. in.)					
Passing	200 mesh	..	5.6	6.1	6.3	7.0	5.9	7.9
„	100 „	..	18.8	19.2	20.9	21.2	21.3	20.8
„	70 „	..	23.0	22.5	23.1	22.0	23.2	19.0
„	50 „	..	13.4	12.4	9.8	9.5	9.6	11.2
„	30 „	..	9.0	9.3	9.8	10.1	10.4	10.9
„	20 „	..	2.6	2.6	2.0	1.7	1.7	1.7
„	10 „	..	0.3	0.3	0.3	0.3	0.3	0.3
„	$\frac{1}{8}$ in. „	..	0.0	0.0	0.0	0.5	0.0	0.5
„	$\frac{1}{4}$ in. „	..	0.0	0.0	0.5	0.0	0.0	0.0
„	$\frac{1}{2}$ in. „	..	0.0	0.0	4.1	5.1	0.0	2.6
„	$\frac{3}{4}$ in. „	..	27.3	27.6	23.2	22.6	27.6	25.1
			100.0	100.0	100.0	100.0	100.0	100.0

It will be seen that only a comparatively small amount of crushing has taken place even in the case of the sample containing up to 25 per cent. of $\frac{3}{4}$ in. granite chippings. Crushing of the aggregate in a test piece to the extent the figures indicate cannot be considered to be a serious matter, as similar crushing of the mineral aggregate undoubtedly takes place in the mixture when subjected to traffic. In fact such variation in grading that has been produced by compaction would be considered to be negligible when testing a new surfacing mixture.

It is realised that on a road compaction is not effected by direct compression only, but that it is assisted by the kneading action of traffic. Many methods of preparing test pieces have been tried, in which compaction has been assisted by tamping, but none gave test pieces so consistently compressed to a high specific gravity as those obtained by direct compression. If a sample contains sufficient

bitumen to receive ultimate compaction at a lower pressure no harm will be done by the use of a higher pressure than the minimum necessary.

It is advisable to allow all moulded test pieces an ageing period of 7 days before testing.

GENERAL NOTES ON MECHANICAL TESTING.

All asphaltic materials possess a measure of plasticity and the rate of application of the load during a test has a very considerable effect. In the mechanical testing of asphalt a press of the hydraulic type, in which the load can be applied at a regular rate of increase by means of an hydraulic accumulator, is preferable. For small loads some type of lever machine is useful, in which a regularly increasing load can be applied by running lead shot into a container suspended from one end of the beam. This latter method of applying the load is especially useful when it is desired to compare the properties of different types of material over a wide range of temperature; the results can then be expressed on one scale.

HARDNESS (RESISTANCE TO IMPRESSION).

The most important test under this heading is the "Hardness Number Test." This has already been described in "Chemistry and Industry" Vol. 51, No. 4, p. 68, and was designed solely for use with mastic asphalt. The test piece can either be a portion of mastic cut from the work or a portion floated to form a rectangle about 3 in. by 3 in., having a minimum thickness of 1 in.

The "Hardness Number" is defined as the depth expressed in hundredths of a centimetre to which a steel rod 6.35 mm. in diameter, with the end ground off square, will penetrate a sample at 25°C. under a load of 100 kg. per square centimetre, during one minute.

Objection has been raised to the test when dealing with heavily granited mastic on the ground that the chippings might interfere with the result. The depth of the penetration of the needle for this type of material is only 3 millimetres at the most, and in practice the effect of floating mastics is to cause some of the matrix to rise to the top of the sample; the test is really made on the matrix which cements the chippings together. In the average sample it is easy to avoid chippings if by any chance some are left projecting above the surface level.

Indentation tests have been made with rods 1 in. and 2 in. in diameter using a load of 20 kg. per square centimetre, applied over a period of 2 hours. Generally speaking the results are proportional to the Hardness Number figure obtained in one minute with a $\frac{1}{4}$ in. diameter rod. There does not therefore appear to be any advantage in using rods of larger diameter as no new information is obtained and the test is unduly prolonged. Rods with rounded ends have been tried but were discarded because the pressure per unit area decreased with increasing penetration of the sample.

The Hardness Number Test has been daily in use for ten years and no practical difficulties have been experienced on account of the influence of chippings near the surface; it has afforded the greatest possible help in designing mastics to meet very varying conditions.

For the most heavily granited road mixtures, and for very hard flooring mastics it is best to make the test at 35°C.

The following are some typical results:—

<i>Building Mastic</i>	<i>Hardness No.</i>
Mastic cut from a roof after 41 years service	15
Flooring mastic—to withstand heavy loads—35 years old ..	3
<i>Road Mastic.</i>	
Mastic which has withstood very heavy traffic at 'bus stops	4
Mastic used for fast-moving main road traffic	15
Mastic which has proved to be too soft, showing marking and tracking	83

Since the method of making this test was first published it has met with widespread acceptance among the leading asphalt contractors in this country.

When interpreting the results of the test all the other features of the mastic must be taken into consideration, for it must be remembered that asphaltic bitumen of 3 penetration, without any mineral aggregate at all, will have a hardness number of about 17 at 25°C.

So far little success has been obtained with indentation tests on steam-rolled materials.

STABILITY TESTS.

In order to obtain a measure of stability a very large number of different tests were devised, all of which were rejected in turn because they did not show a sufficiently marked difference between mixtures proved to be stable from their behaviour on the road and those that for some reason were obviously less stable. Eventually the "Deformation Test" was developed which was fully described in "Chemistry and Industry" Vol. 51, No. 4, pp. 68 and 69.

The test piece consists of a cylinder precisely 2 in. high, and 2 in. in diameter it may either be moulded or cut from the material and ground to shape. When a regularly increasing load is first applied to the cylinder the sample steadily becomes deformed, the extent of deformation being directly proportional to the load, as shown in Fig. II. As the extent of deformation increases and the height of the cylinder becomes still further reduced the sample begins to break down. The figure for "deformation" however, is taken as the load required to deform the cylinder by 20 hundredths of a centimetre, and in the average run of samples the figure lies on the straight portion of the curves.

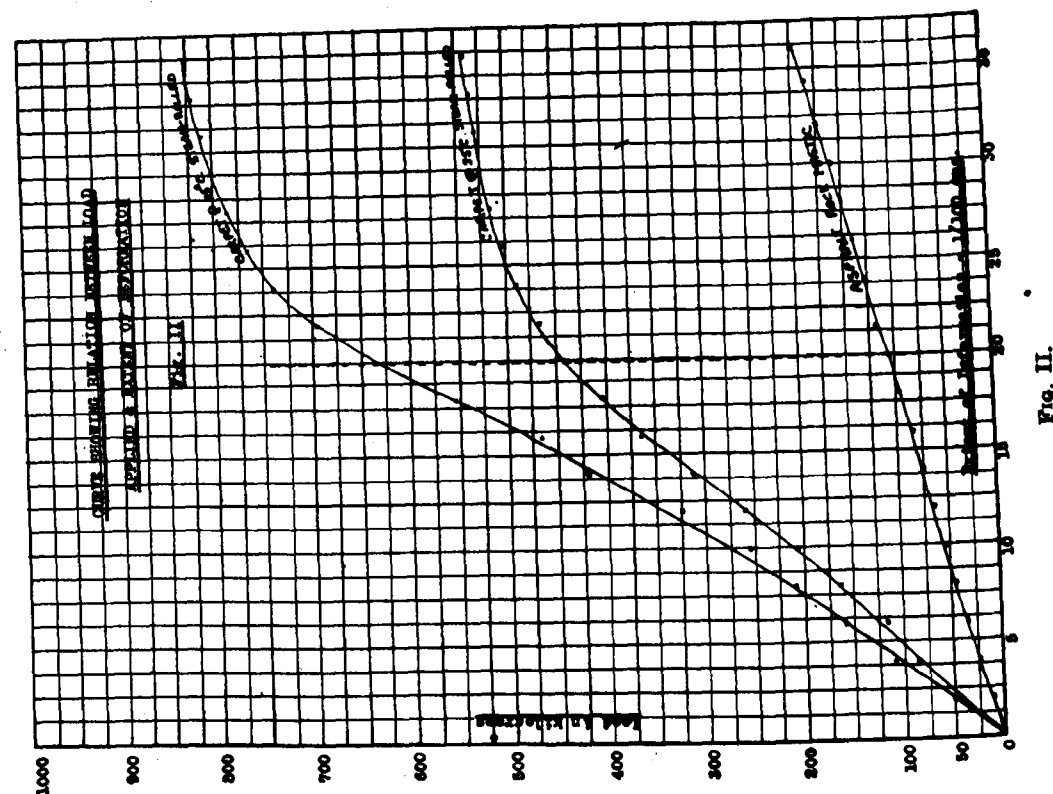


Fig. II.

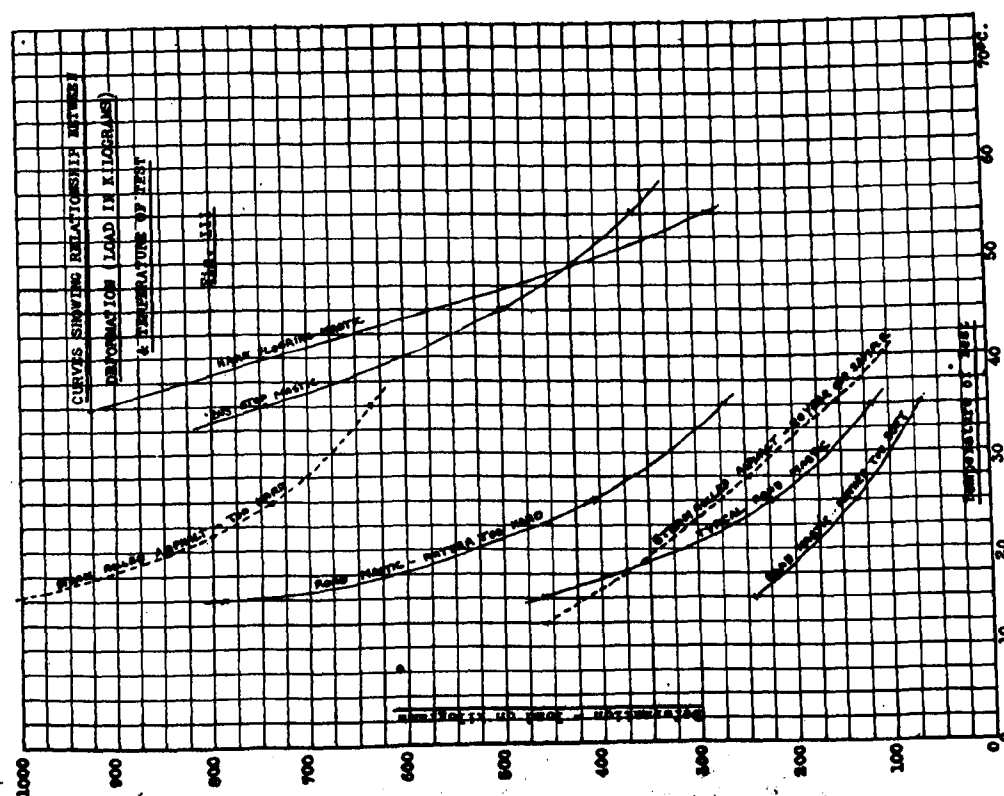


Fig. III.

Typical results are given in the following table:—

Load in kilograms required to cause standard deformation.

Temperature of Test.	15°C.	25°C.	35°C.	45°C.	55°C.
Hard flooring mastic	—	—	908	574	285
Typical road mastic	459	223	119	—	—
Mastic from 'bus stop—very heavy traffic	—	—	744	497	360
Road mastic, rather too hard ..	789	406	270	—	—
Road mastic, which is rather too soft	244	136	67	—	—
Steam-rolled asphalt—has lasted for 20 years	418	280	158	—	—
Steam-rolled asphalt—rather too hard	1,021	738	635	—	—

Fig. III. shows the same figures plotted out in graph form.

The test has been in use for eight years and has enabled the stability of a wide range of materials to be expressed in a simple number, and at temperatures as high as 60°C.

IMPACT TEST.

For the sake of simplicity the same shaped test-piece is employed as for the tensile test, the break being produced at the narrowest point. The test piece is held in position by means of a wedge which rests across the narrowest portion of the slab. The wedge is held firmly in contact with the test piece and is fixed in the sliding plunger upon which the hammer (weighing 1,000 grams) of the machine is dropped from a regularly increasing height, until the slab is fractured. The test is made under water at 15°C. or any desired temperature; the result is expressed either as the number of blows required to produce the fracture or as the aggregate distance in centimetres through which the hammer falls. The machine employed is shewn in Figure IV., but with its water bath removed.

TYPICAL RESULTS.

	No. of blows to fracture.	Aggregate fall of hammer cms.
Road mastic	40	820
Mastic liable to track	69	2,415
Steam-rolled asphalt	51	1,326
Steam-rolled asphalt—rather too soft ..	94	4,465
Steam-rolled asphalt—rather too hard ..	29	435

It is essential that the slab should be supported by the base of the machine and kept in position by the wedge to prevent it from bouncing.

A soft asphalt can show a very high figure in the Impact test; one that is rather too hard gives a comparatively low reading.

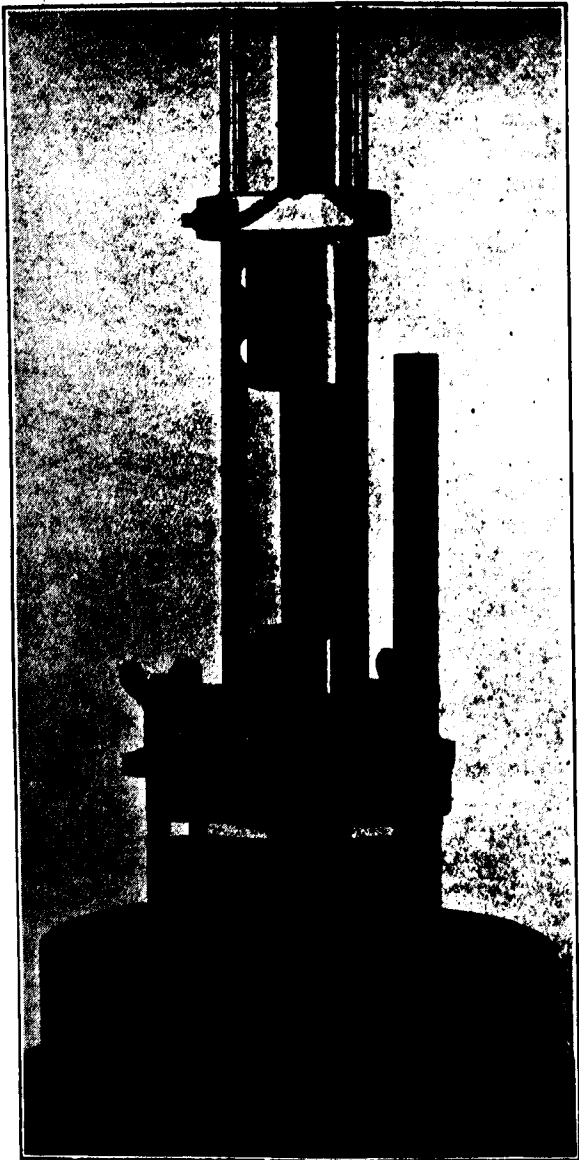


FIG. IV.—Impact Testing Machine.

TENSILE TEST.

The dimensions of the test piece are exactly double those of the standard testing briquette for Portland Cement. Details have been published in "Chemistry and Industry" Vol. 51, No. 4, pp. 69 and 70 and typical results are now given :—

	Tensile Strength.		Elongation. 1/100 cms
	lbs. per sq. in.	kg. per sq. cm.	
Asphalt tile	265	25.7	26
Mastic asphalt	785	55.2	76
Steam-rolled asphalt—tested after 19 years service	340	23.9	42
Steam-rolled asphalt—rather too hard ..	372	26.1	24
Steam-rolled asphalt—rather too soft ..	436	30.7	121

It is absolutely essential to apply the load at the same rate in every case or wide variations result. The elongation of the test piece at the breaking point is of considerable significance. A mixture short of bitumen and one too rich may both show the same tensile strength but the elongation will be markedly different. A high tensile strength does not necessarily indicate a good mixture ; some plastic mixtures with a low tensile strength have given good results when well keyed to the foundation.

1 CM. BALL TEST.

The railway companies on the Continent usually require asphalt tiles to be tested in a Brinell machine and stipulate that the minimum pressure to produce an impression 3 mms. deep with a steel ball 1 cm. in diameter, shall be 500 kilos. No rate of application is specified and it is found that a comparatively small load, if applied for a sufficient length of time, will give the 3 mms. indentation. In an improved method of making the test the hardness testing machine is employed, the steel "needle" being removed and its place taken by the steel ball. The load is applied by running lead shot into a can, suspended from the end of the beam, at the uniform rate of 2,000 grammes per minute until the depth gauge indicates that the ball has penetrated exactly 3 mms. into the sample. The result is expressed as the load in kilograms required to effect this penetration.

INTERPRETATION AND CORRELATION OF RESULTS.

Even when a number of mechanical properties on many different samples have been determined there still remains the difficult problem of interpreting the results. There appear to be so many inconsistencies ; a sample can show a low value in the deformation test if it carries too much bitumen, or, on the other hand, if it carries too little. The tensile strength can be low in a sample short of bitumen, and also in a very rich one. The apparent inconsistencies are chiefly observable in the case of steam-rolled materials, and were only properly understood when a method of making void tests with bitumen was discovered.

Many workers have published articles in which void determinations are made on aggregates using water, paraffin, castor oil, etc. to fill the voids, but the results obtained are not really comparable with what happens when bitumen is used as the void filling medium. The materials mentioned may fill voids which bitumen, owing to its higher viscosity, cannot fill. Bitumen has also the effect of assisting the particles to compact more closely together, and to adopt the densest method of packing.

Briefly, the method consists in measuring the heights of cylinders prepared from the mixture under examination, 5.08 cm. in diameter, each cylinder containing exactly the same solid volume of mineral aggregate, namely, 75 cc. The mixture is carefully made up and introduced into a cylindrical steel mould which has been ground to size after hardening. A load of 12,000 lbs. per square in. is applied to the material at a temperature of 120°C. and the height of the cylinder is measured, whilst under pressure, by means of transfer calipers and a micrometer, by determining the length of the mould plunger protruding from the mould.

A series of cylinders is made with different percentages of bitumen, but with the same mineral aggregate, and it is found that, starting with a small quantity of bitumen, the mixture becomes more compact, and the height is reduced, until a point is reached when an increase in the percentage of bitumen increases the bulk of the cylinder and the latter increases in height. Curves can be plotted showing the relationship between the percentage of bitumen and the height of the cylinder. For each series the curve falls to a minimum and rises again. Not only is the percentage of bitumen at the minimum point an important property of each particular series, but the height of the cylinder containing this particular percentage of bitumen is also of considerable importance.

The mechanical properties of the different mixtures, with one or two exceptions, follow reversed curves, generally reaching a maximum value at the minimum point on the cylinder measurement curve, and declining thereafter. The impact results and the figures representing elongation at the breaking point during the tensile test both increase as the percentage of bitumen is increased.

It is therefore essential that the position on the curve of the particular mixture under examination must be known before the mechanical testing results can be understood properly, and when comparing the properties of different mixtures the amount of bitumen in each should be that required to give the densest cylinder, or it should bear some definite relation to this amount of bitumen.

Apart from their value in connection with mechanical testing, the cylinder measurement curves are of considerable value in designing specifications. Figure V. shows a number of curves plotted for aggregates that have been used on the road and the arrow indicates the percentage of bitumen which was chosen as the specification for the mixture to be laid. It will be observed that in every case except one, which was not successful, more bitumen is added than is necessary to fill the voids completely, and this amount varies according to the traffic conditions the mixture will have to meet.

Figure VI. shows a number of curves obtained in the same way which illustrate the packing effect of different fillers, the same percentage by weight of each filler being used with exactly the same aggregate and the same bitumen. It will be noted that in the case of the aggregate containing 16 per cent. of Whiting sand, the minimum point is lower than and nearer to the origin than with the other fillers. This is probably because the mixture packs so tightly and the voids are so small that it is not possible for the bitumen to penetrate properly, and what happens is that "balls" of filler are coated instead of the individual grains. Portland cement is coarser and "carries" a higher percentage of bitumen. An understanding of the behaviour of different fillers when mixed with bitumen, as shown by these cylinder measurement experiments, is of great help when studying mechanical properties.

Another extremely important property of an asphalt mixture is the penetration of the bitumen which can be recovered from the sample, and it is essential that this should be known before attempts are made to study the results of mechanical testing. In the case of steam-rolled asphalt if the penetration of the recovered

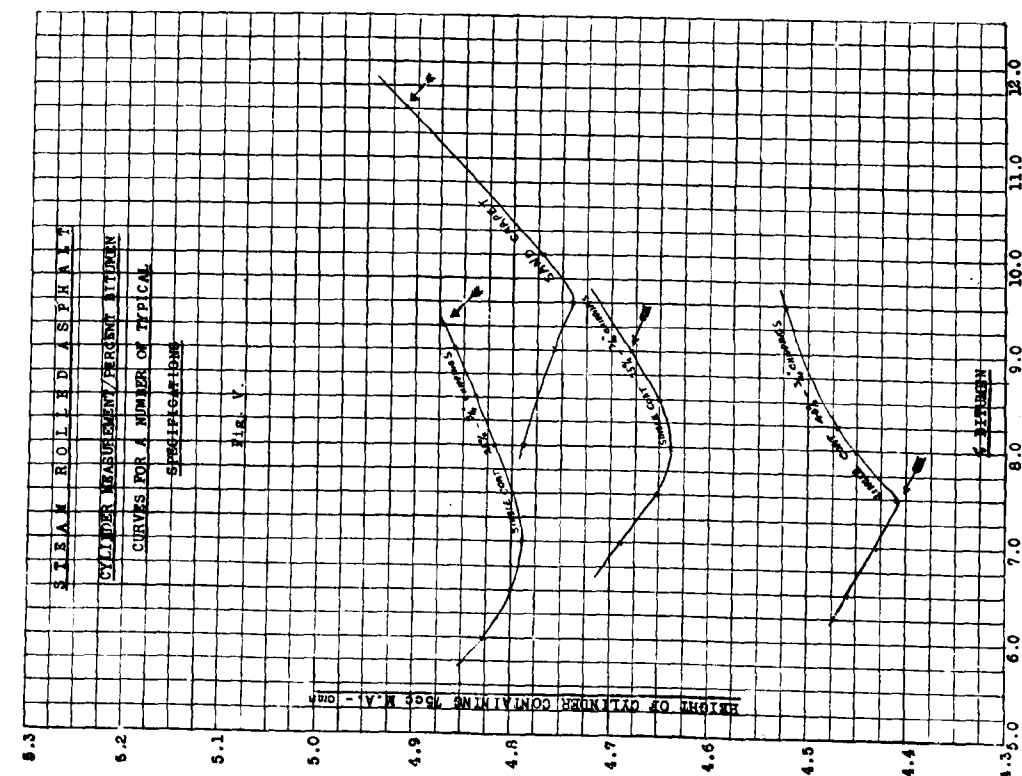


Fig. V.

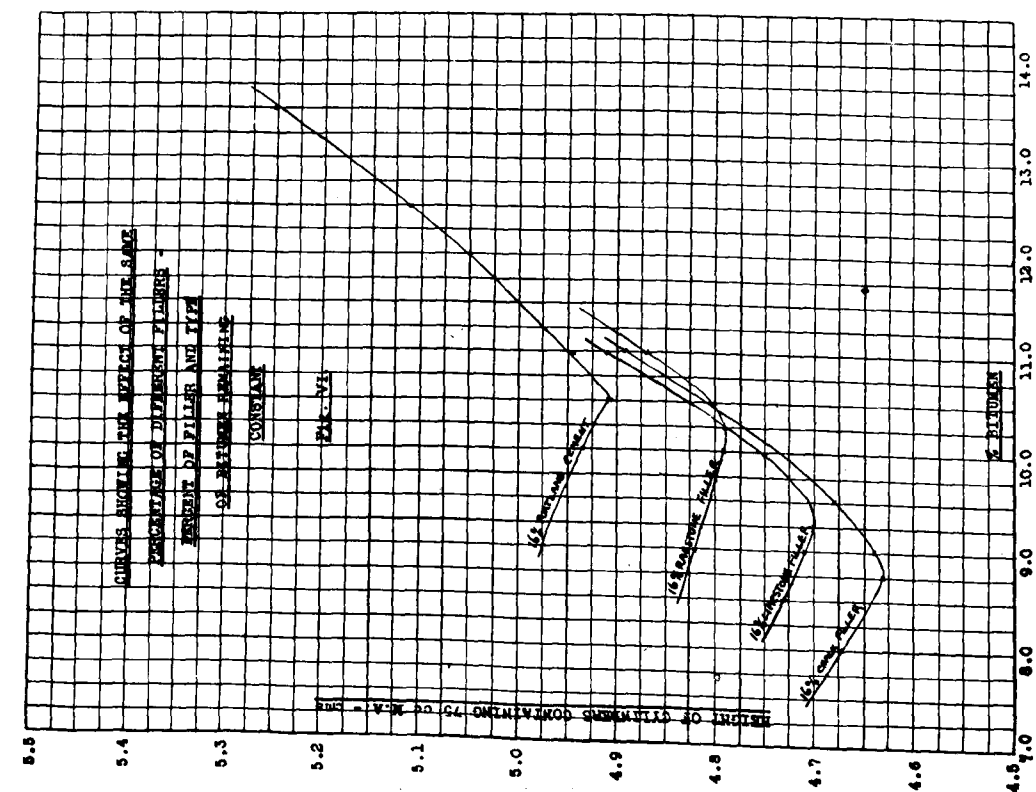


Fig. VI.

bitumen is lower than 20 at 25°C. the mixture will not be satisfactory whatever its mechanical properties.

RECORDING OF INFORMATION.

In order to handle the information that had been collected after the examination of a large number of samples, the "Paramount" punched-hole recording system of the Copeland Chatterson Co. Ltd., was adopted in order to record the information in such a way that it could be handled quickly. The properties of a sample are indicated by clipping out certain of the holes round the edges of the card, each hole standing for a certain number or property. Thus, in the case of steam-rolled asphalt, we are able to show the type, percentage and penetration of the bitumen, results of the impact, tensile (including elongation) and deformation tests, percentage retained 10 mesh, type of filler, life on the road, type of foundation, and information as to how the mixture behaved on the road, by clipping out certain holes as shown in figure VII. Similar cards can be prepared for mastic and asphalt tiles.

It is an easy matter to separate from a stack of cards on which the properties of a large number of different samples cut from the road have been recorded, all those possessing certain factors in common, as for example, those showing a high impact result. This is done by passing a needle through the appropriate hole and lifting the cards, as shewn in figure VIII. Immediately this is done the required cards drop out, being thus separated from those still remaining on the needle. From the details recorded on the card it can be seen how these samples have behaved on the road.

Similarly all cards representing samples that have given good service can be sorted rapidly from those that have been less satisfactory and the properties of the two groups compared.

CONCLUSION.

Although tests on asphalt, from the very nature of the material, admittedly lack the precision with which other engineering materials can be tested, the tests that have been outlined have proved to be of considerable value. They have been developed from a study of what has happened to known mixtures under all conditions of traffic during the last ten to fifteen years, and represent the results of an attempt to explain by laboratory testing why certain asphalt mixtures have been more satisfactory than others.

The larger asphalt contractors have been sufficiently far-seeing to lay their roads to definite specifications under carefully recorded conditions, and it is now possible to cut samples which have been under traffic for lengthy periods and to study their properties. The results of this experience can be drawn upon to guide in the interpretation of the results of tests on new mixtures. There are many gaps in our knowledge but what has been done so far has proved to be definitely useful in the technical control of contracts under widely differing conditions of climate and traffic.

[illegible]

Fig. VII.—Typical Record Card.

Finally, the author wishes to express his thanks to the Directors of Highways Construction, Ltd., for having given permission for the work performed in their research laboratories to be published for the benefit of the industry as a whole.

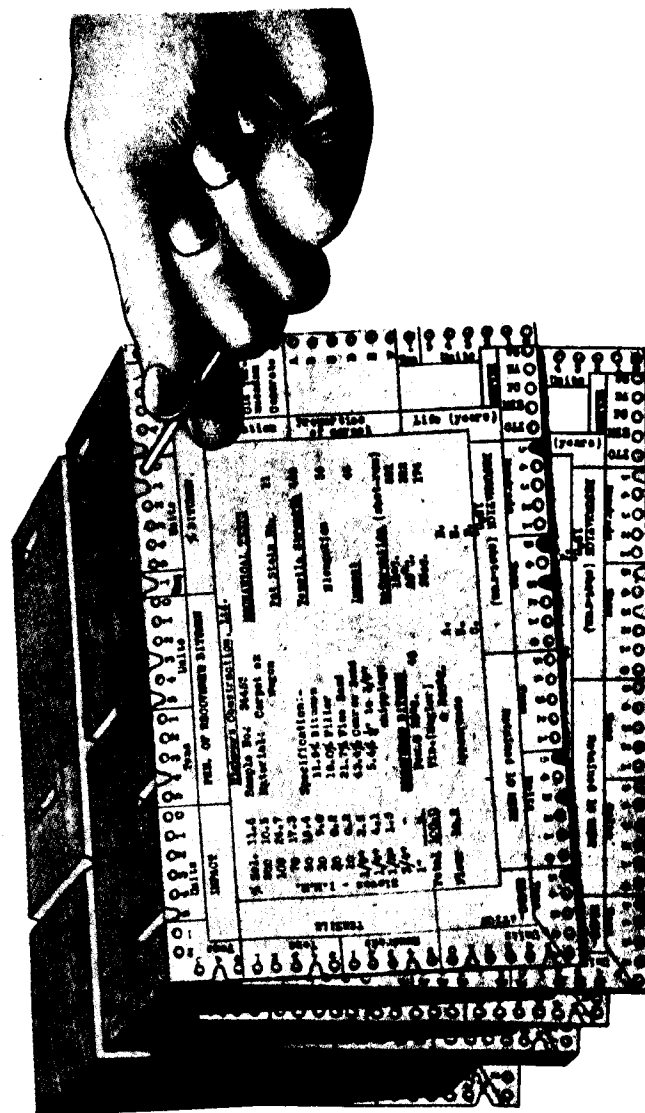


FIG. VIII. — Method of sorting Record Cards.

Mechanical Tests and the Modern Highway.

BY

D. C. BROOME, M.I.P.T., and A. R. THOMAS, M.I.P.T.

MECHANICAL tests may at the outset be defined for the purpose of this paper as tests in which a mechanical stress of any kind is applied to a sample of finished asphalt paving material. The mechanical stress may be one of tension, compression, shear or torsion ; or a complex stress combining two or three of these under varying conditions. In any case, however, it must be borne in mind that the tests are ones carried out on the finished material as laid, and not on the constituents. Further, the object of the tests is or should be as direct an evaluation as possible of the practical value of the material for the particular work to be carried out, taking into consideration the results not only of one test or of one type of test, but also the results of as many tests of different types as possible.

The mechanical damage or deformation suffered by road surfacing or foundation materials due to modern traffic is normally dependent upon four factors :—

- (1) Load.
- (2) Speed.
- (3) Constitution and type of tyre.
- (4) Surface contour.

Load.—To be entirely satisfactory the highway must be designed to withstand deformation by standing loads. Assuming a reasonably stable and smooth surfacing material, however, the effect of load only may be considered relatively small. This would appear to be particularly the case with modern high-speed traffic and in the absence of standing loads, owing to the fact that, given a plane surface, the instantaneous load on any single wheel rarely exceeds 700 lbs. to the square inch. This figure may be taken as an absolute maximum.

Speed.—Again assuming a plane wearing surface, the mechanical stresses transmitted to the asphalt theoretically decrease with increase of speed. To a point this may be assumed to happen in practice, but limits are set by imperfections in the contour of the road surface.

Increased speed means that direct loads are more transitory, and deformation due to vertical pressure alone is reduced, owing to the pronounced phenomena of plastic inertia. On the other hand, higher speeds involve increased liability to damage by correspondingly greater accelerating, decelerating and centrifugal forces transmitted to the road surface.

Constitution and Type of Tyre.—The modern tendency to increase the size of the tyres on all road vehicles has had the effect of greatly reducing vibrational and transient forces due to a combination of vehicle mass, speed, and irregularities in road contour. A load carried by the surface is also decreased by reason of the increased tyre contact area. By this means the static vertical pressure is frequently reduced to well under 100 lbs. per square inch.

Surface Contour.—Perfection of contour is undoubtedly the most important factor in the minimisation of unnecessarily severe mechanical stresses in the road surfacing and base materials..

If the surface is irregular or broken, the effect of vehicular load and speed is greatly increased. To the constant vertical load may be added severe impact loads, the energy of which is, of course, a function not only of the speed and vehicular load, but the amount by which the latter is deflected from travelling in a normally straight course.

As compared with the normally constant static load, the damage due to impact loads is still further increased by reason of the fact that the energy transmitted to, and dissipated in the road surface, is frequently of a vibrational nature. High vibrational amplitudes induced by such shock excitation have a very great disintegrating effect on the surface material, and frequently also on the base coat.

The effect of traffic conditions enumerated above may be divided into two categories :—

- (1) Plastic deformation, due to static loads, accelerating, decelerating, and centrifugal forces.
- (2) Disintegration due to impact loads or due to vibrational energy.

The former usually results in the phenomena normally referred to as "marking," "rutting," "waving" and "pushing," and the latter produces disintegration, either by direct fracture or the loosening of integral stone particles.

The tendency to deformation and/or disintegration resulting from the above-mentioned causes may, in the opinion of the authors, best be measured in the laboratory by tests of :—

- (1) Stability, or resistance to deformation. Including tensile strength, compression, and bending.
- (2) Hardness, or resistance to indentation.
- (3) Resistance to impact.
- (4) Resistance to transmission of vibration.
- (5) Resistance to attrition.

Of these the most important is probably stability, but unfortunately this is also probably the most difficult of adequate measurement in the laboratory in view of the complex nature of the stresses involved. It was at one time the practice amongst many workers to regard the tensile strength test as the simplest measure of stability, but it is extremely doubtful whether this test is of any real practical value, or whether it is possible to interpret the results of tensile strength tests in terms of the actual behaviour of the material on the road. This statement is put forward on the following grounds.

(a) It is very doubtful whether any of the stresses actually operating on a road may be regarded as actual tensile stresses.

(b) As normally carried out, the tensile strength test applied to finished asphalt mixtures is very nearly a ductility test of the bitumen present.

(c) Asphalt mixtures never behave as rigid solids, which rupture at a definite point under a definite tensile stress.

(d) Considerable elongation of the test piece always takes place, and the extent of this elongation together with the "tensile strength" figure finally obtained are dependent to a considerable extent upon the rate of pull. The test is, therefore, purely an arbitrary one.

The stability of an asphalt paving mixture appears rather to depend upon the ease with which one portion of the mixture may be made to flow over or past some other portion of the mixture, the force acting being a particular form of shearing stress leading to plastic flow, and not a tensile force. Even direct compression stresses appear to enter but little into the problem, as apart from the possible crushing of mineral aggregate particles under excessive load almost all modern asphalt mixtures which have been under traffic for a short time show no sign of compression under quite considerable loads. This applies only if the sides of the test piece are adequately supported, as if they are not the test then becomes a test of plastic flow and not a true compression test.

This may readily be illustrated by attempting to carry out compression tests by subjecting cubes or cylinders of suitable size to steadily increasing loads in a hydraulic or other press. Deformation commences under quite a small pressure, and the sample never yields a definite crushing figure, for as the pressure is increased a load is reached at which the sample will compress indefinitely without further increase of load. When tests of this nature are carried out flow cracks almost invariably appear at an early stage, particularly with poor quality mixtures, and some modification of this test is, therefore, necessary to obtain reliable figures for plastic flow, without the complication of cracked samples. The solution to this difficulty would appear to be the testing of a sample supported in a mould with apertures in the sides and/or base. The test then becomes a kind of extrusion test, and the stability of the mixture may be recorded in terms of the pressure necessary to commence plastic flow through the apertures of the mould. This may be regarded as reproducing fairly accurately the stresses acting in a road under many practical circumstances where a pressure from the top tends to displace the asphalt in spite of what may be described as a partial lateral support.

Another aspect of stability or resistance to deformation arises when a road surface is laid upon a foundation or sub-base which is liable to cracking or subsidence. Although these conditions do not obtain on the best jobs they are sufficiently common to merit some consideration, and for asphalt mixtures to be entirely satisfactory they should, as indicated above, be sufficiently stable to withstand displacement in the ordinary way, but should not be so rigid as not to conform to any slight subsidence that may take place in the foundation. If too great a rigidity is obtained and the foundation subsides the asphalt will be left as a bridge and will inevitably crack at the unsupported point. This particular property may readily be tested in the laboratory by loading the centre of a sample supported only at the edges under carefully controlled conditions.

Closely allied to the resistance of a mixture to deformation by plastic flow, is its resistance to actual indentation by standing loads. This form of failure is, under normal conditions, only liable to occur as a result of a load applied to the surface of the road through the medium of a stationary wheel, and whilst plastic flow may be induced along the plane of the wheel, the most serious stress will be a shearing force at the edges of the wheel. This, naturally, applies more particularly to sharp-edged wheels such as those with steel tyres (*e.g.*, coal carts, etc.), and the susceptibility of a given mixture to such indentation may readily be measured in the laboratory under almost exact practical conditions by applying a loaded wheel (or wheel sector) to the surface of a sample under carefully controlled conditions.

Apart from deformation, the modern highway is liable to failure through disintegration due to impact loads or to vibrational forces.

Impact loads may be applied with accuracy in the laboratory, but it is difficult to correlate results of impact tests with practical behaviour on the road as a result of the difficulty of determining:—

(a) The actual value, in foot-pounds, of the impact produced by the transit of high-speed traffic over a surface of irregular contour.

(b) The effect of an enormous number of small impacts succeeding one another as a result of more or less continuous traffic passing over a small irregularity in the road surface.

(c) The extent to which lateral support should be reckoned in a test of this nature.

Some indication of the relative resistivity of mixtures to impact shocks may, however, be obtained in the laboratory by the simple expedient of applying a series of blows of regularly increasing intensity to the surface of a sample until fracture occurs.

Vibrational forces are undoubtedly of considerable importance, being responsible not only for uncomfortable riding to the motorist, but also for considerable disintegrating effect on the road surface, and on the foundation and even an appreciable damaging effect upon adjacent buildings. Owing to the difficulty of measurement, this aspect of the highway problem has received little attention

in the past, but in the authors' opinion it is possible to obtain at least comparative data which is of practical value by means of some form of vibrograph employed either on the roadside to record vibration transmitted by a passing vehicle or in the laboratory to record the vibration transmitted through a sample by a mechanical trip hammer or other source of applied vibration of suitable frequency and intensity.

As may be gathered from the foregoing, an enormous amount of work was necessary in order to develop tests along the lines indicated above in such a way as to ensure as direct a relationship as possible between the results of the tests and the practical behaviour of the materials on the road. This work has been going on for some time, and the bulk of it is being carried out under the auspices of authoritative bodies. It must be made clear, however, that finality has by no means been reached, even on any one particular test. The present stage of the development of some of the foregoing tests in the laboratories of the author's Company may be illustrated by the following brief notes upon some work carried out within recent years.

Tensile Strength.—A limited amount of work has been carried out to investigate primarily the tensile strength of steam-rolled asphalt mixtures of the "topping" or "sand carpet" type using cement bricket moulds of 5 sq. cm. cross section. Typical results obtained are as follows:—

Unduly "rich" mixture	..	..	..	13.5 kg./sq. cm.
Good mixture	..	..	..	9.1 "
"Dry" mixture	..	..	..	5.4 "

Although this work is admittedly open to the criticism that the samples tested were unduly small, the above results and others which have been obtained clearly point to the test being of little value as a direct indication of the practical value of the material under examination. *E.g.*, a high tensile strength is by no means indicative of a satisfactory mixture.

Compression Load.—These tests have been carried out by a steady application of pressure to the surface of a 7 cm. cube in a Richle type of compound lever compression machine, the cubes being unsupported laterally. The same mixtures reported under Tensile Strength above yielded results as follows:—

Unduly "rich" mixture	..	..	..	32.4 kg./sq. cm.
Good mixture	..	..	..	26.4 "
"Dry" mixture	..	..	..	14.3 "

As noted earlier in this paper, tests carried out in this manner yield figures which represent the pressure necessary to produce steady plastic flow in the mixture, and are not "crushing strength" figures. Here again, however, it is evident that that problem is by no means a simple one, the mixture which from practical experience is regarded as unnecessarily rich showing a higher stability than the mixture normally regarded as good.

Further work, however, is tending to the view that for many mixtures a high stability as indicated by a test of this type generally indicates a satisfactory mixture.

Useful results have been obtained by bending tests on samples 18 ins. x 4 ins. x 4 ins. Such a sample is supported on ledges giving a total unsupported span of 16 ins. A steel wheel 18 ins. in diameter, having a tread of 3½ ins. and weighing 170 lbs. is then placed over the centre of the sample.

Subsequent bending of the test sample is measured with "inside" calipers between the bottom of the sample and a plane base plate. This depression is normally recorded as the rate of bending over a period of several hours.

TYPICAL RESULTS.

Asphalt Carpet (good sample)	2.38 mms.
" " (good sample)	8.73 "
" " (using unduly soft matrix)	30.96 "
" " (overheated sample)	0.23 "

Resistance to Indentation.—This test is carried out on samples 10 ins. square and prepared in substantial frames to the thickness to which the material is to be laid on the road. The sample and frame are immersed in a water bath at the test temperature and a wheel sector loaded by means of a lever system to a weight of 400 lbs. brought in contact with the surface of the sample. The load is applied for a period of 6 hours at any given temperature.

This test has been employed extensively and has been found to be of very considerable assistance in determining the practical value of mixtures for meeting specific traffic load conditions.

TYPICAL RESULTS.

	Dry Sand Carpet.	Medium Sand Carpet.	Rich Sand Carpet.	Stone Filled Carpet.	Single Coat Asphalt.	Stone Filled Mastic.
SERIES 1.						
Wheel Sector 6 ins. diameter by 2 ins.						
400 lbs. for 6 hrs. at 25°C. ..	7.5 mm.	5.5 mm.	6.5 mm.	3.0 mm.	3.0 mm.	Nil
400 lbs. further 6 hrs. at 35°C.	—	10.5 mm.	12.5 mm.	5.5 mm.	4.0 mm.	3.5 mm.
400 lbs. further 6 hrs. at 45°C.	—	—	—	10.0 mm.	5.5 mm.	5.0 mm.
SERIES 2.						
Wheel Sector 8 ins. diameter by 3 ins.						
400 lbs. for 6 hrs. at 25°C. ..	4.5 mm.	4.0 mm.	5.5 mm.	2.0 mm.	4.0 mm.	Nil
400 lbs. further 6 hrs. at 35°C.	6.5 mm.	7.0 mm.	8.5 mm.	3.0 mm.	4.5 mm.	2.5 mm.
400 lbs. further 6 hrs. at 45°C.	8.5 mm.	—	14.0 mm.	4.0 mm.	5.0 mm.	3.5 mm.
SERIES 3.						
Wheel Sector 20 ins. diameter by 2 ins.						
400 lbs. for 6 hrs. at 25°C. ..	2.5 mm.	2.5 mm.	2.5 mm.	1.5 mm.	3.5 mm.	—
400 lbs. further 6 hrs. at 35°C.	3.8 mm.	3.5 mm.	3.5 mm.	3.0 mm.	4.5 mm.	—
400 lbs. further 6 hrs. at 45°C.	5.0 mm.	5.0 mm.	6.0 mm.	4.0 mm.	5.5 mm.	—

Resistance to Impact.—A simplified form of Page impact machine has been employed in this connexion, a cylindrical steel weight having approximately an hemispherical head, and weighing 12 lbs., being allowed to fall from progressively increasing heights on to the surface of a cubical asphalt sample having 6 ins. sides. The height at which cracks first appear is noted, and also the height at which complete fracture takes place. The mean value of three tests on each material is recorded.

TYPICAL RESULTS.

	Height to Crack.	Height to Fracture.
Asphalt Carpet (good sample) ..	206 cms.	228 cms.
" " " " ..	218 "	241 "
" " (using unduly soft matrix)	170 "	183 "
" " (overheated sample) ..	148 "	173 "

Resistance to Transmission of Vibration.—This test is carried out with the Vibrograph marketed by the Cambridge Instrument Co., and is designed to measure the nature and extent of the vibration transmitted by various types of asphalt surface. Vibration may be produced by a standard lorry travelling over a standard obstacle on the road and the Vibrograph placed on the side of the road itself or on the kerb ; or alternatively, the vibration may be produced on a small sample in the laboratory by means of a trip hammer.

A typical example of the value of this instrument is the following result of tests carried out on a section of the Kingston By-Pass. The vibrograph was placed on the road surface 1 ft. from the kerb and a car of known weight driven at 20 m.p.h. along the road and over a wooden plank 1 in. in thickness.

	Peak Amplitude.
TEST 1.—Standard car driven at 20 m.p.h. over a pot hole in concrete road	4.90
TEST 2.—Car driven over similar pot hole that had been repaired with tarred macadam	3.40
TEST 3.—Car driven over good section of concrete ..	1.00
TEST 4.—Car driven over adjacent asphalt section ..	0.42

Considering the above tests as a whole, it is evident that further research is necessary before standardisation can be obtained.

There are, however, certain mechanical tests on which little experimental work has been done, but which would appear to merit intensive research. Amongst these may be mentioned :—

- (1) Stability.
- (2) Resistance to Impact.

Stability.—Under the heading of a stability test may be grouped all “resistance to deformation” tests. A universally satisfactory experimental method is difficult to design, but the Emmons & Anderton method shows very great promise. In this case use is made of a heavy-duty hydraulic press, which is employed to squeeze a carefully prepared brick of the test material through standardised large orifices in a steel mould containing the test sample. The aperture areas are great enough to allow the use of large-aggregate mixtures. It is found that for any given mixture a peak pressure exists at which the material commences to flow. This pressure cannot be exceeded, and remains constant during the extrusion by plastic flow of the test material.

By this means a true “stability” value is obtained, and the test is of extreme value owing to its general applicability to all types of asphalt mixture.

It is the considered opinion of the authors that the Emmons & Anderton test, or a modification thereof, is the most valuable mechanical test, from a practical standpoint, yet devised or suggested.

Impact Tests.—In view of the fact that the disruptive forces existing in the case of imperfect road contours are frequently of an “impact” nature, a test designed to impose impact loads on a test sample should be developed.

Some modified form of the Page impact machine will probably prove satisfactory.

The Anvil design of the standard Page machine is not entirely suitable, and a contactor hammer carrying a slightly resilient head, but delivering possibly heavier impact blows over a larger area would appear desirable.

The test sample dimensions should be as large as possible, and the sample itself carried on a non-resilient but fully supporting base.

In conclusion, it cannot be too strongly emphasised that comparatively little is known about the practical importance and experimental methods to be most advantageously employed in the mechanical testing of asphalt. Some experience has certainly been gained in connexion with the tests enumerated above, but the work undertaken in the laboratories of this Company has been more in the nature of initial spade-work, and an endeavour to produce experimental methods which give results directly applicable to practical conditions.



DISCUSSION ON PAPERS BY MESSRS. WILSON, BROOME AND THOMAS.

THE CHAIRMAN (PROF. G. T. MORGAN): I owe my position at this Conference to the fact that I am a Past President of the Society of Chemical Industry which, throughout the last 53 years of its existence, has done so much and with such success to link up chemical science with the various industrial activities of the community, and also that it is my privilege to be Director of Chemical Research in the Department of Scientific Industrial Research. That is a department which touches on the problems of road construction at every point. It is rather less than two years ago since the department in its infinite wisdom decreed that research on road tar should be carried out at the laboratory over which I preside on behalf of the British Road Tar Association. Research has been going on at Teddington on those lines, with the aid of a small staff. We have here to-day Dr. Lee, who is physicist of the group, and Dr. Mitchell, the chemist.

There will be no need for me to go at any length into the technical side of the matter. But I do think that with the short period at their disposal they have done remarkably well in this research on road tar, and on the physical side they have met with great success in the evaluation of the viscosity of tar of all kinds of consistency. They have also studied the interfacial relations between the tar and the various substances with which it comes into contact in road construction.

On the chemical side one or two interesting points have emerged. I may say that I am not entirely a student of chemistry, for I have not only looked at the chemical side but at the other side, because at the outset we find that the quality of this unsavoury road tar is more like beer: that is to say, all lovers of beer know there is no bad beer, only some is better than others. So in the same way in different districts there is no bad road tar, only some are different from others; that is something that we soon learnt in the research on road tar.

I have realised all along the significance of the connection between chemistry and road tar. After all, this morning chemistry was hardly mentioned, but I think that in the long run chemistry will be found industrially important in the study of road

materials. Nevertheless, its value will be indirect rather than direct. For example, there is the work at Teddington for the last eight years on the study of the chemical constituents of low temperature tars, and also other tars, which may, in the long run, be found to be of some use in the application of tar for roads. That is a research which does not get into the evening papers; it has not been in the illustrated weekly papers yet. You can hardly run it as a stunt, but nevertheless it does represent real scientific progress. I have always maintained that in regard to tar, as indeed in the case of any other materials of a chemical nature being employed industrially, those who know most about the chemical constituents of materials like that are most likely to make the best use of them.

MR. D. M. WILSON introducing his Paper, said: During this morning's session the papers were concerned chiefly with a survey of the general problem of the mechanical testing of bituminous materials. This afternoon the papers deal in more detail with the individual tests that have been proposed and used.

The first point I wish to make clear is that, like another commodity which I should not dream of mentioning here, there is no such thing as bad asphalt. Some varieties certainly are not so good as others, and the results of mechanical testing can show the differences. I listened to the discussion this morning and apparently I appear to have approached the problem we are discussing from rather a different point of view from the other speakers. I have always studied the problem from the road end first; the behaviour of different mixtures has been studied on the road, and samples have afterwards been examined in the laboratory to find out whether any differentiation could be made, by means of tests, between materials which have behaved differently on the road. Being a member of a firm of contractors with many millions of square yards of every type of asphalt under maintenance I have had to get results quickly. I have not had the opportunity of going into fundamental details in the way that a Government department could and should.

I have not been too much concerned up to the present as to exactly what property I was measuring as long as the final result expressed in simple figures the difference between satisfactory and less satisfactory materials. The work all the way through has been checked and rechecked against actual road samples, the whole history of which was known and whose behaviour under actual traffic conditions could be observed.

Many difficulties had to be overcome. At an early stage the results obtained were so difficult to understand that it was decided to postpone all work on mechanical testing until a method of recovering the bitumen from a sample in the condition in which it actually existed in the road had been devised. After two years' continuous work a method was found which has now been in daily use for the last eight years. Surprising changes in the penetration of the bitumen can take place during the course of manufacture, and it is my opinion that the results of mechanical testing cannot possibly be properly understood unless the penetration of the bitumen in the finished material is known.

As regards the preparation of test pieces, I know there are many who will feel that the load of 12,000 lbs. per square inch, that I recommend, is unduly high. It is, however, a load that I have found to be necessary and unless our test-pieces are compressed to this degree the results do not properly tie-in with those shown on the road by the same material under traffic. It is admitted that a certain amount of crushing of the aggregate takes place, but I do not think this is a serious matter as similar crushing takes place on the road under traffic. Dr. Neumann tells us in his Paper that he only applies sufficient force to correspond roughly to that applied by the usual type of road roller, but although that may be enough with some materials, from my own experience it would not be sufficient for asphalt mixtures.

The Hardness No. test for mastic is especially important from the point of view of maintaining the roughened surface, which is essential in these days of fast motor traffic. The test enables one to ensure that the mastic is not too soft for the chippings

would then be driven into the surface and it would lose its roughness. On the other hand, if the mastic were too hard it would be difficult to make certain that the chippings would be properly held in the first place. The test has now been adopted by many of the Contractors and other workers in this country and is proving to be most useful. It is useful also as a guide in ascertaining whether asphalt mastics contain asphalt rock or whether the asphalt rock has been contaminated by limestone. Generally speaking, a good asphalt rock can carry a very much higher percentage of bitumen for a given Hardness No. than a synthetic mixture containing limestone. This is probably the reason why asphalt rock mastics are more successful under heavy traffic than limestone mixtures.

Dr. Neumann describes a resistance to impression test on the same lines but employing a smaller load. The test takes five hours but I rather doubt whether it gives any information which is not given by the Hardness No. test in one minute.

The Hardness No. test has not been successfully applied to steam-rolled asphalt but the Deformation test is useful with this material. Although this test was first published two years ago people seem to be rather shy of adopting it. It is extremely useful in showing the stability of a mastic or steam-rolled mixture or even compressed asphalt over a wide range of temperature. The results for each temperature are expressed in a single figure. I think that it is always advisable when developing tests for the guidance of the "practical" man to make certain that the result can be expressed in a simple manner, preferably by a single number.

Mr. Broome and Mr. Thomas mention compression tests and point out how flow cracks appear at an early stage. I think the solution of this difficulty is to stop the test at a still earlier stage and measure the extent of the deformation before cracking occurs rather than to turn to some form of extrusion test.

The impact test when performed in the manner described in my Paper does bring out a marked difference between samples which have behaved differently. It is essential that the slab should be supported by

the rigid base of the machine and not allowed to bounce.

The tensile test gives interesting results although here again it does not necessarily reproduce conditions obtaining on the road. The elongation is probably a better guide to the properties of the material than the actual tensile strength. The conditions for the test have to be carefully controlled, and it is essential to apply the load at the same rate in every case.

Mr. Broome and Mr. Thomas rather throw doubt on the value of the tensile test. The test, like all tests on bituminous materials, is admittedly an arbitrary one. It is not difficult, however, to standardise the rate of loading, and my reply to their objections is that the test does actually give information that is useful; it definitely does bring out differences between samples that would not be disclosed by any other test so far devised. I entirely agree that a high tensile strength is not indicative of a satisfactory mixture and in practically all the tests that have been devised for bituminous materials high values are not generally shown by the best materials. The extremely hard, rigid mixtures do not give the best service and it is essential to use additional bitumen in order to impart that measure of plasticity and water-proofness typical of the asphalts that have given long service.

Difficult as it is to determine the mechanical properties of asphalt, once this has been done there still remains the difficult problem of interpreting the results. Here again difficulties were found in understanding what was happening with steam-rolled materials, and we had to mark time on our main programme until we were able to develop a method of determining voids by using bitumen itself as the void filling medium. This proved to be a very interesting piece of work, and for the first time it was possible to design specifications for various conditions with the certainty that all the various properties of a mixture were taken into consideration. In the cylinder measurement curves shown in Fig. 5 it was found that large scale mixtures manufactured in the plants when measured in the cylinder mould gave points which came correctly on the curve drawn up in the first place from a study of laboratory mixtures. I cannot go into more detail now, but in passing I

would like to point out that in Fig. 6 the same percentage by weight of each filler was used, as fillers are always *weighed* on a plant. Actually if the amount of Portland Cement was increased so that an equal proportion by volume of each filler was used the minimum point would have been shifted only one square down and one square to the left.

Finally, it was necessary to find some way of recording the information collected. The punched hole system was copied from the accountants and has proved to be most useful. It is extremely simple to operate and I have here a pack of cards in five different colours. They are all jumbled up together but by means of a needle it is possible rapidly to sort out the red cards so that they are all together, and similarly the green and the blue. In the same way it is possible from a stack of several hundred cards representing the properties of that number of samples to sort out all those that have behaved in a certain manner. They can then be re-sorted to see whether the poor samples have any feature in common. In this way much useful knowledge has been obtained as to the properties of an asphalt mixture which lead to success, and, on the other hand, to properties which may possibly lead to comparative failure.

In conclusion I would say that the Laboratories on their own cannot do much without help from the surveyors. I have always found surveyors ready and willing to allow samples to be taken and many I know are always prepared to find room for a trial section in order to test out some new type of material. I think it is true to say that in every industry the practical man is taking an ever increasing interest in the results of research work, and he is now beginning to demand a full analysis of the materials he employs, and he is looking to the chemist to tell him some of the properties of the finished material also.

As a chemist I may be allowed to say to the surveyors that we are conscious that we have not been able to assist to as great an extent in the past as we would have wished. It is only within recent years that chemists have come into the industry, and so far they have generally been looked upon as a bit of a nuisance. They were limited in scope

as long as they could only analyse the materials that were to be used. They have been making the most strenuous efforts, however, to increase the range of their knowledge, and the papers we have had presented to-day show how far they have gone in their efforts to study the finished material as a whole. All the problems have not been solved but we can say that we have now something very much more definite to offer the surveyor, and we can at any rate definitely express some of the properties of asphalt by the results of mechanical tests in a way that the engineer is in a position to appreciate.

Mr. D. C. BROOME, introducing his Paper, said: The Paper which Mr. Thomas and I submit to the Congress has for its prime object the stressing of the necessity for considering first and foremost the various factors which in practice affect the satisfactoriness or failure of a road. All the effects of traffic conditions, which are dealt with at some length in the Paper, may be divided into two categories:—

- (1) Plastic deformation, due to static loads, accelerating and decelerating forces.
- (2) Disintegration due to impact loads or to vibrational energy.

The former usually results in the phenomena normally referred to as "marking," "rutting," "waving" and "pushing," and the latter produces disintegration, whether of direct fixture, or by the loosening of integral particles.

All mechanical tests should, therefore, be designed with the especial object of measuring these tendencies to deformation and/or disintegration. The properties of the material employed in the scientific sense, are of subsidiary importance. It does not matter whether the tensile strength of a particular material is high or low so long as it is satisfactory in practice. This is a typical example of the type of test that is apt to yield a totally incorrect view of the excellence or otherwise of a particular mixture. As explained in our Paper, it is very doubtful indeed whether any of the stresses actually operating on a road may be regarded as true tensile stresses. Further, as normally carried out, the tensile strength test applied to finished bituminous paving materials is very nearly a ductility test of the bitumen

present. The important point in this, as in all other aspects of the mechanical test problem, is that the properties of the material are of minor importance—it is the properties of the road which we want to measure.

Amongst the properties of the road itself which are discussed in our Paper, the most important are probably:—

- (1) The tendency to "push," "wave," or "track," which tendency may best be measured of a "stability" test such as that proposed by Emmons & Anderton, which measures the ease with which a specimen of the material concerned is extruded from a steel mould with large apertures in two sides and the base.
- (2) The tendency to "mark" under standing loads, which may best be estimated by direct measurement of the depth of indentation produced by a loaded wheel or wheel sector.
- (3) The tendency to disintegration, which may best be measured by impact, noting the force of the blow necessary to fracture the road mixture.

Considering some of the points raised by the Author of the other paper under consideration this afternoon, I should like to support the importance of the proper preparation of laboratory samples referred to by Major Wilson. It is, I think, essential that some standardised methods should be adopted as soon as sufficient work can be done to determine the best method for such standardisation. Major Wilson's proposal to use a load of 12,000 lbs. per square inch is extremely interesting, but the difficulty here is indicated by Major Wilson himself, when he states that "it is realised that on the road, compaction is not affected by direct compression only, but that it is assisted by the kneading action of traffic." Quite apart from any other consideration, there are very few laboratories in this country in which it is possible to attain this pressure on other than very small samples. This is a matter which should receive careful consideration, as it would seem to me surprising that such high pressures are necessary unless the sample is compressed at an unduly low temperature.

The stability or "deformation" test suggested by Major Wilson is useful in that it is applicable to small samples tested in a relatively small press. Possibly the solution

is along the line suggested this morning in Messrs. Adams and Murdoch's paper, where they suggest the use of an apparatus giving kneading action and not direct pressure. This very factor of convenience is, however, an indication of the limitations of Major Wilson's test in that for tests on a two inch cylinder only materials with fine mineral aggregate may be tested satisfactorily. Further in this test pressure is applied to a sample unsupported laterally. Now in practice on the road there is always at least partial lateral support, and in consequence of this the larger, and supported, test specimen recommended by Emmons and Anderton is preferable. It is interesting to note that the Ministry of Transport in their Report for 1931, express the view that this latter test most closely approaches the conditions of road surface distinction as a result of deformation under the action of traffic.

Finally, I have been considerably impressed by the fact that of all the workers who have submitted papers to this Congress, only one makes reference to what is, perhaps, one of the most common disadvantages of improperly designed bituminous highways to-day—slipperiness. The Road Research Laboratory at Harmondsworth carry out tests on the road itself by means of a specially designed sidecar outfit, but so far as I know, this is the only instrument of its kind in existence, and no reference at all is made in any of the papers to apparatus for measuring slip in the laboratory. This is admittedly an extremely difficult matter but in closing I should like to suggest that this is such a vital matter as to warrant considerable attention upon the part of this Congress.

Mr. F. HOLDEN (*Borough Engineer of Fulham*): The question of mechanical tests is of particular interest to road engineers. These tests enable results to be obtained at a much earlier date than can be obtained on the actual roads. The method of testing the instruments used and, to some extent, the conclusions of all the Authors, seem to be more or less the same. They all seem to have the same difficulty in dealing with bitumen: that is to say, owing to its unstable properties, the difficulty of applying tests to conform with road conditions. Speaking as a layman, they do not seem to be quite what one could reconcile with the

actual conditions on roads. Most of the Authors have more or less admitted that, and there are practical difficulties in the way.

Take, for instance, the stability tests, in which the bitumen is placed in a container and results are obtained by the amount of lateral spread. We have no such conditions in a road, as asphalt when it is put down in a road is in a stable condition and not able to spread itself in the manner of the experiment. It does seem to me that that test of itself does not offer a serious solution of the actual behaviour on the road. This remark also applies to several of the other tests. I feel that experiments should be pursued more particularly with samples that have been in use on the roads. Samples produced in the laboratories, whatever care may have been taken, can only approximately compare to material under actual road conditions. There may be a wide surface expansion taking place, but nothing of that kind can be produced in a small sample.

It has been stated that asphalt should not be too rigid to allow for movements in the sub-surface. In my Borough we use clinker asphalt, which is practically as rigid as concrete when seasoned. I may say that clinker aggregates are much superior, in my opinion, to sand aggregates. If you take samples out of the road after a few years you will find a certain amount of elasticity with the sand, but not with the clinker aggregates. I do not think it is necessary or right that a carpeting should follow any weakness in the sub-structure. If the foundations fail in any way that is a matter which cannot be counteracted by the asphalt surfacing. No matter what type of asphalt carpeting you adopt if your sub-structure is not sound you will not obtain satisfactory results.

There is a very wide field for mechanical testing and, I very much appreciate the interest that has been taken in this by your Society. I am sure that all road engineers will welcome your efforts, and if we can help in any way by putting down test sections, I am sure my colleagues, like myself, would be prepared to do so.

When satisfactory results are available from mechanical tests it will be a great help to road engineers. For instance, take

wood paving. I have tried for years to get a suitable bituminous jointing material for wood paving but without much success. All of you have seen, after storms, disturbed wood surfaces on various roads in London, and it is mainly due to the jointing material. It is either too hard in summer or too brittle in winter; or you get the creosote exuding from the blocks and mixing with the jointing material with disastrous results. The chemist might help us here, and save the ratepayers many thousands of pounds.

I also use bituminous dressings with a great deal of reluctance, as they always absorb the grit after a period of a month or two, and the result is a surface which, in my opinion, is quite unsuitable for traffic. The chemist can help us to evolve a dressing which will leave a surface that is suitable for traffic.

DR. LOMAN (*Holland*): I do not want to criticise any of the papers in particular, but I suppose you would be interested to hear of some of the laboratory experiments that we are doing in Holland, and also the experience we have had on the roads themselves.

I would like to stress one point: it was also dealt with by Professor Clements this morning, namely, that I think that the properties of the components are of supreme value as leading to an exact knowledge of what is happening in these mechanical tests. I think that the work which must be done in preparing our knowledge for the deeper insight into these problems is still very great. Firstly, the properties of asphalt are not yet absolutely known. I think there is a difference between Harmonds-worth's way of treating these asphalt mixtures and ours. We agree that it is of great importance to test road mixtures, but we think that the constituents should be individually examined in the first place; first testing the binder and then testing the action of binder on fillers, and in this way build up all the constituents of the total paving mixture.

Now some points seem to me to be of great value before we can test the total mixture; for instance, the temperature range of the bitumen or of the tar which is used. The properties of the bitumen are greatly influenced by the properties of the

oily medium of the bitumen which is used, and also by the properties which are caused by the oily medium. In this connection I would like to draw your attention to the difference between blown bitumens and distilled bitumens. I think that in future blown bitumens will be used more than the straight distilled products, because experience has shown that very superior blown bitumens can be manufactured.

One of the other points which is of great value in connection with the properties of the road mixtures is the spreading of the bitumen and the absorption of the bitumen on the mineral aggregate. This is also greatly influenced by the properties of the oily medium of the asphalt, and it is certain that synthetic asphalts could be manufactured in which special attention could be given to those qualities. Then we have the question of the voids. Our own material is controlled by our road laboratory in the Hague. All the road samples are sent to this laboratory and the percentage of each constituent is measured, and also the percentage voids. This void percentage proves of great value in trying to find out what are the causes of rupture, breaking and the shelving of the roads. Last year I had some typical experiences of the influence of the foundation on the behaviour of the road. In Holland especially, the sub-soil in some places is very bad: there are weak marshy sub-soils on which very heavy traffic must take place, and we have had some very bad experiences. We have seen that weakness develops; for instance, topeka was not able to stand the same influence of sinking in some places as were our coarse asphalted mixtures.

We also have some experience as to the foundation proper. In Holland in about 1926, we began to build asphalt carpeted roads, and extensive use was made of crushed brick. You know we have a very important brick manufacture in Holland. The crushed brick was generally used in filling in the interstices of the top layer of the foundation before the concrete was put on, and afterwards, about a year or two after laying the carpet, cracks began to form, and have now grown in such a way that about 50 per cent. of those topeka roads have cracked very badly. So we had to take measures to put these asphalt carpets on them. As I said,

the coarse mineral aggregates have cracked much less, about 5 to 10 per cent. as compared with the 50 per cent. of the topeka roads.

We used a mixture of granulated slag and Portland Cement as a covering on the foundation, because we thought it would be able to bind the stone, the top layer of the foundation, better than the loam or clay that we used in former years. But it proved to be very poor, and consequently we abandoned this method, because the expansion and contraction of the mixture of the slag with the cement was so great that the covering was cracked by bulging in some places. The foundation covering lifted, and it broke in the same way as concrete roads without joints sometimes break in summer at high temperatures, and in wet weather.

Now we are going on with this type of work, and I think the first thing we are going to do in mechanical testing is not the testing of the complete road material but only of the binders and the fillers combined, because the binder as such is of more importance than the sand and the aggregate, according to our present knowledge.

MR. D. G. MURDOCH (*Beckton Laboratory, Gas, Light & Coke Co.*): From an examination of the papers presented to the Conference in which definite correlation of certain tests or groups of tests with actual road performance is claimed, it would appear that at least four laboratory tests are required to give the necessary information.

1. Some form of stability test. (Either extrusion or deformation by compression of an unsupported specimen.)
2. Hardness test. (Indentation produced by a loaded rod or wheel sector.)
3. Impact test.
4. Tensile test.

It is clear that different workers are placing varying degrees of reliance on such tests and also that different methods of carrying them out have been adopted. The difference in methods may be either by reason of the different classes of material under investigation, or by reason of a more direct interpretation of results obtained by one particular method.

In the paper presented this morning by Mr. Adam we have stressed the desirability of studying the technique of all the proposed tests—especially the effect of varying the

rate of loading or deformation. Satisfactory classification of materials into good, medium or bad, may well depend upon the most suitable choice of these conditions.

The value of tests which are applicable to a wide range of materials is obvious, and in this connection the Emmons and Anderton stability test (first described in 1925), and the wheel sector hardness test described in the Paper by Messrs. Broome and Thomas, would appear to call for a thorough investigation. It is to be noted that the claims made for the former test do not appear to have been substantiated; Professor Neumann in his Paper does not consider the test particularly suitable, and its weakness and limitations should be brought to light as soon as possible to avoid waste of time.

Mr. Hubbard deals in his Paper with the stability test devised by himself and Mr. Field which is now well known and in use for the control of both plant operation and actual road construction. He also refers to a test for stability developed in the Chicago Paving Laboratory; this is presumably the shear test described in 1929 by H. W. Skidmore. It is claimed (using Skidmore's own words) to "establish a minimum stability for mixtures under any given traffic condition, and to set a maximum beyond which there is no need to go." The test can be modified to deal with mixtures containing large aggregate, and from information received it is proving of considerable practical value.

Major Wilson considers that a laboratory compacted sample should be allowed to age for seven days. While the results of some of our experiments at Beckton suggested that a period of stabilisation would be required for some materials, it was hoped that ageing for 48 hours would suffice to give reproducible results capable of practical interpretation.

Tests within an even shorter period than this will obviously be necessary if control of plant output is desired, and there is evidence that keeping the specimen overnight and then bringing it to the desired temperature over a period of a few hours may be satisfactory.

Major Wilson's observation that the interpretation of the results of laboratory mechanical tests can be satisfactory only

with the aid of the knowledge of the volume composition of the mixture is most important; Mr. Hubbard makes a similar point.

In their discussion of the Tensile test Messrs. Broome and Thomas question its practical value. Their statement that a high tensile strength is by no means indicative of a satisfactory mixture may be generally agreed, but many other workers consider that this, taken in conjunction with the corresponding elongation, is definitely informative. There are certain difficulties with the test that are not quite apparent. I think Mr. Broome mentioned that. Their views on the compression test are in rather sharp contrast with those of Professor Neumann, who claims that the straight-forward test on an unsupported specimen under rigidly controlled conditions is definitely capable of correlation with practice. Professor Neumann considers the action of a plunger in his Resistance to Impression Test is similar to that of a small iron-shod cast wheel; this is, in my opinion, rather doubtful.

As an indication of the present lack of uniformity of technique in the various laboratories engaged on this work, one may instance the fact that in the papers presented to this Conference six different shapes and sizes of tensile specimens have been described or referred to.

DR. LONSDALE (*Road Research Laboratory*): I would like to make a small correction to the paper by Professor Neumann. Referring to the Emmons and Anderton Stability Test, he quotes a remark in the *Experimental Work on Roads in 1931*, as follows: "In England the view is taken that of the mechanical methods for testing paving mixtures containing tar and bitumen, this as a service test most closely approaches the conditions of road surface destruction as the result of deformation under the action of traffic." Now in the translation of the remarks into German and then back into English there has appeared a certain nuance in expression which has destroyed the original wording of the remarks. The actual original remark was that this test simulates more closely than most, one type of road failure.

Our intention was not to compare this test with other specific stability tests but

to compare it with tests in general. I may say that we had not considered at the time any test other than those put forward at Harmondsworth. I am sorry if our remarks were rather misleading.

Coming to the papers to-day, I cannot say anything in criticism because I agree very much with practically all the remarks that were made. The only thing perhaps that I can do is to quote from some of our own laboratory records a few figures in amplification of the remarks that were made by the speakers. Major Wilson and also Mr. Adam and Mr. Murdoch made some remarks about the necessity of temperature control. I think that point ought to be stressed. We made some experiments in the Road Research Laboratory on the compression of rock asphalt. We took cylinders of three inches diameter and three inches high, and made them in a certain way; we found a compressive strength of 2,280 lbs. per sq. in. at 0°C., and 300 lbs. per sq. in. only at 45°C. The decrease in strength as the temperature went up was fairly uniform in that range: as to the results in the ordinary working laboratory range we found that at 20°C. the material had a compressive strength of 1,250 lbs. per sq. in.: at 25°C. a compressive strength of 940 lbs. and at 30°C. a compressive strength of 786 lbs. per sq. in.

If you consider these figures you will see that the drop in strength with the rise in temperature is very sharp even in the ordinary laboratory range: that is to say, you must not have merely a haphazard control, you must have a really accurate measure of control.

The ordinary testing machines we are using now for testing bituminous materials are similar to those used for steel, where there are not very good facilities for temperature control. I think that these and other records show that where you have not got these facilities they must be provided.

The Authors refer to the necessity for controlling the rate of loading. I may quote a few figures in support of their contention. We tested some hot asphalt at 25°C. Again we used 3 inch cylinders with compression. We found that at 0.06 inches per minute the material had a compressive strength of 426 lbs. per sq. in., and at 0.13

inches per minute—twice as fast—it had a compressive strength of 508 lbs. per sq. in. That was 426 as against 508, which was quite a considerable decrease. Now if you put these cylinders at a steady load and leave them at the same temperature for some days you find that they fail ultimately for a load as little as 80 lbs. per sq. in. That is as compared with 426 and 508. It gives you an indication of the extraordinary dependence upon time that these materials have. So that in testing such materials it is necessary to consider very carefully the rate at which you apply the strain.

Major Wilson made some remarks about the preparation of test pieces, and in particular about the loading pressures that are required. I should like to associate myself very much with those remarks. Our own experience bears them out almost exactly. We have found that it is necessary to use pressures of as much as 12,000 lbs. to the sq. in. to obtain compactions of laboratory test pieces, which came to the same as those of similar materials taken from the road. Of course, that very seriously limits the size of the specimen.

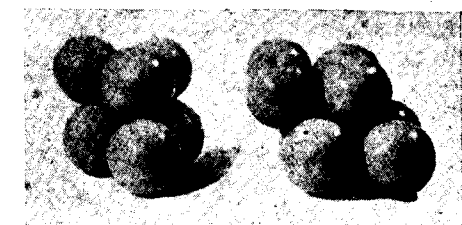
In support of the remarks of Dr. Stradling this morning, it is interesting to note that we find that it is not possible in some cases by direct pressure alone to reach the compaction which is ultimately obtained on the road. The particular material in question with which we failed in this way is rock asphalt. In rock asphalt I have never got a density greater than 2.19, and that is on using pressures up to 20,000 lbs. per sq. in. On the road I have obtained 2.27 density for the top layer of carpet. I have two little models here which will possibly show what has happened (lent by the Royal Institution). Supposing you imagine your rock asphalt consists of equal spheres. These spheres may arrange themselves in one of two ways: they range themselves in a form which is hexagonal or in a form which is cubic. When you place the material in a mould you get some of the aggregates of particles arranged as in Fig. 1 A, or they may, of course, arrange themselves as in 2 A. By direct pressure it is not possible, as you see from the model, to produce further compaction; now if you produce not only pressure but rolling you press them and roll them, and

then, of course, you get the state as in 1 B, which is the most compacted state. In the same way you get 2 B with the hexagonal packing. That, I think, is what is happening in the case of rock asphalt.



1 A

2 A



1 B

2 B

Of course, this is a very rough idea, but it is I think very largely what is happening; and that explains very roughly why with this material you do not get in the laboratory the ultimate compaction that is produced on the road.

Lastly, I should like to associate myself with the remarks of Mr. Broome and Mr. Thomas on the high values that you get sometimes in testing. We have taken our testing technique very largely from experience in steel and non ferrous metals, where you learn that the higher the values you get the more satisfied you are. Now that does not hold with bituminous materials. I think it is fairly safe to say that in most tests you can get too high values as well as too low values. What you want for a specific material is that the value should lie between certain limits, and it is part of our work—much of it still remains to be done—to find out exactly where those limits lie.

DR. LEE: There is one point that I should like to stress, and that is the necessity of interpreting the results of mechanical tests in terms of the physical properties of the

constituents of the samples. It does seem to me that before you can get a correlation between the results of mechanical tests and road behaviour you must know what is happening in your mechanical tests; and the only way you can know that is to resolve your results into the properties of your constituents. There is the underlying assumption, which is probably correct, that these bituminous materials are plastics. I presume that sufficient information has been obtained by the people investigating these materials to interpret their results in the fundamental characteristics of plastic materials. The binder has certain predominant physical properties, which I take it will be viscosity, adhesion and cohesion, and it should be possible to interpret the results of mechanical tests in terms of these properties, together with any specific interaction of the materials with the aggregates.

My work has been confined essentially to the study of the physical properties of viscosity and adhesion, and as Professor Morgan has already stated, we have devised an apparatus which will measure the viscosity of tars and bitumens over practically any range of viscosity.

As an example of the necessity for a correct interpretation of the results of the mechanical tests I should like to quote from the Papers that we have before us this afternoon. I am not quoting this as a criticism of the Papers, but simply as showing the necessity of interpretation. The first is by Mr. Wilson; he says: "Another extremely important property of an asphalt mixture is the penetration of the bitumen which can be recovered from the sample, and it is essential that this should be known before attempts are made to study the results of mechanical testing. In the case of steam-rolled asphalt if the penetration of the recovered bitumen is lower than 20 at 25°C., the mixture will not be satisfactory whatever its mechanical properties."

Now I take that as a very serious criticism of mechanical tests as now devised. It means that whatever results your mechanical tests give, unless you have previously considered the value of the physical properties of one of your constituents these tests by themselves mean nothing at all.

As another illustration may I quote from the Paper by Messrs. Broome and Thomas, who say: "Here again, however, it is evident that the problem is by no means a simple one, the mixture which from practical experience is regarded as unnecessarily rich showing a higher stability than the mixture normally regarded as good."

That is to say, you have really no criterion, or no fundamental criterion, for your satisfactory mixture.

A third illustration is very well shown in a valuable paper we had this morning by Messrs Adam and Murdoch. Curves were given for the tensile and compression strengths for various proportions of constituents, and it was shown that over the range investigated the same value was obtained for two different combinations of the constituents. Now the point arises, why do we have those two values? Obviously from a testing point of view such a result is ambiguous and if we cannot explain it in fundamental units it seems to me our success in correlating our results with road behaviour is going to be more by luck than anything else. I would suggest that much more work is necessary on the lines of this Paper in order to investigate the mechanical tests themselves.

DR. MITCHELL: In the past I have been in close touch with two researches on mechanical testing, and in each case it has been necessary to examine each factor in turn, keeping all the rest constant. Now the outcome of both of those researches was this: that no one test-piece in a mechanical test was of very much value. In the papers presented to-day the gentlemen who have quoted values have not said how many specimens they have tested, or the limits of accuracy obtained, and I should like to urge that in reports and published papers the numbers of specimens and the variations should be stated, so that the probable error of the mean value can be calculated.

Another point that occurred to me as important was the density of the specimen. This has already been stressed in the useful analysis given by Mr. Adam and Mr. Murdoch. I would like to know whether the block density is taken, and whether any specimens which lie outside narrow limits are rejected. I think this is one method by which large

variations could be diminished. I have prepared three blocks from a slate dust filler and tar, and found that the voids in the aggregate while the pressure was still on was something in the order of 30 ± 1 per cent. On removal of the pressure the voids increased to 34 ± 2 . I would like to emphasise that greater attention to the block density during and after compression might be of some value in cutting out variations in mechanical tests.

Reference has been made to the action of water on bituminous mixtures. Water tends to displace tar or bitumen from an aggregate, but as mentioned in one of the papers the addition of a solvent such as benzene or toluene to bitumen entirely changes the properties of the binder, and the adhesion tension is probably altered accordingly.

Recently a paper has appeared on the action of a soap solution on aggregate-tar mixtures. There is no doubt that soap has a remarkable action in removing tar from aggregate—in fact in our laboratory we now use soap solution to clean glass apparatus—but some care has got to be taken in interpreting the results since a new factor is introduced which may or may not run parallel to the action of water.

One last point I would like to emphasise in regard to mechanical testing: that is the necessity for the grading of the aggregate less than 200 mesh. The term "filler" is often used in reports but as this part probably has more effect on the physical properties of the binder than the bigger aggregate it would be extremely useful if an analysis of that part of the mixture could be given.

The Chairman has referred to work on the action of light on tar. It has been found that the surface of tar is affected by the light, and a yellow substance insoluble in benzene is formed the precursor of which is contained in the petroleum soluble portion of tar. This action, however, is probably confined to a very thin outside layer of the tar, and it is unlikely to affect greatly any of the tests that have been mentioned to-day.

MR. ATTWOOLL (*Chief Chemist, Limmer & Trinidad Lake Asphalt Co.*): In considering this matter of mechanical tests I think the first thing one has to consider is what mechanical tests we are going to

do. Are we going to set up a series of arbitrary standards to which we can work, or are we going to endeavour to imitate conditions on the road? In this connection I would like to refer to a remark which Major Wilson made when he stated that in his opinion "mechanical tests do not give actual reproduction of road conditions under traffic, but the results can be expressed in simple figures which make it possible to distinguish materials which are satisfactory or otherwise."

Upon that assumption it should not be very difficult for us to settle this matter. But on the other hand I do not think that we should drag in a lot of outside issues; and while I should like to add my appreciation to the papers that have been given to-day, I think there has been some tendency to deal with matters that are not really associated with mechanical tests, which I gather we are here to consider. I would refer to such questions as that of voids and so forth. There are various opinions on the importance of void determinations in connection with asphalt, but how far we are right or wrong in paying much attention to those, I do not propose to discuss this afternoon. I think, however, that it is a matter which could come directly under the consideration of any panel or committee of the industry which is considering the matter of mechanical tests.

Then Major Turner made reference to the qualities which he as an engineer would look for in a satisfactory road. Among other things he mentioned the question of having a good non-slip surface. This is a feature I am very surprised to find: that all the gentlemen who have given papers have completely ignored. I admit that it is a knotty problem, but it is one of the most important problems with which the industry is faced to-day. We certainly have some information given us by the Harmondsworth station with the particular motor-cycle combination which they employ. Surely with the brains which are at our disposal from all branches of the industry to-day we can produce some means of measuring the resistance to slip of various types of paving, and that should be quite an important point in evaluating the efficiency of any particular specification.

Dr. Lee had made reference to Major Wilson's idea of the importance of the

penetration of the extracted bitumen with regard to mechanical tests, and he, Dr. Lee, said that such a theory constituted an indictment against the value of mechanical tests as a whole. Well perhaps he is right, but the point as I see it is this: while I perhaps do not entirely agree with Major Wilson, it goes to show that one cannot rely upon mechanical tests as being the sole criterion by which asphalt can be judged. If we do that we throw overboard all the accepted practices of the asphalt industry to-day, and I submit that that would be wrong. I think that mechanical tests and the ordinary, normal, physical and chemical tests of the asphalt and its constituents must go hand in hand.

In conclusion I would like to refer to Major Wilson's remarks where he places stress on the value of co-operation from the practical side of the industry. That I think is essential. It is no good our being too academic and forgetting the practical issues. We must rely on the practical and technical sides for giving us assistance and thus enable this mechanical test problem to be brought to a satisfactory conclusion, and I feel sure we have in the industry sufficient data for this purpose. I know that we have the necessary practical experience which will be of inestimable value to the Committees and panels which are set up to-day to consider this question of the mechanical testing of asphalt.

MR. DREW: I am speaking on behalf of Mr. N. H. Taylor, of Singapore, who came home in 1930 and did a year's research under Prof. Clements at the City & Guilds Engineering College—afterwards returning to Singapore to apply his results and to do further work on the problems confronting him there. These problems included the effects of high temperature and tracking caused by solid-tired trolley buses and overloaded motor lorries.

The gist of this work was first published and read before The Society of Chemical Industry twelve months ago.

The item of most interest with regard to the present discussion is the Stability Testing Machine, which he evolved to satisfy his need of a compact machine to give reliable results with stone-filled asphalt mixture.

The necessity for very high consolidating pressure (12,000 lbs. per sq. in.) for test specimens has been stressed to-day—this machine is therefore of interest in that it may be claimed to overcome the arching during compression and testing which was stressed by Dr. Stradling and Prof. Clements. Mr. Taylor's specimen is $4\frac{1}{4}$ ins. in diameter and only $1\frac{1}{4}$ ins. thick—a thickness corresponding to that of many road surfaces—and his consolidating pressure is only 5,000 lbs. per sq. in. which authorities state to be equivalent to the effect of a ten ton roller. It is an agreed point that a road only attains the degree of consolidation equivalent to that caused by 12,000 lbs. per sq. in. moulding pressure after some time in service so that the moulding pressure of 5,000 lbs. per sq. in. may be said to represent the condition in which the road surface has initially to give satisfactory service. The test load is applied to a limited area only (2 ins. diameter) in the centre of the specimen—again an imitation of actual road conditions—the area under compression being supported by the surrounding material until eventually failure takes place by the bursting of this outer ring.

A further advantage is that it fulfils Dr. Spielmann's requirement in that it draws autographically a load-deformation diagram. Mr. Taylor claims that his machine in Singapore made out of a few simple components "... has meant that we know each day at eleven o'clock whether the mixture laid that morning is satisfactory and that, while the trolley buses cannot rut or wave the surface, the mixture will not be cracking up in ten years time owing to its being far too hard."

Accordingly the stability value obtained with this machine, in conjunction with a void determination, is used as a daily routine control of his plant output, whether of new mixture or reconditioned old material. Other tests such as analysis, recovery of bitumen, etc., are done at less frequent intervals.

DR. D. M. WILSON, replying, said: As to Dr. Loman's blown asphalts, we have tried to use them, but we have found them very susceptible to heating, and they are certainly less adhesive than the ordinary distilled material.

The void test is of course of great value,

but it is extremely dangerous to reduce the voids to such an extent that one could not get into the mixture sufficient bitumen to make the material waterproof.

With regard to the ageing of samples, Mr. Murdoch mentioned two days instead of seven days. Results can be obtained the same day, as the test pieces are made, but we know that bitumen undergoes certain changes on heating. We are not yet clear as to what these changes are, but it is advisable to allow a certain time for the bitumen to settle down—the longer the better. Seven days is about the longest ageing time I can afford to give.

I am glad to know that Dr. Lonsdale agrees with me on the question of loading pressure.

Replying to Dr. Lee if the bitumen in the material is harder than 20 at 25°C., damage probably takes place by alternate expansion and contraction, due to temperature changes, and the bitumen is not sufficiently adhesive to cement the grains together. It is only very rarely that one finds a sample of steam-rolled asphalt in which the penetration of the recovered bitumen is so low.

As to Dr. Mitchell's remarks, all the results I have given are the averages of at least three readings. In the case of the tensile test, if the conditions are carefully controlled the individual results are never more than about 5 per cent. from the mean.

Referring to Mr. Drew's remarks about the degree of consolidation, a roller certainly does not complete consolidation. In the case of steam-rolled asphalt and compressed asphalt, the traffic continues to consolidate the material for several years. In fact in the case of compressed asphalt consolidation may go on for 20 years. If there is any question as to the pressure that should be used for moulding it is easy to determine the specific gravity of the material in the road, and then see what pressure must be employed in order to prepare a test piece of some specific gravity.

MR. D. C. BROOME, replying, said: Mr. Holden criticised the stability test, particularly saying that on the road extrusion could not take place, the material being confined all the way round could not spread in any direction. But in reply I would say that it *can* spread upwards; and I think

that because it does occasionally, in the case of badly designed mixtures, actually spread upwards, we should investigate the matter from that point of view.

Mr. Murdoch mentioned what I have said in regard to tensile tests, and remarked particularly upon my note that in my opinion the tensile test was very largely a ductility test. He pointed out that it was also a test of the adhesion of the tar or bitumen to the aggregate. But that of course does not always apply. It is just a question as to the greater adhesivity of the matrix to the aggregate, or the cohesion of the matrix itself.

Mr. Murdoch also entered a plea for standardisation of sample dimensions, and I very heartily support him in that.

Dr. Lonsdale I think made a very important point when he spoke of the fact that very high results were just as bad frequently as very low results. It simply means I think that we must always consider the results of various mechanical tests in conjunction with one another and in conjunction also with other tests; and what is even more important, with our practical experience on the road.

Finally I would like to thank Mr. Drew for drawing our attention to that very excellent article of Mr. Taylor published some time ago. I think the stability test of his is well worth a considerable amount of thought. It has just occurred to me that, listening to Mr. Drew speaking about this particular test, it is of particular interest in that on the outer ring between the actual compressed portion and the outer ring, you are getting there a measure of a tensile strength of the outer portion as well as measuring what we in the ordinary way call stability. In view of the fact that this in very many ways corresponds to the behaviour of the material on the road I think it is a test that we might well consider further.

PROFESSOR CLEMENTS: I do not think a series of papers have been presented in my recollection which have been so practical and which on the face of them carry such indications of their potentialities as far as the road engineer is concerned. The subject opened by these papers has, as we can see by the discussion, not merely aroused an interest which is completely unsatisfied by

the number of speakers, but is emphasised by the large amount of people who have not spoken on this subject, and the interest that has been aroused in the minds of the engineer, and others engaged on this particular construction. What is happening? What is this thing we are constructing? What is taking place with it?

That, I think is something which provides a field of labour for the engineer, for the physicist and for the chemist. The purpose of my speech is to suggest that there should be gathered together for the purposes of co-operation and mutual help towards the advancement and knowledge in this particular branch of science, this particular branch of the work of construction, those interests which cannot commonly meet on a platform such as we have been fortunate in securing in the meeting to-day, under the Chairmanship of Professor Morgan, a chemist of great distinction on the one hand, and this morning an equally distinguished engineer in the person of Major Cook. The interest and the widespread character of this subject is indicated again by the fact that we have here gentlemen so distinguished as Dr. Loman, of Holland, Dr. Nellensteyn, M. le Gavrian, Professor Dr. Neumann and a number of others, all of whom are in their particular spheres working on this problem. The point is that in all these countries, widely separated, they are working to the same goal, and we are equally widely separated here at home because there is not a common meeting ground.

Therefore with that position before us I do most warmly commend to the meeting this afternoon that they should determine here and now that they should group themselves together for the purposes of mutual help, mutual support and mutual guidance in this new science; not merely narrowing it, as we so often do, by looking at the thing from a purely parochial standpoint and from our own immediate sphere, but making it applicable to a wider view of the properties of the materials of construction of all natures.

Therefore, I propose this resolution: That this meeting form itself into a body for the study and development of this subject, in association with an existing organisation and for choice an organisation which will give a common meeting ground to all workers, on

similar lines to the platform which has been furnished by the Chairman to-day in this gathering, and that the institution be a prominent scientific institution, the Society of Chemical Industry.

DR. SPIELMANN: I support most heartily the proposal put forward by Professor Clements, in the hope of being able to establish a group under the ægis, as we may hope, of the Society of Chemical Industry. There is plenty of material to be discussed, and we have nowhere to discuss it. If Professor Clements is a shade optimistic in wanting to include all building material rather than road building materials, that is a matter of experience as to whether the net has been cast too wide or not.

DR. DUNN (*President of the Society of Chemical Industry*): It seems to me that Professor Clements's proposition is an extremely desirable one: speaking even merely from the experience that I have had to-day. I also think that the form which he has suggested the proposed Association should take is a very appropriate one, because the Society of Chemical Industry touches, as I said this afternoon, your work at so very many sides. The Society has members all over the world who are connected, some of them, with almost every variety of industry, and if the Association were to take the form of a subject group in the Society of Chemical Industry I feel sure that it would have that wide and varied support which only a Society like the Society of Chemical Industry could give: that is to say, that you would have brought to your discussion not only your own technical ideas, but also the associated ideas of the members of the Society who were engaged in what I may call related lines of industries.

I can earnestly say that my council are, or would be, very favourably disposed towards the suggestion that has been made. During the last three or four years the Society has branched out in a new direction in the formation of several subject groups, and the work of those subject groups has been so successful that it is desirous of extending its activities in that particular direction; and I think if it is your wish that such an association should be formed as Professor Clements has out-

lined, and that that should take the form of a group of the Society of Chemical Industry, you will be meeting what I think is a tendency of the Society of Chemical Industry at the present moment, and it would probably welcome the suggestion and be very glad to become the parent, shall I say, of this new group in its own Society.

THE CHAIRMAN: In putting Professor Clements's resolution to the meeting I might add one or two words to what the President has said in regard to the Society of Chemical Industry: although it is probably very well known to all present. First it is an Anglo-American Society: it has membership in the United States as

well as all parts of the British Empire with a round total of about 5,000. Secondly it has already three subject groups. By an odd coincidence I have been at the birth of every one of them. In 1918 I presided at the first meeting which led to the formation of the Engineering Group, which has since been a most energetic group of the Society. During my Presidency the other two groups, the Food Group and the Plastics Group have been formed; both are going strong and there seems to be no reason why a similar group should not spring forth and be of considerable value to those who are interested in roads and road construction.

The Motion was carried with acclamation.

CONFERENCE

Under the auspices of the Institution of Gas Engineers.

TUESDAY, 14th NOVEMBER, at 11.0 a.m.

MR. F. P. TARRATT, M.Inst.C.E., M.Inst.Gas E. (*President of the Institution*)
in the Chair.

The following Paper was taken as read :—

Dry Purification. Some New Methods for its Control.

BY

W. A. CURRIE, Jr., A.M.Inst.Gas E.

(*Technical Assistant, Glasgow Corporation Gas Department*).

(NOTE.—This Paper was submitted for the Open Competition arranged by the Congress Committee and was awarded a Special Prize of Five Guineas).

ONE of the most important duties in gas management is to minimise capital expenditure. This may be achieved in some cases by increasing the effectiveness of existing plant, by improvements in the method of working and/or in the methods used in the technical control of the plant. It is with this side of dry purification that the present paper is concerned.

The chief factors affecting dry purification may be listed :—

- (a) Design of the boxes.
- (b) Nature of the purifying material.
- (c) Nature of the gas to be purified.

Examining these singly it will be evident that the alterations in design can only be minor ones if our original object is to be kept in view. These minor alterations will be described after the nature of the purifying conditions have been discussed.

In order to avoid confusion, it is best to make clear at the beginning that the methods of testing and analysis described are suggested as suitable for boxes using a good quality bog ore, thus, the colour of prepared materials varies from reddish-

brown to almost black, so that the fouling test given is not so easily applied to the latter as to the former. The dark coloured materials having pretty much the same colour, fouled and unfouled.

EXAMINATION OF THE MATERIAL.

The most important items of information one requires regarding purified materials are

- (1) Percentage of ferric oxide, water, insoluble matter.
- (2) Percentage of ferric oxide in a state in which it is available for purification at ordinary working temperatures.
- (3) A measure of the sensitivity of the oxide.

The estimation of ferric oxide, water, and insoluble matter do not present any difficulty. Particular attention should be paid to having a large representative sample for the estimation and to using a relatively large quantity for the estimation.

In the estimation of water a preliminary drying in a porcelain basin or metal tray over a flame, with constant stirring with a thermometer to 80°C. or so, reduces the time required and if done with ordinary care need not affect the organic matter. Purifying materials should be, and usually are, purchased on a stated moisture content with a rebate for excess moisture. An arithmetically accurate method of calculating the price to be paid is by the following :—

$$\text{Corrected weight} = \frac{\text{Gross weight (100—W)}}{(100—S)}$$

Where W=Percentage water in material as received.

S= „ „ „ standard.

Payment is made for the corrected weight at the quoted rate. The following table indicates the effect of water on consignments of 100 tons each of varying water content and shows the corrected weight of 45 per cent. water material.

Table 1.

Per cent. water	45	50	55	60	65	70
Corrected weight	100	90.9	81.8	72.7	63.7	55.5

The estimation of ferric oxide should be done by a volumetric method or the weight of alumina in the usual ammonia precipitate determined and allowed for; this is of the order of one per cent. and is quite useless for purification under ordinary conditions. Since materials are usually bought on a specified iron content, the commercial significance will be clear. Some increase in accuracy and decrease in calculation, may be obtained by using the following modification of the dichromate method :—

The dried residue from the moisture determination, amounting to some 500 grams if a kilogram of the sample is dried, is ground in a mortar to an even fineness so that the ore itself passes a 30 sieve. Any fibre not passing is cut as small as possible with a knife or scissors and thoroughly mixed with the ore. The whole is dried again at 105° C and quantities of four grams each are weighed into crucibles. The ignition loss and insoluble matter are determined in the usual way. The iron

solution is diluted to 500 ml. and 100 ml. titrated in the usual way. The burette reading gives the percentage ferric oxide in the dry oxide. Increased accuracy may be fairly claimed on the ground that the sampling gives a fairer sample, and the titre being larger than usual reduces the percentage error.

The capacity and sensitivity of the material are of greater practical importance than the more easily estimated ferric oxide, insoluble, etc., which are used as guides to quality. A high capacity reduces the expense of handling, but the most important quality is the sensitivity. A material twice as sensitive as another, for instance, will require half the number of boxes with the consequent reduction in capital expense and working costs. In order to evaluate these properties, the following fouling test has been devised :—

The fouling is carried out in a prepared hard glass tube, half an inch in bore, and some eighteen inches long. Rings are marked on the outside of the tube at the following distances from one end :—

A, 1½ in. B, 4½ in. C, 10½ in. D, 13½ in.

It is convenient, but not essential to have the distance between the outermost rings marked off in inches and quarter inches.

About 30 grams of the air-dried purifying material is broken down to pass a 20 sieve and thoroughly mixed with sufficient water to give a final moisture content of 20 per cent., or, in special cases, such other figure as is found to get the best results from the material.

A small pad of cotton wool is inserted and held in position at the 13½ in. mark. The purifying material is filled in with steady, but not violent tapping on a wooden block or bench, till the level reaches the 1½ in. mark. A plug of cotton wool is placed on the top. The tube is reversed and short (about 1 in.) pieces of moist lead acetate paper are placed on top followed by a plug of cotton wool.

The tube is clamped in a vertical position, with the test papers on top, and hydrogen sulphide, washed by a solution of ammonium carbonate, and free from air, is passed in at the bottom at such a rate, that one inch of the purifying material is fouled in five minutes. Immediately the lead papers are blacked, the hydrogen sulphide is stopped, and the tube removed.

The material lying between the 1½ in. and 4½ in. marks is removed and revived as is that between the 10½ in. and 13½ in. marks. These are, separately, dried at 105° C and the sulphur extracted from a suitable portion by extraction with carbon disulphide in a soxhlet apparatus.

From the percentage of sulphur found (S) the percentage of available ferric oxide is calculated :—

$$\text{Per cent. available ferric oxide} = \frac{500 S}{3 (100 - S)}$$

The "sensitivity" of the sample is measured by the ratio of the percentage available ferric oxide in the top section to that of the bottom section, and the

"capacity" is measured by the percentage available ferric oxide in the bottom portion.

EXAMINATION OF THE CRUDE GAS.

It need hardly be said that the chief information required regarding the gas covers :—

- (1) Proportion of hydrogen sulphide.
- (2) Proportion of ammonia.
- (3) Proportion of tarry vapours or condensible hydrocarbons.
- (4) Humidity, and (5) Temperature.

The methods in common use for the estimation of hydrogen sulphide and ammonia are either tedious or are liable to considerable error. The following methods have been devised with the objects of reducing the time and apparatus required and maintaining the accuracy of the best methods.

ESTIMATION OF AMMONIA.

A sample of the gas, about 200 cc., is taken in a dry gas-sample tube, so that there is no deposition of water. The sample tube is immersed in water in a thermostat at room temperature for five or ten minutes when the temperature is noted, and the barometer read. These give the gas volume factor. In the case of traces of ammonia, this is an unnecessary refinement.

The ammonia is extracted by blowing quantities of 5 cc. each of 1 per cent. sulphuric acid into the tube through a glass U-tube. These quantities (three being ample) are collected in a nessler tube and after suitable dilution with ammonia-free water, the yellow colour is developed with nessler solution and nesslerised with

$\frac{N}{400}$ ammonium chloride in the usual manner.

Calculation may be simplified by using a chart such as is given in Fig. 1. The method has given excellent agreement with the acid and alkali titration method, and the nessler reagent has not shown any sign of being affected by the sulphide ions extracted from the gas by the dilute acid.

$$\text{Grains ammonia per 100 cu. ft.} = \frac{\text{cc. NH}_4\text{Cl} \times 15.43 \times \text{G.V.F.} \times 28,317 \times 100}{\text{Capacity of tube in cc.} \times 400}$$

For convenience in calculation the reciprocal factors published by the Gas Referees have been used.

ESTIMATION OF HYDROGEN SULPHIDE.

This estimation is carried out by taking a sample in a gas tube as in the case of the ammonia estimation, with precautions, if required, against formation of water in the connections and tube. The procedure is similar to that employed in the previous estimation. A 2 per cent. solution of sodium hydroxide is used for extraction of the hydrogen sulphide, and is used, as before, in three quantities of five cc. each. These are combined in a nessler tube diluted to 50 cc., and a colour developed with a solution of sodium nitroprusside. The colour is nesslerised with a solution of hydrogen sulphide prepared as follows :—

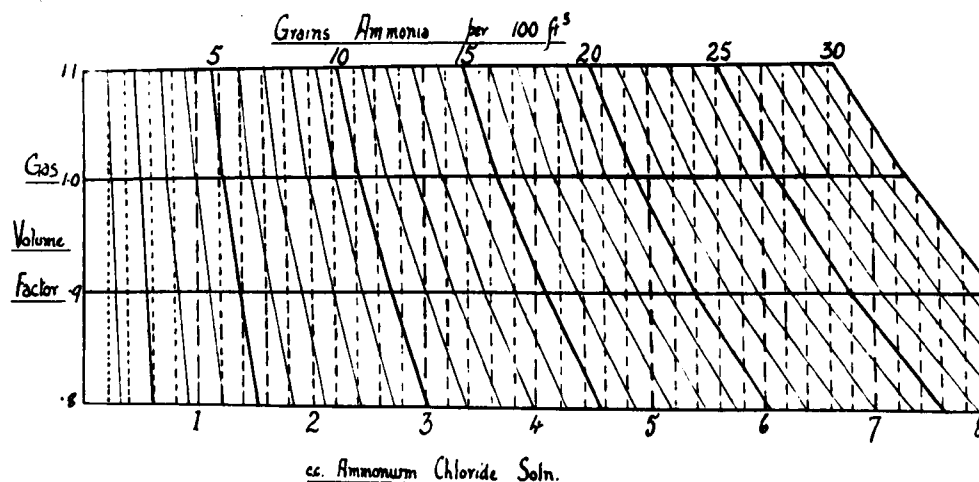


FIG. 1.

50 grams of a 2 per cent. solution of sodium hydroxide are tared in a conical flask, fitted with a cork carrying an inlet and outlet glass tube, the inlet dipping into the solution. Hydrogen sulphide is passed in until the weight increases by 0.2 gram for each litre of solution to be prepared. This stock solution is then diluted in a prepared bottle of the type used for barium hydrate, titanous chloride, etc. solutions, and covered by a quarter inch layer of petroleum ether (B.P.40-60°C. answered well).

This solution is sufficiently stable for use in technological work with occasional standardisation. The solution may be standardised by the following method :—

100 cc. is measured into a long-necked flask, and 10 cc. of 1 per cent. sulphuric acid added followed immediately by an excess (.2 gram) of sodium bicarbonate, then by an excess (20 cc.) of $\frac{N}{10}$ iodine solution. The excess iodine is titrated by $\frac{N}{10}$ thiosulphate.

$$\text{Gram H}_2\text{S per litre} = \frac{\text{cc. Iodine} \times 34}{10 \times 254 \times 100}$$

The nesslerisation is carried out as quickly as possible to avoid oxidation of the hydrogen sulphide. The colour of the sample is developed by adding the dilute (1 per cent. solution) of sodium nitroprusside drop by drop so long as a colour continues to form. An equal quantity is added to the standard, along with 5cc. of the 0.2 per cent. sodium hydroxide, and hydrogen sulphide solution added till the intensity of the colours is equal. The colour given by the sample has a blue tint which is absent from the standard. A very dilute solution (about .5 per cent.) of sodium bicarbonate, added drop by drop as required will give the necessary equalisation of the colours.

$$\text{Grains H}_2\text{S per 100 cu. ft.} = \frac{\text{cc. H}_2\text{S Solution} \times \text{G.V.F.} \times \text{Conc. of Solution}}{\text{Capacity of tube in cc.}}$$

Having dealt with the analysis and testing of the materials and of the gas to be purified, let us return to the first factor given on the first page of this paper, the design of the boxes. Since the paper is restricted to minor alterations, our attention is chiefly directed to the technical control of the process.

The following factors will be generally accepted as the most important :—

- (a) Moisture content.
- (b) Porosity and structure.
- (c) Temperature.

It is now generally agreed that purifying materials work best with a fairly high moisture content, and that optimum purifying capacity and sensitivity is associated with a definite moisture content for each material.

In the case of bog ores worth consideration for purifying purposes the optimum water content is in the region of 20-24 per cent. This has been shown by several workers and curves and need not be shown here. Fig. 2 shows the results of fouling a sample of Dutch ore five times under controlled moisture conditions. The upper curves give the percentage sulphur in the samples after each fouling, and a standard line corresponding to an initial sulphur percentage of 12.5 and no loss of purifying capacity. The lower curves show the increments of sulphur at each fouling expressed as percentages of fouled material and a standard line corresponding to the upper standard line.

The lines show clearly the effect of the water. A previous set of foulings having shown an optimum water content of 21 per cent., samples were prepared containing 16, 20 and 24 per cent. water, and fouled in hard glass tubes with hydrogen sulphide. The moisture in the revived oxide was determined and the percentage water increased to the appropriate figure by adding a calculated weight of water.

It will be seen that curve A (16 per cent.) starts off a little behind the others, and rapidly falls away, the increments settling down to about 4.5 per cent. at the third fouling.

Curve C (24 per cent.), on the other hand, shows the best initial result and holds the lead till the third fouling, where curve B gains a slight lead. Curve C increments show a very rapid drop without any sign of a recovery.

Curve B (20 per cent.) shows a regular deviation from the standard, while the increments show the corresponding similarity, and the highest level of the three samples.

It is evident from the curves that to obtain the best results this material should have initially a water content of 24 per cent. which should be reduced to 20 per cent. at the fourth fouling, and perhaps to 22 per cent. at the second. Calculating an initial water content of 24 per cent., and of hydrated ferric oxide 65 per cent., to the fouled material containing 36 per cent. sulphur, the proportional moisture content is found to be 16 per cent. The 20 per cent. figure would allow some moisture for the saturation of the sulphur present.

From this it is not unreasonable to deduce that the moisture content in the material should be reduced as the sulphur rises so as to maintain the optimum

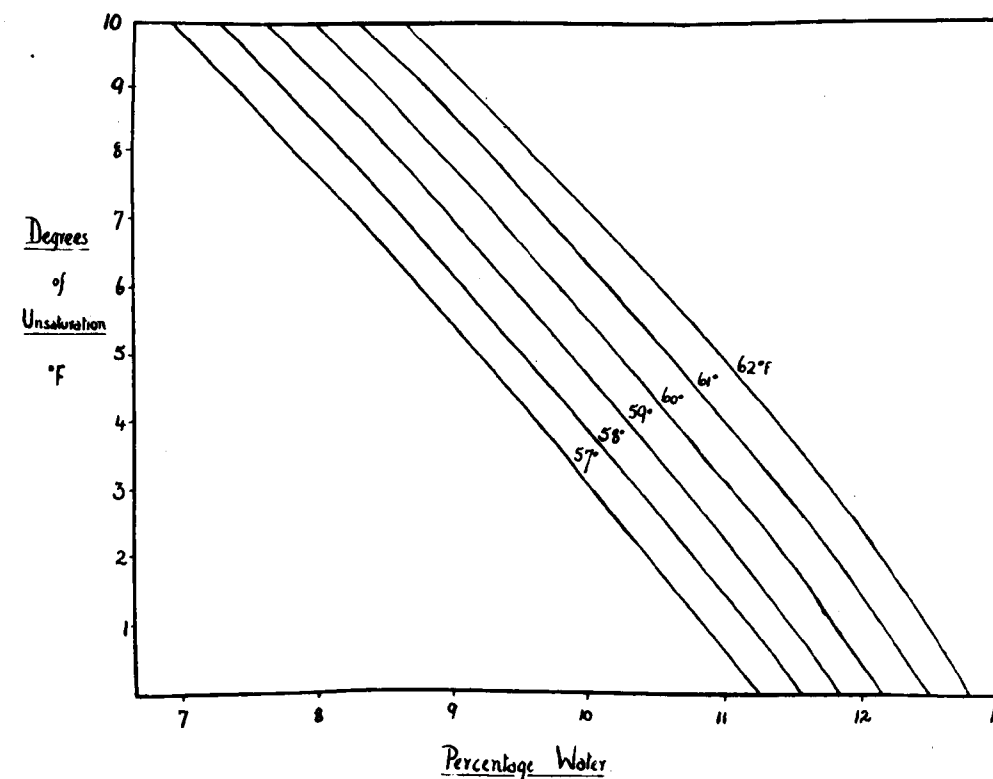
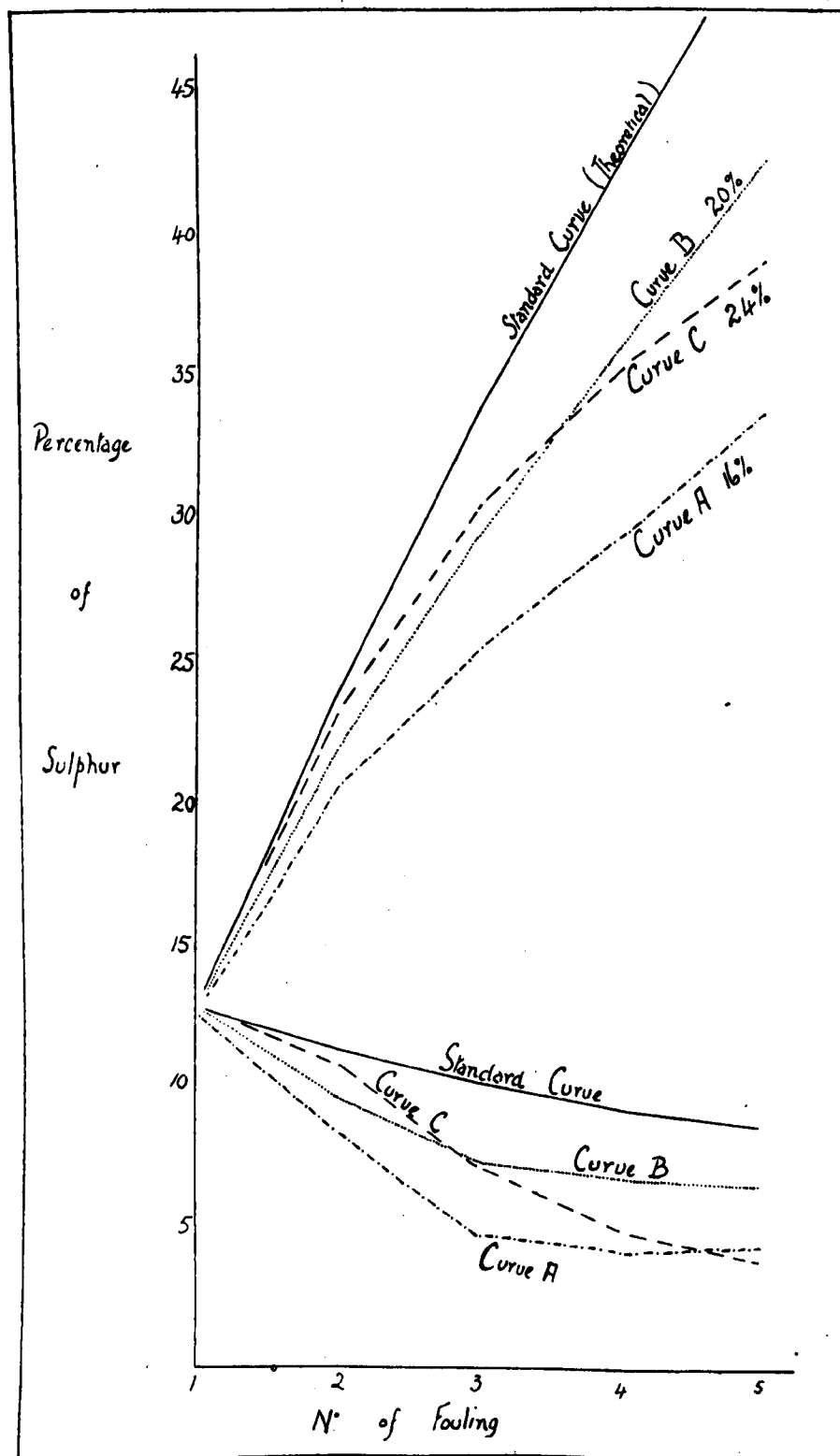


FIG. 3.

water content in the ferric oxide with sufficient to satisfy the sulphur, etc., which have relatively low capacity for water. When the moisture is added in the initial optimum proportion, the excess (for the sulphur) seems to have a waterlogging effect on the ferric oxide.

In order to follow out the deduction as a practical policy, it is necessary to know

- What is the natural moisture content of the ore at varying temperatures, and in contact with gases of varying degrees of saturation.
- What movement of water is likely to take place from the upper to the lower portions of the oxide layer.

Fig. 3 gives the moisture content found in a sample of a German ore in contact with gas of varying humidity. Quantities of 10 gram each dried at 105°C., were subjected to the action of various gases at various temperatures in a glass tube. The humidity of the gas was controlled by using various glycerine solutions and the dew-point found by the ether evaporation apparatus.

The curves show that the capacity of this oxide increases with the degree of saturation of the gas and with the temperature of the oxide during the absorption. The moisture content required in practice 24 to 15 per cent, is not attained at

ordinary temperatures so that it is necessary to take precautions to protect the material from loss of water beyond the reduction allowed.

It is obvious that the gas should be saturated with steam when it enters each individual box and should not rise above, nor fall appreciably below, its initial temperature while it is in the box.

If this proposition is accepted, it follows:—

1. Closed steam heating should be directed to preheating the gas and counter-irradiation where necessary.
(Apart from their effect on the dew-point of the gas it is well known that closed heaters in the boxes lead to short-circuiting due to localised drying of the purifying material).
2. All inlet valves and inter-connections (i.e. centre-valves, etc.) should be lagged to prevent cooling and consequent deposition of water.
3. The four-box system is justified on the ground that the material is revived in a moist atmosphere and drying of the material is minimised.

The next question which arises is the replacement of water lost in revivification (other losses being prevented). Laboratory tests do not bear out the theory that water added to the top of the layer will find its way to the bottom. A sample of German bog-ore containing 38.5 per cent. of water (i.e. nearly twice the requirement) was set to stand in a vertical position in a 1 in. bore tube, 36 in. long for 10 days. At the end of this time, the oxide was removed in six inch sections, representing the zones from the top to the bottom. 20 gram quantities were dried in petrie dishes at 105°C. for 3 hours. The results varied irregularly between 38.51 and 38.57 per cent., so that there was no migration of water.

Fig. 2 indicates that the moisture content could be raised by raising the temperature of the oxide, and saturating with steam-saturated gas. In the absence of practical work from this point of view, it is unwise to dogmatise, but the best policy would appear to be prevention of loss, by close control of revivification conditions.

The remaining factors referred to, structure, porosity and temperature, are not readily studied, but the first two appear to be dependent chiefly on the moisture content, with proportion of clay matter and crystalline structure of the ferric oxide grains as constants for each particular sample.

Temperature/capacity curves for bog-ores, usually show a very level line with a slightly raised maximum between 65° and 70°, while practical experience goes to show a continuous improvement in results with rise in temperature. It is possible that this is explained by Fig. 3, the higher temperatures giving a higher natural moisture content and therefore higher capacity. In addition to this, there is less probability of water-logging (Curve A Fig. 2) when the temperature is high, unless open steam heating is used. Laboratory capacity/temperature curves, being carried out at optimum water content, are not affected by the practical troubles associated with variable water content.

The author is indebted to Mr. J. W. McLusky and Mr. R. Millen for permission to publish the figures given in the Paper.

DISCUSSION.

MR. W. A. CURRIE (introducing his Paper): The Paper is the result of studies of dry purification. They may be divided into (a) chemical tests for process control, and (b) attempts to study the nature of the process. The chemical tests include those on a material for ferric oxide, etc., and the tests on the gas include methods for estimating hydrogen sulphide and ammonia. The attempts to study the nature of the processes include a series of fouling tests. It should be remembered that the process in mind throughout is that using bog-ore and low temperatures with alkaline conditions, and that materials using the Claus reaction at high temperatures are not considered.

MR. C. H. CARDER: The Paper deals almost exclusively with laboratory methods of testing the raw material for dry purification of gas and of the gas to be purified, and to that extent the title under which it is presented is a little misleading, as although these tests are themselves quite important, the methods by which they are carried out (so long as reasonably accurate results are obtained) are relatively of minor importance when considering the control of the dry purification process as a whole.

The chemical analysis of various samples of natural and artificial oxides of iron, and their testing for fouling properties and total economic sulphur extraction capacity, has, of course, been practised on all large works—and I imagine on most small ones—for many years past, and these tests are of supreme importance in the selection of the raw material which is to form the basis of the whole process. Mr. Currie seems, however, at least to me, to introduce a new and quite useful feature into these tests by carrying out his fouling tests in a long and very narrow tube, and analysing in such a manner as to get a sensitivity ratio as well as a saturation test on the one sample, under standardised conditions. It should be noted, however, that although a series of samples tested on this basis will be entirely comparable between themselves and will thus fulfil their object in indicating the most efficient, and subject to price considerations the most economical, material to be purchased, the fact that samples are

crushed to pass a twenty mesh sieve will to some extent vitiate comparison with actual works operation, if single stage (forward rotation) purification is practised.

In the practical control of the dry purification process there are a number of features of major importance from the point of view both of operating efficiency and of ultimate operating cost, which although tied up with the tests which Mr. Currie mentions are not dealt with at all in the Paper; I refer more particularly to such points as:—

1. the periodicity of changing boxes on backwards rotation;
2. the proportion and point of admission of oxygen used for revivification in situ;
3. control of the acidity in the purifying mass;
4. the use of atomised water sprays in the gas stream as an alternative to the use of open steam for simultaneous control of temperature and humidity conditions in active purifiers;
5. control of the volume of gas going forward to each series of purifiers in works where several series of purifiers are used in parallel;
6. the necessity for the maintenance of accurate and complete statistical records of the day to day performance of each box in a series, if the best value is to be obtained from the material in use.

The relative importance of some of these points will vary between different works, according to the precise method of purifier operation which is in use, and the number and size of the purifier boxes in relation to the volume and H₂S content of the gas to be purified. In this connection those members of the Institution who recently visited Canada and the United States of America will doubtless have noticed, amongst other things, the much larger size of the purifier boxes used over that side, and also the much lower sulphur content of the gas to be dealt with. There I must admit I have not checked the detail of the itinerary of the group who went to the States, but in most of the cases they will, I think, have seen liquid purification plants. Taking an all round view, however, I think there is little doubt that actually the most important of

these factors for fully efficient operation is the last, for if complete statistical records are available of the day to day performance of every box, it is a simple matter to trace any departure from the predestined sequence of purifier conditions, and hence to remedy the condition or remove the cause. Such records must necessarily include an identification of the material in each box, the number of days it has been in use, its position in the series, the H_2S , NH_3 and O_2 content of the gas at the inlet and outlet of the box, the average operating temperature, and the volume of gas passed. The total weight of sulphur which has been extracted and retained by the box to date may either be calculated daily, or at each periodic change on backward rotation working; personally, I prefer the latter basis, as actually it involves less work, and can be taken out by the statistical staff at the Central Office and reported back to the works, instead of occupying the time of the technical staff at the works as it normally would if included in the daily return. Consideration of the figure of oxygen absorption in boxes subject to revivification in situ also enables check to be kept on the progress of revivification, and in conjunction with the former figure of total sulphur absorption, gives a very accurate picture of the actual state and potential capacity of the material contained in every box in the series at any time.

It may not be entirely irrelevant here to say that by these methods of statistical control we have on occasion been able to run oxide right through to full commercial saturation—52 to 55 per cent. of sulphur—either without removing it from the purifiers at all or with only once removing through building up of pressure, and without loss of purifying capacity; this when dealing with a series of circular steel boxes each 36 ft. diameter by 15 ft. deep., and holding approximately 180 tons of material in each box, represents of course an appreciable economy in operation. In saying we could do this "on occasion," it does not mean once or twice, but that out of a series of twelve boxes you can count on running eight to ten to final saturation with about 200 to 280 days of use without once handling the material, even when using twice burned oxide.

Incidentally, the test for sensitivity which Mr. Currie mentions, coupled with the

figures for sulphur content of the gas and its rate of flow in relation to the bulk of the purifying material in each box, should enable the periodicity of change (item 1) to be deduced theoretically even before the oxide is purchased, and the information given by the day to day records will very quickly indicate any deviation from best working conditions or draw attention to any factor which has been overlooked in making the calculations.

With regard to the admission of oxygen for revivification in situ, I believe the difficulties experienced of late years in the disposal of effluents have sufficiently emphasised the great undesirability of admitting this at any point prior to the purifiers themselves, but the further advantage of admitting it as a metered supply directly into the actual box—usually the second in a series of four when working on backward rotation—in which it can be most effective, instead of into the main inlet stream of gas, has not always been so fully appreciated.

It will be seen, therefore, that the field for new and more efficient methods in the control of the dry purification process is much wider than has been dealt with by the author of this Paper in his present thesis, and we trust that having made a good beginning by dealing with the laboratory end of the question, he will be encouraged to extend his researches to the control of the practical operation of the process, and in due course to present to the technical bodies of the industry the results of his further investigations.

MR. E. E. CALVERT (*Gas Light and Coke Co., Stratford*): In the opening paragraph of Mr. Currie's Paper he emphasises the necessity of saving money and making the best use of plants that are at our disposal. We all appreciate the advantages of modern plants with up-to-date details, but are not all in the fortunate position to have them, so, therefore, have to employ improvements in the method of working and in the methods used in the technical control of the plant as suggested by the author to achieve the best results.

Although he mentions design of the boxes as being one of the chief factors affecting dry purification, he leaves us to solve our own problems. I should have liked to have

heard his views on the number and depth of tiers of oxide employed in each box. A saving in expenses can be claimed by the use of two tiers, and better still, one tier.

His first tests deal with the new oxides, and I was particularly impressed with the tests for the capacity and sensitivity of the oxides, especially the latter where the moisture content plays such an important part, and I am glad to see that he places moisture content first in the important factors for the technical control of the process.

I should like to know if the data given in Fig. 2 have been obtained in practice or only by laboratory tests. The optimum water content, given as 20 to 24 per cent., has been controlled throughout five foulings in these tests. Will the author inform us how he managed to keep the moisture content to this high figure? One usually has no difficulty with a batch of new material or even where starting with 50 to 75 per cent. of new oxide, but after successive foulings the moisture content is considerably reduced. Now that it is the accepted practice to have gas heaters on the inlet to purifiers it is more difficult to maintain the moisture content of the oxide.

Unless live steam is employed in conjunction with gas heaters the oxide can become too dry to be active. I have used a special valve for admitting steam under control into the gas main after the heaters. This is the West Taylor steam valve as used on the Glover West Vertical Retort for the purpose of steaming the charge. There is still another reason why it is difficult to maintain the moisture content of the oxide, and this is due to the modern method adopted recently of crushing the oxide in mechanical breakers or disintegrators. The fact of breaking the oxide up to such fine or even dusty particles has a tendency to dry it. In view of this I should like to know how the author added water in order to increase the moisture content to the appropriate figure. He states that the gas should be saturated with steam when it enters each individual box. This may be all right with downward flow, but will certainly have a tendency to cake the oxide where an upward flow is used. In the case of the former this can be overcome by digging over or furrowing the top layer at systematic periods.

As regards the factor of porosity and structure of the oxide, this can be controlled by the mixing of old and new material, and it would be interesting to hear if the author adopted any system by which he added new oxide to partially spent material.

If the author carries out his suggestion that the moisture content could be raised by raising the temperature of the oxide with steam saturated gas, I am somewhat surprised the maximum temperatures do not exceed the 65° to 70° F. being the figures mentioned in his Paper.

I should have liked to have heard of some method or system of keeping the daily or shift records for the control of dry purification. By these I refer to changes of swings, hours between changes and the grains of H_2S in the gas at the outlet of each box. But it must be remembered that this is only a snap test; a continuous record of this would, no doubt, be the ideal method. The importance of measuring the air for purification by meters is most desirable and essential from the safety factor point of view.

MR. CLAYTON: I notice on the first page that the author rather confines his criticism to bog ore. I do not know why the other oxides, which are at present on the market, should not have been included, as I consider some of these are quite equal to, or better than, any bog ore imported into England. On the second page are given the percentages of ferric oxide, or rather ferric hydrate. My experience of oxide purification is that the percentage of ferric hydrate in the oxide does not control the purification process. As is shown in the Paper, the amount of ferric hydrate present will only absorb about 15 per cent. sulphur, whilst one of the speakers has stated he can, in practice, put an oxide in the box and withdraw it containing 52 per cent. sulphur. As far as our own experience goes in testing oxide, we do not lay great weight on the percentage of ferric hydrate in the material.

Again, there is a point which has been raised as to the question of sensitivity and capacity. I have not yet understood from the Paper what Mr. Currie means by sensitivity. He states that the capacity is determined by the percentage of active ferric hydrate as determined in his tube test.

I wish to point out that an oxide which will foul to, say 15 per cent. and will not revivify in situ is not a good working oxide. I regard "capacity" as the capability of the oxide in taking up sulphur without giving back-pressure. As regards the sensitivity, this is the capacity of the oxide to absorb sulphuretted hydrogen and rapidly re-oxidise in situ to its original condition. If oxides are exposed to foul gas taken out of the purifier and exposed to the air some will revivify in a few hours and others will only revivify in the course of a few days. The former are sensitive oxides, the latter are insensitive.

With regard to the examination of the crude gas, I think there are two factors not included, namely, the percentage of oxygen and the percentage of prussic acid. Prussic acid is always found in coal gas and should be completely absorbed in the oxide. In many gas works, however, it is fixed in the ammoniacal liquor in the form of sulphocyanide, which causes considerable trouble when the waste liquor reaches the sewage purification plant.

The formation of sulphocyanide in the ammoniacal liquor is caused chiefly by a high oxygen content of the gas and undue exposure to continually circulating liquor. I am afraid that this point is not sufficiently considered in gas works practice.

As regards the oxygen, it is known that it must be carefully controlled to obtain satisfactory purification. It is, in fact, one of the most important factors in controlling the results. The percentage of oxygen required in purification sets, where rotation is practised, depends very largely on the sensitivity of the oxide in use. In other words, on the revivification of the ferric hydrate in situ.

With regard to the test for ammonia, I cannot understand why Mr. Currie has adopted such an elaborate method. I should have thought that the simple method of dissolving ammonia in standard acid and titrating back could not be bettered. The only point with regard to this test is that the ammonia should not be used for back titrating. The ammonia question is really an important one, as we find that at the present time, in many gas works ammonia is passing forward to the purifiers in excessive quantities. My experience is, that if you

enquire at a gas works you will find the standard statement that 4 grains per 100 cu. ft. are being passed into the purifiers. On the other hand, many of the oxides coming into my hands indicate that up to 25 grains ammonia per 100 cu. ft. are entering the set, and this has a very detrimental effect. Again, ammonia reduces the value of the spent oxide for acid-making purposes. It may also pass forward into the purified gas stream, as we have proved by testing the condensate from the mains beyond the boxes and frequently finding ammonia in these liquors.

The question of controlling ammonia passing forward into the boxes is one which is unsatisfactory as far as the engineer is concerned. He generally has to wait some considerable period before getting the results, and, therefore, the control is late in operating.

We have attempted to evolve a simple method so that the ammonia content of the gas can be rapidly determined.

I have here a tube which illustrates what we consider to be a very good and simple method. We find that the best indicator, that is to say, one not acted upon by H_2S is bromphenol blue. This tube is packed with sawdust saturated with a known quantity of standard sulphuric acid to which has been added the indicator. The mixture is so graduated that an inch length of the tube corresponds to 0.5 grains of ammonia. By passing a measured quantity of gas through the tube and measuring the quantity of the mixture which has turned blue a very simple calculation gives the amount of ammonia which is passing forward. This test is obviously a very rapid one.

In this tube 3 ins. of the mixture has been acted upon, that is to say, $1\frac{1}{2}$ grains of ammonia have been absorbed, so that if 50 cu. ft. of gas have passed the meter the gas contains 3 ft. of NH_3 per 100 cu. ft. I consider this method to be a valuable visible control of the ammonia passing.

We have also evolved a similar test for prussic acid. It is probably not generally known that nickel sodium carbonate is an efficient absorbent for prussic acid. A second tube is packed with a standard mixture of nickel sodium carbonate and sawdust. On passing gas containing prussic acid through this mixture the green colour changes to orange, due to the formation of

nickel sodium cyanide. So that, again by measuring off the amount of discoloration and the amount of gas passed, as in the ammonia test, one can, by a simple rapid calculation test the quantity of prussic acid passing forward into the purified gas stream.

With regard to the effect of moisture on the working of the oxide I can thoroughly agree with this. I think 10 to 12 per cent. of moisture in nearly spent oxide is quite sufficient for good working.

The question of temperature in the boxes is mentioned. I do not think this point has been sufficiently appreciated by the gas industry, and from what I have seen on the Continent and in the Ruhr (I think the Ruhr conditions would correspond very closely to the Scottish conditions, as the gas has the same low sulphur content) it is very necessary to maintain the heat in the boxes. We have had cases where the gas has been heated up in the first box to $90^\circ F.$, and as it passed to the far end of the box it was found that half-way across the gas was perfectly cold. This is due to the fact that the radiation from the box cover is extraordinarily great. If the gas be 70° and the atmospheric temperature 60° you have a difference of $10^\circ F.$, which is equal to a radiation loss of 15 B.T.U.'s per square foot per hour. The heat in the boxes is thus rapidly dissipated and the reaction of the oxide is depressed. Instead, therefore, of concentrating so much on heating the gas at the box inlet I think the better method is to conserve the heat whilst in the box by preventing radiation. The atmospheric temperatures in Scotland are low, so that it is more necessary to conserve the heat than it is in English gas works. Scottish oxides, generally speaking, are extraordinarily low in sulphur, and by no means as rich as English oxides, and probably the question of the working temperature is one of the causes of this.

MR. A. L. HOLTON: In Manchester we have very little trouble with purification. On no occasion do we foul more than once. It is our practice to fill the boxes with new and a proportion of the older and spent material to give us practically 15 to 20 per cent. sulphur content. We then find that our oxide, on being removed from the boxes, comes out at 50 to 55 per cent. Our usual practice is to run the boxes for practically

eight to nine months, the rotation being such that we have one gang of men at work continuously. I was surprised to hear one of the speakers say that he admitted air into the second box. It has always been our practice to admit the air on the main inlet to the purifiers with no difficulty whatever.

One of the difficulties in purification that has not been referred to is where you have one stream of gas going to one or more sets of boxes. Personally, I think it is a mistake for this reason that no two sets of boxes throw exactly the same pressure, and if you have a purification area of a definite amount it is vitiated at once by any small differences in back pressure between one set of boxes and the other, and in such a case I advocate very strongly that there shall be a flow meter on each of the sets of boxes in order to regulate the flow of gas to each of the purifiers. I very much prefer one exhaustor dealing with one set of purifiers and measuring the gas by a flow meter and so having very definite conditions. The air is registered in all cases by a simple flow meter and the quantity regulated in that way.

I think it is also advisable practice to have the temperature and the H_2S in the inlet of each of the separate boxes very definitely estimated and recorded, so that you have a purification log and the manager can see exactly how the purification is working. At one period, just for experimental purposes, I recorded the amount of H_2S to be purified and calculated what should have been in the oxide at the end of a period of eight months. When the box was removed I calculated from the percentage of sulphur in the box, the weight of sulphur, and was surprised to find the sum of my daily figures agreed very closely with the sulphur recovered.

MR. CLAYTON: Mr. Holton raised a point which I omitted to mention, that is, the method of testing for sulphuretted hydrogen.

Several years ago at Philadelphia I saw a small control apparatus which is now used in many English gas works. A sample of gas is taken and directly titrated with standard iodine. The burette is so simple that it requires no particular skill to carry out the test. In fact in many gas works the purifier foreman carries out the tests.

Mr. Holton uses this apparatus in his works to ascertain the daily amount of sulphuretted hydrogen passing in and out of each box in his sets of purifiers.

MR. GILBERT B. HOWARTH (*Newcastle-upon-Tyne*): The Paper gives a survey of the chemical tests necessary to secure the efficient operation of purifiers, and has particular reference to the methods by which a suitable grade of bog ore may be selected.

An ordinary chemical analysis, is, of course, the first essential, in order to secure that the proportion of inert constituents is kept below reasonable limits. It is invariably found that only a portion of the ferric oxide is capable of reacting with hydrogen sulphide. This amount, corresponding to what Mr. Currie calls "capacity," is determined by fouling a sample of the oxide with pure hydrogen sulphide in order to ascertain the weight of sulphur that can be collected under the most favourable conditions. We use a similar method of test, and our choice of bog ores is based on the content of "active" oxide, judged by the amount of sulphur taken up.

We appreciate the need for a "sensitivity" test of some kind, but cannot agree that Mr. Currie's method gives the information required. "Sensitivities" obtained by means of pure hydrogen sulphide seem hardly applicable to actual works conditions, where the concentration of hydrogen sulphide is less than 1 per cent. Nine-tenths of the hydrogen sulphide can usually be removed without difficulty, and it is only in dealing with the last traces (of extremely low concentration) that a high "sensitivity" is called for.

We should like to measure the actual rate of reaction of oxides exposed to extremely dilute hydrogen sulphide concentrations, but the experimental arrangements are too complicated for routine use. Rates of reaction are enormously influenced by the temperature and humidity to which the oxides are exposed and by the rate of gas flow. With pure hydrogen sulphide a very considerable temperature rise occurs, with no means of temperature measurement or control. The results are likely to be dominated by the temperatures attained in the testing tube, which bear no relation to the temperatures artificially maintained in

actual purifier boxes. The physical condition of the oxide appears to be quite as important as its chemical constitution, and the addition of water to oxide that has first been dried and ground can hardly be regarded as restoring the characteristics of the original wet oxide.

The curves show the sulphur-absorbing capacity of an oxide with the recommended moisture content of 16 to 24 per cent. These are not directly applicable to works practice, since new oxide as put in the boxes usually begins with about 50 per cent. of water, and this figure must be reduced to about 10 per cent. before the spent material is sold.

The colorimetric methods suggested for the determination of ammonia and hydrogen sulphide in crude gas have undoubted advantages when large numbers of tests are required in a short time. For occasional use, however, the maintenance of the standard solutions would be found troublesome. Colorimetric methods have only limited accuracy, and we prefer to adopt the more usual volumetric tests.

The lagging of pipes and valves would certainly improve heat retention, but in many cases there is a much greater loss of heat from the boxes themselves. We agree that where closed steam heaters are used they should be arranged to preheat the gas before entering the boxes. The use of heaters inside the boxes is apt to cause local drying of the oxide and uneven distribution of the gas flow.

MR. W. A. CURRIE: Some dissatisfaction may be expressed with the usual method of controlling purification. It is because of that that I took such an interest in this side of the work.

The modifications in the tests have all been introduced with the idea of eliminating certain errors, some of those due to condensation from the gas, errors in the gas volume factor which is involved in tests, and chiefly in order to save time.

Mr. Clayton wanted to know what the benefits of the shorter test were. The chief one is time, which he emphasises himself. Any of those tests can be done in a matter of a few minutes, and they are accurate. They require, of course, skilled attention.

Fig. 2 deals with the effect of moisture

in these foulings. The fouling was done in the laboratory. The water was estimated in the residue from the previous test, and sufficient water was added to bring the moisture content up to the figure required. The point that it brings out is that there is less and less water required as the material approaches saturation, and if a constant proportion of 20 per cent. could be maintained, it would do much more harm than good.

This work was done entirely on bog ores. Only bog ores are used at Provan, although other materials which are submitted are tested.

Then with regard to the matter of ferric hydrate. According to researches which have been carried out, there is very little chance of there being any ferric hydrate in ferric oxide, or in the purifying materials. According to the two Papers I was able to turn up, one worker got a hydrate at one place where another got no hydrate, and then the former got a hydrate where the latter could not, and in neither case were they satisfied there could be such a thing as a hydrate; that is to say, a proper chemical hydrate.

The material is revived under alkaline conditions, so that the revivification is a relatively simple matter. There is little or

no chance at any rate of a large proportion of iron disulphide being formed.

Then with regard to the matter of the moisture tests, there have been published researches in which up to 28 per cent. of water was given as the optimum water content. (This was in some tests given by Mr. Reid to the North British Association in about September, 1931).

With regard to the matter of the temperatures, it is very difficult to get a complete set of boxes set up in order to carry out some tests, but the examination of these laboratory tests leads us quite clearly to the conclusion that prevention of loss of heat is much more important than renewing water, because any water that is added to the boxes will lie at the top if it goes into the box at all. It is very likely condensed out in the centre valve.

Then the method Mr. Clayton mentioned when used by a foreman is subject to three errors; the gas volume error, the interference of unsaturated hydro-carbons, and the loss of iodine owing to lack of chemical skill. Sometimes these may sum together and give results which are quite useless. So that if you can get a proper chemical method which can be relied upon, it is much better than any approximate method, and the extra skill required will pay for itself.

The following Paper was taken as read :—

The Qualities of Tars for Use on Roads.

BY

W. E. CONE

(*Technical Adviser, British Road Tar Association*).

SINCE tar and other bituminous substances are materials of very complex chemical composition, their physical properties are also exceedingly diverse.

While certain of these characteristics can be modified within limits by established methods, it would be true to say that values in this respect are largely the outcome of theoretical considerations, and have but little relation to the scientific study of the materials in practical use. Admitted, from our present knowledge we can relate broadly certain properties bituminous materials should possess for road work; just what particular property or combination of properties are most suitable for various types of construction remains to be determined.

It has been said that experience is the only dependable guide to follow in interpreting the significance of the results obtained by the use of bituminous materials, but it would be pertinent to ask what value can be attached to this in the absence of accurate records of all available data regarding the conditions under which the materials are used. Failure of a material might result for reasons entirely remote from its constituent properties, yet in many cases the material is held to blame, in spite of the fact that the failure may have been due to a variety of other causes.

To realise what this means, let us consider some of the factors which influence considerably the results obtained by the use of tar for the construction and maintenance of roads. It is, perhaps, unnecessary to stress the importance of a well drained and strong foundation, but in spite of the greater care and attention which is now given to this aspect of road work, many failures can be directly attributed to weaknesses in this respect. In the case of tarmacadam, how often do we find that the selection of the tar has more regard to the ease with which the finished product can be transported, than to securing the quality of binder best suited for the type of stone or slag to be treated. Consider also the effect of poor grading

and lack of proper temperature control in the mixing operations. Similarly, we often find in the surface treatment of roads that the selected material is expected to give the same efficient results, irrespective of the nature and constitution of the roads to be treated. Reference should also be made to the use of wet chippings, the absence of a roller, and lack of proper temperature control during the tarring operations. If proper cognisance is not taken of these factors, failures are bound to arise. In this respect, the recognition on the part of the user of the significance and possibilities of improved technique, aided by chemical research and practical experiment, is gradually clarifying the situation to a point where we can talk of the qualities of tar in more tangible terms.

It will be seen, from what has already been said, that tar has to meet a variety of usages, which demand a greater degree of flexibility than is commonly associated with other bituminous materials. The extent to which these requirements have been met by tar is too well-known to need repetition here, and if we consider the satisfactory results obtained by its use in all parts of the country, despite the handicaps from which it has suffered, the great advantages of tar become apparent.

With an understanding of the facts, it is not difficult to see the problems that confront those responsible for the preparation of specifications covering the chemical and physical properties of tars for road purposes. Frequently it is suggested that the maximum and minimum limits of the several properties covered in a given specification are too wide, and might with advantage be drawn closer. Consideration of this, however, not only demands a knowledge of the effect of each stipulated limitation upon the other properties included, but also necessitates the systematic study of the material in service, to enable proper values to be assigned to the properties best suited for a particular type of construction. Generally speaking, it has been impossible to make a fair evaluation of the characteristics of the tars employed in different projects, owing to the variety of conditions under which they have been used. Consequently, it has been difficult to interpret the work that has been done, and to determine those characteristics in tars, which make some of more value than others in a particular type of construction.

Such progress that has been brought about in the qualities of road tar is reflected in the present British Standard Specifications.* Originally prepared by the British Road Tar Association, and subsequently published as British Standards, they represent the advances that have been made since the Road Board issued its first Specifications for tar in 1911. The Specifications provide for tar suitable for the surface treatment of roads, and the manufacture of tarmacadam laid by the cold, semi-hot or hot process. They are featured by increasing viscosity ranges in the order of the purposes named, with the other remaining properties grouped in a manner to give the required adhesiveness, penetration and durability.

* British Standard Specifications for Tars No. 1, 2 and 3, issued by the British Standards Institution, 28, Victoria Street, London, S.W.1

The binding or adhesive properties of tar make it particularly suitable for coating all classes of aggregate, and for application to all types of surfaces. The ease and facility with which tar wets a particular surface and retains the full value of its adhesive properties, while being gradually converted into a solid, is one of its most striking characteristics. This ensures a tenacious bond for the retention of aggregates, both in the admixed and applied state, with sufficient retardation in the setting properties of the tar to produce a completely cohesive mixture under compression. It is becoming increasingly recognised that this combination of properties is essential in a binder for the provision of non-skid road surfaces, and it is in this respect that tar has proved so successful. Unlike quick-setting binders, there is no loss of the value of the adhesive properties when a tar dressing is applied, and consequently, no difficulty is experienced in securing the retention of the stone chippings to form a mosaic surface safe for all classes of traffic.

The viscosity or consistency of tar is of value in determining its suitability for a given purpose, and affords some indication of its setting property. Factors which influence the rate of set are the temperature at which the binder is applied, the chilling effect of the road, and the nature of the aggregates. The cumulative effects of these circumstances will be greater in the case of surface treatment than for tarmacadam, as in the former case the tar is fully exposed to the influence of atmospheric agencies, while in the latter case it is practically immune from any attack. From this it will be seen that the control of the setting property of tar is largely dependent upon its initial viscosity, and the subsequent changes brought about by the conditions to which it is subjected. With a knowledge of all these factors, the viscosity of the tar can be adjusted to secure a reasonable degree of control for any type of construction.

The criticisms directed against the durability of tar are a legacy from the days when little or no care was taken in the preparation or selection of the material for road purposes. In addition to this the customary practice of annual tar spraying has given rise to the idea that the life of the binder is limited to this period. Such may have been the case in the past, but it does not hold good at the present time. Granted that there still may be cases where it is both necessary and advisable to renew the dressing every year, the author ventures to suggest that, in a large number of cases, this necessity can be more directly attributed to defects and weaknesses in the existing road than to any lack of properties in the binder. With the general improvement that has been brought about in the qualities of tars, greater durability can be looked for as evidenced by a number of practical road tests carried out in different parts of the country.

It may be gathered from what has been said that the progress of road tar technique has been one of steady growth, which has been brought about by repeated efforts to bring the standard of road making with tar abreast of the requirements of modern traffic conditions. Investigations completed by the British Road Tar Association during the last few years have done a great deal towards the general improvement of tar road construction, which is reflected in the high standard of work to be seen in all parts of the country. The Association

are fully conscious of the necessity to improve in every way possible the quality of road tar and its methods of application, and further improvements are envisaged by the investigations which are now in progress.

In pursuance of this policy, research is being directed into the chemical and physical properties of tars. The chemical examination of tars is concerned with the study of their chemical constituents, and the combination of those constituents which are considered to be important from the view point of road construction.

The physical examination of tars has as its object the correlation of physical properties with the mechanical behaviour of mixtures of tars and aggregates when used in road construction. Attention is also being given to standard methods of testing. On the more practical side, a number of experiments have been carried out in collaboration with the Ministry of Transport and Highway Authorities, which include the surface treatment of various types of roads with tar, and the laying of improved forms of tarmacadam.

The objects aimed at in these experiments are to obtain fuller information regarding the influence which the best constructional methods exert on the results to be obtained by tar, and to study the effects of such methods and the results obtained in practical road work. A prolonged investigation into the traffic bearing capacity of tarmacadam roads has shown the increased resistance of properly balanced mixtures of tar and aggregates to deformation under such stresses as are imposed upon the pavement by heavy traffic conditions. This has led to the development of tar concrete or hot-process tarmacadam, which differs principally from tarmacadam in the character of the aggregate and binder, and also in respect to the laying of the material, which is carried out in the heated state. This material has been tested under heavy traffic, and a variety of road conditions, with entirely satisfactory results.

As regards surface treatment, special attention has been given to the procedure to be adopted for dense and impervious types of roads. In special cases of this kind it may be necessary to depart from the customary practice in vogue and devise new methods in accordance with any particular features these roads may possess. A series of experiments employing different methods of treatment are now under observation, from which it is hoped much valuable information will be derived. The relation between the covering capacity of tars of varying consistency, and the most suitable gauge and quantity of gritting material are also being studied.

The much debated question of the toxic effect of tar on fish life is one that has been responsible for many conflicting opinions regarding the veracity of the allegations made. It was only natural, therefore, that this matter should be made the subject of investigation, if only to combat the attacks directed against tar in this respect. As a result of negotiations with the Ministry of Agriculture and Fisheries, a joint experiment was conducted on a selected length of road adjoining the Ministry's Experimental Station at Alresford, Hampshire, with a tar submitted by the British Road Tar Association. The experiment terminated after eighteen months with a result which leads the Association to think that this problem has

now been solved. The importance of this will be realised by the steps that will be taken shortly to make this special product available for all roads directly draining into fishing streams.

From the above it will be seen that the problems connected with the tar treatment of roads are being dealt with on a broad basis. The Association has so planned its investigations as to cover each of the many phases of road work. In this way it is hoped to obtain information which will be of value to all those concerned with the production and use of road tar. The work is of such a nature that so far it has led to non-spectacular but none the less significant improvements in the construction and maintenance of roads with tar. There can be little doubt, however, that the knowledge that has been steadily accumulated will ultimately lead to important developments. The British Road Tar Association hope through these various activities to continue rendering service to the road industry of Great Britain.

DISCUSSION.

MR. W. E. CONE, introducing his paper, said: The paper may be divided into three parts, the first of which deals with some of the factors which influence considerably the results obtained by the use of tar for the construction and maintenance of roads. In addition, the importance of keeping accurate records of all available data regarding the conditions under which tar is used is stressed, and by the scientific study of the material in service we shall be more able to determine just what particular property or combination of properties are most suitable for various types of construction.

The second part of the paper shows the difficulties that confront those responsible for the preparation of specifications covering the chemical and physical properties of tars for road purposes, in the absence of the data to which I have already referred. Such progress that has been brought about in the qualities of road tar is indicated by reference to the present British Standard Specifications for Tars No. 1, 2 and 3 together with a brief resume of their salient features.

Finally, I have endeavoured to give an outline of the steps that have been taken by the British Road Tar Association to bring the standard of roadmaking with tar abreast of the requirements of modern traffic conditions. From this it will be seen that the problems connected with the tar treatment of roads are being dealt with on a broad basis, and it is a matter of gratification that

the Association has had the helpful advice and collaboration of the Ministry of Transport and highways authorities in carrying out this work.

MR. WESTLAKE: The work of the surface dressing, the treatment of the repairing and the construction of roads, is subject to progressive advance in the same way as all other industries. Probably years ago a good many adopted rule of thumb methods of carrying on their work, but that is now, we hope, ancient history. Scientific and chemical control has really taken charge, and as a result we are getting better work all the way round.

The results of the work of the British Road Tar Association are ready for all those who want assistance in deciding what qualities of tar they should use for the various purposes for which they are required. If they will study the specifications now available and apply them in a proper manner, there is no doubt very improved results will be achieved beyond that which we were accustomed to a good many years ago, and will get rid of that criticism which Mr. Cone has referred to in his paper.

Now as to the application of the tar, sometimes in the course of my travels I come across instances where the chemical and scientific control in the use of the article, while probably the heads of the concerns who are responsible know all about it,

is not carried right down to the workmen. You cannot expect the result to be satisfactory under such circumstances. For instance it is not the practice everywhere to have thermometers so that the workman shall know to what temperature he is heating his material. Thermometers are getting more common, but I am sure very improved results will be obtained if you can always get temperature control right away down to the point on the road where the material is being used. The same thing applies to the use of wet chippings on the top of hot material.

Another point I should just like to mention here, is the recent development which has taken place to get non-skid roads by using a good sized hard stone chipping, and having put your hot tar down, to cover that dressing with a coating of the stones making a complete covering or carpet and then roll them in. That practice is growing and has been developed in the past few years very considerably, and in many places in the country is giving very great satisfaction. That progress has been able to be maintained simply because of the improvements in the quality of the binders which are available now through the research of this Association, and I should like to conclude by congratulating Mr. Cone and the Association on their work, and to mention the very great assistance they have given to the local authorities and to their chief officials throughout the country. I hope that the co-operation which has been begun in recent years will be cemented.

MR. R. G. CLARRY, M.P., (*Chairman, British Road Tar Association*) said: The Association are most anxious to co-operate in every way with road engineers and surveyors. I think you will agree with me that during the past few years there has been a very marked improvement in the quality of tar supplied in all parts of the country. Greater attention has been paid to it both by producers and by distillers, and if there is any criticism of the general situation to-day, I would like to emphasise that it is necessary for all the factors that go to make up a satisfactory job, whether it is tarmacadam or tar spraying, to be suitable and satisfactory. The actual quality of the tar is only one of them, and there may be at least seven or eight other factors. I think it is very

desirable that all those factors move together towards progress and improvement. Such factors as the quality of the materials supplied other than tar, its grading, its condition, the question of foundation, and so on, are all worthy of at least equal attention to the quality of the tar itself. I believe there is a feeling in that direction in different parts of the country where I have had the opportunity of going in connection with the British Road Tar Association. There seems to be a very lively appreciation of the necessity for all the factors making for development and progress to move forward uniformly, and I think if that is done there will be even fewer complaints than there are now of quality of tar. In the complaints that are received or heard of now-a-days, when they are investigated it is found, as often as not, that it is not the actual quality of the tar, but one or other of the factors which have failed and accounts for an unsatisfactory job.

MR. READ: As one of the surveyors whose misfortune it is to answer for the effect of tar sometimes, I cannot help noticing that in this paper what seems to me an important aspect of the tar has been omitted altogether—that is the difference between a road that has been tarred and a road which you are tarring for the first time.

The writer of the paper seems to me to assume that the tar acts as a matrix. I think it does not. Most of our roads have been tarred for years, or else have been made up with tarmacadam or asphalt, and the most useful function of the tar is to act as a temporary solvent of the surface that is already there, so that when you put your roller over the chippings they go well in. Now the tar, if it is not protected by chippings—and of course chippings do disappear—becomes filled with a fine dust, and you cannot prevent your tar becoming slippery, whatever you do with it, and so until next year's chippings go into it, it has got to be gritted occasionally. When your roll it, with the hot solvent on your new chippings, if they are big enough, go well in and form a new surface. But if you have cold weather and a non-tarred road, and you use a tar that is soft enough to act as a flux, it does not hold your chippings until it gets solid, and if there is any traffic it turns them over, and once the chipping is turned over (tar

upwards) it has gone, because it is picked up. We want totally different tars for old tarred roads and new tarred roads, and their qualities could not be the same. On a new tarred road you must have a tar which sets quickly and hard, and on the old road you want rather a soft tar.

MR. H. L. HOLTON: I note that there has been considerable work done on a tar in which the toxic properties are reduced so far as not to be of any ill effect. I notice that steps will be taken shortly to make this special product available. I would like to ask the speaker whether that will be published in another of the standard specifications, or whether it will be issued privately.

Is there a tendency to-day to have a tar bitumen mixture, or is the tendency now that we have got the standard tars for tar only to be used?

MR. W. E. CONE replying: With regard to Mr. Reid's question, I thought perhaps it was answered on the second page of the paper where I stated: "Similarly, we often find in the surface treatment of roads that the selected material is expected to give the same effective results irrespective of the nature and constitution of the roads to be treated." I think the only inference to be drawn from those remarks is that it is essential for certain types of roads that different grades of tar must of necessity be used, having regard to whether they are waterbound, tarmacadam, or other types of bituminous surfacings. I think Mr. Reid and myself will be in agreement on that point. I am not in agreement with Mr. Reid, however, when he suggests that tar does not hold chippings on roads treated for the first

time. There are a number of roads which we have had under observation, where we have experienced no difficulty at all with the first treatment of tar in securing the retention of the gritting material. I think the reason for this is that present day qualities of road tar are considerably in advance of those supplied in the past, and the material is selected with greater care. It may be that the use of too fluid tars has been responsible for the trouble to which Mr. Reid has referred.

I am also grateful for Mr. Holton's appreciative remarks of the work of the British Road Tar Association. It is very gratifying to know that there is recognition of what we are doing for the industry that is responsible for the preparation of road tar, and of our contribution to the improvement of road tar technique. His question as to tar bitumen mixtures is not easy to answer, because in many instances the suppliers of prepared tar are often asked by the highway authorities for tar bitumen mixtures, and as in the main a tar bitumen mixture incorporates 75 per cent., possibly to 80 and 85 per cent., of tar, you can well imagine he does not want to lose that business. At the same time I think there is a growing appreciation that tar alone will in fact, when purchased to standard specification and correctly applied, do all those things in the construction and maintenance of roads that a tar bitumen mixture will do, and I think if I may take the long view, we shall see in the future an even greater appreciation of the use of 100 per cent. tar with a consequent reduction in the amount of bitumen used for that purpose.

CONFERENCE

Under the joint auspices of the Association of Public Lighting Engineers and the Institution of Gas Engineers.

TUESDAY, 14th NOVEMBER, at 3.0 p.m.

MR. E. M. SEVERN (*President of the Association of Public Lighting Engineers*), in the Chair.

The following Paper was taken as read:—

The Lighting of Arterial Roads by Gas.

BY

A. M. BELL, A.M.Inst.GasE.

(*Public Lighting Superintendent, Tottenham and District Gas Company.*)

IN opening my paper I wish to make it perfectly clear that I do not intend to delve into technicalities, but rather try and set out in detail some of the many obstacles with which a public lighting engineer has to contend in solving the problem of efficient lighting for our great arterial roads at the minimum expense to the ratepayers. In my endeavour to make my points clear, I will briefly run over the history of public lighting, which I trust will help to emphasise the various points which I intend to stress.

Approximately 200 years ago, oil lamps and candles or rushlights were the only means of street lighting, and these lamps by law had to be provided and maintained by private owners under a severe penalty for default. To this day some of the mountings to carry these lamps may be seen over gateways or on brackets attached to the walls of some of our older buildings; some of these were very graceful and of pleasing designs. At about this time there was another agent of street lighting, namely, the "link boys" who were employed to guide pedestrians

to their destinations, and during this period it must be remembered how prevalent were footpads and ruffians. Just over 100 years ago came the first great stride towards making our streets safe for law abiding citizens, and this was the utilisation of gas for street lighting.

In 1812, Pall Mall was lighted, and we are told that "people flocked to see the wonderful new gas lamps." It was not, however, until the year 1880, that we hear of the first gas mantles being used. However, it was realised that street lighting was essential to the community, not only for the benefit of the users of the roads, but also as a protective measure—against footpads and robbers. Gas had been in use for practically 73 years when the electric lamp came into the field.

To-day some of our great thoroughfares can aptly be described as magnificently lighted, some good, some bad, some deplorable and others not lighted at all; nevertheless, in England it is in every case the ratepayers who foot the bills for street lighting. Now let me turn to America, where in some of their famous streets magnificent and decorative street lighting is provided by voluntary taxation of the owners of properties fronting the streets. I should like to emphasise these points as I shall refer to them later.

So much for the brief history and outline of some public lighting features, and now let me turn to the question of arterial roads. Arterial roads as we know them are constructed for specific purposes, namely, to make short travelling distances between towns, to divert traffic from busy shopping centres, or to byepass towns. In my paper, I am going to single out one of these arteries, namely, The Great Cambridge Arterial Road which runs through the centre of the area of supply of the undertaking with which I am happily connected, and for the remainder of my paper I shall refer to this artery as "The Road."

The Road was opened to traffic approximately ten years ago. The overall width is made up as follows: 16 ft. footway, 24 ft. carriageway, 10 ft. grass verge, another 24 ft. carriageway and another 16 ft. footway. The down road has not yet been completed and is at present a grass sward. The Road passes through the areas of five local authorities and two counties, and in all is 10½ miles in length, cut in places by main and secondary cross roads, and in one place by the North Circular Road. When The Road was first opened one could traverse the whole length practically without passing a house, factory or building of any sort, and certainly no street lamps. Traffic was extremely light and there was no necessity for point policemen. It was not long before the existence of The Road became widely known and gradually the traffic increased and house building commenced. Then it became necessary for point policemen at various junctions and a few street lamps were erected at dangerous crossings. The Road grew, more houses were erected, then a Council housing estate and some factories were built, and as was only to be expected, accidents occurred. Sample gas and electric lamps were erected for the Council's inspection in one area, but it was not until 1927 that any public lighting scheme matured, this was carried out in Tottenham, where twenty-seven 6-light upright fixing gas lamps were erected on 14 ft. columns, carrying the light

source to 16 ft. above ground level, the standards being spaced 100 feet apart in line on the grass verge in the centre of the road. It was shortly after this time that trees were planted 60 ft. apart on each footway throughout the length of The Road. Traffic had now increased enormously, and in a comparatively short stretch it became necessary for point policemen to be placed at four crossings. The illumination of these policemen was one of the first real difficulties to be tackled, and in three instances this was overcome by erecting two gas lamps at each junction, each lamp fitted with a bullseye which directed a beam of light on to the officer, but in the fourth case we experienced trouble. In the first three cases there were buildings skirting the road, but in the latter, which is at the junction of five roads, conditions were different, for here there were no buildings at all. Lamps were erected, positions altered, spot lights attached and many experiments made, but the policeman was still not visible at any reasonable distance, for his dark uniform was lost in the dark background. The trouble was obvious, but how to overcome it was another matter. I endeavoured to persuade the owner of some vacant land to give permission for an advertising hoarding to be erected which would act as a background for the policeman, but such permission would not be granted. At big expense this great junction was altered, all roads were thrown open wide and an island refuge erected in each neck with a 10-light gas lamp and two bollards fitted with reflex boxes. This alteration tended to slow up the traffic at this point and make traffic control easier. It was at this time that another Council decided to light sections of the road in their area, which were skirted by houses, and extend the lighting as building proceeded. Traffic was by this time increasing rapidly and accidents numerous, in fact a first aid hut was erected, to which was attached a motor ambulance, and I understand that in one day the volunteers attended no less than seven separate accidents.

I have given the above details to show how rapidly conditions changed from the time when the road, practically deserted, wound peacefully through fields and open spaces, traversed by few and inhabited by none, to the present day when no less than 4,927 vehicles were officially recorded as having passed one point in 16 hours. Changes are still taking place, the point policemen previously mentioned have all been withdrawn and traffic operated signals have been installed in their places. The huge junction which cost so much to open up and widen is again being altered and the wide open roads are being narrowed for the construction of a gyratory traffic system. With the advent of this alteration one more Council has adopted gas lighting for the whole of its area and another completed the lighting of its section.

And now to sum up the evidence, as I have said before this road passes through five different Council areas, and the following details are interesting for comparison.

<i>Council.</i>	<i>Length of Road.</i>	<i>No. of Lamps required.</i>	<i>Population of Town.</i>	<i>Rateable Value.</i>
A	2,035 yards	63	158,800	£883,687
B	375 „	9	54,520	£457,673
C	4,700 „	101	78,800	£437,074
D	5,280 „	120	67,869	£505,869
E	5,715 „	130	14,651	£80,917

The Road is primarily used for vehicles, and as it bypasses all shopping centres, it cannot be said to bring trade to any neighbourhood. On one section only is it completely built upon. On section E there is practically no building at all, and it will be noticed that this Council, with the lowest rateable value, has the longest section of the road to light. This is an exceedingly heavy burden for the ratepayers in that district to bear, and emphasises the reasonableness of my contention, that in such cases the authority through whose area the road passes should receive some assistance in meeting the costs of lighting. The death roll of The Road is heavy, and surely this fact alone should emphasise the necessity of good and adequate street lighting. The local Councils are the lighting authorities and the ratepayers are expected to foot the bill for lighting a road which is of little or no interest to them.

I contend that good street lighting is as necessary and as important as any other Public Service, and is one of paramount assistance to the police in their work of maintaining law and order. The cost of installations and the annual expenditure cannot be borne to the same extent by a country town as it can by a wealthy city, neither can a comparatively few residents be expected to contribute by voluntary taxation a large sum, when they already pay for public services. I consider that all roads in the country should be graded, the necessary lighting correspondingly graded, and the expense of same paid out of a common fund to be contributed to by all local and county authorities, and to include a considerable contribution from the road fund.

To all intents and purposes the lighting of The Road so far is uniformly carried out by clock controlled 6-light No. 2 upright fixing low pressure gas lamps with mantles in staggered formation, erected on 14 ft. columns spaced 130 ft. apart in line in the centre of the road, the average ground illumination is 0.25 foot candles, the maximum 1.22 foot candles, and the minimum 0.055 foot candles, height spacing ratio 8.125—1 and the diversity factor 22.18. Class "F," B.S.I. Specification.

All important road junctions are illuminated by 10-light lamps of the same pattern and mounting height. The more recently fixed lamps are fitted with 24 inch diameter flat enamelled steel shades and multi-faced reflectors clipped on to the uprights. These latter attachments add considerably to the efficiency of the lighting. There has been considerable criticism of the lighting, it has frequently been said that it is too good and too lavish, also that the road is illuminated like a greyhound race track. However, in spite of everything I have never heard an adverse criticism. The light is soft with a total absence of glare, and in this connection I should like to mention how deceptive "light" is. As an instance I will refer to an experi-

ment which I have carried out on more than one occasion when taking people to inspect installations. After first inspecting lamps in a road lined with houses on both sides, and then inspecting a road with open fields on either side, the opinion expressed is always that the lighting of the street lined with houses is the better, when actually, as proved by the photometer, it is far from being the case. An installation in one street might be considered admirable, but an identical installation in another type of street would be considered poor. I have found that the average man in the street thinks that if he sees a glare, that it is a good light.

I now propose to touch on one or two details which must be considered when preparing a scheme for the lighting of an arterial road. Unfortunately, for the reasons stated above, in the majority of cases the first point is capital cost and annual charges—these two items as a matter of necessity must be cut down to the lowest possible figure. The next point is to look into the future and ascertain what buildings (if any) will be erected on either side of the road, and whether the road at some future date will have to be widened. If there is no possibility of shops or houses, a high grade of illumination must certainly be provided, for no aid from reflection or assistance from outside sources will be obtained.

Another necessity is uniformity of lighting over the whole length of the road for there is nothing so dangerous or trying to drivers than to run from a well lighted section into an unlighted black patch or into another section with a totally different scheme which may give bad visibility.

There are several pitfalls which must be guarded against. The chief of these I consider is sections of road lighted only on the inside of a bend. A dry section of road so lighted may not appear troublesome, but directly the road becomes wet we get specular reflection or streaks of reflected light running from the observer to each light source, and as the lights would be situated away from bend of road, the whole surface would appear to be black with no possible hope of reflection or silhouetting as an aid. To overcome this difficulty I say definitely, that however high or low the category of illumination may be, lamps placed on both sides of the road are necessary. This question again arises on highly polished road surfaces.

Now I am coming to a point on which I, personally, hold strong views, and this is that I consider the minimum height of the light source recommended under the B.S.I. specification is infinitely preferable for this type of road lighting on account of silhouetting, which although it should not be necessary, is to my mind a very great assistance to drivers of vehicles in rough weather, mist or fog.

Another difficulty with which a public lighting engineer has to contend is the presence of trees planted close to kerbs. On The Road trees were planted 60 ft. apart three feet in from the road face of the kerb. The trees are of the large type, namely, poplar, chestnut, etc., and in the few years that they have been planted, some have already grown from twenty to thirty feet high. In a section of The Road, in the early days, one of the Councils decided to have lamps erected on the footways, and the lighting was quite good, but the trees grew to such an extent that practically all road illumination was cut out and at considerable expense the

position of the lamps had to be moved to the centre of the middle grass strip.

Another common fault is to suspend a lamp in the centre of a road junction immediately over a policeman. This method is entirely wrong in itself, for the light from the lamp merely illuminates the policeman's helmet and the majority of the figure is in shadow. It is agreed that a lamp suspended over the centre of a wide road junction is certainly very advantageous as a means of obtaining uniformity of road illumination, but it is necessary to have the assistance of side lights to illuminate a point policeman. Here again a screen or background is a great aid.

On The Road there are a large number of signs such as "Cross Roads," etc. If such signs are considered necessary by day, how much more necessary is it that they should be illuminated by night? If a road is not lighted at all, I contend that it is imperative that at least every road sign should be illuminated, and I have used every endeavour to further this point, but here again comes the question of the responsibilities of authorities; so far I have only been successful in a very few cases, although it is a subject which I have been trying to emphasise for years.

The lighting of refuges and bollards or guard posts is another item which has received our special attention. A refuge is an obstruction deliberately placed in a thoroughfare, and for this reason alone the greatest care must be taken in selecting the means for lighting it. The bollards should also be illuminated to give every assistance to drivers of vehicles, and reflex signs can be adopted with great advantage.

Whilst considering the subject of refuge lighting I would like to mention a few details which I consider should receive every attention in the lighting of a "roundabout" or gyratory system. In a scheme of this nature many signs or directional notices such as "Keep Left" or "Turn Left" are necessary, and on most arterial roads the centre island, which although guarded by railings, bears no further obstruction. All lights should be shaded from every point of visibility other than in the road or island refuges, thus leaving the illuminated signs clear and distinct.

Until comparatively a short time ago dark patches were visible between lighting units. These dark patches are in reality contrasts of light between the maximum and minimum road illuminations. To overcome this unevenness of illumination, reflectors or refractors are being found of great assistance, but care must be exercised in the selection of one or the other or of the combination of both, in avoiding too directive lighting which will produce "spot light" effects. There is nothing worse to a driver than having to drive through a road and to constantly have his attention distracted by flashes of light, especially in bad weather when windscreens are wet and each drop of water acts as a bullseye to momentarily blind the vision of a driver at each flash. Reflectors and/or refractors when properly applied are of very great assistance in obtaining a more even distribution of light.

The question of maintenance is another matter of considerable importance.

Nothing is more necessary in street lighting than the very highest degree of maintenance service. Nothing does more to harm the merits of either gas or electricity than bad maintenance. A drop of 20 per cent. in efficiency may easily occur by a comparatively small amount of dust and dirt on glass or reflectors, whilst anything up to 50 per cent. efficiency drop may be experienced after neglect of cleaning for a period of a few weeks. Dirty glass or dirty reflectors ruin the efficiency of any installation. Good maintenance pays for itself. Whilst on the subject of maintenance, there is one point which is not widely known, which is that a gas mantle instead of diminishing in illuminating power often actually increases in efficiency up to 1,000 lighting hours, and so with good maintenance a gas installation should not deteriorate.

The technique of modern street lighting is becoming exceedingly high, and it is not only necessary, but essential that every public lighting engineer should be thoroughly experienced in all its branches, not merely conversant with any one form of illuminant, but trained to the technical and practical possibilities of each in the effort to attain a much higher standard of street lighting, which is so necessary in these days of fast moving traffic.

I have tried to be impartial in every way and have made no comparisons between any forms of road illumination. Fair competition is good for one and all, and undoubtedly, the great strides which street lighting has made have been speeded up by competition to the benefit of the industries concerned and the public in general.

I thank the Public Works, Roads and Transport Congress, The Institution of Gas Engineers, and the Association of Public Lighting Engineers for the honour which they have conferred upon me in requesting me to give some notes on arterial road lighting, which I have tried to compile in a comprehensive manner primarily for the guidance of the numerous smaller local authorities and lighting undertakings, and I trust that my remarks may be of assistance to them in overcoming a few difficulties which might not otherwise have been foreseen.

DISCUSSION.

MR. BELL gave an abstract of his Paper and showed a number of lantern slides.

MR. HAROLD DAVIES (*Chesterfield*), opening the discussion, said: I think we can assume that the technicalities in connection with the lighting of arterial roads are not particularly difficult. My concern is the finding of the money to carry out this work, and I should be very interested to hear from the Author of the Paper exactly what treatment he has received from the County Councils and other authorities with whom he has come in contact. My own experience has been rather a sad one. Arterial roads, as you know, are made by County Councils, and the lighting of them is under the control of the different authorities through whose areas the roads go. Very frequently we have to deal with Parish Councils that have no lighting powers whatever, and my experience in approaching Parish Councils is that so long as there is no rateable value on these roads we never get public lighting on them. I think we should have some different method of approach so far as the lighting of public roads is concerned, either through the Ministry of Transport or through the County authorities. Until that is the case we shall never get much further forward.

You will notice in the Paper that the development of lighting on the road described has come about principally because property has been built and rateable value has accrued. We find that these roads are not lit until there is sufficient property to give a reasonable amount of rateable value to assist the authorities in developing the roads from a public lighting point of view.

I recently had to deal with a small Parish Council in connection with this matter, and immediately I came in contact with the gentlemen who might be described as the farmer type. You will not get very far with that type of man. He wants to get something for nothing, and he is willing to have the roads lighted if he does not have to pay anything, but if he has to pay, even if it is only a penny rate, he will not do it. This particular Parish Council were quite willing to have the lights on the road provided that the transport authority, which happened to be my own Corporation, would pay the cost. They said: "You run your 'buses there

and you should put a lamp at every point where the 'buses stop." There may be something in that, but we must not forget that the 'buses there are primarily for the convenience of the people living in that particular district. The ratepayers in that district would not provide a penny towards the cost of lighting, and the roads have had no lighting from that day to this. I do not think we shall ever get anything done at all until they have a different mentality and until we have some different system of allocating an amount to be spent on arterial road lighting.

MR. G. H. WILSON (*Research Laboratories of the General Electric Company, Wembley*), whose remarks were illustrated by lantern slides, said: With regard to the placing and spacing of the posts, in my experience the solution that Mr. Bell has put forward will never be a really satisfactory one, not because it is gas lighting, but because of the arrangement of the posts. My colleagues and I have had an opportunity of carrying out a full scale experiment, on an installation of the new electric discharge lamps, with regard to changing the arrangement of the posts, and the effects were most striking.

This slide shows an installation where the spacing was 139 ft. as compared with 130 ft. on the Great Cambridge Road. The road width was 30 ft. and the mounting height 25 ft. Although the right hand side of the road is fairly well defined, you can see very little on the left curve. The minimum illumination on the left side of the road was three times that on the Great Cambridge Road. I think that in the case of an arterial road you should have such lighting that a motorist feels confident that he can see in the distance even a cat crossing the road. In this installation you could not feel that confidence as regards the left hand side of the road.

We then switched on the other lamps, and the other side of the street became bright, and you could see objects silhouetted against it. That, of course, doubled the load and the running cost. The experiment was therefore tried of turning out every other two lamps.

The installation had still the same characteristic of two lanes of light, so that

the kerbs were well defined. If you were driving on the near side and coming up the road or going down it, you would still have bright streaks enabling you to see well into the distance.

My experience is very definitely that a double side installation, other things being equal, always gives better visibility than single side mounting, and I think central suspension comes next.

It is a great pity that we have not a test for this visibility. As I have said, I think one criterion is that you should be able to see easily, with confidence, small objects in the distance, and with that in mind we carried out some tests with cats in the road. We found that even the best trained cats would not do what we wanted, so we had some cats made up. (*Models produced.*) You see that one is black, with a 5 per cent. reflection factor, and the other is grey, with a 15 per cent. reflection factor. We stood these in the road and generally explored the ease with which we could see them.

When the cats were only about 40 yards away from the observer, they were clearly silhouetted against the background. We then put them 100 yards away, and you could see them quite clearly. In the photograph they are standing in front of a bright streak in the road, and the road is not as bright in the middle. It never will be with side mounting. When they were in the middle they could still be seen, although the grey one had very nearly disappeared, because the illumination on it was so high that its brightness was very nearly the same as that of the background.

We also measured the diversity of brightness in the installation, which, in my opinion, is a very important point.

The maximum diversity from the brightest part to the darkest was only $5\frac{1}{2}$ to 1, which is really a good uniformity of brightness for a street lighting installation.

The last point I wish to make is about the road surface reflection characteristics. The road I have described has a large aggregate bitumen surface, is in my experience quite skid-free, and has very valuable reflection properties which produce this high brightness. The authority saw fit to tar and sand part of the road, for what reason I am not quite certain, but the effect on the lighting was most marked. The abrupt black bar

seen in the photograph and the darkness beyond are due to tarring and sanding that part of the road surface. Although the total reflection factor from the road—its whiteness—has increased, its brightness at night and the ease with which you can see have decreased very materially. I think that is a very important point, and I would urge that authorities responsible should make sure, before treating a road in a way that will impair the lighting, whether it is really necessary to treat it thus.

MR. J. M. WALDRAM (*General Electric Company, Wembley*), whose remarks were illustrated by lantern slides, said: For some time past now street engineers, I think, have been realising more and more that the brightness of a road, rather than the illumination which falls upon it, is an important factor, and that, if the road is dark, although the illumination on it may be high, one is not able to see clearly.

We have a model on which we have tried some experiments, and in this way we have a road that can do something which even the Great Cambridge Road cannot do, namely, bend round to order. You can actually bend the road from side to side and see that, although the illumination remains unchanged, when the lamps are on the inside of the curve you cannot see clearly. That is a point which Mr. Bell has made in his Paper.

The question of the height of the posts is referred to in the Paper, and, if I understand Mr. Bell correctly, he expresses the opinion that the minimum height recommended in the British Standard Specification is preferable to the greater heights which are recommended in that Specification. If that is so I should like to join issue with him on that point. If he works out the position of the streaks to which he has referred, and takes into account their usual length and also the point he has mentioned, that the line of light sources going away to infinity, appears to disappear at the same point as the road, he will find that height is an advantage. If you have very low posts on a wide road, you tend to get a large broad streak in the middle of the road, which is dark, and you cannot do anything with it. As you increase the height of the posts, the width of the dark streak in the middle of the road will diminish. I think Mr. Bell will find that there is an advantage

in increasing the height from that point of view, quite apart from the fact that with greater height one can keep the same spacing ratio and increase the spacing with fewer posts.

With regard to the treatment of the surface, to which Mr. Wilson has referred, we have notice the variation which different types of surfaces show both in the length and in the width of the street which one can see.

This slide shows Farringdon Street, photographed wet and dry. You can see in one photograph the entirely different character of the patch on the road as compared with the other. I draw your attention particularly to the streak running across the road, due to diffused reflection from the surface, which has disappeared in the other photograph. There are some surfaces—I do not know what they are—which do not seem to change their appearance so much when they are wet.

This slide shows another surface in which the change is even more. This was a really wet road; it was pouring with rain when we took the photograph. The streaks are extremely narrow. It is difficult to do very much with such a surface, but there are some aggregates used in road making which do not become so shiny when they are wet as do some of the highly polished surfaces which one finds in towns. It would be a good thing if those responsible for dressing the roads would give particular attention to this point. It has been suggested at various times that the use of a white aggregate of some kind, or some material with white chippings in it, might have some advantage, but I do not think that is necessarily so. I know one case of a road where the whiteness of the surface has been increased, and so far as the headlights of a car are concerned it appears much whiter, but under street lighting it appears black, because it is not the whiteness of the road which is of such importance as the specular reflection which gives rise to the streaks. I hope that particular attention will be given to this point. In using a road it is as important to be able to see clearly as to be able to avoid skidding.

MR. BYASS (*Bridlington*): I belong to a seaside town, and we are trying to improve a great many of our main roads in that town by planting trees. In many of our towns there are no grass verges where we can put

our lamps. The problem is a very difficult one, and my own town is experimenting now, and will continue to do so during next summer, to try to improve its street lighting. Of course, I quite understand the speakers this afternoon refer to main roads, but I do not want this great meeting of practical people to forget those who do not live on the main roads, and who require some real help.

I join issue with the gentleman who referred to the farmers in the villages wanting something for nothing. I myself lived for many years miles away from any town, and the bulk of the farmers are outside the villages; they are not near the village street, but they have to pay for drainage and all kinds of other things, and what do they get for it personally? Nothing. You must look at the matter from their standpoint. There are thousands of villages in this country where a penny rate does not produce £20. The main roads do go through the villages, but the bulk of the farmers are outside the villages. People in the country districts are trying to help to solve the problem of street lighting, and, as one who has spent the greater part of his life in the villages, I do protest against the statement that farmers want something for nothing.

MR. W. M. ROGERSON (*Worsley*): I should like to have some guidance from the people in the London area with respect to the lighting of new main arterial roads. The matter is being discussed now in my district from the point of view of lighting the new arterial road between Manchester and Liverpool. We are often told by motorists that an arterial road of this character is much better unlit than lit, from the motorist's point of view.

I was very interested in the remarks of Mr. Davies, of Chesterfield, with regard to the towns which run motor 'bus services from village to village. He referred to the fact that the people in the villages thought that Chesterfield should light the road because they ran 'buses on it. I suggest that there is something in that. The town is taking money out of the villages and country districts, and it ought to contribute to the cost of lighting those roads that require lighting. The big towns are getting custom from the villages and the seaside resorts are getting something from the urban districts and the rural districts. We are both

providing the roads and lighting the roads for the purpose of taking people into the towns.

We are told that the County Councils are not the lighting authorities and therefore cannot light the roads. In the case of the road to which I have referred, there are three miles of it running through our urban district. There is an abundance of complaints from people in Liverpool, Manchester, Salford and other adjacent towns, about the lighting of the road, and we are told that we are responsible. So far as I am concerned, I am not prepared to recommend my authority to light three miles of that road, seeing that we are not going to get any return from it and it has not been constructed for our particular purposes. We shall not even get rateable value from each side of the part that goes through our district, for the simple reason that there is no available building land on either side of the road. If we paid for the lighting of the road we should be doing something for the benefit of Manchester, Liverpool, Salford and other places, and get no return for it.

I should like to know whether there is any lighting needed on these roads; perhaps someone can tell me whether it is necessary at all, because in going round the Exhibition what do we find? We find bull's-eyes ready to put in the kerbs and other lights for the motorists, and if we have to put those bull's-eyes every few yards on these main roads it is going to take a penny rate from the smaller districts.

MR. H. W. GREGORY (*North Metropolitan Electric Supply Company, Wembley*): I should like to mention first the points on which I agree with Mr. Bell. His conclusion that the best light is obtained by placing lamps on both sides of the road, as distinct from lighting the road by centrally suspended lamps, I am sure is a thoroughly correct conclusion. I think Sir Malcolm Campbell has made one or two observations in the course of the last year or two, in the Press and elsewhere, advocating the lighting of roads by central suspension, but I cannot help thinking that he arrived at that conclusion in reference to an arterial road, where the obstructions are few and where the speed of the vehicle is fairly high. I think the practical difficulties in connection with the

system of centrally suspended lights are such that it cannot be regarded as the best system. Apart from the increase in the capital expenditure involved in the case of certain installations there are much greater difficulties in maintenance, and I think the fact that such a system requires two supports is enough to put it out of court. The column supporting street lamps in any road form an obstruction on the thoroughfare, and the number of collisions that take place is undoubtedly greater than is generally appreciated. In the case of a suburban area it would not be an exaggeration to say that there are six collisions per annum for every thousand columns. From that point of view alone, a system which requires double the number of columns must be put out of consideration.

I think the great importance of the road surface in giving visibility cannot be stressed too much, and I suggest that experiments should be carried out to ascertain the best dusting medium for use when tarring roads and the best type of surface to give us the specular reflections that we require and also the silhouette effect, which is bound up with the type of road surface.

I cannot agree with Mr. Bell in his conclusions with regard to the mounting height of the lamps. The fact that in the 1927 British Standards Institution's Specification for street lighting the glare effect from a given installation was a definite function of its mounting height is, I think, sufficient to suggest that Mr. Bell is rather on the wrong track when he advocates the low mounting height. From experiments I have carried out, it seems to me that the silhouette effect is greatly assisted when the mounting height is considerable. Furthermore, when cruising at a fair speed on an arterial road, which is itself a high speed road, of course one keeps one's eye on anything between, say, a hundred yards and even a quarter of a mile ahead. If one is on the lookout for side turnings, one does have to keep one's eye wavering backwards and forwards for a very considerable distance in front of the car, and, where the mounting height is high, one gets the benefit of silhouettes from the distant lamps, which one does not get to anything like the same extent when the lamps are placed at a lower height and where the image of the silhouette and the light

source itself converge together into such a narrow streak that the two are imperceptible.

I do not quite understand the statement towards the end of the Paper with regard to the increasing efficiency of the light source. It may be that the Author refers to the efficiency of the lumen output per cubic foot of gas, say. That efficiency may increase if the amount of gas passing through the burner is considerably less as time goes on. The lighting authority, however, is not concerned with that but is concerned with the actual total lumen output on the road.

There is no reference in the Paper to the modern type of fitting giving what one might call, for want of a better word, a uni-directional effect of lighting with the traffic stream. I think a great deal more will come of that type of lighting than we have appreciated up to now, particularly in connection with arterial roads. An arterial road begins in an undeveloped state, and one can start with a certain degree of illumination on that road and, if one has an installation which will enable it to be done, the illumination can be augmented at a later date, when development takes place along the road. I think it will be found that, with a uni-directional type of lighting, such a conformation of the lighting units can be arranged that not only will give excellent visibility in the half stage of lighting but can easily be strengthened up when the time arrives to give the full degree of lighting.

MR. F. C. SMITH (*Gas, Light and Coke Company, London*): The remarks of Mr. Wilson and Mr. Waldram perhaps touched on two factors, and two factors only, which do influence visibility. I think both those gentlemen would agree with me that horizontal illumination as such is not of necessity a criterion of good visibility, although I do not think either of them would be inclined to dismiss it as being altogether irrelevant. The fact is that we do not know the weight to attach to these various factors.

I am not prepared to contradict Mr. Wilson's findings; I am only prepared to say that I think possibly we have not gone quite far enough. If I understand Mr. Wilson aright, he considers that equality of brightness is to be aimed at. I am not at all sure that that conclusion is correct.

We have been fortunate in securing a

certain road in London where the Town Council have been (may I say?) enlightened enough to allow us to carry out experimental work on a portion of the road, provided we always maintain a given standard for the horizontal illumination. We therefore propose to conduct experiments, and we hope to be able to consider some of the other factors which concern visibility.

I was very interested in Mr. Waldram's remarks in regard to the different appearance of various aggregates in daylight and night time conditions. He would readily agree, I am sure, that the appearance under night light must be related with the spectrum of the particular light source under which you see the road. I do not think there can be any doubt at all that the colour of the light must have some influence on the appearance of the aggregates at night.

Both Mr. Wilson and Mr. Waldram have done a great deal of work with the object of solving this pressing problem of increased visibility. While agreeing with a good deal of what they have said, I believe there is a great deal more still to be done, and perhaps when we know more about the subject we may be inclined to change some of the views that we hold rather strongly at the present moment.

Mr. Bell suggests in his Paper that the illuminating power of gas mantles often increases with time, and I think it may interest you to know that there is such an increase for a limited period of time, which may easily be from 100 to 200 hours, and then a very gradual decrease.

I believe that we shall have a specification for mantles in the near future, figures which will enable us to say quite clearly the performance to be anticipated from mantles satisfying the specification.

COLONEL OAKES: I think you may be interested in a few facts and figures which emerge from an investigation into fatal road accidents which the National Safety First Association undertook last year covering the period July to December. It was endeavoured to obtain as much information as possible with regard to the illumination at those points where fatal road accidents occurred during hours of darkness. The source of our information was Press reports of coroners' inquests, and we were careful not to make any definite record of the lighting conditions

except in those cases in which there was no conflict of evidence.

Altogether we investigated some 3,029 accidents, of which 1,066 occurred during hours of darkness. In 604 of these 1,066 cases there was no evidence as to the lighting. Presumably, therefore, it was good, or there was no artificial lighting, and in any case the poor lighting or the absence of lighting did not directly affect the accident. In 130 cases there was evidence of good artificial lighting. Of the remaining 332 cases—that is approximately one-third of those which occurred during the hours of darkness—157 occurred where the artificial lighting was poor and 175 where there was no artificial lighting at all. I think it is not an unreasonable assumption that some of the lives lost would have been saved if there had been better lighting at these points.

Mr. Bell's plea for uniformity of lighting on a road is, I think, one which should be supported by all road users, whether pedestrians, cyclists or motorists. I think inferior lighting is worse than no lighting at all.

MR. L. T. MINCHIN (*Gas Light and Coke Company*): In connection with the question of even brightness on a road, I feel that Mr. Wilson rather spoiled his case by using cats for the purpose of his experiments. A cat is a very small object and can easily be within a patch of the road which is of even brightness, whereas a man standing up against an ordinary background will either have a light background to his feet and a dark background to his head or *vice versa*. Consequently I think the main argument for even brightness which has been put forward, that is to say, there will be a certain position in which the brightness of objects and background will be equal, hardly applies to an object of the size of a man, which is, after all, the chief thing we want to avoid. Even if the brightness does vary, as it always does, of course, very markedly from place to place, the effect being a series of streaks, I think you will find it nearly always happens in practice that either the head or the feet of a man are in silhouette, though of course, it is quite possible that an animal of the size of a cat could easily be lost in a single patch.

With regard to the effect of a very small amount of lighting as opposed to none at all, it seems to me that the chief point about

that is that it reduces the glare effect of the headlights used on motor cars. It is an interesting point whether it is better to have an arterial road lighted by infrequent lamps or not lighted at all. I wish to suggest that it is worth while having lamps infrequently placed, for this reason, that the added brightness decreases considerably the glare effect. You may remember that, in a paper read some years ago before the Society of Illuminating Engineers, Mr. Stiles pointed out that even a very low class illumination such as Class H of the B.S.I. specification would reduce the glare effect of a motor headlight to about one-quarter its normal value, i.e., its value if the road was completely dark. It is true that the lamps do not enable you to see anything, but I think they do raise the general level of brightness and therefore reduce the glare effect of the headlamps.

MR. W. J. JONES (*Electric Lamp Manufacturers' Association*): This meeting is being held under the auspices of the Association of Public Lighting Engineers and the Institution of Gas Engineers, and I think that a Congress of this character should also include some reference to the other method of lighting. It seems to me that those interested in that other method of lighting should certainly have been invited to this meeting, particularly when one bears in mind that no less than 40 per cent. of the street lighting in this country is already electric.

I have watched Mr. Bell's methods in North London with very great interest for a number of years, and I have been very interested in the excellent work that he is doing in the lighting of the roads in his area.

I do not think it is sound practice to try to do two things at once with street lighting. If you try to light up a traffic signal from your street lamp, I think invariably the traffic signal is unsuitably lighted or the street lighting suffers.

With regard to lighting on one side of the road, I am surprised that neither Mr. Bell nor any speaker in the discussion has referred to the temporary measure which may be adopted of having very long bracket arms, so as to bring the light source more over the centre of the road. That is a temporary method of improving the situation until it is possible to have lighting on both sides

of the road. I had an opportunity recently of examining in Liverpool similar roads to the Great Cambridge Road, and the engineer there frankly admitted that it would be desirable to have lighting on the opposite side of the road at the earliest opportunity.

The last point I want to mention is in connection with the lighting of policemen. My impression is that the ordinary method of spot lighting is unsatisfactory in the majority of instances. It depends much more on the bulk of the policeman than on the size of his arms. I agree with Mr. Bell that it is desirable to flood from the side, and I would suggest flooding a considerable area, so as to keep that large silhouette effect.

MR. S. B. LANGLANDS (*Glasgow*): With regard to arterial roads and their lighting, I submit once and for all this is a national question and not a question for each little individual authority. If the Ministry of Transport recognise arterial roads as national roads, why do not they recognise the necessity for lighting them nationally? That is bound to come.

Colonel Oakes has claimed that the death roll from accidents is less on welllighted roads. That has not been my experience. We have certain arterial roads in Glasgow which are specially well lighted, but I cannot say that those have the smallest death roll. When there is very good illumination the motorist usually puts his foot on the accelerator. We were carrying out a test one night in the middle of the road, and our lives were in jeopardy all the time, owing to the speed of the motor 'buses, motor cars and motor cycles, the motor cycles often with pillion riders on them.

Reference has been made to road surfaces. I had the privilege of reading a paper before the Municipal and County Engineers on that subject, and we showed slides of the work we had done and stated the conclusions at which we had arrived. A question has been asked this morning as to the best road surface, and I should like to say that we obtained the best results with a grey nidded set, closely packed together. Our photographs are available to anyone who is interested in the matter, and I would also refer them to the paper we presented to the Municipal and County Engineers about a year ago.

MR. A. M. BELL, in reply, said: With regard to the cost of lighting arterial roads,

so far, in our areas the local authorities have naturally provided the lighting. Many deputations have been sent to the Ministry but without success, and eventually the local authorities have carried out the work at their own expense.

Mr. Wilson raised the question of staggered lighting, which he said he considered much better than lamps in line in the centre of the road. Personally I agree with him, but there again the question of cost comes in. The cost is doubled immediately if you have twice the number of lamps, or, if you stagger your existing lamps, you are doing so for one side of the road only, and when the other side of the road is developed you have the cost to meet again.

Mr. Waldram raised the question of the height of the lamps and said he considered it far better to have higher mountings. I agree with him in the case of a straight road and a road which is lined with houses, but I do not agree with him in the case of the particular road with which I have dealt. It is true that part of the road is lined with houses and shops, and in one of the slides you saw some factories, but on the greater part of the road there is nothing of that sort at all; there are simply open fields on either side. In addition to that, the road is not definitely straight; it certainly winds. In a long straight section I would say the heights should be greater, but in winding sections where there is no background I would say definitely they should be kept down to the minimum allowed by the British Standards Specification. We have tried various mounting heights, and the height of our light source is 16 ft.

Mr. Byass raised the question of the best form of lighting when there are trees on the side of the road. I should certainly advise the use of lamps with bracket arms or centrally suspended lamps. He also emphasised the cost of lighting, and I am with him there entirely; I have emphasised that point pretty strongly in my Paper.

Mr. Rogerson asked whether arterial roads should be lit at all. My point is that it all depends on the type of the arterial road, and for what purpose it is used. If it is used chiefly for traffic, as some roads are, and there are very few pedestrians, I should say personally you can afford to leave it, but you should definitely light your

traffic signs, so that a motorist can see if he is coming to a cross road or danger point. If you are going to light it, light it well.

Mr. Gregory referred to the question of higher mounting and also to the point about staggered lighting, to which I have already referred in a previous reply. Staggered lighting means twice the number of posts when the road is completed, and if you go in for centrally suspended lights the same things occurs. It is only a question of the number of posts and the expense, and unfortunately the expense has been almost the greatest consideration.

Colonel Oakes has supplied me with some statistics which form a useful addition to my Paper, and for which I thank him very much.

Mr. Minchin said that the cats referred to by Mr. Wilson were placed in bright patches of the road. That appeared to be so, and again emphasises my point of the value of silhouetting.

Mr. Jones referred to the amount of street lighting now done by electricity. I may say that last year 90.4 per cent. of the street lighting in my Company's area of supply was carried out by gas, and 9.6 by electricity. He also referred to the undesirability of lighting traffic signs from street lamps. The signs that I showed you are absolutely independent of the road lighting; they are installations in themselves, entirely

separate from any street lighting at all, and are additional units just to illuminate the signs. Therefore they do not detract from the street lighting at all.

Mr. Langlands expressed the opinion that the lighting of arterial roads should be a national subject. I have referred very strongly to that in my Paper and I emphasise there the point of who should pay the cost of such lighting.

With regard to the increased efficiency of the gas mantle in the course of time, when we put up test installations I always used to brush all my old mantles off and entirely re-mantle my lamps before carrying out the official test. Then I left them on and when, two or three days afterwards, I made further tests I found in every case that I was getting slightly better results. I could not quite understand it. I heard it mentioned that gas mantles did increase in illuminating power after a period, and I went into the matter very thoroughly and ascertained that that was true. After the first twenty-four hours the majority have a very considerable increase in efficiency.

I have a schedule here of my own tests, which are very complicated, but if anyone connected with the gas industry would like to make use of it I should be pleased to supply the information. Other gentlemen in the gas industry are going into this matter, and I hope that before long we shall arrive at some concrete result.

CONFERENCE

Under the auspices of the Institution of Municipal and County Engineers.

WEDNESDAY, 15th NOVEMBER, at 11.0 a.m.

MAJOR L. ROSEVEARE, O.B.E., M.Inst.C.E. (*President of the Institution*), in the Chair.

The following Paper was taken as read :—

Specifications—in the Light of Tradition, Experience and Research.

BY

B. PRICE DAVIES, F.S.I., M.Inst.M.&Cy.E., M.T.P.I.

(*City Engineer, Bangor, North Wales*).

(NOTE.—This Paper was submitted for the Open Competition arranged by the Congress Committee and was awarded the First Prize of a Gold Medal and One Hundred Guineas).

Part. I—MATERIALS.

“THE time has gone when the materials available were few and local and where traditional knowledge existed as to their best use. To-day there is at our disposal a large range of materials—home and foreign, natural and artificial, simple and composite, variations of the old and new—all requiring their own technique. It is impracticable to rely solely on the slow process of trial and error by individuals for the evolution of this technique. For rapid progress concerted action is needed by the manufacturers, the users and the scientific investigators. And their joint labours can be most simply expressed in terms of standard specifications.

“The prime function of standard specifications is to provide a standard, as high as economic considerations will allow, which will force inferior material into disuse. But a specification should not be regarded as permanently stable. It

should be revised as experience grows and as and when fresh scientific data accumulate. Apart, therefore, from its great industrial value, both to makers and users, at the time of its first issue, the specification will provide a medium whereby the results of laboratory investigations and full sale practice can be readily translated to general industrial use.”

*Extract from the Report of the Building Research Board for 1930,
written by Sir George Humphreys, K.B.E., M.Inst.C.E.,
Chairman.*

INTRODUCTION.

The foregoing extract sums up the position with regard to materials concisely, and forms of construction are also involved in the progressive development of public works.

The work done by the British Standards Institution is noteworthy for its thoroughness and its guidance, and the Institution acts in concert with the Department of Scientific and Industrial Research.

The latter department embraces the National Physical Laboratory, the Building Research Station, the Forest Products Research Board, and the section dealing with Illumination Research.

All these turn out useful information of a specialised character, and they are doing exceedingly good work.

Specialised information is also produced by manufacturers who are now generally equipped with laboratories, while lone enthusiasts in various parts of the country give the results of their research in books, papers, or journals. Information is obtained as well from reports of the Ministry of Health and the Ministry of Transport.

To the specialists who are able to confine their reading to their own particular lines, this is all to the good, and is most welcome, but the man who is mentally staggering under it all is the general practitioner.

The writer is a borough surveyor, and it is doubtful if the general scope of any other practitioner has to be so wide as that of an urban surveyor.

The writer is compiling these notes with the hope that they will be of assistance to his brother surveyors.

The specialist may also glean some insight into his problems in their relation to the problems of other specialists, and it is just as well at times to get out from amongst the trees in order to observe the wood.

The papers will endeavour to give the constructional progressions of the last decade and balance up research with practical experience and tradition. They will include items in which the writer's opinion and experience differ with constructional customs.

The final paper deals with policies which are felt to be necessary for further progression.

LIMES.

Here is a truly traditional material which has been ably dealt with by the Building Research Station in a publication entitled "Limes and Lime Mortars." This publication deals with pozzolanas and lime-washing as well.

The old classifications remain as Fat, Lean and Hydraulic Limes, the latter being subdivided into (a) Feebly (b) Moderately and (c) Eminently Hydraulic.

A product which is gaining favour is ground fat lime (or white or chalk lime) in the marketable form of Hydrated Lime.

It is claimed that instead of the usual month for running lump lime that a day will suffice for hydrated lime.

Ground hydraulic lime has lost favour in recent years, but deserves consideration anew. If used for mortar it should be slaked before final mixing into mortar.

CEMENTS.

The past decade has seen an increase in the kinds of cements. We now have Portland Cement (B.S.S.12—1931), Portland Blast Furnace Cement (B.S.S.146—1932), Rapid Hardening Cement, Quick-setting Cement, and White Cement.

From January 1st, 1933, the bags are to contain one cwt. of cement, and barrels 375 lb. The general basis of weight is 90 lbs. per c. ft.

It is now felt that the fine grinding of cement has increased its shrinking properties, and that a gain in one way is a greater loss in another way.

Quick-setting (or Aluminous) cement has an advantage over Portland cement in that it does not have free lime as the result of mixing into mortar or concrete.

With regard to the strengths of Portland, Rapid Hardening and Aluminous cements, although early strengths vary, the ultimate strengths are very similar.

It is now found that the importance of storage is overdone, for if after long storage, the setting may be slower, the ultimate strengths are similar. Cement, however, should not contain more than 2 per cent. of moisture after storage. The use of cement in a hot state is also unimportant.

Portland Blast-Furnace Cement is of especial merit for fireproof construction and in resisting the action of sea water.

PLASTERS.

Sulphate Plasters include Keene's Cement, Plaster of Paris and many proprietary plasters with a retarded action of setting. They often have a corrosive effect on iron and steel conduits, but are suitable for use with lead and compo pipes, or lead sheathed cables.

POZZOLANAS.

These are of two classes—natural and artificial. They are receiving a good deal of researchful investigation and, in the form of additions to mortars and concretes they are supposed to improve strengths, workability and impermeability. There is not sufficient conclusive information to recommend their general use at present.

Natural pozzolanas are the clayey or siliceous matters of volcanic origin from near Vesuvius, and the volcanic mud of the Rhine. The latter is termed "Trass." Artificial pozzolanas are pounded bricks, burnt clay, and granulated blast-furnace slag.

AGGREGATES (Grading).

The classification of aggregates will probably be influenced by the recent issue of B.S.S. 449 for the "Use of Structural Steel in Building."

The maximum sizes for Mass, Reinforced and Fine concretes are 2 in., $\frac{3}{4}$ in., and $\frac{1}{8}$ in. respectively.

The attempt to set up scientific grading of aggregates on the American density curve seems to have failed to materialise, and we are still on the more practicable basis of simple grading.

B.S.S.(63—1928) for "Broken Stone and Chippings," has the disadvantage of giving too much margin for the sake of uniformity of sizes of stone, while its sizes are not consistent with the sizes of the B.S.S. 410 for Test Sieves. There is need of greater coherence between these two British Standard Specifications, and B.S.S. 449 should not be lost sight of.

The B.S.S. for Broken Stone and Chippings ranges from 3 in. to $\frac{1}{8}$ in. and for the Test Sieves from 2 in. to $\frac{1}{16}$ in. (No. 300).

The writer ventures to suggest the following :—

1. That the sizes for both specifications range from large to small.
2. The B.S.S. for Broken Stone and Chippings has a good basis of uniformity of size in fixing the retaining sieve at a size below. For 3 in. this is $2\frac{1}{2}$ in., and for $2\frac{1}{2}$ in. it is 2 in., and so on. The weakness lies in allowing a margin of 15 per cent. to pass through the retaining sieve, for this might be anything down to dust. The writer does not see the need for this 15 per cent., but if necessary, then it should be limited by the next size below for retaining. For 3 in. stone, the 15 per cent. should not pass the 2 in. sieve although it has passed the first retaining sieve of $2\frac{1}{2}$ in.
3. With chippings the allowance is 30 per cent., which is still worse, and these again should follow the rule recommended. The sieve hole for broken stone is round and that for chippings is square.
4. That the first retaining sieve for $1\frac{1}{2}$ in. stone be a $\frac{3}{4}$ in. square hole, and the 1 in. size eliminated.
5. The mesh sizes of the B.S.S. for Test Sieves are all square. These should follow the rule of the B.S.S. for Broken Stone.
6. That the sizes of the B.S.S.63 for Broken Stone and Chippings be extended upwards in size in complete inches to a limit of 8 in., which is now the maximum size for mixers in America (and this for large mass concrete).
7. That the sizes for chippings of B.S.S.63 be adhered to, but that the first retaining sieve of the $\frac{1}{8}$ in. size be $\frac{3}{16}$ in. and not $\frac{1}{16}$ in.

7. From there downwards the B.S.S. for Test Sieves should operate.
8. That the general classification of aggregates and concretes be as follows :—
 - (a) Very Coarse, over 3 in. and not more than 8 in.
 - (b) Coarse 3 in. to $1\frac{1}{2}$ in. inclusive
 - (c) Medium $\frac{3}{4}$ in. to $\frac{1}{2}$ in. „
 - (d) Fine $\frac{1}{8}$ in. to $\frac{1}{16}$ in. (Test Sieve No. 16) inclusive
 - (e) Very Fine $\frac{1}{80}$ in. (No. 18) to $\frac{1}{40}$ in. (No. 25) „
 - (f) Dust passing $\frac{1}{80}$ in. (No. 30).
9. That the term "Aggregate" should be standardised to mean either freedom from dust or a margin of not more than 2 per cent. when delivered on site.

Aggregates create their own dust in transport and handling, and for fairly weak aggregates both "very fine" and "dust" should be subject to the 2 per cent. margin.

AGGREGATES. (Shape, Size and Quality for Use).

The shapes of aggregates are "round" and "angular."

The round is better for compacting and the angular is better for bond.

Other than for roads and wearing surfaces, the writer believes in the fine aggregate ($\frac{1}{8}$ in. and under) being round and that above being angular. For roads and floors, it is an advantage to have the very fine aggregate ($\frac{1}{80}$ in. to $\frac{1}{40}$ in.) in rounded particles.

During the past few decades there is a tendency to use too small an aggregate for both mortars and concretes. This sets up greater shrinkage on the score of the greater number of cement joints.

The same principle applies to mass concrete, and the use of large aggregates up to 8 in. in size lessens the shrinkage stresses in the mass as well as being more economical.

Breeze aggregate is now condemned for general use, and particularly so when in connection with steel.

Blast Furnace Slag is also of doubtful merit, although good qualities are suitable for fireproof construction.

Ordinary broken brick is similar.

Hard semi-vitreous bricks are very good as aggregates, and they are suitable for fireproof construction.

Lime mortars are very bad for re-use, even with the addition of new lime.

The *Water Content* of a concrete mixture is far more important than the grading of aggregates. For general use, a concrete mixture giving a slump of 2 in. is suitable.

Mixers of a poor type are often seen. Those which whirl the large stone around without incorporating it in the remaining material should be condemned.

The term "sharp sand" is ambiguous, and should not be used.

MORTARS.

B.S.S.449—1932 for the use of structural steel in buildings gives ratios of aggregates in cubic feet per cwt. bag of cement. These are 1-2 $\frac{1}{2}$, 1-3 $\frac{1}{4}$, and 1-5 which on the old basis of volume to volume would be 1-2, 1-3, and 1-4 respectively.

The use of cement-lime mortars has become very popular in America, and mixtures of Portland cement and hydrated lime are marketed in this way. The 1-1-6 mixture for mortar is the most popular. Cement should not be less than 20 per cent. that of hydrated lime in order to be effective.

The writer believes that brown or hydraulic ground lime should be given more trial in this way, and this for walling mortars. The mixture of cement, ground lime (or ground lime alone) and sand should be mixed to the state of damp earth and allowed to slake for a few hours before final mixing for use.

The use of cement mortars has been found to be too strong for structures such as chimney stacks, and for the pointing of walls, and lime mortars or cement-lime mortars are giving better results.

Sundry mortars and bituminous mastics are finding increasing favour, and "Tricosal" for stopping up live leaks appears to be a triumph of modern research.

CONCRETES.

Light-weight concretes are tried, but some, such as pumice concrete, have excessive shrinkages, and are proved to be unsuccessful.

Precast concrete, or cast stone, or again artificial stone is gaining ground. With "Veneered" work the veneer should not be less than 1 in. thick, and it should be cast at the same time as the core. Curing is essential.

STEEL.

Steel for reinforced concrete is covered by B.S.S.15—1930, Steel for Bridges, etc., and General Building Construction, Class A.

In America there is a tendency to limit the number of sizes of bars to eleven, and from $\frac{1}{4}$ in. diameter to 1 $\frac{1}{4}$ in. diameter inclusive. These are stated in sectional areas and not in diameters.

Considerable research work has been carried out for bond resistance as between steel and concrete, and for creep or flow of concrete.

Shrinkage and expansion can be brought about by setting movements, by moisture and by heat. These are often far-reaching in their effects.

Density, Porosity, Permeability and Absorption. Density is a general indication of a good concrete, but not always so.

Concrete can be porous in two ways, namely from pores produced by making the concrete and from pores in the aggregate. On the other hand, the writer has seen houses built of concrete blocks made of lean porous mixes which prove to be free of shrinkage effects, and when rendered with cement they are fairly good for damp resistance.

A porous aggregate is not favoured, and the more impermeable the concrete the less liability there is to undue absorption from contaminating soils and consequent deterioration.

The *Jointing of concrete* has been the subject of much research. It is now acknowledged that tradition is sound on this matter for concrete, as it is for masonry. Before casting against previous work, the weak laitance should be removed by lightly chipping or sand-blasting, the surface washed, and a jointing mortar of 1-1½ mixture laid against it before the concrete is poured. This is for both horizontal and vertical joints.

Joints of beams and slabs should be in the middle third of the span, and those of columns just below the beams. All joints are to be butt joints and feather-edged joints are prohibited; this applies particularly to road-work.

Waterproofing concrete is imperative if it is exposed to the action of destructive waters or soils. This can be done by casing with slate, stone or brick. Coating with bituminous emulsion followed with hot bitumen is good, and impregnation of concrete piles with bitumen on the vacuum process has been carried out.

Surface effects of concrete have developed apace. These are done by adding pigments, by the use of a coloured aggregate, by using retarding solutions, by removing the cast face with air-driven surfacing tools, and the use of white cement has become very popular. Coloured mixtures of cement and aggregates are marketed.

A method of reducing crazing of cement surfaces is to mix the surfacing mortar to the consistence of damp earth and leave it for two hours before final mixing for use. This has the effect of slaking the cement or the lime in the cement.

Concrete for *Heat Insulation* is considered to be best with a high percentage of voids. This is achieved by using but little "fines" in aggregates.

For *Fire Resistance*, limestone and granite aggregates are not suitable. Sandstone, crushed and graded furnace slag, lava, pumice and strong brick, are good, but the sulphuric anhydride content of the slag must not exceed 1 per cent.

Portland blast-furnace cement and blast furnace slag in combination are very good.

Steel should have 2 in. of cover to form good protection against fire.

STONES.

The changes in quarrying stone are great, and huge monsters now rip away the granite sides of the mountains, while the jaws of other monsters chew the monoliths to fine pieces.

Facility of transport is the cause of stones being used in districts which are unfamiliar with their use.

To counter this the Building Research Station will test and report on building stones, and the National Physical Laboratory will do the like for road stones.

Stone is best seasoned (or freed of quarry sap) before dressing, and even before use in concrete.

The use of iron and steel cramps in masonry is condemned, and slate cramps or dowels, alloys of steel, copper or nickel are recommended.

The mixing of different classes of stone in building work is bad, for one kind of stone will bring about the decay of another by contact. To fix sandstone next to limestone is particularly bad. Uniformity is very important, and stones from the same quarry should be of even texture and strength. Uniformity of texture in a stone itself is important as well.

The sulphurous atmospheres of large towns cause stone decay.

The formation of dense skins hinder the moisture movements in stone, for capillary suction and evaporation cause the formation of crystals behind the resisting skin, and exfoliation results.

Water increases 10 per cent. in volume when frozen, and if the structure of the stone is not suitable, flaking occurs.

Expansion of stone through moisture is important, and the following comparison for linear expansion per cent. is of note :—

Bath Stone, 0.006; Portland Stone, 0.008; Darley Dale Sandstone, 0.032; Red Wire-cut Brick, 0.004; Neat Cement, 0.097; Cement Mortars, 1—1, 0.038; 1—2, 0.032; 1—3, 0.014; Artificial Stones, from 0.02 to 0.04; Wood, deal, along grain, 0.07; across grain, 6.9.

The Building Research Station has standardised the following terms :— "efflorescence" for crystals on the surface; "cryptoflorescence" for those within the pores; and "florescence" as a general term for both.

These are caused by moisture movements, and to prevent them the design of a building must be carefully considered. Cement mortars are more apt to cause them than lime mortars.

Common salt and sea-water are harmful to stones, and limestone which has come in contact with sea-water, either by coming from a shore quarry face or by voyage, should not be marketed.

Granites containing pyrites, and basalts liable to "sunburn" should not be used for building work.

B.S.S.(435—1931) for Kerbs and Channels gives photographs of standard forms of dressing granite and whinstone. This principle could be followed up with advantage in the Standard Method of Measurement for Building Works.

A recommendation states that trees should not be nearer to buildings than 32 feet and bushes 16 feet, and this owing to the discolouring effect of the vegetation upon the walls.

BRICKS.

Here we have another good traditional material, as evidenced by the Assyrian brick 2,500 years old from the palace of Nebuchadnezzar at Babylon, which we see in the Library of the Institution of Civil Engineers.

Great strides have been made in recent years in the improvement of quality, and in providing a range of colour and texture effects.

The modern engineering brick of a semi-vitreous nature is a wonderful modern production. It is practically non-absorbent, and is obtained in a variety of heather-brown shades. It is wonderfully strong, and can be used for road surfacing, while tiles of the same character make good wearing floors with pleasing effects.

For hard bricks of this nature it is found on test that there is no strength gain in wetting them, while if wetted they are more apt to slide during setting operations, and the mortar becomes weaker with excess water.

Sand Lime Bricks have a B.S.S.(187—1923) and are suitable for internal work.

Mortar should not be stronger than the units of brick or stone which are bedded in it, and for cavity work a mortar having a good "hang" is an advantage in avoiding droppings.

Shrinkages which are not uniform are a disadvantage in brickwork and stonework, for a facing and backing of different shrinkages can cause cracking in the walls.

A fine pored brick in contact with a large pored brick will draw moisture to its fine pores from the other brick.

Brickwork with reinforcement in its joints is gaining in favour, and this form of construction will probably usurp reinforced concrete in walls.

TERRA-COTTA.

It is found to be a mistake to fill the voids with concrete, and particularly with breeze concrete. The terra-cotta should be strong enough without, and the net volume should not be less than half that of the gross volume.

FLOORS AND ROADS.

B.S.S.(368—1929) is for Concrete Flags, and some manufacturers are to be congratulated upon this class of product. Flags are to be cured for 24 weeks if with ordinary cement, and four weeks if with rapid-hardening cement. Slabs of the latter class are to be marked with an "R." Particulars of tests are given.

B.S.S.(340—1928) is for Concrete Kerbs, Channels and Quadrants in Portland Cement.

Failures of concrete kerbs are in evidence up and down the country, and this specification could be revised with advantage.

Radii are standardised to 6 ft., 8 ft. and 10 ft., and quadrants to 18 in. (This standard is also adopted for Granite Kerb).

It is a mistake to make hard or tight joints for concrete flags or concrete kerbs. They need expansion space.

Roads claim a long list of British Standard Specifications, and these include Tars and numerous types of Asphalt Roads, hot and cold laid, mastic, natural rock and compressed.

Numerous forms of new road surfacings have made their appearance in recent years, including rubber and iron. A type of road which is increasing in popularity is the concrete road, which is a success if it is well and carefully done.

The Building Research Station report the following causes of failures in concrete surfaces :—

(1). Foreign matter in aggregates ; (2) Excess of cement or fine aggregate ; (3) Improper consistence of mix, either too wet or too dry ; (4) Excessive trowelling ; (5) Exposure to frost ; (6) Rapid drying of surface ; (7) Practice of sprinkling wet surface with neat cement.

The most important has been left out—namely, that of not securing a uniform wearing surface with a good wear resisting aggregate, coming right up to the surface in a uniform manner, and this firmly held (but not overwhelmed) with the cement mortar.

Tarmacadam should not be used for surfaces which are not continually trafficked, such as back-yards of housing schemes. Deterioration of surfaces is very marked in such cases.

Concrete is liable to expansion and contraction, and this should be accommodated in expansion joints. Bitumen strips, poured bitumen and cork are suitable for roads, and wood strips suitable for cast-in-situ paths and back-yards. Areas for the former (if not reinforced) would be about 20 yards super, and for the latter about 4 yards super.

Terrazzo, with its rich cement content, is bad for contraction, and metal strips can be employed to form definite joints.

Composition floors have had many failures, often due to differential action of expansion and contraction as between the floor surfacing and the concrete foundation. This has been experienced with tiled floors as well.

ROOF COVERINGS.

Tradition is still maintained, and slates are still the best form of roof covering.

A B.S.S. will probably be issued before long, and meanwhile the Building Research Station has issued a welcome booklet entitled "The Durability of Roofing Slates" (1932).

The chief test given in this booklet, is the sulphuric acid test, which, although it leaves little or no effect on the best qualities of North Wales slates, soon shews up the disadvantages of others, particularly foreign slates. After centuries of use, the best quality Welsh slate is quite fit for re-use.

American slates are better than Belgian, but both are vastly inferior to our home products.

There is a B.S.S.(402—1930) for Clay or Marl Roofing Tiles. This is for plain tiles, and gives a number of tests.

Roof tiles, whether of "plain" or "pan" types, should not be bedded in mortar, nor rendered, nor torched (or pointed). Slates can be subjected to this treatment.

Asbestos cement is used for various forms of roof covering, but it becomes brittle with exposure.

Corrugated iron sheathed with bitumen makes a good roof covering of inexpensive form.

With regard to asphalt roofs, the shrinkages of underlying concrete are not to be forgotten (and this applies to floors and roads as well), and with many failures of mastic asphalt roofs, it is considered advisable to revert to the specifying of natural rock asphalt until the synthetic material has proved efficient.

TIMBER.

A great deal of research work has been done with timber and the Forest Products Research Board have issued many useful booklets.

The tradition that timber is better felled in winter than in summer is still correct, although the reasons given by modern research are different from those of tradition.

Figures 1 to 11 have been prepared in order to elucidate the uses of certain terms and the effects of shrinkage.

Bright sapwood in softwoods is now allowed for internal work. The other sapwood is termed "blue sapwood."

Three classes of conversion are shewn in Figs. 3, 4 and 5, and for framed work and for floors the quarter sawn is preferred. It will be seen from Fig. 3 that the large cuts are the best.

Timber is not available in the qualities often asked for in specifications of buildings and public works, and during the next few years we hope to see a B.S.S. for timber.

Shrinkage of timber longitudinally is but little, and the important point to remember is that tangential shrinkage is twice that of radial shrinkage. Figs. 6 to 11 indicate the effects of this different shrinkage.

The seasoning of timber can be either by air seasoning or kiln seasoning, and sometimes a combination of both is advisable.

The modern basis of seasoning is that of "moisture content," this being an additional percentage of weight on the basis of wood when oven-dry. Apparatus is now manufactured for this form of test.

Timber takes in moisture from the air, and the moisture content varies with fluctuation of air humidity. For an average external temperature of 50°F. in this country, the relative humidity of the air ranges from 80 per cent. to 100 per cent. This reacts on the moisture content of timber as follows:—60 per cent. air humidity means 13 per cent. moisture content for timber, 70—16 per cent., 80—21 per cent., 90—26 per cent., and 100—32 per cent. The average for this range is 18 to 19 per cent. moisture content, and this can be regarded as suitable for timber used for external construction.

For internal construction, however, the suitable moisture content is more like 12 per cent. or 13 per cent.

Air seasoning cannot hope to bring the moisture content sufficiently low for internal work, and with the modern advance of kiln seasoning, and its intelligent control, kiln seasoning is advantageous. It not only lessens the moisture content, but it destroys fungi and insects as well. A defect in timber known as "Collapse" is caused by inefficient kiln drying, and the cells of the timber collapse under such inefficient treatment.

The number of annual rings for good class timber should not be less than 12 nor more than 20 per radial inch. The summer ring is stronger than the spring ring and the quality of timber is influenced greatly by the percentage of the former. In good timber it will be about 30 per cent. of the annual ring.

Timber suffers from decay in structures for want of ventilation, and the writer condemns the use of timber as lintels and bressummers (and particularly so for outside work), as wall plates built in on three sides, and as joists embedded in concrete. Ends of joists should not be walled on tightly, and they should have place for air to circulate all round them, with the exception of the bearing.

To see timber studs and lintels rough-casted over in external work is the writer's anathema.

Our chief sources of supply of softwoods are Northern Europe and Northern America. Softwoods from Central Europe are of very doubtful merit.

The chief constructional timber is *Pinus Sylvestrus*, or Baltic Fir, Northern Pine, Scots Fir and Scots Pine, which are all names for one kind of tree. In timber, this is known as Red Deal or Yellow Deal. The qualities available are not equal to pre-war shipments.

The next is Spruce, which in its best grades is called White Deal, and does not prove to be so durable for external work as Yellow Deal.

The timber which has become increasingly popular is Douglas Fir, also called British Columbian Pine, Oregon Pine and Puget Sound Pine. This is a good rival to Red or Yellow Deal. Pitch Pine is known in America as Southern Pine, and it is very durable.

It is regretted that space will not permit the further discussion on various classes of woods, grades and qualities.

B.S.S.(459—1932) is for British Standard Doors, and is a welcome basis for the specification of internal joinery.

Allowances for dressing (or planing) are $\frac{1}{4}$ in. for the framed work, and $\frac{3}{16}$ in. for panels and covering. These are for two sides.

The writer takes the opportunity of emphasising the need of specifying to nominal sizes, which are the sawn sizes, and stating allowances for planing as above, and not using the "finished sizes" term.

A good rule has been issued by a provincial joint board of architects and builders, which is to the effect that for timber over 2 in. the allowance be $\frac{1}{4}$ in. per planed face, and for 2 in. and under, $\frac{1}{16}$ in.

The B.S.S. for Doors defines "sound" timber as being free of fungal and insect attack. Important tests are given for plywood panels, and standards as to defects are very important.

Before leaving timber, it can be stated that the Sawn Ceiling Lath has ousted the Riven Lath, and this is to the advantage of ceiling work.

IRON AND STEEL.

Here again, we have a full complement of British Standard Specifications to assist us. The most important is the recent issue B.S.S.(449—1932) for the Use of Structural Steel in Buildings. It includes concrete, brickwork and masonry, and is recommended by the Ministry of Health as a guide for use with Building Byelaws. It deals with wind pressures and other matters, including rivetting; but welding is not dealt with.

B.S.S.(51—1929) is for Wrought Iron, and deals with four grades.

B.S.S.(15—1930) is for Structural Steel for Bridges, etc., and General Building Construction. This deals with two classes of steels, namely, grades "A" and "B"; "B" steel is not intended for bridges, plates $\frac{1}{4}$ in. thick and over, rivet bars and heat-treated wire.

The standard basis of weight for steel is given as 3.4 lbs. per foot run per one square inch.

B.S.S.(6—1924) is for Rolled Steel Sections for Structural Purposes. It gives a range of sections and sizes.

B.S.S.(153—1922) is in five parts, but in two books. Here we have considerable reference to other British Standard Specifications, while the surface protection of steel is dealt with to a limited extent.

Wind pressures are given, also areas of bearings and bedplates on granite, sandstone or similar stone, and cement concrete.

The notable loading for highway bridges is given in this B.S.S.

B.S.S.(165—1929) is for Hard Drawn Steel Wire for Concrete Reinforcement.

B.S.S.(28—1932) is for Black Bolts and Nuts, Studs, Lock-nuts and Washers. These range in diameters from $\frac{1}{4}$ in. to $1\frac{1}{2}$ in.

B.S.S.(321—1928) is for General Grey Castings, grades "A" and "C."

The chief developments in structural steelwork are the use of welding instead of rivetting, and the use of steel alloys.

With welding it is claimed that great savings are effected, and it is quite possible that a revision of steel sections may take place in consequence.

Alloys of steel are chiefly brought about by the addition of copper, nickel or chromium. They are claimed to be stronger than ordinary steel, but their chief advantage lies in their being not so liable to corrosion.

NON-FERROUS METALS.

A great development has taken place in this direction, and the rivalry between the metal trades has brought about a considerable amount of research.

The non-ferrous metals largely form their own protection against corrosion, and the following metals are arranged in the order of superiority of protection, the best coming first :—Nickel, Copper, Nickel-Copper Alloys, Nickel-Iron-Chromium Alloys, Bronze and Brasses, Aluminium and Aluminium Alloys.

Copper is not affected by the action of cement and lime (as is the case with lead) and in this way it is suitable for the dampcourse of a parapet wall.

Lead is badly affected by cement, and to a lesser degree by lime, while contact with oak as in valleys or gutters will bring about its deterioration.

Acids destroy lead, and in the case of a pickle factory, the lead glazing bars of roof lights gave up a poisonous composition as the result of corrosive action.

Soils, such as peat, containing dilute organic acids and waters from such soils have a plumbo-solvent effect. Lead can be protected or insulated by means of bitumen saturated strips or sleeves.

The writer has considerable faith in zinc of a stout gauge for flat roof work.

The decay of many metals is brought about by the electrolytic action of stray currents, or by the effect of the contact of two different metals. The latter should be avoided. Even in nailing copper, galvanised iron nails may bring about this effect, and copper nails to copper sheeting is a good rule.

MATERIALS FOR MAINS AND SEWERS.

Concrete Pipes and Spun Iron Pipes have been used in increasing quantities during recent years, and British Standard Specifications will probably cover these in the course of time.

B.S.S.(65—1914) for Salt Glazed Ware Pipes is the standard of a really good article. These can still be used with greater confidence than their newer rivals—concrete pipes, and this in particular in connection with some trade wastes.

There are two grades referred to in this B.S.S. British Standard Pipes of which 5 per cent. are tested on request of the purchaser, and British Standard Tested Pipes, all of which are tested and marked.

The various marks of the British Standards Institution are as follow :—



BE SA

BRITISH STANDARD

The use of these marks is licensed by the British Standards Institution.

Pipes sold as "Best" Pipes are not within the B.S.S. category.

Pipes marked with black bands are rejects, and should not be used for soil drains or soil sewers.

B.S.S.(78—1917) is for Cast Iron Pipes of four grades, "A," "B," "C" and "D." These are well known.

Spun Pipes are manufactured to test pressures of the above grades. They are lighter in weight, and their texture indicates the possibility of less liability to corrosion than ordinary cast iron pipes.

Concrete Pipes of really good shape and of very good quality are marketed. There are two classes of joints, namely, the ogee joint and the socket joint. They have their individual advantages.

Iron and Steel Pipes, lined with concrete or bitumen as a protection against corrosion, are increasing in use.

Lead Wool Joints have the advantage over Run Lead Joints of having the first skeins caulked strongly against the gaskin, and followed up with the caulking of every skein. They have the disadvantage of being liable to bad workmanship.

Large sewers are now made chiefly in barrel fashion, and the egg-shaped sewer is not so popular. Their lining with hard brick is a good measure of protection.

WATER SERVICES AND FITTINGS.

The standardisation of these is done by the British Waterworks Association and the Ministry of Health. They are not altogether consistent.

Manufacturers are licensed to use the following marks. For British Waterworks Association Standard :—



For Ministry of Health Standard :—



The number is the license number of the maker and he can have the same number for both marks.

B.S.S.(61—1913) is for Copper Tubes and their screw threads, and to three grades of strength.

Light copper tubing with connections and fittings which do not require screw threads are becoming increasingly popular. It is generally considered that these tubes can be used three gauges lighter than those which are screw-cut.

Ternary alloys of lead are proving to be better in some ways than lead, and more economical. For pipe and sheet, two thirds the weight of ordinary lead

will suffice. Pipes are marked every yard, and sheet every yard super. The mark is thus, and is licensed by the British Non-Ferrous Metals Research Association.



There are two kinds of ternary alloys, No. 1 and No. 2, and No. 2 is finding more general favour than No. 1.

SURFACE PROTECTION (PAINTS, ETC.)

B.S.S.(381C—1931) gives a useful range of 57 tints of colour.

The range of British Standard Specifications in this direction is very wide, and includes White Lead, Red Lead, Linseed Oil, Turpentine, Tung Oil, Varnish, Creosote, and Paints of different colours. The Building Research Station has been carrying out useful work in connection with the failure of paint films on walls.

Generally it may be stated that it is not wise to paint new walls, that water paints are better for new walls than oil-paints, and that earth colours are the most serviceable colours for new work.

The painting of cement surfaces less than a year old can only be done efficiently with special treatment. This can be done by means of a wash of a special solution to kill off the effects of the free lime of the cement, or by the use of a special insulating paint. A tung oil resin paint is a good insulator.

For walls liable to excessive condensation or moisture, such as in laundries or baths, paints or distempers are not suitable, and lime mortars are not recommended. Finishes in white cement, tiling, brickwork, terra-cotta, faience ware, slate and the like are recommended.

Aluminium paints have become popular and they are durable in sea air. They have good reflective power, and are durable when applied on other surface treatments. They are non-poisonous.

For *Steel Protection* the tradition of red-lead linseed oil paint still holds good, and this after numerous tests.

Tung oil paint is good as a priming coat for steel work.

Steel must be dry and free of rust before painting, and the use of the blow-lamp is recommended in order to achieve this. The first coat can be regarded as protection against rust, and the top coats as protection against the atmosphere.

Oil paints and bituminous paints should not be used together.

For *Wood Protection* and in the case of numerous tests for weathering and toxic resistance, zinc meta-arsenite, copper aceto-arsenite, and copper arsenite were found to be markedly superior to other treatments.

The first is proved to be the best of all resistant to dry rot. It is odourless, colourless, paintable and permanent, and by means of its application the life of the wood is claimed to be trebled.

Creosote is good and impregnation is its best form.

SUNDRY MATERIALS.

Violet ray glass has been marketed strongly in recent years. It is now stated, however, that its use is only justified in big roof-lights, solaria, and verandahs. The thicker the glass, the less the transmission of the violet rays.

Reinforced glass has proved to be expensive in upkeep owing to cracking. The glass with square mesh reinforcement is less liable to crack than that of hexagonal pattern.

Coloured glass affects flies. Red and Yellow glass are the best fly deterrents, and blue and green are not so effective.

In one case, yellow glass was found to be the cause of rancidity in rice food-stuffs, and this was not the case with green glass.

For *Sound Resistance* thick glass is better than thin glass.

There are several British Standard Specifications for sundry materials such as Cast Iron Soil, Vent and Waste Pipes.

An important rule set up by B.S.S.416—1931 is that the “hand” of a fitting, is as you look at it upstream, and not downstream as the writer was taught in his youth.

Wall Boards.—The writer has tried several of these, and agrees with the Building Research Station that claims made for them are extravagant. They respond to air humidity and expand and contract accordingly. They are best used with wood strips over the joints, and angle fillets secured to the walls are essential for ceiling work.

Plaster Slabs.—The writer has a great opinion of plaster slab partitions, but has not as much esteem for plaster ceiling slabs.

The ideal ceiling has yet to be found.

Dampcourses.—For walls, slates bedded in cement still hold their traditional virtue of being the best.

Vitreous ware and lead-cored (or sheathed lead) come next.

Ironmongery.—B.S.S.(445—1932) is for Steel-cased Mortice Locks and for four sizes.

Norfolk (or Suffolk) latches still hold their traditional use for external doors, but the old fashioned tower bolt is surpassed by the modern barrel bolt, which, with its brass knob, is neat and effective.

Part II.—CONSTRUCTION

With Special Reference to Weather and Damp Resistance.

SUB-SOILS.

The B.S.S.(449—1932) for the Use of Structural Steel in Building gives the following permissible loads on sub-soils in tons per square foot.

Alluvial Soil, made ground, very wet sand	up to	$\frac{1}{2}$
Soft clay, wet or loose sand		1
Ordinary fairly dry clay, fine sand and loam		2
Firm dry clay		3
Compact coarse sand, confined sand, London Blue clay, and similar, hard compact gravel		4
Hard solid chalk		6
Shale or soft rock		10
Hard rock		40

Black mud and peat are unreliable even under floors, and such soil should be removed, or pierced with piles or pier foundations. Mud at the back of a retaining wall should be considered as a fluid.

For heavy structures this kind of standardisation is deprecated in Germany, and individual tests are considered necessary.

In this country rock can be found overlying clay, or the rock can have vertical laminations. The writer knows of a heavy structure built on the latter class of rock, and movement is taking place. A dam is known to have failed, although on rock foundation.

Clay soil can shrink up to 25 per cent. of its volume in drying, according to its porosity and normal water content. The latter can vary greatly.

The resistance of sand in foundations is largely dependent upon its closeness or packing. When closely packed it can be ten times as strong as when loosely packed.

A sandy building site can be improved for bearing resistance by means of impregnation, firstly with a solution which is rich in silicic acid, and secondly with a solution of soluble salts or acids. These are injected under pressure, and in this way chemical reactions take place, silicates are formed, and the soil solidified.

An authority on construction has recently worked out the weight of an office building ten storeys high and with basement. He states that the average load per square foot of the whole of the ground area is 1.25 tons.

RETAINING WALLS.

Retaining walls are still largely built on the safe rule that the base must be at least one third the vertical height. For walls supporting roads, the general rule of the Ministry of Transport for ordinary walls is that the base must be at least .35 of the height.

The writer feels that masonry walls are cheaper and better than concrete or reinforced concrete walls, and he has just completed one 24 ft. high which supports a Class "A" road.

Nearly half-a-century ago, Osborne Reynolds stated that dilatancy would place the theory of earth pressures on a truer foundation. This has been disregarded until recently (1930) and now another specialist has experimented with a view of ascertaining the actual forces exerted by granular material of different sorts. He is submitting his results to a meeting of the Institution of Civil Engineers.

It is hoped to prove that the earth pressures estimated for retaining walls are too high. On the other hand it is well to have a good margin of safety for this class of construction.

WEATHER AND DAMP RESISTANCE.

A Committee of the Royal Institute of British Architects with Sir Raymond Unwin, who is now (1932) President of the Institute, published a valuable report in 1929 on Damp Houses. In this report it is truly stated—"That no considerations of economy in cost can justify sacrificing the necessary treatments to secure a reliable waterproof shell for the building as regards roof, walls, and floor, as well as a damp-course protection."

The diseases caused by damp houses are catarrhal diseases such as colds in the head, coughs, bronchitis, etc., and their sequel diseases can be certain rheumatic and cardiac affections.

The Annual Report of the Building Research Station for 1930 states that following an investigation of damp houses after the heavy gales of the winter of 1929-1930, the percentages of causes of damp were as follows:—solid brick walls, 65 per cent.; solid masonry walls, 10 per cent.; defective renderings of brickwork, 20 per cent.; cavity walls, 5 per cent.

The writer took to cavity wall construction over twenty years ago, "since when he had used no other." With a present legacy of solid brickwork houses, and numerous attempts to cure them, he fully endorses the further and following notes in the same Annual Report, for they fit his own experiences and precautions entirely:—

"It does not seem possible to guarantee that a solid brick or masonry wall will exclude damp under all conditions of exposure likely to be experienced in Great Britain."

"No instance has been recorded of the failure of a properly constructed cavity wall to exclude damp."

"Too much emphasis cannot be placed upon the importance of avoiding a capillary bridge across the cavity at door and window openings."

Excellently put in a few words. The writer has built over a hundred houses recently in exposed positions, and they are quite dry.

He has come to the conclusion that the only sure cure for damp solid brickwork is either to slate or to tile it. He has done this recently.

Another alternative is given in a publication which is to nail wood strips on the walls internally, and nail wall boards to the battens. The writer has demolished a large building where battening, lath and plaster, had been done for the same purpose. As a temporary measure this is good, but the system sets up dry rot eventually, as found in the building demolished.

Stone walls are more reliable for damp resistance than brick walls, and this for two main reasons. Firstly, stone as a rule is not so absorbent as brick, and secondly, the capillary path can be broken in by not having many "through stones," and keeping the cores of the walls without mortar.

In places exposed to gales and rains, such as the Lake District, a good flat walling stone is used. Where exposed to the weather, the mortar is kept back from the face of the wall, and the cross joints of the stones kept square butted. The external stones have beds not less than 7 in. wide, and these and the "through stones" and "bonders" are built "watershot," i.e. sloping outwards. The walls are usually not less than 18 in. thick, and although well bonded or interwoven, they are only bedded for a few inches wide on each face (leaving the core without mortar). This is important. In laying, the stones are compacted hard on the beds. These walls are guaranteed to be damp-proof if built in this way by experienced masons.

The writer has had ordinary stone walls built with dry cores and cemented externally, and these stand the drive of heavy weather without shewing damp.

For windows he prefers double hung sashes to casements. With the legacy of houses referred to, complaints about casements are very strong. The wood casements are said by the tenants to be more watertight but less draughty than steel casements.

For weather-proof doorways on exposed winds, porches are essential, and these should have their floors a few inches lower than the general floor level. The rain then driven under the door will not go further than the inner step.

Window and door frames when set too near the front face are more prone to cause leakages than those with 4½ in. reveal. The writer closes the cavity with the frames, and gets no trouble. Steel casements should have wooden frames, and without such wooden frames they are known to heave out the reveals by means of corrosion.

For safe and durable roofs, slates or plain tiles maintain a good tradition, but slates are the more reliable.

The R.I.B.A. Report rightly deprecates doing away with the overhang of the roof at eaves. The writer would add—and at gables as well.

The Report adds the following causes for damp:—

1. Lack of damp-course, either horizontal or vertical.
2. Absence of covering ground inside dwelling or around it.
3. Lack of sub-soil drainage.
4. Porosity and absorption of wall materials.
5. Defects in maintenance, including faulty roof construction.
6. Condensation on internal surfaces of walls.

The Report emphasises the need of a layer of hard broken material between soil and ground floor concrete. This and many other points of damp resistance are found in the Richard Pickering Prize Thesis of the Institution of Municipal and County Engineers for 1925,* and a few points from that Thesis are used in this paper.

Damp-proof courses are essential for any wall structure rising above the roof such as chimney stacks, parapet walls and coped gables. The writer avoids both parapet walls and coped gables as much as possible when designing structures. It is better to take the slated or tiled roofs over and clear of the walls.

There is trouble with stepped flashings. The writer believes in putting a mastic fillet with $\frac{1}{2}$ in. lap over the soakers, and the body of the mastic on the brick-work. This is a good additional safeguard to the flashings, and it should be done (or re-done) after wood shrinkages are finished.

FOUNDATIONS AND GROUND FLOORS

(With Particular Reference to Domestic Buildings.)

The Building Research Station has issued a useful drawing of a section of footings with a view to shewing the cause of dampness arising in the base of a wall. This must have proved to be of educative service, for it is very clear and it has been given much publicity in the technical press.

Fig. 12 incorporates some of the points shewn in that drawing, and its fundamental policy is *that walls in contact with soil attract moisture from the soil*. Not only walls, but floors as well, and Fig. 12 shews how the ground floor concrete assists this creep of damp. The traditional 6 in. of concrete is expensive and comparatively inefficient.

Fig. 13 shews a damp-resisting floor, and the writer believes in placing an impervious brick (without vertical joints) where the wall is in contact with concrete. The cavities must be ventilated. The stone should be non-porous and with ample voids in order to break the capillary path; if this layer can be ventilated, so much the better.

Fig. 14 indicates the method of dealing with a "jump" between the floors of two rooms or of two houses. The writer adopted this system for houses on steep sites a year or so before the war, and there has been no damp trouble in consequence. He is still doing it.

Fig. 15 shews the traditional method of laying wood-blocks on 6 in. of concrete. The writer was taught by his father (to whom he is grateful for a lot of practical information in the past), that it is not good to lay concrete direct on soil, and that an intervening packing of dry stone is most beneficial.

During a recent inspection of a floor like that shewn in Fig. 15 it was found that the layer of rendering had shrunk in setting. After that, it had expanded with creeping moisture and lifted the blocks.

Fig. 16 shews a better method, with a 3 in. concrete layer of good mix, this having been screeded off in one operation. Wood block layers find that blocks

* By the same Author.

bed better on a screeded surface than on a steel-trowelled surface. The steel trowel leaves ridges, and these are inclined to set up a rocking action of the blocks.

Fig. 17 goes a step further, and this for an exceptionally damp site.

FRAME OPENINGS IN CAVITY BRICK-WORK.

Going higher up the structure, Figs. 18 to 21 shew methods of treatment of cavity brickwork at door and window jambs. They explain themselves.

Figs. 22 to 25 do the same for window sills, and again the principle for damp-proof construction is to break the capillary path. Since the war, we are more inclined to use brick sills; unlike stone sills, they call for solid bedding. Pre-war sill construction with stone did not create as much trouble as brick sills. The stone was generally impervious, but more than that, the sills were bedded hollow by means of bedding the ends on strips of slates (D.P.C. in themselves) and lightly jointing the face, or not jointing them at all.

Figs. 26 to 29 deal with door or window heads. Fig. 26 is very bad construction; firstly, a wood lintel shrinks and rots when in contact with the damp outer lining. Then it bridges the cavity, which is contrary to good cavity wall construction.

The cement gutter is bad, for it shrinks in setting, and it is not impervious to moisture.

Fig. 27 is also bad cavity construction, although better than Fig. 26. The metal may be lead, ternary alloy, copper or zinc, or it may be bitumen sheathed metal such as lead cored bitumen or felt damp-course. Here again, the cavity is bridged, and often-times these gutters are filled with mortar droppings. Apart from this, the metal checks the free flow of the moisture on the inner face of the outer lining; the writer is of the opinion that in the case of independent linings (as shewn in Figs. 28 and 29) the wall would be more damp-resistant without the gutter than with it.

Fig. 28 is recommended in the Pickering Prize Paper of 1925, and the writer agrees with this form. The great point with cavity brickwork is that there must be a means of clearing and inspecting the cavities after the wall construction has been completed. In the case of Fig. 28, the frame need not be inserted until the construction, cleaning and inspection are done. Even after many years, if some corrosion or mishap should occur with the metal, then as there is no connection between it and the outer lining, the flow of moisture will still find its way out, and not in.

Fig. 29 shews the principle of Fig. 18, but with the frame near the outer face. The writer does not favour this position for the frame for cavity construction.

CAVITY TIES.

A few words can be inserted here as to ties: Stoneware ties create a lot of trouble for they hold mortar droppings rather badly. The writer has not used them, for when he was using cavity construction for the first time, a builder friend of his invited him to inspect a cavity-built hostel which was very damp. In this case, the stoneware ties contributed largely to the failure.

The writer likes a galvanised iron tie (well galvanised), with a section of 1 in. by $\frac{3}{16}$ in., forked at ends and twisted in the centre.

WEATHER RESISTANCE IN ROOF CONSTRUCTION.

Fig. 30 shews the parapet at the top of a slope roof, and Fig. 31 is a far better form of weather-resistant construction.

Fig. 32 shews a junction of a slope roof with a higher wall, and two sets of conditions are here embodied in one drawing.

The writer is convinced that, where exposed to much weather, slating, tiling or similar construction (which forms a break in the capillary path) is the best solution for this kind of problem of weather-resistance. The photograph which is Fig. 44 is an example of a "jump" in a roof carried out by him during 1932. The tops of the slates are bedded to prevent movement or rattle, and the lead soaker has been given a coat of whitewash in order to make it plainer in the photograph.

The writer agrees in not favouring stacks on hips, but if such is necessary, he recommends two sets of slate damp-proof courses as shewn in Fig. 33, and the rendering of the internal brickwork between the damp-courses in cement.

Figs 34 and 35 shew the wrong and right way of making fillets, and the writer has seen proper cement fillets successful in weather resistance after lead flashings have failed. The lead should be coated with a resilient mastic where the cement mortar is applied: with roof movements, this will allow the soaker to yield from its contact with the cement fillet.

Figs. 36 and 37 shew the inadvisability of filling up a party or dividing wall to the backs of the rafters.

Figs 38 to 42 deal with verge protection and are self-explanatory. The writer has used both verge capping and verge tiles in recent years, and with good results.

Fig. 43 shews a slated eaves suitable for a stormy district. The joint of plate, rafter and a tying ceiling joist makes for rigid construction. This is not the case when a coved ceiling is arranged, and the ceiling joist secured higher up. The writer has seen the collapse of a good ceiling through roof movement recently, and the coved ceiling arrangement contributed to the unfortunate result.

The writer believes strongly in $4\frac{1}{2}$ in. brick partitions being carried through the second storeys of houses in order to stiffen the building, and these form direct supports to the roofs.

Other than the connection as shewn in Fig. 43, the writer believes in keeping the ceiling joists independent of the roof. Otherwise wind-pressures on the roof are transmitted to the ceiling joists, and cracked or falling ceilings are the result. This was the case with the coved ceiling referred to.

The arrangement of closing the eaves is shewn in Fig. 43, but the writer does not care for this, for it bridges the cavity, and it prevents the inspection of the cavity from the roof. When it is done, a D.P.C. should be inserted as shewn.

Fibre boards soften in the rain, and workmen put their feet through them, and for protection against driven snow on the walls, plywoods or matchboards are preferable.

Lime mortar rendering under the slating is assisted with a good helping of hair, and the panel of rendering derives a good deal of support from the rafters, over which it should be well filled.

ROOF CONSTRUCTION.

Figs. 45 to 56 deal with the constructional side of roof work, and structural roof faults often mean failure to weather resistance.

Fig. 45 indicates a good rule for fixing the collar tie or collar beam. The collar should not be higher than a third of the rise, and not half as often indicated. With the latter, spreading walls are the usual result.

Fig. 46 explains itself, while Fig. 47 shews a method often advocated for securing the principal rafter to the tie beam. The writer has seen them in a noted R.E. Barracks having fallen to positions as shewn by the dotted lines.

Fig. 48 shews a bolt instead; this acts as a dowel and the result of shrinkage does not affect it nearly as much as the other. (The bolt can be reversed, if it cannot be tightened in position). The same is done for the collar beam joint of Fig. 49. Fig. 50 shews the three-way strap, and the dotted lines A—B shew the position of the bolt, which if added, would make a very strong joint.

Fig. 51 shews the effect of arranging a solid resistance, mid-way between eaves and ridge. Shrinkage and yield of timber bring about the sags shewn, and the writer arranges such roofs as shewn on Fig. 52, which has the intermediate support below the straight line of eaves to ridge.

Slating is easier and closer with uniform sag as shewn in Fig. 53, and where steel purlins are used, this is a decided advantage. The steel purlin has the nature of rigid resistance though not to the extent of the wall, and to sag the rafters over it helps to keep the roof slate-tight over a period of many years.

The writer has a liking for steel purlins, particularly after a recent inspection of those he fixed over twenty years ago. As shewn in Fig. 54, timber plates can be bolted to them for securing the rafters, and with the nuts inside, these can be tightened after shrinkage.

The steel purlins need not have the wooden plates projecting into party walls, and the writer has used them during recent years for hipped and valleyed roofs in the manner described on the sheet of drawings.

Fig. 55 is a hardy repeat item of building construction books, and this untied roof is absolutely bad construction. It should not be shewn other than as bad construction, because of its thrust action on the supporting walls.

In small buildings, if the roof void is required to be clear of obstructing collars or ties, then Fig. 56 is a method indicating how it can be done. Here a ridge-beam extends from gable to gable, and supports the ridge. If machinery or apparatus is used in the room below, it is useful for suspending hoisting tackle for the moving about of such apparatus. In this type of roof, the writer has used ridge-beams of timber, reinforced concrete and steel, but favours the last mentioned.

Modern garage roof construction is on this principle, for a long lattice girder extends along as a ridge support. The valleys are supported from this ridge girder, leaving them without vertical supports, which is a great advantage in obtaining clear space.

AIR INFILTRATION.

In the case of tests with wind velocities ranging from 5 to 30 miles per hour, the following results were observed :—That workmanship of brickwork had a marked effect, and that the class of mortar and brick had little influence.

Gypsum plaster, if properly applied, stops all infiltration and appears to be more effective on brickwork than with a furring space as behind lathwork. Oil or water paint on walls will reduce infiltration. Cavity wall construction is liable to cause air infiltration and this at shrinkage cracks of wood, such as at frames, skirtings and windows.

GALES AND EARTHQUAKES.

B.S.S.(449—1932) for the Use of Structural Steel in Building gives wind pressure for design at a minimum of 15 lbs. per square foot for the upper two thirds of the vertical projection, with an additional 10 lbs. per square foot upon all projections above general roof level. At the sea coast and at other exposed situations a further provision is necessary. It further states that if the height of a building is less than twice its width and adequately stiffened by walls and floors, the effect of the wind can be neglected.

We get an idea of wind pressure at exposed positions from the following records :—At Old Trafford on October 26th, 1928, the wind speed was 31 miles per hour. In America the wind effect is taken as 20 lbs. per square foot for the first 500 feet height, and an additional 2 lbs. per square foot for each subsequent 100 feet height.

With earthquakes, it is found that buildings with flat monolithic foundations are better without being on piles than connected to hard strata by piles. The soil in this way has a cushion effect.

Flexible structures such as structural steel and wood structures stand shock best, and are the most reliable. Reinforced concrete comes next, but masonry is dangerous. This principle applies to districts in this country which are subject to subsidence, such as colliery districts. In the St. Louis tornado, lime mortar walls offered no resistance, and walls of cement lime mortar on a 1—1—4 basis are recommended. In the same tornado, hipped roofs behaved well.

NATURAL LIGHTING OF BUILDINGS.

Great strides have been made by the Illumination Research Board during recent years, and other writers have also carried out a great deal of research. The study of top lighting of art galleries and museums has had special attention, while hospitals and schools have had a fair share of progressive investigation. The subject of lighting of public buildings is now a science in itself, and before designing it is well worth while reading up the literature on the subject.

This is more than can be dealt with in this paper, but a few practical hints are as follows :—

Generally speaking, north windows are not desirable and the tradition of putting clerical staffs and draughtsmen in “ steady north light ” is not in favour now.

Wide windows are very much better than narrow ones, and heavy mullions should be avoided. The tops of the windows should be kept as near the ceiling as possible. Rooms of greater depth from the windows than 16 ft. should be avoided, and loggias and balconies are not suitable for this country, for they obstruct the light.

Roof lights are particularly good, and for fine-sighted indoor work they are practically essential.

ARTIFICIAL LIGHTING.

This subject has developed enormously, as papers given to previous Congresses testify.

The unit of light used is “ foot-candle ” and this should not be confused with candle power of the source of light. Light is measured by means of a portable photometer as easily as a thermometer is read.

An authority on this subject gives the following in the Journal of the Royal Sanitary Institute (November, 1932) as the foot-candles recommended for the respective purposes :—

Offices, general, 12 ; Drawing Offices, 25-50 ; Foundries and Assembly Shops (rough work), 8 ; Machine Shops (medium work), 10 ; Sewing, light goods, 12 ; Sewing, dark goods, 25-50 ; Laundries and Dry Cleansing, 12 ; Warehouses, 3.

HEATING.

The comparative costs of heating are available from five years of study of a house specially arranged for the purpose. The results are briefly as follows :—

Gas-heated boilers for circulating systems cost 3.7 times those of solid fuel. The use of coal fires to produce results equal to those of good central heating costs 2.7 times as much. This is when coke is used for the boilers. In continuously used rooms, gas fires cost 2.2 times that of coal fires, while in occasionally used rooms, gas fires are cheaper. Electric heating costs 1.57 to 1.98 times as much as gas fires.

Coal fires have other costs which are not taken into account, such as labour, chimney cleaning, etc.

With direct steam radiators, the placing of a long low radiator below the window was found to be the most economical.

Panel heating in walls and ceilings is now considered to be one of the best modern forms of heating. In this way the structure itself is warmed. With low pressure hot water, pipes of special quality of steel are required. The heating can be operated by electrically operated valves controlling the water flow, and in

summer very cold water can be passed through the pipes in order to keep the building cool.

Where free ventilation is required, radiant heating is an advantage.

The class of wall surface and wall structure counts for a lot in heating engineering.

A new instrument called an eupathoscope is now advocated for recording equivalent temperatures.

FIRE-PROOF CONSTRUCTION.

A B.S.S. for fire resistance is in preparation. B.S.S.(449—1932) deals with the subject to a limited extent, and the following few notes are taken from it.

The casing of steelwork is to be solid void-filled brickwork of well burnt bricks, or 1—2—4 concrete. The minimum thickness for external pillars is 4 in. on all sides; for internal pillars, 2 in. ditto; for beams, 2 in. on vertical sides, 1 in. on upper surface, 2 in. on soffits, and increased to $\frac{1}{8}$ of the maximum steel width where such widths exceed 16 in. (For 20 in. steel-width, then $2\frac{1}{2}$ in. of casing). A useful publication of the Building Research Station gives additional information which is incorporated in the following further notes.

The accepted figure of maximum temperature during a conflagration is 1,100°C., and this is the basis of safe design for fire resistance.

Solid wood floors or partitions are good to resist fire; they behave well in relation to other parts of the structure. The fire of a blazing petrol wagon in a 'bus station in the writer's district twisted the steel columns and roof to a medley, but 9×9 in. wood columns were structurally unscathed.

In a fire, large units such as large stones are more apt to crack and break than small units, such as rubble, masonry or bricks. Clay products such as bricks or terra-cotta behave well in a fire.

Clinker-lime mortar is better than sand-lime mortar, and puzzolonic material in mortar or concrete assists in fire resistance. Red brick sand is particularly good, and fire-brick sand gives good results.

Free lime is a serious factor in deterioration of concrete during a fire. Well-burnt brick aggregate is good, while blast-furnace cement and well graded and selected blast-furnace slag also give satisfactory results.

In reinforced concrete, or in concrete cased steel-work, it is unfortunate that heat contracts the concrete and expands the steel.

The use of hollow tiles in floors of a celluloid factory was considered inferior to monolithic construction from the point of view of fire resistance.

Solid plaster partitions are good for fire resistance, for heat insulation and for sound insulation.

A $2\frac{1}{2}$ in. solid plaster partition was found to be just as fire resistant as a $4\frac{1}{2}$ in. hollow plaster partition.

For fire resistant construction, the writer feels that there is a scope for reinforced brick walls.

HEAT INSULATION.

The heat insulation of buildings is worthy of more consideration than is given it generally.

It is here that fibre wall boards can justify one of the numerous claims of their makers, and wood is very suitable. In the latter case, plywood in panelled effect makes a pleasing wall finish. The writer has used both kinds of heat insulation during the past few years, and he finds them satisfactory. Experiments at the Building Research Station reveal that good insulation was found with a combination of layers of (a) $1\frac{1}{2}$ in. cement-gunned concrete, (b) 2 in. of slab cork, (c) 2 in. breeze concrete, and (d) $\frac{1}{2}$ in. of plastering. The writer has had some cement-gun work done, and it is of great density.

Air cavities are not to be depended upon for insulation, and a damp wall is not so good an insulation as a dry wall.

Rooms with good heat insulation cost less in heating maintenance costs, and warm up a lot quicker than if without. A friend of the writer has recently converted a huge stone building to premises of comfortable offices, and insulation board on the walls has helped him materially.

SOUND INSULATION.

Noise has a deterrent effect upon both health and efficiency. Ordinary modern fire-proof buildings, particularly those of structural steel and concrete, are bad for noise.

The claims of sound insulation made by some makers for some fibre-wall boards are extravagant and misleading, as the writer has experienced.

The traditional method of good solid construction for sound resistance is still maintained, and with space insulation the two layers must be without bridging connections. A case of the latter with bridging connections is the ordinary lath and plaster partition, where the stud acts as the bridging connection between two layers of lath and plaster. To improve on this, separate studs extending from ceiling to floor are required and no connection made between the studs of the two respective sides.

Hollow clay blocks, and lath and plaster partitions, have no more sound resistant properties than monolithic construction of the same weight.

Cork slabs are with the best of sound insulators, and it is found that rubber hardens with age, while felt loses its value when compressed under loads.

We may have to return to the traditional pugged floor, while the traditional ceiling, which is independent of the floor above, is free of its vibration, and therefore more sound-proof.

With double walls, an insulating core where there was no structural tie was found to assist greatly in sound prevention. Insulation in ordinary lath and plaster partition increased sound transmission. Soft or weak plastering is better than hard non-porous gypsum plasters for sound resistance.

ACOUSTICS.

This subject cannot be given much space here, but an immense amount of research has been made in recent years, and good literature on the subject is available.

Bad acoustics are caused largely by reverberation, or the sound persisting after the source has ceased.

Wires across a room are useless, and the shape of the ceiling counts for a lot. Segmental or barrel ceilings are particularly bad, and flat and heavily coffered ceilings are much better. At the commencement of his professional career, the writer was taught that at least two thirds of the ceiling must be flat, and he has never experienced any trouble with his own buildings.

Perforated ceilings are recently advocated in one quarter. The writer has the maintenance care of a public hall built about half-a-century ago; it has a flat and coffered ceiling, and the beam effect of the coffering is heavily pierced. The acoustics are excellent.

Other than near the source of sound (where sound reflection is an advantage), walls, floors and ceilings of sound absorbent material should be used. Lime plaster is better than hard plaster for this.

Matt paint surfaces are better for sound absorption than gloss paint surfaces.

WATER SUPPLIES.

Rapid filtration and chlorination are gaining in favour on the score of both efficiency and economy. The writer has had very satisfactory results with this method.

Chlorination with many waters appears to be the only safe method of rendering the water safe from a bacteriological standpoint. With chlorination, even slow sand filters are put to a more rapid action.

With soft peaty waters, lime saturation is in favour, but with an uncertain flow of water and a closed type of lime saturator working from a venturi tube, the writer recommends that, if possible, the main should rise on the down-stream side of the apparatus to a level which is not lower than the top of the lime saturator. By this means, the venturi tube and the lime saturator are always charged with water, which is not the case otherwise and if the flow fluctuates and falls very low.

SEA WORKS.

At Heligoland it was found that seaweed was responsible for much damage, and that it was more inclined to grow on concrete than on brick. Weakness of concrete was evidenced in the joints of the work of successive days.

In this country it is found that it is not good for concrete made with Portland cement to be exposed to sea water until at least four days old. This is an argument in favour of pre-cast blocks. Aluminous cement is stated to stand the action of the sea water much better. For assisting an aluminous concrete surface to set off quickly before the tide comes over it, a sprinkling of Portland cement is stated to be good.

The Institution of Civil Engineers has carried out exhaustive experiments in various parts of the world, and reports of these experiments have been published by the Institution and by the Department of Scientific Research on the subject of "The Deterioration of Structures in Sea Water."

SEWERS AND FLOOD PREVENTION.

On the subject of ventilation of sewers, a writer to the Journal of the Institution of Municipal and County Engineers during 1932 has voiced the condemnation which many feel for the traditional system.

The writer has advocated and acted on the following principles for many years :—

1. Do away with open grid manhole covers in streets. The sight of these in a long street on a frosty morning should convince their strongest advocate of their unhealthy effects, and to use closed covers.
(If the sewers are large enough for sewer-men to enter them, then alternative ventilation should be safely secured, or the men's lives will be in jeopardy).
2. Do not fix traps as between sewers and branch drains.
3. Let the vent shafts of the drains ventilate the whole system of sewers and drains.
4. Take care that all fittings such as gulleys and W.C.'s are trapped.
5. Then do away with the traditional fresh air inlet which is so often a foul air outlet.

For soil pipes and waste pipes to premises, the one pipe system is gaining favour and, with proper antisiphonage pipes and connections, this should win through.

The writer has had a fair experience with flood prevention schemes, and ventures to give the following results of his practical experience.

Fig. 57 shews the usual method of keeping an even gradient for the invert, even when sizes of pipes are increased. Fig. 58 shews what he recommends, which is a stepped gradient for the invert, and an even soffit for increasing sizes. He finds that it is worth sacrificing fall (if it can be spared) in order to do this, for silting is not so liable with a stepped invert, while the step will accelerate the flow of a sluggish sewer above.

Manhole inverts should have their benching edges as high as the tops of the pipes, and increased fall in manholes, particularly at bends, is of great merit.

The writer has had occasion to insert tidal flaps in existing sewers, and after trying the method indicated in Fig. 59, with unsatisfactory results, he has adopted the method of Fig. 60 with satisfactory results. A clear drop is required to keep the flap clear of impeding grit. The velocity of the flow keeps the ramp clear.

Fig. 61 shews a plan in diagram of a typical area which is flooded at abnormal tides, and the arrangement of sewers and stream is largely explanatory. The writer would draw special attention to the principle shewn more plainly in Fig. 62, which is the advisability of keeping the sewers of the uplands with an outfall (B)

above abnormal tide level. The water of both streams and sewers should not be allowed to flood the lowland, and stream-bed and sewers should freely accommodate storm flows.

The tide should not enter the stream bed, and the tide and the stream should not enter the sewer; but the stream and sewer must be able to flow into the tide. Hence, the arrangement of tidal flaps. If the sewer is inclined to overflow during storms, then overflows could be made to the stream, with flaps on the stream side which would prevent the stream entering the sewer. In some cases, it is desirable to be able to turn some of the stream into the sewer. The writer had such an experience when the spate of a stream arrived at high tide level eight hours after a cloud burst, which had taken place higher up the valley. The stream bed near the tide was insufficient, and some of the stream was usefully turned into the sewer, while the tide allowed it.

As a rule, the water descending in the form of rain on the lowland itself, and the sewage of the lowland, are not likely to cause trouble. If it is a good volume, a reservoir should be available in the form of a tank or large sewer, or mechanically operating pumps can be used. These principles largely apply in a similar manner to the inland problems of flood prevention.

Part III.—COHERENCE AND PROGRESSION.

INTRODUCTION.

“The thing that hath been, it is that which shall be; and that which is done, is that which shall be done; and there is no new thing under the sun. Is there anything whereof it may be said, this is new? It hath been already of old time, which was before us.”

Such are the words of the builder king of three thousand years ago, and he claimed to have seen “all the works that were done under the sun.”

His neighbouring country was one of huge temples and pyramids, and whose building traditions were already ancient in his day.

And he, the Solomon of wisdom, was the great modern constructionalist of his generation, and from his specifications were built the numerous buildings and public works which made Jerusalem the famous city of his age.

We, in our day, have inspected the wide range of modern structures and waded through the helpful welter of our technical literature. On the other hand, we have repaired and demolished structures, we have glowed over ancient buildings, and pored over the archives of a constructional past.

And now, in seeking a helpful message for the future, we still find ourselves bound to tradition, and obliged to acknowledge the wisdom of the ancient builder-king.

Yet, it would have been a conceit of our age were it otherwise, for we are not the builders of generation-old structures such as aeroplanes and motor cars. Our work has come down to us through thousands of years and we are the inheritors of a very ancient craft.

In reviewing what has been written in the two previous parts, we discover but little that varies with the soundness of traditional construction. In fact, what is discovered as a variance to tradition has probably been lost in its course, for even yet there are some ancient secrets which modern science has failed to re-discover.

It is true that the range of materials has increased greatly, but that has only thrown us back upon the need of fundamental principles, and in that way we are back with tradition.

Even in modern research, experiments for accelerated tests are generally based on or compared with the information of tradition. Modern tests for slates, for instance, are definitely based upon the traditional characteristics of slates.

With the discovery of “new” material we might ask ourselves whether it has been used some time before in the world’s history. Asphalt, apparently a modern material, is found, after a little thought on traditional lines, to have been used for water-proofing the cradle of a great Hebrew leader about four thousand years ago, while the bricks of the Babylonian palace of Nebuchadnezzar were bedded in a mixture of bitumen and gypsum—each brick having a D.P.C. of its own.

Our experience with wall boards of wood fibre and wood pulp were disappointing because we did not remember the traditional behaviour of the parent material—wood.

Similarly with concrete we were disappointed to find it permeable to moisture and that it cracked through setting shrinkage. Here, again, we expected too much, and forgot the existence of quarry sap and quarry beds, joints and fissures in the parent material—stone.

So without the experience handed forward by tradition, we should be without coherence and without bases of reasoning.

Nor should we forget in this age of cold calculations that we owe a great deal to the inspiration of tradition, for without it we should lack much pleasure and pride of craftsmanship. Shall we cite instances?

Robert Louis Stevenson wrote that little poem, “I have a little shadow,” and when the writer’s children recite it, his thoughts are carried away to a treacherous and tide-covered rock in a desolate Scottish sea. On this, Robert Louis’ grandfather, Robert Stevenson, built the Bell Rock Lighthouse.

We get the story from the grandson, who compiled it from his grandsire’s records. It is a wonderful account, and the former glows with the tradition of it all.

The rock was the scene of a previous legend about Ralph the Rover who cut away its warning bell, only to meet his death later on the self-same spot. Such is the legend which savours of poetic justice.

But the traditional feat of the engineer was greater and more real than this legend, and the beacon of the lighthouse is in another way a beacon of traditional success of man’s history.

For several years the courageous engineer and his staff combatted tide and weather with "water, water, everywhere," in order to give other humans the succour of a warning light. Not only that, but they gave us another tradition to enrich our craft and to inspire us to like efforts.

To a lesser degree do we receive our nearer traditions, and these are oftentimes so near to us that we do not value them sufficiently. The following is an example, and the writer asks pardon for its personal note.

In 1882, which was several years before the writer was thought of, his grandfather and father successfully built a sea wall where two previous failures had taken place.

They were mason builders with no scientific knowledge, and with no literature to help them. Yet they had sufficient knowledge and skill to build that wall, and to build it well, for it was in excellent condition a few years ago, when the writer took his father and his own son to see it.

That knowledge was what tradition had handed on to them by their craftsmen forebears, and to this they added their own sagacity and skill, which brought about success.

It is impossible for the writer to claim any credit for this work, and yet its existence now gives him much pleasurable thought, for to him it is a tradition with family associations.

Similarly with experience and research, bare knowledge alone is often incomplete in its message-carrying powers, and the addition of interest and inspiration counts for a very great deal.

In the wide range of structures covered by the terms "Buildings" and "Public Works," and in the wider range of materials necessary for them, we should not go far in construction if our technical knowledge lacked coherence, nor could we hope for progression without it.

Coherence finds guidance and inspiration in tradition; in experience it finds a sound and direct realisation; and in research it finds a deeper and profounder knowledge.

Under the sub-title of this paper we shall endeavour to deal with a few fundamental principles of construction, and follow these up with coherent policies which the writer feels are necessary for progression.

FUNDAMENTAL PRINCIPLES.

MOVEMENT.

In a universe which is continually moving it is only natural that man is unable to construct in a way which is absolutely inert. He aims at inertness, and the science of his construction is based on this, but movement follows him, although it may be infinitesimal in many cases.

His science, therefore, becomes a means of lessening it or of arranging movement so that the strength or purpose of his structures do not suffer unduly because of it.

Our structures are subject to movement—subject to the changing action of air, heat and moisture. In response to these changes, the materials expand and shrink, and our structures respond to the movements of their materials.

Air will infiltrate through materials in varying degrees, according to its power in the form of wind, and the compactness of the structures of the materials. If dry, it may absorb moisture and cause shrinkage of the material, concrete being an example. If carrying heat or moisture, it may cause expansion.

The effects on materials vary considerably as compared with each other, and also in themselves. A material will shrink with a cause such as heat, and with continued heat expand again to a greater volume than its original state. Another material may act just to the reverse.

Such changes can be either temporary or permanent, or both, and they can be of gradual permanent increase or decrease.

Figs. 1 to 11 indicate the characteristic shrinkages of timber and it is one of the fundamental principles of practical education to learn the characteristic movements of all materials employed.

The effect of movements can be seen from the external appearance of material, but it is just as important to know what the internal movements are. External effects are largely due to internal movements, although internal movements are largely caused by external influences.

It is here that research has done so much for us in recent years, and its experiments, tests and findings have been exceedingly helpful.

Figs. 63 to 71 indicate the effect of movements, and it is hoped that they are sufficiently explanatory without any undue text reference.

Three classes of movements are dealt with, namely "Equal," "Unequal," and "Contrarial," and these for adjacent units and in single units. Fig. 69 shews a balance of movements for the sake of illustration, but this is almost an impossibility. Ordinary expansion and contraction of concrete and steel in reinforced concrete can be cited as an example. For concrete, another movement would be required, and that is "setting shrinkage," which may take several years to shew effect. An example of equal movement would be in the effect of heat on two layers of stone of the same character and size which are laid together.

An example of unequal movement is that of a cement surface laid on a new lime mortar surface. The shrinkages are unequal and the layers come apart.

For contrarial movement, the effect of dry wood blocks laid on new concrete gives a good example. The dry wood blocks expand with moisture from the air, and the concrete shrinks in setting.

For unequal and contrarial movements, yielding mortars are of great assistance. For wood blocks on concrete, a resilient mortar or viscous mastic of bitumen is suitable. This adheres to both surfaces, but allows for yield or slide in its thickness. In other cases non-adherence allows the slide to take place, but retains good bearing.

UNIFORMITY.

Throughout the study of construction the principle of uniformity follows us. In practical work, it is known, in some of its phases, as trying to arrange "like to like." The cement mortar would not adhere to the lime mortar, and this is a typical case. We get the failures of composition floors on concrete, of mastic asphalt on concrete, and numerous others.

Another important kind of uniformity is that of texture. A fine grained texture may expand or shrink more than an open grain texture; or it may absorb moisture at a faster rate and thereby accelerate movements.

In still another way we found that lack of uniformity in the use of different metals in contact caused electrolytic action, and that this resulted in the corrosion of the metals.

For wearing surfaces of floors and roads, uniformity is highly important. Uniformity of texture helps uniform wear, and uniform thickness aids uniformity of impact resistance.

We have all seen the hard knots protruding in wood floors which have to take heavy wear, or of the scaling grain in others, and it makes us agree with having uniform edge-grain boards without knots for wood floors.

MORTAR STRENGTHS.

From the previous parts it will be seen that a good constructional principle is to avoid having a mortar or minor material which is stronger than the major material, such as brick or stone.

This again is a matter of meeting movement, whether internal, such as moisture movement, or external such as the need of a cushion effect in the joints, or lateral "yield," "give" or "slide."

SIZE OF UNITS.

The greater the size of the unit, the greater its bond strength, and the greater its movement. The lesser the size of the units, the greater the elasticity of the construction. A slate roof is an excellent example of this.

DEGREE OF SUITABILITY.

If we take the last paragraph as a basis, then for a certain purpose there is a perfection in a certain size. If the stone is very large, it may crack in position and be extremely difficult to place or replace. On the other hand, if very small, the structure would fall apart for need of bond strength. There is, therefore, when all conditions are summed up, an ideal or perfect size.

In other cases, it may be a matter of ideal porosity for the purpose, such as an internal wall surface in relation to condensation. Then it may be strength, colour, or some other characteristic.

In the use of material we have to study its degree of suitability and for this purpose the knowledge of the characteristics of material is of great importance.

We are now fortunate in being able to ask the aid of research for this purpose, if tradition and experience are insufficient.

THE CAPILLARY PATH.

In relation to constructional materials, water, when in contact, seeks a path and moves along it. This movement, if downwards, may be aided by a direct force such as a head of water or the striking force of rain, while it can have its own gravity pull as well. It will move in all directions in a material if the capillary path is suitable, and it will counteract gravity by means of the capillary pull upwards.

Fig. 72 gives an example of several conditions.

Firstly, we have the actual water in the canal which is directly in contact with the retaining wall for the face F—H. This is a *direct and continual water contact*.

Secondly, we have ground water to the level of I—J, and this makes another *direct water contact* which is *fairly continual*.

Thirdly, there is soil above the ground water level which is moist. It contains ground air which is a mixture of air and water. When the ground water rises, its powerful hydraulic force is exerted, and the moist ground air is bound to have vent upwards; this accounts for many site troubles. Its *contact is continual*.

Fourthly, we have the rain in *direct* but *intermittent contact* with the external side of the wall.

Fifthly, there is the effect of a warm moisture-laden (or humid) atmosphere on the internal face C—D. The humidity is of *intermittent action*.

For the purpose of damp-resistance, materials can be classed as "permeable" and "impermeable." It may be said that no material is absolutely impermeable, but some have this characteristic to a sufficient degree to merit the use of the term. Examples would be some classes of stones, slate, semi-vitreous brick products, and the metals.

For the sake of illustration, the canal wall is assumed to be of impermeable material and the other wall of permeable material.

The soil above the ground water contains moisture. This moisture is derived chiefly from the ground water, and by means of the aid of *capillary paths* in the soil, it defies gravity and rises upwards.

The wall between the ground water level P, and the damp course level M is damp, whereas that below it is completely saturated. The section M—P derives its moisture from the soil with which it is in contact. There is an evaporating face at M—N; and while the evaporation is going on, there is a continual creep of damp from the ground water through the soil and wall above, to the evaporating face. In such a case, the evaporating face aids the movement of damp.

The action is not unlike that of the wick of an oil lamp which carries a limited quantity of oil upwards from the oil-well in feeding the flame. If the flame is not burning the action ceases, or if the oil-well becomes empty the flame dies because it is not fed.

On the external face A—B, there is the intermittent effect of direct saturation from rain. The wall is not permeable and the capillary pull comes into play and draws the moisture slowly but surely inwards.

We will assume that the rain ceases when it has only travelled a third of the wall thickness, and that the sun shines. The position is now reversed, and A—B is an evaporating face, and the moisture action is outwards.

Without being exposed to as much saturation, the internal face C—D goes through a similar process. If incessant rain makes a continual feed to the capillary paths, then its wall moisture will meet the condensation moisture, overcome it, and pass to the internal face. Once this happens, the internal face is rarely the same again.

Condensation in the face of a thick wall cannot pass through it, and returns upon evaporation. The writer has under his care some well-built cottages, which were built originally for coastguards, and such is what happens in them.

In Fig. 72, we have an impermeable damp-course to check the capillary action, and it forms a kind of horizontal dam.

Under the concrete of the ventilated air-space, we have a dry stone layer which makes a horizontal check in the capillary path. The dry filling behind the canal retaining wall acts as a vertical check where above ground water level, and in a similar way.

Figs. 73 to 77 shews various forms of wall sections which have their respective advantages, but with one great disadvantage, namely, that the internal wall condensation must return on the internal face.

Fig. 78 shews ordinary cavity work, which has a complete break in the capillary path, and this construction allows the condensation to pass through for evaporation in the ventilated cavity.

Fig. 79 shews a cavity wall with an impermeable face externally. This checks external moisture, which is an advantage to the life of the wall.

Fig. 80 shews a slated wall, which provides two breaks in the capillary path from the outside, one being between the slates and the other being beneath the slating. The internal condensation has a long way to travel for evaporation to the last mentioned space.

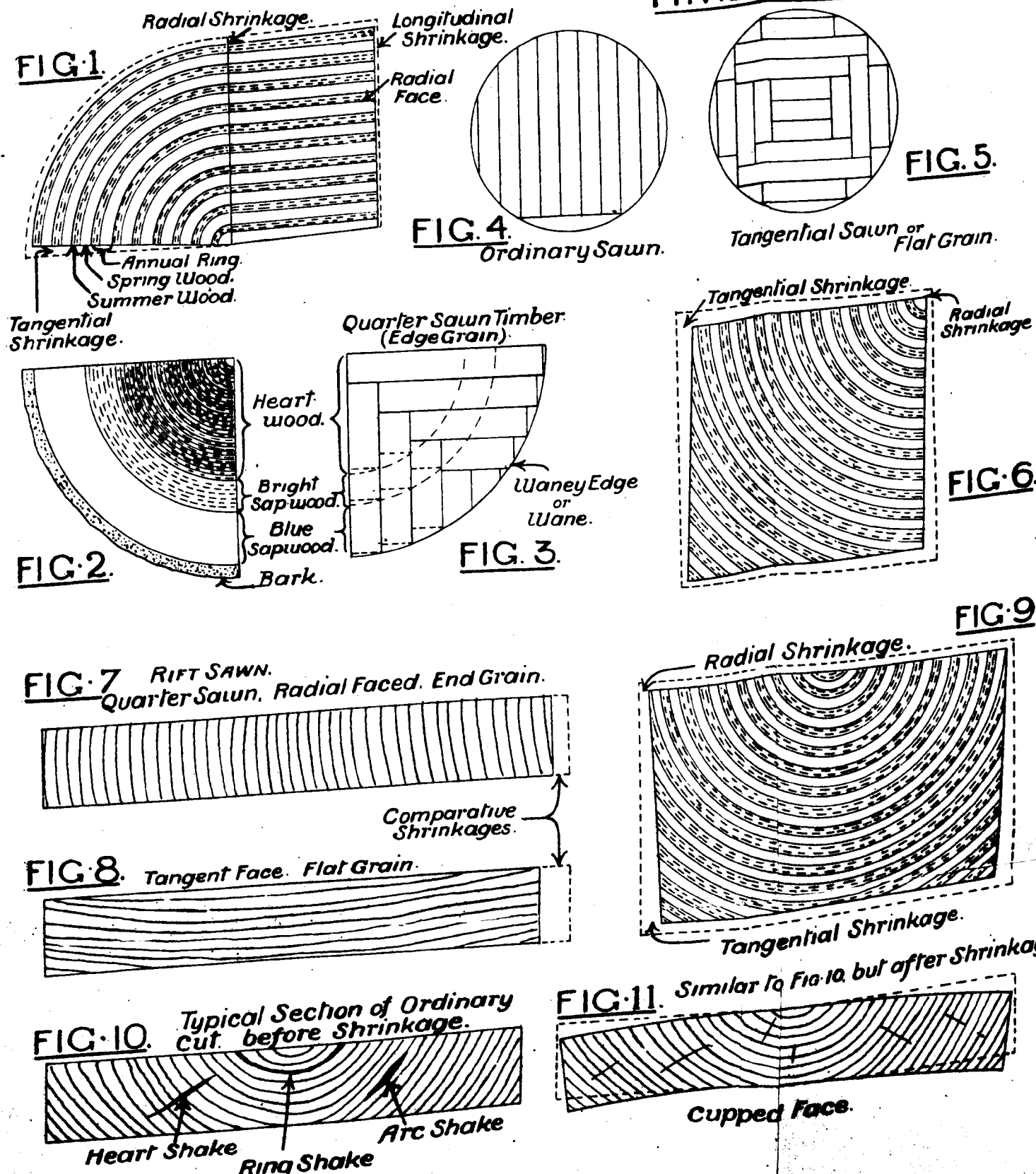
Fig. 81 shews a triple protection, and if one is taken away, it should be the central dam.

For dampcourses against soils, cement renderings are most unsatisfactory. In many cases they assist the capillary pull of moisture inwards. Indeed, this also often happens in external faces of walls above ground.

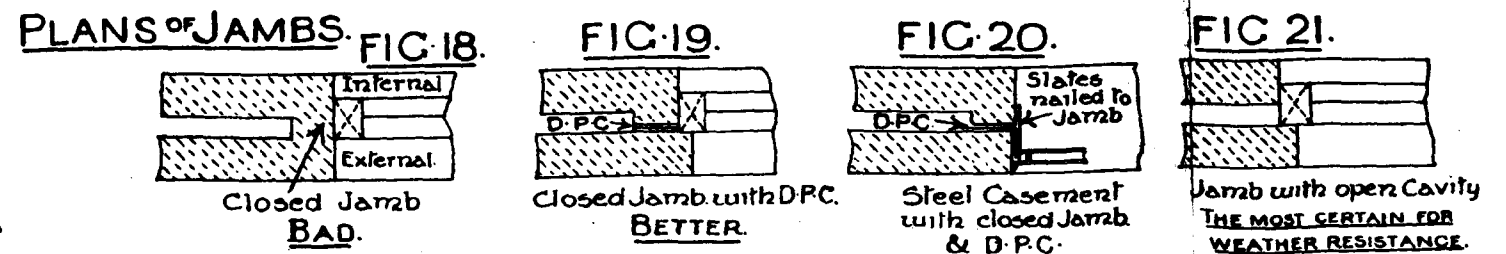
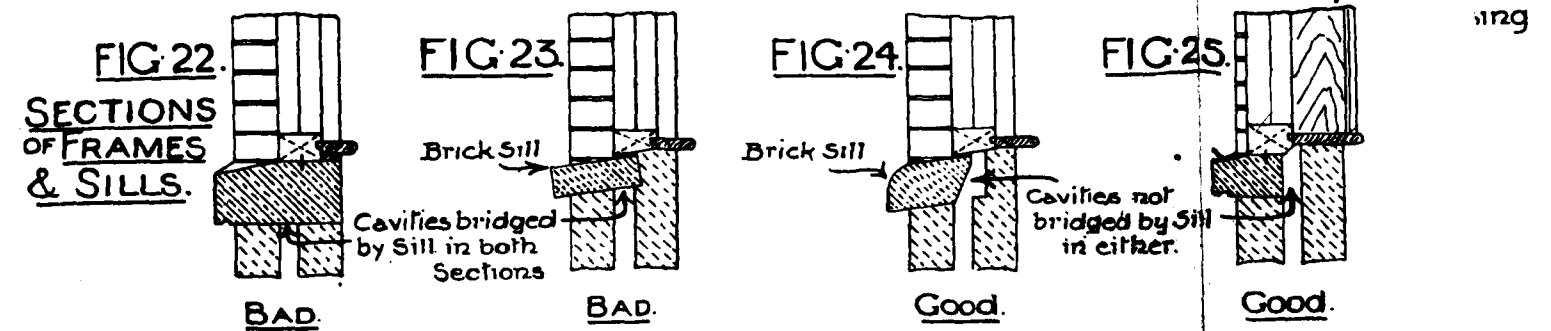
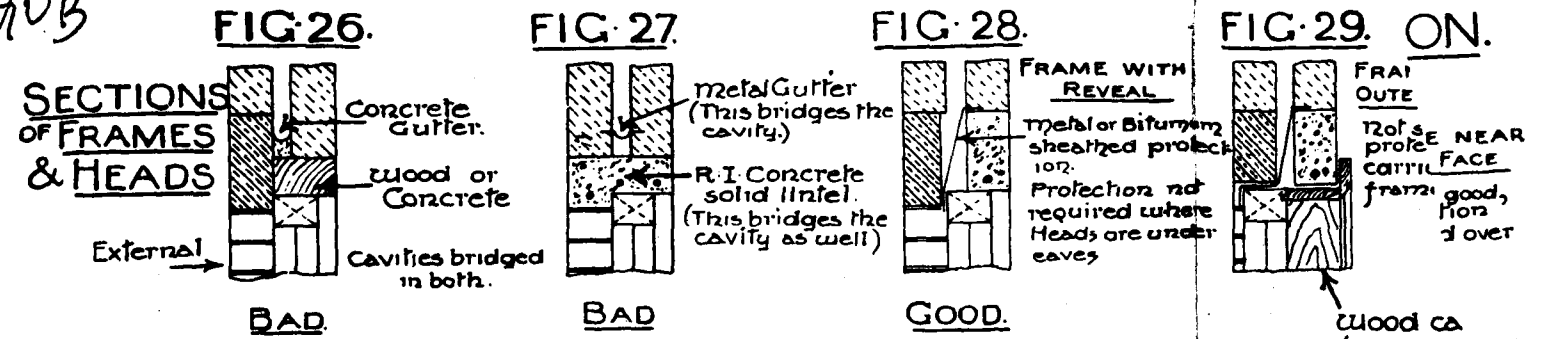
Figs. 82 to 85 are sections of stone walls which explain themselves.

For construction, therefore, we have from a moisture point of view, (a) solid walls, roofs or floors which provide complete connection of capillary paths, (b) partially solid ditto, which bring about partial independence of two layers and thereby form partial breaks in the capillary paths, and (c) definitely independent layers or cavity construction with definite breaks in the capillary paths. The last is the most reliable, and the second next to it.

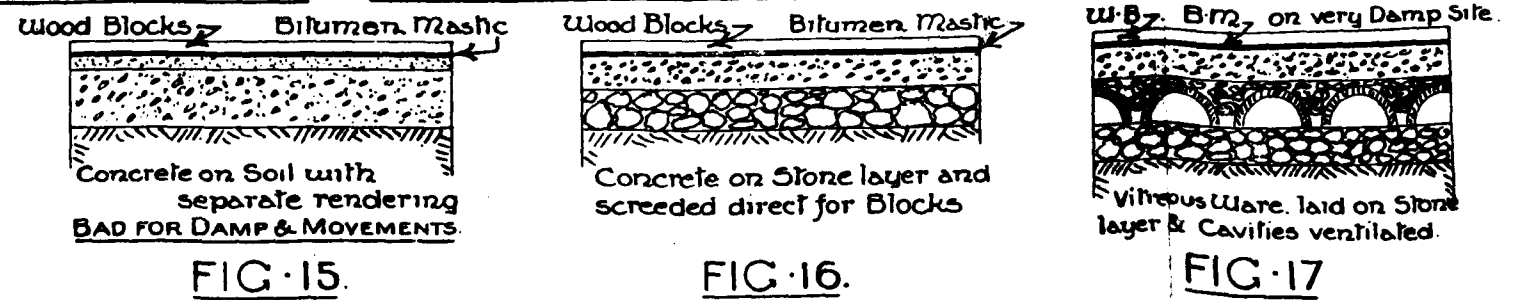
SHRINKAGE & CONVERSION OF TIMBER SECTIONS.



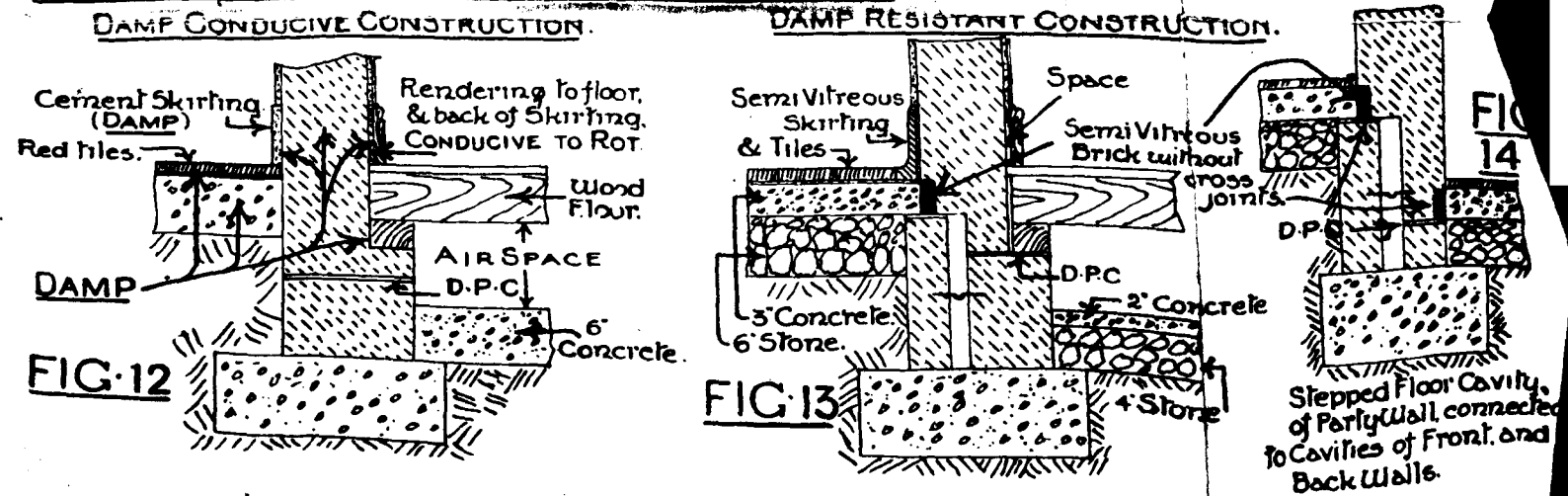
2903 DAMP-RESISTANT WALL & FLOOR CONSTRUCTION



WOOD BLOCK OR COMPOSITION FLOORS, or GROUND FLOORS.



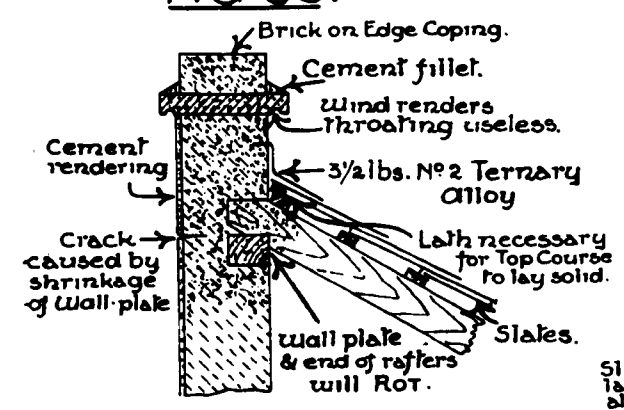
FOUNDATIONS & GROUND FLOORS



WEATHER-RESISTANT · ROOF CONSTRUCTION.

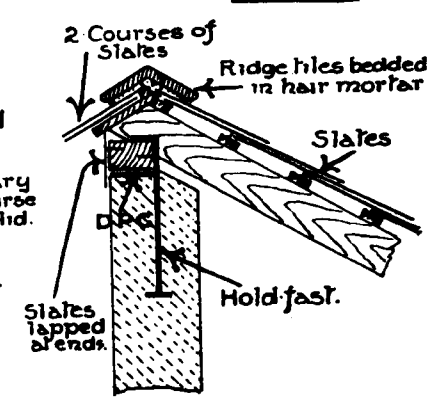
290C

FIG. 30.



DAMP WALL & ROOF CONNECTION.

FIG. 31.



A DRIER & CHEAPER ALTERNATIVE.

FIG. 32.

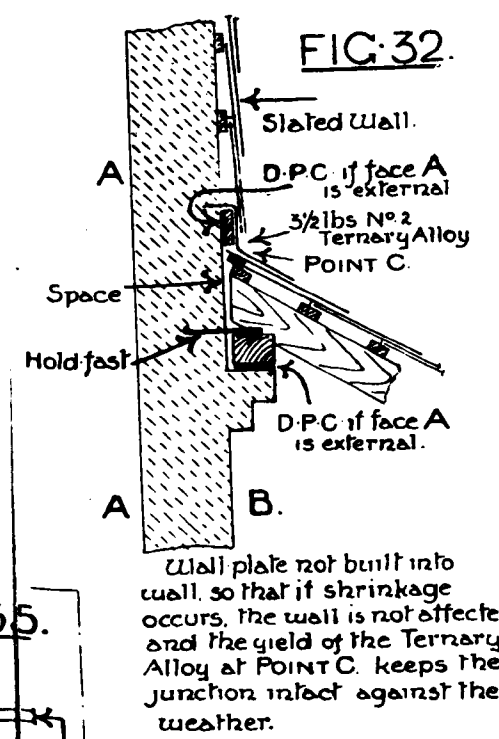
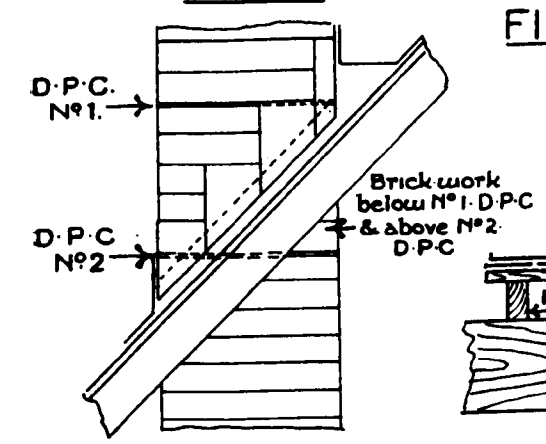


FIG. 33.



ROOF FILLETS.

FIG. 34.

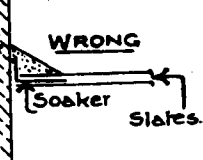
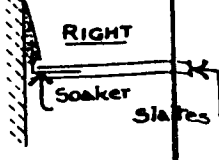


FIG. 35.



PARTY WALLS.

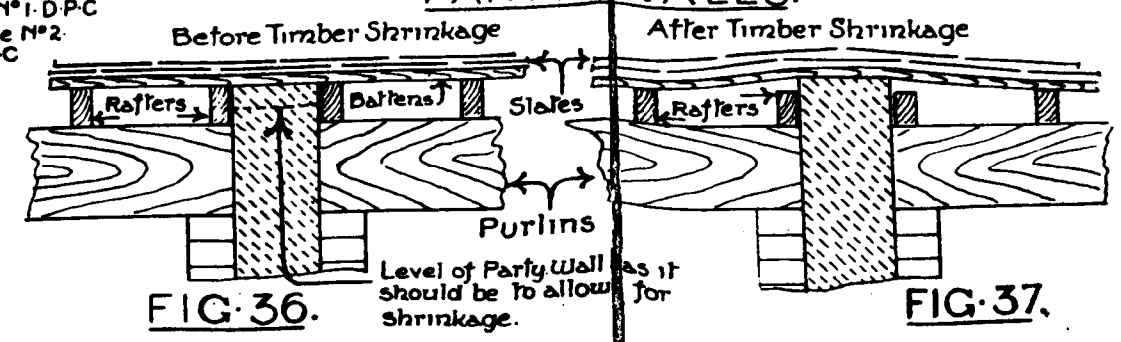
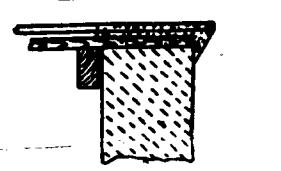


FIG. 36.

FIG. 37.

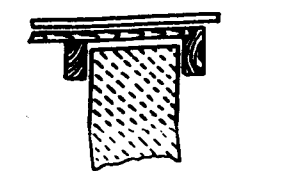
VERGES. (SLATE)

FIG. 38.



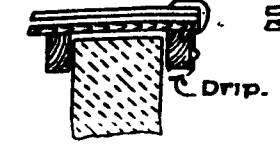
Bedded Verges, causing Damp & Rotting Batters.

FIG. 39.



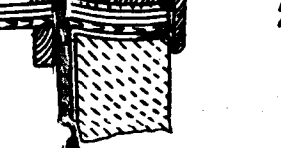
Rafters outside wall, No bedding or pointing. Better appearance & capillary path broken.

FIG. 40.



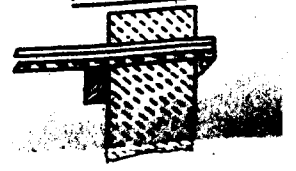
Verge Capping in Zinc or Copper. GOOD PROTECTION.

FIG. 41.



Verge Tiles. GOOD PROTECTION. No pointing required. Supporting Hooks at eaves.

FIG. 42.



Brick bedded on top of Slating and with Supporting Hook at eaves. Much used in stormy districts.

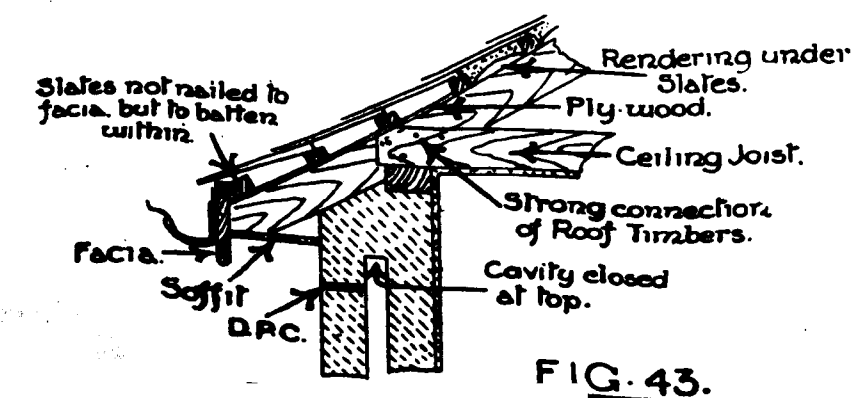


FIG. 43.

FIG. 44.



290D

— ROOF CONSTRUCTION —

FIG. 45.
COLLAR RAFTER

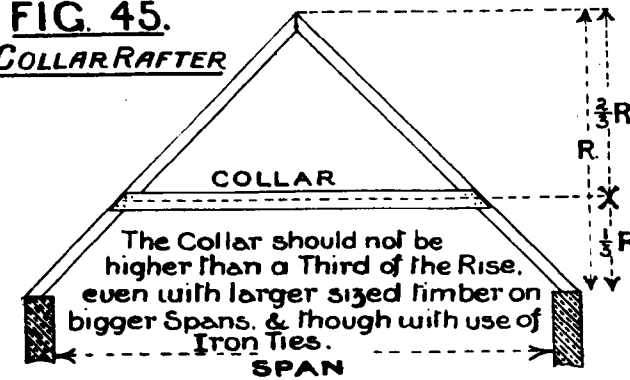


FIG. 46.

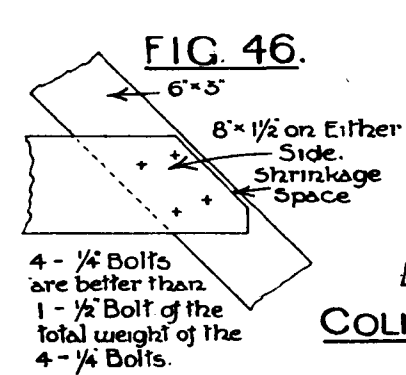
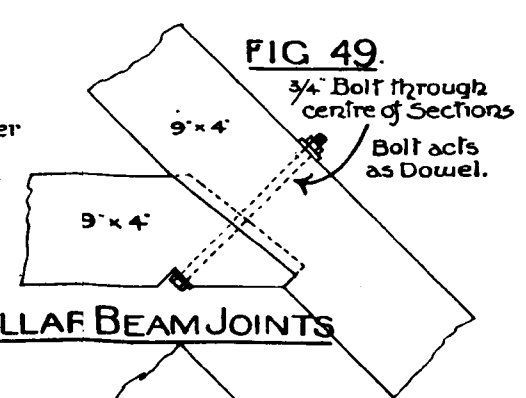
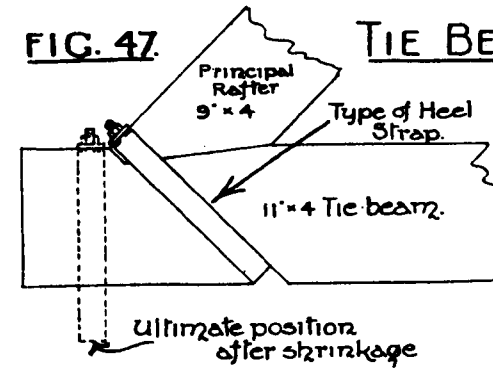


FIG. 49.



COLLAR BEAM JOINTS

FIG. 47.



TIE BEAM JOINTS.

FIG. 48.

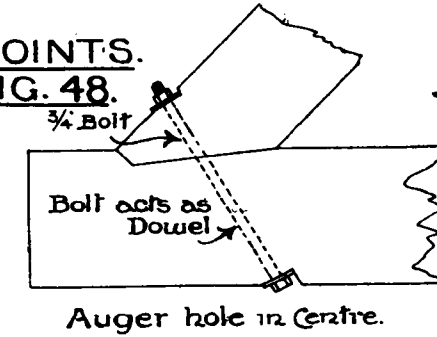
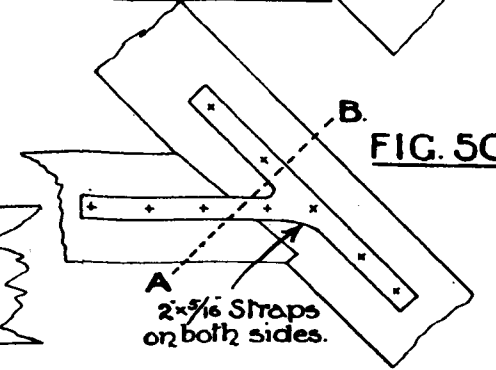


FIG. 50.



Straight Roof Sagged

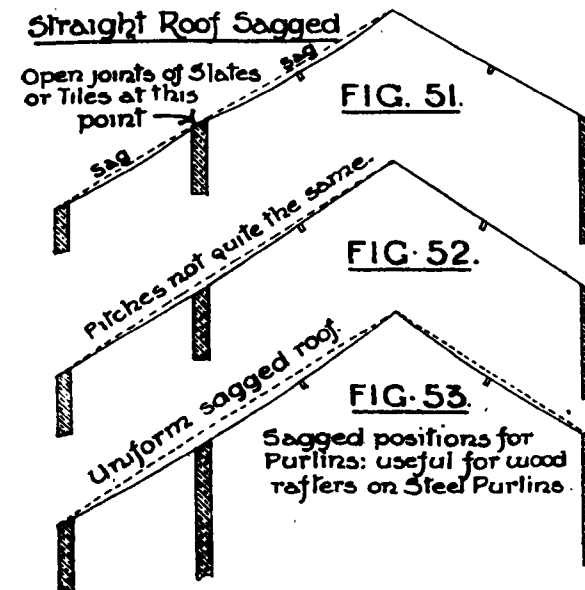


FIG. 51.

FIG. 52.

FIG. 53.

Sagged positions for Purlins: useful for wood rafters on Steel Purlins.

FIG. 54.

STEEL PURLIN

For Hips & Valleys, the Steel Purlin is kept just short of Hip and Valley Rafters, & the plate projects & forms the joint. Bolts can be inserted at each joint.

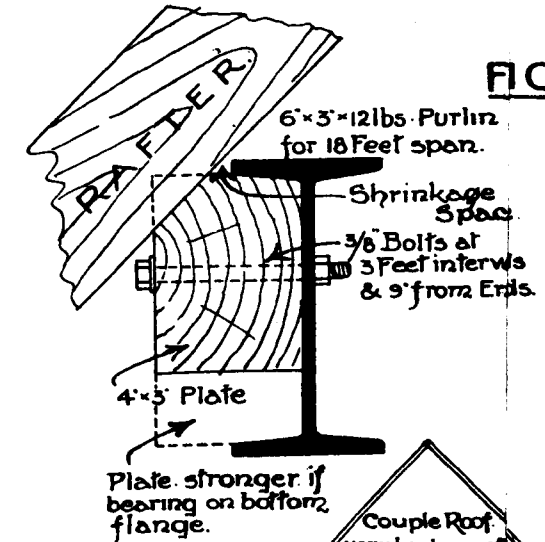
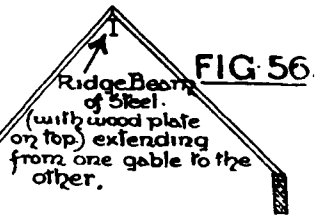


FIG. 55.

Couple Roof very bad construction Thrust on walls very great.

FIG. 56.



SEWERS & FLOOD PREVENTION.

SEWER WITH EVEN GRADIENT TO INVERT.



290 E

FIG. 57.

STEPPED INVERT TO ASSIST SLUGGISH SEWER ABOVE.

SEWER WITH EVEN GRADIENT TO SOFFIT.

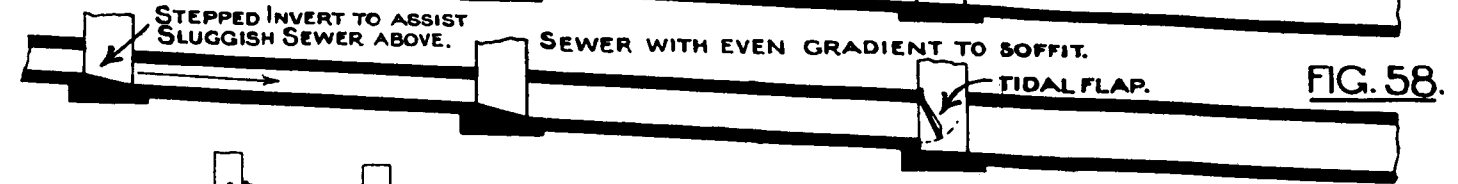


FIG. 58.

FIG. 59.



FIG. 60.

ARRANGING TIDAL FLAP IN EXISTING SEWER.

PRINCIPLES OF FLOOD PREVENTION NEAR SEA-SHORE. PLAN IN DIAGRAM.

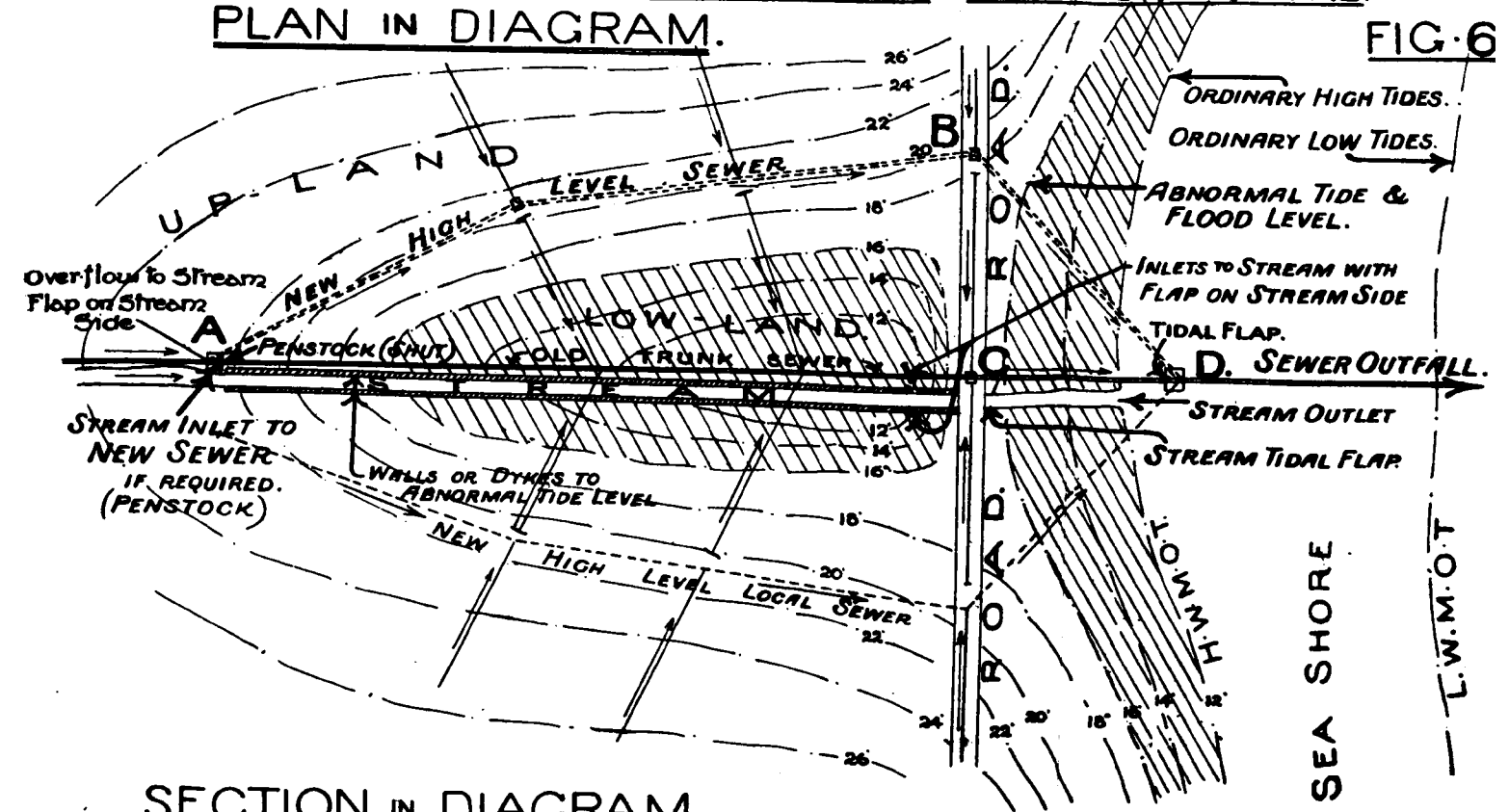


FIG. 6.

SECTION IN DIAGRAM

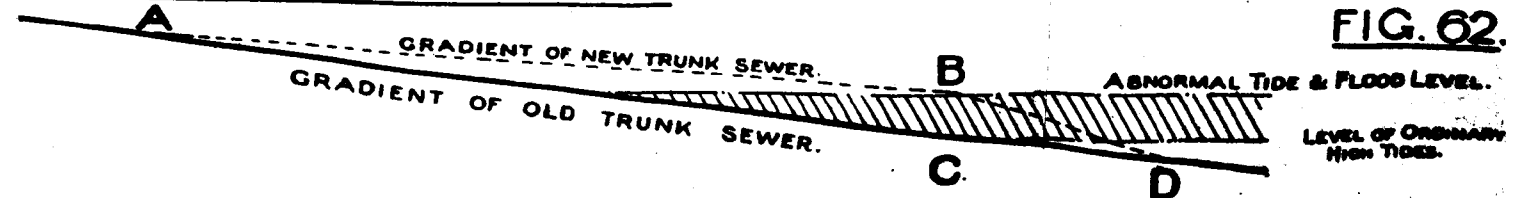
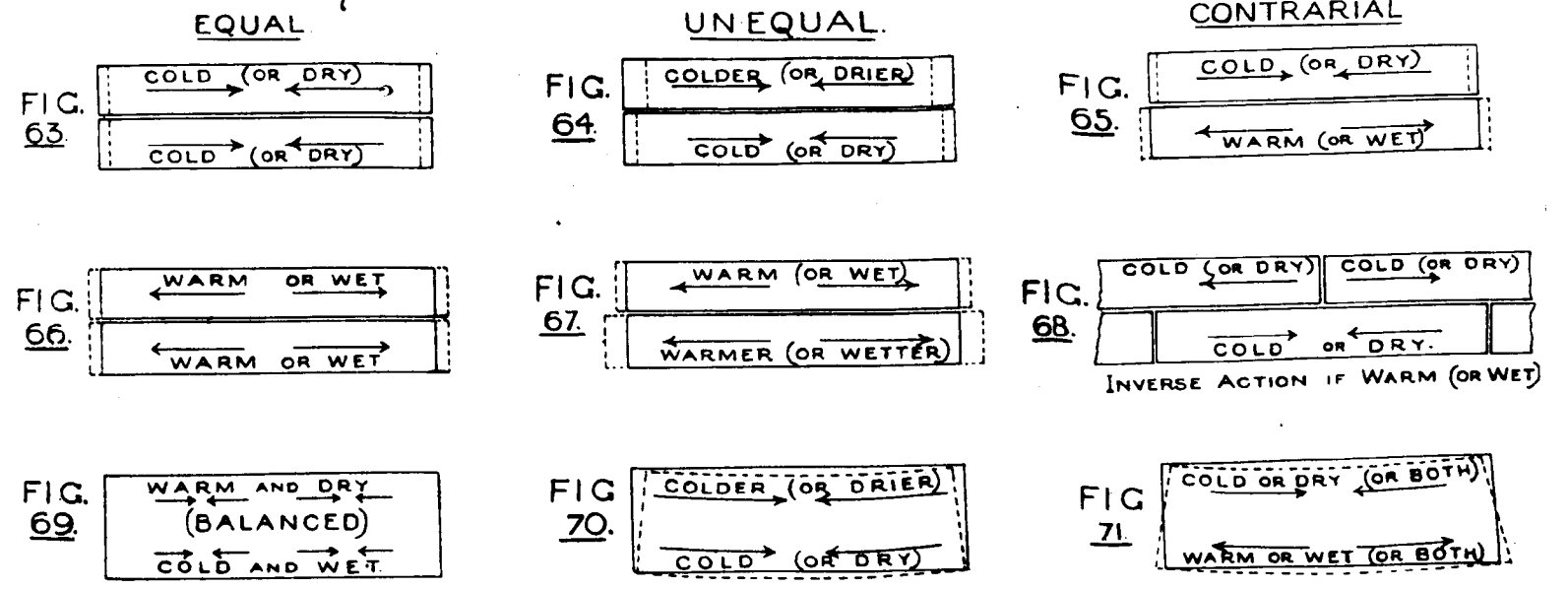


FIG. 62.

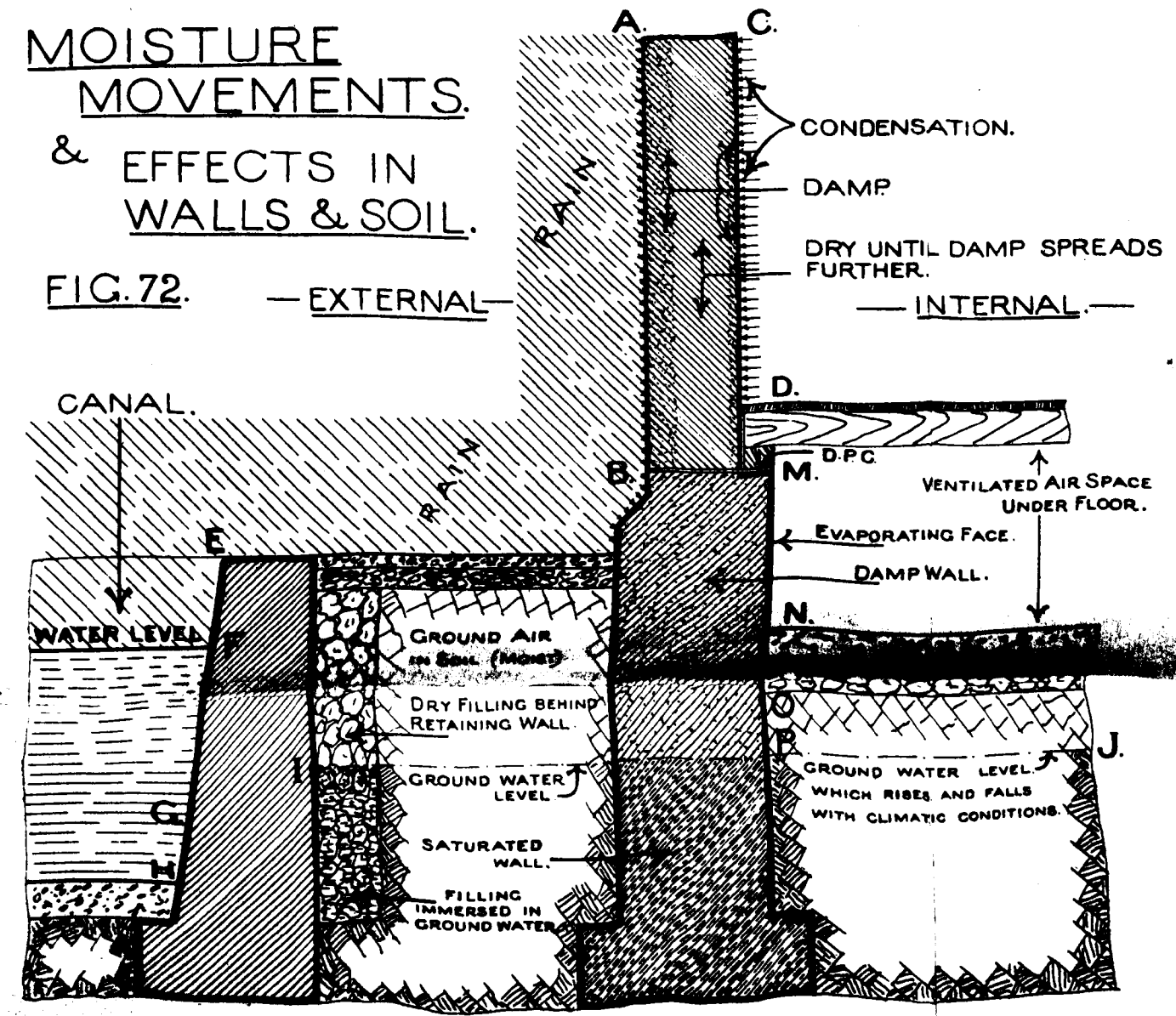
290 F

MOVEMENTS.



MOISTURE MOVEMENTS. & EFFECTS IN WALLS & SOIL.

FIG. 72. — EXTERNAL —



2906

VARIOUS CLASSES OF WALLS. DESIGNED FOR PREVENTION OF DAMP

NOTE.

EXTERNAL FACE
ON LEFT, &
INTERNAL FACE
ON RIGHT, IN
EVERY CASE.



FIG. 73.
IMPERVIOUS
FACE
EXTERNAL.

NOT
RELIABLE.



FIG. 74.
IMPERVIOUS
FACE
INTERNAL.

BAD FOR
CONDENSATION.

NOT
RELIABLE



FIG. 75.
IMPERVIOUS
ON BOTH
FACES.

TRAPPED
MOISTURE OF
CONSTRUCTION

BAD FOR
CONDENSATION



FIG. 76.
IMPERVIOUS
DAM IN
CENTRE.

BETTER
BUT DAM IS
OUT OF SIGHT
FOR
INVESTIGATION



FIG. 77.
DOUBLE PROTECTION
IMPERVIOUS EXTERNAL
FACE AND DAM

GOOD CONSTRUCTION
IF DAM IS NOT LIABLE TO
UNDUE EXPANSION

CONDENSATION
ABSORBED BY INTERNAL
FACE MUST BE EVAPOR-
ATED ON THE SAME FACE

THE MOST
RELIABLE
CLASSES OF WALLS
ARE THOSE WITH
DEFINITE BREAKS
IN THE CAPILLARY
PATH.

CAVITIES
VENTILATED.



FIG. 78.
CAVITY WORK.
EXTERNAL
MOISTURE &
INTERNAL CON-
DENSATION DO
NOT MEET, AND
BOTH HAVE
FREE PASSAGE
TO THE CAVITY

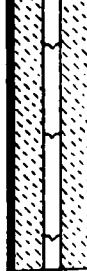


FIG. 79.
CAVITY WORK.
WITH
IMPERVIOUS
EXTERNAL
FACE.

MOISTURE OF
EXTERNAL FACE
IS CHECKED



FIG. 80.
SOLID WORK.
SLATED OR TILED
ON EXTERIOR
FACE, WITH BREAK
IN THE CAPILLARY
PATH.

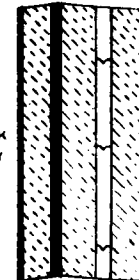


FIG. 81.
TRIPLE PROTECTION
INCLUDING CAVITY

THIS ALLOWS POSSIBLE SEEPAGE
THROUGH DAM (FROM EXTERNAL FACE)
TO HAVE OUTLET AT THE CAVITY.
THE CONDENSATION OF THE INTERNAL
FACE HAS A SIMILAR OUTLET

SUITABLE FOR BASEMENTS

STONE WALLS.

FIG. 82.



ALL JOINTS
FILLED STRONG,
BUT DAMP,
FOR CAPILLARY
PATH IS CONTIN-
UOUS FROM
OUTSIDE TO
INSIDE.

FIG. 83.



WITH CAVITY
STRONG
AND DRY
CAPILLARY
PATH BROKEN.

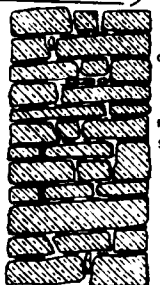
FIG. 84.



(CAPILLARY PATHS PARTIALLY BROKEN.)
CEMENTED FACE
AND CORE NOT
MORTARED BUT
SLATE PINNED
MORTAR KEPT
BACK FROM
EXTERNAL FACE
WHEN WALLED.

DRY

FIG. 85.



WATERSHOT
ON EXTERNAL
FACE
CORE NOT
MORTARED BUT
SLATE PINNED.
JOINTS
1/4 INCH THICK

DRY.

OPEN JOINTS, IN
ORDER TO BREAK
VERTICAL MORTAR
CAPILLARY PATH

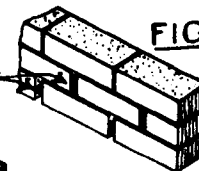
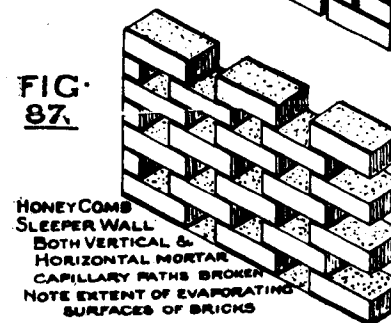
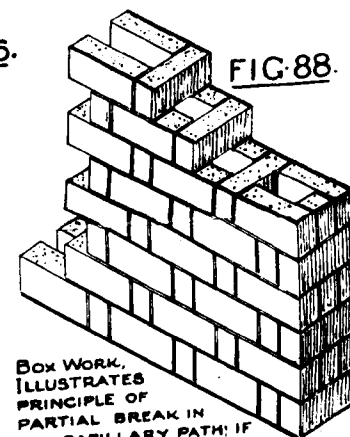


FIG. 86.

FIG. 87.



HONEYCOMB
SLEEPER WALL.
BOTH VERTICAL &
HORIZONTAL MORTAR
CAPILLARY PATHS BROKEN.
NOTE EXTENT OF EVAPORATING
SURFACES OF BRICKS



BOX WORK.
ILLUSTRATES
PRINCIPLE OF
PARTIAL BREAK IN
THE CAPILLARY PATH. IF
VENTILATED, EVAPORATION
TAKES PLACE INSIDE THE WALL.

FIG. 89.



FIG. 90.

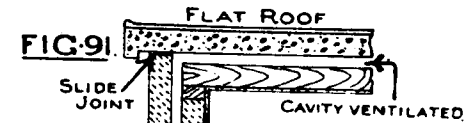
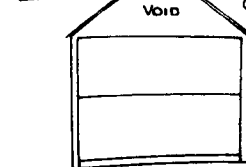


FIG. 91.
FLAT ROOF
BUILDING.
SLIDE JOINT
CAVITY VENTILATED.

FIG. 92.



SADDLE ROOF
BUILDING
CAVITY ALL
ROUND, AND IF
SLATED, THEN
WITH DOUBLE
CAVITY TO ROOF.

CAPILLARY IN VARIOUS WALL SURFACINGS.

FINE PORED MATERIAL DRAWS MOISTURE FROM COARSE PORED MATERIAL, & WIND WILL DRIVE RAIN THROUGH COARSE PORED MATERIAL, IF IN DIRECT CONTACT.

290H

FIG 93.

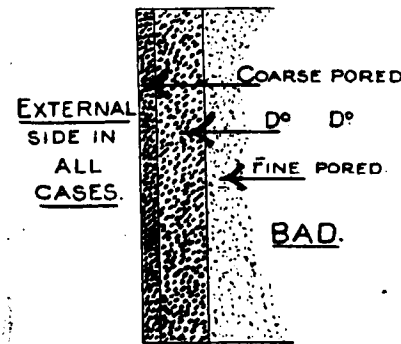


FIG 94.

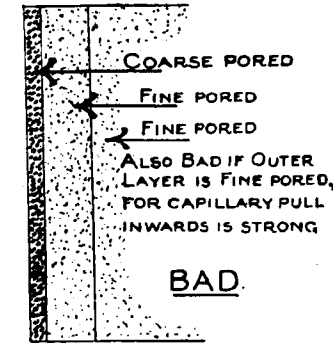


FIG 95.

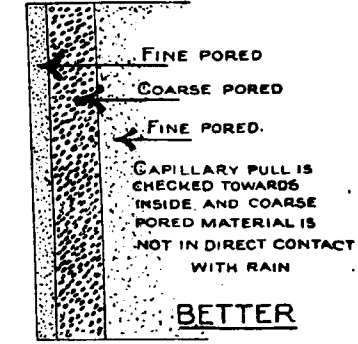


FIG 96.

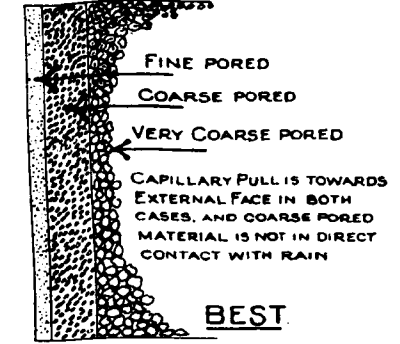


FIG 97.

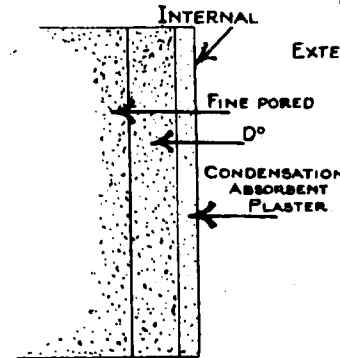


FIG 98. JOINTS OF IMPERVIOUS BRICKS

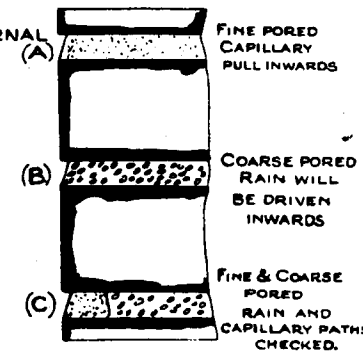


FIG 100.

COUNCIL & COMMITTEES.
MINISTRY OF HEALTH.
" " TRANSPORT.
" " LABOUR.
AIR MINISTRY
INSTITUTIONS & ASSOCIATIONS.
PUBLIC WORKS CONG.
EXHIBITIONS.
NATIONAL PHYSICAL LABORATORY.
BUILDING RESEARCH STATION.
FORESTRY PRODUCTS RESEARCH.
ILLUMINATION RESEARCH.
BRITISH STANDARDS INSTITUTION
MANUFACTURERS RESEARCH.
INDIVIDUAL RESEARCH
JOURNALS:
ENGINEERING.
ARCHITECTURAL
HYGIENE
SUNDRY.
INDUSTRIAL COUNCILS

THE GENERAL TREND OF INFORMATION AND INSTRUCTION FROM ONE SIDE TO ANOTHER, & FROM THE SCIENTIFIC SPECIALIST TO THE CRAFTSMAN SPECIALIST IS VERY OFTEN THROUGH THE
GENERAL TECHNICAL PRACTITIONER
WHO MAY BE A GENERAL BUILDER, ARCHITECT, ENGINEER, OR URBAN SURVEYOR.

BUILDING CONTRACTORS
PUBLIC WORKS DEPT.
MASONS
BRICKLAYERS.
CONCRETEORS.
PAVIORS.
ROAD-MEN.
TRAM TRACK MEN.
STREET LIGHTERS.
CARPENTERS & JOINERS.
SLATERS & TILERS.
PLASTERERS.
PLUMBERS.
PIPE & MAIN LAYERS.
HOT WATER FITTERS.
WATER SUPPLY AND EQUIPMENT.
SEWER DEPT.
SEWAGE DISPOSAL PLANT
REFUSE COLLECTION & DISPOSAL.
RIVER WORKS.
SEA DEFENCE WORKS.
PIERS.
BATHS.
TOWN PLANNING.
HOUSING & PROPERTIES
AERODROME.
WORKSHOPS
TRANSPORT PARKS.

FIG 99

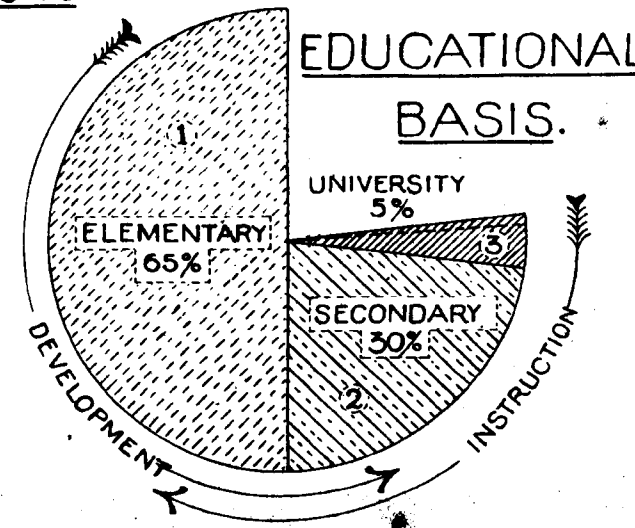


Fig. 86 shews two courses of impermeable bricks with open vertical joints. These are suitable where in contact with ground floor concrete and dry filling, and it is a damp course in itself, both horizontally and vertically.

Fig. 87 shews the usual type of honeycomb sleeper wall. The extent of the evaporating faces should be noted, for it is very doubtful if the capillary action is complete to the wall-plate D.P.C. in such a case.

This same principle of providing evaporation surfaces is found in dampcourse of vitreous tiles. They have holes which provide evaporating surfaces, and if any moisture is inclined to be drawn upwards through the tiles, the evaporation pull checks the capillary pull at these holes.

Fig. 88 indicates the same principle in boxwork walls, and the writer is of the opinion that this form of wall is drier than a 9 in. solid wall. Years ago, he used them as party fences in gardens and at the same time he used 9 in. solid work for lane fences. Upon visiting them this year (1932) he found that the boxwork was weathering better than the solid work. This was probably due to the break in the mortar path from one face to the other.

Fig. 89 gives a line diagram of a flat roof building, solid all round. If the roof expands and is anchored to the walls, it pushes the walls out. This type of movement is very unsatisfactory.

Fig. 90 shews an improvement, and Fig. 91 is a detail of the wall and roof joint. The space under the concrete roof provides a ventilation and an evaporation face for the concrete.

Fig. 92 shews the saddle roof building, which, if slated or plain tiled, has a double break or double cavity at the roof.

With regard to the capillary path, it can be emphasised that in this country (Great Britain) the form of construction which is most reliable is that which provides a complete break in the capillary path as between outside and inside a building, or between the ground and the habitable rooms; next to that comes the construction which provides a partial break in the capillary path.

This applies not only to damp resistance but to heat insulation as well.

It has been mentioned in Part No. 1 that the fine grinding of cement has brought about increased shrinkage properties, and this is a contributory cause to the failures of cement renderings.

There is another cause which is probably more important, and that is the tendency of recent years to use a fine sand for the renderings.

It has been stated previously that a fine pored material will draw moisture from a coarser pored material by means of capillary pull.

On the other hand, the wind will drive rain moisture through a coarse pored cement mortar. The writer has actually seen this done in the vertical cement joints or fillets of concrete roof slabs, and the wind overcame the principle of gravity. The moisture has been known to be driven across a cavity from a defective cross joint in the outer lining.

The writer has found that the most suitable sand particles for final coat cement work are those which range from 30 to 50 per lineal inch.

For undercoat cement work, particles from 10 to 20 are suitable, and even sand passing a $\frac{1}{4}$ in. sieve is being used. This makes a strong and coarse pored rendering, and the fewness of its cement joints (or contacts) lessens the shrinkage.

Figs. 93 to 96 illustrate the uses of fine pored and coarse pored material on external faces of walls.

Fig. 97 shews an internal face with a condensation absorbent plaster. This works well, but as a rule, the more absorbent the plaster, the softer it is, and therefore the less durable for rough use. This form of surface is not recommended for walls liable to excessive condensation such as walls of laundries, baths, etc., nor is it suitable for hospitals on the score of absorption.

Fig. 98 illustrates the same principle in connection with joints of impervious bricks. The writer has used joint (c) for both brickwork and stonework during the past two years (1931 and 1932) and so far (December, 1932) it appears to be successful. It should be borne in mind that the bricks or stones must be of an impervious nature.

POLICIES.

EDUCATION.

The rapid development of specialised lines and the varying complications and scope of modern structures call for a change of policy in our educational system.

The system of education for students is that of good elementary and secondary school education, followed in some cases by a university course. More often it is followed by technical education, which may be at a technical college in the form of full-time, part-time or evening study, or it may be in the form of correspondence study.

All these are useful, and the writer has experienced most of them and this with grateful memories. He has also been a teacher of building subjects in three different districts and was a chief teacher of building subjects in the technical college in an important city for some time. This is mentioned in no boastful sense, but in order to shew that the writer is advocating policies after having experienced those of the near past.

Nor should one forget the practical education of experience by being on actual works and developing a sense of visualising the actual materials, construction, and the labour or plant necessary in order to create a new work. The ability of visualising all this while being over a drawing board, writing a specification, or compiling a bill of quantities is a great asset.

The value of work done by our professional institutions is great, and many of them are on very practical lines. Apart from courses and examinations there is the continual refresher course brought about by Institution meetings. Here papers are not only given, but discussed, and we get the advantage of the range of the practical experiences of many. All this has a broadening influence and keeps the professions from stagnation.

We will now try to analyse the position from an educational standpoint, and see where we stand in view of coherence and progression.

We will deal with the whole range of men employed in buildings and public works from labourers to those of the highest professional standing, and see how they stand in relation to each other.

From the standpoint of scholastic education, we can divide them into three main groups, remembering that the division is only a line and not a gap.

Firstly (1) we have those who get no more than an elementary school education; secondly (2) those who get a secondary school education ranging to matriculation standard; thirdly (3) those of a university education.

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It is understood that many have left at the elementary school stage, but have returned to technical education, and would rank higher in consequence.

We will call this educational standardisation "A," and will now come to the more practical standards of "B," "C" and "D."

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For "C" the designers will be taken namely—1, Draughtsmen. 2, Specialist Designers. 3, General Designers.

For "D" we will take the investigators or researchers, and we get:—

1, Clerical. 2, Special Research, and 3, General Research.

In Classes "B," "C" and "D" there is a general sub-division of (a) Mechanicalists, (b) Specialists, and (c) Generalists. (a) represents the labourers, draughtsmen and clerks whose work is more mechanical than the others, and who are not called upon for much technical knowledge, (b) represents men who specialise in their respective lines, and (c) those who are obliged to have a bird's-eye view of a big range of work.

The General Builder, the Architect, the Surveyor, can come within Class (c), but the man with the greatest range of contact nowadays is the Urban Surveyor, who is obliged to be mostly general in his scope and outlook.

Fig. 100 indicates the position of the General Practitioner in relation to the Specialists. The information supplied by those on the left is largely for those on the right, but as a rule, it has to be passed through the General Practitioner, who has to act as judge or arbitrator of such information.

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This is of important note, for although it aids coherence, it confines the information of many channels to one channel, and this is apt to retard progress in some ways.

In other words, it is not easy to get a quart of milk into a pint bottle. In fact, it is impossible, but the cream of a quart of milk will go into a pint bottle quite easily, and this is the theme of this part of the paper.

One of the difficulties of Research is that it turns out a lot of information which is too scientific in character and in expression to be understood by those for whom it is intended and who could make real use of it. The complaint is that scientific knowledge is not sufficiently advanced generally. Although we can hope and work for this necessary advancement, we have to take things as they are at present, and think out the means of getting over the difficulty.

It is seen from Fig. 99 that grades 1 and 2 are preponderant, and it should be realised that the average educational basis of those responsible for carrying out work is found at the centre of Grade 2, which is half-way between an elementary standard and a matriculation standard.

Scientific results, however, are often published by Grade 3 with a view to being adjudged by those of the best of the grade. In this way, knowledge is not passed back sufficiently lucid for Grade 2 to understand it, and a short circuiting in Grade 3 is the result.

Public criticism in reviews is largely responsible for this, for the results of scientific investigators are reviewed or criticised by highly qualified scientific men.

Such criticisms are necessary, but the use of the knowledge is more necessary.

How is it going to be done? The writer would suggest two definite modes of expression to suit the purpose, namely "Simple Expression" understandable by Grade 2, and "Scientific Expression" understandable by those of Grade 3.

The information should be compiled on this basis, and for Grade 2, scientific proof is not required. The findings should be stated in simple and direct terms, and in an interesting manner. For the other grades it can carry scientific proof, which will help criticism and further progress.

This dual form of expression can be written in two ways in a publication. The Simple Expression can be in the form of paragraphs in ordinary print, and followed in sequence by the Scientific Expression in italics.

Another way would be to give the information in two stages, the first stage of the publication being in Simple Expression and the second in Scientific Expression.

A Congress Author of 1927* has already adopted the latter principle. He gave the Congress a complicated paper on Costing, and later extended it into book form. In the book he has dealt with his subject in three stages of development, the first being simple and elementary, yet necessary to both second and third stages. In this way, the complicated subject of Costing for Buildings and Public Works should make progress.

We now return to the channel of the General Practitioner, whose side table becomes piled with useful information for which he can never find sufficient time.

Dividing information into two forms of expression will help him, and summarising will do a great deal as well.

* The same Author.

Annual Reports of various Institutions and Research Authorities could be issued on the basis of giving a resume of the findings of the year's work. Specialist Journals might assist also in giving the most important matters yearly or quarterly, and this from the standpoint of the General Practitioner.

Another help in the Government Publications would be to give more diagrams, and less prose. The diagram dealing with damp-footings has been referred to and the issue of this diagram has probably achieved more good results than many publications.

AUTHORSHIP.

The writer ventures to make the following criticisms on authors and publishers.

British Standard Specifications should be more widely known, and a more popular price might be helpful. Alternatively, some of them might be grouped into one binding.

It is found that authors of books on special lines make no reference to the British Standard Specifications for materials they deal with, and it is evident from some books that the authors have no knowledge of their existence.

On the other hand, some authors quote unduly and their work is padded out with many pages of British Standard Specifications.

In some cases the heavy and economical hand of the publisher is felt, and a highly technical work prepared for students may be without a great deal of necessary information.

In other cases, publications are largely the "boostings" of various lines of advertised materials, and in consequence they do not carry reliability of expression.

Authors of some books are to be warmly complimented on the improvement of drawings during the past two decades. Isometric projection is useful where plan, elevation, and section are required, and such drawings illustrate construction admirably. If a criticism can be levelled against them, it is that they give too much information at once to the elementary mind, and this might be given in stages of development.

It would be helpful if the negative policies accompanied the positive policies in constructional drawings. They are helpful one to the other, and the writer has tried to indicate this in his own drawings.

Mistakes in construction are rarely made deliberately, but generally through ignorance, and both wrong and right ways should be shewn.

Authorship suffers a good deal from the need of censorship and this both for specialised and general publications. Either of these classes should, before publication, be placed in the hands of critics of four classes, namely (a) General Practitioner, (b) Specialist, (c) General Researcher, and (d) Special Researcher. A fifth would be a literary critic who could help to get the diction to be simple, direct, interesting and expressive.

The writer hopes for pardon for these criticisms, but he feels that Authors have a great influence, and such influence should be on the most effective lines.

STUDENTSHIP.

The writer suggests that the first basis of technical education for both craftsmen, students and professional students should be the same, and this a simple and sound construction, with no frills.

For architects, builders, surveyors and engineers he would suggest the same elementary course, for this would help them to understand each other better.

His suggestion is a Subsidy House for the Working Classes, with accommodation works in the way of fences and small retaining walls.

It is felt that the function of the house should be taught first, and the respective functions of the various parts next. After this bird's-eye view of the subject, such matters as bond of brickwork should follow.

Here is an opportunity for a common ground for the sections of persons dealing with buildings and public works to meet on at the very outset, and a building construction book written on these lines in an interesting and inspiring way would be a great boon. After looking through the Children's Encyclopedia we would pray for an Arthur Mee of building construction to take the work in hand for the sake of our students.

Registration in various forms is to the fore nowadays, and rightly so, and no architect, builder, surveyor or engineer should be registered unless he had a satisfactory knowledge of this class of simple and sound construction.

The study of stresses and strains is largely beyond a Grade 2 mind, and other than a knowledge of the primary terms such as tension and compression, this should not appear in such a book.

The B.S.S. standards for materials should be accepted, and students given a knowledge of their tests.

Building Construction Courses and books for elementary stages should be purged of unnecessary matter. We find our young men spending time swotting the details of the manufacture of Portland Cement and the like. If this did not mean the sacrifice of more important items, it would be to the good. The range and scope of constructional work is wide and varied, and in the light of the limited capacity of a man's brain, we should look on the matter from the standpoint of mental economy.

Our modern building construction books contain many forms of obsolete or seldom called for construction, such as framed partitions or queen-post and hammer-beam roofs, at which our young men employ their labours, without proper advantage.

STANDARDISED INSTRUCTION.

This is where the Specialists can aid the General Practitioners and Students greatly.

We have seen ready reckoners for pounds, shillings and pence since our childhood days, and we have had cause to bless those who laboured for the multitude. We have seen this idea developed into valuation tables and estimating tables, and it is suggested that this principle can be adopted for constructional drawings.

Knight's Annotated Bye-Laws gives a lot of very useful diagrams, indicating maximum lengths, heights and thicknesses of walls, and the Concrete Year Book gives diagrams and tables of reinforced concrete beams and floors.

Here is another opportunity for an editor, namely to produce a book understandable to a Grade 2 mind, which will also give particulars of sizes for girders for various spans and purposes, for roof trusses, for timber joists and rafters, etc. This again would be a real boon.

This book would translate the complicated results of specialist and scientific minds into simple expression, by means of diagrams and tables.

It would make for standardisation, and coherence and progress would be stimulated in other channels.

BUILDING BYE-LAWS.

With the general teaching of the working class house, the necessary application of the bye-laws could be taught (but not in bye-law language).

The book of standardised construction diagrams could incorporate many other items of bye-laws, and the whole matter of building bye-laws would be on a simpler and sounder basis.

At present they are weak on the important matter of weather and damp resistance, and many a surveyor has to look on while a non-weather resisting structure is being erected, for he has not the power to stop it.

In many cases, he wishes that the term "of sufficient strength" gave way to that "of sufficient weather resistance."

QUANTITY SURVEYING.

The issue of the "Standard Method of Measurement of Building Works" as agreed upon between builders and surveyors, was a notable step. Since its issue, text-books on quantity surveying and estimating have been based upon it.

It is recommended that it could be usefully revised from the standpoints of the contractor, manufacturer and engineer. The manufacturer sells his drain-pipes and roof guttering by the yard, and the engineer measures his kerbs by the yard. The S.M.M., however, often uses the foot as its basis. This is not useful for the contractor, who buys his material by the yard only to find that he has price it by the foot. Other recommendations could be made on these lines.

A supplement could be added to the S.M.M. in order to incorporate items public works which are not included in the book at present.

This would help to keep the measurement of buildings and public works standardised basis.

Amendments to such a work could appear at definite annual intervals in the first annual issue of a publication.

NATIONAL SUPPLY.

At this period of economic tribulation (December, 1932) supply as affecting specifications might be mentioned.

From a National standpoint, it is important that a structure should have as much as possible of the goods of its own region of direct exchange.

Timber, for instance, is largely imported into this country, and it is nationally advantageous to preserve it and to conserve its use.

Steel and reinforced concrete have supplanted it on merit in forms such as beams, and this can be extended to steel purlins, and to the greater use of steel roof trusses. The preservation of wood lessens its replacement, and increasing the use of paint, tar, or creosote is to lessen timber imports. It is interesting to note that the primeval forests of this country which are now coal, supply tar and creosote for wood preservation purposes to-day.

CONCLUSION.

We must draw this paper to a close, and other items which surge towards expression must await another opportunity.

As it is, Part I is but a precis of what would be otherwise six papers, where the subject of Materials is dealt with more completely.

We have lingered too long, possibly, with the subject of Specifications in the Light of Tradition, Experience and Research, but the appeal for greater coherence and progress has been the driving force.

It is regrettable that tradition has lost so much information in its course, that experience is often too busy to be able to enrich its generation with the information of its results, and that research is complaining that scientific knowledge is not sufficiently understood.

Were tradition and experience to have better records, and their information handed on in the inspiring glow of romance, there would be a more definite and a surer basis for the education of our generation, and from this we could make a sounder progress.

That experimental houses were built in the post-war period is an example of the unpleasant fact that each generation has to re-discover important fundamentals of good construction. The complicated nature and wide range of buildings and public works are largely responsible for this, and that is why we seek to simplify their ramifications.

We find gratification in the progress made in various ways and particularly in connection with standardisation and research. Standardisation is helped by research, and we would appeal to both to remember the great value of simplicity of expression.

A simple fact is understood by the multitude and the complicated fact by a few.

In consequence, the simple fact lives and it leavens a great industry, the complicated fact fails in its message without having achieved what was intended.

This is greatly.

Contributions are submitted to the bar of the Public Works, Roads and

We have seen, with the earnest hope that they do not fail in the effort of the good days, and with simplicity.

We have seen this
it is suggested that

DISCUSSION.

Mr. B. PRICE DAVIES, in introducing his paper, said: We people of buildings and public works live in a period of great change, a change which is a bit too rapid for tradition, and we have to adjust ourselves to this swift-moving tide. Aiding the movement we get the Standardised Specifications largely issued by the British Standards Institution, but some by other bodies. All of them have done excellent work, and we feel grateful to those few groups of men with specialised knowledge who have laboured so well, and so thoroughly, on behalf of the multitude.

Then to speed up matters still further we have the aid of research. A great deal of research is now done in this country, and by means of the monthly issues of "Building Science Abstracts," the synopses of research from all over the world are handed on to us.

We architects, surveyors, engineers and builders, who revel in the daily contact with actual works, have found long-wished-for solutions of our problems in the literature of research. On the other hand we have the tradition of specifications handed on to us from our forebears, and we have now the advantage of dealing with specifications in the combined light of such tradition, of our own practical experience, and of modern research. In this paper an endeavour has been made to blend all three.

Part I. deals with Materials. It is but a merciful synopsis of what might have been inflicted upon you.

Part II. comes to the more real purpose of the paper, and deals with Construction. As one grows older and more experienced, one becomes convinced that weather-proof and damp-proof construction is insufficiently known and badly taught. Great trouble is taken to see that a structure is safely built from a constructional point of view, but there is no real scientific instruction for weather-proof and damp-proof construction. We are obliged to confess that our post-war housing schemes suffer from this defect in many ways. Even now, after fourteen years of State house building, when we are faced with the clearance of old slum properties and their replacement with new houses, the use of the word "economy" is heard in the land far more than the better

slogan of weather-proof, damp-proof, and conveniently planned houses; in other words, we hear more about money than we do about health. Our building bye-laws suffer in the same way, and some of us with a long practical experience are obliged to look helplessly on when houses are being built on lines of construction which will not be damp and weather-proof. This is one of the chief purposes and messages of this paper.

We now come to Part III., which ventures into the realms of "Coherence and Progression." It deals with the power of tradition and the respect we should have for it. It shows that our modern need is that of obtaining a greater knowledge of fundamental principles, and through the aid of research, to consolidate this extended knowledge so that it becomes a broad and sound tradition for the future. One great fundamental principle to be studied is that of movement, and the realisation that our structures and our materials are not altogether static, needs greater study. Another great fundamental principle is the capillary action in our structures and materials. Under the heading of "Policies," I have commenced with education, and indicated lines for the furtherment of the great majority who are engaged on buildings and public works. It is to be feared that it has been a tendency amongst men of practical experience to worship and to stress unduly the need of education which is beyond them. The result is that students under this influence to-day are striving to attain that which is only 10 per cent. useful, and in achieving it to lose that which is 90 per cent. useful; in other words, architectural students are designing wonderful palaces and engineering students designing dams, and this very often without the knowledge of simple, sound, and everyday construction.

Then I have ventured to suggest censorship for authors. Here I would suggest that the British Standards Institution and the Department of Scientific Research come to our aid. Can I make a public appeal to authors and examiners to have some mercy towards our young men, and to cut out obsolete matter and the call for soul-grinding memorising from books and examination papers? Then again, I have

ventured to give architects, builders, surveyors and engineers a common syllabus of simple and sound construction, and this should be associated with building bye-laws. One could go further and suggest a catechism for examinations, and that 75 per cent. of the examinations be based upon such catechism. This should allay the present tendency which is to make our students into neurotic wrecks before they arrive at the bar of the examinations.

MR. C. GREENWOOD (*Chester*), moving a vote of thanks to Mr. Price Davies, said: The author has referred to the tradition underlying specifications and to the thanks we owe to those who have worked in the past. I am not altogether certain that tradition, which I look on as a regard for things which have gone rather than as a knowledge of things which are past, is altogether to be commended, and it is open to argument, I think, that tradition, instead of promoting progress, can hinder it. There is no doubt that, before the war at any rate, as far as specifications were concerned traditions hindered progress and tended to make specifications hidebound and not up to date. I think that if you look back upon the specifications of that period you will find that they were handed down from one office to another and from one chief to his pupil until they became absolutely out of date, and in many cases if the engineer had attempted strictly to enforce them the contractor could have claimed a breach of contract.

There has been, however, a distinct change since the war. Whatever the evil effects of the war may have been, I think it has had a good effect in this respect, that it has helped to break down traditions, and tradition in respect of specifications as much as anything else, and specifications during the past fifteen years have improved tremendously in quality and have kept pace with modern thought and modern development. I should like to examine for a moment the causes to which this has been due. In the first place, I think it has been due to the setting up of laboratories to test materials and to the scientific investigation of materials not only in the laboratory but actually in use on the job. Engineers have sent their samples to be tested in laboratories and obtained opinions as to the

merits of those materials for their work, and by doing that a higher standard has been maintained. This is particularly noticeable with regard to concrete specifications and steel. No engineer to-day who is carrying out any reinforced concrete work would go forward with it unless he had an opinion with regard to the materials he was going to use, and, having settled on those and their proportions, unless he had his materials tested from time to time on the job and sent samples to the various laboratories. Many laboratories have been set up; we have the National Physical Laboratory at Teddington, the Building Research Laboratory, the Ministry of Transport Experimental Station, and practically every university of any repute with an engineering department attached to it has its own laboratory, and those are open to practically every engineer for the testing of his materials at a very low cost. You can see the effect of laboratories in the progress that has been made in some of the big works in this country. The motor car industry is a case in point; I think the makers would agree that it is the experience they have gained in the laboratory and by testing which has enabled them to make such enormous progress.

Another thing which I think has led to the great improvement in specifications has been the progress which has been made in the British Standard Specifications. As engineers and architects, I think we owe more to the British Standards Institution than to any other body for the progress which has been made. In the past, the engineer and the architect were rather too apt to draw their specifications without any regard whatsoever to the point of view of the manufacturers, and consequently many specifications were drafted with which the manufacturer had very great difficulty in complying. He only managed to comply with them, probably, at a much greater cost than that at which he could have provided a similar and simpler material had he and the engineer been able to get together and look at the matter from each others point of view. That is the great point about the British Standards Institution; it has brought the engineer and the architect into close contact with the manufacturer, and each side has been able to discuss

problems from its own particular standpoint, and by doing that they have been able to evolve a specification suitable for both, and the engineer has obtained as good a material or perhaps a better material at a cheaper price, while the manufacturer has been enabled to go ahead knowing what he will have to meet.

That has another effect. In these days, when everything is rushed and we surveyors have got all sorts of work to do, we can cut down our specifications considerably by referring to the particular British Standard Specification; instead of each engineer writing out what in some cases is verbose literature, he can simply quote the appropriate British Standard Specification. The manufacturer then knows exactly to what he has to tender, and I venture to say that the result is that tenders are much lower than they would be if each engineer followed his own particular fetish.

Further, we can look to the British Standards Institution to keep us up to date in scientific development and modern research; and, as new ideas and materials come along, we shall be able to get these specifications revised from time to time. If we use them in our work, we need feel no qualms that if the work is carried out in accordance with them it will not be satisfactory.

There is another aspect of the matter which is sometimes overlooked. Quite apart from the specifications, in these days of mass production all manufacturers have their own particular methods standardised. For example, taking the case of steel construction. All steel erectors and fabricators have joints standardised for each particular size and load to be carried. There may be other joints just as good, but they standardise this in the shops so that it is known from the drawing office through the pattern shop to the erecting shop, and you get a much simpler and cheaper job and one which is quite satisfactory. If each engineer were to design his own joints they would probably be no better, but they would cost a good deal more.

Another aspect of specifications on which I should like to touch is with regard to patent specifications. In these days there is a good deal of patent material on the market for which the specification is not

divulged, and in those cases it is better to specify results rather than to draw up some general specification dealing with the work. If you go to a firm of repute and specify what the results shall be and get a satisfactory guarantee, that is much better than attempting to draw a very casual sort of specification.

Specifications, of course, are affected in many ways, and it is surprising what influences do affect them. I venture to say that one of those influences is political. We all know what happened at the Ottawa Conference. There is an attempt on the part of the Canadian Government to get this country to use Canadian timber only for carcasing work instead of drawing its supplies, as in the past, from Russia. I make no comment on that except this, that if such a state of affairs does come to pass all the specifications with regard to timber will have to be revised, and that is where we may look to some authority such as the British Standards Institution to draw up specifications which will meet the new situation. If each of us is going to be left to investigate the question of foreign timbers and Canadian timbers for himself, I am afraid we are going to flounder for some considerable time.

I want to make one further remark, which is perhaps a little outside the question of specifications. While I have spoken in great favour of and with thankfulness for the British Standard Specifications, it is unwise to put too great faith in them if we are just going to have one Standard Specification for a particular kind of work. In my opinion, specifications should be graded. It would obviously be absurd to have the same specification for housing work as for a public building like a town hall or cathedral, and I am not at all certain that in the past we have not built too well as far as some of our work is concerned. A good many of the problems which local authorities have to solve to-day, particularly from the point of view of street improvement and slum clearance, are considerably aggravated, more especially with regard to cost, by buildings which have outlived their usefulness but whose construction is such that they seem too expensive to demolish. It is worth considering whether, so far as buildings of that type are concerned, they should not be put up with

the idea that they would last only, say, seventy-five years, the intention being that at the end of that time they would come on the scrap heap and local authorities would have the opportunity of re-developing their towns. Those who are members of local authorities will agree, I think, that if they could do so it would save them an enormous amount of work.

While, however, I am in favour of standardisation of specifications, I hope this will not tend to standardised design. Here flexibility is required if good appearance and varied treatment is to be obtained, and this has been lacking in many of the housing schemes carried out by public authorities during the past few years.

THE MAYOR OF BANGOR, seconding the vote of thanks, spoke of the high esteem in which Mr. Price Davies was held by the Bangor Council, and paid a tribute to his professional literary efforts and his qualities as a public official.

MR. B. MEEK (*Manchester*): In Part II. of the Paper, dealing with retaining walls the author says: "Retaining walls are still largely built on the safe rule that the base must be at least one third the vertical height. For walls supporting roads, the general rule of the Ministry of Transport for ordinary walls is that the base must be at least .35 of the height." Now, this Paper will probably be studied by young engineers, and if they take this as being a safe rule on all grounds and build retaining walls as they are told to here I can imagine that anything like wet clay either under the toe of the wall or behind the wall may give them very heavy trouble. I myself have never known a retaining wall or a dock wall to fail by overturning or to show much sign of overturning, but I have known the wall to dip at the toe and I have known a sliding movement through the inability of the engineer—it is a hard thing to do—to gauge correctly the amount of dampness in his backing. I do think, therefore, that the young engineer should be told that the two points to watch are the pressure under the toe of the wall and the amount of dampness in and the type of ground that he has to uphold. He may have to deal with all sorts of ground, and with many classes of ground this "safe" rule and the Ministry

of Transport rule would be no use at all and would lead to disaster.

The author goes on to say: "The writer feels that masonry walls are cheaper and better than concrete or reinforced concrete walls." I should like him to tell us why. There are many places where you could not build either a concrete wall or a masonry wall but where you could get away with a reinforced concrete wall because it takes up so much less room, and the earth backing acts as part of the gravity weight of the wall.

MR. R. H. JENKINS (*Skegness*): I am heartily glad the author has called attention to the defects of our building bye-laws, which certainly need careful overhaul. We are told by the Ministry that we should keep our bye laws up to date and revise them from time to time, but when we attempt to do so we find that even then we are hide-bound, and in dealing with this matter the author points out quite clearly one very great defect, namely that we cannot insist sufficiently in those bye-laws on weather resistance. This, however, is not the only thing that we cannot control by our bye-laws. I had a case recently where a builder—or at least he called himself a builder on his headed notepaper!—covered his walls and ceilings with asbestos sheeting and then plastered it. It does not need any comment of mine for you to imagine what the result was! I do not know that the builder suffered so much afterwards as the poor unfortunate purchaser, who was not aware of this sort of thing.

It is very unsatisfactory that that sort of thing should be possible, and I am glad that under the heading of "Studentship" the author calls attention to the registration which we are having in these days for architects, engineers and surveyors, and why not for builders also? We are striving to do something in that respect with regard to plumbers and waterworks engineers, but I think it is infinitely more important that there should be some control of builders. I think builders have more effect on our health than possibly any other class of traders in the country.

I should like to give my support to what the author says under the heading of "Sewers and Flood Prevention." The question of the intercepting trap is an old one, and, after

considerable discussion, we have been able to get some novel clauses in our model bye-laws with regard to drainage through the Ministry of Health. Skegness, of course, is a flat district, and I am not sure that those novel clauses would be as beneficial or as successful in a hilly district, but the intercepting trap has been made optional, and we find now that it is not used. Its use had caused a good deal of trouble in regard to blockages and other difficulties. We feel that the fall is of much greater importance than the isolation of the drains, and we have omitted it, and we find we have no trouble with any of the sewer ventilators in the town, and the whole system is kept sweet and clean. We have done away with the fresh air inlet; it was an antiquated affair and its use ought not to be continued anywhere; it so quickly acts in the wrong way.

There is one matter which I think is of considerable interest in regard to house construction and which I feel is very much neglected in our building, namely heat insulation. In these days of economic construction and economic use of materials and heating we should give this matter more attention. There is no doubt that we waste large sums of money in providing heat which is dissipated into the air, whereas it should be retained in the buildings, with, of course, proper provision for ventilation. In that connection, there is a point with which I should like the author to deal rather more fully; I should like to ask whether he feels that the cavity in cavity walls might not be used to greater advantage for the heat insulation of buildings. I know there is one difficulty to overcome, and that is the ventilation which the bye-laws require; but is it not possible to make the outer leaf of the cavity wall so weather-proof that the need for ventilation can be overcome, and so that we can then use the cavity for insulation? As things are now, I feel that the cavity wall is very largely a means of getting rid of a good deal of heat; if we put our hands in the cavity wall, we know if there is a breeze blowing what a terrific current there is. There is only a thickness of 4½ inches of brickwork, and probably the poorest part of the brickwork, and a good deal of heat is dissipated through this part of the wall. With regard to heat conservation, I should like to ask the

author if he does not agree that the ideal form of roof construction is a lightly boarded roof, lightly felted too if you wish in the cheaper form of house, and cross-battened. The extra cost is very small, and in my opinion the results produced are well worth it. One can be assured then of a perfectly damp-proof roof, and it also helps very much with the heat insulation.

It is about time that the attention of all of us was called to the disadvantage of bedded slates on party walls. No doubt many continue to insist on it being done because it is called for by the bye-laws, and the very insistence creates dampness in the house as soon as the roof timbers have shrunk and the slates have become open to the weather. I am very glad the author has called attention to this and many other anomalies.

I wish he had dealt more fully with the ternary alloys of lead. I must confess that what he says is news to me, and it certainly seems to be a matter which should be considered in the waterworks bye-laws with regard to the use of lead pipes for water services. It is not dealt with at all in the model bye-laws, as far as I remember, and I thank the author for calling attention to it.

MR. T. ELCE (*Eccles*): When I received this Paper and read it through, I must confess I experienced some feeling of disappointment. I think that the author set out with the object of writing a paper on specifications, and that when he got part of the way through the matter got somewhat out of his control, so that he finally wrote a paper which could be more accurately described as "Specifications and Building Construction," because it deals with many matters which, strictly speaking, do not come under heading of specifications. I think the Paper would have evoked a good deal more discussion if we had had present with us to-day those members of our staffs who are more intimately connected with the details of building construction than are we engineers. After all, the engineer to a large authority is more engaged with control of policy and with broad outlines than with the actual details of construction, and it is a matter of great difficulty for an engineer to a large authority to devote his time to the details which the author has so admirably set out in this Paper.

There are many points in connection with the assisted housing schemes of 1919 in particular, which I think the author says have been very largely experimental, which should prove disastrous in the maintenance of the buildings. The author mentions the question of capillary attraction, but there is one point to which he does not refer and which has been brought very forcibly to my notice. In the 1919 schemes there was a great craze for the construction of solid concrete floors. The author shows in some of his sketches the paths by which capillary attraction takes place. I have found by actual experiment in connection with the maintenance of these houses that there is one very important path which is not shown on these sketches. As you all know, concrete is a material which expands and contracts. The concrete floors are laid between the brick walls of the houses; the concrete contracts and leaves a certain gap between the concrete and the brickwork which eventually gets filled up with something, usually some form of dirt, and I have found that a great deal of the dampness in the plaster walls of the houses is due to capillary attraction not only up the brickwork through the mortar joints but also through this path between the concrete and the brickwork, and it gradually spreads out until you get damp showing sometimes to a height of 4 feet. There are methods of preventing this, and I have experimented very largely with them, but I will not go into those matters at present.

I think that if engineers to local authorities would only realise the very valuable work which is being done by the Building Research Station, and would study the reports issued by that Station carefully, they would find a solution of many of their problems with regard to the maintenance of buildings. I am responsible for the maintenance of over twelve hundred houses and questions often arise in connection with that to which I have to apply my mind. Mine is only a single mind, but in the reports of the Building Research Station you get the concentration of a large number of highly scientific and highly trained minds which are applied to the solution of the problems which arise in our everyday life. I am very thankful that this question of building research has been taken out of the hands of un-

qualified and untechnical people. I do not say that with any disrespect for the practical man, but, after all, the practical man is concerned with putting up a building; he is not particularly concerned with its subsequent maintenance, which falls on the person who purchases it. The reports which are issued by the Building Research Station are amongst the most valuable documents published.

With regard to the question of building bye-laws, it must of course be borne in mind that a set of building bye-laws does not purport to be a full specification for the construction of the building. We are always urged, when considering the revision of building bye-laws, to make them more elastic, and personally I think that is a wrong attitude to take. The building bye-laws are meant to protect the subsequent occupiers of houses. We have revised our bye-laws recently, and it is a matter of great regret that the Ministry of Health takes up the attitude that one of the primary considerations regarding bye-laws should be elasticity. I think there is a tendency to overdo that. Not only do they ask us to make our building bye-laws more elastic, but they take away from us the powers we formerly had of issuing or refusing to issue a certificate of habitation. Their contention is that the certificate of habitation is *ultra vires*, and that if it were contested in the courts it would be held that there is no offence in occupying a house without first having a certificate of habitation. If we are going to make our building bye-laws more elastic, and allow builders to do all these things which the unscrupulous builder does not hesitate to do, there may be trouble. There are good builders and bad builders, and the bad builder will not hesitate for one moment to try to get away with anything. I think our building bye-laws should be sufficiently strong to prevent the exploitation of the subsequent occupiers of those houses.

With regard to the question of the use of timber for lintels and bressummers, I entirely agree with the author. I have recently had an experience of some interest in this connection. Some offices of ours, which I am glad to say I am not occupying, were showing signs of damp coming through the roof, and this was evidently due to the box-cutter. Taking that off we found that the ends of

the spars were all decayed. The wall plate was decayed, and that had been built in on three sides, and in some cases on all four sides. Lower down the wall, about two feet down, were the lintels to the windows, and in every case without exception those were decayed, and how they had stood up was a miracle. They have been replaced by reinforced concrete.

Mr. Jenkins mentioned the question of ternary alloys. I have had a great deal to do with this question recently, because I have been interested in a case brought against the Manchester Corporation for negligence, and the case turned on the question of whether the Manchester Corporation Water Department had used sufficient care to ensure that there should be no leak. In the discussion which took place with regard to this case, the question of the material used in the lead service pipe was considered, and it was an exceptional opportunity for me to gain some knowledge on the question of lead pipes, ternary alloy pipes and copper pipes. You may be interested to learn the result of my experience.

The Manchester Corporation now use ternary alloys for service pipes. That may be of interest to some of you, and you may ask what is ternary alloy is. It is an alloy composed of lead and other metals, and the advantage of it is that it is much lighter in weight than lead and, although its price is higher—the price of ternary alloy is based on the price of lead, and if the lead costs £14 a ton, ternary alloy will probably cost about £26 a ton—the weight is very much less than that of lead, and when the price of lead is high ternary alloy is much cheaper to use than lead. If the price of lead drops below about £12 a ton, lead becomes cheaper to use.

It was always thought that the cause of failure of lead service pipes under pressure was due to bursts or due to corrosion from the outside—I call it corrosion for want of a better name; you can call it decay or whatever you like. It has been found by investigation by technical men, however, that the majority of failures of lead service pipes underground under our highways are not due to vibration owing to traffic, and indeed that can be ignored almost entirely. The principal cause of failure in lead service pipes comes from the inside of the pipe.

Although we know there are lead pipes in existence which have been in the ground since the days of the Roman Empire, and although we know there are lead pipes which have been in use for over eighty years and which are still sound, that may be due to the fact that in the old days the lead that was used in the manufacture of lead service pipes was an alloy; it was not all pure lead. Modern methods of lead manufacture mean that it is practically pure lead; the silver is all taken out. When lead service pipes are laid in the ground, they are connected with fittings such as taps, w.c. cisterns, and so on. These fittings may be perfect when they are put in, and are all tested by the water authorities, but in course of time some of the fittings become defective and set up what is known as water hammer. You have it in all sorts of cases. The effect of water hammer on a lead pipe is to produce a series of very fine cracks on the inside of the pipe, and in the course of time, with continued water hammer and continued use, those cracks gradually extend until they reach to the outside of the pipe. That is entirely contrary to all previously accepted theories on the subject, and I should advise you if you have the opportunity of inspecting any lead service pipes which have failed, to avail yourselves of it. If you will take a lead service pipe which has been under a street, take the length where the burst has occurred and put a section of the pipe under the microscope, you will see very clearly what I mean. I have recently examined many pipes which have been taken up, and I have seen on the inside of the pipe—the pipe being apparently sound—a series of very fine cracks.

From that point of view alone I think it is safe to say that in a very few years the use of lead for water service pipes under pressure will be a thing of the past. We had an experience recently where a service pipe was put down ten years ago at a cost of £180. We have now on that pipe two bursts a month. The lead was manufactured by one of the best manufacturers, but I am convinced that if that pipe had been put down in ternary alloy we should have had no bursts, because every burst I have examined has shown that it was due to water hammer and not to the nature of the ground.

MR. W. A. MITCHELL (*Stalybridge*): In the section dealing with bricks, the author says: "Brickwork with reinforcement in its joints is gaining in favour, and this form of construction will probably usurp reinforced concrete in walls." I feel sure that that is a matter on which many of us will disagree with the author, as I certainly do.

On the next page, under the heading "Roof Coverings," he says: "Asbestos cement is used for various forms of roof covering, but it becomes brittle with exposure." I believe that is quite correct of the asbestos slates used many years ago, but I doubt whether it can be said of the slates which are being used at the present time. Quite rightly, the author favours slates—Welsh slates!—but I sometimes wish that the makers would colour some of them. I think it is possible in these days.

The author does not altogether agree with cement rendering. I think many people have found, however, that cement rendering does serve a useful purpose.

It seems a pity when so many points are brought forward in a paper like this that they may get put on one side. When we read the papers of many years ago, it is surprising what a lot there is in them of interest which never seems to have been brought up to date, and you may be certain there is a great deal in this Paper of interest, even if the author has gone beyond the question of specifications. I think it would be a good thing if in our Institution of Municipal and County Engineers a bureau were set up to which members could communicate matters which they felt were of interest and importance and which could make extracts from such papers as this and tabulate the information for use when required. I think much good could be done in that way.

MR. F. HEWITT (*Burnley*): In Part I., under the heading "Aggregates," the author deals with concrete mixtures, and I should like to ask him whether he does not consider his statement with regard to the 2 in. slump rather sweeping. Would not he have a different slump for different classes of work? Two inches seems to me excessive for some work.

On the next page, with regard to the stopping of live leaks, I am glad the author

has mentioned "Tricosal," which with "Silka" and similar substances will be found of very great use. One can use them whilst the water is actually issuing from the leak under a fair amount of pressure.

Under the heading "Bricks," whilst one would admit at once that there is no gain in strength in wetting bricks, is not there something in wetting them to remove dust and also to prevent excessive absorption of water from the mortar?

With regard to reinforced brickwork, in my opinion reinforcement is particularly good in 11 in. cavity walls. There is a tendency to use an excessive number of bats, and where the work is built upon there should be extra strength provided and this can very well be given by reinforcement.

At the bottom of the same page, in the section headed "Floors and Roads," the author refers to concrete flags needing expansion space. I do not think there is any need for expansion space in the small area that a concrete flag covers, but I have found that unless you allow a reasonable space between them, it is a very difficult thing to get them up for gas, water and central services generally, and almost invariably a large number are broken before they can be relaid.

I do not know if the Author has had actual experience of cork for expansion joints. I think it would be quite good for footpath work, but I am not so sure about its use for roads. If anyone present has had experience of that I should like to know about it.

Composition floors and tiled floors are mentioned. I take it the Author does not mean that the tiles themselves contract and crack, but that the concrete underneath cracks and causes them to separate. I have had that trouble in public conveniences.

Mr. Elce has mentioned lead piping. I have had a great deal of lead piping taken out in my area where I have a number of water supplies. A large number of the pipes have been damaged by shock and water hammer, but in other cases the damage has been from a source which Mr. Elce did not mention and to which the Author does not refer. It is external damage; not due to traffic, though we have had damage due to traffic. The latter trouble

has arisen because, as you know, most of our regulations insist on a depth of only about two feet before a service pipe enters a house, and very often the plumber interprets that as two feet also below the highway. Consequently vibration or heavy vehicles are apt not only to break the lead pipe but, if the main itself is not sufficiently deep, to break the stop taps as well. With regard to lead pipes being damaged externally, I have had them damaged owing to their being laid through ashes and also through their being laid through farmyards. Thirdly I believe that although in some parts of the country there are clay soils which actually preserve the lead, in a part of the country where I was surveyor for a time the clay had a very deleterious effect upon lead pipes. My Council called in Mr. A. B. Searle, the well-known authority on clays. We were in a magnesian limestone district and the pipes were to be used upon a large housing scheme. He recommended us to lay the service pipes in a surround of local limestone, which I believe has been found to work well and has actually preserved the lead pipes.

Turning to the first paragraph of Part II., I think a warning note should be sounded—though I believe the Author has not overlooked the point—with regard to clay. One could say a tremendous lot about the dangers of this subsoil, and a table such as the author gives at the top of the page must be used with very great caution where clay is concerned. The Author speaks about its porosity and water content. Water content, of course, makes all the difference with regard to the bearing power of the clay.

With regard to retaining walls, Mr. Meek said he had not heard of a retaining wall which failed from overturning. I have. Generally it has been of excessive length, and of course not properly designed. I do not altogether agree with the .35 rule for thickness—if one may call it so. I think in America .4 rule for thickness at any point is preferred, not only for retaining walls but for abutments of bridges, which are very often designed on the principle of retaining walls. What the Author might have mentioned, I think, is allowance for loads anywhere near a retaining wall. The Ministry of Transport standard load, if I remember aright, works out at an equivalent

additional height of wall of three feet, and in designing retaining walls where any traffic can come within the 45° plane—that is to say, if you have a wall eight feet high, any traffic within eight feet of it—then I always add an assumed three feet to the height in using the .35 or the .4 rule. Another very frequent source of failure, as I think the Author will agree, is sliding, particularly on clay soils.

On the next page, with regard to earth pressures, I think it is generally admitted that Rankine's formula gives excessive thrusts, but as we very often have to assume an angle of repose for the earth, taken from a table, or what we think it will be from looking at the actual material, at any rate the formula does give us a fair margin for safety.

Under the heading "Weather and Damp Resistance," the Author refers to the report of the Building Research Station with regard to solid masonry walls and solid brick walls. I have found that most stone walls are more prone to damp than brick walls. I do not know whether there is anything in the point he mentions about the particular stone walls being eighteen inches thick, which is rather a big thickness. I must say, however, that most of the dampness in the areas where I have been has occurred in stone walls; not that I am setting myself against the Research Department.

Under the heading "Gales and Earthquakes," the Author refers to subsidence, and he puts reinforced concrete third when dealing with structures which are subject to shock or subsidence—I am not sure to which he refers. In a colliery district it is important that one should be able to raise or replace the decking of a bridge upon its abutments without rebuilding the whole bridge. If you have a homogeneous structure such as reinforced concrete for bridge work in a colliery or other district where subsidence is liable to occur, the entire structure is much more prone to serious damage.

At the end of Part II. respecting manholes, I do not like the suggestion that we should give increased fall in manholes. My experience is that contractors like to do that. I agree we should give more at bends, but when a straight pipe goes through a manhole

I prefer to carry through the invert of the sewer with the lesser of the two gradients. By such means I do get some idea of what is occurring in the sewer with the lesser gradient.

With regard to copper for water services, cisterns, cylinders, boilers and so on, I have had cases where deposits of copper sulphate have occurred as a result of using this material. I have been in touch with the Non-ferrous Metals Research Association and the Copper and Brass Extended Users Council but have not been able to get to the bottom of what is in some cases a serious matter. There are cases where enamelled pans are very much discoloured and people are in great fear of poisoning.

Finally, with regard to bye-laws, it seems a great pity that we Surveyors should legally be more or less compelled to confine ourselves to seeing that the bye-laws are adhered to, which sometimes means that we have to stand by and see very inferior work being done, simply because there is nothing in the bye-laws to enable us to say to a builder "I will not allow this inferior work to go on."

THE CHAIRMAN (MAJOR L. ROSEVEARE): In Part I. there is a very interesting discussion with regard to aggregates, and I am sorry there has been no criticism of what the Author says there. He suggests that the round is better for compacting and the angular for bond, but you will appreciate, I think, that it depends very much on the district and the stone available as to whether round or angular aggregate is economically available. I should like to know what proportions he suggests of cement and ground lime for chimneys. He states that 2 in. of concrete cover for steel is necessary for protection against fire, but I think he will agree it is also necessary for protection against sea water. That has been proved by experiments which have been carried out by the Institution of Civil Engineers. Most of us, I think, will agree with the speaker who suggested that he did not share the Author's idea with regard to reinforced brickwork usurping reinforced concrete in structures. I am definitely of opinion that, as Mr. Meek suggested, reinforced concrete will carry the day in most conditions.

With regard to concrete and asphalt roofs,

the Author does not mention the problem which occurs very often where extreme variations of heat and cold occur. Personally, I am very much against the concrete roof which has steel girders built into it; localised expansion is experienced, which is the cause of many roofs leaking. It is much better to insist on a reinforcement right through the whole of the roofing.

So far as the various alloys for steel are concerned, copper has definitely been found to be an improvement on other alloys for sea work.

In the section entitled "Heating," the Author makes rather dogmatic statements as to the relative costs of gas, electricity and coal. Those contrasts are of no use unless he gives the basic costs of gas, coal and electricity.

With regard to the chlorination and filtration of water, I should be glad to know if he has had any experience of the Katadyn system, which is a German process in which silver is used instead of chlorine.

So far as his diagrams for sewers at the end of the paper are concerned, I cannot agree with Mr. Hewitt that the extra fall in the manhole is not satisfactory; I think definitely it is the better way to do it. There are always head losses in a sewer at a manhole, incidental to the change of formation of the water and branch connections. I suggest, however, that the Author should include in those manholes a bell mouth at the outlet. In a comparatively short length of sewer that I put in in Birmingham we experimented and found that by putting on bell mouths the discharge was increased by 5 per cent., which is an appreciable amount in the case of a large sewer.

I am very much against his proposal for putting a ramp into the sewer to make the flap effective. It is definitely bad, because if a long dry weather flow is experienced consolidation of detritus will occur just above the ramp and, especially with a flat fall, it would be difficult to get away even in time of storm. A far better way, I suggest, would be to have a balanced flap valve which can open very readily, because experience goes to prove that a considerable amount of flush occurs just underneath even a balanced valve, which would do away with any accumulation of grit at the outlet.

As to the special pleadings incidental

to his diagram regarding sewer work, it seems to me that this is a special case which requires special treatment, but he has lost a considerable amount of head by the lengthening of his outfall sewer, and I am not in agreement with his proposal to have a free outlet for his outfall sewer. It is definitely unsatisfactory in many ways. More smell is noticeable by discharging the water above high water mark, as suggested, and also flocculent matter is not drowned as when the discharge is under water.

I think those of us who have worked in different parts of the country will agree with the Author in toto in what he says regarding the standardisation of measurement of building work. The difference of measurements in brickwork varies considerably. I quite agree with the Author, moreover, in his criticism of the present-day bye-laws; I think many of those present will have experienced that in the case of Rural District Councils the bye-laws are worth very little; daily I have complaints from just outside the town where I live at the present time of their impotence in preventing unsatisfactory work going in. It will have a tendency to bring about with the present houses the slum effects from which we are suffering at the present time, and which began at the time when houses were rushed up at the industrial revolution in this country about a century ago. I consider the cutting down of the strength of the bye-laws, particularly outside the cities in Rural District Council areas, should be fought very strongly.

MR. B. PRICE DAVIES, in reply, said: Mr. Greenwood, in his very able contribution, dealt with very many matters, but I shall be able to reply only to a few. His statement that tradition has hindered progress is true, but we must give tradition its true value. In the case of many things which have been handed down to us from the past, the reasons for doing the work in the traditional way have been lost, and we are apt to continue the traditional method without realising the reasons for it. There is one thing which can be added to what he said about standardisation, and that is that standardisation aids competitive tenders. When people are on the same basis, on the same footing, you are able to get better

tenders from them. With regard to building houses which will last only for seventy-five years, I think it would be a retrograde idea if we in this generation built houses which would last only for that length of time. I think we should build houses of a sufficiently good standard to last a century, and in that regard we can point out that it is not altogether wise to curtail the size of houses or to build them according to unsuitable plans.

I am very grateful to Mr. Meek for coming forward and pointing out some matters which were missed in my paper. With regard to the advantages of stone retaining walls, there are some advantages in my district; one is that I feel stone walls fit in with the character of the district better than concrete walls; there is a certain amount of expression about them which is lacking with concrete walls. Secondly, we have the experience of concrete walls showing cracks, which are not altogether nice to look at. Not only that, but the additional bulk of a stone retaining wall lessens the expense of imported filling, where this is necessary. They are also cheaper in my district.

With regard to the observations of Mr. Jenkins, I think the question of building bye-laws is very important, and personally I should like the fact to be better realised that one model standard may not be suitable for the whole of the country. If it is to be suitable, then that model standard should be sufficiently good for the very wet districts of the country. I refer particularly to Wales and Cumberland. It is quite true that people in the south of England are not faced with the same troubles as we are in these other districts, but with the trouble we have with our gales and heavy rains we have to think not only of the construction of houses but of the plans as well. The houses I am building in Bangor now have porches both back and front arranged within the containing outer main walls. In the case of the houses built in previous years we are obliged to tack on porches. I think more consideration should be given to this matter.

The suggestion with regard to registration is very important; in my view, engineers, surveyors and builders ought to be on some sort of common footing. Everybody seems

to be working piecemeal without a definite policy. I have suggested in my Paper that all three should go through the same elementary course, preferably a subsidy house with accommodation works in the way of fences and small retaining walls. This would be a far better grounding for our young men than that they should be put to designing things which perhaps they will never have the opportunity of doing in practice.

With regard to intercepting traps, I have never believed in them. Heat insulation and cavity brickwork is a very important matter. We cannot count on so much heat insulation with cavity brickwork as we can with solid brickwork, but on the other hand properly made cavity brickwork is the only way to secure dry walls with brickwork in wet districts. I believe the demand for ventilation of the cavities is overdone; you will often find a cavity brick wall studded with ventilators, and I think that is particularly bad; it takes away from the heat insulation of a building, and you will find that with the contraction of window frames, door frames and so on you have a certain amount of infiltration; there is no need to overdo it. One thing which is very important with regard to insulation is to see that the cross joints of the inner lining are well filled, in order to give the inner lining of the cavity brickwork all the insulation which you can.

I agree with Mr. Jenkins that the best roof is one which is boarded, felted and cross-battened. I have a building which I am shortly putting up right in the heart of Snowdonia, and I intend doing that; but this class of work in general is more necessary with tiles than with slates, and particularly with tiles of the interlocking type more than the plain type. We are able, however, to do something with slates which we cannot do with either of the two classes of tiles; we are able to render underneath the slates with hair mortar, and that proves to be a very good insulation and keeps the slates in position.

With regard to ternary alloys, one speaker said he was not familiar with the point. One of the purposes of this Paper is to try to give information on new matters. I gave myself a refresher course on specifications to bring myself up to date. In setting about it, I perhaps covered more ground than would be usual, and I

thought it wise to pass on certain points with regard to certain new items of which it might interest others to know.

So far as the contraction of floor concrete where against the brickwork is concerned, it is true there is contraction between the floor concrete and the brickwork, which tends to become filled with dirt, and that is one reason why in the Paper I have recommended the use of impervious bricks (bricks which do not absorb moisture) when you build right up against the concrete, and I would go further and suggest that you should not use mortar joints, which are subject to capillary effect, on that particular course. Cork is certainly useful. I have seen it used with wood blocks lately, and it has the advantage that if the concrete each side contracts again the cork will expand and prevent dirt getting into the joint.

With regard to brickwork with reinforcement, there are two classes of reinforcement. There is the mesh reinforcement which you put in the brickwork, and which I used as far back as 1912. That is useful in some cases. I would point out that there is not so much need of it with cavity brickwork as with solid brickwork. With 11 in. cavity brickwork you are able to get a bond of $4\frac{1}{2}$ in. on your brickwork, whereas with 9 in. solid work you get only $2\frac{1}{2}$ in., and my experience is that you get fewer cracks with cavity brickwork than you do with solid brickwork in consequence. So far as asbestos cement being brittle is concerned, possibly a development has occurred recently which has improved it, but my own experience with sheeting which was fixed up some years ago is that it is very apt to crack in places.

In referring to the colouring of slates, Mr. Mitchell touched on a question which I myself am stressing on the slate quarry people of North Wales. I have pointed out to them that their slates are the best roof covering in the world, but that on the other hand architects are apt to object to their uniformity of colour and to say that a blue or purple colour is not suitable. I have told them that they ought to try to do something to improve the colour of the slates, by bringing out green slates, for instance, but they say that their slate is of such a quality that they cannot get anything to make an impression on it. I heard only a week

or two ago, however, that a certain process has been discovered in the Festiniog area which will help this forward;

I have little faith in cement rendering, but I have endeavoured to show in my Paper the fundamental principle of the capillary action between the fine-pored and coarse-pored cement work, and about the time I was writing this Paper I had a wall rendered on that principle. As yet I have not had any complaints about it.

Mr. Hewitt said my statement about 2 in. slump is rather sweeping. I feel inclined to agree with him; that should only be given for general work. That is what I had in mind. So far as the wetting of bricks is concerned, I think he will find that I referred to hard bricks, and I meant impervious bricks. In the case of bricks which are rather absorbent it is a different matter; you really want to wet those; but in the case of hard, impervious bricks it is not altogether good policy to give them a sliding action on the mortar. It has been ascertained by tests that the removal of the dust in the case of bricks of that class does not count for much.

With regard to lead decay, that was one of the most interesting things which I read in this research work, and I have pointed out the folly of putting it in contact with cement and other things. Lead laid in oak, for instance, is liable to decay. A great deal of research has been done on this matter, and we should adjust our specifications to suit it. The liability of stone walls to damp is a very interesting point, and we find in North Wales that if you want a stone-built building the best thing to do is to line it inside with brickwork. If you

follow the principles of the Paper you will know why—because of the condensation on the inside of the wall. With a stone wall inside it is quite common, on a very wet day when the air is laden with moisture, to see the position and shape of the stones outlined on the wall. The mortar joints of the stones have continued the capillary action and absorb the moisture from the face, but, where the plastering mortar overlies the stone, the moisture can get only as far as the stone, and then it recoils. I have spoken about this matter to a man who has had very great experience in regard to it, and he agrees to this cause; so it is not good policy to put a very hard stone on the inside of a building under plaster work.

The Chairman has dealt with increased fall in manholes. You want 2 in. cover for sea water and other purposes. With regard to lime and cement, it is found in some places that if cement mortar is used for certain structures which should have a certain amount of yield, such as a chimney stack, under wind pressure, that cement mortar is not entirely suitable. The mixture put forward by the Americans is 1 part of cement, 1 part of lime and 5 or 6 parts of aggregate. With regard to the comment on gas, coal and electricity costs, those are not my opinions; I have taken them from a pamphlet which dealt with research on the subject. The Chairman's remark about putting a bell mouth at the outlet of the sewer is very interesting, and that is something which we ought to bear in mind. With regard to the ramp in the sewer, I referred to that because I found from practical experience that the ramp did its work well.

CONFERENCE

Under the auspices of the County Land Agents Association.

WEDNESDAY, 15th NOVEMBER, at 11.0 a.m.

MR. H. L. FRENCH (*Principal Assistant Secretary, Ministry of Agriculture and Fisheries*),
in the Chair.

The following Paper was taken as read :—

The Productive Saving of the Unemployed through (1) Allotments, (2) Small Holdings, linked by (3) National Agricultural Co-operation.

BY THE LATE
F. H. OSMOND-SMITH, F.S.I.,
(Formerly County Land Agent, Glamorgan C.C.).

(NOTE.—This Paper was submitted for the Open Competition arranged by the Congress Committee and was awarded a Special Prize of Five Guineas).

(1) ALLOTMENTS.

“The Magic of property turns sand to gold . . . Give a man the secure possession of a bleak rock and he will turn it into a garden.”—*Arthur Young*.

INTRODUCTION.

UNFORTUNATELY, the great majority of people in the United Kingdom have been so long cut off from any connection with the land that they have, until quite recently, ceased to realise it was a subject which affected them particularly, and regarded it as being one of a number of industries instead of the root one on which all the others depended. Fear of starvation during the war, coupled with the shortage of food, made some of us think furiously, and proved to a certain extent that “the best way to appeal to a man is through his stomach.”

Inducements and promises galore were made to agriculturists of a Utopia if they would only increase food production, to which they gallantly responded under tremendous disabilities. What was their reward? The Corn Production Act was passed ensuring them guaranteed prices, but the hunger having been appeased, we fell back once more to the same old rut and “Never again” was forgotten, “Once More” took its place and the Act was repealed, largely on the ground of economy, and how false that thesis has proved is seen by the disastrous results it has produced.

Fortunately, once more we have been awakened out of sleep, and active measures have been and are being taken (on which our present able and energetic Minister of Agriculture is to be congratulated) to cope with meat, milk, corn and pigs. It cannot, however, be too strongly stated that it is now up to agriculturists to play their part, and for not only the Government but the people as a whole to demand it, and if such help as is being given is not *actively* responded to (not mechanically), it will almost certainly be withdrawn. The adoption of business methods including grading, bulk production, and last but not most important organised marketing, to replace the happy-go-lucky ones of the past, must form component parts. The object of this paper is not, however, to deal with what the Government has done, or, *up to the time of writing*, proposes to do, but what appears to the writer and many others to be a vital complement, viz., Land Resettlement by the means of allotments and small holdings, particularly for the unemployed, and to endeavour to prove this must inevitably form an essential component of a sound reasonably balanced comprehensive agricultural scheme. This was recognised by the pioneer of small holdings and allotments, Mr. Jesse Collings, who pointed out in 1905 that the only effective method of dealing with unemployment was to remove its cause through the agency of the above, and render the urban districts less top heavy and the rural ones better balanced. Although the theme is an old one, its importance, both from the national and humane point of view, justifies its supporters (although it involves hard labour) at times adopting the attitude of the importunate widow with the confident hope of securing similar ultimate success. Examples and figures have, as far as possible, been excluded from the context.

THEIR EFFECT ON PRODUCTION, MORALE AND HEALTH.

Thousands of allottees, during the Great War, proved the quotation heading this paper up to the hilt on land impregnated with boulders, even going to the extent of blasting them out, and also on cleared woodland, breaks, tips, etc., and are only too anxious to do so again if afforded reasonable means as they should clearly be, not only in their own interest but that of our Country for retaining and extending their morale, which unhappily shows and naturally shows a tendency to decline owing to the canker of unemployment. Proof of this is seen in the following extract from the report on last season's work of an allotment scheme in a South Wales mining area by one of the organisers of the Society of Friends (which Society has done such invaluable work in trying to maintain the Allotment Movement, as far as their means admit, when Government financial assistance was withdrawn) :—

"Unemployed men—poor fellows—are mostly two-thirds dead and the other third pretty cold. When I say this I am intensely serious. Wretchedness, suffering and long-deferred hope destroys these men's confidence in themselves and leads them to mistrust everybody and everything. We must begin much earlier another year, for it needs much time to resurrect these poor men and to vitalise them into action. They must be inspired and encouraged by personal contact continuously. They must never be let drift ;"

whilst a writer in "The Times," describing the lethargy and demoralisation which follows compulsory unemployment, and comparing what is being done there and here, ended up by stating : "The outstanding fact is that it is generally recognised in Germany, but not here, that an unemployed man needs something to do to keep his soul alive."

Sir Francis Acland who has been in close personal touch with allotments, particularly in districts where unemployment is rife, states "that the lowering of morale has increased to an alarming extent *during the last year or two* compared with what it was three or four years ago, the difference being that the men in these districts are rotting and have rotted, body, soul and spirit, for want of something to do."

It should be the first duty of the Government to see that these men should not be allowed to drift, particularly those who have been out of work for years. This is not a question of arithmetic getting a little better or worse when the numbers of the unemployed go down or up, but it gets wholly worse and very much worse every month that a large number of men are left wholly without anything. Consequently, it is evident the unemployment problem is not merely one of money or arithmetic, but occupation and employment.

SOME FINANCIAL CONSIDERATIONS.

Turning for a moment from the question of morale to that of money and economy (which is naturally one of the stock arguments against allotments) ; twenty-nine men who were receiving treatment in clinics or waiting to go into sanatoria for tuberculosis, were put on an allotment scheme at Sheffield. Following a season's work on allotments twenty-three were discharged *absolutely cured*. These cost the State three shillings a year each, and with the Authority providing the land free, the maximum cost was ten shillings per head, whereas institutional treatment for tuberculosis (without certainty of cure) would have cost £2 a week or more. Again, the superintendent of one of the largest institutions for mental treatment in the country has stated that four out of every five men who come under his treatment do so as the result of continued worry, but that if he had the opportunity of prescribing allotments a few months before they came to the institution he would not see one in ten entering therein. These two striking examples, I suggest, might be profitably placarded in a prominent position in the offices of the Chancellor of the Exchequer, the Ministry of Health, the Board of Control and some of those of our local authorities who are too apt to look askance at the movement.

The fact of endeavouring to insure against the imminent danger of a number of our unemployed becoming permanently unemployed is on financial grounds (apart from that of obligation) economically sound and common sense, and will

be one materially affecting successive Ministers of Health, Public Assistance Committees, and last but not least our already overburdened ratepayers. Going back for a moment to the quotation at the heading of this paper, a tale told in the House of Commons appears relevant. A number of unemployed men had been set to work on a rubbish tip and very bad land which they had tackled. One plot was pointed out as outstandingly good to the deputation from the Town Council who went round to inspect it, and one dear old gentleman, when he saw the striking improvement, remarked "May the Lord be praised for all His abundant mercies." The allottees rejoined : "Yes, but you should have seen it two months ago when the Lord had it all to Himself."

SOME ANSWERS TO OBJECTORS TO ALLOTMENT EXTENSION.

1. The number has declined and consequently extension is unnecessary. Whilst it is perfectly true that the numbers have gone down, this is largely due to men being dispossessed owing to only being provided on land leased for short terms, days of *toil* have gone with little monetary compensation, and either no suitable alternative accommodation has been provided or the rebuff has naturally so upset the allottees that they would not face the risk again. Frankly, the writer would not do so, and I do not believe any appreciable number of the readers of this paper would either. Here is a striking example from a colliery district which came under the writer's personal observation. Some five acres of sidling land, poor and practically unfenced, was sublet by the farmer, with the owner's concurrence, to a number of allottees thirty-five years ago subject to it being taken up at short notice if required. The land has been in their occupation up to the present time, has been thoroughly reclaimed, fenced, and the land made and well cropped. The landlord is now desirous of adding this land to a poultry holding on land of his adjoining, and to let it to a tenant who has been in occupation for two years, stating that he *wants* the land occupied by the allottees (he does not, however, *require* it). The Allotment Authority is now *considering* stepping in and acquiring the land, and should they default the County Council will take action for the protection of the allottees. Of the thirty-five allottees, one man has held his allotment for thirty-four years and none of the remainder have held theirs for less than eighteen. It seems neither fair nor reasonable that these men should be exposed to uncertainty of tenure or authorities put to needless expense. The only cure is the provision of permanent allotments and land acquired at far shorter notice than now exists.

2. That a number of allotments are practically derelict. This is applicable, in the main, to cases where the men have not the means to cultivate them, and is not due to declining interest. Where the allottees have means, as far as my personal observation goes, the standard of cultivation of the great majority has been remarkably good.

3. Some local authorities find the cost of rent collection not only difficult but expensive. The formation of an Allotment Association, or affiliation to an existing one, appears an obvious remedy.

4. Objection on the ground of cost has already been dealt with, and, I hope, proved largely fallacious, having regard to the fact that the expenditure is a pro-

ductive one. It has been estimated by good authorities in a position to know, that 300,000 allottees could have been placed in the Spring of 1933 and have grown produce to the value of £1,800,000—surely this is economic.

CONCLUSION OF PART (1).

The patience, fortitude and restraint shown by these men has been remarkable and magnificent, and every effort should be made to prevent their being entirely submerged in a slough of despond which must submerge a vast number if we still persist in looking on pityingly and passively. Let us remember "an ounce of help is worth a ton of pity."

(2) SMALL HOLDINGS.

Particularly for the Unemployed.

Allotments have been dealt with first because they are the first step in the agricultural ladder affording opportunities to men out of employment to grow their own produce, or, if in work, to do so in their spare time, but leading on to the goal of self-supporting small holdings, and, ultimately, to the family farm. The remarks previously made as to the paramount necessity of finding occupation for men who are out of work naturally applies equally forcibly to small holdings, and the class of small holding to which your attention is particularly drawn is the smaller type of holding having areas varying from three acres upwards to ten. Such holdings would be provided with a house and small set of buildings and be devoted mainly to poultry, market gardening and horticulture. To a limited extent, in some cases, they would provide men with full time employment and in others with part time on farms and in the villages. This type of holding is particularly suitable for the unemployed since it can be provided at the minimum cost and the produce therefrom is in the greatest demand. The holdings are easily managed, necessitate closer settlement, and facilitate co-operation for purchase, sale and transport, which are important factors, and afford ready facilities for economical agricultural instruction where such is required as it is bound to be in a number of cases not only for stocking and cultivation but also in grading and marketing.

With regard to poultry farming, the success of the Lancashire County Council holders is well known. Examples of its success, quoted by Mr. Rosbotham, the able and energetic Chairman of the Lancashire Small Holdings Committee, are contained in the Appendix and demonstrate that such holdings can be profitably and widely increased if the necessary factors are observed, which are :—

- (1) Suitable tenant and wife.
- (2) Suitable breed for particular soil and conditions.
- (3) Suitable feeding and management.
- (4) Suitable manuring.
- (5) Organised marketing.

Nos. 2, 3 and 4 are now safely established facts based on practice which can readily be ascertained. We imported 2,995,440,000 eggs in 1930 in shell, and if the average

laying capacity per hen is reckoned as 150 eggs (a conservative estimate), 20,000,000 hens would be required to produce the number imported. Taking a three acre holding to carry 1,000 birds, 20,000 holders could be absorbed on 60,000 acres. If this number of men were placed with 10,000 market garden holdings added (it is an incontrovertible fact that the miners and industrialists proved their ability to grow garden produce during the war and this seems *prima facie* evidence that they should succeed as market gardeners), we have with the 300,000 allotment holders 330,000 men as a *starting basis*, but inquiry would doubtless reveal the fact that a vastly larger number would be required.

The critics say the idea of placing unemployed on the land is a mere dream and a dreadful hazard. Other European countries who have an enlightened agricultural policy have not found it so, but a paying one. They have adopted it in the past and are extending it. I suggest seriously and respectfully for consideration that such criticism is a slander on our men and that what the foreigner has done the Britisher can do equally well. This has been proved on a scheme of the Lancashire County Council. Out of 145 tenants of equipped holdings up to five acres, thirty-five were farm labourers, ten market gardeners. Other occupations of the remainder, prior to taking up holdings, were as follows :—

Poultry farmers, stock-keepers, accountants, blacksmiths, boilermen, brick-setters, builders, butchers, chemists' assistants, clerks, coal dealers, commercial travellers, cotton operatives, decorators, draughtsmen, engineers, engine winders, foundry workers, game-keepers, general labourers, insurance agents, miners, motor drivers, painters, pipe-makers, platelayers, plumbers, police pensioners, produce dealers, railwaymen, scavengers, schoolmasters, seamen, skepmakers, textile machinists, and turners. Of these 145 men, only 15 have been failures.

In this connection, we should notice carefully that we are the only country in Europe where such holdings are practically unobtainable for the existing farm worker's advancement, and that his means of subsistence is the standard farm wage apart from perquisites. These men have not even the benefit of unemployment insurance. Is it surprising that under such conditions, coupled to a minor degree with the attraction of town life, that large numbers have migrated to the industrial districts? This proved detrimental to the town workers in times of prosperity as it resulted in a number of them being displaced, but in times of trade depression; coupled with the rapidly increasing labour devices which have and are being introduced, it has become an absolute menace, and the urban population now recognise that it can only be remedied by a scheme of Land Re-settlement. This can be readily effected under suitable conditions, such being suitable land and equipment, in which connection the character of the man and his wife are the most important capital assets, coupled with ability and land sense. Therefore, the most careful and stringent selection is required for the success of the scheme and to prevent untold misery for the would-be occupiers. The cruelest act that can be perpetrated is simply to put a man on land because *he thinks* he wants it, resulting in speedy disillusionment and unsettlement for all concerned. This is waste, whereas conducted on proper lines it is a measure, though a somewhat costly one, of ultimate economy, being productive settling of thousands and vastly increasing home food

production, much of which can be grown on good land lying idle at the present time or only half productive and leading eventually to the natural national regeneration of our countryside.

MACHINERY REQUIRED FOR SETTLEMENT.

During the war land was obtained at short notice under emergency powers. Similar powers are again required and justified (more especially in the case of badly cultivated land). Red tape was practically abolished, wide powers were entrusted to those responsible for carrying out the work, and the intolerable delay of reference from committee to committee and department to department, causing endless waste of time and money, was avoided. The success of the structure was mainly effected by a national appeal on emergency grounds which was met in a splendid manner and no doubt would be again responded to by men of goodwill of all parties co-operating to achieve the desired end, in an elastic scheme suitable to meet the varying requirements of different districts. The settlers will need stringent supervision and *real help* from those in charge of them. This should be coupled with a renewal of the loan system initiated under the Land Facilities Act of 1919 which is a practically perfectly safe and sound procedure, provided always that the most scrupulous care is taken in selecting tenants to whom advances are made. If this is not done, loss must accrue in the same way as it does by selecting the wrong type of men for holdings.

A FEW FIGURES DEMONSTRATING NECESSITY FOR ACTION.

A plain statement of fact of our population, number of rural workers, small holdings, etc., compared with those of other European countries will explain our necessity better than a series of arguments which frequently only lead to confusion of thought or sometimes nowhere.

Germany has about half the population to the square mile that we have, and has 7,000,000 to 8,000,000 workers on the soil. Taking our population in proportion, we should have 4,500,000 either farmers or labourers. How many have we? About 1,200,000. Germany is a Protectionist country.

Holland and Belgium are practically Free Trade. If we take the former in proportion to our own, we should have 3,500,000 not 1,200,000. Taking Belgium (an industrial country and more comparable to our own country and as densely populated as we are), to come up to her standard we should have 3,000,000 not 1,200,000.

From this it would certainly appear that "there's something rotten in the State of Denmark"—No! pardon the slip, I meant the United Kingdom, certainly not Denmark! What is it? It is certainly not due to Free Trade or Protection, but it is that we have far too few small holdings (particularly of the smaller type). Germany has 1,800,000 and we have 400,000 large and small. The Germans have a large number of the smaller type which form a reservoir for farmers to draw on at seasonal periods.

Under the 1908 Small Holdings Act about 20,000 holders were settled, under the Act for providing ex-Service men with holdings 25,000, or up to date about

50,000. We ought in regard to our normal small holdings to get back to our normal pre-war figure of 30,000 new acres per annum instead of the 4,000 acres to which we have sunk. Land, buildings and money are now cheap, and 10,000 men were on the waiting lists a year ago, some of whom are pre-war applicants.

Labour.—In 1921 there were 998,000 men engaged on the land, to-day there are 809,000—a loss of 189,000 in eleven years or an average of 17,181 per annum over a period of eleven years, but in the last three years *no less than 80,000 have gone*, or an average of 26,667, which should certainly make us all think furiously—may it do so!

CONCLUSION OF PART (2).

We have land and men waiting, the produce is required in the home market, some of the men must inevitably deteriorate and become a permanent charge on the State or rates if nothing is done. We need the will and the drive, and judging from the short experience we have had of our gallant Minister of Agriculture appear fortunate in possessing a skilful and forceful driver who will keep us on the rails, and a number of us not only hope but expect he will land us not only safely but speedily to the destination we are and have been seeking.

(3) NATIONAL AGRICULTURAL CO-OPERATION.

"UNION IS STRENGTH."

The importance of domestic and family co-operation has been alluded to in Part (2), and it is desirable to realise the absolute need for such a system from the business end to be grafted on to any scheme of settlement in order to make it succeed. This subject has in the past been tackled in a somewhat spasmodic rather than a regulated way, and consequently the results which have accrued have been somewhat disappointing with some notable outstanding exceptions. It is a well known fact that the success of small holdings has been largely due to an intensive system of this kind particularly in Denmark, Germany and Ireland (thanks largely to the foresight of the late Sir Horace Plunkett) and also in the majority of European countries. It must be patent to anyone that an organised industry always progresses, and must always do so, infinitely better than one which is not, and that this applies more particularly to smaller units than larger ones, otherwise the babies get swallowed up as is seen by the number of small holdings merged into large farms, which, to a certain extent, is responsible for the present shortage and also for the number of by-takes attached to large farms.

Agricultural co-operation must be applied in the spirit as well as from the business standpoint, and this should apply not only to the holders but should start at the top in Parliament, in order to get a stable policy, through the various departments of the State whom the subject affects, the officers of local authorities, agricultural societies and unions, landowners, farmers, small holders and allottees. This could and should be achieved and taken up far more actively than it has been done in the past by the State. It is gratifying to note that steps in this direction are being taken, to a certain extent, in the Agricultural Marketing Act and the Wheat

Quota Act, but a very wide field has still to be covered. Agriculturists in the past have made a boast of their independence and delighted to vie with their neighbours in bringing off a better deal. Consequently, many of the exponents of co-operation have felt they are more or less ramming their heads against a brick wall and thrown up the sponge in disgust, which is not surprising, but it has to be stuck out to the end until success is achieved.

Facilities are afforded to small holders under Section 49, s.s.1, of the Small Holdings Act for the creation of such a system for the purchase of requisites, sale of produce, credit banking, insurance or otherwise, which objects afford a comprehensive field for action, whilst Section 3 gives County Councils powers to sell or let one or more small holdings to a number of persons working on a co-operative system, or to sell or let small holdings to any association for the purposes of creating or promoting small holdings constituted in such a way that the profits are prohibited or restricted. These two sections, applied together, appear to form an approximate basis of settlement.

ADVANTAGES OF THE COLONY SYSTEM.

The late Sir Horace Plunkett once described isolated small holdings in units as not only being anomalous but in nine cases out of ten as largely useless or inefficient, which is a truth very few people will be disposed to quarrel with and the majority to uphold. The colony system admits of economic and intensive management, and readily admits of agricultural education facilities on the land, produce can be bought and sold in bulk, and transport charges can be reduced to a minimum.

SUGGESTIONS FOR FORMATION OF CO-OPERATIVE SOCIETIES (WITH OUTLINE SCHEME).

The suggestions and draft scheme set out hereunder have been drawn up for adoption at the request of a number of statutory and non-statutory small holders for their protection, advancement, and profit, to enable them to meet the objects set out in Section 49 of the Small Holdings Act of 1908. It is proposed, at a later date, to zone the county into four or five suitable geographical divisions, if this scheme proves successful, and to link these up to a central committee consisting of representatives from each. It is included in this paper for the purpose of information and in the hope that others may consider the advisability of adopting similar schemes in their respective counties.

DRAFT SCHEME FOR THE.....SMALL HOLDERS' PRODUCTS, LTD.

Objects.—It is proposed to organise a Small Holders' Trading Association operating in..... Its primary object is to organise the sale of Small Holders' products in the urban areas of..... The Society shall have power to carry on the businesses of wholesale and retail dealers in dairy, farm and garden produce, eggs and poultry, and agricultural requirements. The Society shall also have power to carry on any other activities which may seem calculated to conduce to the more profitable working of Small Holdings.

Powers.—The Society shall have power to do all things necessary or expedient for the accomplishment of its objects, including the power to deal in any appropriate way with land or buildings (with special reference to the provisions set out in Section 49, s.s's. 1 and 2 of the Small Holdings Acts).

Shares.—Shares shall be transferable but not withdrawable. They shall be of the nominal value of £1 and shall be payable in full on application, or, 10/- paid on application and the remainder to be payable as the Committee may direct subject to two weeks' notice, or by deduction from the proceeds of sale of members' produce.

Shares to be held by Members.—It is proposed that all members should pay a subscription of five shillings per annum and should subscribe capital as nearly as possible in accordance with the extent to which they will use the society. In order to achieve this end the number of shares to be held will be based on the rental of the holding, and it is estimated that each member's liability in respect of shares will be not less than 5 per cent. or more than 10 per cent. of his rental.

Membership.—Any Small Holder, statutory and non-statutory, holding not less than three acres or more than 50, or, if exceeding 50 acres is at the date of sale or letting of an annual value, for the purposes of Income Tax, not exceeding one hundred pounds, unless otherwise determined in exceptional cases, shall be eligible for membership.

Area.—All Small Holders as above defined within the scheduled parishes in..... shall be eligible for membership. The Society shall have power to extend or restrict its area for supply and sale purposes in accordance with the contingencies of trade.

Registration and Rules.—The Society shall be registered under the Industrial and Provident Societies Acts.

Suggested Methods of Operation.—(1) At the commencement it is proposed that the Society should rent one or more suitable stalls in the City (or Town) of..... Public Market for retail sales. Sales would be conducted from the stall, but would be carried on as the Society would conduct its trade in a private shop. Customers would be canvassed and goods would be suitably prepared and delivered to all customers where necessary. The Society should provide consumers with every possible service, and would strive by every possible means to supply *prime quality graded commodities at an equitable price.*

(2) For purposes of handling and grading the Society to rent or erect suitable premises in a convenient place just outside the City of..... Rents within the City area are very high, and it is believed that by having suitable premises just outside, overhead charges can be greatly reduced without incurring any additional transportation charges.

(3) For the purpose of slaughter of fat stock and preparation for sale, it is proposed that the..... Municipal Abattoir be used.

(4) In order to facilitate matters in connection with securing premises in the Public Market and Abattoir, the Provisional Committee of the Society should

appoint not less than three or more than five representatives to negotiate with the City authorities concerned.

(5) The amount of capital required is estimated to be not more than £500 at the outset, and this amount should provide for both fixed and trading capital.

(6) It is proposed that before the Society begins operation, a sign-up of one hundred members representing a minimum share holding of £250 be secured.

(7) The Society shall do everything in its power by means of a well organised canvassing system and an efficiently conducted delivery service system, to sell as large a proportion as possible of the commodities supplied by members direct to consumers. Surpluses will have to be disposed of on the wholesale markets to the best possible advantage. It may therefore be necessary to adopt a system of pool prices for some or all commodities handled in order to ensure equitable payment to all members.

(8) The commodities to be handled include :—

- (a) Fresh meat—beef, mutton and lamb, pork.
- (b) Eggs and poultry.
- (c) Vegetables, fruit and flowers.
- (d) Milk and dairy produce.

It is suggested that the Society should commence with (b) and (c) extending to meat as soon as a trading connection with consumers has been established, and to milk later if the conditions of the market and the resources of the Society reasonably justify such a procedure.

(9) It is intended to arrange meetings at the following centres, viz..... and lastly a mass meeting at the City (or Town) of.....for the explanation and the promotion of the scheme. At these meetings arrangements are to be made for local canvass and other matters and at the final meeting at..... a representative committee of the whole area should be formed to consider the rules and the final details of the scheme.

General.—It is suggested that the scheme should be started on a basis of voluntary co-operation as this would make possible the establishment of an active trading society at an early date. A scheme under the Agricultural Marketing Act would be very complicated for the purpose in view and it would take a long period before it could come into operation if accepted. When the Society starts operation on a voluntary basis a committee could be appointed to consider the desirability of a scheme under the Marketing Act and if a report in favour of such a scheme is submitted steps could be taken for its preparation and submission. If such a scheme were accepted by producers the voluntary organisation could be liquidated and the business taken over without a break in its continuity, under the new scheme.

APPENDIX.

EXAMPLES OF CLOSE SETTLEMENT IN LANCASHIRE ON EQUIPPED SMALL HOLDINGS OF UP TO TEN ACRES.

1. *Hutton Scheme.*—Area 4 acres. The tenant has been in occupation five years and was formerly an agricultural labourer, but now a full time holder with his boy of ten. Soil—heavy clay and very wet. Started £100 in debt and has now 1,150 poultry (Rhode Island Reds and White Leghorns). The tenant has erected several poultry houses, also his own cowsheds and piggeries for his stock of three milking cows, four heifers, two calves (for which he has to buy hay) and twenty store pigs. In addition to paying his debt of £100, he has spent, from his profits £700 on buildings and equipment, etc., and states he has £800 invested in the Bank, giving a total of £1,600 made in five years.

2. In this case, the holding is one of 5½ acres. Rent £31 17s. 6d. The tenant has a stock of 1,000 poultry (Rhode Island Reds, White Wyandottes and Leghorns) and two geese. This man obtained a certificate of merit at the Lancashire Utility Poultry Society, and has well fitted rooms, cabins for laying stock, brooders, incubating and rearing appliances, and a provender house.

3. Another holding at Hutton of 7½ acres on damp heavy soil—the occupier who is a cotton broker took 1½ acres in 1925, owing to the cotton depression, but continued his attendance at the Cotton Exchange awaiting a revival of business, and, consequently, has had to employ labour—a man and a boy. After being in occupation for 2½ years, he purchased 6½ acres adjoining that which he rents. This man has 2,000 poultry well housed. The initial amount of his capital was £300, and his present profits from the holding £600 per annum.

4. Holding near Ormskirk of 10 acres. Soil—sandy, in a low and damp situation. The occupier was formerly an agricultural labourer, and, starting as a part timer, he built his way up and has now a man to work for him. He has been in occupation for ten years, combines poultry keeping with horticulture and market gardening and has erected from his profits glass houses covering 6,000 sq. ft. This man states he finds the combination of horticulture and poultry good, the manure being of great value to the crops, whilst surplus green food is fed to the poultry.

5. The last case is that of a holding of 2½ acres, equipped with a cottage and small outbuildings, and used for horticulture. The occupier had been brought up as a gardener and had practically no capital to start with. With the assistance of his wife, son, and daughter, he has from a small beginning, year by year increased his stock, including greenhouses and other buildings, and now owns over a thousand pounds worth. In addition to other buildings, he has six greenhouses and a motor wagon to take his produce to the market at Liverpool. He has recently opened a retail florist's shop in the village (the daughter manages the shop) where he sells some of the produce produced on the holding. He has a large trade with a multiple firm in bedding out plants and flowers. Four years ago he purchased his holding through the Council under the 1926 Act. The reasons for his success are character,

good business acumen, and a remarkably good wife. This is really an outstanding example of what can be done by co-operative family working on a very limited area by a man starting from the very bottom, and cannot be broadcast too widely.

N.B.—The above examples could be added to, but are considered sufficiently conclusive evidence to prove that thousands can make a good living on small holdings under a close system of settlement and augment the national home produced food supply of the country and in the direction that it is most required.

DISCUSSION.

THE CHAIRMAN (Mr. H. L. French), having conveyed the apologies of Sir Charles Howell Thomas for his inability to preside over the meeting, said: It is a great pleasure for me to be back again in the atmosphere of the work of the county land agents. It is more than four and a-half years since I left the Land Division of the Ministry of Agriculture, and, although my friend and colleague, Mr. Mitchell, is good enough to discuss with me from time to time some of his problems, I regret the termination of the close association which I had with county land agents in the years 1918 to 1928, when they and the officers of the Ministry were co-operating in work which I think many of us look back upon as probably the most useful contribution we shall ever be able to make to the well being of this country.

My regret goes further than that, because I realise that, through no fault at all of the officers who are in charge of small holdings work in the counties and at the Ministry, the operations under the Small Holdings Act are far less active and energetic to-day than they were in the days to which I have referred. To many of us there is bound to be a feeling of sorrow when we think that we developed a machine until it was moving at top speed and undertaking work of really national importance with a very high degree of efficiency, and just then the petrol ran out and, although the machine continues, many of us do not consider that it is fulfilling the functions that it is capable of fulfilling to the great advantage of the nation. One only hopes that, if this period of terrible financial stringency is now coming to an end, the Powers that Be will realise how extremely important are the functions of the Small Holdings Committees of this country.

All of us will regard it as extremely sad

that Mr. Osmond-Smith's contributions will not be available in future at gatherings of this kind. He was a man of great energy and great enthusiasm. I do not think anybody who knew him ever had any doubt about where his heart was; his heart was in this work, and to him it was more important, I believe, than anything else in life.

The meeting rose as a mark of respect to the memory of the late Mr. Osmond-Smith.

MAJOR C. REGINALD HARDING (*County Land Agent of Surrey*), introducing Mr. Osmond-Smith's Paper, said: From what I knew of Osmond-Smith I think the Chairman was absolutely correct in saying that he was a man of great energy and enthusiasm and that his heart really was in small holdings work. We on the County Land Agents' Association already feel a great gap since he has passed on. We think with pleasure and gratitude of the enormous amount of enthusiasm that he always displayed, and we miss him very much.

The Paper is divided into three parts. The first deals with allotments, and I think we may say that Mr. Osmond-Smith strongly advocates greater energy in the provision of allotments, particularly for the unemployed, and holds that sufficient has not been done up to the present to provide them. The second part of the Paper relates to small holdings, with which we are more immediately concerned, and you will observe that Mr. Osmond-Smith strongly advocates the smaller type of holding, that is to say, up to about ten acres, for poultry, market gardening, flower growing, and so on, and he instances the successful examples which he saw in Lancashire. Those examples which he has given from Lancashire are, of course,

excellent ones, but they can be paralleled, I think, elsewhere, although I believe it is the case that in Lancashire there are more of the three-acre mixed holdings than in most other counties.

Perhaps I might dwell for a moment on this point of policy, because it is a very important one. We know the Ministry of Agriculture at the present moment are rather stressing the advisability of paying more attention to the type of holding to which I have just referred, and not everybody agrees with their policy. It would be presumptuous for me to express a view as to whether that policy is right or wrong, and I am not going to do so, but perhaps I may say that it may be quite right in certain areas whilst it is inadvisable in others. At the same time I venture to make this further observation, that I think the Ministry are quite right, if I may say so with great respect, in thinking that there is room for further holdings of this type in certain areas.

Another point to which Mr. Osmond-Smith calls attention in the Paper and which I personally do not think has been given sufficient thought is the catastrophic loss of agricultural labourers in the last eleven years, a loss which has been particularly rapid in the last three years. I hope we shall hear more of that, because, of course, it is from every point of view perfectly deplorable.

In the section relating to small holdings Mr. Osmond-Smith calls attention to the very much closer land settlement that exists in other countries, such as Germany, Holland, Belgium and Denmark. The third section of the Paper relates to agricultural co-operation.

MR. A. EVERY-CLAYTON (*County Land Agent, Monmouth*): The title of the Paper, "The Productive Saving of the Unemployed" is undoubtedly the problem that is facing the nation at the present time.

Consider this anomaly. First of all, we have large imports of foods of all kinds. We may say that practically every kind of food is better when it is fresh. Secondly, we have considerable areas of land which is practically derelict, or, at any rate, is not being put to its best possible use. Thirdly, we have idle capital. Fourthly—and, I think, worst of all—we have, besides derelict land, derelict men. The problem is to bring

those four things into harmony; to get the land used, to use the money to advantage, to get our food supply produced on our own land, without having to bring it in in ships and to pay other people for it, and to redeem these derelict men and set them on their feet.

I have no doubt that Osmond-Smith was moved to write this Paper by what he had seen in the industrial valleys of Glamorgan, as I have been moved to support what he has said by what I have seen in the industrial valleys of Monmouth. Those who have not visited such areas can have no idea of the deplorable condition of the people there and the deplorable waste of manhood, young manhood especially, which is going on. There are literally thousands of men who have been employed all their lives but who now find themselves, and have found themselves for the past two or three years, quite unable to get work and without any prospect of getting work of the kind that they have had before. Those men are ranked now as unemployed, and I suggest that we should try to keep our minds on the right track when we talk about the unemployed. The word "unemployed" is very often used in a sort of tone which indicates that the speaker regards these men not only as unemployed but as unemployable. From my own experience I can say that, although there may be some unemployables among them, there are many who are quite a good type of man to put on a small holding. We have had some ourselves who have been quite a success, and I have no doubt there are hundreds of others also, but unless something is done for them they will continue in the ranks of the unemployed and sink from bad to worse.

I suggest that we should do more than has yet been done to safeguard our own markets, because it is not going to be much good putting men on the land, especially on these small 4½ to 5 acre holdings, unless they can dispose of their produce. Some of us have had experience already of holdings where the men have simply not been able to market their produce when they have got it. Therefore the first step obviously, to my mind, is to secure our own markets and perhaps to do that by a fairly drastic extension of the quota principle, that is to say, by reducing and keeping on reducing our imports of things

which we might and could quite well grow at home.

I also suggest that something should be done to simplify our machinery. Under the heading "Machinery required for Settlement," reference is made in the Paper to "the intolerable delay of reference from committee to committee and department to department, causing endless waste of time and money." In the different counties there are different committees and different arrangements, but for my own part I most heartily endorse what Mr. Osmond-Smith says in this connection, and I suggest that what we want is to have Small Holdings Committees who will be masters in their own house, with full delegated powers to carry out all that has to be done with regard to the acquisition of land and its equipment for small holdings purposes.

Mr. J. BYASS (Yorkshire): I think I have some little right to speak on agriculture, because I was brought up on a farm. I was amazed to read in the "Daily Telegraph" the other day that in a case before the Recorder, when a farmer said that his son had worked for him for years without a wage, the Recorder said: "This is a new sort of son." The Recorder knows nothing about agriculture or he would never have made that statement. I myself never had a wage until I left home, when I was twenty-one. This applies not only to farmers and their families whom I know personally but also to the small holders. Many a small holder to-day could not make a living if it were not for his family working for him without a wage.

I have gone through Mr. Osmond-Smith's Paper and I noticed at the beginning of it a statement that agriculture is the root industry on which others depend. I quite agree with that, and I am certain of this, that on the right and proper use of the land depends the success of our nation. Our nation must have food, but we have got to do away with this fetish of cheap food and procuring food at a price under the cost of production. Cheap food is a grand thing, but the people who are asked to provide cheap food should not have to provide it under the cost of production. In the last year more farmers have gone down than ever before.

Mr. Osmond-Smith refers in his Paper

to the Corn Production Act and says it was passed to ensure guaranteed prices, and he continues: "But, the hunger having been appeased, we fell back once more to the same old rut and 'never again' was forgotten." If that Act had never been repealed there would have been hundreds of farmers on the land to-day who have gone down, and there would have been thousands of men working on the land to-day who have gone to swell the ranks of the unemployed in our towns.

We are told that the Corn Production Act was repealed, but it was not; only part of it was repealed. That is where the difficulty comes in. The part about the guaranteed price was repealed, but not the part about the guaranteed wage. No farmer worth his salt objects to paying a good wage, but he must be able to sell his produce so that he can make the money with which to pay his employees. What is the result of what has happened? Farmers are having to do with fewer men and there are more unemployed in agriculture than ever before.

Every encouragement should be given to all those who are connected with the land. I think every credit should be given to the landowner for what he has done for the nation. One of the biggest calamities that ever came to this country was when the old style landlords had to break up their estates. Encouragement should be given to the landowners, the farmers, the allotment holders and small holders, and the workers who are employed on the land.

Mr. Osmond-Smith also says that it is up to agriculturists to play their part in return for what the Ministry of Agriculture has done for them. We say that the only thing that has been done for the benefit of agriculture is the introduction of the wheat quota. The other schemes just now are on trial, and nobody can say what the result will be. I know people in the milk business, and these various schemes have got to be worked out. I give credit to the Minister of Agriculture for endeavouring in a practical way to solve some of these problems, but I say that up to now the only real benefit has been the wheat quota, and, as you know, farmers have to wait twelve months after they have sold their produce before they get the full benefit of the quota. Under present conditions farmers and allotment holders and small holders have got to live on what

they produce from the land. My son has just sold his barley at 27s. 6d. and wheat at 18s., and beef is an atrocious price. No British farmer can produce beef to-day at the price that he gets in selling it.

We talk about putting the unemployed on small holdings, but the nation will make a great mistake if it puts on a small holding anybody who knows nothing about it. The great mistake that the nation made at the close of the War was in putting ex-soldiers on to small holdings who knew nothing whatever about the work. Many of them lost the whole of the little sum of money that they got at the end of the War. Then the Government turned a lot of practical farmers off what we call the Sunk Island Farm Colony in the East Riding of Yorkshire and put on a lot of men who knew nothing about farming. These men could not make a living, and you who have to pay the taxes of this country had to finance this scheme to the extent of thousands and thousands of pounds. The result of that Government farm colony was a disaster.

With regard to getting land for nothing and putting the unemployed on it, that is all right and I should be glad if something more could be done in that direction, but you have to consider this: In my own town we have allotments and we have an Association that is doing this very thing. The Borough Council has allowed a certain number of allotments to be given to the unemployed rent free. But what is the result? The men on the adjoining small holdings, who are paying rent, are now saying: "Why should we pay rent when these other men are getting the land for nothing?" Looking at the matter from a practical point of view, the day must come when we shall have to stop this philanthropic movement. These men cannot be kept for life on land for which they are paying nothing.

With regard to the egg business, which is for ever being brought before the nation, and the question of the eggs which are sent here from Germany, Mr. Clayton has just said that something should be done to stop the importation of things that we can supply ourselves in reason, but you must consider the conditions of the people in Germany and Belgium. They neither pay the wages nor have the hours to work that people have in this country.

Many small holders with 25 or 50 acres have to work all the hours that the Lord sends them. In a book issued some time ago by the Ministry of Agriculture there is the statement that a small holder needs a good wife. But a man's wife does not want to be slaving all the hours of daylight and some in the dark as well, and I do not think it was fair to make that statement in the booklet to which I have referred.

This problem can be solved only when we get back to the economic question and when farming can be made to pay. More men will then be employed upon the land; they will come back from the towns, where they are swelling the ranks of the unemployed.

COUNCILLOR BURNS (Yorkshire): My few remarks must be from the point of view of the allotment holder. Whenever you hear that subject mentioned you should express thanks to the Society of Friends for what they have done to help people to get back to the land in this country.

When you are considering the question of getting the unemployed back to the land, the provision of tools has to be considered. It is an expensive matter, and facilities for obtaining tools ought to be given from the National Treasury or from the local rates. The men should not be dependent upon charity in this respect. Tools should be provided for them and seeds as well, and, in order to prevent people getting on to the land and ruining both the land and themselves, someone should be appointed to train them and show them how to carry out their work.

The great difficulty seems to me to be in acquiring the land. I happen to be a member of the Allotments Committee at Hensworth, and when £200 is charged per acre for the purchase of land it cannot be made profitable for the people who are working it. The land ought to be cheaper, and I should like to ask Major Harding whether he does not think that, if the land of England is going to be bought back—I would not purchase it myself; I would take it—£20 per acre is quite sufficient to pay the present owners by way of compensation for returning the land to us. Mr. Byass will correct me if I am wrong, but I should say that the land in England does not average more than £1 per acre when it is let. If the owner who sells

it invests the £20 at 5 per cent. interest, it will bring him in that £1 per acre. When £200 or £300 per acre is asked for the land, I say that the patriotism of the owners is in question.

If we could get the Government and our public authorities to take this matter in hand seriously and give these people the land on reasonable terms, giving them also facilities and opportunities and encouragement, we could grow the finest food in this country and we should not need to talk about imports, for we could supply the food for our own people here.

COUNCILLOR ABBOTT (*Yorkshire*): Mr. Burns has touched upon one of the main difficulties, namely, the price we have to pay for the land. It means that the price we have to charge the allotment holders makes it difficult for those who are unemployed or partially unemployed. The food they can produce on the allotments helps them materially in the larder.

We have just had a difficulty on our Council about a certain piece of land which was bought for allotments during the life of the late Labour Government. It was naturally expected that the people would be able to have this land rent free. We had quite a number of applications and we had every hope that the land would be cultivated, but when the new Government came into power the position with regard to allotments was altered. The consequence was that we had a number of the allotments remaining vacant, and recently the Council wanted to turn this piece of land into a playing field for children. I rigidly opposed that idea. I wanted to see men put on to this land, because I knew the difficulties they were having to contend with by reason of unemployment and short-time working. Fortunately I got my way.

I should like to see legislation passed for the nation to take over the land. If the present owners got possession of the land honestly, they should be paid for it. If they got it dishonestly, they cannot complain if they do not get paid for it, because they have received rent for it in past years.

I want to see this allotment movement prosper, because I realise that it is a great help to us as a nation. I think we ought to find ways and means of raising money to purchase land for allotments at an equitable

price; I agree with Mr. Burns that £20 per acre is quite sufficient. I traverse a good deal of agricultural country in my employment on the railway, and I see that in many cases large pieces of fields are left uncultivated. This land is let to the farmers at a far cheaper rate than allotment holders have to pay, and I contend that, if they will not cultivate the whole of that land, they are not taking out that which they are putting in in return for it. I should like to see the land more fully cultivated than it is at present.

We have, I believe, in our area about five or six groups of allotments, and we have quite a number of derelict allotments which are a source of trouble to those who are cultivating the adjoining allotments. A man who takes care of his allotment and cultivates it as it should be cultivated does not want a piece of land adjoining to be growing all kinds of weeds. Our Council sends a man round to hoe down the various weeds in the unoccupied allotments so that they will not be a source of danger to the cultivated allotments. We have a scheme now for dealing with men of sixty years of age and upwards, and we are trying to find some means of allowing them to cultivate the vacant allotments at a reduced rent. I think from an economic point of view it would be better to have them cultivated at a lower rent than we are charging the other allotment holders than to have them unoccupied, but I see the danger there. It will naturally cause some unrest in the mind of the man who is paying the ordinary rent for his allotment if the man who cultivates the adjoining allotment is getting it at a reduced rent.

CAPTAIN PULFORD (*County Land Agent, Shropshire*): I think we should take off our hats to the Society of Friends for the work they have done for the unemployed, and I do hope that the Minister will do as he suggested the other day and storm the Treasury in order to get more money for this work. I think the Society of Friends can continue the work that they are doing much better than it could be done by the County Councils.

With regard to the smaller holdings for the unemployed that Mr. Osmond-Smith mentions in his Paper, particularly with reference to colonies, I do hope that the Ministry will go into the history of the colony system and profit by past experience.

The colony is nothing new. It was tried twenty-seven years ago in two places, and both those colonies were failures.

It is true that in Lancashire small poultry holdings are a marked success, but the County Land Agent of Lancashire said last night that it is largely due to the Lancashire character. The particular men who have tackled the poultry industry in Lancashire would probably succeed if they tackled some other branch of agriculture. In Shropshire the poultry farmers are sending petitions to the Ministry, through the National Farmers' Union, asking to be helped out of the difficult times on which they have fallen. They are nearly all bankrupt. Last night land agents met together to compare experiences with regard to these smaller holdings, and, with the exception of two counties, it might almost be said they were a failure. That has been my own experience. Of 33 men with holdings under ten acres, all but three are also working for employers. Therefore, although the system may succeed in Lancashire, I hope the Ministry will thoroughly consider the matter before they endeavour to persuade County Councils to extend this five to ten acre scheme throughout the whole country, because I do not think it would succeed. From the Return of the Land Division of the Ministry which was published a few weeks ago it would appear that the Ministry hold the same view with regard to these smaller holdings as that which is expressed in Mr. Osmond-Smith's Paper, and I should be glad to know if that is the case.

In a London paper a few days ago one of the chief officers of the Ministry made certain statements about small holdings, particularly with regard to the colony system and not putting houses on the land, with which we as County Land Agents certainly do not agree. There must be houses on the land. Perhaps the Chairman will tell us whether that article expresses the Ministry's official view. We in the Midlands think that the smallest holding which a man can make successful is from 25 to 30 acres.

MAJOR T. G. ELLIS (*County Land Agent, Norfolk*): The question of allotments does not interest me very much. We have plenty of land in Norfolk, and I find that in rural districts the best thing is to give a good garden to the country cottage.

Previous speakers seem to have dragged up a lot of old grievances, but I think that, instead of thinking about what has happened in the past, we should look ahead and find a solution for the problem in the future. One of the chief grievances of two of the previous speakers appear to be the cost of land. If they like to come down into Norfolk we can let them have plenty of cheap land. They can have it for less than £20 an acre; in fact, they can have something for nothing! They may have to pay a little tithe on it, by the way.

With regard to the type of holding, I do not think any hard and fast rule can be laid down. We have various sizes of holdings, and I do not think it is possible to say that one is better than another. Personally I was not very keen on what I call the Ministry's "pet" holding, but we have created a few lately and have been able to let them, and I am impressed by facts and not by theories.

MR. SANDS (*Isleworth*): If this scheme of returning men to the land is to succeed, wherever there is a colony of small holders or allotment holders there should be a capable man to teach them how to dig. Digging the soil is a most important factor in crop production. Another point which I think has never been considered is how to treat the soil after it has been tilled. There are some fertilisers advertised which really are poisonous to the land.

There are three things necessary in this business of going back to the land. First, the men must know how to cultivate the soil; if they do not, they had better keep off it. Secondly, they must know how to feed the soil, and, thirdly, they must use lime. If the soil is cultivated and fed properly and treated with lime, you need not do anything else; you will get good crops.

We are trying in our little way to help the allotment holder by telling him he can get from the cities and the towns his requirements for the soil, and we are approaching Councils for the purpose of getting them to turn their waste into valuable manure for the allotment holders at a cheap price, so that these men who are going back to the land will have something to put into it. We are encouraging Councils to employ labour not in destroying the stuff in the dustbins but in recovering it and making it

valuable for the land, because it came from the land.

MAJOR HARDING: I think the only question I have been asked was that put by Mr. Burns with regard to the best method of providing cheap land for allotments in towns. I do not think I can give an entirely satisfactory answer to that question. It seems to me that you cannot differentiate between the price paid for land required for allotments and the price paid for land required for any other purpose in urban areas. I think the best method of avoiding difficulty in future in getting land for allotments is to make ample provision for allotment land in town planning schemes and to avoid the too close building which has obtained in the past in urban areas.

There were two points that Mr. Clayton stressed in his very interesting speech and which I think rather carried on the trend of Mr. Osmond-Smith's argument. Mr. Clayton pointed out that ultimately, if we are going to have closer land settlement, we must keep in view the necessity of limiting gradually the imports of foods that we can produce at home. That is obvious and most important, it seems to me, and in the reorganisation schemes which are now being tried out the principle is recognised that we have got to tackle the marketing question at the same time as any very big scheme for closer land settlement, or perhaps rather in front of it. That is an absolutely fundamental point.

Mr. Clayton also referred to Mr. Osmond-Smith's remarks with regard to the machinery for the acquisition of land, and I think that what Mr. Clayton said was unanswerable. The machinery for the acquisition of land for small holdings has become very involved, complicated, difficult and unsatisfactory. In the early days—my memory goes back to 1908—the Small Holdings Committees

obtained their land more quickly and easily than many of them do now. The Small Holdings Committee has usually only delegated powers of management from the Agricultural Committee. The Finance Committee very often has a lot to say about the question, and even the County Council may turn it down at the end. The result of all that is that your negotiations are seriously handicapped, and very often you may lose a suitable property while the various Committees are considering the matter. I should therefore like to associate myself very cordially with the remarks of Mr. Osmond-Smith and Mr. Clayton with reference to this subject.

Of course, what Mr. Byass said was all-important, namely, that agriculture as a whole must be considered and that it is the fundamental and indeed the only absolutely essential industry in the country.

THE CHAIRMAN (Mr. H. L. French): Captain Pulford referred to an article which appeared recently in a London newspaper on the subject of small holdings and he asked me whether, seeing that that article was written by an officer of the Ministry, it represented the official views of the Ministry on the subject with which it dealt. The officer who wrote the article, Sir Daniel Hall, is one of the most eminent and respected officers of the Ministry of Agriculture. He has done a tremendous amount of work for agriculture in this country. He is not, however, a whole time officer of the Ministry, and many of his activities, whether they be an address on the wireless or an article such as that to which reference has been made, are carried out in that part of his time which does not belong to the Government. The article in question, stimulating and suggestive as it was and most valuable from many points of view, was in no sense an official pronouncement.

The following Paper was taken as read:—

Rats and Musk Rats.

BY

MARTIN A. C. HINTON,

Deputy Keeper of Zoology, British Museum (N.H.)

TWO species of rat occur in Britain; both are aliens but the dates of their arrival in this country are different.

The first species is *Rattus rattus*—the "Black Rat," "House Rat," "Ship Rat," "Alexandrine Rat," etc. of popular writers. This is a comparatively small elegantly and slenderly built creature, with a sharp muzzle, large, naked, and almost translucent ears which reach or cover the eyes when pressed forwards. The tail is at least as long as the combined length of the head and body and often longer. The fur is soft, but in adults it is usually intermixed with many slender grooved bristles, which impart a somewhat harsh quality and bristling appearance to the coat as a whole. The weight of an adult is rarely more than 8 ozs. and is usually less. The measurements of 2 adults in millimetres are:—

Head and Body.		Tail.		Hindfoot.		Ear.
188	..	224	..	33.6	..	26
214	..	252	..	38	..	25.5

The second species is *Rattus norvegicus*, the "Common Rat," "Brown Rat," "Grey Rat," "Hanover Rat," "Norway Rat," "Sewer Rat," etc. of books.

This is a much larger, more heavily and clumsily built animal, with a blunt muzzle, relatively small, thick ears which scarcely reach the eyes when pressed forwards. The tail is short and stout and is never as long as the combined length of the head and body. The fur is softer than in *R. rattus* the intermixed bristles being fewer and finer than in that species. Adults normally weigh from 14—17 ozs. but specimens weighing between 20 and 30 ozs. have been frequently recorded. Measurements of two adults:

Head and Body.		Tail.		Hindfoot.		Ear.
254	..	222	..	43	..	20
267	..	229	..	45	..	20

Although much is said in popular works on natural history about the colour differences of rats, no reliance can be placed upon colour in distinguishing these two species from each other. "Black Rats" are very often brown or grey; "Brown Rats" are quite frequently black. In their primitive wild races *R. rattus* and *R. norvegicus* have brown or grey backs and whitish or at least light-coloured bellies. In association with man, probably as the result of close inbreeding in human buildings or on ships, the coloration has been disturbed and a complete series of forms showing every gradation from the primitive wild colour to black on the one hand and to white on the other can be demonstrated. Domestication, coupled possibly with change of food and climate, has thus disturbed the colour of rats as it has done the colours of cats, dogs, horses, and cattle.

The high fecundity of rats and mice is notorious. The natural rate of breeding is very rapid, 3 weeks to a month's gestation (according to whether the female is nursing or not) and 8 young usually in a litter. Sometimes the litters are much larger, anything up to 20. Abundance of food, warm shelter and exposure to sunlight all favour multiplication.

The staple food of all rats is grain either in the natural state or as manufactured products. But almost all edible stuffs will do; and large quantities of fish, flesh, offal, and filth of all descriptions are readily eaten. It is not necessary to go into details of destructiveness or to hazard a guess at the annual cost of maintaining a large population of rats in a country like Britain.

Rattus rattus is a native of the hot eastern countries, the forests of India and Malay being apparently the true home of the species. It was first introduced into Britain, so far as our knowledge goes, about the time of the Crusades.

Rattus norvegicus is a native of Central Asia—the belt of country from the shores of Lake Baikal to the Caspian Sea being apparently its original home. It first came into Western Europe about the beginning of the XVIIIth century and in the early years of that century arrived in Britain.

R. rattus is a comparatively delicate species which in cold and temperate countries is entirely dependent upon the shelter given it by man during the winter months. It is primitively an arboreal species and its great gymnastic powers have enabled it to become the common rat on ships.

R. norvegicus is a hardy form which spends much time in the water and in digging and burrowing. It is not at all dependent upon human shelter in cold temperate countries like Britain, but can live out of doors all the year round. Naturally it seeks the cosiest quarters that can be found.

Through the middle ages down to the beginning of the XVIIIth century *R. rattus* was the common rat in Britain. It was the species responsible for the great outbreaks of plague which ravaged Britain and Europe at frequent intervals, and it is still the chief species responsible for plague in the warmer countries of the East and other parts of the world. Its danger in this connexion arises from the very close association it is apt to form with man.

The arrival of the Brown or Common Rat (*R. norvegicus*) in the early part of the XVIIIth century was a very important event. Being much more vigorous and hardy than the Black Rat, it was not at all dependent upon human shelter; whereas *R. rattus* could not get through a single winter without our houses and other buildings. Once the Brown Rat obtained a footing in this country no means of ejecting it could be devised. In a few years it spread all over the country using the rivers, canals, and ditches, as its chief highways. From the stream side it entered the drains, and from the drains it entered the basements of the houses. Passing upwards from the basements, it went, floor by floor, up to the garrets. This triumphal progress occupied about a century; it resulted in the practical extinction of the relatively weak and delicate *R. rattus*. By the close of the XIXth century the latter, so far as Britain is concerned, could be found only on our ships, where its gymnastic accomplishments gave it an advantage, and on the top floors of certain solidly built granaries and breweries in some of our large ports. In such places small and temporary colonies were formed from time to time, the Black Rats being introduced with the cargoes from grain ships.

In the present century we began to re-build central London. A great effort was made to make the basements and ground floors rat-proof; and we succeeded in shutting out the Brown Rat. Thus in one prominent street in the City the new buildings after 10 or 20 years still remain almost free from the pest; whereas in an adjoining older building as many as 5,000 *R. norvegicus* were taken recently in the course of 6 months. Similar changes have taken place in many other British cities with precisely similar results.

In denying the Brown Rat access to our new palaces we failed to remember the Black Rat. It had been virtually extinct in our towns for so long that no one thought of the possibility that in certain circumstances it might recover its lost territory. In reality *R. rattus* has been coming to our ports in every ship, clamouring to deaf ears for re-admittance to our land for more than a century, but in the face of its rival, the Brown Rat, it could do nothing without our assistance. But we have now shut the rival out, established our kitchens on the top floors, lit with nice open sky lights, linked up roofs, and bridged the streets with telephone wires and cables. No primitive arboreal species could desire better arrangements. Every night there is a procession along the cables and over the roofs; new colonies of *R. rattus* are established in every possible place. A new building may acquire a heavy infestation within a fortnight of occupation. Nine tenths of the rats now caught in buildings in Central London are *R. rattus*—this in a place where 30 years ago not one *R. rattus* could be found. We are thus fast getting back to the state of affairs which existed in the XVIIth century not only in London, but in many other of the larger ports. If this goes on we shall certainly be once more in peril of plague. Improved sanitation has little or nothing to do with it. The one great obstacle in the way of a recrudescence of plague in London is that so few people now sleep in the city; that nightly exodus means safety. But what would happen if the Black Rat were to get a footing in the crowded dock-side slums of our great ports I tremble to think. We are rebuilding slums; but if we rebuild with only an eye to *R. norvegicus*, i.e., if we make

only the basements rat proof and do not devise means of rat-proofing the roofs, our condition after rebuilding the slums will be, as regards the peril of plague, far worse than it is at present. Especial means of isolating the roofs is now the chief desideratum.

A few words must be said about Rat control over the country at large. It is an utter mistake to suppose that any permanent relief can be obtained by simple methods of destruction. Rat weeks bring a little temporary relief and that is all. If you could succeed in bringing the entire rat population down to the verge of extinction and did nothing more than that you would have the whole trouble re-developed and on the same scale within a dozen years. It is not rat destruction we want so much as rat prevention; we must extend the experiments tried in our newly built cities and adapt them to the needs of suburban and rural surroundings. You cannot rat-proof the open country and it might not be to your advantage if you could. But you can rat-proof dwellings, outhouses, farms, farm-buildings, stacks, and the pens and places in which you keep your domestic animals. You can keep your sewers reasonably free from rats. The cost of such preventive measures is unquestionably high, but every farthing spent is productive of permanent relief; and when one considers the enormous annual toll levied on this country directly and indirectly by rats the cost of prevention becomes relatively insignificant. If we were to spend £10,000,000 forthwith in rat-proofing it would pay us handsomely.

Now this work if it were undertaken should not be done blindly or haphazardly by Local Authorities, with or without State support; it should be done in accordance with a definite well-thought out and thoroughly scientific plan. Its progress and effects should be watched by a skilled biologist working with adequate assistance. As taught by our recent experience with the two kinds of rats in London and elsewhere, we see that competition for the right to live and breed, the struggle for existence, is a very real thing. Shut the door to one species and you open it to another; eliminate one group of organisms and there are many others to seize upon its place. That is what I meant a moment ago when I said that rat-proofing the open country might not be to your advantage even if it were possible. No man can say what would take the place of the rats and what the effect of such an exchange would be. In dealing with Nature you must never forget that if you create a vacancy it is your own very difficult business to keep it vacant. There is no harder task than that in the world; and prevention or elimination should never be attempted without complete scientific control.

THE MUSK RAT (*Ondatra zibethica*) is a large North American Rodent. It is closely related to our common British Water Vole and is indeed the largest known Vole; weight up to 4½ lbs. During the last few years, i.e., between 1927 and 1932, many hundreds, perhaps thousands, of Musk Rats were imported into Britain and these were distributed to at least two hundred centres dotted about Great Britain from the far North of Scotland to the South Coast; from North Wales and the west coast of Cornwall to the east coast in Yorkshire, Suffolk, and Kent. In most establishments the rats were kept in pens of varying degrees of security, ranging



from wooden rabbit hutches to elaborate structures of galvanized iron, brick and concrete; but escapes took place even from the strongest establishments and as in the Farnham district gave rise to infestation. At at least four places in Scotland, namely in the Black Isle; in Kincardineshire, in the valley of the Bervie; in Perthshire, round about Auchterarder; and in Dumfries, near Thornhill, Musk Rats were either set at or are known to have gained their liberty. Usually, as at White Moss Loch in Perthshire, the rats were liberated in an enclosure; but the fencing of such enclosures, fondly imagined to be secure by the Musk Rat farmers, was ludicrously inadequate for such an active and powerful creature as the Musk Rat. In England a few were liberated in Yorkshire, on the coast at Redcar in or before 1927; in Suffolk a few were turned down in an inadequately fenced pond near Beccles; in Bucks. a large number, nearly 200, were set free in 1928 in an enclosure on top of a bare chalk hill near Great Missenden—a most unsuitable site from which there is reason to think that many escapes into the more attractive surrounding country took place. It is impossible to give a full account of all the liberations and escapes which have taken place in England; the map (p. 5) shows the localities in which serious infestation is known to occur (Shropshire and surrounding countries; Sussex and Surrey) and those in which one or more Musk Rats at large have been killed. But a very important introduction must be mentioned, namely that which took place in October, 1929 at Shrawardine, Shropshire. This was a well thought out experiment; the owner of the farm, Mr. Charnock Wilson, spent some 12 or 18 months in preparing the 65 acre artificial lake at Shrawardine for the reception of his Musk Rats, and he consulted the Ministry of Agriculture before making the introduction. These rats came from Ontario. A large number died on the voyage, but 60 pairs survived and were turned out on the shores of the lake. The enclosing fence was considerably higher and it was carried down into the earth to a greater depth than the one at White Moss Loch; but it was no more effective in preventing escapes. Musk Rats were probably escaping from Shrawardine before the end of 1930, and by May 1931, they were being killed in the Severn. Up and down that river and its tributaries the Musk Rats made their way with great speed. The country between Shrewsbury and Welshpool is extraordinarily rich in pools, swamps and ditches; and in these days of agricultural depression and neglect it is as waterlogged a tract as you can find anywhere in Britain. Food for Musk Rats abounds at all seasons. For them the Upper Severn Basin is a near approach to Paradise; by the Spring of 1933 the official trappers in Shropshire were operating over an area of more than 700 square miles.

Perthshire (with part of Stirlingshire), the Severn Basin, and the valleys of the Arun and Adur in Sussex, with a north-western extension to the Wey between Farnham and Guildford, are the scenes of the most serious infestations in this island of which we possess definite information. But there are grave reasons for suspecting infestation in many other parts of this country; the postponement of adequate enquiries, pending the receipt of reports from a none too observant general public, is likely to prove fatal to whatever small chance we still possess of eradicating this pest.

Musk Rats have also been introduced into Ireland. I am told that thousands of them are now to be found between Tipperary and the Shannon and that their presence in this area constitutes a direct threat to the Shannon dam. The danger, of course, to all such works does not lie in the possibility of a direct frontal attack upon the dam, but in the chance of the dam being outflanked by Musk Rat drilling.

The rapid rise in numbers, from an original 5 to 100,000,000 in 21 years in spite of unrelenting persecution, in Central Europe and the amazing speed with which the animal has spread through that region is evidence of the great fecundity of the Musk Rat. Three litters of from 5 to 8 or more at a birth in a year is quite the normal rate of increase. But conditions in Great Britain are more favourable in average years to the Musk Rat than in any other country (with the possible exception of Ireland) in which it has made its appearance. Climatic extremes are almost unknown here and food, quite apart from the winter stores, is abundant all through the year. We had evidence in Shropshire last winter that young were being born as late as November or even December, and breeding commenced again in February. So the breeding season looks like being prolonged in this country, and five or six litters in a season are quite possible with gestation lasting only a month. High fecundity is the great motive force of this species as of most other murines.

The presence of large colonies entails grave risks in a country like Britain. Burrowing is for this animal a never-ending activity, and it may cause enormous damage to the banks of streams, canals, and reservoirs, to railway embankments, to roads and bridges. Disastrous collapses, floods, and the conversion of much valuable land into quagmire must be the inevitable consequences of allowing the Musk Rat population to rip. In America where the Musk Rat is surrounded by all sorts of natural checks it can only be tolerated in large numbers in those vast marshy districts which have been rendered unfit for anything better by the Musk Rat action of thousands of years. Thus in California last year they had to launch a Musk Rat campaign to deal with invaders from the Colorado River which were taking advantage of the new Californian irrigation works. Musk Rats first crossed the German frontier in 1915 from Czecho-Slovakia, and in the following two years they did so much damage that the newspapers came out with jocular headlines announcing that the Musk Rat had declared war on Germany too. So serious was the threat to German communications that the authorities had to deflect men from military duty to deal with it. On several occasions during the past sixteen years one or other of the hard-pressed German State Governments has sought economy by reducing or abolishing its expenditure upon Musk Rat control. In each case the Government has repented the economy; for after the elapse of two or three years it has been forced by the damage done to take up the work again only to find that neglect had greatly increased the total necessary expense.

To cope with this new pest we need the services of a considerable number of men, highly trained in the art of detecting the presence of this elusive creature. These men should work under skilled biological control. Canadian methods of capture are not sufficient for the purpose of eradicating the pest; they have been developed

for the purpose of obtaining good yields of pelts in the winter season from a dense Musk Rat population and not for detecting and eliminating a scattered population. German methods are better, but owing to the nature of this country are not altogether sufficient. We have to evolve our own technique.

Preventive work here is of the utmost importance. As regards the Musk Rat, drainage is the all important preventive measure; for in draining the land you diminish the Musk Rat capacity of the country.

DISCUSSION.

MR. MARTIN A. C. HINTON, whose remarks were illustrated by lantern slides, said: In the first part of my Paper I have set out those essential facts which should be familiar to everybody concerning the two species of rat now infesting this country. I have described their zoological characters, high fecundity, habits and histories, and their relations to each other, to the climate of this country and to man. Those who require further information on these matters will find it in the Economic Guide to Rats and Mice published by the Natural History Branch of the British Museum. It will be useful to say a little more about infestation and control than appears in the Paper.

We must realise and must never forget that the size, distribution and local density of the population formed by any particular species of rat depend mainly upon such things as space, food, shelter, the constitution and habits of the species, weather conditions, the presence and absence or relative abundance of competing species, and upon the attitude of man towards the species. Of these things, only two, namely, the constitution and habits of the particular species and the weather, are entirely independent of human control. On the other hand, the amount of space, food and shelter available for a particular species and the amount and kind of competition it must face depend very largely upon our own actions or lack of action.

Of our two species of rat, one, the robust, hardy and ferocious Common Rat, *Rattus norvegicus*, has practically the whole country open to it in all seasons. All it requires is sufficient food and water, with, in the absence of man-made shelter, soil into which it can burrow and establish snug quarters against the coming of winter and rough weather. There is hardly an acre of

land in this country totally unsuitable for the existence of this species, and there is hardly a mine, tunnel or sewer in which, given access to food of some sort, it cannot thrive. Naturally its abundance varies with the character of the locality and with the seasons, and when life becomes too hard in the open country this animal quickly seeks better conditions. Thus in the autumn the villages and towns receive huge reinforcements of their rat population from the surrounding country. This is not solely due to the worsening of the weather and growing scarcity of food. Breeding between the early spring and the late autumn carries the rat population in November up to a peak in which there is a vast preponderance of immature and adolescent individuals. It is at this season of the year that you may count upon getting a rat as a guest if you deserve one, for weather, food, shelter and increased numbers acting together drive the species into every accessible place capable of accommodating one more rat.

We have heard this morning about the desirability of increasing the number of allotments and small holdings, and we are assured that such a scheme is going to save the morale of our unemployed and produce great economic benefits. In giving effect to such a scheme, however, we should not lose sight of the fact that every new allotment and small holding, every extension of the cultivated area, every increase of yield and every new poultry pen or pigsty means a corresponding increase in the rat capacity of the country, a proportionate rise of the rat population and an increase in the direct and indirect cost of maintaining it. We have had previous experience of this during the war. The face of the country is being very rapidly changed. All those improvements and extensions which are taking place round

so many towns and along the new roads are benefiting the Common Rat no less than the Common Man. The position which is developing demands, I think, not only the utmost vigilance of the authorities but the best scientific skill available. I have not time now to deal with methods, but one short sentence may be useful: Prevention is better than Squill.

We now come to the second species, the Black Rat, *Rattus rattus*. This animal fortunately, by reason of its delicate constitution, is wholly at our mercy in this country. Here it is utterly dependent upon human shelter, without which it could not survive an average English winter. We have nothing to fear from it in the open country at this moment, for, as the events of the eighteenth and nineteenth centuries show this species cannot succeed against the much harder Common Rat in an open and fair competition for this land. After virtual extinction in Britain, the Black Rat has succeeded in re-establishing itself in our great ports, solely because we have unintentionally turned the balance in its favour. In rebuilding our cities we have shut out the Common Rat, but, forgetting its existence, we have left the door or rather the skylight open for the Black Rat. The swift progress made by this species in colonising the new London during the last thirty years is described in the paper. The risk of a recrudescence of plague, which the return of this species to London and other cities entails, is a very real one. It is urgently necessary that attention should be given to the prevention of the further spread of this species. For example, to rebuild the slums for the accommodation of a dense population along lines which shut out the Common Rat but leave the new buildings exposed to the attack of the Black Rat is to invite disaster. Plague may come by accident at any moment, but, as a recent notorious book shows, it may come by design just before the outbreak of war. It would be quite easy to-day to infect the Black Rat in scores of places in London and other cities, and so let plague loose. That is a possibility which is fully appreciated abroad. But, quite apart from war and its crimes, the risk of accident is grave enough to make this change in the nature of our urban rat population one of the

most urgent matters calling for national attention.

In the second part of my Paper I have described the introduction to and rapid spread through Britain of that formidable North American rodent, the Musk Rat. I have mentioned also its amazing progress in Central Europe, where, from a single introduction of five individuals at a locality in Bohemia, an army of countless millions has arisen since 1905, has overrun country after country, in spite of every effort made to stem its progress and compass its destruction, and has caused the most serious damage to property and to public works. Migrate in the autumn, migrate in the spring, for great distances and at all but incredible speed, burrow and dig wherever possible, and breed by litters in each of five or six months of the year, are the standing orders to this army on the Continent. In Britain the orders are similar, but the conditions as regards waterways, climate and the abundance of food are more favourable. Breeding here will occupy nine or ten months of the year, instead of five or six months. Moreover, in this country we have not started with a few from one centre but with many hundreds, possibly thousands, from a very large number of centres. Every Musk Rat farm that existed in this country was a potential centre. We do not know exactly how many of these farms there were, but there were fully two hundred of them distributed throughout the island. The map in the Paper shows the chief known centres of infestation, those in central and eastern Scotland, in the Shropshire area and in Hants and Sussex. It also shows the many localities in which Musk Rats are known to have been at large.

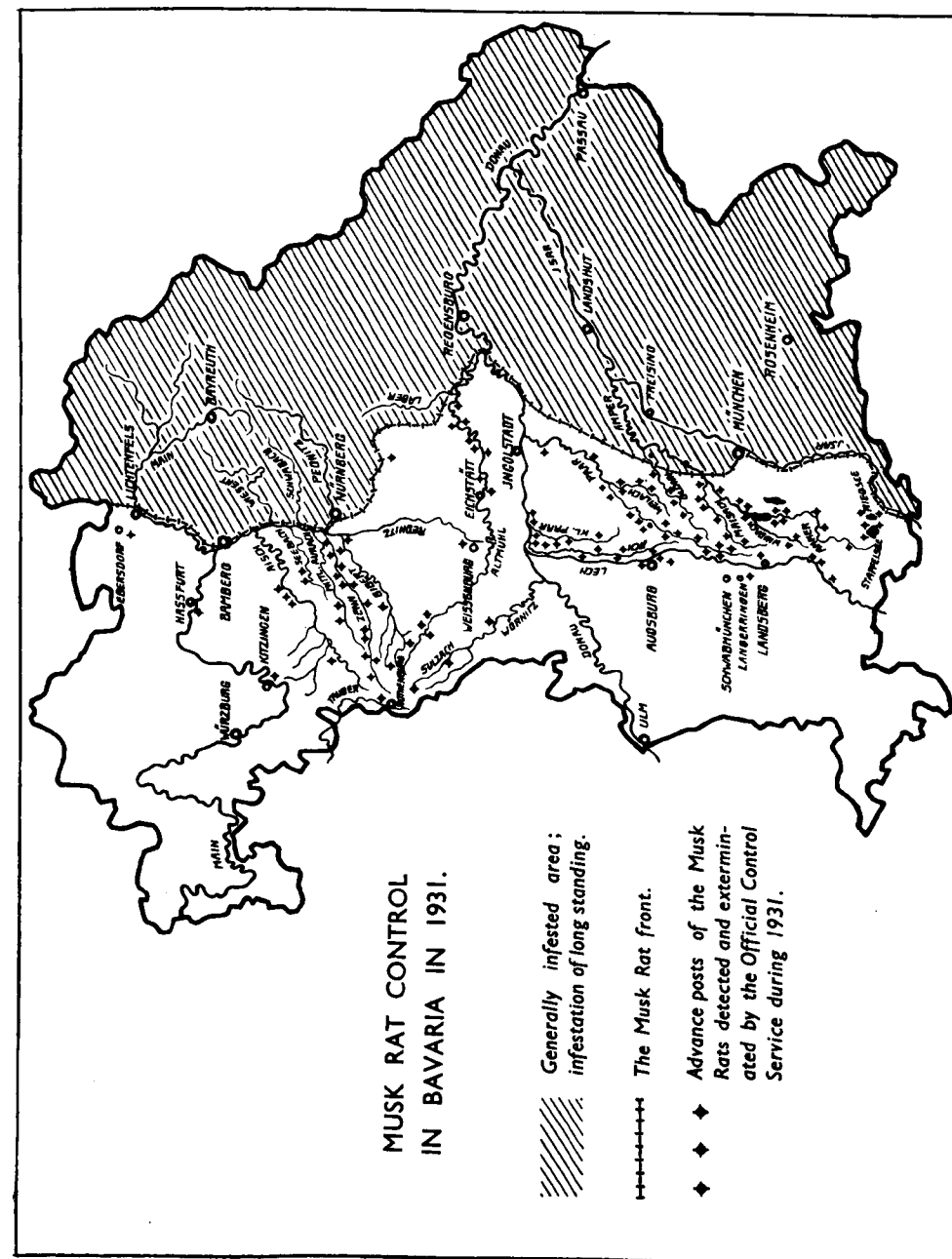
The position now, as I understand it, is a most difficult one. We have had an exceptionally dry year. In one way that, no doubt, has favoured us by slowing down the rate of increase, for in many places the Musk Rats have had to move on in search of new quarters, instead of remaining at home to breed. On the other hand, the drought has probably driven them much further afield than would otherwise have been the case. We have to deal with a widely scattered but in most districts sparse Musk Rat population. It is important that each colony should be found and eliminated, for

each undetected or imperfectly treated colony may form a new centre from which infestation of the surrounding country can swiftly proceed. The detection and elimination of small scattered colonies is a very difficult business, calling for observational powers and a technique far beyond anything possessed by the finest Musk Rat trapper that ever came out of Canada. The Canadian technique has been devised simply for the purpose of getting a good harvest of winter skins from a dense Musk Rat population. Summer trapping is practically unknown in North America, and no trapper in that continent would dream of trying his skill in any place where Musk Rats were not several times more numerous than they are, for example, in any Salopian locality. But elimination depends upon the detection of the presence of even a single Musk Rat and on the ability to catch it when detected. For perfect skill of that kind we have to go to Bavaria and not to Canada.

Let us look at what the Musk Rat does in Bavaria. The shaded portion of the map (shown on the screen) represents the generally infested area of Bavaria, in a hopeless state now for lack of money and for lack of experience in earlier years. Every autumn and every spring large numbers of Musk Rats leave the shaded area and pass by way of the streams right across the clear country to the west, establishing colonies in all suitable places as they go. If these colonies were not detected and eliminated, Western Bavaria would speedily become as heavily infested as the eastern portion. The official staff, under Dr. Pustet and Herr Roith, watch the migrations. The settling places of the rats are carefully noted. They are often the same in successive years, which makes the task easier. During the summer a careful survey of each colony is made, and an attack is carefully planned and delivered usually with complete success. Practically all the rats are taken alive, and there are no escapes to other districts. At the end of the summer the position is substantially what it was twelve months before. This map shows the operations which were carried out in Bavaria in one year. The crosses represent the number of colonies actually found by Herr Roith and his assistants and cleaned out during that year. They traced them in the autumn and in the spring, and during the

summer they worked at each of these places and cleared the rats out, so that at the end of the year the position was the same as it was at the beginning.

There is a little pond in Shropshire which I examined at the beginning of last February with Herr Roith, the Bavarian trapper, and our chief and most expert Canadian trapper. In the centre of the pond there was a little island, chiefly composed of floating vegetation. On the side of it there were two or three small Musk Rat houses and a series of burrows radiated for long distances into the banks all round the pond. Several rats have been caught here, and the colony was said to have been completely wiped out. Roith made a quick survey and said there was still a rat there. That being disputed, Roith went further. He said: "It is a half-grown male and I will catch it." Stopping up all the burrows but two and putting a spring trap into a drain-pipe that could not be stopped, Roith went on to the island, destroyed the houses and made a most violent commotion lasting for about twenty minutes. He then came ashore, fitted his cage into the most likely of the two burrows he had left open, and probed that burrow systematically, and in two or three minutes he produced the half-grown male alive, as promised. Having performed a few tricks with it, he put it back into the pond and let it go, and then he repeated his performance and caught it again, just to show us that he was completely master of the situation. Later in the day we went to a much more complicated place, a 16-acre pool and marsh with large islands and a dense thicket on one shore. This had been comparatively heavily infested, but it was claimed as quite cleaned up. Roith went round that great pool, keeping us shivering in the cold while he did so. He spent about twenty minutes in going right round it, and on the way he found a large sub-aqueous burrow which no one else in the party could possibly have detected. It ran from under the water straight into the bank, which was covered by the dense thicket. Roith examined it and said there were two adult rats in it. He set to work in the thicket, with the Canadian to help him, and in the course of half an hour he brought out the two adult rats alive.



No doubt Roith possesses exceptional skill, but it is not an unattainable excellence. There are many men working on the German staffs with Roith's methods who are, for most practical purposes, just as efficient as Roith himself. Roith's methods are the best so far devised. They are not wholly sufficient to cope with the conditions peculiar to Britain, but they form undoubtedly the best foundation for our future operations, and it is to be hoped that every effort will be made to train men in their use.

Sooner or later we shall be forced, I think, to undertake a systematic survey of all the inland waters of this island from the point of view of Musk Rat control. That is a matter which should be borne in mind when considering the Inland Water Survey discussed in the current number of "Nature." The Musk Rat is a very elusive animal. If our trappers are unable to detect its presence in all conditions with certainty, how much less can we depend upon the chance of being supplied with early information concerning new colonies by the general public? In Germany, in districts which have been subject to invasion by this species twice a year for ten years or more, the farmers, gamekeepers and other rural folk, although no whit less intelligent or observant than the corresponding people here, still do not know the animal and cannot detect its arrival.

There is, I am afraid, no short cut to Musk Rat control left in this country. Some have thought it possible that biology would be able to provide a special disease for the newcomer. It is a fond hope. Even if such a thing were discovered, it would hardly be effective unless we possessed a very dense Musk Rat population, and even then it could not be trusted to work the miracle of complete elimination. The one thing that can shorten the road for us, pending the development of a really satisfactory technique, is to press on with the great work of draining the land. That will assuredly diminish the Musk Rat capacity of the country.

In conclusion, I would say that the problems connected with animal and insect pests are all very closely related. They have arisen because of breaches of one set of principles and they have got to be solved

by observing and appealing to exactly the same set of principles. It therefore seems to me that the scientific man can greatly shorten the way for the practical man, and no attempt at controlling these things should be made without adequate scientific assistance.

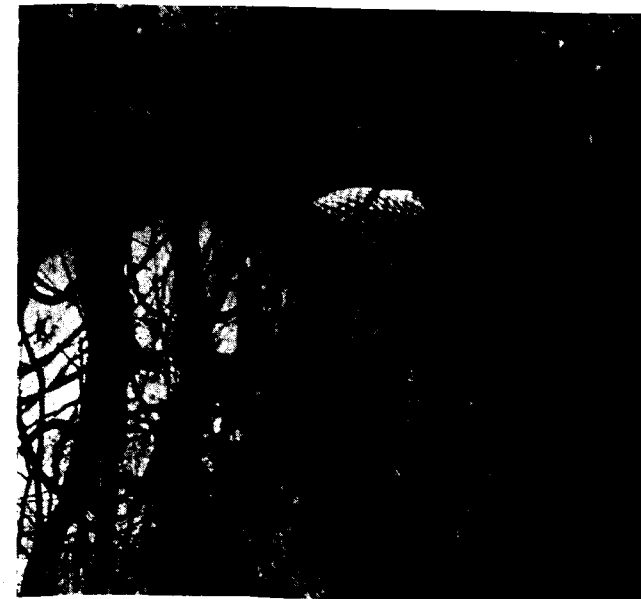
DR. W. T. CALMAN, F.R.S. (*Keeper of Zoology, British Museum*): There are two points which I should like to put before the meeting. In the first place, biology is not an exact science. It is rarely possible to predict biological results, even when we know all the conditions, and of all the departments of biology that which is known as animal oecology is perhaps one of the least exact, because we can rarely be sure that we know all the conditions. I should therefore hesitate to assert that we can predict with astronomical exactitude what will happen to the musk rat population in this country. It is even within the bounds of possibility that the musk rats may fail to establish themselves and that the population may die out, but I wish to emphasise that what is conceivable or possible may be wildly improbable. As Mr. Hinton, I hope, has convinced you, the history of the musk rat invasion of Central Europe justifies us in anticipating the gravest possible results if musk rats are allowed to maintain a footing in this country. While it might be desirable, if this were purely an academic question, to ask for some further evidence or to wait a little longer to see what was going to happen, I think Mr. Hinton must have convinced you that in this matter the stakes are far too heavy for us to contemplate a moment's unnecessary delay.

In the second place, we at the Natural History Museum can claim to have been the first to direct public attention in this country to the menace of the musk rat. We are glad that it is now being seriously tackled by the Ministry of Agriculture. I think the Chairman will agree with me that the Ministry is naturally and quite properly unwilling to go too far ahead of public opinion in such a matter as this, and your Association can render a service to the country by spreading as widely as possible a knowledge of the dangers ahead and of the steps that are being taken to meet them. You will thus help to develop that public opinion which will justify the Ministry in extending its efforts

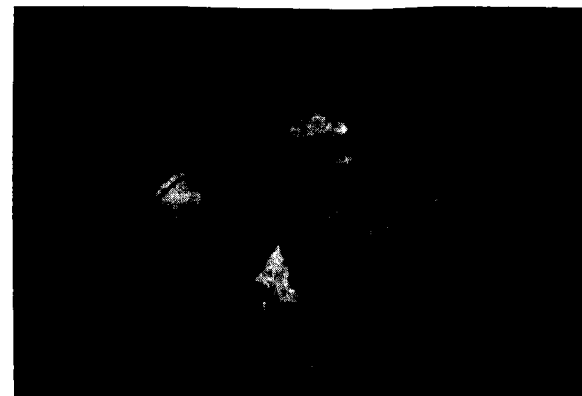


BURROWS OF MUSK RAT in bank of Severn, Shropshire, exposed by the collapse of the bank; December, 1932.

ROITH AT WORK on Sascott Pool, just lifting cage containing one of the Musk Rats. February, 1933.



SASCOTT POOL; the two Musk Rats duly extracted.



even more widely and intensively than it has done up to the present.

MR. S. H. COLLINS (*County Land Agent, Berkshire*): Sir Thomas Horder, President of the Federation of Medical and Allied Services, says that the cost to this country of the food eaten and destroyed by rats and mice and the damage done by them is something in the region of £99,000,000 per annum. In the light of the figures in the Budget of 1932/33 for the Army and the Navy and the Air Force, which amounted to £109,000,000, this figure is, to say the least, extraordinary and most alarming. The cost is enormous and the menace to public health a real danger.

If I were capable of putting forward a scheme for the prosecution of a national campaign for the control or destruction of rats in the whole of this country, then I ought not to be here; the Government ought to be making use of my services, instead of allowing me to spend my time elsewhere. But the Rats and Mice Destruction Act of 1919 has now been in operation for some fourteen years. It would perhaps be unfair to say in every case that it has failed, but there is a very great difficulty in getting an Act of this kind administered properly in counties by authorities such as the County Councils. County Councils, as you know, are composed of many kinds of members, farmers and others, and it is exceedingly difficult to administer an Act of this kind and to get one set of farmers to serve a notice upon a man who may be their neighbour.

I suppose it is true to say that the bad prices of agricultural produce within the last few years have resulted in a certain amount of carelessness on the part of farmers in not properly wiring their ricks at the time of thatching, and many rats which would otherwise have been killed have been allowed to escape. Bearing in mind that one pair of rats may be responsible for the production of 800 in the course of a year, I leave you to imagine what may be the result of a few rats getting away from a few ricks on only one farm. Again, farmers and others, choked with the word "economy," have considered it a waste of a cartridge to shoot the rats.

I hope that the Government, guided by the wisdom of the appropriate Department, will try again and bring in a measure which

will be really helpful and which can be administered as a national scheme. I know that we have had Rat Weeks, but I venture to suggest that whatever work has been done has not even touched the fringe of the rat destruction which is so necessary in this country.

In Berkshire, the Council have seen fit to try the experiment of having an official rat catcher, provided with transport, gas and poisons, not in order to take upon themselves the responsibility of killing other people's rats, for that is the duty of those people as occupiers, but to show them and demonstrate to them that, by the consistent and proper use of gas and suitable poisons, it is possible to keep down the number of rats on any particular premises. During Rat Week an article on the subject appeared in seven different county papers, 1,354 circulars were sent out to farmers, corn merchants, and others in the county, and 175 specially prepared posters were put up all over the county. The result was a request for further information from three ordinary householders!

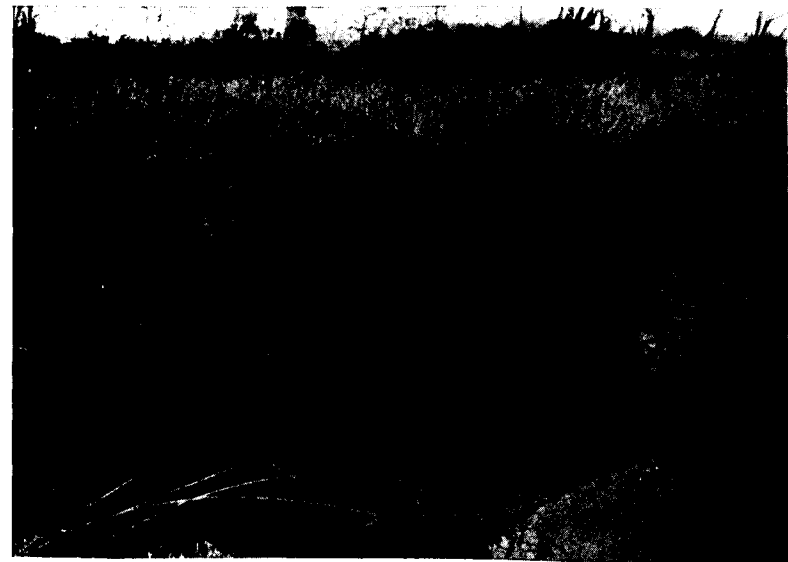
Mr. Hinton says in his Paper that £10,000,000 could be well spent on this matter. In these days of Disarmament Conferences perhaps it would be possible to postpone the building of one battleship for a year in order to organise a land force so that we might at any rate save a certain proportion of the total cost of rats and mice in this country at the present time.

With regard to musk rats, I cannot speak with a great deal of personal practical experience in this respect, but I am glad that restrictions have been placed by the Minister on the importation and breeding of this pest and I hope that those restrictions will be most rigidly maintained. The musk rat can be and will be, if it is not watched carefully, a very great menace all over the country. Within our county borough there were killed not so long ago two excellent specimens of the musk rat. I found that a pair had been kept in a back garden, wired in by wire of one inch mesh in a very unsatisfactory manner, with an ordinary enamelled bowl as their swimming bath. The keeping of such animals in that way is, as you will realise, a very very serious matter. Others have been kept in converted green-houses, and in that case again it is possible



MUSK RAT 'HOUSE' in open pond, Shropshire; height about 5ft. 6in. above the water level.

December, 1932.



MUSK RAT 'HOUSE' concealed in a marsh in Shropshire, December, 1932.

for them to escape far more easily than is generally imagined.

The matter of extermination is extraordinarily costly, but, both in the case of rats and in the case of musk rats, I cannot help thinking that the time has arrived when it has become a national and not a local authorities' problem. The local authorities should exercise all the powers that they possibly can, but I think the time is certainly ripe now for national action. It is difficult to emphasise the importance of the loss caused by rats and mice, but I think others are in a better position than I am to speak of the real danger to public health. I do hope it will not be very long before the Government bring in another measure which they will see is properly and rigidly enforced in every part of the country.

MR. E. R. PULESTON JONES (*County Land Agent, Montgomery*): Mr. Hinton probably knows more than any other man about rats. I am really alarmed at what will be the ultimate consequences of this foreign invasion. I come from the borders of the area that was heavily infested in Shropshire, and my first surprise came when about twenty musk rats were trapped in a pool adjoining the main road, less than half a mile from the town. I had passed the spot three or four times a week, but I had never suspected musk rats, nor were there any easily recognisable indications of their presence. In my county there are surely thousands of similar backwaters, many of them not seen by a dozen people in the year. There are also many thousands of miles of ditches and water-

courses in the county, in any yard of which a pair of musk rats could take up their abode and multiply rapidly. Some of our lands adjoining the Severn are well below flood water level and they are protected by large earth embankments, a portion of the small holdings estate being within one of these areas. Four years ago we had a breach in the embankment—it is not known whether it was caused by musk rats—and the total expenditure of money directly attributable to this breach was practically £17,000, there being many other losses as well. I have been told that the catching of musk rats is a very expensive business. The figure of £10 a rat has been suggested, but, if there is one pair of musk rats, it is surely worth a great deal more than £20 to get rid of them.

The presence of musk rats in such a district as I have described is a very serious matter. It does not take a great deal to weaken the embankments, and, unless immediate precautions are taken, I can foresee continual damage with continual floods in these low-lying areas.

I do not know what are the real hopes of the Ministry in the matter of eradicating this pest completely, but with so many breeding places beyond the ken of man I am afraid it is going to be an impossibility. Our sincere hope is that the Ministry will for the future press its destruction campaign with the same vigour that it has displayed in pressing it during the last year or two. Thus, if the musk rat cannot be completely eradicated, we hope it will be kept within reasonable control.

CONFERENCE

Under the auspices of the Institution of Municipal and County Engineers.

WEDNESDAY, 15th NOVEMBER, at 3.0 p.m.

SIR HENRY P. MAYBURY, G.B.E., K.C.M.G., C.B. (*Chairman of the Congress Organising Committee*), in the Chair.

The two following Papers were taken as read:—

The Development of Road Bridges in Great Britain.

BY

C. H. BRESSEY, C.B., C.B.E., F.S.I.

(*Chief Engineer, Roads Department, Ministry of Transport*).

THE following notes, for which I am largely indebted to other members of the Ministry of Transport staff, are merely intended to serve as a running commentary upon the contents of this book,* and as a general sketch in non-technical language of the progress of bridge building in this country. In selecting particular bridges for mention as exemplifying various types of construction, I have refrained from quoting the names of the responsible architects and engineers, as this information (wherever ascertainable) appears invariably in the detailed account annexed to each bridge illustration in the volume.

Bridges can be divided, broadly speaking, into three classes:

- (1) Beam bridges—i.e., bridges whose main members are subject to bending without direct axial thrust or tension.
- (2) Arch bridges, which are subject to bending in a minor degree, but whose main characteristic is direct thrust.
- (3) Chain or suspension bridges—the reverse of arches—which are subject to direct tension, but which may also have to resist a relatively small amount of bending proportionate to their stiffness.

* "British Bridges," published by the Congress Organising Committee in connection with the Photographic Exhibition of Bridges arranged as part of the present Congress and Exhibition.

The oldest bridges in this country, as in others, were probably of the first type, and generally of timber. No very ancient road bridges built of this material now exist here, but the larger ones may well have been somewhat similar to the modern Wiggshall St. Germans bridge (page 207).* In districts where suitable stone is to be found, lintel bridges such as the Post Bridge, Dartmoor (page 71) still exist.

Timber beam bridges of the open lattice type were fully developed in America, but not to anything like the same extent in this country.

The first wrought-iron girder road bridge had a span of $31\frac{1}{2}$ feet and was built near Glasgow in 1841, but the first large girder bridge of iron in Great Britain was the High Level Bridge, Newcastle-on-Tyne, which was designed by Robert Stephenson and T. E. Harrison and built in 1849. The girders are formed of cast-iron ribs with concealed wrought-iron tension chords—advantage being thus taken of the characteristic qualities of these two materials. The bridge is of two tiers and carries a railway and roadway. It has six 125 feet spans.

Wrought-iron plate girder bridges were constructed during the nineteenth century in large numbers, and nowadays this is the standard type in steel for the smaller spans. Steel, which gradually superseded wrought-iron during the last quarter of the nineteenth century, introduced no new principle of construction, but furnished the bridge engineer with a somewhat stronger and more uniformly reliable material. Allensford Bridge, over the Derwent in Northumberland, which is a three span structure, is a good modern example. Another is the East Linton Bridge in Scotland (Fig. 1), which has three spans and is of the cantilever and suspended span type. With this arrangement, the stresses in the girders are less than if three simple spans of the same lengths had been employed.

One of the latest developments in structural steel work is that of welding the various parts of the bridge or girder together, instead of connecting them by rivets or bolts. The bridge carrying the Northern Approach to the great Tees vertical lift bridge, Middlesbrough, over the L. & N.E.R. (Figs. 2 & 3) is a welded structure. It is a combination of the suspended span and portal frame types.

Plate girder bridges become unsuitable for large spans, owing to their size and unwieldiness, and are replaced by trusses. A typical modern example of a road bridge designed on this principle is the Carlton Bridge, Yorkshire (page 336), which is of the N type with a slightly curved top boom. It has a span of 250 feet and was built in 1927. Another is the Valley Bridge, Scarborough (page 355) with four spans of 150 and 152 ft., a 40 ft. carriageway and 12 ft. footways. It was completed in 1928.

Reinforced concrete has been used of late years in the construction of a large number of bridges of the first two types—beam and arch. It was invented in 1865 by Monier. Its main principle is the reinforcement of those parts of a concrete structure subject to tension by steel bars embedded in the material, since concrete is strong in compression, but relatively weak in tension. The first reinforced concrete



Fig. 1.—East Linton Bridge.

References are to pages of the book, "British Bridges"; see footnote on page 348.

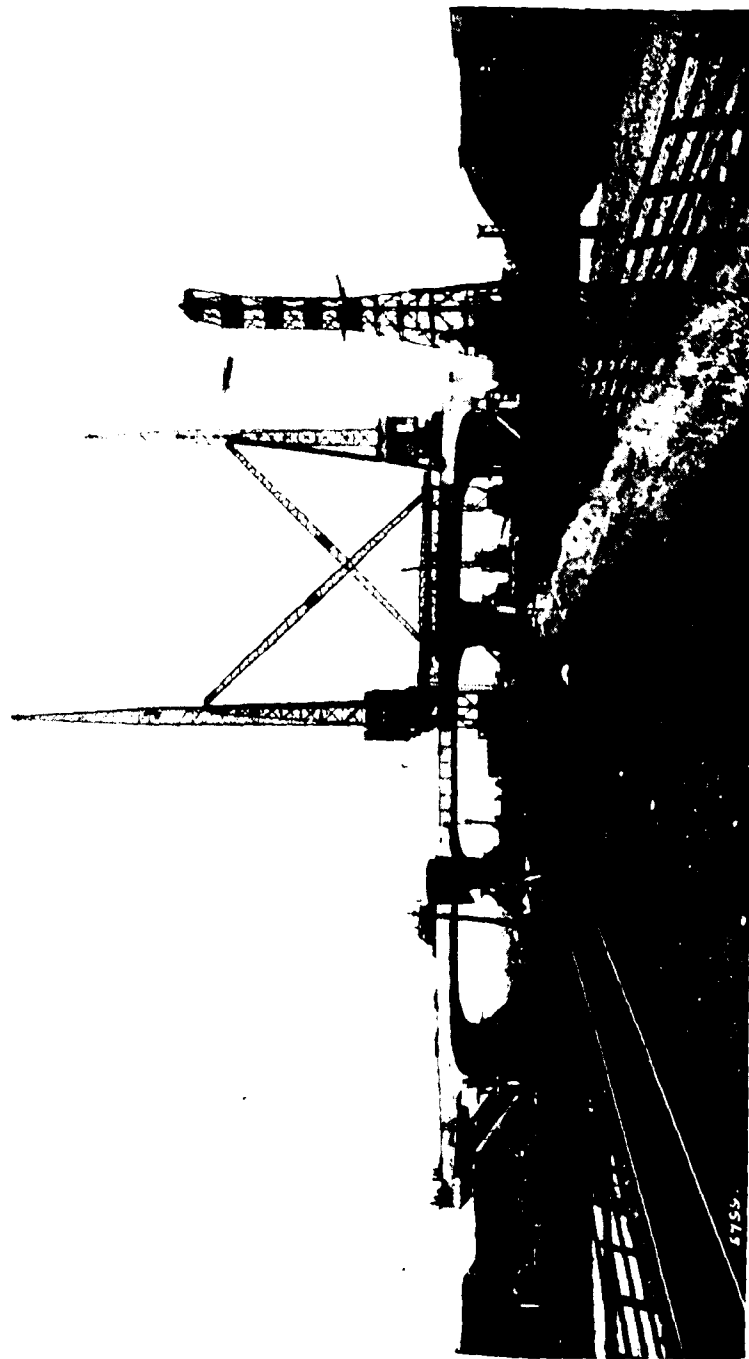


Fig. 2.

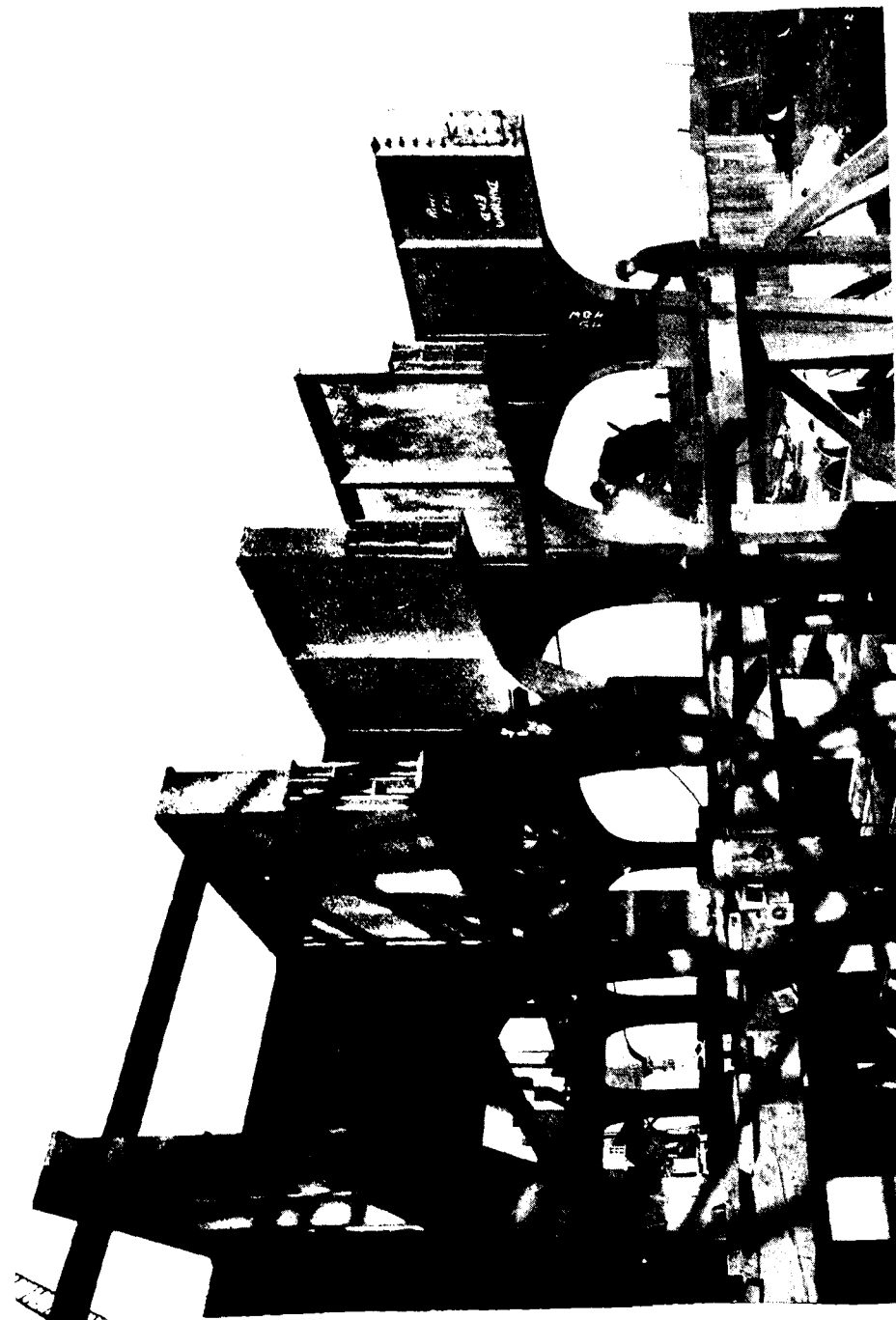


Fig. 3.

bridge in Great Britain was built at Satterthwaite, Lancashire, in 1902. It has a single span of 43 ft. 7 in. Another early reinforced concrete structure is a private bridge near Clitheroe, Lancashire, constructed in 1903. The spans are two in number, each 44 ft. clear.

Reinforced concrete "beam" bridges are now very numerous and are either of the plain slab type for the shortest spans, a combination of beam and slab for moderate spans and occasionally for larger spans of the truss type. Reinforced concrete slab decking is increasingly used for steel bridges.

The viaduct carrying the Chelmsford By-Pass road over the River Chelmer (page 101) is an example of concrete beam and slab construction. It has a length of 1,662 feet and a width of 44 feet, and was completed in 1932.

A cross-section of a reinforced concrete aqueduct, not yet completed, which will carry the Grand Union Canal over the North Circular Road round London, is shown in Fig. 4. It has been constructed in halves and the maintenance of the canal traffic during its erection has, as may be imagined, not been too easy to arrange.

The George V. bridge over the Clyde in Glasgow (page 465), though it appears to be an arch, is actually a continuous beam bridge. The superstructure rests on roller bearings and is independent of the substructure. Considerable difficulties had to be overcome in the design, owing to the limited construction depth available. This bridge was finished in 1928.

If, in multispan bridges, the beams are made continuous over the piers, the bending moments at the centres of the spans are reduced and less material has to be provided at these sections. For single span bridges, a similar result attends the rigid fixing of the deck to the tops of the abutments. In both cases, the foundations must be above suspicion.

The latter type of bridge is known as the portal or rigid frame, and the largest example of the kind in this country is the reinforced concrete Wisbech Bridge in Cambridgeshire (Isle of Ely) (page 25 and Fig. 5). It has a span of 92 ft. 6 ins., and a width of 45 feet. The portal type of construction has also been adapted to steel bridges and a large structure of this kind will carry the Oxford Northern By-Pass road over the Great Western Railway.

The new bridge at Montrose (page 435) is an example of a large reinforced concrete cantilever truss bridge with a short suspended span. It was built on the site of an old suspension bridge, the abutments of which were adapted to form part of the new structure, and was opened in 1930.

There is one other main class of bridge in which the beam principle is adopted. Movable or opening bridges have been used since quite early times, the earliest being usually of the draw or bascule type. A swing bridge was invented by Leonardo da Vinci at the end of the 15th century. Drawbridges were used to a large extent in mediaeval times for purposes of defence, and Old London Bridge had a draw span.

Some of the earliest swing bridges in Great Britain were built in the London Dock area in 1805. A 44 ft. 9 in. span double leaf cast-iron swing bridge was built at St. Katharine's Dock in 1818, and somewhat similar bridges were constructed

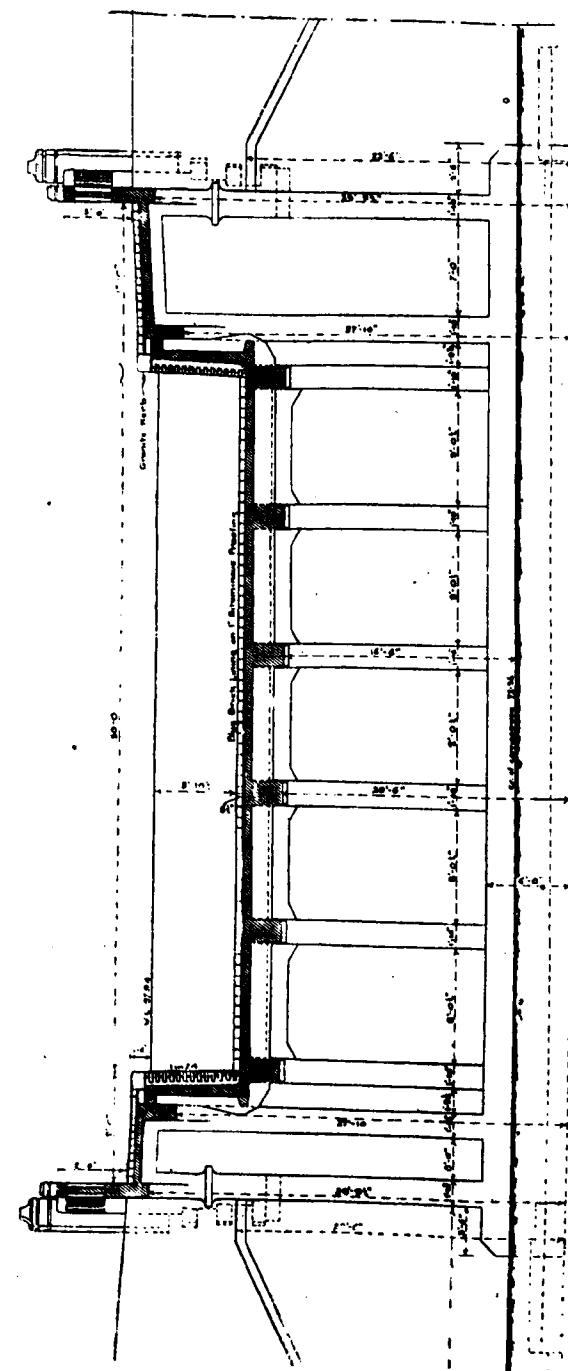


Fig. 4.—Grand Union Canal Bridge, North Circular Road, Middlesex.

over the Caledonian Canal a little later. The demands of road traffic, both in London and in Scotland, have necessitated the supersession of many of these early bridges.

Swing bridges are usually the most convenient type of opening bridge, where the width of the road is not too great compared with that of the waterway. They may have either plate girders or, for the larger spans, trusses. This type of bridge becomes uneconomical where the span is small and road width large, particularly for single spans where the whole bridge has to swing back on to the bank of the waterway. At Fort Augustus is a plate girder single span swing-bridge constructed in 1932 to replace an old cast-iron swing bridge. It carries the Fort William—Inverness road over the Caledonian Canal, and has a clear span of 40 feet and width of 24 feet. Power is provided by a petrol engine. The Boothferry Bridge in Yorkshire (page 333), the lowest point at which the Ouse can be crossed, is an example of a double span truss swing bridge. It was constructed in 1929, and the larger of the two swing spans gives a clear waterway of 125 feet. An interesting variant of this type of bridge is the Acton swing bridge over the Weaver Navigation in Cheshire (page 27). This has two 82 feet spans. It is situated in the brine pumping area near Northwich, and in common with other similar bridges in this area, bears on a pontoon. The method of construction and operation will be evident from Fig. 6. The main weight of the structure rests on the pontoon, and necessary adjustments, due to settlement of the foundations, are easy to make.

Bascule bridges, in which the bridge span and counterweights turn on a horizontal shaft, have been constructed during the last hundred years. The first in England was designed by S. M. Rendell. It was 32 feet long and was built at Kingsbridge, Devon, in 1831.

The Tower Bridge, London (page 181), is a double leaf structure of this type. A recent example is the double leaf Spalding Bridge, Lincolnshire (page 171). It was completed in 1927 and has a double leaf centre span of 49 feet.

The bascule type of bridge has been largely superseded in Great Britain by the Scherzer rolling lift, the first of which in this country was constructed about 1905 to carry road and railway over the Swale in Kent near Sittingbourne. Instead of turning about a shaft, the moving span of a bridge of this kind rolls along a pair of rails, the counterweights being so arranged that the span is balanced in any position. This type of bridge generally requires less power to operate than a bascule bridge. The method of working can be realised from the photograph of the Corporation Road Bridge, Grimsby (Fig. 7), which was completed in 1928 and has a 45 feet lifting span. The largest bridge of this kind in England is that at Keadby, also in Lincolnshire (page 170), which carries road and railway over the Trent. It has a lifting span of 150 feet and the width of the bridge is 55 feet. A slightly different type of rolling lift bridge, with enclosed counterweights, is Haven Bridge, Great Yarmouth (page 201). This bridge is of the double leaf type, with an opening span 90 feet long. It was completed in 1930, and is the fifth bridge on the site. The temporary bridge which was in use during the erection of this bridge was of somewhat unusual type. The balance weights were carried on wheels, which rolled

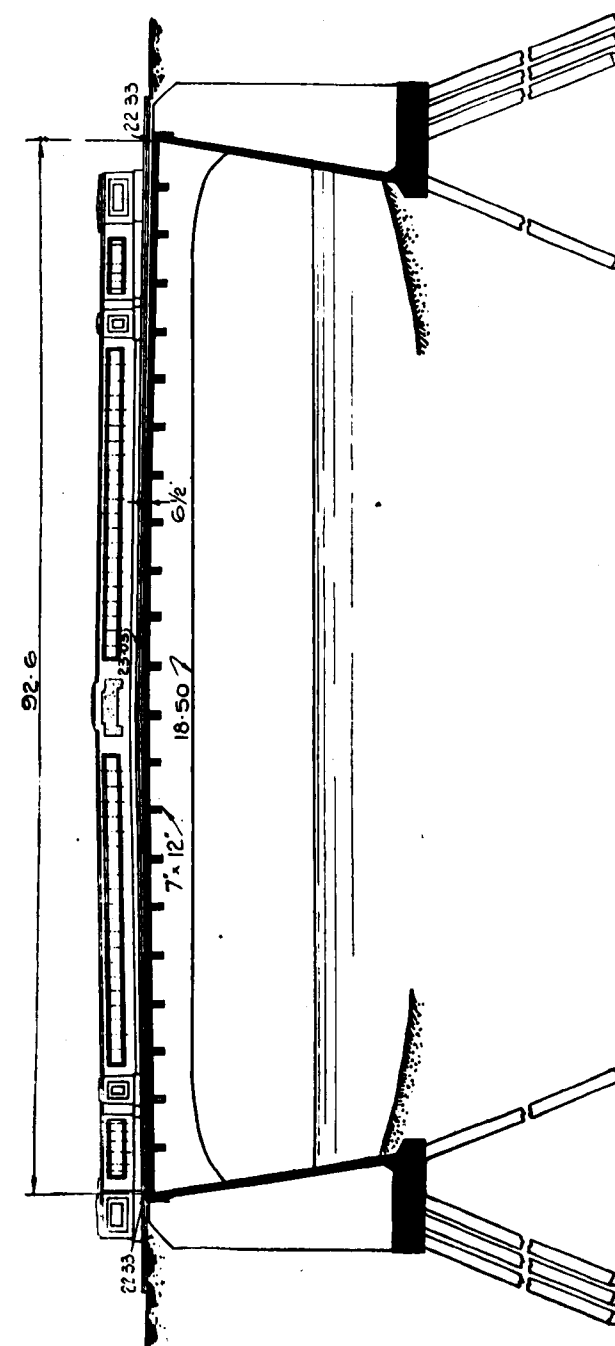


Fig. 5.—Wisbech Bridge.

up and down tracks, the gradient of which at any point was calculated so that the lifting span of the bridge was always exactly balanced.

A particularly useful type of bridge where space is limited is the vertical lift. There are not many examples of this class of structure in England, but a large bridge of this kind is now being erected over the Tees at Middlesbrough. It will have a clear span of 250 feet with a headroom over the river of 120 feet, and the towers will be 170 feet high. The total width of the roadway will be 56 feet and the cost of the whole scheme, including land and approaches, about £500,000. The method of operation will be at once evident from Fig. 8.

The new bridge connecting Canvey Island with the mainland of Essex is an example of an inexpensive type of small opening bridge. Rails are laid on the bed of the waterway, and on these the opening leaves of the bridge run back on to the approach viaducts when a boat has to be let through.

Mention must be made of one other type of moving bridge. Large transporter bridges exist at Widnes (page 155), (which has a span of 1,000 feet, the largest of any bridge in England), Middlesbrough (page 347) and Newport (page 419). In all these the main span, which has the necessary headroom across the river, carries rails on which runs a trolley. A car provided for passengers and vehicles is slung from this trolley, which moves to and fro, as required, across the bridge, carrying the car and passengers with it.

The Middlesbrough transporter bridge across the Tees is of the cantilever type and has a span of 470 feet. It was opened in 1911, and the car, which has accommodation for 600 passengers and 6 vehicles, is operated electrically.

ARCH BRIDGES.—In an arch bridge, the main characteristic is direct thrust with subsidiary bending only. Bridges of this type were used freely by the Romans, but no bridge of Roman date is known to exist in this country. Mediaeval masonry arches are extremely common, some dating back as far as the 12th century, and up to the present day arches of both brick and stone have continued to be built, though in modern times it is more usual for these materials to be employed as facing only.

The most famous mediaeval bridge in England was Old London Bridge (page 173 and frontispiece).

Another notable bridge is the Monnow Bridge at Monmouth, which has a fortified gate tower (page 415).

Many mediaeval bridges were provided with chantry chapels. Only four of these now exist—at St. Ives (page 135), Wakefield (page 359), Rotherham (page 351) and Bradford-on-Avon (page 317). St. Ives Bridge, which replaced a former wooden bridge, was built about 1414. The altar of the chapel, which was dedicated to St. Leger or St. Lawrence, was consecrated in 1426. In 1736 two storeys in white brick were added to the chapel, but were removed in 1930, when the chapel became a museum. The largest span of the bridge is 30 feet, and its width varies from 12 ft. 6 in. to 13 ft. 6 in.

One of the most remarkable of mediaeval bridges is the Trinity Bridge, Crowland, which is formed of three segmental half arches meeting at a central point (page 165).

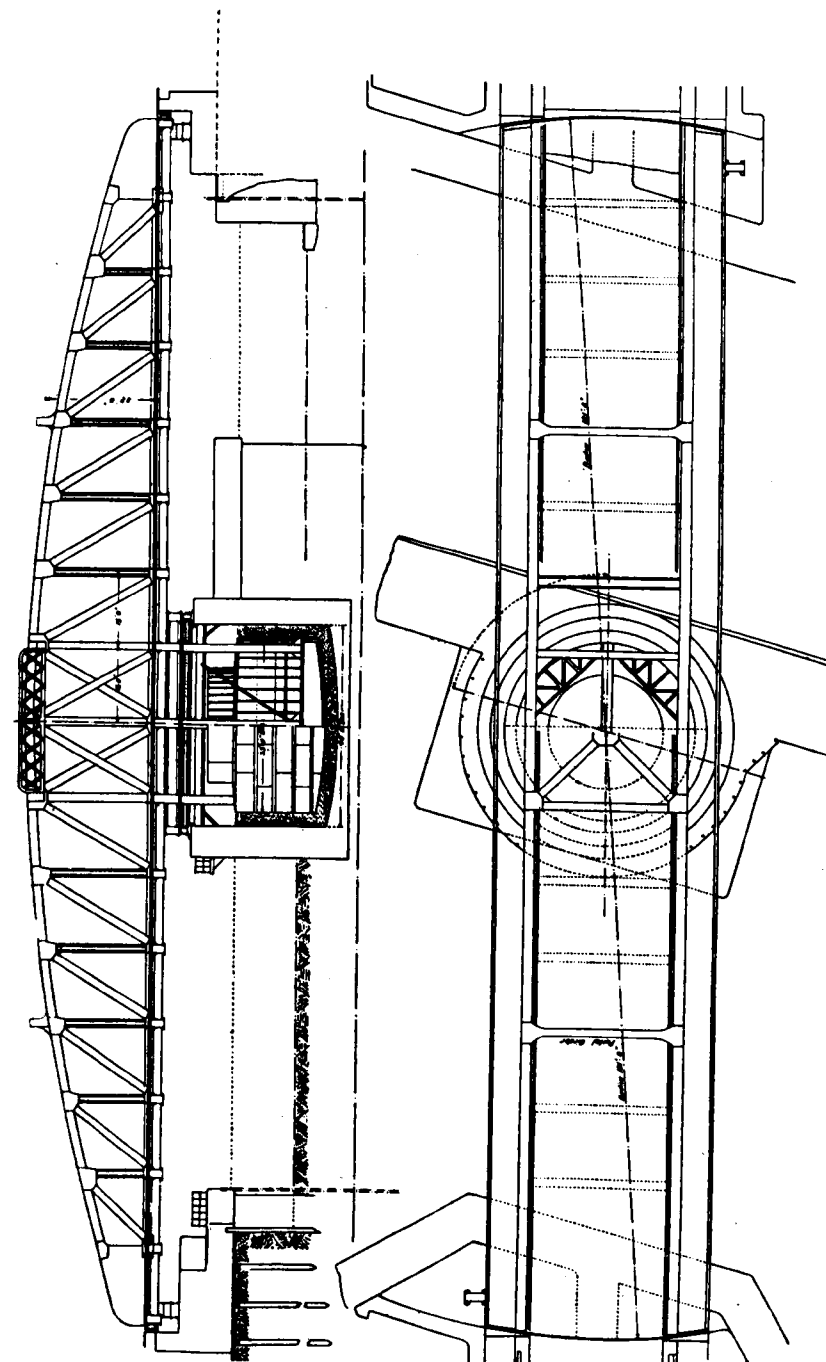


Fig. 6.—Acton Swing Bridge, Cheshire.



Fig. 7.—Corporation Road Bridge, Grimsby.

Twizel Bridge, Northumberland (page 227), which existed in 1513, when the English troops under the Earl of Surrey passed over it on their way to the battle of Flodden Field, has the largest span (90 feet, with a rise of 43 feet 6 inches) of any mediaeval bridge in Great Britain. It is built of dressed ashlar, and has five narrow chamfered ribs.

Stirling Old Bridge (page 489) claimed high importance in mediaeval times as providing the lowest crossing of the Forth.

Dart Bridge, Buckfastleigh, South Devon (page 67), is a good example of a mediaeval bridge widened in the nineteenth century, and again within the last few years. It was originally built in the 15th century and was widened in 1827 by flat arches springing from the cutwaters. Its width was then 20 feet, and in 1929 it was widened again on one side to 40 feet by taking down the 1827 arches, lengthening the original mediaeval arches in reinforced concrete and re-building the 1827 work and the facing as far as possible with the old materials.

Abingdon Bridge (pages 12-15) furnishes an admirable example of a successful operation for the insertion of a wide navigation arch without detriment to the picturesque appearance of the ancient structure.

Bideford Bridge (page 61) during its lengthy history has undergone many changes, the last of which was the widening carried out in 1923 by means of precast reinforced concrete corbels, which detract in no way from the hearty bluntness of the original design.

Waterloo Bridge (page 185) is entitled to a prominent place in any work dealing with English Bridges, but has been rendered too familiar by recent controversies to call for additional comments.

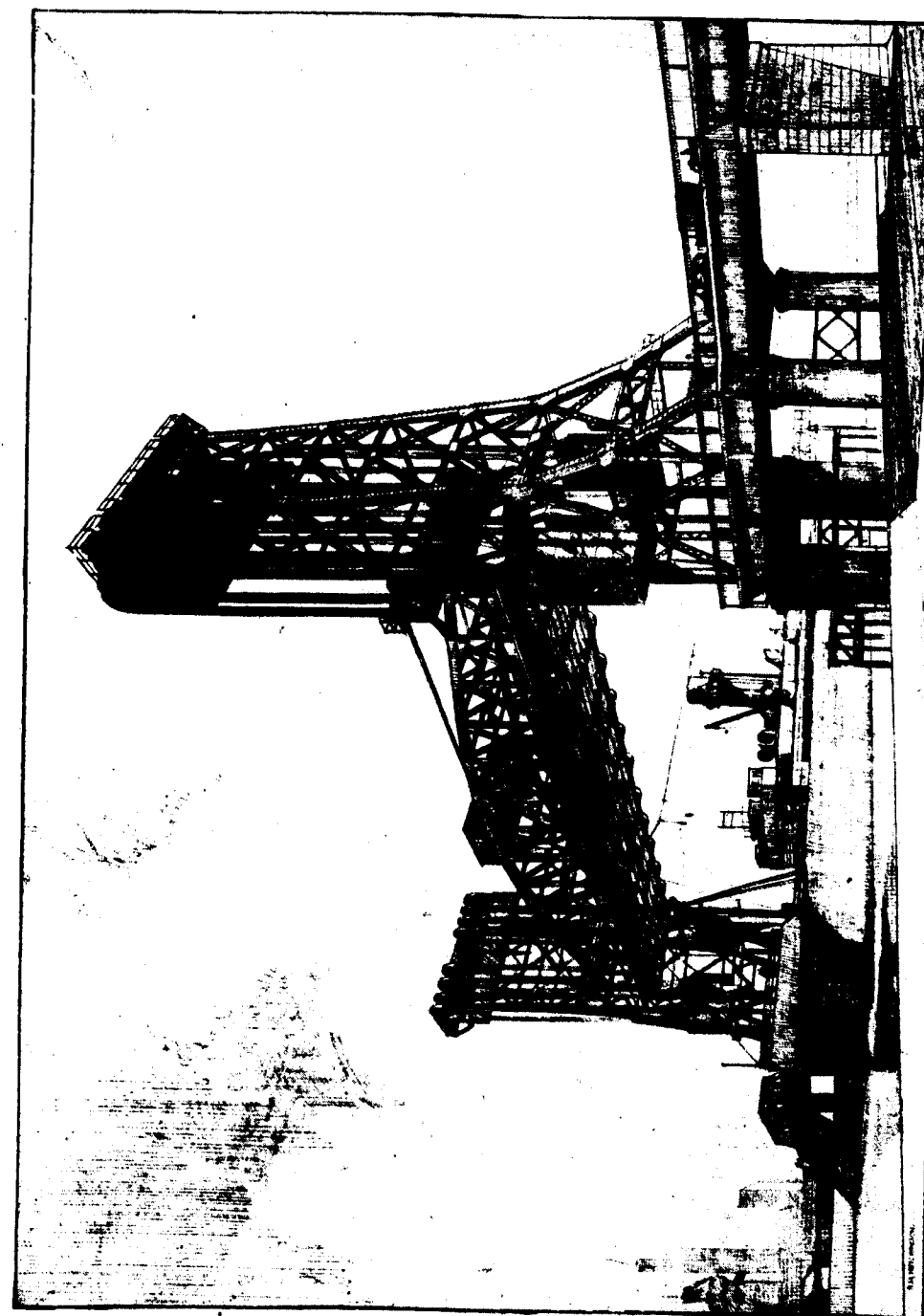


Fig. 8.—Tees (Newport) Bridge.

Pulteney Bridge, Bath (page 259), deserves special mention as one of the few surviving examples of a once common type, viz., the bridge supporting lines of houses.

Grosvenor Bridge, Chester (page 33), claims the distinction of displaying the masonry arch of longest span in England. The design is justly admired for its shapely proportions.

English Bridge, Shrewsbury (page 255), bears eloquent testimony to the skilful care of engineers and contractors in increasing the width and reducing the gradients without destroying the identity of John Gwynne's 18th century design.

Worcester Bridge (page 329), another of John Gwynne's designs, after having been disfigured for many years by cast-iron excrescences, has recently been judiciously widened in such a manner as to perpetuate the original design.

Cast-iron was first used for arches in the latter half of the 18th century. The first bridge in the world entirely built of iron was Ironbridge, Coalbrookdale, Shropshire (page 251).

Another interesting cast-iron bridge is the Waterloo Bridge, Bettws-y-coed, designed by Telford (page 379 and Fig. 9). This has been strengthened by removing the original deck, encasing the inner arch ribs in reinforced concrete, and providing a new reinforced concrete deck.

In 1801, Telford and Douglas presented to Parliament a scheme for re-building London Bridge with an iron arch having a span of 600 feet and a clear headroom of 65 feet.

One of the largest cast-iron arch bridges in England is the Holt Fleet Bridge, Ombersley, Worcestershire (page 330), which also has been strengthened and redecked in reinforced concrete.

A more recent cast-iron bridge, which had a wrought-iron superstructure, and has been strengthened with concrete and widened in steel is the Trent Bridge, Nottingham (page 232).

Westminster Bridge, designed by T. Page, and constructed in 1862, has the middle 52 feet of each rib wrought-iron and the rest cast-iron.

Many of the old cast-iron arch bridges were neither hinged nor definitely fixed, but had their rib ends fitted into grooved sockets in abutment bearing castings. Modern steel arches usually have hinges at the springings, mainly for convenience in construction. The largest British example of such an arch is the Tyne Bridge, Newcastle-upon-Tyne (page 231). While with a three-hinged arch moderate unequal settlement and spread of the abutments would not be objectionable, with a two-hinged arch no spread is permissible. Fixed arches without hinges cannot be used where either unequal settlement or spread is anticipated. A single hinge at the crown is not often adopted.

Owing to the fear of possible unequal settlement, due to the presence of disused mine workings, the Sunderland-Wearmouth Bridge (page 91) was constructed with three hinges, one at each springing and one at the crown.

The most recent Thames Bridge within the County of London is that at Lambeth (page 189), which has five spans of two hinged steel arches.

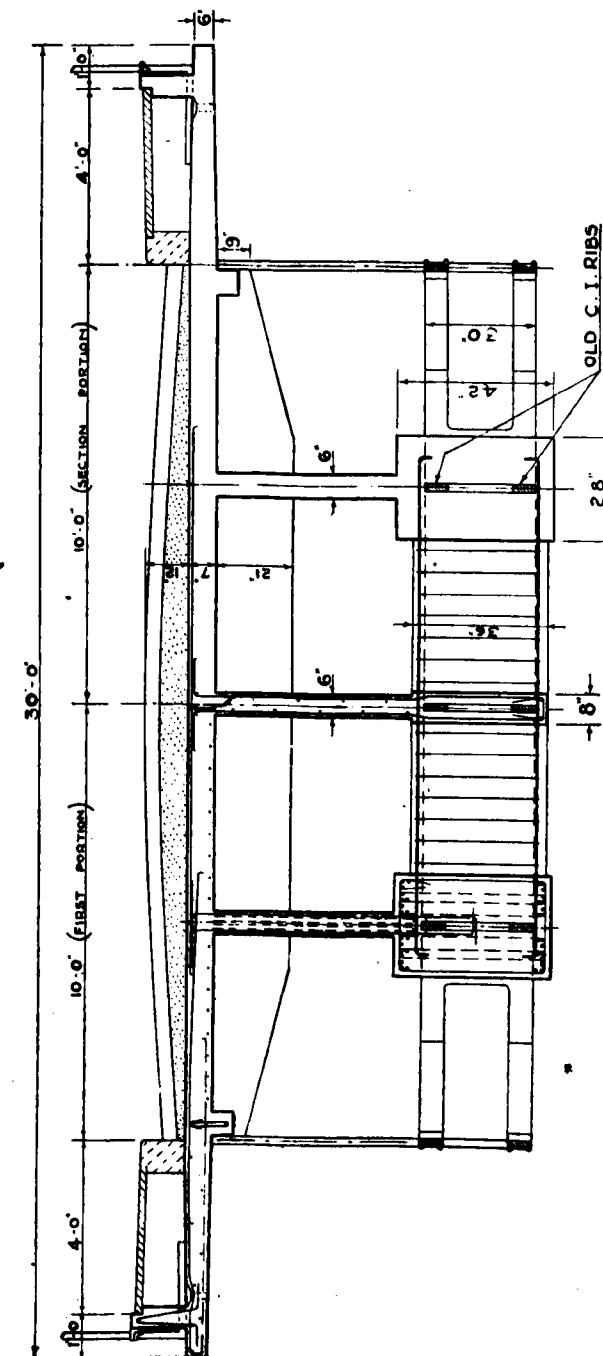


Fig. 9.—Waterloo Bridge, Bettws-y-Coed.

Many reinforced concrete arch bridges have now been constructed. Most of these are fixed, and have no hinges, though temporary hinges have occasionally been employed during construction. For moderate spans, the spandrel filled vault arch is more economical, but for longer spans, the bridge usually consists of a reinforced concrete deck supported on posts carried up on independent arch ribs (open spandrel type). An example of a small spandrel filled arch is the bridge at Harlow Mill, Essex (page 105). An example of an open spandrel arch is the new Hampton Court Bridge (page 197). A series of arch ribs connected by a thin vault supports posts carrying the deck, but the general appearance is that of a spandrel filled arch.

The largest reinforced concrete bridge in the country is the Royal Tweed Bridge, Berwick (page 219). This is naturally of the open spandrel type. A noticeable feature is that the roadway is on a gradient and the arches consequently increase in size from south to north.

An example of an open spandrel arch with false spandrel walls is the fine bridge at Invergarry on the Inverness—Fort William Road (page 457).

Wansford Bridge, Northamptonshire (page 213) lies on the Great North Road, and is an example of a plain unreinforced concrete arch bridge.

If the ends of an arch rib are connected by a tie, the rib will exert no thrust on the abutments. Such a bridge is really of the beam type and is known as a "bowstring." Bowstrings may be built either in steel or reinforced concrete, and are often economical, as the abutments can be relatively inexpensive compared with those of an arch, where the bearing capacity of the ground is not very good.

An example of a reinforced concrete bowstring bridge is that at Stow, Norfolk (page 205). Foryd Bridge (page 393) is a two span steel bowstring.

SUSPENSION BRIDGES.—The modern suspension bridge may be said to be descended from the simple rope bridge slung across a gorge, of which many are still in use in tropical and undeveloped countries.

The first suspension bridge in England was constructed in 1741. It crossed the Tees near High Force, Middleton-in-Teesdale, and was 70 feet long. It was only 2 feet wide, as the floor was arranged directly on the cables with a railing on each side. It fell in 1802.

Telford made plans for a suspension bridge at Runcorn in 1814. Each cable was to have had 36 bars $\frac{1}{4}$ in. square and bound by wire. The centre span was to have been 1,000 feet with 500 feet approach spans.

The first large suspension bridge built in Britain was the Union Bridge over the Tweed near Berwick. It was erected in 1820, was 20 feet wide and had a span of 440 feet. There were six chains on each side, each of 2 inch round wrought-iron. Six months after construction, it was blown down in a storm.

The largest suspension bridges in this country are those at Clifton, Bristol (page 113), (which has a main span 702 feet centre to centre of piers, and the main chains of which originally formed a part of the old Hungerford Suspension Bridge at Charing Cross), and over the Menai Straits (page 368). Other old suspension

bridges of smaller span exist at Marlow, Chelsea, Hammersmith, Aberdeen and elsewhere. No modern suspension bridges exist in this country, mainly because this type of bridge is comparatively uneconomical except for very large spans.

At Kalemouth, just over the Border, is a small suspension bridge of peculiar type. It has every other suspender attached to the middle of a link—obviously a bad and uneconomical arrangement.

The bridge at Scotswood, Newcastle-upon-Tyne, is an example of an old suspension bridge strengthened and widened to take an increased load (page 229).

The Albert Bridge over the Thames in London was opened in 1873. It is 710 feet between abutments, with a centre span of 383 feet, and side spans of 145 feet and 146 feet. There is a 27 feet carriageway and two 7 feet footpaths. Tie bars radiate from the tower tops to various points on the deck, while an eye-bar cable supports some of the deck load by means of suspenders. The bridge is interesting as a hybrid type, embodying features of both suspension and cantilever principles.

TUNNELS.—There are a few examples here and there of road tunnels constructed during the 19th century. The longest of these is the Horn Hill Tunnel, Beaminster, Dorset (page 79). Others are at Reigate, Surrey, and Charmouth, Dorset.

The longest road tunnel (not sub-aqueous) in Great Britain is that at Penmaenbach, North Wales (page 378).

Of sub-aqueous tunnels, the longest in England is the Mersey (page 151).

The foregoing notes will have served their purpose if they bring to the minds of readers the fascinating variety of the problems that confront the bridge builder and the ingenuity displayed for hundreds of years past by the members of that great craft, which evokes to-day a higher degree of skill than ever before.

For some of the information on the earlier bridges, I am indebted to H. G. Tyrell's "History of Bridge Engineering," O. E. Hovey's "Movable Bridges," and Messrs. L. G. Mouchel and Partners.

The Design of Superstructures for Small Bridges.

BY

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THE manner in which the Author's paper on "The Design of Bridge Sub-structures" was received at the last Congress left him with the thought that a brief companion paper on Superstructures might not be altogether inappropriate. The design of superstructures is, perhaps, less of a problem to the average engineer, and there is certainly less chance of serious error, but there is still plenty of scope for wasteful design.

Because of the extent of the subject it is necessary to limit the discussion to the smaller bridges. Fixed arches are omitted as the design of concrete bridges of this type was discussed by the author in a previous paper,* and steel arches are almost invariably hinged. The design of portal frame bridges was discussed by G. H. Hargreaves in an earlier paper,† and this type may therefore be omitted in the present review. Several other less common types such as multiple span continuous girder bridges, two hinged and three hinged arches, bowstring girders are omitted through limitation of space and time: the design of these types so far as reinforced concrete is concerned, together with the general theory underlying reinforced concrete bridge design is included in a book‡ recently published which deals with bridge problems in this material much more fully than can be attempted in a brief paper.

The author therefore considers that simple demonstration of the method of design with a free and detailed discussion of one or two types will best serve the

* The Design of Fixed Symmetrical Reinforced Concrete Arches: Paper No. 9, Public Works, Roads and Transport Congress, 1931.
† A Simplified Method for the Design of Single Span Frame Bridges: Paper No. 5, Public Works, Roads and Transport Congress, 1929.
‡ Reinforced Concrete Bridge Design, by C. S. Chetty and Haddon C. Adams (Messrs. Chapman & Hall, Ltd.).

present purpose, and this paper includes the following types which, together with the arch, form the majority of our smaller modern bridges:—

- I Simple slab bridge.
- II Reinforced concrete deck-girder bridge.
- III Plate girder bridge.

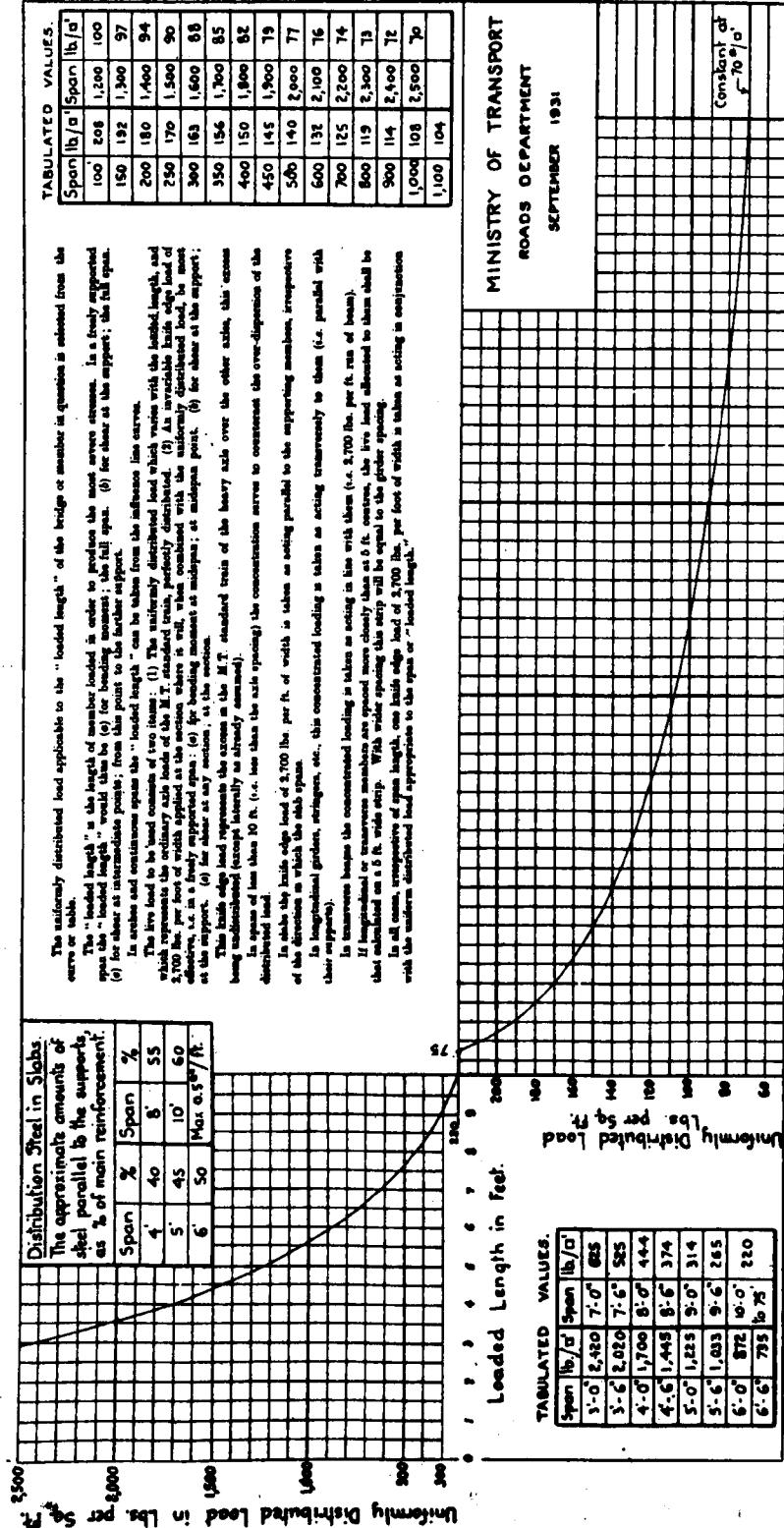
In the examples the live load adopted is the Ministry of Transport Equivalent Loading described in Fig. 1. A working knowledge of the elements of reinforced concrete design is assumed, as in the earlier paper on Bridge Substructures. The Notation is given in the Appendix.

Table I. shows the concrete stresses allowed in bridge work by the Ministry of Transport for various mixes.

TABLE I.

CONCRETE MIX. Cement : Fine Aggregate : Coarse Aggregate :	WORKING STRESS. ' f.	MODULAR RATIO.	CRUSHING STRENGTH OF CONCRETE IN 6 in. CUBES.	
			At 28 days with ordinary Portland Cement. At 7 days with Rapid Hardening Portland Cement.	An additional test (if required) as an indication, at 7 days with ordinary P.C., at 3 days with R.H.P.C., should give results as below.
lb. : cu. ft. : cu. ft.	lb./sq. in.	n	lb./sq. in.	lb./sq. in.
A : 2 : 4	5A + 300	—	15A + 900	10A + 600
90 : 2 : 4	750	15	2,250	1,500
120 : 2 : 4	900	15	2,700	1,800
150 : 2 : 4	1,050	12	3,150	2,100
180 : 2 : 4	1,200	10	3,600	2,400

STANDARD LOAD FOR HIGHWAY BRIDGES. EQUIVALENT LOADING CURVE.



Carriageways and Footpaths.

The width necessary for a road depends upon its locality and the traffic it will be called upon to carry. The carriageway would be designed to accommodate two, three or four lanes of traffic, each assumed to be 10 ft. wide, although in a number of cases, multiples of 9 ft. have been used. Footpaths should be not less than 5 ft. wide, and near towns, 7 ft. to 7 ft. 6 in. Where footways are not provided a guard kerb 1 ft. wide for protection of the parapet should be taken as the standard. For the normal lightly trafficked road a 20 ft. carriageway with one 5 ft. footway is suitable, while in towns a 30 ft. carriageway with either one or two 7 ft. 6 in. footways may be suitable. Where the bridge is approached by curves the footways may conveniently be made about a foot wider to allow for encroachment of the bodies of vehicles, while the carriageway itself should be widened and transition curves and superelevation should always be employed.

Occasionally 10 ft. footways are used when there is a likelihood of future widening of the carriageway; in this case care should be taken so to detail the slab and kerb that the widening can be conveniently effected.

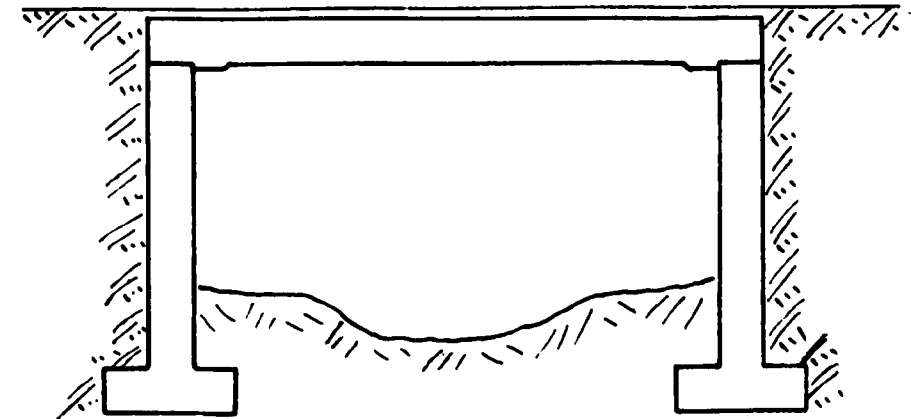


Fig. 2.

I. SIMPLE SLAB BRIDGE.

This is the simplest of all reinforced concrete bridge types, the easiest to construct and for short spans generally, if designed as described below, by far the most economical. Advantage is taken of the rigid deck to strut the abutments at the top as may be seen from Fig. 2, so that these abutments consist of reinforced concrete slabs designed as simply supported vertical beams. A few minutes may perhaps be spared to discuss this bridge as a whole. It was described in the Bridge Sub-structure paper previously referred to, but many engineers in this country are still comparatively unfamiliar with the type.

Bridge engineering in Great Britain is in a somewhat peculiar condition. The scientific method of design is comparatively modern and has been applied much more

extensively to modern materials, with the result that in this sphere we can show, from Coalbrookdale, Menai, Forth, to Sydney Harbour Bridge (designed in Great Britain) a brilliant record. In the larger reinforced concrete bridges too we need scarcely be ashamed. But we have also an older record, a tradition as inspiring if not scientifically as brilliant. Many a beautiful mediaeval bridge still stands to-day to witness to the fact that men with a love of service, and a sense of the dignity of craftsmanship, could minister to the needs of their time quite effectually without the aid of mathematician.

This early method, however, could not be applied to the larger or modern type of bridge. A steel or reinforced concrete bridge *must* be scientifically designed, and it is to be regretted that occasionally an exponent of the old school, lacking the old experience, may attempt to apply the old method to the new material. He is naturally insular in outlook and rigorously rejects, without examination, anything which claims to have primarily a scientific basis.

There are others who may reject what they believe to be a new type of bridge through personal unfamiliarity with it. They will readily construct the uprights of a frame bridge without designing them as "self-supporting," or the side walls of a culvert, but they hesitate in the case of a slab bridge, not realising that thousands of similar bridges have been successfully constructed in the past two decades. Quite often will a heavy mass abutment be constructed at extravagant cost, on a foundation bed which is much less capable of supporting the heavy than the lighter form of construction.

Let this suffice for the author's claim for an honest consideration for the simple slab type of bridge; the biggest (but not the only) saving lies in the light abutments, and these will not again be referred to as they were dealt with in the previous paper.

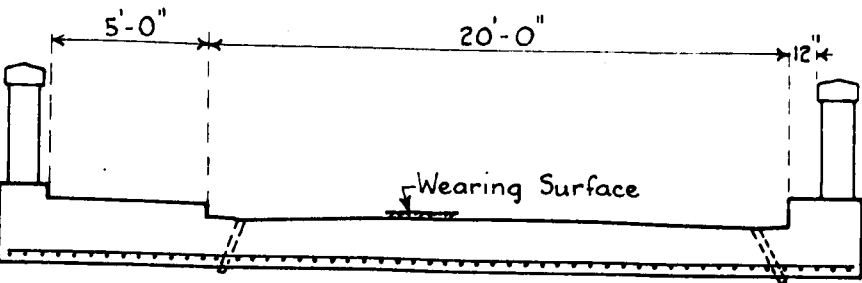


Fig. 3.

The deck slab is fairly thick, and the quantities of both steel and concrete are generally higher than in a corresponding reinforced concrete deck girder superstructure. The placing of reinforcing steel and concrete however is much simpler, and the shuttering is most economical both in quantity and in labour. In order to reduce the dead load of the deck slab it may be desirable in certain cases to use the richer mixes of concrete such as 120 lb. : 2 : 4 and 150 lb. : 2 : 4. No filling should be used on the deck, but the top surface of the concrete should be cambered to give the necessary cross section so that the wearing surface may be uniform in thickness—

say 2 inches of asphalt or 3 inches of tarmacadam. A typical cross section is shown in Fig. 3. The design thickness (for resisting moment) may reasonably be taken as the average of thicknesses at crown and at gutter. The camber, if a good surface is to be maintained on the bridge, may reasonably be 1% (mid-ordinate) of the carriageway width. A longitudinal camber of from 1 to 2 inches is generally provided for drainage and appearance. The slab soffit is made level in the cross section, but will of course take the longitudinal camber provided in the road surface and parapet.

Slab superstructures may prove economical up to spans of about 30 ft. at which length the deck slab is rather heavy, and if this type were employed the richer concrete mixes would almost certainly be used.

Fig. 4 gives the live load bending moments in a one-foot wide strip calculated for various spans on the basis of the Ministry of Transport Equivalent Loading.

The following tables give slab thicknesses and reinforcement suitable for the Ministry of Transport Equivalent Loading for three mixes of concrete. The clear concrete cover to the bars has been taken as 1 inch or 1 1/16 inch with bars of larger diameter than 1 1/4 inches. The wearing surface has been assumed as 30 lb. per square foot. The method of calculation is demonstrated below.

TABLE IIA.

Concrete mix 90 lb. : 2 : 4. n=15 f_s=16,000 f_c=750.

Effective Span in feet.	Slab Thickness in inches.	Main reinforcement.
10	10 1/2	3/4" φ bars @ 5" cts.
12	12	7/8" φ " @ 5 1/2" "
14	14	1" φ " @ 7" "
16	15	1" φ " @ 6" "
18	17	1" φ " @ 5 1/2" "
20	18	1 1/8" φ " @ 6" "
22	20	1 1/4" φ " @ 7" "
24	22	1 1/4" φ " @ 6 1/2" "
26	24	1 3/8" φ " @ 7" "

TABLE IIB.

Concrete Mix 120 lb. : 2 : 4. n=15 f_s=16,000 f_c=900.

Effective Span in feet.	Slab Thickness in inches.	Main reinforcement.
12	11	1" φ bars φ 6 1/2" cts.
14	12	1" φ " @ 6" "
16	13 1/2	1 1/8" φ " @ 6 1/2" "
18	15	1 1/8" φ " @ 6" "
20	16	1 1/8" φ " @ 5 1/2" "
22	18	1 1/4" φ " @ 6" "
24	19	1 1/4" φ " @ 5 1/2" "
26	20	1 3/8" φ " @ 6" "
28	22	1 3/8" φ " @ 6" "
30	23	1 3/8" φ " @ 5 1/4" "

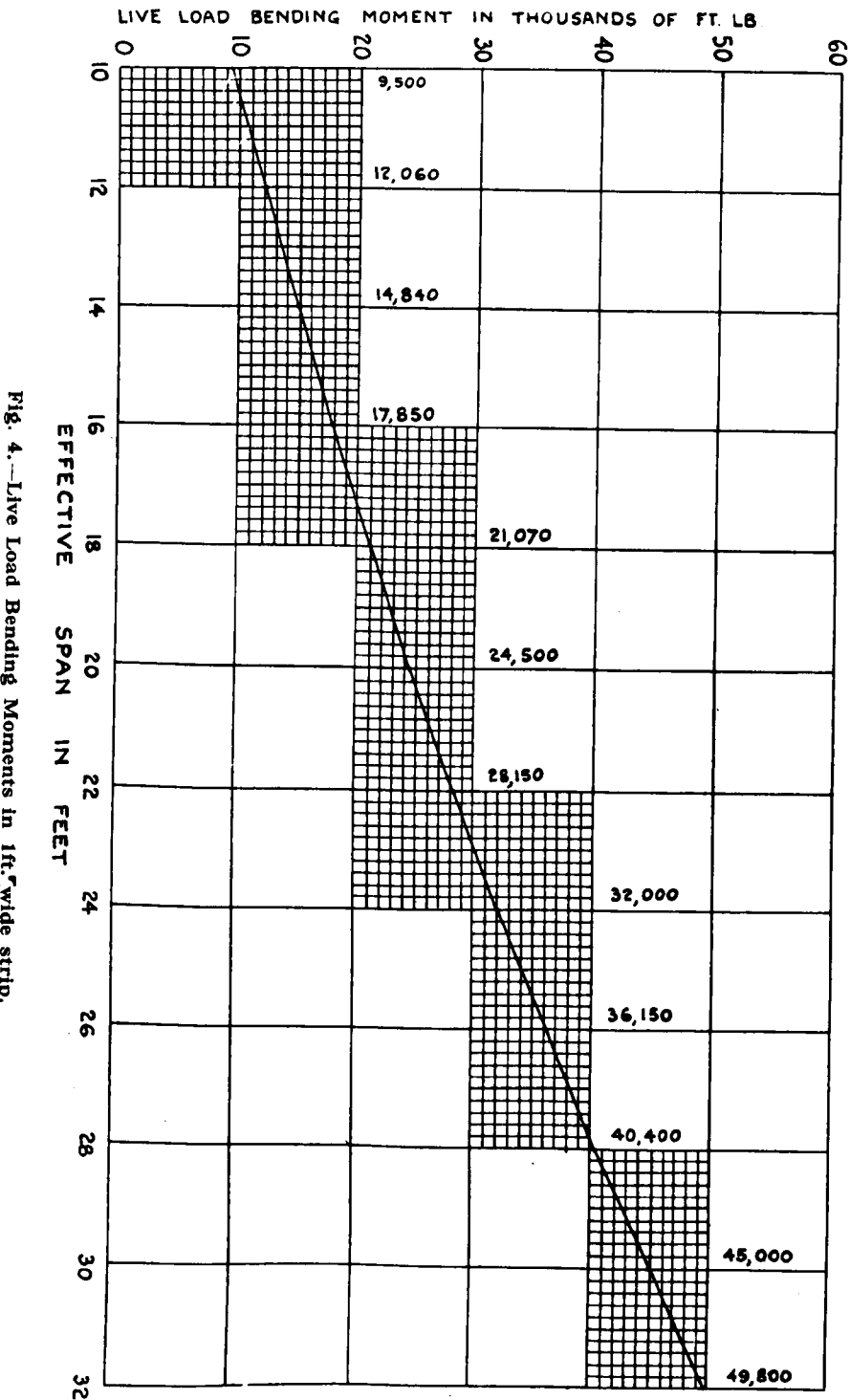


Fig. 4.—Live Load Bending Moments in 1ft. wide strip.

TABLE IIc.

Concrete Mix 150 lb. : 2 : 4 $n=12$ $f_s=16,000$ $f_c=1,050$.

Effective Span in feet.	Slab Thickness in inches.	Main reinforcement.
18	14	$1\frac{1}{8}"\phi$ bars @ $5\frac{1}{2}"$ cts.
20	15	$1\frac{1}{8}"\phi$ „ @ $5"$ „
22	16	$1\frac{1}{4}"\phi$ „ @ $5\frac{1}{2}"$ „
24	$17\frac{1}{2}$	$1\frac{3}{8}"\phi$ „ @ $6\frac{1}{2}"$ „
26	19	$1\frac{3}{8}"\phi$ „ @ $6"$ „
28	20	$1\frac{3}{8}"\phi$ „ @ $5\frac{1}{2}"$ „
30	22	$1\frac{3}{8}"\phi$ „ @ $5"$ „
32	23	$1\frac{3}{8}"\phi$ „ @ $5"$ „

Example.

22 ft. effective span. 90 lb. : 2 : 4 mix. $f_s=16,000$ and $f_c=750$.

Assume slab thickness 20 in.

Dead Load.

$$\begin{array}{rcl} \text{Wearing surface} & = & 30 \\ \text{Deck slab } 20 \times 12 & = & 240 \\ \hline & & 270 \text{ lb. per sq. ft} \end{array}$$

Bending Moments.

$$\begin{array}{rcl} \text{D.L.M.} & \frac{1}{8} \cdot 270 \cdot 22^2 = & 16,350 \\ \text{L.L.M.} & \left\{ \begin{array}{l} \frac{1}{8} \cdot 220 \cdot 22^2 = 13,300 \\ \frac{1}{4} \cdot 2,700 \cdot 22 = 14,850 \end{array} \right. & \\ \hline & & 44,500 \text{ ft. lb.} \end{array}$$

Effective depth, $d=18\frac{3}{8}"$.

$$\begin{array}{rcl} R = \frac{44,500}{(18\frac{3}{8})^2} = & 132 & \\ p = & 0.0096 & \\ A_s = & 2.12 \text{ sq. in.} & \end{array}$$

Use $1\frac{1}{4}"\phi$ bars at 7" centres.

Suitable slab thicknesses for intermediate span lengths may be taken from Fig. 5, employing the appropriate percentage of steel, using the *effective* depth in calculating the sectional area of the slab.

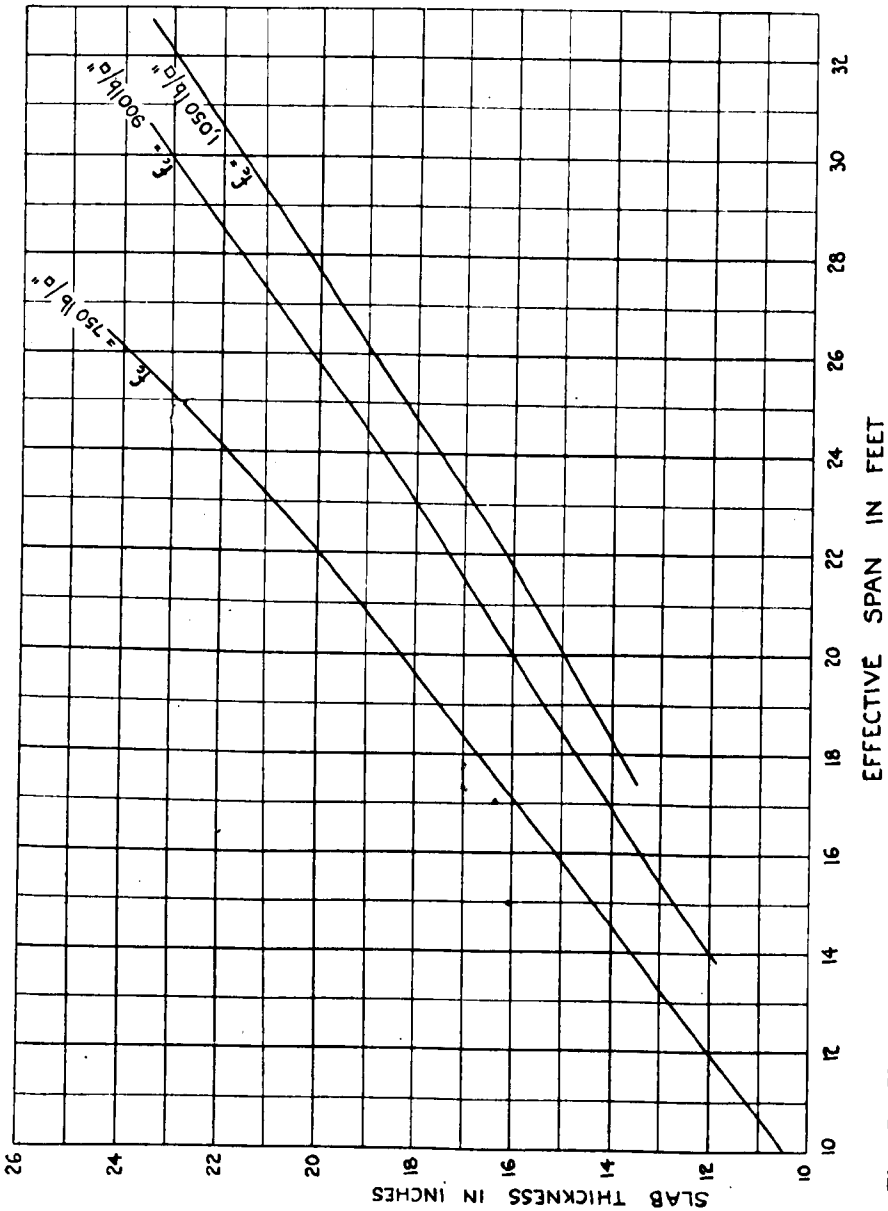


Fig. 5.—Slab thickness required for various spans with various strengths of concrete, for M.T. equivalent loading (based on 3" wearing surface and 1" clear cover to bars).

II. REINFORCED CONCRETE DECK GIRDER BRIDGES.

With the longer spans the slab bridge becomes uneconomical owing to the excessive thickness of slab required : the dead load increases and becomes excessive in proportion with the live load. In a reinforced concrete section subjected to simple bending the neutral axis is somewhat less than half way down from the compression face of the concrete, and since the concrete lying below the neutral plane is in tension and its tensile strength must be neglected, a large portion of the concrete is performing the functions only of embedding and stressing the steel, and resisting shear : both of these functions can be performed adequately with much less concrete

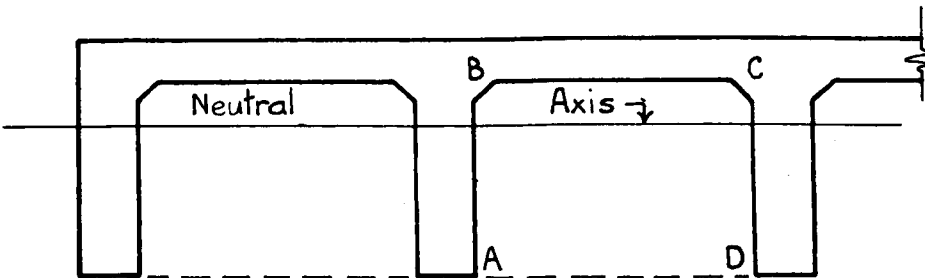


Fig. 6.

than lies below the neutral plane in a thick slab. For this reason we box out portions of the slab as shown in Fig. 6. The stage at which the change over from slab to T-beam design is made depends on the relative costs, balancing the saving in concrete against the extra and more complicated shuttering of the beam sides AB and CD. There is a little more in it really than this as the reinforcement becomes more complicated and a little less efficient when two or more layers of bars have to be provided in the bottom of the stem. Shear reinforcement will be discussed later.

The boxing out generally extends up above the neutral axis as the portion of concrete in the compression area immediately above the N.A. is low stressed and has but a small leverage. The thickness of the top portion of the section shown in Fig. 6 is generally governed by another consideration : it forms the floor or deck slab, and as such spans transversely between the beams ; the thickness of the deck slab and the spacing of the beams or girders are thus inter-dependent. The stresses in the deck from its action as a slab are in no wise detrimental to the action as a compression flange in the T-beam as the two sets of stresses (apart from secondary distribution stresses) are mutually at right-angles.

The design of the reinforced concrete deck girder superstructure thus resolves itself into the design of the deck slab and the design of the T-beams. Fig. 7 is a typical cross-section, from which it will be seen that the deck slab is slightly cambered across the roadway (mid-ordinate 1 per cent. of carriageway width is suitable, set out on a parabolic curve) so that the wearing surface of say 2 inches of asphalt or 3 inches of tarmacadam may be of uniform thickness. The soffits of the girders in a transverse section are at a constant level, so that the middle girders are a little deeper than those at the sides ; it is, however, not worth while to vary the quantity

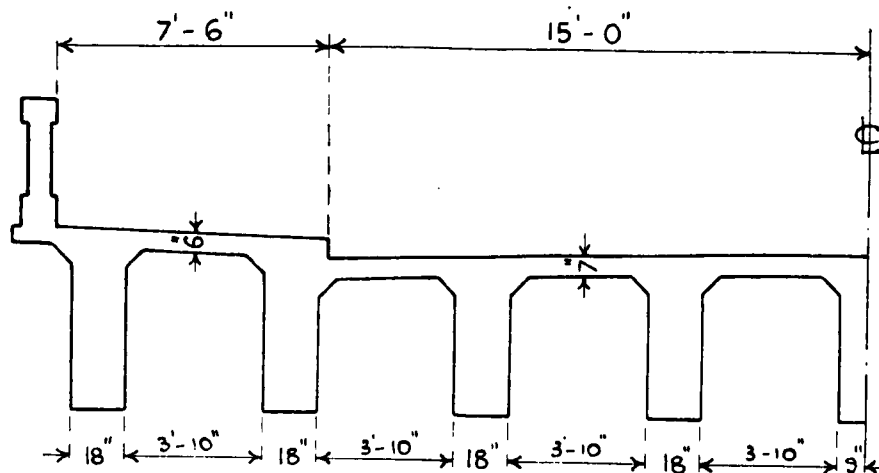


Fig. 7.

of reinforcing steel, and the side girders should have the full design depth. Fillets are used at the junction of beam and slab, and for design purposes the effective span of the slab is taken as the clear span between beams. The overall depth of the girders, including the slab, is generally made between $\frac{1}{10}$ and $\frac{1}{8}$ of the span, the shallower depth being used where headroom is an important consideration. The width of the beam is generally from $\frac{1}{2}$ to $\frac{1}{3}$ of the depth of the beam below the slab, but is controlled mainly by consideration of the shear; it should be wide enough to accommodate at least four bars in a layer with comfortable clearances between and cover outside them.

The deck slab should, generally speaking, be not less than 7 ins. thick, although in exceptional cases, where limitation of dead load is a consideration, a 6 in. thickness may be used with a richer mix. A 7 in. slab, stressed to 750 lb. per square inch with the Ministry of Transport Equivalent Loading and the method of design described below, will span 3 ft. 10 in. (clear between beams); a $7\frac{1}{2}$ in. slab, 4 ft. 8 ins.; 8 in. slab, 5 ft. 8 ins.; an $8\frac{1}{2}$ in. slab, 7 ft. 3 ins.; and a 9 in. slab, 8 ft. 3 ins. With richer mixes and higher stresses larger spans can of course be adopted.

If the slab thickness is selected the approximate girder spacing is determined, but the exact spacing will depend upon the arrangement of the girders below the footpath, and the exact width of the carriageway; a convenient arrangement is shown in Fig. 7.

Solution by the Theorem of Three Moment, or by the use of standard influence lines when the spans are all equal, are the usual methods adopted for continuous beams and slabs, and all the supports are assumed to remain at the same level. In deck girder construction for bridges, however, the spans are fairly lengthy and the girders do not form rigid supports for the deck slab; it is therefore reasonable for live load to calculate the "free" bending moment (i.e., bending moment on a freely supported span of the same length and under the same system of loading)

and to employ a "reduction" factor in order to allow for continuity. This method, which is simple and direct, probably gives as accurate a result as the more complicated methods. The Theorem of Three Moments should however be used when the supports are rigid, or where the continuous spans vary appreciably in length. The "reduction" factor employed in British practice is 0.8 for both mid-span and support, and this is slightly more exacting (as it has to cover all cases) than the Theorem of Three Moments is likely to prove. Fig. 7 shows a half cross-section of a superstructure designed in this manner. The carriageway is 30 ft., and there are two footways each of width 7 ft. 6 in. The clear span of the bridge between abutments is taken as 55 ft. The concrete mix adopted is 90 lb. : 2 : 4, for which the permissible concrete stress in compression is 750 lb. per square inch.

Design of Deck Slab.

An 18 in. wide beam will accommodate six bars in each layer, and selecting the maximum slab span of 3 ft. 10 in. clear between beams it is seen that the parapet lies just outside the outermost beam. Since in the outermost span for which the live load is only 100 lb. per square foot, the slab is below the footpath, the beam spacing here might be increased, but a deep girder immediately below a solid parapet is apt to appear heavy and ugly, and it has been considered desirable in the present instance to leave the first beam set back as shown. The weight of the parapet will provide a fixing moment maintaining the continuity effect of the slab. The outermost beam may, if preferred, be made shallower than the roadway beams.

The effective span of the slab, since fillets are provided, is taken equal to the clear span which is 3 ft. 10 ins.

Dead Load.

2 in. wearing surface	=	20
7 in. concrete slab, 7×12	=	84
Total	=	104 lb. per square foot.

Live Load. (From Fig. 1).

Uniformly distributed load, 1,800 lb. per sq. ft.
Knife edge load at midspan, 2,700 lb. per ft. of width.

Bending Moment (in a 1 ft. wide strip).

D.L.M. $\frac{1}{12} \times 104 \times (3.83)^2$	=	127
"Free" $\frac{1}{8} \times 1,800 \times (3.83)^2$	=	3,300
L.L.M. $\frac{1}{4} \times 2,700 \times (3.83)^2$	=	2,585
Reduced L.L. Moment	=	$0.8 \times 5,885 = 4,708$
Total B.M.	=	4,835 ft. lb.

Slab thickness=7 in. Clear cover to bars= $\frac{3}{4}$ in. Assume $d=6$ in.

$$R = \frac{4,835}{6^2} = 134 \quad p = .0097 \quad A_s = 0.70 \text{ sq. in.}$$

$\frac{3}{8}$ in. diameter bars at 5 in. centres supply 0.74 sq. in. These bars should be used as main reinforcement running straight through in both top and bottom of the slab. The stress in the steel as compressive reinforcement has been ignored.

Distribution Steel (see Fig. 1) 39 per cent. of $0.70 = 0.273$ sq. in.

Use $\frac{1}{2}$ in. diam. bars at 9 in. centres.

Footway Slab.

The live load on footway slabs is taken as 100 lb. per sq. ft. and the contingency of a vehicle mounting the kerb is *considered*, but it is unnecessary to design for a heavy wheel load at the normal stresses. As the live load is comparatively light the calculated slab thickness would be small, but it is usual to make these slabs not less than about 5 or 6 in. thick. The kerb may, in special cases, be formed of granite, or the concrete may be armoured with steel in the form of an angle; on most roads, however, it will be sufficient to use plain concrete kerbs, but the arris should be avoided by rounding or chamfering the edge. The concrete kerb should preferably be added separately from the structural members, and should be of a high quality; it should be jointed at short intervals (every few feet) so as to avoid shrinkage cracks.

When service pipes have to be accommodated they may be either slung below the slab, between the girders (in which case they are always accessible from below), or else carried in a trench formed by depressing the slab; in the latter case the trench is generally filled with sand and the top surface is rendered with tarmacadam or paved with slabs. With a trench below the footpath it becomes necessary to avoid any appreciable cantilever moment from the weight of the parapet, and the outer beam has to be placed below the parapet; this may make the elevation appear heavy and unpleasing. The difficulty can be got over, with a certain amount of expense if a transverse stiffening rib is provided, somewhat in the form of a knee brace in a plate-girder bridge, to transfer the cantilever moment to the main system; such complications however are generally to be avoided. The footway surface should be made to slope from the parapet towards the gutter with a fall of about $\frac{1}{4}$ in. per ft. In the present design the parapet, including the base, weighs approximately 330 lb. per foot run.

Cantilever Moment.

Parapet	$330 \times 0.92 = 303$
Slab overhang	$120 \times 0.83 = 100$

403 ft. lb.

Footpath (assumed 6 in. thick with 1 in. asphalt).

$$\text{"Free" moment} = \frac{1}{8} \cdot (100 + 82) \cdot (3.83)^2 = 334 \text{ ft. lb.}$$

The cantilever moment is sufficient to reverse the midspan bending moment, so that only top reinforcement is required. The bending moments are almost negligible and only a nominal amount of reinforcement is required. Occasional bars would be added in the bottom of the slab, in detailing, to provide for the contingency of a vehicle mounting the kerb.

Roadway Beams. Clear span 55 ft. Effective span $56\frac{1}{2}$ ft. say.

Dead Load. (Width of roadway allotted per beam = 5.33 ft.)

Deck and W.S.	$5.33 \times 104 = 555$
Beam	$45 \times 18 = 810$
Fillets	$= 36$

Total $= 1,401$ lb. per ft. run.

Live Load.

Uniformly distributed load $= 5.33 \times 220 = 1,174$ lb. per sq. ft.
Knife edge load $5.33 \times 2,700 = 14,400$ lb.

Check beam section for shear.

$$\text{D.L.V.} = \frac{56\frac{1}{2}}{2} \times 1,401 = 39,600$$

$$\text{L.L.V.} = \frac{56\frac{1}{2}}{2} \times 1,174 = 33,150$$

$$\text{Knife edge load} = 14,400$$

$$\text{Total shear} = \underline{\underline{87,150 \text{ lb.}}}$$

$$(\text{assume } d = 46\frac{1}{2} \text{ in.}) \quad v = \frac{87,150}{18 \times .9 \times 46\frac{1}{2}} = 116 \text{ lb. per sq. in.}$$

Bending Moment.

$$\text{D.L.M.} = \frac{1}{8} \times 1,401 \times (56\frac{1}{2})^2 = 560,000$$

$$\text{L.L.M.} = \left(\frac{1}{8} \times 1,174 \times (56\frac{1}{2})^2 + \frac{1}{4} \times 14,400 \times 56\frac{1}{2} \right) = 203,000$$

1,232,000 ft. lb.

First approximation of A_s requirement, assuming centre of compression 3 in. from top surface of slab,* and "lever arm" equal to 43 in.

* The compression in the stem below the slab, assuming the N.A. falls below the underside of the slab, is disregarded as having little effect on the resisting moment. The centre of compression in the slab must then be above the mid-point.

$$\text{Approximate } A_s = \frac{1,232,000 \times 12}{16,000 \times 43} = 21.5 \text{ sq. in.}$$

Try 18 bars, $1\frac{1}{2}$ in. diam., in 3 layers = 22.09 sq. in.

The width of the flange for design purposes is limited to the least of the following:—

- (1) From midspan to midspan of the deck slab.
- (2) Twelve times the slab thickness.
- (3) One quarter of the effective span of the T-beam.

In the present design the first criterion governs and the flange width is 5 ft. 4 in. The section of the T-beam is shown in Fig. 8. For evaluating the stresses T-beam design charts such as may be found in the standard text books on reinforced concrete design should be used. That used in the present instance is on p. 57 of *Reinforced Concrete Bridge Design*.

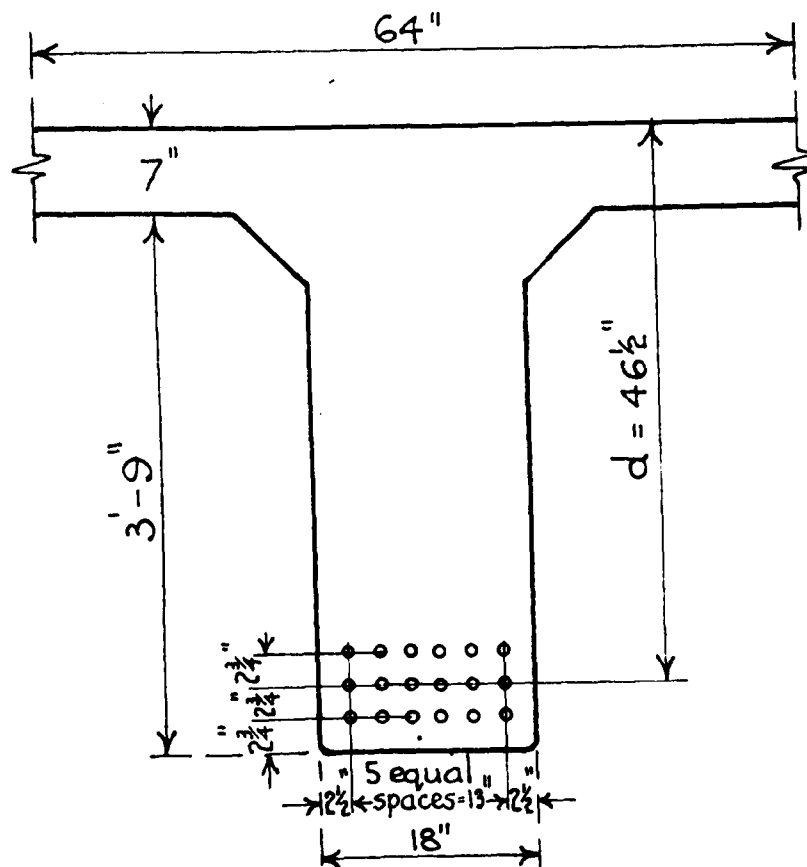


Fig. 8.

$$\frac{t}{d} = \frac{7}{46\frac{1}{2}} = 0.151 \quad p = \frac{22.09}{64 \times 46\frac{1}{2}} = .00742$$

for which $j = .93$ and $k = 0.47$

$$\text{then average } f_s = \frac{1,232,000 \times 12}{22.09 \times .93 \times 46\frac{1}{2}} = 15,500 \text{ lb. per sq. in.}$$

$$\text{Distance from neutral axis to C.G. of bars} = (1-k)d = 25.3 \text{ in.}$$

$$\text{Steel stress in lowest bars} = 15,500 \times \frac{25.3 + 0.23}{25.3} = 15,680 \text{ lb. per sq. in.}$$

Owing to the fact that concrete stress below the flange has been neglected the "lever arm" used above is longer than the actual, so that the real value of f_c will be slightly higher than that calculated.

$$\text{Concrete stress, } f_c = \frac{15,500 \times 0.47}{15 \times 0.53} = 887 \text{ lb. per sq. in.}$$

This stress is appreciably in excess of the allowable and it would appear to be necessary either to thicken the slab (in which case the slab span and girder spacing may be increased) or to use compressive reinforcement. In the latter case, as the neutral axis is well below the flange, some economy will result from a calculation of the compressive stress below the flange.

In practice the two methods should be compared for economy, but as the first method is merely a repetition of the above calculations with revised dimensions, it is considered to be more helpful to demonstrate the second method here. When the compressive stress in the concrete in the first approximation is only moderately in excess of the allowable stress, allowances for compressive stress below the flange and in the bars used for hanging the stirrups may possibly bring the calculated stress within the permissible limit. The T-beam may now be considered as made up of several parts (see Fig. 9).

(1) A simple rectangular section ABCD, under normal stresses, so that $f_c = 750$ lb. per sq. in., $f_s = 16,000$ lb. per sq. in. The corresponding values of R , p , k and j are $R = 133\frac{1}{2}$, $p = .0097$, $k = 0.413$, $j = 0.862$. The position of the neutral axis is determined by the modular ratio and the steel and concrete stress ratio, as may be seen from Fig. 9. Since in this particular design the stress in the lowest layer of bars is less than 1 per cent. in excess of the stress at the centre of gravity of the group it is satisfactory to take the effective depth d to the C.G., calculating on a steel stress of 16,000 lb. per sq. in. at this depth. In shallow beams where there is a considerable difference in stress between the layers of bars it would be necessary to base the calculations on a reduced stress at the C.G. of the group so that, for convenience, d could still be measured to that point. The values for R , p , k and j would then have to be based on the "reduced" stress.

The resisting moment of the simple rectangular beam would be equal to

$$R \cdot b d^2 = \frac{133\frac{1}{2} \times 18 \times (46\frac{1}{2})^2}{12} = 433,500 \text{ ft. lb. and the required steel,}$$

$$A_{s1} = .0097 \times 18 \times 46\frac{1}{2} = 8.12 \text{ sq. in.}$$

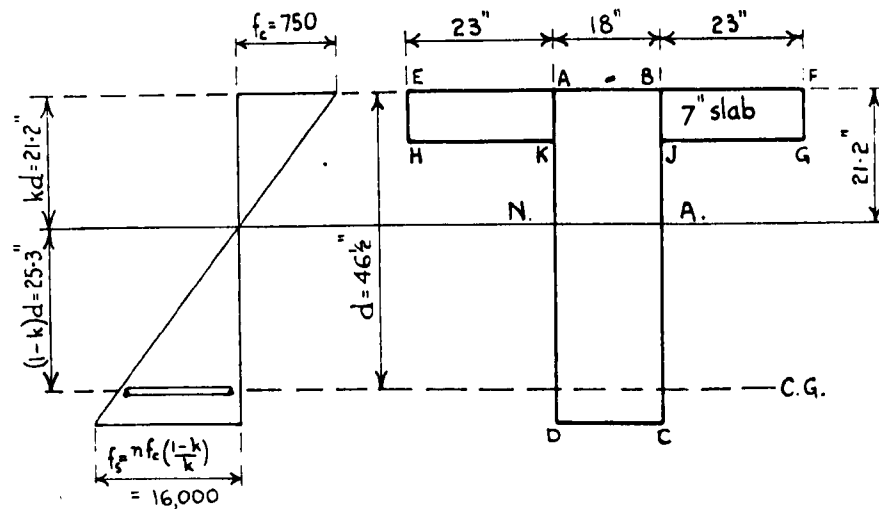


Fig. 9.

(2) The flange projections, AKHE and BFGJ acting in conjunction with additional tensile reinforcement as a couple.

The average stress in the flange is

$$750 \times \frac{21.2 - 3.5}{21.2} = 626 \text{ lb. per sq. in.}$$

∴ Total stress in these portions = $46 \times 7 \times 626 = 201,500$ lb. (compression).

The additional tensile steel, $A_{s2} = \frac{201,500}{16,000} = 12.60$ sq. in.

These forces acting as a couple with a lever-arm of 43 in. produce a resisting moment equal to

$$201,500 \times \frac{43}{12} = 720,000 \text{ ft. lb.}$$

The total resisting moment thus provided for in the T-beam section is $433,500 + 720,000 = 1,153,500$ ft. lb.

The resisting moment remaining to be provided by additional reinforcement (both tensile and compressive) therefore = $1,232,000 - 1,153,500 = 78,500$ ft. lb.

The forces providing this resisting moment will act as a couple with a lever arm of 44 inches, and will therefore each be equal to $\frac{78,500 \times 12}{44} = 21,400$ lb.

Compressive Steel. Assuming that the compressive steel is placed $2\frac{1}{2}$ inches (measured to centres of bars) below the concrete face, the concrete stress in this position is

$$750 \times \frac{21.1 - 2.5}{21.2} = 662 \text{ lb. per sq. in.}$$

The steel will be stressed to n times this intensity; allowing for the displacement of concrete by the bars the additional total stress will be $(n-1) \times 662 \times A_s$, and this must equal the necessary force of 21,400 lb.

$$14 \times 662 \times A_s = 21,400$$

$$\therefore A_s = \frac{21,400}{14 \times 662} = 2.31 \text{ sq. in.}$$

Four $\frac{7}{8}$ in. diameter bars can suitably be employed for this purpose, and these can act as the wiring bars from which to hang the stirrups in the middle portion of the beam span.

Tension Steel. The further additional tensile steel A_{s3} will be

$$\frac{21,400}{16,000} = 1.34 \text{ sq. in.}$$

The total tensile steel required is thus $8.12 + 12.60 + 1.34 = 22.06$ sq. in., so that the reinforcing steel already provided (18 bars, $1\frac{1}{4}$ in. diam. = 22.09 sq. in.) is satisfactory.

We must now turn our attention to the diagonal tension, or "shear," reinforcement in the web.

The maximum total shear is 87,150 lb. and since the unit shear does not exceed 120 lb. one-third of the shear resistance may be assumed from the concrete, leaving 58,100 lb. to be resisted by web reinforcement. Shear reinforcement is provided generally by a combination of bent-up bars and stirrups. The bent-up bars run approximately parallel with the planes of diagonal tension and are the more efficient; they should be bent up in pairs and spaced not further apart than $\frac{1}{2}d$, which in the present design is 35 in., measured along the neutral plane.

One pair of $1\frac{1}{4}$ in. bent-up bars would in shear resistance thus be good for $\frac{2 \times 1.227 \times 16,000 \times .9 \times 46\frac{1}{2} \times 1.41^*}{35} = 66,100$ lb. This is seen to be sufficient, so that vertical stirrups at a nominal spacing only need be employed; $\frac{1}{2}$ in. diameter bars in the form of links will be used, spaced at 18 in. centres.

Had the bent-up bars proved only partially efficient to counteract the shear, the balance of shear remaining for the stirrups would control the stirrup spacing:—

$$s = \frac{A_s \times f_s \times j \times d}{\text{Remaining Shear.}}$$

The maximum shear would be calculated at various sections in the beams so that the stirrup spacing might widen out to a maximum of say $\frac{d}{2}$ or $\frac{2}{3}d$. In many cases 12 in. is regarded as a suitable maximum spacing. The maximum shear at any section X—X in a beam AB will occur with the live load as shown in Fig. 10—the

* 1.41 is the efficiency factor. The formula is developed for vertical stirrups which make an angle of approximately 45° with the plane of diagonal tension; when applied to bent-up bars lying approximately in this plane an efficiency factor of Sec. 45° is used.

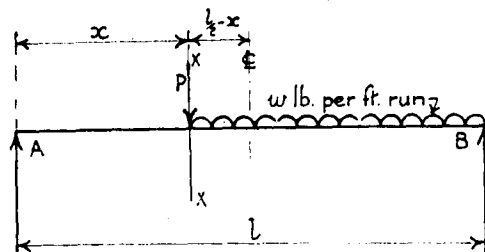


Fig. 10.

uniformly distributed load extending from the section in question to the farther support, and the concentrated load being placed at the section. The shear would then be calculated as follows:—

$$D.L.V. = \left(\frac{l}{2} - x\right) \times \text{dead load per ft. run.}$$

$$L.L.V. = \begin{cases} \frac{(l-x)^2}{2} \times \frac{w}{l}, & \text{where } w \text{ is the distributed load per ft. run.} \\ + \frac{P(l-x)}{l}, & \text{where } P \text{ is the concentrated load.} \end{cases}$$

The maximum shear at the section will then be the sum of the dead and live load shears.

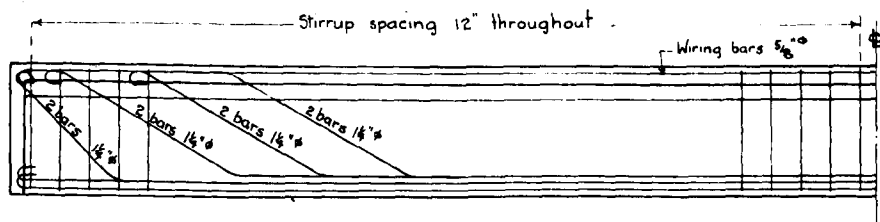


Fig. 11.

The bars in the top two layers would be bent up in pairs as shown in Fig. 11. The first pair to be bent up leave behind 89 per cent. of the cross sectional area of tensile steel in the bottom of the beam, and this should be checked against the requirement for bending moment. The section is at a distance of $15\frac{1}{2}$ ft. from the mid span, or 13 ft. from the theoretical support.

Bending Moment (maximum) at Section where first pair of bars bend up.

$$D.L.M. \quad 28\frac{1}{2} \times 1,401 \times 13 - 13 \times 1,401 \times 6\frac{1}{2} = 514,000 - 118,500 = 395,500$$

$$L.L.M. \quad \begin{cases} \text{By proportion with dead load, } 395,500 \times \frac{1,174}{1,401} = 331,500 \\ 14,400 \times \frac{43\frac{1}{2}}{56\frac{1}{2}} \times 13 = 144,000 \end{cases}$$

$$\underline{\underline{871,000 \text{ ft. lb.}}}$$

This bending moment is no more than 71 per cent. of the maximum moment at mid-span, and is therefore adequately provided for.

It may be seen by inspection that the remaining bends leave the bending moment requirements well met.

Shear at Section where first pair of bent-up bars cross the neutral axis. (20 ft. from mid-span).

$$D.L.V. = 20 \times 1,401 = 28,020$$

$$L.L.V. = \begin{cases} 48\frac{1}{2} \times 1,174 \times \frac{24\frac{1}{2}}{56\frac{1}{2}} = 24,200 \\ 14,400 \times \frac{48\frac{1}{2}}{56\frac{1}{2}} = 12,300 \end{cases}$$

$$\underline{\underline{64,520 \text{ lb.}}}$$

Stirrup spacing (using $\frac{1}{2}$ in. diam. double links, and taking one-third of the shear on the concrete).

$$s = \frac{0.785 \times 16,000 \times .9 \times 46\frac{1}{2}}{\frac{2}{3} \times 64,520} = 12.2 \text{ in.}$$

This is a suitable maximum spacing and will be used throughout the beam.

Bond stress in tensile reinforcement near supports.

Ten bars are run through to the support, and $\Sigma_o = 39.3$

$$\therefore u = \frac{87,150}{39.3 \times .9 \times 46\frac{1}{2}} = 53 \text{ lb. per sq. in.}$$

This is a satisfactorily low value, but it is good practice always to anchor these bars with hooks as close to the end of the beam as possible, allowing say two or three inches of concrete as end cover.

Kerb Beam.

When the Theorem of Three Moments is employed in the design of the deck slab the dead and live load shears occurring on each side of the various beams are determined and the load per foot run of beam follows at once: when however the "reduction factor" method is used, the loads allotted to the various beams (assuming these to be at a fairly uniform spacing) are taken from mid-span to mid-span of the deck slab connecting them (as was done in the case of "Roadway Beams"). With this latter method the error involved is not great for the interior spans of a series of equal spans; with the parapet supported on a cantilever slab the error may in exceptional cases become appreciable in the two outer beams. The parapet beam will carry a little more than the load calculated in this simple manner, and the second beams (in the present case, the kerb beam) a little less. It is therefore safe to extend this method to the case of the kerb beam, but to re-examine it in the

design of the parapet beam. The load allotted to the kerb beam will thus be the total dead load included from mid-span to mid-span of deck slab on either side of it, and the live load will be as for the roadway beams for the portion of deck falling within the limits of the carriageway, and 100 lb. per sq. ft. for the portion of deck allotted to the footpath. The design of the kerb beam would then be conducted in the same manner as has already been demonstrated for the roadway beams. As the flange is at varying levels on either side of the beam the kerb beam may be treated as an inverted L beam, that is, a partial T-beam neglecting the flange at the lower level. If the concrete stresses should then prove too high the compression in the dropped flange might be computed from a knowledge of the position of the neutral axis; the method will be obvious from the demonstration of the design of the T-beam when consideration was given to the compression in the web above the neutral axis.

Parapet Beam.

The loading carried by this beam may be calculated by applying the Theorem of Three Moments to the solution of the deck slab, but as has been explained the variable girder deflections may render this method not appreciably more accurate than some simpler method such as either one of those given below. If the loading from the deck slab is taken as from mid-span, the dead load allotted to the girder, apart from its own weight, will be :

$$\begin{array}{r} \text{from parapet} \quad 330 \text{ lb.} \\ \text{from deck slab, } 6 \times 61 = 366 \\ \hline 696 \text{ lb.} \\ \hline \end{array}$$

This value will err on the low side. A value erring on the high side is obtained by assuming the footpath slab hinged about the kerb girder, and taking moments about the hinge: if the parapet girder reaction is R_p then

$$\begin{aligned} R_p \times 4.58 - [(330 \times 6.25) + (504 \times 3.5)] &= 0 \\ \text{from which } R_p &= \frac{2065 + 1765}{4.58} = 837 \text{ lb.} \end{aligned}$$

It would be not unreasonable to select a figure falling between these two values; two considerations may possibly influence the choice: at some future period it might become necessary for the girder to carry additional load, as if service pipes or cable ducts are extended, or if the parapet should be rebuilt in a heavier style; or if it be decided that the parapet girder should, for the sake of appearance (and because it carries a lighter load), be made shallower than the interior girders, it will be more flexible; for these reasons the value of 837 lb. might reasonably be used in the present design. The cantilever portion of the footway slab available for live load is negligible, and the live load may be allotted to the parapet girder as from mid-span of the slab. The parapet girder design would then proceed in the same manner as for the roadway beams.

The parapet should be constructed so as to be as free from stress as possible. If the girders are allowed to take up their dead load deflection before the parapet is erected, there will be no tendency, at least so far as dead load is concerned, for the parapet to act as a girder. The remaining difficulty is shrinkage, and to avoid trouble from this source, expansion joints should be provided wherever they can be conveniently arranged; a joint can generally be made to occur where the parapet rail runs into a pilaster by providing a housing, the gap being filled with a strip of bituminous felt.

Curtain Wall.

This is constructed at the "fixed" end of the girders, as shown in Fig. 12A, to prevent the back fill from tumbling through on to the bridge seat of the abutment. At the "free" or expansion end, the same arrangement is sometimes employed, but as the pressure between the wall and the fill interferes to a certain extent with the free movement of the structure on expansion, and also with the smoothness of the road surface, it is more usual to employ some other detail such as that shown in Fig. 12B.

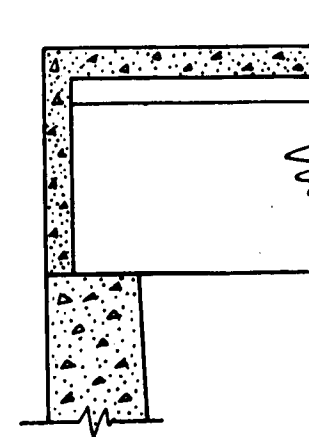


Fig. 12a.

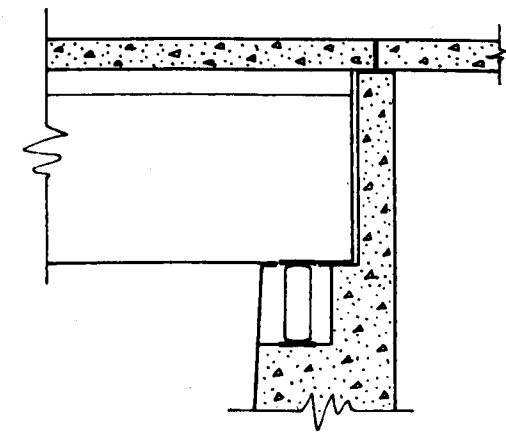


Fig. 12b.

Bearings.

At one end, which on a gradient is the higher one, expansion bearings are provided under each girder. The simplest form for a reinforced concrete deck girder bridge is the simple cast-iron rocker, bearing on steel plates, as illustrated in Fig. 13. The rocker, which is segmental in shape, is made 5 or 6 in. thick depending on span (spans for deck girder bridges range from 30 to 70 ft.). The load per linear inch of rocker may be taken as $300d$, where d is the diameter of the rocker in inches; as the rock is made 1 in. narrower than the girder it supports this unit load determines the diameter (depth). The compressive stress in the rocker section should not exceed 9,000 lb. per sq. in., but this is seldom a controlling factor. Lugs may be cast on

the rocker at either end to engage in slots in the plates so as to hold the rocker in place should the load at any time be taken off them. A pair of 2 in. diameter holes are provided for handling. The plates are usually 1 in. or more in thickness, 8 in. wide, and the same length as the rocker: their strength in bending should be checked on the assumption that the plate acts as a double cantilever, under uniform loading, balanced across a knife edge (rocker contact). The plates should be planed in the direction of the expansion. Rocker and plates should be well painted. These

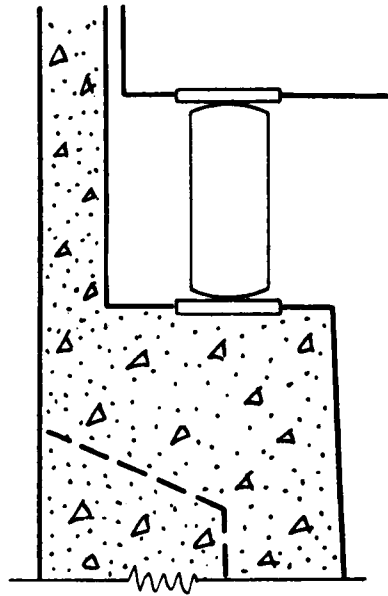


Fig. 13.

bearings are accommodated in open pockets in the abutment top. The sole and bed plates are inset in the concrete of the girder and abutment so as to be left standing $\frac{1}{2}$ in. proud.

This expansion bearing freely permits the two movements which occur at the end of the superstructure—longitudinal movement due to expansion and contraction, and angular movement due to end inclination which accompanies deflection. This latter movement is small in a superstructure of the type now under discussion, and is generally neglected at the “fixed” end where the girder is allowed to rest directly on the concrete surface of the abutment. A chamfer would be provided on the front edge of the bridge seat to prevent spalling of the concrete, as the bearing intensity would naturally be most severe at the front edge. The pressure intensity probably becomes much more evenly distributed in time owing to the effect of plastic yield. In highway bridges of normal width the transverse expansion of the deck is seldom appreciably in excess of that of the abutments, so that the expansion bearings are arranged to provide for longitudinal expansion only.

At the "fixed" end the roadway surface can continue uninterrupted beyond the limits of the bridge, but at the "free" or expansion end the expansion joint must continue through the deck slab. The most suitable expansion device to use here is perhaps a sliding plate detailed as shown in Fig. 14. In the footway slab the detail shown in Fig. 15 is suitable.

Horizontal Curves.

When the carriageway over a bridge forms part of a curved road, it should be dealt with in exactly the same way as if no bridge existed; the bridge is constructed to serve a need, not to impose restrictions: superelevation and transition curves should be used and the roadway should, if necessary, be widened. The bridge seat, that is, the actual bearing area, should always be constructed level, and the girders may be benched up as shown in Fig. 16 by varying amounts, or the bridge seat may be stepped. In the case of a slab bridge the method shown in Fig. 17 is adopted.

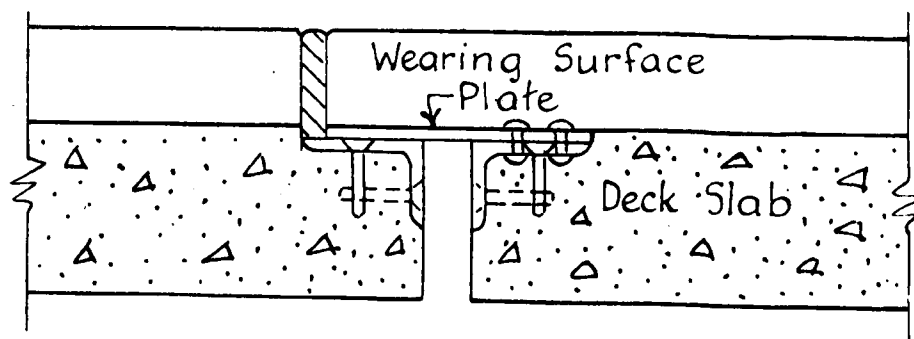


Fig. 14.

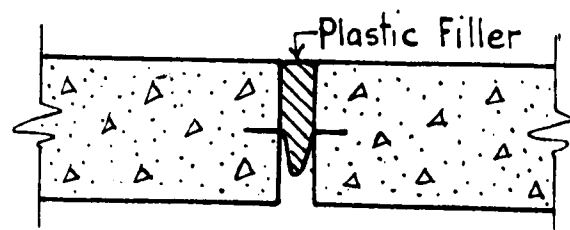


Fig. 15.

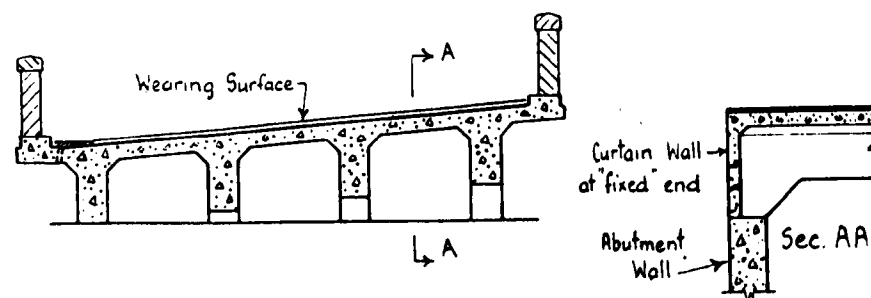


Fig. 16.

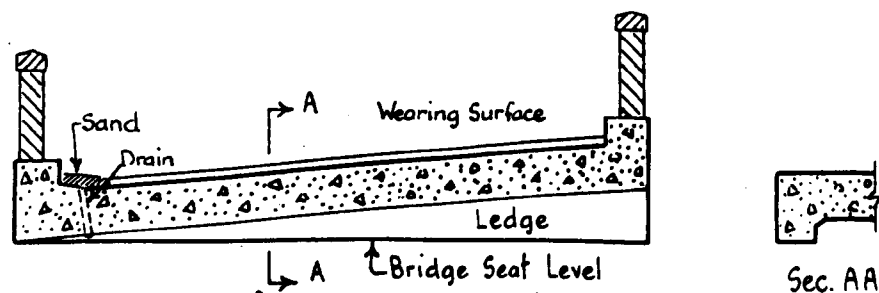


Fig. 17.

STEEL BRIDGES.

There is some difficulty in making a single span plate through-girder appear really pleasing; it is generally constructed under a severe handicap from the immediate locality, as may be seen from Fig. 18. With multiple spans the appearance is more attractive as the perspective in Fig. 42 will show. Details of this bridge are given in Fig. 43, the floor being of the type adopted in the design example. There is less difficulty with the deck-girder as Figs. 19 and 19A demonstrate. Details of a plate deck-girder are shown in Fig. 44.

Much more opportunity for artistry is afforded in the larger bridges where simple lines, easy curves and well balanced proportions give all that is required in many cases to constitute a fine bridge; examples may be seen in Figs. 20 and 21. Fig. 22 is another view of the bridge in Fig. 21, from a different angle and showing a little more detail. Fig. 23 is a photograph of a steel cantilever bridge with a simple and light handrail. Figs. 24 and 25 show other types of steel bridge which allow scope for ingenuity in the design. The tendency in steel bridge design is all towards the elimination of unnecessary and complicated details such as are involved in lattice work (except perhaps for handrailing). Plane surfaces are simple to construct and easy to paint and lend themselves more to suitable proportioning.

Painting of structures is another sphere in which advance has been made. Strong colours such as black and red have given way to the less conspicuous and much more pleasing "battle-ship" grey: A delicate and suitable colour adds to the dignity of a well-designed bridge.

III.—PLATE GIRDER BRIDGES.

Plate girder bridges are used more commonly for railway than for road bridges where the difficulty sometimes experienced of making them fit in pleasingly with the surroundings rather operates against their selection. The type is frequently selected for bridges over railways because of the speed of erection and the avoidance of falsework. The usual spans range from say 40 to 100 ft., although both shorter and longer bridge spans than these have occasionally been employed. Within this range they are lighter than concrete bridges of the deck girder type and may thus prove suitable where foundation difficulties impose a restriction on the permissible dead load. They are sometimes adopted for bridges having an appreciable skew where the span of the supporting members is necessarily fairly large and where a comparatively flexible deck not monolithic with the beams will minimise the complex torsional stresses resulting from the skew. The cost of maintenance is a factor which has to be considered; to encase the girders in concrete would be uneconomical and would destroy the claims advanced above, unless the concrete be applied in the form of gunite. Gunite supplies a sheath of concrete, dense owing to the high pressure resulting from the method of its application, and effective as a protection against corrosion. The simplest method is to paint the steelwork, and if this is done thoroughly at regular intervals the structure will have a long useful life; the fact that proper maintenance is sometimes neglected, and the steelwork is allowed to rust, has had an influence on the choice between steel and reinforced concrete as a building material. There are, however, on the market various brands of

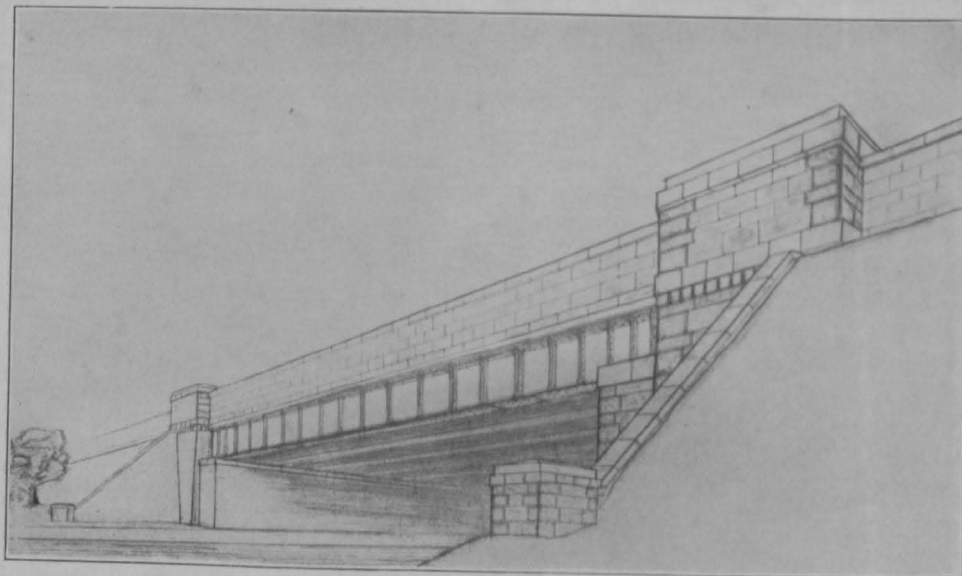


FIG. 19.

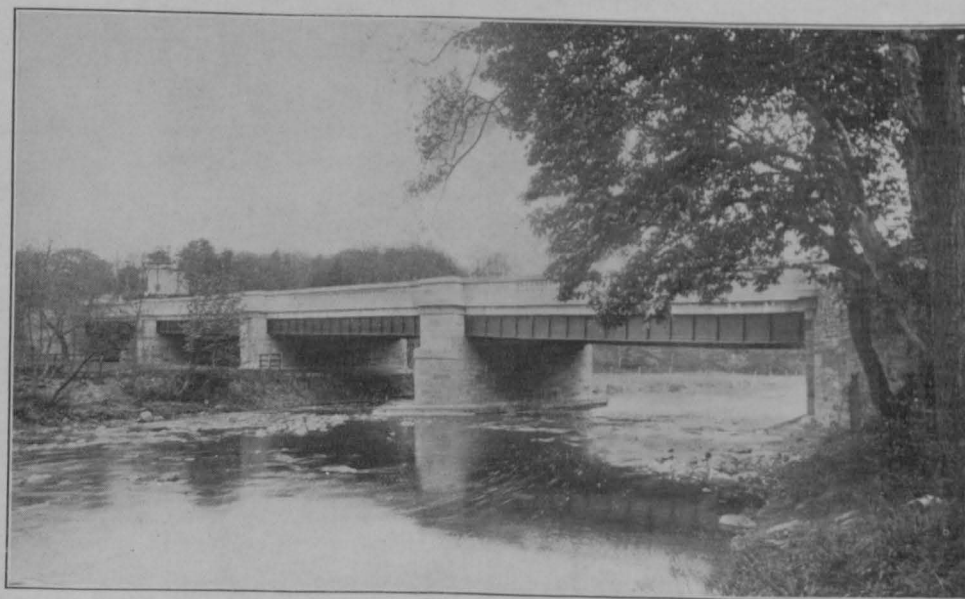


FIG 19A.—Allensford Bridge.

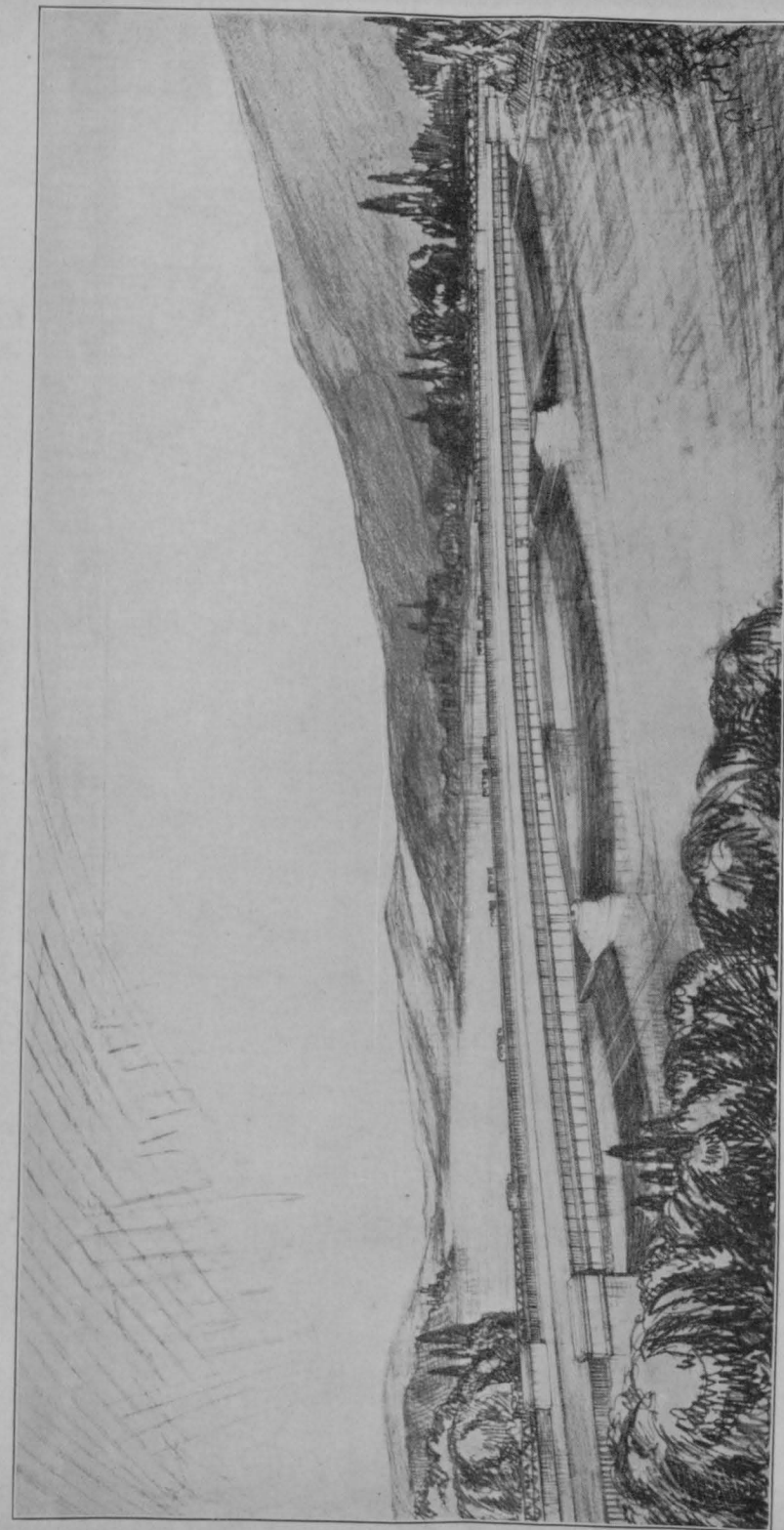
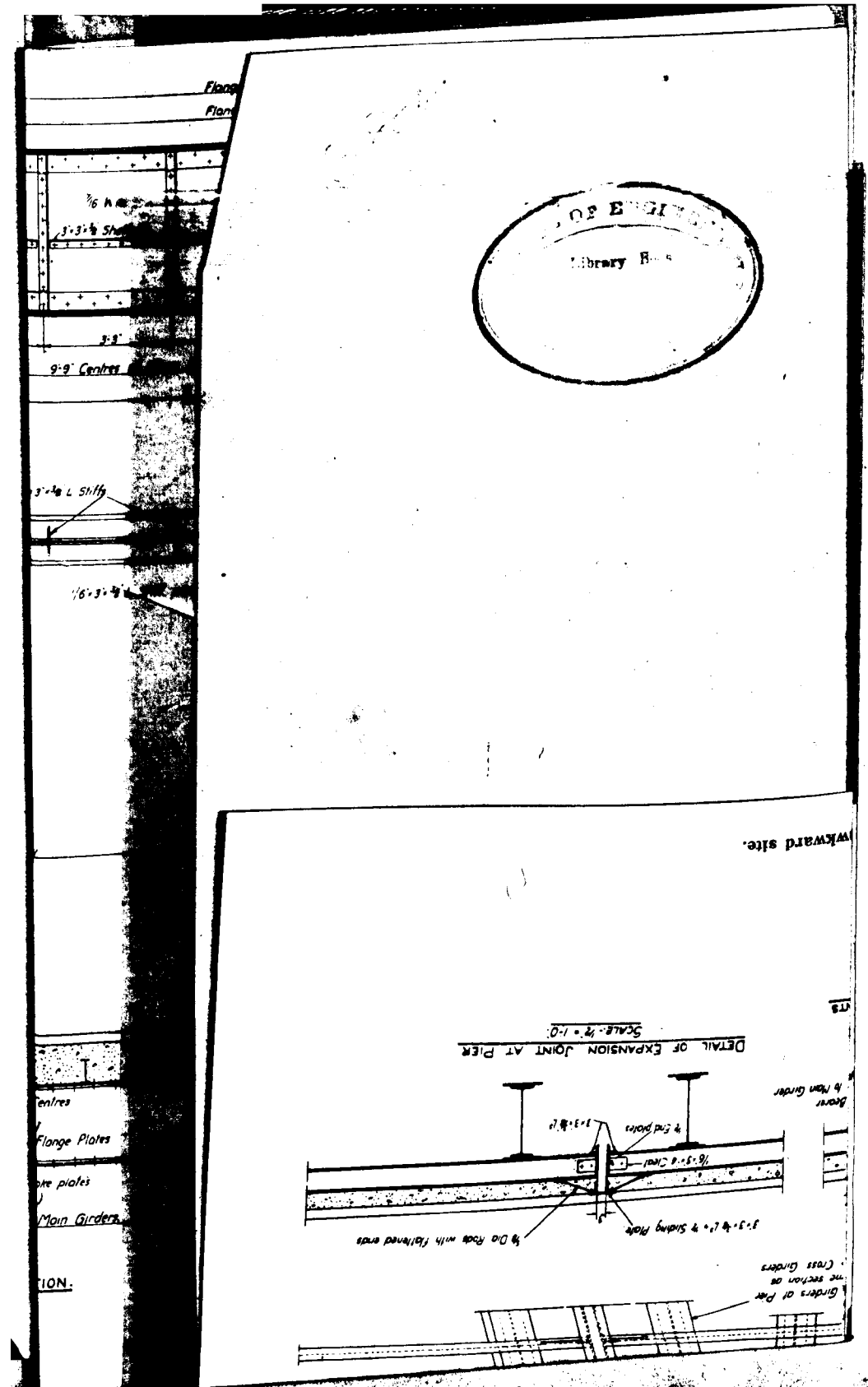


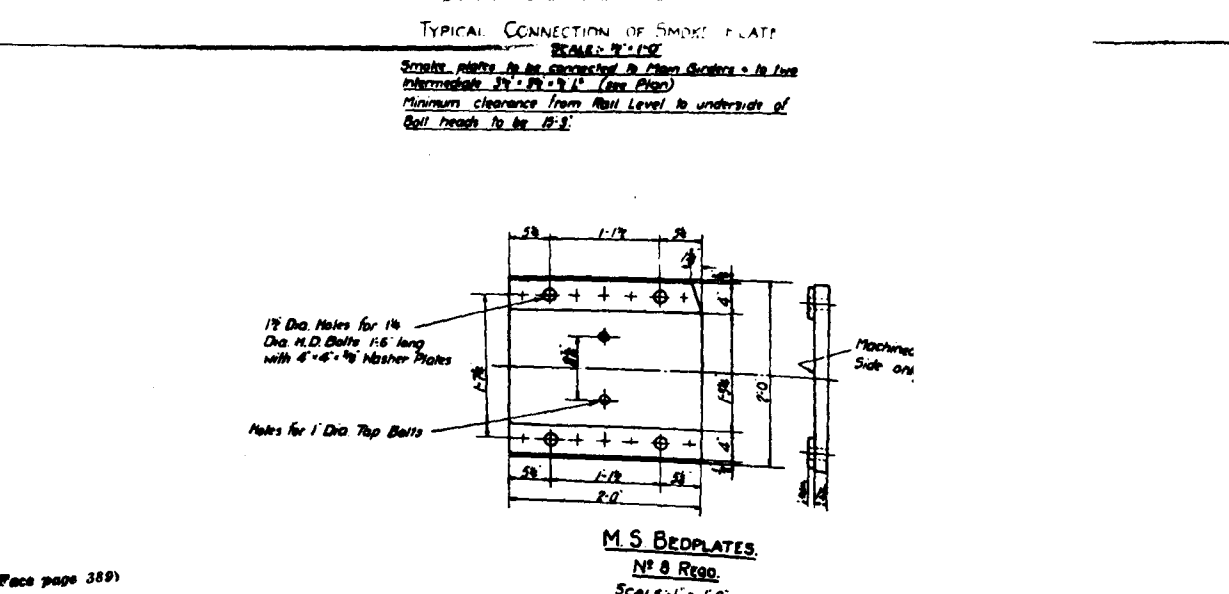
FIG. 20.



FIG. 21.—Augartenbrücke over the Danube Canal in Vienna.

(From a photograph kindly supplied by the British Steelworks Association.)





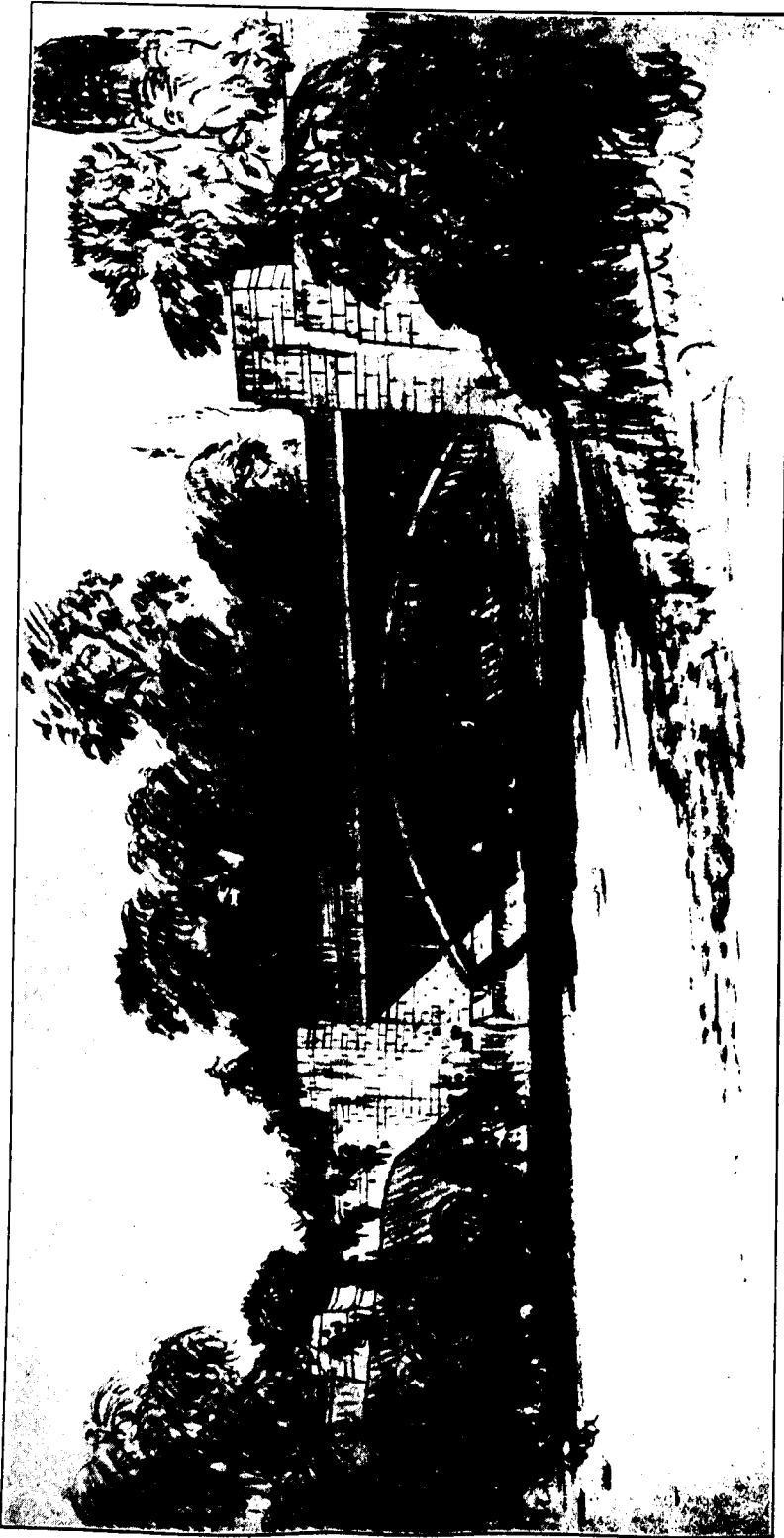
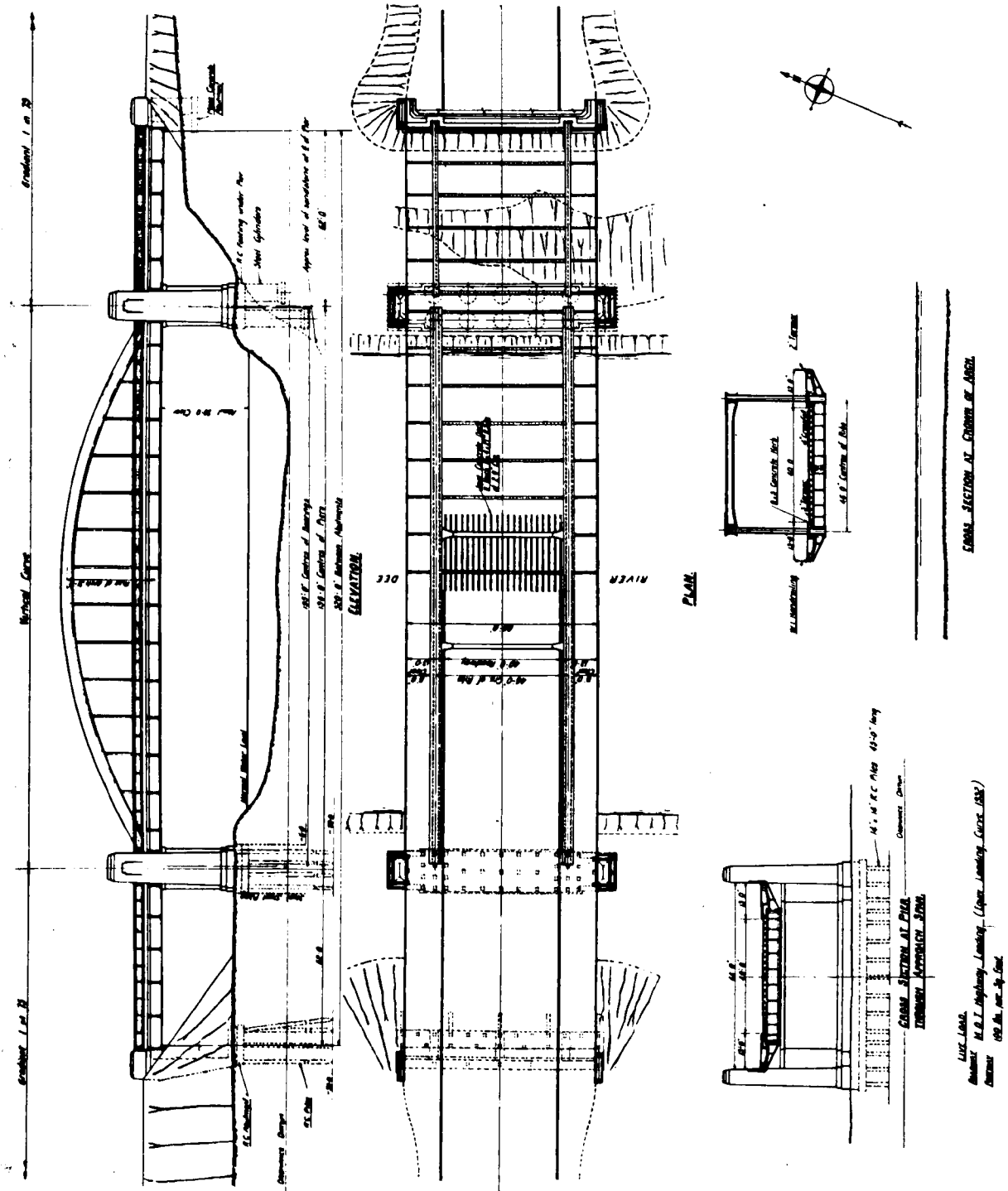


FIG. 24.—A two-hinged Steel Arch.



steel having a copper content, which, experience has shown, has a definite retarding effect on corrosion. High tensile steel for structural work is coming into more frequent use, and the author understands that a new British Standard Specification for this material will be issued in a few months.

There are two types—the plate deck-girder and the plate through-girder bridge. The deck-girder is generally used where head-room allows: it is generally more economical as the load is carried directly to the abutments. The through-girder is used where head-room is restricted and where the roadway is fairly narrow; the loads are carried by the stringers to the floor-beams, by these to the main girders, and thence to the abutments: it is more difficult to treat architecturally as the deep plate girders with top and bottom flanges and with stiffeners is not pleasing in appearance and can scarcely be masked.

The second type includes all of the design points likely to arise in the first type and some further ones beside, so that for demonstration purposes the second type will be selected. Footpaths, when provided, should be cantilevered out from the main girders so as to reduce the span of, and neutralise some of the positive bending moment in, the floor-beams. In a skew through-girder bridge the floor-beams are placed at right angles to the main girder, and the first full-length floor-beam (BC in Fig. 26) is made to frame in over the bearing at the obtuse corner of the superstructure; a trimmer-beam, AB, spanning between the two end bearings is incorporated to pick up the ends of the stringers in the end triangular panel (ABC). The detailed calculations for a skew plate-girder bridge would unduly prolong this paper and become tedious to the reader, so that an example will be given of a bridge having a square span.

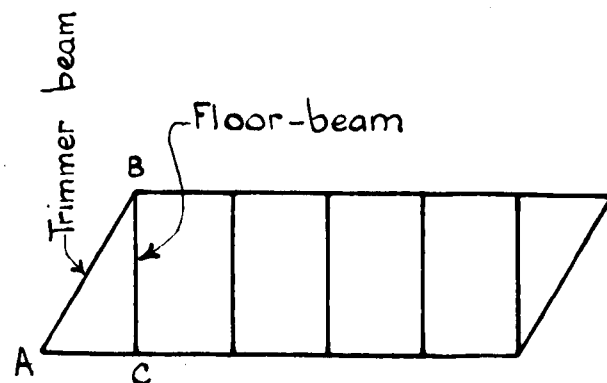


Fig. 26.

Example.

Design a plate through-girder superstructure having a clear span of 87 ft. Roadway width 20 ft. (Generally a footpath would be required, and this would be cantilevered outside the main girders. It is omitted here for purposes of simplicity. No very difficult points occur in its design).

The specification governing the design of the steelwork is the current British Standard Specification for Girder Bridges, No. 153 (now under revision); Parts 1 and 2 are published as revised May, 1933, but Parts 3, 4 and 5 are still those published in 1923; in Part 3, clauses 13, 14 and 18 have been revised and issued under date of

September, 1933. The loading governing the design is the Ministry of Transport Equivalent Loading as shown in Fig. 1.

The stringer spacing will depend upon the span suitable for the deck slab, and since the live load allocated to each stringer must be at least that calculated on a 5 ft. wide strip, it will generally be economical to space the stringers at about 5 ft. centres. The exact spacing will depend on the roadway width and in the present case 5 ft. is a suitable spacing to adopt, with 4 ft. 6 in. for the side bays to allow for loss of continuity effect in the deck slab. If in detailing the deck slab the reinforcing bars are run straight through in both top and bottom of the slab, advantage may be taken of the compressive strength of the steel reinforcement to keep the deck slab as thin as possible; the minimum thickness is taken as 7 in. (In exceptional cases such as in very long span bridges where dead load must be reduced to a minimum, the deck slab may be made only 6 in. thick).

DESIGN OF DECK SLAB.

Dead Load.	Wearing surface, 2 in. asphalt	= 20
	Concrete slab, 7 × 12	= 84
		—
	Total	= 104 lb. per sq. ft.
		—

Bending Moment ("Continuity reduction" factor used for live load = 0.8).

$$\text{D.L.M. (at support)} = \frac{1}{12} \cdot 104 \cdot 5^2 = 217$$

$$\text{L.L.M.} = \left(\frac{1}{16} \cdot 1225 \cdot 5^2 = 3,063 \right)$$

$$= \left(\frac{1}{8} \cdot 2700 \cdot 5 = 2,700 \right)$$

$$5,980 \text{ ft. lb.}$$

A good quality concrete should be used for the deck slab; in the present design a 120 lb : 2 : 4 mix will be used, for which the allowable compressive stress is 900 lb. per sq. in. (see Table I). For full efficiency of both steel and concrete the steel ratio p is .0129, and $R = 174 \frac{1}{2}$, and the moment of resistance of such a slab is obtained from the formula $M = R \cdot b \cdot d^2$. Assuming $\frac{5}{8}$ in. diam. bars and a clear concrete cover of $\frac{3}{4}$ in. the effective depth, $d = 5.94$ in.

$$M = \frac{174 \frac{1}{2} \times 12 \times (5.94)^2}{12} = 6,150 \text{ ft. lb.}$$

This is slightly in excess of the requirement and it will be unnecessary therefore to rely on compressive reinforcement. Using the applied bending moment,

$$R = \frac{5,980}{(5.94)^2} = 170, \text{ for which } p = .0126$$

$$A_s = 12 \times 5.94 \times .0126 = 0.897 \text{ sq. in.}$$

The reinforcing steel supplied would be $\frac{5}{8}$ in. diam. bars at 4 in. centres (= 0.92 sq. in.), or $\frac{3}{4}$ in. diam. bars at 6 in. centres (= 0.88 sq. in.), and these would be run straight through in both top and bottom of the slab in a direction at right angles to the stringers; the smaller diameter bars at closer spacing afford more bond area. The distribution steel employed (see Fig. 1) would be 45 per cent. of the main reinforcement,

$$0.45 \times 0.897 = 0.404 \text{ sq. in.}$$

$\frac{1}{2}$ in. diam. bars at 6 in. centres = 0.39 sq. in., and these would be arranged as shown in Fig. 27.

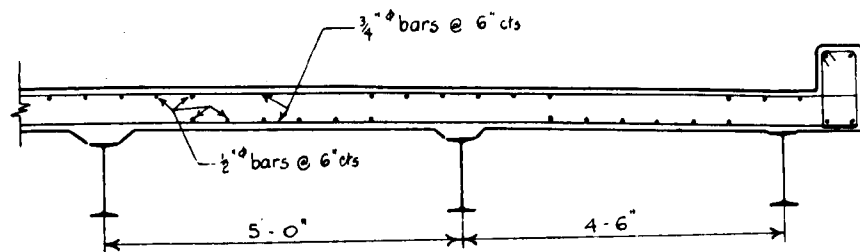


Fig. 27.

The deck slab would be cambered transversely to provide for surface drainage; if the mid-ordinate is made 1 per cent. of the carriageway width, this will be 0.20 ft. or $2\frac{1}{2}$ in. The slab should be constructed of constant thickness, and the stringers can be erected at a constant level if the deck slab is raised a small distance above the stringers as shown in Fig. 27. The longitudinal distribution bars should be increased in the top of the slab over the floor-beams as some negative moment is bound to occur at this point, whether or not the concrete slab is benched on to the floor-beam flange.

At the ends of the deck slab the main reinforcing steel should be increased for a short distance as there will be no secondary bending in a longitudinal direction to relieve the bending moments in the direction of the slab span.

DESIGN OF STRINGERS.

The floor beams are generally spaced from 10 to 20 ft. apart, and the stringers will span as simply supported beams between them. The effective span of the main girders is approximately 90 ft. so that 9 panels at 10 ft. might be a suitable arrangement. With a comparatively short span, the stringers are less flexible and there is less danger of the deck slab cracking above the floor beam from lack of continuity in the top flange of the stringer.

Dead Load.

From 5 ft. strip of deck slab and W.S.,	$5 \times 104 = 520$ lb.
Assumed weight of R.S.J.	30
	550 lb. per ft. run.

Live Load.

Uniformly distributed load	$5 \times 220 = 1,100$ lb. per ft. run.
Knife edge load	$5 \times 2,700 = 13,500$ lb.

It is reasonable to suppose that the deck slab will exercise sufficient restraint on the compression flanges of the stringers to prevent buckling, so that no reduction on the 9 tons (20,160 lb.) per sq. in. need be made in the allowable stress.

Bending Moment.

D.L.M.	$\frac{1}{8} \cdot 550 \cdot 10^2 = 6,875$
	$\frac{1}{8} \cdot 1,100 \cdot 10^2 = 13,750$
L.L.M.	$\frac{1}{4} \cdot 13,500 \cdot 10 = 33,750$
	54,375 ft. lb.

$$\text{Required section modulus, } Z = \frac{54,375 \times 12}{20,160} = 32.4 \text{ in.}^3$$

Use a 12 in. $\times$ 5 in. R.S.J. (30 lb.), $Z = 34.49 \text{ in.}^3$

$$\text{Then } = \frac{54,560 \times 12}{34.49} = 19,000 \text{ lb. per sq. in. (8}\frac{1}{2} \text{ tons approx.)}$$

Shear.

D.L.V.	$5 \times 550 = 2,750$
	$5 \times 1,100 = 5,500$
L.L.V.	Concentration = 13,500
	21,750 lb.

$$\text{Average unit shear} = \frac{21,750}{12 \times 0.33} = 5,500 \text{ lb. per sq. in.}$$

The allowable average shear stress is 12,320 lb. per sq. in. (5 tons); it is generally unnecessary to calculate shear in the stringers, as with normal proportions fibre stress in bending governs.

Connexion to Floor Beam. (See Fig. 28).

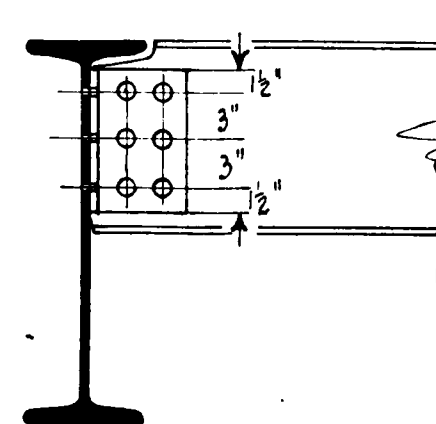


Fig. 28.

Standard cleats are used for this purpose and in some cases shelf angles are also employed.

Design of Floor Beams (spaced at 10 ft. centres).

The loading is represented diagrammatically in Fig. 29. The concentrations at B, C and D will each be equal to the shear reactions from the stringers which frame in on either side of the floor beam; the knife edge load will occur immediately above the beam, and therefore should not be included in the stringer reactions which will then become $2(2,750 + 5,500) = 16,500$ lb. A and E will each be equal to approximately* one half of this amount, or 8,250 lb. The distributed load will be that due to the dead load of the floor beam (assume 90 lb. per ft. run) and the knife-edge load of 2,700 lb. per ft. run.

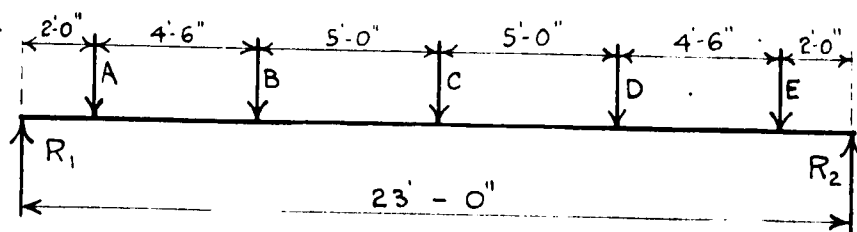


Fig. 29.

Shear.

$$R_1 = \frac{23}{2}(2,700 + 90) + 16,500\left(\frac{1}{2} + 1 + \frac{1}{2}\right)$$

$$= 32,100 + 33,000 = 65,100 \text{ lb.}$$

Bending Moment.

$$M = 65,100 \times 11\frac{1}{2} - 33,000 \times 5 - 32,100 \times 5\frac{1}{2}$$

$$= 749,000 - 165,000 - 184,500 = 399,500 \text{ ft. lb.}$$

If an R.S.J. is employed it will be necessary to rivet a plate to either flange for the middle 8 to 10 ft. The compression flange is not "stayed" in the same way as in the stringers, so that some reduction in the general 9 tons per sq. in. stress will have to be made to conform to the B.S.S. (Part 3, Clause 18). The allowable stress is given by the formula $9(1 - 0.01 \frac{l}{b})$ tons per sq. in. If it is reasonable to assume the floor-beam as stiffened at the points where the stringers frame in, $l = 5$ ft., and with a 24 in. $\times$ 7 $\frac{1}{2}$ in. R.S.J., $b = 7\frac{1}{2}$ in., $\frac{l}{b}$ therefore equals 8, and the allowable

* It is unnecessary in a demonstration of the method to occupy space in calculating kerf weight, etc., in the same way the knife edge load has for simplicity been assumed over the full span of 23 ft. and the weight of the stringer connexion cleats has been neglected. In actual designs the loads should be taken more accurately.

stress is $9 \times 0.92 = 8.28$ tons per sq. in. (18,550 lb.). The required section modulus will be

$$Z = \frac{399,500 \times 12}{8.28 \times 2,240} = 259 \text{ in.}^3$$

The steel handbooks give details and properties of compound girders, and a section suitable for these floor-beams could be made up of an R.S.J. 24 in. $\times$ 7 $\frac{1}{2}$ in. (90 lb.) having a plate 9 in. $\times$ $\frac{1}{2}$ in. rivetted to each flange with $\frac{7}{8}$ in. rivets; the section modulus is 273.3 in.³. It would not be considered worth while to differentiate between the tension and compression flanges although a working stress of 9 tons per sq. in. is permitted in the tension flange.

The end floor beams carry a lighter load than the intermediates and may, if desired, be made of lighter design.

Alternative Floor System.

It may in some cases, with fairly narrow roadways, be economical to dispense with stringers by placing the floor-beams closer together. In the bridge now under discussion, if the same floor slab were used, the floor-beams would be spaced at about 5 ft. centres. The dead load from the deck slab would be 520 lb. per ft. run as in the case of the stringers, the uniformly distributed load would be 1,100 lb. per ft. run, and the knife edge load 2,700 lb. per ft. run. These aggregate 4,320 lb. per ft. run, or say 4,400 including the weight of the beam itself.

Bending Moment.

$$M = \frac{1}{8} \cdot 4,400 \cdot 23^2 = 291,000 \text{ ft. lb.}$$

$$\text{Required section modulus, } Z = \frac{291,000 \times 12}{9 \times 2,240} = 173 \text{ in.}^3$$

The section modulus of a 24 in. $\times$ 7 $\frac{1}{2}$ in. (90 lb.) R.S.J. is 203.6, so that the spacing could be increased if the deck slab be re-designed for a slightly longer span. The deck slab would be cambered as before and would be benched on the top flange of the floor beams in the manner employed for the stringers in the first design. This floor system without stringers is simpler to construct and even when it requires a little more steelwork than the stringer system, it may, owing to the reduced labour requirements, prove economical; with wide roadways it is more economical to use stringers.

Design of Main Girders (see Fig. 30).

Adopting the floor system as designed with stringers the main loading is brought into the main girders at 10 ft. intervals. With the roadway fully loaded the concentration at each load point will be the shear calculated at the ends of floor beams, less that due to the knife-edge load which will occur at only one point in the span.

$$65,100 - \frac{23}{2} \cdot 2,700 = 65,100 - 31,100 = 34,000 \text{ lb.}$$

The effective depth of the main girders is generally from $\frac{1}{10}$ to $\frac{1}{12}$ of the span, but may be somewhat less in exceptional cases. In the present design a 7 ft. 6 in. deep web plate will be adopted, and the thickness will be assumed as $\frac{1}{2}$ in. In determining the maximum bending moment an allowance of 500 lb. per ft. run will be made for the weight of the girder itself.

Bending Moment at mid-span.

Due to floor beam loads,	$4 \times 34,000(45-20) =$	3,400,000
„ „ knife edge load (approx.)	$*\frac{1}{4} \times 31,100 \times 90 =$	700,000
„ „ dead load of girder	$\frac{1}{8} \times 600 \times 90^2 =$	608,000
		4,708,000 ft. lb.

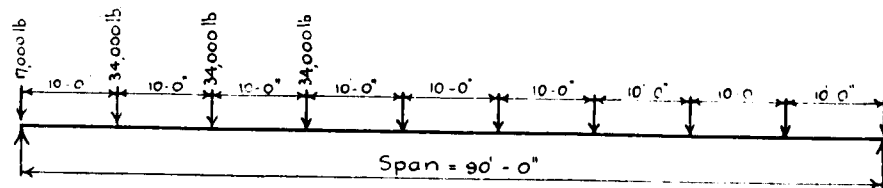


Fig. 30.

Approximate net flange area required (tension flange)

$$\frac{4,708,000 \times 12}{90 \times 20,160} = 31.3 \text{ sq. in.}$$

The B.S.S. states that "Flange angles shall form as large a part of the area of the flange as practicable, and the number of flange plates shall be reduced to a minimum." The flange angles are generally made to form from $\frac{1}{3}$ to $\frac{1}{2}$ of the total area, and in a girder of appreciable span at least three cover plates would be employed for each flange, one of which plates should extend for the full length of the girder.

Trial Section.

Web 90 in. $\times$ $\frac{1}{2}$ in.	= 153.0 lb.
4 Angles, 6 in. $\times$ 6 in. $\times$ $\frac{3}{4}$ in.	= 114.76 lb.
6 Cover plates 16 in. $\times$ $\frac{3}{8}$ in.	= 122.40 lb.

$$390.16 \text{ lb.}$$

Assume stiffeners, rivets, etc. = 80

Dead load of girder approximately = 470 lb. per ft. run.

* The knife-edge load will be brought on to the girder by the floor-beam nearest to mid-span; for simplicity in the present design it has been assumed at mid-span: the error involved is small and is on the safe side.

Flange Area (Rivets $\frac{7}{8}$ in., holes $\frac{1}{16}$ in.) see Fig. 31.

Instead of determining the moment of inertia and section modulus of the built-up girder, it is simpler to assume the bending stresses as borne wholly by the flange;

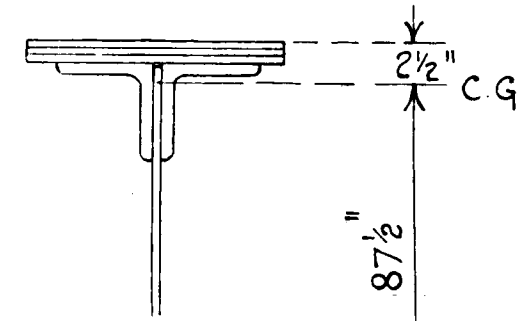


Fig. 31.

in order to make some allowance for the stress in the outer fibres of the web, it is usual to assume $\frac{1}{8}$ of the gross web area as net flange area in both compression and tension.

<i>Gross Area.</i>	<i>Rivet Holes.</i>	<i>Net area.*</i>	<i>Distance of C.G. from top of outer plate.</i>	<i>= Moments about top of outer plate.</i>
2 angles, 6"×6"× $\frac{3}{4}$ " = 16.874	—4× $\frac{1}{8}$ × $\frac{3}{4}$ = 14.06		2.885	40.60
3 plates, 16"× $\frac{3}{8}$ " = 18.0	—6× $\frac{1}{8}$ × $\frac{3}{8}$ = 15.89		0.563	8.95
$\frac{1}{8}$ of web, 90"× $\frac{1}{2}$ " = (11.25× $\frac{1}{2}$)	= 5.62		6.75	37.95
40.494 sq. ins.		35.57 sq. in.		87.50

Distance of C.G. of flange from top of outer plate

$$\frac{87.50}{35.57} = 2.46 \text{ in.}$$

The distance back to back of angles is made slightly more (say $\frac{1}{4}$ in.) than the depth of the web plate for a constructional reason. The over-all depth of the girder is thus 7' 6" + 2 $\times$ 1 $\frac{1}{4}$ " + $\frac{1}{4}$ " = 7' 8 $\frac{1}{2}$ ", and the effective depth is 7' 3 $\frac{1}{2}$ " = 87 $\frac{1}{2}$ ".

Tension Flange.

The average stress in the tension flange will be

$$\frac{4,708,000 \times 12}{35.57 \times 87.5} = 18,150 \text{ lb. per sq. in.}$$

Assuming the neutral axis at half the depth, the stress in the extreme fibre would be

$$\frac{18,150 \times (43.75 + 2.5)}{43.75} = 19,200 \text{ lb. per sq. in.}$$

This is a little below the maximum permissible stress, and the flange area might be slightly reduced if desired.

Compression Flange.

Stiffeners will be provided at all floor-beams and midway between them so that they will occur at 5 ft. intervals. The permissible compressive stress in the flange is obtained by the formula :—*

$$\begin{aligned} 9(1-0.0075\frac{l}{b}) &= 9(1-0.0075 \times \frac{60}{16}) \\ &= 8.74 \text{ tons per sq. in. (19,600 lb.)} \end{aligned}$$

Since the compressive stress is calculated on the gross section the actual stress will be well below the maximum permissible.

$$\text{Average} = \frac{4,708,000 \times 12}{40.49 \times 87.5} = 15,950 \text{ lb. per sq. in.}$$

This is a low stress but the B.S.S. infers that the gross area of the compression flange should be equal to the gross area of the tension flange.

Three plates have been used in the make-up of each flange. One plate would be run (with splice) for the full length of the girder to act as a protection to the angles and web joint. The other two plates would be stopped off at different points depending upon the bending moment requirements. The maximum bending moment can be found at various sections quite easily by moving the knife-edge load (as the only variable) from section to section. The cover plates then act in the same way as the tensile reinforcement in the bottom of the reinforced concrete girder, and the points where the plates may be stopped are found in the same way that the bends are determined for the bent-up bars: the bent-up bars, however, are anchored in the beam and are already stressed at the bend; the cover plates must be "anchored" by carrying them beyond the point at which they are calculated to stop. In this extended length sufficient rivets are employed at a pitch not to exceed $4\frac{1}{2}$ rivet diameters to develop one half of the strength of the plate, and the same rivet pitch should extend for a further equal distance inside the theoretical stopping-off point.†

Connecting the Flange to the Web.

General Case (see Fig. 32).

Rivets are employed to develop the stress in the flange. Under load the girder deflects, the web bears on the rivets and the rivets in turn bear on the flange angles and plates. We have to consider the bearing intensity of the rivet on both web and flange units, and the shear stress in the rivet itself: one or other of these will help to govern the rivet spacing.

* B.S.S. No. 153, Part 3, Clause 18 (revised September, 1933).

† B.S.S. No. 153, Part 4, Clause 11.

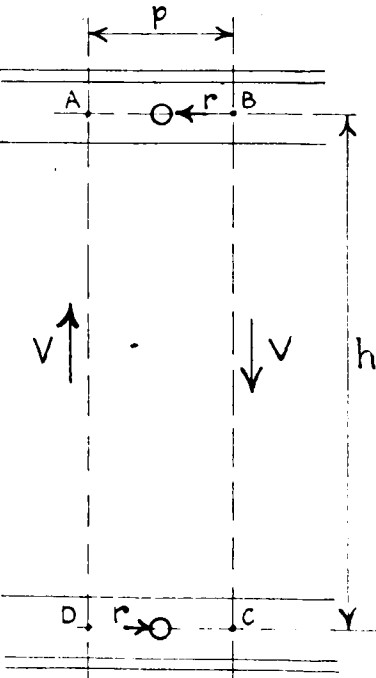


Fig. 32.

Consider the small strip of girder represented in Fig. 32, the length of which is taken equal to the rivet pitch p so that the flange stress increment is that due to one rivet; the length is short and the shear V may be taken as constant. Considering the strip of web, the forces acting upon it are indicated by the arrows; the shear forces V are supplied from the adjacent web, and the forces r acting through the rivets are the reactions developed in the flanges as a result of the bending of the web. Taking moments about D,

$$\begin{aligned} V \cdot p &= r \cdot h \\ \therefore p &= \frac{r \cdot h}{V} \end{aligned}$$

r will be taken as the allowable bearing value of the rivet on either unit, or as the value in double or single shear as the case may be.

Vertical Legs of Angles (Fig. 33).

The rivet will be in double shear, and the bearing value will probably determine the pitch. Since $\frac{1}{8}$ of the web has been included as flange area, a portion of the total stress only has to be transferred. Since the tension flange only is required to work at the maximum stress the sectional areas used to proportion the loads for transfer through the rivets will be taken as the *net* areas.

The allowable bearing stress in shop rivets† is 15 tons per sq. in. A $\frac{7}{8}$ in. rivet bearing on a $\frac{1}{2}$ in. web plate has a value of 6.56 tons, or 14,700 lb. The double

† B.S.S. allows the effective diameter of the rivet to be taken as equal to the rivet hole which is $\frac{1}{16}$ in. greater than the nominal size of the rivet. The present design uses the nominal diameter as the effective, and this is the safer practice.

shear value for a $\frac{7}{8}$ in. shop rivet, at an allowable stress of 6 tons per sq. in. is 7.22 tons, so that the bearing value governs.

The maximum shear in the girder will occur near the support, when the knife edge load is brought into the main girder by the first floor-beam framing in after leaving the support.

Shear.

Due to D.L. of girder	$= 45 \times 470$	$= 21,200$
„ „ floor-beam loads	$= 4 \times 34,000$	$= 136,000$
„ „ knife edge load		$= 31,100$

Total shear $= 188,300$ lb.

The flange near the support will consist of:—

2 angles $6'' \times 6'' \times \frac{3}{4}''$ with net area	$= 14.06$ sq. in.
1 plate $16'' \times \frac{3}{8}''$ with net area	$= 5.30$ sq. in.
	$\hline 19.36$ sq. in.
$\frac{1}{8}$ web	$= 5.62$ sq. in.
	$\hline$
Total	$= 24.98$

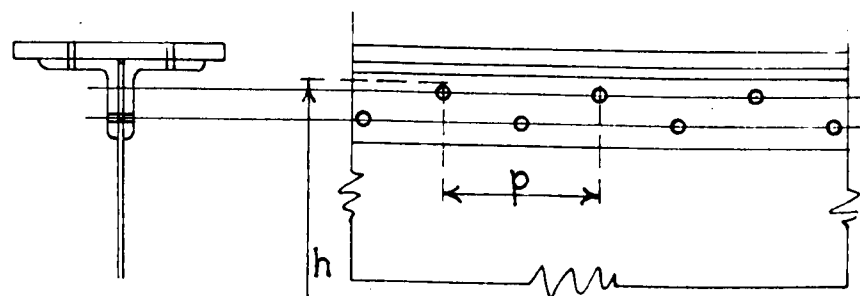


Fig. 33.

The shear to be transferred by rivets is thus

$$\frac{19.36}{24.98} \text{ of } 188,300 = 146,000 \text{ lb.}$$

With double gauge lines (staggered rivets) the rivet pitch in each gauge line will thus be (using an average value of $83\frac{1}{2}$ in. for h)

$$= \frac{2 \times 14,700 \times 83\frac{1}{2}}{146,000} = 16.8 \text{ in.}$$

The maximum pitch permissible in each gauge line is 12 in. and this spacing would be adopted.

Where the flange area is increased by the additional plates the proportion of shear to be transferred will be greater although the total shear will be less, and the rivet spacing can be calculated at these points in the manner demonstrated above.

Horizontal Legs of Angles.

The shear to be transferred near the support will be $\frac{5.30}{24.98}$ of 188,300. It is

obvious that the maximum allowable pitch of 12 in. in each gauge line would in the present design govern. In other cases the method of calculating the pitch is exactly the same as for the vertical legs of the angles. In detailing the B.S.S. should be consulted for edge distances, etc., and the positions of the gauge lines, etc., are shown in the standard steel handbooks.

Combined Stress on Rivets.

When any loading is brought directly on to a flange, as in a deck-girder where the deck is made to rest directly on the top flange, a further stress occurs in the rivet. In Fig. 34 if the load on a rivet in the vertical leg calculated as previously described is r , and the vertical load from the weight of the deck etc. is w , these two forces must be combined as vectors and the resultant stress R calculated and this will govern the rivet spacing.

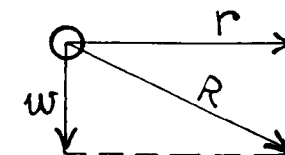


Fig. 34.

Rivets passing through packing, and carrying calculated stress must be detailed to work at lower stress, as must also field rivets. The B.S.S. should be consulted for these regulations.

Flange Splices.

Whenever possible the flange units are constructed without splices, but where this is impossible the splices are arranged at different points for the various units. An additional plate would be provided on the outside of the flange; if the angles are spliced a short length of angle might possibly be used, machined to fit snug to the main angles, otherwise bent plates would be employed. Sufficient rivets should always be provided to develop the full strength of the plates it is required to connect. It will often be convenient to extend the outer cover plates slightly so as to make the extension act as a splice to a joint arranged in the plate below.

Web Splice.

It is impossible in spans of appreciable length to obtain a web plate in one piece. The splice is made either at mid-span where the shear is a minimum, or at a third point where the shear is comparatively low and where the bending moment is not a maximum. It is generally considered better to employ three splice plates on either side of the web, as shown in Fig. 35, the one plate to develop shear resistance and the pair to resist the bending moment for which $\frac{1}{3}$ of the web bears the responsibility. This type should always be employed when the splice is made at mid-span where the bending moment is a maximum. If the section selected is one where the moment is comparatively small (and this is seldom the case) a single plate might be used.

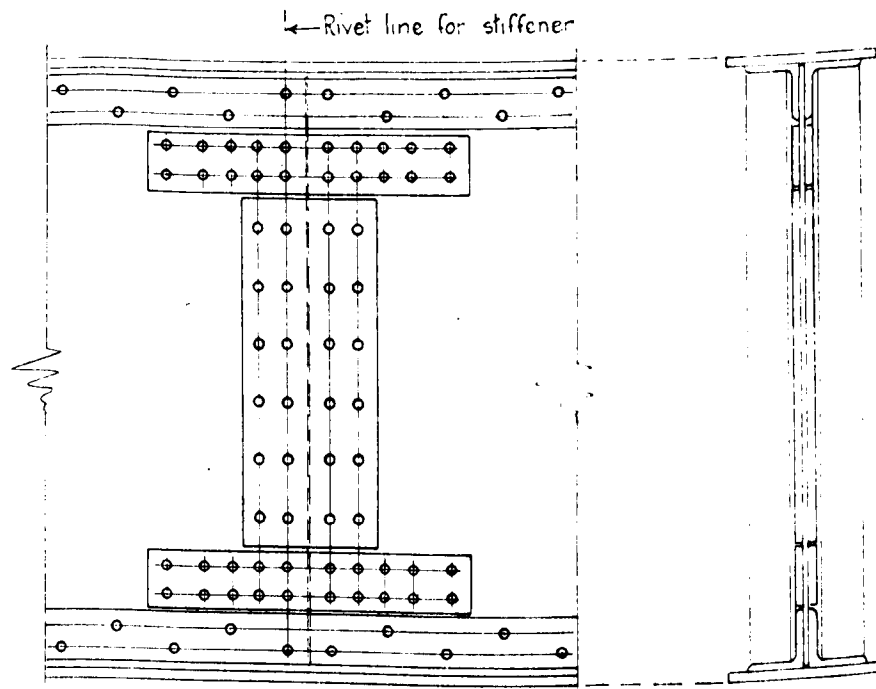


Fig. 35.

Assuming a splice to occur at a one-third point the shear would be calculated at that section with live load over the two-thirds of the span, and the knife edge load on the nearest loaded floor-beam. If the maximum shear at the section is V_1 the number of $\frac{3}{8}$ " rivets required for the shear splice on each side of the joint is $\frac{V_1}{14,700}$;

this assumes shop rivets with a bearing value on the $\frac{1}{2}$ in. web of 14,700 lb. These rivets would be arranged in two vertical rows as shown in Fig. 35, and would be subject to the maximum spacing requirements of the B.S.S.

The moment plates should be designed for the maximum moment at the section and would be stressed in proportion to their distance from the neutral axis: they should develop the same resisting moment as would be calculated for $\frac{1}{3}$ of the web as flange area at that section: the cross-sectional area of the plates should be taken after deduction is made for rivet holes, and the number of rivets should be sufficient to develop the calculated strength of the plates.

If the splice is made at mid-span where the flange is working at maximum stress the following method may be adopted.

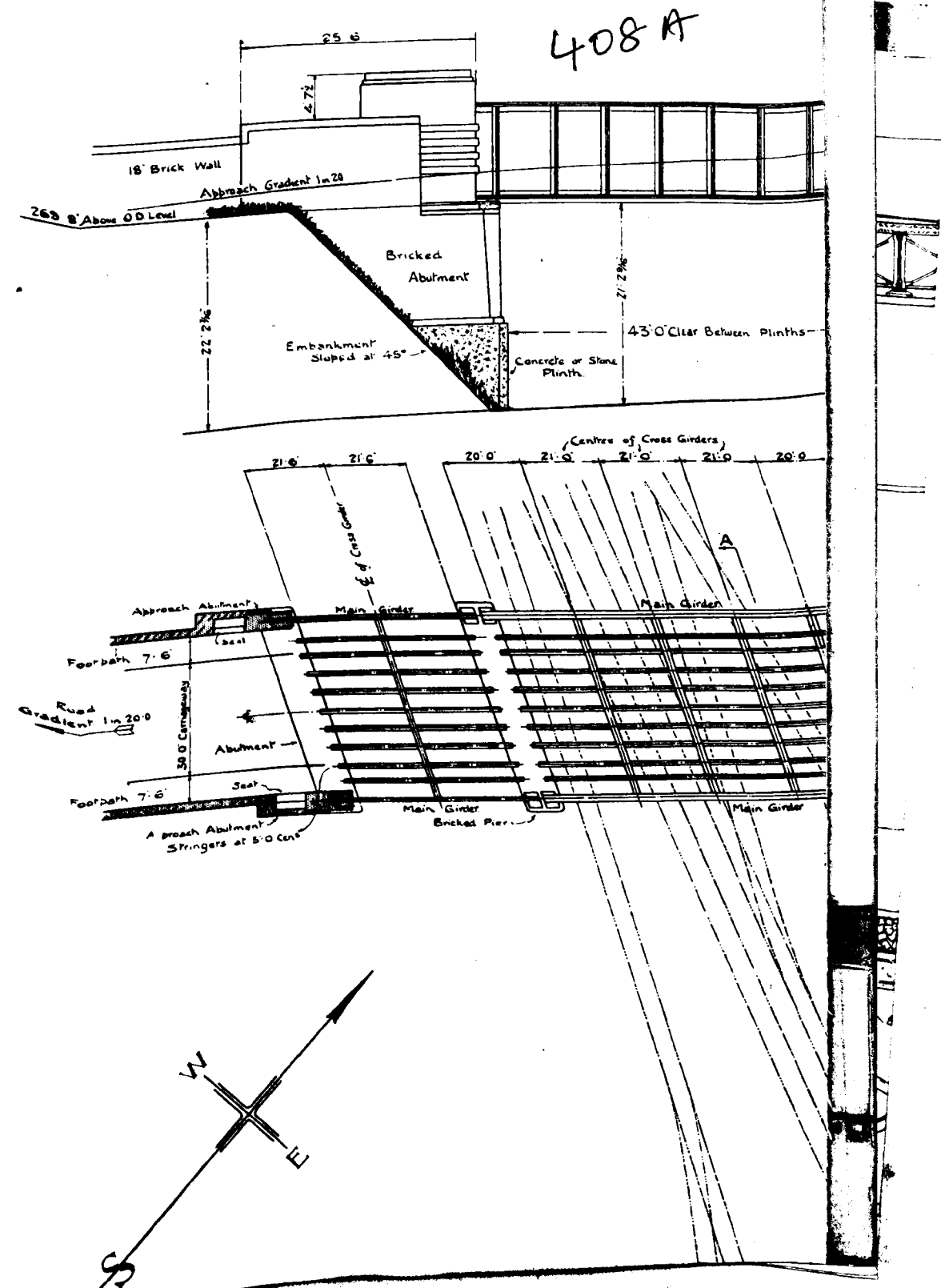
If f = allowable unit stress in flange.

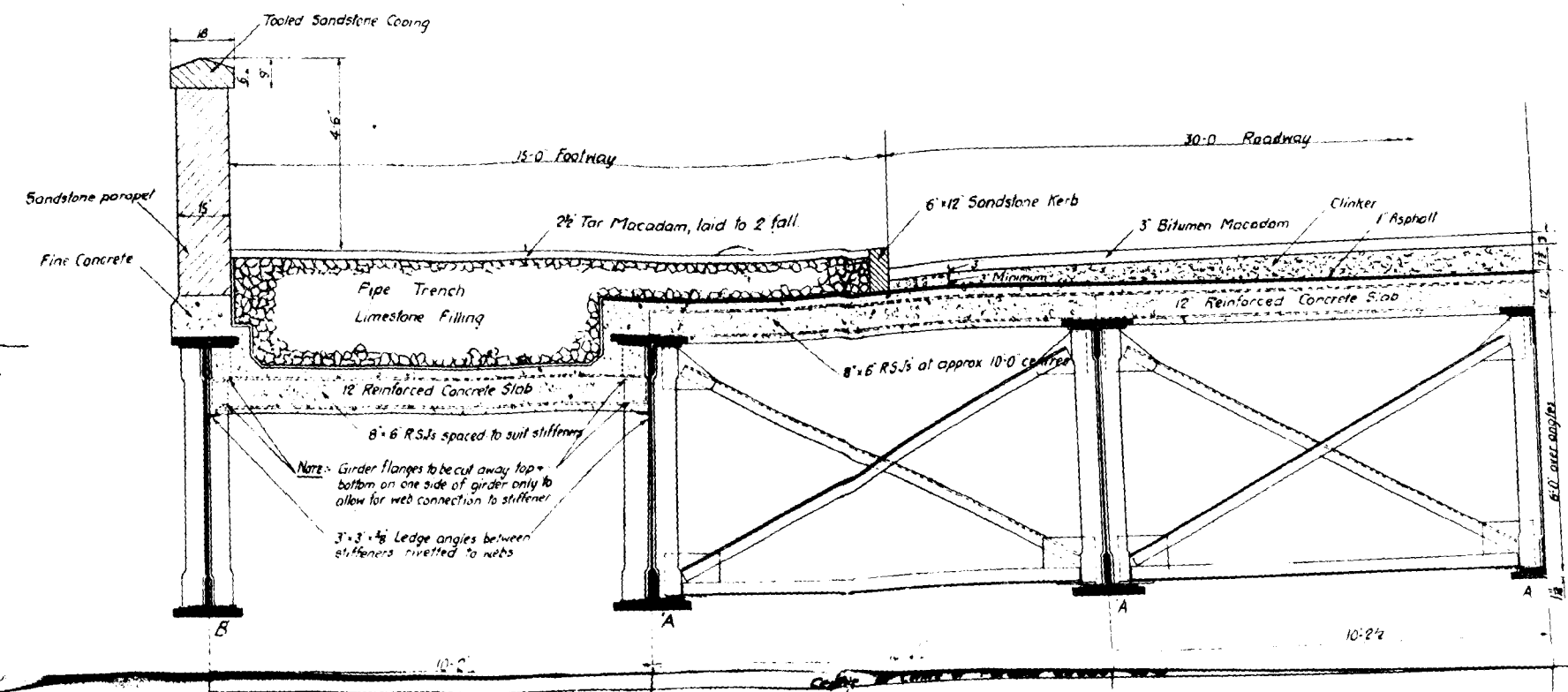
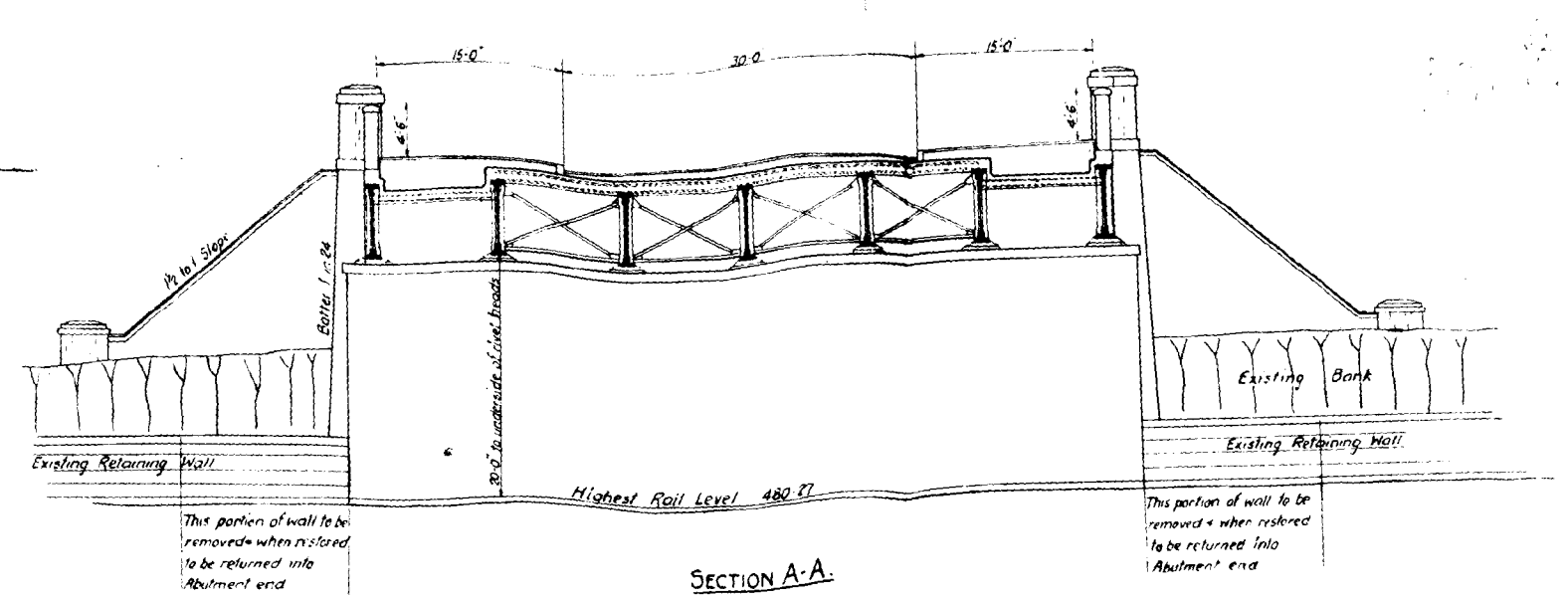
A_w = total cross-sectional area of the web.

d = effective depth of the girder.

d_1 = distance between centres of gravity of moment splice plates.

F = total stress in each pair of moment splice plates.





HALF CROSS SECTION.

NOTES:- Girders 'A' to be composed of 716 web, 6" x 8" x 1" main angles, ~~three~~ ^{two} 20" x 1" flange plates top and bottom at centre
Levels of soffits of main angles of bottom flanges to be the same for all girders.

NOTES IN REFERENCE TO STONENORK

NOTES IN REFERENCE TO DIRECTION:

- Facing of abutments, parapets & wing walls to be coursed rock-faced sandstone
- All quoins to be margin drafted
- Copings to pilasters & wing walls to be tooled
- String courses of pilasters & parapets to be finished smooth
- Plaques to be provided at both centres of inner faces of parapet walls for inscriptions etc. as directed

NOTE: Depth of foundations to be determined on site, notwithstanding dimensions shown.

NOTE - Live Load - M.T. Standard Loading 1927 - over full width between parapets.

FIG. 44.—Single Span Plate Deck-Girder Bridge.

BY HADDON C. ADAMS.

f_1 = unit stress in moment splice plates, and equals $f \cdot \frac{d_1}{d}$

V = maximum shear at the section.

r = governing rivet stress (probably bearing).

Then the assumed moment of resistance of the web is :—

$$f \cdot \frac{A_w}{8} \cdot d = F \cdot d_1 \quad \therefore F = f \cdot \frac{A_w}{8} \cdot \frac{d}{d_1}$$

r should be reduced in proportion to distance from neutral axis, so that the rivet stress adopted will be $r \cdot \frac{d_1}{d} = r_1$ say.

The number of rivets in the moment splice plate on each side of the splice will be $\frac{F}{r_1}$.

The net sectional area of one pair of plates will be equal to $\frac{F}{f_1}$.

In detailing the shear plates enough sectional area should be provided (through the line of the rivets) to resist the total shear V : by this consideration the calculated thickness of plate will probably be less than the thickness of the moment plates ; for convenience, and to avoid packing, they are generally made of the same thickness.

Stiffeners.

Stiffeners are required at the ends of the girders, at the inner edges of the bearing plates, at all floor-beams and at other intermediate points not farther apart than the depth of the girder (7' 6") or 6 ft. The B.S.S. provides no guide as to the varying of spacing with changing shear. A suitable spacing in the present design is 5 ft.

They are designed as "struts" with an assumed effective length equal to $\frac{3}{4}$ of the depth of the girder. The stiffeners above the bearing plate are designed for the full shear while intermediate stiffeners are designed for $\frac{3}{4}$ of the shear at the section.

It is not quite clear from the B.S.S. (No. 153) which of the formulas for reduced stress given in clause 18 of Part 3 applies to stiffeners, but it is assumed to be the following :—

$$9 \left(1 - 0.01 \frac{l}{b}\right) \text{ tons per sq. in.}$$

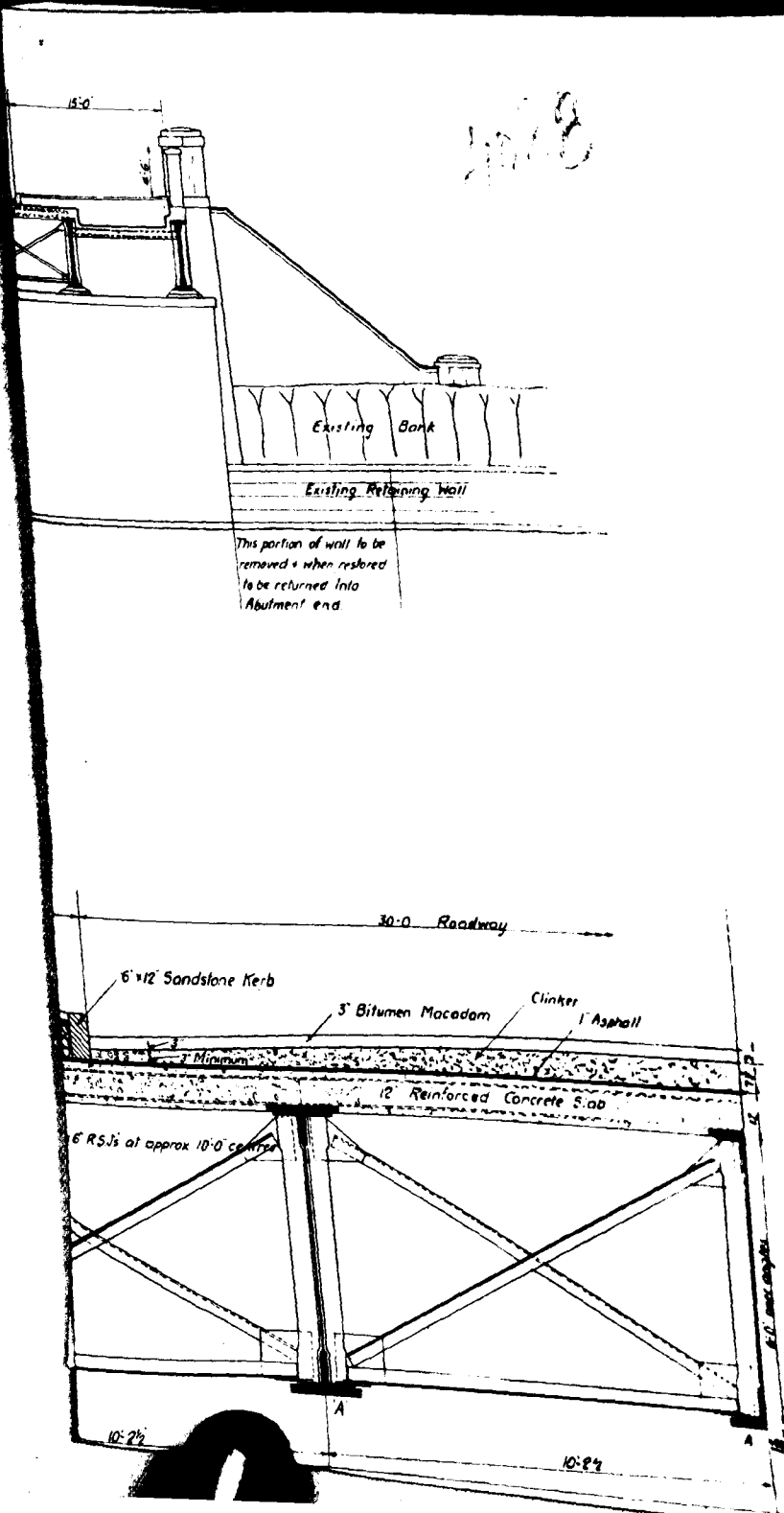
The total shear near the bearing is 188,300 lb. Assuming uncrimped angles to be employed, with $\frac{3}{4}$ in. packing (thickness of flange angles), and with 5 in. outstanding legs, $b = 2 \times (5 + \frac{3}{4}) + \frac{1}{2} = 12$ in., and the allowable stress is

$$20,160 \left(1 - 0.01 \frac{90}{12}\right) = 18,600 \text{ lb. per sq. in.}$$

Required gross area = $\frac{188,300}{18,600} = 10.1$ sq. in. Either angles or tees may be used.

2 Angles $5" \times 4" \times \frac{3}{8}"$ supply 10.47 sq. in.

At floor-beams the stiffener (which should be an angle) would be used in the connexion as shown in Fig. 36. On the roadway side of the girder a pair of angles



f_1 = unit stress in moment splice plates, and equals $f \cdot \frac{d_1}{d}$

V = maximum shear at the section.

r = governing rivet stress (probably bearing).

Then the assumed moment of resistance of the web is :—

$$f \cdot \frac{A_w}{8} \cdot d = F \cdot d_1 \quad \therefore F = f \cdot \frac{A_w}{8} \cdot \frac{d}{d_1}$$

r should be reduced in proportion to distance from neutral axis, so that the rivet stress adopted will be $r \cdot \frac{d_1}{d} = r_1$ say.

The number of rivets in the moment splice plate on each side of the splice will be $\frac{F}{r_1}$.

The net sectional area of one pair of plates will be equal to $\frac{F}{f_1}$.

In detailing the shear plates enough sectional area should be provided (through the line of the rivets) to resist the total shear V : by this consideration the calculated thickness of plate will probably be less than the thickness of the moment plates ; for convenience, and to avoid packing, they are generally made of the same thickness.

Stiffeners.

Stiffeners are required at the ends of the girders, at the inner edges of the bearing plates, at all floor-beams and at other intermediate points not farther apart than the depth of the girder (7' 6") or 6 ft. The B.S.S. provides no guide as to the varying of spacing with changing shear. A suitable spacing in the present design is 5 ft.

They are designed as "struts" with an assumed effective length equal to $\frac{3}{4}$ of the depth of the girder. The stiffeners above the bearing plate are designed for the full shear while intermediate stiffeners are designed for $\frac{2}{3}$ of the shear at the section.

It is not quite clear from the B.S.S. (No. 153) which of the formulas for reduced stress given in clause 18 of Part 3 applies to stiffeners, but it is assumed to be the following :—

$$9 \left(1 - 0.01 \frac{l}{b}\right) \text{ tons per sq. in.}$$

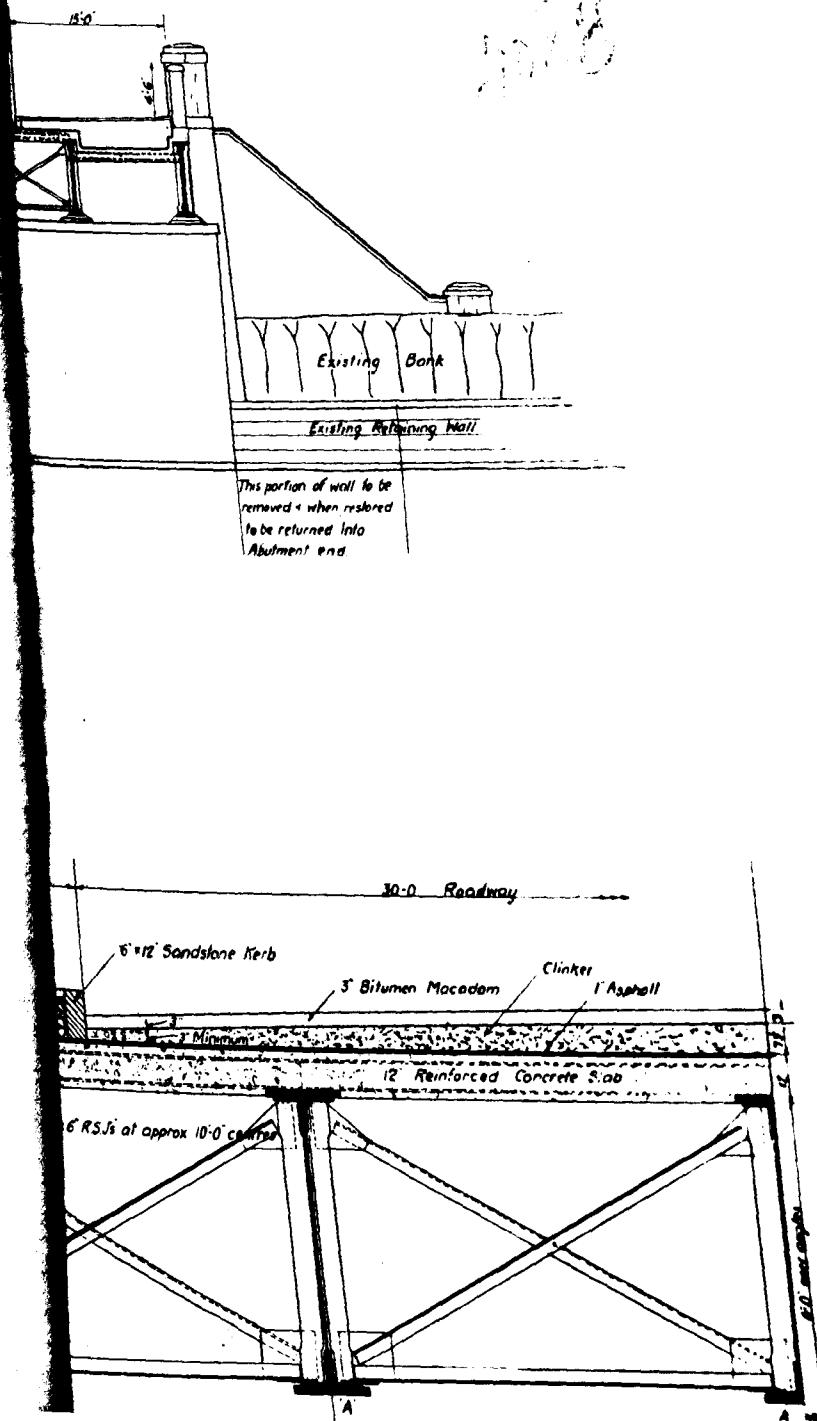
The total shear near the bearing is 188,300 lb. Assuming uncrimped angles to be employed, with $\frac{3}{4}$ in. packing (thickness of flange angles), and with 5 in. outstanding legs, $b = 2 \times (5 + \frac{3}{4}) + \frac{1}{2} = 12$ in., and the allowable stress is

$$20,160 \left(1 - 0.01 \frac{90}{12}\right) = 18,600 \text{ lb. per sq. in.}$$

Required gross area = $\frac{188,300}{18,600} = 10.1$ sq. in. Either angles or tees may be used.

2 Angles $5" \times 4" \times \frac{3}{8}"$ supply 10.47 sq. in.

At floor-beams the stiffener (which should be an angle) would be used in the connexion as shown in Fig. 36. On the roadway side of the girder a pair of angles



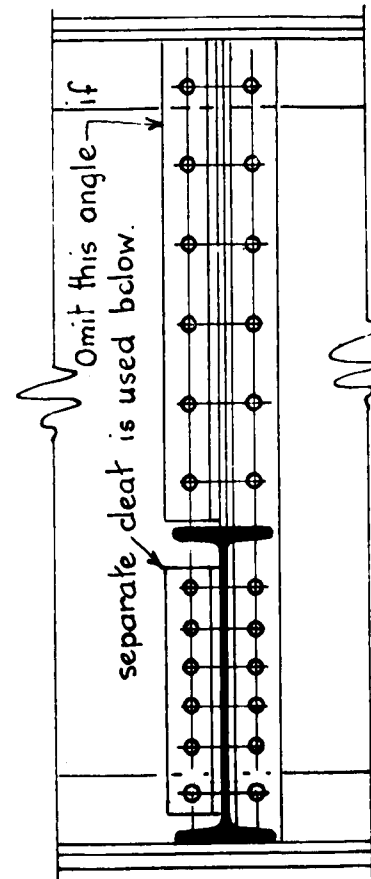


Fig. 36.

would be used and both might possibly run the full depth, although it is fairly common practice to extend one of them for only the depth of the floor beam. The flange of the floor-beam is chipped away to allow the angle to be placed flush up against the web. The connexion must be designed to take the maximum shear in the floor-beam. In order to provide additional stiffness to the compression flange of the main girder a knee brace may be employed. This is formed by the triangular plate seen in Fig. 37 which is connected by a pair of angles to the top flange of the floor beam. Sometimes the knee brace is extended down along the dotted line AA in which case the floor-beam is stopped at this section and the two butt together and are connected by splice plates on either side of the web. If the floor-beam is a built-up section, the flange angles are detailed to run on and so assist in making the splice.

Intermediate stiffeners may be crimped or packed out as preferred. The sectional area required will be less than that calculated at the bearings. The rivets must be sufficient to develop the shear at the section, but the maximum spacing of

6 in. can generally be used. The stiffeners should be machined so as to bear closely on the compression flange; at the tension flange a loose fit is all that is necessary, and this is easier for fabrication.

Wind Bracing.

The reinforced concrete deck, if it is secured to the floor-beams, is sufficiently stiff as a horizontal beam to brace the structure against distortion from wind loads. If united action is doubtful bottom laterals may be employed. These are made up of angles rivetted to gusset plates connected to the ends of the floor-beams close to the main girders (see Fig 38). Single angles are used, and these are placed diagonally

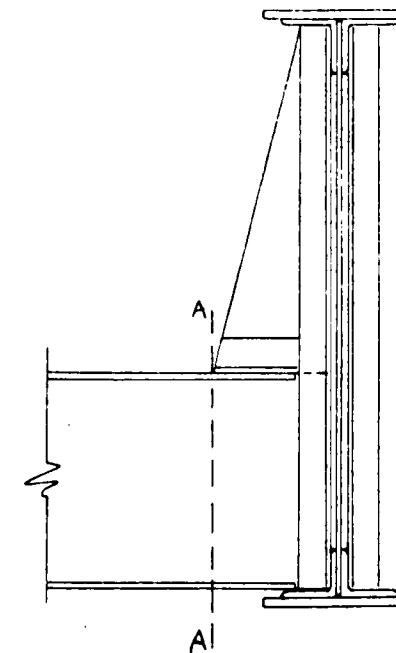


Fig. 37.

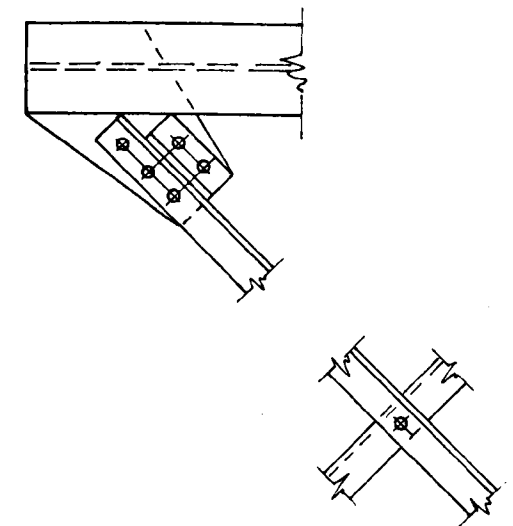


Fig. 38.

across each panel and are rivetted together at intersections to prevent rattle. With the panel proportions in the present design the angles would extend across two panels so as to intersect at approximately 45° , and the intersection would have to be made with a gusset plate. Owing to their slenderness they are disregarded when in compression. The wind loads are assumed as if concentrated at panel points and the angle acting in tension is designed to take the shear in the panel.

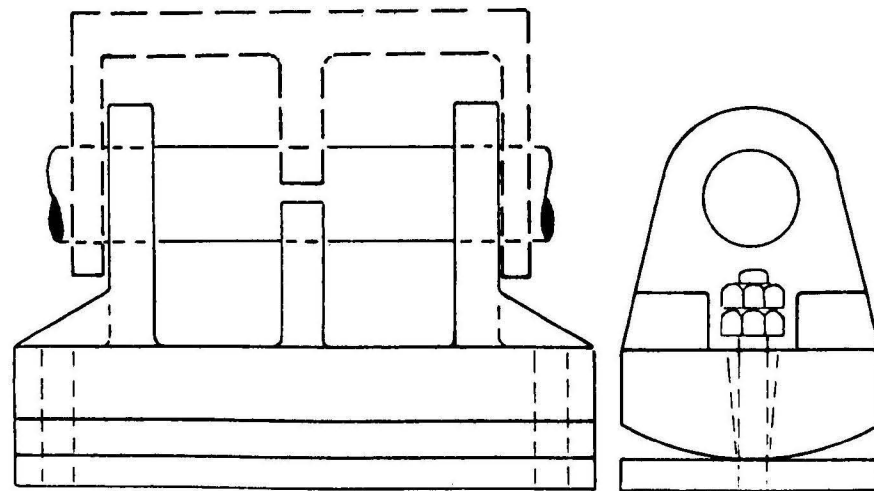


Fig. 39 (part)

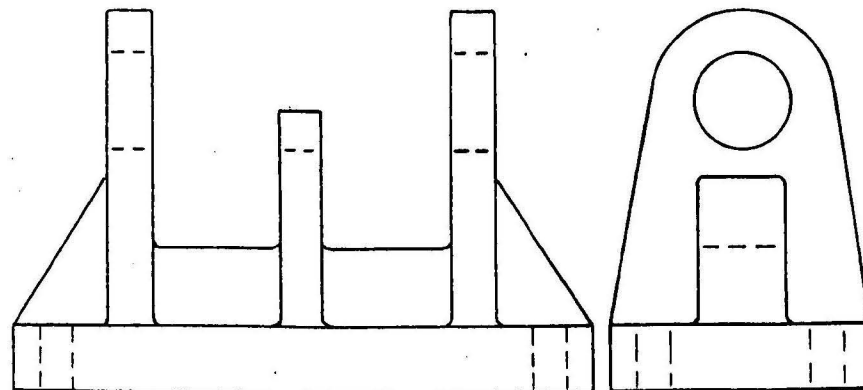


Fig. 39 (part)

End Bearings.

Although the B.S.S. does not require that bearings for bridges of spans less than 100 ft. shall freely permit deflection, it is more satisfactory if they do so. Suitable types of bearing for the main girder are shown in Figs. 39 and 40. Fig. 39 shows a rocker for the free end and a bolster for the "fixed" end; both of which bearings, by reason of the pin, permit free deflection. When very heavy loads have to be borne the roller type shown in Fig. 40 is preferable; the "fixed" end would in this case also rest on a bolster.

If no end floor-beam or trimmer beam is provided the movement of the ends of the stringers over the abutments can be taken care of by a detail such as shown in Section in Fig. 41. The slots, and the joint in the deck slab should be provided so

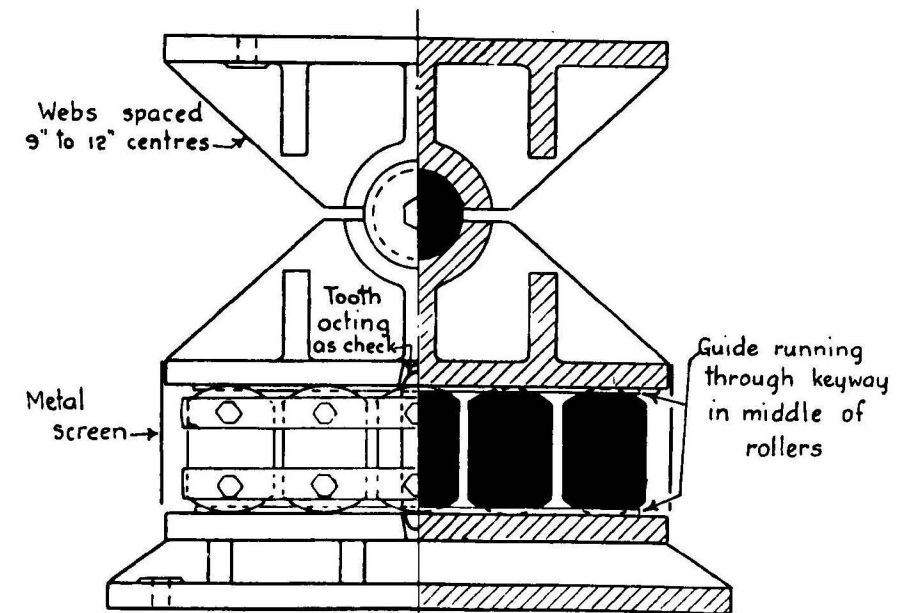


Fig. 40.

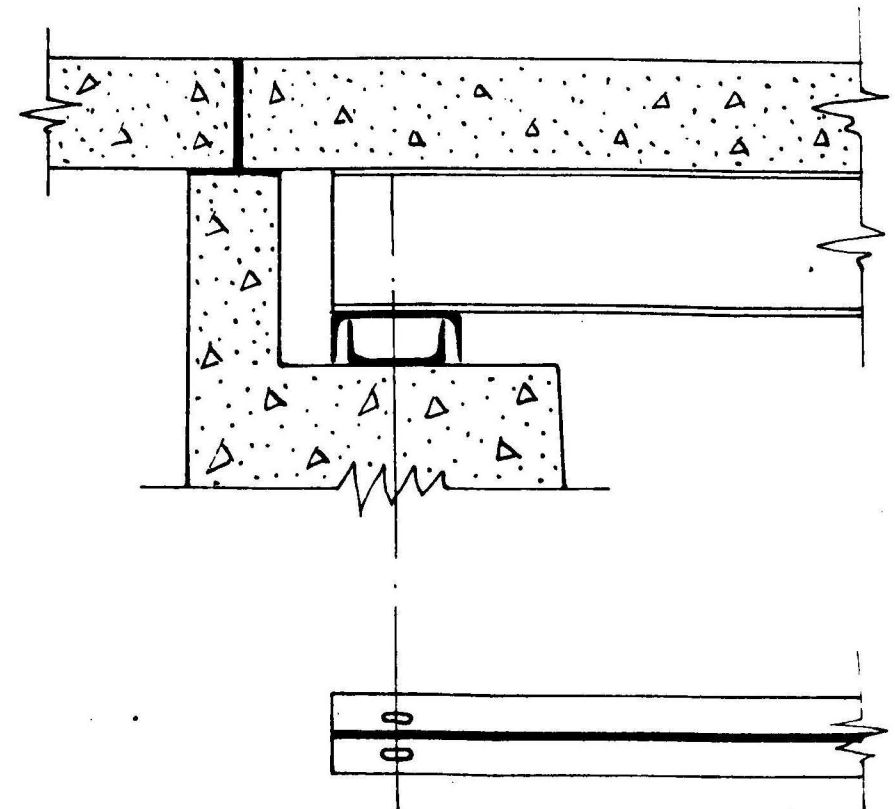


Fig. 41.

as to allow for a total movement due to expansion and contraction of at least 1 in. per 100 ft. of span. The channels forming the bearing are anchored to the abutment by rag bolts.

Drainage.

If it is possible to discharge drainage water directly below the bridge 2 in. diameter glazed earthenware pipes may be set almost vertically through the deck slab in the gutters at about 10 ft. intervals. Generally, however, it will be necessary to take the drainage water along the gutters to gulleys placed just beyond the ends of the bridge. The longitudinal camber should be sufficient to cause the flow.

Detailing.

In detailing thought must be given to constructional difficulties likely to be encountered. Details should be so arranged as to facilitate the assembling of members in confined spaces, clearances should be liberal, and all parts should be made accessible for painting.

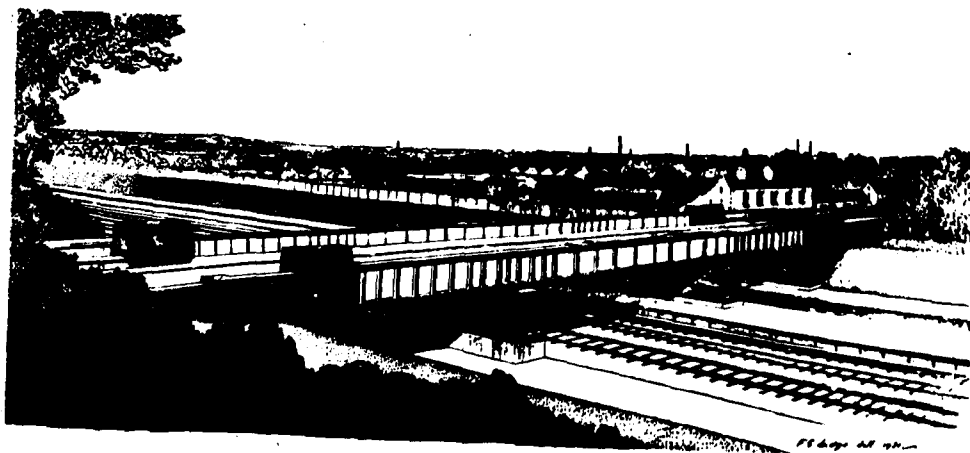


FIG. 42.—Proposed Design for steel bridge over the Railway.

APPENDIX.

NOTATION.

GENERAL.

l = span length.

W.S. = Wearing Surface.

D.L. = Dead Load.

L.L. = Live Load.

M = Bending Moment.

V = Total shear at a section.

C.G. = Centre of gravity.

I = Moment of Inertia.

REINFORCED CONCRETE.

b = Breadth of unit considered.

d = Effective depth.

p = Steel ratio.

R = A constant representing $f_s \times p \times j$.

A_s = Cross-sectional area of reinforcing steel in unit considered.

f_c = Unit compressive stress in concrete at extreme fibre.

f_s = Unit tensile stress in reinforcing steel.

v = Unit shear (maximum) in concrete section.

t = Slab thickness.

k = Fractional part of d giving depth to neutral axis.

j = Fractional part of d giving "lever arm" or vertical distance between centres of compression and tension.

s = Stirrup spacing.

u = Unit bond stress.

Σ_o = Sum of bar perimeters in a group, or per unit width of section.

STEEL.

Z = Section modulus.

l = "Unsupported" length of compressive unit.

b = Breadth.

p = Rivet pitch.

r = Rivet working strength (as governed by bearing or shear).

$\left. \begin{matrix} h \\ d \end{matrix} \right\}$ = Effective depth of girder.

f = Allowable unit stress in flange.

A_w = Total cross-sectional area of web.

d_1 = Distance between centres of gravity of moment splice plates.

F = Total stress in each pair of moment splice plates.

f_1 = Unit stress in moment splice plates.

DISCUSSION ON PAPERS BY MESSRS. C. H. BRESSEY AND H. C. ADAMS.

MR. BRESSEY (introducing his Paper), said: The Paper deals, I think, fairly exhaustively with the different sorts of bridges which we find through the countryside, both ancient and modern. There are one or two practical points to which I should like to draw attention. One of those will be—judging from the experience gained by the Ministry of Transport—the extreme need for the careful upkeep of bridges. There is sometimes a tendency in remote parts of the country to think that if a bridge has been soundly built in the first instance it can be left in complete safety for a good many decades. In some counties the practice is coming into vogue of making a periodical inspection of those bridges and registering results for future reference. That practice is an extremely useful one and will, I hope, become even more general.

Another point is the tendency in some districts to attach so much importance to the picturesque that the bridges are allowed to become almost smothered in vegetation. From particulars supplied to me the other day of an inspection of an ancient bridge, it was found there were several tree trunks growing from it, measuring no less than 6 in. in diameter. Obviously it was a well-constructed bridge to stand strains of that kind for so long a period.

Which reminds me of the fact that Gray's "Elegy" has probably been the ruin of many modern houses, and ancient buildings; his phrase, "the ivy mantled tower," struck the public fancy and everyone wanted their tower ivy-mantled, with the result that a great deterioration of stone work took place, with very undesirable results.

Another point I would like to mention is the desirability of controlling the architectural design of buildings on the approaches to bridges. Of late years, unfortunately, one has seen many bridges built with the highest degree of architectural and engineering skill, but the approaches have been left to the unfettered activities of private enterprise, with the result that we see very incongruous buildings disfiguring the approaches; the discordant background has spoilt the bridges, which would not have happened if the surroundings had been more carefully tended.

The lecture gives numerous illustrations of existing structures, but one is bound to admit that a great deal still remains to be done, and the Minister of Transport in his preface to the book on Bridges refers particularly to the problem of weak, dangerous and narrow bridges which possess no architectural merit, and the reconstruction of which he would like to see undertaken with the utmost vigour by local authorities generally.

MR. H. C. ADAMS (introducing his Paper), said: I was privileged to present to you at the last Congress two Papers on Bridge Design. Since in 1923 Captain Mitchell, with Colonel Hawkins, of Berkshire, first read a Paper on a certain aspect of bridge design, the association of the Bridge section staff of the Ministry of Transport with this Congress has been continuous. The range of subjects with which we have endeavoured to deal has included, amongst others, the strengthening and widening of bridges, the design of deep culverts, the design of portal or rigid frame bridges, the design of arches, the design of bridge abutments, piers and retaining walls. The present Paper merely continues that series.

You will understand, of course, that what little has been compressed within the compass of this short Paper is the result of my personal views. I have had the advantage of association and discussion with my colleagues and seniors in the Ministry of Transport, but neither they nor the Ministry can in any way be held responsible for the views expressed.

The Paper is divided into two parts, dealing respectively with reinforced concrete and with structural steel. There was neither space nor time to deal with the aesthetics of design, and in the three simple types demonstrated in the Paper the strength of the structure only has been considered.

The design of the deck in a simple slab bridge presents no difficulties, but the tables and design charts included in the Paper, for which they were specially prepared, may perhaps be of interest. The design of the reinforced concrete deck girder bridge is a little less simple. The opportunity was seized of demonstrating the method of allowing for compression in the stem of a

T-beam for the exceptional case when this becomes of importance.

The second half of the Paper deals with the design of the steel plate girder bridge. The trend in steel bridge design is all in the direction of simplification of detail, contributing to ease of fabrication and of erection, and affording free access for painting. A number of illustrations are included in the Paper to suggest the range of possibilities for design in this material, and in the present age, bristling as it is with scientific discovery and invention, we look for yet further developments.

THE CHAIRMAN (Sir Henry Maybury): You will agree, gentlemen, we have had very useful expositions of both Papers from past-masters on the subject. I have just been reminded that Mr. Adams was our first prize-winner last time, and it is very gratifying to see the continuance of his interest, and the work which he has put into the Paper. I am sure you will all agree with me that our congratulations are due to Mr. Adams for the masterly way in which he deals with the subjects he has put up for discussion.

SIR FREDERICK BERRYMAN: I do not suppose anybody is more completely unqualified to speak on the technical subject of bridge building than I am. Let me approach it rather from the administrative side. A point that occurs to me is the great advantage of the spread of knowledge of the simple principles of bridge building, and I base it on past experience. It may be common to others; possibly some of you, having constructed, after deep thought and measured reflection, a comparatively small bridge, situated on some beautiful undulating and semi-liquid peat foundation, have had the following criticism: "Oh, why on earth do you want to spend all that money on a little bridge like that?" I think, from the administrative point of view, it is of the greatest advantage to know how much in the construction of a bridge is like that of an iceberg, out of sight; how much there is beneath the surface.

There is another point in connection with this matter, and that is what is sometimes known as "neophobia," or the profound and intense dislike of anything that is new. That feeling of irritation often appears on the production of a new and possibly unusual design; and I would suggest that before

definitely assessing criticisms that arise from new and, in a sense, strange designs, it is as well to wait, say, for a certain number of years, because it is not unusual to find those criticisms varied after a period, if not indeed reversed. (Hear, hear). At the same time, one fully realises the advisability of having full regard to the æsthetic and artistic effect, and I think those photographs outside are a really splendid collection; they show that this side has not been lost sight of by any means in the engineering world. There are many examples there of bridges which have been most admirably widened, and (to put it in the most delicate way I can), you do not know it.

Again, on this particular subject, there is, I think, well worthy of consideration, the advantage of, where possible, using local stone for facing, for parapets, and for copings. (Hear, hear). It is, I think, generally admitted that however good your concrete work may be it is impossible, or almost impossible, ever to get the pleasing effect which you can from a suitable natural stone. As an administrator, I understand that the preparation and designs of the detailed drawings of a bridge take a very long time and a very great deal of thought, a proposition with which there is no reason whatever to quarrel. Now, it may be contemplated to construct, or reconstruct, an important bridge. The first step taken is to proceed to the Ministry and see what grant is available, but frequently the reply is: "At present we have no money available at all." Then sometimes the step is taken of saying: "Well, if that is the case, we are not going on with the plans." But I believe those who have had happy experience, as I have, of the Ministry, for some years past have noticed that from time to time changes of policy occur. On that change of policy it is often sought to put work in hand without undue delay. Enquiries are made whether if the grant is available the bridge is ready for construction. Sometimes the reply is: "We stopped our plans until the grant was promised." Sometimes that view has not been taken and their plans are all ready. Should there not be sufficient funds available to give grants to both it seems that the second authority would have no mean advantage.

MR. MAXWELL AYRTON: All of us who are engaged in the design of buildings or bridges

at the present time suffer from a serious defect in the education of the layman and the public upon such matters. For many years past, since education has become general in fact, the public have been taught always to look back when they are considering anything of artistic merit: in the teaching of architecture, painting and all artistic work, they are always educated to look back to the past and very little to the present. That, to my mind, has caused a serious defect, which is gradually being overcome I admit, but it has caused in the public mind the feeling that the art of design is a thing that is lost, and it does not exist at the moment, and that to produce anything artistic we must look back for it and in a sense work backwards instead of forwards.

I feel very strongly that the designers of these very beautiful old bridges were men who were not primarily concerned with designing a beautiful bridge. What they were concerned with was the building of the best possible bridge within the very confined limitations of their time. They had to build with the local material, whatever it was, with nothing like the engineering knowledge or the appliances available for finding out difficulties with regard to foundations, and so on. And their plant—what can it have been? What they were fundamentally concerned with in designing those bridges was to build the best possible bridge they could at the time, and that fundamental and singleness of thought produced naturally very beautiful things. I will admit that they are all enhanced in value through age and the glamour of history, but not one of those men sat down thinking: "I am going to design a beautiful bridge." He used what material was at hand with such assistance as was available to his utmost capacity.

What follows? At the present time the result has been that architecture is very frequently looked upon by the public as a sort of sop thrown in at the last moment to the public; a sort of last coat of paint. It should not be that. When harking back and looking at old bridges and thinking they were designed by wonderful designers of bridges, the public have not got used to looking at the very marvellous beauty of a perfectly straightforward and magnificent piece of engineering. It is deplorable to

think of that. I think that in the last few years there has been a great stride. Naturally, as an architect I am very much in favour of the collaboration of engineers and architects, but I would like to stress that the work of both professions should be regarded as one rather than separate entities, and I am sure that the public will gradually learn to appreciate more and more as things of beauty all great engineering feats made possible by the fullest use of modern science, materials and construction, and more particularly those in which engineers and architects have collaborated in the true sense of the word.

MR. REES JEFFREYS: Those who have heard the two Papers this afternoon, and have looked at the photographs in the Exhibition, can go away assured that so far as the road engineers of this country are concerned they will do all that is necessary to give us the bridges we want. The fact that in Great Britain we are relatively so backward in bridges, that we are not giving the traffic to-day the bridges that it wants, is not due to any faults on the part of the engineers. (Hear, hear). Throughout the country when I make contact with my old friends, the county and borough engineers, they all say: "We will build the bridges, but where is the money?" Perhaps, therefore, we ought to consider the subject of finance. A Royal Commission has drawn attention to the number of weak bridges and has advised the Government to get on with a bridge-building programme. But that recommendation has not been acted upon. That we have a bridge problem is due to the lack of foresight of Parliament in the past; but Parliament, instead of dealing with the question constructively, is now approaching it once more on the line of placing further restrictions upon traffic.

We cannot in this developing country, when industry requires cheap transport, afford to be relatively so badly off in the matter of bridges. How then are we to provide the finance? I suggest the question of bridges has got to be dealt with more and more from a national rather than from a local point of view. The local burdens do not always correspond with the national benefit. I am going to throw out one suggestion. It will not appeal very much to my friends at the Treasury, but I do think it is one that those with whom the responsi-

bility rests for providing bridges for the traffic needs should seriously take into consideration.

Bridges have long lives; there are many bridges in this country built 500 years ago, and still doing good service. To pay for bridges out of revenue, therefore, has not the same strong case as paying for road reconstruction out of revenue. There is a stronger case for building bridges out of loan money than any other form of public expenditure connected with roads and bridges. At the present time there is a restriction upon raising loans for public works. I do not see how this bridge problem is going to be solved in a satisfactory manner in our lifetime unless there is a big loan raised. There are many arguments pro and con. In a few minutes I cannot argue the Treasury case, and I cannot argue the other side, but my considered conclusion is, having seen both sides of the argument, that as soon as it is permissible to raise loans for public works there should be a 50 years' bridges loan raised of at least 100 million pounds sterling. At the present time we could raise that loan on the security of the Road Fund at under 3 per cent. I suggest therefore that a loan of 100 million pounds should be raised on the security of the Road Fund to carry through a national bridge programme. The bridges included in the programme should not depend on whether the plans were ready or not, but because the bridge is wanted by the trade and traffic of the country.

M. P. LE GAVRIAN (*Chief of the Road Service in France*): I am not prepared at all to speak about bridges to-day; my business of course is about roads and bridges, but in France at present our main duty is to improve our national road system. I do not know whether you are aware that two years ago the French Parliament increased the national system of national roads—that means the principal highways in the country—by erecting about 40,000 kilometres (say 25,000 miles) of small roads: Department roads and additional roads. So our major task at present is to take charge of that very large system and improve the roads by widening them, straightening bad curves and so on. We have also rather interesting work going on in the mountains;

I mean some very high passes in certain places of interest.

MR. FITZSIMONS: Mr. Maxwell Ayrton rather implied that engineers, even old engineers, do not exercise efforts to obtain structures which have good appearances. From the time when I was a pupil I have been taught that one of the most important things for a bridge engineer to take into consideration is to obtain in appearance as much as one possibly can from the particular materials which are available for the structure. These materials are usually dictated by the amount of money which happens to be available for the particular job. I think it is very wrong (this is of course from an engineer's point of view) for architects to hide the construction which the engineer has designed. Mr. Ayrton's work on bridges leads me to think that he does make serious efforts to obtain good architectural treatment without obliterating the engineering design. One can see cases which have been recently under the observation of the public where the engineer's work has been masked. The external appearance of the arches of some bridges has been so reduced in architectural treatment that if constructed on those sizes they would probably not be able to carry the load for which they were intended. I am one of those who believe that the combination of the architect with the engineer is important, but I most emphatically think that the appearance of the bridge should indicate truly the engineering construction.

I also rather agree with Mr. Ayrton in his point of view that artistic treatment should not become simply an added ornament. I think it is a great mistake to hang inappropriate things on to the bridge, as is sometimes done. A bridge may be a very simple structure, and a simple structure will, if properly treated, look very well indeed. The old bridges which we admire are simple engineering structures constructed with local materials and with very little effort made at ornamentation.

With regard to Mr. Adams' Paper, on the second and third pages are two tables of loadings which are very useful and have summarised a lot of odd facts into concrete form. But I would like to call Mr. Adams' attention to the fact that the working stress of ordinary concrete is put down as 750 lbs.

to the square inch; later in the Paper I find that a reinforced concrete slab, with steel top and bottom, has been treated in a manner with which I disagree. Mr. Adams is presumably working to the stress of 750 lbs. per square inch. He designs this slab but properly notes that the stress in steel compressive reinforcement has been ignored. If you take the particular slab referred to on page 376 you will find that if you do not ignore the steel—and I do not see any reason why you should—the stress in the concrete is 600 lbs. to the square inch. Now, that is the stress which was permissible some years ago, and the Ministry of Transport has raised this (and I think quite rightly) to 750 lbs. Although this slab purports to have been designed on up-to-date lines, the actual stress is 20 per cent. below the maximum permissible. This slab, designed about 6 in. thick, with a little more steel, can be stressed to 744 lbs. in the concrete and 15,550 lbs. in the steel. The peculiar thing about it is that there is a very small saving in cost. It amounts to about 2 per cent. in this case. I think the method Mr. Adams recommends should be reconsidered as it seems to me a pity that, having jumped the stress up to 750 lbs., it has not been worked to.

This is not an isolated case, for in 1931 Mr. Chettie and Mr. Adams wrote a Paper that was published in "Roads and Road Construction"; and there were several slabs all more or less on the same lines. I think it is generally considered that the compression of steel should be taken into consideration, and that it is an advantage to insist on working up to the raised stress, because it has the effect of making the neutral axis relatively lower, so putting into tension less of the concrete in the lower section of the beam.

I think anybody accustomed to bridge construction who looks at Figure 7 will see there is something "fishy" about the carrying of the parapet. We see a little further on calculations for the slab underneath the parapet, but Mr. Adams has not taken into consideration the most important duty of the parapet, which is to resist lateral forces; and I think that if a crowd of bullocks got off the roadway and charged against this parapet they would cause trouble; and as far as I can see he only considers the weight

of the parapet itself as requiring support. At the base of the parapet there is a little bit of slab only about 6 in. thick which is carrying a parapet at least 12 in. wide.

I am very pleased to notice that attention has been called to steel bridges. Steel bridges appear recently to have been rather neglected, and it seems a great pity. I suppose it has been the fetish of maintenance and the fact that steel construction has kept up its price compared with reinforced concrete. They have some disadvantages, but for some reason or other steel work designers have avoided dealing with structures in the manner of reinforced concrete designers, the reinforced concrete designer does not hesitate to make a continuous girder, but for some reason or other continuous girders in steel seem to have become gradually *non est*.

COLONEL BRESSEY: Except in America.

MR. FITZSIMONS: Yes. I think we have been frightened by the danger of settlement; but really there is rather more danger from the settlement of an abutment or a pier to a concrete structure than there is to one of steel. The steel structure will give and "say" nothing about it; any defect will not be very serious; but concrete will crack if there is an uneven settlement. I am very pleased to see that attention has been called to steel structures, many of which have an artistic appearance.

I think a great deal more might be done with steel construction, and my view is that in designing steel work more attention should be paid to accessibility for maintenance. In works which were constructed about 50 years ago one found that engineers seemed to pay little attention to the question as to how a girder that they erected might be painted. I have seen dozens of girders with a half inch space between two flat surfaces five or more inches deep. How could anyone get a paint brush in to paint it? The result is that these structures deteriorated very much indeed, thus falsely giving steel a bad reputation in regard to maintenance. There is no reason why sufficient attention should not be given to design so as to give proper spaces for painting and ventilation, there is no reason why steel girders should not be perfectly protected.

MR. L. JENKINS (West Ham): I would like to obtain what Mr. Adams considers as modern in regard to bridges, and what is an

ancient bridge as there are undoubtedly various opinions as to what is ancient and what is modern.

Mr. Adams refers to reinforced concrete, and says that this material has allowed us to build bridges of dimensions and spans which would have been absolutely impossible with the older methods of construction and materials. I think it will be agreed by all that reinforced concrete has enabled us to build bridges in situations where it seemed impossible in days gone by. But I do think there is a tendency to carry the use of reinforced concrete to extremes, as for instance the introduction of reinforced concrete to bridges in circumstances where old and tried materials have sufficed and stood up to their work. For long bridges in difficult situations reinforced concrete has proved a great boon.

In the ordinary bridge of masonry or brickwork there is plenty of scope to bring in ornamental features. This form of construction lends itself to architectural effect, and it can still hold its own as regards lasting properties. The works executed by the engineer are in the main based upon his experience and the knowledge of the materials he uses, they have stood the test of time and have a considerable number of years of wear to their credit.

I submit that our ideas of building generally, not only in regard to bridges, are changing. In the older days of building, structures were put up with the idea of building for all time. I fancy that nowadays we are quite satisfied if the structure remains up for a far shorter period; and it is not altogether unexplainable, because the modes of life are changing so rapidly that a newly erected structure may answer the purpose for the time being, and in a few years hence say 50 or 100 years be quite out of date. (Hear, hear). The rate of change now is far greater than it was 500 years ago.

Mr. Adams refers to three types of bridges, and we have examples of each at Stratford under construction. Referring to page 373 I am very interested in the way he had treated the subject and refers to this bridge superstructure as a thick slab; I believe he looks upon it as "boxed out"—rather than the idea of individual beams. He appears to have taken a thick slab and made perforations through it and left

uprights standing as beams. This view appeals to me very much, because I have under construction at the moment a bridge to carry sewers over a river 60 ft. between abutments in two spans. At one end there are four sewers about 9 ft. in diameter; then they increase in number to six. In designing this bridge I treated it as a huge slab 12 ft. in thickness, about 50 ft. in width at one end, broadening out to about 70 ft. at the other. These 9 ft. sewers take the form of perforations through the slab, making the sewers homogeneous with the slab. There are no moving loads to cater for over the bridge, and the concrete inverts of the sewers convey the loads to the vertical components of the slab. This structure has several novel features. The West Ham Corporation have recently built a bridge to carry the High Street, Stratford, which is subjected to very heavy traffic travelling between London and the Eastern Counties. I have not dealt with this bridge in the same way as the Sewer Bridge but as a structure composed of T-beams and constructed on the lines indicated in the Paper. Mr. Adams explains that in building your "T" beam, you take it that half the span to the next beam is part of the particular beam you are designing, and this method provides a homogeneous structure. But it is not always possible to do that. You cannot always build your beam and your slab at one time; there are many cases where you have to build your beams separately, and then to put your slab over them. That is not so economical, but we cannot avoid this in many cases as we have to keep road traffic going. I should like to refer to the tables on pages 369–70, and to say that in my judgment they are put in a very clear, concise and labour-saving fashion, and to have them incorporated with the Paper will add very greatly to the value of it.

I think that most engineers who design bridges would like me to express to the Ministry of Transport our appreciation of the assistance we get at all times from their officers in the days when Sir Henry had charge, and now with Colonel Bresse and his assistants. I want to pay my tribute to the excellent work they are doing and to say that I consider they have brought all their requirements up to date; they have made them in accord with recent practice, and

with the knowledge we have of the materials available for use and the tests carried out, we are now able to deal with our problems with greater assurance.

MR. TAYLOR (*Rhondda*): You have been speaking here about high finance and the difficulty of raising money, but many of us have to carry on in these days with improvised methods and to do the best we can with the cheapest possible material. I come from a district which was famous for coal, for subsidence and now for distress. I wish to pay a tribute particularly to Mr. Adams for this and the previous Papers, and to the other officers of the Ministry who have placed their experience at the disposal of the small engineers; because we have still to build a lot of little structures that we cannot get loans for, and unless we know some little about it we will be squandering public money.

There are one or two little things where I quarrel with Mr. Adams. One is in relation to the rivet pitches in his design for steel girders, because unfortunately in a district like mine (which subsides so terribly at times, and is only equalled by the salt mining districts as regards subsidence), I had to come to the Ministry some years ago with reference to a bridge which from 1875 till 1925 had subsided 26 ft. I have at the moment a steel bridge of 75 ft. span, the abutments of which are coming together, and since 1923 one abutment has moved forward 2 ft. We have many cases of bridges on the move, and all our structures have to be built on the lines of allowing free movement for the girders, and movement which we can rectify quite easily. What we have been doing, with the sanction of the Ministry, since 1925, is to split the bridges, where we can, longitudinally, into two halves, so that we can deal with one half while the other is in use, and that method has been very useful. My experience has been altogether in the direction of steel bridges. Owing to our poverty-stricken state we have had to re-use our old bridge material, using it again for lighter loading or for shorter spans; and this has been done by direct labour; that is to say, we design bridges, with the assistance of the Ministry, and that assistance has always been most readily and most courteously given even although they could not give us any money.

We cannot afford to spend money on decoration, and even if we did the natural surroundings of the district are not such as to warrant the expenditure. Our idea is to produce the strongest and the best looking bridge with the lowest possible expenditure.

I find that with the old wrought-iron bridges, which I am pulling out constantly, 50 years or more old, when we cut into them we find that in many cases there is the mill scale still on the plates where the angles join them, and in all cases their condition is better than newer steel bridges. It is true the old engineers used fairly close pitches. On reading Mr. Adam's Paper I find he shows a pitch of 12 in. as being permissible. Well, please do not listen to him in that respect. If you use anything above 6 ins. in a district like mine, where we are getting up to 120 ins. of rainfall each year, the wet is sure to get between the parts, particularly at the junction between the bottom of the web and the flange angles. I notice the Great Western Railway Company when they want to save rivets put the outer row in close pitch and then leave out every other at the root of the angle.

One word about the newer steels. I have been privileged by being allowed to go through different bridge manufacturers' yards, and have found this most helpful, as one sees a great variety of constructional methods, both good and bad.

With regard to copper-bearing steel, I have used a little and am very pleased with it in every way. But after seeing one or two of the modern so-called corrosion-resisting steels in the works during the process of fabrication, being cut by oxy-acetylene, and a certain amount of heat treatment for stiffeners, gussets, etc., and after discussion with works managers, foremen and skilled workmen, I have decided for the present to leave patent steels alone. The specimens shown me did not behave uniformly well during fabrication.

My office staff has just been trying to find the cheapest bridge possible for a crossing of 240 ft. long over very treacherous ground from the point of view of subsidence, but the subsoil is otherwise good. The Ministry cannot give us a grant in aid, and therefore we have to cut expenditure down to the last possible penny. The Rhondda Council

preferred to spend money in the office investigating the possibilities in the way of design, and we have investigated about 10 schemes, and have tried to arrive very closely at the probable final costs. It is found for that particular crossing, where the piers are low, the cheapest span is 30 ft. I have of necessity been very partial to steel, as everybody knows in South Wales, and have always refused to consider reinforced concrete because of the possibility of moving supports. But I find the cheapest possible structure is one of reinforced concrete T-beams with the beams fairly close together. Then there follows an encased broad flange beam structure, which unfortunately we cannot use because the material is only rolled on the Continent. The third is solid slab floor of reinforced concrete. The fourth is one of plated steel joists, and last of all a plate girder design. I found if the spans were increased to 40 ft. there was a little saving in piers, but more money was required in the superstructure.

MR. BOLTON: As a contractor I should like to say that I am sure engineers of to-day would still feel and believe that there are contractors who have a love of their work. (Hear, hear). I heard just now one gentleman, an architect, I believe, criticising the old structures, and he said he believed they were more or less shoved up to suit the exigencies of the moment or the amount of money they had to spend. Would anybody dare to tell me that such men as Gwynn, Rennie and Brunel built bridges with that at the back of their minds. Not only did they engineer them but they built them. Consider that beautiful old bridge at Shrewsbury, the English bridge, the wonderful way the cornice was arranged so as to get an equal shadow across the spandrells at the arches. It must have been the work of considerable thought.

Now as to ferro-concrete. It is all very well but is it not coming to the pitch to-day when there is as much steel in a ferro-concrete bridge as there would be in a steel girder bridge. I think it is almost a sin to call it a ferro-concrete bridge. I say this seriously, because I see no bridge where there is more iron and steel in it than would be necessary if it were built of plate girders.

Then again, about the cost. We hear a lot about the Ministry of Transport not

shelling out any money. Do you wonder? A nice cold joint of meat is just as nice to me without any parsley round the dish. Then look at some of these bridges to-day with all those arrises and beadings and flutings and one thing and the other; it is costing 50s. for concrete and 100s. for the shuttering. I am going to be bold enough to say it is just to satisfy the whims of a particular engineer, nothing else. The neighbourhood does not need it at all.

Another gentleman spoke about using brick and stone, which is to be found in the neighbourhood. I think it was Mr. Jenkins. Why not? Why go and get concrete materials perhaps 10, 15 or 20 miles when you can get stone within five or six miles? Then to my idea as a contractor the ideal bridge is one with a stone facing, or even nice brick. I do not know whether you saw the designs for the old Clopton Bridge at Stratford-on-Avon. It was very nice and in brick, and it would match the new theatre. With regard to ferro-concrete again, engineers have no faith in ferro-concrete, because I am going to ask why no railway bridges are built of ferro-concrete. We are told it is because of the Board of Trade.

THE CHAIRMAN: Oh no.

MR. BOLTON: If the Board of Trade will not allow the railways to do it then I say we have two departments, the Ministry of Transport and the Board of Trade, at cross-purposes.

THE CHAIRMAN: No, you are quite wrong.

MR. BOLTON: I am very glad to hear it. Then can you tell me why we have no railway bridges built with ferro-concrete?

THE CHAIRMAN: I was taught to be cautious.

MR. BOLTON: If ferro-concrete is all it is held up to be I should like to see some railway bridges built of it. Again, we have here nothing said about ferro-concrete tunnels. I do not know whether it interests Mr. Adams, but we have no standard work that I can refer to on railway tunnels.

MR. BRESSEY, replying, said: I was very interested in what Sir Frederick Berryman said in regard to reinforced concrete and his suggestion that the criticism directed to modern bridges would need to be reviewed in a few years' time. It is remarkable that the criticism of bridges so seldom takes into

account the cost. You read the most sapient criticisms in the papers, but not once, I think, have I seen our journalistic advisers refer to cost, and criticism is very much beside the point unless that is taken into account. Sir Frederick Berryman entertained grave doubts as to the wisdom of using reinforced concrete without some form of facing. I think that suggests a line of investigation which ought to be pursued very persistently by those interested in concrete; that is how to arrange your shuttering so that the reinforced concrete may be left complete in itself when the shuttering is struck, so avoiding the necessity of providing brick or masonry facings as accessories, or of adding an artificial surface by bush hammering, which is sometimes done to excess. I have seen bridges of which you can only see the underside by crawling, and yet even that underside has been subjected to bush hammering.

Everyone will agree I think with Mr. Maxwell Ayrton that designers should look forward rather than backward, and I think anyone looking through this very admirable book of bridges, if they put a mark against the bridges that please them best, will find the favourites to be the plain, bluff, hearty, workaday bridges, without what we may call fancy dress trimmings attached to them. I am sure that that impression would be gained by any careful observer who scrutinised the designs in the book.

Mr. Rees Jeffreys would almost give one the impression that no bridge works were proceeding in this country. That would be an unfortunate impression. Mr. Jenkins spoke of the very important bridges in West Ham and Stratford. There is a very large bridge in progress at Middlesbrough over the Tees, and I believe that in the next few months another large bridge will be built over the Forth at Kincardine, forming the lowest road crossing over the River Forth. May I repeat that the Ministry are anxious that everything should be done by local authorities to promote the rebuilding of weak bridges, the existence of which everyone deploras. The quite unnecessary suspicion that is sometimes cast on metal is particularly interesting when one considers that on the Menai Bridge—which is over 100 years old—the wrought iron links put in by Telford are mostly in use to-day, while the traffic is

increasing persistently and perpetually, although there are certain limits as to weight and speed.

The last speaker spoke of restrictions alleged to be imposed by the Board of Trade upon the construction of railway bridges. This is a misapprehension. No restriction of the sort referred to has been imposed, and there would be no difficulty in quoting instances of reinforced concrete bridges built over railways.

MR. H. C. ADAMS: For the present I will merely correct one or two wrong impressions. At the back of my paper there are one or two folder plates. It must not be taken that we at the Ministry recommend all of the details shown in those plates. For instance, in one of the designs some skew floor beams are shown. These tend to make the job more expensive because of the angles at which the floor beams and stringers connect. For skew bridges we suggest practically in every case that the floor beams should be framed in square to the main girders. In the Paper I have included a diagram (Fig. 26) which shows that detail.

In the design of the concrete floor slab for the plate girder in one of the large illustrations the reinforcement is shown projecting a short distance only beyond the support in the top of the slab; we suggest the detail in another portion of the Paper (Fig. 27) where the reinforcing bars in the top of the slab are taken completely across the roadway.

Mr. Jenkins enquired what I considered to be a "modern type" of bridge. I should say, generally speaking, all those bridges for which close and accurate detailed calculations are required; these would include structural steel bridges, and all bridges in reinforced-concrete.

I am afraid Mr. Bolton slightly misunderstood a remark of Mr. Maxwell Ayrton's. I will risk correcting him. Mr. Maxwell Ayrton referred to the beautiful mediæval bridges and their designers. He said those designers did not sit down and make up their minds to design a beautiful bridge; they merely sought their materials in the neighbourhood and built. He meant, I think, to imply that they were natural engineers, architects and builders of bridges; they saw the need; they selected the materials that were nearest at hand, and they built as best they could;

the result was in many cases a beautiful bridge. (Hear, hear).

I agree fully with Mr. Fitzsimons in the remarks he made about decoration of bridges. I think artistic appeal should be sought in the general lines of the bridge and in the structure itself, and that embellishments should not be made by prodigal plastering on of decorations afterwards, so as to hide the main features.

Referring to a remark of Sir Frederick Berryman's, and I will risk speaking for my department on this point, I would say that where money is not at once available for projected bridge schemes, we would say: "Do proceed with your plans, if there is any chance of that bridge being built, so that when the money is available you may go ahead without delay." The bridge section of the Ministry of Transport is always ready, indeed is anxious, to discuss these schemes in their earliest or "pencil" stage.

A number of slides illustrating bridges were then shown by Colonel Bressey.

The following further communication has been received from Mr. H. C. ADAMS: Time did not allow for reply, during the session, to the technical points arising from the discussion of this Paper; the following is intended to deal with such points.

Mr. Fitzsimons raised a question concerning the allowance for compressive stress in the steel in a reinforced concrete slab. The point may perhaps be best understood by referring to Fig. 27. The requirements for tensile reinforcement are calculated at mid-span and support, but by the method of detailing adopted the reinforcing bars are extended through the compressive area of the concrete; there is no definite necessity to do this, and some designers prefer to bend their bars away from the tension face beyond the point of contraflexure. The main reason the bars have been run straight through in the slab is for ease of construction, and the extra security provided by this method is all to the good, but it has not been relied upon in the design. The criticism offered is that such allowance should be made.

In the first place, if this is done, and the slab is reduced in thickness, the quantity of reinforcement must be increased, and the shear stresses in the slab, and the bond

stresses in the bars, are also increased. Mr. Fitzsimons calculates the net saving in cost to be 2 per cent. on the cost of the deck carriageway; in a fairly large deck girder span this gives a total saving on paper of about £4 or £5. It is perhaps doubtful if a real saving would in practice result, but the Author considers that there would be a loss of actual strength with the thinner slab. There would however be a slight saving in weight, and this might be worth while in a very long span steel bridge with a reinforced concrete floor.

The claim made for the gain resulting from a relative lowering of the neutral axis is, I think, a very doubtful one as it must result in a greater extension of the extreme fibres of the concrete in the tension area (as the concrete cover to the bars must remain the same), and there is therefore a tendency towards larger "cracks" (microscopic) in the tension face of the member. This point would arise only if the slab is made thinner as in practice the actual stresses and position of the neutral axis will depend solely on the construction adopted and in no way on the method of calculation.

The method of calculation was the same when a concrete unit stress of 600 lb. was the maximum, so that the increase to 750 lb. has been taken advantage of. There is nothing to prevent deck-slabs being calculated, where preferred, in the manner advocated by Mr. Fitzsimons, but the Author suggests that there is no real gain, and there is obviously a greater reserve of strength in the slab which, calculated by the same method, gives an appreciably lower stress. It should of course be borne in mind that in general deck slabs should be not less than 7 in. thick, and any attempt at saving of concrete by use of additional reinforcing steel should therefore be made by an increase in span rather than by a thinning of the slab below 7 ins.

The next point is that concerning the effect of lateral forces on the parapet. Many parapets are purely gravity sections constructed in masonry, and their resistance moments at the base are small. In an emergency such as Mr. Fitzsimons suggests (a charge of bullocks) there would undoubtedly be a distribution along the parapet of the applied local forces, and for such a contingency higher working stresses are

permissible; the reserve of strength in a 6 in. reinforced concrete slab is sufficient, the Author considers, to resist the lateral forces which the parapet may be called upon to sustain.

Mr. Taylor's criticism of the wide rivet pitch is probably merited. The calculations in the Paper were made to comply with the B.S.S. requirements, and the 12 in. pitch referred to is used with staggered rivets in each line of a double gauge. Weathering is an important consideration, and a closer spacing near outside edges where damp is likely to penetrate is to be recommended.

The Author is in full agreement with both Mr. Lionel Jenkins and Mr. Bolton when they advocate the use of local materials such as masonry and brick. When these can be economically employed they should be used. Since structurally, apart from substructures, they are suitable only for arches, it is difficult, with our modern live loads, to employ these materials for lengthy spans.

Mr. Bolton referred to the enormous quantity of reinforcing steel in reinforced concrete structures. Although his remarks might possibly apply to an exceptional scheme here and there, it cannot be said to be generally true; if there were as much steel (or a quantity even approaching it) in a reinforced concrete bridge as in a corresponding steel structure the cost of the reinforced concrete bridge would quickly render it obsolete, as competition between the two materials is keen. Economy is generally the ruling factor.

There is one more point, not raised in the discussion, but to which I must refer. The formula used for the reduced stress in the compression flange of a plate girder in the B.S.S. is not entirely clear, but a coefficient of 0.0075 was used with $\frac{l}{b}$ when it appears that 0.01 is the more appropriate. It also appears that the value for l might more reasonably have been taken as 120 ins. (the distance between knee-braces) rather than 60 ins. (the distance between stiffeners).

The following communication was received from Mr. A. W. LEGAT: In reading through the paper there are certain points which occur to me and on which I would ask Mr. Adams' further opinion. On the second page we are given a table in which I notice all concrete

mixes have the fine aggregate and coarse aggregate in the proportions of 2 : 4. Whilst this ratio is generally applicable to graded shingle, it is not generally ideal for a crushed aggregate, and particularly crushed whin which is the usual aggregate in Scotland, and in some other parts of the country. The reason is that voids in the whin aggregate form a higher proportion than in the case of shingle. A further factor is that sand bulks up considerably under different conditions of moisture, a perfectly dry sand and inundated sand giving the smallest and practically equal volume. Any percentage of moisture between these, such as is inadvertently present on works, causes a bulking of the material. With cement "bulking" has been taken care of by specifying the cement by weight, but this is impracticable in the case of sand. The 2 : 4 ratio is probably the minimum to give maximum strength under laboratory conditions, but in practical work, particularly where whin is used, better results may be obtained by using ratios such as 1 : 2 : 3. In water retaining work 1 : 2 : 2 cement, sand and coarse aggregate has been found excellent in practical construction. Not only have these ratios given splendid crushing results, but they have been found much more "workable" by the contractor, and I have found more cases of contractors being proud of their concrete where such ratios have been used than where the ratios mentioned in the paper have been adopted.

Mention is made of the necessity for scientific design in modern bridge work. It may be interesting to note that for a certain stone masonry arch 100 feet span, providing a roadway 80 feet above the valley, built in 1799, one drawing was provided, this consisting of a rough perspective sketch on which the thicknesses of arch ring, spandrel walls, and approach walls were marked in writing. For the new reinforced concrete bridge which is now replacing this, eighty double elephant detail drawings have been prepared.

In connection with slab bridges, I think there is one point to which insufficient attention is sometimes given; that is, the division of the total width into panels by means of beams. Taking a total bridge width of 40 feet, it may be divided up in several ways. In all probability one of the

particular ways will prove more economical than the others. The fact that one sees bridges having such widely varying spacing of beams as four feet to ten feet is an indication that this point might be given a little further consideration. A similar case occurs in arch rib bridges. In some cases to carry a 40 foot roadway, one may find only two ribs, while in other cases as many as five ribs have been used. Some time ago I saw a reinforced concrete bridge in which the width of the arch ribs was practically the same as the width of the slab spanning between these ribs. Considerations of the cost of shuttering, complications of reinforcement, and difficulties of concreting and of economy indicate that in this particular case it would have been better to provide a solid barrel type of construction rather than a ribbed structure or alternatively fewer ribs. Square panels for bridges decks are also worthy of attention. Not only do they provide a hidden factor of strength, but due to the fact that approximately equal steel is used in both directions they are less liable to temperature and contraction cracks. In addition they are economical both in cost and in dead weight.

Sketches are given of cross sections of a bridge in which the girders are comparatively deep (Figs 6 and 7). I have noticed that in such deep girders where only main bottom steel and top steel and the usual stirrups is provided, deep hair cracks sometimes develop extending from a few inches above the main steel to the underside of the slab. This appears to be due to surface contraction of the concrete. When one considers it has been found necessary to provide temperature or contraction reinforcement in slab work, it is not surprising that such cracks should develop in the sides of deep girders where as a general rule no contraction reinforcement is provided. In consequence, in recent work we have introduced longitudinal bars wired to the insides of the stirrups at about 12 in. spacing throughout their depth, and on both sides of the beam. This should prevent such defects.

Mention is made of "comfortable clearances between the bars and the cover outside them." In Fig. 8, the cover allowed appears to be 1½ in. clear from the main bars to the outside of the concrete on the sides of the beam, and 2½ in. on the soffit. This is

more than is usually provided but it would, I think, be an advance in reinforced concrete design if the cover in beams of this size were as given by Mr. Adams, and the cover to slab steel, etc., made in proportion.

Sketches are given of proposed expansion joints, and I think a study and experience of these will emphasise that the ideal expansion joint for reinforced concrete work has not yet been designed. Most of us interested in this class of construction are still looking for it and the person who ultimately discovers it will do a real service to reinforced concrete.

Turning to the steel bridges shown, it is evident that a major decision to be made in considering a bridge scheme is whether reinforced concrete or structural steel shall be used. The efficiency of both types to carry their load is generally admitted and has been shown in practice to be equal and the decision must, therefore, rest on questions of relative cost, relative upkeep, and relative life. For many sites there is no great difference in the relative cost of a structural steel and of a concrete bridge, the tendency being perhaps a little in favour of concrete. In the majority of cases, therefore, the decision will require to be made mainly on points of upkeep and probable life. In this connection I would suggest that much might still be done in the design of structural steel bridges to avoid pockets in which moisture can lie, and which are inaccessible for attention and painting. I have particularly in mind three cases—one of a steel plate girder bridge in which steel troughing was used. The troughing was accessible on the underside, but not on the top. In consequence after 30 odd years, moisture caused corrosion to such an extent that in many places the web of the girder was completely corroded through along the line of the troughing, necessitating a new bridge.

The second case is one in which a steel girder was encased in concrete. There seems to be some controversy on the point, but in my experience concrete does not *in practice* adhere intimately to rolled steel joists, plate girders, and similar steel erections which have comparatively large plane surfaces. On the other hand it has been shown repeatedly that it does adhere most intimately to round steel rods. The reason is probably that concrete in setting contracts around the steel rods, whilst it is unable to

contract in a similar way around structural steel members. In consequence, the encasing of structural steel work by concrete for outside constructions requires to be given very careful attention and sufficient reinforcement introduced to bind the concrete together and around the structural steel members. If not, cracking, percolation and corrosion will occur which in the case I have in mind necessitated renewal in 30 years.

The third instance I have in mind is that of a bridge in which the painting of the steel has been neglected to such a degree that after a period of about 40 years the structure can no longer safely carry its load.

From my own observation, therefore, I am of opinion that if structural steel is to have adequate life, it should be specially designed so that all parts may be accessible for painting, and that it is better to leave it exposed so that it can be painted rather than to encase it in a somewhat doubtful manner which might permit moisture to get in between the steel and the encasing, and so cause corrosion which may only ultimately become evident by the collapse of the member.

Turning to the detail drawings of steel bridges given by Mr. Adams, it is interesting to note that in two out of three cases, reinforced concrete deck slabs are shown, this construction being generally recognised, I think, as the most economical form of deck construction even for steel bridges. It is also permanent and effective.

In Fig. 18, it would appear that the longitudinal joists encased in the concrete bridge deck are exposed on the underside. This is to my mind one of the cases where further attention should be given to either protecting the steel adequately or to leaving it fully exposed so that it may be adequately protected from time to time. If the flanges shown are not painted at frequent intervals, it is obvious corrosion will commence and will spread into these parts surrounded by the concrete, and even if they are painted, it is very doubtful whether the edges of the bottom flanges will be protected to such a degree as to prevent moisture from percolating along the surface between the concrete and the steel. A better type of deck construction than this design might I think be devised showing at one and the same time

a saving in cost, deadweight, upkeep, and an increase in life. I would also express similar objections to the partial covering of the side plate girders with concrete as shown on the cross section.

In Fig. 43 and on the cross section, the reinforced concrete deck slab is shown extended under the kerb. The thickness of the concrete under the kerb proper would appear to be only $3\frac{1}{2}$ in., whilst immediately outside the kerb it increases to $7\frac{1}{2}$ in. I think there would be considerable risk of a crack developing at the internal angle which is a particularly bad position due to the fact that water from the road will drain down to the gutter immediately over and probably percolate through. In the same design I notice that the slab is thickened from $7\frac{1}{2}$ in. at the kerb to $9\frac{1}{2}$ in. at the centre to provide the camber to the roadway. In Fig. 27 the camber is produced by providing pads over the rolled steel joists, the slab itself remaining the same thickness throughout. I shall be glad to know which Mr. Adams considers the better way of dealing with this.

In Fig. 44, on the half cross section is shown a half-casing with concrete of the top flange of the side girder and of the girder near the centre of the footpath. The arrangement of this appears to be such that one would expect considerable cracking and disintegration to occur. I should be glad to have Mr. Adams' views on this point.

The slab for the pipe duct in this design has a span of approximately 10 ft. and is 12 in. thick, but it has a bearing of only 3 in. on the ledge angles. I should be glad to know if Mr. Adams considers this sufficient. In comparatively light floor work 3 in. bearing is the minimum which is ever adopted, but personally I would not like to provide such a small bearing in the case of such a heavy slab in a roadway bridge subject to considerable vibration.

Coming to the discussion, I was very pleased to hear Col. Bressay express appreciation of any bridge widening schemes where after completion one is not aware that widening has been carried out. This is ideal. He also suggested that although there may not be grants available at the moment, local Authorities should proceed with the preparation of schemes for new bridges and for bridge improvements. This raises a point

of some difficulty which I have encountered. In works where a consultant is required, until the Authority has some indication that a grant will be made no funds are available either for fees or for trial pits or borings. If some arrangement could be made to overcome this difficulty I think it probable that many more essential schemes would be prepared in readiness for the time when grants become available. Mention was also made of the facing of concrete bridges with local stone. Although attractive, this is a comparatively expensive finish, and I would like to see more attention given to actual finishes of the concrete itself. Not only would it be more economical, but in many cases it would, I think, be more in keeping with the structural design.

Some emphasis was given to the term "beautiful" as applied to old bridges, and whilst one would agree that this term is correctly applied in some cases, there are many in which I would suggest that it is the hand of time rather than the hand of the bridge builder which has produced this real beauty. Stripped of moss, ivy, and surrounding foliage, some of these structures would be revealed as somewhat clumsy in appearance, and I do feel that when time has mellowed in an equal degree the bridges which are being constructed to-day, our successors will compare them favourably with the bridges of the past.

I would like to thank Mr. Taylor of Rhondda for the very interesting information he gave us regarding bridge work in his own district and of his experiences in dealing with quite unusual subsidence and ground movements. His experience that a bridge having small spans and many simple supports proved cheaper than the same bridge divided into larger spans is comparable with experience in factory construction where it is found that the total cost reduces as the spacing of columns is decreased down to very small practical spacings.

Mr. Bolton stated there were no railway bridges in reinforced concrete. I should like to call his attention to a very large railway bridge just completed in Northern Ireland, and constructed in reinforced concrete. One may be quite sure this was not done without the fullest investigation of the possibilities of the material by the railway engineers concerned. It is common

knowledge that whilst in this country comparatively few railway bridges have been constructed in reinforced concrete, there are many examples to be found on the Continent and in America. Mr. Bolton also made the statement that in some works he has dealt with there has been as much reinforcement in the concrete as there would have been structural steel in a steel bridge. His experience, if this is the case, is exceptional, and it would, I am sure, be of interest if he could give further details. I have followed reinforced concrete construction fairly closely for several years and I know of no properly designed reinforced concrete member, slab, beam, girder, column, or arch, in which the weight of reinforcement approaches what would have been necessary if the work had been carried out in structural steel. He further proceeded to tell us that the shuttering in reinforced concrete work was an exceedingly expensive item, stating that one might pay 50s. for concrete and 100s. for shuttering. Unfortunately Mr. Bolton did not supply the unit in each case. 50s. may be a reasonable rate for concrete per cubic yard, but 100s. per square yard would obviously be an absurd rate. As a matter of fact in the general run of jobs, one can take the total cost of the work as equally divided between concrete, reinforcement and shuttering, although this ruling is open to appreciable variation dependent on the type of work. In spite of Mr. Bolton's experience it is a matter of common knowledge that a reinforced concrete column is invariably cheaper than a structural steel column designed to carry the same load. As mentioned previously, a reinforced concrete deck slab is recognised even by those specialising in structural steel design as the cheapest form of deck construction at the present time. Arches are constructed much more economically in concrete, and girders where the deck slab is used as the top flange are also more economical than steel. These are not general statements made without investigation, but are open to positive proof by comparison with detail designs and prices.

Mr. Bolton has also suggested that all the old bridges of steel which he has seen have been in good condition. I think it would be advisable for him to enquire whether some of these to which he refers are not made of wrought iron, rather than steel,

particularly in view of the age which he suggested these bridges to be. It is generally agreed that wrought iron is a more durable material than structural steel and that cast iron is still more durable, but to-day both materials have been supplanted by structural steel in bridge work, and it is generally recognised that unless steel bridges are protected or painted at frequent intervals throughout their lives corrosion develops and progresses rapidly.

The following comments have been received from Mr. H. C. ADAMS on Mr. Legat's contribution: I am sorry there was not time for Mr. Legat to make his remarks during the session at the Congress as they would have been of great interest to all bridge engineers there. I find myself in practically entire agreement with the opinions he expresses, and I will therefore confine my present comments to those questions which have definitely been put to me to answer.

The ratio of sand to cement given as 2 : 4 in the paper is intended to apply to dry sand, and proper allowance should always be made for the bulking effect of the sand. Even then there are many cases, particularly with crushed rock which is apt to give a harsh and unworkable concrete with the normal sand content, when the ratio should be modified by decreasing the coarse aggregate. In the absence of preliminary tests to determine the consistent strength of the concrete under field conditions, any modification should be made by maintaining the ratio of cement to sand and decreasing the coarse aggregate content to what the mortar so formed can comfortably absorb.

In deep girders I too have found the hair

cracks as a result of surface shrinkage to which Mr. Legat calls attention, and referring to old designs of my own I find that temperature steel consisting of $\frac{1}{2}$ in. bars at 12 in. spacing was generally used in the sides of such girders, and I consider the practice is to be recommended.

The folding plates included in the paper were not given as perfect samples of detailing, but were selected, almost at random, for the purpose of provoking discussion of such points as Mr. Legat has raised. The type of floor best suited to a steel bridge, I consider to be the detail shown in Figure 27; another method of provoking a cambered floor of uniform thickness which has been successfully employed is to vary the heights of the stringers with relation to the floor-beams, the lowest ones (at the kerb) being in the position shown in Figure 28, but this slightly complicates the fabrication of the steelwork. Both of these methods leave the steelwork free for painting, and after all it is probably far more satisfactory to protect the steel by regular painting than by attempting to protect it by encasing it in concrete (unless gunite is used). This being the opinion of the Author, he naturally agrees with Mr. Legat in his criticism of certain details in the folding plates, and would in time expect to find a certain amount of disintegration of the surrounding concrete.

The 3 in. ledge is on the small side, but the danger from vibration is somewhat lessened by the joists which also act as ties connecting the parapet and kerb girders at the level of the depressed footway slab; these are spaced fairly closely so that the slab spans between them and not directly between the main girders and the 3 in. ledges referred to are not the real supports.

CONFERENCE

Under the auspices of the British Waterworks Association.

THURSDAY, 16th NOVEMBER, 1933 at 11.0 a.m.

MR. G. M. ROBERTSON, J.P. (*President of the Association*), in the Chair.

The following Paper was taken as read:—

Pooling of Supplies by interconnection of Water Undertakings, Regional Grids and Trunk Mains through Rural Areas.

BY

ALAN E. L. CHORLTON, C.B.E., M.P., M.Inst.C.E., M.I.Mech.E.

(*President, Institution of Mechanical Engineers.*)

THE water supply of this country and its proper distribution to the inhabitants has become one of the most important questions of the day.

It may be said that this has always been so in principle, and no doubt many believe that it has consistently been followed out in practice, but the long continued fine dry weather this summer has revealed, through many channels of which the Press has been the most vocal, how very incomplete, how piecemeal, that practice has been. One might almost say that it is the best example of the development of any public supply we have on intensely individualistic lines.

To use the word "watertight" seems not at all inappropriate for the occasion.

The supply by nature is a common one; rain is anybody's, but the collection, control and distribution has, it is alleged, been left to the unordered grasp of those with long pockets who came first.

The scarcity that has lately been experienced in so many districts has again focussed the urgent need for action for the carrying out of some adequate scheme or schemes of supply with the least delay. That these regional supply networks should form part of a complete national plan is certainly what would normally be expected to-day.

Numerous Royal Commissions and Committees have reported on water questions during the last fifty years, and it may be noted in passing that a valuable digest of their recommendations was prepared by Mr. G. P. Warner Terry.

Various institutions and associations have in the past urged the need in the national interests for some improvement in the control of the various sources of water. They have urged, in the strongest terms, that in order that the water supplies of the country may be properly conserved and utilised to the best advantage of the community, it is necessary to set up a Central Water Authority, which should be empowered :—

- (1) To control the allocation of water for all public health purposes ;
- (2) To act as an advisory body to Parliamentary Committees dealing with Bills relating to the above ; and
- (3) To collect information as to water supplies (underground and surface water) to enable them to perform their duties.

They have also recommended that local jurisdiction as regards the several water interests considered by them should be in the hands of a body which can act for the whole of one or more watersheds.

Sir John Snell's Committee reporting in 1920 said :—

" We have examined the matter from the point of view of all interests, including those of water power, and land drainage and with regard to the whole country, and we have come to similar conclusions."

They further said :—

" We find that the difficulty in fairly allocating water is becoming greater year by year in England and Wales, and the evidence we have heard proves beyond doubt the urgent necessity in the national interests of some measure of control of all water, both underground and surface, in order that the available supplies may be impartially reviewed and allocated and may be made to suffice for all purposes in the future.

In consequence of the increase of population, the improvement in conditions of life and the growing requirements of industry, the demand for water is steadily increasing, and the problem of meeting future needs is giving rise to considerable anxiety in many parts of England and Wales."

The tendency in industry and other activities under the conditions we have to meet to-day is to adopt some form of co-ordinated working. The day of the individual enterprise is over ; we must combine more, and compete less.

The years since the War have seen a general acceptance of the principle that many individual units of production or supply, working and competing separately,

cannot continue to exist for long with the best efficiency. They must adopt some form of co-ordinated working under a uniform control.

In industry this allows of specialisation, so that in a variety of the products they are allocated so that each factory makes but a single article, or is limited to a small range of similar ones, and output and efficiency rise because of the concentration on the narrower issue.

This development in industry has not received the degree of acceptance in the field of public utilities which supply the common needs of the people that might have been expected, with the notable exception of electricity.

The supply of this common need has outstripped any parallel example in industry, for we have in the electricity grid a nation-wide supply under the control of one central authority.

With this striking achievement before us it is rather remarkable that we have had so few proposals to extend the principle to other common supplies, such as water and gas.

Many agree in principle that as time goes on under the modern conditions of living, the movement of population into the country to meet the increasing claims of agriculture, and from the extension of industry in the south, that a system based to some extent in its ultimate development on the lines of that used for electricity will be necessary for water, but they hesitate to accept the need to-day as being dire enough to tear up the older methods, and adopt the new ones.

Gas is quietly making progress in this direction much more than is water ; the view ahead of those concerned seems clearer.

A common water supply is the oldest public utility there is, for it was recognised in very early times that pure water was the basis for the good health of the community.

The reports in the Press, and of Medical Officers of Health hardly lead us to the belief that we accept this as literally as we should.

It is interesting to note that the Romans carried their demands for water to such an extent that it was said that 100,000,000 gallons were delivered to Rome daily by their aqueducts, an almost unbelievable quantity for those days.

Communal water supply in London developed earlier than elsewhere, maybe because a relatively large population existed so long ago. In the North and the Midlands the industrial expansion was the main reason that forced the development of public supply, the rapidly growing population of many industrial towns and the insanitary conditions that followed eventually compelling the authorities concerned to take action. If we had continued in the haphazard way that had been customary until the beginning of the nineteenth century, appalling epidemics might have followed. One calls to mind those of the Middle Ages, which were due to the insanitary conditions prevailing and to the meagre and poisoned water supplies available.

The industrial towns in the North each developed as an individual unit with its own public utilities ; and thus each town had a water supply of its own. Nothing

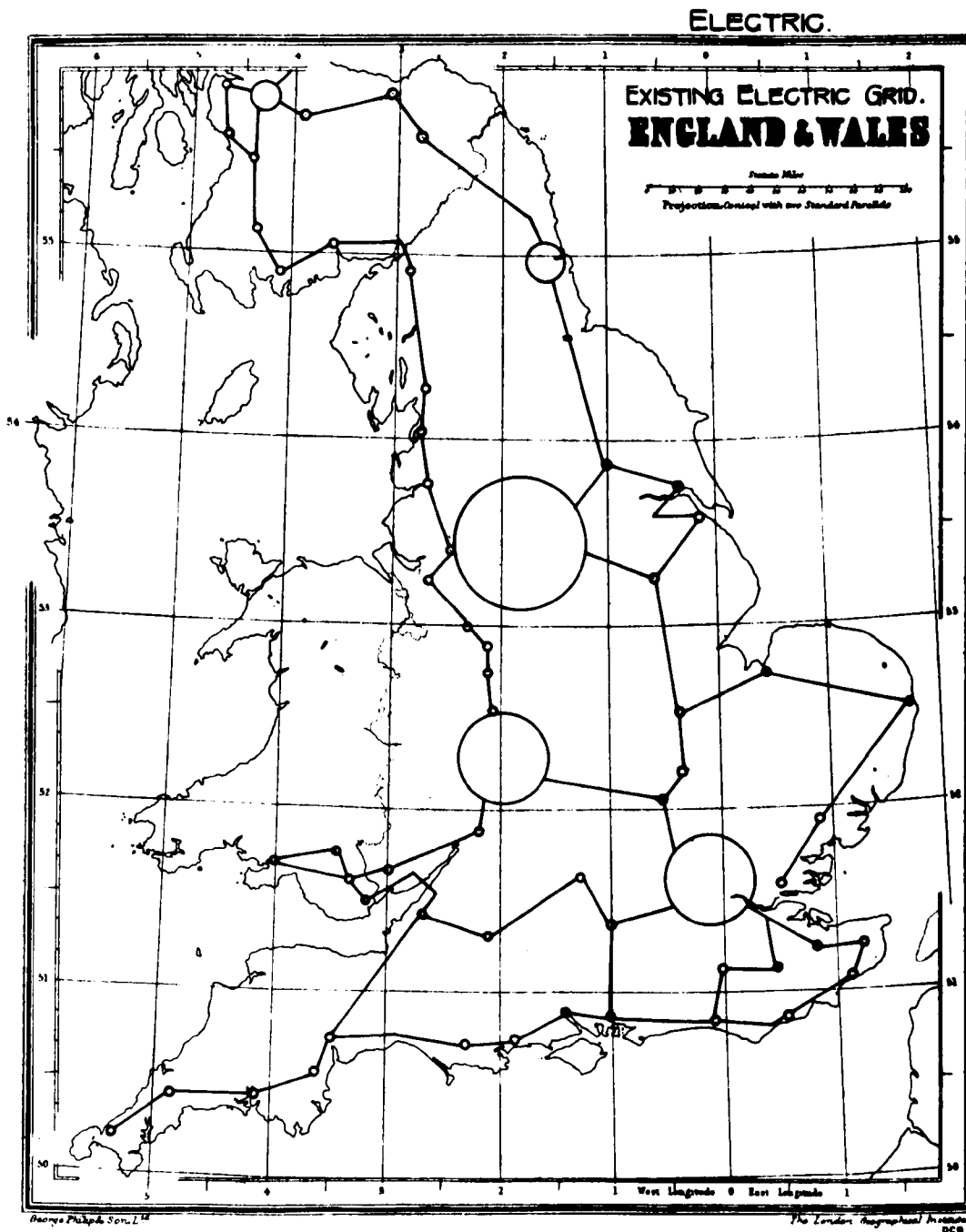


Figure 1.

is more remarkable than this expansion in distinct units, and, in spite of the fact that it must have been recognised in most cases as not being the most economical method, yet the feeling for individual action and the opposition to joint working under a common control for public undertakings was, and is to-day, still extraordinarily strong. To this rule municipalities are no exception.

The industrial age in England as it became paramount absorbed to such an overwhelming extent the interests both in time and in money of the most forceful part of the community that agriculture which is displaced, together with the rural areas concerned, were left without men or means to develop the supply of this common need in a similar way.

Much may be claimed to have been done already to meet the water demands of the villages of the countryside, but equally so the reports of Medical Officers of Health, the recurring instances of little or no supply, often of dubious quality, given in the Press, of which we may perhaps take Mrs. Wintringham's letter in *The Times* of the 16th September as a good summary and the culminating point—all show how very much there is still to be carried through.

How really urgent it is from the national health point of view, the Medical Officers' Reports reveal.

It may be useful to give excerpts from Mrs. Wintringham's letter:—

"It is a problem not of a dry year only; it is one of long-standing importance. . .

"We are amazed that the present state of affairs in the English countryside can be allowed to remain from year to year with so little improvement. . .

"In some villages in East Yorkshire people are absolutely dependent on rain water. Those who can afford to dig cisterns or buy tanks manage to exist for a certain length of time in a drought, but the cottages have no water after about a fortnight's dry weather. It is impossible to have proper baths or a decent washing day, and we hear of one case where a woman must save the water from her own washing to hand on to her neighbour for use the next day. In this village women have had to pay 1/- for a cartload of water to wash clothes. . .

"In Lincolnshire, at least one village, every house is dependent on a water cart for its supply. In another, on the occasion of the birth of a baby, water had to be fetched from six miles away. In another, fourteen people shared the same pump, the property of another landlord, who only allowed it for drinking purposes. After heavy rains the water was coffee-coloured and had to be boiled; and two or three of the wells used in the parish were condemned years ago. Women who have households of 11 and 12 persons to wash for are entirely dependent on the water cart. Sanitary conditions are shocking, and in one village the attendance at school has dropped from 90 per cent. to 75 per cent. owing to the lowered vitality of the children. . .

"In Cornwall, some farms cannot get a Grade A licence for milk, because there is no water supply for the necessary cooling of the milk on the premises.

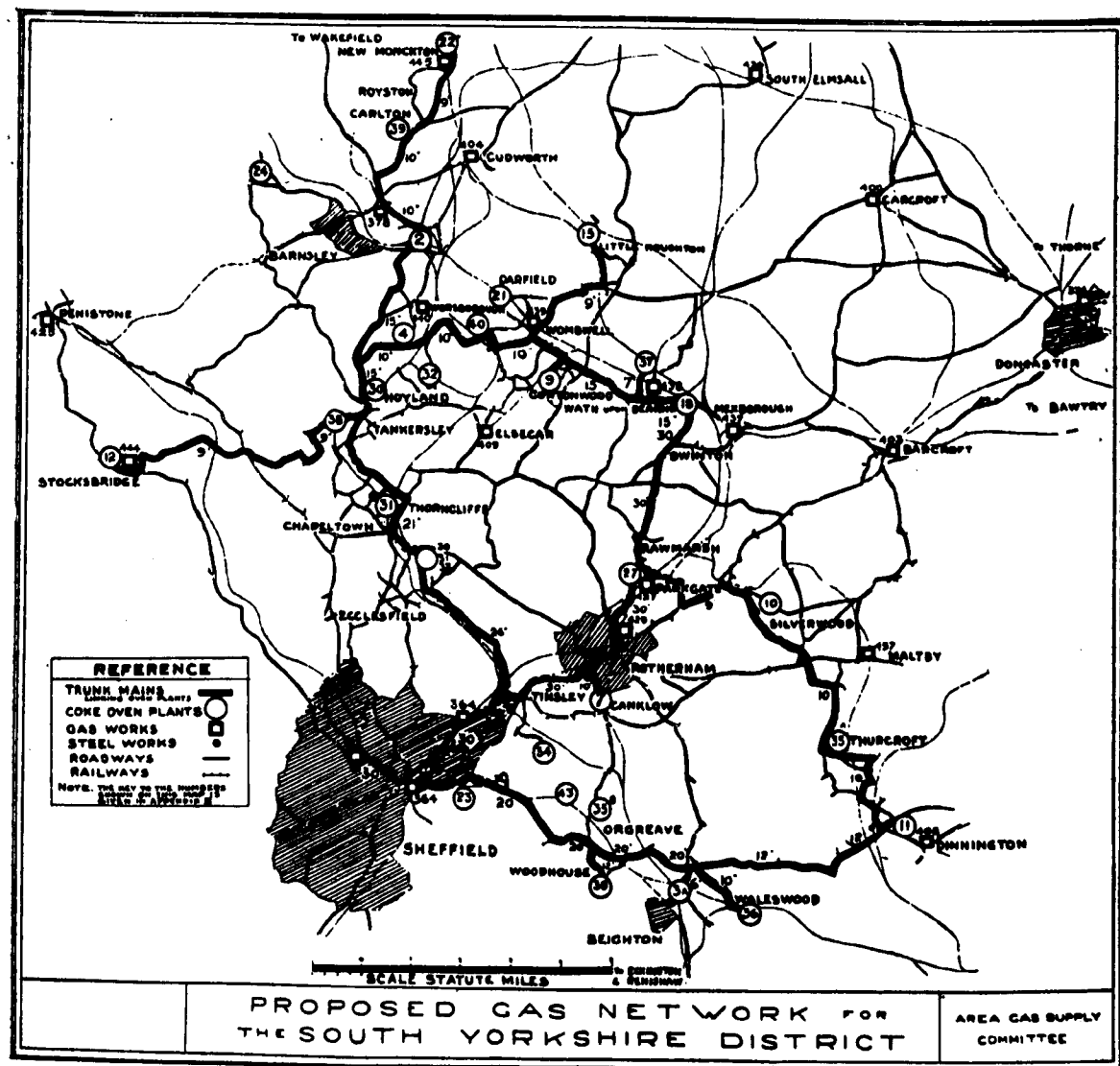


Figure 2.

In some villages on the Berkshire Downs, people have had (not only this year) to pay as much as 3d. for one bucket of water. . .

"It is, for instance, impossible to produce clean milk in some districts, for there is not the abundant supply of clean water necessary to wash all the buckets and other dairy utensils, or to clean the cows and stalls, or to give the cows in milk enough to drink. From a village in Somerset we hear that the water supply 'for cattle and human beings is filthy; dewponds or wells, 70 per cent. of which have been condemned as putrid and unfit for dietetic purposes.'

"In most of the cases quoted above, and in dozens of others, the consumers have appealed to their local authorities, and various schemes for improvement have been discussed, but generally without result. The local authorities have shown themselves to be unable to remedy the existing state of things without Government help. Even if conditions remained unchanged inaction would be serious enough, but conditions are not static. Houses are being built, the population in many districts is rapidly growing, canning factories are being put up, and all sorts of schemes are being mooted of immense significance to the country which cannot possibly succeed without proper water supply. It is not unreasonable to suppose that consumers would be willing to pay something towards the cost of improvements; they have paid towards their supply of electricity and gas, and water is at least as great a necessity. But the whole burden of a satisfactory scheme is too heavy for the consumer and too heavy for most local authorities.

"It is, therefore, undoubtedly, a matter of urgency that the Government should give assistance, on the same scale as that on which it has assisted roads. . . With help of this kind, the local authorities could then carry out at any rate some of the excellent suggestions of the Ministry of Health; without it, these suggestions will remain in many districts a dead letter. The setting up of Joint Advisory Committees of the various local authorities, as recommended by the Ministry, to improve rural water supplies in their own districts, would then have some effectiveness, and there would not be a constant blocking of reform through fear of an immediate crippling increase in the rates. . .

"As things are at present, it is clearly futile to pursue any policy for the improvement of agriculture or of national health, for as long as the water supply is inadequate to meet the needs of cleanliness to both man and beast, no development schemes can hope for success."

Take the case of a certain town in the east counties, the supply to which had for a long time past been inadequate, and had failed on a number of occasions with deplorable consequences.

In the rural district nearby there are no water supplies of any description in use, the villages depend almost entirely on rain water and what they can cart from the rivers and "drains." In times of drought like the present the position is extremely serious, the district is a very important one and consists largely of one of the most important agricultural areas in England largely given up to potato

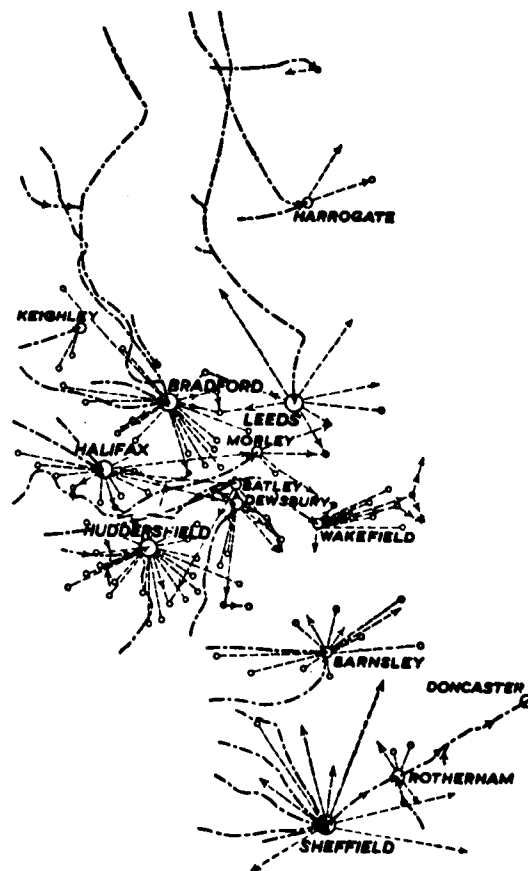


Figure 3.

growing and other market garden crops, some of the villages are very large and there is a widely scattered population.

In a certain case, a Regional Water Scheme was got out, designed to supply water to the whole area of Holland and the south-eastern portion of Lindsay, including the rural districts and including a supplementary supply to the Borough of Boston. This was an admirable scheme, and the whole of the water required would have been obtained from the excellent supply at Bourne owned by the Spalding Urban District Council; however, the District Councils entirely failed to come to any sort of agreement in the matter, and since no more grants were obtainable from the Unemployment Grants Committee, the scheme was looked upon as dead.

These examples present, perhaps in an incomplete state, the rural side of the problem, a scarcity of supply in many cases far from any large and well-stocked undertakings, no linking up or inter-connecting with such systems is immediately possible. Local grid supply schemes similar to that mentioned have been striven for by far-sighted people in the districts concerned, but have fallen through for

lack of agreement and the objections of the few who saw no gain. In effect, the interests of the few outweighed the needs of the many, and there is no existing power that can be invoked to remedy this difficulty. This is greatly to be regretted, because it is in all probability, the way the rural problem should first be dealt with by local networks comprising selected areas.

Reverting to industry, in the district of Yorkshire and Lancashire, a particularly good case can be made out for joint working by pooling the supplies through the linking-up of the existing undertakings.

In some cases the principle of joint working has been accepted, as in the joint scheme of the Derwent Valley Water Board. This authority supplies water to Leicester, Sheffield, Derby and Nottingham in the proportions of 35.72 per cent., 25 per cent. and 14.28 per cent. respectively.

On the Lancashire side of the Pennine Hills, Liverpool and Manchester are the chief distributing authorities for their own and some neighbouring areas, drawing their respective supplies from Lake Vrynwy in Wales, and from Thirlmere in the Lake District.

There are also, of course, many other relatively large towns with their own water undertakings such as Bolton, Oldham, Preston, Blackburn. There is, however, no inter-connection or any joint use, and if, for instance, Liverpool required more water, then the Haweswater Scheme, started by Manchester but not fully proceeded with, could not supply it, even though it had been found not now necessary. Nor could the collective redundant supplies of the country be made use of farther afield. There is no co-ordination or linking up with the West Riding. The intervening hills do not present the difficulty pictured; the cost of tunnelling; for an existing but disused canal tunnel can be adopted, apart from this the lower elevations from Kirby Lonsdale, south east, can be used.

The proposition of Bradford to supply 10 million gallons per day to Hull was turned down, a particularly unfortunate thing, as it was a real case of linking-up by cross country mains to use a redundant supply. It is not necessary to quote in addition, Birmingham and the South Staffordshire Water Co., and various other contiguous undertakings.

The system of the South Staffordshire Company might, however, be cited as a good example of a regional grid supplied from many sources, mostly by pumping, and which from the success of its daily practice answers many, in fact, most of the criticisms advanced against the larger grid proposed, the multiple of many such undertakings. It is also a good example of a pressure supply against the preferred gravity, one of the criticisms.

The Nottinghamshire area is also one of many deep wells owned and operated by separate Companies.

A plan of the West Riding district with the maze of different mains supplying the manufacturing towns in it is given at the end.

It is interesting to compare some of the water undertakings in this country



Figure 4.

with others abroad, particularly to indicate the long distances the water is brought from. It seems also necessary to do this because some critics persist in considering it an almost insurmountable difficulty in practice on the score of mains, etc.

Los Angeles, for instance, takes 280,000,000 gallons per day (the same total as the Metropolitan Water Board) from a distance of 223 miles, while Glasgow in Loch Katrine has a supply of 75,000,000 gallons, but only from a distance of 23 miles; Birmingham takes a similar quantity from a source 73 miles distance in the centre of Wales. San Francisco, with the Hetch Hetchy aqueduct from catchment areas near the Yosemite National Park 156 miles away, takes 400,000,000 gallons per day, whilst Manchester draws only 50,000,000 gallons from Thirlmere, 96 miles away, and Liverpool 40,000,000 from Vrynwy, 68 miles away. The latest New York aqueduct is capable of delivering 500,000,000 gallons from the Catskill Mountains, 120 miles away. These figures illustrate the distance, traversed often over mountain districts, and the heavy engineering work entailed.

Any problems arising out of an extended and inter-connected water system in

this country would be much smaller than those that have been successfully solved abroad.

There is another water supply scheme that some mention must be made of to indicate to those who have criticised bringing water from the wet areas to the dry ones in England, how far some countries abroad are prepared to do this. This is the Apulian aqueduct in Italy, conveying water from the western slopes of the Apennines behind Naples down to the dry districts in the heel of Italy (Foggia, Bari, Lecce, etc.), 8,000 square miles in extent. This extraordinary piece of work involves several long tunnels, one of which is 10 miles long, and in many places long bridges are called for. The water capacity is 5 cubic metres per second, delivered to a population of 3,000,000 in 266 connexions by a system of 841 kilometres of main and trunk pipe and 550 miles of distribution pipe. One can form a better idea of the nature of this undertaking when one knows the difficult terrain traversed; in addition, it must be remembered that it was carried out in Italy under more difficult conditions than any obtaining in this country, and took many years to construct.

Returning now to the problems in our own country, and to what has arisen to make it necessary that we should reconsider the methods of development of supply that have been practised in the past.

The admirable work done by all those concerned in the development of the water supplies of this country is fully acknowledged, and this paper is in no sense a criticism. It is none the less a difficult matter whilst paying tribute to the excellent work done by all, notably the officials of the Ministry of Health, to put forward suggestions which may in certain cases go against the policy they have pursued and may be interpreted incorrectly.

One might remark, however, that there is always a real risk of progress tending to be materially slowed down by the brake of too much experience, mainly by reason of the rules and regulations derived from it. The conventions thus set up are, indeed, hard taskmasters, and in consequence, not infrequently progress actually moves forward through ignorance of these limitations that have become to be thought almost immutable laws rather than out of knowledge.

We have for consideration first the dire need of various rural districts, and it is quite proper that this claim should receive first attention.

This can be met most expeditiously by the creation of local networks or grids over regional areas, using, if possible, local sources of supply. If they are not available in sufficient quantity, then the water must come from elsewhere. In any case, such regional grids should be inter-connected to those lying nearest to them.

In connection with this rural demand, we must take into account not only a considerable increase in gallons per head that the rising generation will call for, but also no inconsiderable migration of town dwellers with their 35 gallon ideas into the country, to supply the labour required in the revival of the agricultural industry.

The normal increase per head is, of course, going steadily on all over the country, and is not a new problem in any way, but it must not be overlooked. It is interesting to compare the amount used per head in different towns:—

	Gallons per head.
Ardrossan	78.5
Ashton-in-Makerfield	12.
Bridge of Allan	85.71
Dorchester	58.68
Irvine	91.5
M.W.B.	38.82
Paisley	81
South Kent	15
Dunblane	130
Glemsford U.D.C.	6.8

One point that arises from a study of these returns is the discovery of yet another virtue of Scotsmen, in that they use more water than Englishmen, on the score presumably that cleanliness is next to godliness, yet there is the obvious risk in their remaining with us.

But another explanation puts it down to the conversion to the water carriage system, England and Wales not having reached the standard of Scotland, the different pursuits of the inhabitants and to waste.

The flushing cisterns in Scotland are of 3 gallon capacity against 2 in England.

What the consumption will rise to in England in fifteen years, it is difficult to say, but it will prove no small difficulty for the London area.

In this matter of rising demand it might be pointed out that in the United States consumptions of over 100 gallons are not unusual.

But another factor and one of very serious national importance, is the movement of population, and its effects. This is too often neglected by the local supply protagonists.

An exceedingly interesting analysis was made in *The Times* of this under the heading of "The Population Trap," in which the general slowing up of the growth of the population to a standstill and then to a decline was pointed out, shewing how any increase would be in certain areas and the decrease in others, with its effects. It was pointed out that:—

"An expanding population has been normal in Great Britain since mediæval times. During the past two centuries the rate of expansion has been conspicuously rapid. In England and Wales the population which had probably been doubled between 1500 and 1800, doubled again by 1850, and yet again by 1910. Between the censuses of 1911 and 1931 new recruitment was still probable equal to the entire population of England and Wales as it stood at the Reformation. This steady increase has stamped itself deeply on the English habit of mind. We have the outlook of an expanding nation. That there should always be a surplus available for colonization overseas, a constantly growing home market, a dense and increasing mass of people to

share taxation, capital development and common services has come to be regarded almost as part of the natural order of things.

"All the same this expansion is not natural and inevitable; it is a temporary phase which is in fact already nearly at an end.

"Such rough forecasts as have so far been attempted suggest that the results may be surprising to those who have not followed the subject closely. If the recent suspension of emigration continues, the population of Great Britain should reach its peak before 1940, while if the pre-slump rate of emigration were revived the fall would begin instantly, and would produce within the next generation a population lower by something like 5,000,000. The loss in that event would be more than equivalent to the disappearance of every present inhabitant of the County of London, or of everyone in Lancashire, Yorkshire and Cheshire.

"Some decline in the near future appears inevitable, and in certain not very remote eventualities the drop may be sudden and heavy. But its incidence is bound to prove uneven, as between different areas.

"The effects of this turn of the tide of population must in any case be immense. If some areas are permitted to encourage unplanned growth, such as we have seen in Greater London recently, by attracting population from other parts which are left derelict, the social and economic consequences may well amount to a national catastrophe. While population as a whole was multiplying it mattered comparatively little which regions succeeded best in attracting the surplus. When population as a whole is shrinking it must evidently be a major political task to minimise hardship to any region through an unfair share of the burden falling upon it."

It continues:—

"Examples of the new type of situation to be faced are already beginning to occur. A year ago the Waterworks Committee of Manchester Corporation decided to postpone its Haweswater undertaking, on which over £1,000,000 had already been spent, and a further obligation of £300,000 legally assumed."

The Manchester authorities have made public an explanatory statement of this state of affairs.

If unemployment figures in some of the cotton districts are studied, the alarm expressed in this article is only too well founded. It is certainly not realised by those responsible in the places concerned.

The problem is, in the main, a two-fold one:—

- (1) To devise regional schemes of supply for rural areas, using if at all possible water from sources near at hand.
- (2) To make use of the water supplies of the North and the industrial areas in which redundancy will probably occur.

How are these different aspects to be reconciled? Again, quoting Sir John Snell's Committee, they said in 1920:—

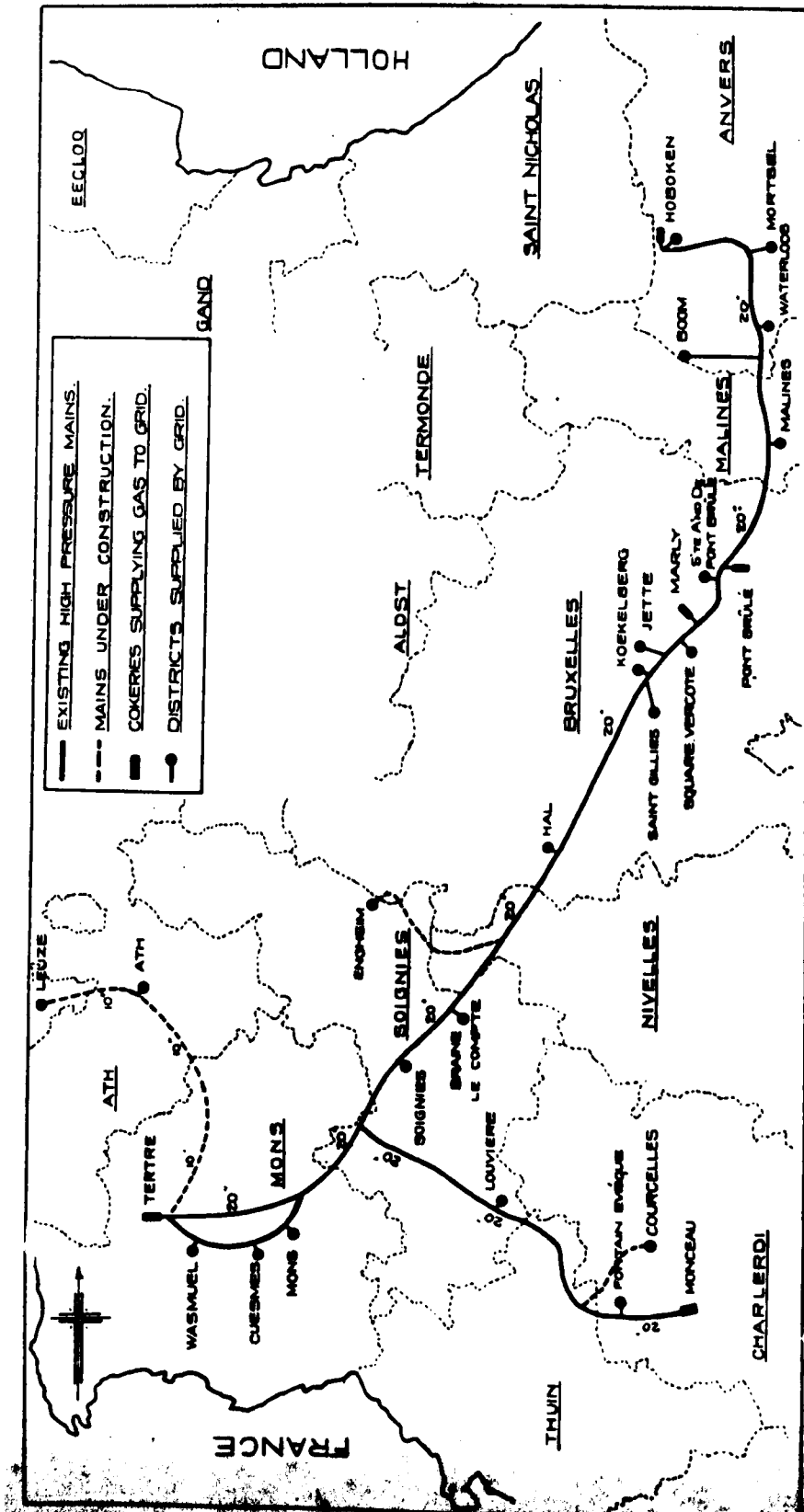


Figure 5.

"At present there is no department charged with the duty of exercising general control over the use of water in the interest of the whole community.

"Notwithstanding the fact that such control in relation to specific purposes, such as water supply, has been recommended as essential by numerous Royal Commissions, Select Committees and other bodies during the last fifty years, no remedial legislation has been passed.

"In our opinion such control should now be established in relation to all uses of water. The water resources of the country cannot otherwise be properly conserved and fully and systematically used for all purposes, and there is a real danger that at no distant date some of our communities in England and Wales may not be able to provide themselves with proper and adequate water supplies unless such control is established.

"The provision of adequate and proper public water supplies must, of course, always be the primary consideration, but it is also of great importance that the requirements of the community for water for power and other purposes should be met as far as practicable.

"The allocation of water has become too serious a matter to be left solely to a succession of Parliamentary Committees which are constituted from time to time to deal with particular Bills and have no continuity of existence, and which are unprovided with machinery by which schemes can be considered in relation to and co-ordinated with national resources and needs for all purposes."

A Central Organisation bearing in mind that adopted for electricity, seems to be indicated, and by it and through its Sub-Committees and Offices, the sources of supply could be totalled up and fairly allocated.

In any organisation the claims of each area would be investigated, the plans for the local networks or grids got out, and the powers of the original Act would enable such a scheme or schemes to be carried through, as the electricity extensions were.

The lack of this power in the 1929 Act would be provided for.

It would be the work of the main committee of this Water Board to fit all regional schemes into a national one, by which they would all be inter-connected and thus able to draw on each other if necessity called, or from some extra storage like the Lake District, but such inter-connecting trunk mains would not be put in until required.

It is difficult to account for the objections that have been raised to this scheme of inter-connection of undertakings. It can only be explained by a misunderstanding of what was intended.

The word "grid" was used as an illustration in the first instance to convey the idea that inter-connection of districts was intended in order to pool supplies, as in the electricity scheme. West/east and north/south trunk mains were suggested as forming part of it, but more particularly as a means of making use of the heavy rainfall of the Pennines and Lake Districts, and any redundancy from

towns in that area. To say, as has been said "that the country would be covered with a network of mains from which water could be drawn at any point, on the analogy of the electricity grid"—is quite an exaggerated and erroneous view to take of the proposal, putting up a bogey to frighten people.

Such an immediate interpretation of the proposal, apart from the misunderstanding they reveal, do little credit to the experience and knowledge of the comparative characteristics of water and electricity, which advocates of the proposed scheme of the inter-connection of undertakings possess.

The other points of criticism raised, as that the water would have to be taken from different levels, and that when it was available locally from wells they would not be used but the distant supply, do not reveal a reasonable consideration of the proposal; it is not constructive criticism.

The difference in levels, intervening hills, etc., can be met if they have to be, though in one case when a tunnel might be called for it has been pointed out that one already exists.

As to the trunk mains and the pressure, it must not be overlooked that the low speed in most mains of but 3 ft. per second allows of economically boosting the pressure to increase the flow, as has been done by Manchester on the Thirlmere aqueduct at Lostock, a proposal advanced as an alternative to an additional Thirlmere main by the author many years ago, but not favourably considered at that time.

As to unremunerative mains, the reply is they would not be put in until required.

The main criticism of a national widespread inter-connected supply seems to be based on the idea that it would be carried out as a whole at once. This is not at all the intention as this paper seeks to more clearly indicate, but it is strongly emphasized that anything done now should form part of a complete national plan and not a continuation of the individualistic method so largely followed up to now.

All the points so far raised can be foreseen and properly provided for.

The electricity scheme had a much more difficult state of affairs to deal with and overcame it.

To restrict any schemes to benefit local districts without considering inter-connection with others, when in fifteen years the population of the North will be less, and in the London district very considerably more, seems a view too parochial to be contemplated in these days.

As a matter of interest and to give an indication in general lines of how the supply of some public utilities is now envisaged and developing in this and other countries, a map of the electric grid with the trunk mains indicated has been reproduced in Fig. 1.

As a further illustration of the grid principle, the gas net recommended by the Area Committee and now being completed, is shewn in Fig. 2.

It is regretted that the distinct water mains of the different towns and companies cannot be included in this map, but an area nearby—not inter-connected it may be noted—is shewn in Fig. 3.

The complete gas grid (trunk mains) for Germany is shewn in Fig. 4 and for Belgium in Fig. 5.

A diagram of the existing grid of the Metropolitan Water Board with the surrounding water undertakings is not yet available for reproduction, but it is suggested that the grid should be extended to an area with approximately a fifty mile radius.

Note.—Figure 3 included in this Paper is reproduced by the courtesy of "Engineering."

DISCUSSION.

MR. A. E. L. CHORLTON introducing his Paper, said: The water supplies of this country have been enquired into on many occasions, and recommendations made by Royal Commissions, Committees, and various other bodies, and I think those all amount in the first place to a suggestion that it is a matter of such great importance that it is thoroughly justified and worthy of having a central control, a water board, or whatever you like to call it, if it is going to receive the consideration that such an important matter should receive to-day. Up to now water has always been dealt with as a separate question for each separate community, whatever that community may have been working through, either a municipal or some local council.

In the early days of my examination I used as my base those parts of the country in which water was in superabundance. One found that the practice, where the authority was a large enough one and possessed of sufficient means, was to push out to distant gathering grounds and construct long aqueducts accordingly. Thus one saw the big cities of the northern counties go out to the hills to the wet spots to obtain their supplies. It began to be evident that if one had to consider a widespread supply one must take into account these big undertakings, as well as the possible local remaining supplies that existed in those districts. That meant in practice to translate when needed such large supplies to any part of the country, and this introduced a system of longer distance aqueducts or high pressure

water mains than had been customary up to the present in this country. Without considering any detail of the why and wherefore of those particular proposals, I thought it best to examine what had been done abroad in the way of long distance supply there, and the Paper mentions some of those particular schemes in America and on the Continent. We are generally, I suppose, particularly on the West coast, rather a wetter country than a drier one, and it never seems to have occurred to us how necessary it might be, and to what extent we should go in conveying water from one part to another. But a relatively much poorer country than our own has an outstanding scheme where water is taken from the centre, behind Naples, right down to the heel of Italy by one of the most remarkable aqueducts that we know of, far greater than any of the Roman ones. The American aqueducts are frequently long, and many of them carry a much larger quantity than ours.

Then the summer came on us with an exceptional period of drought. That made it clear that the really urgent need was a supply for the rural areas. It became evident that the rural areas required even an earlier treatment than any more widespread connection of wet areas of supply. The first work, therefore, that arises is the creation of local grids in certain areas that have suffered during this year.

Now it did seem clear to me that even with those considerations in front of one it would be a great mistake to-day to under-

take any work at all. That was not part and parcel of a larger scheme when the larger scheme came to be carried out. I have been criticised, and in the Ministry of Health Report you will find it, and I have seen it in other places, where it is said that it was not a practical or commercial proposition to undertake any such widespread plan like laying trunk mains all over the country. I have never made any such proposition. I am a practical person enough to know that you are not going to put down more than you want, but that the man in control to-day must look into the future as well as the present.

Now this scheme that I have submitted does that, and my main point is that any scheme should form part of a main scheme for the whole country. To do that means setting up either within the Ministry of Health or as a separate commission—like was done with electricity—a water board whose duty it shall be to ascertain the complete water capacity of the country, and then to see that it is fairly distributed to all, ultimately, I suggest, by interconnected schemes to all the areas concerned. If we are going to have a big revival in agriculture, we are going to have more people in the country than have been there for years. Many of those people will come from towns, and no up-to-date town has less than 30 gallons a head. If you are going to move them into the country, then the rural supplies are totally inadequate, and I venture to think in many cases the local supply will not prove sufficient even if grouped.

Another point that has had to be taken into account is: Where is the population going to increase most in the future? If it is going to increase in the south more than in the north, then there is every reason why you should interconnect undertakings in order that existing supplies in the north should be available for the south. If you are going to have an increase in London in the next fifty years up to 12 million people, if you are going to raise the consumption to 60 gallons per head, you are going to get a consumption that will offer twice the present capacity of the Metropolitan Water Board.

Whether you are going to supply the whole of that from the Thames Valley, or whether you are going to interconnect with

other areas where there is a great natural supply, the hilly areas, is a point for your consideration. But it is important that we should think of the country as a whole, and of the future, and the way the population is going to either remain, move, grow, or change, and the demands for industry also.

The plans show that abroad the idea of a widespread interconnected supply is a common one, and Belgium, for instance, has it already for gas. I have put in the gas scheme, because it is a pipe scheme, and pipes are in the ground. If you make any reference to the electric supply here, the water people say "That is quite a different thing, you cannot compare them." At the same time those of us who have taken electricity courses know that the first way that they get you to an understanding of what its actions are is to compare it to water. However, there are engineers in this country who are fully able to tackle any of the difficulties that will arise out of this situation.

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The author is of the opinion that water engineers and authorities in this country are too conservative and bound by tradition, as compared with their electrical brethren. Whilst there may be some foundation for such an opinion, I believe that this difference must be in the nature of things, and instead of being a fault, may be considered a virtue. Water engineering is one of the oldest branches of the profession, whilst electricity is almost in its infancy. As the sources of water are, within limits and in the main everlasting, works for their utilisation are consequently of a permanent character, but in the case of electricity, the most up-to-date generating station may be obsolete in ten or fifteen years, and therefore electrical

engineers quite properly adopt a much shorter outlook in carrying out their schemes.

As regards supplies in rural areas, there is urgent need of improvement, but the author does not deal with the one great difficulty, viz., that of cost. Again, in connection with urban supplies, it must be admitted that there is overlapping in some cases resulting from the development of water undertakings, particularly in the north, on individualistic lines, and the plea for co-ordination is justified.

It is, however, the author's scheme for the establishment of a national water grid which will provoke the keenest discussion. Although no mention is made of a national grid in the title of the Paper, the author definitely advocates that future water supply schemes should be laid out in such a way as to lead ultimately to a system of national aqueducts, by means of which water can be passed from one area to another or supplied to any of them from some general reserve.

In support of his idea of a water grid, he instances the cases of the South Staffordshire and the metropolitan undertakings as examples of miniature water grids already in existence in this country, and refers to the great quantities of water conveyed from distant sources in America and Italy.

I suggest that in using these as illustrations of what might be done over the whole country, he has failed to appreciate the fundamental difference in the lay-out of an undertaking deriving its supplies from underground or local surface sources as compared with an undertaking deriving its supplies from a distant catchment area. The South Staffordshire is an excellent example of the utilisation of local underground supplies upon sound engineering principles. As the quantity of water that can be obtained from any single well or borehole is limited and can only be maintained provided no other well is sunk in its immediate neighbourhood, it naturally follows that, as increased supplies are required, additional wells have to be put down over a widely scattered area and connected to other wells in the same area by a network of mains. On the other hand, a supply from a distant catchment area may be likened to a tree, of which the roots correspond to the impounding reservoir with

its tributary streams, the trunk to the main aqueduct, and the branches to the lateral mains leading the water to places where it is required. As regards the American and Italian long distance schemes mentioned by the author, these have been forced upon the authorities responsible for them, for the good reason that there were no nearer suitable sources.

The author sees no difficulty in combining the distant source with distribution grids generally over the country, but I fear he has seriously under-estimated the physical difficulties and cost of such a scheme.

Illustrating the theory of a national water grid, the author visualises a branch from the Haweswater aqueduct passing from west to east across the Pennines into Yorkshire, with connections to Northallerton, Bradford, Leeds, Harrogate, York and other towns. Then, apparently, the aqueduct is to be continued to the south supplying places in Lincolnshire, and eventually being produced to London. In addition to this branch, the original Haweswater aqueduct is to supply Manchester and intermediate places in Lancashire, with an extension to Liverpool. No explanation is offered as to how the 75 million gallons per day which Haweswater is capable of producing is to satisfy the needs of so many places on the proposed aqueducts.

The author is not daunted by the problem of carrying his cross-country aqueduct over the Pennines, and suggests that tunnelling may be avoided, but if not, a disused canal tunnel is available.

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The author may suggest other possible sources in the Lake District, but although a greatly increased quantity of water can be obtained from that area, it would be from a much lower elevation than Hawes-

water. Ullswater is the only remaining high level lake, and a supply of about 120 to 135 million gallons per day could be obtained from a reservoir at that place having a top water level of 513 O.D. The other lakes are at much lower levels, and heavy pumping or tunnelling would be required if any of these sources were to be used for supplies to areas on the eastern side of the country. Elsewhere the author has stated the Pennines might be surmounted by a novel form of syphon; it would be interesting to have further details of this proposal.

The author has no hesitation in adopting pumps on his proposed national mains, and cites the case of the boosting plant installed by Manchester on the Thirlmere aqueduct at Lostock. He further suggests that the cost of the mains may be considerably reduced by running them at high pressure with velocities considerably in excess of those in common use.

Whilst boosting to a limited degree may be usefully adopted in certain cases, it is certain that it is not an economical proposition under normal conditions to increase the velocity from say 3 to 6 feet per second by boosting. The delivery of a main only increases proportionately with the square root of the head, and it would be more economical to provide a second main to run at a moderate velocity than to attempt to work at the figure suggested by the author.

The adoption of the boosting plant at Lostock was due to special circumstances, and provides no evidence in support of the adoption of similar methods in normal circumstances. When the time arrived for the fourth instalment of the Thirlmere aqueduct to be continued from Lostock towards Manchester, it was known that the rate of increase in the consumption of water in Manchester had fallen much below the figure estimated when the work was commenced, and that only a small proportion of the delivery of a new main would be required in the near future. Also, the aqueduct divided at Lostock, one of the existing mains passing to the south of the city, whilst two went to the north-east, and there was some doubt as to which route the fourth line should follow. A further important consideration was caused by the physical configuration of the ground traversed

by the aqueduct between Lostock and Manchester. In one place, where the aqueduct was carried through a tunnel, this had been driven at an elevation practically on the hydraulic gradient, and it was found that considerable difficulty was experienced in getting the full quantity of water through this section of the aqueduct. A small increase in pressure at the Lostock end of the main gave a greatly increased delivery.

In most cases where it is desired to increase the carrying capacity of an aqueduct composed of pressure mains, it is more economical to lay a new main in successive lengths, with cross-connections to the existing mains—each of the lengths of the new pipe being so proportioned that the delivery of the aqueduct as a whole is gradually increased by the amounts required to meet increased consumption. The advantage of this method is that no capital expenditure is lying idle, and when fully developed the authority has the tangible asset of a complete new main.

As regards the cost of such a system as that recommended in the Paper, the author has expressed the opinion that the cost of a water grid would be less than that of the electricity grid, and also that the electricity scheme had a much more difficult state of affairs to deal with than would be the case with water. I believe he is under a serious misapprehension in making such a comparison. He states that the cost of laying large mains is considerably less than in the past owing to the employment of labour-saving machines, such as mechanical excavators and tractors. Actual experience proves the contrary. On the Vyrnwy aqueduct three pipes of the same diameter have been laid side by side. The first one laid between 1888-92 cost £10,500 per mile; the second laid between 1902-5 cost £9,500 per mile, whilst the third pipe laid between 1925-31 cost £19,500 per mile. It will thus be seen that the cost of laying a main at the present time is more than double that of about twenty-five years ago, in spite of the fact that the older main was of cast-iron, all excavation being done by hand and haulage by horses, whereas the latest main consists of light steel tubes 30 feet in length (as compared with 12 feet lengths of the cast-iron main), and mechanical excavators and motor tractors were made full use of. To

give an idea of the cost of modern aqueducts formed of pressure mains, a careful estimate shows that an aqueduct composed of five mains, each capable of carrying 20 million gallons per day, or 100 million gallons daily in all, and working at a normal velocity would cost about £140,000 per mile. The main lines of the author's aqueducts would require to be of a larger capacity than 100 million gallons per day, but the figure I have given will suffice to indicate the enormous cost of the author's proposals.

Another fallacy in the author's proposals is the statement that at certain points in the aqueducts power may be recovered by installing turbines. Whether the turbines are to be placed on the main pipes or on branches from them is not clear, but in any event no more extravagant method could be devised than to bring water for scores of miles for the generation of electrical energy. If any surplus pressure is available it could best be used by reducing the diameter of the mains.

I believe that the true solution of the problem of water supply lies in the development of regional areas, and this accords with the report of the Duke of Richmond's Commission who recommended in 1869 that, when any town belonging to a large group, particularly if forming the nucleus of it, comes to Parliament for a Water Bill, the scheme should be so designed as to include the whole group.

Generally these regional areas would best be formed by the grouping of a number of smaller authorities round one of the large cities as a nucleus. The composition of each group would vary with the elevation and geographical position of the constituent authorities, the position of the source and the quantity of water available.

Under the direction of the Ministry of Health, good work is already being carried out on these lines, and if the present Paper can hasten the progress of this movement and also assist in the improvement of rural supplies, it will have served a valuable purpose.

In my opinion, the author has regarded the problem too much from a mechanical point of view, while his proposed water grid would be grossly extravagant and would entirely fail to use the national water resources to the best advantage.

MR. F. J. HASELDINE (*Barnet*): As Col. Davidson has covered a good deal of ground which might be covered by other engineers I shall confine my observations to one particular aspect of this case, and that is the suggestion which Mr. Chorlton has made that one of the reasons for bringing an aqueduct right down through England is the future requirements of London. It is a generally accepted principle in water supplies that the local resources shall be developed to their utmost before an authority is allowed to go any distance for a further supply of water. Therefore, I thought it would be as well to see roughly what is the capacity of London's parish pump. We have two rivers, the Thames and the Lea, and we have a number of wells. The figures on which I have based my remarks are published in the Annual Report of the Metropolitan Water Board. Taking the average rainfall of the Thames, and making the usual deductions which an engineer would make to cover a dry period of three years, and evaporation, I find that the average daily supply of water available in the Thames is the extraordinary figure of 1,321 million gallons a day. Now by the Thames Conservancy Act of 1911 the Metropolitan Water Board are not allowed to take water out of the Thames when the flow over Teddington Weir falls below 170 million gallons a day. I do not think any engineer would suggest that that is a quantity which should be left in the river every day in the year. Obviously they would want more. Then, again, the River Thames question is not the ordinary impounding reservoir problem where you can put a dam across the river, because you cannot do that in the case of the Thames, and you have to pump the water out of the Thames into your storage reservoirs. It may not be feasible to put down sufficient machinery to pump the peak floods, so a certain quantity of this 1,321 million gallons a day would have to go by. I, therefore, suggest that all things considered, it would not be unreasonable to take from this 1,321 million gallons a day, say, one-third, namely, 440 million gallons, which would still leave a quantity of 880 million gallons which could be used for purposes of public supply.

Next I have looked into the question of the Lea. The Metropolitan Water Board,

as successors of the old New River and East London Water Companies, are entitled to the whole of the water flowing into and down the River Lea, by the River Lea Water Act of 1855. Making similar calculations I find that the River Lea and the big wells in the Lea Valley would be good for something like 108 million gallons a day. Here again a certain quantity, although very small, 5.4 gallons a day, has to be left for navigation. Assuming again one could not take the peak floods, I suggest reducing the quantity of 108 million gallons a day to 80 million gallons a day.

There is a third big supply which is at the call of the Metropolitan Water Board, and that is the Kent wells, which, as far as I can see from the figures published in the Metropolitan Water Board returns, are capable of giving about 25 million gallons a day. So if you add all those figures together you get London's parish pump, when fully developed, capable of supplying about 985 million gallons a day, and the supply into the Metropolitan Water Board's district for the year ending 31st March, 1932, was about 283 million gallons a day. I think these few figures will show that so far as London is concerned there is adequate water available, and that we in London will not desire to provide funds to contribute towards the grandiose scheme to bring water from a great distance.

I would like to suggest to Mr. Chorlton that he might look at this problem along the following lines; firstly, as Colonel Davidson has said, the solution would appear to be in the formation of regional committees, and I think Mr. Chorlton might press for some information to be prepared as to the areas in this country which are not now within the area of a statutory water undertaking, and to make some move to ensure they are brought into such an area. He would then be able to make use of Section 35 of the Waterworks Clauses Act of 1847, which lays down the terms on which a statutory water undertaking have to take water to any part of their area if the revenue received in water rates amounts to a certain percentage on the capital cost of laying the necessary main.

Should Mr. Chorlton fail in this, or should the area be so scattered, or so poor that they cannot comply with Section 35 of the

1847 Act, then I suggest that he still has another string to his bow, and to my mind it is a very powerful one. That is the Local Government Act of 1929, Section 57, which is as follows: "The council of a county may agree to contribute towards the expenditure incurred whether before or after the commencement of this Act by the council of a district wholly or partly within the county in the provision or maintenance of any sewers or sewage disposal works or of a supply of water." I do suggest to him that if he will look along the problem on those lines he will be doing something of very great value to the country.

ALDERMAN MAJOR E. J. CLARKE (*Leeds Corporation Waterworks*): Taking first the question of rural districts, the deterring factor in rural supplies from impounding works is that of cost, not only the cost of providing the works, but also the cost of distribution, against which can only be put a light demand with low financial returns for the capital outlay. If one is to treat the distribution of water in a purely business way, I cannot at the present stage of rural development see farms being connected, except in cases where they happen to be close to the mains—trunk or distribution—of a water undertaker. In fact, I very much doubt whether a farmer who consistently used water by meter, as water is used on a farm, could make ends meet if he had to pay for it at a price at which water can be distributed on a commercial basis to-day. In any case it would only be used when the local supply was not available. It must be borne in mind that farms and houses in rural areas (isolated or grouped in villages) have not been put up haphazardly. Their proximity to a water supply of some sort is certain, and in the case of isolated cottages and villages there is invariably the possibility of providing storage. In these days of filtration and sterilisation there is no need for any section of the community to be without a pure and wholesome supply if the property owner and the appropriate authority carry out their functions. In fairness to these authorities, in so far as village supplies are concerned, they are as a body usually willing to do that, but suitable schemes are often voted down at the ratepayers' meetings because of the cost.

A state of drought in a rural area affects

comparatively few people. Its consequences cannot be compared with the dangers likely to arise where the supply in a crowded city or urban area ceases. On the question of closet flushing, 2½ gallons is the quantity generally in Leeds, with 3 gallons per flush at an extra charge in cabinet installations instead of the 2 gallons given in the Paper.

It has always appeared unsound to me to rail at the "long pocket" of the large undertakers in the matter of the acquisition of drainage areas for the construction of reservoirs. Instead of being a drawback it is a veritable god-send to the district below such works, in that it provides a steady flow of compensation water throughout a time when normally the stream below the reservoir would be depleted, and, by reason of the trunk main, it provides a means of supply to local authorities through whose area such main passes, if they are prepared to take it on terms which are usually arranged between the parties when the Bill for acquiring land and the construction of the works is before the Special Committee in the House.

I have looked in vain in Mr. Chorlton's Paper for some information as to who would "foot the bill" for the very considerable expenditure involved in his proposals. In some respects it is unfortunate that this suggested scheme has been associated in any way with either an electricity or a gas grid scheme. Electricity and gas have to be manufactured at certain suitable points, but water is distributed naturally over the country so that the only similarity is that one can conjure up a scheme by drawing lines from place to place over a map.

The electricity grid scheme has been described as successful, but I have yet to know, in spite of the efforts being made to that end, that the rural populations are taking up the current to any great extent, and I wonder whether water undertakers, be they companies or local authorities, would be in favour of the financial methods of that scheme in the matter of the building up of reserve funds being applied to their undertakings. I am expecting at any moment to hear that a "sewerage grid" should also be established. In fact, to be quite correct, this should precede the water grid.

The very high consumptions at home and

abroad quoted in the Paper are well-known to everyone connected with the waterworks industry. Certain authorities in these islands have larger consumptions per head than others, due to special trade conditions or other reasons, but it can be safely said that an overall average of 35 gallons per head for trade and domestic use is, speaking generally, ample, and it is the object of the rules and regulations to keep water consumptions within reasonable limits. Excessive use or "abuse" simply means that larger sewerage systems have to be provided to carry and treat larger volumes than would be otherwise necessary. To British water undertakers the *per capita* figures of consumption in some of the American cities can only be described as fantastic, and the building of constructional works to cope with such figures is simply construction for the perpetuation of waste.

In another place Mr. Chorlton has been suggesting that with the reported migration of certain trades to the south, and particularly to the vicinity of the Metropolis, the waters of our Cumberland and Westmorland lakes should also be forced into this "down south" movement, so that the dwellers there as well as those on the way, and even into the farthest corners of this land of ours, can have the chance of the soft upland waters of the north, which they may or may not require and which they are at liberty to refuse to take at all. Let me tell Mr. Chorlton that far from having a decrease in our supply, our consumption is up on last year half a million a day. We have none to spare for Mr. Chorlton and his disciples.

One can do nearly anything if sufficient funds are available, but we are a commercial nation and must stand or fall by the standards that have carried us to where we are to-day. There is little doubt in my mind that with the cost of constructional works—whether one builds impounding reservoirs or raises the shores of lakes—there is a definite limit to the economical cost of storage and distribution of water from such sources when compared with that from local underground sources or from rivers, now that modern filtration and sterilisation have come so definitely to our aid.

In spite of the way Mr. Chorlton has met

criticism on certain points in his Paper, the fact remains that the inter-connection of existing water systems bristles with difficulties, there being, in fact, no standard for water in any of its essential features or characteristics.

As impounding reservoirs are at all levels it follows that the inter-connection of distribution mains is not likely to be generally successful, and any help one authority could give another would, except in very few cases, be by delivering water into the receiving authority's reservoirs, either impounding or storage.

The Bradford Corporation proposal for the supply of areas in the East Riding (referred to in the Paper) cannot be described as a "water grid" as the proposal was to feed the main from one source which would simply mean an extension of their area of supply.

We have our regional water committees in some parts of the country, but they have no statutory powers whatsoever; and we may have a central water authority, but when duties are delegated to it I think you will find that you will have to continue to "deliver the goods" through the statutory water undertakings of this country as individual units, leaving it to them to make such arrangements they may find necessary as to linking up for mutual help with their neighbours. The machinery for the water supply of this country of ours is already set up. If individuals or communities wish to have new or improved supplies the existing machinery can meet their demands, but they must be prepared to pay for them.

If Mr. Chorlton would use his influence in accelerating the setting up of machinery for bringing about a reduction in the quantities of compensation water (or even providing for a sliding scale of reduced quantities during periods of drought) he would be doing a great work for the water-works industry, and very few (if any) would be prejudiced by it, as with the displacement of water energy by other means of motive power the large quantity of water now put into the rivers from reservoirs is not really essential, the purpose for which it was originally intended having disappeared—in most cases, long ago.

MR. DOUGLAS F. WORGER said: My remarks are principally connected with that

portion of the Paper referring to a supply to rural district areas which incidentally I have studied very closely for the past seven years and find that over six million people in rural districts in England are still without a piped water supply. So far as these are concerned, during the last six years I have worked out in detail the possibilities and comparative cost of the usual reservoir system, and the Bruston auto-pneumatic system in some 75 cases in 25 different counties in England, so that my results are founded on facts from figures, and are not based upon thoughts, hopes or wishes.

That the author raises most important and valuable points is beyond question, and criticism should, therefore, be of a constructive rather than a destructive character. I find that roughly there are some 77 paragraphs in the Paper, 60 of which I absolutely agree with, and especially with the clause referring to Mr. Warner Terry's most useful digest, which would certainly bear reprinting.

On the question of principles I strongly agree with the author's support of the three statements at the bottom of page 441, local supply from whatever source, whether well, boring, spring, rivulet, upper reaches of river and rivers, even, should first be called on as the source for the surrounding demand, and whatever there may be to spare should be used for the next nearest requirements.

That rivers may in many cases be now profitably drawn upon when economic mechanical purification is used has been shown by the greatest authority, the late Sir Alexander Houston, in his Paper read before this Congress in 1925, since when much further progress on these lines has been made.

It may be within the recollection of some of the senior members here that the Duke of Richmond's Royal Commission of 1866-1869 strongly formulated the direction that local water sources should be conserved for local consumption. Hitherto it has been impossible to deal with any of the smaller sources owing to the financial impossibility of any local authority dealing on an economic basis with the smaller groups of houses or villages. Now, however, it is very different, as it has been proved that "decentralisation"

is not only a possibility but can be economically used by means of the Bruston system with pumping plant driven by steam, petrol, electricity, crude oil, or almost any power, for with such a small group as 120 houses at five persons per house equal 600 population at 25 gallons per head equalling 15,000 gallons per day plus 50 per cent. for maximum supply equal 22,500 gallons per day, the capital cost for which would be about £200 for pumping plant, £2,000 for mains equal annually to £150 for loan charges and £140 for running charges, a total of £290 per annum, whilst the receipts from the rates would amount to £316 per annum, more than fully paying under the worst conditions of such a minimum supply. With an ordinary small village of say 1,000 to 2,000 persons the slight increase in the loan charges with practically nothing additional in running charges eliminates all difficulties of a financial type whatever. From my experience of actual running this system for seven years I am absolutely convinced that if one complete rural district council's area with some say twenty villages was to adopt the system on the proper lines, in less than twelve months it would be started in practically every county in England.

I take it that the author's intention is to speak of the grid system in relation to supply of water for general and domestic supplies, and not with a view of using the grid principle to convey water for power purposes to all parts of the country.

If this is not the case I should like to say with the greatest respect that although I agree entirely with his remarks and the quotations from Sir John Snell's report on page 432 of his Paper, I do not think it would be profitable to use the water grid for power purposes except with strict limitations, as the electric grid for such purposes must be far cheaper, and power should be obtained from that whenever practicable.

I had the honour to read a Paper at the Public Health Congress of 1930 giving the experience of the working at Princes Risborough of the Bruston system for rural districts and then proved quite clearly that it enabled "decentralisation" to be effectively used for all such villages too small for economical working on the ordinary system. This enables the capital cost to

be reduced by from 30 to 40 per cent. at least and the running labour charges by 66 per cent., as one man only is required instead of three men per day. Eleven different places are now running on this system, three in Bucks, three in Berks, and one each in Essex, Flint, Herts, Sussex and Somerset, and several others are under consideration, and in one of the last put to work with Diesel engines the pumping costs for fuel and lubricating oil works out at $\frac{1}{4}$ d. per 1,000 gallons pumped to 375 ft. head.

I say, therefore, that before any necessity arises for a grid system of any kind for rural districts it is essential that the considered findings of a Royal Commission should be adopted and the results seen before attempting any system which may be perfectly right for all large towns, congested areas, etc., but which are certainly not required for those six million people who, unlike those larger bodies, are now absolutely without water.

To confirm this I may add here that in the Ministry of Health Advisory Committee's Report of Rural Water Supply in 1929, on the very first page I see in Clause 2—"Cost is the Principal Obstacle." In clause 3 they state "Piped supplies are being steadily extended, but it is Utopian to expect them in every case." From my investigations, I contend it is not now Utopian. I venture to say that in the case of at least 80 per cent. of those six million people the necessarily small sources of supply of substantially good water for rural districts could be obtained, and is it not right that these people without water should have the first consideration. There are several clauses in this Report almost all of difficulties which would be overcome by such a trial, and several recommendations and lines of action that are very highly desirable would be proved. In clause 16 they again mention finance, implying that water is a local rather than a national service. If it can be done cheaply, as I maintain, it does not want the national help, although there may be a few of the remaining 20 per cent. who with some financial assistance could also obtain it. Again, in clause 17 the whole difficulty for agriculturists and dairy farmers could be easily overcome.

ANALYSIS OF A RURAL WATER COMPANY.

Houses and Population supplied, Total Water Pumped and Per Head Per Day, Receipts, Expenditure for Maintenance, Management, and Combined, Total and Per House, Profit and Dividend Paid.

Year ending.	Houses supplied.	Population.	Water pumped per annum.	Per head per day.	Receipts.		Maintenance.		Management.		Maintenance and Management.		Profit.		Dividend declared on Pref. Ord. Def. Ord.		Contin- gency Fund.
					Total.	Per House.	Total.	Per House.	Total.	Per House.	Total.	Per House.	Total.	Per House.	Per Cent.	Per Cent.	
March 31					£	£	£	£	£	£	£	£	£	£	£	£	£
1927	104	520	2,953,063	15.55	487	4.68	335	3.22	159	1.52	494	4.75	-87	Nil	Nil	Nil	-
1928	167	835	6,480,092	21.26	737	4.41	484	2.89	157	.94	641	3.83	+96	Nil	Nil	Nil	-
1929	212	1,060	9,053,820	23.40	1,029	4.85	523	2.46	180	.84	703	3.31	327	Nil	Nil	Nil	-
1930	272	1,360	12,000,313	24.18	1,312	4.82	658	2.41	161	.59	819	3.01	493	2½	Nil	Nil	-
1931	294	1,470	12,669,500	23.67	1,414	4.80	628	2.13	224	.76	852	2.89	562	5	Nil	Nil	-
1932	322	1,610	14,304,687	23.94	1,650	4.96	654	1.96	264	.79	918	2.76	732	6	Nil	Nil	230
1933	334	1,670	13,884,760	23.04	1,648	4.93	598	1.79	287	.85	885	2.64	763	6	2	345	

With regard to the basis of Rating (clause 19), this would assist everyone, but I submit that the grid question for the whole of the places where it might ultimately be required would be very greatly simplified and reduced in quantity and, therefore, cost by the utilising first of all these small sources for the local requirements. I cannot help suggesting that the rural district councils appear as the proper authorities to act, but there is another very important matter that has been very rightly dealt with by the author in the first five paragraphs on page 445, that of "Control." In connection with this I would point out that with "Decentralisation," if the rural district councils were working in conjunction with the county councils for water purposes a saving of an additional at least £1,000,000 in each county could easily be obtained, by arranging for a smaller amount than the 100 per cent. reserve plant at each station by each county keeping in reserve for actual breakdowns, or burst mains (90 per cent. necessity arising from these items), a couple of portable pumping units mounted on lorries which in less than an hour could be available at any of the decentralised stations in the county.

In conclusion I would point out that nothing has been stated by the author as to cost of the grid system, but those who have had any experience of pumping large quantities of water through hilly districts for distances of, say, only 50 miles, must be aware that the relative cost per 1,000 gallons of water pumped over a head that would certainly average from 300 to 400 ft. must, even understating the figure largely, be several times greater than using the water within some few miles of its source and thereby avoiding the friction and the high cost caused by the length, and head necessary in the large grid mains, that could be certainly saved or adjourned for a long period if all these local sources could be first utilised.

ALDERMAN A. R. ATKEY (*Nottingham*): The only observation I would like to add to the discussion is, that whilst we here are naturally primarily interested in the problem of water supplies, there are some of us occupying public positions who are reminded by our constituents, or by our critics, that

apart from our particular interest in water supplies we are the trustees for the public in respect to the general expenditure upon any kind of public work. It may be an advantage, perhaps, to have had this Paper read this morning, because it gives some of our technical members the opportunity of dispelling any idea that this scheme was either a feasible or practical one. But even had the reader of the Paper, and the idealists, proved that it was a glorious thing, where the cost does not matter and millions do not count, I should have ventured to agree with the outside atmosphere with regard to public men who get flairs for great ideals without any conscience or reference to the cost of carrying their ideals into existence. I think in this, as in many of the other social proposals put before us to-day, it would be well for us to bear in mind and profit by the example set to succeeding generations by the late Cecil John Rhodes. I suppose the world never had a greater dreamer or a man with more wonderful and marvellous ideas. He went a good deal further than the suggestion of a water grid. He wanted an empire grid. He wanted to spread the British Empire all over the world. He harnessed his idea of this great scheme to this tenet, and laid it down as the first principle of his grid scheme that "it is no use having great ideals unless you have got the money to carry them out." Now if modern idealists, whether it be with regard to an electricity grid, or sewer grid, or any other form of grid, would adopt that principle first, I think some of us might die with a happier thought than that of having handed down a terrible "baby" to the generations who follow us. It is from that angle that I am delighted to think that the Paper we have heard this morning will serve rather as a warning than as an example of the line for water authorities to take. I was delighted that Colonel Davidson gave us a few figures with regard to cost. The social reformers, I can imagine, are all feeling most happy with the thought of any scheme which would permit them to spend £140,000 a mile! Reckon up the miles and multiply them by £140,000! Then you can go before any constituency with an irresistible appeal.

SIR WM. CUNDIFF: The main object of the Paper, namely, to improve the water

supplies of the country is one with which on general principles, all those interested in existing supplies must be in agreement. The methods by which, however, he hopes to obtain the ideal of a piped supply to every potential consumer in the country, are of course open to considerable criticism not only from engineering but also from financial points of view. The interest which Mr. Chorlton has taken in the question of what he terms "a water grid" has been well known in Manchester for a number of years past, and personally, I have the greatest sympathy with his ideals. As the Chairman of the Manchester Waterworks Committee there are, however, points in his Paper to which I desire to reply.

He quotes at very great length a letter which appeared in *The Times* last January under the heading of "The Population Trap," and he dismisses my reply to that letter with very little more than a line of printed matter in his Paper. I think that having set out in such full detail the article itself, he should have given my reply a little more consideration. With your permission I should like to quote from my letter. I stated: "The probable future growth of population in the various areas is a matter which must always receive the closest consideration in the efficient management of municipal affairs, and this is particularly so in waterworks administration, where so often provision has to be commenced years ahead for the actual requirements of the future. The Waterworks Committee have always considered population in laying down their works programmes and the position as disclosed by the Census of 1931 occasioned them not the slightest surprise. The Census of 1921 drew particular attention to the substantial fall in the rate of intercensal increase in this area. The subsequent annual returns of the Registrar-General supplemented by the local vital statistics proved that little if any improvement in the rate of growth was taking place. The Waterworks Committee in deciding their policy have to bear in mind that, whilst their undertaking is the second largest, they are as well the largest bulk supplying authority in the country. The aqueduct from Thirlmere stretching over 100 miles, does in fact form a huge water grid for the actual or potential

supply of innumerable rural and urban areas who have definite statutory rights of demanding a supply subject to certain conditions. When Parliament sanctioned the Thirlmere and Haweswater schemes in 1879 and 1919 respectively, the onus of granting bulk supplies to water authorities within the neighbourhood of the aqueduct was imposed by Parliament, a burden which the Corporation have undertaken and carried out to the best of their ability." I further stated: "It is also necessary to provide for the increasing domestic consumption per head in detail and bulk areas caused by improved sanitation. Further, the supply of water for trade purposes which takes over one-third of the quantity supplied in detail, has been consistently growing subject to temporary set-backs due to trade depression, etc. Although the population of Lancashire has grown only 2 per cent. in ten years, between 1921 and 1929 the trade demand grew from 16.5 to 18.4 million gallons a day, but has subsequently fallen to 17.4 in 1931 on account of trade depression. It will, therefore, be realised that the Waterworks Committee could not merely rely on population statistics, as is suggested by your correspondent, and although these did form a basis, many material adjustments had to be made for the above and various other local factors which are too detailed to be mentioned here. Parliamentary powers for the Haweswater scheme were obtained in 1919. . . It is interesting to note that the population then estimated for at 1931 was only 16,000 more than that subsequently disclosed by the Census, 1931. When it is remembered that the area of supply covers 169 square miles of rural and urban areas, with a present population of 1,491,000, and that as a precaution for safety estimates must err on the side of an over-statement, I think it will be agreed, for purposes of waterworks administration, the estimate was a correct one. The date when the population would probably approach substantial saturation point in this water supply area was submitted in 1926 as 1943, which is in rough agreement with your correspondent's dates of 1940 and 1950."

I further drew attention to a mis-statement in one of the latter paragraphs of the article, which is amongst those quoted by Mr. Chorlton. This is the statement that the

revival in emigration would produce within the next generation a population lower by something like 5 million. The incorrect part of the statement is that: "The loss in that event would be more than equivalent to the disappearance of every present inhabitant of the County of London, or of everyone in Lancashire, Yorkshire and Cheshire." I pointed out in my letter that Lancashire's population alone exceeds that of the County of London by some 640,000, while Yorkshire's population is only 8,000 less than that of the County of London. It is evident that the writer of the article omitted to include the county boroughs in his population figures for the counties; a very considerable item in the population of Lancashire and Yorkshire."

With regard to the general question of a "grid" for water supply, you will observe from extracts of my letter already quoted that Parliament has imposed on Manchester the duty of supplying any authority, within certain limits, who desires water from Manchester's Lake District undertaking. This was the result of petitions presented to Parliament at the time powers were granted for the Thirlmere and Haweswater schemes. But what is the result when we come to enquire as to the needs of the various authorities? Practically no one wants to share in the Haweswater scheme, because Parliament insisted that those who drew water from Haweswater and benefited through Manchester's initiative should pay a proportionate share of the cost from the time that they signified their intention to participate in the scheme and the benefits arising therefrom. This, I think, will be found to be the stumbling block in any voluntary scheme for a "water grid." The local authorities and the potential individual users are averse from paying for the benefits of a pure water supply, although these are undoubtedly amongst the foremost necessities of life.

One other point I would like to draw attention to is the statement in which reference is made to the boosting of water by Manchester on the Thirlmere aqueduct at Lostock. I do not quite agree with Mr. Chorlton when he says that this is the same proposal he advanced as an alternative to an additional Thirlmere main years ago and which proposal was not favourably

considered at the time. So far as I am aware Mr. Chorlton's proposal was to boost water all the way from Thirlmere. This, however, I think he will admit is a very different proposition from boosting on the last length of pipe line, when I tell you that the aqueduct consists of long lengths of tunnel and cut and cover, in addition to pipe. The suggestion would mean boosting plant and pumps, together with electrical supply for their operation at the north end of every one of the 31 syphon pipes between Thirlmere and Manchester. This, of course, under present conditions would be much more costly than the laying of the pipes down to Lostock as connecting links between the tunnel and cut and cover as has been done by Manchester when they laid their fourth line.

The idea of regional schemes whereby a central authority for each region would control the whole of the water supply in each area, possibly a natural water-shedding area, has my heartiest support. At the present time Manchester is prepared to go forward with the Haweswater scheme if the local water authorities in the north-west of England will come forward and tabulate their requirements from such scheme for the next ten years, but as I said before the great stumbling block in this matter is finance, and unless authorities are prepared to shoulder their fair share of the financial burden it can hardly be expected that large authorities like Manchester, who have their own financial troubles in times like the present, can carry the whole burden for other authorities.

To sum up, I think that the paragraph where Mr. Chorlton visualises a central organisation for investigating and allocating supplies, is one which is worthy of further consideration. In this connection the British Waterworks Association, as representing most of the existing water authorities, might well take the initial steps by setting up a committee to investigate the possibility of some co-ordinating scheme, having regard to both the engineering and financial problems involved.

MR. G. A. PARFITT (*Norwich*): I think so far as schemes for the supplies for rural areas are concerned a lot could be done if the statutory powers that we possess were made more elastic. It would be helpful if

we got down to something practicable in the way of facilitated supplies to those rural areas. I therefore suggest that if there was a provision in a general Act of Parliament enabling undertakers to distribute outside their areas at the request of the District Council on a guarantee from the District Council, this might be helpful for the development of rural supplies. Under the Local Government Act of 1929, Section 57, the County Council may make a grant to the Rural District Council in the event of their deciding upon a scheme of water supply. I think that with the revenue derived from the extension into their area plus the grant or a portion of the grant, it might go a long way towards the meeting of the guarantee that the Rural District Council would be responsible for. I hope that something can be done in this direction to help statutory undertakings to supply and distribute outside their statutory areas.

MR. F. L. BALL (*Mid-Kent*): I think we want exact knowledge of the condition of rural water supply. In 1914 the Local Government Board issued a very valuable return as to water undertakings in England and Wales, in which the position of the water supply in every rural parish in England and Wales was set out. I wish that the Ministry of Health would find themselves able to bring that return up-to-date. I confess I am surprised at Mr. Worger's statement that there are six million people in this country without a water supply.

In the letter from Mrs. Winttingham it is suggested that the Government should give the same assistance for water supply as they have done to the construction of roads. In my opinion it is unwise to appeal to the Government until we have tried out the existing powers. The power at present possessed by a Rural District Council to charge over the whole of the area the necessary cost of the water supply of one parish, and the important power that was emphasised by Mr. Haseldine of the power of the County Council to contribute to that, would, in my opinion, be sufficient in a great majority of cases to cover the cost of a water supply.

I hope you will not think it egotistic on my part if I tell you something of the figures of our own companies. We have the Mid-Kent Water Company, the South Kent Water Company and the East Kent Water

Company under one common control, and for years they have endeavoured to carry out the principles advocated by the Chairman. They are all interconnected among themselves, and in addition, they are connected with four adjoining companies and with four adjoining local authorities. The three water companies between them supply nearly 200 parishes with a population of 135,000, which you will see is somewhere round about an average population of 700 for a parish. The area of supply is 700 square miles, which is more than half the rural area of the County of Kent. I think if I give you the figures of our own supply that will put before you the real difficulty of rural water supply. The three water companies between them supply over 27,000 houses, the average rateable value of which is £14, and the number of houses per mile of main is thirty-two. We supply these 200 villages from five main pumping stations. Ours is, perhaps, rather a more centralised supply than Mr. Worger's idea, but I am glad to say that we have been able to supply these villages satisfactorily and also to pay a reasonable return upon the capital.

MR. J. K. SWALES (*Sheffield*): What is the urgent problem that this scheme is designed to meet? So far as I see the problem, it is mainly one of the supply to rural districts. That is not a question of shortage of water. Except in a few isolated cases, there is water sufficient for rural supplies within reasonable distances. It is simply a question of cost of furnishing such supplies, and that cost is largely determined by that of distribution mains and service reservoirs being higher in relation to the number of premises served. That will obtain in the case of a so-called grid. I do not think the real problem which this scheme is supposed to meet has been properly expounded.

MR. CHORLTON (replying): I do not want anybody here to think that this has been a propaganda measure for any particular purpose. I will admit that our difficulties in Lancashire and in Manchester in carrying through the big Haweswater scheme made me, in the first instance, try to find out a way of making use of it. It seemed to me that a scheme of that size was really a national asset, and that it should not be

beyond the wit of the engineers and others in this country to make use of it. One of the towns in the West Riding, perhaps not so luckily fixed as the town represented by our friend from Leeds, made a proposition to supply water across to Hull, which was in effect almost exactly similar to the proposition I made myself. This, I felt, was a considerable fortification of my idea, because it came from a practical man, a waterworks engineer, Mr. Newlands, who knew about the difficulties. You must not blame me in other cases for failing in the early stages to receive support in a practical way. Unfortunately that proposition was turned down, it was direct evidence of the possibility of any town with a larger supply than they really wanted to use to make use of it in another district.

Speaking generally, my first proposition is that the water supplies of this country should be safeguarded by a special authority, whether under the Ministry of Health or as a separate body, centrally controlled. I do not think Colonel Davidson said anything about that particular point. It is a basic point. He must not ride off on an important national subject like this by catching me out on the cost of the main per mile, because after all, Colonel Davidson, from his experience, which is far greater than mine, may be right, but we must not spoil our consideration of the larger issue by any of the smaller details. Do you, therefore, agree or disagree that water in this country is so important that it ought to be centrally controlled; and, secondly, do you agree that whatever schemes are brought forward at the present time should be part and parcel, or taken full account of in any other scheme that may be in existence or may be intended for the future?

I must take a certain amount of exception to the concentration of some of the earlier criticisms upon the grandiose nature of the scheme. I do not think that is quite fair to me, for I have tried so often to rub it in that the first considerations are the rural areas; that is, grids for the rural areas would be those that would be attended to first. But to do so in a proper way you must have a special authority to handle them, give permission for them, and see that they fit in with the larger scheme. The 1929 Act has no powers to compel

people to be reasonable, and you know, many of you, that there have been quite good schemes, brought up by a few people who did not see what they were going to get out of it. I think you will admit there is a water shortage in many parts of the country. It has been shown by our friend who said there were six million people who had no regular supply. Are we going to allow ourselves to rest content with criticisms of parts of the scheme I have put forward when this important problem is before you?

On the question of cost, I agree that that is the crux of the whole thing. The only way that this will be met will be by the central authority not allowing schemes of a grandiose nature to go forward until the development of the country has been sufficient. I have no thought of putting in a network of big mains throughout the country when there is no demand for them. It would be absurd. I do feel any scheme brought forward should be part of a whole, and if any of the areas cannot supply, or have an insufficient source of supply, that it should be possible to draw from other areas. I equally feel that the national supply of the lakes and the wet districts should be borne in mind in connection with the other supplies, and I think it is a vast pity that a magnificent undertaking like Haweswater, which might possibly have been raised to 100 millions a day, should be forced to be carried on only to such a small extent as compared with the original proposition as to be really more of a load to Manchester than an advantage.

Colonel Davidson rather indicated that the regional development, which was right and proper, had not been considered or stated by me, and his criticism was, therefore, confined to the case of these large mains about the country. That is hardly fair, because in this Paper I expressly stated that no large mains would be put in until the regional grids had been dealt with first. I never invented this word "grid" in this application. I have had to bear all this comparison with the electricity grid, arising from the thoughts that grid suggests with its exposed mains all over the country.

The criticism on my turbine remark (not in this Paper) is a perfectly fair one. It is a slip in one of many paragraphs. The real possibility of turbine use is in compensation

water discharge from large reservoirs in the hills, and that has been tried in one or two cases, but it has a limited use, I believe, even then.

The syphon question is also one of considerable difficulty; to discuss it would mean I should have to depart from the Paper on the general subject into the particular one, and I am afraid I cannot undertake to do that. I cannot do the job of the water engineers.

The question of pumping, which is in that and arises out of it, is also mentioned by Sir William Cundiff in regard to an earlier proposal of mine of which the Lostock installation is a type. It is a very difficult problem to answer in brief. The conditions vary a good deal in the different circumstances. Of course you cannot boost up tunnels and open supply aqueducts. You must stick to the pipe. There are many cases in which if you are below 3 ft. per second in the supply main you can go up to 6 without undue loss. I think the possibilities of pumping under special circumstances are a little overlooked. There is in the North a general belief in gravitation supply. But when you come to another part of the country it is always by pump. The practice between the two is not at all clear. It is desirable that there should be a relation, otherwise in some districts they will tell you pumping is too dear, yet in other districts they find it is satisfactory and sufficient. With regard to the point where pumping comes in, it is so important that I think it deserves a Paper of its own, and I cannot now say anything further about it. With regard to the question of using the water resources in the vicinity for the local supply areas to the best advantage, I think I have dealt with that. I am sorry that it does not appear to be sufficiently clear that my propositions all refer to making use of local water and bringing the other in as the distant supply called for at a later date. Mr. Haseldine again spoke about the gigantic scheme. There never has been any thought of carrying out a widespread large capacity system of grid trunk mains at once, and I do not think that such criticism is quite fair to the Paper.

Another has dealt with the supplies in the London area. This information is very valuable and interesting, but not strictly

germane to the Paper. There is not any point of real difference. If you decide to get the whole of your supplies from the London area, why not? I should not say it is right and proper, but I do say any scheme for London should be part and parcel of the scheme to cover larger areas, and they should be interconnected, so that if there is more water it can go somewhere else where they have less water.

As to the practicability of using the Thames water to the extent proposed, that is for others to say. No doubt it can be done by a very large storage reservoir. There again the solution is the regional committee. That is what I have proposed: regional areas, but connected, and under one centre, so that they shall all be properly drawn up with regard to each other.

Major Clarke is fortunate in that he is still expanding in Leeds, but Sheffield had to get a special rate for the opposite reason. Speaking generally, about the problems of interconnection, I see no real impracticability in the job. After all I am not a water engineer in the sense of supply. For many years I was concerned with the development of pumps of special types, notably the pumps Sir William has in at Lostock. They were derived from my pumps. He will remember apart from this the scheme of Bradford which I have spoken of in which the excess water was to go across to Hull. He objects to the comparison with electricity and gas. There is a certain amount of reason in his objection, but I rather wanted to convey it in a wider sense than a direct connection, as it were, between the two. Interconnection between authorities, between works, and between undertakings is taking place, and I do not think it was unfair to bring these forward to illustrate it for water, but I do not want you to take it that there is a strict analogy upon which you can assess values one with the other. When you have in Belgium a gas grid owned by an English company it seems very strange that we lack similar progress in this country.

Sir William Cundiff referred to the central control, which I think he favoured. You get less risks of local interests overriding national ones. It was interesting to learn that Manchester would go forward

with the full scheme if it could be allowed to supply others outside the area.

Mr. Parfitt of Norwich dealt with a modification in the Act to enable them to take in a supply outside their areas. Well, in an interconnected scheme that would be provided for by a central authority.

Mr. Ball of Mid-Kent told us that he had already interconnected all their undertakings and really had a grid working—to use that word again—in that part of the country. No doubt it would be valuable from the results that they have obtained there to try and translate them into other areas.

Mr. Swales rather turned us on to the question of cost, which is perfectly sound. Only a careful investigation of the whole problem will ever put that in its right place. We cannot go into the construction of long distance schemes, or even very large local grids, without going into the cost most thoroughly and considering all other supplies of all the people in this district surrounding them.

The following communication was received from MR. F. K. SINCLAIR (*Colne Valley Water Company*): I am not in agreement with the complacent attitude of certain previous speakers as to the present position of total independence of the innumerable water authorities throughout the country. It would appear that the references to a formidable trunk main grid has obscured in the minds of critics, the smaller, but, to my mind, the most valuable points of the Paper.

Mr. Chorlton advocates interconnecting links between adjacent water undertakings, and whereas I am at loss to understand where any real difficulty can arise in effecting this from a practical point of view in hundreds of cases I consider very definite advantages are to be derived in so doing.

I do not consider that the principle is applicable in all cases by any means, but I do believe that the existence of universal legislation to allow of interchange of surplus supplies from one area to less fortunate neighbouring areas would not only be a measure of national advantage, but one which many water authorities would welcome. I believe that the root of much of the opposition to interlinking lies in the fear of individual water authorities, that such a

step would eventually result in the usurpation of their functions as supply authorities. Such has not been the case with the advent of the electricity grid as regards the continued existence of distribution authorities. Small generating stations have certainly (and in some cases inadvisably in the interests of economy) been scrapped, but this aspect is not analogous to water—electricity can be generated at almost any spot, but water sources cannot be transferred and concentrated at large centres—existing water sources must continue to be utilised, and practically every existing water supply authority must continue as a “selected station.” As Engineer of the authority affording the second largest supply (excepting the Metropolitan Water Board) within fifty miles radius round London, mentioned in the Paper, I will confine my remarks specifically to that area.

The outer London area is growing at a rate which is equalled nowhere else in the country, and the zone of saturation of building has practically extended from six miles in the north-west section, to over ten during the last fifteen years, and to a similar extent in other directions. The largest source of water is the River Thames, and Mr. Haseldine has already given some very interesting figures in this regard. The Metropolitan Water Board have already connections for bulk supply to seven adjoining undertakings (although be it noted at prices as divergent as 4½d. and 2/- per 1,000 gallons) but these undertakings have no power to pass on water to the authorities lying beyond. As London spreads outwards the outlying authorities will need assistance. It, therefore, follows that facilities should be provided for transferring water from the centre of London outwards, but also every facility should be given in the interest of economy for water sources in the outlying areas to be exploited to the full. The utilisation of water near to a source is certainly in the radial area round London cheaper than pumping it long distances from the Thames.

Further, the value of deep well sources must not be overlooked in distinction to river derived water in the coincidence of minimum yield and maximum supply demand with the latter and absence from the former. Too little attention has been given to this

important aspect by Parliament in restricting the taking of underground water around London, where undoubtedly valuable supplies are still unharnessed, running to waste, or into rivers whence their subsequent withdrawal means costly filtration, and loss by evaporation from settling reservoirs.

Remarking on some aspects of the present position of supplies in the London area, it is notable that the Colne Valley Water Act, 1922, simultaneously authorised purchase of water in bulk from any undertaking, and repealed a then existing clause for supplying adjoining authorities in bulk at that portion of the area of supply farthest removed from London. Can any position be more farcical than this—which I think is common in many places—that an authority is debarred, other than by costly parliamentary procedure from coming to the assistance of a neighbour in times of emergency when both trunk and distribution mains of adjacent authorities may lie within a few yards of each other, at several places.

It is well-known in the London area that proposals to utilise underground and river sources passing through the outlying districts surrounding the Metropolis court the bitterest opposition from other water authorities, some of whom have resources many times the needs already at their disposal, and that well pumping stations exist where only a portion of the total water actually available is permitted to be utilised although the capital has already been spent whereby the whole of the water can be used.

I submit there is a very good case indeed in the London area for removal of the obstructive legislation which prevents co-operation between water authorities within that region, and will allow interchange of supplies where such is desirable, and utilisation of existing and unexploited resources throughout that area as near as possible to the centres of demand.

There is much room for a better spirit of understanding between water undertakings and for substitution of a public as opposed to a parochial-minded attitude in water supply schemes.

The water industry can and should progress by co-operation and not await the day, which will surely otherwise come in spite of, and largely because of, the complacency of a large section, when the Govern-

ment will step in and re-organise it in a way which will probably be tempered with many of the uneconomic proposals in Mr. Chorlton's Paper, as well as those of real value.

I think we should look to the British Waterworks Association to take active steps to encourage co-operation, both regional and national, and in so doing it should endeavour to provide assurances to allay the mutual suspicion which is evident and justifiable under certain conditions between authorities. The Association should further consider what steps can be taken to remove the obstructions to progress existing under the only present available means of getting authorisation for works.

The following communication has been received from Mr. O. W. BERRY (*Wells R.D.C.*): While I quite agree as to the urgency of the question of water supplies in rural areas, neither the author, nor the subsequent speakers, appeared to come to grips with the real problem, as much of the discussion was of such a "grandiose" nature, in which huge water undertakings and large cities were the principal items discussed, and if by chance the question of cost was mentioned, the figures referred to millions. One gentleman from Kent did give some interesting figures from actual schemes, which helped to illustrate the difficulties in a rural district.

I am convinced that regional water supply must come, but the first consideration must be cost. How can a rural area afford a water supply? Firstly, it must be remembered that land has been derated; secondly, owing to the derating of land, it is questionable whether the representatives on rural councils truly represent the ratepayers of the areas, in that the agriculturist is often still in the majority, and as a class are not generally considered very keen on providing public services; whereas the house owner, now the predominant ratepayer and potential consumer of water, is unable to carry sufficient weight in the Council Chamber to push forward schemes of public water supplies to the proper extent; and thirdly, the rural ratepayer has to contribute his quota towards an increased County Rate (by reason of grants in aid of rural water supplies) as well as the special expenses rate for water

in his own area. Even when the County Councils make grants of 25 to 30 per cent. under the 1929 Act, the rate would be so heavy on many rural areas as to be prohibitive; hence, I can see no prospect unless the Government will also make considerable grants. If the necessary funds could be so provided, I think there would be little difficulty in the majority of cases. By so doing, the Government would provide money for schemes which would give work to a vast number of unemployed, work which could be done at any time of the year, work which would provide one of the essentials of life in the rural areas, and work which would give to the country a most valuable asset and be the principal incentive to the re-population of the country districts.

Now to consider the question of rating for a few moments. Consider a district such as mine of say fifteen parishes, five of which already have public supplies of water with loans partially paid off in varying extent, five other parishes supplied largely from private estate supplies, and the remaining five without water and urgently in need of it. These latter five parishes cannot be supplied with water if they alone are to be rated owing to the heavy cost, but it might be possible with the aid of grants, if the rate could be spread over the whole fifteen parishes. But, naturally, the other ten parishes strongly object, some of them having almost completed the repayment of their loans. How are these conflicting views to be reconciled.

It seems imperative that the Ministry of Health should make definite provision for such and similar cases, whereby the County Councils and/or Rural Councils may spread the rate over their whole area on an equitable basis, or, if necessary, over a whole region. Also, I suggest the Ministry might look after the interests of the small local authorities to a greater extent than in the past by insisting upon adequate safeguards and the provision of water, in the cases of larger public authorities taking water from or passing through such areas with trunk mains.

I quite agree with the principle of regional water supplies provided they are kept within their economic limits and their activities co-ordinated by some properly constituted "Water Supply Board," leaving the manage-

ment and control to the "Regional Board." some regions may be very small, others very large, but all economic entities, the parish boundary, the rural district boundary, and the county boundary where water supply is concerned being wiped out in favour of the regional boundary. I venture to suggest that a large part of the country would naturally resolve itself into regions, and only requires the expert technical assistance and control of the "Regional Boards," backed up by the "Water Supply Board," to squash the petty jealousies of the local authorities concerned and formulate workable schemes.

It is suggested in this connection that, in the very early stages of the formulating of schemes, it might be very advantageous if the Ministry of Health would place at the disposal of the "Regional Boards" Engineers and Financial Experts to assist and give advice on technical difficulties before the Consulting Engineer is called in, in order to expedite the preparation of schemes and save the waste of time of, perhaps, ill-advised schemes which would never be sanctioned by the "Water Supply Board."

With regard to the engineering aspect of regional water supply, there would, undoubtedly, be difficulties in some areas as to the sources of supply, and bold measures would have to be adopted, but a tremendous amount could be done by developing local supplies to the full, and it is on this local development that regional water supply must depend for success.

Such questions as allowance per head, storage and service reservoirs, velocities, boosting, size of mains, steel, cast-iron or asbestos tubes, and a host of other technical items are all of such minor importance as only to be considered relative to each particular scheme.

Given the supply of water and the funds available, there will be little difficulty in delivering the goods.

The following communication has been received from Mr. EDGAR MORTON (*Manchester*): As one who has to some extent investigated the available water resources of the country, perhaps I may be permitted a few observations on the geological aspect.

Many of us who have read Mr. Chorlton's most interesting contribution will feel indebted to him for setting out so clearly

his views with regard to a National Scheme of Water Supply.

The idea of a National Grid System applied to the distribution of water has been repeatedly before us in the last few years, and it must be admitted that many of us have been under the impression, or illusion, that such a national scheme in effect, involved the harnessing of the available surface resources of water in the wet mountainous regions of Wales and the Lake District, or the moorlands of the Pennines, and the conveying of such waters to the drier southern and eastern parts of the country by means of a network of trunk mains. Apart from the engineering and financial difficulties involved in such an undertaking, upon which I am not qualified to speak, a very serious objection appeared to lie in the fact that vast local reserves of water supply would, apparently, be overlooked and ultimately wasted.

Mr. Chorlton has now made it clear however, that the proposal is to utilise such local resources by the initial development of "grids" over regional areas, which latter may subsequently be interconnected in such a manner that a shortage of supply in one district may be met by a redundant supply from an adjoining area, or if needs be, from some extra storage situated for example in the Lake District.

The idea of, and necessity for regional schemes in rural districts formed the basis of the two Papers on "Rural Water Supply" which were read before this Association at Blackpool in July last and which were to a large extent complementary. Mr. Thomas Marsland dealt with the engineering, administrative and financial sides, and myself with the hydro-geological aspect, and I endeavoured to show, with special reference to three selected areas, that the extent of these local grids would depend more upon geological than upon geographical boundaries.

The Mid-Cheshire Plain is a striking example of the necessity for a local grid. The existing situation with regard to water supply in the central portion of the plain is deplorable, and can only be adequately dealt with by co-operation of the various

authorities, and efforts are at present being made in this direction. The Vyrnwy Aqueduct runs along the western boundary of the plain, and trunk mains bring water from the undertakings of the Manchester and Stockport Corporations into the north-eastern part of the plain. Apart, however, from the cost of purchasing water from such external sources in bulk, and distributing it in detail, the use of such waters would probably imply that the large reserves of subterranean water which exist locally, in the areas bounding the plain, would never be exploited. Joint action on the part of the adjacent authorities should render the development of these local reserves practicable, and the whole of the plain would thus, ultimately, be supplied. If it should subsequently prove desirable, this local grid could be linked up with the Liverpool, Manchester and Stockport undertakings so as to render it possible to draw on these supplies, if and when required, in the manner suggested by Mr. Chorlton.

A somewhat similar case can be made out for the limestone tract in North Derbyshire, and Mr. Chorlton mentions the unfortunate situation, with regard to public water supply, in certain parts of Lincolnshire, where again the only solution in the rural areas is the ultimate formation of a joint scheme. The regional scheme mentioned by Mr. Chorlton was turned down through local disagreement, and has now resulted in one of the larger authorities attempting to establish works in an adjacent area where the natural reserves of water are limited and are likely to be fully required by the local authorities in the near future.

The point of these remarks is to emphasise the need of developing local resources of water supply by the formation of regional grids in the first instance, the interconnection may follow at a later period, if it should then prove desirable, but unless such local reserves are exploited there is the ultimate danger that they will be left permanently untapped, and supplies from distant sources utilised instead, and such a situation would, I submit, not be in accordance with a sound National Policy in regard to Public Health and Economy.

CONFERENCE

Under the auspices of the British Waterworks Association.

THURSDAY, 16th NOVEMBER, at 11.0 a.m.

MR. G. M. ROBERTSON, J.P. (*President of the Association*), in the Chair.

The following Paper was taken as read:—

Water Pollution Research.

BY

A. PARKER, D.Sc., F.I.C., M.I.Chem.E.

Assistant Director of Water Pollution Research, Department of Scientific and Industrial Research.

INTRODUCTION.

SERIOUS deterioration in the condition of the rivers and streams of this country soon resulted from the development of industry during the last century and crowding of the population in industrial areas, especially in the North of England. In the first half of that century practically all waste waters from trade processes and large quantities of domestic sewage were discharged, without any preliminary treatment, into the nearest streams, which were considered to be the natural channels for the reception of such wastes. By the Towns Improvement Clauses Act, 1847, Local Authorities were sometimes even required to discharge crude sewage into rivers. Conditions became so bad by the middle of the century that many of the rivers and streams were little better than open foul-smelling sewers. It is not surprising, therefore, that since that time attention has frequently been directed to the need for satisfactory methods of preventing or reducing pollution. The subject has been considered by several Royal Commissions, particularly the two Commissions on Rivers Pollution appointed in 1865 and 1868 and the Commission on Sewage Disposal which was set up in 1898. Legal enactments include the Rivers

Pollution Prevention Acts, 1876 and 1893, and the Salmon and Freshwater Fisheries Act, 1923.

The duty of enforcing the Rivers Pollution Prevention Act, 1876, was originally entrusted only to the local sanitary authorities, *i.e.*, town councils and urban and rural district councils. Under Section 14 of the Local Government Act, 1888, county councils were given concurrent powers throughout their administrative counties. The same section also gave power to the Local Government Board (now the Ministry of Health) to set up, by Provisional Order, subject to confirmation by Parliament, joint committees or similar bodies for the purpose of administering the Rivers Pollution Prevention Act. Under this section three such bodies have been formed: (1) the Ribble Joint Committee, (2) the Mersey and Irwell Joint Committee and (3) the West Riding of Yorkshire Rivers Board. In addition to their ordinary duties, these three joint committees or rivers boards have done valuable work in advising traders and Local Authorities regarding the most suitable methods of treatment and disposal of waste waters and thus in reducing the pollution of the rivers under their jurisdiction. Useful work has also been carried out by the Thames Conservancy Board and the Lee Conservancy Board which were set up as the result of special legislation.

Although there was some improvement during the latter part of last century in the condition of several rivers flowing through industrial areas, they still receive excessive quantities of polluting discharges. In addition, during the last few decades new industries have been developed, factories have been set up in areas not previously industrialised, and there have been consequent movements in the population with the result that many rivers and streams which were comparatively pure until a few years ago are now receiving effluents of various kinds.

It is certain that the prevention of pollution of the rivers and streams of this country will become of greater importance every year with the growth of the population and the development of industry. Growth of the population increases the work of sewage disposal and improved sanitation is throwing a greater burden on the water supplies, the purity of which is an important factor affecting the health of the community. In addition to plentiful supplies of water of good quality for domestic and agricultural purposes, large quantities of comparatively pure water are required for many industrial processes. Available sources, both surface and underground, of unpolluted water are gradually being depleted and there is no doubt that many rivers which are at present polluted will have to be utilised in the future as sources of supply, after treatment, for both domestic and industrial purposes. Further, the problems of river pollution are of importance in that they affect not only the health and recreations of the population but also the interests of farmers, landowners and fishermen.

The Royal Commission on Sewage Disposal, whose comprehensive inquiry during the years 1898 to 1915 into methods of treatment and disposal of sewage and trade waste waters produced results of great value, recognised that satisfactory means of disposal of polluting liquids from many industrial operations were either unknown or impracticable, and that the problems involved could not be solved without

further knowledge. Among the recommendations of this Commission was the establishment of a central authority whose duties should include the investigation of problems in the purification of polluting discharges and the collection and correlation of the results of investigations by others.

Since 1915, the importance of the subject has been stressed on several occasions. In February, 1927, public opinion was focussed on the matter by a deputation representative of the British Waterworks Association, the Salmon and Trout Association and other bodies, which was received by the late Lord Balfour, then Lord President of the Council. In consequence of the views expressed by these and other independent authorities and by several Government Departments, the Water Pollution Research Board was set up in June, 1927, by the Department of Scientific and Industrial Research. This Board was appointed to submit schemes for research on the prevention of the pollution of rivers and other sources of water supply and on any relevant matters affecting the purity of water supplies, and to supervise approved investigations. At the same time a Joint Advisory Committee on River Pollution was appointed by the Ministers of Health and of Agriculture and Fisheries to deal with the legislative and administrative aspects of the question. Later, in March 1928, the Scottish Advisory Committee on Rivers Pollution Prevention was set up by the President of the Scottish Board of Health to report on the position with regard to the pollution of rivers and streams (including estuaries) in Scotland.

THE WORK OF THE WATER POLLUTION RESEARCH BOARD.

Since its appointment, the Water Pollution Research Board has initiated a number of investigations in connexion with the treatment and disposal of waste waters from beet sugar factories, the treatment and disposal of effluents from dairies and milk products factories, the base-exchange process of water softening, the causes of the corrosive and plumbo-solvent action of certain waters on mains and service pipes, and bacteriological and physical chemical problems associated with processes of purification of sewage. In addition, a comprehensive chemical, biological and hydrographical survey of the River Tees has been carried out and an investigation of the River Mersey was begun in April, 1933. The research staff has also assisted other investigators by directing attention to appropriate scientific and technical literature and by indicating the most promising methods of attacking the problems to be solved. In this connexion, informative summaries of current literature relating to water supplies, sewage, trade waste waters, river pollution and kindred subjects are systematically prepared and published monthly.

Beet Sugar Factory Effluents.—When the Water Pollution Research Board began its activities, the beet sugar industry had only recently developed on an extensive scale in Great Britain, but already several serious cases of the pollution of rivers by the waste waters had occurred. Preliminary work soon indicated that it might be advisable to suggest modifications in the factory processes so as to reduce the quantities or alter the composition of the effluents rather than to consider only methods of purification. It was important, therefore, that the investigation should be proceeded with as rapidly as possible, before other factories were erected or existing factories enlarged. The work on this problem, which has now been com-

pleted, was carried out in co-operation with the industry, which made a substantial contribution towards the cost.

The quantities and nature of the waste waters can best be explained by a description of the factory processes. On arrival at the factory, the beets are conveyed by water carriage along flumes to washers in which they are washed to remove adhering soil and debris. In a factory of average size, 1,000 to 1,500 tons of beet are dealt with each day and the total quantity of fluming and washing water varies from 2.5 to 3.5 million gallons. After washing, the beets are cut into small slices or cossettes from which the sugar is extracted with hot juice or water, usually in a battery of diffusers; the diffusers are cleaned periodically by washing with water. The spent cossettes are then pressed to reduce their moisture content. Water removed from the spent cossettes, together with the washings from the diffusers, is generally known as process water and amounts to 300,000 to 500,000 gallons per day. Clarification of the solution of sugar is effected by several processes and the purified juice is evaporated to crystallise the sugar. A large quantity of cooling water is required during the concentration of the juice and from 75 to 80 per cent. of the water in the juice is removed and condensed in the process. The total quantity of water from the condensers is of the order of 3 million gallons per 1,000 tons of beet extracted; this water is often used again in the flumes for carrying the beet to the washers. From this brief description of the factory processes, it will be noted that the principal effluents for disposal are fluming and washing water, 2.5 to 3.5 million gallons per 1,000 tons of beet, and process water, 300,000 to 500,000 gallons per 1,000 tons of beet. The fluming and washing water carries soil and beet debris and contains small amounts of dissolved organic and inorganic substances. It is definitely polluting in character, but though larger in quantity it is not so objectionable as process water, which contains 0.2 to 0.4 per cent. of sugar, ferments rapidly on storage and takes up large quantities of oxygen from any river into which it may be discharged.

As a result of the investigations carried out during 1927-1930, the Water Pollution Research Board definitely concluded that by suitable modifications in the factory processes, the whole or at least the major quantities of the fluming and washing water and of the process water can be re-used in the factory, leaving little or no effluent for disposal. Certain factories have for several seasons re-used the fluming and washing water after simple treatment by screening and sedimentation to remove solid matter and the re-use of this water has proved to be entirely satisfactory. At some factories the cossettes are extracted by a continuous process of diffusion in which the water removed from the spent cossettes is returned to the diffuser. By this method there is very little process water for disposal. Even with the intermittent process of extraction in a battery of diffusers, large scale trials in the factory showed that after preliminary treatment with lime or by other methods, the process water can be satisfactorily re-used in place of fresh water. During the last beet sugar season, the whole of the process water was in fact re-used at one factory with battery diffusers and as a result the opinion has been expressed that, in addition to preventing pollution, the costs of making the necessary modifications for the re-use of the process water are at least counter-balanced by resulting economies.

Although it had been shown that the waste waters from a beet sugar factory can be largely re-used, it was realised that it might be necessary on occasion to discharge a proportion of the waste waters or that some factories might prefer to purify the wastes sufficiently to allow of their discharge into a river rather than to re-use them. After preliminary experiments it was decided that, as a method of purification, the process of biological oxidation on percolating filters showed promise of success. This process, which is similar to that in operation at many sewage works, was accordingly investigated in laboratory experiments at the Rothamsted Experimental Station and in large scale experiments at the beet sugar factory at Colwick. In addition to the chemical examination of the effluents before and after treatment, the fauna and flora of the filters have been systematically studied. As an example of the amount of work involved it may be mentioned that over 800 strains of bacteria were isolated from the large scale filters for physiological examination in the laboratory. The experiments have proved that, under certain conditions, beet sugar factory effluents can be sufficiently purified by biological filtration to allow of their discharge, except into the smaller streams, without causing serious pollution. It has been demonstrated, therefore, that gross contamination of rivers by effluents from beet sugar factories can be avoided and there is no doubt that during the past two or three years this type of pollution has been much reduced.

Milk Factory Effluents.—In recent years there have been many instances of serious pollution of rivers and streams by effluents from milk collecting and distributing depots and from factories making milk products. Pollution of this kind is likely to become even more serious in the future with further development towards centralisation in the industry unless satisfactory means can be adopted for treatment and disposal of the effluents. The problem is in many respects similar to that of purification of waste waters from beet sugar factories. Laboratory experiments carried out at the Rothamsted Experimental Station for the Water Pollution Research Board have shown that effluents of the type produced at milk collecting and distributing depots can be satisfactorily purified by treatment in two stages. In the first stage the effluent is stored in a tank for one or two days during which fermentation occurs with the separation of fats and protein. The liquid from the fermentation stage is then biologically oxidised in percolating filters. Methods of disposal of the solid matter which separates during storage or fermentation and methods of treatment of wastes containing whey or other milk products will be investigated later.

Survey of the River Tees.—The survey of the River Tees was undertaken with the objects of obtaining more precise information than was previously available on the effects of different kinds of effluents, both sewage and industrial, on a river, and of assessing the power of a river to recover from the effects of polluting discharges. This survey provides a good example of what can be achieved by organised co-operation of specialists in different branches of science, for it has included chemical, bacteriological, botanical, zoological and hydrographical observations and experiments.

From the hydrographical measurements, it has been shown that the water in the estuary at depths below one fathom has a tendency to move up river over each

tidal cycle of ebb and flood. The water in the top layer, however, has a strong net movement down river, and the volume moving down river in this layer is greater than the net volume moving up river in the lower layers. A circulatory system is thus set up and is superimposed on the to-and-fro movement of the tides. It has been concluded, therefore, that polluting matter is not readily conveyed to the sea unless it is in the surface layer when it reaches the estuary.

Large quantities of crude sewage and of industrial effluents are discharged into the estuary of the Tees, especially in the section from Stockton to Cargo Fleet. The principal industrial effluents are those derived from coke ovens and containing tar acids, naphthalene, cyanide, etc., and spent pickle liquor, which is an acid solution of iron produced during the cleansing of iron and steel. Oxidation of the sewage and effluents occurs in the estuary at the expense of dissolved oxygen. The Tees was formerly a noted salmon river, but for many years large numbers of fish have been killed in the estuary, especially salmon and sea trout smolts during their migration in the spring to the sea. Various observations and experiments included in the survey have proved that in 1930 and 1931 the death of migrating smolts was due not to the deficiency of dissolved oxygen but to cyanides, which were frequently found in lethal concentrations. Other poisonous substances, including tar acids, were not found in toxic concentrations and it has been concluded that in the absence of cyanides, migrating smolts would not have been killed in 1930 and 1931. This conclusion marks a distinct step forward, for although several explanations had previously been offered, it had never before been suggested that cyanides were responsible for the death of fish in the River Tees. Another interesting result of the survey is that experiments in the laboratory and on a semi-technical scale have demonstrated that cyanides in coke oven effluents can readily be converted into relatively non-toxic ferrocyanide by treatment of the effluents with spent pickle liquor and lime. There is no doubt that installations of coke ovens to be erected in the future in the Tees area will be so designed as to avoid the necessity of discharging any appreciable quantity of polluting effluent.

In the non-tidal or upper reach of the river, there is only one point at which any very large quantity of polluting matter enters and this pollution is derived from sewage. Further downstream for a distance of about 15 miles there is no polluting discharge of any importance. The work in the non-tidal reach, therefore, has consisted mainly of observations of the effects of sewage pollution on the chemical composition of the river water and on the fauna and flora. At the same time the factors which influence the rate of self-purification of the river from sewage pollution have been systematically studied not only from the results of chemical and bacteriological examination of samples of river water, but also by means of experiments under controlled conditions in the laboratory. Of these factors, temperature is the most important, the rate of self-purification increasing rapidly as the temperature is raised from about 10° to 20°C. The occurrence of certain plants and animals has been correlated with the conditions of the water as determined by chemical analysis and several new and little-known algae have been discovered. In addition, useful knowledge has been obtained with regard to the food of fish.

River Mersey Investigation.—Earlier this year an investigation was begun in reference to the deposition of silt and other matter in the estuary of the River Mersey. This investigation, which is likely to occupy two or three years, is being carried out at the sole cost of the Merseyside Local Authorities and the Mersey Docks and Harbour Board and associated bodies. Deposition of solid matter in the estuary has for many years necessitated extensive dredging to preserve a navigable channel and it has been stated that the character of the material deposited is such that dredging is often difficult. The object of the investigation is to ascertain the effects of the discharge of crude sewage on the amount and character of the deposits, a subject which has for a long time given rise to much local controversy. The information sought is obviously of importance to Mersey-side not only as regards navigation but also in connexion with local problems of sewage disposal.

Base-Exchange Process of Water Softening.—In the base-exchange process of water softening, the hard water is passed through a bed containing granules of sodium zeolite whereby the calcium and magnesium in the water are replaced by sodium, and calcium and magnesium zeolites are formed. Periodically the zeolite is regenerated by treatment with a solution of common salt. There are two main types of base-exchange materials in use for water softening, synthetic products, prepared by the interaction of solutions of sodium aluminate and sodium silicate, and certain minerals. The minerals are usually subjected to preliminary treatment either by heating or with a solution of sodium silicate or by other methods to increase their base-exchange values and to render them more resistant to disintegration. They may be sub-divided into two groups, glauconites, which are practically non-porous and have the appearance of dark green or brown sand, and relatively porous materials which resemble granulated brick in physical structure. The synthetic products are definitely gels and are porous.

Although the process is not much used by water supply undertakings in this country, it is being widely adopted in one form or another by industrial undertakings, institutions and private consumers. When the Water Pollution Research Board was appointed there was a good deal of scattered information about the process, much of it unpublished, but the mode of action of the base-exchange materials was imperfectly understood. Arrangements were made, therefore, for an investigation of the process to be carried out at the Department's Chemical Research Laboratory at Teddington. In the first place the scientific and technical literature on the subject was studied, several installations were inspected, and the information thus collected was summarised and published in the form of a technical paper.

The experimental work has included determinations of the exchange values of different types of material with various rates of flow of water and conditions of regeneration with brine. Base-exchange values are usually expressed as the weight of the equivalent quantity of lime (CaO) in lbs. removed from water by 1 cu. ft. of material when, under specified conditions, hard water is passed through the softener until the issuing water just ceases to be of zero hardness. The weight of 1 cu. ft. of material varies considerably with the type of material and to some extent with size grading. For example, 1 cu. ft. of a glauconite may weigh as much as about 100

lbs. whereas the weight of 1 cu. ft. of a synthetic zeolite is only about 50 lbs. Under similar conditions of rate of flow of water undergoing treatment (about 70 gallons per hour per cu. ft. of base-exchange material) and of regeneration with a 5 per cent. solution of salt, typical examples of a glauconite, a porous mineral and a synthetic material gave exchange values of about 0.4, 0.6 and 1.0 lb. per cu. ft.

Over the range of rate of flow used in various experiments (20 to 200 gallons of water per hour per cu. ft. of base-exchange material) the exchange value of a glauconite is approximately constant but the exchange values of porous minerals and synthetic materials decrease somewhat as the rate of flow is increased. As might be expected the presence of sodium chloride in the hard water undergoing treatment reduces the quantity of water which can be softened by 1 cu. ft. of any particular base-exchange material. For example, in one series of experiments, a typical glauconite did not produce water of zero hardness from Teddington tap water to which 0.5 per cent of sodium chloride had been added and as little as 0.05 per cent. of sodium chloride in the water prevented complete softening by a synthetic material.

The question is sometimes raised as to whether appreciable quantities of base-exchange material are dissolved by the treated water and a few experiments have been carried out with the object of obtaining information on this point. At a rate of flow of about 70 gallons per hour per cu. ft., a representative commercial rate, the quantities of silica taken up at ordinary temperature by water having an initial silica content of 7 parts per million were in most cases too small to be measured. With very low rates of flow measurable but not important increases in dissolved silica occurred. As the temperature is increased the amount of silica dissolved also increases.

With regard to methods of regeneration both single and double regeneration have been employed with solutions of common salt varying in concentration from 2.5 to 20 per cent. and in volume from 0.5 to 2.0 cu. ft. per cu. ft. of base-exchange material. Single regeneration consists of passing the salt solution only once through the material. In double regeneration the material is first treated with the solution from a previous regeneration and then with a fresh solution which is afterwards used for the first stage of the next regeneration. It has been found that, in general, the exchange value increases with the quantity of salt used to a maximum value which is characteristic of the particular material and is not exceeded by the use of more salt. Experiments have also been made with the object of ascertaining whether sea water can be satisfactorily used for the regeneration of base-exchange materials. The sea water contained the following percentages of cations in solution: sodium, 1.092; potassium, 0.043; calcium, 0.046; magnesium, 0.127. The results have shown that after regeneration with sea water, base-exchange materials will soften considerable quantities of hard water. As might be expected, however, owing to the presence of calcium and magnesium, sea water is not so effective as an equal volume of a solution of common salt containing sodium in the same concentration.

Contamination of Water by Lead.—It is well known that many natural waters have a solvent or erosive action on lead service pipes, with the result that the water,

unless submitted to previous treatment to prevent this action, may become contaminated with lead in such quantity as to give rise to cases of poisoning among consumers. Lead in drinking water has on many occasions been the cause of considerable trouble in different parts of the world. There is, however, a lack of exact information not only as regards the best methods and conditions of treatment of plumbo-solvent waters, but also on the relationship between plumbo-solvent character and composition of the water. In view of the importance of the subject from the standpoint of public health, arrangements have been made for an investigation into the conditions affecting the action of water on lead to be carried out at the Department's Chemical Research Laboratory.

In the first place the literature on the subject has been surveyed and a technical paper summarising the information thus collected is now in the press for publication. As a result of the survey some of the main features of the problems have been selected for investigation and experiments have been begun.

Sewage Disposal.—Investigations carried out and in progress in connexion with the treatment and disposal of sewage relate to the biology of the activated sludge process, the biological oxidation of such constituents of sewage as cellulose and fats, the amount and nature of the suspended and colloidal matter in sewage and the conditions to be observed in certain tests employed in determining the character and composition of sewage and sewage effluents if trustworthy results are to be obtained. The experiments have been made at the London School of Hygiene and Tropical Medicine, University College, London, the Rothamsted Experimental Station, and the works of the Birmingham, Tame and Rea Drainage Board. Many of the results obtained have already been published.

Encouragement and Co-ordination of Research.—In addition to the investigations carried out by the Department on the recommendation of the Water Pollution Research Board, valuable work on particular problems is being done by other Government Departments, local authorities, various organisations, and individuals. Through the Director of Research, the Board is kept informed of the progress of the different inquiries and of developments relating to the purity of rivers and other sources of water supply, with a view to encouraging promising investigations and co-ordinating the results.

CONCLUDING NOTE.

It must be emphasised that the object of this paper is to give a brief review of the investigations inaugurated by the Water Pollution Research Board and of some of the results obtained. No attempt has been made to describe any one of the investigations in detail, but for the information of those who may be interested in particular sections of the work, a list of reports, technical papers and other publications arising out of the work of the Board is given at the end of this paper.

PUBLICATIONS ARISING OUT OF THE WORK OF THE WATER POLLUTION
RESEARCH BOARD.

General.

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Beet Sugar Factory Effluents.

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Survey of the River Tees.

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- (18) Bassindale, R., Southgate, B. A., and Pentelow, F. T. K. The Effect of Cyanides on the Gill Colour of Fish. *J. Marine Biol. Assoc.*, Plymouth, 1933, 18, 671.
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Base-Exchange Process of Water Softening, etc.

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DISCUSSION.

DR. A. PARKER (introducing his Paper) said: We have just received a most interesting paper by Mr. Alan Chorlton on a scheme for linking up the water supply systems of the country with a view to insuring that the quantities of water desirable for domestic, agricultural and industrial purposes are readily accessible. My paper briefly describes the work carried out by the Water Pollution Research Board of the Department of Scientific and Industrial Research with the object of ensuring that the supplies are of good quality, as judged by chemical and bacteriological standards, and that they are not detrimental to public health or unsuitable for other purposes for which they may be required.

Serious deterioration in the condition of the rivers and streams of this country began during the earlier years of last century with the development of industry and the crowding of the population in industrial areas, especially in the North of England. By the middle of the century many of the rivers and streams were little better than open foul-smelling sewers. It is not surprising, therefore, that attention has fre-

quently been directed to the need for satisfactory methods of preventing or reducing pollution. The subject has been considered by several Royal Commissions, particularly the two Commissions on River Pollution appointed in 1865 and 1868 and the Commission on Sewage Disposal set up in 1898. This last Commission recognised that satisfactory means of disposal of polluting liquids from many industrial operations were either unknown or impracticable, and that the problems involved could not be solved without further knowledge.

Prevention of water pollution must become of greater importance every year with the growth of the population and the development of industry. Growth of the population increases the work of sewage disposal and improved sanitation is throwing a greater burden on the water supplies. Available sources of unpolluted water are gradually being depleted and there is no doubt that many rivers which are at present polluted will have to be utilised in the future as sources of supply, after treatment, for domestic and other purposes.

Since the war, the importance of the subject

has been stressed on several occasions. In 1927, public opinion was focussed on the matter by a deputation representative of the British Waterworks Association, the Salmon and Trout Association and other bodies, which was received by the late Lord Balfour. As one of the results, the Water Pollution Research Board was appointed to submit schemes for research on the prevention of the pollution of rivers and other sources of water supply and on any relevant matters affecting the purity of water supplies, and to supervise approved investigations.

Since its appointment in 1927, the Board has initiated investigations in connexion with the treatment and disposal of waste waters from beet sugar factories, the treatment and disposal of effluents from dairies and milk products factories, the base-exchange process of water softening, the cause of the corrosive and plumbo-solvent action of certain waters on mains and service pipes, and bacteriological and physical chemical problems associated with processes of purification of sewage. In addition, a comprehensive chemical, biological and hydrographical survey of the River Tees has been carried out and an investigation of the River Mersey was begun in April, 1933. The staff also prepare informative summaries of current literature relating to water supplies, sewage, trade waste waters, river pollution and kindred subjects; these summaries are published monthly.

From the investigation of the problem of disposal of beet sugar factory effluents it has definitely been concluded that the various waste waters, after simple preliminary treatment, can be satisfactorily re-used in the factory processes, leaving little or no effluent for disposal. It has also been shown, that, under certain conditions, the waste waters can be sufficiently purified by biological oxidation in percolating filters to allow of their discharge, except into the smaller streams, without causing serious pollution.

In recent years there have been many instances of serious pollution of rivers and streams by effluents from dairies and milk products factories. Pollution of this kind is likely to become even more serious with further development towards centralisation in the industry unless satisfactory means can

be adopted for treatment and disposal of the effluents. Laboratory experiments for the Water Pollution Research Board have shown that effluents of the type produced at milk collecting and distributing depots can be satisfactorily purified in two stages. In the first stage, fats and other solid matter are separated by a process of fermentation and in the second stage the liquid is biologically oxidised in percolating filters.

The survey of the River Tees was undertaken with the object of obtaining more precise information than previously available on the effects of different kinds of effluents, both sewage and industrial, on a river. This survey provides a good example of organised co-operation in research of specialists in different branches of science, for it has included chemical, bacteriological, botanical, zoological and hydrographical observations and experiments. The work on the non-tidal or upper reach of the river consisted mainly of observations of the effects of sewage pollution on the chemical composition of the river water and on the fauna and flora. At the same time the factors which influence the rate of self-purification of the river from sewage pollution have been studied not only by examination of samples of water from the river but also by means of experiments under controlled conditions in the laboratory. Of these factors, temperature is the most important, the rate of self-purification increasing rapidly as the temperature is raised from 10 degrees to 20 degrees Centigrade. In the estuary of the Tees, various observations and experiments proved that in 1930 and 1931 the death of migrating salmon and sea trout smolts was caused primarily by cyanides discharged with effluents from coke ovens. There is no doubt that installations of coke ovens to be erected in the future in the Tees area will be so designed as to avoid the necessity of discharging any appreciable quantity of polluting effluent.

Deposition of solid matter in the estuary of the River Mersey has for many years necessitated extensive dredging to preserve a navigable channel and it has been stated that the character of the material deposited is such that dredging is often difficult. In response to an invitation from the Merseyside Local Authorities and the Mersey Docks and Harbour Board and associated bodies an

investigation of the subject was begun some months ago with the object of ascertaining the effects of the discharges of crude sewage on the quantity and character of the deposited solid matter.

Experimental work on the base-exchange process of water softening has included determinations of the exchange values of different types of material with various rates of flow of water and conditions of regeneration with brine. Experiments have also been made on the exchange values of materials regenerated with sea water in place of brine. Owing to the presence of calcium and magnesium, sea water is not so effective as an equal volume of a solution of common salt containing sodium in the same concentration. A summary of existing knowledge of the base-exchange process of water softening has been published as a technical paper.

Lead in drinking water has on many occasions been the cause of considerable trouble in different parts of the world. There is, however, a lack of exact knowledge not only as regards the best methods and conditions of treatment of plumbo-solvent waters, but also on the relationship between plumbo-solvent character and composition of the water. An investigation of the subject is in progress at the Department's Chemical Research Laboratory. The literature on the subject has been surveyed and a technical paper summarising the information thus collected is now in the press for publication.

Investigations carried out and in progress in connexion with the treatment and disposal of sewage relate to the biology of the activated sludge process, the biological oxidation of such constituents of sewage as cellulose and fats, the amount and nature of the colloidal and suspended matter in sewage and the conditions to be observed in certain tests of sewage and sewage effluents if trustworthy results are to be obtained.

In a written communication, Mr. J. H. COSTE, stated that Dr. Parker's paper was of considerable interest, although it was rather difficult to discuss. The historical introduction was a valuable summary of the facts which had brought about the present position. A strong justification for the paper and for the existence of the Water Pollution Research Board was given in the sentence on the second page: "It is certain

that the prevention of pollution of the rivers and streams of this country will become of greater importance every year with the growth of the population and the development of industry." It might, perhaps, be uncertain whether the population would continue to increase or whether a stationary state was not being approached, but it was shifting, there were few districts which might not become much more populous, and the immigrants could not be expected to bring their water supply with them. As to industry, there seemed every prospect that it would both develop and require increasing quantities of water. As to the Board itself, it was undertaking a large programme of work of great importance. The sugar beet problem has been solved and apparently the industry has availed itself to some extent of the knowledge obtained. The work on the Tees has already been productive of useful new observations, and it must be remembered that work of this kind was not like *ad hoc* laboratory experiments. One had to make a large number of observations of variables that could not be controlled and when sufficient results were obtained find out the best sort of statistical analysis to enable, if possible, cause and effect to be sorted out. The interesting fact that self purification increased rapidly with temperature had been observed in the upper tidal reaches of the Thames by the speaker but this was also true of the less desirable biochemical processes. He had followed the work on base exchange softening and had had to point out to engineering colleagues that the process was likely to fail, as stated in the paper, with waters from tidal sources which contained large proportions of salt. The work on lead in water was needed, as recent researches in Scotland had shown that lead poisoning by water supplies was by no means a thing of the past.

It was very gratifying that biologists as well as chemists were working on some of the problems investigated, and the hydrographical work of engineers enabled a more reasoned survey of the results to be obtained.

If one criticism might be made it was that he would have liked to have felt that some of the researches undertaken had been more directly under the control of Dr. Calvert and Dr. Parker than seemed to have been the case, for some recently published

work appeared to be rather of educational value to the authors than the discovery of hitherto unknown facts.

DR. CALVERT: It was largely at the instigation of this Association when they organised the deputation to Lord Balfour in 1927, that the Water Pollution Research Board was set up. At that time, the Government decided to set up two bodies, a Joint Advisory Committee on River Pollution to investigate the legislative and administrative aspects of the question, and the Water Pollution Board to investigate the research and technical sides. It is within my knowledge that waterworks' engineers are faced with very difficult pollution problems, and by pollution I do not merely mean organic matter. Your problems in regard to tastes and odours I would include in this same pollution problem; and I would like it to be known that any information which is in the disposal of the Water Pollution Research Board is freely at the disposal of Members of this Association.

ALDERMAN FLETCHER (*Birkenhead*): In our scheme in Birkenhead we had consider-

able difficulty at the inception of the scheme with regard to the purification of water and the diminution of odours and discoloration effected through peat foundations. Fortunately, we have been successful in effecting something in eliminating the many complaints the Dee Fishery Board brought against the Birkenhead Corporation in the early years of the scheme, some ten years ago; and so far as the purification of our upland water supply is concerned in Birkenhead the Dee Fishery Board have made no complaints during the past two years. That I attribute to some extent to these informative papers and Conferences.

DR. PARKER: The paucity of speakers does not necessarily indicate a lack of interest in the subject. In this particular case I have given a general review of the work of the Board and not discussed details in regard to any one investigation. This is the first paper to the Association on the work of the Water Pollution Research Board. It is for that reason that I considered it preferable to give a general review rather than to deal with only one particular aspect.

The following Paper was taken as read :—

The Financial Management of Municipal Trading Departments.

BY

SYDNEY LARKIN, F.S.A.A., F.I.M.T.A.

(*City Treasurer, Coventry.*)

1.—This subject involves one of the most important administrative problems with which municipal people have to deal. It will be useful to have it discussed by the members of this Association. It should, I venture to suggest, be discussed as dispassionately as possible without undue reference to particular circumstances. The question has suffered in the past by being raised as a purely local question, and proposals and counter-proposals have been debated almost entirely from the point of view of personalities and with no reference to principles. Further, these local discussions have frequently been conducted as a duel between two officials not always willing to see each other's point of view. When the discussion goes beyond the officials it is carried on by persons whose ideas of administration are not always perfectly clear. The first thing to realise is that the problem is one of manage-

ment and not of personal status of officials. One cannot blink the fact that, in some instances, the discussion arises through one or other of the officials concerned trying to increase or maintain his importance in the little world in which he moves. A more regrettable aspect of the position is brought to our notice when organisations whose reason for existence is the scientific consideration of the management of municipal undertakings have joined in these local contests or the sole purpose of trying to maintain the personal status of their members.

2.—Let me state the problem in my own way. In doing so, I must go outside the realm of finance and deal with the whole question of management. Municipalities, among other activities, own and run certain businesses. The most usual are water, gas, electricity and transport undertakings. It is important, nevertheless, to note that there are other municipal concerns (schools, roads and hospitals, for instance) which are of an importance not inferior to that of any of the four trading undertakings I have mentioned. The trading undertakings are, therefore, but a part of the business of the municipality. Nor are we entitled to claim that because these four undertakings may be run at a profit or at a loss there is some particular brand of genius necessary for their management. I need hardly remind the members of this Association how easy it is to make a profit on a water undertaking or to assure them that it is not much more difficult in the case of gas and electricity undertakings. Transport presents different problems and it will be sufficient to mention that the indisposition of the public to board the trams or buses in sufficient numbers at the fares charged is not always overcome by raising the price. The point I first of all insist upon, therefore, is that the running of a large sewerage system and sewage disposal works, for example, is not rendered easier by the fact that quarterly bills are not sent out for that useful service.

3.—It may be contended by some that the difference between trading undertakings and the others lies in some inherent quality which rests in the usual municipal service and which is absent from the trading service. I will not put it any stronger than that, but if there is any inherent quality in the usual municipal service it is only the social necessity of such service. Now there is no service more essential than the provision of water, and water supply has never been considered to be necessarily a municipal service. One feels no such shock on hearing of a water company as one would on hearing of a sewerage company. It is, therefore, only our habit of thinking in well-worn channels which suggests that there is any inherent difference between the trading departments and the other departments of a municipality.

4.—We must not, either, try to dodge our problem by suggesting that these undertakings are unsuitable for municipal management. We are not here to consider that suggestion. The sole point is that the undertakings belong to the local authority and are managed by a council duly elected in the constitutional way acting for the local authority. We must not even stop to complain that there is no guarantee that the people elected are cut out by nature for the management of a public utility undertaking.

5.—The council are, I think, bound to employ a town clerk, a treasurer, a surveyor, a medical officer and a sanitary inspector. They may appoint other officers to help in running the municipal machine. It is the practice of the council

to appoint committees to look after the details of their various activities, the council meeting once a month to consider, and perhaps approve, the doings of the various committees. It is the universal custom to appoint what I will call engineer-managers to look after the technicalities of the trading undertakings and, nearly always, separate committees are set up to deal with the respective undertakings.

6.—In addition to separate committees for each trading department, the council usually appoint a finance committee which should supervise the finances of the council, a term which of necessity includes the finances of a trading undertaking. Where several undertakings exist, it seems to be the clear duty of the council to impose upon the finance committee the duty of supervising all purely financial operations of the departments—cash receipts and payments, questions of security for debtors, and so on—in order to secure uniformity of practice as well as economy. Matters relating to loans and investments would naturally fall within the finance committee's duties. It is more common, however, for each committee in charge of a trading department to constitute itself a finance committee for that particular branch of the council's work. So long as these committees are adequately advised on financial matters, the system works with a fair degree of satisfaction, although it is difficult sometimes to secure uniformity of treatment of the same problem by the various committees.

7.—There are two main "schools of thought"—if one may adopt such a phrase to describe different degrees of mental confusion—in connection with the management of municipal trading departments. One maintains that the engineer-manager, being responsible to his committee (or even, some would say, to the council) for the success or otherwise of the concern, must necessarily have complete control of all phases of the work, i.e., he must be supreme as regards (1) engineering and technical work, (2) stores control, (3) accounting, including costing, and (4) price fixing. Any separation of one of these phases of management, or part of one, is regarded as evidence of dual control and is therefore said to be inimical to the best interests of the undertaking. It may also in some instances be alleged that any division of functions leads to duplication of effort and is costly. As a corollary to this, it almost (if not quite) follows that the committee in charge of the undertaking can only be a registering committee. Disagreement with the engineer-manager would undoubtedly cause an awkward situation to arise.

8.—The second "school of thought" states that, since the undertaking is owned by the municipality, it should be run as a municipal undertaking, i.e., the town clerk should undertake the secretarial and legal work, the treasurer should look after finance and accountancy, the borough surveyor should supervise buildings, etc., while the engineer-manager should rest content with such matters as remain, viz., all things which cannot be called legal or financial or which have not been dealt with by some other department to which, functionally, they would fall. It is contended that this system produces no difficulties and that the functional organisation is the proper one.

9.—Before proceeding to discuss an alternative to these two methods, may I remind you that the whole question is often complicated by historical events. In a large number of cases of municipal ownership, the undertaking has been taken over

from company ownership and there has been a continuance of the old company organisation. In at least one important town the office of "secretary" still exists in the trading departments—no doubt a legacy from the company stage of existence. This is an exceptional case and to all intents and purposes the undertakings might just as well not be municipal so far as they throw any light on the problem before us. More often, the company organisation is grafted on to the municipal organisation with as much completeness as the circumstances allow. It would, however, simplify matters if we could ignore the present practice entirely (because it always affects the sub-conscious minds of municipal administrators) and suppose that a modern municipality is creating trading undertakings for the first time in history. It is extremely improbable that we should find the council seeking highly skilled engineers of various sorts in order to put them in separate charge of the respective undertakings and subordinating to them groups of minor people who would look after such departments as accounts, purchases, sales and so on. It is obvious that the council might secure the cleverest engineers in the world in their own spheres and yet find that they had engaged mere children in administrative matters and something less than children in commerce and accountancy.

10.—The council would not, I suggest, appoint separate committees to deal with each undertaking. They would not arrive at the priceless position at which so many municipalities have arisen, where the committees work in so many watertight compartments and, if there should be a matter of common interest to two departments, solemnly appoint a joint sub-committee to consider it and report back to the separate committees. The council would hardly contemplate the possibility of committees working in direct competition with each other, as is found in the case of gas and electricity committees.

11.—It would, I think, be fair to assume that the modern municipality which is about to engage in trading for the first time would delegate the detailed work to a single trading committee which would naturally look after the whole of the trading undertakings of the council. A company with separate departments would never constitute a separate board of directors for each department, particularly if the number of people temperamentally and otherwise fitted to manage a trading undertaking is small. This latter fact should not be ignored by anyone discussing this topic. It is a most important phenomenon of democratic government and should be considered to be a prime reason for the single trading committee.

12.—A second reason, almost as cogent, is that there must be in all dealings between the council and the consumers a uniform policy uniformly carried out. It may be said that it is easy for the council to decide on uniformity of policy with separate committees. It is not easy. It is virtually impossible. But even if the council be such as to be able to lay down uniform policies for its trading committees, it would soon be found that variations in the interpretation and carrying out of those policies would soon arise and become acute.

13.—A third reason for a single trading committee is the desirability of co-ordinating effort. The question of gas and electricity supplies—the matter of trams and buses (but strange to say, we have never heard of separate committees

for trams and buses)—the problem of main-laying and the breaking up of roads—the reading of meters and inspection of services—security for the payment of consumers' accounts—purchases—sales policies—all these are matters for co-ordination and can only be satisfactorily dealt with by a single committee.

14.—This committee would be advised by the town clerk, the treasurer and the general-manager of the trading undertakings. This latter office could, of course, be split up into as many parts as there are undertakings and I see no reason why several people should not jointly hold the position of general-manager of trading undertakings. They need not be qualified in anything but management. I suggest that the temporary absence of one of them would be met by one of the others taking charge for the time being of the department usually looked after by the absent one. They would be interchangeable. The general managers would have been appointed for their administrative and commercial ability and not for their skill in designing a tramcar or a reservoir. Each separate department would naturally have its proper complement of technical officials in the shape of works managers, engineers and so on.

15.—The position of the treasurer would be that of financial adviser to the trading committee. He would not, I hope, pose as an expert in anything but his own particular subject, but he would work in close co-operation with the general managers for the welfare of the departments. There will probably not be much question that the treasurer should deal with the receipt of cash, the payment of accounts, and the supervision of the relations of the municipality with its bankers and with the Inland Revenue Department. It will no doubt also be agreed that the raising of the necessary capital should be left to the treasurer who in this matter would take his directions from the finance committee of the council.

16.—The treasurer would, in my view, take responsibility for the organisation of the accountancy section of each department. It will be recognised that the general managers would not pretend to be experts in constructive accountancy and although they would know precisely what sort of information they require for the good conduct of their business they would not claim to be able to say exactly what was the best technique of getting that information. The location and status of the accountancy sections would depend on the size of the municipality and the available premises. As a general rule, it could be stated, I think, that smooth working is engendered if the corporation administrative departments are housed in one building so that the general managers and other chief officials are close together. However located, it must be possible for the general manager to obtain all the information he wants without personal reference to the treasurer. Those of you who are in the municipal service must be familiar with the astounding practice of officials writing long and frequent letters to one another. Occasionally, some more daring official walks into another department and asks for some information or other which is necessary for the good conduct of the corporation's business. I have heard of such rashness being reprimanded by what I will call official No. 2, writing to official No. 1 and telling him that if he wants any information from his (No 2's) department will he please write for it. Anyhow, in order to avoid the slightest temptation for one official to write to another on the question of accountancy, I would, if possible,

place the accountancy section under the direct control of the general manager, leaving with the treasurer the duty of supervising methods, advising on staff, and obtaining such information as he himself wants. It may be economical in many instances for the routine accountancy work to be done mechanically. In that case, I would not suggest duplication of machinery. The important part of accountancy is the primary record. That would be produced by the accountancy staff which I have attached (if the town is large enough) to the general manager. The production of results would then be carried out by mechanical means which would not necessarily be wholly employed on the work of one department. All this depends on the bulk of work and on the general principle that it pays to keep machines pretty fully employed.

17.—These accountancy sections would be fairly constant in their composition. They would each be in charge of a qualified accountant. I should deprecate what is now a common practice of letting assistants grow up in one particular section. Municipal staffs are, in the opinion of some, on the whole superior to the staffs of companies, but there is a tremendous tendency to grooviness and I should recommend, very strongly, occasional changes in sectional accountancy staffs with the particular object of ensuring that the qualified men (of whom there should be several) would all be keen to take up any vacant position of sectional chief and also be capable of doing so. It would be impossible for the general manager to have his eye on some old and subservient member of the staff for promotion.

18.—It should be stated here that there are well founded objections to the accountancy staff being under the control of an engineer-manager. Cases occur with regularity if not with frequency where frauds—sometimes of alarming dimensions—are rendered possible by reason of the fact that the accountancy section is under the complete control of the engineer-manager. I think that if the accountancy methods and the staff appointments are subject to the approval of the treasurer, the risk of collusive fraud is decreased. But it must be admitted that the complete divorce of accountancy from executive work is the only common sense way of avoiding such frauds as we have in mind. It will be interesting to hear other views as to how the danger of (1) large frauds and (2) wasteful administration can be met. I mention wasteful administration because I have seen many self-contained municipal trading departments which are monuments of extravagance. It is a state of affairs which is bound to exist to some extent in monopolistic concerns—whether company or municipal—and more particularly in municipal undertakings. Where there is a tendency towards wasteful administration, one way of checking it is to ensure that the financial officer is armed with full powers of effective criticism. One way of doing that is to make it as difficult as possible for the executive officer to "cook" subsidiary accounts of costs and stores so that they give the results which he desires rather than those which actually exist.

19.—The treasurer, as I have said, must be the financial adviser of the trading committee. There does not seem to be any justification for the finances of the trading committee to be considered by the finance committee—except in one or two matters to which I have referred. The following financial matters will be considered

by the trading committee and the treasurer's opinion would no doubt be given on them :—

(a) *Estimates of expenditure and income.*—These are, I fear, not often placed before trading committees but I submit that they are fundamental to the sound management of a trading undertaking. In the present circumstances, I may with advantage mention the water undertaking where, as you know, one has to look many years ahead in matters of supply. In this, water differs very much from gas and transport. In these cases additional loads can be dealt with in a fairly short period and, of course, the additional demand is practically always observable in ample time for action to be taken. That is only one aspect of the subject of estimates of expenditure and income and is particularly applicable to the desirability of framing estimates for some years ahead. A further important reason for the consideration of estimates is that water charges are becoming more and more subject to approval by the central authority and it is incumbent on the trading committee to see that proper regard is paid to the consumers' interests in this matter. Estimates also tend to curb extravagant management.

(b) *Establishment and Appointments.*—This is not a financial question, but I mention it in order to complete the picture. It is often alleged that a trading committee knows best what officials it needs and how much should be paid to them. It probably does not know anything of the kind and, in any case, the municipality is a big concern—much bigger than its component parts—and it is always advisable to have the questions of appointments and salaries dealt with by an Establishment Committee in order that some uniformity may be achieved throughout the service of the municipality. In anticipatory answer to objections to this, I must insist that the trading undertaking is but a small part of a larger concern and no claim on the part of an undertaking to treat itself as a separate entity can be substantiated. Besides which, most ridiculous results have ensued from this attitude. I remember one town where the gas department happened (through no particular virtue of its own) to be earning huge profits and was paying very handsome salaries to a staff which was probably too large, while the water department (again helpless in the matter) was run at a loss involving a heavy charge on the rates and paid very poor salaries to a staff just as able and loyal as the staff of the gas department. That, of course, is not an example of good municipal government.

(c) *Extensions of Services.*—It is possible that financial advice to the trading committee would be limited to the suggestion that no service should be undertaken unless the minimum gross income to be derived therefrom equalled 10 per cent. of the additional capital outlay involved. This is often taken by committees to imply that a service given on this basis is a profitable one. Obviously it is not so and therefore an additional factor should always be the probability of growth of the income from the new service to an extent which will cover all expenses. In some cases, the financial advice would go further and recommend an extension of a service so long as the income was sufficient to produce some contribution to the standing charges of the undertaking. It is conceivable, of course, that a point is arrived at when an extension will increase the standing charges to such a degree as to disturb the whole costs of the undertaking.

(d) *Fixing of Charges.*—In one municipal industry, at least, the variety of scales of charges is such that an impartial inquirer might well wonder on what principles these charges had been arrived at. For the purpose of this paper I submit that the art of price fixing is not the peculiar gift of any particular profession and that the treasurer's advice to the trading committee ought in most cases to be sought. If for no other reason than the fact that two heads are better than one, it would be advisable to have a joint report by the general manager and the treasurer on all questions of revision of charges. It is probable that few will disagree with my assertion that the fixing of prices in municipal undertakings is chaotic and the reason is no doubt due to the uncritical acceptance by the trading committee of the recommendations of officials. In no branch of municipal work has the empirical method been so unjustifiably followed. In transport, for example, the hit or miss method of fixing fares is almost universal. Electricity and gas charges will hardly stand being looked into. The domestic consumers are the subject of a monopoly and therefore cannot really complain. Those consumers who are not the subject of a monopoly (i.e. those who could satisfy their demands from another source) are probably being charged a lower price than the facts justify and there is therefore no risk of the loss of their custom. Water, so far as the charge for domestic consumption is concerned, presents a very easy problem, although there are, in fact, many diversities of minor importance between the scales of different undertakings. Metered supplies, too, do not present the complications of other municipal commodities, but I would suggest that the concurrence of the treasurer be sought to the scale of charges for measured supplies.

(e) *Periods for the repayment of borrowed money.*—There are two ways of looking at this problem. One is to ask for the longest possible period for repayment, consistent with the life of the asset or expenditure, and the other is to ask for the shortest possible period for repayment consistent with the ability of the undertaking to provide the money necessary for redemption. It is probable that more weight should be paid to the treasurer's opinion on this question than to that of the general manager.

(f) *Allocation of Profits.*—The trading committee should be influenced by the treasurer's opinion on this matter but clearly there should be some settled policy which may be followed year by year. It would, in this case, be well for the trading committee to have the critical opinion of the general manager on the proposals of the treasurer, in order to ensure that the undertaking is not being robbed for any purpose!

(g) *Utilisation of Reserves.*—This is a subject on which the treasurer's opinion is often taken. Where it is merely a question of investment, there would be no doubt as to this. Where there is a proposal to fall back on the reserve for the recoupment of losses or the provision of capital assets, there are again grounds for taking the treasurer's advice.

(h) *Provision of Working Capital.*—This is a purely financial question and the trading committee would no doubt look to the treasurer for guidance.

20.—What is, of course, of paramount importance is that there should be complete co-operation not only between the various council officials (that is achieved more often than some people think) but also between the committees of the council. My method for securing the latter is to form only one committee for the trading undertakings. That should be effective. As regards the former, we have a long way still to go and we must rely on the general improvement in the quality of the officials which, I have no doubt you will agree, we are seeing year by year.

21.—I have, in accordance with my usual practice, tried to make my paper somewhat provocative and also (if I may say it with modesty) to include some constructive suggestions for the better management of municipal trading departments. I trust that some benefit will accrue from the discussion.

DISCUSSION.

MR. SYDNEY LARKIN, introducing his Paper, said: I will just refer to three main points on the subject. The first is my somewhat bold insistence on the financial unity of municipalities. It seems impossible, the longer we go on in municipal government, to contemplate any diversity of financial policy on the part of the various committees of the town councils; and for that reason only—and I think it is a strong reason—one ought to take all possible steps to ensure some uniformity of financial policy on the part of a single body, namely, the municipality. Of course, one realises that, in theory at any rate, the council is responsible for all matters of finance and all matters of organisation; and that would be very well, if you could carry it out. But there are difficulties, and therefore one has to try to put forward some sort of scheme more in keeping with practical work. By that I mean that you must look to some official or other, to a group of officials if you like, for guidance in these particular problems. Although no official has any status in this matter of the organisation of finance, it is necessary in my view to look to some official for guidance.

The second point probably is of more importance. But I do not know that I am not speaking to the converted when I am speaking to you. That is the question of budgetary control. There are various reasons for that. It is not at all common in municipal organisations, but in water undertakings I should think it is fairly well followed. Even after some thirty years' wide experience in municipal work, I have come to the conclusion that it is a sort of settled idea that

municipal trading organisations can make no mistake. I do not want any of you members of municipal bodies to take this too much to heart, but they seem to think that notwithstanding the fact that they have made an unfortunate loss this year, they can put it right by increasing the price next year.

Another point is this: they never seem to learn any lesson from the past, and they never seem to think there is anything in the future to beware of. Now this budgetary control, or budgetary system, without doubt improves managerial control. I think that any manager of a concern can work better if he has a budget to work upon. It also, I think, ensures some economy in expenditure. It involves thinking ahead and putting your thoughts into figures. It also involves notice being taken of any variation from a settled plan. It demands explanation of any deviation from what you thought ought to have happened.

The third problem is that of personnel. It is a mere truism to say that no matter what system you adopt for the management of your municipal undertakings, the really important thing is the men employed. The difficulties, if they are difficulties, or differences of opinion, may only result from differences in point of view. But so long as you have the right men in the right position—and by the right men I mean men of the right character and attainments—I think that probably no fault will be found in the financial management of a trading undertaking of municipalities.

There is a difficulty, of course, in municipal work. We are dealing entirely with salaried

men. In ordinary life there are rewards and risks, which do operate to prevent slackness and bad management, but the absence of this in municipal life makes it more and more important for councils to ensure that the men whom they appoint to their important positions should be men of the right attainment and the right character.

MR. G. R. ATKEY (*Nottingham*): The Paper assumes, for its fundamental basis, a superiority complex on the part of the permanent official and a mental deficiency on the part of the public men who run our municipal trading undertakings.

I will deal with only a very few of the statements made in the Paper, and if you will take them as samples of the bulk I think you will form a fair idea of the merits of the claim put forward by Mr. Larkin for the very high position that, quite rightly from his point of view, city treasurers should occupy in connection with municipal trading undertakings. We are specially interested in this gathering in trading undertakings. I join issue on the very first paragraph, where Mr. Larkin suggests that the subject has suffered in the past by being raised as a purely local question. Well, if Mr. Larkin had had any experience outside the narrow groove of official life, he would have known that of all the valuable contributions that are ever given to any great undertaking or any great subject, the most valuable lessons are those that are taught by local experiment, by trial and error; these are the real bases of constructional work in any great enterprise; and to suggest that because the problem has been tested out locally it has suffered is, in my view, an entirely incorrect point of view to take.

Mr. Larkin says: "When the discussion goes beyond the officials it is carried on by persons whose ideas of administration are not always perfectly clear." I would submit to you, as leading counsel for the defendants, that the want of clarity lies in this Paper, and not in the public men here who represent those who, it is suggested, have ideas "not always perfectly clear."

Mr. Larkin says: "... I must go outside the realm of finance and deal with the whole question of management." That is where I think Mr. Larkin gets out of his depth. I am prepared to decorate him with all kinds of haloes, from the point of view of

being able to deal in the realms of high finance. I am not going to presume to any knowledge of at any rate his type of finance; men of figures who juggle with public accounts and present them, even to their own committees, let alone the "man in the street," in a form in which it is utterly impossible for them to be understood, are gentlemen for whom I have the highest admiration.

Mr. Larkin proceeds to point out that municipalities, among other activities, own and run certain businesses. The most usual are water, gas, electricity, and transport undertakings. He goes on to say: "It is important, nevertheless, to note that there are other municipal concerns (schools, roads and hospitals, for instance) which are of an importance not inferior to that of any of the four trading undertakings I have mentioned."

I am quite prepared to admit that they are not in any way inferior. As a matter of fact I do not think any comparison is either necessary or even desirable. Those that are mentioned are the ordinary characteristic undertakings of public bodies, dating from the time when we came to the conclusion that we had better hire somebody to clean the public streets and take the dirt away, rather than do this work ourselves. But there is an important and vast difference between those functions of the local authority and those they have later entered into by definitely purchasing, and becoming the owners of, specific trading undertakings; and I am here to tell Mr. Larkin, and all who think with him, that it requires a different mentality entirely to run a business undertaking successfully, from what it does to run a public health service. There is in such service nothing to do but spend money, economically if you will, but in the ordinary functions of a municipality. That is where I think Mr. Larkin goes entirely wrong. There is not only a fundamental difference between the ordinary undertakings and the trading undertakings of a municipality, but there is an essential difference between the trading undertakings themselves, and the man, or committee, that may be quite able—and find it congenial—to run successfully a tramway undertaking, might entirely fail to so run a gas or an electricity or a water undertaking.

Then Mr. Larkin says: "Nor are we

entitled to claim that because these four undertakings may be run at a profit or at a loss there is some particular brand of genius necessary for their management."

I am surprised at Mr. Larkin making that suggestion. Water engineers, gas engineers, electricity engineers, and transport engineers, are men of a type that demands a special genius, if you are going to make your undertaking successful. And it is necessary to have in those great undertakings the specialist and the expert, if these businesses are to be run as ordinary outside businesses are run, that is, intelligently and with the idea of making good, instead of being run as the ordinary normal corporation business is run, to which you have previously referred.

Amongst my other activities I was once a member of a municipal staff myself. But fortunately, some inherent desire to "get a move on" caused me to embark on the more treacherous whirlpool of commercial competition. Therefore, I can remember the time when I should have fully endorsed Mr. Larkin's suggestion, where he says that "municipal staffs, in the opinion of some, are on the whole superior to the staffs of companies." Well, I do not know where the basis for that suggestion, even on the part of "some" comes in, because the staffs of companies have got to jolly well earn their money! No one, in their wildest flights of imagination, would ever suggest that that applied to a municipal staff. (Laughter).

Here is another typical suggestion, and I do not think it is in any way qualified. This is all Mr. Larkin's own: "It is often alleged"—"alleged," mark you—"that a trading committee knows best what officials it needs"—fancy anybody making an allegation like that. "It is often alleged that a trading committee knows best what officials it needs and how much should be paid to them."

Mr. Larkin proceeds to add: "It probably does not know anything of the kind." Well, if that is a sample of the committees with which Mr. Larkin has come into contact, I am really not surprised at the production of this Paper. How many chairmen of water committees and companies would admit that they do not know anything at all as to the kind of man that is suitable to run their business or what is the appropriate salary to pay him?

But the crux of this Paper lies in the suggestion that so unimportant are those trading undertakings, that there is no necessity for them to be run separately; they should all be run by one committee of the corporation. Of course, Mr. Larkin knows very well that if you had one committee to run water, trams, electricity, and gas, there is not a single member of that committee who would ever live long enough to know anything of real value about any of them. The consequence is, that the great big "I am" at the back of all these great big undertakings controlling all the finance and running the show, would be "His Royal Highness the City Treasurer." (Laughter).

Mr. Larkin lets the cat out of the bag in the last paragraph. He says: "I have, in accordance with my usual practice, tried to make my Paper somewhat provocative."

I congratulate Mr. Larkin upon the success of his efforts in the provocative direction. He also says that the idea at the back of his mind has been to include some constructive suggestion; and I congratulate him on that. He has certainly laid before us a very constructive suggestion, but the entire edifice is one that is to be raised to the greater glorification of officials in general, and city treasurers in particular. All I can say is that as a contribution to the lighter side of life this Paper is a most delightful example, but I hope that, neither inside this Association nor anywhere outside, will anybody regard it as other than a humorous contribution to our discussions.

MR. BURNS (*Hemsworth U.D.C.*): I regard Mr. Larkin's Paper as a great defence of officialism. That seems to be the atmosphere of the whole Conference: "Thee pat my back and I will pat thine," and it is tiring. I blame delegates of public authorities for allowing the platform to entertain so many officials, and so few of the delegates.

Mr. Larkin has given us an official defence of his department—shall I say "compartment"? Of course, with officialism looming so large in the public life of this country officials think that there are brains in only one compartment, the one in which they themselves are interested. I have every respect for officials, but I have no respect for officialism, and that is where this Paper

wants to lead us to. We need to get it out of the minds of the men who are in good stable positions, that at any rate they need only advocate their own positions. That is not public service as I know it, and I do say to them that we expect them to be more qualified and more efficient than the men who are in capitalistic organisations. They have a higher and a nobler calling than those men who are trying to run a business for private profit. Therefore the dignity of their calling demands that they should be public servants as well as looking after their own departments.

Mr. Larkin says that those of us who are publicly elected do not know how to run the business. Well, perhaps we do not. We know more than he knows about public life, in this country anyway. I suggest that we who are publicly elected should make our voices heard more here and in the Council Chamber, then these people will have less to trouble about and less to complain about.

I hope that in future your employers will show you that they are bosses—and that it is not a case of simply telling us: "This is the amount you have to spend, and how you must spend it"; and then being told: "We will pass it" and go home. That is not the right attitude to take in public service. Mr. Larkin is forgiven because he has only put in his Paper what is the atmosphere amongst the officials in public life. You heard it this morning. Every time you get up here, it is just your own little compartment, it is not the National public life at all, and it is time somebody told you. I think all public officials are possessed of the superiority complex.

We know our business; that we can control our business, that we can expect our officials to give us all the help they can, but we do not expect them to come here and give us a good hiding.

MR. ANNAXIN (*Harrogate*): I claim that the affairs of Harrogate are as well managed as any borough in this country, and I say without the slightest fear that a great part of that is due to the officials. I am perfectly certain of this: that if we did not allow

ourselves to be guided at times by our officials we should go wrong. I am speaking as a late official of nineteen years' experience and I have been twenty-three consecutive years on the Council. I want to say that my experience of officials has been that they earn every penny that they get, and if councils do not pay them (I do not say they do not) they cannot expect to get the best-class servant.

I agree with the writer of the Paper on one or two points. It depends on the character of the men that you get. You may get good men, but you must pay them well, and they will do their very best for you and will earn every penny that they get.

MR. WILLIAMS (*Widnes*): There has been so much adverse comment on the Paper that I do feel it is absolutely necessary for someone to get up and state what an excellent Paper it is in constructive ideas. As one who has done a considerable amount of municipal work, who is connected with an extremely large undertaking, I can assure you that the value of the accountants' work is underestimated far too much in connection with public work, and it would be proved effectively to these people who have made adverse comments if they would study the thing carefully; and especially the matters proposed by Mr. Larkin. I have no hesitation in saying that they would have figures submitted to them and have advice given to them which would be of the utmost value and reduce public expenditure to a great deal less than it is at the present time. That is the proved experience of many of the largest undertakings in this country.

MR. LARKIN, in reply, said: There is not much to reply to. I am not sure whether Mr. Burns agrees with me, or not. I rather fancy that we do see eye to eye, and if he thinks he disagrees I do not know that he is right.

With regard to Alderman Atkey, how on earth any alderman from Nottingham—Nottingham, mind you—can get up and try to tell this Association how to run a trading undertaking beats me.

The following Paper was taken as read :—

Fire Fighting Apparatus.

BY

COMMANDER A. N. G. FIREBRACE, R.N. (Retd.)

(Senior Divisional Officer, London Fire Brigade.)

I AM dividing my lecture into four parts and am offering you a few comments on some of the contributions made by the Architect, the Fire Engineer, the Water Engineer and the Fire Brigade to the science of combating fire.

Part I.

Roof.

From the fire-fighting point of view, flat roofs are much to be preferred to the sloping variety. These latter provide lurking places for fire which are difficult to get at, and they afford only precarious foothold to firemen whether they are putting out a fire in the roof itself or are using it as a platform from which to fight a fire in an adjoining building.

FIRE STEPS.

Warehouse buildings in London are now allowed to go to a height of 100 ft. Above the 80 ft. level the walls must be set back so as to form fire steps 6 ft. wide, and these must have direct access to staircases. This arrangement is of great assistance to firemen in enabling them to surround a fire in the upper storeys.

Setting back to provide fire steps is now a recognised principle in building, and examples can be seen in many parts of London.

STAIRCASES.

Large warehouse buildings will normally have at least one tower, or unenclosed staircase. There are two points to note about a tower staircase. First, it is strongly constructed with the idea that it will remain standing even though a fire should make the rest of the building collapse; and secondly, it is designed with open air lobbies so that it should not become smoke-logged. Thus it should give firemen an excellent platform from which to fight a fire.

WINDOW VENTS.

An alternative to these open staircases, namely, window vents, has recently been introduced in London. It consists of an arrangement whereby a proportion of the windows in the building can be opened mechanically from the street level,

thus providing large smoke vents from all floors. Smoke is liable to delay a fireman from getting at a fire; if there were no smoke problem, fires would go out much more quickly and with a much reduced expenditure of water. Therefore, money spent on ventilated staircases, smoke vents of all types and smoke helmets for firemen, is well spent.

It is important to bear in mind that in the event of a fire this window opening device must be operated by the fire brigade only. Otherwise a small fire might be fanned by the draught into a big one.

The general principle governing the handling of door and window ventilation when fires occur is: "Don't open up any ventilation until the firemen actually have their branches in position, after that open up as much ventilation as possible." A fireman wants the smoke to be vented and the fire to show up.

Vents over lift shafts and staircases are, of course, designed to "go" automatically in case of fire, and thus to encourage the smoke and fire to go into the air instead of mushrooming horizontally into the building.

EXTERNAL STAIRCASES.

The fireman finds external staircases very useful to work from. A recent fire at a wholesale druggists, which was somewhat spectacular owing to the big volume of smoke generated, was extinguished mainly by firemen working on an outside staircase at the back of the building.

BASEMENTS.

A welcome feature in a few large buildings recently erected in London is the arrangement whereby the basement and sub-basement are constructed directly open to the air on one or more or all sides. Also light wells are now sometimes sunk to the very lowest level of the building, as witness Unilever House. Thus in the event of a fire, smoke can readily make its way out and firemen readily make their way into the seat of the fire.

The architect who employs this feature makes a very valuable contribution towards minimising the fire risk in his building, and towards saving firemen from smoke exposure, sometimes more severe than they should be called upon to experience.

BASEMENT AND SUB-BASEMENT VENTS.

In order to allow the fire brigade to clear a basement of smoke and so enable firemen to get down the stairs to the basement, pavement lights are in suitable cases made of light construction so that they can be broken by the fire brigade.

If the basement is to be used as a garage, special explosion vents are provided.

For sub-basements, ventilating shafts, usually 30 sq. ft. in area, are sometimes provided so that the smoke may be given a direct way out to the air, thus lessening the possibilities of this level becoming smoke logged.

SUB-BASEMENTS.

In the sub-basement will usually be found the compartments containing boilers and oil fuel tanks; these rooms should have no communication with the rest of the building and be entered directly from the open air.

A fire here would give off dense black smoke. Direct entrance from the outside will provide some possibility that the firemen will be able to bring their extinguishing appliances, either water or foam, to the seat of the fire. Should an oil fuel fire be allowed to gain the upper hand through difficulties of approach and through the absence of any fire protective system, it might well be that the resultant heat would partially wreck the building through distortion of the steel structure.

PARTITION WALLS.

To ensure against a fire becoming uncontrollable, buildings should be cut up into cells of a reasonable size, *i.e.*, not exceeding 500,000 cu. ft., with the exception of basements and storeys above the 80 ft. level, where cells should not exceed 250,000 cu. ft.

Commerce to-day continues to call for more and more spaciousness, bigger and bigger cells. Even where partition walls are constructed to divide up a trade building they are almost invariably perforated by a number of doorways, the aggregate doorway length being sometimes equal to the total length of the solid portions of the wall. These doorways are protected by double fire resisting doors or double roller shutters held open in such a way that they close automatically in case of fire. If these doors are closed or close automatically in the event of a fire, the partition wall functions as it was intended to do—it limits the spread and size of the fire.

There are a great many other ways in which an architect can provide a defence against fire, but time does not permit me to deal with them here.

Part II.

Now we will take a look at some of the ways in which the fire engineer can prepare a defence against fire.

SPRINKLERS.

The most efficient and well-tried of the various installations that can be provided by the fire engineer is the sprinkler system. A sprinkler installation consists of a system of overhead pipes with sprinkler heads placed at about 10 ft. intervals. The latest type of sprinkler head is fitted with a bulb made of hard glass which keeps a valve on its seating, so holding the water back.

The bulb is filled with a liquid having a very high coefficient of expansion. When the heat from a fire expands the liquid, the glass will break into little pieces, the valve will be released and the water will spray out on to the fire.

The efficiency of sprinklers depends, of course, on a good water supply—a running pressure of at least 5 lbs. per square inch at the highest point of the sprinkler installation, with a 2 in. waste open, is the minimum that is accepted, but the higher the pressure the greater is the extinguishing effect. For greater reliability (and thus to obtain an increased rebate from the insurance companies), an alternative water supply is necessary, and this can be provided by another independent water main if available, an overhead tank or a pressure tank. A number of applicants for permission to erect large buildings ask to have the requirement for fitting sprinklers waived, yet they should know that sprinklers will not only give them excellent fire protection (and, therefore, peace of mind) but result in a big insurance rebate. The money thus saved pays an adequate dividend on the capital invested in the sprinkler installation.

It may not be always realised what a difference is made to owners of sprinklered buildings, if for any reason the water authority decreases the pressure in its mains. A drop of a few pounds may render a few installations incapable of functioning properly on the top storeys, and may have the effect of causing direct financial loss to the owners by disqualifying them from receiving certain insurance rebates.

Almost every time that a large country house is burnt out you hear that insufficient water was available; naturally, one cannot expect to have large water mains available along every country road.

It may be news to some that it is perfectly feasible to sprinkler a country house without ruining the appearance of the rooms; there are ways of rendering the sprinkler heads inconspicuous. Since adequate water mains will not generally be available, water is usually supplied in such cases from a pressure tank which may be placed some distance from the house. I know of at least five cases where private houses have been sprinklered.

The following statistics of the last 100 fires in sprinklered buildings in London (they occurred between 30th March, 1929, and 4th November, 1933) will be of interest as showing the reliability and economic operation of sprinklers:—

In 58 per cent. of these fires 1 sprinkler head either extinguished the fire or held it in check.

In 82 per cent. of these fires 3 heads or under either extinguished the fire or held it in check.

In 96 per cent. of these fires 8 heads or under either extinguished the fire or held it in check.

At the four remaining fires from 10 to 27 sprinkler heads opened and the fires were held in check.

There would seem to be at least two good reasons why water authorities should do all in their power to encourage the installation of sprinklers.

Firstly, the more sprinklers there are fitted, the less water will be required for fire extinguishing purposes; that is certain. The sprinkler is most economical in its use of water. A sprinkler head discharges only 12 gallons per minute at

10 lbs. pressure, and 30 gallons per minute at 60 lbs pressure, while a motor pump at work will deliver, say, 500 gallons per minute.

Secondly, the more sprinklers are fitted the fewer burnt out buildings will there be, the less unemployment and interference with trade, and consequently water revenue will be conserved. Perhaps not all water authorities recognize this, since their charges vary considerably. Some supply water to sprinkler installations free; some make only a nominal charge; some charge a fixed sum per sprinkler head per annum—in London this charge is 4d. per 100 square feet per annum plus a guinea per annum for each sealed drain valve.

I appreciate, however, that I have presented only one side of the question.

There is an interesting article on this subject in the October number of the National Fire Protection Association's Quarterly, an American periodical.

DRENCHERS.

Drenchers are employed to prevent a fire in an adjoining risk from entering the building on which the drenchers are fitted. With hand operated drenchers large quantities of water are liable to be expended. With the automatically operated type only the heads immediately affected by the heat would open and water would thus be conserved. Each type—the hand operated and automatic—has its advantages, but unless there is an extremely good water supply so many hand operated drencher heads may come into action in neighbouring buildings that there may not be left enough water to supply the fire brigade pumps.

The insurance companies allow no rebate on automatically operated drenchers. Apparently, they are not yet satisfied that the heads will stand up to the weather exposure, that the opening of one head will not cool the head beneath it and so prevent it actuating, and that the fire may not get by the drencher head into the building before the head has had time to operate. Nevertheless, there are many automatic drenchers fitted in London to-day.

EMULSION METHOD OF FIRE EXTINCTION.

This is an ingenious system, using water only, for putting out oil fires.

Water sprayers, one sprayer to every 12 square feet, are fitted so that every space, concealed or otherwise, can be bombarded with spray under pressure. A pressure of at least 40 lbs. per square inch is required, 100 lbs. per square inch is preferable. Should a fire occur, these sprays are turned on either by hand or automatically by means of a detector head, as may be arranged. Sprayers may be close to the potential fire, or they may be as much as twenty feet away—in the ceiling. The emulsion heads or sprayers have a $\frac{1}{4}$ in. orifice as compared with the $\frac{1}{2}$ in. of the sprinkler head.

The bombardment of the surface of the burning oil results in its being broken up into a multitude of tiny globules each surrounded by a thin film of water. Chemists call this effect an emulsion.

Now an emulsion will not burn, as the flame only reaches the water film surrounding the oil globules. Thus, the surface of the liquid has been made non-inflammable and the fire at once goes out.

This system has received Board of Trade approval for ship installations, and it has been fitted in a number of shore risks. A combined sprinkler and "emulsion" installation is being fitted at the big Battersea Power Station, where nearly half a million gallons of oil will form part of the risk when the station is in full working order. I understand that four other large power stations are adopting an emulsion form of protection. So far the system has only had a chance to prove its worth under test conditions.

A year ago I witnessed the ignition of a quantity of oil in a model of part of the boiler room of a 15,000 ton ship. When the sprayers were turned on the fire went out almost immediately.

The extinguishing of petrol fires by an emulsion method is a bigger problem than that of putting out oil fires. Nevertheless, definite progress in this direction has been made during the last year.

DRY RISERS.

Imagine firemen laboriously laying out a line of hose up the stairs to the top floor of, say, Shell-Mex House. By the time that they had done this, and got a message back to the fire brigade pump to tell the driver to start pumping, I should estimate that at least twenty minutes would have elapsed. That is a very long time to allow a fire to go unattacked.

There are two ways in which time may be saved: First, by fitting dry risers—there is one fitted to Shell-Mex House.

A dry riser consists of a 4 in. galvanised steel pipe normally empty, but through which water can be pumped by the fire brigade as soon as firemen have carried up hose and connected it to the outlets nearest the fire. It is usual to provide outlets only on floors above the 60 ft. level. The use of the dry riser should about halve the time taken to get water on to a fire. A year ago there were but six dry risers fitted in London. Now there are fifteen completed and eleven more contemplated. So you see they are coming into fashion. A dry riser is a very simple and comparatively inexpensive affair. It costs about £80 for an 80 ft. building.

Dry risers are not a new principle. St. Paul's Cathedral has had one for many years. It is tested periodically by playing water over the golden cross.

The second way to save time in getting water on to fires in high buildings is to ensure that lifts are always available for the use of the fire brigade. In New York skyscrapers this is compulsory. Here we sometimes find lifts are not available after working hours, and it takes a good many minutes for a fireman carrying a 67 lb. length of hose to walk up 100 ft. of stairs. Even the youngest fireman would not be at his firefighting best after a climb of this nature.

Nothing makes one more appreciate the necessity for fitting dry risers or hydrants or sprinklers than to stand on the top floor of comparatively high

buildings, as I have, and watch a fire spread while firemen are hoisting hose into position. Dry risers have come to stay.

FOAM INLETS.

One of the best agents for putting out an oil fuel fire is foam, but should an oil fuel fire break out in a basement it would in many cases be impossible to get the hose conveying the foam down the stairs to the fire because of the thick black smoke coming up, and because under these conditions the firemen, even though they were protected with oxygen breathing apparatus, would quite likely not be able to make their way to the fire.

To get over this difficulty the foam inlet has been designed. It is just a plain length of piping down which foam can be pumped direct to the oil fuel chamber and boiler room. Foam inlets have not yet had a chance to prove themselves under fire conditions. There are now about thirty-five foam inlets in London to-day.

CARBON DIOXIDE.

Fire extinguishing systems employing CO₂ gas are sometimes installed by electricity supply undertakings to protect oil-cooled transformers, high tension cables and switch gear. The risk here is largely an oil risk, the main danger being the possibility that owing to the generation of great heat, the casing of a transformer may burst and burning oil be precipitated into the compartment.

If this occurs, the heat will actuate heat detectors and an electric circuit will be closed. A klaxon warning signal will at once sound so that the personnel may run out, and twenty seconds later the contents of batteries of CO₂ flasks will be discharged into the compartment through a number of nozzles.

The action of CO₂ when released on to a fire is to create an atmosphere so devoid of oxygen that the fire goes out.

In order to prevent the access of oxygen from the outside air, it is also arranged that simultaneously with the release of the CO₂ gas the ventilation shutters close and the fans stop, so sealing up the compartment.

CO₂ shows to the best advantage when dealing with oil or electric fires, and of course, the more enclosed the space the better. Quite a number of power stations are protected by CO₂. In one case the CO₂ batteries contain as much as 9,000 lbs. of liquid CO₂.

A large number of ships also have CO₂ fire extinguishing plants. Here a central CO₂ battery connects with the holds and other compartments by means of pipes. In some cases these pipes are made to fulfil a dual purpose—besides being used for the passage of CO₂ gas, they are also employed in connection with a fire-detecting device. The smoke from a fire in the compartment protected will be sucked by a fan up the pipe to a smoke-detecting cabinet. When this happens a visible and audible signal is given, whereupon CO₂ can be released down the tube leading to the compartment on fire.

INTERNAL HYDRANTS.

With an occasional exception, as for example, the stage risk of a theatre, the practice in London is to recommend that hydrants to take large 2½ in. hose be not fitted inside buildings. Untrained employees and women find 2½ in. hose very difficult to handle. 1½ in. hose is in every way more suitable; it is fitted to the hydrant system in Unilever House and, incidentally, to that in Buckingham Palace.

The danger of fitting hydrants is, of course, that the employees will fight the fire unsuccessfully and omit to call the fire brigade until the fire has reached considerable dimensions. It should, therefore, be a very strict rule that, whenever a private hydrant is got to work, the fire brigade must be called. While employees have put out many fires themselves with their own hydrants, a number of cases have occurred where employees have fought a fire unsuccessfully and have not called the fire brigade until the fire has assumed large proportions. At London fires I have sometimes seen lines of hose with water running to waste, which have been got to work by employees and subsequently abandoned.

Part III.

Without the water engineer fire brigades would, indeed, be in a bad way. They would have to rely on water from ponds, rivers, canals, wells, etc.; and these are seldom available.

The time has not yet arrived when the fireman can rely on other fire extinguishing media, such as foam, inert gases, carbon tetra-chloride, methyl-Bromide, etc., for putting out any but the smaller fires.

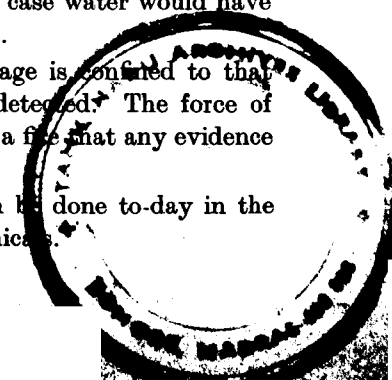
There are many reasons for this, among them the following:—

- (1) Immense quantities of these chemicals would be required to extinguish a big fire and the transport of them from fire station to fire would be difficult.
- (2) The cost would usually be prohibitive.
- (3) The difficulty of application renders it quite out of the question to use them for extinguishing large fires.
- (4) Their action is not nearly so positive as the action of water.
- (5) It is necessary for firemen to wear expensive oxygen breathing apparatus when applying inert gas in quantity.
- (6) There is a very real danger of re-ignition.

There is little incentive to fire brigades to use anything but water on the larger fires. There would always be the risk of a failure, in which case water would have to be used on a fire that had been given time to spread.

The advantages of not using water are, that the damage is confined to that caused by the fire and that arson would be more easily detected. The force of water from the firemen's branches so knocks things about at a fire that any evidence of arson is usually obliterated.

In the last section of my lecture I will show what can be done to-day in the way of extinguishing fires by the use of gases and chemicals.



It seems, therefore, that the fireman will still be dependent for many years to come upon water. Here are some of the things for which a fireman dreams and occasionally gets :—

- (a) Practically inexhaustible mains which will supply the full pumping capacity of his brigade—in London we have seventy 500 gallon pumps always available. It may be interesting to you to know that in London we are experimenting with special hydrant indicating tablets to indicate that the mains to which they are fixed are 12 ins. or more in diameter. They are a rough guide to officers when selecting hydrants into which to set their pumps.
- (b) In neighbourhoods where there are theatres and large sprinklered buildings mains should be duplicated and fed from different sources. There would then be less chance of these buildings being left without protection in the event of a main being under repair. It is a serious matter for a theatre to admit several thousand people when its principal fire-protective apparatus is out of action.
- (c) The bigger the pressure in the mains the better the fireman is pleased because there is then more likelihood of the top storey sprinklers functioning satisfactorily on a fire. If the pressure in the supply mains is low, many sprinklered buildings will require to instal automatic booster pumps or hydraulic injectors.
- (d) Next, a fireman wants his hydrants not too far apart. In the City of London they are from 150 to 250 feet apart and are all double hydrants, so that two pumps can set into each.

One more requirement :—

- (e) If the traffic is not to be held up by lines of hose, hydrants must be provided on both sides of the road.

It occurred to me that you would be interested to know how much water is required to extinguish a big fire.

A factory last June, a very quick, fierce, but short fire which, incidentally, jumped an 80 ft. street, required 1,075,580 gallons (4,800 tons), all taken from the M.W.B. mains.

The fire at Rum Quay last April required upwards of 6 million gallons of water, almost all of this coming from the docks.

At the fire at Butler's Wharf in March, 1931, which lasted for four days, 16 million gallons (71,428 tons) were expended, but here a large percentage of the total was obtained from the Thames. This 16 million gallons would have sufficed to fill the whole building from truck to keelson more than five times over. I am told that the lake in St. James's Park holds 9 million gallons, so we required nearly twice this amount of water.

I should be sorry if I have given you the impression that we are wasteful with water; every care is taken to prevent undue water expenditure and its corollary, water damage. The moment a fire is seen to be coming under control a propor-

tion of the branches are at once knocked off, and whenever floats are engaged at a fire they are always kept at work to the last, since they draw their water from river, canal or dock.

What an enormous saving of water would have been effected in these cases had sprinklers been available!

SHORTAGE OF WATER AT FIRES.

One of the most trying things that can happen to a fireman is to arrive at a fire and find that there is insufficient water to attack it properly—to have to watch it spread unchecked, and, perhaps, to see the property burned out.

It is not often that we are short of water in London; nevertheless, it does occasionally occur.

Perhaps not everyone knows that in London, on the one hand, the London County Council has no power to spend money in laying mains for fire extinguishing apparatus, whilst on the other hand, the Metropolitan Water Board is legally liable to provide a water supply sufficient for domestic purposes only.

If that supply is sufficient for fire extinguishing needs so much the better; if not, so much the worse for the property at risk, and for the fire brigade who have to put out the fire.

It may be of interest to you to know that the London Fire Brigade has a small branch wholly concerned with water and water mains; the fitting of new hydrants and the repair of old ones; investigation of claims for damage through hydrant leakage; ascertaining pressures and flows of hydrants, particularly in cases of shortage of water at fires.

It is the further duty of this branch to examine the sprinkler, drencher and hydrant plans for buildings controlled under the London Building Act, and for theatres under the Metropolis Management and Building Acts Amendment Act of 1878, and especially to watch that an adequate water supply is provided for them. A sprinkler installation having less than 115 heads may be fed from a 4 ins. main and supply pipe, above that a 6 ins. main and supply pipe is required.

The practice in London is to require two separate water supplies for a modern theatre—one to serve the hydrants and fire curtain drencher, the other to supply the sprinkler installation.

WATER GRID.

I was very interested to see in the Press the other day that a national water grid is proposed.

The electricity grid is now well under way, proposals for a water grid and a gas grid are under discussion; the signs are not lacking, I am glad to say, that we shall one day have a fire brigade grid, i.e., perfect co-operation between all the fire brigades in the country.

Then we shall no longer have a totally different standard of fire protection on one side of a street in one local authority's area from that available on the other side of the street under a different municipality.

Just one more point about water. A British fire engineer is experimenting with a method of breaking down the surface tension of water, with a view to giving water for fire extinguishing purposes more penetrating (soaking in) power. Whether this will prove a success in application remains to be seen, but it is certainly an interesting development.

Part IV.

Lastly, we come to fire brigade equipment.

We will begin with the various types of hand chemical extinguishers. The most common type is the soda-acid extinguisher. There are no less than 171 makes recognised by the Fire Offices Committee. To apply the term "chemical extinguisher" to this group is somewhat misleading, as the chemical action is confined merely to effecting the discharge of the liquid, which is, for all practical purposes, water.

This is the best all-round extinguisher available.

A rival to this group is the modern hand pump. Its strong point is its simplicity. It can be tested as often as you wish by actually using it, and no one is afraid of it. If I were equipping a country house with fire extinguishing apparatus, some of these hand pumps would be included.

As regards extinguishers which project either chemicals or gas, each has its special advantage and each its disadvantage. None is ideal for all purposes, and only an expert is competent to select the most suitable type for a given risk.

Carbon tetra-chloride.—There are no less than 46 makes of this type of extinguisher recognised by the Fire Offices Committee. When carbon tetra-chloride strikes the fire it vaporises and blankets the surface of the burning liquid.

It is very effective for small motor car fires and (since it is a non-conductor) small electrical fires. These extinguishers require frequent inspection, or when the time comes to use them on a fire the container may be found to be empty through leakage. This type should not be used in a confined space, or serious physical trouble may occur; this is supported by unimpeachable evidence.

Methyl Bromide.—This is very effective for quenching fire—several times as powerful as the same quantity of carbon tetra-chloride. It is, however, many times more expensive. Methyl bromide extinguishers are standard fitting on R.A.F. machines, and that is as good a recommendation for them as you could wish to have. They are, of course, effective for motor launch fires and are safe to use on electrical fires. They are effective against alcohol fires. Methyl bromide emerges as a liquid, but breaks up very rapidly under the influence of heat. It gets its effect partly from its freezing action and partly by blanketing the fire with inert gas. The main disadvantages of methyl bromide are :—

- (1) It gives off very unpleasant fumes. As to the effect of these unpleasant fumes chemists and other experts differ.
- (2) Its high cost.

Carbon-dioxide.—CO₂ issues from the extinguisher in the form of a gas. This type is specially good for petrol risks and small electrical hazards. The effect of discharging the extinguisher is to so dilute the atmosphere surrounding the fire that the fire goes out from lack of oxygen. Its disadvantages are :—

- (1) It is very heavy.
- (2) It does not throw its contents very far.
- (3) It has to be sent away to be recharged.
- (4) The gas is liable to be dissipated if used in the open air.
- (5) With fires in solids there is always a danger of re-ignition if the concentration of the gas is not maintained until the substance which has been on fire has cooled below the ignition point.

Nevertheless, in spite of these disadvantages this type of extinguisher decidedly has its place in the world of fire protection.

Foam.—In a foam extinguisher two solutions mix when the extinguisher is actuated. The resultant chemical reaction produces foam which covers the surface of the burning liquid, so excluding the oxygen in the air. It is a very good extinguisher for small oil or petrol fires; it keeps the surface of the oil covered so that it cannot re-ignite.

Now as to the larger fire brigade apparatus.

THE ESCAPE VAN.

The escape van carries 40 gallons of water which can be applied very quickly to a fire by means of a small pump. It is certain that future machines of this type will carry a large pump either at the rear or amidships. The escape van carrying only an escape and a first aid tank will become a thing of the past.

PUMPS.

There is a growing tendency to break away from the old type of body and to design pump bodies so that firemen will have some protection from the weather and will not be in danger of being thrown off while they are rigging themselves on the way to the fire.

Paris and Edinburgh favour the completely covered-in body. Here the men are wholly protected from the weather—an important factor where long runs under wintry conditions have to be undertaken.

EMERGENCY TENDER.

Large towns have a fire appliance known as an Emergency Tender. It carries all sorts of gear which may be required at large or unusual fires, such as floodlights, apparatus for reviving persons overcome by smoke or fumes, acetylene cutting plant and self-contained breathing apparatus. The latest type of Emergency Tender to be placed in commission follows char-a-banc lines. It has been bought by West Ham and is a considerable improvement on existing types—a courageous breakaway from tradition.

SMOKE HELMETS.

With the oxygen type of breathing apparatus or smoke helmet, a man can remain one hour in any atmosphere, however poisonous. London is increasing its smoke helmet equipment, and will in future carry smoke helmets on some of its pumps as well as on its emergency tenders. In this way they will be more quickly available at the start of smoky jobs—the seat of the fire will be reached more quickly—and firemen will be protected from the very severe conditions of smoke and fumes so often endured to-day. The increased use of smoke helmets should certainly result in the conservation of water for fire extinguishing purposes.

TURNTABLE LADDERS.

The primary function of a turntable ladder is that of a water tower. It is much quicker to get water on to a roof or upper floors using a turntable ladder than by taking a line of hose up the staircase.

Modern turntable ladders are constructed of steel and in this country run to 100 ft. London will shortly have four of this type, a very considerable improvement on its wooden predecessor. Turntable ladders can be bought up to 150 ft. in height.

FOAM TENDER.

Foam machines were formerly designed on the same principle as many foam installations supplied to ships for protecting their oil-fuel boiler rooms. With this type the tank is divided into two compartments each containing a different chemical solution. These solutions are pumped along twin hose until they arrive at the nozzle, where they mix and produce foam.

This type of foam producer is no longer made for land services. It has been superseded by the foam generator.

FOAM GENERATOR.

The foam generator can be kept in action so long as the supply of water and foam powder lasts.

This system of foam production is effective, but not ideal. It is expensive—it costs between £1 and £2 per minute while in action. Further, the tins of powder are bulky and heavy to transport.

AIR FOAM.

Chemically-produced foam now has a rival in air foam.

This is produced by mounting on a fire brigade pump chassis a foam beater, which draws in water, air and saponin in certain proportions and beats them mechanically into foam.

This system seems to have proved successful in Sweden and Denmark, but it has made almost no progress in this country. Possibly owing to being handicapped

by difficulties in regard to patent rights, air foam tests in this country have not been very successful.

The advantages claimed for air foam are:—

- (1) A great saving in space and weight—a small tank of saponin is carried instead of many bulky tins of powder.
- (2) A large saving in cost.

The opponents of air foam say that this is not nearly so big as is claimed, because according to them, the percentage of saponin that will have to be used to get really good foam is much higher than the .2 per cent. claimed.

- (3) Universal application with minimum water expenditure.

The disadvantage of the air foam machine is that it is married permanently to one chassis; if that chassis is under repair the air foam machine will be out of action.

The foam generator is free from this disadvantage.

Air foam is unlikely to make any headway in this country until it has given better test results, and until it is marketed openly by a British firm of fire engineers.

On the whole, I am of opinion that given equally good foam, the air foam method has definite advantages over the chemical foam method, at all events for the larger fire brigades.

MOBILE CO₂ EQUIPMENT.

The value of CO₂ having been proved in fixed installations both ashore, and, over a period of many years, afloat, certain fire engineers are now turning their attention to the production of mobile CO₂ appliances.

Redcar has added to its equipment a large motor fire appliance carrying batteries of CO₂ gas.

It tows a trailer pump as an auxiliary in case the fire is unsuitable for attack by CO₂, and because, with fires involving solids, a little damping down with water may be required after the discharge of the gas.

In another brigade the CO₂ battery is the auxiliary, being mounted on a trailer towed behind an ordinary motor pump.

I understand that an experimental motor fire appliance carrying nine cylinders of CO₂ and three CO₂ hose reels has just been completed for service at an aerodrome against crash fires. It also carries a 50 gallon water tank.

There is, of course, no question of really big fires being tackled with CO₂; that would, at present, be quite impracticable.

THE SZILVAY SYSTEM.

The most elaborate appliance for extinguishing fire by means of inert gases is the Szilvay Machine. I saw it in action against test fires at the Paris Fire Exhibition in 1932.

In this system, fires are extinguished by pumping bi-carbonate of soda on to them with CO₂ gas, obtained (and this is the interesting and original point) by purifying and treating the exhaust gases of the internal combustion engine which propels the appliance.

The all-round utility of either this machine or the large CO₂ appliance is in no way comparable with that of the ordinary motor pump. Apart from their special suitability for certain particular risks, their main advantage lies in the fact that they eliminate water damage.

To purchase, maintain and man either of these machines as an extra appliance would be a very expensive matter. If designed to a reasonable size in combination with a standard water pump, or on a small scale as a substitute for the water first aid appliance, the Szilvay machine would, I think, attract more attention.

CONCLUSION.

In this necessarily limited survey I have endeavoured to show you some aspects of the fight against fire.

Progress demands that fire loss for the United Kingdom of between 8 and 9 million pounds per annum must be reduced. Many energetic minds in a number of professions are working towards this end; they will not fail to be successful.

DISCUSSION.

COMMANDER FIREBRACE, presenting his paper, showed a number of lantern slides illustrating the types of buildings and appliances referred to.

A delegate asked whether it was correct that a fire brigade can always take any water that is available when they get to a fire: whether the owner of the water, or the company concerned, will endeavour to stop them.

COMMANDER FIREBRACE: Of course, the answer is very simple. You must use the water first, and find out afterwards whether you are allowed to. After the fire is out that can be referred to the solicitors. If there is water, nobody in his senses would neglect to take it. But if you do take water from certain hydrants, even in London, the owners of these hydrants will have to pay. I only discovered one of these instances quite recently.

MR. WARNER TERRY: If you will address your query to the Secretary of the British Waterworks Association, I can give you two or three cases which will put you right.

MR. BURNS (*Hemsworth*): Will our Lecturer give us a few ideas as to what is the most expeditious and most efficient means?

COMMANDER FIREBRACE: As I say in my paper, for a great many years we shall be dependent on water for putting out fires. Certain risks are best protected by emulsion, certain other risks by CO₂, others by foam, etc., and I am afraid that you will have to go to a fire engineer to tell you which is most suited to your own particular risk. Of course, an official in my position has to be very careful not to recommend one firm against another; one can only talk generally about systems. Obviously for large oil fires you have emulsion, CO₂, or foam. Some oil fires, particularly oil fuel fires, can be put out by using hand sprayers; petrol is more difficult to extinguish, but definite progress is being made in putting out petrol with spray.

A DELEGATE: What can you tell us about putting out heath fires?

COMMANDER FIREBRACE: Personally, I do not know much about heath and gorse fires; we do get a good many in London but we generally have water available within a reasonable distance and use that. I can appreciate that in the country you may not have water within several miles. I noticed that at the last Paris Fire Exhibition they

were selling wire beaters for beating out this type of fire.

A DELEGATE: Can you use extincteurs for gorse fires?

COMMANDER FIREBRACE: The extincteur is too small; you would want vast numbers of them, and the extincteur is, of course, very heavy to use.

MR. C. T. CUSS (*Great Western Railway, Swindon*): We have seen on the screen some hand fire extinguishers; we call them "first-aid appliances." In this country in 1914 we were rather behind the times, and when war came it was necessary to equip the Red Cross trains constructed for America with appliances suitable to withstand climatic conditions in St. Petersburg. No appliances then marketed in this country would withstand frost. They would all burst. So we had to fall back on the Great Western standard fire extinguishers.

These were first designed and manufactured about 1910. They were charged with a solution of calcium-chloride, costing less than 1d. a gallon. The liquid was expelled by CO₂, and the stream was controlled through a valve. I should be obliged if Commander Firebrace would say why there is general adherence to antediluvian contraptions to extinguish fires, when the saving of life and

property would result from the successful use of the simple appliances I have referred to. It was widely thought until 1910 that one type of appliance would be sufficient to extinguish every kind of fire, but it was very soon found that a railway required at least nine types. But there were not nine types, or even one, capable of withstanding frost and purchasable in this country, and we therefore had to turn our hands to manufacturing additional supplies of our standard pressure extinguisher for this purpose. In consequence for 22 years we have manufactured for our large requirements nine types of appliances required to tackle the various kinds of fires which may occur in the railway range of rolling stock, equipment and buildings, ships and road vehicles. It is highly desirable that these simple and effective appliances should be better known and more widely utilised for the protection of life and property, thus saving precious lives and something like half the thirty million pounds of money per annum lost in Great Britain through fire.

COMMANDER FIREBRACE: It is difficult to reply to that, but if there is any good in it, the Fire Service is ready to test it, and the manufacturers in this country are prepared to market it.

The following Paper was taken as read :—

The Legal Aspect of Water Supply for Fire Protection Purposes.

BY

JOHN HALL,

Clerk and Solicitor to the Fylde Water Board.

AMONG the many aphorisms inculcated in plastic minds in our youthful days is one to the effect that "fire is a good servant, but a bad master." In our more mature years we realize that the truth of this is fully borne out. It equally applies with respect to water. And even at the present day, in this century of progress, if a "good servant" is required to beat the "bad master" fire, an abundant water supply is the great desideratum.

The questions of fire protection and water supplies are essentially matters affecting the public at large, and consequently Parliament has seen fit to deal with them, or at any rate, with certain aspects, in the public interest. It is perhaps unnecessary for me to add that with reference to any matters not embraced within parliamentary provisions ordinary legal principles apply.

For instance, Parliament has imposed an imperative duty upon water undertakers to afford a supply of water for domestic purposes; but for trade supplies the ordinary law of contract applies. As, therefore, a supply of water for fire protection purposes is not a "domestic supply" it follows that such a supply would be governed by the ordinary principles of the law relating to contracts if Parliament had not otherwise intervened. We find the subject is dealt with in Sections 38 to 43 and Section 35 of the Waterworks Clauses Act 1847. It will be convenient to refer to the details of those sections.

Section 38 requires water undertakers, at the request of the local authority of the district, to "fix proper fire-plugs in the main and other pipes belonging to them" at distances of not more than 100 yards apart (unless some other distance is prescribed) "and at such places as may be most proper and convenient for the supply of water for extinguishing any fire which may break out within the limits of the special Act." In case of dispute as to the position or number of the fire-plugs it will be settled by the inspector (if any is appointed by the local authority) or by two justices or in Scotland by the Sheriff.

By Section 39 the water undertakers are required to "renew, and keep in effective order, every such fire-plug," and also to deposit a key thereof at each place where any public Fire Engine is kept and in such other places as may be appointed by the local authority. They are also required to "put up a public notice in some conspicuous place in each street in which such fire-plug is situated, showing its situation, which notice the undertakers may put up on any house or building in such street." The cost of these fire-plugs "and the expense of fixing placing and maintaining the same in repair and of providing such keys as aforesaid" is to be defrayed by the local authority (Section 40).

Section 41 provides that the water undertakers shall "at the request and expense of the owner or occupier of any work or manufactory situated in any street in which there shall be a pipe of the undertakers place and maintain in effective order a fireplug (to be used only for extinguishing fires) as near as conveniently may be to such work or manufactory."

Section 42 requires that the water undertakers shall at all times keep charged with water, under the pressure specified in Section 35, "all their pipes to which fire-plugs shall be fixed unless prevented by frost unusual drought or other unavoidable cause or accident or during necessary repairs and shall allow all persons at all times to take and use such water for extinguishing fire without making compensation for the same."

With regard to the pressure, Section 35 of the Act provides that the supply "shall be constantly laid on at such pressure as will make the water reach the top storey of the highest houses" within the limits of the special Act "unless it be provided by the special Act that the water to be supplied by the undertakers need not be constantly laid on under pressure."

Section 43 is the last of this series of Sections. ("The sting is in the tail") It lays down that if the undertakers (except when prevented as aforesaid) "neglect or refuse to fix maintain or repair such fire-plugs" . . . or "neglect to keep their pipes charged under such pressure as aforesaid" they shall be liable to a penalty of £10 and also forfeit to the local authority the sum of 40s. for every day during which such refusal or neglect shall continue after notice in writing shall have been given to the undertakers of the want of supply.

It will be seen, therefore, that there is a definite statutory obligation imposed (under penalties) upon water undertakers to fix and maintain fire-plugs at the request (and cost) of (a) local authorities and (b) owners or occupiers of works and factories.

Furthermore, Parliament has, by Section 66 of the Public Health Act, 1875, imposed a definite duty upon all urban authorities to "cause fire-plugs and all necessary works machinery and assistance for securing an efficient supply of water in case of fire to be provided and maintained." They are also required by the same Section to "paint or mark on the buildings and walls within the streets, words or marks near to such fire-plugs to denote the situation thereof." This latter requirement is one of the greatest importance, and a local authority will be liable for any damage sustained by reason of an error in the indication plate. (See *Dawson & Co. v. Bingley U.D.C.*, 1911, 2 K.B. 149).

If a rural district council provide a water supply in their district they may be presumed to have power to fix fire hydrants in the mains as part of the works. Section 51 of the Public Health Act, 1875, which authorizes them to provide a water supply also empowers them to "do any other necessary acts." In any event, a rural council may apply to the Minister of Health under Section 276 of the Public Health Act, 1875, for a grant of "urban powers."

Although water undertakers are not bound to fix fire-plugs unless specifically requested as above mentioned, yet an imperative duty is cast on urban authorities

to make this provision. Still, even then, it has been held that Section 38 does not impose any duty on the water undertakers to provide a pipe of sufficient capacity to carry a proper fire-plug in a place where an existing pipe is insufficient for that purpose. If, therefore, the urban authority require a fire-plug there, they must pay for the necessary new pipe (See *Wells Water Co. v. Wells Town Council*, 1886, 51, J.P. 135).

With respect to sprinklers, of which considerable use is now made, there is no general legislation governing these. In the absence, therefore, of special provisions in private Acts of Parliament, the position is governed by any agreement between the parties. Thus, water undertakers are able to protect themselves against claims for penalties or damages.

In the case of fire-plugs, however, as already pointed out there is a definite statutory obligation that the water undertakers shall keep all their pipes to which fire-plugs are fixed charged with water at such a pressure as will make the water reach the top storey of the highest house in their area of supply. But there are two important exceptions, viz. :—

(a) Unless it be provided by their special Act that the water need not be constantly laid on under pressure (Section 35); and

(b) Unless prevented by frost, unusual drought or other unavoidable cause or accident, or during necessary repairs (Section 42).

A very usual provision to be found in private Acts is to the effect that the water supplied by the undertakers need not at any time be delivered at a pressure greater than that to be afforded by gravitation from a certain reservoir. With such a provision the water undertakers may rest fairly comfortably whatever may be said by the fire authorities! Thus, in times of "peak demand" and of reduced level in the reservoir, the pressure in the mains may be far from what the "fire-fighters" may desire yet the situation must be accepted as it is.

Another point is worthy of notice. By Section 42 of the Waterworks Clauses Act, 1847, the undertakers are required to allow the use of their water for fire extinguishment purposes without payment. (This is one thing generally overlooked by people who grumble at water rates!) But this privilege only applies to water taken from the undertakers' mains to which fire-plugs are fixed. In this connection, the case of *Weardale and Conselt Water Co. v. Chester-le-Street Co-operative Society*, (1904, 2 K.B. 240) may be referred to. The Society owned a pipe running from the Company's main across the Society's field to supply them with water for agricultural purposes. In this pipe a fire-plug had been fixed by the Company at the request and cost of the Society. A haystack belonging to the Society caught fire, and they used water from this fire-plug to extinguish it. They claimed to use the water gratuitously by virtue of Section 42, but the Court decided they must pay. The free supply must only come from a fire-plug on the Company's mains.

I have not thought it necessary to deal with the Metropolitan area. I think it might safely be presumed that the London Fire Brigade and the London County Council will be fully acquainted with the position under Section 32 of the Metropolitan Fire Brigade Act, 1865 and Section 34 of the Metropolis Water Act, 1871!

DISCUSSION.

MR. JOHN HALL, introducing his Paper, said: When I was asked to prepare a brief Paper on the legal aspect of water-supply for fire extinguishing, I collected in this Paper the statutory provisions which deal with the question. Anything outside the statutory provisions is the subject of the ordinary law of contract, which is part of the general law of the land.

MR. A. J. ROBINSON: I would refer to the paragraph reading: "Although water undertakers are not bound to fix fire-plugs unless specifically requested as above mentioned, yet an imperative duty is cast on urban authorities to make this provision. Still, even then, it has been held that Section 38 does not impose any duty on the water undertakers to provide a pipe of sufficient capacity to carry a proper fire-plug in a place where an existing pipe is insufficient for that purpose."

In the course of my experience during the last two or three years, my Board have had requests to them from local authorities to put down larger sized pipes, in order to give a better pressure for fire purposes. Some three years ago there was a short length of pipe, 3 inches in diameter, supplying a few houses in a side street, and a certain council requested my Board to put down a larger pipe in order to give a better pressure for fire purposes. The pipe that was there was quite sufficient to fulfil all the statutory obligations resting on my Board, and, I think quite rightly, my Board politely and respectfully refused to put down such a larger pipe. Only this year we had a request to put down pipes for fire purposes, in order to protect property which might become involved, due to gorse and heath fires. A good many big gorse fires took place in the district supplied by my Board, and I had a letter from the clerk of a certain council asking my Board to give their attention to the question of improving the facilities for fire protection, on account of the serious-

ness of gorse and heath fires that were taking place and what might be involved as a consequence of them. I began to look into the matter and found that the law on this matter was very beautifully and clearly put at a meeting of the Professional Fire Brigades Association in July, 1930, in a Paper submitted by Mr. G. Baxter, the Water Engineer of the City of Dundee. He set out the statutory obligations of a water authority: they are contained in Sections 35 and 38 to 43 of the Waterworks Clauses Act 1847. Under those clauses he said that the water authority is required to give facilities to any local authority for taking water from its mains for fire extinguishing purposes, to fix and maintain in effective order, and renew fire hydrants when and where required by and at the expense of the local authority, and to keep mains charged under such pressure, unless otherwise provided by the special act under which it operates, as will make the water reach to the top storey of the highest house, within its limits of supply; to supply the water required without compensation for the same.

I wrote to the clerk of the council in question and I quoted these remarks of Mr. Baxter, and pointed out that there was no obligation on my Board to put water mains down in order to protect properties from fires that might take place on heath or gorse lands. I said that my Board would be perfectly willing to put such pipes down, provided the Council would pay for them; and I think that is the correct attitude for any water undertaking to take.

Where a council is a fire authority and a water authority, the question may not arise in quite such an active form, but where the water supply is in the hands of a board or a company, then it seems to me that some councils have got the idea that the board or the company should, at their own cost, put down all additional and larger water mains necessary for fire purposes.

CONFERENCE

Under the auspices of the Institution of Municipal and County Engineers.

THURSDAY, 16th NOVEMBER, at 11.0 a.m.

MR. C. H. BRESSEY, C.B., C.B.E. (*Chief Engineer, Roads Department, Ministry of Transport*),
in the Chair.

The following two Papers were taken as read:—

Office Efficiency in a Highways Department.

BY

E. TASKER, A.M.Inst.C.E.

(*Chief Engineering Assistant, Gloucestershire C.C.*)

(NOTE.—This Paper was submitted for the open competition arranged by the Congress Committee, and was awarded the Second Prize of a Silver Medal and Fifty Guineas).

NOW that major improvement schemes for roads and bridges are in abeyance, the time is opportune to consider whether the efficiency of the department is 100 per cent. and if not in what way the standard may be raised. Now is the time to overhaul every phase of the organisation. The financial state of the Country demands that every possible effort should be made to eliminate waste.

GROWTH OF OFFICE ORGANISATION.

The author found that the cost of organisation of a certain county Highway Department was thirteen times greater than twenty years ago. The expenditure of over half a million pounds per annum for a Highway Department is controlled from the office. It is imperative then that a thorough investigation should be made of the whole of office duties to obtain *maximum* efficiency.

EFFICIENCY DESIGN.

“Efficiency” is defined by Professor Rankine as being “the ratio of useful work to energy expended.” As engineers, we are accustomed to applying this definition to determine the usefulness of machines and appliances.

EXAMPLES OF EFFICIENCY.

In seeing the disorder and waste in many engineering contrivances, Lord Kelvin (1824—1908), the eminent professor and scientist applied himself rigorously to devise more efficient ways of diverting the forces of nature to the use and convenience of man. His profound theoretical knowledge was turned to practical use in his many inventions in connection with dynamos, telegraphy, navigation, cables, etc. His many improvements save huge sums in engineering enterprises. This efficiency outlook applied to a highways department would produce real economy to-day.

We find the same thought expressed, probably with more regard to office organisation, by Disraeli in 1852 in the House of Commons when he said, “If you make your establishments efficient, you will find almost as a natural consequence that you will save money; and therefore I take it, that efficiency and not retrenchment, is the parent of economy.” In 1863 he wrote, “Economy does not consist in the reckless reduction in establishments, on the contrary such a course almost necessarily tends to increase expenditure. There can be no economy where there is no efficiency.”

A reflection on the lives of successful men shows that the teachings of universities is not alone productive of the highest results, but that the good works of Edison, Brunel, Telford, Lincoln and others were the outcome of perpetual application to produce the best results.

UNEMPLOYMENT.

A remedy for the relief of British unemployment is that every British employer and employee, in workshop and office, diligently applies every possible method and system to do his work and produce his goods in the most efficient manner. Thus, without reducing our standard of living, British goods would be produced at such a lower cost that we should experience an unprecedented boom in orders from abroad. Costs too being lower, our own purchasing power would be greater, which again would result in more home employment. Efficiency, therefore, is of national importance.

GROWTH OF WORK.

The growth of work in a highways department has been so gradual that the change in conditions has not always been detected. When an increase in office work occurs there are two ways of dealing with it. One is to carry out the work in the same way and increase the staff, the other is to devise a more efficient way and use the same staff. Efficiency particularly appeals to engineers for the Americans have said that “An engineer can do with a shilling that for which a fool requires a pound.” To-day structures are not erected by rule of thumb. The Sydney Harbour Bridge, the first of its magnitude, was not built on experience, but was the product of scientific forethought. Every detail was planned. The same forethought and planning is required in organisation.

Highways departments, particularly with county councils, have grown into large organisations. Complex problems present themselves. A small commercial firm may make good profits, but large firms are apt to become bureaucratic, bound by red tape, lacking in team play and personal efficiency: initiative is suppressed.

The successful large firms, insurance companies, departmental stores, etc., maintain a high standard of efficiency by staff training, awards on results, making use of every possible device, method, apparatus and machinery to reduce costs, keeping detail records, charts and analyses. The initiative and zeal of the personnel of successful private firms is inculcated too by acknowledgment of results from managers endowed with more freedom, latitude and power than public officials. Efficiency in public service is consequently more difficult and requires careful investigation.

Despite the recent years of depression, some firms have made good profits: they have been the "efficient few."

TYPES OF EFFICIENCY.

We have the military and civil service type of efficiency. There is a clockwork system of routine. The standardisation eliminates waste. All duties are allocated to the most minute detail. It produces an almost errorless organisation of power without responsibility. The law of seniority is enforced at the cost and sacrifice of all other considerations. It produces a disinterested soul-less existence lacking in initiative and sense of proportion. It has, however, effected amazing savings in the Post Office Savings Bank, that colossal department.

There is the American type of efficiency, with its tables, statistics, graphs, charts, diagrams, and organisation-machine methods, producing work of ruthless exactness.

Then there is the family organisation with its family traits and influences, where duties are not clearly defined, where directors give instructions direct to workmen. Family views have more influence than results. Favouritism is rife; there is chaos, lack of records, and poor results. This organisation cannot usually survive many generations.

Efficiency is not a system, it is a perpetual improvement. It consists of taking every duty, even the ordinary matter of fact job, and finding a way to do it better and at less cost. For example, the author once witnessed six entries being made for every article ordered and upon investigation, one firm found that 17 entries were necessary to withdraw one article from stock. In some highways departments, requisitions are completely re-copied into an order book. A simply extended system of carbon copies eliminates this duplication.

PSYCHOLOGY.

The Utopian efficiency is that which has the discipline of the military style combined with the exactness of the statistical organisation and the happy relations of the family firm. This ideal is difficult to attain, particularly in local government service. It requires great tact and diplomacy, an esprit-de-corps with unfailing loyalty, and unprecedented team work. Psychological effects must be borne in mind. Sports clubs, libraries, lounges and canteens all help to develop comradeship, yet individually, each one should have a thorough knowledge of his subject and be a master of his own particular job. A highway authority cannot institute profit sharing, bonus awards, prizes, or commission, but an incentive can be inculcated by a system of double increments for meritorious service, and honoraria or improved

status on securing some recognized qualification. Good health is essential to keenness and the value of a night at the theatre and a week-end break cannot be overestimated. A sense of humour prevents apathy and stimulates interest: we pay well for humour. Our lifetime's earnings would form a poor year's income for the stars of another sphere! By means of transference of duties, increased output can often be secured by avoiding square pegs in round holes. Young men have a reputation for activity and experimental work, investigations and initiative, while age and experience develop accurate judgment but tend to retrenchment and an adherence to old methods. Each outlook has its uses. A man is a failure as a school teacher if he likes not boys; a senior official obtains better results when he is fond of men. The snob and self-centred man breeds a cold atmosphere which is destructive of good results. The egoistic man who gets his own way by domineering does not get loyalty and support. The true leader carries his staff and colleagues with him.

ENVIRONMENT.

General.—The author makes no apology for treating with environment as a section of office efficiency, for whereas the requirements may be known to all, office conditions sometimes are such that improvements on the lines indicated would increase the standard of efficiency.

In practical work, workmen are supplied with proper tools for their particular job, for example special forks for spreading tarred macadam, special sprayers for surface spraying of roads, etc. It is said that good workmen have good tools. In the same way the best results are obtained when proper office appliances are provided for each special job.

Buildings.—In office accommodation rooms should be arranged to avoid unnecessary walking about. Walking time is waste time. In the city offices at Edinburgh, a transporter system having carriers working on a miniature railway principle, operated electrically, conveys files from one section to another. Items which may be considered are: Are there any detached contingents? Is the arrangement satisfactory for sectionalisation and supervision? Is communication difficult and inefficient? Has the accommodation increased in relation to the increase in staff during the last twenty years? Are there too many small rooms? It has been found from tests that large rooms are more economical than small. Although alterations to existing buildings present difficulties, it is often possible to effect improvements by adding or removing partitions, altering the positions of doors and re-arranging the different sections of work.

Floor space.—The average floor space required is 100 square feet (including aisles, desks and chairs) for each clerk, and 200 square feet for each drawing office worker, including central table and plan chests. Aisles 3 ft. to 3 ft. 6 in. wide and spaces of 4 ft. between desks are desirable.

Ventilation.—Ventilation in offices is an important feature. Lack of good ventilation often causes office workers to catch colds. Bearing in mind that a cold costs the employer from £4 to £5, capital expenditure on improving ventilation

is quickly recovered. For large buildings, the "Plenum" system with sealed windows excluding the polluted atmosphere of towns is the best known method of ventilation. Air, admitted into a chamber, filtered, aerated and in times of infection disinfected, is propelled along ducts, admitted to the rooms at a height which gives freedom from draught. The foul air is extracted from the base of the rooms. A fine example of this system is at the College of Technology, Manchester, where many pounds of soot and impurities are extracted from the atmosphere. To enter the building from the streets is invigorating. Even when working long hours one's vitality is maintained. This system effects a real economy. There is increased output, a better degree of accuracy and better health among the workers. Recently, efficient firms have installed "Vita" glass.

The author recently saw a drawing office of a highway authority where seven assistants were crowded into an ill-ventilated and badly lighted room. No better example could be found of the high cost to employers due to such bad office conditions. The best record held by the staff was, that only during one winter had one member of the staff worked without illness. A vital point is that foul air in addition to giving bad health produces drowsiness, reduces output and accuracy. Overcrowding is not an economy.

Heating.—The correct temperature for office workers is 65°. The open fire, by means of its ventilating properties is still the healthiest means of heating, but is really unsuited to offices in that its effects are local and there is considerable waste of time in re-fuelling. Central heating is now almost universal, though radiators creating a dry stifling heat are not healthy. Gas fires are convenient and the more modern types are less injurious than the old patterns. Electric radiators are good and have the advantage of being portable. In many buildings the convenient and easily controlled electric tubular heating has been recently installed, controlled by thermostats and time switches. The best system in existence, however, is the "Plenum" system, where pure air is heated and propelled through the rooms at correct temperature.

Lighting.—Natural light produces the best results. The position and size of windows, which admit most light from the top, can sometimes be altered with advantage. Modern steel frames obstruct less light than wood. In blocks of buildings, wells constructed with white glazed bricks reflect natural light. Further, droppers can be attached to windows to reflect light on to the ceilings. Improvements are also effected by keeping the ceilings white, with a deep white frieze and light coloured walls. Good lighting tends to accuracy and maximum output, besides saving the light account.

If artificial light has to be used, it should be diffused to avoid glare. Electric light can easily be moved so as to give the best possible height and position. Left hand light and freedom from shadow affords the best results.

Noise.—Noise is a nuisance. It can be mitigated in several ways. Sound absorbing plaster or a fibrous material applied to the walls and roof is efficacious. The floor can be covered with a thick cork compound, while double windows can be fixed adjacent to traffic. Office furniture, chairs, desks, stools, etc., can be fitted with domes of silence, or rubber pads.

It is usually possible to arrange that all machines, typewriters, printing apparatus, etc., are in separate rooms. If, however, it is impossible, the noise can be minimised by using silent typewriters and placing instruments on rubber pads. Noise is a disturbing factor and should be reduced to the minimum. Slamming doors may be avoided by installing auto-closers. Loud-voiced, noisy workers should be given an outside job.

Furniture.—Office and sedentary work is unnatural—it lacks open air and physical exercise. This will have its effect in coming generations unless we do all possible to prevent deterioration and maintain a good standard of physique. Much can be done by a little capital expenditure in providing scientifically designed chairs of the correct height with hip support, the main dimensions being adjustable. A desk specially designed for the task to be performed is an economy. Desks facing one way have been found to give the best results. A hygienic covering is provided in linoleum for table tops, green being the best colour. Furnishing firms have made a special study of supplying office furniture for special tasks, e.g., the typist's desk with accessible drawers and trays for letter papers, carbons, rack for holding notebook if shorthand is used, etc.

When new furnishings are being purchased, the advantages of steel equipment merit consideration. The fireproof material is neat, occupies the minimum space, is businesslike, cleaner and more hygienic than wood which absorbs dirt and a film of oil and grease, which in time harbours insects. Stove enamelled steel preserves the material in a rustless condition.

TELEPHONES.

It is not surprising that the telephone, invented in 1876, is familiar to all and that 99 per cent. of highway offices now make use of the instrument, but it is surprising that telephone efficiency in highways departments only averages about 60 per cent. It is because of its potentialities that the following observations are made.

Cost of walking time.—If officials, who are paid from 2s. 6d. to 10s. per hour, have to make several journeys per day walking to and from different offices and departments, the loss to a Council is considerable, as shewn in the analysis:—

Average, 3 journeys per day each 10 minutes :

			s.	d.
3 senior officials	@ 5/-	per hour =	7	6 per day.
4 officials	@ 3/-	" =	6	0 "
6 "	@ 2/-	" =	6	0 "
8 "	@ 1/6	" =	6	0 "
5 "	@ 1/-	" =	2	6 "
Total			28	0

Cost per annum to one department, £400.

The actual cost to any department can be ascertained on this basis and it will be seen that it is a costly waste to eliminate mechanical inter-communication between offices and departments.

Inter-communication.—Two, systems of telephonic inter-communication are available.

Automatic key board.—With the automatic press button equipment, each department, office or desk, has a key board on which each button, immediately it is depressed puts the operator into direct communication with any of the departments, etc., connected to the set. Many special devices can be introduced, for instance transmitters (suitable for the stores, depot, or repair shed where there is considerable noise) and alarm bells. A loud-speaker transmitter can be attached enabling one to speak to a whole department; this eliminates walking time in the distribution of summonses to meetings, general instructions, etc.

With the automatic key board, no central switch board operator is required and as the system is purely inter-departmental there is no delay or necessity to speak through the post office exchange.

Private branch automatic.—The automatic dial apparatus has similar advantages and can be used for any number of lines, but has been superseded by the press button where the number of lines is limited to about 30.

Dictagraph.—A telephonic instrument of particular service in a highways department is the dictagraph. An official may listen to a committee without being in personal attendance and can continue his normal work until any particular item of the agenda is reached upon which he may wish to give evidence.

Conversely, the official may speak through the instrument to any member of the staff or any room from any part of his own room while both his hands are free for other work.

Improvements.—An observance of the following points also increases office efficiency :—

- (1) An extension of the Post Office telephone to a convenient place in every room where an official has occasion to converse with persons outside his own building.
- (2) A central switch board and operator for the whole building. This is an economy; delays are minimised, and errors by the public in calling wrong departments are avoided. It also saves the time of the many officers required to operate detached exchanges.
- (3) In the absence of the official required, phone messages are recorded by substitutes. Errors in transcribing are minimised when a duplicated pad, with standard headings, is installed at every telephone, the data being filled in by the substitute :—

Message for Mr....., date.....,
time....., from..... firm, Mr.....
speaking, phone number....., message.....
action required..... by..... (date),
phone message being confirmed.....

- (4) An adjustable extending telephone set from a wall bracket is sometimes a further saver of time and space.

The cost of installation and operation of the above is saved in the first few months of its working.

Teleautograph.—Particularly applicable to the technical side of a highways department is the electrically operated machine known as the Teleautograph. By its means, one is able to transmit a diagram or drawing over the phone.

Wireless.—During recent years, wireless telephones have been introduced and improved. Their latest application should be considered when making new installations or extensions.

MACHINERY.

Typewriters.—About 40 years ago typewriters came into use, filing was commenced, and one commenced working in an orderly manner. To conduct the work of a large highway department to-day with a quill pen for correspondence can be better imagined than described, yet there was apathy and even antagonism towards the introduction of typewriters.

Machinery.—The same resistance is shewn to-day to the introduction of other office machines. As office efficiency is influenced very largely by machinery, it is important to analyse the problem. The view is often expressed that machinery creates unemployment. This is ridiculous, as is proved by taking it to its logical conclusions. Without machinery we should all resort to manual labour. Food, clothing, housing, etc., would be such an excessive price that we should be unable to pay our way. Our homes would be cruder than those of our forefathers. Our standard of living would be lower than that of the Chinese. On the contrary, we find to-day that by efficiency aided by machinery, we are able to produce goods at so low a price that multitudes can afford their purchase. For example to take one trade: a few years ago a four-seater saloon car cost £500. To-day, due to efficiency, including machinery, a good four-seater saloon car can be bought for less than £200. The result has been that many more people have purchased cars. This has provided more employment, not only directly in the motor car works but in all the allied trades, from getting, mining, and smelting of the raw materials, the scientific production of high grade material, the making of machinery, the manufacture and sales of all accessories, increased transport and employment for transport workers, fuel supply from production to distribution, the maintenance and repair of vehicles in action; employment has ensued even in building and highway sections. Had Austin, Morris and others not considered efficiency and elimination of waste, including the best extended use of machinery, the price of cars would still be so excessive and the vehicles so crude that there would be few in commission. Our exports, too, would not be so high.

Machinery, therefore, lowers the cost of goods, secures higher wages, shorter hours, more leisure and a higher standard of living.

There is no limit to human wants. Buyers are not confined to Europe. If Japan can sell to Britain, why cannot we sell to the far East?

The harnessing of steam by James Watt in 1769 led to a more scientific use of machinery and a more efficient form of power. For the moment it appeared to displace labour. In effect, however, it led to a boom in Britain's trade—an impetus to employment.

History repeats. We are prosperous when we are the leaders in industry. The most efficient nation is the most prosperous and has the highest standard of living.

The author has dealt with this point at length as it is vital. The principle must be grasped because the psychic impression determines the inauguration of office efficiency methods.

With this complex, one may now consider the desirability and effect of office machines.

MACHINES.

Road machines.—Machinery appeals to engineers. The breaking of stones by hand is past history. The conveyance of road materials by team labour is also an obsolete method. Each year sees more efficient lorries fitted with special devices for tipping, etc., so as to reduce costs to a minimum. Developments in science bring the Diesel engine into play. In the manufacture of the many preparations for modern roads, we find it is economy to use specially designed, costly machinery. Hand labour for surface spraying and gritting, mixing of concrete and breaking up roads is being supplanted by efficient machinery giving quicker and more scientifically controlled operations. In fact, at each Public Works Congress, one becomes impressed by the extended use of machinery. The Institution of Municipal and County Engineers has recently added to the Testamur examination the subject of machines.

Office machines.—In office organisation, however, there is scope for making fuller use of machinery with a higher percentage of efficiency, giving reduced costs and greater accuracy. Here again Government Departments have led the way. At the Post Office Savings Bank, by a capital expenditure of £104,000 on specialized machinery, there was a saving in the first year of £140,000.

Typewriter.—Exactly a hundred years ago, the goose quill gave way to the steel pen. This has now been superseded by the fountain pen, but no office to-day would attempt correspondence with that expedient. Probably the first machine to be introduced into an office was the typewriter: it is now indispensable. Although invented in 1874, it did not come into general use until 16 years later. (See also "Typing" under "Correspondence.")

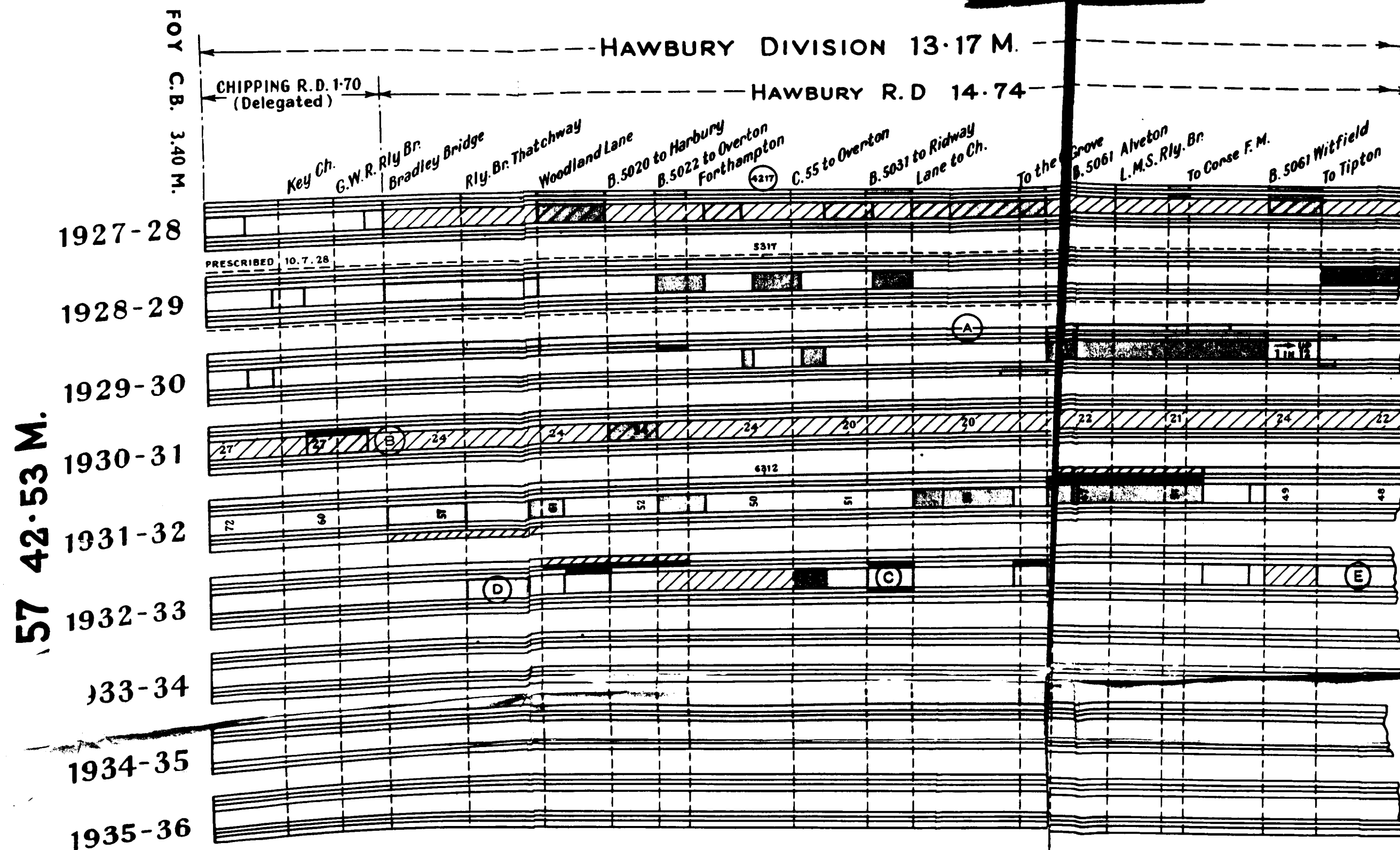
Dictating machine.—In discussing "Correspondence," a detailed description is given of this most valuable time-saving machine.

Calculating machines.—Calculating machinery is not new. The first machine, on the bead-frame principle was used in the Far East. Adding machines have been in use for 300 years. Improvements have been made from time to time and in 1875 the John Scott medal for Meritorious Inventions was awarded to F. S. Baldwin for his calculating machine.

522 A

57 42.53 M.	FOY C.B. 3.40 M.	CHIPPING R.D. 1-70 (Delegated)			
		Key Ch. G.W.R. Rly Br. Bradley Bridge Rly. Br. T.			
		1927-28			
			PRESCRIBED	10.7.28	
		1928-29			
		1929-30			
		1930-31	27	27	24
		1931-32	22	3	5
		1932-33			(D)
		1933-34			

HIGHWAYS DEPARTMENT.



REFERENCE.

LINEAR SCALE 1 INCH TO 1 MILE.

BOUNDARY OF A DIVISION.

BOUNDARY OF A RURAL DISTRICT.

KERB. CARRIAGEWAY. KERB. BUILDING LINES PRESCRIBED. FOOTPATH. HAUNCH. FOOTPATH.

CARRIAGEWAY. 20 FEET WIDE. HIGHWAY 60 FEET WIDE.

5317 20 8

TRAFFIC CENSUS 5317 TONS PER DIEM.

CARRIAGEWAY

WATERBOUND MACADAM.
TARRED MACADAM.
ASPHALT MACADAM.
ASPHALT.
CONCRETE.
SURFACE SPRAYING.

HAUNCH

STONE.
CONCRETE.

KERB

STONE.
CONCRETE.

FOOTPATH

VERGE.
TRACK.
METALLED.
TARRED MACADAM.
CONCRETE.
SURFACE SPRAYING.

CENSUS POINT.

M.T. PERMIT N°

- (A) FATAL ACCIDENT FILE NO. 973/2
- (B) BR. RECONST., F.C., 30' SPAN, 40' BETWEEN PARA. 986/3.
- (C) 7" R.C. F'NDATION 2" ASPHALT SURFACE, FILE 1126/7
- (D) HOT-BIT.
- (E) COLDPHALT.

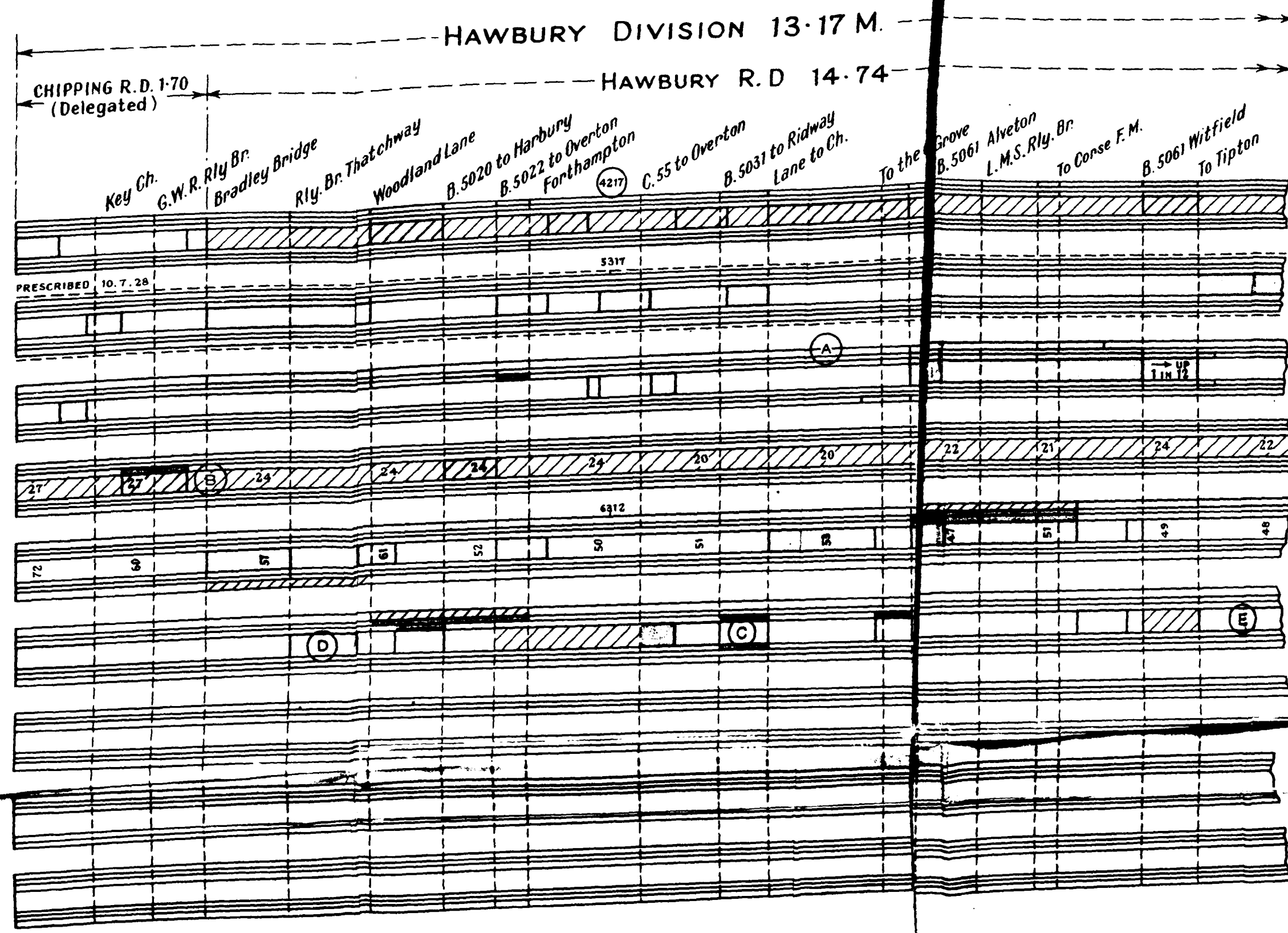
57 42.53 M.

522 A

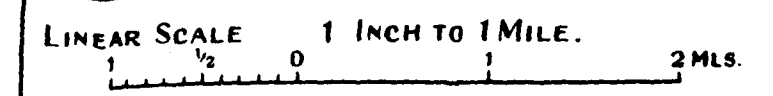
HIGHWAYS DEPARTMENT.

57 42.53 M.

FOY C.B. 3.40 M.



REFERENCE.



BOUNDARY OF A DIVISION. -----

BOUNDARY OF A RURAL DISTRICT. -----



CARRIAGEWAY. 20 FEET WIDE	5317	TRAFFIC CENSUS
HIGHWAY 60 FEET WIDE.	20 8	5317 TONS PER DIEM.

CARRIAGEWAY		WATERBOUND MACADAM.
"		TARRED MACADAM.
"		ASPHALT MACADAM.
"		ASPHALT.
"		CONCRETE.
"		SURFACE SPRAYING.
HAUNCH		STONE.
"		CONCRETE.
KERB		STONE.
"		CONCRETE.
FOOTPATH		VERGE.
"		TRACK.
"		METALLED.
"		TARRED MACADAM.
"		CONCRETE.
"		SURFACE SPRAYING.

CENSUS POINT.	M.T. PERMIT N°
(A) FATAL ACCIDENT	FILE NO. 973/2
(B) BR. RECONST., F.C., 30' SPAN, 40' BETWEEN PARA. 986/3.	
(C) 7" R.C. F'NDATION 2" ASPHALT SURFACE, FILE 1126/7	
(D) HOT-BIT.	
(E) COLDPAHLT.	

Book-keeping machines.—The old method of book-keeping by pen and ledger is a laborious way, fraught with delays and inconveniences. The difficulty, too, of balancing and the time taken in finding an error is fully appreciated by those engaged on the detail work.

Standardisation of forms, etc., will minimise the number of machines. Work may be done by juniors in one quarter of the time required by the pen and ledger methods.

A keyboard machine enables a statement to be typed on a sheet inserted round the platen. The figures are automatically recorded in their correct columns and simultaneously added or subtracted by depressing the appropriate keys. Carbon copies can be made at the same time.

The advantages of machinery for accounting are :—

- Saving in time and money ;
- Arithmetical calculations are errorless ;
- Posting is quicker ;
- Mechanical arithmetic proves a daily balance ;
- Perfect legibility ;
- Complicated accountancy is more easily handled.

The saving of time will be appreciated when it is remembered that the machine will by the one operation post, make the statement, add the figures, debit and credit the amounts, and prove the work correct.

There is a great saving of checking, and freedom from error in copying and recopying.

The use of these machines is so essential to efficiency that the leading Banks and branch offices have adopted them during recent years.

A big advantage to a highways department is that the costs are daily kept up to date and can be ascertained immediately.

The machines selected will depend on the size of office and to what extent it is advisable to have *printed* records or whether *totals only* would be satisfactory. Consideration should be given as to what extent descriptive matter is necessary, requiring the typewriter model. The keyboard type is best for addition and subtraction, but the crank type is preferable for calculations.

The types of accounting machines may be classified as follows :—

Adding and calculating (non-listing).—It has been ascertained that 80 per cent. of accounting work is addition work. Adding machines are therefore invaluable. The non-listing types store, without recording, the figures used, and the answer to the addition is produced whenever the lever is depressed ; or in the crank method, of which there are some 20 varieties, the result is read off from indicators.

These machines are quicker than the adding-listing types.

REFERENCE.

AR SCALE 1 INCH TO 1 MILE. 2 MLS.

BOUNDARY OF A DIVISION.

BOUNDARY OF A RURAL DISTRICT.

BUILDING LINES PRESCRIBED
FOOTPATH
HAUNCH
FOOTPATH

AGEWAY.
ET WIDE
WAY 60
WIDE.

5317
20 8

TRAFFIC CENSUS
5317 TONS
PER DIEM

RIAGEWAY

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NCH

B

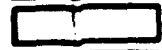
PATH



WATERBOUND MACADAM.



TARRED MACADAM.



ASPHALT MACADAM.



ASPHALT.



CONCRETE.



SURFACE SPRAYING.



STONE.



CONCRETE.



STONE.



CONCRETE.



GE.

Adding-listing machines.—These machines, as their name implies, prepare a list and record each item in column form in addition to making additions. They give a printed record of the operator's work. By a split keyboard, quantities and amounts may be listed and added simultaneously. The machine can work two distinct sections independently. This type gives flexibility at minimum cost but is somewhat slower than non-listing types unless motor driven.

Typing and adding-listing machines.—With these machines, one may use as a typewriter or as an adding-listing machine. There are two types :—

- (1) Typewriter principle.
- (2) Flat bed models which will ride along and enter direct into a bound book.

For a highways department, the typing and adding-listing type on the typewriter principle, using loose leaf ledgers, is the best. All the work of the accounts section may be done with this machine.

Census Returns.—In 1870, Professor Hollerith invented sorting and tabulating machines primarily for the population census by the American Government. They were taken up by the British Government in 1911. Leading insurance companies, railways, etc., have also found them a boon, as they are to any large firm wishing to economise.

Punching, Sorting and Tabulating Machines.—In a large department these machines save more time than any other machine or device. They may be operated by juniors or girls.

The system comprises recording information by series of punched holes in cards. In lieu of writing up descriptive data in ledgers and bound books, punched holes on thin manilla cards, $7\frac{3}{8}$ in. $\times$ $3\frac{1}{2}$ in., record the information of a complete entry. The cards are divided into 45 columns though they are not always all in commission. The machine will punch up to 800 cards per hour.

There are three processes :—

- (1) Punching ;
- (2) Sorting ;
- (3) Tabulating.

The work is made possible by a system of numerical coding. Each material, granite, slag, limestone, kerb, etc., has a code number with an issuing unit of tons, lineal yards, etc., and sub-numbers to the code number for the different varieties of each material, e.g., kerb (concrete, granite, stone, etc.). Every employee has a number, as also each highway division. Great care is required in the coding which must embrace *all* operations, materials, etc., and be capable of extension from time to time. The sorting machine segregates the cards and the tabulating machine reproduces mechanically the information for any desired allocation. To find the cost of any particular job, segregation by machine takes place of all cards on which any item of cost occurs for that particular job. Resetting these cards in the machine, further segregation will give the various sub-divisions of the works.

The tabulation will give the total of each works operation and the cost of the whole job.

The sorting machines will sort 21,000 cards per hour. (Compare this with hand sorting of time sheets, etc.)

The punching and sorting machines are subsidiary or preparatory to the tabulating machine.

For highway work the basis is the actual time sheet from which the data is abstracted and punched.

The application of these machines to a highways department means that instead of each division and delegated area having clerks for time sheets, allocations and costs, the time sheets, initialled by the foreman and Divisional or District Surveyor, are sent to the head office. Here, with one fifth the clerical staff, the data is recorded sorted and tabulated direct into the allocations and analyses required for the Ministry, Committee, Finance Department, Budget, etc. This centralisation is a big economy. There is greater accuracy and speed. Costs are available immediately without the laborious hand labour of sorting all time sheets, allocating and costing : delay is avoided.

Duplicating Machines.—These machines need no introduction. All offices find them indispensable for circulars, minutes, committee agenda, etc. The only problem here is : Are we using the most efficient type of machine ?

One of the first duplicators was patented by James Watt in 1780.

Early duplicators consisted of a rather unpleasant-smelling gelatine substance of a clayey colour, run into a flat bed or tray.

Later, in 1881, a special pen was used on wax stencil paper. Owing to lack of speed and the limited number of copies, this type has been superseded.

Eighteen years later stencils fixed on a rotary drum became very popular. A modern machine with a self feeding device, has an arrangement for automatic interleaving with blotting paper, utilising hard and not absorbent papers. A counting device may be added and the machine electrically driven.

The typesetting duplicator enables one to perfectly reproduce typewritten matter even to the signature, which may be in a different colour of ink. The machine, usually electrically driven, works at a very high speed.

Addressing Machine.—In most offices, many envelopes are addressed every day, for window envelopes have their disadvantages. In highway departments many of the correspondents have frequent communications addressed to them, e.g., outdoor staff, delegated Surveyors, Officials to all neighbouring authorities, Councillors, Builders, Contractors, Secretaries and Officials of Engineering Societies, Institutions and Transport Associations, etc. Often printed envelopes are used for the *most* frequent correspondents, but for the others the laborious hand written envelope is used.

The addressing machine, invented within the last quarter of a century and perfected within recent years, has a useful field, particularly in Highway Offices. The fact that printing establishments use these machines is proof of their usefulness.

The machines, operated by hand, treadle, or electricity, use either type-plates or stencils. Stencils are specially prepared, indestructible, extremely thin, Japanese fibre papers. Each address is typewritten on a stencil which is filed in a drawer or nest of drawers, in alphabetical order.

When a supply of addresses is required the stencils are placed in the magazine of the machine. Automatic feeding brings each stencil in turn into contact with a fresh envelope. Once the stencils are checked, no error can be made. The letter for Mr. Jones of Bond Street is not addressed to Glasgow, nor is Mr. McTavish's cheque sent to London. As the envelopes are addressed the stencils are automatically stacked in their sequence. Any special stencil can readily be found.

Should any address not be required, a key is depressed. Without delay, the stencil is passed along without coming into contact with the envelope which is held in place for the next stencil. If, however, a supply of envelopes of one particular address is required, then the stencil is held while the required number of envelopes is printed.

Up to 7,000 envelopes can be addressed in an hour, whereas by hand the corresponding number would be 60.

The work is not limited to envelopes. Wage sheets, labels, tags, addressing agenda and minutes, heading accounts, circulars, office notices, etc., can also be printed, bearing the various data, name, address, wage deductions for insurances, etc.

Office Printing Machines.—For very large organisations, particularly where printing is required at short notice, the office printing machine has its uses. By its use, an efficient operator can print most of the stationery required for the Council's Departments. The machines may be run from an ordinary electric lighting service at little more than the cost of an electric lamp.

Franking Machines.—Since the Universal Postal Union Convention of 1922, the use of franking machines has been permitted provided the postage value is printed in bright red. Leading insurance companies and others have adopted this efficient method and a saving results to all large departments: the machine will frank up to 30,000 letters per hour.

There are five types of machines; some models automatically feed and seal the mail.

The advantages are economy, perfect check on the postage account, and saving of time. Their general use would save enormous sums per annum to our State Post Office Department.

Stamp Affixing Machines.—These can be used for smaller offices.

Dictagraph, Pneumatic Tubes and Teleautograph.—These machines are mentioned elsewhere.

Other Machines whose use is general or dependent on special circumstances are :—

Numbering Machine.

Stapling Machine.

Letter Opener.

Signograph.

Folding Machine.

Envelope Sealer.

Paper Fastener.

Pencil Sharpener.

Perforating Machine.

Photographic Machine.

Photostat.

(The last two machines are described under "Drawing Office").

Extended use of Machines.—With the demand for more detailed information, records and investigations, the growth of office work seems inevitable. London's spectacular growth seems due in no small measure to centralisation and concentration on office organisations.

The extended use of office machinery is therefore imminent.

Care of Machinery.—Machinery requires regular inspection, cleaning, oiling, minor repairs and adjustments. Usually on a staff there is an employee to whom machinery has a fascination and who has an aptitude for its maintenance. Economy results in allotting to him the duty of being responsible for the care and maintenance of office appliances. Even where machinery is maintained under contract, he can save delays and inconveniences and, by regular attention, avoid breakdowns and prolong the useful lives of the machines.

STATISTICS, RECORDS, CHARTS.

To-day a large Highways Department spends over half a million pounds per annum. It is essential, then, that we have wise spending. Technical analyses enable one to see at a glance the effect of different works, or the potential value of different experiments. Statistics are indispensable.

Clerical and Technical.—It has always been a matter of surprise that, whereas an army of clerks is employed to keep books and clerical records, there is often not sufficient technical staff to keep statistics so that one may see whether value is being obtained for the money expended, and whether the most economical types of work are being carried out.

America.—Several years ago, eighty firms in America started statistical departments. Only two have suspended their actions. This is practical proof of their usefulness.

Diagram of Road Works.—The author has designed a chart which shows at a glance a wealth of information. The complete set for all the classified roads forms an invaluable record: the most useful chart in the office. It will be seen from the reference that the diagram represents, in plan, a highway. The carriage-

way, the widest portion, is central, bounded on each side first by haunching, then by kerbing. The footpath is placed on the outer sides and beyond this, shewn dotted, is the Building Line (if any) giving the date of prescription.

The following details are recorded :—

- (1) The mileage of each classified road in the administrative county.
- (2) The mileage of each classified road in each highway division.
- (3) The mileage of each classified road in each rural district.
- (4) The mileage of each classified road delegated.
- (5) The mileage of the classified road traversed in the county boroughs.
- (6) The exact boundary points.
- (7) The location of different points along the routes.
- (8) The intersections of classified roads.
- (9) Location of all bridges.
- (10) The location and permanent number of the Ministry of Transport census points.
- (11) The intensity of traffic in tons per diem at each census.
- (12) The width of the highway at intervals along the route.
- (13) The width of the carriageway at intervals along the route.
- (14) Exceptional gradients.
- (15) The length over which improvement and building lines have been prescribed.
- (16) The exact type of surfacing carried out each year on every section of road.
- (17) Lengths of road surface-sprayed.
- (18) Type of haunching and lengths located.
- (19) The nature of kerbing and lengths located.
- (20) Footpath work.
- (21) Special schemes.

Many uses of the chart will be apparent, but a big advantage is that one can readily ascertain the comparative values of the different methods and materials for re-surfacing.

When preparing the annual estimate the chart is invaluable. It aids practical vision from the office. One can see when each stretch of road was last treated. Often, one's estimate is limited to a definite figure and one has to select which section of road to include and which to omit or postpone for another year. The diagram often enables one to decide which lengths have prior claim from the point of view of condition, recent repair, traffic intensity, etc.

Taking a case from actual practice, the highest head of expenditure for twelve months in a certain highway department was 60.4 per cent., which was in respect of re-surfacing. The most profitable statistics, therefore, deal with re-surfacing. The factors to be considered are :—

- (1) The initial cost.
- (2) The years of life.
- (3) The traffic on the road per unit width of carriageway,

e.g. one sees from the chart that " X " type of re-surfacing has had a life of " Y " years on a carriageway " Z " feet wide with a total traffic of " K " tons per diem.

The cost per mile of re-surfacing per annum, per unit width of carriageway per ton of traffic, is therefore—

$$X = \frac{C}{Y K L} \quad \text{where } C \text{ equals the total cost of the work over } L \text{ miles measured from the chart.}$$

If a type of re-surfacing is used involving very high initial cost with a view to longevity, the interest on the outlay of used capital advanced must be taken into account when comparing with a method having a much lower initial cost.

The diagram is a valuable aid to office efficiency. The most economical type of work is discernible.

Surface Spraying.—In the same annual expenditure, surface spraying represented 22.1 per cent. of the cost. As re-surfacing and surface spraying may be carried out on the same section of carriageway during the same year, cross hatching has been used on the diagram to illustrate ordinary tar spraying. This enables one to see underneath, the type of re-surfacing used.

Surface spraying, originally intended for laying dust, has now become a surface treatment for the preservation of the underlying crust ; in fact, with modern bitumen emulsions and $\frac{1}{8}$ in. cubical chippings, the treatment is tantamount to re-surfacing. The treatment is, therefore shewn under its respective colour of red for tarred macadam, blue for asphalt macadam, etc., and each type has a letter to which the reference gives explanation.

Haunching and Kerbing.—Haunching and kerbing absorbed 5.9 per cent. of expenditure and are shown in different colours representing stone, concrete, or granite.

Special Works.—If it is desired that any special works should be recorded, their location can be indicated on the diagram which is drawn to a linear scale and their description given in the reference, e.g., a bridge widening or reconstruction.

Bridge Register.—The diagram may embrace the bridge register by giving the type, span, width between parapets, head room, approach gradients and other useful data.

Warning Signs.—Useful in an office is a map shewing the positions of all warning signs. These can be numbered and a schedule will shew in tabular form :—

- (1) The type of sign—wood, concrete, iron, etc.
- (2) The height of the sign from the ground.
- (3) The wording on the sign.
- (4) The colour.
- (5) Whether illuminated, reflex, etc., and if so the nature of the reflection, e.g. studs, lenses, etc.
- (6) The size of the lettering.

Direction Signs.—On a further map, or amalgamated on the previous map, the direction signs should be located with similar tabulated references.

Accidents.—It is alarming to think that on the roads of England, we are (in peace time) killing off civilians at the same rate as soldiers in the Boer War! The yearly toll is nearly 7,000 lives. Accident reports, prepared by Surveyors, shew that 85 per cent. of the accidents are due to human failure or errors of judgment. But closer investigation shews that most of the accidents, other than those involving pedestrians, occur on bends, corners, cross roads and roads which, under certain atmospheric conditions are inclined to be slippery.

Under the Road Traffic Act, 1930, all accidents are now reported. By co-operation with the Police Authorities, it should be possible to have a complete record, which, plotted on a map of the county, will soon shew, under a period of years, the places where accidents are of frequent occurrence. (The information could, in fact, be plotted on the diagram of Road Works).

Loss of life is so serious that the author is of the opinion that the time has come when an allocation should be made in the annual estimate specifically for dealing with improvements to minimise accidents. All Surveyors will be able to call to mind cases where corners, etc., have been widened and more accidents have occurred after widening than before. "Widening" is not always an "improvement" from the point of view of mitigating the risk of accident. These improvement works require most careful and detailed consideration. Efficiency would accrue by this phase of work being controlled by one man who studies and specialises in this sphere.

Automatic Signals.—With the thousands of warning signs in existence in the country, a disregard of their purpose has been inevitable. The author is of the opinion that in the near future the cross road danger will be eliminated by automatic traffic signals. The vehicular actuated signals are the most efficient type known and, with the extension of electric supply under the grid system, a comprehensive programme of signals appears imminent, but the signals of the future will probably be those operated by a travelling vehicle cutting a beam of light. This will be a most efficient type. All road works and maintenance on road pads will be eliminated.

Traffic Diagrams.—In deciding how to allocate the annual estimate, regard must be paid to the relative traffic intensities. A useful chart is one where the classified roads are shewn diagrammatically on a map to a scale of say 2 miles to an inch for any particular county area. From the census returns which are taken tri-annually, the weight of traffic in tons per diem can be plotted to a scale of 10,000 tons per inch, the thickness of the line representing the intensity of traffic. The relative importance of the various routes are visualised instantly.

If a certain number of census points, say 10, are selected and the aggregate weight plotted in graph form for each year, the rate of increase or decrease in traffic is readily seen. This gives valuable justification for a variation in the amount of the annual estimate.

Procedure Tables.—To-day, before works can be commenced, the routine of a complicated procedure has to be followed. Procedure has become so involved

that it is essential to have a chart or table so that one may avoid irregularities such as, for example, giving instructions for commencing work before the land has been acquired, or before the statutory undertakers have attended to their mains and services.

Improvement Schemes.—The following comprehensive schedule enables one to locate every step. Each scheme can be written down the first column of a table and the various stages enumerated along the top. By plotting, the stage of every scheme is instantly apparent.

The various stages for improvement schemes are :—

- (1) Preliminary report.
- (2) Survey and levels.
- (3) Plans with improvement and building lines.
- (4) Plans in triplicate to District Valuer for report on land to be acquired.
- (5) Submit proposals to interested parties : Town Planning Authority, railway and canal company, bus companies, statutory undertakers.
- (6) Detailed estimate.
- (7) Approval of Highways Committee.
- (8) Application to Ministry of Transport for grant.
- (9) Application to M.H. for loan.
- (10) Detailed drawings and stress calculations to Ministry of Transport for bridge schemes.
- (11) Obtain Ministry's approval.
- (12) Acquire land.
- (13) Preparation of Specification and Bill of Quantities in full detail.
- (14) Advertise for tenders.
- (15) Supply quantities to contractors.
- (16) Receive and summarise tenders.
- (17) Acceptance of tender by Committee subject to Ministry's approval.
- (18) Submit list of tenders and details to Ministry.
- (19) Issue of grant.
- (20) Accept tender.
- (21) Drawings, specification, etc., sent to Clerk of Council for preparation of contract.
- (22) Advertise, interview and appoint clerk of works.
- (23) Supply contractor and clerk of works with drawings, specification, etc.
- (24) After signing contract, approve materials.
- (25) Advertise in the press and affix notice for closing road (Road Traffic Act, 1930, Sec. 47), and legal procedure in connection therewith.
- (26) Order to contractor to commence, giving possession of site.
- (27) Set out works.
- (28) Interim payments to contractor.
- (29) Requisition on Ministry for interim payments of grant.
- (30) On completion, measure up and agree final certificate.
- (31) Submit cost to Ministry.
- (32) Report cost to Committee.

- (33) Add the improvement to office ordnance sheets and other office charts and records.
- (34) Complete drawing of work as carried out.
- (35) Index and file away all drawings.
- (36) On completion of maintenance period, inspect works, and pay retention money.
- (37) Requisition for balance of grant.
- (38) File away all correspondence.

Improvement and Building Lines.—Similar procedure charts or tables are required in connexion with the prescription of Improvement and Building lines. Where a number of routes, or sections of routes are being dealt with simultaneously, and are at different stages, they are essential statistics :—

- (1) Decision to prescribe.
- (2) Surveys and levels.
- (3) Prepare plans and cross sections.
- (4) Report to Highways Committee for approval.
- (5) Inspection by sub-committee (if applicable).
- (6) Notices posted to owners, occupiers, etc.
- (7) Plans submitted to Rural District Councils, Urban District Councils, and Town Planning Authorities.
- (8) Objections received within 6 weeks from owners and occupiers.
- (9) Objections received within 3 months from Authorities.
- (10) Objections considered.
- (11) Amendments (if any) approved by Committee.
- (12) Plans forwarded to Ministry of Transport.
- (13) Approval by Ministry.
- (14) Lines prescribed by County Council.
- (15) Notices sent out to owners, etc., re prescription of Building Line.

Private Street Works.—In private street works procedure must be rigidly followed. In the past, heavy losses have fallen on certain councils due to errors and omissions in procedure. All County Councils work under the Private Street Works Act, 1892 and the procedure recommended when working under that Act is here given :—

- (1) Ascertain general wishes of the owners.
- (2) Survey.
- (3) Measure frontages with steel tape.
- (4) Levels (gradients, depths sewers and mains, threshold levels).
- (5) Ascertain names and addresses of owners.
- (6) Inquire from sanitary authority, the condition of sewer.
- (7) Circularise all statutory undertakers re conditions, size and depth of mains and services. Any need for repairs or renewals.
- (8) Ask owners of vacant plots to make connections to sewer, services and mains.
- (9) Observations of Town Planning Authorities re widths, Improvement and Building lines.
- (10) Comply with building bye-laws for new streets.
- (11) Plans and sections.

- (12) Specification.
- (13) Estimate.
- (14) Provisional apportionment.
- (15) Resolution of Highways Committee.
- (16) Index of owners.
- (17) Supply Clerk of Council with plans, owners' names and addresses for serving notices.
- (18) Post notices in street and insert in press.
- (19) Consider objections.
- (20) If no amendments, commence work after one month from serving notice.
- (21) Supply plans, etc., to Clerk of Works, or foreman.
- (22) Keep separate cost ledger.
- (23) On completion, cost up.
- (24) Final apportionment.
- (25) Verify names and addresses of owners.
- (26) Supply Clerk of Council with final apportionment and amended list of owners for recovery of cost.
- (27) Report completion to Highways Committee for resolution for the private street to become a highway repairable by the inhabitants at large.
- (28) File away all correspondence.

The chart would be as follows :—

PRIVATE STREET WORKS PROCEDURE CHART.

Year	Road	1	2	3	4	etc.	26	27	28
1932	George St.	3/1	5/1	5/1	5/1	—	16/9	18/9	20/9
1932	Alfred St...	19/1	20/1	20/1	20/1	—	16/9	18/9	20/9
1932	Nash Road	7/8	8/8	10/8	16/8	—	—	—	—
etc.									

Photographs.—Photographic records taken before commencing operations, during construction and on completion, are often valuable. A photograph enclosed with a report will often enable one better to visualise the practical conditions. On occasions a photograph would remove ambiguity, save further correspondence and a visit. A better use could be made of this expedient. It can be an aid to efficiency.

General Procedure.—Most routine, which, by virtue of an increasing number of interested bodies has become more involved, can be efficiently treated on the lines illustrated above.

COSTS.

Costing Systems.—Costing systems are in operation in every office. They enable one to see the position to date and give a useful check on schemes in progress and graphs can be plotted showing the expenditure under the various allocations to ensure the correct apportionment at the various stages of the financial year.

Comparative costs.—But the most valuable part of costs is in the form of *comparative costs*. In methods of construction there are many alternatives. Conditions are changing rapidly and what may have been the most economical method a few years ago may now be obsolete.

Advancement.—Two hundred years ago we were using the same method of lighting as the ancient Egyptians—oil lamps. But during the last 30 years, many more scientific improvements have been propounded than ever before in so short a space of time during the history of the world.

Frequent analyses.—It is imperative then, if we are to maintain efficiency, that we analyse our costs at frequent intervals.

Re-surfacing.—The most important analysis is in connection with re-surfacing. In making comparisons between different materials, or different methods of laying the materials, it is essential that all other conditions are equal. This may seem obvious, but from inspections of special experimental road lengths, the author has found these conditions sometimes disregarded. A recent case had two test lengths varying in width, gradient, radius of curvature and depth of filling. There is always more wear at a change of gradient: superelevation which is constant at any cross section cannot always be correct when used by vehicles at varying speeds. To analyse re-surfacing, the following conditions should be constant:—foundations, drainage, traffic intensities, width of road, gradient, curvature, superelevation (a straight road is preferable) and weather conditions at time of construction.

Other operations in road work should be similarly analysed.

Contract v. Direct Labour.—If works are carried out by direct labour, an occasional invitation to tender will shew whether direct labour is more economical than contract. If the latter, then investigation is necessary to diagnose the trouble and to put into operation remedial measures.

Bridges.—In bridge work, we shew our national trait of conservatism. The reason is that there is little thanks for experiments that prove successful, and trouble if they go awry. It is not surprising then that some departments have old orthodox methods for bridge design and construction. Some offices adhere to the mass abutments and steel troughing, others to a superstructure of steel joists encased in concrete, while some still cling to the tried methods of steel plate girders. Different sites, span, etc., demand different treatment but often useful facts will be revealed if, occasionally, an alternative design is prepared and costed for the same site.

A bridge is a public monument and as such one is entitled to make as aesthetically pleasing a structure for a bridge as a bank. Beauty is often a matter of proportion, not necessarily increased cost. At the same time, one often has a choice of materials. Comparisons of costs of parapets (for example, in brick, stone, in situ concrete, pre-cast concrete, balusters, iron railings, posts and tube, etc.) are useful. From alternative tenders received, the author once found that an in situ concrete parapet cost less than concrete posts and tube.

Culverts.—Culvert design, too, has many alternatives. A county borough recently undertook a scheme of brick and steel joist construction (a typical railway

method of 80 years ago) for culverting a brook through the town at a cost of several thousand pounds in excess of that required by a modern design. Tenders received have shewn that concrete tubes used for culverts cost up to 35 per cent. more than modern designs. Office costs shew that an economical culvert is obtainable by using pre-cast concrete slabs for invert, walls and roof (the last named being reinforced). Ease and rapidity in construction are commendable features.

Concrete Stresses.—The Ministry give alternative mixes and corresponding stresses for concrete design. Trial designs and costs will prove the most economical mix for any particular structure.

Correspondence.—The analysis of costs for correspondence is treated separately.

Staff.—The foregoing remarks shew that now major schemes are in abeyance, technical staff can, by investigatory work, give a more useful service to the community in its strivings for economy than by increasing the numbers of the unemployed.

The foregoing remarks shew the need for thorough analyses of every phase of work.

STANDARDISATION.

Standardisation is not a new subject. It has been developed to a high pitch of perfection in works (engineering, chemical, etc.). One sees clearly the advantages of standardisation when watching, for example, the ease and speed with which the many operations are performed as a piece of rubber passes along a conveyor belt and emerges at the other end a complete car tyre! After a visit to old works, managed on ill-conditioned lines, one realises that if every workshop and office in this country had standardisation to the utmost limit possible, there would be an unprecedented boom of prosperity by securing the markets now held by our foreign competitors.

The subject, therefore, is of paramount importance.

Government Departments.—Standardisation has not yet been so fully developed in offices as in works. Probably Local Authorities have not appreciated its economy. Government departments have, however, led the way and give fine examples of office efficiency in respect of standardisation. During the past ten years, the Post Office Savings Bank has made savings of many thousand pounds per annum by this means.

Natural Laws.—It is interesting to compare with nature. The bee has a standard way of making honey, while the hive is perfectly standardised by the worker's production, the comb, etc.; light reduces in intensity with the square of the distance. In music consecutive fifths have a standard effect! To take sport—the best results ensue when one observes at golf, the standard stance, grip, swing, etc. There is the standard of bogey or par.

American Government.—Output is increased if every duty is standardised in its closest detail; its stance or sitting position, lighting, heating, environment, suitability of desk or furniture, accessibility of requisites of frequent reference, etc. By standardisation, the American Government saved £400,000 in one year from the mere capital expenditure of £52,000 to efficiency experts.

Forms.—Reference is made under “Correspondence” to standardised letters, and under “Telephones” to receipt forms. Work in an office is never constant but always changing. A periodic overhaul of forms will reveal whether or no they satisfy requirements, or whether they call for superfluous information. Are there too many forms, or too few? By combining information and amalgamating, it is often possible to reduce the number of forms. Upon investigation, a railway company discovered that it had 3,679 forms. By scrapping 370 which were useless, and consolidating 750 with others, the company saved £11,000 per annum. Forms are usually used for Accounts, Bills, Costs, Estimates, Invoices, Insurances, Ministry Returns, Orders, Requisitions, Salaries, Stores, Taxes on Property, Travelling and other expenses, Tenders and Wages.

Colour.—Forms of different colours for different purposes are readily distinguishable. Some offices have a different colour for each Highway Division.

Road Widths.—The Ministry have laid down standard widths for roads. This is an example of good economy. Recently a trunk road scheme had a carriageway 20 ft. wide. This was the agreed width suitable for the traffic. There was a constant stream of traffic but not sufficient to justify the next standard width which makes provision for three lines, viz., 30 ft. The widening, therefore, which was being carried out at each end of the trunk road scheme—24 ft.—was a sheer waste by providing 4 ft. of redundant carriageway. Memorandum No. 336 (Roads) dated 6th August, 1930, gives standardisation in road making.

Building Lines.—The prescription of improvement and building lines provides a further example of economy from standardisation. Definite widths are agreed and provision made for compliance therewith. As development takes place it will be on pre-determined standardised widths, eliminating costly compensation by subsequent acquisition of property to effect a necessary widening. If improvement schemes are being held in abeyance, an extension of prescription would be economically using technical staff.

Town Planning.—Town Planning Schemes, too, give further scope for standardisation in respect of highway widths, building densities, allocations in zoning, etc.

B.S.I.—The British Standards Institution are doing a good work in eliminating waste by their standardisation applied to specifications.

Technical Calculations.—Standard loading for highway bridges and the recent standard stresses for concrete as laid down by the Ministry of Transport are welcomed by all designers. By simplifying technical calculations, they effect economies. By the impact chart, they avoid the wasteful cost of over designing.

Contracts.—By their standardised conditions of contract, uniformity is obtained without the expenditure of time devoted independently by all Highway Authorities. In a Highways Department, however, economies can be effected by having standardised specifications and standard schedules of work for contract works, e.g. bridges, concrete, culverts, steel, etc.

Road Signs.—The Ministry keep in touch with changing traffic conditions. By having a standardised set of comprehensive road signs, uniformity exists throughout the country. This not only has the advantage that all motorists readily grasp the true meaning of road signs, but by eliminating a multiplicity of signs it enables manufacturers to concentrate on a few standard types. Production costs are therefore reduced.

Potentialities.—Consequently we see that there are many things which can be standardised. Every article and every duty should receive detailed study. It is surprising how further economies can be effected by standardisation to its extreme limit. Most offices are capable of further savings under this heading.

DRAWING OFFICE.

In Highway Departments, the importance of the drawing office has increased during recent years. In the days of ‘Stone-cracker John,’ work was done with cheap labour. To-day greater precision is necessary and in order to confer with all the authorities and associations concerned, drawings have to be prepared to delineate the proposals.

Environment.—It always seems paradoxical that, from some points of view, efficiency in the form of increased output should first be considered in the works, secondly in the general office and lastly in the drawing office. The works have found that correct environment produces maximum results. Efficient private firms have found that this rule applies to the drawing office. The old-fashioned fixed table with high stool from which an assistant has to stand when working anywhere except at the bottom of the drawing board, produces unnecessary fatigue and loss in output. The modern table is detached, portable and adjustable. It is placed near the window, or ray, to obtain left hand north light, the slope of the board is adjustable so that the assistant can work on all parts of his board while he remains seated in a low adjustable chair with hip support. The toothed straight edge slides along the board in perfect alignment. The equipment has containers to hold a draughtsman’s entire accessories within working reach. A complete set of requirements (scales, ink, set squares, colours, brushes, etc.) for each assistant is usually less costly than paying for the walking time involved in borrowing.

Materials.—As a result of recent improvements in materials, the whole process of tracing can be entirely eliminated. Tracing cloth with a specially prepared dull face on each side will take pencil drawings direct, from which prints can be made. Waterproof tracing cloth can be obtained which is unaffected by rain, splashes, etc.; the material can even be immersed in water.

To use a portion of an ordnance sheet which covers a large area, at 6s. 8d. per sheet, is often less costly as a key plan, etc., than specially prepared tracings, especially in built-up areas.

Useful materials are :—

Oxalic acid, to remove lines from ferro gallic prints.

Chloride of lime, to remove certain water colours from drawings and prints.

Petrol, or art gum, to remove pencil lines from tracing cloth.

Erasive paste, to remove ink lines from tracings without disturbing the surface.

Ship or yacht curves, to give transitions which the railway curves omit.

Adjustable set squares.

Stencils are usually economical, but a draughtsman's time is saved if he acquires the art of printing with a brush.

Sectional papers have many uses.

Printing Processes.—Ferro-prussiate paper, invented by Sir John Herschel in 1840, still has an unequalled use where clearness and reproduction of minute details are required without additions by colouring to the prints. Prints made by this process are still the lowest in cost.

The true-to-scale process, invented in 1905, or the ferro-gelatine process, is a good commercial proposition. The "Photo-litho" printing process is probably the finest known method of making prints. Copies can be made on hand-made papers, cartridge, or tracing cloth, and as no water is used copies are true to scale. The process, however, is unnecessarily costly: only for exceptional prints is the extra cost justifiable. Ferro-gallic prints are usually sufficiently accurate for most practical purposes.

The Dyeline process, using a diaze compound as a base, has possibilities. The elimination of washing and drying are in its favour and a positive print can be made as quickly and cheaply as a blue print.

Printing Machinery.—The electric copying machine, invented about 1896, revolutionised drawing office methods. Since that date, however, many improvements have been made, and the vertical machine has been superseded by the continuous feed machine. This is particularly useful in Highway Departments where long prints (e.g., shewing by-pass routes), are required. America has led the way in using a complete machine comprising printing, washing and drying—the acme of efficiency for drawing office printing.

The photostat, a photographic machine for copying plans, title deeds, documents, letter press, opaque originals, etc., without a dark room, is economical when used in conjunction with other large departments.

CORRESPONDENCE.

In a Highways Department, unlike, for example, an Accountant's Department, a considerable amount of correspondence is necessary. Opportunities for effecting economy are revealed when an analysis of the cost is prepared.

Analysis of Cost.—By studying the analysis, later given in detail, one can formulate a system which will save time and reduce costs.

Chief Costs.—The analysis shows that the largest items are the executive officer's time, and that of the shorthand-typist. It is, therefore, essential to concentrate on reducing the cost of these items. If this can be done, the executive officer is more free to investigate matters of policy and carry out inspections, while the shorthand-typist is able to undertake additional duties.

As there is now no need for the shorthand-typist to attend for dictation, the whole cost of the shorthand-typist in taking down shorthand can be saved. The

executive officer dictates to an instrument in 60 hours what would take 100 hours with the shorthand-typist—a saving of 40 per cent. No one to-day in a large office would handwrite correspondence prior to typing: this would take 140 to 150 hours. To economise we must speed up, avoid delays and make the fullest possible use of every efficient labour saving device.

Detail Analysis.—The following is a typical example of the cost of a letter:—

Cost per 100 Letters.

Letters per annum=12,000.

Average number of letters dictated by Chief Executive Officer to shorthand-typist=100 per week.

	£	s.	d.
(1) Salary of Chief Executive Officer=£1,000 p.a. 6,000 letters dictated by this official, $\frac{1}{4}$ of his time on correspondence, say, 100 letters per week	5	0	0
(2) Salary of shorthand-typist, $\frac{3}{4}$ of his time @ £5 per week ..	3	15	0
(3) Rent of office, furniture, lighting and heating, £200 p.a. for whole office. £42 p.a. allocated to correspondence: per week	16	6	
(4) Salary of filing clerk, $\frac{1}{4}$ of his time @ £3 per week	15	0	
(5) Postage—100 letters @ 1½d.	12	6	
(6) Office boy, $\frac{1}{4}$ of his time with letter book, addressing, postage book, etc., @ £1 per week	5	0	
(7) Stationery, envelopes, notepaper	2	8	
Cost per 100 Letters	£11	6	8
Cost per Letter	2	3	

The author ventures to say that unless one has previously ascertained the cost of correspondence, the above deduction reveals amazing facts. On a similar basis it is possible to ascertain the actual cost in any department.

Recently, a large American firm found by analysis that their 182,000 letters per month were costing 1s. 10d. each. The Company was spending £192,000 per annum.

Penny Post.—In passing, the effect of a reduction to the penny post is seen in true perspective. The saving to a department would be a very small percentage of the cost of correspondence, but the loss in revenue to the country would be considerable.

Average Cost.—The figure of 2s. 3d. per letter is not representative of the average cost of letters from the department, but an average of those letters dictated by the chief executive officer.

Alternative Analysis.—It is seen that the chief items of cost are the time of the chief executive officer (£5), and the salary of the shorthand-typist (£3 15 0).

The following analysis has therefore been prepared to shew how a considerable economy can be effected by a saving in these two items :—

Cost per 100 letters dictated by the chief executive officer to a recording machine :

	£	s.	d.
(1) Salary of chief executive officer, 60 per cent. of £5	3	0	0
(2) Salary of typist (shorthand not required) $\frac{1}{2}$ to $\frac{3}{4}$ of previous time @ £3 per week	1	2	6
(3) Proportional reduction, say	9	4	
(4) Filing Clerk	15	0	
(5) Postage	12	6	
(6) Office boy	5	0	
(7) Stationery	2	8	
(8) Cost of dictating machine and maintenance (initial cost £125), per week	2	3	
Cost per 100 letters	£6	9	3
Cost per letter	1	3	$\frac{1}{2}$

A saving of over 40 per cent. The use of the dictating machine is so essential to efficiency and economy that it merits description.

Dictating Machine.—There are two machines on the market similar in the fundamental principles. A phonographic instrument, mounted on a portable steel frame on four wheels, records dictation on a revolving wax cylinder. Driven by electricity at a negligible cost from any ordinary lighting or other plug, the instrument can be started and stopped at any instant by using the switch at the dictator's desk. Records, which are placed in the frame of the dictating machine, can be collected at regular intervals by the typist. Upon insertion in the typist's transcribing machine, the dictator's voice is reproduced while actually typing. The transcribing machine can reproduce the voice at any speed quite irrespective of the rate of dictation.

In working, the dictator may listen to his report and amend, revise or correct, if desired. It is significant that all delay is avoided. There is no waiting for the typist after being summoned, no waiting or delay in the typist reading over the shorthand notes when amendments may be required, etc. The official may dictate at any speed, he is not dependent on the abilities of the individual shorthand-typist, or of the substitute in case of illness, holidays, etc.

The cylinders may be re-used 100 times. After typing, a thin shaving is peeled off by inserting in an instrument provided for that purpose. Their cost, therefore is only equal to that of the displaced notebooks and pencils. One cylinder receives 10 average length letters, approximately 1,000 words in all.

Advantages.—The advantages of a dictating machine may be summarised as follows :—

- (1) 40 per cent. saving in the time of the chief executive officer for dictation.

- (2) Eliminates time taken for shorthand.
- (3) No waiting for typist.
- (4) Being portable, one may dictate at *any* time, e.g., when typist is at lunch, after hours, or at home.
- (5) Dictate at any speed, or pause without distraction : the instrument will record at 200 words per minute if desired. 80 words per minute is the average for shorthand.
- (6) Amendments are made without a waste of typist's time : it is easier to write shorthand than read it.
- (7) The typist can type twice the number of letters.
- (8) Invaluable for reports, committees, etc.
- (9) Time saved in that there is no need to re-read the mail. A spontaneous reply may be immediately dictated.
- (10) An exact message or instructions given on the phone are permanently recorded.
- (11) The instrument is always ready to take down sundry notes, messages, or instructions throughout the day.
- (12) The instrument is foolproof and thoroughly reliable. There are no errors in transcribing phonetics.
- (13) Flexibility increases secretarial capacity without increasing staff.
- (14) Users have universally found that the method improves one's style, is more exact, prevents rambling, results in better planning, and correspondence has a more conversational and personal appeal.

No office to-day is without a typewriter or telephone. Where dictating machines have once been used, no office would ever devote the extra time required by their omission. One railway company made a saving of £7,000 per annum.

The approximate cost of the instrument is as follows :—

Initial cost of the machine :—	£	s.	d.
1. Executive Dictating Machine	48	10	0
1. Secretarial Transcribing Machine	48	10	0
1. Record Shaving Machine	28	0	0
Total	£125	0	0

Maintenance costs are negligible. The cylinders, at 2s. 6d. each, will receive 10,000 words, or 1,000 average length letters=0.03d. per letter. Electric current for a large institution is usually on a low rate, and the quantity required to work the machine is also negligible.

Standardised Letters.—As many similar matters are dealt with by highway authorities in the course of a year, printed forms are used and matters frequently dealt with by letters are on stencilled forms. By a close investigation it is often possible to extend this system of standardised correspondence. New conditions grow so gradually as imperceptibly to become established procedure. Government departments in this respect have shown the way in making the fullest possible use of

standardised letters, which can be dealt with by juniors and again relieve the higher paid executives.

Standardised letters may be used for the following :—

- (1) Formal acknowledgments.
- (2) The various stages of road openings.
- (3) Forwarding letters to outdoor staff and others for observations and report.
- (4) Forwarding returns to the Ministry of Transport.
- (5) Forwarding Minutes, Agendas, etc.
- (6) Forwarding Statements of Accounts.
- (7) Various stages of land acquisition.
- (8) Reporting all accidents.
- (9) Reporting interviews.

Copying Letters.—A man named Mill patented in 1714 an iron copying press. A special ink was used, and by exerting a pressure an impression was made on a blank sheet. Later, the famous engineer, James Watt, patented the screw press. A special ink was again used, composed of gum, vitriol, gall, etc. Frequent filtering was required, and the ink took two months to prepare, but the principle had been grasped that with special ink and a damp surface a copy was obtained when pressure was applied.

It is interesting to note the mention in Dickens' books of the letter press in office scenes.

Letter book.—The press letter book is now obsolete, for the following reasons :—

- (1) It takes longer than modern methods.
- (2) Water and other accessories are required.
- (3) Too much water often disfigures the original *after signature*.
- (4) Too little water causes too faint an impression, often illegible in the letter book.
- (5) It is occasionally necessary to re-type letters.
- (6) The letter press and letter books occupy too much room.
- (7) Urgent letters cannot be despatched immediately they are signed, owing to delay of copying.

Carbon copy.—By making an additional carbon copy, a chronological sequence of letters can be preserved, superseding the letter book in a more economical and efficient form. The letters are indexed in the same way as the old letter book.

The advantages of this method are :—

- (1) No water or sundries are required.
- (2) No smudged copies produced.
- (3) The old-fashioned cumbersome press is eliminated.
- (4) Letters are ready for despatch immediately signed.
- (5) The last minute rush is obviated.

There are disadvantages, however, in that there is no copy of the signature. This is somewhat mitigated by the clerk stamping the carbon copy of each letter to tally with the signed original, and a note made at the same time of those letters which are signed "per pro."

The serious disadvantage, however, of the carbon copy is that if, at the time of signing, alterations or amendments are made on the original, they are often omitted from the copy. This position may be alleviated by attaching the copy to the original until the letters are sealed. When, however, a letter has to be re-typed owing to amendments, there is a grave risk of the wrong carbon copy being filed.

Roller Copier.—The rapid roller copier on the mangle principle is the most efficient known method of copying letters. An operating drum, containing a roll of specially prepared thin, tough paper, is passed between two rollers pressed together by a lever. The letters to be copied, stacked on a tray, are automatically fed through the machine as each letter in turn comes in contact with the copying paper. Some designs have scientific moisteners. After feeding, a lever cuts off at regular intervals the size of the letters and the copies are sorted from the originals. In large offices, electric apparatus is used, while in small offices the machine is operated by hand. Upon extraction, the bundled copies are bound into letter book form, the pages numbered through another machine, and the letters are indexed in the ordinary way.

The advantage of this performance is that no water is required, consequently no smudged copies are made, and the copy is an exact facsimile, including the signature, corrections, amendments, etc.

General Observations on Correspondence.

Correspondence is an important phase in office management: badly worded letters may result in heavy costs, delays, losses, or compensation.

Procedure.—The method adopted in efficient offices may be outlined as follows :

All letters received are sorted by the Secretary. Formal letters, quotations, advices, accounts, etc., are passed to the various members of the staff concerned, while the remainder are attached to their appropriate files, and arranged in groups. A list is prepared of the telephone numbers for all controversial matters, or matters which can be dealt with expeditiously by telephone conversation.

The third group, requiring "yes" or "no," are so marked by the executive officer so that the secretary may prepare the necessary reply.

From the fourth group, letters, after being read, are marked out for further information, data, statistics, etc., from the members of the staff.

Finally, the group of important letters, or letters dealing with policy, are tackled.

Style.—Although a good style is usually maintained, a letter should neither be a literary composition, nor should it be written with formal dignity. Unfortunately, the bigger the department, the more formal, crude and disinterested the correspondence becomes. Imagine receiving a friendly letter from one of the big railway companies!

A letter should always be complete and not ambiguous. So as to minimise further correspondence, one should anticipate the reply and the close of a letter should always be definite so as to result in action.

Filing.—To facilitate filing, different subjects always form separate letters. Should a letter be received embracing more than one subject, carbon copies should be made and a copy attached to each appropriate file.

Checking.—Relying on the typist, one is apt to slip into the habit of forgetting to check the four essentials:—name, initials, address and date. A very disturbing letter was recently received from a gentleman residing at Gartage Court. Unfortunately, the typist, in addressing the letter, had inadvertently substituted the second letter of the alphabet for the fourth letter in the name of the gentleman's residence!

Letters having facts, figures, statistics, etc., prepared by assistants, should be checked after typing and initialled before presenting for signature. When signatures are illegible, they should be typed unless printed in the letter head.

Enclosures.—For easy reference of the postal clerk, letters having enclosures are so marked. When enclosing plans, the drawing number, or some definite reference from the plan should be made in the letter. Similarly, when forwarding detailed estimates, statistics, charts, etc., the amount, date, or other definite reference should always be given. When sending copies of letters, the date, subject matter and reference of the enclosed letter should be stated.

Conclusion.—On reflection, one cannot help recalling the famous letter of Mr. Micawber,

“Thanking you kindly in advance, we are, Dear Sir, and beg to remain, your obedient servants.”

Typing.—When more than twelve words are involved, it is usually quicker to type than to pen.

Continuance in the use of typewriters after their useful life has been expended is not economy because the loss in output more than offsets the price of a new machine.

Best typing results are obtained when an adequate number of good machines with rubber pneumatic keys are provided, standing on a firm, stable and rigid base: portable machines are unsuitable. If a separate room cannot be used for machinery, silent typewriters are desirable. Special typewriters are available for special work, some purely for correspondence, but for a Surveyor's department where tabulations and estimates are required, the brief size is necessary. A clear type which will cut stencils and make extra carbon copies should be selected, while a good grip is essential so that one can type cards for card index work, etc.

Formerly most typewriters were American, but to-day there are many good British makers. With regard to service, the best policy is to have a contract for maintenance, when quantity and quality will be assured, and to trade in the machines after four or five years use.

Carbons.—For durable and uniformly clear copies, the hard quality black is usually the most permanent and satisfactory, with an even tissue, but not necessarily on a heavy dressing. The bright and attractive blue and purple carbons, heavily coated, give a good first copy but quickly deteriorate and are liable to fade.

FILING.

The importance of filing will be appreciated when it is realised that in a Surveyor's department, where 20 years ago there were only 5,000 letters per annum, there are now 12,000. If we consider this rate of progress, it is almost impossible to imagine the magnitude which will obtain in another 20 years time.

American Government.—Recently the American Government investigated different systems of filing in different departments. In the most efficient department (Post Office), filing costs were 26/- per 1,000 letters, while £4 was the extreme figure of another department. The total cost was £52,000 per annum. It will be seen therefore that an efficient filing system is a necessary economy to the country.

Purpose.—The purpose of filing is to enable one readily to refer to any matter that has at any time been recorded.

Essentials.—The essentials of a good system are simplicity, accuracy and low cost. The principle is that there is one place for everything, and everything is in its place.

From experience in different offices, the author has observed various systems.

Complicated Systems.—A fault attending some of the systems still in use is that the working in practice becomes far too complicated. As explained later, this is generally due to classifying instead of indexing, e.g., in some offices, files are grouped into such headings as Road Schemes, Committee Files, Current Matters, Town Planning, Ministry of Transport, etc. These systems, while occasionally working satisfactorily under one man, become quite unworkable in the absence of the filing clerk, who, in addition to his systematic record, relies on his memory to a large extent. With a complicated system, staff members tend to ignore office filing and resort to individual filing. This involves extra work and often many additional copies being made of a variety of matters for personal storage. The test of a system is that it can be easily worked in the absence of the filing clerk.

Developments.—The earliest form of file was the spike or spindle file. Papers were speared chronologically until the spindle was full, when the bundle was deposited in a dead locker. The pigeon hole superseded this arrangement and some two dozen pigeon holes housed the incoming letters in an alphabetical way.

As correspondence grew, letters were filed chronologically in book form with an alphabetical index attached to each book.

From 1882 to 1890 filing systems consisted of drawers or cabinets used for housing files which held punched papers in a horizontal manner. If the drawers are small a large amount of office space is required; if the drawers are large, then a locker holds so many files that they become difficult of access. They are, too, more difficult still to replace. Although this system can still be seen in some offices, the vertical filing system is more efficient.

Types of Filing.—There are, we may say, four distinct types of filing in use to-day and a standard case is taken to show the actual working in practice under each system.

Standard Case :—

“ As the result of a complaint by the Borden Parish Council, in which Councillor Jenkins is taking an active part, a corner improvement is proposed on the Dundee Road, at the junction with Nairn Lane and Major Downham is being approached for acquisition of land : application is being made to the Ministry of Transport for a grant.”

1. *Classification.*—This system has been popular and in some offices is still in use.

Matters are filed, for example, under the names of respective Rural District Councils, Parish Councils, Transport, Road Schemes, Bridge Schemes, Town Planning Matters, Committee Files, etc. The system is possible of unlimited expansion, wherein lies its danger. A disadvantage which will be readily seen is that unless one knows the exact locality, name of parish, etc., it is impossible to find the required file, furthermore, one is always in doubt under which heading to file, *e.g.*, under what heading would one file the standard case ? The system involves an enormous duplication of work, in that all letters dealing with more than one area, Parish, or Rural District, must be copied and filed under each relevant area.

This is not a satisfactory system for a Surveyor's office.

2. *Chronological.*—Only in a very small office is the old system of filing by date satisfactory, for before one can refer to a letter, the date must be known. In effect, the letter book has taken the place of the chronological file.

3. *Alphabetical.*—This system is favoured by many. Files, arranged vertically, commence at the top left hand corner with ‘A’ and proceed through the alphabet as one travels from left to right.

This may appear sound and satisfactory, but the real disadvantage is that the filing clerk must read every letter. Imagine, too, the difficulty in filing the standard case.

Occasionally the files on edge are placed in a drawer in such a way that each series of files is preceded by a lettered guide card.

4. *Numerical.*—For a Highway Department this is the best system in current use. All files, placed vertically, are arranged in numerical order. If the last file was 967, then the next file *on whatever subject* becomes 968. The files should not be arranged in any grouping system whatsoever, for the key to the whole situation is controlled by the card index : the filing clerk must spare no effort in cross indexing. A separate card is used for each letter, and where there is considerable correspondence in one particular sphere, *e.g.*, Improvements, Ministry of Transport, etc., a separate card kept in its alphabetical position can be used for such specific headings. By this system, *any* member of the staff can find any document without hesitation, even if his knowledge of the subject matter is so scanty as to know only one fact in connection with the correspondence. On the different alphabetical cards would be the appropriate entries in respect of the standard case, *i.e.*, entries would appear on cards “B,” “C” (Corner Improvements), “D,” “G” and “M” (Ministry of Transport), *e.g.*,

Separate Card	Description	File
B.	Borden Ph. C. Complaint, Dundee Rd.	968
C. (" Corner Impts.")	Dundee Rd. and Nairn La.	968
D.	Dundee Rd. Impt. Corner Nairn La. Downham, Maj., Land, Dundee Rd.	968 968
J.	Jenkins, Corrpd. Dundee Rd.	968
M. (" M/T ")	Corner Impt. Dundee Rd. Nairn La.	968

Abbreviations should be used wherever possible and a standard card kept in the card index drawer tabulating all abbreviations.

The reference on all outgoing letters will be 968. In many offices, to enable one to refer to the Official responsible for the preparation of the data, the initials of the assistant and typist are often added, *e.g.*, if prepared by Mr. Jones and typed by Mr. Smith, the reference will be 968/J/AS. The double initials signify that a more senior member of the staff, *e.g.*, Stuart, uses the sole initial “S,” consequently Arthur Smith uses his full initials.

On receipt of the morning mail, it is a quick and easy matter for the filing clerk, or indeed any other member of the staff, to readily find the appropriate file for every incoming letter when the reference (by means of the file number) is given by your correspondent.

Sub-Files.—If the correspondence for any scheme becomes voluminous one may desire to have collected together all the correspondence in connection with any specific phase. For this purpose a sub-file *in the same general holder* may be made, *e.g.*, 968/1 Land acquisition.

The most difficult case to file is usually a bridge scheme, for it often introduces every phase of work, *e.g.*, Acquisition of Land, Contract, Direct Labour, Grant, Corner Improvement, Correspondence with the District Valuer, the Ministry of Transport, Application for Loan, Quotations, Clerk of Work, etc. The sub-files are therefore numbered 968/1, 968/2, etc., up to 968/10.

Small Files.—For miscellaneous correspondence, when two or three letters may constitute a file, sub-files can be used and several of these sub-files placed in one holder.

Type of File.—In regard to the type of file used, many excellent kinds are now manufactured. The type selected should have a simple mechanism, permitting quick additions to the file and one which will securely hold the correspondence,

irrespective of the size of the sheets : the margin must not be unreasonably obstructed. In fact the type with a single hole in the top left hand corner is very satisfactory.

Follow up System.—In order that no matter should be left in suspense due to a correspondent failing to reply, a reminder or follow system is necessary. To place appropriate files in an abeyance drawer only further complicates filing by adding to source of storage. A simple card index system is efficient, whereby the date and file number are entered each day on a card which is brought forward in fourteen days time (or whatever period is selected).

Card Index.—Card Index systems can advantageously be applied to a variety of office operations, and the visible card index merits consideration.

Pigeon Holes.—For members of the out-door staff, Councillors and persons to whom letters are often despatched, a battery of pigeon holes is most useful. Sundry matters which accumulate throughout the day can be placed directly into the allocated space by any member of the staff.

Steel Cabinets.—Steel filing cases are available with the advantage that in addition to being fireproof, they occupy the minimum of space, the drawers open promptly on frictionless bearings, and the whole case can be controlled by master or automatic locks.

Accommodation.—For large offices, best use is made of available accommodation when the library system of stalls is installed.

FILING DRAWINGS.

In Highway Departments there has been a steady growth of technical work. Whereas in the olden days works were carried out without plans, to-day more detail is required, works are more carefully estimated, and plans are prepared for most works, including surfacing, super-elevation, etc. It is therefore imperative to have an efficient system of filing and referencing all drawings. The importance of filing drawings will be appreciated when we are aware that schemes are often amended in the drafting stages. It is, too, important that plans be properly filed, for many abandoned schemes are resuscitated after a number of years.

Comparison with Correspondence.—It is interesting to make a comparison between correspondence and drawings. Both are for conveying information, and the table compares the standard data :—

Correspondence	Drawings
Heading (Subject matter).	Title.
Date.	Date.
Office address.	Address of Drawing Office.
Signature.	Signature and name of responsible Engineer.
Initials of Typist.	Initials of Draughtsman.
File No.	Reference :—Drawing No. and File No.

Additional data required on drawings which are not required on correspondence are cardinal points, scale and location, *e.g.*, Key plan if applicable, showing the classified routes and the distances from the nearest towns.

Although the standard information is obviously required it is surprising how often some of the items are omitted from plans received.

Referencing.—It will have been the unhappy experience of many that whereas they are able to read through the file of correspondence clearly, it is often a matter of great difficulty and sometimes an impossibility to marry the various drawings to the correspondence. One so often sees mentioned, "A plan is enclosed showing the proposal." If all drawings are numbered, the ambiguity is removed by stating in the correspondence "Drawing No. is enclosed."

Drawing Register.—All that is required is that a register and an index shall be kept of all drawings prepared. The table gives a suitable form of register :—

Drawing No.	Description	Date	Draughtsman	Remarks	File	Roll No.
329	High St., Balby ..	5.2.27	L.C.F.	—	954	K.4
330	Super-Elevation Dundee Road	6.2.27	C.K.J.	See Drg. 305	968	K.5
331	Downham's Land, Dundee Road	6.2.27	L.C.F.	Accomp. letter to Owner	968	K.5

This register of contents arranged numerically according to the Drawing No. forms a ready method of finding the exact drawing, whether it has been filed in the correspondence file 968, or in the locker of roll number K.5. It is not, however, an index.

Index of Drawings.—An index of drawings corresponding with the card index for correspondence is necessary. Similar problems arise, *e.g.*, one may classify instead of index, that is, one may have drawers for important schemes, "Current Work," "Bridge Schemes," "Town Planning," etc., but this complication renders a search very difficult. A card index, having the drawings cross-indexed, gives the solution. The index can be arranged as follows :—

Separate Card	Description	Roll
B.	Balby, High St.	K.4
D.	Downham's Land, Dundee Rd.	K.5
G.	Gulley details, Dundee Rd.	K.5
H.	High St., Balby	K.4
N.	Nairn Lane, Corner Improvement	K.5

If a book be used instead of a card index, each letter has, of course, a separate set of pages in the index book, which may be of the loose leaf edition.

Folders.—The only difficulty which arises with plans is, that whereas letters can be filed up to foolscap size, plans range to double elephant size (and sometimes even larger).

Drawings may either be folded and placed with the correspondence, or rolled and kept separately. In the former case, smaller plans present no difficulties, but large plans become bulky and require special separate holders. The folding of plans, too, is not entirely satisfactory, for in the course of years, prints perish along the creases. On the whole, having in mind the many drafts and amendments which inevitably take place, separate rolls are preferable in a Highway Surveyor's Department. Small pigeon holes should hold the plans either in cardboard rolls or in a dust-proof cupboard.

Each pigeon hole receives a different letter, viz., A.B. . . . Z., 1A. 1B. . . . 1Z., 2A. 2B. . . . etc.

Assuming the last scheme was,

Corner Improvements, Hepworth Road, 2K/32, then the next scheme, irrespective of its classification (Bridges, Town Planning, etc.) will be 2K/33. When the pigeon hole 2K is nearly full, the next pigeon hole of 2L will be commenced.

The library arrangement of stalls or cupboards is the best form for accessibility.

Where this scheme has been in operation, it has been found to work admirably in practice.

ELIMINATION OF WASTE.

To have an efficient department, one must eliminate waste. A list has been compiled of office wastes and from experience in different offices the author has arranged them in approximately their order of importance. No office has 100 per cent. efficiency. Some are nearer than others, but the author is of the opinion that even the most efficient will find in these remarks suggestions which would render further improvements possible.

1. *Insufficient Technical Data, Graphs, Charts and Diagrams.*—The purpose of an office is to serve. Clerical records are kept so that one may see how the money has been spent. Technical records are required to see how the money can be saved. The manner in which half a million pounds and more is expended is determined by the office. The office must have data—not only in the way of a costing system—but data, taking into account all factors, initial cost, life, maintenance, wear, etc., so that comparisons of *value* can be made.

The Ministry of Transport has led the way. From its experimental roads and tests at the National Physical Laboratory, the fruits of real economy will ensue.

All Highway Departments carry out tests from time to time, but the author wishes to stress the importance of a considerable extension of this practice. Every possible alternative in materials, construction, labour, haulage and machinery should be closely analysed. Charts and diagrams regularly prepared will reveal avenues for further experiments. The technical results will shew where the quality

can be improved while simultaneously the cost is reduced: in a word, an increase in the percentage efficiency.

2. *Useless Work.*—This section is probably more applicable to Local Government Departments than private firms. The system of control by Committees is such that often fruitless reports and alternative schemes are requested. The author calls to mind a case where seventeen elaborate elevations were prepared for a bridge: finally the Committee selected the elevation of the existing structure.

3. *Inter-communication.*—Details and costs due to the lack of efficient internal communication are given elsewhere. These losses are often considerable.

4. *Standardisation.*—The saving by standardisation has been proved in the works. The time has now come to extend the system in the office.

5. *Verbal Messages.*—The cost per annum of errors by wrong interpretation of verbal messages is considerable. A system of chits from a perforated duplicate book is desirable.

6. *Travelling Facilities.*—When the cost of waiting time of technical staff is tabulated, there is a saving in granting travelling facilities for inspection, survey work, etc.

7. *The Cost of Shorthand.*—Potential savings under this head are treated under "Correspondence."

8. *Delayed Interviews.*—A staff queue waiting to see an official becomes a costly procession. A system of pre-arranged times can usually be devised.

9. *Delivering Messages.*—The cost involved by staff walking about to deliver messages can be reduced by having (a) a messenger on tour at fixed intervals: (b) the teleprinter which, by means of a wire, transmits and receives typewritten messages. The machines are used by insurance companies, banks and police. In Great Britain some 3,000 are in existence while the Americans are using 65,000.

10. *The Start.*—The first half hour never goes with a full swing.

11. *Filing.*—Searches for lost files and misplaced correspondence are expensive.

12. *Human v. Mechanical Calculators.*—Most calculations can now be performed more economically by machine than the old laborious brain-fag method. Comptometers, etc., are particularly economical for financial calculations.

13. *Ledger Posting.*—Machine posting by the punched card system is an amazingly efficient method in comparison with the old fashioned clerk, pen and ledger routine. Government Departments, Insurance Companies and large commercial firms and the large Highway Departments who have mechanised have effected immeasurable savings.

14. *Allocations.*—Hand sorting is costly.

15. *Errors.*—The cost of these is immeasurable. Machines tend to reduce them.

16. *Tracings.*—To employ qualified assistants for tracings is wasteful. Tracers can be engaged at less than half the price.

17. *Quotations.*—In a large office, many assistants invite tenders for special materials. An indexed book of quotations is useful for estimating.

18. *Unnecessary Correspondence.*
19. *Furniture Arrangement.*—A re-arrangement of cupboards, desks, tables, etc., is sometimes desirable.
20. *Unsuitable Furnishing.*—There is a loss in output by using desks, chairs, and stools which are not suited to the task.
21. *Size of Rooms.*—Small rooms, involving much walking about and lacking adequate supervision, mean small output.
22. *Bad Planning.*—Detached and scattered quarters result in loss.
23. *Bound Books.*—Loose leaf books controlled by card indices increase efficiency.
24. *Personnel.*—There is a correct personnel: too small a staff means loss in statistics, arrears in work, errors due to haste and lowering the vitality of the workers; too large a staff breeds laziness and destroys initiative.
25. *Small Orders.*—When one traces the full routine of an order, it is found that the cost of small orders is a disproportionate cost of the price of the goods, and sometimes exceeds the virtual price.
26. *Slow Workmanship.*—Slow draughtsmanship, typing, etc., due to lack in skill, causes losses.
27. *Printing.*—Old fashioned methods are costly. Modern duplicators and office printing machines are time and money savers.
28. *Addressing Letters.*—Hand or typewritten addresses are unnecessary costs. See remarks re "Addressing Machines."
29. *Stamp Affixer.*—Sticking stamps by hand is wasteful in a large department.
30. *Lavatory Accommodation.*—A large basement convenience is not an economy. Small conveniently placed lavatories are time savers.
31. *Unsuitable Lighting.*—(See environment).
32. *Wrong Temperature.*—Ditto.
33. *Bad Ventilation.*—Ditto.
34. *Illness.*—Delays, errors and absence due to and following staff illnesses are costly items to the employers. Capital expenditure in providing healthy offices is soon recovered.
35. *Waste in Supplies.*—A central stationery department secures good results.
36. *Office Costs.*—Office costs will be unnecessarily high unless frequently analysed.
37. *Psychological Losses.*—Further losses are caused by apathy, dissatisfaction, inaptitude, labouring under an injustice, antagonism, favouritism.

CONCLUSION.

It will have been seen from the above that the subject of efficiency is not one, like a problem in design, which is dealt with in an orthodox way in a text book. It presents different problems in different offices.

Complex.—Familiarity breeds contempt. The outlook, therefore, should be to view one's work each day as if for the first time. A task may have been performed in a satisfactory way for some time—but the test of efficiency is not whether the system seems to be working all right, but whether or no there is a better known way of performing each task.

Science.—Advances in science are inconceivable: to maintain efficiency one has to advance perpetual improvements.

100 *Per cent.*—Efficiency embraces two phases:—

- (1) Investigation.
- (2) Action.

The avenues for investigation are legion. The author has attempted to indicate definite lines for attack so that after investigation action will bring the efficiency of a Highways Department nearer to the ideal of 100 per cent.

Control over Highway Expenditure.

BY

P. TAIT.

(Finance Department, Ministry of Transport).

(1) In the discharge of my official duties as the officer immediately responsible for the financial examination of current expenditure attracting grants from the Road Fund, it has been my privilege to visit a considerable number of Highway Authorities throughout the country; and I desire to place on record, at the outset, my respect for local government administration generally, and to tender through the medium of this paper my gratitude for the courtesy continuously extended by the officials to my colleagues and myself.

(2) I have to add that the views *hereinafter expressed are entirely my own, and are without official significance or approval.* If the expression of these views will but help us all to appreciate more fully the immensity of the problems with which we have to deal and the advantages that will accrue to the public service from co-operation between the Ministry and the Authorities, the purpose of this paper will have been achieved.

(3) In the consideration of the question of financial control, it will be convenient first to review the statutory powers and duties of Highway Authorities and those of the Minister of Transport, then to pass to the exercise of those powers and duties.

(4) The Highway Act, 1835, started with the common law liability of the parish to maintain the highways within it, and provided for an organisation simple and parochial in character. Another Highway Act was passed in 1862, the main object

of which was to attain greater efficiency and economy by enlarging the areas of highway administration. Then followed the Public Health Act, 1875, which mapped out the whole of England into urban and rural sanitary districts and made urban districts highway authorities. The Highways and Locomotives Act, 1888, sought to make areas and authorities more uniform because prior thereto, as roads became disturnpiked, the burden of repair was unequally distributed over the various parishes. The Local Government Act of the same year vested the control of main roads in the county council and threw the whole cost of maintenance of these roads upon the County rate. In 1894, another Local Government Act converted urban and rural sanitary authorities into urban and rural district councils, abolished highway boards, and made rural district councils highway authorities. The Local Government Act, 1929, defined main roads as county roads; transferred to county councils the functions with respect to highways in rural districts; transferred all bridges repairable by the inhabitants at large carrying county roads and all classified roads in urban districts to county councils, though reserving rights of certain urban district councils to maintain county roads subject to contributions by county councils; provided for agreements between county councils and urban district councils regarding unclassified roads and the delegation of road functions by county councils to district councils. By this Act also "Classification" grants from the Road Fund to the maintenance and improvement of classified roads in London and county boroughs were discontinued, as also grants towards the maintenance of unclassified roads in counties. In their place, a compensatory contribution from the Road Fund was included in the lump sum or "block" grants devised by the Act.

(5) The Development and Road Improvement Funds Act, 1909, authorised the creation of the Road Board. This Board was given powers, with the approval of the Treasury, to make advances to county councils and other highway authorities on such terms as the Board might consider fit. Powers were also given to construct any new road which appeared to the Board to be required for the purpose of facilitating road traffic. By a series of Orders in Council made under the Ministry of Transport Act, 1919, the Minister succeeded to all the powers and duties of the Road Board in addition to responsibilities in respect of railways, tramways, canals, ferries, docks, harbours etc. It is of interest to note that this Act empowered the Minister to make advances also for the purpose of *maintenance* of roads, bridges and ferries, whereas the powers of the Road Board were limited to the making of advances to works of improvement only. This Act also provided for the appointment of Advisory Committees to give expert advice and assistance to the Minister in connection with the exercise and performance of his powers and duties. The Roads Advisory Committee, which deals with highway matters is comprised of representatives of the County and Municipal Associations, the Royal Agricultural Society and of motoring, labour and commercial interests. The Roads Act, 1920, created the Road Fund and subsequent Acts have extended the purposes for which the Fund may be employed.

(6) The powers and duties of a highway authority for road maintenance and improvement purposes are not impaired by the exercise of the powers and duties of the Minister. If an authority could finance its operations without assistance

from the Road Fund, it would enjoy almost complete freedom of action within its statutory powers. Clause 24 of the Ministry of Transport Act, 1919, lays it down that "nothing in this Act shall be construed as giving power to the Minister to impose any conditions upon a local authority which shall entail expenditure without consent by such local authority."

(7) The advent of the motor car with its great range of movement, and the development of long distance goods and passenger transport services by road, have increased very considerably the financial burden of the highway authorities. This burden has arisen largely from expenditure on the main roads where construction and maintenance costs are heaviest, and which now serve increasing streams of through traffic. The imposition of special taxation on motor users to help defray this expenditure became necessary, and Parliament having made available very substantial sums of money has invested the Minister with discretionary powers in the disbursement of the Road Fund. The initiative in the determination of works and the executive in the performance of them is in the control of the highway authorities. The inherent right of the Minister to maintain a position in the partnership which will enable him to satisfy Parliament and the community at large that the funds at his disposal are properly disbursed is exercised through the "power of the purse."

(8) The following statistics will serve to indicate the dimensions of the task of providing adequate traffic facilities throughout the country; whilst the number of spending units, as represented by highway authorities, and the vast sums of money expended annually will suggest the advantages that should accrue from co-operation between the Ministry and the Authorities.

(a) Highway Authorities in Great Britain, 1933.

England and Wales.

County Councils (including London County Council)	62
County Borough Councils	83
Metropolitan Borough Councils (including the City of London) ..	29
Municipal or Non-County Boroughs	263
Urban District Councils	752
Total	1,189

Scotland.

County Councils	31
Large Burghs	24
Small Burghs	171
Total	226

Total for Great Britain 1,415

(b) Statement showing growth of expenditure during the past 50 years taken from the Local Taxation Returns.

Year.	<i>England and Wales.</i>					
	<i>Expenditure not out of loans.</i>			<i>Expenditure out of loans.</i>		<i>Total.</i>
	£			£		
1884-5	..	..	..	5,632,310	2,629,793	8,262,103
1894-5	..	..	..	7,444,190	1,385,139	8,829,329
1904-5	..	..	..	10,586,614	4,427,328	15,013,942
1914-5	..	..	..	13,426,226	3,031,854	16,458,080
1924-5	..	..	..	40,642,738	9,994,590	50,637,328
1930-1	..	..	..	43,258,907	18,125,748	61,384,655

In addition to the figures for 1930-31, loan charges amounting to £9,156,264 had to be met.

Scotland.

(c) The particulars available for Scotland are as follows :—

Year.	Scotland.			Expenditure out of Capital Receipts.	Total.			
	Expenditure out of Ordinary Receipts.							
		£	£			£		
1894-5	..	..	..	669,192	..	129,201	..	798,393
1904-5	..	..	..	1,054,657	..	165,850	..	1,220,507
1914-5	..	..	..	1,484,147	..	171,053	..	1,655,200
1924-5	..	..	..	5,341,603	..	959,387	..	6,300,990
1929-30	..	..	..	6,281,738	..	1,300,673	..	7,582,411

(d) Miles of highway for which authorities are responsible, 1931-32.

		<i>England and Wales.</i>		<i>Scotland.</i>	<i>Total Return.</i>		
Class I Roads..	..	..	20,061	..	6,452	..	26,513
Class II Roads	..	..	12,566	..	3,916	..	16,482
			32,627	..	10,368	..	42,995
Unclassified roads	..	..	118,776	..	15,020	..	133,796
Grand Totals	..	..	151,403	..	25,388	..	176,791

(9) The necessity for control over highway expenditure is constant from the works proposal stage to their completion. The life of a road, under modern conditions, depends upon a number of factors, the weight and density of traffic, the alignment and gradient of the road surface, the subsoil and drainage of the road bed, and the form of construction of the road. Simple maintenance by patching may be more costly and less satisfactory than reconditioning in the same materials, and renewal to the same specifications will be wasteful when an improved form of construction is required, whilst neglect of maintenance will precipitate reconstruction and inflate the ultimate costs. There are a number of forms of approved

construction and many varieties of proprietary and other specifications; whilst local stones vary in quality and the purposes for which they may be employed.

Thus highly technical considerations are involved when determining the relative merit of works proposals. For this reason, it is suggested that charts should be prepared and maintained, as the specimen chart annexed to this paper. The history of each section of road in respect of which works proposals are under review, would thus be available to the highway committees. The Board of a Company would most certainly require to have information as to the wear and tear of factory machinery before deciding upon replacements or the continuance of expensive maintenance.

A further suggestion is made for the purpose of regulating and conserving available funds, that highway authorities should extend the practice of forecasting expenditure—more particularly that to be incurred in reconditioning and reconstruction works—for two or maybe three years ahead, so that economy in expenditure upon maintenance may be secured.

(10) Under the common method of preparing annual programmes of work, the surveyor, having either exact information or a good idea as to the money available to him, reviews the needs of the roads in his area and presents his proposals for the consideration of the highways committee. In due course, the proposals of the highway authorities with the applications for grants, supported by estimates of cost and in respect of improvement works, details of designs and specifications also, are received by the Ministry and grants to approved works are issued within the budget limitations.

(11) As an indication of the scope of the demands upon the Road Fund, a summary of current headings of expenditure is given below :—

Statutory and other charges.

- Administration Expenses, including London Traffic Committee and Traffic Commissioners.
- Compensation (Section 116 Road Traffic Act, 1930).
- Motor patrols.
- Experimental work.
- Surveys and preliminary expenses.
- Motor Tax Revenue—Costs of collection.
- Compensation to Local Authorities (Section 3(4) (b) Roads Act, 1920).
- Interest on Exchequer advances (Section 36(2) Finance Act, 1931).
- Loan charges (Unemployment Grants Committee cases).
- General Exchequer Contribution (Section 87(1) Local Government Act, 1929 and Section 54(1) Local Government (Scotland) Act, 1929).

Grants.

- Salaries etc. of Local Authorities' Surveyors.
- Traffic census.
- Traffic regulation.
- Maintenance and improvement of Class I and II roads and bridges (including loan charges).

Major Improvements and other road purposes.

Normal annual programme (current year).

Normal annual programme (prior years).

Special road programmes for relief of unemployment.

Grant works 1920-25 programmes.

Five years' programme.

Trunk road programme 1920.

Works recommended by Royal Commission on London cross river traffic, etc., etc.

(12) The two principal categories of expenditure are in respect of:—

(a) The maintenance and improvement of Class I and II roads and bridges ("Classification" grants).

(b) Major improvements, widenings, diversions, realignment and regrading works (Improvement grants).

The definition of maintenance for "Classification" grant purposes has been given in Circulars issued by the Ministry as "resurfacing a carriageway in a similar material to existing material; patching, surface tarring, etc.; repairs to surface water drainage, renewal of kerbs; maintenance of guard posts, milestones, retaining walls, etc." The definition of improvement for "Classification" grant purposes has also been given in the circulars as "The substitution of an improved material for that in existence; construction of new systems of surface water drainage; provision of new kerbs, channelling, culverts and paving, new road signs, etc." Works of widening roads, improvement of corners, curves and gradients, the acquisition of land or buildings are excluded from "Classification" grants, but are accepted for Improvement grants.

(13) With regard to category (a), nearly one half of the normal income of the Road Fund available after prior charges have been met, is allocated each year for this purpose. These grants were introduced when the classification of the roads was completed in 1921 and for the period 1921-22 to 1932-33 grants aggregating to over £98,000,000 have been issued for works on Class I and Class II roads and bridges. The percentages that the grants now bear to the approved expenditure are 60 and 50 for Class I and Class II roads and bridges respectively. It is the present practice to make payments on account of grants issued upon requisitions submitted by the highway authorities, quarterly, showing the expenditure incurred to the end of the quarter. 90 per cent. of the grant payable on the amounts expended each quarter is advanced, the 10 per cent. balance being retained and paid with the final instalment on receipt of a certified statement of grant earning expenditure for the year.

(14) The total value of the grants issued under category (b) since the Road Fund was established in 1920 up to and including the financial year 1932-33 exceeds £97,000,000. The percentages that these grants have borne to the approved expenditure have varied from 25 to 100. The rates for Improvement grants on classified roads are ordinarily the same as for "Classification" grants, viz. 60 per cent. and

50 per cent. Advances of grant upon major improvement schemes are available in anticipation of expenditure. Requisitions during the progress of the work may be presented monthly to show the expenditure incurred and that estimated to be incurred during the current month. As in the case of the "Classification" grants, 10 per cent. of each grant payable is retained until the certified statement of expenditure upon the completed works is received and approved.

(15) Having decided what works shall be carried out, the next consideration is the method of execution. Road construction operations have attracted the attention of large scale public works contractors who have at their command the best technical advice, highly trained organisations and extensive mechanical equipment. The contractors have reputations to maintain and the goodwill of highway authorities to preserve, and it may fairly be said that they have contributed in large measure to the improved standard of highway engineering to-day and to the knowledge and experience of the profession. The primary purpose of the activities of contractors, however, is to produce profits and most certainly to avoid losses. The more severe the competition for works, the less the margin of profit allowed for in the tenders and the greater the need to cut things fine in the buying and in the execution of the works and to ensure that every legitimate claim to extras is presented.

The principal objectives of the Surveyor when carrying out works by direct labour are to make a sound job, and to keep within his estimate of the cost. In attaining the latter objective the merit of success depends upon the margin for contingencies disclosed and hidden in the estimate.

(16) Comparison between the costs of work carried out by contract and that by direct labour ought to be available for the guidance of each highway authority. In the case of a few authorities, sealed tenders are required from the Surveyor for works that may be let to contract. In one case, the Engineer, if his sealed tender is accepted, directs one of his technical assistants to carry out the works in all respects as if he were an independent contractor. His works are measured up each month and variation, omission and extra works orders are demanded, priced and issued. A Divisional Engineer is responsible to see that the work is satisfactory and the Chief Clerk is advised of the estimated quantities of the principal materials to be ordered and explanations are required of any excess or short demands. By this means, his staff are trained and his Council is provided with information to satisfy them that the value of works carried out is commensurate with the costs.

When considering the contractors' tenders against the direct labour estimates allowance will, of course, be made for the difference in supervisory and other overhead expenses.

CONTRACT WORKS.

(17) The practice of the past has undoubtedly been that the bulk of the construction work throughout the country has been put out to contract. For this reason, contract matters which from experience appear to be worthy of reference, will be dealt with first. This opportunity is taken of remarking that the number and variety of the points raised do not indicate any general laxity of control. The

writer's respect for Local Government administration has already been expressed, and it is thus only necessary to explain that the need for attention to these points having arisen from time to time, their incorporation in this paper will, it is hoped, serve a useful purpose.

(18) It is not necessary to describe the essentials of a contract, form and consideration, matters of mutual consent, declared intentions, etc., but it is worth while directing attention to the importance of the employment of uniform conditions of contract throughout the country for road construction operations. Experience has demonstrated the importance of contracts being drawn so that every reasonable protection is secured to the highway authority and all rightful considerations provided to the contractor. These matters have received the attention of the Ministry of Transport and standard conditions of contract have been prepared and adopted after discussion with the Federation of Civil Engineering Contractors. These are available to all authorities, and their employment generally throughout the country will enable contractors to tender at short notice with a full knowledge of the terms and conditions upon which their offers are made.

(19) As the contract into which the highway authority and the contractor enter includes the form of tender or offer, the conditions of tender, the conditions of contract, the specifications, the bill of quantities, and the drawings, great care needs to be exercised that each part is complete and consistent with each other part. The practice of linking by marginal reference each item in the bill of quantities with the paragraph in the specifications relating to the operation is useful as thereby complaints as to misunderstanding of requirements are obviated and the completeness of the documents is more likely to be assured. The schedule of day work prices (labour, materials and haulage) also deserves consideration. Some authorities include quantities so that the day work schedule can be priced out and included in the total tender value to act as a deterrent to abnormally high rates for labour and materials being inserted.

(20) The "Invitation to tender" stage in the process of placing a contract is important for the exercise of financial control. Before the issue of the tender forms, Surveyors should reassure themselves that the bill of quantities covers all operations, that the items are clearly and fully described, and that they are in accordance with the specifications and drawings. More especially should they re-examine the design and the specifications to confirm their opinion that they are the best for the purpose in view. This point is stressed because frequently designs or specifications have been amended after the contracts have been let. It is wise, of course, to make amendments whilst it is possible during the progress of the works when improvement and/or economy can be secured, but the real serious thinking about the details of the works should precede the invitation to tender.

(21) Much has been said from time to time about the procedure employed by highway authorities when receiving and selecting tenders for contracts and supplies, and still this matter is constantly under review. The adoption of the following rules of procedure, where not already in use, may be found to be useful:—

(a) All invitations to tender to be issued over the signature of the Clerk of the Council. It is an administrative action.

- (b) The sealed tenders to be called for by a specified date and time, and to be opened in the presence of a limited number of members of the Council, the Clerk, the Surveyor, and the Accountant or their respective representatives.
- (c) Contract tenders to be examined at the above meeting for alterations, erasures or obvious inaccuracies and every tender to be initialled and the total price restated thereon.
- (d) Consideration should not be given to tenders that arrive late.
- (e) The successful tender should be accepted on the total price offered and when errors of addition or multiplication are observed the contractor should be required to make amendments in the unit prices of operations or their values so that the total remains unaltered. Certainly, no amendment should be invited or allowed on a badly priced item when otherwise the tender is in order. This suggestion may appear too obvious to have deserved comment, but tenders have been returned and contractors have taken the opportunity to increase bad prices and their totals.

The acceptance of the lowest tender is not always in the best interests of the Council, but the reasons for passing over the lowest tender must be sufficient to satisfy the public conscience. In all grant aided cases, the reasons for passing over the lowest tender should be furnished to the Minister. The decision must be taken by the Authority but the Minister would be likely to limit his grant to the amount of the lowest tender if the reasons do not appear to him adequate.

(22) Having accepted a tender, steps should be taken forthwith to complete the formalities of the contract under seal and to secure the bond of surety for due performance. An occasion has arisen of substantial loss arising from default when the bond of surety had not been completed.

(23) From a considerable experience of contract claims and disputes throughout the country, the following observations are offered, not in a spirit of criticism, but in the hope that the younger generation of engineers will find the variety of causes that give rise to difficulties of sufficient interest to them to invite their attention to the importance of correct procedure and detailed day to day records of works progress.

(24) Each party to a contract has rights and obligations which they must preserve and fulfil. Surveyors on their part must observe to do all that is required of them under the terms of the contract at the right moment and in the correct form. The Ministry standard form of contract sets forth the procedure. They must also see to it that nothing is done or omitted to be done by them or their assistants which may prejudice the rights of their councils or lay the latter open to claims to compensation or relief. It will also save them considerable trouble if they will see to it that the contractors exercise their rights in proper form.

(25) Every variation, omission or extra works order should be confirmed in writing and the effect upon the contract price stated therein. Failure to fix or agree prices for extra and varied works at the time the order has been issued has proved a

fruitful cause of difficulty and loss. All prices for extra or varied works should be based upon the unit prices in the contract as far as it is practicable to construct the new prices therefrom.

(26) The right to order variations whether by omission or addition is very wide under the standard contract. None the less, great care should be exercised in making them. To invite tenders on drawings which are going to be subjected to large and substantial alterations is to invite trouble. It is always difficult for a contractor to substantiate a claim that the contract has been abandoned; but his best opportunities for making such a claim arise on large variations. A surveyor will avoid much friction, accordingly, by seeing that the tender plans fairly represent the works which he proposes to construct. He should also see that his orders for variations are given strictly in the manner provided by the Variations Clause in his contract. If he omits work, it must be with the intention that that work is not going to be done at all. He has no right to omit work with the intention of getting it done by somebody else. It should, perhaps, be added that though the contractors generally know from experience the risks of financial loss that they may sustain by reason of variations in road construction operations, and though they are given an opportunity when tendering of taking cover in their schedule prices for the risks, the free exercise of the contract right to require variations may impose upon them very serious hardships in respect of which they have no remedy.

(27) The contractor by his tender implies a warranty of competence satisfactorily to perform all the works specified in the contract. Care should be taken, accordingly, that in an endeavour to help, orders are not given, nor action taken, which may relieve the contractor of his control over any stage of the work whereby he may be encouraged to claim that the order or action imposed upon him a method of working different from that which he would have employed, and more costly in operation.

(28) The waiver of a contract condition such as the release of retention money before due date, extension of contract time without written application from the contractor, the failure on the part of the Council to notify in writing within the specified time any non-observance or non-performance by the contractors of any of the terms, covenants, and conditions of the contract which may involve a loss for which the Sureties are responsible, or the making of any requirement not within the contemplation of the contract, may invalidate the bond of surety and prejudice the rights of the Council in the contract. The bond of surety invariably specifies as a condition precedent to the admission of liability, that any material departure from the contract shall be subject to the Surety's consent. The Surety relies upon the accumulated retention money and the value of the contractor's plant for part cover in the event of default and failure of the contractor to discharge the liabilities arising therefrom. Strict adherence to the terms of the contract and the surety bond is therefore essential.

(29) A diary should be kept in which should be recorded daily all matters of importance, or matters that may become important, whilst the contract is in progress.

(30) Work on a time basis should be restricted as expenditure thereon is difficult to control and the competitive element of the contract becomes less effective as the measure of time work increases. Time work should be specially ordered in writing and time sheets and other evidences of cost should be required by the engineer for control purposes.

(31) The lump sum items included in the tender for preliminary and overhead contract expenses may not be increased, as measurement items are increased, when additional works are ordered and the period of working is prolonged thereby, *provided* that the extra works are incidental to, and within the contemplation of, the contract. The lump sum prices tendered by the contractor should be regarded as covering all expenditure and risk on the items and services specified which may be incurred in the performance of *all* the works that may properly be required to be done under the contract.

(32) Few contract disputes are purely questions of measurement and price; they generally introduce matters of interpretation of specifications, legal considerations, and questions of fact relating to hindrance to operations, and variations in the character of the works. The validity of the separate claims should first be determined, then their value. The practice of making concessions when the claim is not legally valid in the belief that equity demands that hardships should be rectified, leads to expectations that in similar circumstances elsewhere relief will be afforded. As this practice becomes general, a tendency may develop for the contractors to rely more upon the expectation of relief than the terms of the contract. Collaboration between the Surveyors and the Clerks of the councils on these matters is imperative and legal advice might often, with advantage, be sought at an earlier stage in the dispute than is customary. In this connection it may be well to recall a condition that if grant is required on an arbitration award the terms of reference to the arbitrator must receive the Ministry's prior approval. The Minister does not require the authorities to subrogate their rights to him in these matters, but by reason of the substantial financial interest of the Road Fund in the matters at issue, the Minister requires to be satisfied that recourse to arbitration is unavoidable. In a number of cases referred to the Ministry further negotiations have ensued, and the need for arbitration has been obviated.

(33) The Ministry of Transport standard form of contract contains a condition that absolutely debar a claim that is not presented in proper form when the circumstances happen that give rise to the claim. Unless the Surveyor has knowledge of the claim at the time he cannot take steps to remove the cause of claim or to measure it as it matures and make financial provision to meet it. Claims not presented in the monthly returns of work should be rejected.

(34) Contractors should be required to support each special claim with the information in the following form:—

- (a) Brief description of claim.
- (b) Location of work or service.
- (c) Amount of claim to date, how calculated, and whether complete or continuing.

- (d) By whom work or service ordered, and when, with reference to instruction.
- (e) Clause or condition of contract upon which claim is founded.
- (f) Any other relevant information to enable claims to be verified and valued.

Upon receipt of this information, the written observations of the resident engineer should be obtained so that all material facts are available upon which the merits of each claim can be examined. Failure to deal promptly and adequately with contract claims has often proved expensive. It is often impossible to value a claim at the end of a two or three years job when the circumstances existing at the time have not been placed on record, and especially when the Assistant who had knowledge of the circumstances is no longer available. As far as possible, every claim should be settled as soon as notified. Contractors must take all reasonable steps to minimise their loss to entitle them to full compensation.

(35) A contract may be discharged by agreement, breach, or for other reasons given in the documents. Variations in the character of the operations in respect of design, method of working or the omission of works, if substantial enough, may encourage a contractor to claim that the contract has been abandoned or breached. When a contract has been abandoned or breached, the unit prices may be no longer binding in respect of the operation affected and may have to be settled on a *quantum meruit* basis. If there is any reason to believe that a claim may be presented for abandonment or breach, even though such a claim may be capable of rejection on merit, careful notes should be made of the works as they progress, with particular reference to the efforts made by the Contractors to minimise their losses.

(36) The contractor should prepare and submit his final account for payment as the Council is not adequately protected when the surveyor prepares the final measurement and value bill and sends it to the contractor for adoption and presentation.

(37) Lessons to be learnt from difficulties that have arisen from technical breaches of contract and other causes :—

- (a) When the Engineer is of opinion that an advance should be withheld from the contractor his first step should be to read carefully the clause in the contract dealing with advances, and to act precisely in accordance with its requirements. In this respect, the clause in the Standard Contract provides that upon receipt of the contractor's monthly return the engineer shall grant to the contractors a certificate of value. The contractors are therefore entitled to this certificate in every case, and the engineer who desires the advance to be withheld, cannot do so by withholding the certificate. What he may do is to add to his certificate a qualifying statement of the kind indicated by the Contract Clause, *e.g.*, that the progress of the works or the contractor's conduct is not satisfactory, and the council can then, upon this qualified certificate, refuse to make an advance. This is the only way in which the surveyor can safely get an advance withheld under the Standard Contract.

- (b) Before altering the form of construction by omission or variation consider well whether the alteration will throw upon the contractor a burden from which a claim to compensation or relief may arise.
 - (c) The contractor has a right to do all the work for which he has tendered, and an omission order may only be issued when it is intended that the work shall not be done. Work may not be taken out of a contract, therefore, and given to another contractor or be performed by direct labour without giving the contractor a right to compensation for loss of profit and perhaps opening up a claim that the contract has been abandoned.
 - (d) A contract under seal may not be varied except as provided in its conditions, otherwise than by a supplementary written agreement also under seal, and no informal arrangement between the parties that is not in agreement with the contract can be enforced.
 - (e) Extensions of contract time should only be given for reasons outside the control of the contractor. There is no provision in the contract which will empower an engineer to extend the time for reasons within the control of the contractor. The rights of the council to liquidated damages for non completion of contract at due date should not be waived.
 - (f) Great caution should be exercised in the course pursued in taking works out of the hands of a contractor, and every step taken and letter written should be based upon legal advice. The measurement of completed and uncompleted works should be taken and inventories of the plant and materials on the site prepared and agreed on the date of cessation of works under the contract so that the ultimate settlement may be facilitated.
 - (g) Occasions have arisen when contractors have claimed submission to arbitration of items of claims that are not valid under the contract, or, if valid, are debarred by the neglect of the contractors to disclose in the monthly returns of work the items of claim as they arose in accordance with the requirements of the standard contract. The highway authority is entitled to the protection of the contract against any award being made in respect of such claims. It is a matter for considered legal advice in each case whether these items of claim can be withheld from submission to the Arbitrator or, if submission is agreed upon, what terms of reference shall be employed to secure that the Arbitrator in his award does not deprive the highway authority of its rights under the contract.
 - (h) The Engineer should take care not to delay the issue of drawings or orders and when complaints are made verbally or in writing, those complaints should be noted and steps taken to discharge the Council's obligations under the contract so that claims to compensation may be obviated.
- (38) The need for economy, which should not be associated necessarily with periods of financial stringency, requires that the progress of expenditure on contract works should be constantly under review. Physical supervision, by which means alone the Surveyor can certify satisfactory performance, requires to be exercised with an up to date knowledge of progressive expenditure and the balance of funds

available for completion. Periodical reviews of the measurements completed and a valuation at contract unit prices of uncompleted works should be made so that a revised estimate of total cost may be ascertained. When the works are subject to Ministry of Transport grant, the importance of discovering in good time a risk of over expenditure is increased because the Ministry will not ordinarily entertain applications for grant to excess expenditure unless prior approval has been obtained.

DIRECT LABOUR WORKS.

(39) With regard to direct labour operation, the County Councils, as highway authorities, expended over £13,000,000 in the year 1930-31 alone on the maintenance and improvement works to which "classification" grants were issued, and a great deal of work on grant aided major improvement schemes was also carried out by direct labour. In these operations responsibilities arose for the direction and control of large numbers of men, the manufacture, purchase and use of vast quantities of materials, the organisation of works, and the employment of valuable machinery and equipment.

(40) The day has long since passed when reliance upon physical supervision was regarded as adequate for the purposes of control over expenditure. The severity of competition with its constant demand for reduced costs of production have compelled the industrial world to adopt a system of accounts which will disclose the costs of every operation in the process of manufacture and the day to day variations in those costs. In highway operations also competition has forced the contractors to provide their supervisory staff with details of progressive costs which will show the financial position as the works progress as an aid to physical control.

(41) It must be recognised, however, that for cost accounting purposes, there are essential differences between industrial works and road construction operations. The exact repetition work of the factory which justifies detailed process costing and enables definite conclusions to be drawn from the unit costing figures, does not exist in road construction operations. Soils vary, weather conditions change, prices of materials depend upon location of works, and other local conditions make comparison between the unit costs of two similarly described operations at different places of limited value only. Another essential difference is that physical supervision in the factory is an easy matter whereas the extensive areas over which road works are distributed make supervision difficult. The need to facilitate control by costs records is, therefore, more urgent. Justification for the employment of costing records is not now required; an increasing sense of appreciation of their value has been in evidence for some years past, and what is now desired is a standardised system of cost records for all highway operations, that can be employed without a great expenditure of money on staff and forms and which will be tied in or reconciled with the finance accounts of each authority.

(42) It is all important that waste and unproductive expenditure shall be eliminated and that a satisfactory output of work shall be secured from labour and machinery. Experience over many years now has proved conclusively that the

expenditure upon adequate systems of cost accounts can, by their proper employment, be recovered many times over. A number of highway authorities have introduced costing records as an aid to executive control and valuable results have been obtained. Every such instance is a tribute to the zeal of the officials in their endeavour to satisfy themselves and their Councils that every effort is being made to carry out work economically.

(43) There has been considerable discussion of the question whether the cost records should be maintained by the Accountant or the Surveyor. On the one hand it may be said:—

- (a) That the maintenance of financial records is a responsibility that properly falls to be discharged by the Accountant and that the cost records should form part of the Statutory Accounts.
- (b) That each spending department, tramways, highways, infirmaries, etc. should keep detailed cost accounts and that it is more economical and more satisfactory for the authority that all these accounts should be controlled by one official.
- (c) That all the advantages of cost records can be equally well secured to the Surveyor when the records are maintained by the Accountant; whilst the Surveyor being relieved of responsibilities for financial records is thus freed to concentrate his energies upon the technical duties for which his training and experience more particularly equip him.
- (d) That as a general principle, the official who expends money should not have control over the records of that expenditure. This is a principle of commercial prudence.
- (e) That in the industrial world the Accountant is invariably charged with the responsibility for the cost records and that there would appear to be no reason, other than past practice in the case of highway authorities, for any other arrangement to obtain.
- (f) That in many cases cost accounts on satisfactory lines have yet to be introduced and that it is accordingly opportune that the Accountant should assume the responsibility from the outset.

On the other hand it may be urged:—

- (g) That it is an indispensable requirement that these records should be immediately, and at all times, available to the Surveyor and his staff, and that there is need for constant collaboration between the cost clerk and the headquarter's technical and works staff. That the work is more closely allied to the technical than the financial side.
- (h) That it is more important for this work that a competent cost clerk shall be employed than to have the experienced advice of the Accountant available, and that given a competent cost clerk reconciliation between the cost records and the finance accounts is a matter of procedure only.
- (i) That the Surveyor has the responsibility for the proper disbursement of highway funds entrusted to him, and that he should, accordingly, have

within his own control, the records upon which he must depend for the efficient discharge of his duties.

- (j) That the transfer of the cost records to the Accountant will involve both officials in correspondence on matters of detail without securing any compensating advantage to the Council.

As all claims to grant from the Road Fund have to be prepared from the Surveyor's records because they alone are maintained upon an "income and expenditure" basis as distinct from the "receipts and payments" basis of the Finance account, and as a number of services are carried out by the Surveyor for public undertakings upon a recoverable basis, the Accountant would appear to have a clear measure of responsibility to satisfy himself that the sums due to his Council are correctly assessed and promptly recovered. It is for each Council to decide to which official these records shall be entrusted. If to the Surveyor, the responsibility of the Accountant can best be discharged by the exercise of the right of internal audit.

(44) When considering the requirements of a Standardised System of Cost Accounts it is necessary to have regard to the information required by the Minister of Transport in support of claims to grant payments, and to that essential to the surveyors for purposes of executive control. The standardised system should aim at bringing out the true site costs or, if desired, the all-in costs of all operations to the highway authority and provision should be made for segregating in the process of costing, the non-grant earning services and operations to enable claims to grant to be prepared, and checked at audit, with facility.

A sound system of costing should enable all the requirements of the Ministry to be met.

It will be of value, also, if with the employment of a standardised system, the codes used for identifying construction operations can be universally adopted throughout the country.

(45) The draft cost accounting system outlined in this paper has been designed to facilitate reconciliation between the finance accounts and the cost records, and to provide convenient means of producing progressive operation unit costs. Expenditure upon labour and materials is carried simultaneously into the control and the cost accounts and reconciled each month whilst all other expenditure is carried through the control account (specimen 3 of annexed chart) to the cost accounts. Provision has also been made for disclosing the differences in expenditure between the payments made to merchants for supplies and services each calendar month which period will not coincide with that covered by the four (or five) weekly costing periods in each month, also that between expenditure on plant and the scale allowances accepted for grant purposes. Materials are brought into the cost accounts at the value of the deliveries to the job and the adjustment for unconsumed materials is effected in the process of ascertaining unit operation costs.

The system is more fully described in the appendix and the charts.

(46) The labour output is the "great variable" in operation costs, and the difficulties of controlling output peculiar to road construction works make it the more

necessary that labour costs shall receive constant and studied attention. Standards of output for each operation in terms of volume and cost should be set up, against which the efficiency of the labour employed should be compared at frequent intervals. This is being done by a number of highway authorities with surprisingly satisfactory results, and without harassing the men employed.

(47) Expenditure upon materials consumed in the operations carried out by directly employed labour is even larger than upon wages. Over one-third of the total cost of the works is represented by the cost of the materials. There are a number of problems incidental to the purchase and receipt of materials for road operations, and it would appear desirable that a special sub-committee of each council should be charged with the responsibility for control over all purchases.

(48) The appointment of a central purchasing committee by every authority which shall be charged with the responsibility of standardising supplies, regulating stocks and controlling purchases of materials is well worth consideration. This Committee would have the advice and assistance of the responsible officials of each department but the control over the invitations to tender, acceptance and the placing of orders should be vested entirely in the Committee. The delegation of powers to the responsible heads of departments should be conditioned to ensure that the policy of the central purchasing committee is strictly adhered to. Where such committees have been established their operations began with a small list of materials and this list has been expanded until the whole range of supplies is now controlled. The supplies for tramways, housing, highways, markets cleansing for example include many items common to all of these services. The several departments furnish a list of their approximate requirements of all materials and the committee gathers together and classifies all supplies, prepares forms of tender and specification and issues invitations to tender. Tenders when received are opened in the presence of members of the purchasing committee and submitted for consideration of that Committee and the chief official of the department concerned with the bulk of the supplies under tender. As soon as the contracts are placed all correspondence as to supplies is conducted by the department ordering the same. The clerk's department advises on the forms of tender and executes the contract on behalf of the Council. The report of one of the authorities where early progress was made in this matter gives instances of the valuable service of the Central Purchasing Committee in reducing the number of varieties of each class of store—disinfectants, towels, uniforms, etc. The placing of contracts for bulk supplies resulted in a very substantial saving in expenditure.

(49) The enormous requirements of the highway, tramway and housing departments of local authorities in respect of cement, and other supplies, and the very large sums expended in premiums for insurance suggest the desirability of collective bargaining for the supply of these commodities and the standardisation of rates.

(50) When materials are subject to "ring" prices, tenders sometimes do not disclose the price at which purchases can be effected. Indeed, there is a limit to the value of purchase by tender for supplies that are not to be taken at an early date, and experience has shown that notwithstanding the annual tender prices

substantial reductions can be obtained when bulk deliveries are asked for during the year. The remarks in paragraph 21 of this paper relating to the receiving of contract works tenders apply *mutatis mutandis* to tenders for materials.

(51) Considerable difficulty is experienced, in dealing with supplies for highways. Road metal, for example, required by a county council is usually priced in the tenders for delivery at railway stations throughout the county. There are the several gauges of metal also to be priced and the quality of the stone may vary considerably. Thus a low price may not be an acceptable one nor a high price represent an uneconomic purchase. The cost of works would rise perceptibly if the best stone only was requisitioned and the price of that stone would also respond to the demand. Moreover, the cost of haulage is so substantial that one could understand the quarry owners by agreement, or force of circumstances, finding a safe market for their supplies in the immediate vicinity of their quarries. Tenders, accordingly, may not secure the stone at a reasonable price. The procedure adopted by some authorities where haulage by road is necessary, of obtaining ex quarry prices and entering into separate haulage contracts on a ton mile basis may result in more advantageous quotations generally from the quarries. Engineers recognise the importance of organising the haulage so that the materials are delivered to the works in "parcels" that can be readily handled and at intervals between each delivery, so timed that the labour may be kept fully employed in handling it.

(52) The bulk of the materials purchased is delivered by the ton or the cube yard and difficulty has been experienced in checking the quantities. Road materials are expensive by the time they reach the site of the works for use and a 5 per cent. variation in quantity delivered cannot easily be detected with bulk supplies. In the majority of deliveries the authority must depend upon the weights furnished by the supplier, weights on the railway tickets, and weights of the haulier.

The first is paid for his materials on a weight basis; the second weighs a proportion only of the trucks and if weighing facilities are not readily available accepts the weights stated by the supplier; and the haulier is only interested to satisfy himself that the weights are not more than stated by the supplier. Thus, in many instances there is not an independent check of the supplier's stated weights. Delivery by volume can be checked if checkers capable of measuring up the quantities in the lorries are employed. This question is one that the technical officials of highway authorities are more capable of discussing but in order that this important matter may receive consideration at the Congress, the following proposal is made for debate: That suppliers should submit samples and therewith state the specific gravity of each material and the factor for converting the ton weight into the cube yardage volume. Orders should be placed for the measurement of the materials at the point of delivery on the cube yard basis, allowance being made in the price for the shaking down of the materials during transit. Checking money, say 1d. or 2d. an hour extra, might be paid to workmen who will make themselves efficient at this work and can be trusted, and who, unless the deliveries make whole time duty necessary, will be detailed daily for this duty in addition to their normal work. Samples should be available for inspection by the checkers at the timekeeper's office or some other

convenient place so that the checkers may be able to direct attention immediately to any defective materials.

(53) *Machinery and plant.* The effective use of the valuable plant owned by the highway authorities is an essential to real economy, and for that reason history sheets should be kept of every item showing the percentage of use to possible employment and its earnings in relation to its cost. Provision for such a record has been embodied in the cost records drafted for incorporation in this paper.

(54) *Overhead costs.* How many jobs, whether carried out by contract or by direct labour, are completed within the time specified? and what is the cost to authorities in salaries and overhead charges by reason of the delays in completing works? Very satisfactory results have attended the efforts of some of the authorities to deal with this question by the employment of time progress charts. In order to fix the period of construction, each of the principal operations in their order must be reviewed. Chart the estimated times for each operation and record thereon the actual progress of the works against the estimated times. Some operations are dependent upon the completion of others and special attention should be given to the primary operations. A simple form of chart will answer in the form of two parallel lines. On the lower one plot the dates when each operation should commence, and on the upper line the dates upon which each should be completed. The vertical line on the chart should be gauged to show percentages of work and the line or curve of estimated progress on the chart should be drawn to indicate the percentage of work it is estimated should be done at the end of each calendar month. Against each operation line record the actual line or curve of progress and from the results decide the action necessary to speed up progress or to adjust the order of works.

(55) The primary purpose of cost records is that at frequent intervals the progressive unit costs of the operations shall be disclosed and the expenditure upon the records will never be fully justified unless the figures produced are examined immediately by the engineers and used by them as an aid to control operation costs. To obtain unit costs the works must be measured as they progress, but as this business takes up a lot of time at the end of each month, though it must necessarily be done on contract works, the measurements may be taken progressively week by week, one fourth of the operations being measured each week. When the engineer measures up he will also record the quantities of unconsumed materials in respect of each operation measured so that the unit costs may not be inflated by the charges for unconsumed materials. The values of materials carried direct to the job analysis will be the materials delivered to site and one adjustment only at the end of the job will be necessary in the cost accounts for unconsumed materials. In the matter of the measurements, it is sincerely hoped that the authorities will have this work done thoroughly as the value of the records is dependent upon correct measurements. Cost records that are well kept and properly applied will save an authority very much more in money than the cost to be incurred in the provision of adequate staff. Indeed, the inadequacy of the staff may be responsible for many thousands of pounds of loss to an authority each year. At this present time there are hundreds of young engineers out of employment, and it is false economy to neglect the technical duties essential to this work.

(56) No paper dealing with matters of control over expenditure would be complete without a reference therein to the part to be played by internal audit. The existence of internal audit is no longer regarded as an indication of distrust, but as an essential feature of every modern business organisation. If this work is carried out in a spirit of helpfulness, as it ought to be, the achievement of efficiency will be facilitated.

(57) In conclusion, however complete and perfect rules of procedure and systems of accounting may be, they are really of less moment in the attainment of efficiency than the personnel of the organisation. Real efficiency is found invariably to spring from individual ability and effort, and those to whom success has come most easily are those most ready to acknowledge the importance of, and the assistance derived from, correct procedure and accurate accounting.

It only remains to be added that the Chairmen and Convenors of the several committees of each highway authority throughout the country, who bring, without remuneration, their experience and wisdom to the task of solving the problems of highway administration, and who, by their confidence and encouragement inspire the loyalty of the officials, make a far greater contribution to the efficiency of the local administrations than is generally known or acknowledged.

APPENDIX.

NOTES ON THE COST ACCOUNTING SYSTEM OUTLINED IN THE ACCOMPANYING CHARTS.

JOB NUMBERING.

1. The road identity number of each county road should form the basis of the system of job numbering. It is suggested accordingly that all maintenance and improvement "Classification" grant work, *e.g.*, on road No. A.72 carried out during the financial year 1932-33 should be given the job number 72/32. The classification letters A and B are not necessary because it only occasionally happens that two roads of the same number exist in the same county. In such cases the letters A and B should be prefixed to the job number. The financial year 1933-34 will be identified as 33, and 1934-35 as 34. The value of all the labour employed, materials consumed, and services rendered during the financial year, including scavenging and incidental services, will be charged to the one job number. To meet the requirement that expenditure in each divisional area shall be kept separate, and to enable comparison to be effected between the operation unit costs in each division, different coloured forms of return, as is usual, will be employed, but at the outset it will be convenient for many authorities to introduce the system with the minimum of job numbers and codes. The costs of maintenance and improvement works to which "Classification" grants relate can be extracted from the job code analysis and summarised separately for the purpose of the Ministry of Transport returns.

2. Major improvement and reconstruction works to which improvement grants are made should be identified by the road also, 72/1, 2, 3, 4, etc. Expenditure upon unclassified roads and other operations should be charged to jobs numbered serially 1, 2, 3, 4, etc.

3. Job identity letters should be given to each self-contained manufacturing outfit—*e.g.*, quarries producing materials for general use, tar macadam and asphalt production plants, etc., and to depots for the storage of plant and materials so that expenditure may find its way to the jobs through the cost of materials and not direct. Similarly, job identity letters should be given to machinery plant and equipment so that the daily charges only for the use of the plant may find their way into the cost records. All overhead expenses of an administrative character should be given a job identity letter also. Thus :—

D. 1, 2, 3, etc. Depots. (Construction expenditure, maintenance and operation).

D.1 Depot at Thomas Street Monkton.

D.2 Depot at Priestleigh.

The codes will be the headings under which this expenditure is desired to be classified. It will be necessary to code separately all depot supervision costs, clerks, etc., because such costs may not be charged to grant earning works. Expenditure upon the handling of materials should also be segregated as such charges do rank for grant.

M. 1, 2, 3, etc. Manufacture of Materials—self-contained units.

M. 1 Quarry at Downside.

M. 2 Quarry at Topside.

M.16 Tar macadam plant at Outside.

The codes in this case will be the normal headings of manufacturing expenditure. Labour on various operations, plant purchase and maintenance, haulage, etc.

O. Overheads. All administration and non-grant earning expenses of that character. Supervision, premiums on workmen's compensation insurance. All payments made by the Treasurer and the Surveyor for overhead services that will be chargeable to jobs, other than payments which fall to be allocated to depots, manufactures and plant jobs.

The codes for expenditure will be the headings under which this expenditure is usually classified.

P. Plant. Purchase, maintenance, insurance and running expenses (including light plant and tools).

The codes will be the items of plant to which the expenditure relates and a sub-analysis will then be made on the separate plant history sheets.

4. Code Numbering. Typical codes for maintenance and improvement works on County Roads.

Carriageway works.

1. All general maintenance such as pot-hole filling, cutting back grass edges, and minor maintenance works.
2. Tar-spraying and gritting.
3. Scarifying and miscellaneous operations incidental to strengthening haunches and reconditioning foundations.
4. Scarifying and miscellaneous operations incidental to resurfacing to same specifications as existing surface.
5. Scarifying and miscellaneous operations incidental to reconditioning foundations to improved specifications.
6. Scarifying and miscellaneous operations incidental to resurfacing to improved specifications.

Footpaths, etc.

7. All maintenance work on footpaths, kerbs, channelling, replacing trees, fencing.
8. All new works, paving on footpaths, new kerbing and channelling, planting, trees, new fences.

Drainage works.

9. Repairs to surface water drainage, gullies, etc.
10. Provision of new surface water drainage, gullies, etc.
11. Provision of combined surface water and foul sewer drains.

Traffic and public safety, etc., services.

12. Repairs or renewal of guard-posts, road signs, direction posts, name signs, warning signs, reflecting mirrors, milestones, fences, necessary for the protection of the public.
13. Provision of new guard posts, road signs, direction posts, name signs, warning signs, reflecting mirrors, milestones, fences necessary for the protection of the public.
14. Maintenance of retaining and sea walls necessary for the support of the highway.
15. Construction of new retaining and sea walls.

Bridges.

16. Maintenance of all road bridges.
17. Reconstruction of all road bridges.
18. Maintenance and working of swing bridges as defined in Classification grant circulars.

Loan charges.

19. Charges in respect of loans admissible as Classification grant expenditure.

Inadmissible items of expenditure.

20. Scavenging, street cleansing, snow and water clearing, clearing of gullies, expenditure within tramway limits.

Recoverable services.

21. Filling in trenches opened up by gas and other undertakings, etc.

Extra codes.

R.S. Road-side stocks not for immediate use.

X. Unallocatable and unproductive expenditure. Tea boys, etc.

5. It will be observed in the classification of works for code purposes that more than one operation has been grouped under a single code number. Authorities generally, especially those who employ Holerith or other machines for analysis and cast purposes, will desire to have the unit costs of each separate operation taken out, and indeed many may consider it necessary to analyse the operation costs still further, *e.g.*, when concreting is being carried out on a large scale to ascertain the component costs of the works of preparation, mixing, spreading, etc. This can be done by sub-coding the operations and analysing in further detail; or when unit costs are found to be abnormally high or low to ascertain what the detailed operations actually cost per unit of work by re-analysing the primary records of expenditure which contain all the essential data. There is an advantage in limiting the number of codes when a revised system is first brought into use, and introducing the sub-codes when the records are established and when the necessary staff is available.

The suggested codes are typical only, and if a standardised cost accounting system should be introduced the engineers should decide the operations to be coded.

6. Work upon improvement grants will be coded in accordance with the items in the bills of quantities—code numbers being given for all operations the progressive unit costs of which are essential—and for groups of operations in respect of which lump sum provisions will be adequate. On all works, however, a special code X should be employed to cover unproductive expenditure, *e.g.*, tea boys, lost time, etc.

7. NOTES ON THE SPECIMENS SET FORTH IN THE CHARTS.

Specimen 1.—Time Sheet.

The actual design of the time sheet is left to each Authority, so that any special information the Council or the Surveyor may desire for control or statistical purposes may be provided for. The minimum particulars essential are data from which the wages sheets can be prepared (name, occupation, hourly wage, etc.); notes as to jobs and operations on which employed and time spent on each job and operation to nearest half hour should be furnished by the men. How time occupied when not working—sick, waiting orders, etc.; notes of out-of-pocket expenses due to be refunded, etc. Each authority should also decide whether the time sheet shall be used by men operating plant to record the particulars of the plant and its use for

the plant history record (Spec. 11), or whether separate returns shall be provided for plant. All information essential for the cost records should be entered on the time sheet.

Specimen 3.—Control Account.

In the first three columns are posted the actual sums expended on wages, materials and miscellaneous each calendar month, and the totals should therefore agree with the finance account of the Authority. The cross cast totals are taken from the cost records. The only difference in respect of wages, if any, will be payments made by way of advances etc., to men after the close of the last costing period of the calendar month. Post that difference, when proved, to column L D which has been provided to meet a similar difficulty with materials. Clear such entries in the month following.

Materials costs will be similarly treated, a column for rebates discounts has been provided to bring out the differences in expenditure carried to the cost accounts.

In respect of miscellaneous accounts, the actual expenditure for the calendar month is taken into the cost account so that the cross totals should agree with the amount expended shown in column 3.

Against the item overheads in this account post the allocations to each job as brought out in Specimen 13. The aggregate of the cross totals for overheads should equal the total of the postings to column O in this control account after deducting the total of column R for rebates discounts. (*See note (e) below*).

The cross totals in respect of the charges for plant raised against each job (see Specimen 13) are also posted to the control account and column P is credited by writing out the total posted thereto. The difference between the aggregate amounts of the cross totals and the total for the month of Job P will represent the profit or loss on the use of the plant. This difference should agree with the difference between the totals brought out in Specimens 10 and 12.

Thus this account will show in respect of every month—

- (a) Column 3.—The cumulative total of expenditure incurred.
- (b) Job Columns.—The cumulative total of costs charged in cost records against each job.
- (c) Column D.—The total expenditure to date in respect of depots. The depot accounts of income and expenditure will be kept separately.
- (d) Column M.—The amount of expenditure allocated to manufacturing units whose accounts will also be separate.
- (e) Column O.—As only the overhead expenses properly chargeable to jobs will have been brought into the works cost accounts, there will be a residue of expenditure allocated to overheads which will represent administration and non-grant earning overhead expenses. This residue will appear in column O for cross cast purposes and the figure should agree with the allocation in Specimen 14.
- (f) Column P.—The red ink or black ink balance in this column will represent the profit or loss on the working of the plant.

(g) Column L.D.—The actual figure in this column will represent the late deliveries in respect of materials and late advances, etc., of wages not yet carried into the cost records.

(h) Column R.—This should show Nil as the rebates and discounts have been cleared each month in the distribution of overheads.

Specimen 4.—Job Sheet. Analysis to operation codes.

A working sheet. A job sheet is required for every job in hand and one each in addition for depots, manufacturing units, overheads and plant. The ruling of this sheet is used for other purposes, see specimens 7, 8, 10, 13 and 14, and it can be used for specimens 12 and 15. Cheap paper will serve for the working sheets. The first column in this specimen is marked "Particulars" but in practice this column can be used for a binding margin or for notes. The first entry to be made under each operation code is entered on the top line, thus economising in space. It need hardly be added that postings in bulk will be made to this record whenever a number of men have been engaged on the same operation. Note code X for unproductive and unallocatable wage payments, e.g., tea boys, waiting and sick time (if paid for), etc. These will find their way to operation codes when the overheads are distributed. Note also, code R.S. (Roadside Stocks) for wages paid to labour handling or breaking the roadside materials. Carry operation totals of each job sheet to the summary of operation costs (Specimen 15).

Specimen 5.—Job Summary Sheet.

Into this summary are gathered the totals of the wages "Analysis to operation codes" for the 4 (or 5) weekly costing periods of the month. The grand total of the summary should agree with the total wages paid as shown in the third column of specimen 3. The cross totals are posted to the allocation to jobs record (Specimen 3).

Order Forms, Delivery Notes, Invoices, Stores Issue Notes, Stores Return Notes.

In order that the Authority may record the commitments entered into, the quantities and the unit prices of the materials required on each order should be recorded on the office copy of the order. If an "Open" order is issued state probable total quantity on office copy. As with Time Sheets see that all essential data is entered upon the Delivery Notes, Invoices, etc., to facilitate posting to records.

Specimen 6.—Materials liability record.

The value of orders, deliveries and payments are recorded in respect of each merchant, depot or manufacturing unit. The last three columns in the deliveries section are reserved for particulars of deliveries after the close of the last weekly costing period each month to facilitate reconciliation between the cost records and the finance accounts.

Specimen 7.—Analysis to operations codes (materials).

This form serves the same purpose for materials as Specimen 4 serves for wages, and the form is identical in outline. It will be appreciated that the aggregate of the 4 (or 5) weekly costing job totals from the job summary sheets will not equal

the total of the accounts passed for payment as in third column of specimen 3, because the expenditure shown in column 3 will include deliveries up to and including the last day of the calendar month whilst the cost records will only take account of deliveries up to the close of the last cost week of the month. Each month there will be overlapping differences to be reconciled. Trade and cash discounts, as recorded in specimen 6, will be taken into account in the expenditure shown in the column provided for the purpose but will not be allowed for in the postings to the cost records. Post the discounts to the column provided in specimen 3 in red ink and a cross cast should then be obtained. Note the R.S. code for roadside stocks. The rebates and discounts will be deducted from the operation costs when the overheads adjustment is made each month.

Specimen 8.—Analysis to operation costs (Miscellaneous accounts).

On-costs. These are analysed to jobs and codes after the accounts have been examined and passed for payment. A liability record similar to that used for materials should be kept, but as labour and materials expenditure represents so large a proportion of the cost of the operations it will not be necessary specially to record the charges in respect of services rendered after the close of the last weekly costing period of the month. Carry the whole expenditure on on-costs, less discounts and rebates, into the cost accounts each month. General overhead expenses, will as with labour and materials go direct to Job O. The expenditure and cost record totals should agree.

Specimen 10.—Analysis of plant expenditure to items of plant.

Into this statement are gathered the labour materials and miscellaneous expenditure allocated to Job P. (Plant). The expenditure is here analysed to each item of plant.

Specimen 11.—Plant history record.

This is a permanent record. In respect of every item of operative plant a record of the expenditure thereon, its use and earnings are recorded and this record forms the basis of charges to be raised for the use of the plant. The charges will be based on scaled Ministry of Transport allowances. The average unit cost per hour or day of working, will also be ascertained and comparison effected between the actual expenditure and the charges raised, whereby reconciliation may be effected between the cost and the control accounts.

Specimen 12.—Plant charges analysed to jobs and operation codes.

This is a working sheet which is used to ascertain the direct on-costs to jobs and operation codes. The last analysis column is reserved for general on-cost charges to be distributed later.

Specimen 13.—On-costs analysis to operation codes.

This working sheet is employed to bring together all on-costs after analysis to operation codes. The miscellaneous (on-costs) expenditure code analysis comes from Specimen 8.

The plant code analysis expenditure from Specimen 12. The overhead code analysis is arrived at by a process described on the chart just below Specimen 14. This is the distribution of Job O. allocations.

Specimen 15.—Summary of operation costs (each job).

This is the permanent record of operation costs for each job. In it expenditure on labour and materials are posted each week whilst the miscellaneous payments, and overhead charges are posted each month after the actual expenditure and the assessed charges for plant, etc., have been ascertained. The Code X is an important one to watch for control purposes as it represents unallocatable and unproductive expenditure.

Specimen 16.—Engineer's measurements.

To obtain unit costs, the volume of work performed must be measured, and if the progressive expenditure is to be controlled, the unit costs must be ascertained at frequent intervals. The suggestion made is that each week one fourth of the operations should be measured and the unit cost of each ascertained forthwith. The engineer when measuring up should also state the quantity of unconsumed materials on the site relating to each of the measured operations. This will ensure that only the net value of the materials consumed in the measured work shall be included in the unit figure to be ascertained.

Specimen 17.—Monthly progress report and revised estimate.

The Council and the Surveyor should know how the works are progressing in relation to the financial provision therefor, and this form allows that to be ascertained.

8. Questions are bound to arise as to how certain items of expenditure shall be carried into the cost account, and a few of them are anticipated hereunder as a guide to cost clerks.

1. Q. Materials delivered to the roadside in anticipation of future works. Stone that may have subsequently to be broken at the roadside.

A. Charge all expenditure in producing or purchasing, hauling and handling the metal to the road job number (not to Depot) and analyse to code R.S. provided in the summaries. As lengthsmen draw supplies from the dumps for patching they should record in their returns the quantities used to the nearest half cube yard and the value of the drawn material will be debited to the operation code and credited to the R.S. code in the relative analysis sheets. The balances of roadside stocks can be periodically checked and values adjusted, if necessary.

2. Q. Payments made to injured men under Workmen's Compensation Acts.

A. This is recoverable expenditure generally. Charge to Job O. (overheads) and allocate to a separate code thereunder.

3. Q. Labour employed operating plant and machinery on road works (excluding labour employed in repairing plant and machinery).

A. Charge wages direct to works job and operation code.

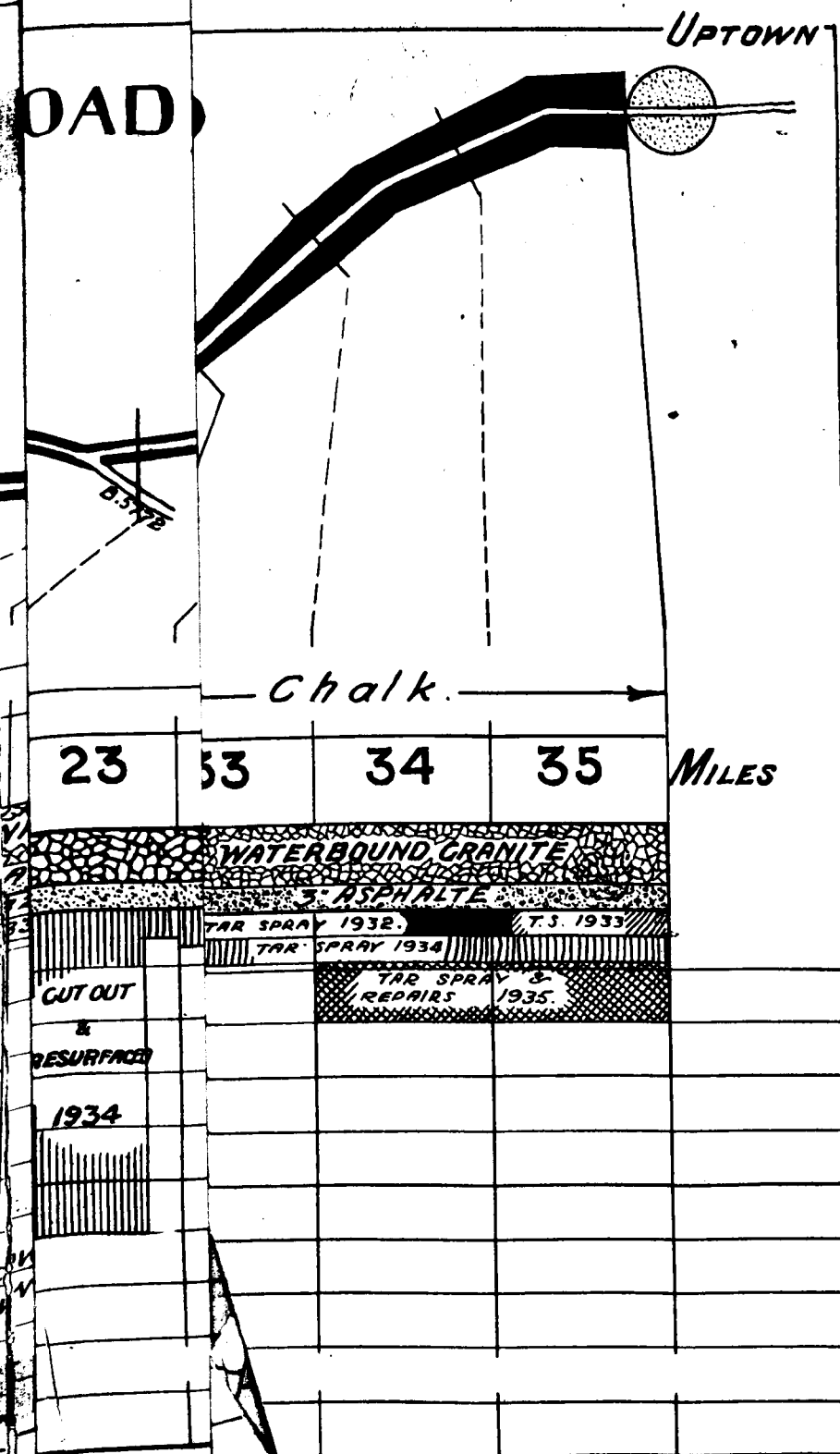
4. Q. Labour employed in repairing machinery and in sharpening tools (excluding plant, machinery and tools employed in the manufacture of materials, expenditure upon which comes into the cost accounts included in materials).

- i. Heavy plant on which percentage of initial cost and running charges form the basis of the M/T allowance.
- ii. Plant and machinery in respect of which inclusive hourly or daily allowances are available.
- iii. Light plant and tools for which an overall percentage on the cost of the works is allowed.

A. Charge all to Job P. (Plant) and through Job P. to the plant history records.

- i. The cost of running repairs will be added to the calculated percentage allowance when ascertaining the charge for grant purposes against each job.
- ii. The cost of all repairs is included in the hourly or daily allowances so that the appropriate allowance only will be charged.
- iii. These charges are all covered by the over-all percentage allowance. The amounts charged in the final claims will be posted to the earnings column of the "light plant and tools" code. The records of expenditure and earnings are necessary for reconciliation purposes with the finance account.

To the practical man the question will arise as to the cost in respect of staff and stationery of introducing such a system of accounts. There is obviously a prodigious amount of valuing, sorting, casting and record work to be done. Even with the simplest form of account the many jobs in progress in a county at any one time necessitate the preparation of time and wages sheets, orders and store accounts, returns of output etc. to enable allocations of expenditure to be made to the various financial sanctions, and subsidiary records have to be maintained to provide the information required by the Council and its Committees and to furnish the returns required by Government departments. The proposed cost accounting system does not increase the number of the primary vouchers but utilises the information available therefrom. If the system as proposed is to be adopted and the whole of the work of analysis and record is to be done by clerical labour, then each authority must be prepared to engage additional clerical staff and to expend a substantial sum each year on analysis forms. This expenditure, if general experience is a reliable guide, will be recovered several times over from the results to be obtained. It is not necessary, however, to spend additional money on staff and stationery as there are available to-day calculating machines that will carry through the whole of the analysis, casting, and recording work much more expeditiously and economically than can be achieved by clerical labour, and the machine can be employed for other services of the Council. For this reason the Congress need only address itself to the merits of the system proposed.



COUNTY - COUNCIL

MAIN ROAD

KINGSTOWN

TRAFFIC DENSITY (AVERAGE DAILY TONNAGE)

SCALE: 1 INCH = 20,000 TONS.

Downside

-Gravel Subsoil

-Chalk

FOUNDATION.

SURFACE.

V-

2/-

5/-

4/5/

6/

7/-

8/-

39/-

40/

NOTE:

THE PURPOSE OF THIS CHART IS TO SHOW:-

(1) ORIGINAL FOUNDATION AND SURFACING ALONG RO1

(2) ALL MAINTENANCE OR IMPROVEMENTS COSTS YEAR

(3) TO DIRECT ATTENTION (AT SIGHT) TO HIGH & LOW COSTS IN HIGH TRAFFIC DENSITIES AND SUBSOILS IN PART EXPLANATION OF HIGH COSTS.

(Face page 580)-1

MAIN ROAD SURFACING CHART

A 500

SCALE: 1 INCH TO 1 MILE

UPTOWN

Downside

A.544

B.5794

A.522

D.578

A.521

Chalk

Clay Bed

Chalk

13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31 32 33 34 35 MILES

9" HARDCORE

9" CONCRETE (R)

WATERBOUND GRANITE

TAR SPRAY 1933

3" TARMACADAM

TAR SPRAY 1932

TAR SPRAY 1934

TAR SPRAY & REPAIRS 1934

3" TARMACADAM

TAR SPRAY 1933

T.S. 1934

3" ASPHALT

TAR SPRAY 1932

TAR SPRAY 1934

TAR SPRAY & REPAIRS 1935

REPAIRS

GUT OUT & RESURFACE 1934

IT MAY BE DESIRABLE TO DISTINGUISH THE SEVERAL SPECIFICATIONS BY COLOURS OR CROSS HATCHING IN WHICH CASE THE YEARS WILL BE DISTINGUISHED BY NUMBERS.

580B

SPECIMEN 2.

SPECIMEN 1

ALL PAYMENTS FOR WAGES
SUMS DUE UNDER WORKMENS' COMPN ACTS
N.H.I. ETC., INSURANCES
ALLOWANCES - AND ALL PAYMENTS
MADE THROUGH WAGES SHEETS

SPECIMEN 3.

SPECIMEN 5.

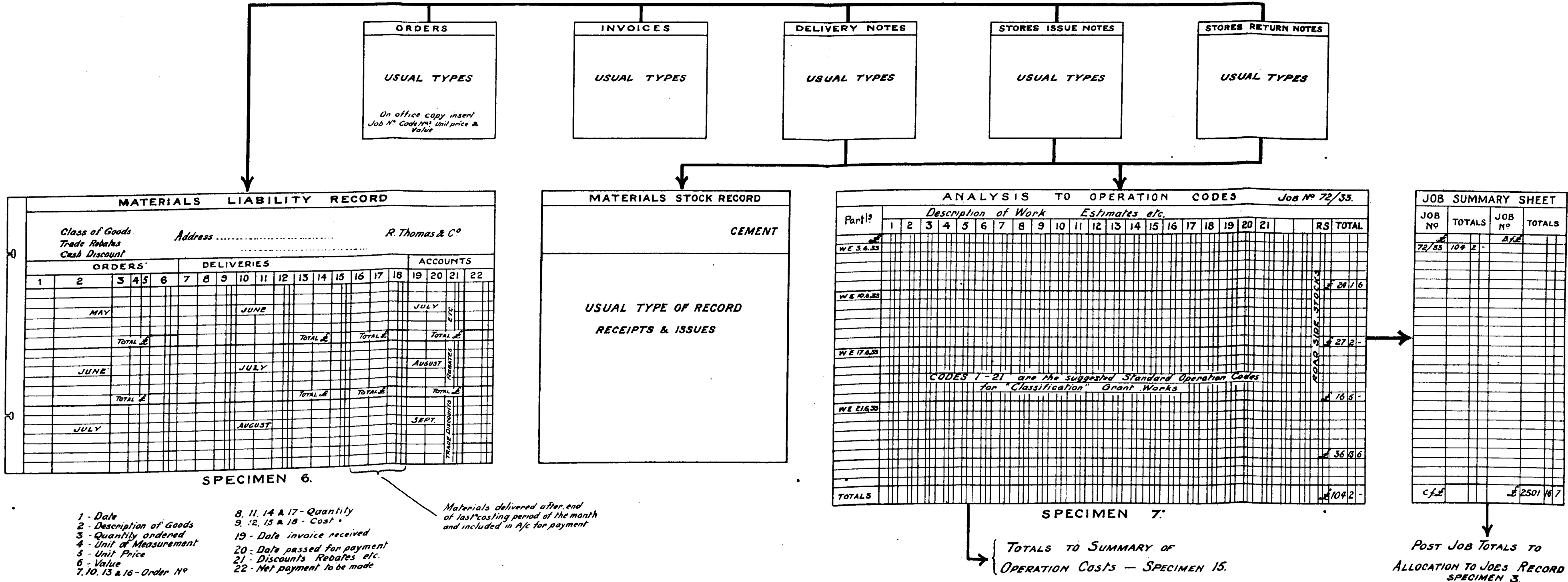
SPECIMEN 4.

SPECIMEN 15.

580C

MATERIALS

COSTS OF ALL MATERIALS DELIVERED TO WORKS - DEPOTS - MANUFACTURING UNITS & FOR PLANT REPAIRS ETC.



ALL EXPENDITURE (OTHER THAN LABOUR & MATERIAL) PAYMENTS BY TREASURER OR BY SURVEYOR FROM IMPREST FOR JOBS AND ADMINISTRATION SERVICES

GANGER'S RETURNS

*Giving details of
Hired Team, Labour,
Rollers etc, Times working,
When working etc.*

[illegible][illegible][illegible][illegible][illegible]

TOTALS TO SPECIMEN 13.

➤ *POST JOB TOTALS TO ALLOCATION JOBS RECORD
SPECIMEN 3.*

OVERHEADS

FINAL COSTS

UNIT COSTS

AND

REVISED

SPECIMEN 14.

ONCOSTS DISTRIBUTION

PROCEDURE

PLANT Direct operation charges already coded on each job but there may be plant charges that are chargeable as a general overhead.

see SPECIMEN 13.

OVERHEADS Having ascertained total chargeable to jobs - allocate on basis of total expenditure to date on each job - SPECIMEN 3.

Expenditure to date on each job - SPECIMEN 5.
To each job allocation thus ascertained add expenditure against X
SPECIMENS 4, 8 AND 13

Distribute resultant totals for each job to the operation codes on basis of total expenditure on each code shown in specimen 15. Then post to SPECIMEN 13.

SPECIMEN 15.

ENGINEERS NOTES
Weather conditions
Breakdowns etc.

NOTE To obtain full cost measured, add 20% on expenditure for current month. Oncosts not posted to SA

Date 19

SPECIMEN

DISCUSSION ON PAPERS BY MESSRS. E. TASKER AND P. TAIT.

MR. E. TASKER, introducing his Paper, said: In holding appointments in various parts of the country one cannot fail to observe that certain sections of Highways Departments are efficient in some parts of the country, whereas in other parts other sections are efficient. It has been a source of pleasure to me to collate information and set it forth as a Paper on "Efficiency." The design of an engineering structure is more or less a mathematical treatise on orthodox lines, which presents little scope for discussion, but I trust that the suggestions made in my Paper afford ample scope for a good discussion. It is not suggested that the Paper is a list of recommendations; recommendations can be made only in respect of a specific department.

Investigation reveals amazing facts. In preparing the data for this Paper the most astounding discovery I made was that the administrative costs of a certain County Highways Department is thirteen times greater than it was twenty years ago. I do not wish it to be inferred that it costs thirteen times as much to administer road works. To-day work is more technical, more survey plans and detailed estimates have to be prepared, the accountant yearly calls for more figures, and we have to reach agreement with an ever increasing number of authorities and associations. All these things add to the administrative costs. Twenty years ago some of the administration was distributed among Rural District Councils: to-day it comes under one head.

I am indebted to the County Surveyor of Gloucestershire for permission to use the table and chart (pages 592-3). They show that on county roads traffic is now twice as great as in 1926, five times as great as in 1922, and thirteen times as great as in 1911. Such an increase in traffic has naturally meant an increase in road works, and inevitably an increase in administration.

The running of a private commercial firm is a different matter with a very large undertaking from a one-man business. We are in competition with foreign countries. If we are to retain our position as the premier industrial nation, we must reproduce those conditions which brought us to that position. In the industrial revolution the trade of

Britain increased; there was an unprecedented boom in trade. That was due in no small measure to the introduction of machinery, and not only to the introduction of it but to the fact that we were ahead of our foreign competitors; we were more efficient than they were. A repetition of those conditions will again put us in the forefront.

If private firms, large commercial undertakings, find that office machinery and methods of efficiency—some of which I have mentioned in my Paper—increase their profits, then such machinery and methods of efficiency are commendable to highway authorities, who are out not only to reduce expenditure, but to effect economy. It is sometimes thought that a machine is obsolete only when it is too old to be repaired, but a machine is obsolete as soon as it can be replaced by another machine producing a higher percentage of efficiency, although the displaced machine may be comparatively new.

I should like to refer to a remark made by Mr. Adams in respect of arch design two years ago, and to apply that remark to the subject of this Paper. Mr. Adams said: "There is a school which continually looks back instead of forward and assumes that we have now reached the stage when we may rest on our oars." No such stage is ever reached. Efficiency means perpetual improvement.

MR. P. TAIT, introducing his Paper, said: I do not propose to go over the ground of any of the subject matter of the Paper itself but rather to give you the objectives I had in mind when preparing it. In the first instance, I set out to show the statutory powers and duties of the highway authorities and those of the Minister of Transport, their separate and conjoint responsibilities, and the need for co-operation between the parties. Then I deal with the matter of contract disputes which has engaged a very great deal of my attention, and I have drawn attention to the variety of problems and difficulties that have arisen in the hope that we may derive benefit in the future from the experiences of the past. As to the need for cost accounting, I think the time is ripe for the introduction of a standardised system of accounts. I find, as I go round the country, that the technical officers of the highway

authorities and the accountants all seem to agree in desiring that whatever system is introduced shall be as simple as possible, certainly in its early stages.

At the close of the Paper I draw attention to the fact that with a costing system there is no need for heavy additional staff charges to be incurred. Mr. Tasker in his Paper has made considerable reference to the use of machinery as an aid to clerical work, and he has so dealt with it there that I need only ask you to accept my assurance that by the use of machinery the burden of work that is incidental to costing operations can be removed.

The Paper that is before you to-day is not the Paper that I originally prepared. I have stated at the beginning that it is without official significance or approval, but there are some aspects of control over expenditure which it has been considered should be eliminated from the Paper, and for that reason I am only going to make casual references to them without giving my views.

The first stage at which control over highway expenditure can be effected is in the formation of policy, by the officials of both central and local government. Next I should like to emphasise the importance of forecasting expenditure to which reference has been made in the Paper, and I leave it to you who have a practical and everyday acquaintance with the difficulties of budgeting and the making of financial provisions, to consider how far you can increase control over expenditure by forecasting and obtaining timely authorisations for financial expenditure.

I want also to leave the thought with you this morning that it would be a good thing if, in respect of each type of grant where funds have to be recovered, time limits were placed in which requisitions for advances, etc., should be submitted, and if also a follow-up procedure were adopted, so that the money that is due to the authorities would be promptly collected.

There is yet another aspect of the case for control, namely, effective presentation of progressive expenditure in diagrammatic and chart form. I think we should remember that the duties of County Surveyors are largely administrative, and that they have to rely to a considerable extent upon their technical assistants. If accordingly they

can have the details of progressive expenditure in diagrammatic form it will save their time and help them to notice the trend or tendencies of expenditure.

Engineers to-day spend a great deal of their time in close touch with contract problems, and I suggest that it would be a good thing if the Examining Board of the Institution of Civil Engineers would include within the syllabus of its examination a working knowledge of the law relating to contracts. I feel that this would help the technical officials of highway authorities very considerably in the discharge of their arduous and responsible duties.

I should like to emphasise the importance of the costing system and to indicate the considerations that I had in mind when I prepared the particular system that I have embodied in the Paper in diagrammatic form.

First of all, I have assumed that it is all-important, especially on large-scale construction works, that the engineer should have red-hot reliable information of the unit costs of operations as they progress. Secondly, there should be, as the works progress, a reconciliation between the costing and the finance records. In the system that I have put before you to-day I have produced a control account which I believe will maintain a constant reconciliation between the two records.

With cost accounts the information that will come up to the surveyor will not be on the lines of so much in wages, so much in material, so much in use of plant. The information will come to him in the form in which the surveyor as a rule bills and prices his operations, the cost per unit of operation, and I do feel that, if that information comes to the principal technical officers and to the Highway Committees in that form, they will be able easily to discover the progress of their expenditure.

In tackling the first objective, that of obtaining red hot progressive unit costs, I have provided for the posting to the cost records of the liabilities on wages and materials at the earliest stage at which they become costs, and have left haulage, plant and miscellaneous expenditure items of cost to be analysed and carried to the cost records after the actual expenditure has been determined and the accounts for the same have been passed for payment.

With wages, I do not think that you will find much difficulty. Every week or fortnight you know what sum you have expended in wages. With regard to materials, however, I realise that difficulties will arise in costing from delivery and stores issue notes, but good outdoor organisation will assist very considerably.

After all, what is the purpose of all this cost accounting? The experience of the past has amply demonstrated the fact that, when you cost your operations in detail, the knowledge acquired leads to a definite reduction in expenditure. I am satisfied that the cost of the work is amply recovered in the savings that are effected. In going round the country, I have seen some remarkable results that have been achieved by the technical officers and the accountants where cost accounting systems have been introduced.

In conclusion, the purpose of my Paper is to bring nearer the day when, by system and record, we may be able to reduce our highway expenditure to a figure commensurate with the value of the work that is carried out, that we may have efficiency, and I feel that, in saying this to you, I am speaking to technical and accounting officers who have the matter very much at heart.

SIR WILLIAM RAY (*London County Council*): The authority for whom I perform most of my public work is in no sense a highway authority, but in a long period of local administration, one is bound to come up against the problem of highways and their cost, and I think all of us, whether our local interests lie in the direction of highways or education or anything else, cannot help having opinions on the matter of highway expenditure.

Mr. Tait's Paper summarises admirably the position to-day, and I think Mr. Tait indicates very fairly and very considerably, from the local authorities' point of view, a line of country that we might very well explore in the future. Consequently I think we who are interested in the highway and local work generally owe a very deep debt of gratitude to Mr. Tait for the extraordinarily unofficial way, if I may use that term, in which he has approached the problems that are before us.

Perhaps there are one or two points that I might make as an amateur administrator as distinct from the professional man.

Their outlook occasionally must be divergent. I do not know who prevails in the end; very often it all depends on the strength of character of the official man! Speaking from the point of view of the elected person, I think, in view of the fact that road expenditure has grown enormously in recent years, in view of the fact that highways and transport combined are undoubtedly going to be of enormous importance in all local administration in the future, highways and transport may take first place in the local administration in the days to come. At the moment we are engaged in public assistance and education and public accounts and all that kind of thing, but the linking up of the Ministry of Transport so completely with our own ordinary road expenditure, the enormous growth in road traffic and the development which I think is bound to ensue in road traffic are going to make highway and traffic administration one of the most important branches of local administration work. It is because of that point of view and the part that the central Government now plays in the matter that questions connected with the employment of direct labour as against contractors, the standardisation somewhat of contracts and the development of the system of accounting costs are, to my mind, probably the most important points which affect us who are connected with local administration to-day. I am firmly convinced that, from everybody's point of view, not merely for the satisfaction of the gentlemen who write to the Press every November, of the ordinary ratepayer, of the Councillor, or of the ordinary contractor, the time has come to realise that, because of the magnitude of our work, whenever tenders are invited and local engineers and surveyors are asked to make estimates we ought to accept no other condition beyond a scaled tender being put in by our own officers. That may be opposed to many interests and many points of view, but, now that we have arrived at the position when the local authority is seriously engaging in competition with those who provide the money which we spend—the local authorities have no source of income except the source of income of the industries in their districts—I think that, in fairness to the industrial magnates and the people who provide the money which we spend on our services, our

own officers ought to put in sealed tenders when they are in competition with those who are outside. That is a bone which I think probably many will be delighted to pick, but that is a view that I hold strongly at the present time, not in the interests of contractors but in the interests of the officers and of the administration, because there is always subconsciously in the minds of people a feeling that outside people are not treated as fairly as they might be.

Again, I think we are reaching a stage now in road construction and so on when there certainly can be more standardisation of methods. With the thousands of miles of roadway in this country, we ought to have developed by now a technique which, generally speaking, could be universally applied, and I think, in the interests of the ordinary provider of the necessities of war, there ought to be a standardisation which ultimately must result in a great saving of public money.

The last point I want to make is that in all branches of industry to-day costs accountancy is the practice. It is found to pay, and it has been found to expedite the way in which work is carried on, and, now that you are engaged in gigantic operations instead of minor operations, I think it stands to reason that what is a real success in practically every industry one can think of may well be a real success when applied to the work which we are all engaged in doing. Perhaps at the moment we have not reached a standard which we can regard as in the nature of final in its method, but there is no doubt that it is bound to come, and the sooner it comes from our professional men on their own initiative the better it is going to be for everybody concerned.

Mr. J. B. L. MEEK (*Manchester*): In paragraph (15) Mr. Tait says: "The principal objectives of the Surveyor when carrying out works by direct labour are to make a sound job and to keep within his estimate of the cost." As far as I know, they are not. The principal aims of a surveyor are to make a sound job and to make an economical job. Whether the estimate is exceeded or not does not enter into his head so much, or at any rate it ought not to do so. You may easily be and you often are faced with an over-expenditure that you cannot avoid. Unforeseen things happen, and, if you are

worrying the whole time as to whether you are incurring over-expenditure or not, the temptation may arise to scamp the extra work in order to keep inside your estimate, which would be a most deplorable thing and one which I hope no engineer would ever consider doing.

We hear a very great deal about over-expenditure. From an engineering point of view, you can learn quite as much from under-expenditure. My own system is that on every job I have a reason given for either the over-expenditure or the under-expenditure, and legitimate over-expenditure is probably sometimes better than careless under-expenditure through bad estimating. If we did not hear so much about this over-expenditure and had some inquiries about the under-expenditure, I think we should learn a great deal more.

In paragraph (15) of his Paper Mr. Tait continues: "In attaining the latter objective the merit of success depends upon the margin for contingencies disclosed and hidden in the estimate." I hope Mr. Tait does not mean what he says there, because the way to attain the merit of success in carrying out a job is entirely by your organisation. You do not make your estimates by guess work, but you make a plan of your work, and you have got your contingencies. If your contingencies are not used, there is nothing to show against this item, but if your contingencies are used they have to be shown. If, when you have got the unit cost of the labour, transport and everything else, you are then going to start off and hide something, you will be laying up trouble for yourself and will get no good out of it at all.

In paragraph (16) Mr. Tait says: "Comparison between the costs of work carried out by contract and that by direct labour ought to be available for the guidance of each highway authority." Now I do hope that there is never any intention in that clause of asking a contractor to put in a tender for a job merely because the engineer wants to know what the job should cost. That would be absolutely indefensible, because it costs a contractor a great deal to make a tender on a large job. I do think that, unless there is a *bona fide* desire to let a job by tender, it is hardly straightforward or right to ask contractors to tender. They ought not to be asked to tender merely in order to find out

what their tender would be. If an authority has an engineer who, after he has taken his observations, made his plans and made his estimate on those plans, cannot then give a sound estimate to his Council or his employers as to what that job will cost and also give them the proper advice as to whether it is a job that can be carried out by contract or would be cheaper by direct labour, they need not ask contractors to help them. The Council or the engineer's employers have got a good remedy for that; they ought to get another engineer!

There is a suggestion in the Paper that standard forms of contract should be adopted. I am not quite in agreement with that, but I do think it saves a lot of time if you have some standard clauses on which you can build up your contracts, but I do not see how you can possibly have a standard form of contract unless you have standard jobs, and I do not see how your jobs can be standardised. Every job is different. I should warn engineers very strongly that, before they ever attempt to issue a specification for any job at all, they should go through it very carefully and build up the specification for that job and for no other job.

THE CHAIRMAN: I would point out that a standard form of contract is not the same as a standard form of specification.

MR. MEEK: As long as we are clear on that, it is all right.

Mr. Tait makes a suggestion about opening tenders. I do not know whether he has worked with Councils as long as I have, but, if he can get his Council to sit round a table while the staff check the contractors' figures and one thing and another, he is extremely lucky. I think the best thing to do is to have a small Committee and simply open the tenders and note the total price, and then let the engineer at the next meeting of the Committee make recommendations as to which tender should be accepted. It is not always advantageous to accept the lowest tender. You have to give your reasons for the choice you make.

Mr. Tait seems to think that we do not treat our contractors firmly enough, that we do not keep them in their place. I should like to say here that I do not believe in any engineer setting himself up as a policeman to see that a job is carried out exactly in accordance with the letter of the law. That

would be a costly business. My own idea is that the engineer and the contractor should work together to make as good and sound a job as possible, and there must be give and take on both sides. The engineer, of course, has the greater responsibility and he ought not to give up that responsibility. However good a contractor you may have, when all is said and done the engineer has to direct the job and tell the contractor exactly how he wants the work carried out. The engineer, of course, takes the responsibility for any unforeseen circumstances; otherwise you have to resort to the old-fashioned business of putting in a clause which makes the contractor responsible for everything that happens from any cause whatever. If you do that the contractor is bound to cover himself. That cover is paid for by your employers, whether it is actually required or not. They pay for it rather than pay for extras, and in most cases it will be a great deal cheaper to pay for legitimate extras as certified by the engineer.

With regard to claims, if there is one awful job an engineer has to do it is to settle claims. You know perfectly well that some of these claims are quite legitimate and just and you have every sympathy with them, but you have to sit down and think about the question carefully and perhaps give a decision against your contractor, because you are the arbitrator, the referee, between your contractor and your employer. I always think a very good rule to adopt in giving decisions on claims is this. Always make up your mind with this in view: "If the matter is taken to arbitration, can I stand a severe cross-examination on this claim or not?" If you can, you generally are somewhere near right in your decision.

In the section headed "Direct Labour Works" Mr. Tait touches on cost records, and I should like to say here and now that really the value of costing is to produce quickly and cheaply information that helps the engineer; it is not to produce a volume of statistics for comparison with somebody else's statistics. Then Mr. Tait goes on to discuss very fairly whether the accountant or the surveyor should keep the cost records. It seems to me that the only person who can keep them is the surveyor or the engineer. Your cost of works after all boils down to the day's work a man should be able to do in

various branches of work, and I do not think that anybody except the engineer has the training to know the value of the day's work. The basis of labour costing is your timekeeper. As your timekeeper goes round checking the men's time, he also books, as you all know, the allocation of the various jobs on which the men are engaged. When that is done he balances that up with the cost clerk and the wages clerk, and at the end of the week you have your wages balancing with your cost of work. That is then handed to another clerk, the cost of works clerk, who compares it with the engineer's measurements, and every week you get your labour cost. I do not think you want much else as the job goes on. Your materials you buy, and you cannot very well alter the cost of materials week by week, but the weekly labour cost is a most valuable thing which can be ascertained quite cheaply.

In paragraph (48) Mr. Tait advises buying by a Central Purchasing Committee for the whole Corporation, and I quite agree with that. I think in bulk buying for ordinary routine materials there must be a great saving. Of course, that could not be done when an engineer is carrying out a job by direct labour. In that case it is assumed that he is doing so because he can do the job more cheaply in that way than by employing a contractor, and, if he is to do that, he should have the contractor's advantages—he should be able to buy when, where and how he likes and get his men where he likes, and, if they are not satisfactory, discharge them at once and get some others. You must trust someone, and if you have a job to be carried out by direct labour you surely ought to be able to trust your engineer without tying him down to having to go to Committees, and so forth. If he has to do that, whilst he is trying to buy some tons of stone, for instance, somebody else may get it at a very much cheaper rate, and he has missed his market.

In the Appendix to his Paper Mr. Tait sets out a model system of cost accounting. It seems to me that it is rather cumbersome and that it is really a system of preparing data for comparison with other jobs in different parts of the country. Of course, an engineer knows that such comparisons are extremely dangerous and useless in many cases. You need a great many details before you can get a comparison, and the

labour required for doing that would be enormous. I do not think the cost of works can ever be useful as a comparison unless it is very carefully detailed out, but I do think the cost of works is essential to guide you in carrying out your work by direct labour, to see that you are getting a day's work from your men. Also, if you have got many jobs on hand, it does give you an indication of where a weak spot is and you can get to it and put it right while the job is going on. After the job is over you can have your on-costs added. Your taxes and rates, etc., come in in large amounts and very irregularly. At the end of the job you have comparisons of what the work costs as compared with the estimates. I do think, however, that in carrying out work by direct labour it is much better to make your estimate on the prime cost and to keep to your prime cost, and then at the end add every other charge to it.

MR. A. C. HUGHES (*Hants County Council*): I should like to deal with a few points in Mr. Tasker's Paper. The remarks by Disraeli which are quoted at the beginning of the Paper were unknown to me before. I think they are particularly appropriate at the present time, especially the second one, written in 1863: "Economy does not consist in the reckless reduction in establishments; on the contrary, such a course almost necessarily tends to increase expenditure." That is a point that perhaps some of our Councils might well bear in mind at the present time.

Mr. Tasker gives in his Paper a rather imposing and formidable list of machines for use in offices. Of course, there can be no doubt as to the advantage to be gained from them, but I am not quite sure whether it is entirely desirable to mechanise the office of a public authority. It would, at any rate, kill the present system of promotion. In Hampshire—and I except it is the case with most local authorities—we have an entrance examination for the clerical staff, and we always look on every probationer as a potential chief clerk of his department.

I think if the boys were put for any length of time in charge of soul-destroying machines, they would lose their initiative, and I think the inevitable result would be that the recruitment of the county services would fall off in quality, or we should have to have two

grades, somewhat similar to the practice in the Civil Service. While in the case of the Civil Service that system seems to work admirably, I think that the other system is by far the more practical and certainly the more democratic system.

I should like to join issue with Mr. Tasker on the cost of writing letters. It rather scared me when I saw the figure which Mr. Tasker gives. We went into the matter in some detail in the correspondence section, and we found that apparently Mr. Tasker's filing clerk and typist were not particularly good performers, because the cost ought to be and can be very much less than that given in the Paper. With precisely the same data but putting in a different production for the individual persons, we found that the letters of the Chief Officer cost 1s. 1d. each. I think, considering the type of letter which the Chief Officer has to write in the normal way, 1s. 1d. is a very reasonable cost, especially when you think of what we have to pay a lawyer when he writes a letter for us!

Mr. Tasker does not say anything about pre-costing. I am afraid that is perhaps an incursion on Mr. Tait's Paper, but I do attach very great importance to what I call pre-costing. It is something which gives you your commitments. You place large orders at the beginning of a contract which you are carrying out by direct labour, and you know that certain wages are going to be paid, and by devising a very simple little system you can tell quite easily what your commitments will be for a couple of months ahead. That is a very important matter, especially in the case of those authorities that still have the receipts and payments form of accounts. I take it that it is a matter for county accountants more than for county surveyors and county engineers, but I hope it will not be long before the receipts and payments form of accounts is abolished.

With regard to the road and bridge list which Mr. Tasker mentions, those of us who have that find it very useful indeed; I refer to the diagram on which you put down the progress of your work every year. I suggest, as an improvement or addition, putting above it a strip cut from an ordnance map on a suitable scale, on which you mark the sections referred to by name on the diagram below.

Another suggestion I should like to make is

this. If you put the bridges on a map such as I have mentioned you will have very great difficulty in finding them quickly, and at any rate you have not got a great deal of room to put in the details, and I think it will be found that the compilation of a really accurate bridge list, giving in great detail the types of the structures and the history of them, will pay you time and time again for the trouble you take in making it, when you want to refer quickly to some particular bridge and find out all about it.

Mr. Tasker gives in his Paper some very excellent details of the procedure to be followed with improvement schemes and improvement and building lines. I notice one thing he has not provided for, and that is the sending of the plans to the Ministry before they are taken to your Committee. The Ministry, quite properly, are trying to achieve some form of standardisation in the widening of roads. It has happened, and I am afraid it must happen in all authorities, that the suggestions you put up do not quite agree with those standard ideas. If you put your plans before your Committee first and carry on with the procedure, you may find that some alteration has to be made and you have to start all over again. It has been my practice to send those plans to the Ministry before I put them before my Committee, and I think you will find that that saves a good deal of trouble. Under the headings "Improvement Schemes" and "Improvement and Buildings Lines" I think it should be stated that before the plans are placed before the Committee they should be sent to the Ministry of Transport for approval.

There is another step in the procedure in connection with improvement and building lines which Mr. Tasker has not mentioned, but which I feel sure he has dealt with in his own office, namely, that before you ask the Committee to prescribe a line you should get an estimate of the compensation involved and see whether you can get a grant from the Ministry of Transport.

MR. E. H. FORD (*Coventry*): I think Mr. Tasker's Paper is really summed up by the statement in the paragraph headed "Psychology" which says: "This ideal"—that is, the Utopian efficiency to which reference is made in the preceding sentence—"is difficult to attain, particularly in local

government service. It requires great tact and diplomacy, an *esprit-de-corps* with unflinching loyalty, and unprecedented team work." The "Conclusion" at the end of the Paper also sums up the whole matter.

I think we should utter a word of warning to some of the younger and more enthusiastic members who read this Paper. I do not think you can place absolute reliance on any system or on any machine. I believe that to-day individuality and keenness on the part of every member of the staff will count for much, and I think also that the eye of experience can always see when waste or inefficiency is going on, without waiting for a graph or any other costing system to point it out. That is only a note of warning. I do not mean to imply that I do not agree with the various points Mr. Tasker has made in his Paper.

One finds very great help in the use of machines, but I was rather amused at the remarks Mr. Tasker makes about the dictagraph, where he refers to the engineer listening in to his Committee and continuing his normal work at the same time! We are all supposed to be supermen, I know, but I can hardly conceive that system being very much good. I was also rather amused by the statement, also in relation to the dictagraph: "The official may speak through the instrument to any member of the staff or any room from any part of his own room while both his hands are free for other work."

Mr. M. T. HUGHES (*West Sussex County Council*), speaking on Mr. Tait's Paper, said: My own view of this matter is that we should not try to run before we can walk, and I think that to initiate a costing system which goes into meticulous detail is going to take us on the wrong road. We have to be particularly careful that the system, as it is outlined at first, achieves two main objects. The first of those objects is to supply, not in great detail, information to the engineer, as Mr. Tait has said, red hot, to enable him to know, so far as the finance is concerned, the progress of his work. The second is to supply statistics for comparative purposes.

A costing system must, I think, be divided into two distinct parts; one for maintenance and one for special improvements.

I will deal very briefly with special improvements. In my opinion it is necessary that the engineer in charge should keep some

sort of costing record, and to a very large extent that must be a daily record. His records must be locked up periodically—say fortnightly or monthly—with the main records at the head office. I join issue with Mr. Tait when he attempts to base a costing system on delivery notes. I think that the information at present contained in delivery notes is such as to be too unreliable to incorporate in a costing system. It would necessitate a subsidiary costing system of credits against the costing heads for adjustment purposes. Most of us could elaborate a costing system, but the difficulty is to devise that costing system in such a way that the hundreds of steps are taken at the right time and in the right place, in order to collect the many subsidiary totals until the final total for a certain classification of expenditure is obtained. That is the difficulty which a costing system presents.

With regard to maintenance expenditure, take, say, half a million pounds, there may be three hundred sections of main units each having twenty headings of subsidiary costs, so that you run into something like four to six thousand minor units of cost.

I am satisfied in my own mind that any such costing system undertaken by manual labour will be unsatisfactory and uneconomic. We have got to face the fact that such a system must be carried out by machines.

I know I shall meet with many opponents when I say this, but in my opinion any costing system must be the basis of or locked up with the accounting records. I prefer "the basis of," and I prefer it for two reasons. Firstly, if it is the basis of the accounting system there is no necessity for a subsequent adjustment with the costing records. Secondly, at the present moment the costing records generally are not associated, although they may be agreed in total, with the accounting records. Now because they are not "associated with" they do not come under the purview of the District Auditor, and no claim on the Ministry of Transport is certified by the District Auditor. No other Government Department in the country except the Ministry of Transport disburses grants to local authorities except on the certificate of a District Auditor. The Government disburses on classification grants, some £13,000,000, and the only check it has is made by a very small staff of financial

officers at the Ministry of Transport totally insufficient to deal with those claims and to see that, so far as the Government is concerned, the funds are being properly distributed. I say for that one reason alone it is vitally necessary, in my opinion, that any costing system should form the basis of the accounting system.

Mr. Meek, of the City of Manchester, indicated that it is not necessary for a costing system to supply figures for the purpose of comparisons. If a standardised costing system is brought into force—and I hope it will be—at the instigation of the Ministry of Transport, then, as a result of that standardisation of costs, statistics will be prepared in the Ministry of Transport which will be of vital importance to the country in connection with highway costs, not only to the local authorities themselves but also to the Minister, and it is completely beyond my comprehension how any intelligent person to-day can say that records of that character can be of no use unless multifarious factors are brought into consideration. We all admit that it is going to be a most difficult task, but, unless it is tackled and started, there will be no birth and there will be no growth in this particular sphere.

Mr. E. H. COLLCUTT (*Cornwall County Council*): There is no detail in this Paper of Mr. Tait's that is not familiar to every surveyor in the room. Ninety per cent. of what is stated in the Paper is the practice in, shall we say, ninety per cent. of the county surveyors' offices of the country. I have been astounded during the discussion, except in the case of the two surveyors who have spoken, at the lack of knowledge displayed and the lack of touch with the work of the highways system of the County Councils of England and also with the practice of the Committees of those County Councils. Do these gentlemen imagine that county surveyors do not put in tenders? They are quite right. The county surveyor submits an open estimate which is available for everybody to see, and never is a job carried out, in my experience, without the county surveyor's detailed estimate. Why call for his sealed tender?

Now Mr. Tait's Paper is a good Paper, if I may say so, and it calls for a discussion. It has brought me some three hundred miles to make an appeal to him. Like Sir

William Ray, who has probably given us more worry in the past twelve months than any other man in the country, Mr. Tait has it in his power to give the highways department of every rural district council, every urban district council and every county council, in this country, a vast increase of clerical work, if he likes to turn his mind in that direction. I am going to appeal to Mr. Tait to sit down and think what it is exactly that he wants. He wrote this Paper with a purpose. He knew that a proposal had come from the Ministry of Transport that our accounts should be standardised and he wanted to draw an opinion from us, and I am prepared to give him one. Mr. Tait has the opportunity of seeing the accounts of every county council in England, and he can therefore give every county surveyor a new hint here and there as to how he can improve his costing system. That I admit, and I think that we are under a very great debt of gratitude to Mr. Tait and his Department for the manner in which they have carried out their duties, but I see a considerable amount of danger in this proposal of the standardisation of highway accounts.

In paragraph (43) Mr. Tait says: "There has been considerable discussion of the question whether the cost records should be maintained by the Accountant or the Surveyor." The surveyors have been keeping these costs for years. I have a detailed costing system which is open to any member of the Council or any member of the Ministry of Transport. It is quite untrue to say that grants are made without access to the details of the costs of the work, an observation which has just been made by an accountant. It is quite untrue that these vast sums are paid out by the Government without such details. The most intimate details are given to them; in fact, far more details than they require.

Mr. Tait is going to take a very great part, I believe, in forming this system of standardisation of accounts, and I ask him to limit his costing accounts to his requirements.

When I was at the Road Board as an Engineering Inspector I was given a room full of documents familiar to every one of you, namely, the returns of the surveyors of their cost of tar spraying. I do not know how many of those returns there were, but I

should think about 20,000 or 30,000, and I was told to make use of them. I disgraced myself for ever with the Road Board by saying that I did not need 20,000 forms to tell me that the cost of tar spraying in those days was 3 point something pence per square yard, and that the best thing they could do with those forms was to put them in the wastepaper basket. We do not want a repetition of that kind of thing. The Ministry have been assisting us very much lately in cutting down unnecessary forms and in trying to simplify matters for us. I am one of those who think that the man who wants to know the cost of his work is the surveyor and not the county accountant. I believe we are entering upon a phase of too much centralisation of costing. What can the Ministry do with these sheaves of returns that they get? They can only average them and use them on that basis; they cannot use the details. The accountant cannot use the details. He may publish as many details of costs out of the surveyor's returns as he likes, but those details are not used by the County Councillors for whom they are prepared, because they cannot understand them. The county surveyor personally can only use them to a limited extent. He does not go altogether by instinct as to whether a job is costing more money than it should do. He goes by the costing figure which is put on his table on a Monday morning. There may be fifty of those costing figures put on his table, and how much time can be given to the detail of them? The man who wants to know what each job is costing is the divisional surveyor who is carrying out the job. I have seen in my experience headquarter costing in the county surveyor's office, and I have had to deal with divisional surveyors who overspent their money. When the divisional surveyor was asked to explain he said: "Because I asked for the cost of such and such an item three weeks or a month before and I only got it when it was too late to be of any use." In many offices in this country we are giving our minds too much to central costing rather than costing by the man on the job.

May I speak for my county for one moment? I believe it is not the general practice, but the costing of my county is done in the divisional surveyor's offices,

and the divisional surveyor is given his money on his detailed estimate and he is told to account for it afterwards. He knows what his own job is costing and he is able to answer satisfactorily to his chief and to his Committee. Of course, we must not lose sight of the fact that costing systems give you a splendid comparison which you can apply to the next case, but they do not help you with the case on which you have already overspent. Perhaps "overspent" is not quite the right word; I mean the case in which you have spent your money badly.

SIR SEYMOUR WILLIAMS: There are two very bad diseases which are prevalent in this country now; one is Formitis and the other is Statisticitis. They lead to people using forms and statistics not as a means to an end but as an end in themselves. I think the man at the top who deals with statistics and so forth should realise that the man at the bottom has got to do a job of work and that the less he is bothered with statistics and forms the more efficiently his work will be conducted. People who call for returns should always satisfy themselves that there is a sound reason for requiring those returns, and they should get rid of them as soon as they can.

I want to refer to the observations made by a county treasurer a few minutes ago. He wants to make all the figures, returns and so forth of the surveyor conform to his basis of accountancy. That is another danger. I try to make it clear to my people that the accountancy department is the servant of the other departments and not their master. I hope accountants will bear that in mind when they are dealing with these matters. There is always a danger of the expert—whoever he may be—getting so engrossed in his subject that he loses sight of his surroundings and the purpose for which he exists.

COLONEL SINNOTT (*Gloucestershire C.C.*): I should like to say a word with regard to the remarks made by Mr. Hughes, of Hampshire. With reference to the question of improvement and building lines, in my own county I find the procedure which is laid down in the Act works on the whole admirably, and I think it is desirable that the matter should be brought to practically a final stage before it is presented to the Ministry of Transport. I say that for this reason: the town planning authorities have to be consulted, and they

are now becoming a very widely spread net, and their whole attitude and that of the Rural District Councils and the individuals affected must be expressed on matters which concern them before final decisions are made.

With regard to Mr. Tait's Paper on the vexed question of work being carried out by direct labour or by contractors there is a great deal to be said. One is faced, of course, with the difficulty that there are contractors and contractors, and if we are tied to taking the lowest tender, irrespective of other factors, I am inclined to think that a great deal of our work is better done by direct labour.

MR. E. TASKER, in reply, said: I should like to thank Mr. Hughes for his remarks and deal with the dictating machines and the cost of correspondence. I would point out that this is not any specific case. I know of no department where these salaries and apportionments apply. It is a hypothetical case on which one may base an estimate for any particular department.

I was pleased that Mr. Hughes supported the case for tabulating work. If anyone doubts whether it is an economy to go to the trouble of tabulating the work done, he has only to sit down and estimate the cost of ascertaining that information (as and when required) at spasmodic intervals.

I should like to thank Sir Seymour Williams for supporting some remarks which I make in my Paper under the heading "Forms," where it is pointed out that a certain railway company was able, on investigation, to scrap some 370 forms. There is a risk of some of our forms becoming perfectly useless, and sometimes we can usefully amalgamate the information on one form instead of having it on many forms.

With a Paper like Mr. Tait's coupled with mine, one could not hope to evade criticisms of the accountants. They yearly call for more figures, and really one cannot see the

use of a lot of the figures that are prepared in accordance with their requests. They certainly increase the cost of administration, and, supposing they can prove that you have spent some £50,000 on drainage works, you still have to ask the engineer whether it was an economy. The accountant cannot tell you. It may be that twice that amount of money expended on drainage would still have been economy.

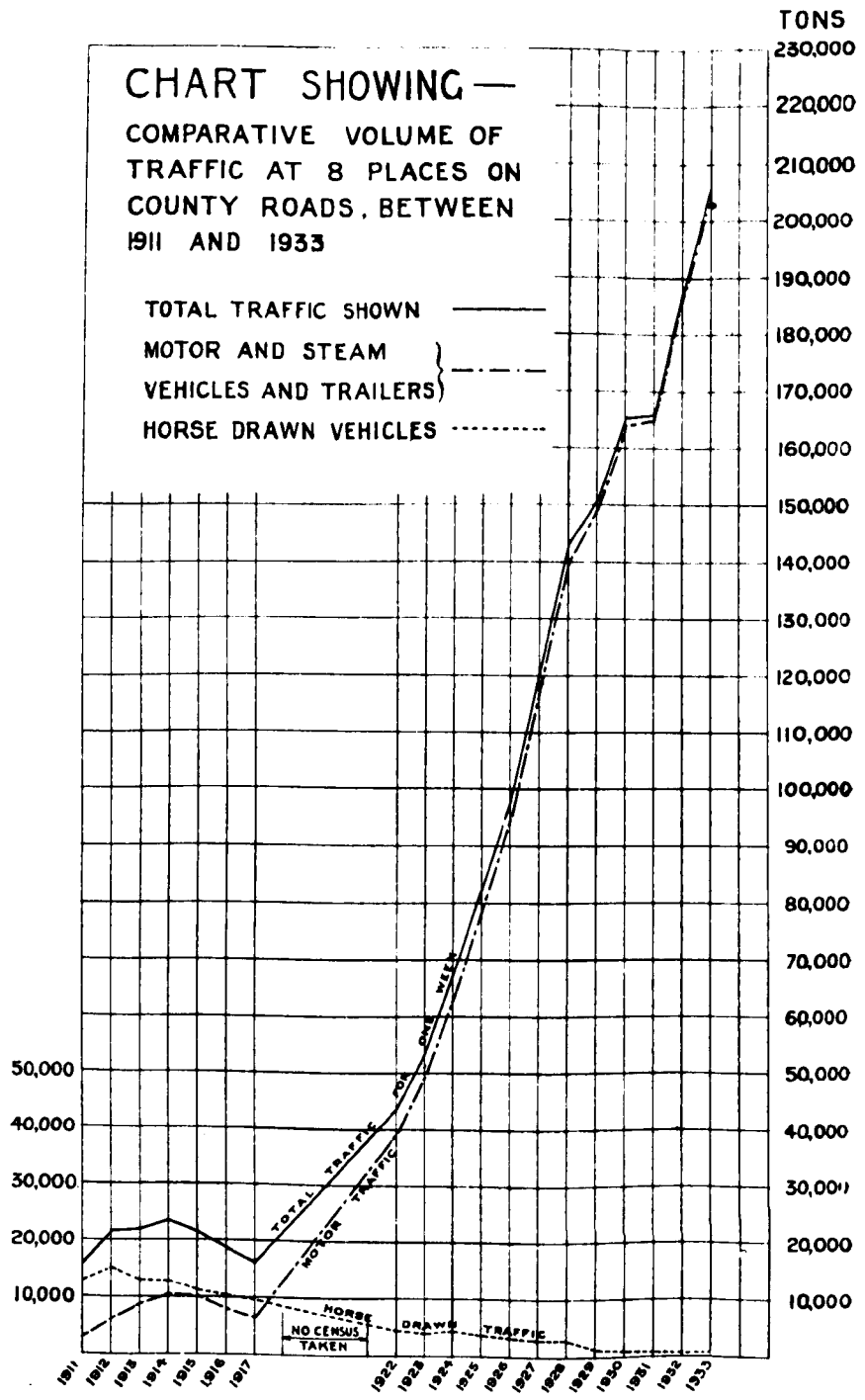
With regard to accountants and the tremendous amount of figures they call for, Henry Ford did not make his money by smart finance. He made it by efficiency, particularly in the works on the job.

MR. TAIT, in reply, said: I think that the criticisms made by Mr. Meek, the City Engineer of Manchester, may be regarded as complementary or additional to my Paper, and I am in sympathy and agreement with some of them. In some respects Mr. Meek's observations rather approached the question that I had put from another aspect.

With regard to the standard form of contract, to which Mr. Meek referred, the standard form I had in mind was not the specification. A contract is made up of the offer, the terms of contract, the specification, drawings, and the like, and I had in mind only the conditions of contract. I quite understand that there are differences in the specifications, and that each contract must therefore be drawn, as far as the specification is concerned, entirely independent of other contracts.

On the question that was raised of too many returns, I do feel that this conference will have served a very useful purpose if it only brings out the important fact that, if you are going to get details that you cannot or will not use, all the effort and time are wasted. Unless official returns have a definite value and are going to be put to a useful purpose, something should be done to limit them.

COUNTY OF GLOUCESTER



COUNTY SURVEYOR'S OFFICE
SHIRE HALL, GLOUCESTER.

(Chart referred to by Mr. Tasker, see page 581.)

DISCUSSION.

GLOUCESTERSHIRE COUNTY COUNCIL.
COUNTY SURVEYOR'S DEPARTMENT.

Table showing Volume in tons per week of Traffic in eight places on County Roads.

Route.	Location.	1911	1912	1913	1914	1915	1916	1917	1922	1923	1924	1925	1926	1927	1928	1929	1930	1931	1932	1933
A.40	Staverton ..	3,404	4,644	4,804	4,713	5,183	4,100	3,128	12,017	14,079	18,618	19,430	23,185	31,087	39,902	42,718	45,139	38,519	46,477	54,636
A.419	Brockworth	2,427	4,492	3,507	3,832	3,046	3,287	2,964	4,843	6,905	8,203	10,474	12,409	13,695	14,352	15,990	17,197	17,846	19,750	22,616
A.419	Winstone ..	1,415	2,797	3,280	3,329	3,177	1,975	1,619	2,212	2,457	3,828	4,312	5,152	6,122	6,286	5,307	7,353	7,504	7,956	8,617
A.38	Whitminster	1,164	1,826	1,891	2,434	1,921	1,809	1,148	10,835	13,076	16,135	22,188	28,267	31,456	38,769	38,596	44,561	47,159	57,042	54,977
A.437	Tidenham	2,876	2,480	2,638	2,713	2,338	2,080	1,906	4,022	4,042	5,480	6,584	6,904	9,326	10,759	12,280	12,478	13,632	16,383	19,291
B.4215	Newent ..	2,929	3,320	3,023	3,527	3,036	2,483	2,516	2,353	3,342	3,727	4,187	5,532	6,439	6,996	7,616	8,063	8,259	7,872	9,863
A.40	Northleach	976	1,096	1,804	1,681	1,420	2,129	2,139	3,093	3,943	5,000	5,909	6,799	8,287	11,747	12,855	12,658	14,362	14,256	15,163
A.46	Sodbury ..	950	1,068	1,106	1,534	1,119	993	1,067	4,641	6,272	6,999	9,899	9,926	14,610	14,719	15,758	18,045	18,811	18,084	20,654
TOTAL	..	16,141	21,723	22,035	23,763	21,840	18,856	16,487	44,016	53,816	67,990	82,983	98,264	120,622	143,530	151,102	165,514	166,092	187,820	205,847

NOTE.—Census taken from 6 a.m. to 10 p.m. during the second week in August each year.
No Census taken 1918—1921.
1914—17. Horse drawn traffic was equal to motor traffic.
Prior to 1914, horse drawn traffic was in excess of motor traffic.
1933, Horse drawn traffic negligible (1,000 tons), in comparison with motor traffic (206,000 tons).
Total traffic in 1933 equals twice that of 1926.
equals three times that of 1924.
equals four times that of 1923.
equals five times that of 1922.
equals thirteen times that of 1911.

CONFERENCE

Under the auspices of the Institution of Municipal and County Engineers.

THURSDAY, 16th NOVEMBER at 3.0 p.m.

MAJOR L. ROSEVEARE, O.B.E., M.Inst.C.E. (*President of the Institution*), in the Chair.

The following Paper was taken as read :—

Some Considerations affecting the Economical Reconstruction of Rural Roads.

BY

D. G. R. TIDDY, F.S.I., M.Inst.C.E. & Cy.E.

(*District Highway Surveyor, Somerset*).

(NOTE.—This Paper was submitted for the Open Competition arranged by the Congress Committee and was awarded the Fourth Prize (£100 Guineas).)

THE reconstruction or adaptation of rural roads to meet the insistent demands of an increased and possibly still expanding volume of traffic is an everyday problem with a very large number of Surveyors. There must indeed be very few who have not at some time or other been called upon to carry out schemes of this nature.

Usually no great constructional problems are involved. It is a comparatively simple matter to construct a road in such a manner that it fulfils all the requirements of a first class road. The Surveyor will however desire to satisfy himself that in all his schemes the result he wishes to obtain cannot be achieved for less money, and a high degree of technical efficiency is necessary to ensure that both in design and execution maximum economy is obtained.

That much abused word economy means, of course, the art of applying money or wealth wisely. In its narrower sense, and in the sense in which financial stress compels us to regard it, it has come to mean the art of saving money or of spending as little as possible.

In adapting a rural road to meet the demands of modern motor traffic, it is

usually the case that nothing less than entire reconstruction will suffice, entailing some or all of the following operations :—

- (1) Widening of the carriageway and adjustment of horizontal alignment.
- (2) Strengthening and foundation work and drainage.
- (3) Improvement at bends and corners.
- (4) Resurfacing.

It will therefore be not out of place to discuss these various items separately, with special reference to their economical aspect, remembering that the object is to find the cheapest methods of obtaining satisfactory results.

(1) WIDENING OF CARRIAGEWAY AND ADJUSTMENT OF HORIZONTAL ALIGNMENT.

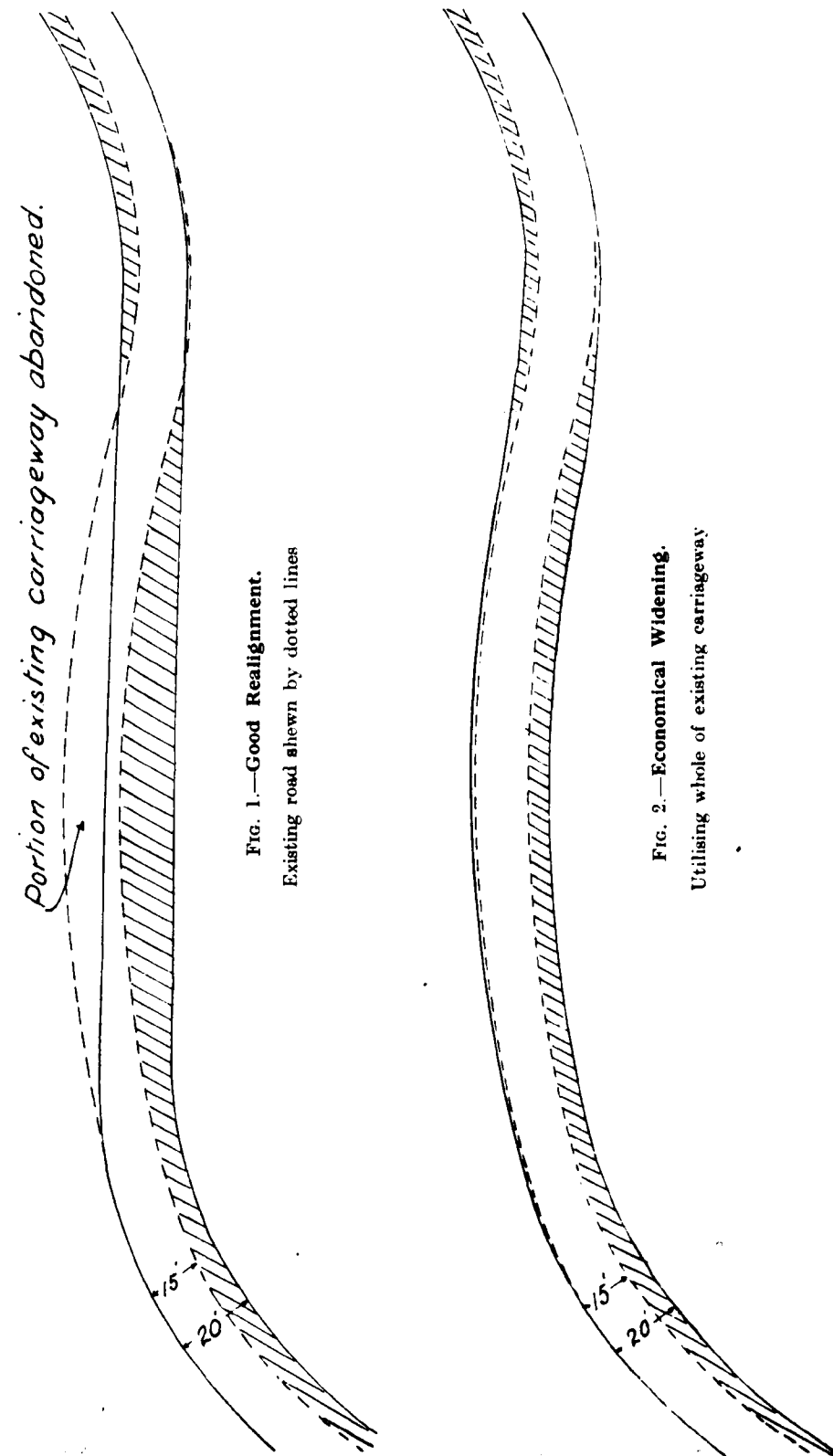
The question of width must be governed entirely by local circumstances. A twenty foot carriageway is probably sufficient on rural roads, such as we are discussing, where traffic flows easily and where standing vehicles are not likely to be encountered. The added width can often be obtained by taking in sufficient of the adjoining grass verges.

Very careful consideration must be given in determining whether the widening shall be carried out on one side only of the existing carriageway or a little on each side. The conditions which govern the choice of method are :—

- (a) The desirability of utilising the entire width of the existing road so that the area of the widening will be reduced to a minimum.
- (b) The desirability of making the alignment such that the new road shall run in as straight a line as possible.
- (c) The possible necessity of adapting the alignment which will cost least to carry out.

Generally speaking, roads in this country do not run in straight lines for any considerable distances and it is desirable to align them in such a manner that they consist of a series of straight lines connected by easy curves, as shewn in Figure 1. Assuming however cost to be the dominant factor, it might be permissible to modify the alignment as shewn in Figure 2. The economy of this latter alignment lies in the fact that the whole of the existing carriageway is utilised and there will be a considerable saving in cost due to the fact that it entails the minimum amount of widening to obtain the desired width. The shaded portions indicate the area of added carriageway in each case, and it will be apparent that the work entailed in Figure 2 is considerably less than that shewn in Figure 1. Circumstances may be such that a compromise between the two is possible. The two sketches illustrate that where, for financial reasons, it may not be possible to obtain the most desired alignment, a considerable improvement may nevertheless be obtained, within the limits of the sum of money available.

Where a road runs along a hillside so that one side is in cutting and the other on embankment as shewn in Figure 3, widening should almost be invariably carried out on the side which is in cutting; and a footpath formed on the low side, to the end that traffic is kept well away from the edge of the embankment. This method



of widening will usually be the more expensive, but this is a case where probably a little more spent on initial cost will result in lasting economy. The economy will of course be obtained by avoiding what may be the costly and troublesome maintenance of an embankment and retaining wall. Incidentally a footpath constructed on the low side of such a road is likely to be much more used than one against a cutting would be, because of the more pleasing prospect which will be opened out over the valley below.

In dealing with the cutting on the high side of the road, it is generally advisable to excavate the side until the natural angle of repose of the soil is obtained, leaving the surface of the bank slightly concave. The alternative method of forming a low revetment wall should be investigated, because it is possible that the saving in excavation, plus the saving in cost if land is being acquired, will more than compensate for the cost of the wall. At any rate, for the purposes of economy, all possible alternatives must, in this as in every other matter be examined and compared.

(2) STRENGTHENING AND FOUNDATION WORK AND DRAINAGE.

The Roadbed.—The economic importance of the proper preparation of the roadbed lies in the fact that it requires only manual labour and the use of the cheapest kind of material to increase its bearing power to such an extent that the cost of the foundation proper can be decreased vastly in proportion to the sum spent in the preparation of the road bed.

The road bed must of course be stable and practically incompressible. There should be no hesitancy in spending sufficient money on the drainage of the road bed, if drainage is necessary. The surface soil and decayed vegetable matter should only be removed to sufficient depth to allow of the construction of the foundation proper. Where, however, it is necessary on account of unsatisfactory subsoil to excavate to a depth below the required subgrade, the material of which the foundation proper is composed should not be carried down to this depth, but the excess depth may be filled with the cheapest suitable material available (gravel, ashes, etc.) and compacted by rolling. The road bed should be compacted to such an extent that it will support the superimposed foundation so that the latter, when consolidated by rolling and traffic, does not sink to any appreciable extent into the surface of the road bed. It is sounder practice to compensate for any yield in the subsoil by providing cheaper suitable material to the underside of the foundation, than by the simple but extravagant process of merely adding the more expensive material to the top as the foundation is consolidated.

The economy of the proper preparation of the road bed is well understood by those whose unfortunate experience it may have been to witness the disappearance into the bowels of the earth of a carefully constructed Telford foundation under the weight of a steam roller!

The Foundation.—The essential requirement of the foundation is that it shall be of sufficient strength to support the surface and loads superimposed by traffic, without deformation, and to transmit the same to the roadbed.

The selection of the material of which the foundation is to be made is not difficult, because the choice is usually very limited and generally resolves itself into

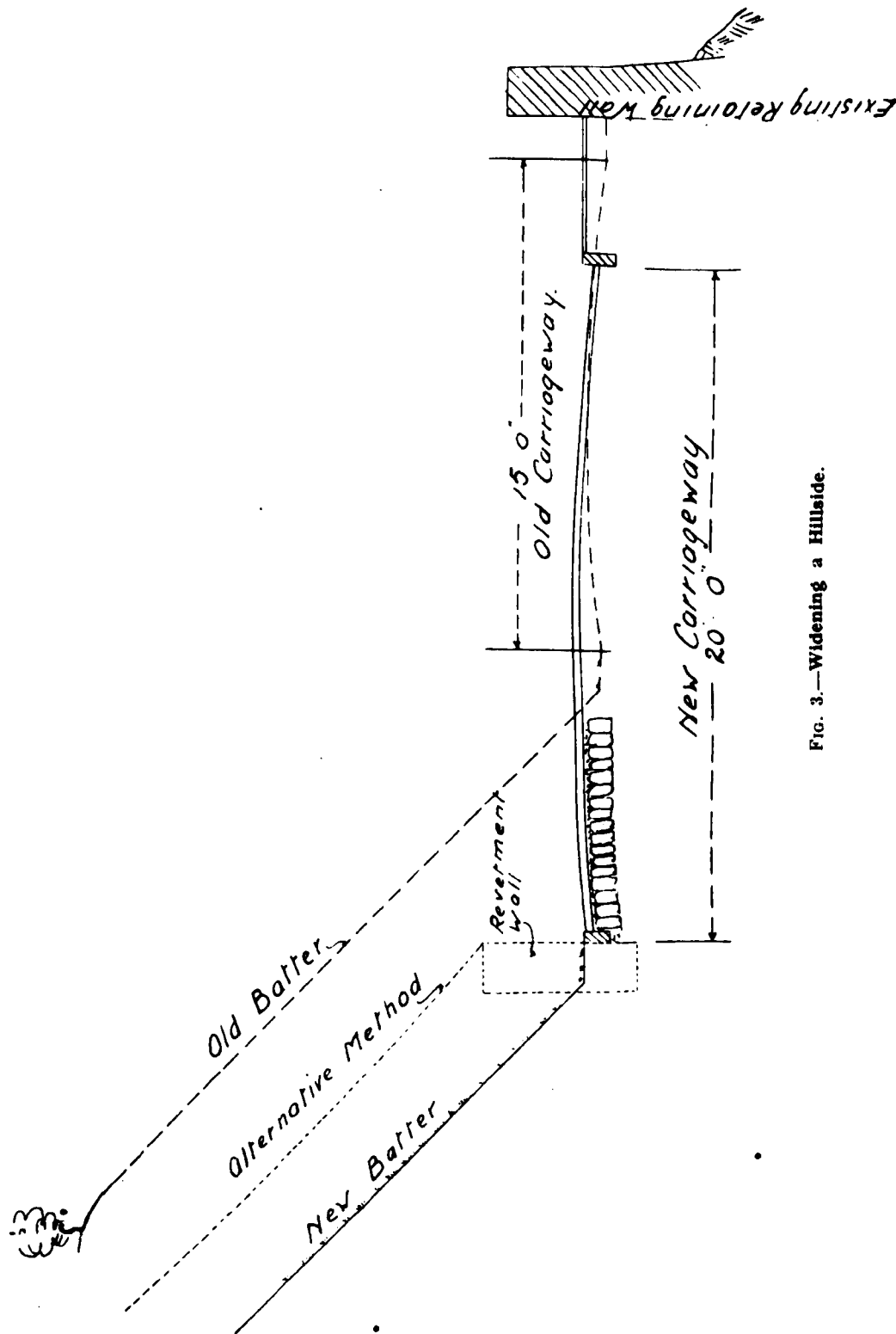


FIG. 3.—Widening a Hillside.

either block stone, and the construction of a Telford foundation, or concrete, either plain or reinforced.

Concrete has grown rapidly in favour of recent years, even supplanting stone where local conditions would appear to be favourable to the latter. Causes contributing to this change may be the suitability of local aggregate, ease of handling and transportation and possibly in a small degree legitimate commercial propaganda.

It is not the purpose of this paper to discuss the relative merits of these two materials as a medium for road foundation work. Each probably has its place in the successful construction of roads. The balance of advantage would, however, appear to lie with block stone when dealing with the foundationing of country roads. If, however, concrete is cheaper it should be used. Cost should be the ruling factor. It cannot unfortunately be stated with any degree of mathematical precision what thickness and quality of concrete is equal in wearing value to a given thickness of block stone. There is no table of equivalents for our guidance, and the matter must rest entirely upon the knowledge and ability of the Highway Surveyor. He will determine what thickness of concrete would be required on the one hand, and what thickness of block stone would be required on the other, estimate the cost of each and probably select the cheapest.

Blockstone Foundations.—In the construction of a Telford foundation, any stone that will withstand a reasonable amount of compression is suitable. Economy in construction will be obtained if stone within a wide range of sizes is used, because quarry costs are thereby reduced and the various sizes can be adapted to the job. A finished thickness of eight inches is probably sufficient to secure an adequate foundation. It would, however, be wasteful in such a case to specify that the foundation must be constructed of stones exactly eight inches in depth. The specification should take into account the "fragmentation" which is most easily attained at the quarries from which the material is likely to be obtained. Good workmanship in the laying of a Telford foundation will show great economy in material, and the skilled man will probably construct a stronger foundation eight inches thick than a less highly skilled one may at ten inches thick. Although in the interests of economy sizes should not be rigidly specified, it will probably be found economical to specify that stones shall be from five to ten inches deep and three to six inches wide, as these sizes can be produced at the quarry without undue labour, can readily be handled on the job, and will therefore be cheaper.

Interstices in the closely laid foundation can generally best be filled by breaking off protruding corners and by old material taken from the surface of the existing carriageway from places where it is necessary to scarify in order to obtain the required cross section.

Where portions of the existing carriageway are abandoned owing to re-alignment, it is often economical to break them up and to salve the old materials for use in improving the new road bed, to fill interstices in the block stone foundation, or to shape the road to its new cross section and as a base coat in the construction of footpaths.

The economy of this procedure is determined by comparing the cost of salving these old materials with the cost of obtaining entirely new material.

Concrete Foundations.—Where concrete is used for foundation work, points to be considered from an economy standpoint are :—

- (1) The thickness of concrete required.
- (2) Whether reinforcement is necessary.
- (3) The grading and proportioning.

Factors governing the design are indeterminate but a minimum thickness of six inches is generally considered necessary under the most favourable conditions.

Reinforcement is desirable in a newly made and yielding subsoil, but the possibility of so improving the bearing power of the subsoil to such an extent as to dispense with the necessity for reinforcement should be considered. A few pence per square yard spent in this manner may save the necessity of spending a much larger sum on reinforcement. Generally speaking however, if "slab strength" is required it is an economy to use reinforcement in preference to increasing the depth of the concrete.

In proportioning the ingredients of the concrete, economy will lie in selecting that proportion of cement to aggregate which will give sufficient strength with the minimum content of cement.

For this class of work it is not economical to incur the extra expense involved by the use of quick hardening cements, because there are little or no compensating advantages. The extra price demanded for this material increases the cost of the concrete considerably. The following table shows the relative costs of materials for various proportions based on ordinary cement at 55s. per ton, quick hardening cement at 62s. 6d. per ton and aggregate at 8s. 6d. per ton, in a slab 8 in. thick.

Proportion of Cement to aggregate.	Cost per sq. yd. Materials only. 8 in. slab.
	s. d.
1 : 2 : 4 (ordinary cement)	6 3
1 : 2 : 4 (quick hardening cement)	6 8
1 : 2½ : 5 (ordinary cement)	5 10
1 : 2½ : 5 (quick hardening cement)	6 2

Although these figures shew only a small variation per square yard, when translated into miles the differences are considerable. For instance, in a widening of 9 ft., the difference between the cost of 1 : 2½ : 5 concrete made with ordinary cement and the cost of 1 : 2 : 4 concrete made with quick hardening cement amounts to £220 per mile of road.

These figures merely emphasize the importance of comparing the cost of alternative gradings.

It is, of course, necessary to give very careful consideration to the thickness of the slab, because the cost will vary directly with the depth and any unnecessary thickness will result in unredeemable waste.

Surface Drainage.—In drainage works it hardly need be said that sufficient money must be spent to make it efficient.

Ultimate economy will result by ensuring that the system is such that any blockages can be readily located and cleared without the necessity for breaking road surfaces, and to this end it is necessary to place catchpits or inspection chambers in such numbers and in such positions as to ensure that every length of drain can be rodded.

Economy in initial cost can be obtained by using the lowest quality (thirds) stoneware pipes and by laying all longitudinal drains in the grass verges. They can then be laid at a lesser depth than if subject to the weight of traffic. Lighter construction in catchpits will be permissible if set well back—4½ in. brickwork, or 4 in. concrete placed behind rough shuttering will suffice for the walls, and castings can be correspondingly lighter.

Kerbing.—To prevent the lateral spreading of the surface some form of kerbing is essential and it is false economy to endeavour to do without it. There is, however, no need to provide heavy kerbs which stand several inches above the finished road level. That portion of a kerb which stands above road level has little or no economic value and cannot be justified on grounds of utility and is therefore wasteful. Economy is better served by the construction of in situ kerbs which finish flush with the surface of the road. The economy is twofold because the cost of the high kerb is saved and a submerged kerb can conveniently form part of the carriageway, and a consequent saving effected in the width of macadam or asphaltic surfacing. Figure 4 illustrates the point.

It is of course conceded that where, on account of restricted width, the footpath must abut immediately on the carriageway, without any intervening grass verge, a high kerb is necessary for the protection of pedestrians.

By using submerged kerbs 5 in. wide and allowing them to form part of the carriageway, there is a saving of 489 sq. yds. of surfacing and 65 c. yds. of pre-cast concrete per mile, when compared with a high kerb 5 in. wide which projects 4 in. above the surface. This saving might easily amount to as much as £250 per mile.

In situ kerbs the surface of which has been treated with "Snowcrete" form an adequate guide to traffic during foggy weather.

(3) IMPROVEMENT AT BENDS AND CORNERS.

In dealing with bends and corners the object is to promote safety without unduly curtailing speed. The primary cause of most accidents is probably speed, and it is rather paradoxical that our efforts to secure safety must have the effect of increasing speed at potential danger points. The improvement of bends and corners is effected by aligning hedges and fences so that a long length of vision is secured horizontally, and by altering the vertical alignment of the surface to compensate for the centrifugal force which is exerted on the road by a vehicle moving in a circular direction. This latter operation is of course effected by superelevating the outer edge of the curve.

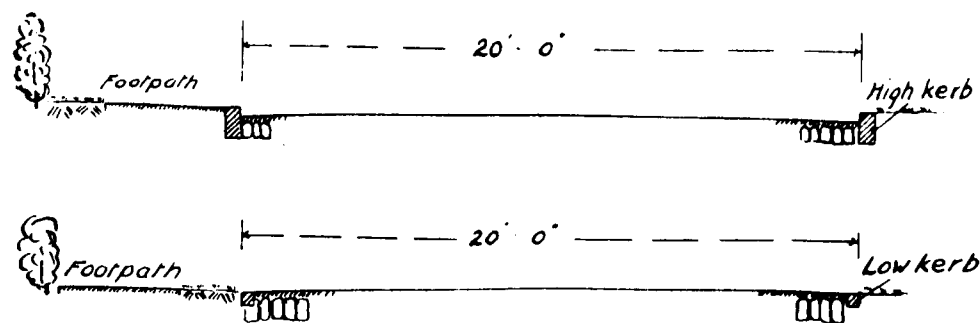


FIG. 4.—Economy of Low Kerbs.

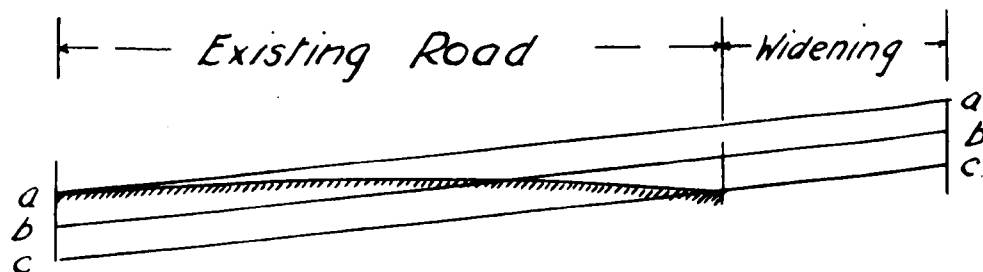


FIG. 5.—Alternative Methods of applying Superelevation.

In dealing with bends and corners, it is often difficult on account of the serpentine windings of our English roads to effect a sufficient improvement merely by opening up and widening the existing road, and it is often necessary to divert the course of the road in order to get a satisfactory alignment. It will generally be cheaper to widen an existing road than to construct a diversion, although it may not be so if a short diversion will cut off a long length of the existing route. At any rate it will be necessary to prepare alternative schemes and estimates.

It is difficult to suggest what the maximum degree of curvature should be on a modern road, but generally speaking if an existing road after improving is likely to have bends and corners which will materially slow down traffic and still require the provision of danger signs or traffic lines, the improvement should be considered inadequate and a complete diversion of the road to avoid these danger points is justified.

In the economic investigation of this matter it is impossible to come to a decision on a money estimate alone, because the field of investigation must take account of the relative values to traffic of alternative schemes and ensure that the measure of value of any improvement is commensurate with the expense involved.

In the banking of bends to compensate for centrifugal force, there are three methods of securing the desired result (Fig. 5).

- (1) By superelevating the outer edge of the curve only, as shewn by the line a—a.
- (2) By depressing the inner edge only as shewn by the line c—c.
- (3) By a give and take line involving both (1) and (2) as shewn by the line b—b.

By merely superelevating the outer edge as shewn by the line a—a the whole, of the existing road is utilised as a foundation, while if a give and take line such as b—b is employed a portion only of the existing road remains undisturbed, whereas if the line c—c is used any value which might lie in the existing road is wholly destroyed, and this method will be the most expensive.

The relative economy of various cross sections should be ascertained by comparing estimates of possible alternatives. Economy will be secured by comparing estimates of these alternatives and by adopting the cheapest method.

While on the subject of superelevation it should be remembered that where the road being treated is on a gradient, and the outside of the curve is on the up side of the road, care should be taken to ensure that the gradient on the up side is not materially increased as might be the case if the cross section indicated by the line a—a is adopted.

(4) SURFACING.

Before commencing surfacing operations, the form of the cross section should be carefully checked to ensure that it conforms to the required shape so that no waste will occur by using expensive surfacing material merely for the purpose of adjusting the camber.

Resurfacing over the whole width is generally necessary, but the feasibility of deferring this operation for a few years, and only making up the added width, should be considered. If the old surface is good and is expected to have several years useful life it is obviously wasteful not to utilise it.

The popularity of bituminous and tarred macadams reflects the suitability of this kind of material for rural roads. It is usual to lay this material in one or two coats to a finished thickness of 3 in. If laid in two coats, the bottom coat is normally composed of aggregate graded from $2\frac{1}{2}$ in. to $\frac{1}{2}$ in., and this is spread to the full thickness required. The topping coat of $\frac{1}{2}$ in. to $\frac{1}{2}$ in. gauge is rolled into the base coat to fill the interstices. Laid in this manner, the bottom coat will cover from $6\frac{1}{2}$ to 7 sq. yds. per ton, and the topping coat will require about one ton of material to 40 sq. yds.

The cost of surfacing material will vary directly in proportion to the thickness at which it is laid, and in the interests of economy it is necessary to determine whether the usual thickness can be reduced.

There has of recent years been a marked improvement in the binding and wearing qualities of tarry and bituminous binders and this improvement might be taken advantage of in reducing the thickness of wearing surfaces without decreasing the crust strength. It has been found that a carefully graded macadam composed of aggregate with no size above $1\frac{1}{2}$ in. mixed with a suitable binder is capable of producing an excellent surface, if laid in one coat to a finished thickness of 2 in. As this material so laid will cover about 10 sq. yds. per ton, the saving in cost is very appreciable.

Alternatives for comparison which should be considered are water bound macadam, grouted macadam, and various kinds of asphaltic and proprietary materials.

The selection of the surfacing material must depend upon the judgment of the Surveyor. It can, however, be confidently stated that the cheapest will seldom be the most economical and that the most expensive will not necessarily be best.

GENERAL ECONOMY IN MATERIALS.

In works of road reconstruction the bulk of the money spent goes in the purchase of materials, and it is often found that the cost of materials represents from 70 per cent. to 80 per cent. of the total expenditure, and this to some extent explains why road widening schemes fail to reduce unemployment, in areas where materials are not produced, to the extent often anticipated. Direct labour costs may be as little as 15 per cent. of the whole, and it is obvious therefore that economies should be looked for by avoiding the wasteful use of materials by stressing them to their full safe capacities. Money spent in experimental tests and scientific research, and the dissemination of knowledge gained thereby, will no doubt be found to give the greatest measure of economy and, having regard to the economical importance of the matter, more might profitably be done in this direction.

ECONOMY OF SPEED IN CONSTRUCTION.

In road construction it is the aim of the Surveyor to ensure that every pound spent is directly productive and to see the value reflected in the completed structure. There is however necessarily a certain sum which must be spent in connection with every scheme which is unproductive, and this sum in the efficiently organised job will form a minimum percentage of the cost of the whole.

Such items as fall under this head are lighting, watching, traffic control, insurance, supervision, hire of machinery, etc. The cost of these items is largely dependent upon the time taken in carrying out the work and therefore the question of speed is of economical importance.

Speed is facilitated by intelligent organisation and is attained by ensuring that the various operations are proceeded with simultaneously and by commencing operations on as long a section of road as possible (having due regard to the requirements of traffic using the road during the execution of the works) and by a progressive shortening of the length being dealt with as the works proceed.

The organisation in this respect might be a front gang excavating for widening and foundation work, a second gang laying and consolidating the foundationing material, and a third gang resurfacing, followed by a gang employed in cleaning up, returfing, etc.

The strength of each gang should be such that the gang immediately behind is close up to, but never quite catches, the gang in front.

ECONOMICS OF ROADS.

The economic value of a road lies in its ability to fulfil its function adequately at a minimum cost. The main function of a road is to carry traffic and its economy will therefore depend upon how cheaply it does this.

Dividing the total cost by the total traffic will enable the cost per ton-mile or ton-yard to be ascertained.

Various values and conditions have, however, to be assumed in treating of this subject and anything approaching precision cannot be attained. It might, however, be of academic interest to discuss very briefly the various factors involved.

In dealing with the cost of a reconstructed road, it is convenient to treat all items of expense as an annual charge and divide the same by the total tonnage of traffic carried in one year.

The total annual cost of a road is made up of the following items :—

- (a) Annual capital charges.
- (b) Annual maintenance charges.
- (c) Cost of the road to traffic using it.

Items (a) and (b) can be ascertained or estimated with reasonably sufficient accuracy, but item (c) can never be ascertained or even closely approximated. It will consist of such items of expense as the cost of repairs to vehicles occasioned through uneven surfaces, etc., loss of time and speed due to gradients or badly designed bends and cross road, loss due to the necessity for closing part of the road for frequent repair, loss due to accidents arising out of slippery surfaces, injury to merchandise, and a number of other items which can be readily visualised but cannot be expressed in pounds, shillings and pence. It is, however, beyond question that these items must be considered when discussing the question of road economy, because their cost might be very heavy, and the road which fulfils its function with the smallest cost to the traffic using it is of greater economic value than one over which the cost of operating traffic is unduly high.

Again, the question of width will also materially affect the calculation. The cost of reconstructing and maintaining a road will vary almost directly with the width, but provided the road is of reasonable width the traffic will not vary to any very great extent, and the ton-mile basis can therefore be very misleading, and it might be more equitable to compare the cost on a ton-square yard basis.

For example, assume a 20 foot road costing annually £500 per mile, and to carry 4,000 tons of traffic per day. The cost per ton-mile is :—

$$\frac{£500}{4,000 \times 365} = .082 \text{ pence per mile.}$$

Assume, however, the same road to be double the width, and therefore, to cost annually twice as much (£1,000 per mile). The cost per ton-mile is :—

$$\frac{£1,000}{4,000 \times 365} = .164 \text{ pence per ton-mile.}$$

which is exactly double the figure obtained on the assumption that the road is half the width and therefore costs only half as much.

If, however, the calculation in each of the above cases is reduced to a ton-square yard basis, the cost in each case will be the same, and having regard to the greater amenity value of the wider road and the additional facilities it offers for the

accommodation of traffic, it might in the widest sense be a more economical proposition than the narrower road, in spite of the latter being only half the cost per ton-mile.

Finally it can be said that the Surveyor needs to be very prudent in his interpretation of the demand for economy. The modernistic tendency to eliminate as superfluous anything that cannot be justified by its utility is to be commended, but nothing can or will be gained by abandoning sound engineering principles in favour of risky expedients.

The final value of all road works will be determined after the benefits which they give have accrued and are fully appreciated, by which time both their initial cost, and the Surveyor concerned, will probably have been completely forgotten.

DISCUSSION.

MR. D. G. R. TIDDY, presenting his paper, said: It is essential that we should understand and practise the principles of highway economy. It is, I think, more important still that we should convince the public that they are getting excellent value for all the money that is being spent on roads, and if I am successful in getting those of you who are far more able than I to talk about this subject, some of us will feel amply rewarded for having attended this Conference.

COLONEL STEAD (*Somerset*), proposing a vote of thanks to Mr. Tiddy, said: I would like to support, first of all, Mr. Tiddy's contention in regard to the financial aspect of the problems connected with rural roads—in fact I go so far as to offer the opinion that the main problem connected with this work is financial. (Hear, hear). I am afraid that a good deal of so-called economy which has been forced upon us in the last year or two will turn out to be a false economy. Those of us who travel over considerable mileages of road will, without doubt, recall to mind almost at once instances within our own knowledge of where that sort of thing has already occurred. One of the conditions Mr. Tiddy lays down is that the roads should be as straight as possible. I think they should be reasonably straight, but I am no advocate of taking all the bends out of our charming rural roads by making them straight racing tracks. They lack of charm, they are very monotonous to drive over, they are very difficult to travel over at night when you are meeting oncoming traffic, and they have other disadvantages.

Referring to Mr. Tiddy's notes on widenings in cuttings, I have a sneaking liking for a low revetment wall. I think it tends to show a finish to the work. It is rather more economical in the amount of cutting one has to do. It assists the drainage of the cutting, especially in those cases where there is a longitudinal drain along that side of the margin, and I think in nine cases out of ten it will be found that the provision of a wall of that kind will not be more expensive than carrying out the full cutting.

I congratulate Mr. Tiddy on the very light way in which he got over his roadbed troubles. I think he will have more trouble in dealing with questions in regard to the roadbed than with some other parts of his paper. He has not given us any indication of how he would deal with, for instance, an elastic clay. We have a great deal to do with soft clays in my county, and it is one of the most difficult problems to get stability in a clay bed. I am rather of the opinion that you cannot do better than underdrain it as well as you can—clay is very difficult to drain—to provide side drainage and to cover the clay with a very good blanket of clinker or ashes. That blanket will, in most cases, prevent the clay from working up into the stone foundation under the pressure of traffic.

With regard to the foundation, I am still a very great believer in the old block stone foundation, probably because I am fortunately placed in the work I have to do, and with millions of tons of very fine stone available for the purpose.

There is just a small point of detail which

is not in the paper, and that is the necessity for insistence on the very careful filling in of the interstices in block stone pavements. That is one of the difficulties in making a really good block stone foundation.

I disagree with Mr. Tiddy on the question of kerbs and kerbing. Mr. Tiddy does not like the upstanding kerb. Where there is a footpath the pedestrian is entitled to be protected from the vehicular traffic using the roadway. I think the upstanding kerb is necessary actually to confine the traffic to that portion of the carriageway which is provided for it, and I am not prepared to agree that there should be no physical barrier between the footpath and the carriageway. I do not think the low submerged kerb fulfils one of the functions claimed for it. It is not a really good driving line at night, because either the growth comes over it, or the first time the road is dressed the tar gets on to it.

I strongly support everything Mr. Tiddy says about the necessity for further research work. We are not getting sufficient research work on the more simple problems of our work, and I am pleased to think that there is a hope that with a new Research Board being set up we may get more attention paid to them.

Mr. Tiddy, thinks I think rightly—that provided the job is good and efficient, we need not worry ourselves unduly about the criticisms we get on cost and perhaps on the extras as well as the cost. It is quite definite that if the job is good and sound, even if we do overspend on it, the criticism of the job will always be good after we are long forgotten and after the fact that we have overspent is forgotten too.

MR. H. V. OVERFIELD (*Salisbury*), seconding the vote of thanks, said: To me the paper seems to be roughly divisible into two parts. First the technical details of construction and, second, the economics of roads. On the first part, we have the sound experience of a practical man, and I am in complete agreement with all he says. I regard the second part of his paper as an indication that he has been troubled, like many people in the world to-day, by the constant references to the economic problems and I think there is a good deal too much of that to-day. He realises that the greatest economy he can exercise is to do his work

well and thoroughly. I think it may be safely said that an engineer seldom has an opportunity of deciding how much money is to be spent on his roads; but he certainly can and should say how far the money allotted will go. For instance, he must decide if it is better to take a reduced length and complete a piece of reconstruction, or he might decide to take a narrow width of road, sufficient for the time being, so that future widening can be readily carried out without altering or wasting the work which has already been done.

Alternatively, he might apply the funds available to improving corners and opening up sight lines. Again, he might decide to lay foundations and defer the final surfacing until more money is available. Those, I think, are points which an engineer must decide for himself, but I submit that whatever work is done should be done well and with a view to making it permanent.

A good foundation is the highest economy in all road work. The well-consolidated material in old roads is often a *good* foundation than could be produced artificially after its removal except at great expense. I think in rural roads this is particularly the case, and great economy can be shown by leaving the old road untouched and laying the new surface on top of the old road. Fortunately in the country they are not troubled with difficulties of levels such as we have in towns where every doorstep or shop entrance must be considered. In the country they can go on building up year after year, thus effecting a tremendous saving on foundations. I will not pursue the argument of concrete block versus stone for foundations, but concrete for rural roads seems to me from Mr. Tiddy's own figures, to be so expensive as to be uneconomical.

Surface drainage is obviously an economy in that scour is prevented and also the disintegration which occur when water lies on the road, both the breaking up of the surface and the softening of foundation.

Kerbing may be considered an economy in so far as it saves the annual cost of siding the road, and as Mr. Tiddy very rightly says, prevents the surfacing from spreading.

With regard to bends and corners, it is unfortunate that a good deal of surfacing is still being carried out on quite important roads, and nearly always on rural roads,

without banking the corners. The banking should not be excessive, as there are still horses in the rural districts; but however much it may appear that the banking encourages speed, it should be remembered that it also increases safety, as the drivers have more definite control of steering and there is very much less risk of skidding if the brakes have to be applied.

In his remarks on surfacing materials, Mr. Tiddy seems to have forgotten to mention the horse, which must still be a most important consideration for rural surveyors. What surface is he to provide to suit the horse? What economy could he effect by using surfacing materials which would not require the annual tar-spraying or surface dressing—probably £120 or more a mile? Capitalise that figure and you will have enough to provide a permanent non-skid surface in the first place.

Towards the end of his paper, Mr. Tiddy writes about economy of speed in construction, and I think he overstates the importance of it. In my opinion, the best economy is to take sufficient time over every operation, not to push the men who are placing the pitching, not to hurry the steam-rolling, and finally, not to lay the surface until the foundation is thoroughly consolidated. Time is an essential factor in this, and I would stress the point that the greatest economy is secured by leaving road foundations under traffic for several months so that the vibration and weight of traffic and the weather may play their part in producing something similar to the conditions in the old roads which have been under traffic for many years. It is worth notice that in certain countries noted for their good roads, foundations are sometimes laid one year, brought to a reasonably smooth surface, and left for one or two years before the final surfacing coat is laid. A longer life can then be expected of the surface with a much better running top throughout its life.

The concluding paragraph in Mr. Tiddy's paper shows, I think, that he is somewhat confused as to what he wishes to say, but I think the question that he is really asking himself is "can we afford good roads?" I have looked up some figures and I find the total expenditure in the whole country on roads is something over £50,000,000 a year on about 177,000 miles. Towards

this sum, the taxation of road vehicles provides over £28,000,000. Undoubtedly it is a tremendous expenditure, but it only works out at 26s. per annum per head of the population, or 6d. per week—less than a penny per day. But this expenditure has produced the finest road system in the world, and I feel confident that if we go on as we have been doing, in the course of a few years nearly all our rural roads, in addition to the main roads, will be brought to a sufficiently high standard to please even the fastidious motorist.

Mr. M. B. McBETH (*Bathgate*): I think the Powers that Be must now all realise that this so-called scheme of economy which they forced us to carry out during the last few years was the most false economy that was ever entered into in this country. In my view it is very much better to spend money on work and wages rather than paying men the dole. In my case I had some 200 men reduced to 98, and at least 95 per cent. of those dismissed went on the dole.

With regard to the widening of existing roads, I quite agree with the speaker that a 20 ft. width is usually sufficient. I do not agree, however, that so much should be done in the way of re-alignment. I think the example which is shown does not call for re-alignment at all. The line of sight is quite sufficient for safe driving for anybody who is using reasonable caution. To me, the re-alignment of a rural road such as this is a sheer waste of money, and if anything at all should be done, it should be done more on the lines of Fig. No. 2 than Fig. No. 1. If Fig. No. 1 were adopted, you would do away with a considerable portion of the old surface and the old solid foundation which the last speaker stressed. Probably there is no better foundation than the old consolidated road. No. 1 is liable to settlement, and there would be great difficulty in getting a true camber for a long time because of the inequality in the stability of the new and old foundations and the consequent uneven settlement.

With regard to the questions of strengthening, foundation work, and drainage, in my view drainage is the very first problem that a surveyor should apply himself to when making a new road, because if a road is not properly drained, it will never be a satis-

factory road. I may here remark that a plea is made in the Paper for shallower drainage. To my mind, that is a very great mistake and one that should be entirely avoided by all road makers. It is sheer waste to put down a drain that is not going to serve its purpose. If you are going to put down a drain, you want it to take subsoil drainage as well as surface drainage, and if your subsoil drainage is all right, then you should not have very much difficulty in maintaining your road.

The speaker says: "The surface soil and decayed vegetable matter should only be removed to sufficient depth to allow of the construction of the foundation proper." I disagree with him there. Vegetable matter should be entirely removed. I agree with the first speaker that a low revetment wall at the foot of a slope is real economy and is extremely useful from many points of view.

A statement is made that "cost should be the real factor. It cannot, unfortunately be stated with any degree of mathematical precision what thickness and quality of concrete is equal in wearing value to a given thickness of block stone." I do not think you will get any engineer who has experience in concrete to agree with that. The knowledge of concrete has now reached the stage at which it is quite possible to arrive at the proper thickness of concrete required for a road. Further down, Mr. Tiddy says: "In the construction of a Telford foundation, any stone that will withstand a reasonable amount of compression is suitable." "Any stone" should not be used, and we must remember that while our rural roads are now only carrying light traffic, traffic is getting heavier every day and we should not make a road for to-day but for the future.

With regard to the thickness of foundation, I should say that eight inches throughout should be insisted on as a minimum, and on no account should any stone less than the full depth of the foundation be used. Stones which cannot be used for wedging and packing, should be passed through the crusher and converted into metal or chippings.

It is stated that "reinforcement is desirable in a newly made and yielding subsoil." I do not know that reinforcement is necessary in a newly made road. If you

are making a new road, you ought to make your road with such materials as would suit the circumstances of the case, and the above statement should be qualified. Does Mr. Tiddy refer to a new road over moss or a new road made under ordinary circumstances on a fairly sound subsoil?

With regard to the question of kerbing, I agree with the first speaker. Pedestrians do not receive the protection to which they are entitled, and as the construction or condition of the road is usually blamed when an accident takes place, the road engineer should take every possible care to protect the pedestrian as well as satisfy the needs of other road users.

With regard to the improvement at bends and corners. I am afraid in the past we surveyors have worked too vigorously in making a road far too safe for the speed hog and less safe for the ordinary user of the road. There is no reason whatever why we should straighten up all our bends and corners. It gets most monotonous driving along a straight road and during night time the dazzle caused by powerful headlights of approaching cars is not only a nuisance but a danger.

Three types of cross sections are shown in Fig. 5. I should say that (c) should always be avoided; (b) is questionable and depends on circumstances. It will generally be found that if you do not scarify your old road and break your surface, you will be making a very much stronger road indeed, and cheaper and better in the long run, because real economy is to make a good job. It will therefore be much safer in my view to adhere to (a) where you are leaving the old structure and superimposing the new work on it. With regard to surfacing, I am afraid that to wait a few years is rather too long. If you can wait for a few years, then it seems to me that there is no call for improving the old road. I should say that about one year should be the maximum period that should elapse before final surfacing is carried out.

In a rural road I do not think it is really necessary to consider the question of topping. It seems sheer extravagance. In my own area we do not use topping; we lay down ordinary coatings of tar macadam and we seal these with filled bitumen. The bitumen is squeegeed on to the new coat, chips

immediately applied, and rolled in with a light petrol roller. This treatment not only suffices for rural roads but it suffices for the most heavily trafficked roads. I have one road in my area carrying 8,000 tons a day, part of which was so treated seven years ago and we have never spent a copper on it since. It is, however, now getting polished and we must do something to roughen the surface. That surfacing is still, so far as shape and stability are concerned, perfect. Mr. Tiddy also refers to the improvement in the binding qualities of tar and bituminous binders. At a meeting here the other day, it was said "there was no bad tar and no bad bitumen." I disagree entirely. There are still very good tars and bad tars, and good bitumens and bad bitumens on the market. The surveyor must find out for himself whether the material he is using is the best.

Reference is made to water-bound macadam. To my mind, water-bound is a sheer waste. The day of the water-bound is past, and anybody who lays water-bound macadam to-day is throwing away his money.

Then it is stated that about 70 or 80 per cent. of the total expenditure goes in the cost of materials. I do not think, strictly speaking, that is correct, because we must remember that in the production of these materials, a great deal of labour is used, and while to the authority actually carrying out the work the amount of money paid in wages may be comparatively low, we must remember that we are giving employment to a great many other people in other places. Then reference is made to the question of doing the work simultaneously. I agree with the second speaker and disagree with the statements made by the author.

In the whole of the meetings which I have attended here, I have not heard anything helpful regarding the question of slippery surfaces. It is high time something was done to effect a cure. Last week I saw a solvent being applied to an asphalt surface which was then coated with chips. Some of that particular work had been done about a fortnight before I saw it, and it still presented quite a respectable surface. Whether it will be a permanent improvement or not, I do not know.

With regard to the calculation at the bottom of the page, I think you will find

that the conclusion arrived at does not work out in practice, because when you widen a road you distribute the traffic and the wear and tear is very much less on the wider than on the narrow surface, and therefore I do not think you will find when you double the width of the road that your expenditure is increased to the extent shown here.

MR. J. OWENS (*Bath*): I am rather surprised that Mr. Tiddy should not have qualified the statement with regard to the re-alignment of roads. I think Fig. 1 should definitely be qualified. Traffic flows far more easily between bends, if you like to call them such, with intermediate transition curves. If you have straight roads between bends it seems to me to be obvious that the road hog will "blind" along it until he is suddenly jerked to almost a standstill at the bend.

I am rather surprised to find in many districts that where it is impossible to super-elevate to assist the traffic, the white line is still stuck in the dead centre of the road. I think a proportion of somewhere about five-ninths should be allocated to the traffic on the outside of the bend. Where on the other hand the road is super-elevated, I would make a very revolutionary suggestion, and that is that a raised kerb should be put in the centre of the road, commencing at the tangent points. I should raise it three inches, and thus compel the traffic to use the whole of the super-elevated road, and I would put a suitable reflector on either side at the commencement of the kerb.

I entirely disagree with Mr. Tiddy's suggestion of keeping the kerb level the same as the carriageway. Carriageways must be clearly defined. It is not only the safety of the pedestrian that counts. The raised kerb has definite advantages. One of them, by no means least, is the question of drainage. Another is the clear definition of carriageway. If a motorist, particularly in the winter, goes along a highway, the vertical face of a kerb gives him more confidence. If there is no kerb and only a grass verge, the average motorist will keep further away from the verge, and that is a potential danger, I think, to other traffic using the road.

With regard to economies on roads in the last portion of the paper, I think the basis there should be a careful examination

of materials from the point of view of the number of years life you are going to assess, and from that basis you could get at the true road charges, and when comparisons are made I much prefer to consider them in terms of ton-miles-foot width every time. I think to adopt the square yard basis would put your figures right out of court for the purpose of estimating economic value. If traffic census figures are available you should make comparisons.

MR. O. W. BERRY (*Wells*): Several speakers have already mentioned the question of alignment. I hate the straight road and I would prefer the recommendation of the last speaker with regard to the transitional curves. Those curves want very carefully setting out. The curves on many of the new roads offend the eye.

With regard to the question of how a road should be widened, I think next to cost, the most important thing to consider from a rural point of view is the maximum length of road where you can strengthen the quarters. Most of our rural roads are very weak on the quarters, and I think if you can so improve your alignment and at the same time extend the length over which that road is made, then you will do the maximum amount of good.

On the question of revetment wall, be very careful as to its height. I think it is essential that it should be battered, otherwise if you are on a hill and traffic happens to be dragging down that side you will find very serious trouble.

One point that requires very careful attention is the lateral drainage of the road-bed in reconstruction work. One very often finds that you have to take out perhaps only a small area and in doing so you may excavate, as it were, a saucer, and if that saucer is not properly drained you will never get a suitable foundation.

With regard to the kerb, Mr. Tiddy mentions that where by reason of the restricted width of the road the path has to come immediately against the carriageway he would advocate a high kerb. I would like to stress the height at which the kerb is set. I have seen many cases where new kerbing has been put in and in a year or so the surveyor comes along and re-makes the road with a surface up to the top of the kerb. Up comes the kerb again.

I think if surveyors would pay a little more attention to the height at which the kerb is set, a good deal of money will be saved.

On the question of surfacing, Mr. Tiddy mentions that in recent years there has been marked improvement in the binding and wearing qualities of tarry and bituminous binders. I suggest that there has been a great improvement also in the quality of surface dressing materials, and for that reason I do not know whether he was not rather inclined to overstress the importance of bituminous macadam, and whether there is still not a very big use for water-bound macadam, or perhaps rather semi-grouted macadam, which will give several years wear. I prefer myself in reconstruction work to put down this type of surface and get as much wear out of it as I can and then put down a better surface later on. I think the old water-bound surface still has something to be said for it when properly surface dressed.

I quite agree with dealing on the basis of the ton mile. If we get on the ton square yard basis, road widths may get altogether out of proportion, and personally I would much rather have a narrower road that is a sound road with the traffic using the whole width of it, than a greater width with perhaps the construction not so strong and the traffic not using the whole of it.

MR. W. H. LINTERN (*Shepton Mallet*): With regard to the question of foundations, I think it must be dependent entirely on how far the block stone has to be got to make the road and as to whether we should use concrete or stone. In my district block stone can be got very cheaply and in my opinion block stone in those instances makes a really good job and one does not want to use all concrete. If the block stone is difficult to get, it would no doubt be better to use concrete.

I should have liked to see Mr. Tiddy's remarks with regard to the widening of the cross roads. We have many miles of cross roads that are carrying all sorts of lorry traffic, and instead of being about 15 feet wide they are about 10 feet or 11 feet. Those roads which were carrying just ordinary carts and waggons are now subject to the traffic of heavy petrol lorries, stone lorries and all sorts of things, and those are roads which really do want attention. It has been

my practice for some years that when a road gets in bad condition and has to be re-surfaced, by putting in block stone sides those roads were then made out to 15 feet wide. It gives vehicles a chance of passing each other without going on to the verge. I think that is a great service to the public who use those roads. It seems to me we do really want to turn our attention especially to those things, to roads which are to-day 10 feet wide and ought to be made 15 feet wide. The roads which are 15 feet wide and want to be made to 20 feet wide I think, are roads of greater importance. The Ministry of Transport should help the County Councils to do it. The roads are roads which are kept up more especially by the ratepayers of the County in which they are situated.

MR. J. LOVELL (*Somerset*): In my opinion, the authorities responsible for the reconstruction and strengthening of rural roads have more difficult problems to deal with than borough or urban authorities, as many of the roads in rural districts are without adequate foundations, and are also narrow. The speed of all vehicular traffic is much faster on rural roads than when passing through towns, and it is the pulsating hammering action of heavily laden vehicles travelling at fast speeds which is causing so much damage to many rural roads. Fortunately the wheels of many of the heavy vehicles are now fitted with pneumatic tyres, and we can hope for some benefit in this direction in the future.

Mr. Tiddy states that the road bed should be stable and practically incompressible, also that the road bed should be compacted to such an extent that it will support the superimposed foundation so that the latter when consolidated by rolling does not sink to any appreciable extent into the surface of the road bed. No difficulty need be experienced in the preparation of the road bed where the subsoil is not of a soft or spongy nature, but there are hundreds of miles of rural roads constructed on marshy land. Many of these have to carry fast and heavy traffic, and it is the reconstruction or adaptation of these roads to meet the demands of increasing traffic which is causing anxiety, at the present time, to the authorities responsible for their upkeep. I know of many miles of roads constructed

on peat with only narrow margins between the carriageways and deep ditches. At times the ditches are full of water and at other times they are dry. Will Mr. Tiddy tell me how, having due regard to economy, these roads should be reconstructed? The peat, of course, yields readily to pressure of traffic, and concrete piles cannot be considered on the ground of cost. Should Mr. Tiddy recommend brushwood I should like to know how the brushwood should be laid. Should it be tied up in bundles, and, if so, should the bundles be laid in alternate layers crosswise and lengthwise or should the brushwood be laid crosswise only?

I take it from Mr. Tiddy's paper that he advocates the shaping of the road bed to the same convexity as the finished surface, and that a Telford foundation should be constructed. I think Telford directed that the foundation should be laid with the broadest ends of the stones downward. I do, however, know a surveyor who lays the foundation with the narrowest ends of the stones downward, and I have not known a foundation constructed by him give trouble. My personal opinion is that the stones should be laid with the broadest and narrowest ends downward alternately.

With regard to kerbing, Mr. Tiddy says: "To prevent the lateral spreading of the surface some form of kerbing is essential." In my opinion the movement of any surfacing material is governed quite as much, if not more, by the quality of the surface material than it is by the kerb. I could take Mr. Tiddy to roads where there is a kerbed footpath on one side and on the other side there is a grass margin only and there is as much movement on one side of the road as there is on the other. In my opinion, if surfacing material will move laterally, it will also literally move in every other direction. With regard to surfacing material, Mr. Tiddy states that the popularity of bituminous and tarred macadams reflects the suitability of this kind of material for rural roads and that alternatives for comparison such as water-bound macadam, grouted macadam, etc., should be considered. I agree with Mr. Tiddy that there are quite a number of small local quarries from which suitable material could be obtained.

MR. P. STURDY (*Somerset Rural Community Council*): It is pleasing to hear that at long last road experts are beginning to be a little bit unanimous on the subject of super-elevation of curves. That movement has not gone far enough yet. I believe I am right in thinking that Somerset was the first county to take up that super-elevation question seriously. But there are other counties with magnificent road surfaces where they are not doing their duty to the public by merely marking out the curves and putting "Dangerous curve" there, and not super-elevating them. In regard to the raised kerb, I think there is no question that on curves the safety of the raised kerb is very great at night, for this reason: your flat kerb will not show the reflected lights of an on-coming car, but the raised kerb, even though it be somewhat tarry, does do so, and that helps not only to show the alignment of the curve, but it does help you to see a pedestrian walking.

With regard to long stretches I agree with Colonel Stead that from a great many points of view the safety and beauty of construction have serious disadvantages. I would rather suggest that on long straight flat plain country, as for instance Salisbury Plain, or any parts of East Anglia, they have a beauty of their own. But as against that, our English country at any rate towards the western part, is broken country, and surely the alignment of the road to be beautiful should follow more or less the alignment of the country itself, and although nothing is more ugly than an ugly curve, and nothing is more exasperating and costly than an immense number of very bad and sudden curves, to eliminate all curves would be a serious destruction. The important point is to get your curves beautiful and easy and above all visible. From the point of view of economy, braking hard on the entrance to a curve, is very costly for the road surface, to say nothing of the cost to your own car and tyres. Again, where you are joining a straight into a curve, I believe we should be wise in taking a note from the railway engineer's book. In other words: Do not use the tangent curve, but the parabolic. It is a slight difference, but it has made an enormous difference in railway travel, and I am convinced it will

add to safety on the roads. If you are driving a car I am convinced your car will not take a tangent curve, but it will take a parabolic.

On the question of research, I am not at all certain that one of the most useful purposes of research that could be carried out would not be to enquire into the behaviour of our good old friend the steam roller. I am not so certain that the steam roller is the last word in machinery in consolidating either the foundation or the surface. Look along in the light of somebody else's headlights on an absolutely new road, and you will not find that surface is a plane. It is a series of flat waves. Who has been responsible for those flat waves? If it is a concrete road, it may be the incompetence of the contractor's foreman in not seeing his men use their skids properly. The concrete road is rare, and I am inclined to think the fault lies with the steam roller.

In ending off the repairs of surfacing, far too many counties and districts still end up squarely across the road. I am convinced that laying them at least 45 degrees should be the minimum of ending off even for the day's work. Ending off straight gives every car a bump. It gives the steam roller a bump, and if you have a bump down you may be dead certain you are going to begin a ripple and, therefore, in the very end of repairing your road you are preparing for its destruction.

There are certain forms of surfacing which seem at long last to be entirely satisfactory, but there is one very insidious gritty material, and that is sea worn gravel of about the size of beans and peas. They are highly polished by the sea, and they are very handy, especially in certain parts of England. They come from various well-known beaches. The other day in Somerset, where I am thankful to say they are not used, I was coming out of a lane on to a delightful main road. It was a blind corner and it was slightly down hill. I was therefore taking it easily, luckily for me. A flock of sheep suddenly appeared in the main road in front of me. So my brakes went down, and to my dismay although it was a hot dry day my car was completely out of control, although at the moment of applying the brakes I doubt whether I was doing

seven miles an hour. I was so interested in the phenomenon that I stopped the car to look at it, and I could hardly walk on the surface because it was so slippery.

MR. TIDDY (replying): With regard to straight line alignment of the road, I think myself we are bound to cater for speed and safety in so far as the two are compatible, and you need only insert a curve when a road has to change direction by reason of the character of the country through which it runs. I think it is really folly to insert curves merely for the sake of the curve. It is certainly wasteful.

A subsoil of clay is an extremely difficult subsoil, but I think clay has got a reasonably high bearing point when it is dry, and that one's efforts should be directed to dewatering and localising and possible movement.

On Mr. Lovell's question as to catering for the horse, I think it is economically impossible to provide the road that is most suitable for the horse. The best we can do is to provide a road that will be as suitable as possible for the horse without impairing its efficiency as a motor way.

Mr. McBeth in his query as to the thickness of concrete, rather suggests that a concrete slab on the road can be theoretically designed. I think it can be theoretically designed, but I think the assumptions upon which he bases his theory might in practice be wrong. You get such a variation in the bearing power of subsoils over a comparatively small area that it is very difficult to design theoretically a concrete slab.

With regard to topping, when using tarred or bituminous macadam, I think if you provide a topping you are spending money very wisely. But my idea of topping is not that it should remain on the top of your base, but it should be rolled into it and it should eventually wear into it and fill the voids in the base coat as far as possible. I think a full grout would be expensive. It is very useful where a macadam road adjoins tramlines in making a good joint.

I think the difficulty of slippery surfaces is being very quickly overcome by providing a hard stone wearing surface in the form of a surface dressing.

There is, of course, a big divergence of opinion as to whether a high kerb or a low kerb should be used, but what I meant to convey in my paper was that the kerb should not be put down indiscriminately. You should always consider whether you are getting value for the money you are spending on it. For instance, I think it is very wasteful for a high kerb to be kept against a grass verge, especially when its only use is to act as a guide for traffic at night. If you want a guide for traffic at night, you can provide it far more cheaply than by providing a heavy, continuous kerb.

With regard to Mr. Sturdy's questions, I think it is now the general practice to insert a parabolic transition in all curves. I do not think any of us would knowingly be guilty of using grit the size of peas or beans. The smaller size of the same kind of material is, I think, a very suitable material for this class of work.

CONFERENCE

Under the auspices of the Institute of Sewage Purification.

FRIDAY, 17th NOVEMBER, at 11.0 a.m.

MR. J. HAWORTH, M.B.E., F.I.C. (*President of the Institute*), in the Chair.

The following Paper was taken as read:—

Recent Developments in Methods of Sewage Works Analysis.

BY

JOHN T. THOMPSON, M.Sc., F.I.C.

Chemist to Sewerage Committee and Works Manager, Knostrop Sewage Works, Leeds.

(NOTE.—This Paper was submitted for the Open Competition arranged by the Congress Committee and was awarded a Special Prize of Five Guineas).

THE subject of this paper is a perennial one, but it has periodically produced valuable discussions at this section of the Congress and is due for further consideration. Since 1929, when "Methods of Chemical Analysis as applied to Sewage and Sewage Effluents" was published by the Ministry of Health, chemists have had time to form a reliable opinion of their value for the control of the different stages of sewage purification, and for registering the quality of the final effluents passing into rivers and streams from the standpoint of Rivers Authorities. The chief objects of this paper are, therefore, to give chemists an opportunity of pooling their experience of the above tests and also to review recent work done with the object of improving the methods of analysis, more particularly the R.C. test, which, though universally recognised as sound in principle, has never won the goodwill of sewage works chemists because of its cumbersome procedure.

In the first place it will be useful, especially to those who are not members of the Institute of Sewage Purification, to note the historical development of the

question. In 1922 Mr. Gibbon of the Ministry of Health urged the members of our old Association to organise team work among its members for the investigation of some of the difficult problems of sewage treatment, with a view to the improvement of existing processes. Success on these lines would minimise the waste of public funds on the construction of inefficient works. When the Council considered this important suggestion, it became clear that the first step was to standardise methods of analysis and the recording of results so that those obtained at different works should be strictly comparable; to this end, they immediately appointed a Committee of Chemists to deal with the whole question.

The position at that time was clearly stated in an important paper presented to this Congress in 1923 on "Sewage Works Analysis and Standards of Purification" (Association of Managers of Sewage Disposal Works, Proceedings 1923, page 95) in which Mr. Garner pointed out how varied were the methods of analysis employed by sewage works chemists, public analysts and chemists of River Authorities. He made a strong plea for uniformity of technique and records in conducting these empirical tests, in order that results might be comparable throughout the country. This had been done some time ago by the Public Health Association of America, who revised the "Standard Methods" about every five years. He also gave figures which show that the use of distilled water for dilution in the R.C. test gives, on the average, results 27 per cent. higher than when tap water is used, but this figure might possibly be reversed in another laboratory.

To meet the difficulty of variable results obtained with different dilution waters, he favoured Theriault's proposal to use tap water which had been stored until its B.O.D. figure was not greater than 0.06 parts per 100,000.

In 1924 our Committee completed their careful enquiry into standard tests: their report was adopted by the Council and forwarded to the Ministry. The same year a conference of professional men was called by the Ministry to consider this report and to formulate a system of standard tests, but it failed to arrive at any agreement on the subject.

In 1927 Mr. O'Shaughnessy and his colleagues again brought the question before this section of the Congress (Association of Managers of Sewage Disposal Works, Proceedings 1927, p. 105). He reviewed recent work published by Johnson, Cooper & Read, Abbott and others; then he gave tables of discordant results obtained by different tests, and also from the same test carried out at different dilutions. The important discussion which followed only emphasised the urgent need for all chemists to conform to a standardised technique and uniform expression of the results of analysis.

In 1929 this object was partly attained for, after a long interval—the incubation period in this case was five years at zero—the Ministry of Health published "Methods of Chemical Analysis as applied to Sewage and Sewage Effluents." This publication embodies the recommendations of the Association for "Alkalinity and Acidity," "Hydrogen Ion Concentration" and "Sludge Analysis," but the rest is largely copied from Royal Commission on Sewage Disposal, Report IV, Part V, 1904: therefore, the descriptions of the approved tests are too elaborate, and too many

alternative methods are included; this only tends to confuse the chemist who is inexperienced in sewage analysis.

For instance, under Kjeldahl Process p. 20, there are minute instructions for the preparation of sugar solution; then results are quoted (p. 25) to show that reduction with zinc and acid is sufficient and that the addition of sugar really only lengthens the estimation; again, under "Solids in Suspension" p. 41, "The crucible is then dried at 100° or 105° C." The former temperature is generally used in this country. Also the Crum Nitrometer Method (p. 15), Horsley's Pyrogallic Acid Method (p. 17) and Scudder's Dissolved Oxygen Test (p. 31) are ancient history, and should have been omitted.

BIOCHEMICAL OXYGEN DEMAND.

It is generally agreed that some test measuring the biochemical absorption of dissolved oxygen from solution is essential for judging the quality of sewage effluents in relation to purification processes and river pollution. A standard technique must be worked out for this purpose which will give accurate comparable results in different places.

In their 1924 report to the Ministry our Association were not able to recommend the Rideal-Winkler method of estimating dissolved oxygen absorbed from solution in five days at 18.3° C. (R.C. Test), because it gave discordant results, from causes which were not fully understood; they state:—

"The problem of the diluting water has not yet been solved. A large amount of work has been done from time to time on various factors affecting it but no conclusive result has been reached. Recently attention has been turned to the possibilities of well aerated distilled water as a diluent, and at the present time a good deal of work is being done as to the possibilities of obtaining either a chalked aerated distilled water or a conductivity water, which, when prepared by several different chemists under their own laboratory conditions, will give uniform results in the case of any given sample. Some idea of the peculiar nature of the problem may be gained from the fact that in one part of the country, chemists working both with tap water and distilled water for diluting purposes find that the tap water gives consistently the lower results of the two, while in another part of the country other chemists experience exactly the reverse. Even canal water has given a lower figure when used for diluting than either tap or distilled water.

"An instance of the discrepancies arising between individual chemists may be cited in the case of triplicate samples of effluents examined by three members of the Committee. The samples of effluent were collected in bulk and the three bottles filled in a manner which precluded any serious difference in the liquor filling them. The three lots of aerated chalked distilled water used for diluting purposes were prepared in the three laboratories under identical conditions of chalking and aeration. On comparing results over a period of 6 weeks it was found:—

- (1) That on no occasion did the three laboratories agree upon any one sample.
- (2) That in the case of the greatest and smallest discrepancies between the laboratories, in one case the highest figure was 116 per cent. more than the lowest figure, and in the other case the highest figure was 16.5 per

cent. more than the lowest figure. These were the greatest and least discrepancies.

- (3) That in one set of six samples tested, laboratory A returned the highest figure three times, and the lowest figure three times: laboratory B returned the highest figure once, the medium figure three times, and the lowest figure twice: and laboratory C the highest figure twice, the medium figure three times and the lowest figure once.

"In view of the present position of the problem it is evident that a great deal of work will have to be done by chemists in various parts of the country, and their results collected and co-ordinated before any definite judgment can be formed on the test as proposed by the Royal Commission. There are, however, one or two points which the Committee would urge.

"First, whatever method of carrying out the test be ultimately adopted, if it involves an incubation period, that period should be reduced to a maximum of 48 hours. If a test for the biochemical oxygen demand of an effluent is to attain its greatest utility, it must be a good weapon in the hands of the sewage chemist, in addition to its use as a legal standard of purity. And its maximum utility as a means of control cannot be attained with a period of five days taken up before results are available. Alteration in the time of incubation would mean alteration in the limit of absorption, but the value of the test would not thereby be decreased: on the other hand the shorter period of incubation would greatly increase its value as a means of control in biochemical processes.

"Second, the Committee would urge that consideration be given to the possibilities of a 24 hours test on the well aerated undiluted sample. Such a test could be easily standardised, is easy of manipulation, and it does away with the difficulty connected with the diluting water, which, it should be remembered, is under the present proposals a purely arbitrary addition both as regards its quantity and its nature. It is probable that a '24 hours, undiluted' test could be worked out which would be as valuable as the present proposals and eliminate many of the difficulties. There is undoubtedly at the present time a strong feeling in favour of a test on these lines."

In spite of this and similar evidence which had accumulated in the interval of five years, the R.C. Test is given in "Methods of Chemical Analysis, etc.," p. 45, without giving any detailed instructions for preparing a standard diluting water, which is known to be the essential, if the chief source of error is to be avoided. Dilution with tap water is recommended but this varies chemically and bacteriologically according to its source; therefore, to keep it over night and shake a little time before the determinations are made is not likely to give concordant results in different laboratories. It would be better to aerate the water first, then allow it to stand at 18° C. for at least 48 hours, to ensure that the water has become stable relative to the absorption of oxygen. The blank should not absorb more than .06 pts. oxygen per 100,000 in five days. Even then it is doubtful whether the R.C. Test is accurate enough in cases which may involve dispute, as claimed. For example, the results obtained by the author with this test on the duplicate

of official samples of effluent taken by the West Riding Rivers Board during the last three years show a discrepancy of from 2.8 to 30%, or an average of about 12%.

Table 1 gives duplicate results of the R.C. Test and the modified Miller Test on Leeds percolating bed effluents, showing the effect of dilution with aerated tap water which had been stored until its absorption of O₂ was negligible:—

TABLE 1.
Parts per 100,000.

No.	N ₂ as Free NH ₃	N ₂ as Nitrates.	O ₂ Absorbed in 4 hrs.	Suspended Solids.	DILUTION 1 to 4.		DILUTION 1 to 9.	
					R.C. Test.	Miller.	R.C. Test.	Miller.
1.	.124	.380	4.32	7.4	2.53	—	2.25	—
					2.47		3.09	
2.	.224	.420	3.89	6.8	2.59	—	2.24	—
					2.43		1.70	
3.	.044	.480	2.93	8.4	3.83	3.50	3.83	3.37
					3.83	3.40	4.06	3.40
4.	.068	.620	2.98	4.0	2.60	2.37	2.36	2.50
					2.65	2.25	2.91	2.50
5.	.224	.580	4.83	8.6	4.00	—	4.06	—
					4.00		3.95	
6.	.064	.680	3.53	12.2	3.66	3.00	3.62	3.00
					3.66	2.90	3.49	3.00
7.	.168	.780	2.94	9.2	3.21	2.57	2.94	2.50
					3.27	2.50	2.92	2.50
8.	.064	.500	2.19	6.6	2.14	2.17	2.48	2.15
					2.25	2.25	2.48	2.15

In the above comparison special care was taken to eliminate all possible errors by carrying out the work under uniform conditions. The same reagents and diluting water were used, also the same approximate time interval was taken for each stage of the R.C. test; the incubation period in all cases was 5 days. It will be observed that there is good agreement between duplicate figures for both tests at dilutions of 1 to 4; this also applies to dilutions of 1 to 9 for samples Nos. 5 to 8, which are effluents from domestic sewage containing only a little trade waste. With samples Nos. 1 to 4, derived from sewage containing about one third its volume of mixed trade waste, at dilution 1 to 9 there is an average difference between duplicate figures of about 19 per cent. for R.C. test, but the corresponding Miller duplicates agree well.

Both tests give a lower average figure for the B.O.D. after 5 days incubation at the greater dilution for samples Nos. 5 to 8, but the error is only about 1 per cent.

In the case of industrial effluents (1 to 4) the effects of dilution are erratic: the average R.C. figures for No. 4 agree well, for Nos. 1 and 3 show an average increase of over 4 per cent. at the greater dilution, and for No. 2 a decrease of 21 per cent. The corresponding Miller tests show an increase of 8 per cent. on No. 4 and a decrease of 2 per cent. on No. 3.

From these results it is fair to infer that under quite uniform conditions, which could not be attained in different laboratories, the R.C. test gives consistent results with effluents from domestic sewage, but with effluents from an industrial sewage, especially at dilutions greater than 1 to 4, the results vary considerably. It is clear that with both classes of effluents the Miller test gives more uniform figures than the R.C. test.

REVIEW OF RECENT WORK.

At this stage it will be useful to review the most important recent work done on this subject, chiefly in America and Germany.

In 1930, a Symposium by a number of United States chemists prominent in sewage work was published (S.W.J. 2, 347), giving their views on the standardisation of tests. This made evident the confusion which existed in the estimation of B.O.D., and the urgent need for standardising the dilution water, because both distilled and tap water were proved to give variable results in different places.

Urbain & Miller (J. Amer. Waterworks Association, 1930, 22, 1261) shewed that the determinations of dissolved oxygen by the Winkler Method or by the Rideal-Stewart modification were wholly unreliable for waters containing more than 50 p.p.m., of iron and for waters containing less than this amount if titration does not immediately follow the preceding parts of the determination.

Bach (Gesund. Ing. 1931, 54, 39; W.P.B. Summary 1931, 4, 170) confirmed the findings of Haas (Gesund. Ing. 1929, 52, 846) that effluents containing sulphite pulp waste rapidly removed all evidence of dissolved oxygen as determined by Winkler method because the oxygen oxidises the sulphite more readily than the manganese hydroxide precipitated in the determination, but sodium sulphite up to 100 mg. per litre does not affect the Miller test if done immediately.

Measurements of the B.O.D. of sewage effluents and of "artificial sewage" prepared from old nutrient gelatine, by the dilution method, showed that the same sample gave widely different results (20 days incubation), which increased with, but not in proportion to, increasing dilution. The water used was tap water containing 0.5 gm. per litre sodium carbonate. The general conclusion was that no reliable and rapid method for the determination of B.O.D. of strongly polluted water and sewage had yet been worked out.

Sierp & Fransemeier (Tech. Gemundelb. 1931, 34, 233, 250, 260, 271, 289, 301, 313; W.P.B. Summary 1932, 5, 12 and 122) point out that the amount of oxygen taken up by a stream is dependent on the condition of the stream, the salt content, the temperature, the barometric pressure and partial pressure: the speed of oxygen absorption is dependent on the surface area, the movement and the oxygen deficit.

The apparatus for the direct estimation of dissolved oxygen is described; the results obtained by this method show general agreement with those by the dilution method. Its advantage over the latter is that it avoids the errors due to the use of chemicals and large dilutions.

To study the effect of bacterial poisoning, B.O.D. determinations were made on domestic sewage sterilised with formalin; this showed chemical decomposition only. In formalin treated samples the test could not be carried beyond 5 days by the dilution method as all the available oxygen was used up; similar samples showed a low B.O.D. by the direct method; it may be that formalin is more easily oxidised in dilute than in concentrated solution or that formalin in dilute solution supports biological decomposition.

It was also observed that when the direct method was applied to a domestic sewage containing 100 mg. of phenol per litre, with both air and oxygen, the decomposition of phenol was complete in 3 days showing that oxygen exerted no sterilising effect.

Theriault (Public Health Rep. (U.S.) Supplement 90, 193), gives detailed instructions for the estimation of dissolved oxygen and B.O.D. The Rideal-Stewart modification for use in the presence of nitrites, ferrous salts, etc., an alkaline hypochlorite modification for overcoming the interference due to sulphite waste liquors and the original Winkler method in the case of water or liquors polluted with relatively stable organic matter in the absence of readily oxidisable mineral or organic substances, are described. The use of buffered synthetic dilution water instead of stored tap water is recommended.

Theriault and McNamee (Dissolved oxygen in presence of organic matter, hypochlorites and sulphite wastes. Indust. and Eng. Chem. Anal. Edit. 1932, 4, 59) carried out an important critical study of the interference of various substances in solution with the estimation of dissolved oxygen by Winkler's method. The presence of glucose caused an apparent loss of dissolved oxygen, which increases with increasing amounts of sugar.

The Rideal-Stewart modification was only partly effective in counteracting the interference. This apparent loss of oxygen is probably due to the reduction of manganic hydroxide in alkaline solution by the decomposition products of the glucose.

If this period of alkalinity is reduced to less than 25 secs., reasonably accurate results can be obtained even in the presence of 5,000 p.p.m., of glucose. Reducing the period of alkalinity to a minimum is also effective in reducing interference to peptone, concentrated sewage mixtures, sludge liquors and sulphite wastes. In the last case it represses the effect of the organic matter in sulphite waste, but not that of inorganic constituents such as sulphites, polythionates, etc. These substances would still interfere with the Winkler results by reducing the manganic hydroxide or removing iodine. This error can be remedied by preliminary treatment with alkaline hypochlorite solution, which oxidises the thiosulphates and higher polythionates, and subsequent removal of undecomposed hypochlorite by acidification in the presence of an iodide and neutralisation of the liberated iodine with

dilute sodium sulphite solution. This modification gives reasonably accurate results with digester waste below dilutions of 1 to 300. Stronger solutions would rarely occur in practice.

In May 1932 an important preliminary report on "The Determination of Dissolved Oxygen by the Winkler Method" was published by the Committee on Methods of Sewage Analysis of the Federation of Sewage Works Associations (S.W.J. 1932, 4, 413). This report contains a description of sampling apparatus, instructions for the preparation of the numerous solutions required and a detailed account of the procedure necessary to carry out the test with its numerous modifications. At first sight this seems very elaborate, but this minute standardisation is evidently essential in order to obtain comparable results with the Winkler method. The most interesting parts of the report are those dealing with the preliminary procedure necessary to prevent the interference of various substances which are liable to occur in an industrial sewage, with the accuracy of the estimation.

It is stated that the permanganate (Rideal-Stewart) modification should be applied in determining the dissolved oxygen in liquids containing ferrous salts, sulphites and in partly nitrified effluents or, in general, whenever a sample may contain 0.1 p.p.m., or more of nitrogen as nitrites. When potassium oxalate is added to destroy excess permanganate, the use of large excess should be avoided or the results will be too low, at the same time perfect decolorisation must be secured, for if any brown tint remain the results will be too high. In order to hasten decolorisation when iron salts are known to be present (e.g., in mine wastes, etc.) potassium fluoride (2 ml. of 40 per cent. solution) should be added along with the permanganate. Because ferric salts are readily reduced to the ferrous condition by oxalates in daylight, the decolorisation should proceed in the dark. The above preliminary treatment is ineffective with samples containing paper mill waste for the permanganate does not completely oxidise sulphites thiosulphates and polythionates to sulphates, so the final results are too low. A practical degree of accuracy may be obtained by treatment of such samples with an alkaline solution of sodium hypochlorite to decompose polythionates and oxidise sulphites, thiosulphates, etc., to sulphates. The solution is then acidified and after addition of potassium iodide, the liberated iodine is removed with dilute sodium sulphite solution. Dissolved oxygen may then be determined by the regular Winkler procedure.

In September, 1932, a further important Progress Report was published by the Joint B.O.D. Committee of the Great Lakes and Ohio Rivers Boards with the approval of the Committee on Sewage Analysis of the Federation of Sewage Works Association—"Recommended Uniform Procedure for B.O.D. Determinations" (S.W.J., 4, 738). This is virtually a continuation of the report just summarised. It is stated that dilution water should have the following characteristics at the time of use:—

- (a) Its 5 days B.O.D. should be less than 0.2 p.p.m.
- (b) It should be neither supersaturated nor greatly undersaturated with dissolved oxygen at the standard temperature of 20°C.

- (c) It should be practically free from interfering substances such as iron salts and nitrites and from inhibitory substances such as free chlorine, chloramines and copper salts.
- (d) The p.H. value and mineral salt content should be favourable to biological growth.

In many localities it may be impossible to secure a suitable natural water for dilution, therefore, for comparison it is desirable to provide a dilution water of readily reproducible characteristics. Since the use of distilled water alone is inadvisable, it is recommended that fully aerated distilled water containing 0.3 grm. per litre of sodium bicarbonate should be used for dilution. Further co-ordinated research is required on the suitability of synthetic water.

Biological activity may be inhibited if a sample is unduly acid or alkaline, i.e., outside the range p.H. 5.5-9.0, therefore, adjustment should be made with dilute hydrochloric acid until acid to cresol red, or with dilute sodium carbonate until alkaline to bromthymol blue.

As the test depends on the symbiotic activity of bacteria and plankton, it is necessary to insure the presence of these organisms, especially in the examination of industrial wastes, chlorinated sewage, etc. The seeding is accomplished by adding sewage (1 ml. per litre) or river water (10-20 ml.) to the dilution water.

Good river water or sewage effluents of excellent quality may frequently be incubated without dilution for the 5 day test. In other cases the dilution should be such that at least 1 p.p.m. of oxygen is present at the end of the test, but with nitrified effluents 2 p.p.m. is desirable. Details for the complete procedure for B.O.D. determination are given, together with an exhaustive list of references.

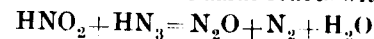
Dr. Kessener, The Hague, Holland, uses sodium azide to prevent nitrite troubles instead of the Rideal-Stewart modification of the Winkler estimation. This reagent was first proposed by Alsterberg in 1925 (Biochem. Zeitschrift Bd. 159, p. 36.—Bd. 170, p. 30), but is probably little known in this country.

Dr. Kessener's procedure for the Winkler-Azide Method is as follows:—

To a 250-300 mls. bottle of sample is added:—

1. 3 mls. of a solution of 330 grms. per litre NaOH, 200 grms. per litre KI and 5 grms. per litre NaN_3 .
2. 3 mls. of a solution of 400 grms. per litre $\text{MnCl}_2 \cdot 4 \text{H}_2\text{O}$ and after mixing and sedimentation for at least one hour.
3. 6 mls. Conc. HCl , or, if a quantity of ferric iron is present, 6 mls. Conc. H_3PO_4 , Sp. Gr. 1.7.
4. Titration with thiosulphate as usual.

This method is found to be more accurate than the R.C. Test up to a nitrite concentration of 2 pts. per 100,000 N_2O_3 . The Author confirmed this statement and found that, by increasing the quantity of sodium azide, nitrites up to 5 pts. N_2O_3 could be destroyed. After acidification the azide reacts with the nitrites as follows:—



It is true that the dissolved oxygen in water, or water polluted by small quantities of stable organic matter, may be accurately estimated by the Rideal-Winkler method, but after considering the elaborate precautions indicated above, which become necessary when this test is applied to sewage works analysis, one is driven to the conclusion that if it had not had the blessing of the Royal Commission on Sewage Disposal it would have been abandoned long ago.

DISSOLVED OXYGEN AND B.O.D. ESTIMATIONS BY THE MODIFIED MILLER TEST.

The author published a brief preliminary note on this subject in Proceedings Assoc. M. Sewage Disposal Works 1927, p. 184, but it can now be dealt with in some detail.

From the preceding survey of recent work, it is clear that the "R.C. 5 days" test (M. of Health, Methods of Sewage Analysis 1929, p. 45) is unsatisfactory in the following respects:—

- (a) As a method of estimating dissolved oxygen. So many active reagents are used that it gives inaccurate results when applied to the complex mixture of unstable substances, which often occur in sewage, trade wastes and effluents. If this defect is overcome by applying the elaborate modifications set out in the American reports the test becomes too cumbersome for control purposes on a Sewage Works.
- (b) As a method of estimating B.O.D. The incubation period is too long for practical purposes. Halliwell (ibid. p. 48 and Appendix 5) shows that similar results can be obtained by reducing the incubation period to 3 days at $26.7^\circ C$., but this temperature is too high for the biochemical changes which take place in a purification plant or river to be fairly represented.

Again, the error due to the large volume of dilution water necessary to supply sufficient oxygen for the incubation, especially if the water is not very carefully standardised, may be very considerable.

The author submits to the Congress that the modified Miller test described below is superior to the R.C. test under both headings and can be carried out in a small fraction of the time with less apparatus and fewer standard solutions.

(a) DISSOLVED OXYGEN BY MODIFIED MILLER METHOD.

Like the original test described by Miller (J.S.C.I. 1914, 33, 185⁹) the modification depends on the oxidation of an alkaline solution of ferrous hydroxide-tartrate complex by the dissolved oxygen. The end point is indicated by the reduction of methylene blue to colourless solution. The choice of methylene blue or phenosafranin is a matter of personal preference.

The solutions required are:—

- (1) Alkaline Tartrate: 350 grms. pure Rochelle Salt + 100 grms. pure caustic soda per litre.
- (2) Ferrous Ammonium Sulphate: 10.75 grms. pure A.R. Salt + 10 ml. pure A.R. Sulphuric Acid per litre.

This stock solution is diluted with an equal volume of air-free distilled water, i.e., 5.375 grms. salt per litre, for use in the titration. It should be previously standardised against water of known oxygen content.

- (3) Indicator Solution: 1 gm. Methylene Blue S.S. per litre.

Procedure:—If the sample contains suspended solids, it is allowed to settle for a few minutes; 50 ml. of the clear liquid is placed in a 100 ml. Nessler cylinder, care being taken to avoid aeration, and the surface is protected from the air by adding about 3 ml. pure paraffin oil; 2 drops Methylene Blue and 5 ml. alkaline tartrate solution are then added.

The ferrous ammonium sulphate solution is placed in a 20 ml. burette, graduated in $\frac{1}{50}$ ml. and fitted with a 2 way tap so that it can be filled from a stock bottle with the minimum risk of aeration. Its jet is elongated to dip below the 50 ml. mark on the Nessler cylinder. In this way, sulphate solution is run in, 1 ml. at a time, and finally 0.05 ml.: the liquid is stirred between each addition by the slow up and down movement of a glass rod, bent round at the end to fit the cylinder; care must be taken not to break the surface. The end point, when the blue is discharged, is quite sharp with $\frac{1}{50}$ ml.

The m.l.s of ferrous ammonium sulphate (5.375 grms. per litre) used, divided by 4 gives parts per 100,000 dissolved oxygen in solution.

The ferrous hydroxide-tartrate complex, which is the active agent in this reaction, is evidently more easily oxidised by dissolved oxygen than sulphites or nitrites are; therefore, within the limits likely to be found in trade wastes or sewage works effluents, the estimation of dissolved oxygen by the Miller method has the great advantage of being unaffected by the presence of sulphites and nitrites.

In Table 2 are analyses illustrating this point in comparison with the Winkler and R.C. test. It also shows the effect of ferric salts, as iron ammonium alum, on the three tests. The estimations were done upon stable aerated tap-water to which the necessary amounts of 1 per cent. solutions of the salts were added.

In carrying out the R.C. test, sufficient permanganate was added to maintain a purple tint for 10 minutes, then the excess was destroyed with potassium oxalate solution.

TABLE 2.
Parts per 100,000.

Reagent added.	Method.	Time of Estimation.	Blank.	Parts of reagent added.			
				2.5	5	10	20
Sodium Sulphite	Miller	At once	.987	.987	.987	1.00	1.00
		½ hour	—	.987	.987	.987	.940
		1 hour	—	.987	.940	.925	.875
	R.C.	At once	.972	.937	.868	.767	.462
	Winkler	At once	.972	.812	.608	.338	Nil
Sodium Nitrite	Miller	At once	.540	.550	.540	.540	.540
		1 hour	—	.540	.540	.540	.550
	R.C.	At once	.587	.587	.587	.560	.631
		1 hour	—	.587	.575	.688	.700
	Winkler	At once	.587	2.56	—	—	—
Iron Alum as parts of Fe ₂ O ₃	Miller	At once	.862	.850	.862	.862	.875
	R.C.	At once	.622	.631	.643	.665	.825
	Winkler		.631	—	.654	.699	.778

These figures indicate the following effects on the estimation of dissolved oxygen by :—

1. Modified Miller Method.

(a) Sodium Sulphite up to concentration of 20 parts per 100,000 has no effect, if the estimation is done at once : if it is carried out after ½ hr., the highest concentration causes a reduction of the dissolved oxygen figure : after 1 hr., this decrease is noticeable with 5 parts per 100,000 and becomes very marked with 20 parts sulphite.

(b) Sodium Nitrite up to 20 parts per 100,000 has no effect on the estimation, even after standing 1 hr. before titration.

(c) Iron Alum has no effect on the estimation up to 20 parts Fe₂O₃ per 100,000, but at this strength a certain amount of colloidal ferric hydroxide is formed on the addition of alkaline tartrate, which gives the indicator a green tint and makes the end point yellow, consequently the result is rather high. If 3 cc. of 40 per cent. potassium fluoride is added before titration, this difficulty is overcome for the liquid remains clear blue and the end point is quite sharp.

2. R.C. (Rideal-Stewart Winkler) Method.

- (a) This method gives low results even with 2.5 parts per 100,000 sulphite.
- (b) With sodium nitrite up to 5 parts per 100,000 the results are good, beyond that point they become irregular.
- (c) The addition of ferric salt causes an apparent increase in the oxygen figure as the dose is increased.

3. Winkler Method.

This method is useless in the presence of sulphites and nitrites. Ferric salts cause an apparent increase of dissolved oxygen similar to the figures for R.C. test.

(b) ESTIMATION OF B.O.D. BY USING OXYGEN.

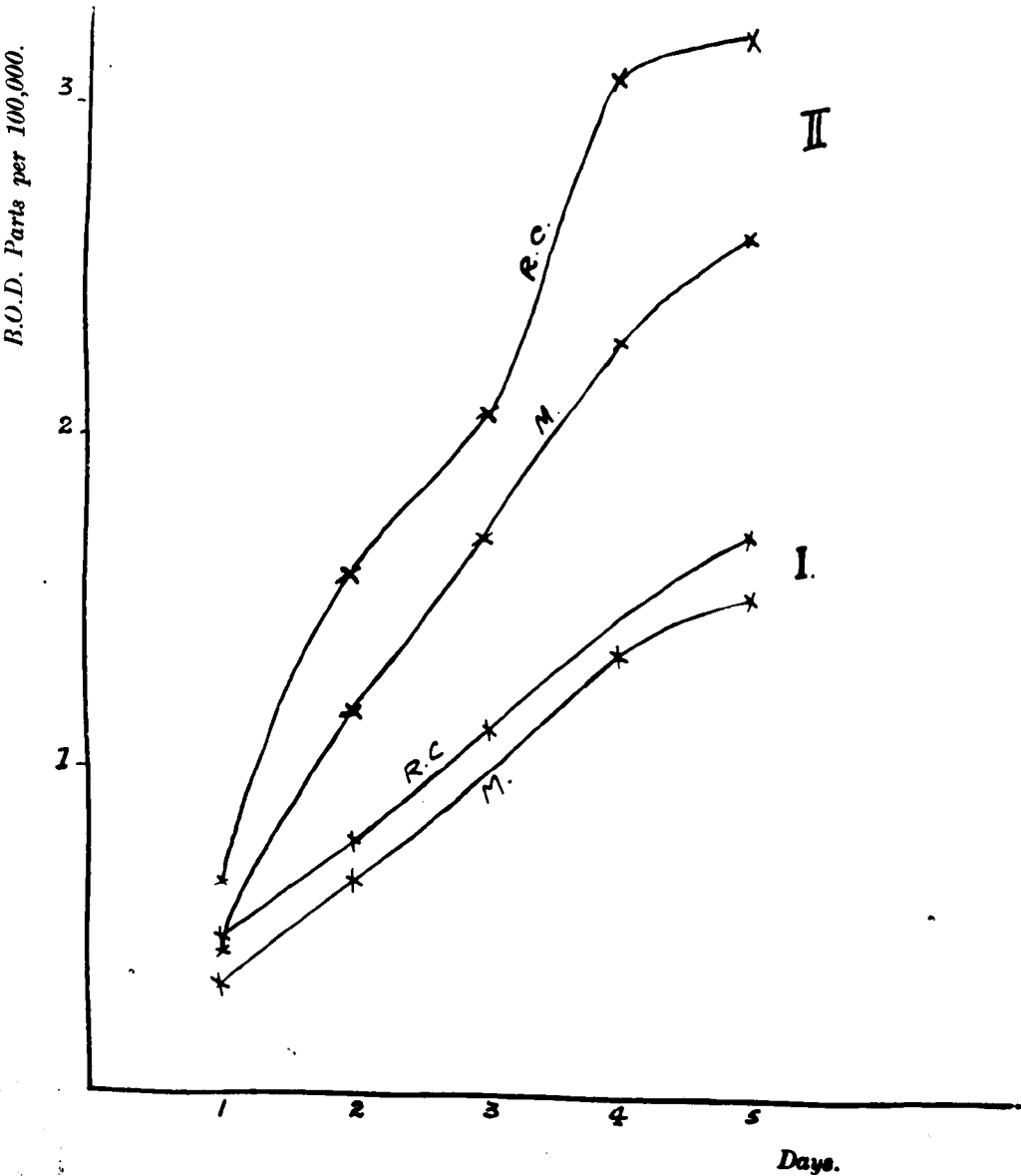
It is generally agreed that a method of estimating the B.O.D. of an effluent or river water, which could be carried out in not more than 48 hours and which would avoid the errors always associated with the supply of the necessary oxygen by means of aerated dilution water, would be a great boon to those who have to control sewage purification plant. The author maintains that this object can be attained by saturating the sample itself with oxygen instead of diluting it with water saturated with air.

The solubility of oxygen in water is more than double that of nitrogen, but when water is saturated with air the amount of each gas dissolved is directly proportioned to its partial pressure (Dalton's Law). For example, at 15°C. water dissolves 1 part per 100,000 oxygen and 1.66 parts per 100,000 nitrogen when saturated with air. But the solubility of oxygen in water at 15°C. is 4.8 parts per 100,000. Therefore, if an undiluted effluent or river sample is saturated with oxygen instead of air, an ample supply of oxygen is provided without introducing the complication of dilution water or chemicals which might affect the biochemical processes taking place in the sample.

Procedure :—About 250 mls. of the samples to be saturated with oxygen are placed in narrow bottles and connected together wash-bottle fashion in series. The tubes passing to the bottom of each bottle are drawn out so as to pass small bubbles of gas and thus aid solution. A slow stream of oxygen is bubbled through the series for about 10 minutes at such a rate that any suspended solids in the samples

It will be observed that the B.O.D. results by the Miller Method are consistently lower than those by the R.C. Method for the corresponding periods of incubation, but the Curves (Fig. 1) show clearly that the Miller figures increase more regularly with longer incubation than the latter, especially for II "Bad" Effluents.

When the corresponding comparison of tests was applied to River Aire Samples, it will be seen from Table 3, III that the results were divergent. The Miller figures were normal and similar to those obtained from bed effluents, but the R.C. figures show little increase with longer incubation, so that after "5 days" they are, on the average, over 50 per cent. below the corresponding Miller figure. No satisfactory explanation of this curious retardation in the absorption of oxygen has yet been found, but a similar phenomenon has been observed occasionally in the case of bed effluents. Apparently dilution has checked biological activity in the R.C. Test.



To find out what relationship exists between the B.O.D. figure by the "R.C. 5 days" Test, and that obtained by the Miller Estimation with 24 and 48 hours incubation, analyses of a number of effluents were made over a period of three months. It is of interest to note that the ratios for good effluents are in agreement with those obtained by the Royal Commission using the dilution method for 24 hours, 48 hours, and 5 days tests. (8th Report, Vol. II., p 81).

The results are classified on the basis of the R.C. test and the average figures for these groups are given in Table 4.

TABLE 4.
Parts per 100,000.

Class and No. of Samples.	N ₂ as Free NH ₃	O ₂ Absorb- ed in 4 Hrs.	N ₂ as Nitrates	Sus- pended Solids.	B.O.D. Estimation.			Ratio $\frac{2}{1}$	Ratio $\frac{3}{1}$	Ratio $\frac{3}{2}$
					1	2	3			
					Miller 24 Hrs.	Miller 48 Hrs.	R.C. 5 Days.			
Very Good (5)	.074	1.85	.76	3.5	.26	.47	.666	1.88	2.56	1.41
Good (8)	.110	2.02	.58	3.8	.52	.82	1.57	1.58	3.02	1.92
Bad (11)	.248	2.76	.39	8.4	.80	1.17	2.59	1.46	3.24	2.21
Very Bad (3)	.446	4.35	.08	7.1	1.52	2.22	4.93	1.46	3.24	2.22

The results of the two methods of estimating B.O.D. do not agree well, chiefly because the R.C. figures are more irregular. The average ratios between the B.O.D. figures are interesting; that between the Miller "48 hours" and Miller "24 hours" shows a decrease of 22.3 per cent. as the average quality of effluent decreases. This might be anticipated, for the poorer effluents contain more unstable organic matter and therefore should give a relatively higher "24 hours" figure; but the ratios of R.C. "5 days" figure to the "24 hours" and "48 hours" Miller figures both show an increase as the quality of effluent decreases, especially in the latter case; it is not at all obvious why this should be so.

It will also be observed that in the case of "bad" and "very bad" effluent the different ratios given in Table 4 are practically constant; therefore, whatever may be the cause of the variation of ratios discussed in the preceding paragraph, it does not operate with two latter classes of effluent.

The investigation recorded in this paper clearly indicates that the modified Miller method of estimating dissolved oxygen is much simpler, quicker and less liable to interference from unstable substances commonly found in sewage, trade wastes and sewage works effluents than the R.C. test. Also, for the estimation of B.O.D., the Miller method, combined with the use of oxygen to saturate the undiluted sample, before incubation for 24 or 48 hours, gives more reliable results than the R.C. "5 days" method, using aerated tap water for dilution.

OTHER RECENT RESEARCH ON ANALYTICAL METHODS.

Dr. Lloyd, Reader in Zoology at Leeds University, recently found that the Humus Sludge, settled out from bacteria bed effluents, was rich in a motile protozoan *Polytoma uvella*, which separated as a grey surface film when the humus was allowed to stand for a few days. This organism was subcultured in equal parts of humus and bed effluent which had been partially sterilised at 80 C. for 1 hour. By the use of this culture he has been able to devise a biological method of grading water and effluents according to their dissolved oxygen and nitrate content. His brief summary of this research (Journal of Hygiene, 1933, Vol. xxxiii, 2, p. 183) is given below:—

Lloyd has recently suggested a biological method of estimating the quality of the effluents and this may have advantages over the chemical methods. The reaction on which the test is based is carried out in tubes 60 mm. long and of 4 mm. bore, and at any ordinary room temperature. The tubes are inoculated with one tenth of a cubic centimeter of a culture rich in a motile protozoan called *Polytoma uvella*, and certain motile bacteria. On to the inoculum is run a column of the water to be tested, to a depth of 40 mm. Inoculum and water lie distinct but the active organisms leave the inoculum in a conspicuous blanket like layer, spoken of as the blanket, and this begins to ascend the tube.

The behaviour of the aggregation is associated very closely with the degree of pollution of the water tested and it appears to afford a convenient and rapid method of estimating the quality of the effluents by referring them to a series of defined grades as follows. In control tubes of tap water (included in each series) the blanket climbs steadily, travelling upwards about 2 mm. in the first hour and about 6-8 mm. during four hours, according to the activity of the culture which decreases with its age. In a bacteria bed effluent of high quality the blanket climbs more slowly than in tap water or at the same speed, because the presence of nitrate or nitrite causes a slight lag. In a bacteria bed effluent of moderate quality the blanket climbs more quickly than in the control and fades somewhat but does not lose its identity. In a bacteria bed effluent of poor quality it fades entirely and no reaggregation can be detected within 4 hours. In a bad bacteria bed effluent or crude sewage it disperses and regathers visibly at or near the meniscus within an hour.

The movement is of course, dependent on the oxygen available in the water tested. The organisms are using up the oxygen as they climb, so the less present the more rapidly they ascend and *vice versa*. In theory the test should take cognizance of the oxygen affinity any inert substances present may possess and at the same time the influence on the effluents of the living organisms, whether these are depriving the water of its oxygen, or supplying it. By this means one should get away from the empiricism of the chemical tests. The technique and interpretation of the test are readily acquired and the method of culture is not difficult. It would be possible to issue the necessary seed in a dry and purified state for an initial culture.

SUMMARY AND CONCLUSIONS.

A brief account of recent research on the subject is given with special reference to the estimation of dissolved oxygen and B.O.D., which are admittedly very essential in sewage analysis.

The R.C. test described in the Ministry of Health "Methods of Chemical Analysis" 1929, is criticised, and the elaborate modifications worked out by American chemists to standardise this test so as to obtain accurate comparable results in different localities are pointed out.

A modification of Miller's method of estimating dissolved oxygen is described in detail and results quoted to show that it is much simpler and gives more accurate results than the R.C. test.

To avoid the errors inherent to the dilution method of estimating B.O.D., the author also proposes that it is better to saturate the undiluted sample with oxygen instead of air, and incubate for 24 hours or 48 hours. This method avoids the awkward 5 days incubation period, which is of little value for the control of purification plant.

The author desires that his proposals should be thoroughly tested by other chemists under different conditions in the hope that they may form the basis of a really satisfactory technique, which will be of permanent value to the sewage works chemist and to the rivers authorities.

DISCUSSION.

Mr. J. T. THOMPSON, introducing his Paper, said: As this Paper was prepared a year ago, it requires bringing up to date. In the interval interesting publications bearing on the subject have appeared. The fifth report of the Water Pollution Research Board for the year ending June, 1932, contains the following statement:— "Preliminary investigations have been made on the test for the B.O.D. of effluents in five days. Some uncertainty in the application of this test, in the experiments on beet sugar factories effluents, has been experienced owing to the large probable error of the results. Even with careful control of the conditions of the test a single determination may vary by as much as 9 per cent. from the mean of several determinations. It has been found that the absorption of oxygen is affected by dissolved salts and nitrogenous compounds in the dilution water employed. The initial bacterial content of the water also affects the progress of oxygen absorption by solutions of sucrose."

The American Public Health Association, moreover, has recently published the seventh edition of "Standard Methods for the

Examination of Water and Sewage." A section dealing with "Rapid Methods of Water Analysis for Boiler Purposes" has been added. Little change has been made in the procedures for the examination of sewages and effluents, except that for B.O.D. The sodium nitrate method has been omitted leaving the dilution method using the Rideal-Stewart modification of the Winkler estimation as the standard one, but they state that this method is unreliable for waters polluted with sulphide, sulphite and hypochlorite wastes. To eliminate errors due to the different sources of dilution water, aerated distilled water containing three hundred parts per million sodium bicarbonate is recommended for general use. This water should be free from appreciable demand of its own, namely less than 0.2 parts per million. The standard period of incubation is five days at 20°C.

The ortho-tolidine method for the estimation of chlorine in water is presented in a more exact manner. Owing to turbidity and other interfering factors in raw sewage and effluents, this method is not recommended; iodometric titrations are preferred in these cases. In this connection the recent

work of Lea ("Chemical Control of Sewage Chlorination. The use and value of the ortho-tolidine test." *Journal of the Society of Chemical Industry*, 1933. 52. 245 T.) is of special interest. An arbitrary definition of "chlorine demand" is given; it is defined as "the parts per million of chlorine as chlorine water (1.0 gram of chlorine per litre) required to be added to 250 cc. of the sewage so as to produce a trace of residual chlorine colour with ortho-tolidine reagent after ten minutes contact of chlorine and sewage." Standardised conditions for the estimation are clearly described; the bacteriological significance of the chlorine demand point has been verified and it has been established that effective sterilisation is not attained until the chlorine demand has been satisfied. "Standard Methods" includes two appendices; the first on "Drinking Water Standards;" the second contains non-standard methods which have not reached the state of general acceptance that makes it possible to include them in the standard text.

An apparatus for the rapid estimation of oxygen or other gases dissolved in water is described by Hoather (*Journal of the Society of Chemical Industry*, 1933. 52. 689). It provides a rapid means of expelling gases from a sample of water by boiling under slightly reduced pressure, followed by collection, measurement and treatment of the gases with absorbents. Using a solution of oxygen in water, comparisons were made with the Winkler Method and agreement obtained within 1 per cent. Quite recently Mears and Evans have published an interesting note (*Journal of the Society of Chemical Industry*, 1933. 52. 349 T.) on the "Rapid Elimination of Oxygen from Water or Aqueous Solutions" by washing out the oxygen with carbon dioxide. Those of us who have tried to provide oxygen-free water by the boiling and cooling method will appreciate the difficulties which these gentlemen have tried to get over in that way. A simple approximate method of gauging the dissolved oxygen in water by observing the colour changes after the sample is shaken with a mixture of solid magnesia and ferrous ammonium sulphate is also described. Further work on the determination of dissolved oxygen in the presence of sulphite is published by Haase (*Z. anal. Chem.* 1932. 90. 241; *Journal*

of the Society of Chemical Industry, 1933. 52 B.94). The important investigations of Mills on the ultimate analyses of sewage and the nature and amount of colloids in sewage are perhaps outside the scope of this Paper. (*Journal of the Society of Chemical Industry*, 1932. 51. 505 T., 255 T., 349 T., 374 T.)

In order to reduce possible errors to a minimum all the comparative tests with the Royal Commission and Miller methods recorded in this Paper have been carried out by the Author under uniform conditions. To compare the effect of using distilled water containing three hundred parts per million sodium bicarbonate, recommended in the American Standard Methods, instead of Leeds tap water on the Royal Commission test the following analyses were carried out in duplicate on percolating filter effluents:

Sample	R.C. 5-day test (1 to 9)			N ₂ as free NH ₃	N ₂ as nitrates	O ₂ abs. in 4 hrs.	sup. sol.	NaHCO ₃		tap water
	1	2	3					dist.	water	
1	0.010	0.010	0.020	0.136	0.48	2.39	4.6	1.95	1.88	1.88
2	0.010	0.010	0.020	0.136	0.56	2.67	4.2	1.85	2.42	2.42
3	0.010	0.010	0.020	0.136	0.48	2.41	3.6	2.54	2.87	2.87
4	0.010	0.010	0.020	0.136	0.42	3.46	9.8	3.43	3.37	3.37
5	0.010	0.010	0.020	0.136	0.26	4.14	8.6	4.50	4.96	4.96
River Aire	0.154	0.154	0.154	0.154	nil	2.12	2.6	1.52	1.49	1.49

In three cases (1, 4 and river) the agreement is fairly good; for the rest, tap water gives a higher B.O.D. figure than when distilled water is used for dilution. This is further evidence that if a standard dilution water had been stated for the Royal Commission test, perhaps the greatest source of error would have been removed.

The present investigation had been carried out from the view-point of the works manager in relation to plant control on one hand and river pollution on the other. Unfortunately the results given only refer to oxidised effluents, but as opportunity occurs it is proposed to extend the enquiry to the estimation of the B.O.D. of crude sewages and tank effluents. For this purpose the modified Miller estimation, combined with the use of a standard dilution water, e.g. distilled water containing sodium bicarbonate, saturated with pure oxygen, should provide a satisfactory method and reduce the errors due to dilution to a minimum.

Improvement in the methods of analysing sewage, effluents and river water lies in the direction of the standardisation of tests, like the above, which allow both biological and chemical changes to operate during a fixed incubation period, and in the gradual elimination of empirical chemical tests such as the "oxygen absorbed from permanganate" test, which have been handed on to us from water analysis practice. The proposals here to substitute the modified Miller test for the Rideal-Stewart Winkler test and to use pure oxygen instead of air for saturation of a standard dilution water where such is necessary for the B.O.D. estimation, mean a much simpler procedure, a shorter incubation period, and less risk of error in the case of samples derived from sewage containing trade wastes.

Although the twenty-four hours' incubation is the most convenient for works practice, as stated in the Paper, probably forty-eight hours' incubation is better from the Rivers Board point of view, for the longer period would minimise any initial irregularities in oxidation.

Lloyd's Polytoma Test, referred to in the Paper, is very interesting and breaks new ground in that it provides an entirely biological indication of the quality of effluents.

The movement and appearance of the blanket depends on the amount of nitrites and nitrates present as well as on the dissolved oxygen. The technique and interpretation of the results are not difficult after a little experience and give a rapid indication of the stage which purification has reached in the sample, but it would probably be rather difficult to compare results obtained at different works, for the personal factor is greater than in chemical tests.

I regret that it has not been possible to make the investigation more complete, owing to the necessity for works supervision and other causes, but I hope that sufficient has been done not only to lead other chemists thoroughly to try out my proposals but to inspire the younger chemists to break away from old traditional methods and determine to improve our analytical technique and make it adequate for all the purposes of the improve methods of sewage disposal which have been successfully developed in recent years.

I have received the following communication from Mr. H. KESSENER (The Hague): "I have much pleasure in congratulating Mr. Thompson on his valuable Paper. Mr. Thompson discusses particularly the value of methods for determination of dissolved oxygen and biochemical oxygen demand in connection with the control of effluents at the works. From this point of view I quite agree with him about the practical value of the modified Miller test. We find it very simple and useful for sewage works practice where not a very high accuracy is required and the Winkler method is too elaborate. Mr. Thompson will, however, agree with me that for research work, where a high accuracy is essential, the Winkler test will maintain its value. For example in the experimental work done by our Institute to determine the oxygenation-capacity of aeration-tanks by re-oxygenation of de-oxygenated water (Annual Report 1932), it proved possible by using bottles with very well-fitted stoppers to obtain an accuracy of 0.05 parts per million.

"I am quite in agreement with Mr. Thompson's strong criticism of the Rideal-Stewart modification, which we abandoned a long time ago. With regard to the nitrite difficulties, as Mr. Thompson reports, the

Alsterberg modification has proved to be very efficient and much simpler than the Rideal-Stewart modification. When large amounts of organic matter were present we always found lower results with the Rideal-Stewart than with the Winkler Azide modification. This fact was demonstrated very clearly in the article (quoted by Mr. Thompson) of Theriault and McNamee who developed a better and simpler modification.

"With regard to B.O.D., the estimation of the five days' value by the dilution method has undoubtedly its fallacies. It is a fruitful idea to use pure oxygen for oxygenation of the samples, so doing away with dilution if effluents or river waters are examined, or diminishing the fallacies of the dilution method if crude sewage or tank effluents are analysed. It is clear, as Mr. Thompson states, that it is of great value for a sewage works manager to have at his disposal a method which could give him within the shortest possible time an idea of the quality of his final effluent. The biological test recommended by Lloyd might, for example, become a useful indicator if further developed and standardised.

I may just add in parenthesis that although Lloyd's test is useful on an individual works, it is going to be rather difficult to get comparable results on different works, because the personal factor, as you can easily see from these photographs, of recognising the thickness and fading of that tiny blanket, introduces a bigger personal error than ordinary chemical estimations.

"The greater value of obtaining B.O.D. results in a short time in sewage works practice will probably counterbalance the danger that in applying short incubation periods, initial irregularities in the biochemical oxidation may have an excessive influence on the reliability of the biochemical oxygen demand figures obtained. In research work, where the time factor is of subordinate importance, it may be desirable to use a method which gives as reliable a figure as possible for the real complete biochemical oxygen demand to be satisfied in a projected or existing purification plant; for example, for determining the purification capacity of an activated sludge installation, a subject which is discussed in the Annual Report for 1931. A method for estimating exactly the complete B.O.D.—preferably

the B.O.D. of the carbon oxidation stage as contrasted with the nitrification stage has not yet been sufficiently developed. The ratio of five days B.O.D. to complete B.O.D., estimated by the United States Public Health Service, on an average of practical figures of normal sewages to be 68 per cent., varies if the sewage contains certain amounts of trade wastes which have a great bearing on the aerobic digestibility of the organic matter. This problem might well be tackled by constructing a time curve of oxygen absorption on the Sierp Franckmeier method. As Mr. Thompson has for many years studied the simplification of analytical methods for the sewage works manager, I suggest he should also devote his time and expert knowledge to perfecting analytical methods for research work."

Mr. A. C. SEIVER, moving a vote of thanks to the Author, said: "As many of you know, I am now the living representative of Dr. S. Rideal, and I thought it my duty to come here to try to keep alive the memory of the first President of the Institute. In regard to one or two points, I may be able to clear up little errors in the original technique. First of all, the water used in our laboratory for diluting purposes always came from a deep well, about 550 ft. deep, in the London basin, and, as you probably know, water of that type has a particular chemical characteristic: it is very rich in chlorides. It contains about 14 parts per 100,000 of chlorine as Cl_2 . The total solids are between 70 and 75. Bacteriologically, it is almost sterile. That water, as I say, has always been supplied to our office, and we have obtained very consistent results with domestic sewages when diluted with this water.

During the last four or five years, however, I have had a very wide experience of beet sugar effluents in particular: I have examined many thousands of samples of them from every factory in England, and I agree with Mr. Thompson and with the conclusions of the Water Pollution Research Board that figures for the Rideal-Stewart modification of the five days' tests, when applied to trade wastes and in particular to beet sugar effluents, must be applied with caution.

In the first place, however, many of Mr. Thompson's figures are given to the third place of decimals, and he will forgive me if I suggest that the significant accuracy of

this test can never be extended to three decimal places: personally, I would never give more than the first, the nearest, decimal. You have only to look at the matter from the mathematical point of view to see why. The probable error, particularly when greater dilutions than 4 to 1 are employed, is large, and therefore the second or third decimal place becomes, in my view, unreasonable. If, however, you consider only the nearest decimal place I think you will find that Mr. Thompson is not on quite such strong ground in comparing the Miller and Rideal-Stewart tests as he seems to think.

I am afraid I have not had time to look up the reference in the report of the Royal Commission, but I think you will find that in that report there is an error in describing the methods for carrying out the Rideal-Stewart modification, and I think I am right in saying that if you tried to carry it out in the way there stated you could not do it at all. I believe it says that you should acidify the water with 1 cc. of strong sulphuric acid, whereas in fact the quantity should be 0.3 or 0.4 cc. of sulphuric acid, and that in fact is the quantity we have always used. How the error crept in I do not know: it happened at a time when I was far too young to take any interest in such things!

At the end of the section headed "Biochemical oxygen demand" the Author says: "It is fair to infer that under quite uniform conditions, which could not be attained in different laboratories, the R.C. test gives consistent results with effluents from domestic sewage." For the life of me, I cannot see why this test could not be so standardised that it could be done in precisely the same way in a laboratory in Timbuctoo as in one in Victoria Street. It is a very simple test, and I do not see why it could not be standardised. Various ways of standardising the diluting water have been suggested. I confirm the fact that trade wastes at high dilution do give somewhat misleading results, because of the mathematical error involved in making great dilutions.

The instructions given in the paragraph on "Procedure" indicate that the sewage in the Miller test should be allowed to settle. Surely that is not right? The five days' test of the Royal Commission is surely in

the presence of suspended solids and not after their separation. The Miller method is certainly one which is worth looking into. I have had comparatively little personal experience of it, but I do not think it can ever replace the Rideal-Stewart method as a method of determining dissolved oxygen, because, unless very special apparatus is available, it is impossible to pour sewage from one vessel to another and avoid aeration. It is obviously impossible. The whole principle of the determination of dissolved oxygen in effluent or river water depends on using special apparatus to take the sample and avoiding any agitation or pouring or aeration of the sample afterwards.

At the bottom of the same page, the Author says "In carrying out the R.C. test, sufficient permanganate was added to maintain a purple tint for ten minutes." I think I am correct in saying that the right period is 20 minutes, and in that case, of course, it does more or less vitiate the value of the figures in Table 2 with regard to sodium nitrite.

Under the heading "R.C. (Rideal-Stewart Winkler) Method" the Author says, in paragraph (c), "The addition of ferric salt causes an apparent increase in the oxygen figure as the dose is increased." That statement depends on one figure, 0.825, and I venture to suggest to Mr. Thompson that, in the absence of other evidence, that is rather a sweeping statement to make on one figure. I may be wrong there, but Mr. Thompson will be able to deal with that point in his reply.

Dealing with the estimation of B.O.D. by using oxygen, he says "There is no appreciable absorption of oxygen in this brief period." That would not be true with beet sugar effluents, because they mop up oxygen at a great rate: and a number of other highly oxygen-absorbing trade wastes do the same thing. The temperature of oxygenation is not mentioned there, and it seems to me that that is rather important. Perhaps Mr. Thompson will give us some information on the temperature he employs and whether he has any information as to the effect of temperature. I feel that there must be quite a marked temperature coefficient. I also feel sure that Mr. Thompson, in developing this method, will introduce and work out a much more scientific apparatus

for the dissolution of his oxygen. It strikes me as rather peculiar to admit that the oxygenation in a number of cylinders is different, and that then one has to change them round and so on. I am sure that could be overcome.

One very great source of error in this five days' test is undoubtedly the temperature of incubation, and I know for a fact that many clever chemists all over the country do not bother to have a proper thermostat for doing this test, but simply leave it in the room at room temperature. I most strongly assert, however, that it is in the highest degree important to incubate in a proper thermostat if results of any appreciable accuracy are required, because the effect of temperature variations during the five days' storage of the samples is enormous; the temperature coefficient is very great indeed, and errors of the order of 100 or 200 per cent. can be made by simply putting the bottles in an ordinary laboratory, where the temperature at this time of the year may go down to very nearly if not below freezing point at night.

It seems to me that some test other than the Rideal-Stewart five days' test is required for a sewage works manager who does want the result out within a reasonably short period. Of course, for the ordinary analyst outside the sewage works the five days' period is rather convenient, because it gives him time to complete the rest of the analysis, and it is always an excuse for keeping the analysis five days at least. But I appreciate that the man in charge of the works wants to know sooner than that whether his results are good or bad, and I know that most of you have your own pet way of doing that. Someone mentioned to me yesterday that he had a standard solution of permanganate which he ran into a standard amount of effluent and waited to see how long the colour took to fade, and that gave him a very good idea of how things were going; and for a particular works I think that is a very good idea. Another method is a determination of nitrates by a very simple titration with indigo and the drawing of a graph. I do not suggest that the result of that is accurate, but if you draw a graph over a period of years, as I have done in the case of one works, the peaks in the curve always correspond to satisfactory periods

and the depressions in the curve to the burbling of the local river authorities.

Mr. W. D. SCOLLER seconding the vote of thanks, said: The burden of the Paper seems to be that the Ministry of Health's methods are too conservative, and the Author says, rather drastically, that some of their methods are ancient history. He also complains that the work of the Committee of the Association of Sewage Works Managers which investigated these methods has largely been ignored by the Ministry of Health. I do not agree with him, however, in what he says about the methods of the Ministry: I think those methods were an immense advance on anything that we had ever had previously, but I hope that the Ministry will, like the American Association, revise their methods every few years, and I should like to add that it would be a good thing if the Ministry would also bring out standard methods for the bacteriological analysis of water. Such methods are at present scattered about in many periodicals, and if a thoroughly up-to-date series of methods on the bacteriology of water and sewage were issued by the Ministry of Health it would be a very great boon to workers in these branches.

Mr. Thompson refers to three members of the Committee of the Association of Sewage Works Managers who investigated these methods. I was one of them, and I have looked up my old Papers of 1924, when the results were obtained, and I can find only three samples where I had Mr. Thompson's results. The first one refers to an effluent from Bradford Sewage Works, which had a large amount of trade waste. The samples were examined in the Huddersfield laboratory, and the result of the five days' test was 1.65. Mr. Thompson did the same thing in his laboratory at Leeds, and he got 1.69. In the second case, I sent samples from Huddersfield to Mr. Thompson, and my figure was 2.15 and his was 2.10. Then I had a sample from Leeds, and my result was 1.0 and his was 1.62. In two of those three cases, Huddersfield and Bradford, which are very strong trade effluents, the results were practically the same, but with the Leeds samples, which have not anything like the trade effluents that Bradford and Huddersfield have, the results were anomalous.

Mr. Thompson says that the results of

the Royal Commission test are unreliable with trade sewage, and in Table I the results by the Miller method agree but are always lower than those by the Royal Commission method. I think that ought to be investigated further, and I suggest that if a gasometric test had been done at the same time we should have had some information as to which was the more reliable of the two tests.

We must all congratulate Mr. Thompson on the account of recent research work which he has given us, pointing out the substances which interfere with the Royal Commission test and the cumbersome methods which have been used in America to prevent the interference. His objections to the Royal Commission test are two in number; one is because of the interfering substances and the other because of the incubation period being too long. He has examined three substances and found that they interfere with the Royal Commission test, but I do not think those substances often occur in England. The only place where I know that sulphites interfere is in our own town of Huddersfield, and, although he says that it is not likely that you will get more than 20 parts of sulphite in a sewage, we get 80 parts at the present time. What he says about the Miller test, namely that it is not affected by sulphites, is quite true, but we cannot use the Miller test at Huddersfield; the colour of the liquid is too strong. In cases, therefore, where sulphites occur it is usually because of the manufacture of dyes, and the Miller test is not applicable because of the colour. That is the only kind of liquid of which I know which interferes with the Miller test, and I should like to know if Mr. Thompson has ever come across any other liquids which interfere with it.

In proposing the use of oxygen instead of air, Mr. Thompson says "Samples of river water and good effluents have a B.O.D. of less than 0.8 part per 100,000 in 24 hours at 18.3°C." From his Table 3, however, it will be seen that good effluents absorb .337 and bad effluents .43 in 24 hours, and yet in the text he says that good effluents absorb less than .8. I cannot quite understand that, unless some error has crept into it and Mr. Thompson meant 48 hours instead of 24. The same objection that I

mentioned in connection with coloured effluents also applies in the case of this oxygen test on undiluted samples, because of course the undiluted sample is of much stronger colour than the diluted sample. The Ministry of Health compared the Miller test with the Royal Commission test and found very good agreement, but they said that the Miller test was unreliable for small concentrations of oxygen. I should have thought Mr. Thompson would make a special point of that, and I should be glad to know if he has done any work in connection with it.

The vast amount of work which has been done and the records we have cannot be thrown on one side by a new test unless a large amount of work has been done on the new test and the old results have been correlated. For my own part, with regard to getting a quick result I always find the percentage purification obtained by a biological process on the four hours' oxygen absorbed test is quite reliable. If you get a purification of over 66 per cent. on the liquid which you are putting on to a filter or on to an activated sludge plant or bi-aeration plant, then the five days' test will come out on the right side.

Mr. Thompson asks that his proposals may be thoroughly tested by other chemists, and I think that is a good idea and will undoubtedly have to be done.

MR. J. H. COSTE: This Paper reviews a subject which certainly cannot be said to be in a satisfactory state. When people first began to think of analysing sewage and sewage effluents, they adapted the methods which had been found to give useful results, and one might say to be more or less successful, in the examination of water, and those methods were usually adapted by using smaller quantities of sewage than of water, because, as you all know, sewage is a richer material than water. They were not altogether successful, however, for the purpose of showing how a sewage effluent would affect a stream or how much of a given effluent a stream could safely receive.

The biological oxygen demand test was developed by a man whose name has not been mentioned this morning, Walter Edward Adeney. It is true he is nearly eighty years old and lives in Ireland, but it was he

who developed this test and showed what the fundamental meaning of it was, or perhaps I should say was intended to be. He investigated the rates of oxidation of the carbon and of the nitrogen not only in sewages but in pure organic substances, and he found that the carbon was almost completely oxidised before any appreciable oxidation of nitrogen took place. That was really a quantitative confirmation of observations which had been made by Schloesing and Muntz in France and by Warrington in this country on nitrification, and when we speak of that test I think the name of Adeney should be remembered. He deserves the whole credit of it, and it was conceived on sound principles; but unfortunately, like many things conceived on sound principles, it has been found extremely difficult to put those principles into practical application, and that is the cause of a great deal of the material of this Paper and of the discussion this morning.

The test was originally applied, as perhaps many of you remember, by having a bottle with the liquid to be tested and air above it and measuring, I think by a differential method, the loss of oxygen or the loss of volume from the air which was due to oxygen. It is a very difficult thing to get an equilibrium between a gas and a liquid. If the whole thing had been shaken during the five days of the test the results might have been trustworthy; as it was it was found that they were not, and the process was modified. Mr. Sciver will perhaps tell me whether it was Dr. Rideal who suggested using oxygenated water as the source of oxygen.

MR. SCIVER: To the best of my knowledge it was.

MR. COSTE: I was not quite sure, but the Rideal-Stewart modification consisted principally, I think, in this, that using as they did the Winkler process for determining oxygen, they also introduced a means of getting rid of the effect of certain interfering substances.

In considering the Winkler test, it should be remembered why that test was brought out. Winkler, at a time when a precise knowledge of the solubility of oxygen in water at various temperatures was desired, and when the figures available by Roscoe and Dittmar, and the much earlier figures

by Bunsen, were not very concordant, started a careful investigation, by means of this method which he had worked out, of the solubility of oxygen in water. Winkler's figures are those which I expect most of you use. There are later figures by Fox, which I think on the whole are perhaps a little better, but Winkler studied the question both in that way and gasometrically and got out a good series of results.

This process was found so satisfactory with pure waters that Winkler himself, and Rideal, Stewart and others introduced various modifications to make it suitable for waters that were far from pure. Mr. Thompson has shown that some of these modifications are not always satisfactory. It is obvious that the process must fail if you have anything in the water that will reduce iodine. I think Mr. Sciver will confirm the fact that if you have ferric salts you are almost bound to have trouble.

MR. SCIVER: Yes.

MR. COSTE: You raised that point, but I think Mr. Thompson's point was that the reaction between ferric chloride and potassium iodide was well known to every pharmacist, who refers a prescription with those things in it back to the prescriber. There is, however, a process of determining dissolved oxygen in water which is extremely satisfactory under almost any conditions. It is not as simple as the manganese process, but it is a gasometric process. You take a bottle or flask of, say 500 cc., put some calcite in it and a little dilute hydrochloric acid, let it rest a little while, wash the acid away, fill the flask with the liquid to be examined, and run in a suitable amount, about 10 cc., of hydrochloric acid. You put in a stopper with a delivery tube and collect the oxygen and nitrogen over potash. I quite see that that process would not be suitable for a lot of routine work, but we have used it on a very large scale; in fact, I see someone here to-day who has used it on many hundreds of such determinations. Where you have any real trouble about determining dissolved oxygen and do not want to use an elaborate gasometric method, there is a very simple method; you have a bottle with a cork in it and a delivery tube, a vessel of potash and some hydrochloric acid, a graduated tube and pyrogallol acid.

Letts and others used, and some of them

gave their names to, a very old process which you will find in Mohr's old book on volumetric analysis—seventy years old, I think it is. It is now, I think, known as the Albert Levy process. Albert Levy modified it, but it is really the old Mohr process. Letts used it when working with Adeney with considerable success, but I do not think it is very much used.

Returning to the B.O.D. test, the time required, as has been pointed out, militates very greatly against its general application. I can see that no sewage works manager would wish to wait five days to know what his effluent was like, and no doubt the river authorities in many cases would already have told him what it was like! Adeney, however, used it because he found that that did in the main represent the time required for carbon oxidation. The subsequent oxidation of nitrogen might be allowed to go on in the stream by itself, so he found the more insistent demand. There was therefore this rational basis for the process, which I think it is perhaps inadvisable to neglect.

Work by various people is mentioned in the Paper. Sierp and Fransemeier pointed out facts which are undoubtedly true, but which have been known for a very long time. Dibdin, in 1894 or 1895, published a curve showing the relation of the rate of absorption to the dissolved oxygen content of water. It was put in a L.C.C. publication which had, I should imagine, a very limited sale, I suppose some copies may have been sold; I know a great many were given away. It was a classic in its way, and it contained a curve showing this relationship. Then Dittmar, in one of the "Challenger" reports, showed that sea water dissolved less of the gases of air than fresh water. That, of course, is again a long time ago.

The relation of absorption to surface area, movement and oxygen deficit are well known facts of physical chemistry, first systematised by Bohr in relation to carbon dioxide and restated later by Adeney and Becker in a series of papers that are classical. I discussed these matters in 1917 in a paper read before the London section of the Society of Chemical Industry, and there is a long list of references there. A colleague is about to experiment with Sierp's apparatus. I have not been able to see any description

of it, but one can gather what it is like.

Table 2 would have been increased in value, I think, if the dissolved oxygen content of the liquids had been determined by a gasometric process, but it certainly seems to show that the Miller process has advantages in certain cases. It is apparently really a kind of modification of the old Mohr process. The use of oxygen itself rather than air seems to have some advantages, and should be the subject of more experiment. It seems to me that it is something we should go a little cautiously about, because it may be that the presence of an inert gas like nitrogen may have some bearing on the changes that go on. I do not know whether it would have, but that may be so.

With regard to the temperature of incubation, here again the question arises of what the test is desired to show. If it is to be a guide as to the effect in summer of an effluent on a stream, the higher temperature surely seems more appropriate; but if it is to give an all the year round average, 15° seems more suitable. There is always the difficulty with that test of whether you are using it as a standard whereby A. can compare his effluent with that of B., or whether you are going to use it as a means of finding out how your effluent is going to behave in the stream into which you are going to send it.

The following contribution to the discussion was received from Mr. J. H. GARNER (*Chief Inspector, West Riding of Yorkshire Rivers Board*): Mr. Thompson says in his Paper that the chief objects of it are to give chemists an opportunity to pool their experiences of the methods of chemical analysis as applied to sewage and sewage effluents set out in the Ministry of Health's publication, and also to review recent work done with the object of improving those methods of analysis, more particularly the Royal Commission test for determining the absorption of dissolved oxygen in five days—a test which, though universally recognised as sound in principle, he says has never won the good will of sewage works chemists because of its cumbersome procedure. As the bulk of Mr. Thompson's Paper is concerned with the dissolved oxygen absorption test, or, as it is now commonly termed, the biochemical oxygen

demand determination, I do not intend to say much about the other tests set out in the Ministry of Health's handbook. My own opinion is that the book has served a very useful purpose generally. It has tended towards that uniformity of technique and expression of results for which I specially pleaded in the paper I read at the 1923 congress. Still greater uniformity, as well as more satisfactory working results, would be achieved if only more sewage works chemists and managers would spend half-a-crown on a copy of "Methods of Chemical Analysis as Applied to Sewage and Sewage Effluents" and would adopt the procedure recommended for those tests which should be in regular use at their works.

Admittedly, the Ministry of Health publication had to be based upon a compromise between the various chemists who took part in its preparation. The more common methods are well described, and chemists of even moderate ability will find them easy to perform. When Mr. Thompson says that the descriptions and alternative methods only tend to confuse the chemist who is inexperienced in sewage analysis, does not the fault lie in the inexperience of the chemist and not in the elaborate descriptions of the tests and the inclusion of alternative methods? The Ministry of Health could hardly be expected to publish anything in the nature of a Mrs. Beeton's recipe book, but there is nothing to prevent the Institution from incorporating in its forthcoming textbook more detailed methods for performing some of the tests! If that book ever emerges into daylight, detailed instructions down to the last tenth of a cubic centimetre could be given for the use of those who need such nice distinctions.

Coming now to the main portion of the Paper, which deals with dissolved oxygen absorption or biochemical oxygen demand, I think that much of the controversy which has centred round this test would not have arisen had many of those who have taken part in it studied more carefully the reports of the Royal Commission on Sewage Disposal which deal with the subject, and had not read into them more than they contain or are intended to convey. It will be impossible to deal adequately this morning with the great amount of careful work carried out by the Royal Commission's

chemists, but to discuss Mr. Thompson's Paper in its proper perspective in relation to conditions existing in this country and, after all, home conditions should be our fundamental it will at least be necessary to recall that the Royal Commission test for determining dissolved oxygen absorption and the standard of purification based upon it were arrived at by working back from the results of prolonged observations on streams and the effects produced on them by the discharge of sewage effluents under varying conditions of dilution.

The temperature and time of incubation, and the amount of dilution were all adopted in an attempt to bring the test into agreement with usual natural conditions in this country. Consequently, attempts to introduce innovations which would have the effect of creating conditions in the test never likely to be reproduced in natural circumstances are, from the outset, open to criticism and objection.

Personally, I do not feel disposed to agree that the Royal Commission test is at all cumbersome; it is one which I delighted to carry out when I had greater opportunities for doing laboratory work, and I always found it possible to obtain identical results from duplicate determinations made on the same sample under the same conditions.

Mr. Thompson ought really to have gone back to the paper which I read at the annual conference held at the Hotel Russell in December, 1922. In that paper I was the first to draw attention to the effect of different tap waters used for dilution purposes in the Royal Commission test. My criticism was not directed against the test itself, but against its use as the basis of a legal standard until it could be proved capable of yielding in different laboratories concordant results for the same sample if the recommended procedure were adhered to and the requisite apparatus and manipulative skill were available. That innocent paper has proved to be the cause of far more research work being undertaken in connection with determinations of biochemical oxygen demand than could ever have been foreseen. Since 1922, some hundred papers have appeared dealing with various factors associated with the test. Unfortunately, as I said before, some of these papers are hypercritical, and some of those which have

been published abroad relate to conditions not within the general scope of the Royal Commission's test and suggested standard. I am inclined to think that Mr. Thompson has partly fallen into similar errors and misconceptions. Nevertheless, regarding the Paper solely as an account of chemical investigation, I would like to congratulate him upon the work which he has described.

The analytical figures given in Table 1, are of peculiar interest to me; bearing in mind that the standard for sewage effluents suggested by the Royal Commission on Sewage Disposal, namely, that the suspended solids should not exceed 3 parts per 100,000, and that the amount of dissolved oxygen absorbed in five days at 65°F. should not exceed 2.0 parts per 100,000, it will be seen that all the samples should have been condemned as unsatisfactory as regards suspended solids. The results of the biochemical oxygen demand determination are here therefore of secondary importance. The amount of nitric nitrogen present would also appear to indicate that had the suspended solids been reduced below 3 parts per 100,000 there would have been a considerable reduction in the oxygen absorbed in four hours' figures and in the biochemical oxygen demand figures. One might conclude from the figures that the main point for consideration in connection with effluents such as those represented by the analyses is the elimination of suspended matter, and that if this were effected the effluents would be generally satisfactory.

Similar remarks, but to a less degree, appear to apply to Table 3, parts I and II. I fail to see the force of any argument that the Royal Commission test should be discarded in favour of the modified Miller test because the former may be interfered with when sodium sulphite, sodium nitrite or iron alum is present. The amounts of these substances added in the experiments recorded in Table 2 represent conditions which are not likely to arise in connection with sewage effluents in this country—at least at sewage works under the supervision of an active rivers board.

If I am not mistaken, the main work on determining the biochemical oxygen demand of effluents containing these substances has been carried out in America upon partially-treated mixtures of sewage and trade refuse,

and with the object of ascertaining how little treatment could safely be given under conditions which are not at all parallel with those existing in this country.

The use of the Miller method for estimating oxygen in solution has much to recommend it, especially in connection with field work, and furnishes results comparable with those obtained by the Rideal-Stewart Winkler method. I have satisfied myself on this point after making estimations by both methods side-by-side when carrying out river survey work.

If Mr. Thompson had been content to limit his application of the Miller method to the determination of dissolved oxygen contents of samples before and after incubation when carrying out the ordinary Royal Commission test for dissolved oxygen absorption in five days, I should have been quite in agreement with him excluding, of course, cases of abnormal sewages. I cannot, however, at the present time support him in regard to the new methods which he suggests, as the saturation of the samples with oxygen instead of air creates conditions far removed from those which exist naturally. I would still prefer to adhere to the procedure recommended by the Royal Commission on Sewage Disposal, using a tap water of good quality, having an oxygen absorption in five days of not more than from 0.02 to 0.04 parts per 100,000. From a large number of experiments which have been made, I have found that Wakefield tap water, after storage for at least 24 hours at 65°F., does not absorb, after incubation for five days, more than 0.01 parts per 100,000 dissolved oxygen.

After incubation for ten days, the average amount of dissolved oxygen absorbed has been found to be 0.03 parts per 100,000, and when the incubation has been extended as long as thirty days the absorption has not been more than 0.08 parts per 100,000. Working with a water of this type, it is possible in the same laboratory to obtain comparable results from samples of effluent.

In conclusion, I should like to inform the Author that the preparation of the Ministry of Health's "Methods of Chemical Analysis as applied to Sewage and Sewage Effluents" did not require an incubation period of five years at zero. The temperature was occasionally rather tropical.

I shudder to think what Mr. Scudder would say to the Author in reply to the latter's statement that Scudder's dissolved oxygen test is ancient history and should have been omitted from "Methods of Analysis!" I warn him to beware!

MR. THOMPSON, in reply, said: Mr. Seiver says the sugar in certain trade waste, if shaken up with oxygen, will absorb it very readily. In a case like that, of course, you would not attempt to saturate it with oxygen direct; you would use oxygenated water for dilution. He referred to inaccuracy due to O_2 absorbed from the air when pouring from one vessel to another in the Miller test, but a similar operation has to be done in both cases. There is a bottle to fill in the Rideal-Stewart Winkler test, just as you have to pour the sample into a cylinder in the Miller test, and in the latter the surface is covered with paraffin to protect it from the air.

With regard to Mr. Scouler's remarks, my criticism was not that the Royal Commission had failed to do excellent work in establishing the R.C. test, but rather that the Ministry of Health publication of 1929 was practically a copy of the tests proposed by the Commission in 1904, without any bringing them up to date. The brownish colour of the Huddersfield effluent is likely to interfere with the end point of the Miller test, but I

should like to ask Mr. Scouler if it does not interfere almost equally with the thio-sulphate titration of the R.C. test. I have not had time to investigate the results of the Miller test on very weak solutions of oxygen; that is one of the points which ought to be looked into.

I was very interested in the historical review which Mr. Coste gave us, and particularly in his reference to the work of Warrington. I remember reading those papers with very great interest when I was a student at Leeds University many years ago. The use of pure oxygen instead of air is, of course, an innovation, and the idea should be thoroughly tested out by other chemists. My work has necessarily been limited to one class of effluent sewage only, but we want to find out whether it is of general application or not.

After Mr. Garner's contribution I suppose I ought to feel duly sat on. I admit that at the present moment the Royal Commission test is generally accepted as the standard one for the estimation of oxygen in solution, yet as this Paper indicates there is a growing volume of evidence that the results are not reliable under certain conditions or comparable unless the dilution water is carefully standardised; therefore we should push ahead and improve our analytical procedure to keep pace with progress in sewage purification.

The following Paper was taken as read:—

The Disposal of Surplus Activated Sludge.

BY

H. D. BELL, F.I.C., F.C.S.

(Manager and Chemist, Barnsley Sewage Disposal Works).

(NOTE.—This Paper was submitted for the Open Competition arranged by the Congress Committee and was awarded a Special Prize of Five Guineas).

THE disposal of the waste products of man, since the growth of civilisation caused him to congregate in communities, has probably always been associated with its own particular problems, even before the water carriage system gave us the name SEWAGE. Early in the seventeenth century history provides us with such an instance in the censure incurred by William Shakespeare's father for not providing adequate disposal of dung from the front of his dwelling. It is not necessary here to recapitulate the stages by which the present methods of sewage purification have been evolved, but it is desirable to note that there has been a much greater concentration of effort to purify the liquid constituent, perhaps in some measure due to legal pressure exerted to prevent pollution of rivers, than has been expended on the disposal of the solid constituents, namely sludge.

Almost every improvement in the methods of sewage purification has been followed by its own particular problem of sludge disposal. Some 23 years ago, or thereabouts, a process of sewage purification was evolved in which some of the solid matter became partially oxidised, and in that state formed an integral part of the purification of the liquid constituent. I refer, of course, to what is now known as the Activated Sludge Process. It was pointed out that one of the advantages in this new method of sewage purification was that the surplus activated sludge not required for purification of sewage would produce a very valuable fertiliser on account of its high nitrogen content. But again history repeated itself, and although the solid portion of activated sludge may contain a high nitrogen value, it has been found impossible by means of ordinary sludge presses to obtain a "cake," nor has any other process been shown yet by which the dried constituent of this sludge can be proved to have retained its originally high content of nitrogen.

Activated sludge, as most people connected with sewage purification are aware, is a liquor whose solid contents seldom amount to more than 1.0 per cent., and more often are about 0.5 to 0.7 per cent. This solid matter is partially oxidised, light and flocculent in suspension, and exhibits a very great reluctance to separate from its high supernatant liquor content, and thus is a relatively large volume to be disposed of, each day, compared with detritus or ordinary sedimentation or precipitation tank sludge.

It has been stated that digestion is one form of disposal and, on sewage disposal works where other types of sludge are undergoing digestion, it has been found possible to include surplus activated sludge without apparent diminution in activity by this process.

On other sewage disposal works where there is no convenience for sludge digestion, the prospect of constructing additional tanks and probably pumping plants, at times like the present, might be considered prohibitive if the sole purpose was a means for the preliminary disposal of activated sludge by digestion. On works where drying beds are used for the preliminary disposal of detritus and sedimentation sludge, attempts have already been made to use this method for dealing with activated sludge. The author has had no success with this method, either for activated sludge alone or its mixture with ordinary tank sludge. Pumping it on to areas of land, trenching, etc., has also proved ineffectual, perhaps to some extent due to the heavy clay sub-soil. Kershaw appears to have found a solution of his difficulties in the disposal of this unaccommodating form of sludge, by pumping it on to plots of land upon which a coarse water grass is cultivated, as he has stated that this method appears to dispose of the sludge without any form of nuisance at Epsom. The author experienced great difficulty in attempting to dispose of this sludge on an area of three acres of land per annum, as the major volume of the liquor remained on the surface of the land, until the whole area became foul and water-logged, and, in addition, portions of the liquor from time to time found their way through cracks in the sub-soil, discharging eventually into the final effluent open conduit. It had thus become evident some four years ago that some other method would have to be found for dealing with this surplus activated sludge, and research was commenced with the object of detaching the solid from some portion of the high water content as a preliminary to subsequent disposal.

After some two years engaged in this research, when time and circumstances permitted, certain discoveries were made, which later were embodied in a paper written in June, 1932, and read in London in November, 1932⁽¹⁾. In this paper a theory was advanced that certain inert materials attracted the light solid particles of activated sludge, producing coagulation and a separation of a comparatively large proportion of the supernatant liquor; also that certain other materials had an attraction for moisture present in other types of sludge, and that, if the latter materials were used to form the top layer of a drying bed, it was possible to make the sludge dry more rapidly. These inert materials thus fell into two classes

(1) Bell, H. D. "Activated Sludge: A New Process for Partial De-watering and Subsequent Disposal," read at Public Health Congress, Nov. 17th, 1932, in London.

on account of their physical attraction for solids and moisture respectively, and it was suggested that the use of the former would effect a preliminary separation of liquor from activated sludge, and the latter a more rapid removal of moisture, thus providing a means of disposal for this form of sludge. The results of the experiments carried out in this research were embodied in two statements which appeared in that paper, and were as follows:—

- (1) Sharp and rough surfaces attract light solids suspended in an aqueous liquor, and repel water.
- (2) Smooth and rounded surfaces attract water, and repel solids suspended in an aqueous liquor.

How far these statements can be considered as true must remain for such time as will allow them to be proved or disproved, but, in the discussion which followed the paper, a certain amount of acceptance was granted to part of the first statement, namely the attraction of light solids by rough surfaces. It has already been suggested by the author in a paper read at Leeds in January, 1926⁽²⁾, that smooth and rounded grains attract moisture from moist sludge, and this theory is borne out to some extent by the fact that waterworks engineers choose a water-worn sand, that is, a sand with smooth and rounded grains, for the filter medium in pressure sand filters used for the production of drinking water. Whether the actual terms "attract" and "repel" are generally accepted or otherwise is not of material consequence at present, but there can be no doubt in the minds of those who have carried out work of this nature that a smooth and rounded grained sand offers less resistance to the passage of water through it than a sand composed of sharp and pointed grains. In the paper read in November, 1932⁽¹⁾, it was shown that a sand with pointed grains produced a greater separation of liquor from activated sludge than a sand with smooth and rounded grains, thereby showing that the former with its rough surfaced contour attracted light particles suspended in a liquor. If one material exhibits less resistance to the passage of water through it than another, there must be some form of "repelling" power set up by the latter, and some form of "attraction" by the former.

The author has found in practice that where the surface of a drying bed is a sharp ash, the sludge invariably adheres to the ash. On the other hand, where the surface is composed of a smoothed grained sand, the sludge leaves it readily. In consequence of this experience, when using a bed whose top layer is a smooth and rounded grained sand, before passing any sludge on to it the surface is lightly dusted over with sharp ash, and on removal of the "cake" the surface of the bed remains intact, the ash forming the underside of the "cake." Thus, it is quite reasonable to state that there is some substantiation for the statements that smooth and rounded surfaces "repel" moist solids and that rough surfaces "attract" similar matter.

(2) Bell, H. D. "Recent Experiments in De-watering Sewage Sludge," read at Leeds in January, 1926, at Yorks. Dist. Assocn. Man. of Sew. Disp. Works.

Having established by experiment in the laboratory that it was possible to separate up to 65 per cent. of the supernatant liquor from activated sludge by mixing it with inert material having a rough surfaced contour, it was decided to recommend the County Borough of Barnsley to lay down a plant embracing this discovery to deal with the surplus activated sludge from a Bio-Aeration Unit, which deals with a D.W.F. of 500,000 gallons of sewage. The original scheme, at an estimated cost of £1,150, comprised a tank for the settlement of the mixture of sludge and coagulant, a mixing plant, a Rototiller for incorporating the deposit with the soil, and four drying beds, two of which were to be used for experimental purposes with a view to producing a marketable fertiliser. This scheme was passed by the Council in December, 1930, and submitted to the Ministry of Health for a loan, and to the Unemployment Grants Committee for financial aid, but the latter refused a grant for the scheme. It was then decided to drop the drying beds for the time being, and another application was made to the Ministry of Health to borrow £774, which was granted, and construction began towards the end of 1931. The new process came into regular use on August 23rd, 1932, and since that date the surplus activated sludge has been dealt with by the new method, the results of which, up to date, will be found on the table accompanying this paper.

The plant devised for this new process for partially de-watering activated sludge is essentially a mixer and a tank for settlement. In detail, the settling tank is rectangular in shape, and is constructed in reinforced concrete, supported by pillars on a concrete raft. The floor of the tank falls from both ends with a gradient of 1 in 12 to a central carrier which in turn, with a similar gradient, falls to the outlet valve, the latter situated on the outside of the tank. A floating-arm valve is provided to draw off the separated liquor, which passes direct to the return channel in the aeration tank of the Bio-Aeration Unit. There is also a stilling box fixed in one corner of the tank, which also acts as the inlet for the mixture of sludge and coagulant. The capacity of the tank is 10,720 gallons up to the level of an overflow weir, and any liquor passing over the latter joins the pipe discharging the settled liquor into the return channel of the Unit. The mixing plant is situated upon a platform in such a position that the mixed liquor may gravitate to the stilling box in the settling tank, and consists of a water-wheel tank, an automatic feed, and an elevator, the latter being driven by a 3 B.H.P. electric motor. The water-wheel tank is fed from above by the sludge, and supplies the motive power for driving the automatic feed for the coagulant, the latter being connected by sprocket wheels and chain to the water-wheel spindle. The automatic feed is a worm conveyor rotating in a horizontal sleeve, the latter being fed with the coagulant from a hopper situated immediately above one end. The hopper is supplied with the coagulant by the elevator, which raises the material from a storage shed situated at a lower level. At the opposite end of the worm conveyor from the hopper, the coagulant is delivered into a perpendicular chute immediately above a rectangular carrier receiving the tail liquor from the water-wheel tank, and, by means of baffles and sharp bends, contact between the coagulant and the solid particles in the sludge is made as the mixture passes forward into the stilling box in the settling tank. The automatic feed has also two devices for regulating the addition of the coagulant,

COUNTY BOROUGH OF BARNSLEY SEWAGE DISPOSAL WORKS.

THE DISPOSAL OF SURPLUS ACTIVATED SLUDGE.

Table showing results obtained by Coagulation Process up to date.

1932. Period Ending.	No. of Days per Period.	Volume in Gallons of			Dry Co- agulant added in lbs.	Weight in lbs. of dry Coagulant per 1,000 Galls.	Moisture in		Proportion of dry A.S. to dry Coagu- lant in dry Deposit.	Reduction in Bulk due to Sep- aration of Liquor.	Moisture in Deposit as Calcu- lated on dry Matter Content.
		Activated Sludge dealt with.	Separated Liquor re- turned to Bio-Unit.	Deposit discharged from Set- tling Tank.			Activated Sludge before Treatment.	Deposit on removal from Tank.	A.S. Per ct.	Coag. Per ct.	
Sept. 15	24	134,125	97,285	38,671	9,670	72.10	99.39	94.77	46	54	95.07
Oct. 13	27	181,723	132,962	48,166	18,401	101.26	99.42	93.58	36	64	94.16
Nov. 10	31	194,043	136,411	58,260	17,952	92.52	98.26	93.74	43	57	94.66
Dec. 8	28	198,111	140,097	58,850	18,426	93.00	99.33	93.28	42	58	94.64
Dec. 23	15	110,682	82,020	29,021	11,096	100.25	99.45	93.38	36	64	94.10
Totals—	123	818,684	588,775	232,968	75,545						
Averages—						92.2	99.37	93.75	41	59	94.5
Weight in tons—		3,677.3		1,124.4	33.7					71.9 by Volume	69.6 by Weight

and as the rate of rotation of the worm conveyor depends directly on the volume of sludge passing through the water-wheel tank, any given proportion of the coagulant, within certain limits, can thus be made to synchronise with the volume of sludge being dealt with. This mixing plant was supplied to the author's requirements by Messrs. Bowes, Scott & Western, Ltd., of Orchard Street, Victoria Street, Westminster, and erected by Messrs. W. Dunk & Sons, Ltd., of Barnsley. The settling tank platform for mixer, and distributing carriers were constructed by Mr. H. Taylor, A.M.Inst.C.E., Borough Engineer and Surveyor of Barnsley.

The whole discharge of surplus activated sludge, after mixing with the coagulant, is passed into the settling tank, and then allowed to settle for half-an-hour. The floating-arm valve is then opened, and the separated liquor discharged rapidly until the deposit is just visible through the liquor. The valve is then closed down until about one-quarter open, and reduced still further as the level of the liquor approaches the deposit, until the latter is practically free from liquor on its surface. The floating-arm valve is then closed, the outlet valve opened, and the deposit discharged along distributing carriers on to plots of land mechanically tilled by means of the Rototiller. The time occupied in delivering the mixed liquor into the settling tank is governed entirely by the rate of pumping the surplus sludge from its reception chamber on the bio-aeration unit, and averages about 30 minutes, the drawing-off of the main volume of separated liquor about one hour, the remaining volume allowed three hours to drain off slowly, and the discharge of the deposit about 20 minutes, the complete treatment occupying five hours.

In the laboratory experiments, a period of three hours was the average time allowed for settlement of the deposit, but in practice with the new plant half-an-hour appears to be sufficient. It must, however, be borne in mind that the deposit of coagulated sludge begins to settle as soon as it leaves the bottom of the stilling box, so that when the whole of the mixture has been passed into the tank there is always 4 to 6 inches in depth of clear liquor near the surface, and a further half hour's detention ensures a rapid discharge of the liquor without disturbing any of the lighter portions of the deposit. It is not found necessary for anyone to be on duty during the whole period of five hours, only occasional attention being required during the discharge of separated liquor to adjust the floating-arm valve as the liquor approaches the deposit. From experience gained over the first four months in which this plant has been at work, it is quite evident, owing to the rapidity exhibited by the deposit in settling out, that a continuous flow tank could be adapted quite satisfactorily for this treatment of activated sludge on a larger works, and on one or two occasions the overflow from the settling tank has been brought into use for this purpose, when a larger volume of surplus activated sludge was available than the settling tank would hold at one filling.

If it is anticipated that there will be more surplus activated sludge in the day than will constitute the filling of the tank in the morning, the major volume of separated liquor is drawn off, and a further volume of mixed sludge and coagulant is passed into the tank on the top of the deposit therein. The separated liquor is discharged as before, and the final deposit from both fillings discharged by the

outlet valve. In this way, a total volume of surplus sludge up to 17,000 gallons has been dealt with in eight hours.

As this paper has to be dispatched before December 31st, 1932, it is only possible to include results for a period of a little more than four months. It is satisfactory to note that although only such a short period has elapsed, and a period in which like all pioneer plants its little idiosyncrasies have had to be discovered and remedied, yet not only has it justified the hopes entertained during the experiments carried out in the laboratory, but it has yielded a larger separation of liquor than was anticipated. As a consequence of this larger separation, not only is the deposit smaller in bulk, but also it is considerably less mobile, inasmuch as difficulty has been experienced in distributing it over somewhat remote plots of land. Two months after the plant had been at work, a small drying bed was constructed, and during November and December this bed has received several discharges of deposit. The surface of the bed has been composed as far as possible with sand washed from detritus, and has smooth and rounded grains, and although the weather has been very showery, a "cake" has been produced within five days with a moisture content of 80 per cent. On removal of this semi-dried deposit to a dump, moisture continues to leave it, and within twenty days moistures have been recorded as low as 70 per cent., although both the drying bed and the dump are in no way sheltered from the weather.

In consequence of the results obtained by the use of this drying bed, which was sufficiently large to be able to deal with one complete discharge of deposit from the settling tank, the Council have passed a scheme for the construction of 12 drying beds each 72 feet long by 12 feet wide, at a cost of £376. The average volume of the deposit has been 1,942 gallons, which allows an average depth of a little over four inches over the whole of each bed. Immediately the deposit reaches the bed, further liquor runs off its surface, and the whole volume settles down to about 2 to 2½ inches within the first few hours. Thus the area suggested, namely 1,152 square yards, should allow ample provision for the disposal of the whole of the surplus sludge derived from a bio-aeration unit dealing with a D.W.F. of 500,000 gallons of sewage, although this area amounts to 19 persons per square yard per annum. When it is considered that before this plant was put into operation, an area of three acres of land per annum was found to be insufficient for the disposal of the surplus activated sludge from this bio-aeration unit, and another three acres used during each of the second and third years, whereas now it can be dealt with on an area slightly less than one-quarter of an acre, the value of the separation of a large proportion of the supernatant liquor as a preliminary action, can be better appreciated. The drying beds will be so constructed that their drainings and the liquor which runs off the surface of the deposit will pass on to the land, and be incorporated with the soil by means of the Rototiller.

It may be interesting now to revert to the laboratory experiments and note how they compare with the results obtained on the large scale. In the former, the coagulant used was fine ash derived from boiler house clinker, passed through different sizes of sieves, and then added to the sludge in glass cylinders of varying diameters. The amounts of coagulant used varied from 1.0 to 2.5 grammes per

100 ccs. of sludge, and after shaking the contents of each vessel, the separation of liquor was noted at intervals during periods of settlement in comparison with a similar vessel containing sludge only. The results obtained showed that the finer the powder the greater the separation of liquor when equal weights of the coagulant were used with similar volumes of sludge. Hence, as it was anticipated almost from the commencement of these experiments that there would be a dilution of the solids present in activated sludge by the coagulant in the final dried deposit, it was essential to discover how far that dilution could be reduced without appreciably decreasing the volume of separated liquor. In the early experiments the proportion of coagulant in the dried deposit amounted to something like 80 per cent., but by using finer grade material, practically dust, the proportion came down to 62—65 per cent. It was also noticed that wider vessels gave a proportionally larger separation of liquor when the amounts of coagulant and sludge were the same, this confirming the work done by Clifford & Windridge* at Wolverhampton. In practice with the new plant, the average proportion of coagulant to dry solids in activated sludge is shown on the table as 59 : 41 respectively, which is better than was obtained in the laboratory. There have been several occasions when the proportion of coagulant has amounted to as low as 45 per cent. The addition of the coagulant has amounted to an average of 92.2 lbs. per 1,000 gallons of activated sludge, and the average proportion of separated liquor is 71.9 per cent. This is a greater volume of liquor separated by means of a smaller proportional weight of coagulant than occurred in the laboratory experiments. The explanation of this is assumed to be (a) perhaps the more intimate contact obtained between the particles of finer coagulant and the solid particles of activated sludge by better mixing, and (b) a still wider vessel for settlement in the concrete tank than could be obtained in the laboratory. In comparing the weight of coagulant added with the weight of the activated sludge treated, the former is slightly less than 0.916 per cent. In the laboratory, the coagulants used were :—clay, clinker, ash, several kinds of sand, crushed stone, ground polarite, brick dust (ballast), ash from burnt sludge, ash from burnt gob heaps, and other allied materials, together with various combinations and different grades of fineness. In practice with the new plant, efforts have been made, and successfully, to obtain the coagulant as much as possible in dust form and thus avoid the cost of screening or crushing, although burnt sludge has been used with quite good results.

It has already been mentioned that it was anticipated that there would be a dilution of the nitrogen content in activated sludge by the coagulant, and having in view a prospect of converting the dried deposit into a marketable fertiliser, it was decided to try various combinations of basic slag with other dust and/or burnt sludge. Three such experiments have been made with the new plant, and the deposit passed on to the drying bed. The average separation of liquor in these three was 71.8 per cent, and the moisture in the "cake" on removal from the bed averaged 79.9 per cent. It is not expected that they will be dry enough to powder before this paper has to be dispatched, but an analysis of the powder will

* Clifford, W. & Windridge, "The Settlement of Activated Sludge," read at the Summer Conference of Association of Managers of Sewage Disposal Works, Lytham St. Anne's, July, 1932.

be available when the paper is read. It is sufficient for the time being to state that the presence of powdered basic slag in no way interferes with the separation of liquor either in the preliminary stage in the plant or on the drying bed, rather its presence appears to be beneficial.

The percentage moisture for the deposit leaving the tank is possibly a little lower than the true figure, as the deposit is not a homogeneous mixture, and in the taking of samples it is possible that too large a proportion of the heavier matter is included therewith. If the percentage moisture is calculated on the basis of dry solid matter present in the coagulant and the original activated sludge, and assuming that the separated liquor has a specific gravity of 1.0, the moisture figure becomes 94.5 per cent. On the table the moisture figure for this deposit is given as 93.75 per cent., and in all probability the true moisture is approximately 94 per cent.

This paper would hardly be complete unless some return of the running costs were included, and the following costs have been determined on the last 28 days :—

	s.	d.
Preparing coagulant, and feeding it to elevator	1	2
Coagulant (except when basic slag is used)		8
Electric current, lubrication, etc.		2
Decanting separated liquor and discharging deposit ..	1	2
Daily cost of running plant	3	2

The plant is in operation six days per week, the average volume dealt with has been 47,800 gallons per week, and the cost is therefore approximately four shillings per 10,000 gallons of activated sludge dealt with. The experiments with the drying bed are not included in the above costs, and it is estimated that when the 12 new beds are ready, the whole work connected with the plant and drying beds will occupy three-quarters of one man's time, making a total cost of £2 1s. 9d. per week. From this it is estimated that one ton of the dried and powdered deposit will approximate thirteen shillings, exclusive of any basic slag which may be used as a constituent of the coagulant. There is a works in South Yorkshire where a powdered product is obtained from activated sludge after digestion, and the price obtained amounts to thirty shillings per ton. Thus even on a 50 per cent. dilution of the nitrogen content, activated sludge could be disposed of at a profit, as far as its disposal is concerned by this process. If in addition to this, basic slag or some other allied material forms part of the coagulant, the dilution of nitrogen can be compensated by the substitution of a phosphate, and the resultant powdered fertiliser should not only find a ready market, but also produce an increased revenue.

Investigation is still continuing with the latter objects in view, as well as modifications and improvements in other details of the process.

It may be asserted that nothing has been included in the costs for repairs and renewals, but there is very little about the plant which is likely to require repair or renewal for a considerable period. The plant, that is the mechanical portion

of it, is seldom at work for more than 5 hours per week, so that its repairs and renewals will amount to very little in the course of a year.

In conclusion, the author desires to point out that whereas in the discussion on the paper given in November, 1932, only one part of one of the statements was accepted, and then with a rider, that it was not new, yet this process is the application of these statements. Assuming that there is some truth, though not as yet accepted, in these two statements, it must certainly be acknowledged that the process described in this paper is the first to be laid down embracing these theories, and to that extent is therefore new. The results already obtained, even after so short a trial, show that the whole of the surplus activated sludge derived from a half million gallon bio-aeration unit can be dealt with on an area approximately one-twelfth of that used formerly, and without nuisance. Furthermore, it is held that these results have, to a certain extent, substantiated the theory of "attraction" of light suspended solids by rough surfaces, and lastly the manner in which the supernatant liquor so readily leaves the deposit, both on drying beds and on land, suggests some form of "repulsion" of water.

DISCUSSION.

MR. BELL, introducing his Paper, said: You will notice that it has been necessary to refer to some of the statements which appeared in a Paper I read last year at the Public Health Congress, in order to show the connection between the theories suggested therein and their application in the Paper now before you. I am sorry that only about four months of working of the process is presented, owing to the Paper having to be dispatched to the adjudicators before the end of 1932, which to some extent renders the information nearly twelve months out of date.

A description of the plant and process is given, together with a table of the results obtained during the first period of work. It will be noted that a larger volume of liquor is separated from the activated sludge by a smaller proportion of coagulant in practice than occurred in the early laboratory experiments, which reduces the dilution of nitrogen in the final product. You will also note the reasons advanced for selecting drying beds for the disposal of the deposit rather than land, and that the area of drying beds suggested for dealing with the whole year's output from the process, whilst being apparently an ample provision for present requirements, is still equal to only 19 persons per square yard per annum.

Since the date when this Paper was written, the plant has dealt with 1,480,000 gallons of activated sludge, making some 2,300,000

gallons in all. The average separation of liquor over the whole period has been 73.2 per cent. and the weight of coagulant added 94 lbs. per 1,000 gallons of sludge. During this period, about 14 months, there have been no repairs or renewals of the plant, and therefore I am still unable to estimate an annual cost for these items. In the constitution of the anhydrous deposit, the coagulant added as an average over the whole period of work up to the present time amounts to 57½ per cent., the dry activated sludge being 42½ per cent. Although the coagulant certainly does dilute the nitrogen content of the original activated sludge, there is apparently no actual loss of nitrogen such as occurs in the digestion process of disposal of this type of sludge.

The analyses of the final products, which were not available when the Paper was written, are now supplied, the constitution being given on the anhydrous content:—

	"A"	"B"	"C"
Total Nitrogen ..	1.67	2.02	1.68
Other organic and volatile matter..	39.58	34.37	32.64
Lime ..	5.46	14.02	19.36
Calcium phosphate as $\text{Ca}_3(\text{PO}_4)_2$..	3.06	3.16	6.08
Other mineral matter	50.23	46.43	40.24
	100.00	100.00	100.00

"A" was dried coagulated activated sludge taken from a dump of carted sludge which had been disposed of on land, and which contained no basic slag as part of coagulant. "B" was dried on a drying bed and basic slag formed part of the coagulant. "C" was dried on a drying bed, and the coagulant was wholly composed of basic slag. Each sample contained about 5 to 6 per cent. of moisture when the sample arrived in the laboratory for analysis.

As only one drying bed is in use at present, has been impossible to accumulate a very large weight, but some seven tons have been powdered and trials made with it as a fertiliser during this summer, the results of which have been very gratifying. A small amount has been sold at £2 8s. per ton, although one or two trial loads were disposed of at £1 per ton, as such. It has been shown that one ton of dried deposit, in which basic slag forms no part of the coagulant, can be dried and powdered for 13s., and if basic slag forms part of the coagulant, quite an appreciable content of phosphate in the final product can be adjusted at a cost of 24s. per ton, powdered and bagged, which shows a good margin of profit as a practical possibility. This type of fertiliser is one in which there must be an almost complete absence of weed seeds, by virtue of the normal constitution of both activated sludge and the coagulants, which is an added attraction from the product obtained from ordinary sedimentation tank sludge, and its higher content of plant food must eventually find a good market.

MR. MAKEPEACE, moving a vote of thanks to Mr. Bell, said: The question in which Mr. Bell has keenly interested himself during the last four or five years is one of great interest to many of us, particularly those who have small works on activated sludge lines in operation, and more particularly with regard to the efficient disposal of the surplus sludge in a satisfactory and rapid manner. It would appear from this Paper that Mr. Bell has proved the statement he made a little over twelve months ago, that there were peculiar occurrences in the treatment of his liquor on mixing it with specific and special coagulants. I was particularly impressed by what he said at that time, and it was with pleasure that I found, on reading the present Paper, that he appeared to have substantiated his earlier statements.

One regrettable feature, however, is that he has only had the opportunity of giving you the experience of about three months with this new method. I say that advisedly, because we have had previous experience of methods of treatment of activated sludge which gave promise of success but in regard to which after a short period there has been disappointment. In the present case, however, Mr. Bell makes the startling statement that, by his special method of treatment, in half an hour he can take off a considerable amount of water, and in five hours the whole operation of mixing his coagulant with his active sludge is completed and it is ready to be passed on his beds for drying purposes. Moreover, though his liquid sludge is put on the bed to an average of 4 in. thick, in a few hours it is reduced to 2½ in., and in five days he is able to dig it off, and after a total period of about 21 days his surplus activated sludge is reduced to a 70 per cent. moisture. That, on the face of it, is a wonderful achievement if it can be maintained, and I shall watch with very great interest the further investigations of Mr. Bell in these directions.

He has made a very definite attempt to prove that smooth particles and sharp particles have a special action on the mixing of the coagulant, the drying of the sludge on the beds themselves, and ready removal of same without serious loss of the filtering material. This is a problem which no doubt has occurred to quite a number of you on your ordinary sludge beds. It has certainly occurred to myself, and on more than one occasion we have had sludge beds of the ordinary type with different kinds of material in order to test the practicability of this idea. We found that there was a good deal of picking up of the fine material from the sludge beds under the methods we adopted, which included the use of sand, ashes, fine slag, and sagger dust, but we were not successful beyond the first two or three operations. However, we found later on a much more simple, practical and permanent method of leaving the ashes on the bed after the sludge had been dried, and this simple operation consisted of seeing that the top 2 in. of each bed were rolled to a very hard face in order to prepare it for the sludge about to be deposited on it. That very simple operation certainly reduced the loss of our ashes by at least 80 per cent. in one

year, and it has occurred to me that some similar simple operation of this kind might be of help to Mr. Bell in his further investigations, though he may, of course, have practised it himself.

Another startling feature about this method is the statement made by Mr. Bell that by this method we should be able to dispose of the whole of the sludge from a town on drying beds on a basis of 10 persons per square yard. I feel sure he does not wish to give that impression, or, if he does, I do not think he can be right, because here he is dealing only with the surplus activated sludge from a section of his plant, while his statement would give the impression that the whole of the sludge made at the sewage works can be dealt with on sludge beds in this way, all of which is not activated sludge, on a basis of 19 persons to the square yard. That is a serious statement, and I feel that a wrong impression may be conveyed.

MR. F. R. O'SHAUGHNESSY, seconding the vote of thanks, said: There is one matter of congratulation in that Mr. Bell will now have something to attract him away from his pet achorutes and certainly, although we all admit the value of what Mr. Bell has done in that direction, and the very important use which achorutes has in ordinary practice if intelligently used, I venture to suggest that this present contribution of his, which is now maturing into something on a semi-works scale, is possibly an even more important contribution to the solution of some of our difficulties.

Its merits are manifold. At this stage, of course one may have some difficulty in expressing any criticism; one has simply to take the evidence which is furnished by Mr. Bell, and those of us who feel sufficient confidence and have sufficient enterprise can check and repeat the work which Mr. Bell has so carefully described. It certainly seems to me, judging the facts as described by him, that this process promises to be one which can be used on a continuous flow basis. It has a great advantage over the method used by the one place in America which is exploiting a method of recovering activated sludge on a large scale, namely that of Milwaukee, because this process is a very simple one and can be applied almost anywhere, as far as the information given by Mr. Bell goes.

With regard to the criticism raised by Mr. Makepeace with reference to the disposal of such a large quantity of sludge on such a small area—that is, 19 persons to the square yard—I take it that statement should be elaborated in the way that he suggests; that is to say, the activated sludge is presumably derived from a sedimented sewage and represents only a portion of the actual sludge-forming material which is brought along in the sewage and which has to be dealt with in the ordinary way. I gather from conversation with Mr. Bell, however, that the material which is lifted from his drying bed undergoes a further process of drying in sheds, and he tells me he is able to reduce the water content considerably.

This method appeals to me enormously, and it has the virtue that no artificial heat is applied to this very sensitive activated sludge; as heat may reduce its value as manure. The moment you begin to heat a material like that you feel you are taking away from its natural virtues. That simplification is therefore an advantage.

MR. J. H. COSTE: I am both a county agricultural analyst and an adviser to a rather large sewage undertaking which is now experimenting on a very large scale with activated sludge. Some years ago, two workers at the Rothamsted experimental station showed that activated sludge had a very high fertilising value. They published a Paper in which photographs of plants grown in pot experiments were given, and the effect was very marked. The high nitrogen content, of course, is very greatly in its favour, but that has, I think, been exploited in a very unjustifiable way; you see statements that activated sludge contains 6 per cent. of nitrogen, and that sort of thing. As a matter of fact, it does not; it contains about 0.06 per cent. of nitrogen. If you look at those statements very carefully, however, you usually see some little note which shows that they really refer to dry matter.

Mr. Bell, being a chemist, has had that fully in mind, and has experimented in various ways to obtain a fertiliser which can honestly be sold to farmers. That is where my dual capacity comes in. One feels that many of these things one has to analyse might have been given away, or people might have thought it worth while to cart

them some little distance, but to sell them is frequently a very unfair thing to an industry which is still in a rather primitive state and which is very poor.

It is clear from Mr. Bell's experiments that some sort of diluent must be used, and it was, I think, a very happy idea to use a diluent which in effect was not a diluent, namely basic slag, because basic slag not only contains from 15 to 18 per cent. of P_2O_5 , but, being basic, there is a good excess of lime, and one knows that lime favours the action of the nitrifying organisms in the soil by raising the pH to a suitable figure. In any case, of course, if the final product is to be sent away freight charges must be considered, and I think these materials, if they had to be carried very far, might prove expensive. Another matter which has to be considered is that at present the gas companies are producing sulphate of ammonia on a large scale, and they find it very difficult to get a remunerative price for it. Now, sulphate of ammonia contains about 20 per cent. of nitrogen. On the other hand, this product contains a largish amount of organic matter, which on poor soils is of value; not that the non-nitrogenous part of it has any nutritive value to plants, but it retains water in the soil and maintains that curious property which farmers describe as tilth, which is of use to the operations of cultivation of a soil.

Another point is the physical meaning of these observations with different shapes of sand particles. One would like to know something about that. It is a little difficult, of course, to visualise what happens in Mr. Bell's experiments, but there is one point which I should like to mention. A sphere, as you all know, affords the least surface relative to its mass of any form of solid, whereas these sharp and splintery particles must afford a very large surface, and it seems to me it is a question of surface action; but it would be interesting if the physics of the matter could be examined a little more fully.

It is not every works, I think, which gets a large excess of activated sludge to deal with; it depends very much, of course, on the way of working; but certainly I can honestly say, as one whose original chemical work was in the agricultural line, that this is the most hopeful of the fertilisers which have been

made or sought to be made or exploited from sewage.

MR. S. DUXBURY: Of the numerous Papers we have had presented before us, seldom have we considered the bacterial content of the sludge concerned, for we have always assumed all sludges to be alike, and that if we had solved the difficulty of drying a sludge from one plant, we should have obtained a method for drying them all. In all sludges we have the numerous bacteria which have brought about the essential changes towards purification and the formation of these sludges. The quantity and classification of these bacteria vary in detritus, sedimentation, precipitation (chemical), septic, humus, and activated sludges, and as bacteria are mainly protoplasm, or a jelly-like substance contained in a cell, their motivity or power of producing motion, along with their specific gravity, do not aid settlement or the drying of the sludge concerned. Some organisms are unable to withstand drying for even a few hours, while others can withstand complete dessication for a considerable length of time.

All sludges contain a varying amount of inert matter and the lesser the bacterial content, the more quickly it will dry.

In Mr. Bell's experiments he has separated the numerous live bacteria by the addition of certain inert materials, thus exposing a greater area of the more gelatinous sludge to the drying atmosphere.

In my opinion it does not follow that because Mr. Bell is drying Barnsley activated sludge at the cost as set out in his Paper, other sludges could be dried on similar lines at the same price. Under ordinary favourable conditions of life the shape of bacteria remains constant, but if the conditions were made unfavourable the protoplasm contained in them would degenerate; thus the sludge would have a greater specific gravity, the motivity would be reduced, and the sludge would dry more quickly. I am sure many of you will agree we do not pay sufficient importance to the bacterial content of sludges in relation to drying.

I am not surprised to read that Mr. Bell is unable to dry a gelatinous sludge on a small area of unsuitable land, but I am sure any kind of sludge can be dried on suitable land providing the area is in ratio to the gelatinous nature of the sludge, and further,

for smaller works, at a cost much less than any other method yet known.

May I say that Mr. Bell's method of adding inert material to sludge tends to drown his sorrows in the supernatant water. It reminds me of the man who takes drink in excess to drown his sorrows, yet I am sure he will agree the man can sleep it off and is all right in the morning, but with the sludge you have the added material with you always.

MR. BELL: In reply to what Mr. Makepeace said about the picking up of material from a drying bed by sludge, I may say that I quite agree with his rolling methods, because we have had them in use now for some two or three years. Undoubtedly if the immediate surface of a bed is composed of small rounded grains of sand rolled hard, so that no foot-mark can be made on it by the ordinary workman's heel, you have a type of bed which is best suited for drying humus sludge, sedimentation sludge or activated sludge, but, in order to make that surface sound, so that it may be used time after time, with the least amount of renewal of the surface, the latter is lightly dusted over with a fine gritty powder before discharging the sludge on to the bed. The sludge as it dries adheres to the fine powder and leaves the surface practically untouched. A great deal depends on having the surface of the drying bed hard before each discharge of sludge takes place.

With regard to 19 persons to the square yard, when the drying beds now in course of construction are completed the whole area will be 1,152 square yards, and it is certainly my belief that the whole of the surplus activated sludge from a 500,000 gallons dry weather flow activated sludge unit can be easily dealt with on that 1,152 square yards,

except perhaps in periods of long frost of from five to six weeks duration. Apart from that, rain or fine those beds will do the work without any difficulty.

Mr. O'Shaughnessy is quite right in suggesting that these are not the only drying beds which we have attached to this unit. We have some drying beds which deal with the sedimentation sludge, and that area is equivalent to 13.9 persons per square yard. There are also some drying beds which deal with the detritus portion of the sludge, equivalent to 125 persons per square yard. When you add these figures together and divide them up you will see something of what we have been doing.

In reply to Mr. Coste, I do think that the organic content of the activated sludge does offer to the farmer something in the way of a tilth, and as such would improve the ordinary manure from a sewage source.

With regard to Mr. Duxbury's remarks, with reference to the encouragement of drying there are a good many tips which most sewage managers have used in the past and will probably employ for many years to come. I do not propose to say much about the bacterial side, because I do not know very much about it. There is no doubt that on sludge dumps the moisture content of which varies from 30 to 60, where natural heating has taken place, you invariably find a white fungus, which is usually the seat of the driest portion, and, if a partially dried sludge is mixed with a fresh wet cake of sludge, that white mould or fungus appears again between any two surfaces. Whether it has anything to do with the drying and removal of the moisture I am not prepared to say at the present time, but that is a suggestion on which someone else might work.

CONFERENCE

Under the auspices of the Institution of Municipal and County Engineers.

FRIDAY, 17th NOVEMBER, at 11.0 a.m.

MR. E. A. SANDFORD FAWCETT, C.B., M.Inst.C.E. (*Vice-Chairman of the Congress Organising Committee*), in the Chair.

The following Paper was taken as read:—

The Design and Construction of Municipal Aerodromes.

BY

T. LLOYD ROBERTS.

(*Assistant Engineer, Anglesey C.C.*).

(NOTE.—This Paper was submitted for the Open Competition arranged by the Congress Committee and was awarded a Special Prize of Five Guineas).

INTRODUCTION.

THE growth of commercial and civil aviation in this country has increased to such an extent during recent years, that all progressive Municipal Authorities should give urgent consideration to the problem of establishing suitable airports for the use of all types of aircraft. So one might anticipate a future when the design, construction, and management of airports will be considered one of the most important duties of municipal engineers.

The following notes have been compiled as a guide to those about to undertake the responsible task of designing and constructing a municipal aerodrome.

SELECTION OF SITE.

The first important problem with which the aerodrome designer is confronted, is the selection of a suitable site, and in this direction he must be guided by many factors.

From a commercial point of view, it is essential that the airport should be as near to the town centre as possible. Owing to the difficulty of finding suitable sites in developed areas, and the exorbitant cost of the land when it is available,

many authorities have no option but to build airports on the outskirts of the town. The provision of an adequate means of transport between the town centre and the airport, such as a good wide road, compensates for this disadvantage. A site near the town has other advantages in the form of existing electric, gas, water, and drainage services.

On the other hand, the proximity of a town has one disadvantage, as in this country single-engined and twin-engined aircraft flying over towns are compelled to keep an altitude of 6,000 feet, and 3,000 feet respectively. Thus, it will be seen that, to function properly, the airport would have to be increased in area considerably, and would be uneconomical to construct and maintain.

In this country the prevailing wind is South-West, and a site which is most likely to be free from town smoke and fog, the greatest enemies of pilots, will be one situated on the South-West side of the town.

Sites on plains, near large rivers, and in narrow valleys are subject to fogs and mists. On the other hand, elevated sites are often covered by low lying clouds, which are just as bad as fog. Where cloud ceiling altitude records are available, they should be consulted in order to select a site below the average ceiling altitude.

Local air currents and eddies also govern the selection of a suitable site. The best possible way in which the existence of such can be determined is by actual test flights over the proposed area by experienced pilots. These flights should be carried out under varying weather conditions.

The site must be easy to locate from the air, and have clear approaches. All objects within one mile of a proposed site must be examined. Any which are higher than one-fifteenth part of their distance from the perimeter of the landing area, and which occupy considerable air space, will constitute serious hazards to flying.

With a view of curtailing preparatory work to a minimum, the site should be fairly level. It must be borne in mind that no gradient on the finished flying area must exceed 1 in 50. Dead level sites are uneconomical because of the difficulty of effectually draining them.

The soil found in this country is generally suitable for use, but it may be stated that clay and loam are to be avoided as far as possible. The stratification of the sub-soil can be ascertained by trial holes placed at regular intervals over the site, and plotting the results. Sub-soils with a bearing capacity below two tons per square foot are considered unsafe for the use of the heavier types of aircraft.

AREA OF SITE.

The area of an airport is governed by Government regulations. It is essential that there should be a prepared flying area with a minimum run of 600 yards in all directions. As aircraft develop most of their trouble immediately after taking off, the flying area must be surrounded by a belt of land at least 100 yards wide and free from any obstructions except fences, which must not be more than three feet high.

At high altitudes the buoyancy of the atmosphere is considerably less than at sea level, and this has a direct bearing upon the performance of aircraft. To conquer it a greater taking off speed is required, and consequently a longer run. A good rule is to increase the minimum distance by 15 per cent. for every 2,000 feet rise above sea level.

As much as possible of the land surrounding a proposed site should be acquired, as in most cases the establishment of an airport will greatly enhance the value of such land, and the purchase will prove a profitable investment. In the meantime, the land can be let as allotments, or for grazing. In addition, some of the land should be allotted for public use, considering the interest taken in aeronautics at the present time.

As previously mentioned, no high buildings or other obstructions may be built within a mile of the perimeter of the landing area. Failure to comply with this requirement may result in the licence being cancelled by the Air Ministry, thereby causing heavy loss to the municipality. The height of buildings may be restricted by legislation. Owners injuriously affected must be compensated, the compensation being assessed under the Land Clauses (Consolidation) Act. It may be noted that owners would not be adversely affected, since a building 30 feet high could be built at a distance of 150 yards from the edge of the prepared landing area.

The Town and Country Planning Act, 1932, which was recently passed by Parliament, enables local authorities to include in their town planning schemes special height restrictions for buildings in the vicinity of aerodromes, subject to the owner's right to claim compensation.

ACQUISITION OF LAND.

Under the Air Navigation Act, 1920, a local authority is empowered to borrow money, upon the security of the rates, for the purpose of acquiring land with the intention of subsequently developing it into an airport.

The Public Works Facilities Act, 1930, makes the compulsory acquisition of land for an aerodrome possible, provided the Ministry of Health is satisfied that the work will contribute to the relief of unemployment.

SURFACING.

Before dealing with the work of preparing a suitable surface to an airport, the characteristics of a good landing area might be mentioned.

The surface must be able to stand hard wear, and be easy and inexpensive to repair.

It must be resilient so as to absorb part of the shock of landing, and yet no amount of wheel sinkage must take place.

The surface must be suitable for use at all times of the year, and must be quick drying. To ensure this it must be well drained, but not so dry as to be dusty.

Finally, it must be perfectly smooth, or aircraft might be considerably damaged and the port would become unpopular. Smoothness of surface also eliminates the possibility of heavy shadows at night, when the area is floodlighted.

Turf possesses all the above characteristics, provided it is well designed and maintained.

As a rule, a suitable turf surface can be obtained in this country at the lowest capital cost and annual maintenance cost. It is therefore unnecessary to deal at length with the problem of landing strip planning, as used in countries where natural surfaces are often composed of loose materials.

Landing strips are specially prepared turf surfaces, provided with central runways, usually of concrete or tarmacadam. The strip must be of a minimum width of 500 feet, with a central paved surface of 100 feet width. They are laid down to run in the direction of the principal winds, and airports are referred to as two, four, six, or eight-way fields, according to whether they have one, two, three, or four landing strips. For an all-ways field, the landing strips must be planned so that pilots will not have to land or take off at an angle of more than $22\frac{1}{2}$ degrees across any wind.

Runways are similar in construction to highways. The camber should be about 1 in 150, and means of drainage must be provided at the edges. The joints between the runway and turf surfaces must be quite flush to enable aircraft to taxi across if necessary. To facilitate the turning about of aircraft at the ends of runways, circles of 150 feet diameter should be formed. It is customary, on busy airports, to join the ends of runways with paved taxi-strips, in order to reserve the former for aircraft landing and taking off.

PREPARATORY WORK.

On every surface some preparatory work is necessary to bring it up to the required standard of efficiency, and the different operations will be briefly described.

Clearing of site.—Hedges may be removed by encircling them with wire rope, and hauling out with a caterpillar tractor.

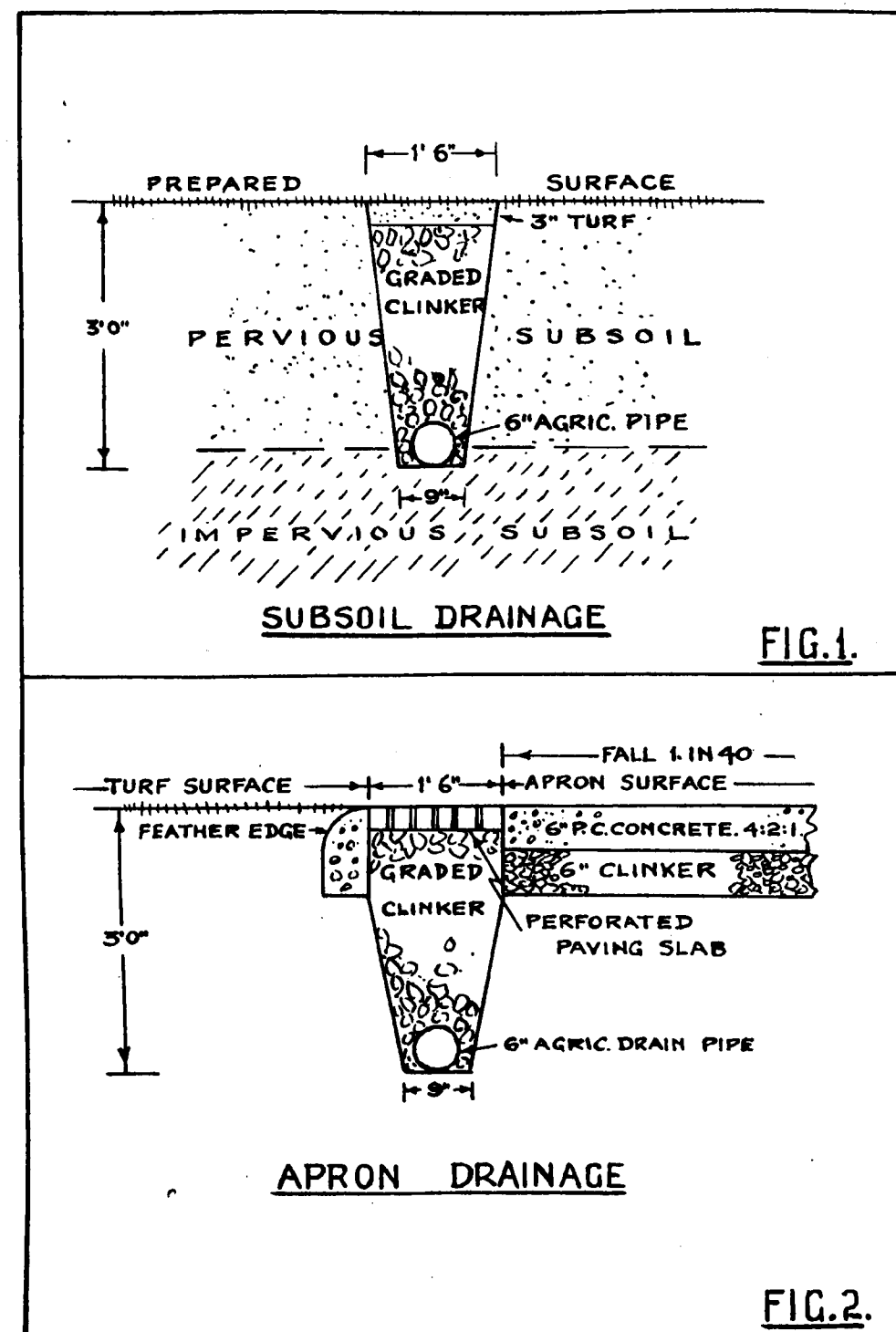
Trees are felled in the ordinary way, and the roots are removed by hauling.

In the event of there being any buildings on a particular site, they must be demolished, and care must be taken to remove all the foundation work.

Filling in ditches.—Ditches may be filled in with the soil arising from the demolition of hedge banks, etc. Any ditches which drain adjoining lands should be preserved. Diverting these is preferable to culverting them, considering the expense of repairing a damaged or blocked culvert.

Arable land.—Following heavy rain, this sort of land should be rolled with a 10-ton roller, hauled by a caterpillar tractor. The rolling is to be carried out several times in all directions. After rolling, and during fine weather, grading may be done, the tractor and grader travelling over the surface several times in different directions. The grader cuts down the hummocks and dumps the spoil in the hollows. Further rolling may be done until the surface is thoroughly consolidated and levelled.

Pasture land.—As a rule, several years weathering and root spreading will have resulted in the formation of a hard compact surface, which should be preserved. The ground, however, will require some preparation. This can be brought



about by ploughing and levelling only, provided the surface is fairly level. A disc plough may be used, and if the discs are set to give a depth of about $1\frac{1}{2}$ to 2 inches, the bottom soil will not be disturbed. The surface should be twice ploughed, the second operation being carried out at right angles to the first. The loose grass and roots arising from this work may be gathered into heaps and burnt. After ploughing the whole surface must be rolled in the manner previously described.

If the ground consists of hummocks and depressions, grading must be resorted to. Before grading, the top soil is excavated, by road type scrapers, to a depth of about four inches, and stacked for re-use. The grading is followed by rolling as before, and then the turf is replaced and adequately watered and rolled.

Plantation land.—This type of land requires special preparation. After the bushes, trees, and undergrowth have been removed, there will be small roots left in the ground, which cannot be removed by hauling. To clear these a killifer or scarifier must be used. It will generally suffice to traverse the ground three or four times in different directions. The debris left may be gathered into heaps and burnt. The surface must be then rolled, and graded if necessary.

The finished surface of the whole site must be thoroughly consolidated, even, and no gradient must exceed 1 in 50.

As a test for consolidation, the Air Ministry stipulates that a loaded 3-ton lorry must be driven slowly over the site, and no amount of wheel sinkage must take place.

Smoothness of surface is determined by another test. An ordinary motor car is driven over the site in all directions at 20 miles per hour, and the surface must be so smooth as to cause no discomfort to the passengers.

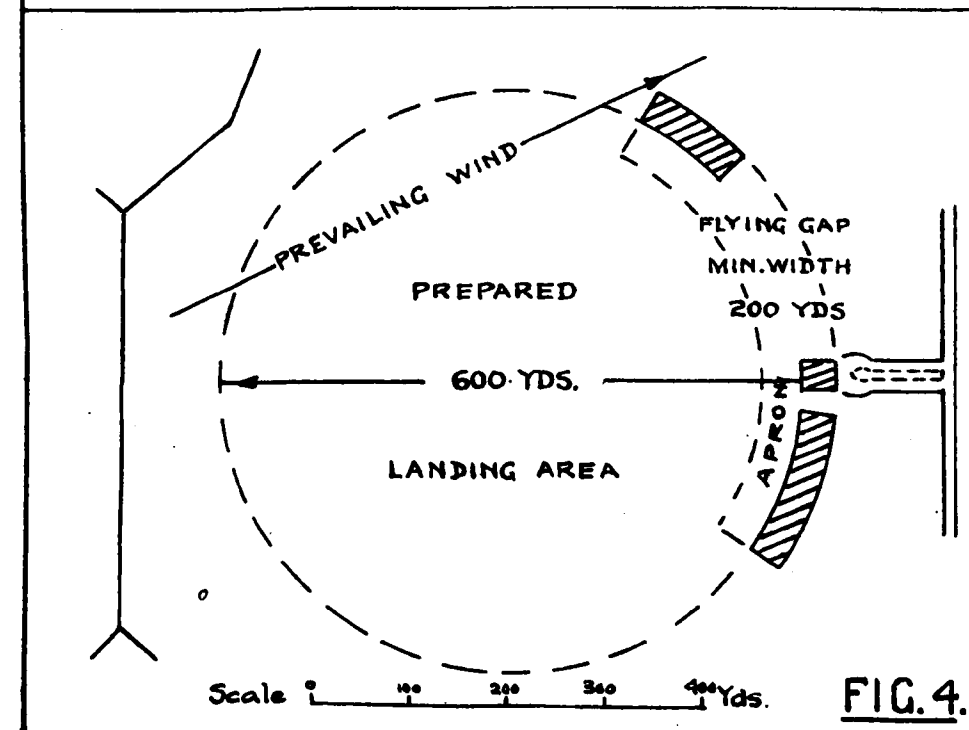
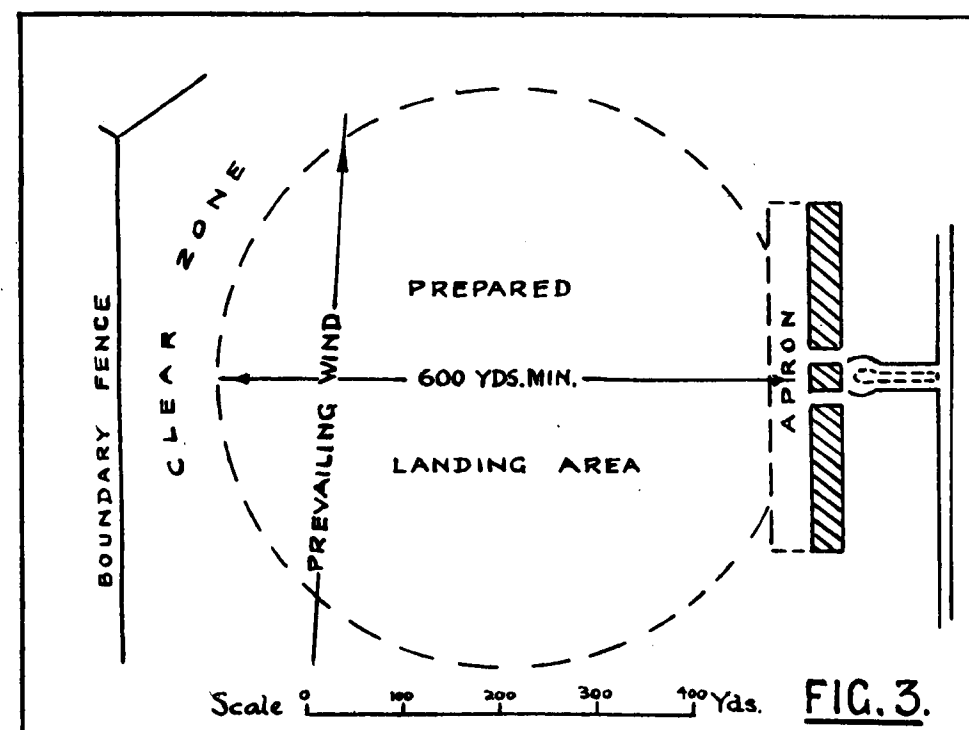
These two tests should be carried out before seeding, as the results determine whether any additional grading and rolling is required.

Drainage.—Drainage is one of the most important points in airport construction, and it may be classed under two headings:

- (a) Sub-soil drainage, and
- (b) Surface water drainage of turf area and apron.

(a) Where a thin layer of pervious soil overlies an impervious substratum, sub-soil drainage will often be necessary. The route of the main drains can follow the course of old ditches, and the branch drains must be laid diagonally with the fall of the ground. The latter, under normal circumstances, may be laid about 80 feet to 100 feet apart. Open jointed agricultural pipes must be used for all drains, and the trenches are filled in with graded clinker, as shown in Fig. 1, to within 3 inches of the top. The top of the trench is finished with turfing. Drains should be laid to such a depth so as to prevent freezing in winter time, and to proper falls. Where the pervious soil is not of great depth, it is good practice to lay the drains to the level of the impervious substratum.

(b) The high state of consolidation of the landing area prevents the soakage of water into the subsoil to any great extent. Where sub-soil drains are provided, these will absorb some of the surface water, provided the trenches are filled with



clinker to within 3 inches of the top. Most of the surface water will run off the prepared surface, and to prevent the boundaries becoming saturated during heavy storms, drains must be provided here. They may be constructed similar to the sub-soil drains, with the exception that the clinker filling is carried to the top.

In the case of a site which is almost level, the prepared area may be formed dome-shaped to provide an adequate run off for surface water.

Apron drainage will be described later.

SEEDING.

The final operation of preparing the ground is that of seeding, which should preferably be carried out in the early spring. The work should be entrusted to a firm experienced in this class of work.

The class of seed required for any particular site depends to a large extent upon the nature of the soil. It is, therefore, useless to attempt to quote an universal seed specification, but the characteristics of various suitable grasses may be mentioned.

The turf must be able to resist the attacks of tail skids and wheels, and to bind the top soil together effectually the grasses must have sturdy, creeping roots. The grass should also grow rapidly, but fairly short, to do away with the necessity of continuous mowing.

A judicious mixture of Creeping Red Fescue, Yarrow, and Clover will give the desired results, provided the soil is suitable. In very moist atmospheres Timothy might be added to the mixture. About one hundred pounds of the mixture should be allowed to the acre.

Before sowing, the consolidated surface must be disc harrowed, the discs being set to give a depth of $\frac{1}{4}$ inch, to loosen the top soil. After seeding the whole surface is finally rolled and watered.

APRON CONSTRUCTION.

The Apron is that part of the aerodrome directly in front of the buildings, on which aircraft are moored when not in the hangars, loaded, and refueled. It is an essential part of an airport, and the materials used in its construction must be hard, durable, and dustless. The retarding effect of the surface also simplifies the handling of aircraft using it in wet weather. Tarmacadam possesses all these characteristics, and is in use on most aerodromes in this country.

The apron must be as wide as possible, and never less than 120 feet.

If tarmacadam is used in its construction, it should be laid in two coats on 6 inches of clinker. The bottom coat may be 3 inches thick, and composed of $\frac{3}{4}$ to 1 $\frac{1}{2}$ inches gauge macadam. The top coat may be 1 $\frac{1}{2}$ inches thick, and composed of $\frac{3}{4}$ to $\frac{1}{2}$ inch gauge macadam. The whole is laid hot, and rolled until perfectly level.

Portland cement concrete, either in the form of situ-cast or pre-cast blocks, may also be used for apron construction. It resists wear and tear better than tarmacadam, but it is not so easy to repair.

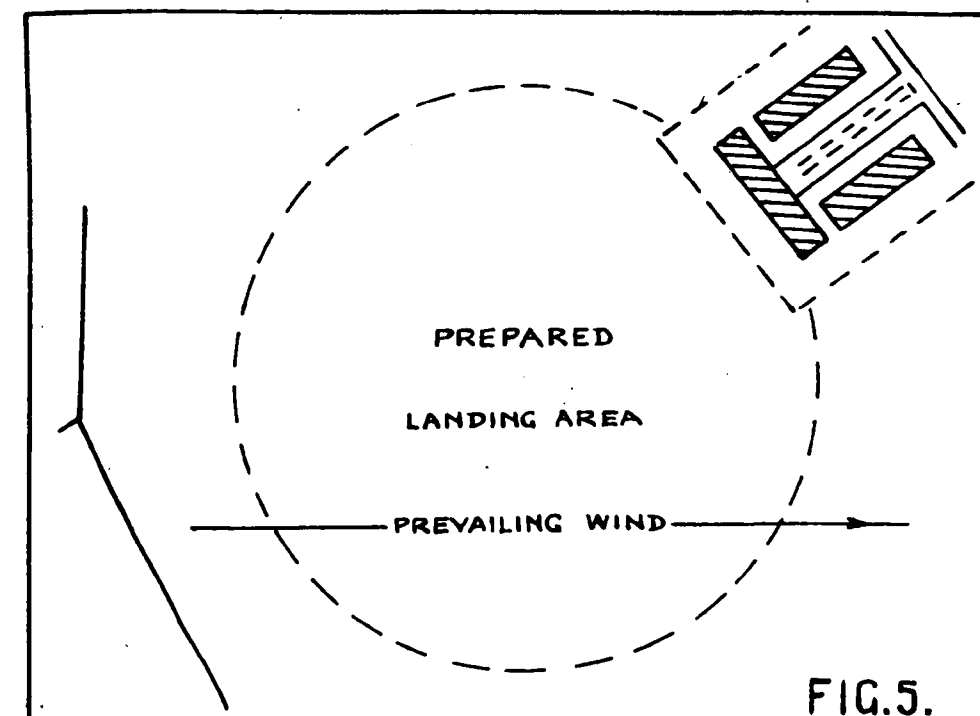


FIG. 5.

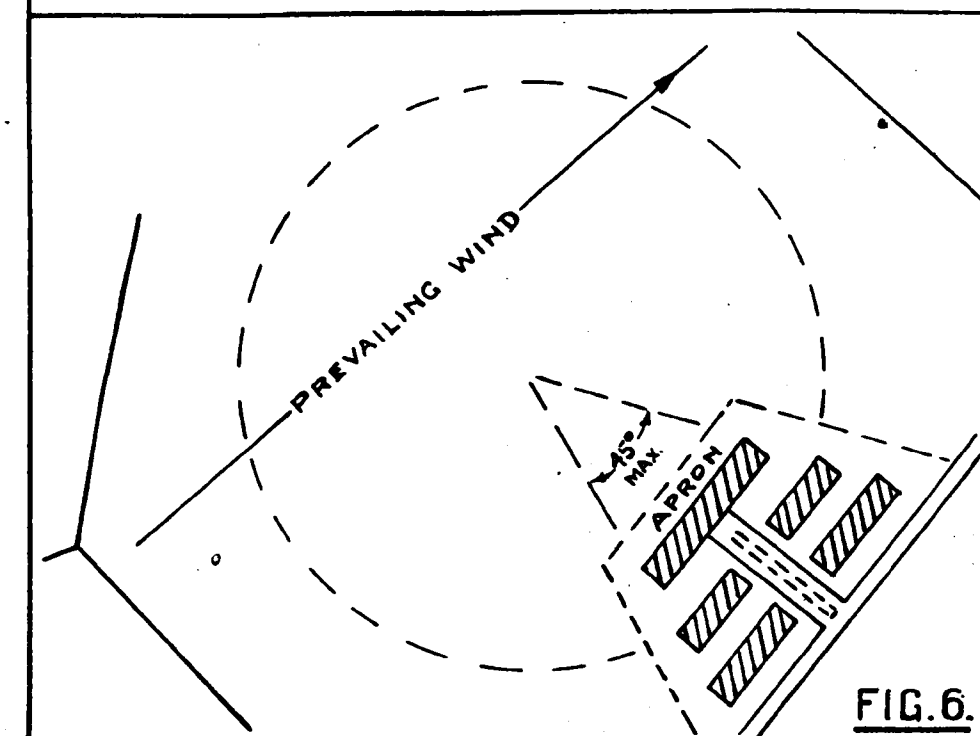


FIG. 6.

The concrete may be of a minimum thickness of 6 inches, of 4 : 2 : 1 mixture, and laid on a 6 inches bed of clinker. Situ-cast paving may be constructed in bays about 20 feet by 10 feet, with expansion joints between them.

Aprons should have a fall of 1 in 40 either towards the buildings or field. The latter method is preferable from the point of view of drainage. To prevent erosion of the turfed surface where it adjoins the apron, the latter may be finished off in the form of a feather edge with a convex slope, as shown in Fig. 2.

Apron Drainage.—Where the apron has a fall towards the field, means of drainage must be provided at the edge. Drains should be constructed in the same manner as previously described for general field drainage. The only difference is, that in this case, the top of the trench is finished off with a perforated paving slab (Fig. 2).

In the event of the apron being laid to fall inwards, effectual drainage is a much more complicated and expensive item. The drains must be laid beneath the paving, and to do away with the possibility of breakages, either stoneware pipes surrounded with 6 inches of concrete, or cast iron pipes must be used. Storm water inlets in the form of heavy cast iron road type gullies with silt buckets must be provided.

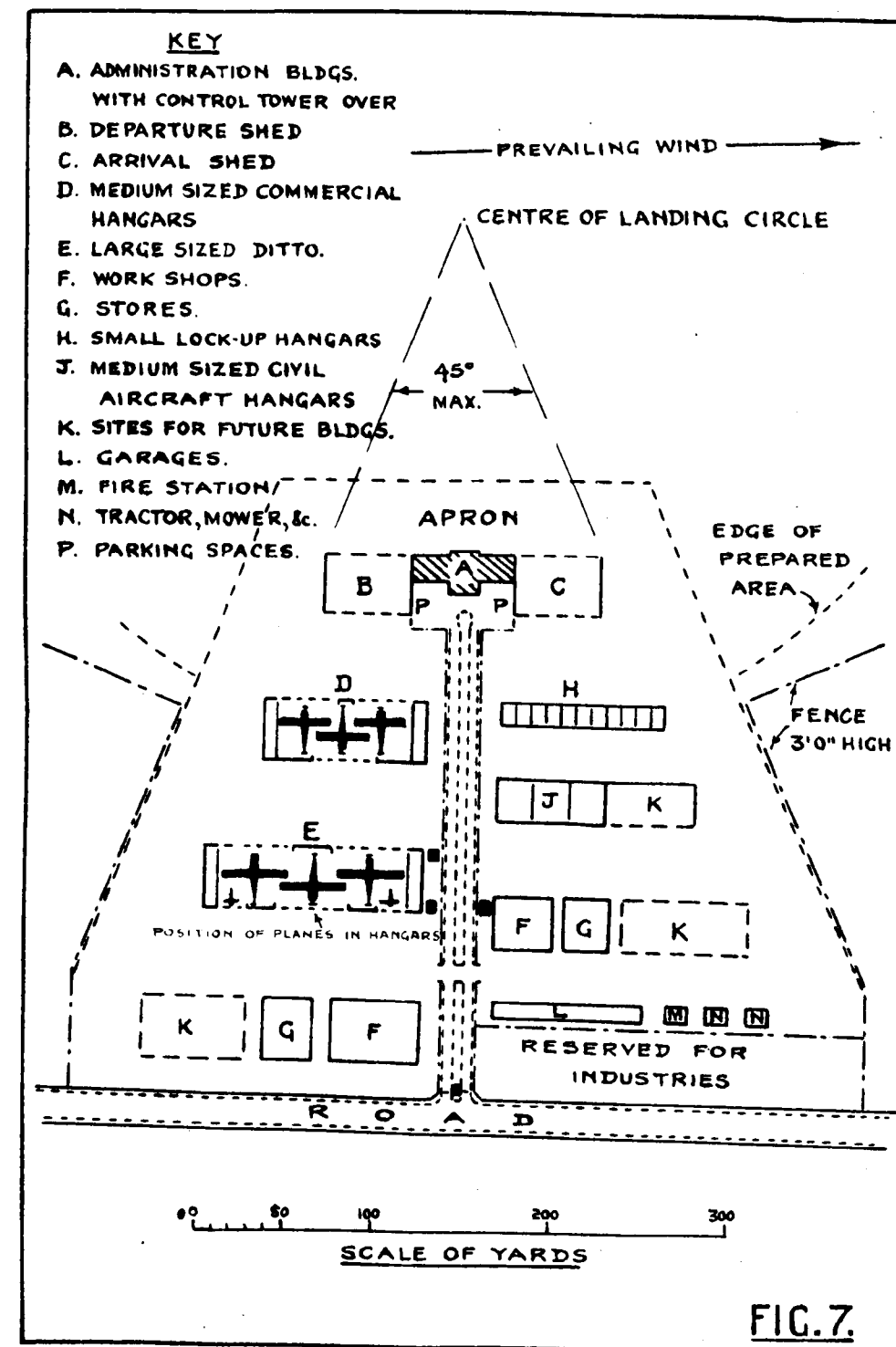
BUILDINGS.

The general building requirements of a municipal aerodrome are :—

- (1) Hangars for housing commercial and private aircraft.
- (2) Workshops for both classes.
- (3) Stores for petrol, oil, engine components, etc.
- (4) Administration buildings comprising waiting room, restaurant, booking office, meteorological office, wireless department, first aid department, staff offices, post office, and lavatories for both sexes. Where the airport is intended to be a terminal as well as an intermediate port, the necessary accommodation for police, customs, and immigration officers should be provided.
- (5) The control tower, from which the whole aerodrome is supervised. Its placing requires careful consideration, as it must command a good view of the whole field, apron, and hangars.
- (6) Departure and arrival sheds.
- (7) Miscellaneous small buildings, such as, garages, fire station, tractor shed, mower shed, roller shed, aerodrome police lodges, mechanics' houses, etc.

GROUPING OF BUILDINGS.

Buildings may be grouped in several ways. Figs. 3 and 4 show buildings arranged in a straight line along one side of the field, and along the periphery of the landing circle. In these two cases, the chief obstruction to the aerodrome is



its own buildings, and for this reason the methods should be avoided as far as possible. If the buildings are placed across important winds, flying gaps at least 200 yards wide should be provided between them at frequent intervals as shown. This has the effect of segregating the buildings, and causing difficulties in management.

Another type of plan is that in which the buildings are sited on a little used segment of the circle. (Fig. 5). Although the field frontage is narrow in this case, the plan has its disadvantages. A considerable area of land is required for the buildings, they are too far from the flying area, and placing the control tower in a good position is a difficult matter.

The fourth and best method of grouping is that known as the Plan Duval (Fig. 6). The buildings are sited within a wedge-shaped area, whose apex is at the centre of the flying circle, and whose sides subtend an angle of not more than 45 degrees. This is the maximum angle permissible, considering the fact that aircraft must take off and land at an angle less than 23 degrees across and into the wind. This arrangement, having a narrow frontage, presents the minimum of obstruction to flying, and provided a little used segment of the circle is used, it is very efficient.

After deciding upon the method of grouping, every building must be placed in its proper position.

In Fig. 7, an attempt has been made to draw out an ideal method of grouping and placing buildings.

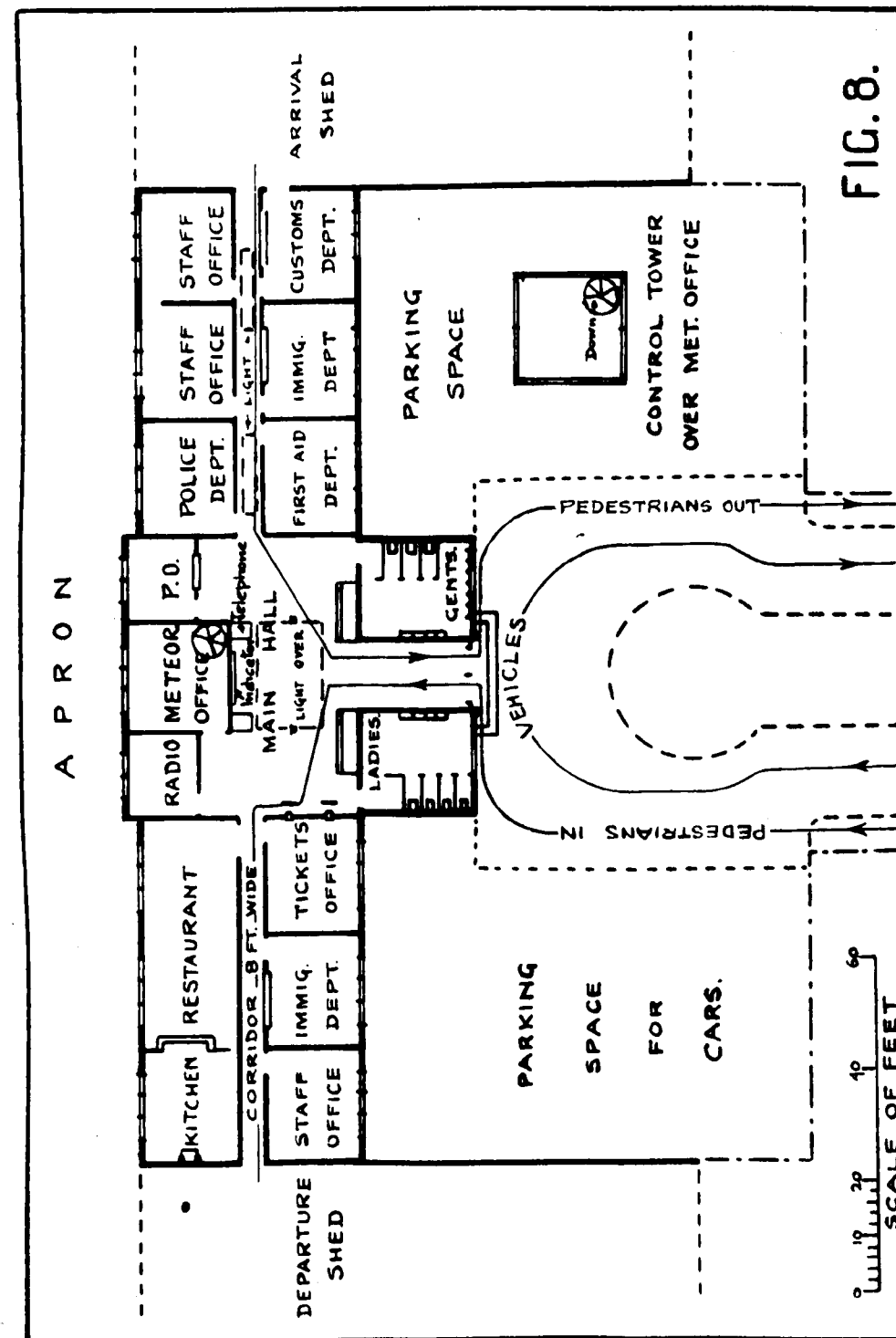
The method used is the Plan Duval, and a part of the wedge inside the flying area is used for building purposes. This does not take away from the efficiency of the airport, as the prevailing wind is almost parallel to the building frontage.

The administration buildings are placed near the landing area, and the control tower is situated centrally on top of them. For the sake of comfort, a departure and arrival shed is provided, one on each side of the administration buildings. Leading up to the latter is a roadway, with two carriageways, 16 feet wide, separated by a 20 feet grass verge. Two 6 feet footways are also provided. The central grass verge is finished off near the administration buildings in the form of a circle of 30 feet diameter. Parking spaces for cars are provided alongside the departure and arrival sheds as shown in Fig. 8.

It is desirable to segregate commercial and civil aircraft, and with this end in view the hangars, workshops, and stores for each kind are placed on opposite sides of the approach road.

Behind the departure shed are the hangars for large commercial aircraft, and behind these are the workshops and stores.

The same method is adopted as regards the civil aircraft buildings. These buildings take up less room than the commercial ones, and for this reason, the fire station, motor garages, tractor shed, and other minor buildings are also placed on this side.



Means of transport from one side of the wedge to the other is provided by the link road near the workshops. This is for the convenience of lorries, fire engine, and other vehicles, and is not intended for the use of aircraft. At the main entrance gates an aerodrome police lodge is placed on the central grass verge, so that full supervision of all vehicular and pedestrian traffic entering the airport is ensured.

There is ample space between the buildings for manoeuvring large aircraft and sites have been reserved for future buildings.

The largest commercial hangar will accommodate a Handley Page type aircraft (dimensions—span 130 ft., length 90 ft., height 27 ft.). The smallest lock-up civil aircraft hangar will house a De Havilland "Puss Moth," (dimensions when folded—span 13 ft., length 26 ft. 3 in., height 7 ft.).

PLANNING OF BUILDINGS.

The only buildings which present any difficulties in planning are the administration buildings.

The functions of administration of a municipal airport, are divided between several authorities, but it is better to avoid the segregation of the departments, and to house them in one building. Fig. 8 illustrates the planning of administration buildings on these lines. The port for which they are suitable is intended for use as a terminal, as well as an intermediate station, and hence the inclusion of customs, immigration, and police offices.

The plan does not require describing in detail. As will be noticed, outgoing and incoming pedestrian traffic is divided at the entrance to the main hall, which arrangement is very desirable where possible. The radio department, meteorological office, post office, and control tower are grouped together on one side of the main hall, which co-operation demands. Another point worth mentioning is that the lavatories for both sexes are easily accessible from the main hall or waiting room. In the latter, there are two telephone kiosks, two stalls, and an arrival and departure service indicator. In order that no aeroplane might be over-weighted, every aerodrome booking office, should be equipped with a weighing machine. The platform is usually placed outside the booking office, and the recording dial inside.

EQUIPMENT.

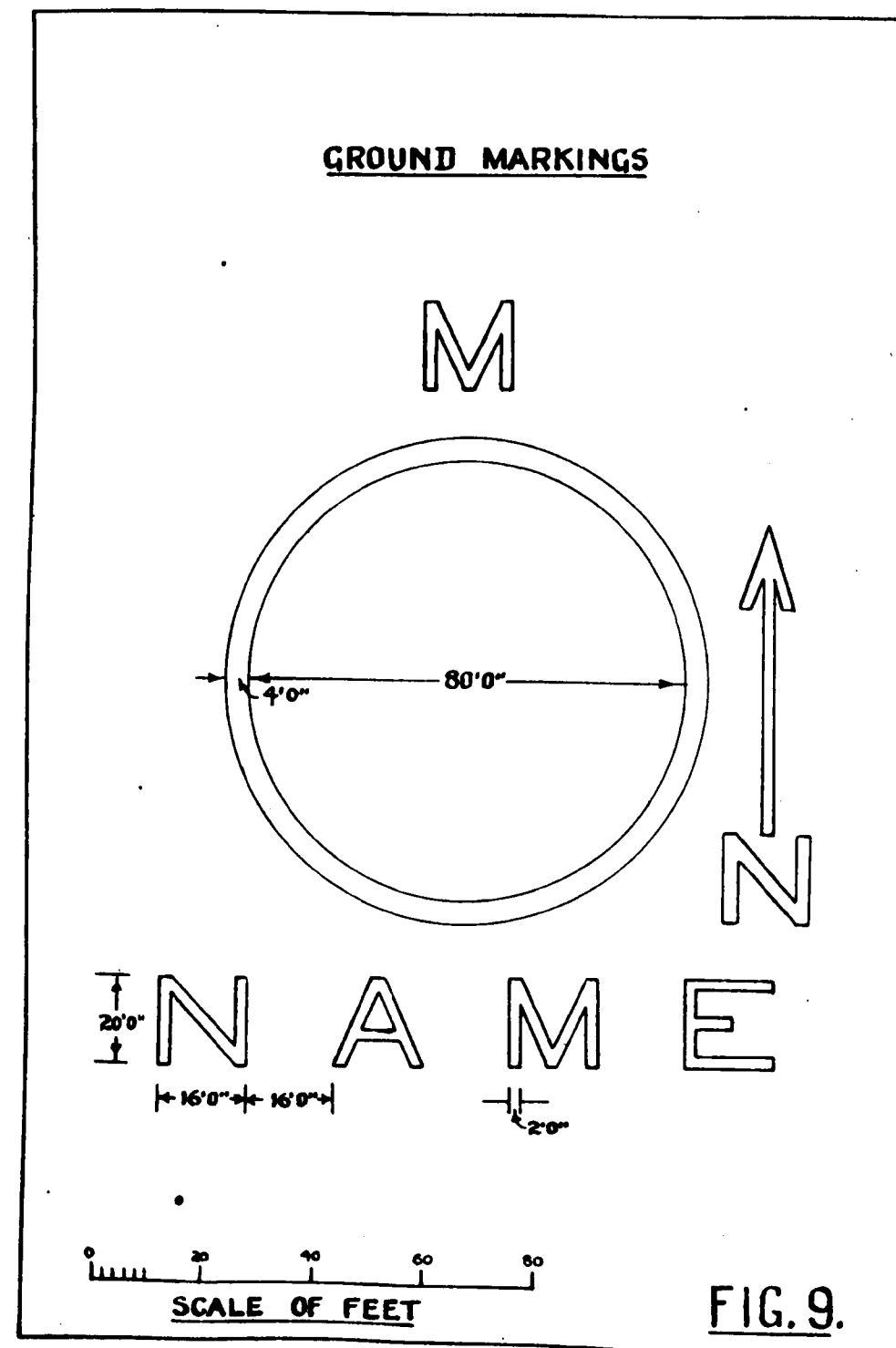
(a) Equipment for day use.

(1) General ground markings as shown in Fig. 9.

(i) *Location Marker*.—This consists of a circle, 75 ft. (minimum) in diameter, and with an annulus not less than one twentieth the size of the diameter.

(ii) *Name of Town*, which is constructed near the latter in letters not less than 20 feet in length, and 16 feet wide, and spaced about 16 feet apart.

(iii) *North Point* in the form of an arrow, about 50 feet in length, and marked with the letter "N."



- (iv) *Classification Mark.*—A municipal aerodrome might be marked with the letter "M," placed on the side of the location mark opposite the name of the town.

All the foregoing markings must be plainly visible from the air, and for this reason are constructed of a white or yellow material.

The simplest method is to dig a trench about 6 inches deep, and fill it with white Portland cement concrete. When the ground is covered with snow, markings so constructed will be invisible, and to avoid this, they may be constructed on the roof of hangars by means of metal letters raised on legs.

(2) *A Wind Direction Indicator* may consist of a cone made of fabric stretched on hoops, the whole being slung to a mast. The cone should be about 20 feet in length, and not less than 4 feet and 2 feet diameter at the ends as shown in Fig. 10, and painted yellow and black hoops.

Another form of wind indicator in use is the steel T fitted with a rudder. The T in use at Croydon, is 20 feet long, 10 feet wide at the head, and each limb is 2 feet wide. The T type is more efficient than the cone type.

(3) *Boundary Markers.*—These may consist of framed markers about 10 feet in length, and made of 1½ inch deal boards, fitted as shown in Fig. 11, and painted black and yellow every alternate foot. They should be erected at 250 feet intervals, and at every corner along the boundaries of the prepared surface.

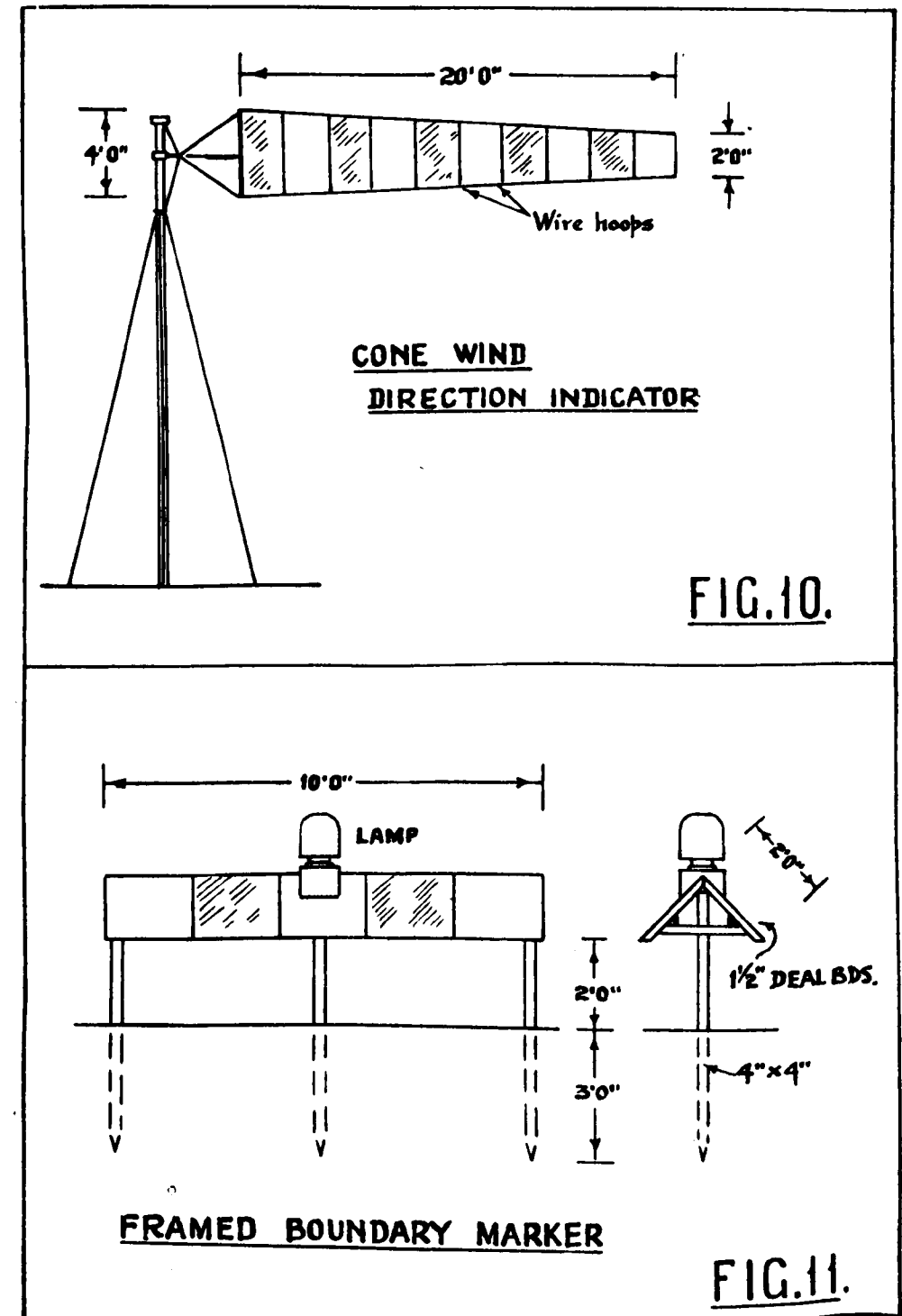
(4) *Obstruction Markers.*—All obstructions, such as high poles, chimneys, towers, etc., must be clearly marked by painting them near the top in alternate black and yellow bands.

(b) Equipment for night use.

(1) *Landing Lights.*—These are usually in the form of a floodlight, which illuminates the landing area. A series of batteries may be arranged around the periphery of the landing area. In this manner, only the batteries needed are used in landing, and this does away with the possibility of a pilot being blinded by having to land facing a powerful light. Mobile floodlights may also be used advantageously, as they can be moved about to suit the direction of the wind. In floodlighting, black shadows and glare must be avoided, and for this reason the surface must be perfectly even.

(2) *Boundary Lights.*—The best method of defining boundaries at night is by means of flashing yellow lights, placed at a distance of not more than 250 feet apart. These lights should be visible from every angle of approach throughout the 360 degrees. They may be placed on top of the day markers, as shown in Fig. 11. At the present time, flashing red lights are used in this country, but it is felt that there is not sufficient distinction between them and obstruction lights.

(3) *Obstruction Lights.*—All hangars, buildings, trees, poles, etc., must have stationary red lights fixed on top. Where the structures are very tall, it is advisable to fix lights at intervals of about 10 feet, starting from the top. As in the previous case, they must be visible from all angles of approach.



(4) *Wind Direction Indicator.*—The fabric cone used in the day time may be floodlighted, or lighted from within by internal lamps at night. Where a T indicator is used, it can be rendered plainly visible at night by means of lamps fitted on top of the limbs (Fig. 12).

(5) *Location Marker, etc.*—All ground markings may be floodlighted at night. If the raised letter type of markers are used, they may be fitted with lamps.

It is unnecessary to mention the advantages of electric light over every other form of illuminant, and it should be universally used in airport lighting.

DISCUSSION.

MR. T. LLOYD ROBERTS (introducing his Paper), said: The Paper is divided into two main parts, namely, the design and construction of municipal aerodromes. These may be further subdivided into the design of the field area, the planning of the various types of buildings, the construction of the field area and the construction of buildings.

The design and construction of the field area are perhaps the most important sides of the subject as far as the majority of local authorities are concerned. I am referring to the smaller and medium sized towns that do not need an airport equipped with large buildings, but there is no reason why they should not establish a licensed landing ground, or at least reserve the land for this purpose.

I think I am right when I say that, for the purpose of granting a licence, the Air Ministry do not demand any buildings. The only qualification necessary is a landing ground which affords absolute safety to the aircraft and public using it.

After the field has been established, further developments could be proceeded with as the increase in traffic demands. It is important from an economical point of view that the initial and all further stages of development should be treated as part only of the completed scheme.

Varying sites will present different problems in planning and construction, and it may be added that it is always desirable to consult one of the firms experienced in this class of work.

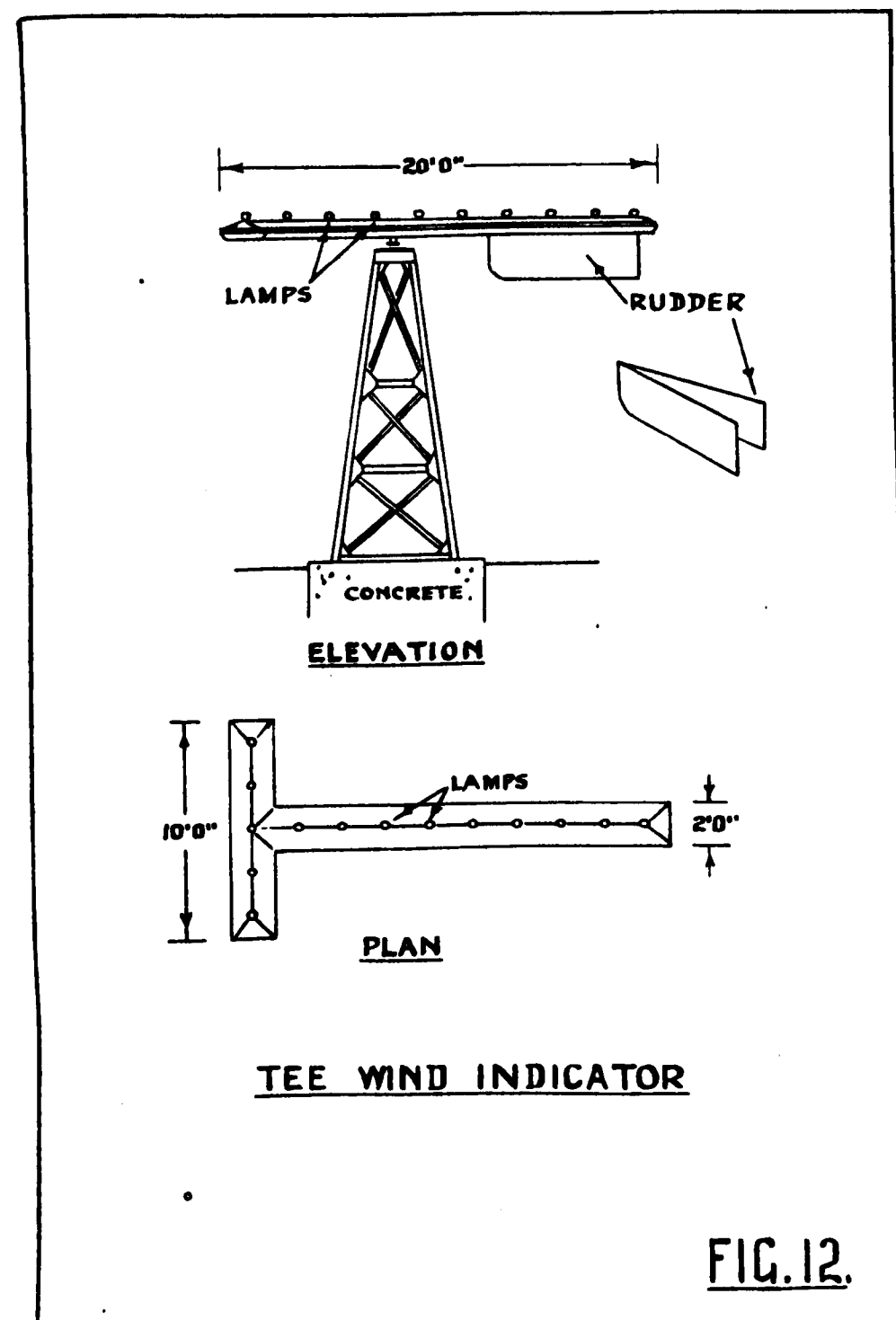
With regard to buildings, the planning and placing of these require careful consideration. The usual methods are outlined in the Paper. Here again the governing factor should be safety.

The materials used in the construction of buildings will vary with the size and importance of the aerodrome. Systems of drainage, heating, ventilation, lighting and so forth will be similar to those of other public buildings.

Like other public works, aerodromes established to-day should be suitable for use for the next forty or fifty years, but it is extremely difficult if not impossible to forecast the development in aviation over this same period. There is only one thing that can be looked forward to with any degree of certainty, and that is that aircraft will increase in size and weight.

MR. A. T. GOOSEMAN (*Leicester*), proposing a vote of thanks to Mr. Lloyd Roberts, said: At the beginning of the Paper Mr. Lloyd Roberts deals with the site, and briefly the requirements are these: It should be near a town, and gas, electricity, water and drainage should be available, and, in my opinion, in addition to that, it is a very great advantage to have it adjoining a railway. Mr. Lloyd Roberts says it should be on the side of the town from which the prevailing wind blows, in order to eliminate danger from smoke and fog, and it should be on a plateau. He says the flying area should have a minimum run of 600 yards in all directions, but I should like to suggest that any person looking for an aerodrome site should allow for an extension to at least 1,000 yards in the future.

It will be noticed, of course, that these conditions are also the conditions for an ideal building site. It is only when one commences to search for such a site that one realises how very rare they are. In my own town the only site that complied with the whole of these conditions had already been



purchased by the Housing Committee for housing purposes, but, after prolonged negotiations, we were able to earmark it for an aerodrome.

I should like to take this opportunity of urging all local authorities who have not already earmarked land for an aerodrome to do so; otherwise I am afraid they will be too late, because, as building develops on the outskirts of a town, this land will be wanted for building purposes. The result will be that the price will go up by leaps and bounds, and the erection of an aerodrome will be a very costly matter for the local authority. In our town planning scheme some few years ago we allocated certain land for allotments. A portion of the area was purchased, and when the remainder was required two or three years later we found that the price was three times the price of the first purchase, because development had taken place. Therefore it is a business proposition to allocate and purchase land now.

Under the heading "Acquisition of Land," Mr. Lloyd Roberts points out that compulsory acquisition of land for aerodromes is possible under the Public Works Facilities Act, 1930. This Act, of course, is a very useful one, because we all know that, when local authorities contemplate the purchase of land, it is astonishing how the presumed value increases.

The Author of the Paper also refers to the preparatory work on the surface of the land, and I think that is one of the most important things in connection with the laying out of an aerodrome. He refers to "hummocks and depressions," and I wonder if he includes in that expression ridges and furrows. I feel that more attention should be called to this most important matter. It has been found by experience during the last few years that, if this ridge and furrow land is not dealt with in a very thorough and comprehensive manner at the initial stages of the construction of an aerodrome, the ridges and furrows will reappear in a short time. My attention has been called to one aerodrome, laid out ten years ago, where the ridges and furrows are now reappearing, and I know of cases where they have reappeared within two or three years. I think the only way to deal with the matter is to deep plough the bottom of the furrows, cross plough, grade

and roll before levelling and soiling. A considerable amount of judgment must be used in connection with this work.

The Author, in dealing with the question of drainage, does not appear to have considered mole drainage, which is a very suitable way of dealing with clay land and is also very cheap. We are carrying out mole drainage on our aerodrome, and it costs us only £3 an acre.

In connection with apron construction, I am of opinion that concrete is more suitable than tarmacadam in front of the buildings. The initial cost when concrete is used for this purpose may be slightly greater, but its upkeep is more economical.

The Author deals with the grouping of buildings and the design of the essential buildings of an air port. This is a matter of very great importance, and I am pleased to see that Mr. Lloyd Roberts has dealt with it in such an able manner. We who are responsible for the lay-out of aerodromes must be careful that we are not accused of development in a haphazard manner and without proper planning. The Plan Duval, to which the Author refers in his Paper, has many advantages. Buildings should be erected at right angles to the prevailing wind, wherever possible, and again in this case a certain amount of space should be allowed for future developments, because at this stage we cannot estimate what our requirements will be in the future.

Dealing with equipment, the name of the town should be marked near the landing circle, running east and west, and another matter of importance is that fences should be painted white or yellow.

The Author deals with landing lights for night flying. I am of opinion that the best method of dealing with this question to-day is the erection of a flood light on the lighthouse principle, near to the control tower. An essential part of the equipment is a shadow bar attached to the flood lighting set, and the machine should be capable of operating as a beacon when required.

In conclusion, I should like to impress upon municipal and county engineers that in the construction and lay-out of an aerodrome their departments are exceptionally well equipped. They have on their staffs experienced valuers and surveyors to survey the land, and engineers who are experienced

in drainage, road construction, levelling and the best method of preparing the surface and handling the volume of earth to be dealt with; specialists in town planning, who will deal with this as part of the town planning scheme; architects who can be consulted in connection with the design and grouping of the buildings; chemists and agriculturists who are competent to advise on the quality of the soil and the appropriate seeding; and mechanical engineers to deal with the lighting of the grounds and heating of the buildings.

Mr. M. S. ROGERS (*Anglesey*), seconding the vote of thanks, said: This Paper deals with a subject with which only a few municipal and county engineers have had anything to do at all, though many of them will have to deal with it sooner or later. Aeroplanes are not like motor cars, which can go a hundred yards and then stop. There must be an economical distance between aerodromes where aeroplanes can land. Of course, occasionally they have to land anywhere, but we cannot make provision for that. The economical distance between aerodromes might be 10, 20, 30, 40 or 50 miles, so that I do not think we can have them dotted around every municipal borough area or in each county. Again, I do not see that, where there is a suitable ground within ten miles of a town and a good railway and road service, it would be any detriment to have aerodromes erected at that distance from a town.

With regard to the apron to the landing ground, Mr. Lloyd Roberts states in his Paper that there should be a fall of 1 in 40 either towards the buildings or away from the buildings. I take it that the fall is partly for drainage purposes and partly for ease in taking the aeroplane out on to the landing ground or bringing it back. If you have the apron falling away from the aerodrome, the aeroplanes will go down easily enough but it will be very hard to pull them back. I should think a fall of much less than 1 in 40 would answer the purpose in this instance.

Referring to the buildings, at this stage I think it would be foolish to erect buildings of permanent materials such as brick and stone. The matter is in its infancy at present, but no doubt it will develop rapidly, so that what one might put up to-day in brick and stone may be out of date in ten years' time. So many changes might have

come about by then that it may be necessary to alter the buildings in order to bring them up to date. That is a point which I think has now been realised with regard to the building of schools. In the early days schools could not be built strongly enough, but it was not very long before the type of plan changed entirely from one having a large central hall to one having a separate central hall and class rooms. The consequence is that some schools built twenty years ago are out of date to-day, chiefly because the authorities will not go to the expense of modernising them. Therefore I think that aerodrome buildings of a temporary nature should be erected now. I do not mean that we should put up sheds that would desecrate the amenities of the countryside; the buildings should be constructed in such a manner that they will not do that, but they should be of a temporary nature, so that the cost of re-planning them will not be anything like as great as it would be if they were permanent buildings. Local authorities will then be quite willing to bring them up to date when necessary.

Mr. G. H. WHITAKER (*Cardiff*): Seeing that we have built an aerodrome at Cardiff, I think it may be of interest to those present to hear of the difficulties that we have had to overcome. According to Mr. Lloyd Roberts's views, we have not chosen the right site! We selected a site alongside the Bristol Channel, where, of course, there is occasional mist, but the Great Western Railway Company have been running a service throughout the summer from Birmingham *via* Cardiff to Torquay and Plymouth and they have never had any difficulty in coming to Cardiff, but on an elevation of 800 ft. near Teignmouth for the Torquay Station they have been perilously near trouble owing to low-lying clouds. If you have low-lying land (our land was covered by the sea six or seven times every year) there is one great advantage in it, inasmuch as you can buy it very cheaply. The difficulty of drainage is a very important one. We have chosen land in which, in the whole 120 acres that we have got for the aerodrome, there is not a difference in level of 15 ins. That is another mistake we have made, according to Mr. Lloyd Roberts. By a big system of drainage and by the adoption of what Mr. Gooseman brought to your notice, mole draining, we

have now made the surface very good. If the sea is over the aerodrome it is obviously not very convenient when an aeroplane wants to come down, so we had to build a sea bank with a face to the sea. We had to put rubble facing in for about 10 ft. in depth where wave action recurred.

The total cost of the aerodrome purchase and draining has been only £18,000, which, divided by 120 acres, comes to only about £150 per acre. That includes the cost of the land, which was in the neighbourhood of between £50 and £60 per acre. I think marshy land might be used in other places for aerodromes; it is much cheaper than land which is potential building land.

Mr. Lloyd Roberts makes a point of the advisability of purchasing the adjoining land, and we have done that. On two sides of our aerodrome we have the Bristol Channel and the estuary of the River Rhymney, and on the other two sides we have provided a belt of land for what is the bugbear of most municipal engineers, i.e., permanent allotments. The provision of permanent allotments means that we have a 150 yard belt of land which ensures that we are going to have an easy means of approach and can easily give the 1 in 15 rise which is absolutely necessary. We have town planned this area, and we have included in the town planning scheme a provision that no building may be erected within 150 yards of the aerodrome, that between 150 yards and 400 yards of the aerodrome no building higher than 30 ft. may be erected, and that outside that belt, for another 100 yards, no building may be erected that is more than 50 ft. high. That, of course, is a very useful provision, but, at the same time, some firm prepared to build aeroplanes and bring work to the district might find this the most suitable area to establish themselves in, and one might be inclined to let them do so, but in the most suitable position.

Mr. Gooseman mentioned that it might be very useful to have an aerodrome alongside a railway. If the telegraph lines and things like that are underground, it would be all right, but certainly you do not want telegraph lines very near the perimeter of your aerodrome. We were very concerned, when we had selected our site and commenced the work, to find that the electricity power lines for the grid system were going to be very

close to us. By means of a little negotiation we have managed to get them put up a little further away; otherwise they would have seriously minimised the success of our scheme.

Municipal authorities are obviously for a few years going to have a dead loss financially in the provision of an aerodrome. I was very amazed to find that the Templehof Aerodrome in Berlin seemed to be the gathering ground of the population for an evening's entertainment. At a cost equivalent to about twopence halfpenny people can go and spend the evening at an open air café, which can accommodate at least 5,000 to 10,000 people, watching the different evolutions of the flying men. That seems to be the greatest source of income that the aerodrome has got.

With regard to the suggestion made by Mr. Lloyd Roberts that the name of the aerodrome should be put on the roof of the hangar, I did consider putting the name "Cardiff" in big white letters on the roof of the hangar, but when I mentioned that to the Chairman of the Aero Club in Cardiff he said: "Yes, that is all right, but suppose the visibility is not good and I think it is the name of the landing ground and I come down on the roof of the hangar!" He said it would not do at all.

It has been suggested that we should put up buildings at our aerodrome for the approach by air equivalent to our civic buildings in Cardiff, but I am afraid our finances would not allow us to do that at the present time.

MR. J. S. BULLOUGH (*Norwich*): The Norwich aerodrome is 200 acres in extent and stands on a high plateau with the River Yare only half a mile away on the south of the aerodrome. That, of course, is a convenience in finding the aerodrome in fine weather, but in times of hostilities and war it would be rather a fatal thing to the aerodrome, because it would give the enemy a chance of tracing the aerodrome from the river. As a matter of fact, during the War Norwich was extraordinarily lucky. There are two rivers, one running through the centre of the city and the other skirting the boundary of the city. The Germans came up that river many times, but they always took the wrong turning and they never got a single bomb on to Norwich.

With regard to levelling, we had to level up some 70 acres; we are just completing that work now. It would have cost us about £10,000, but the Council were anxious to give a certain amount of employment; in fact, I doubt if we should have got a grant from the Unemployment Grants Committee if we had not been able to show that we were planning employment for a certain number of men. The work therefore cost the Corporation an additional £3,000.

Norwich was rather fortunate with regard to equipment, because its aerodrome was used as a testing ground during the War and a larger number of hangars were built, but most of them stand away from the aerodrome, across the main road. They are to-day occupied by various firms for storage. On the aerodrome itself there are two hangars. They are of a temporary construction, made with steel frames and corrugated iron covering, and they were bought from the War Office for quite a small sum—£600, I think. They have been repaired at a cost of £400 each, and they are absolutely weatherproof. In half of one of those hangars the club house for the Flying Club has been built. That has been a great asset and a great help to Norwich, because the whole of the manning of the municipal aerodrome is done by the Flying Club, the Corporation paying a sum of £250 a year to help the Club in running the aerodrome. The actual conversion of the club house cost £1,800, and for that sum the Club has got extremely comfortable premises; it has a large lounge, a billiard room, a dining room, the necessary kitchens, and about six cubicles with lavatory accommodation, so that pilots can have their meals at the club and pass the night there.

I think Mr. Gooseman said something about the buildings being at right angles to the prevailing wind. I disagree with that; I think that the buildings should be in line with the prevailing wind, so that as the aeroplanes come down they do not come towards the buildings but come alongside them.

In the Paper, apparently the buildings are in various positions relative to the prevailing wind. In Norwich in actual fact we have got the hangars in the wrong position. If the prevailing wind is south-west I should place the buildings on the south, so that,

assuming the wind was in the prevalent direction, the aeroplanes would come round the north, facing to the wind, and come down so that they were more or less alongside the hangars. I do not think we shall change the position at Norwich, because we have got so many hangars on the north side now, and, even if we made our new buildings on the south, there would always be these hangars on the north which are used for industrial purposes now, so that, as aeroplanes have to keep high and clear of these buildings, we might as well keep all the buildings together. It is hardly worth while changing them right across the aerodrome. That is a matter that requires careful consideration, and of course our buildings at the present time are only of a temporary nature; they will probably have a life of some fifteen years.

At Norwich we are fortunate in the fact that we have had to do practically no drainage on the landing ground. The ground is not level as we understand the term "level" when applied to a cricket pitch. It has been levelled in the rough, so that there is no gradient sharper than 1 in 60, which is satisfactory to the Ministry, and it is sufficient for the purpose. As the ground is gravel and flint we have found that no difficulty is experienced in the way of water standing on the landing ground.

MR. E. A. EVANS (*Dentghshire*): Mr. Gooseman spoke of mole drainage. If there are any farmers present I think they will agree with me that the life of mole drainage is very short, and that one does not reckon to get any benefit from it after a period of at most fifteen years. It follows, therefore, that the surface of the ground would have to be disturbed for further drainage within a comparatively short period after the time of initial mole drainage.

MR. J. L. BECKETT (*Tynemouth*): Mr. Lloyd Roberts says that there must be a minimum run of 600 yards in all directions. That, of course, is a Ministry requirement, and I agree with that, but Mr. Gooseman mentioned that we ought to look ahead and reserve 1,000 yards, and I do not agree with that, for two reasons.

In the first place, of course, we have to consider the cost of land. Mr. Whitaker was very fortunate in being able to obtain land at £100 an acre. Most local authorities will have to pay about £600 an acre. That

is what we are going to be called upon to pay in connection with an aerodrome for which we are reserving land under the town planning scheme.

On the question of aviation, we are not going to perpetuate the present type of aeroplane which requires such a large landing space. At the present time we have a light aeroplane which is the type, I think, which requires a large landing space to make a proper landing. The heavier planes do not require the same amount of landing space.

I think, therefore, it is necessary to reserve only the minimum run of 600 yards, and that will be found ample for the future. All the necessary further extensions, I think, can be provided by zoning the height of the buildings under the 1932 Town Planning Act; we can get all the extensions we want under that. I should like to hear the views of Mr. Lloyd Roberts on this point.

Another point on which I should like to hear Mr. Lloyd Roberts is as to whether, in studying this subject, he has come across any cases where land which is now being used by local authorities for tipping purposes could be used for aerodromes. We have one such piece of land in Tynemouth, which would give us the minimum Ministry requirement for the size of aerodrome. That land would be unsuitable for anything like building purposes for a great number of years, and I think that, in cases where such land is in a suitable position, the matter of reserving it for aerodromes should be very carefully considered.

MR. L. M. PERKIN (*Tunbridge Wells*): Mr. Lloyd Roberts says in his Paper that subsoils with a bearing capacity below two tons per square foot are considered unsafe for the use of the heavier types of aircraft, and I am wondering whether that limit is really high enough. I believe I am correct in saying that at the present time the maximum weight of aircraft is about 13 tons, and that weight is going to be delivered on three wheels at the most, and probably on two wheels, giving a weight on each wheel of approximately $6\frac{1}{2}$ tons, or an impact of 12 tons at least. Seeing that the bearing surface of the inflated tyre is rather on the small side—I should not think more than one or two square feet—I think 2 tons per square foot is rather small.

Mr. Lloyd Roberts also mentions a

minimum run of 600 yards in all directions, a point which has been dealt with by previous speakers. I am rather wondering whether it is realised that in their Regulations the Ministry say that 600 yards minimum will only be recognised in rather exceptional circumstances, and whether on that account we should not make a note to the effect that 600 yards is rather a risky limit. It might save time in the event of any engineer looking for a site and finding one which would not be large enough to be accepted eventually by the Ministry.

With regard to the question of the preparation of the soil, it seems to me that the whole of the aircraft, or at any rate the large aircraft, leaving and arriving at the aerodrome is going to take off or come down immediately in front of the two sheds marked B and C in Fig. 7, which would impose a terrific strain on the turf there. I think it has been proved that at least 100 yards of turf should be treated in some way. You can make a sort of tarmacadam by treating the soil with a bitumen mix in a concrete mixer and well rolling the mixture in. Mr. Lloyd Roberts made no mention of that in his Paper, and I was wondering whether he had considered it.

Turning to the actual plan of the aerodrome, no mention is made of a club. A previous speaker has raised the point that a club is a very great advantage to an aerodrome. Heston would hardly be in existence except for the club, and the same applies to Brooklands too. The club grounds form a considerable source of revenue in laying out an aerodrome from a municipal point of view.

Referring again to the plans, it seems to me it would be rather a difficult business to get into the hangars, as there is not very much room. I do not know whether Mr. Lloyd Roberts has considered the system that is used in America more than in England to-day, that is, instead of having these large draughty sheds, where, if by any chance the wind is blowing towards the aerodrome, the draught would be considerable, to have a collapsible steel tube projecting from the front of the tunnel towards the aeroplane and coming to the side of the aeroplane, behind the wings, where the passengers leave the plane by a door. By that means they get absolutely under cover from aeroplane to aerodrome. That seems to me a consider-

ably cheaper plan than having those two sheds, which are going to be rather costly to construct, and I think it would be considerably better in working.

Mr. Lloyd Roberts states that the only buildings which present any difficulties in planning are the administration buildings. I think that statement is rather open to dispute, to put it mildly. This is a point that has not been raised so far by any of the speakers in the discussion. It seems to me that the hangars are going to present some difficulties, especially if you are going to cater for larger liners than those of to-day.

On the question of hangars another problem presents itself. Mr. Lloyd Roberts mentions that the Plan Duval is the most satisfactory to-day. I know that has been introduced at Liverpool and Doncaster and many of the more recent English aerodromes. Has Mr. Lloyd Roberts considered the system which is used more on the Continent, that is to say, having very large hangars? I believe I am right in saying that at the majority of the new German aerodromes, where they seem to have gone ahead with great strides and have vast aerodromes, the hangars themselves are really colossal. The Americans also have large hangars, 500 ft. in length and about 300 ft. in depth. It has occurred to me that, although the cost of erecting these might be prohibitive, there is something to be said for the system, inasmuch as when aeroplanes change, as they will do in the near future, the hangars will be suitable for any size. The hangars built in England seem to cater for three or five planes of a set size at the moment, so that when the aeroplanes change in size the hangars will have to be altered. At the present day hangars are only temporary affairs and easily moved.

There is one other point in connection with hangars which I want to refer to, and that is the question of heating. I should like to know if anybody can tell me from a practical point of view whether heating is a possibility and whether, if so, it is an essential or merely a luxury. It seems to me that the heating of a large hangar is going to be a costly business when you consider the loss of heat through the open and loosely fitting doors.

With regard to lighting, Mr. Lloyd Roberts does not mention the Neon tubes. They seem to have a very piercing effect, and I was wondering whether they could not be used

with great effect in outlining aerodrome signs, more particularly with a name sign, which could be raised in white letters. It seems to me that such lights would show up better than the lane of lights or lamps which Mr. Lloyd Roberts shows in his Paper. In connection with the flood lighting of the landing ground, Mr. Lloyd Roberts says that a series of batteries may be arranged around the periphery of the landing area. -I know that is done a good deal, but it seems to me rather costly, which is a disadvantage, especially in the case of a municipal aerodrome which is just starting. Has Mr. Lloyd Roberts considered the method of having a couple of flood lights fixed on the terminal buildings, with two or three of these battery flood lights put on the landing ground to suit the wind blowing on any particular night? I think that might be a more economical and satisfactory method to adopt.

MR. E. S. LIMINGTON (*Margate*): A point which has not been mentioned is that this need not be a one-town show. Two or three towns can group together, where they are within a reasonable distance of one another, and so share the expense of a municipal aerodrome. In our corner of Kent we have been considering the question of a municipal aerodrome shared by three authorities. One has dropped out, another has agreed, without any opposition, to give up the idea of sharing an aerodrome, and the third came to a decision on the matter by a vote which went right against those who wished to have the aerodrome. I and one or two others, however, have got this question opened up and it has been referred back, and I believe that in time we shall have a municipal aerodrome shared by these three authorities. You can quite understand that the average burgess is frightened of the expense when there is no hope of making a profit for a good many years.

With regard to mole drainage, it is quite true that it does not last a long time, but here again expense is the essence of the whole thing. We do not know what municipal aerodromes will be in fifteen years' time, and, if mole drainage will suit for fifteen years, why not cut down the initial expense and do it, and then substitute other means afterwards, if necessary?

Another gentleman raised the point of

ridges and furrows, and he spoke of ploughing and cross-ploughing. I would suggest that where you have furrows you should turn three furrows into one, starting fairly deep and then getting fairly shallow. Then your cross-ploughing will practically level your field. With the tractors and cultivators and disc harrows that one can get to-day it can be done at very little expense, and you can help the poor farmer by employing him to do it for you!

MR. J. E. ACFIELD (*Leeds*): I think perhaps our experience in Leeds may be helpful. In the first place, I may say that Leeds jointly with Bradford bought an estate of 153 acres for an aerodrome, and at present we have a full commercial licence for an area of 61 acres. Those of you who know the country in the neighbourhood of Leeds and Bradford will realise how difficult it was to find a suitable site. The flying expert whom we consulted was very much concerned that some of the land we did find, which was suitably level, was at such a high altitude. A meteorological expert from the University conducted a series of observations over a period of three months, not only on the aerodrome which we now have, which is 650 ft. above sea level, but also on other lower sites, and it was found that the visibility on our present site was not inferior to that on the lower sites; in fact, it was better than on the majority of them. I hope you will not draw the inference from this that all high landing grounds are suitable, but it is certainly evident that in this particular case the altitude of the site was not a disadvantage.

There has been no difficulty in carrying on the operations of the aerodrome owned jointly by the two municipalities. There is a joint Committee which meets at regular intervals, and, as a matter of fact, at the moment the legal work is carried on by the Town Clerk of Bradford and the engineering work by my Department.

With regard to drainage, two types of drainage were used, one the ordinary herringbone type and the other the mole drainage. It is obvious that the mole drainage can be used only with certain subsoils and where there is a reasonably good fall. I do not think that, if it requires renewal, the amount of disturbance of the surface will be at all serious.

This aerodrome is in the area of two other authorities, neither Leeds nor Bradford, and we shall be dependent on the good offices of these authorities to see that under their town planning schemes they preserve the conditions round the aerodrome that are essential; unfortunately only one of these authorities has taken steps to town plan its area. The buildings on the site, with the exception of the club house, are only temporary at present; I think it would be very unwise to erect permanent buildings at the present time, until it is possible more closely to visualise the requirements of the future.

I think there is no question that it is a definite advantage to have a club or some other body to lease the site and to operate the aerodrome. It gives a considerable amount of publicity, which is a definite advantage.

MR. R. F. O'CONNOR (*Cork*): We are particularly interested in Ireland in the question of aerodrome construction not so much from the point of view of municipal aerodromes as from the larger point of view of Trans-Atlantic air ports.

My own scheme for Cork Harbour is to establish an air port there with adequate landing water for seaplanes, the sheltered water available measuring two to three miles in all directions. Adjoining this we have selected a site for the aerodrome. It is formed of a tidal mud flat, the land being covered at high water, as it is only two feet above high tide level. It is only a case of damming the site at both ends and reclaiming the land, and we can reclaim about 500 acres of land at a cost of £10,000 or £11,000. There is no cost for the land. I should be glad of information from anyone here who has the experience of constructing an aerodrome on reclaimed land. I understand it has been the practice in Holland in a number of cases, but I have not been able to trace any actual localities where it has been done. The site that we have naturally lends itself to absolutely perfect drainage. It is not flat but slopes gradually.

Another factor to be considered is the cultivation of the land. It seems to me that this is a farmer's job. A good deal depends on the nature of the seeds used. I notice that several firms are specialising in seeds for aerodromes, and to my mind that is a very important factor in the construction

of a grass area for aerodromes. I do not think that in this country we need to have the concrete runway that is necessary in the United States. The grass will be sufficient for many years to come.

The lay-out of the buildings is another point with which Mr. Lloyd Roberts deals in his Paper. He advocates the "Plan Duval," and there is no doubt that at present that seems to be the most popular plan. Sir Alan Cobham's excellent design for Liverpool is somewhat similar to Mr. Lloyd Roberts' plan, except in the lay-out of the hangars. The buildings are placed in a wedge right in the centre of the flying ground, and I think engineers should discuss with flying men the question as to whether that is not rather overdoing it. I am not a flying man myself, but I can imagine that, when landing on a large area of ground on a foggy day or in a hurricane, or at any time when the light is bad, the pilot would like to have no obstructions at all. I notice, however, that some flying men do not seem to mind that sort of thing.

In May last a very interesting paper on aerodrome design was read by Squadron-Leader Nigel Norman before the Architectural Association, and his opinion is that flying strips are quite good enough for landing. It is the practice in the States to put buildings in between the strips, their ideal being a four-way strip aerodrome, with eight alternative directions of flight and an angle of 45 deg. between the strips. I think that engineers and flying men should come together and arrange a standard practice in this matter.

MR. D. H. SHAW (*Dunfermline*): My authority has been considering for some time the question of providing a landing ground, not an aerodrome. We are to some extent directly interested in the Continent. We have in our area two silk factories which have both got direct connection with Swiss firms, and there is a good deal of coming and going. The representatives of the Swiss firms come to London by air and then to Dunfermline by train via Edinburgh, but recently a commercial firm has started a service by air to Edinburgh.

Some little time ago Sir Alan Cobham made a very complete survey of the area of Dunfermline in connection with his own private flying, and within the confines of the

city he could not find a suitable landing ground, owing to the very hilly nature of the district. A later inspection was made by an expert and we did get a piece of ground which he considered was excellent, but it came within the prohibited area around Rosyth Dockyard, which is within the city, and the Air Ministry would not relax the flying conditions. They prohibited flying within a mile and a-half of Rosyth Dockyard, and all the efforts the local authorities have made to get a relaxation have been ineffective, so we have had to abandon the idea of a landing ground within that area. I think civil flying is so important as a reserve to the defences of the country that the Air Ministry might have taken a wider view. If they were afraid of foreign planes coming over, they could surely have made restrictions dealing with that.

With reference to mole draining, probably it is not known to municipal engineers that there has been a development of mole draining whereby permanent drainage can be obtained. Excellent models of the machine have been shown at various agricultural shows, and it is now on the market. I think that, if attention were given to this, considerable expense in the construction of aerodromes could be saved.

MR. LLOYD ROBERTS, in reply, said: Mr. Rogers referred to the fall in the apron. The fall I have mentioned in my Paper is the usual one given for the purpose of drainage.

With reference to the question of buildings, I mentioned in my introductory remarks that all stages in the development should be part of the completed scheme. By that I mean that it is unwise to build temporary buildings at some considerable expense, as you may find that in a few years' time you have to pull them down and put up permanent buildings. As I said, the Ministry do not demand any buildings, and if anything is needed I think that the minimum should be erected.

Mr. Whitaker referred to the name of the town being put on the roof of the hangar. I state in my Paper that, as markings on the ground may become covered with snow, the name might be put on the roof of hangars by means of metal letters raised on legs. Mr. Bullough referred to the buildings in relation to prevailing winds. Fig. 4 shows

buildings placed across the prevailing wind and a flying gap of 200 yards is provided, which is the minimum width. The other figures in the Paper show the buildings almost parallel to the prevailing wind.

Mr. Beckett referred to the size of aerodromes in relation to future aircraft, and he mentioned the helicopter and similar types of aircraft. I think I am right in saying that the helicopter is satisfactory as far as landing is concerned, but it has not done anything as far as taking off is concerned yet.

Mr. Beckett also referred to land used for tipping purposes and suggested that, although it was no use for building purposes, it might be suitable for an aerodrome, but in my opinion land unsuitable for building purposes would also be unsuitable as an aerodrome site.

Mr. Perkis referred to the bearing capacity of the soil. I think he replied to his own question when he mentioned the wheel base and the inflated tyres. If he works out the problem, using the figures he quoted, he will find that it does not come to much more than two tons per square foot. He also referred to 600 yards' run being the minimum. That is so, and I only referred to it as the minimum.

With regard to the treatment of the soil, mentioned by Mr. Perkis, I think that does not come into the purview of this Paper, but is a question of maintenance.

Mr. Perkis also referred to the club type of aerodrome and mentioned Heston and Brooklands. I think Heston was first of all a purely private club aerodrome, and so was Brooklands.

With reference to the telescopic steel tubes mentioned by Mr. Perkis, these are used in America, but I think they are used there because they cannot get the sheds in. In new aerodromes in this country, at Liverpool,

for instance, arrival and departure sheds are provided.

Mr. Perkis referred to the planning of hangars and he said that the construction of hangars would present more difficulty than the construction of the administration buildings. I said in the Paper that the planning of the administration buildings gives more trouble than that of any other building. I did not mean the construction, but the planning, which is quite a different thing from the construction. There is great difficulty in constructing the hangars, the greatest trouble being the span of the roofs.

Mr. Perkis mentioned the large hangars with the long frontage and the small depth. I think he will find that I have referred to that in my Paper. Figs. 3 and 4 show that type of building, and in those two cases the chief obstruction to the aerodrome is its own buildings.

Mr. Perkis also mentioned the Neon tubes. They are used considerably, especially on wind indicators. The batteries type of floodlighting is used on the Amsterdam aerodrome, which I think is considered one of the best lit ports in Europe. In the sentence following that referring to the batteries I mention that mobile floodlights may also be used advantageously.

Mr. O'Connor referred to the runways used in America. I think they are used there because the soil is not suitable to be used without them.

The attention of the Editor has been drawn to the fact that a Paper entitled "Notes on the Preparation of Aircraft Landing Grounds" was read by Mr. W. E. C. Chamberlain, Chief Engineering Assistant, City Engineer's Department, Portsmouth, before the Portsmouth staff, and published in the "Surveyor" on 7th August, 1931.

CONFERENCE

Under the auspices of the Institute of Sewage Purification.

FRIDAY, 17th NOVEMBER, at 3.0 p.m.

DR. H. T. CALVERT, M.B.E., D.Sc., Ph.D. (*Chemical Inspector, Ministry of Health*), in the Chair.

The following two Papers were taken as read:—

Present Day Conceptions of Sewerage and Sewage Treatment.

Part I.—Sewerage.

Part II.—Sewage Treatment.

BY

GRANVILLE BERRY

(*Engineering Assistant, Nelson Corporation*).

(NOTE.—This Paper was submitted for the Open Competition arranged by the Congress Committee and was awarded the Third Prize of a Bronze Medal and Twenty Guineas).

IT has long been felt by many engineers responsible for works of sewerage and sewage treatment that the present artificial boundaries to Local Authorities have been limiting the economic usefulness of such schemes and that, if extensive economies such as are called for at the present time are to be made, a more "Regional" than "Local" aspect must be held of the works involved.

Realising this and the impracticability of local authorities adequately dealing with major problems of sewerage and sewage disposal, efforts have been made in some districts (cf. West Middlesex Joint Drainage Committee) to co-ordinate these services with a view to their being more economically met and conforming more to the natural contours of the district and to the position and volume of river water into which excess storm water and sewage effluents have to be discharged.

To this end the recent Local Government Act gives the County Authorities the power to render assistance to urban authorities towards both the provision and maintenance of such works.

This fact, coupled with developments in Town and Regional Planning, extension of boundaries, etc., has gone far towards making possible the creation of joint drainage schemes to include wider and more extensive areas, the co-ordination of works

of sewage disposal, and the dismantling of small uneconomic works and the throwing of large tracts of valuable land into more productive use.

These factors have considerably changed, in the last few years, the whole conception of the administrative side of sewerage and sewage treatment, and the need cannot be too much impressed on all local authorities (including County Councils) of the active co-operation of all concerned in order to lead to a simplification of the whole problem and considerably to reduce many engineering difficulties that are found under present conditions.

When Town Planning Schemes are being prepared and advantage being taken of zoning for various purposes it should be realised that the same careful thought should be given with a view to retaining areas of land for sewage disposal works and making provision for main trunk sewer schemes that will be called for as development proceeds, as that which is given to the choice of building and factory sites.

Briefly the new conception of the administrative functions of sewerage and sewage treatment may be said to confer such advantages as lead to :—

1. The laying down of a natural sewerage scheme in districts where the land lends itself to drainage into an area at present sewered by another authority.
2. The prevention of pollution in rivers and streams by the adoption of up-to-date treatment processes and the purification of larger volumes of sewage.
3. The scrapping of inefficient works without much additional increase in capital expenditure being incurred, and the making of considerable economies in maintenance and administration.
4. The possibility of the separate treatment of trade wastes of a more refractory character if found advisable in intensely industrialised districts.

PART I.

SEWERAGE.

The problem of the satisfactory sewerage of an extensive district has during recent years come to be regarded as perhaps the most difficult of problems confronting municipal engineers, and whether it be the laying down of entirely new schemes or works for the relief of built-up areas subject to flooding, engineers throughout the country are being called upon to deal with this difficult phase of public service.

Proper construction and adequate maintenance alone are not enough—it is more essential that the basis of calculation and the method of design employed closely approximate to the results experienced when the scheme is in operation and dealing with the maximum load.

Many of the present failures of sewers to stand up to excessive storms, with consequent flooding and extensive damage to property, attach no blame to the engineer who put down the original scheme, as in most cases the assumed life (or loan period) has been considerably exceeded and the local authority has not made

allowances as work has proceeded and increasing areas have been connected up as development has taken place.

When dealing with many new or relief sewer schemes it is essential that due regard be given to the probable demands that will be placed upon the sewerage system at the end of say the next 30 years, and that in designing the scheme the somewhat empirical methods employed up to recent years be avoided and give way to a more scientifically designed scheme that will be able satisfactorily to deal with the storm water sewage by taking into account such important factors as intensity and duration of storm, impermeability and natural features of the drainage area, etc., that play an important part in determining the run-off that has to be provided for.

Considerable economies are being found possible through the employment of such improved methods of design and by reason of the smaller and more economical sections of sewers that are being employed and which, while meeting the demands placed upon them, have not an excessive capacity over that found theoretically to be necessary.

STORMWATER ALLOWANCES.

The most serious difficulties that are brought to the problem of satisfactory sewerage are chiefly those of making reasonable allowances for dealing with storm water and which allowances are dependent not on the total amount of rain falling over the drainage area but on the duration and intensity of the storm.

The standard rain gauge, recording as it does the total volume of rain falling during a given period of time (usually over 24 hours) is not of much use for ordinary purposes of sewer design, since it is not volumes but intensities that enter into our calculations.

In determining rainfall intensity the employment of automatic recording rain gauges is desirable and will record results to varying limits—a useful chart division being that of vertical intervals of .01 inch and horizontal ten minute intervals such that an observer may read off the maximum rate of fall over very short periods of time with considerable accuracy and thus determine the maximum intensity at any and all periods of the day or of any particular storm, and which maximum value will be found to be considerably higher than the heaviest daily rainfall.

Results over long periods indicate a relation that may be expressed in an equation of the form

$$R = \frac{a}{T+b}$$

where R = Intensity of Rainfall in inches per hour ;

T = Duration of Storm in minutes ;

a and b = Constants.

Results obtained by many experimenters over prolonged periods of time also indicate relations connected by a curve such that

$$R = \frac{C}{T+30}$$

where “ C ” for any area is approximately equal to $25 \times$ Maximum daily rainfall ; and for any drainage area there is a critical period “ T ” when “ R ” is a maximum

and above and below this value of "T" less flooding will be experienced. The time "T" closely approximates to that taken for the rainfall at the most remote point on the sewer branches to reach the point on the main sewer under consideration plus an allowance to cover time taken for rain water to find its way into the sewers; and unless the capacity of the main sewer at the point of convergence of the branch sewer groups is able to take this volume, then flooding is likely to occur.

Generally speaking the bigger the drainage area the less the likelihood of flooding, since a very heavy storm is purely "local," in addition to which "R" will be found to vary inversely as "T" or $R \propto \frac{1}{T}$ such that "R" for rain falling over a period of 40 minutes duration is considerably less than over a period of say 5 minutes within that period, and the heavier the rainfall the less the time of duration.

This indicates the critical period beforementioned when intensity is at a maximum and the problem resolves itself into one of determining this critical period "T."

If a longer period of time be taken as a basis, then less reliable results for purposes of design will be obtained since the results will give a reduction in intensity and discharge.

Alternatively if a shorter period be taken the results will give a greater intensity and discharge than is to be found in actual practice.

An extra allowance is made by some American engineers in determining "T" to take into account initial and varying friction on the invert surface of the pipe as volume increases.

Results obtained over a period of 17 years at Savannah give curves that may be expressed as follows :—

Period of occurrence of storms (Number per year)			Intensity (R)
0.5	..	..	163
			T+27
1	..	..	141
			T+27
2	..	..	104
			T+22
3	..	..	86
			T+19
4	..	..	73
			T+17
5	..	..	63
			T+17

If "D" is taken as percentage of rainfall discharged, then the maximum run off will be equal to "Q" where

$$Q = R_r \times D \times A.p \text{ cu. ft. per sec.}$$

R_r being intensity at critical period T;
and A.p being drainage area in impermeable acres.

Then taking (1) $R = \frac{C}{T+30}$ for short time storms (1 in 3 years),

and (2) $R = \frac{3.C}{T+30}$ for longer time periods (1 in 30 years)

we have a method of estimating the maximum rainfall intensity over any period without the existence of automatic rainfall records.

Taking D_{max} as Maximum Daily Rainfall

$$(1) R = \frac{25 \times D_{max}}{T+30} \quad \text{and} \quad (2) R = \frac{3 (25 \times D_{max})}{T+30}$$

INTENSITY-DURATION CURVES.

In fixing allowances to take into account ordinary storms a somewhat empirical method much adopted in the past has been to take an arbitrary figure of $\frac{1}{2}$ —1 inch per hour over the total area but it is becoming generally accepted to-day that such provision is not adequate and that greater precision is needed—especially in matters of intensity, if flooding is to be avoided and economical sections of sewers laid down, particularly in low-lying districts.

Realising this, it is becoming more common to-day for intensity-duration curves to be plotted when sewerage schemes are being prepared. (See Drawing No. 1).

Taking a large number of storms and plotting their intensities to the varying time, a curve may be drawn that will include the majority of storms that are met with any frequency.

It is desirable whenever such curves are plotted that they cover an adequate period—taking 5 years as a minimum and preferably a period of 20 years.

The working curve decided upon should preferably have an equation found for it in order that comparison may be made with other towns and districts.

Since the maximum rate of run-off only occurs when the duration of the storm is either equal to or greater than the time of concentration, "T" is taken as duration of storm equals true time of concentration, and the problem then resolves itself into one primarily of finding the values of the constants "a" and "b," in the equation of the general form $R = \frac{a}{T+b}$

TYPICAL EQUATIONS FOR LARGE TOWNS.

The following equations have been established when adopting a working curve to include all except abnormal storms over their own local areas.

BIRMINGHAM .. $R = \frac{40}{T+20}$ (See Fig. 2, Drawing No. 1).

SOUTH SHIELDS $R = \frac{20}{T+8}$

EASTBOURNE (a) $R = \frac{26}{T+5}$ for storms of 0-35 mins. duration ;

(b) $R = \frac{44}{T+33}$ for storms of 35-100 mins. duration.

Where local records are not yet available over any considerable period, reasonable values are now available for use as a result of the valuable work carried out by the Departmental Committee on Rainfall and Run Off.

The conclusions of this Committee as a result of extensive investigations of storms of 10, 15, 30 and 60 minutes duration occurring between the years 1921-27 give a good idea of the factors to be taken into consideration and of the methods to adopt when attempting to arrive at results that will shew a reasonable approximation in actual practice to those adopted for purposes of design.

CONCLUSIONS.

- (a) That these records did not indicate that any grouping of the stations was necessary on any geographical basis and that therefore one standard curve might conveniently be adopted for all stations : subject to proviso that exceptional cases should be considered on their merit where adequate records are available of the frequency and duration of storms.
- (b) That as a general principle and for the practical purposes of sewer design this curve should cover all except the 2 or 3 highest storms during the seven years period, for the average of all the stations. These "excepted" storms might be regarded as adequately provided for—with due consideration to economy—by the margin of safety which in practice usually exists (e.g. storage capacity, permissible surcharge, excess of actual size of pipe above theoretical requirements, etc.)

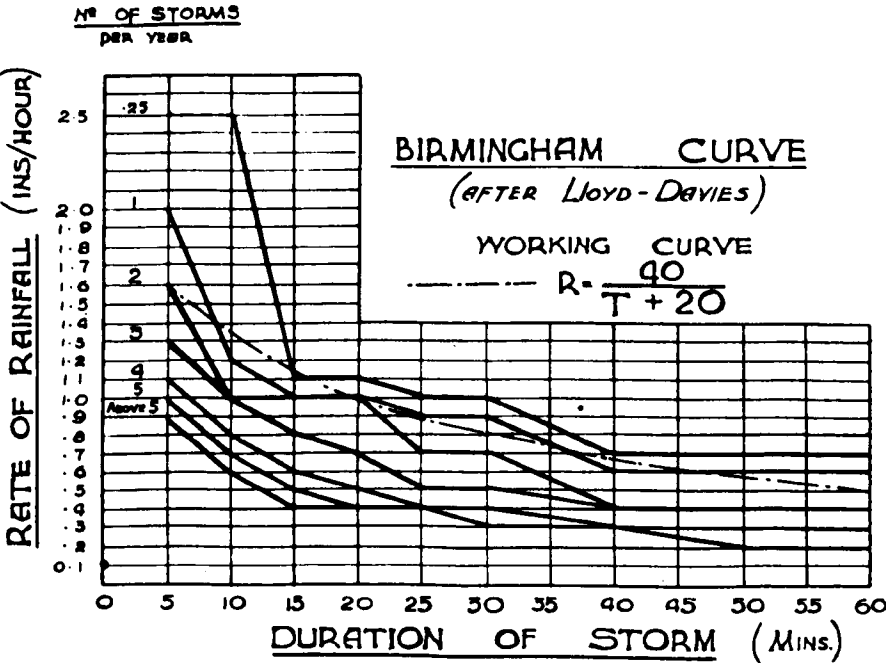
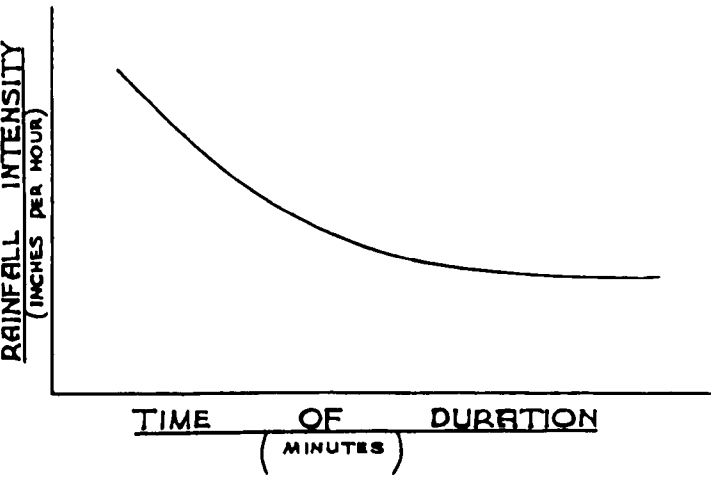
The available values for general use above mentioned being

(a) $R = \frac{30}{T+10}$ for storms of from 5-20 mins. duration ;

(b) $R = \frac{40}{T+20}$ for storms of 20-100 mins. duration.

where R=Intensity of Rainfall in inches per hour,
and T=Time of Concentration (or duration of storm) in minutes.

TYPICAL INTENSITY-DURATION CURVE



QUANTITIES OF SEWAGE TO BE ALLOWED FOR.

In addition to the problem of Storm Water Sewage the total sewage arriving at the outfall sewer at the works that has to be considered includes

- | | |
|-----------------------------------|----------|
| (a) Domestic Sewage | } D.W.F. |
| (b) Trade Wastes | |
| (c) Infiltration of Ground Water. | |

In the design of any sewerage system allowance can be made with considerable accuracy for both (a) and (b) though the determination of (c) often presents considerable difficulty and it is at the best a very indeterminate quantity.

(a) *Domestic Sewage*.—The curve of sewage discharge is found to follow very closely the curve of water consumption and for all practical purposes the D.W.F. from domestic properties may be taken as equivalent to the product of number of houses $\times$ population per house $\times$ water consumption per head per day, and which figure will, on account of leakage and other factors, be on the safe side for purposes of calculating the dry weather flow.

(b) *Trade Wastes*.—The total volume of trade waste may generally be ascertained from figures giving the intake water consumption where discharge is made only into the sewers. Generally speaking trade wastes are admitted to the public sewers, but when of a highly polluted character are admitted only after preliminary treatment, particularly where acid discharges are to be expected or where dyeing and bleaching, the manufacture of artificial silk, beet sugar, etc., is carried out or where sewages containing appreciable amounts of grease and oil compounds are met with.

(c) *Infiltration of Ground Water*.—The volume of ground water that finds its way into the sewer is dependent principally on the number and type of joints, upon the type of jointing material employed and upon the nature and condition of the ground through which the sewer is laid.

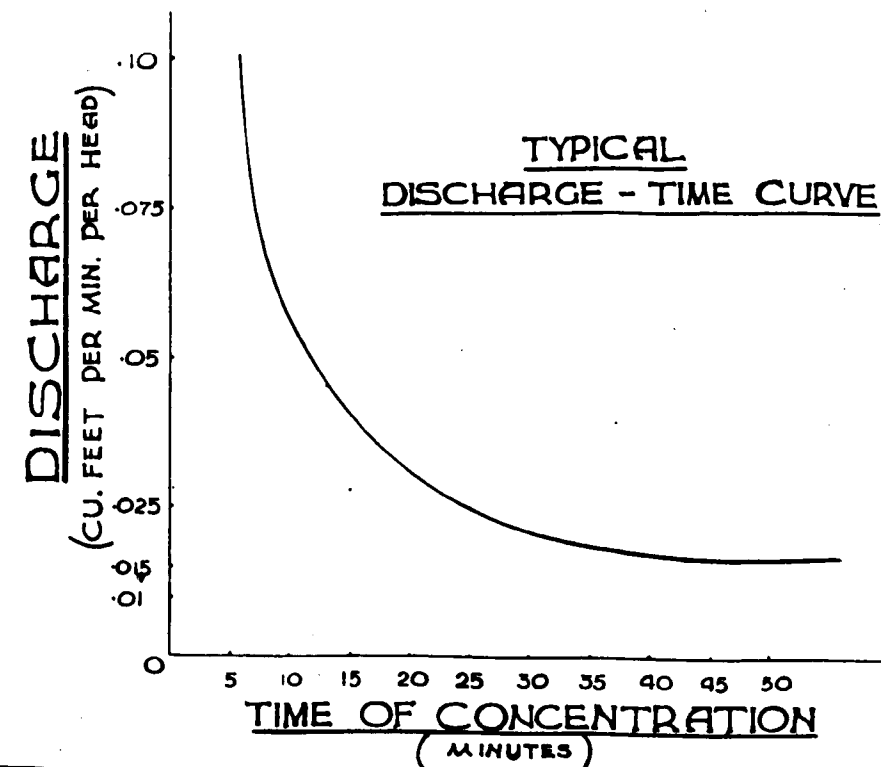
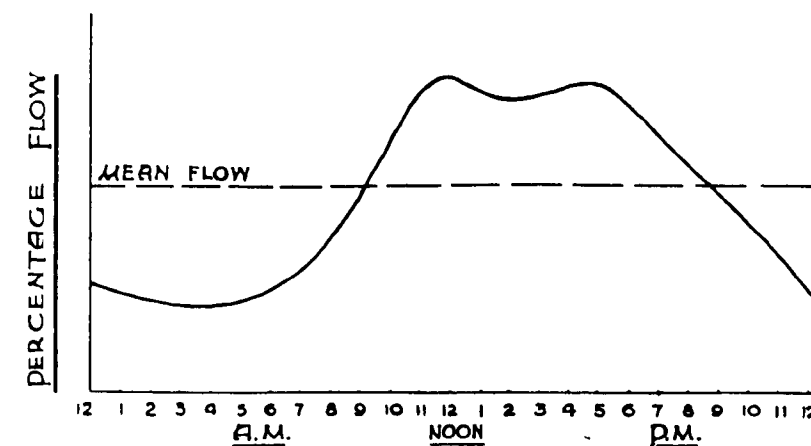
Unless care is taken in settling the filling in the sewer trenches and in seeing that all pipes are well jointed, both infiltration and leakage are bound to be considerable.

In designing new sewerage works allowance should be made for infiltration of ground water according to local circumstances and may be as much as 1 gallon per minute per mile, but more particularly affects the total volume of sewage to be treated at the works.

POPULATION DENSITY.

In making allowances for population groups in calculating discharge, considerable variation will be found to exist to-day as compared with 20 years ago and the number of houses per acre as well as the number of persons per house is considerably reduced, and whereas twenty years ago a figure of 5-6 persons per house and of 40 houses per acre was common, this has now been reduced to such smaller dimensions of the nature of 4-4.5 persons per house and from 12-15 houses per acre—a reduction on

2.

CURVE OF SEWAGE DISCHARGE

the dry weather flow on water consumption (of population) alone of as much as 70 per cent., against which, however, there are definite indications of higher water consumption per head per day.

A usual value is to take this volume of D.W.F. as being discharged into the sewers over a period of 6 or 8 hours when calculating discharge.

The curve of sewage discharge (D.W.F.) for an industrial district may be taken as approximating to that shewn in Fig. 1, Drawing No. 2.

An important fact to be borne in mind in respect of population is that the population factor must be one that will satisfy the building density say 30 years hence, and generally speaking in areas that are controlled by Town Planning Schemes the population increase can be calculated "X" years hence by a simple knowledge of the number of areas likely to be opened up for building and the number of houses allowed per acre in the development of such building sites.

Where other factors affect the population (such as the extension of local industries) a curve may be plotted giving a population-years relationship enabling the population in "X" years to be estimated with considerable accuracy.

The curve will be one of the form $X = a.b^n$;

where X = population at end of any census period ;

a = population at commencement of census period ;

b = ratio $\frac{\text{population at end}}{\text{pop. at beginning}}$ of any series of "n" census periods.

AREA-TIME DIAGRAMS.

The employment of area-time diagrams in sewerage schemes has somewhat recently come into fairly extensive use and they may satisfactorily be employed at important sewer junctions along the path of the main sewer to be safe against the possibility of flooding at points of intersection with subsidiary main sewers.

The diagram in Fig. 1, Drawing No. 3, shews the line of a subsidiary main sewer being joined by its branches drawing the sewage from extensive districts limited by lengths, "AA₁" "DD₁" "EF₁" etc.

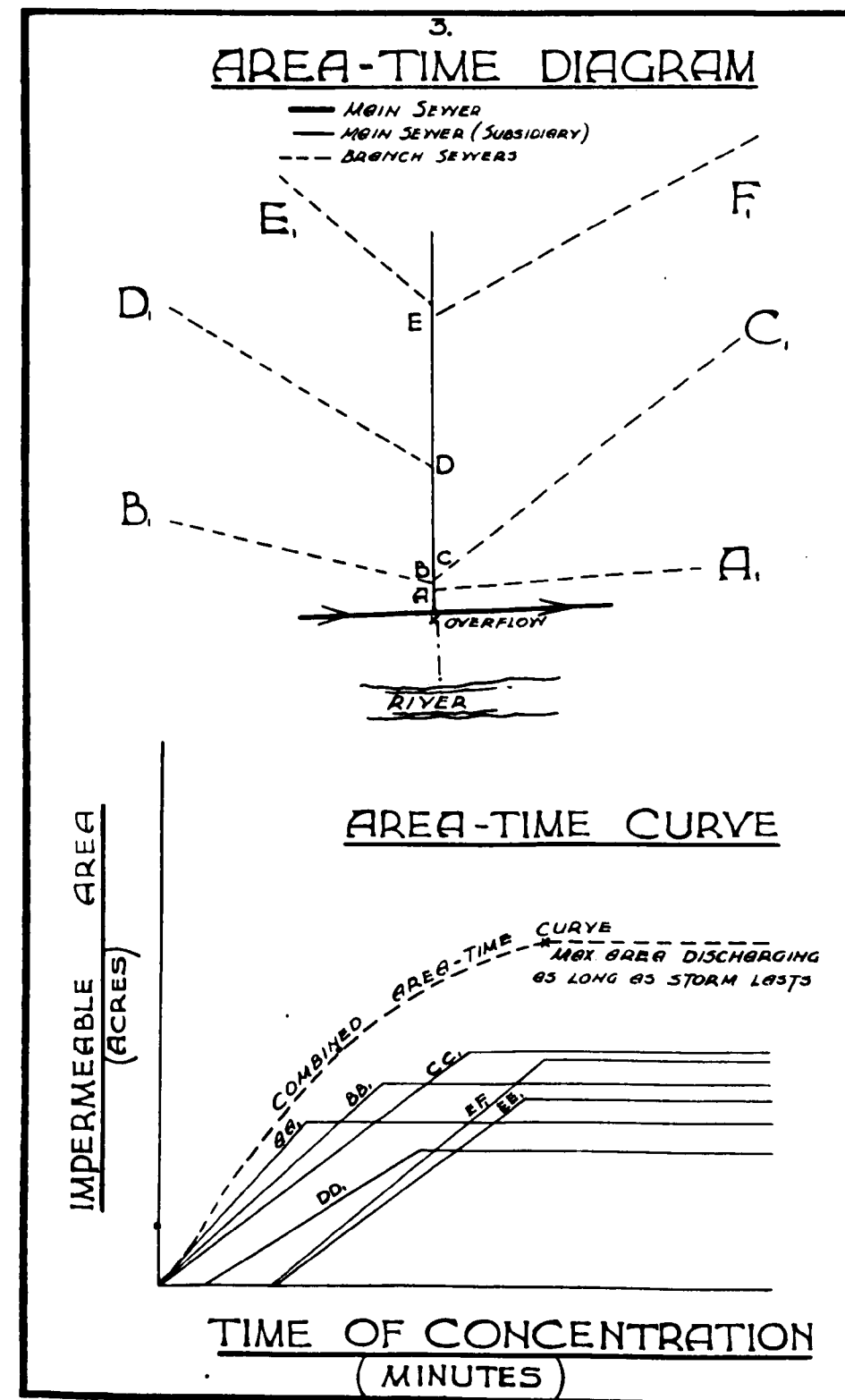
Area-time diagrams may be got out for each of the sewer branches "AA₁" "DD₁" "EF₁" etc., and the time taken to flow from point "A₁" at the extremity of branch sewer "AA₁" to where it discharges into the subsidiary main sewer at point "A" may be calculated taking length and velocity into account, when we have

$$T = \frac{L}{V}$$

To the calculated value of "T" must be added an entrance allowance of from 2—5 mins. (a usual figure is 3 mins.) such that

$$T = \frac{L}{V} + e$$

where "e" is time for first run off of storm water to find its way into the sewer branch under consideration before it commences to travel along the line "AA₁"



<i>Class of District.</i>			<i>Impermeability Factor.</i>
Densely built-up industrial	..	..	0.70—0.90
Built-up Residential	..	..	0.50—0.70
Rural area (some houses)	..	..	0.10—0.25
Parks and Open Spaces	..	..	0.10—0.30
Gardens, Lawns, etc.	..	..	0.05—0.25
Wooded Areas	..	..	0.01—0.20

A method also employed for making allowances for impermeability is to employ a value expressed as a factor of the population per acre ; but the results are probably more liable to error on account of variation in housing and population density and other factors.

Lloyd Davies gives a figure for Birmingham (1906) as being equal to 0.0105 population.

VELOCITY AND DISCHARGE AS AFFECTING DESIGN.

Considerable diversity of practice exists in the determination of discharge and velocity—formulae exist that are both cumbersome and unsuitable for sewers under varying conditions, and the sewers themselves give actual values that are found to vary appreciably from those taken for purposes of design after continued use over a number of years.

Especially is the diversity of results noticeable in the smaller and larger sizes of pipes and considerable work has been done in the past by various experimenters that gives us as sound a basis for consideration as it is possible to obtain at the present time.

The formulæ derived by Santo Crimp and Bruges may be taken as a safe one so far as practical sewer design goes, but small differences will be found to exist when comparing its results with those given by formulæ derived by Bazin, Darcy, Eytelwein, Kutter and others.

After considering a large number of investigations as to which were the more reliable formulae for practical purposes of design Crimp and Bruges came to the conclusion that the well known Kutter formula did on the whole give most reliable results, but at the same time was so complex that its use was somewhat restricted.

The formula evolved by Crimp and Bruges to meet this difficulty was expressed as

$$V = 124 \sqrt[3]{R^2} \cdot \sqrt{S}$$

where V = velocity in feet per second

R= hydraulic mean depth

$$S = \text{ratio} \frac{\text{fall}}{\text{length}}$$

The authors finding that by employing $\sqrt[3]{R^2}$ a reasonable allowance was made for the effect on the velocity of variations in depth of flow at various points.

This formula is obviously much simpler to work out than the original Kutter formula (given below) and may be taken as approximating to that of Kutter when the co-efficient of roughness of invert surface of pipe varies from .012 to .013.

As the results of all calculations for velocity and discharge are dependent on this co-efficient of roughness which again is dependent on the type and condition of invert surface of pipe, Crimp suggests that a variation of as much as 10 per cent. may be expected in actual practice over those given by any formula.

$$\text{KUTTER V} = \left\{ \frac{41.6 + \frac{1.811}{n} + \frac{.00281}{S}}{1 + \left(41.6 + \frac{.00281}{S} \right) \frac{n}{\sqrt{R}}} \right\} \sqrt{R.S}$$

For purposes of comparison the following well-known formulæ are given

$$\text{DARCY } V = \frac{\sqrt{64.4 R. S}}{\mu}$$

where $\mu = \alpha \left(1 + \frac{\beta}{R} \right)$

and $\alpha = .0037285$

$$\beta = .2296629$$

EYTELWEIN $V=55\sqrt{R \cdot 2 f}$

where V is in feet per minute,

and $f =$ fall in feet per mile.

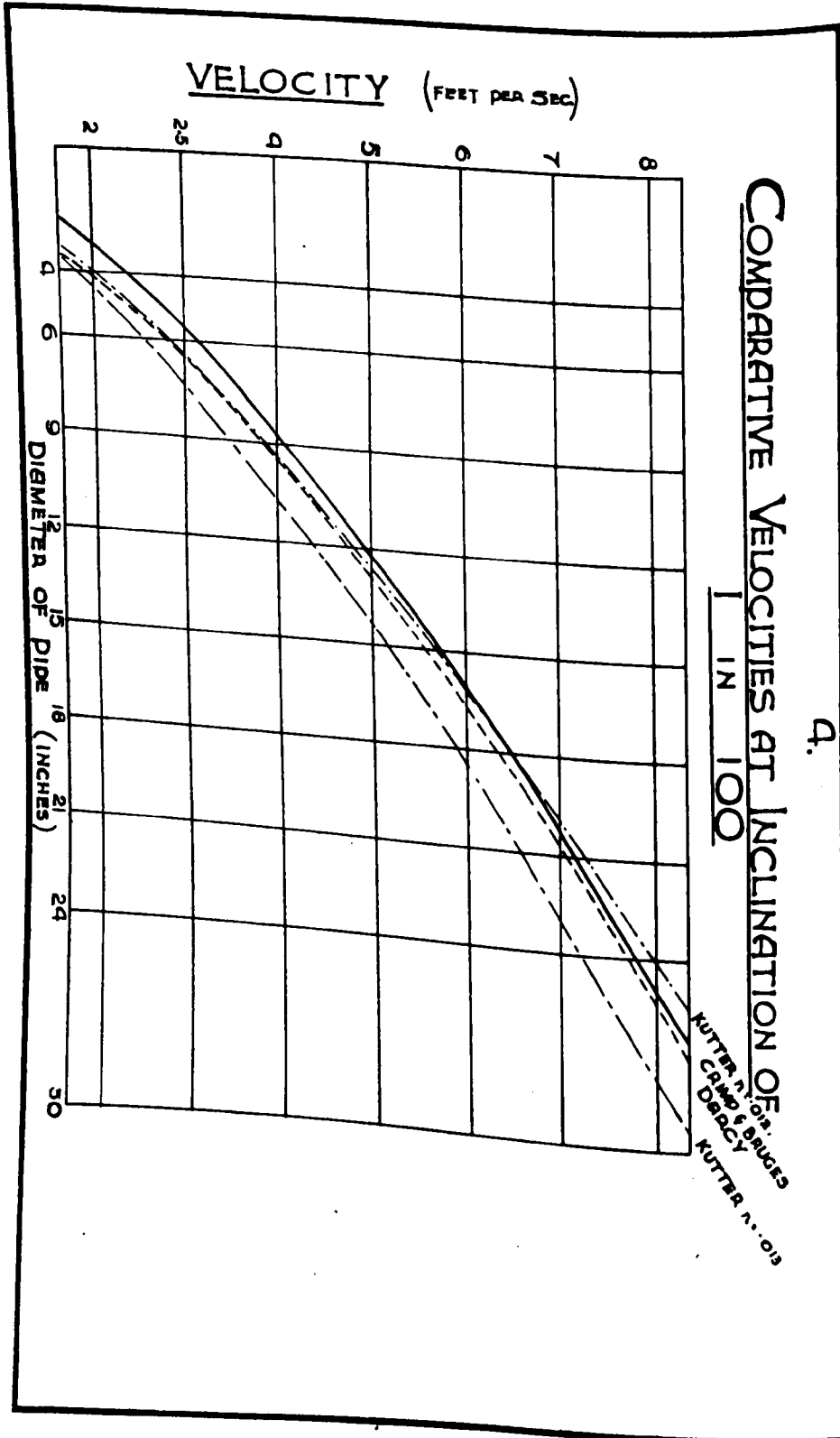
$$\text{BAZIN V} = \sqrt{\frac{\text{R.S}}{.0000457 \left(1 + \frac{7984}{\text{R}} \right)}}$$

The fundamental formulæ of Chezy

$$V = C\sqrt{R} \cdot S$$

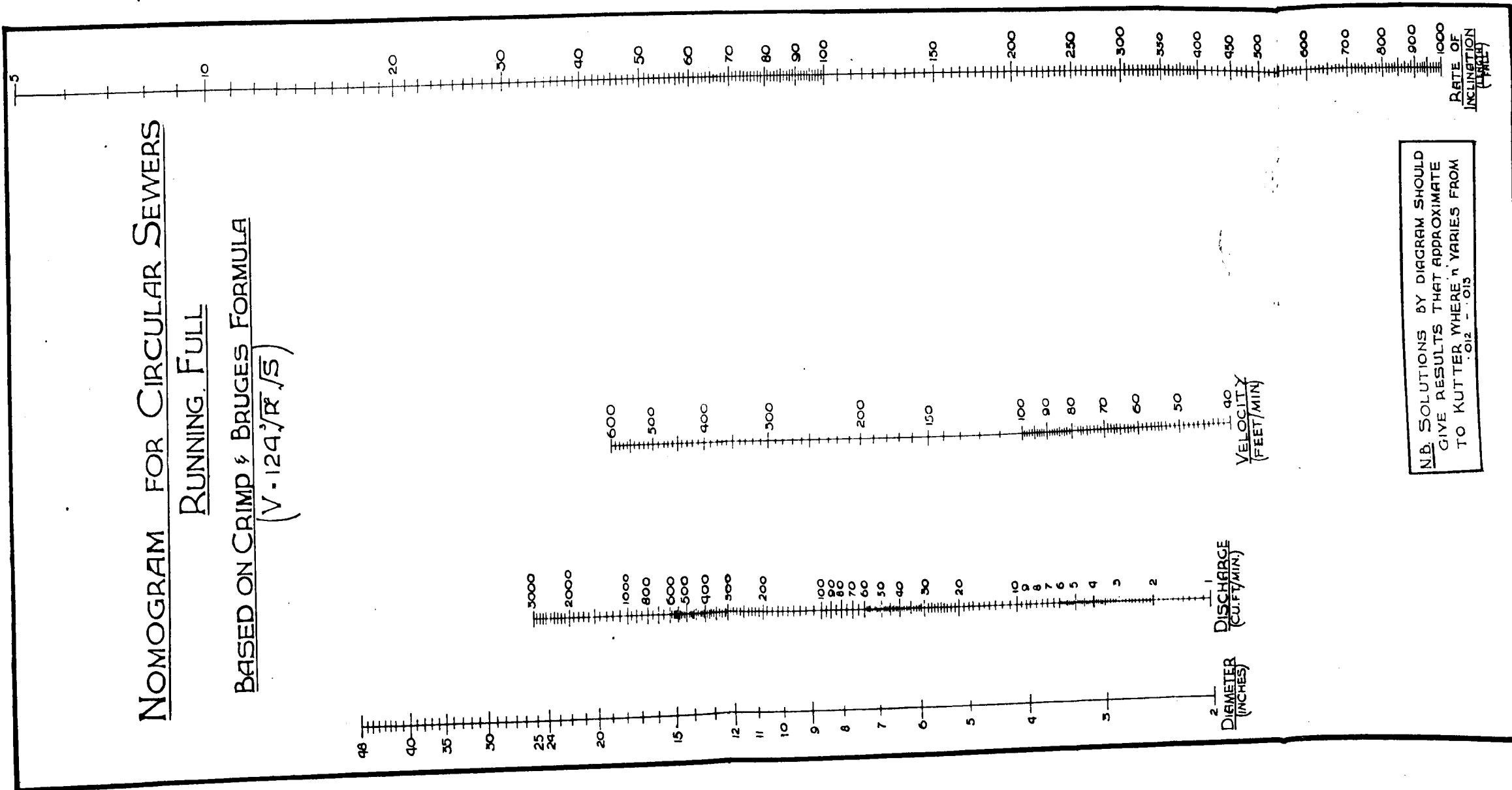
has been employed in comparing values of C for the different formulæ given above taking a self cleansing velocity of 3 feet per second and sizes of pipes used in general practice. These values may be taken as approximately correct for general work.





(Face page 702.)

so that a velocity of 3 feet/sec. is generally
that is likely to get into the sewer.



No.	Originator of Formula.	Diameter of Pipes in Inches.							
		6	9	12	15	18	21	24	30
1	Bazin	111	120	125	129	132	134	135	138
2	Crimp and Bruges ..	88	94	98	102	105	108	111	115
3	Darcy	105	108	109	110	111	111	112	112
4	Eytelwein	104	104	104	104	104	104	104	104
5	Kutter	70	79	85	90	94	98	101	106
Average Values		96	101	104	107	109	111	113	115

See Drawing No. 4.

In all these calculations it is usual to calculate both velocity and discharge from the invert gradient of the sewer, though in actual practice it is the hydraulic gradient that determines these values and which may vary considerably at different points along the line of the sewer.

Each increase at junctions of tributary sewers and drains gives less and less inclination than indicated by the invert gradient.

DIAGRAMS FOR SOLUTION OF FORMULÆ.

In order to simplify the laborious task of solving any velocity formula both readily and accurately the employment of diagrams for the solution of the various formulæ has grown into use in recent years.

It is obvious that these diagrams (or Nomograms) will vary as the formulæ, but by reference to the given Nomogram it will be seen that the various factors—diameter and inclination of pipes, velocity, discharge, etc., may be readily determined by placing a straight-edge on any two known values: the intersection with the unknown factor giving the value to the particular formula (Crimp) to which the diagram has been drawn.

SELF CLEANSING VELOCITIES.

An important point with reference to velocity is that of the D.W.F. as affecting self cleansing of the sewer under conditions of minimum flow.

Considerable differences existed over a number of years as to the critical velocity that would carry along such solids as generally find their way into the sewer and so prevent accumulation of deposit and consequent blockage of the sewer.

A common value for the velocity to remove certain of these solid substances may be taken as

River Mud	0.2 feet per second
Common Clay	0.5 „ „
River Sand	2.0 „ „
Large Shingle	3.0 „ „

so that a velocity of 3 feet/sec. is generally speaking sufficient to sweep away anything that is likely to get into the sewer.

While the general principle of increase in inclination of sewer for reduction in diameter is generally practised the value is particularly affected by type and condition of invert (salt glazed, concrete, brick, etc.,) and in recent years the lower limit to self cleansing has been slightly reduced.

A self-cleansing velocity for general use with pipe sewers may safely be taken at

Pipe Sizes.

3 feet/sec.	for 6 in., 9 in. and 12 in.
2.5	„ 15 in., 18 in. and 24 in.

SIZES OF PIPES.

On any new line of sewer the practice to-day to determine the size of the pipe to employ is generally one of trial and error. An assumed diameter of pipe is taken and having plotted a section and determined the inclination, the velocity and discharge for this size of pipe is determined and checked against the total quantity of sewage and storm water that has to be carried.

Knowing the proposed line and level of the sewer the time of concentration for all important points may be found, and, an allowance for entry into the sewerage system having been made, the intensity to allow is determined from the equation expressing the "Working" Rainfall Intensity Curve.

SYSTEMS OF LAYING DOWN SEWERAGE SCHEMES.

The "Combined" system and the "Separate" system of sewerage have both been used in past years to such an extent that their use seems to justify us in drawing certain conclusions from practical experience and observation on these methods and it seems to be becoming more and more recognised that a satisfactory and economical system of sewerage—particularly for any large urban area comprising both built-up and undeveloped areas is not to be found by the exclusive use of any one system, but by a skilful co-ordination of both systems in such a way that advantage may be taken of the separate system for the more residential areas and the combined system may be retained for dealing with dense population centres where the separate system is neither desirable nor economical.

Alternatively or additionally a properly arranged system of storm overflows on the sewer proper arranged to carry away excess rain water over 6 D.W.F. may avoid some expense in laying down two sets of sewers and all the complications they involve, and in addition ensure that the putrescible organic matter, grit, etc., that is among the first washings of the storm finds its way to the Sewage Works and not into the stream. At the same time this method has the effect of subdividing the whole drainage area into smaller sections each gravitating to a point where the overflow is situated; the capacity of the subsequent sewer being reduced at each of such overflows below that which would otherwise be necessary.

Where sewage has to be pumped, however, considerable economies are obviously possible both in power consumption and treatment costs by the use of the separate system of sewerage.

DUAL SEWERAGE SCHEMES.

A recent development in the sewerage of municipal housing estates has been to lay down a system of sewerage in such a way that economies in constructional costs are made either by superimposing one sewer on top of the other or by running the two pipes together in parallel.

In order to obviate future trouble that may arise when full development is not taking place when the sewerage system is laid down, junctions are left for future connections to be made to minimise such trouble when the remaining development takes place.

PRACTICAL SEWER CONSTRUCTION.

Constructional work in sewerage has been materially the same over a number of years, but present day practice shews considerable variation in actual constructional methods.

Generally speaking the types of sewer employed may be classified as follows

<i>Size of Sewer</i>	<i>Material</i>
Sewers of Small Section	Salt glazed earthenware.
Sewers of Large Section	P.C. Concrete, brick faced, Concrete invert blocks, Plain and reinforced concrete.
Sewers under pressure ..	C.I. Pipes, R.C. Pipes.

The use of egg-shaped sewers seems to have been somewhat lessened in recent years due more to difficulties arising in actual construction than from any doubt as to their efficiency.

The usual requirements so far as the Ministry of Health is concerned (where loans are sought) may be taken from the following :—

<i>Depth of Pipe</i>	<i>Requirements</i>	<i>Max. Loan Period</i>
Under 4 feet ..	Surrounded 6 in. Concrete ..	30 years
14-20 feet ..	Haunched in Concrete ..	30 „
Over 20 feet ..	Surrounded 6 in. Concrete ..	30 „

it being generally assumed that with all sewers of 18 in. diameter and greater they be haunched in concrete when the depth exceeds 4 feet and is under 20 feet.

The most pronounced development in type of pipe employed in recent years has been the extended use of Stanford jointed pipes with a double ring of bituminous compound, flexible jointed pipes and concrete "spun" pipes, the latter having a low porosity and providing a good smooth invert surface.

The increased strength gained by the employment of reinforcement in concrete pipes seems as yet to be limited to less than 10 per cent. over that of the plain concrete pipe and it would appear that at the present time, when the question of loan periods is under consideration by the Ministry of Health, the employment of reinforced concrete pipes is not regarded very favourably.

PART II.

SEWAGE TREATMENT.

Before proceeding with any scheme of extensions or alterations to existing works it is essential that as accurate a record as is possible should be made of the volume of sewage to be dealt with.

Where the total flow is based on the water consumption it must be realised that an accurate figure for the particular area concerned should be obtained, as a small variation in the number of gallons per head per day over a large population may make a considerable difference to the total flow to be dealt with at the treatment works.

The volumes of trade waste waters may generally be determined with a considerable degree of accuracy, and in recent years it has been realised that considerable volumes of subsoil water, for which allowance should be made, reach the sewage works, however carefully the sewers may have been constructed.

The average value for water consumption for large towns in this country may be found to approximate to about 30 gallons per head per day for domestic purposes alone, which figure should be regarded as a low one where designing for future populations.

It is as well when comparing German and American sewage practice to bear in mind the average values for large towns in those countries, which are roughly about 40 and 100 gallons per head per day respectively.

Some doubt exists at the present time as to the requirements that should be fulfilled when arriving at a figure for capacity of tanks, etc., and whilst many towns treat fully up to 3×Total D.W.F. (including trade waste plus infiltration) the general requirements of the Ministry of Health would seem to be fulfilled by providing sufficient capacity to deal fully with the following volumes according to type of sewerage system.

<i>Combined System.</i>	<i>Separate System.</i>
3×Domestic	2×Domestic
+	+
1 ¹ / ₁₀ Trade Waste	1 ¹ / ₁₀ Trade Waste

with partial treatment up to 6×D.W.F.

However, some Rivers Boards when going through schemes prepared by Local Authorities within their area are suggesting that such figures might be increased to take in infiltration water and trade waste taken as being discharged in 12 hours, giving,

3 × Domestic
2 ¹ / ₁₀ × Trade Waste
1 ¹ / ₁₀ × Infiltration Water

the latter figure being found to be considerable on most works to-day and being responsible for as much as 20 per cent. of the total flow.

MEASUREMENT OF FLOW.

At the present time although the obvious value of a correct record of the flow of sewage is recognised there are considerable numbers of the smaller works that have no type of flow-measuring and recording apparatus.

Up to recent years the problem had (where possible) been mainly dealt with by means of various types of orifice and rectangular and V-notch weirs which could only be employed in many cases at considerable loss of "head" and were also liable to hold up some of the smaller settleable solids.

The most recent development in this direction, the "Flume" type of recorder, has neither of these disadvantages, gives a reliable and accurate method of measuring flow and is neither affected by velocity of approach nor requires any considerable head—this being obtained by the fall in hydraulic gradient due to increased velocity at the "throat"; and at the same time provides a clear passage for the sewage—the small loss in head through the flume being partly recovered as the channel widens out and the velocity again decreases.

"Venturi" tubes have also been adopted in recent years, and are operating under reduced head, the sewage flowing through a tube that reduces in area, and in which loss of head is proportional to the square of the velocity—as the tube again widens out the velocity is again decreased and loss in head recovered.

STRENGTH OF SEWAGE.

Apart from the volume of sewage to be dealt with the major consideration affecting design of works and determining sizes and capacities of tanks, detention periods, etc., is that of the strength of the sewage which may be classified by the oxygen absorbed from an acid solution of potassium permanganate in 4 hours at 27°C. with the following classification :

<i>Nature of Sewage.</i>	<i>O² Absorbed from KM_nO₄ (Parts/100,000)</i>
Weak	7—8
Medium	10—12
Strong	17—25

CHOICE OF TYPE OF SEWAGE PURIFICATION PROCESS.

It is probably the first time in the history of sewage purification processes that so careful a choice of the type of process to adopt is being made. Too frequently in the past have plants been put down that have not given the results expected of them, even after considerable capital expenditure has been incurred, and for the simple reason that the plant though admirably suited for dealing with some types of sewage is totally unable to effect satisfactory purification of the particular sewage it is called upon to deal with.

This trouble has been noticeable in the eager adoption by some authorities of new methods of purification, such as the activated sludge process, without any previous knowledge as to whether the sewage to be treated lends itself to, say, an intensive aeration process of this type.

It may be further stated (with considerable experimental justification) that the type of process adopted bears a definite relation to the percentage purification attainable and that maximum efficiency can only be obtained when the process adopted is found experimentally to be capable of dealing with the particular type of sewage requiring to be purified.

In such an experimental determination it will be necessary to take into account such factors as strength of sewage, volume and type of trade wastes, oxygen absorbed and acidity, rate of discharge, etc., and in addition the further factor of type of sewerage system (whether combined or partial) employed to deliver the sewage at the outfall.

Land treatment as practised over a long period of years has produced good results, but its use has been limited and as urbanisation has gone on apace it has generally speaking yielded over its functions and responsibilities to more mechanical processes that seek artificially to follow the purifying agencies of nature.

THE VARIOUS PROCESSES IN THE PURIFICATION AND DISPOSAL OF SEWAGE.

For many years sewage treatment processes followed well defined lines, but in recent years not only have marked changes been brought about in such matters as design and lay-out of tanks, filters, etc., but advances have been made in the creation of totally new processes such as the activated sludge process which may be regarded as an attempt to create a single system that would constitute a summation of the major processes of liquefaction, oxidation and settlement that lie between the preliminary treatment processes and final discharge into the stream.

For this reason in considering present practice and reviewing modern developments the various stages in the whole process of purification will be discussed in the sequence in which they are usually to be found at sewage treatment works.

- (1) DETRITUS TANKS (including Grit Channels) ;
- (2) SCREENS AND SCREENING (including Grease Treatment) ;
- (3) STORM WATER TREATMENT ;
- (4) SEDIMENTATION TREATMENT ;
- (5) PERCOLATING FILTERS ;
- (6) HUMUS TANKS ;
- (7) SLUDGE TREATMENT (including Sludge Digestion) :

THE ACTIVATED SLUDGE PROCESS OF PURIFICATION.

(1) DETRITUS TANKS (INCLUDING GRIT CHANNELS).

The detritus tanks have been in the past an important stage in the preliminary treatment of sewage and their efficiency has depended solely on reducing the rate of flow to a velocity such that the heavier mineral solids in suspension were able to settle out from the lighter suspended organic solids and sink to the bottom of the tank and from there be removed.

Difficulties are experienced, however, in maintaining the desirable velocity of 1 foot per second over any long period, and under varying conditions of flow, and the results have been that trouble has arisen due to the velocity of flow through the tanks having been either increased above or decreased below that theoretically required for maximum deposition of the settleable grit and other mineral matter. When the velocity has been reduced considerable amounts of organic solids have been settled out with the grit, and when the velocity has been increased only a relatively small portion of the total settleable matter has been settled out, but has gone forward to interfere with and to impair the efficiency of the later stages in the processes of purification.

The usual allowance of at least two tanks of a minimum capacity equal to one per cent. of the dry weather flow was formulated at a time when sewerage schemes were generally laid down on the "combined" system but where the "separate" system of sewerage is put down and street washings, etc., excluded from the sewers, there is a feeling that the old capacity is unsuitable for the particular case and that the detritus tanks are relatively of less importance.

Recent developments that have taken place with a view to obtaining greater efficiency and more reliable results from this stage in the treatment of sewage have led to the extended use (more particularly on the Continent) of grit channels that regulate the flow of sewage at a velocity of about 1 foot per second. They are usually made up of long shallow channels with a depth of flow of about 4 feet. It is found that deposition goes on up to a depth of about 2 ft. 6 in., and in order to guard against a reduction in velocity and a settlement of organic solids with the grit filter plates are being fitted into the channel bottoms and air introduced into the detritus once each day—the organic matter being separated out from the grit which then settles on its own.

Various attempts are being made to remove the deposited solids continuously and an interesting development in this direction is the Dorr Detritor which has been evolved in order to effect this more completely.

The Dorr Detritor consists of a settling tank with collecting mechanism and a washing chamber where the grit is cleaned and removed via an inclined plane to discharge into jubilee wagons.

The flat bottomed collecting tank is square in plan with half round corners and the sewage enters from the effluent channel by means of vertical openings up the side of the wall giving uniform velocity at each point of entrance along the full length of the tank. The sewage flows horizontally across the tank and discharges over a cill into a carrier while the grit is forced outwards to a chute and so into the narrow washing chamber by means of scraper attachments fitted with scoops.

Cleaning apparatus is attached to the washing chamber and the washed grit moves up the inclined floor of the chamber to the point of discharge.

The difficulties of maintaining uniform velocity for settlement are said to be eliminated and it is claimed that the Detritor reduces the putrescible organic matter discharged with the grit to less than 2.5 per cent.

(2) SCREENS AND SCREENING (INCLUDING GREASE TREATMENT).

The process of screening to intercept and remove the larger floating bodies such as rags, paper, etc., that come down with the sewage has been subject to much criticism in recent years and doubts are expressed to-day as to the efficiency of the old system of screening owing to the obvious tendency to remove a large amount of organic matter that could be more effectively dealt with (and with less nuisance) at a later stage in the process of purification.

Many developments have taken place in the last decade in regard to the practices and mechanical processes of screening, and as sedimentation has advanced and attained a higher relative efficiency, the type of screen employed and the nature of the substance sought to be removed has changed so that to-day a larger spacing of bars that will intercept only the larger floating bodies has come into general use—at least on new works and extensions—and has resulted in a reduction, both in volume and nuisance producing power of the screenings.

Wide variation will be found in practice as to the best position in which the screening chamber should be placed, and while it would appear that under certain circumstances the Ministry of Health favour the placing of screens after detritus treatment, on many large works the screens are placed immediately before the detritus tanks and a higher velocity (2 feet per second) is maintained over that at which the grit is settled out.

Compared with the reduction of suspended solids by the sedimentation tanks the screening chamber has an efficiency of about 25–30 per cent. and in determining the area and type of screens to be employed on any works greater care should be taken by making a careful selection taking into account type of sedimentation process adopted and volume and type of suspended solids that are expected to be received at the works.

The idea held at one time that the employment of fine screens would reduce subsequent sedimentation treatment has now been largely abandoned and where a high degree of purification and freedom from nuisance is demanded fine screens are not employed.

Developments in equipment.—For large works electrical-power-driven automatically-cleaned screening and raking apparatus is now generally employed, and many developments in screening mechanism are to be found.

In this country the general practice is for the employment of fixed bar screens set at 60° to the horizontal—the greater portion of the screenings being retained on the upper portions of the inclined screen and the screen being automatically cleaned by means of rakes and teeth, which are continuously pulled between the parallel bars, in some cases delivering on to belt conveyors.

Moveable screens cleaned by water jets are to be found on some large works in America, and other interesting developments include the drum screen and the Dorr Bar screen, the operation of which is mechanically controlled by an automatic switch that starts the raking apparatus when the solids retained by the screen reach a certain height up the screen bars; the raking mechanism being automatically stopped when the bars have been cleaned.

Grab Type Screens.—There has been an interesting development in recent years in the form of the “grab” type of screen employed with a view to overcoming some of the inherent disadvantages such as wear and tear of mechanical parts, links, teeth, etc., due to immersion, stoppages as a result of the accumulation of waste products on the chain links and other factors that greatly reduce the efficiency of the older form of screening mechanism.

Briefly, the “grab” mechanism is mounted on a travelling carriage that moves vertically between guides. When the carriage is moving vertically downwards the rake teeth run parallel to the carriage, turning to a horizontal position at the maximum depth, passing through the screen bars and bringing up the screenings on the rake as the carriage rises, the teeth reverting to a vertical position as maximum height risen is reached and the process automatically repeating itself. The rake clearing equipment propels the screenings into a trough from whence they are either dumped into hoppers or run away in jubilee wagons to be disposed of as desired.

Disposal of screenings.—Attention has been focussed in recent years on the difficult problem of dealing with screen deposits and of reducing the very objectionable organic nuisance that usually attaches itself to their disposal, and whilst the total volume of screenings has noticeably decreased and burying in rural districts may be carried out with impunity, it is realised that for more urban areas such disposal is neither possible nor desirable.

Incineration is practised at some works and considerable experimental work has been done in the last few years with a view to making the disposal at least support itself.

On distillation one ton of screenings has been found to comprise :—

Moisture	..	..	..	85 per cent.
Fuel Oils	..	..	..	100 lbs.
Fertilizer Base	..	..	..	100 lbs.
Gas (400 B.T.U.)	..	..	..	800 c.ft.

which analysis may be considered as indicating a desirable avenue along which to approach the problem of disposal.

A recent development that promises good results where separate sludge digestion is carried out is that of mixing the screenings with ripe sludge and allowing to digest in the sludge digestion chamber.

Grease Treatment.—The extended use of mineral oils and greases consequent upon industrial and transport development has been found seriously to affect many

of the processes of sewage treatment including both screening and sedimentation, and considerably reduces the efficiency of biological methods of purification depending for their success on effective aeration.

To remove oils and fats from sedimentation tanks these tanks have been fitted with grease and scum collectors, and at several German works there have been constructed skimming tanks through which the sewage flows and where oils and fats are separated out from the suspended solids to which they attach themselves by means of air blasts from porous plates fitted along the bottom of the tank, the fatty compounds rising to the surface and being skimmed off.

Grease extraction from sludge is practised in this country in some of the industrial districts, such as the Yorkshire woollen district, the whole bulk of the separated and sedimented solids being run into large vats heated by means of steam coils and from which the sludge passes forward to the presses and the liquid grease is extracted.

Where sludge digestion is practised oil traps have been introduced at some works to trap the mineral oils which assist the formation of scum and retard the process of digestion.

(3) STORM WATER TREATMENT.

The overflow cill set at 3 D.W.F. should be placed immediately below the screening chamber and should control the entrance to the storm tanks. The usual capacity for storm water tanks (at least 2 tanks) that has been regarded as necessary is $\frac{1}{2}$ D.W.F., but on some schemes constructed in recent years both in this country and in America (where storm tanks are less usual) this figure has under certain conditions been increased up to nearly $\frac{1}{2}$ D.W.F.

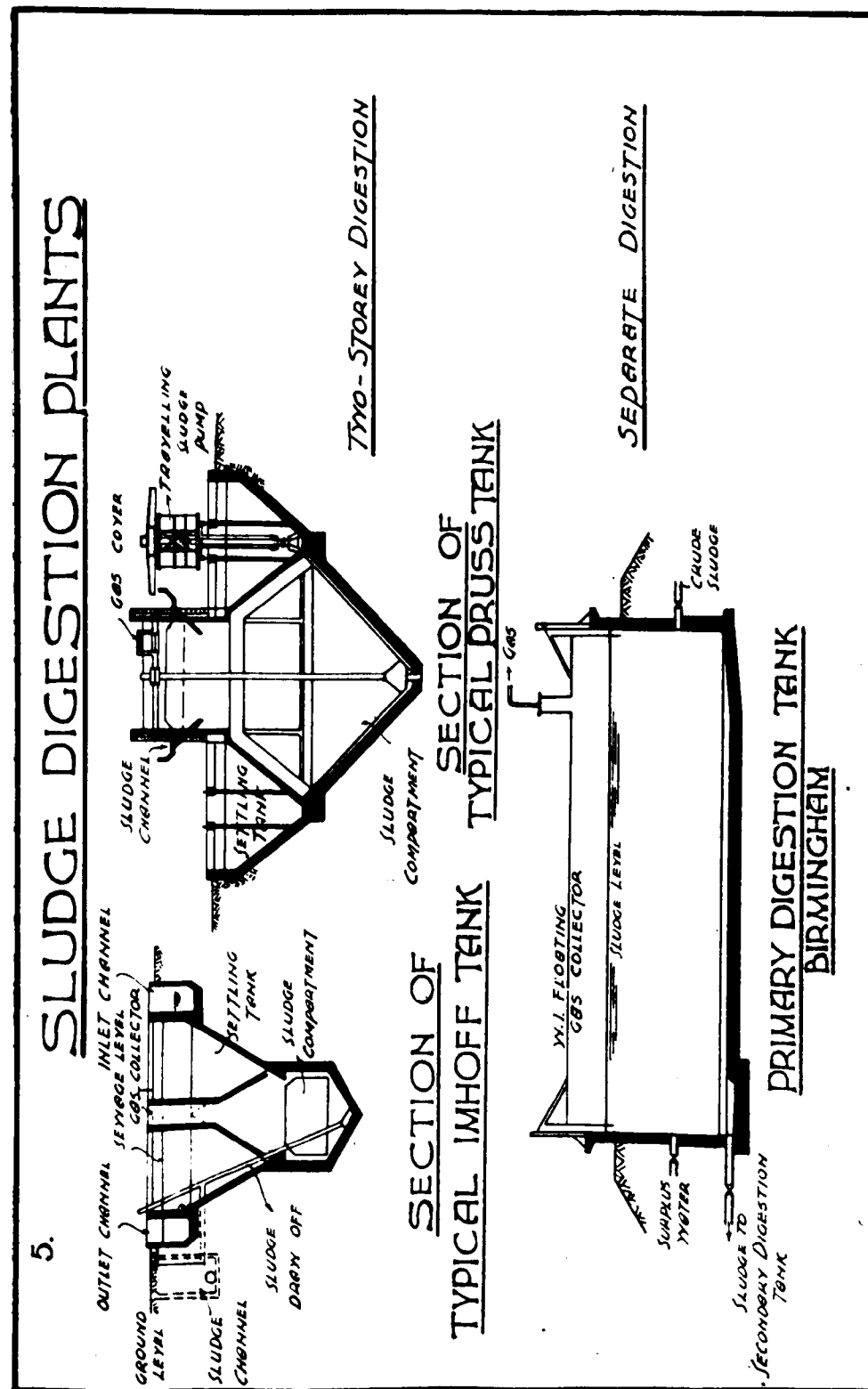
The tanks are so laid down usually that when completely filled they operate on the continuous flow principle and should be so arranged as to be easily emptied.

The storm water tanks perform an invaluable service during storms of short duration particularly if a long cill is provided that does not subject the settling tanks to excessive head of storm sewage, in enabling the various stages to do their share fully in the process of purification and prevent the sewage from getting upset during its passage through the various stages—especially so in the later stages of purification such as humus tanks when final settlement is taking place.

On works designed to deal fully with 3 D.W.F. in times of storm from 3—6 D.W.F. is passed through the storm tanks and excess is passed direct to the river which is by that time usually much above its normal water level and flowing at an increased rate.

(4) SEDIMENTATION TREATMENT.

The process of sedimentation still remains the most important process at most sewage works, but during recent years it has undergone considerable changes affecting the whole principle of sedimentation as well as such other factors as design of tanks, tank capacities, etc.



It appears to be generally accepted among engineers to-day that the maximum efficiency of this stage can only be obtained by maintaining the process as one of pure sedimentation and neither depending on biological agencies nor allowing the tanks to get into a septic condition, and yet of obtaining as near as possible complete liquefaction and separation of solids before going forward to the further treatment by oxidation.

The principal difficulty in this stage of sewage treatment is that of clearing out the sludge either continuously or at frequent intervals to prevent the tank getting into a septic condition and gas being given off.

Trouble has been experienced in many works where the nominal available tankage has been there but has not been able to effect satisfactory stage purification of the tank liquor, and with the old (and much used) rectangular type of settling tank allowance should be made for loss of capacity when either primary or secondary settling tanks are closed during sludging operations the actual available tankage being considerably reduced in the ratio $\frac{\text{actual}}{\text{nominal}}$ tankage and decreasing directly as deposition of sludge takes place, reaching a minimum during sludging of the tanks.

This type of settling tank is usually built in large units and the manual sludging of a pair of preliminary tanks of average size may be found to occupy as much as one week and of secondary settling tanks one and a half weeks in fine weather.

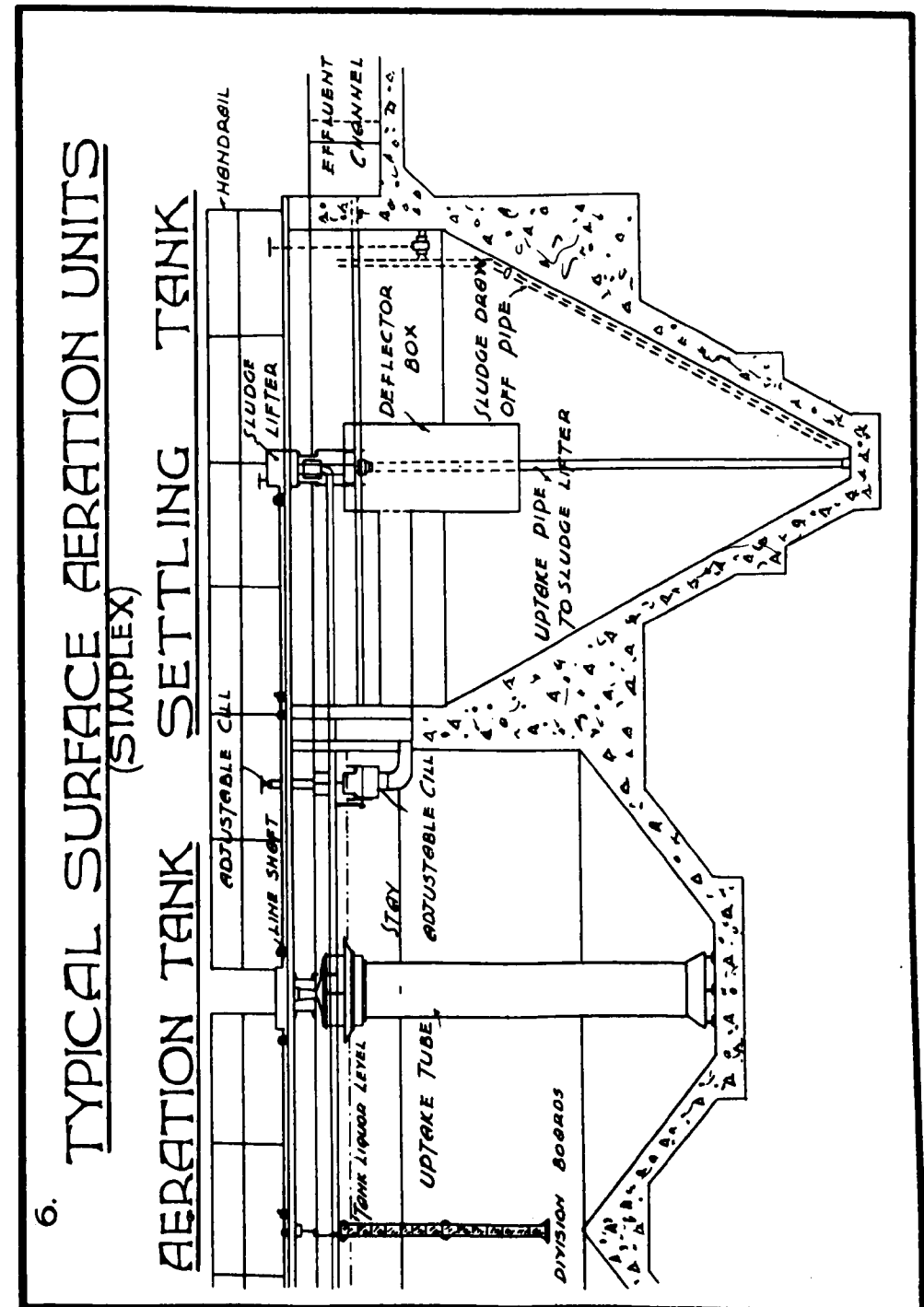
Many factors such as size of particles, currents, temperature, etc., affect sedimentation and greater attention has been paid during recent years to such factors as design of tanks and to questions of baffling, velocities, detention periods and capacities.

Until the coming of the upward flow Dortmund tank (see drawing No. 6) the flow had been of the horizontal type but it would appear to-day that both the horizontal and the vertical flow type of tank are able to settle out suspended solids in an efficient manner and that both may have a future before them.

The upward flow tanks are found to assist settlement by carrying the sewage into contact with the downward flow of suspended solids as upward flow of sewage takes place when the upward velocity does not exceed the velocity at which the smallest particles will settle out.

High costs are one of the major difficulties of this type of construction on account of the deep excavations (20—25 feet) that are called for.

After the vertical flow method has had a considerable trial there seems in some directions to be a tendency to retain the horizontal flow type with the provision of mechanical means for sludge removal, being removed either by hydrostatic head or slow moving helical scrapers employing mechanism that concentrates the total volume of the sludge at the bottom of the tank for frequent or continuous withdrawal and so avoid both septicity and loss in tank capacity while maintaining the desired



rate of flow. As it is essential that the revolving mechanism be very slow moving to avoid any stirring of settled sludge little power is required to maintain motion.

Among the interesting developments in sedimentation may be mentioned the Prüss Sedimentation Tank which consists of a circular tank with outward flow from centre to circumference and over cills of tank; the mechanical sludging being effected by slow moving scraper arms and a sludge being yielded of 86–90 per cent. water content.

The Dorr Clarifier—another tank of the continuous flow type—is also employed with a view to the early removal of sludge, and may be taken as a representative type of the sedimentation tank that seeks to remove continuously all sludge deposits. Revolving scraper arms are employed with shallow tanks of the horizontal flow type.

The two-storey Imhoff Tank has been much used in Germany and America though it has not shewn much development in this country. The Imhoff tank (fig. 1, drawing 5) comprises an upper sedimentation chamber and a lower sludge compartment—the sewage solids passing downwards from the sedimentation chamber into the lower compartment and so preventing the former from getting into a septic condition.

The lower chamber acts as a sludge digestion chamber and usually has sufficient storage capacity in large plants to allow it to remain for several months—the gas being drawn off and passed to the gasholder.

Detention periods.—The tank liquor from the sedimentation tank should be run off before it gets septic and on this account long detention periods are to be avoided.

Greater care is being taken in fixing detention periods and capacities, and such factors as type of sewage, amount of suspended solids possible to be settled out, etc., should be taken into account before deciding on any detention periods to allow for in design.

With upward flow tanks of the Dortmund type considerable reductions in detention periods have been obtained, as small as 8 and 9 hours having been employed under favourable conditions as against 10–15 hours with tanks in which the sludge is allowed to accumulate and reduce the capacity of the tank.

The average loss of capacity on tanks from which the sludge has to be cleaned out by manual labour is in the nature of 25 per cent. of the total tank capacity by reason of this accumulation of sludge between sludging operations.

Taking a detention period of 12 hours D.W.F. as an average period for this type of tank it gives a loss of capacity over all tanks of 3 hours D.W.F. which would suggest that with the increased capacity of self sludging tanks a less detention period of the nature of 9 hours D.W.F. might be employed with equally satisfactory results; which indication seems to be borne out by actual experience with this type of tank.

(5) PERCOLATING FILTERS.

Present day practice clearly indicates the acknowledged superiority of the percolating filter (sprinkler) over the contact bed, and comparative results have shewn that given favourable conditions for oxidation the percolating filter is capable of working at twice the rate of filtration of the contact bed, that it will produce a more stable effluent and give a higher degree of nitrification.

Many interesting developments in both design and construction have been taking place in recent years and at the same time a new conception has been taken on of the whole process, it being realised that the process is not so much one of filtration but a biological process dependent on the maintenance of ample oxygen supplies for the aerobic bacteria to do their work.

Considerable difficulties are being experienced in many districts in obtaining a good hard clinker as media owing to the recent developments in gas production and the employment of retorts, etc., that produce quantities of ash but little if any clinker.

With this problem to the fore experiments are being carried out with other types of media and among those being used extensively may be mentioned gravel, stone, and slag.

Using experimental filters with these substances as media it has been found that the accumulated solids in the stone and gravel filters were only about half the quantity retained in the slag filter when the percentage voids present in the three types of media were 44.5 per cent. gravel, 49.8 per cent. stone, and 52.6 per cent. slag.

At Bradford an economic and efficient media has been found in good hard Yorkshire coal, the filter beds being built to a depth of 6 feet and dealing with a strong sewage at the rate of 35 gallons per cube yard of material.

Respecting size and grading of media it would appear that the fine topping that was at one time extensively employed on percolating filters has now been largely abandoned with a view to maintaining more satisfactorily the available air supplies.

Opinion varies as to the most satisfactory type of filter wall from an aeration standpoint and the general tendency to-day is for solid wall filters to be built that will conserve the heat and work better and with less nuisance than the old open brickwork type.

However, many experienced managers of sewage works consider that the advantages of a semi-solid wall in inducing horizontal draughts of air through the bed more than outweigh any advantages offered by the solid wall.

Recent experimental work seems to reinforce this latter belief as better oxidation and more rapid filtration have been obtained with horizontal air draughts in addition to vertical air draughts induced by under drainage than when the former were excluded; the amount of oxidation taking place between leaving the jet and impinging on the surface of the media being found to be negligible.

Improvements in design leading to simplification of control and operation are evidenced by alterations in draw-off of effluent from floor of filter, type of under-

drainage employed, etc., and whereas in the earlier type of percolating filter the flow from the filter floor was outwards into circular or partly circular channels this has been largely superseded by falling the concrete floor towards the center (1 in 50) and from there collecting and running off the effluent to the humus channel the sprinkler being equipped with wash-out pipes that allow of the beds being periodically cleansed of accumulated solids.

Many new types of "film" spray have been developed in recent years that to control the extent of the spray from each individual hole in the sprinkler arm attempts are being made with sprinkler holes fitted with copper ferrules to minimize wearing and trouble due to corrosion the holes usually being of considerably larger diameter than have been previously employed.

Automatic Dosing Siphons. In equipment a very marked feature is the automatic dosing siphons and elevators for filters designed to give a more uniform and automatically regulated rate of dosing to the beds than has been previously. Whatever the flow may be that is reaching the works only the necessary group of sprinklers is brought into action, automatically and in such a way that the flow is distributed equally to all the beds in the filter group and maintain sprinklers in operation only so long as there is sufficient head of sewage to them.

Travelling Distributors. With a view to efficiency and to economy in constructional costs rectangular travelling distributors are coming into use on large works. The economies that are possible are chiefly due to the use of capital costs and to the fact that a greater area of contact is obtained, as with travelling distributors probably not more than 80 per cent efficiency is possible in continuous beds.

Rectangular distributors are usually operated by the flow of the tank but where insufficient head is available mechanical power may be employed, the beds being of varying widths up to say 100 feet with a distributor range of 200 feet, and considerable increase in head is required for self-propagation that required for revolving sprinklers.

The rectangular distributor is based on the principle of the water wheel driven by electrical or cable transmission, running on rails and being supplied with tank effluent by siphon action giving continuous feed so long as any effluent is in the channel, automatic adjustment being made for length of travel and so on. It is possible to control large areas of beds by single sets of travelling distributors and attain a high efficiency.

Cubical contents for treating up to 3 D.W.F. In actual practice it will be found that rates of filtration may be doubled in wet weather and that in laying down works and extensions that are to treat fully up to 3 D.W.F. sufficient capacity should be provided if the cubical contents are calculated on 1½ D.W.F.

The following minimum values may be taken for purposes of design for treating varying types of sewage, the figures being expressed in gallons per yard of material.

TYPE OF SEWAGE.

Sedimentation Treatment.	Type of Media.					
	STRONG.		AVERAGE.		WEAK.	
	Coarse.	Fine.	Coarse.	Fine.	Coarse.	Fine.
Continuous	45	—	70	—	100	100
Quiescent	50	25	100	70	130	130

Coarse Media being taken as that retained on a 1 inch mesh screen, and *Fine Media* being taken as that passing a ½ inch mesh screen.

N.B.—Where much suspended matter is to be found in the tank liquor it is essential that coarse media be employed for satisfactory oxidation.

(6) HUMUS TANKS.

Many developments have taken place in recent years in attempting to settle out more efficiently the light flocculent solids (humus) that are thrown out of suspension in the filters and find their way into the final settlement tanks.

The process is essentially one of simple sedimentation by reducing the velocity to that at which the maximum settlement may be expected to take place.

Of recent years the practice has been to construct humus tanks of double the capacity (i.e. of 4 hours D.W.F.) to allow of the more effective settlement of the flocculent sludge.

The old type of humus tank having been found to necessitate a heavy annual expenditure for cleaning and maintenance it has been sought to obviate this expense by the adoption of humus tanks of the upward flow Dortmund type and whilst producing effluents of a very high standard of purity have cut out the heavy expenditure that previously was incurred.

Against this must be placed the very light flocculent nature of the humus which is thought by many to be more effectively settled out in shallow tanks of the horizontal flow type—the shallow tank and the horizontal flow tending to minimise vertical currents and the fact that with all forms of mechanically sludged tank sludge deposits will adhere to the sides of the tank and if not dealt with are liable to cause a secondary putrefaction.

(7) SLUDGE TREATMENT AND DISPOSAL (INCLUDING SLUDGE DIGESTION).

When deciding on any type of purification process to adopt, particularly in urban areas it is now generally recognised that one of the most important considerations must attach to the efficient treatment and disposal of sludge.

Up to recent years research seems to have been concentrated on the primary problem of obtaining an effluent able to conform to the requirements of the various Rivers Boards and advances in this direction (as with the activated sludge system) have led to increased difficulties in sludge disposal.

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The rectangular distributor is based on the principle of the water wheel and driven by electrical or cable transmission, running on rails and being supplied with tank effluent by syphon action giving continuous feed so long as any effluent remains in the channel, automatic adjustment being made for length of travel and return. It is possible to control large areas of beds by single sets of travelling distributors and attain a high efficiency.

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This disadvantage may be slightly offset by the greater value of the sludge as a fertiliser base, but the manufacture and marketing of fertilisers from any type of sludge though proving successful in a few cases at the present time would not be economically possible if new capital costs had to be incurred, and in the construction of new works this avenue may be neglected entirely as an economic method of disposal.

Up to recent years sludge treatment in this country had shewn little actual development and had certainly not even attempted to keep pace with the improvements that had been adopted with a view to obtaining a higher standard of purity in the effluent but had usually consisted of the provision of sludge drying beds and in some cases sludge presses.

The two important developments that are now being adopted either alternatively or additionally to drying beds are sludge digestion and pumping sludge on to available pasture land within reasonable distance of the works.

The latter method has been found very successful in dealing with the sludge from activated sludge plants that has a water content of upwards of 98 per cent., but is limited in its application.

The sludge is usually pumped through pipes fitted with flexible joints by means of compressed air ejectors and is run over large areas of land, as much as 40,000 gallons to the acre being disposed of. Where the land rises fairly rapidly away from the works, sludge wells may be constructed at the extent of the first lift with ejectors to raise the sludge from this point and so give a more extensive area under the direct control of the works.

Successful results have been obtained with a mixed humus and activated sludge, and in actual costs this method of disposal has been found to effect a reasonable saving over that of disposal by sludge presses.

Where sludge drying beds are employed the sludge depth that has been found most satisfactory in recent years is one made up of layers of 6 inches thick, and where sludge digestion is carried out before being run on to sludge drying beds it has been found possible under favourable conditions to reduce the drying bed capacity by as much as 50 per cent.

Glass covered and mechanically emptied sludge drying beds are operated on some American works and allow work to go on rapidly independent of weather conditions, but are not considered economically justifiable in this country. Interesting developments that are found over there at present include experimental work on vacuum filters and the employment of rotary driers.

SLUDGE DIGESTION.

In sludge treatment the most important developments have been in the practical application of the principles of anaerobic sludge digestion. Generally speaking digestion is not carried to finality but increases the rapidity with which drying on sludge drying beds may be accomplished, and at the same time provides volumes of gas that may be converted into electrical energy by means of gas engines and reduce power costs on the treatment works.

As a result of a large amount of work that has been carried out the practical advantages of the application of this principle are now available and the author considers it may justifiably be claimed to-day that another stage in the whole process of sewage treatment and disposal is ready for being adopted as one of the accepted processes in the treatment of sewage sludge.

Nevertheless a considerable variation in practice and wide diversity of opinion exists as to the most efficient and economical method by which the process of digestion may best be accomplished.

Sludge digestion experience in the last few years on large scale plants has indicated that the rate of working of the anaerobic organisms can be increased by the employment of various devices that control such important factors as temperature, alkalinity and stirring.

STIRRING IN DIGESTION CHAMBERS.

Dr. Prüss asserts that the employment of mechanical stirring that keeps the sludge in circulation results in a considerable increase in gas yield, that it breaks up the surface scum, leads to smaller sizes in tanks and more than pays for the additional constructional costs incurred in its provision.

On the other hand Dr. Sierp suggests that the employment of stirring devices gives an increase in gas that consists largely of useless carbon dioxide.

The recent modification made by Dr. Prüss in employing stirring devices that include only the upper two-thirds of the digestion tank is an interesting variation in this practice.

At Essen (see Fig. 2, Drawing 5) the sewage is detained in settling tanks situated on each side and acting as insulation for the digestion tank, for a period of $1\frac{1}{2}$ hours and the settled sludge is lifted by means of a travelling pump into the digestion chamber. To allow of the ready transmission of the sewage temperature (16.5°C) to the digestion tank the walls separating it off from the settling tanks are only lightly built and the digestion tank has a storage capacity of 200,000 gallons.

The mixing of the fresh sludge with that already digesting is accomplished by means of two screw impellers that are brought into action over a period of 2 hours each day when the fresh batch of sewage has been admitted to the tank.

INSULATION AND TEMPERATURE CONTROL.

Heating of sludge digestion tanks is easily effected where separate sludge digestion is carried out and may be effected by the employment of steam coils, though considerable difficulties are being experienced in obtaining uniform distribution of heat over the whole volume of the sludge in the tanks owing to its low conductivity.

The maintenance of favourable conditions for the most rapid digestion is one of the principal difficulties in sludge digestion practice and the temperature at which the digestion is carried out considerably affects both the rate of digestion and the gas yield.

Experience indicates a lower limit to anaerobic activity of 10°C . and an upper limit of about 40°C . The optimum temperature, which varies but little under widely differing climatic conditions and is not necessarily the economic temperature for sludge digestion, seems to lie between 25° and 30°C .; the most rapid increases in digestion taking place when the temperature rises immediately above 18°C .

To ensure maximum efficiency in sludge digestion tanks, good insulation should be provided against loss of heat in sludge. Such insulation as is required is already there in the case of two-storey digestion tanks (Imhoff) (Fig. 1, Drawing 5), but the problem is more complex with separate digestion processes and in attempting to insulate tanks advantage has been taken of the low conductivity of the digesting sludge by placing a sludge jacket around the digestion tank or by employing some form of construction such as that employed by Prüss (Fig. 2, Drawing 5) that provides insulation to the digestion tank by placing the settling tanks on either side of it.

SEEDING AND pH CONTROL.

The anaerobic organisms have to be present in sufficient numbers to carry forward the process of digestion which increases rapidly as the sludge from the sedimentation tank starts to disintegrate, and in recent years experience has taught the value of correct pH control where acidity develops before that stage has been reached when natural processes effect neutralisation and has resulted in maintaining and speeding up the digestion processes, being particularly valuable where new works are being brought into operation by preventing an acid fermentation due to the fresh sludge before complete mixing with ripe sludge has taken place. The seeding of ripe sludge with the fresh incoming sludge before going forward to the digestion chamber is found to stimulate the digestion processes by providing and maintaining the conditions best suited to digestion.

METHODS OF EFFECTING SLUDGE DIGESTION.

Considerable difference exists between American practice and that opening up in this country; the higher water consumption in America per head per day (100 gallons) and the lesser degree of sedimentation and final purity required where dilution is practised extensively resulting in a smaller bulk of sludge having to be dealt with.

The Imhoff and single stage separate digestion tanks seem to have filled the need so far as general sludge digestion practice is concerned in America but, owing to the greater complexities introduced into the digestion of sludge in this country, and in order chiefly to prevent the rapid exhaustion of the gaseous products, a system of primary and secondary digestion in separate digestion tanks had to be considered, and at Birmingham (the largest separate digestion plant in the world) considerable experience has been gained with this type of digestion process.

At the Birmingham Works the sludge is allowed to remain in the primary tank (see Fig. 3, Drawing 5) until a certain stage is reached in the fermentation process, when the sludge is run off and pumped into secondary digestion tanks where it is

allowed to remain until most of the gas has been given off, when the sludge is run off to be further dried on sludge drying beds.

The separate digestion process is one in which the sludge that is withdrawn from the sedimentation tanks is digested in a separate tank as against the two-storey Imhoff method that seeks to combine both sedimentation and digestion in one operation.

When comparing the relative advantages of separate digestion tanks with two storey tanks the following factors should be taken into consideration and weighed carefully one against the other for any particular scheme under consideration.

TWO STOREY DIGESTION TANKS.

Advantages.

1. Little supervision necessary.
2. Freedom from nuisance (smell).
3. Tank insulated against variations in external temperature.
4. Small superficial area required.
5. Continuous withdrawal of sedimented sludge to digestion tank.
6. Higher calorific value of gas produced.
7. No power costs in removing sedimented sludge to digestion tank.

Disadvantages.

1. Deep excavations and high constructional costs.
2. Stirring and heating of digestion chamber not practicable.
3. No control over acid reaction of sludge.
4. Difficulty in efficient gas collection.

SEPARATE DIGESTION TANKS.

Disadvantages.

1. Larger amount of supervision necessary.
2. Less freedom from smell.
3. No method of insulation against loss of heat except at increased cost of construction.
4. Greater superficial area required for sedimentation and digestion.
5. Difficulty of effecting complete withdrawal of sludge from any type of sedimentation tank.
6. Gas produced of less calorific value.
7. High power costs in removing sedimented sludge to separate digestion tank.

Advantages.

1. Shallow excavation and low constructional costs.
2. Stirring and heating equipment may be employed.
3. Effective pH control possible.
4. Ready means available for gas collection.

GAS YIELD FROM VARIOUS TYPES OF DIGESTION PROCESS.

<i>Situation.</i>				<i>Digestion Process.</i>			<i>Cubic foot per head per day.</i>
Germany—							
Essen-Rellinghausen	..	..	..	Two-storey	..	..	0.21
Stuttgart	..	..	..	Two-storey	..	..	0.29
America—							
Charlotte	..	..	..	Separate	..	..	0.32
North Toronto	..	..	..	Separate with stirring and heating	..	..	0.67
Salem, Ohio	..	..	..	Separate with stirring and heating	..	..	1.38
England—							
Birmingham	..	..	..	Separate (Two stage)	..	..	.39 *
Bath	..	..	..	Separate	..	..	.53 †

* At the Birmingham Works only part of the gas is collected, and the volume of gas collected during the year ended 31st May, 1931, was 58 million cubic feet, and represented the primary digestion gas-yield from a population of approximately 400,000.

† This figure was obtained on an experimental plant, but under actual working conditions probably not more than 50% of this would be recoverable for use.

STAGE DIGESTION PROCESSES.

Perhaps the most important development in sludge digestion processes lies in stage digestion by which it is sought to separate the two reactions due to the separation of nitrogenous and carbonaceous solids.

Realising that a large proportion of inorganic solids are to be found in sludge that delay the digestion processes, attempts have been made to create a system that will remove inorganic sludge early in the process and hasten the digestion of the more organic part of the sludge.

On introducing the sludge into separate digestion tanks it will be found that there is a separation of the more settleable sludge (higher specific gravity) and by passing through a series of tanks and withdrawing at each stage only the rapidly settled sludge it is sought to speed up the process, and by shortening detention periods to effect digestion in a relatively short period.

THERMOPHILIC DIGESTION.

Probably the development in sludge digestion that is being most watched at the present time is that of high temperature (thermophilic) digestion. Experimental work by Rudolfs and others has shewn that the organisms affecting digestion and gas production work best at higher temperatures and so lessen the necessary period of detention in the digestion tank.

Working at 125° F. Rudolfs has been able to lessen detention periods by nearly 80 per cent. of those necessary where digestion is carried out at 74° F. and has after 48 hours digestion at this temperature (125°F.) found that organic solids were reduced by 50 per cent., after which time the rate of digestion slows down considerably.

Thermophilic digestion is as yet only in an early experimental stage and such important factors as control of alkalinity and organic nuisance, of effective insulation of tanks and of stirring of digesting sludge remain to be tried out on large scale units before the practical advantages of the system can be realised.

ACTIVATED SLUDGE SYSTEM OF PURIFICATION.

In the attempts that have been made to provide a "complete" process of purification, the nearest approach to success has without doubt been that achieved by the activated sludge and bio-aeration systems, and under favourable conditions they have been able to produce a clear, stable and well clarified effluent, and may be considered as the most important development in recent years in biological methods of sewage purification.

The system is essentially one that depends for success on the rapid cultivation of the aerobic organisms in the activated sludge and no importance is attached to anaerobic activity, little sludge being digested and any tendency towards septicity being detrimental to the efficiency of the whole process.

The aeration tanks see the breaking down and oxidising of the nitrogenous matter when the highly biologically active sludge is brought into contact with the incoming sewage and the aerobic bacteria working without the assistance of the anaerobic organisms avoid the preliminary stage common to the old septic tank.

The sludge obtained contains upwards of 98 per cent. water, is rich in nitrogen and phosphates and has a greater manurial value than ordinary humus sludge.

All sewages are not suited to activated sludge treatment and the process is particularly affected by some types of trade waste.

The hopes held out for this process in the earlier stages, that the process would cut out preliminary settlement entirely as well as subsequent treatment on filters, have now been largely abandoned—at least so far as this country is concerned.

Various improvements and developments that had been indicated by earlier experience are now being put into operation as is evidenced by modifications in diffuser plates, revolving vanes, adjustable cills, etc., and the general use of the continuous flow system over the earlier method of fill and draw.

TYPES OF ACTIVATED SLUDGE UNIT.

The mechanical system of obtaining agitation of the sewage and aeration by mixing with the atmosphere, employed chiefly as a stage process, is more practised in this country and on the Continent than in America where the diffused air system is employed extensively as a "complete" purification process.

Generally speaking considerably less detention periods are employed and a certain amount of flexibility in control is obtained with the diffused air method, but more

power seems to be devoted to maintaining the particles of sludge in circulation than to accomplishing actual aeration.

MECHANICAL SYSTEMS (SIMPLEX; HAWORTH (SHEFFIELD) AND HARTLEY).

Simplex (See Drawing No. 6).—It is the aeration tank that is of primary importance and it has a conical base with a central tube coned at the bottom and fixed just above the tank bottom. A revolving cone fitted with vanes is attached to the top and suspended from a vertical shaft being revolved from a horizontal shaft driven through bevel gears.

Rapidity of flow is maintained by the central uptake tube and as the cone revolves the liquid sewage is thrown out by the vanes in the form of a fine wave film, the sewage then moving downwards in the form of a spiral and fresh supplies of sewage rising up the central tube to take the place of that dispersed over the surface; the whole contents being circulated once in a period of 20 minutes.

As the sewage enters the aeration tank it is met by the requisite amount of activated sludge varying from 10-12 per cent. by volume.

In designing a plant a definite detention period is employed which is sufficient for purification to take place of the particular type of sewage to be dealt with.

Various refinements are now being adopted to obtain longer contact with the air and adjustable cills (see Drawing 6) are being fitted and so arranged that the level of the sewage in the aeration tank may be adjusted within limits that will give increased and controlled immersion of the revolving vanes when intensity of aeration and rapidity of circulation may be increased. This is a useful and much needed improvement and allows greater control to be exercised over the varying volume and character of the sewage received at the works.

Haworth (Sheffield).—This system employs a series of shallow bio-aeration tanks in parallel divided up into one long continuous channel about 4 feet in width and from 3—5 feet deep and by which a much larger tank area is obtained. The sewage flows along the channels at about $1\frac{1}{2}$ feet per second and aeration is obtained by means of paddle wheels situated centrally in the channels and propelling the sewage along and bringing it into contact with the air.

The Hartley System is a development of the above principle and the essential difference is that the paddles are inclined and fitted at the end of the channels to combat loss of head on the turn; in addition the system employs submerged baffles that extend diagonally part way across the channels and give increased contact with the free surface.

Both methods require long detention periods. (15 hours).

THE DIFFUSED AIR SYSTEM.

In this system fine bubbles of air are continuously blown through the sewage from diffuser plates fitted in the bottom of the tanks either in the ridge and furrow system or arranged along the side of the tank to give spiral flow, longer contact and reduced air consumption.

Detention periods are usually about 6 hours with an air consumption of 5-6 lbs. per square inch depending on the strength and character of the sewage treated.

COMBINED MECHANICAL AND DIFFUSED AIR SYSTEMS.

An interesting development in this type of process is to be found at the Recklinghausen Works (Germany) which combines both the mechanical and diffused air systems.

It consists of a long control shaft to which is attached a number of paddle wheels partly immersed in the sewage and which break up the surface film and increase the rate of aeration by carrying sewage into air and air into sewage. In addition to which diffused air is continuously intermixed with the sewage so that both artificial and natural means of aeration are obtained.

REACTIVATION.

One of the principal difficulties encountered in bio-aeration systems of sewage treatment has been that of keeping the activated sludge in good condition after it has been carefully built up, and the advisability of keeping a reserve supply of ready built up and conditioned sludge where the sewage is liable to be upset by trade wastes, etc., is being generally acknowledged. Reactivation tanks have been employed in the last few years of similar design to aeration tanks (Simplex) to maintain this ample supply of activated sludge in good condition and it has been found that the aeration process has given better results under variable conditions. The usual provision has been to provide reactivation tanks of a quarter the aeration tank capacity.

PRELIMINARY SETTLEMENT.

Preliminary settlement has been found advisable with many sewages particularly those containing strong trade wastes and to reduce trouble due to bulking of the sludge, etc.

Detention periods are usually short and of 20 to 40 minutes duration.

PARTIAL TREATMENT.

The rate at which oxidation goes on in any batch of sewage is very rapid during the first hour when as much as two-thirds of the purification may be effected but the rate of working thereafter steadily decreases until the relative efficiency of the aeration process is down to that of the percolating filter, and with this in mind the latter are being employed (in this country) with shorter detention periods in the aeration tank, resulting in reduced power costs, less tank capacity and an increased rate of working of the filters.

So far as future developments may be foreshadowed in this country it appears to the author that the future of the activated sludge system of purification lies in its use as a stage process rather than as a complete system of purification.

SETTLEMENT OF ACTIVATED SLUDGE.

The activated sludge settles out in upward flow Dortmund tanks (see Drawing 6) and as the sludge settles to the bottom of the tank the effluent rises to the surface and decants over cills into the effluent channels.

It is essential that the sludge should not be left either in the bottom of the tank or on the inclined sides otherwise bubbles of gas will appear and clots of sludge rise to the surface of the tank liquor.

The time allowed for settlement varies from 30-90 minutes but over 70 per cent. of the settlement takes place in the first 15 minutes and 80 per cent. in the first half hour, after which the rate of settlement slows down considerably.

The settled sludge is partly returned to the reactivation tanks and the aeration tanks, the surplus being drawn off by hydrostatic head for disposal.

SUBMERGED CONTACT AERATORS.

Submerged contact aerators have been introduced at some Continental works earlier in the process than the aeration tank with a view to increasing the surface contact of the sewage, reducing detention periods in the subsequent aeration tanks and preventing settlement of suspended solids from taking place. The agitation created is induced by means of air jets.

PUMPS AND PUMPING.

Considerable advances have been made in recent years in the design of pumps for use where the gravitational system of sewerage does not deliver the sewage at the works but to which it has to be lifted prior to treatment.

The use of steam and reciprocating pumps has been partly superseded by the employment of automatically operated electrical centrifugal pumps and ejectors that are better able to deal with sudden loads imposed upon them.

Stand-by petrol engines are installed on some works and interesting developments may be observed in the employment of crude oil engines of the Deisel type and where sludge digestion is practised provision is being made for the utilisation of the sludge gas by means of gas engines for supplying the power necessary for all sections of the plant.

The non-chokeable centrifugal pump is employed where large volumes of sewage are to be raised and the head to pump against is small. Specially designed strong impeller blades are fitted that are capable of dealing with crude sewage, and where discharge has to be made into the sea without preliminary treatment centrifugal pumps are now available that will break down the larger organic solids before discharge is made.

In designing pumping equipment it is essential that the equipment be able satisfactorily to deal with the peak flow and some works treating up to $6 \times D.W.F.$ (full and partial treatment) employ a series of three pumps of varying diameter that give considerable saving in power costs and are so arranged that the first is able to deal with up to the normal dry weather flow, the second together with the first will take up to $3 \times D.W.F.$ and the whole series of three will deal with the maximum flow of $6 \times D.W.F.$ in times of storm; but it is essential that, wherever pumping of sewage has to be resorted to, all possible storm water shall be kept out of the sewers.

Considerable developments have been taking place in recent years both in principles of sewage purification and disposal and in the design and operation of mechanical processes that seek to reduce the work of an objectionable character to an absolute minimum, and at the same time are leading to smaller areas of land being required and to a higher standard of efficiency and therefore a greater degree of purity being attained.

In the review that has been made of the various factors that are operating in sewage treatment and of the vastly changing principles that are governing the laying down of sewerage schemes the Author hopes that some small contribution may be made towards the solution of these difficult problems and to the general advancement of the whole practice of Sewerage and Sewage Treatment.

DISCUSSION.

MR. GRANVILLE BERRY (introducing his Paper) said: In tackling the whole problem of both sewerage and sewage disposal at the present time the principal difficulty is not so much one of inability either of the engineer or the manager to carry out the necessary works, as it is largely due to the lack of interest of members of local authorities and to a smaller extent of engineers themselves. I think this lack of interest is probably primarily due to the fact that so far no public recognition has been received of the value of sewerage and sewage treatment, and I suggest that at the present moment the time is opportune for sewerage and sewage treatment to be placed on the same basis as roads and road transport, and given an official send-off by the Ministry itself. At the present time large sums of money are being expended annually by local authorities on both sections of the subject, and the amount of knowledge and practical experience is rather small on the more difficult aspects of the problem.

In the realm of sewerage after you have carried out your most intricate calculations there is always a certain indeterminate factor still remaining, and the same holds good in the design of sewage works on the various schemes. I would suggest that to get over this difficulty some organised research is required at the moment that would co-ordinate the results of all local authorities who would carry out individual research in matters of sewage treatment and the hydraulics of sewer design, and would further co-ordinate the developments not only in this country but on Continental and American Works, in order that some distinct contribution may be made to the

development of the whole problem. Unless we have a large amount of research with regard to the dual problem I do not see that the economies that are called for at the present time can be attained.

There is a large amount of flooding in certain parts of the country at the moment; and in other parts, where no flooding exists; I would suggest that in many cases the fact that the sewers are able to take the sewage with no flooding is merely because they have been given such an abnormal capacity that they would be able to take twice the amount that they are called upon to take in normal times. Unless a more scientific method is developed and fostered in designing works of sewerage and sewage disposal, I do not think any economies are possible in maintenance or constructional costs.

I would like to mention one section of the Paper with regard to the desirability of having a more regional than local conception of the value of sewage and sewerage. I think that the time has come when small local authorities could readily take on the larger conception and realise that those functions they are carrying out are not so much their own but they are services that require to be treated on a more national basis; and if we can only get a larger amount of this regional conception of sewerage and sewage treatment, I think it would lead to greater efficiency and to larger economy in maintenance and reconstruction, and lead at the same time to a higher degree of purity being obtained.

MR. JOSHUA BOLTON (Bury), proposing a vote of thanks to the Author, said: Mr.

Berry points out that in past years people have been over sanguine of the virtues of new processes, and I quite agree with him on this point. In fact, at one time I began to worry as to whether my appointment would be secure because a scheme was put forward to dispense with sewage works. By simply putting one or two tabloids down the W.C. in the morning we were informed that the sewage would be completely purified in its passage through the sewers, and by the time it reached the outfall it would be sufficiently pure to enter the stream. I am glad to see so many of you still in office.

I cannot quite agree with the paragraph which reads: "It may be further stated (with considerable experimental justification) that the type of process adopted bears a definite relation to the percentage purification attainable and that maximum efficiency can only be obtained when the process adopted is found experimentally to be capable of dealing with the particular type of sewage requiring to be purified." I think instead of type of process Mr. Berry ought to have stated size of plant, because my experience teaches me that whatever sewage can be dealt with by percolating filters can be dealt with by activated sludge, or whatever sewage can be dealt with by activated sludge can be dealt with by percolating filters they are both biological processes. In the case of an activated sludge plant dealing with a sewage containing inhibitory trade wastes it would be most unreasonable to expect that the same detention period which is required for a domestic sewage would bring about a satisfactory effluent. On the other hand, if you attempted to put 100 gallons per cube yard of strong tank effluent on a percolating bed you would soon meet with disaster. This was realised long ago when the Royal Commission was sitting, and in the Requirements of the Ministry of Health, provision is made for greater capacities of percolating beds. Nearly three times as much being required for a strong sewage as is required for a weak sewage, and I think you will find in both processes that the size has to be more or less proportional to the strength of sewage.

At Bury we have for years plotted curves of analytical results from activated sludge and percolating beds, and they have kept remarkably close together during the whole period.

Further on in the Paper Mr. Berry refers to the difficulty of obtaining media for percolating beds, and mentions gravel, stone and slag as alternatives to clinker. I should like to draw attention to the amount of available coke from the low temperature carbonisation plants. This can now be obtained graded to any suitable size. It is quite hard and its lightness renders it a cheap and effective medium. Recently I have been able to get excellent coke laid in percolating beds at 10s. per cube yard, which compares favourably I think with any other media.

Mr. Berry seems rather inclined to think that a greater head is required for travelling distributors than that required for revolving distributors. This is quite true if the travelling distributor is to be self-propelled, but with an electrically propelled travelling distributor the head is actually less than that required for a revolving one. Particularly if you have to deal with normal up to three times the D.W.F.

There are several things in favour of electrically propelled distributors. You are not subject to stoppages with low flows, and stoppages through wind pressure. The power taken is only 1 H.P. per acre of bed, so a halfpenny per hour per acre would supply all the power required a low figure for the advantages obtained.

MR. L. F. MOUNTFORT, seconding the vote of thanks, said: The question of sewerage is not one with which members of sewage works usually have much to do. It relates more to the design of the plant which conveys the sewage down to the purification works, but as the Paper deals with a good deal of that side of the question I would like to make one or two remarks upon it. First of all, with regard to the formula which Mr. Berry introduces in regard to the question of rainfall intensity as compared with duration. That of course is a well-known formula, and is the one we generally adopt. But we must remember that after all it is an empirical formula, and in using formulae of that type it is very important to realise not only their use but their limitations. The limitations are possibly more important than the uses. If we take a formula of the type

$R = \frac{a}{T + b}$ that formula of course represents the average intensities of storms of

various durations. It has been found that the longer the duration of a storm the less is its average intensity. We can of course use this formula, assuming we have our correct constants, to find out the total amount of rain brought down in any particular storm. If we have a storm which has the average intensity given by that formula and which lasts for T minutes, the intensity being expressed by R inches per hour, we have only to multiply the expression here by $\frac{T}{60}$ which

is the total time, and we get the total rainfall in inches during that storm. When you put the formula into that shape you find you have a formula which has this peculiarity, that it definitely limits the total amount of rain that can fall in a storm no matter how long it lasts. That I think will show us the artificiality of that formula.

Regarding the data at the bottom of the sixth page, and these two formulae are the usual ones taken, and I believe recommended by the Ministry for adoption, if we take the second one as applying to storms of usual duration we find that if we multiply that formula by $\frac{T}{60}$ no matter what value

we give to T , a storm can never bring down more than two-thirds of an inch of rain. Now storms in my experience which bring down more than two-thirds of an inch of rain are of fairly frequent occurrence. I have known them to occur two or three times at least every year, and I suggest for that reason perhaps these particular values of the constants given in that formula and the results obtained from that formula may be found in many cases to be on the low side, because you certainly get a bigger precipitation in any storms than is obtained by that formula.

I would like to say a few words on the formula for the design of sewers, and the general design of sewers. The Author gives one or two formulae. They are all very well known to engineers who have to design those works. He has given us the Chezy coefficient corresponding to these various formulae, and we see there is a considerable variation amongst them. The science of hydraulic engineering, especially applied to sewers, must be largely empirical; you cannot devise any purely rational formula

to take account of that sort of phenomenon. It is perhaps fortunate that pipe sewers are made in certain standard sizes, and when the engineer enters his table or his diagram for a size of sewer and finds, for example, that he wants a pipe 22½ in. diameter, he will naturally put in the next largest size, and that is the way he gets over the difficulty. When we consider that for a given gradient the quantity will vary as the fifth power of the diameter, the putting in of the next size makes a considerable difference to the quantity of sewage which can be brought down, a difference usually far greater than would be accounted for by any uncertainty in the coefficient.

With regard to the general design of sewers to bring down both sewage and storm water, the Author suggests that a trial and error method is the usual one to adopt. Of course we do have to do that I admit, but there is one very general rule which we bear in mind in designing sewers which have to bring down a great amount of flood water, especially when you have, as in this case, to maintain a self-cleansing velocity. That is that the gradient of your sewer must be determined by the minimum flow, and the size of your sewer by the maximum flow. Now if you know what your minimum flow is and you know what your self-cleansing velocity is intended to be you can immediately find the gradient of that sewer without bothering about the size. You do not need to bother about the size until you deal with the maximum flow that is coming down the sewer. There is a method I have found useful myself, and it may commend itself to others. If you take a sewer which is flowing half full at a particular gradient you can discharge that same quantity on that same gradient through any larger size of sewer without appreciably affecting your velocity. Now that gives you a method at once of determining what your gradient must be. If you have your minimum flow you can find out the gradient of a sewer which would bring that minimum flow when running half full. That must be the minimum gradient of the sewer you put in, no matter what larger size it may be. If that is done, even when you have the small quantity flowing down the larger size of sewer you will still obtain your self-cleansing velocity.

I would now like to deal with the matter

under "Quantities of sewage to be allowed for," and at greater length under "sewage treatment." Under the former heading there are three things placed down: a, b and c; the two first are bracketed together and they are called dry weather flow; the third one is referred to as infiltration water.

Now, surely it is rather a moot point as to whether your dry weather flow should not include your infiltration water. The design of your scheme must in the long run be based upon a combination of quantity and strength. When you are designing a scheme for a certain dry weather flow you naturally want to know what the strength of the sewage is to combine with your dry weather flow, before you know what to do. How are you to ascertain the strength of your dry weather flow if it is not to include infiltration? The only way you can gauge it is to take a sample of the water that is coming down, and the infiltration is included, therefore the sample upon which you base your calculations must include infiltration water. Therefore if you design a sewer based on that calculation you must include the infiltration with the dry weather flow. One disadvantage of including the infiltration in the dry weather flow is that your dry weather flow ceases to be a solid foundation on which you can build and becomes more or less a quicksand. The dry weather flow taken in any sewer is usually calculated over a week in which there has been no appreciable quantity of rain. In the case of a sewer containing a fair amount of infiltration water, you can do that throughout any year and in as many weeks as you like, and in no case that I am acquainted with will you get a comparable dry weather flow; it varies in every week in the year. So for that reason the dry weather flow in any one week is not a very safe basis on which to design a scheme.

I am glad to see that the Author has introduced the nomogram as a method for determining the size of sewers. The nomogram is a very handy idea, and it commends itself very much to engineers as being so simple to use.

Now one or two matters in connection with sewage treatment itself. Referring to sludging of large open type tanks, the Author says: "This type of settling tank is usually built in large units and the manual sludging of a pair of preliminary tanks of average

size may be found to occupy as much as one week and of secondary settling tanks one and a-half weeks in fine weather." Later he says: "The average loss of capacity on tanks from which the sludge has to be cleaned out by manual labour is in the nature of 25 per cent. of the total tank capacity by reason of this accumulation of sludge between sludging operations."

Now I have several large open tanks and they are cleaned by manual operations in that way, and I can assure Mr. Berry that it does not need anything like that time to do the work. I find the total average reduction of capacity in my tanks, due to decanting the supernatant water removing the sludge and filling up again, does not amount to more than 10 per cent. of the tank capacity, and I think there is no reason why it should be any greater. The Author says: "Many interesting developments in both design and construction have been taking place in recent years and at the same time a new conception has been taken on of the whole process, it being realised that the process is not so much one of filtration but a biological process dependent on the maintenance of ample oxygen supplies for the aerobic bacteria to do their work."

Is it only of recent years that this conception has been taken; is it only of recent years that we have realised that a bacterial filter is not a mere filter of the sewage? Surely that principle has been realised ever since we had a biological purification plant.

MR. A. J. MARTIN: The Author says that a self-cleansing velocity for sewers may be 3 ft. or 2½ ft. per second. I think anyone who looked into the subject would be surprised to find in how few sewers in this country you get these velocities with the ordinary dry weather flow. In order to get them you would often have either to put in pumping stations or to lay sewers at a great depth in water-logged ground, and if it is a choice between spending money in that way or putting up with a lower, but still a self-cleansing velocity, I think one would be satisfied with the latter.

He says that egg-shaped sewers have of late tended to fall into disuse. It has always seemed to me that the advantages of an egg-shaped sewer were over-rated. I had occasion, many years ago, when I was very severely limited for fall, to look into the

question of putting in an oval sewer, and I found to my astonishment that instead of getting a better velocity in the oval sewer I got a worse one. It arose in this way: the cross section of my oval sewer would have been 15 ins. deeper than that of the corresponding circular sewer. That 15 ins. would of course have to be taken out of the available fall, thereby flattening the gradient. I should therefore have got a worse velocity in an oval sewer than I did in the circular sewer.

I am entirely with the Author in deprecating the design of detritus tanks on the basis of capacity. The essential point is to get a proper velocity. I should like to ask why it is that in installations where there are a number of detritus tanks they are so often made all of the same size. Consider the object of a detritus tank: you want to be able to proportion the capacity in use at any moment as nearly as possible to the flow. If you put in four tanks of the same size you can only have capacities of the order of 1, 2, 3 and 4. I always vary the depths of my tanks: I make the second one twice as deep as the first, and the others four times and eight times as deep respectively. By so doing one can get capacities of 1, 2, 3, 4, 5 and so on up to 15. I venture to suggest that that is the proper basis on which to design detritus tanks.

With regard to storm overflows, it is a very common plan, I believe, to put an overflow weir at the entrance to your works which will come into operation immediately the flow exceeds three times the dry-weather rate. I refer to the weir that separates the ordinary sewage from the surplus flow which is sent through the storm-water tanks. Even in dry weather you may get a flow at certain hours in the morning at three times the average dry-weather rate. If you have a flushing tank on the outfall sewer the overflow weir would often come into operation in perfectly dry weather. I have never, therefore, so far as I can remember, put in an overflow weir which is brought into operation by a momentary excess in the flow. I regulate the outlets from my tanks so that they can take up ten or even twenty times the dry-weather flow for 20 minutes or half an hour while the first foul rush is coming down, before the overflow weir comes into operation.

There was rather a craze a few years ago for glass-covered sludge beds. I think experience has shown that the advantages of a glass-covered bed are overrated. In the first place, if you spend a certain amount of money you can either put down one square yard of glass-covered beds, or, with the same money, three square yards of ordinary open beds, and on the latter you can probably deal with at least three times as much sludge as you can on your glass-covered beds. Moreover experience during the last few years has shown that rain is not such a hindrance to the drying of digested sludge as had been supposed.

The Author refers to aeration tanks. Some 15 years ago, in an article in "The Surveyor," I pointed out that the cost of working the activated sludge process was largely due to the amount of power required to keep the sewage moving at a given velocity, and to keep the sludge in circulation. I pointed out that in an outfall sewer you have that velocity provided free of charge; and I suggested that instead of putting down very expensive aeration tanks you should pump your activated sludge back some distance up the outfall sewer and use that sewer as an aeration tank. I also suggested that in order to bring fresh surfaces into contact with the air by means of a spiral flow you should put in deflectors or equivalent devices. I was therefore gratified to find that our President is adopting that principle in his latest works. It is true that he is not using his outfall sewer as an aeration tank, but he is building an aeration tank with a succession of channels with no mechanism for producing a velocity, but simply utilising the fall in the channels. I suggest that he might go further and instead of putting down any tanks at all that he utilise his outfall sewer as an aeration tank.

MR. HICKS: A couple of years ago in one of our Institute's examination papers there was a compulsory question in which was given the size of a number of filter beds and the character of the sewage, and you were asked to estimate the population of the district—a very interesting question, and one in which you had to know the particular requirements of the Ministry of Health. I handed that question to quite a lot of sewage works managers and I got quite a variation in the numbers of the population in the

district, because there evidently existed, and still exists, quite a vague conception as to what is meant by the three times dry weather flow in the calculation of the size or cubic capacity of your filter beds; and in fact I believe the design now is that your filters, which pass say 100 gallons per cubic yard per day do that in normal dry weather flow and pass up to 300 gallons per cubic yard per day with three times dry weather flow. I would like Mr. Berry to confirm me in that, as I am not absolutely certain. I would also like him to explain exactly what he means by the statement that sufficient capacity will be provided if the cubical contents are calculated on $1\frac{1}{2}$ dry weather flow. In connection with activated sludge purification I think he has made a mistake; that he has landed himself in the position of distinguishing between methods of activated sludge purification. He says: "In the attempts that have been made to provide a 'complete' process of purification, the nearest approach to success has without doubt been that achieved by the activated sludge and bio-aeration systems."

Now if you carry that argument through and you separate the activated sludge systems you get this further on in the Paper: "One of the principal difficulties encountered in bio-aeration systems of sewage treatment has been that of keeping the activated sludge in good condition." Obviously, if you read right through you have not got the same difficulty with an activated sludge system that you may get with a bio-aeration system.

There is another question Mr. Berry mentions: "Preliminary settlement has been found advisable with many sewages, particularly those containing strong wastes, and to reduce trouble due to bulking of the sludge."

Does Mr. Berry suggest that it is possible to reduce bulking in an activated sludge system by preliminary settlement, and if so could he give figures to justify that statement. He goes on to speak about the partial treatment and the relative efficiency of the aeration process, and says: "The rate at which oxidation goes on in any batch of sewage is very rapid during the first hour when as much as two-thirds of the purification may be effected, but the rate of working thereafter steadily decreases until the relative efficiency of the aeration process is down to that of the percolating filters, and with

this in mind the latter are being employed (in this country) with shorter detention periods in the aeration tanks, resulting in reduced power costs, less tank capacity and an increased rate of working of the filters."

From that, can I take it as an assumption that you have to design your plant first of all to give you the most efficient purification in your two sections: the high efficiency of the activated sludge in the first section, followed also by a higher efficiency in the second? If so, does an activated sludge with a percolating filter following give you a greater over-all efficiency than maintaining both separately? It is a very vexed question; he goes on, "So far as future developments may be foreshadowed in this country it appears to the author that the future of the activated sludge system of purification lies in its use as a stage process rather than as a complete system of purification."

That is where the importance lies so much. Are we to assume that our future line of development is to be on the basis of varying our treatment in sedimentation tanks followed by an activated sludge system, followed by a percolating filter, or is it not rather the suggestion that in view of the fact that so many authorities are going in for "full purification" schemes that full purification by activated sludge alone is preferable. In Manchester you have a 16 million gallon plant with full treatment for full purification.

I am interested to know that he is suggesting that in the system of mechanical aeration involving a cone he instances being able to move the pills up and down to give you greater rapidity of circulation in your cone. But I have heard that it is possible to move the cone itself and thus get greater aeration in that manner.

MR. GRANVILLE BERRY, in reply, said: With regard to Mr. Bolton's suggestion regarding the relation of percolating filters, and what he calls the bio-aeration system, I think people who have experience of trade wastes on the two types of plant will have found that they are better able to look after their plant with percolating filters under varying conditions when subject to trade wastes than they are with bio-aeration systems. There is an essential necessity, generally speaking, so far as my experience goes, for having a preliminary settlement

prior to going through what Mr. Bolton calls bio-aeration systems.

Mr. Mountfort seemed to be under the impression that was held about fifty years ago, that the total volume of rain received on an area is a determining factor. One idea I had in writing this Paper was to try and explode that idea, and a lot of the ideas that have been held, and are held at the present day, as to the methods of design of sewerage systems. The amount of rainfall does not matter, it is the question of intensity that is the primary matter. I think that is logically borne out in the method of treatment here in the Paper. I agree with Mr. Mountfort that the formula given is not the only one, but it is recommended by the Ministry and probably gives the most accurate results. The formula he quotes possesses the same disadvantage he mentions.

The question of infiltration I agree should be included with the other two sections. I think you will find it is more in the nature of a printer's error, and I think you will find that I include the three sections together in the second half of the Paper.

On the question of the time required for manual sludging with the old type of tank, Mr. Mountfort seemed to dispute the period taken. All I have to say is that the time is that actually taken on works I am acquainted with; and I think you will find many members of your Institution are quite prepared to bear me out on that point.

As to Mr. Martin, I think the value I have suggested in the Paper may be taken as desirable from a self-cleansing standpoint; though, naturally, with the different areas one has to deal with, one cannot always have either the maximum or minimum condition one desires.

Then Mr. Hicks on the question of the cubical contents. I think the method outlined in the Paper can be taken as being generally accepted as far as the engineering side goes, in making allowances in dealing with percolating filters at the present time. He mentions that I made a grave mistake in not distinguishing between activated sludge and bio-aeration. Well, if I had been bringing forward this Paper before some people who had no knowledge whatever of sewage disposal I should have gone to great length to tell them exactly what is the difference. But assuming, as I do, that the

people here are conversant with the differences, and that generally speaking they refer to those subjects themselves in those terms, I think you will quite understand the meaning in the Paper.

On the question of bulking, I am conversant with one works in particular where on the installation of the bio-aeration system a considerable amount of trouble was found due to bulking, and it has been found possible by means of preliminary settlement to reduce the occurrence of that phenomenon. I think that is borne out by other works. The suggestion seemed to be made that we could not quite get to know what percolating filters were to be used for on the bio-aeration *cum* activated sludge method. Well, I think you will find that, generally speaking, the tendency to-day is to make this aerating system definitely one of a partial method of treating sewage. I can point to many large works in the country which have just been constructed, which some of you may have seen, and they are definitely working on that principle; there is one large works dealing with a population of 100,000, and they are retaining their old settling tanks and replacing their percolating filters by the bio-aeration system. The experience we have had at Nelson in regard to the method of bio-aeration treatment of sewage was that it merely meant that we could treat the normal amount of which we were capable under normal conditions with better results by taking the system and operating it over a certain period, and then putting the whole volume through the percolating filters. That is an experience that has been borne out in the rest of the country. But I think it is right to assume that for many years to come the method must essentially be a partial method rather than a complete process, to get any success. One has to make certain in laying down works that the works will be able to deal with the sewage. You know there are one or two places, even in this country, where new methods have been introduced and where when they have been put into operation they have failed; and from the engineer's standpoint, if the only works you can put down are modern works which fail, then you are not going to be of much use to the local authority. You have to be on the safe side from a practical standpoint.

The following Paper was taken as read :

The Logical Design of Separate Sludge Digestion Plant, and its Effect upon other Phases of Sewage Treatment.

BY

A. S. LOWE, B.Sc., A.M.Inst.C.E.

(NOTE.— This Paper was submitted for the open competition arranged by the Congress Committee, and was awarded a Special Prize of Five Guineas).

THE liquid effluent from a sewage plant can be purified to almost any desired degree by a variety of means without aerial nuisance and upon a reasonable area of ground.

For many years now the sludge problem has been the major problem. Its disposal has been attended with serious nuisance and where, as in the majority of cases, lagooning or drying on beds is practised the area of land required is immense.

Sludge digestion, properly conducted, offers a complete solution of the nuisance problem and very greatly reduces the area required for drying beds.

Sludge digestion in separate tanks, although first practised in this country has made very slow progress in the subsequent 20 years and development has lagged behind that of other countries, notably Germany and the United States.

The reason for this is that the pioneer plant, at Birmingham, was necessarily of the open tank type and subsequent plants have been modelled as closely as possible on this successful plant, without much attempt at providing the conditions which experiment and experience have shown to be requisite if the process is to be kept under control and to operate successfully on any but the most amenable sludge.

KNOWN OPTIMUM CONDITIONS.

The following are the conditions known to be best for methane digestion :—

- (1) Temperature 80° F.
- (2) Alkalinity pH 7. or above.
- (3) Moisture content low.

- (4) Feed : The raw sludge should be introduced in small quantities at a time and should be fresh.
- (5) Inoculation : The raw sludge must be brought in contact with a sufficient quantity of " seed " or digested sludge. The determination of this quantity will be referred to later.

It is also established that if the temperature is maintained at 80° F. and also a sufficient body of seed sludge is present and readily available to the raw sludge then the correct pH value will be maintained.

OPEN TANKS.

The use of open rectangular tanks of considerable area for digestion has several important disadvantages.

- (1) The temperature cannot be maintained at the optimum of 80° F. In winter the temperature may fall so low that digestion will be in danger of ceasing altogether. An acid condition of the sludge, foaming and other troubles may develop as a consequence.
- (2) A thick scum forms on the surface of the sludge, and although this may be beneficial in preventing loss of heat it interferes with the uniform production of gas and delays the complete digestion of the sludge.
- (3) Layers of water form at varying depths in the tanks and the decantation of this water, with consequent thickening of the sludge is almost impossible.
- (4) Banks of inert material form in the tank and have to be cleaned out by hand, involving the emptying of the tank. This may be reduced to some extent by adopting primary and secondary tanks and making the primary of such size that the sludge passes out of it before it has exhausted its gas forming material and become inert*. By this means the secondary tank collects most of the inert matter. Even with this arrangement, however, due to short-circuiting and also the presence of some inorganic particles in the sludge, silting up of the primary tank will also occur.
- (5) Since the raw sludge is introduced at one end of the tank and the digested sludge drawn off at the other, it is obvious that although a large body of ripe seed material may be present in the tank it is not at all readily available to the incoming raw sludge. For this reason it is necessary to pump back some of the seed sludge to the influent and mix it with the raw sludge.
- (6) Collection of gas by floating covers is expensive and much of it must be lost.

For these reasons the capacity required in open digestion tanks is very large and uncertain, 5 cubic feet to 8 cubic feet per head of population being found necessary

*Whitehead & O'Shaughnessy on "The Treatment of Sewage Sludge by Bacterial Digestion," (Proc. Inst. C.E., Vol. 233, Pt. I).

under varying climatic conditions. They are consequently costly unless constructed in the roughest possible way. The operation of the process in such tanks must be uncertain and requires close and skilled attention to maintain. The labour required for periodic cleaning out and pumping charges for recirculating seed sludge are considerable.

HEATED TANKS.

In order to provide the first of the optimum conditions for digestion it is necessary, in all but tropical countries, to add heat to the sludge.

The sludge may be heated before entering the tank and/or heat may be added to the sludge while in the tank, either by adding hot water or by arranging heating coils in the tank.

All three methods have been tried in Germany and heating coils in the tank are now general in that country and America. Thick sludge being an essential requirement for alkaline digestion the addition of hot water was clearly undesirable. The fear which was held for some years that the heating coils would become caked with sludge and so lose their efficiency was found to be unfounded provided the water circulated in these coils was not raised to more than 120° F. The possibility of corrosion of the coils was also found to be slight, ordinary galvanised iron pipes being found best for this purpose.

Whichever method of heating is adopted it is essential that the loss of heat from the sludge must be prevented as far as possible, otherwise the amount of heat required will be uneconomical. A closed top tank therefore becomes necessary.

For this reason the shallow rectangular tank is unsuitable on account of the high cost of roofing it and deeper tanks were tried, the circular form being adopted for reasons of economy in construction.

This form also has definite advantages in connection with the fifth of the optimum conditions already mentioned, since if the feed is at the top and the draw off of digested sludge at the bottom the requisite seed material is present vertically beneath the raw sludge and is continually and automatically brought in contact with it by the action of the gas evolved, which raises particles of digested sludge to the surface.

In Germany Dr. Prüss places an impeller and draught tube in the tank to intensify this action by completely circulating the tank contents. This has the undesirable effect of mixing raw sludge with the digested material which is about to be discharged and we believe that Dr. Prüss has now modified the system so as to stir only the upper part of the tank contents.

Another device to the same end is a submerged hood and draught tube in which the gases collect and act as a lift to circulate the sludge up the centre and down the sides of the tank.

It is doubtful whether vertical circulation serves any useful purpose except perhaps in starting a new tank, since it is proved that the natural action of the gas effects all the seeding necessary.

Another advantage of the circular shape of tank is that a thickener mechanism can be installed which by gentle stirring of the sludge prevents the formation of water and sludge strata and allows the solids to thicken at the bottom of the tank while the water separates to the top and can be overflowed. Where such a mechanism is used the fully digested sludge is mechanically discharged to a central sump, the bottom of the tank being flat. This arrangement is preferable to a hopper bottom, both on the score of cost and also because the digested sludge is heavy and of high mineral content, which makes a positive discharge desirable. This increase in gravity of the material as it digests assists the natural thickening action in a deep tank.

A deep tank of relatively small area also makes it very much easier to prevent scum formation than a tank of large area.

The vertical circulation of some or all of the tank contents before mentioned is an effective method of preventing scum formation, but where a thickener mechanism is employed scum formation is easily and effectively prevented by means of horizontal arms secured to the thickener shaft in such a way that they revolve within an inch or two of the under side of the roof.

Any particles which become gas-borne and rise to the surface to form scum are broken up by these arms, lose their gas, and at once fall back into the mass of digesting material where their active digestion continues instead of remaining at the surface as an inert scum.

For this and other reasons the liquid level in the tank is normally kept against the underside of the roof, whether the latter is fixed or floating. The question of floating roofs will be referred to again later.

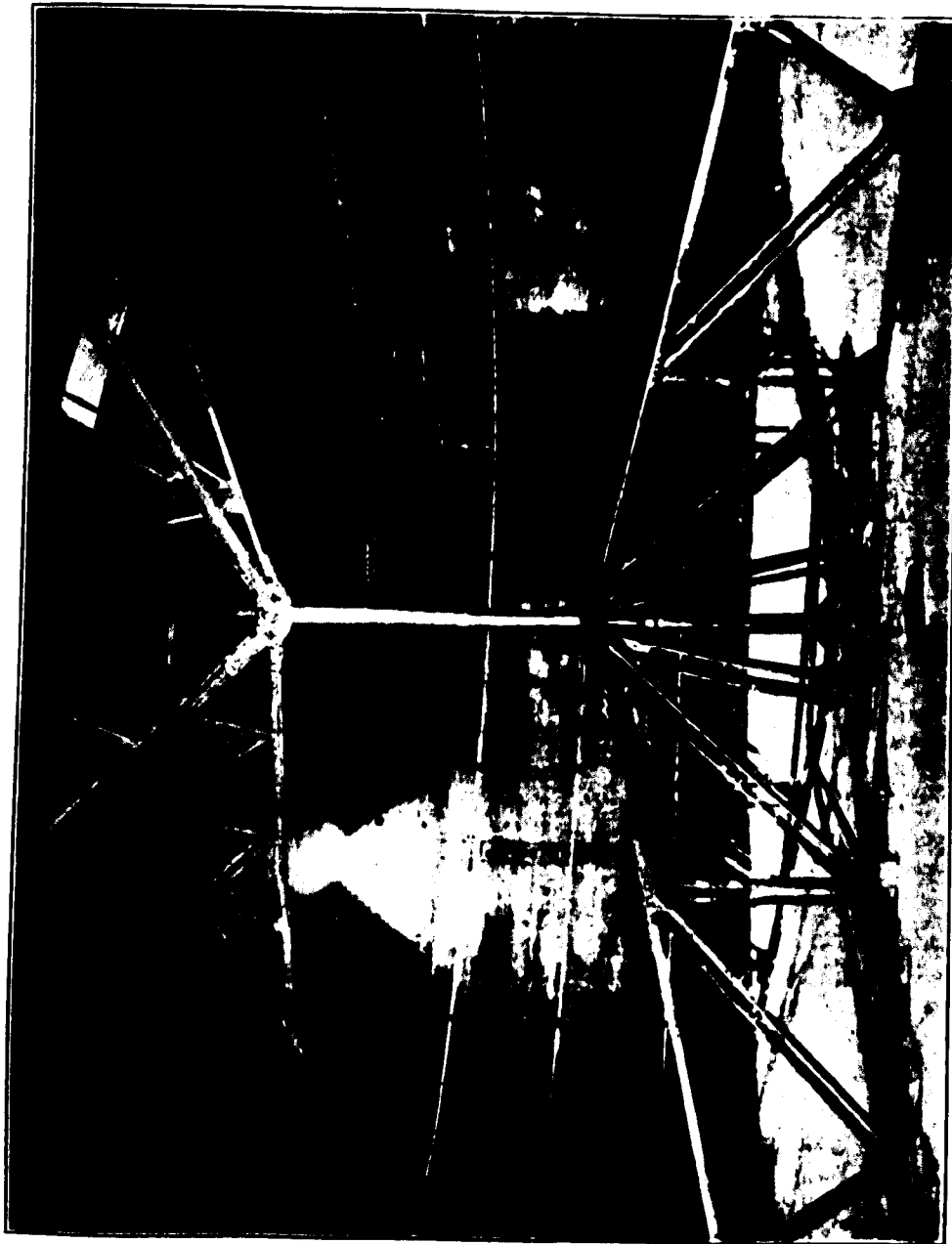
These arms, together with horizontal splash baffles on the outlet of the sludge feed pipes in the roof, effect a very good distribution of the raw sludge over the whole area of the tank.

The adoption of a relatively deep cylindrical tank is therefore one of those rare cases where ease of construction happens to coincide with the best form for technical purposes, since it provides a solution to all the difficulties inherent in the open digestion tank by allowing :—

1. The optimum temperature to be maintained economically.
2. The prevention of scum formation.
3. Decantation of water and thickening of sludge.
4. Easy removal of the digested material without recourse to secondary digestion and without any hand labour.
5. Ready seeding of the raw sludge.
6. Collection of all the gas evolved.

CAPACITY OF HEATED DIGESTION TANKS.

Since the digestion process properly carried out under optimum conditions in heated tanks with sludge thickener and scum breaker is a controlled process independent of any outside circumstances, except the nature and condition of the sludge which with well designed sedimentation units should be constant within



Inside of a Digestion Tank fitted with Heating Coils, Scum Breaker and Thickener.

(Reproduced by courtesy of The Dorr Company, Ltd.)

reasonable limits, it should be possible to determine closely the digestion tank capacity required in any particular case.

On Graph No. 1, A illustrates the reduction in weight experienced by 1 lb. of dry volatile matter by digestion at 80° F. in a given time and shows that practically full reduction takes place in 40 days, the reduction after this period being so slow as not to be worth while attempting in practice.

B shows the cumulative weight made up by adding 1 lb. of inorganic matter per day and is, of course, a straight line, and C, the cumulative weight made up by adding 1 lb. of volatile matter, which digests, per day.

The difference between B and C is due to the progressive reduction in weight of the volatile matter by digestion at 80° F.

Graph II illustrates the effects both of digestion and of thickening upon the volume occupied by volatile and inorganic matter.

A shows the cumulative volume occupied if 1 lb. of inorganic matter is added per day if the water content remains constant at 93 per cent. and is, of course, a straight line.

B shows the increase in solids concentration under the action of the thickener in a given time.

C shows the cumulative volume occupied if 1 lb. of inorganic matter is added per day at 93 per cent. water, the difference between C and A, being due to the progressive thickening.

D shows the cumulative volume occupied if 1 lb. of volatile matter is added per day at 93 per cent. water under the action of digestion at 80° F. and thickening. The difference between D and C is due to reduction by digestion.

E shows the cumulative volume occupied if 1 lb. of volatile matter is added per day if the water content remains constant at 93 per cent. water. The difference between E and D is due to thickening only.

With this information and knowing the quantity of dry solids to be dealt with in the digester per day and the percentage of volatile matter in these solids it is possible to calculate the theoretical capacity required in the digestion tank. (Where trade wastes likely to be inimical to digestion are present a test of the digestibility of the volatiles and comparison with Graph I A will allow of the necessary adjustments being made).

Example 1.

Population, 10,000.

Dry solids per capita per day, .15.

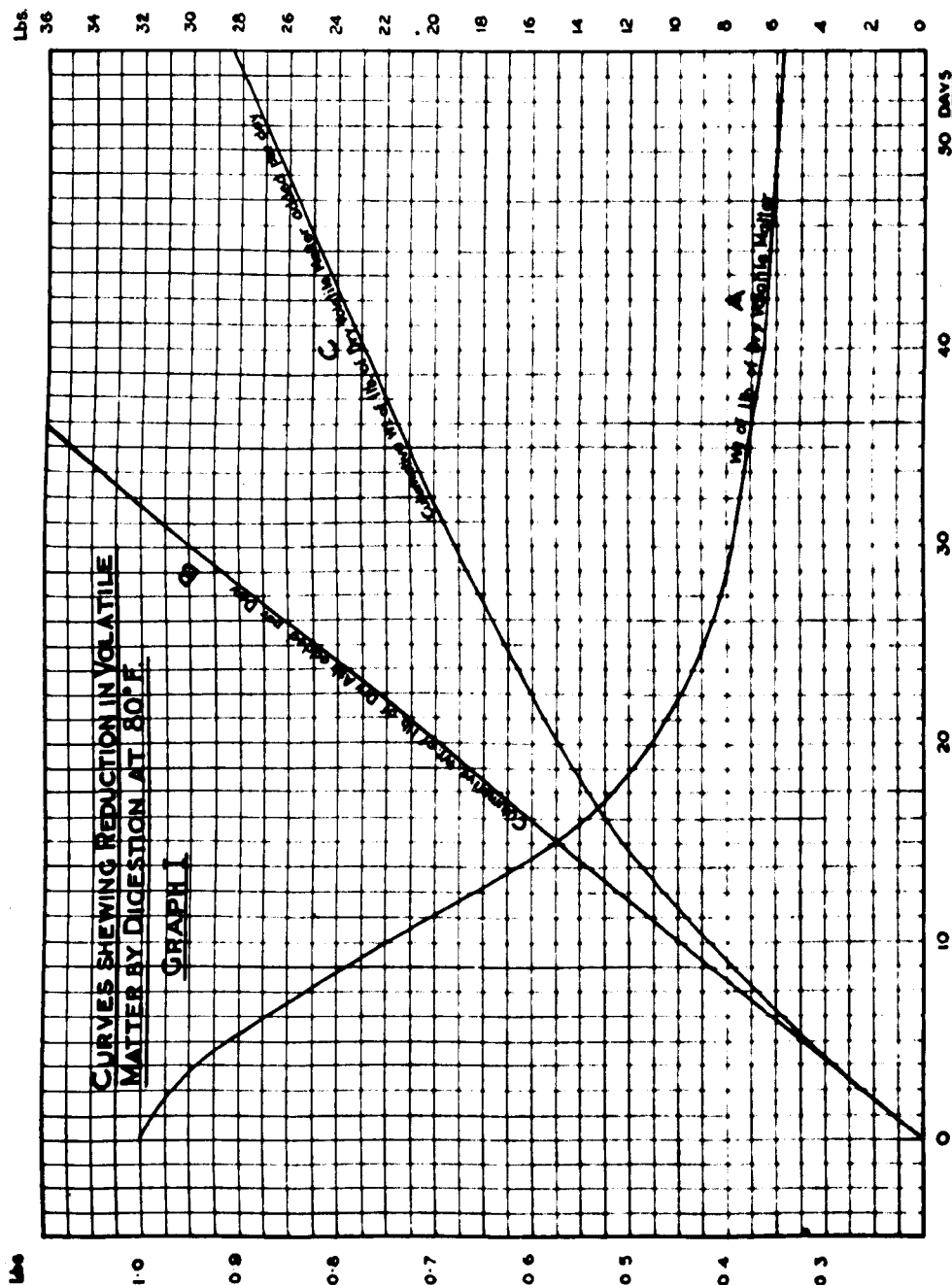
Recovery, 90 per cent.

Volatile matter in the solids, 75 per cent.

Then the total solids per day in sludge, $1,500 \times .9 = 1,350$ lbs.

of these Volatiles, $1,350 \times .75 = 1,012$ lbs.

and Ash $1,350 \times .25 = 338$ lbs.



Cumulative capacity required for 40 days in digester :—

For Volatiles (Graph II D) $1,012 \times 4 = 4,048$ c. ft.

For Ash (Graph II C) $338 \times 6.75 = 2,280$ „

Total 6,328 „

This is equivalent to .63 c. ft. per head of population and compares with the capacity of .90 c. ft. per capita which Dr. Imhoff finds satisfactory in this type of tank at Essen.

A recent review* of the capacities of heated digestion plants actually in operation reveals that in most cases this capacity is much exceeded. On Graph III these capacities have been plotted against population and as cubic feet per capita. From this it will be seen that about 1.5 c. ft. per capita has been adopted in almost every case.

1.5 c. ft. per capita on a population of 10,000 = 15,000 c. ft.

Subtracting the capacity found in Example 1 = 6,328 „

The space available for additional seed sludge = 8,672 „

In experimental work it has always been found that if a quantity of volatile seed matter is added to the raw sludge, equal to the volatile content of the raw sludge added, inoculation takes place and digestion is readily initiated.

Therefore, neglecting the seeding value of the digesting sludge present in Example 1, we have the following, if it is desired to provide this amount of ripe volatile seed material :—

At the end of 40 days digestion the volatiles have been reduced to 37 per cent. of their original weight (Graph I A) so the 1,012 lbs. have been reduced to 375 lbs.

The ash, of course, remains at 338 lbs.

To supply 1012 lbs. of seed volatiles for 1012 lbs. of volatiles in the raw sludge added on the 41st day we require digested sludge containing $1012 + \left(\frac{1012}{375} \times 338 \right) = 1927$ lbs. of dry solids.

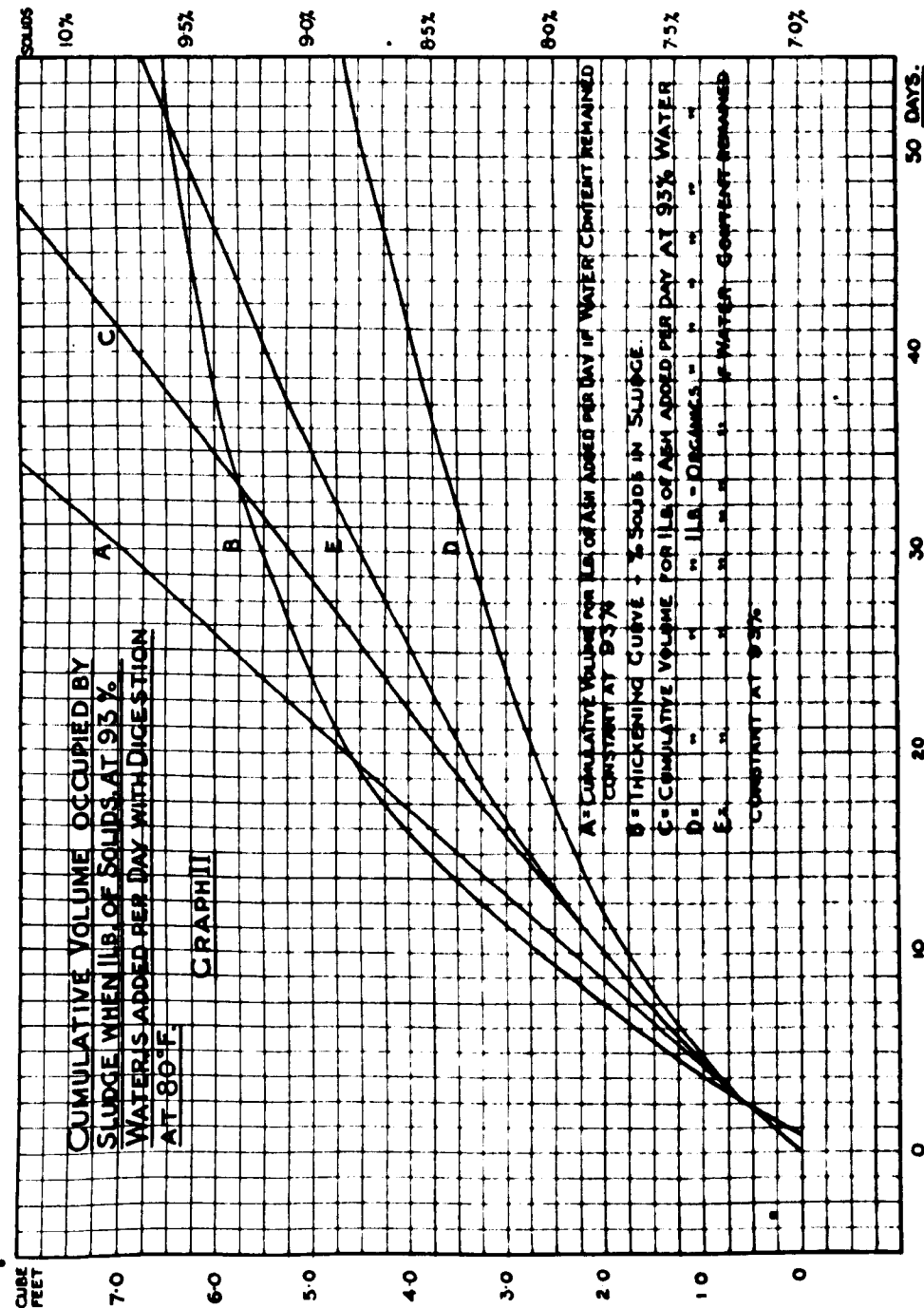
These solids contain 90.5 per cent. water (Graph II B) and so occupy .15 c. ft. per lb. (Graph IV).

Therefore volume required to provide the necessary seed volatile material = $1927 \times .15 = 290$ c. ft.

It is therefore seen that with a digester capacity of 1.5 c. ft. per capita there is available in the digester $\frac{8,672}{290} = 30$ lbs. of volatile seed matter for each 1 lb. of volatile matter in the raw sludge fed to the digester each day.

Since 75 per cent. volatiles in the sludge solids may be on the high side for the

*A questionnaire sent to operators of heated digestion tanks by the West Kent Main Sewerage Board. The author is indebted to Mr. Scott Murray, Engineer to the Board, for permission to quote from this.



average sludge, it is of interest to consider the case where the volatiles are extremely low for a detritus-free sludge :—

Example II.

Taking the same population, solids and recovery as in

Example I we have total solids = 1350 lbs.

Assume Volatile matter in the solids to be 50 per cent. .. = 675 ..

The ash also = 675 „

For 40 days digestion capacity required for Volatiles = $675 \times 4 = 2,700$ c.ft.

and capacity required for Ash = 675×6.75 = 4,560 „

Total = 7,260 c. ft.

Equivalent to .73 c. ft. per head of population.

At 1.5 c. ft. per capita on 10,000 population capacity . . = 15,000 c. ft.

Therefore space available for seed = 15,000—7,260 . . . = 7,740 c. ft.

After 40 days the Volatiles are $675 \times .37 \dots \dots = 250$ lbs.

and the Ash remains at = 675 lbs.

Therefore to supply 675 lbs. of volatile dry solids for seed (i.e. 1 lb. of seed volatile for 1 lb. of raw volatile added) we require $675 + (\frac{675}{250} \times 675) = 2,505$ lbs. total of digested solids.

These contain 90.5 per cent. water and so occupy $2,505 \times .15 = 376$ c. ft.

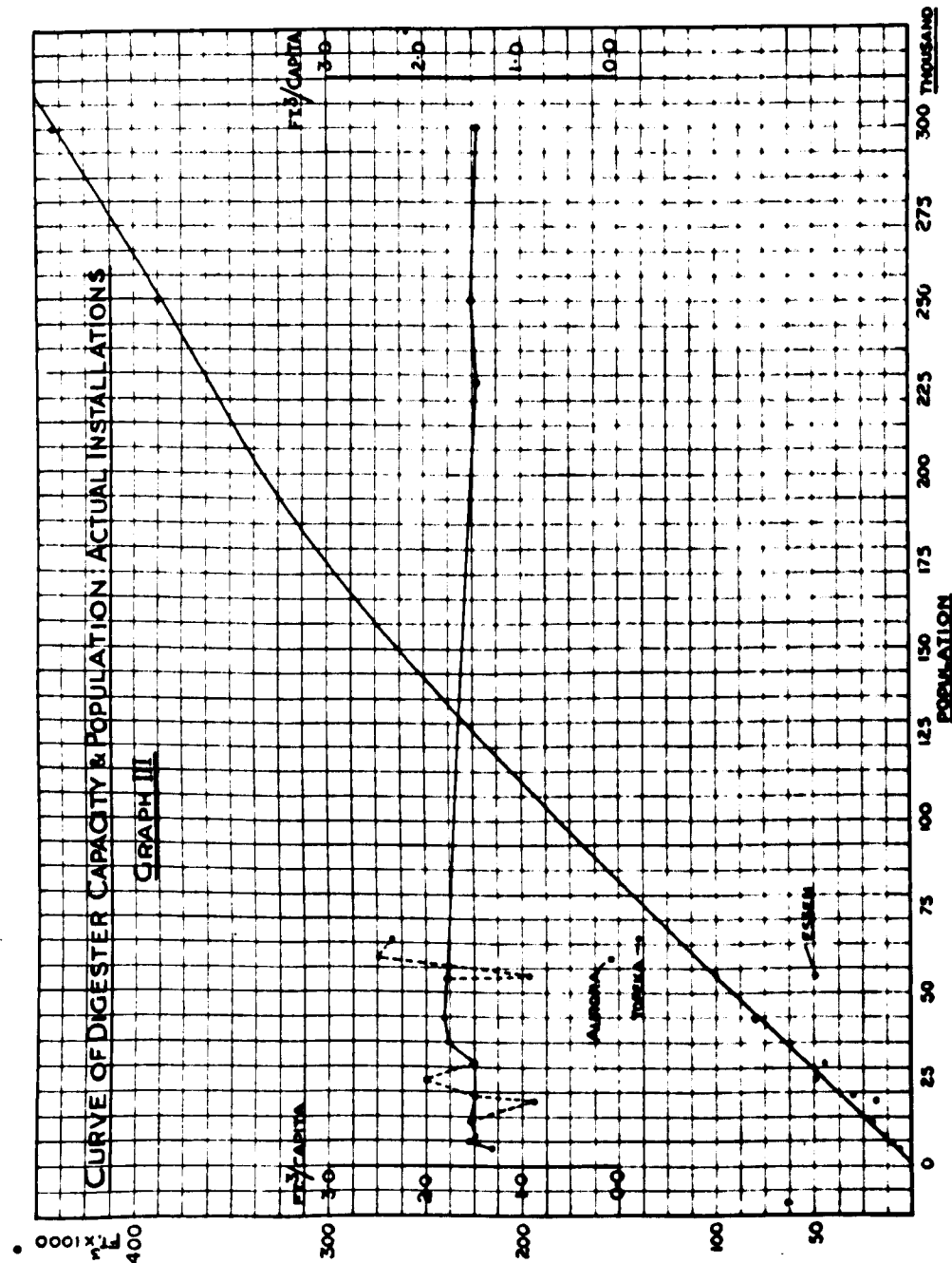
Therefore the amount of volatile seed available in the digester = $\frac{7,740}{376} = 20.6$ lbs.
for each 1 lb. of volatile matter in the raw sludge added each day.

It therefore seems that a capacity of 1.5 c. ft. per capita provides for twenty to thirty times the maximum amount of seed sludge found necessary by experiment and gives a total digester capacity between 50 per cent. and 100 per cent. greater than is theoretically necessary.

The reason for such a large discrepancy between theory and practice is probably due to provision having been made for one or more of the following :—

1. Possible future increase in population.
2. High moisture content in the raw sludge.
3. Septic condition of the raw sludge.
4. Raw sludge being fed to the digester in relatively large amounts at long intervals.

Except where a full size digestion plant is built *small enough*, and in conjunction with sedimentation units capable of supplying it with sludge in the best condition, it is impossible to check theoretical results. The only such plant known to the Author is that of Dr. Imhoff at Essen Rellinghausen and this agrees very closely with the results given in Example I and II. It therefore seems that where proper facilities are provided for obtaining the sludge in the best condition .75 to 1.0 c. ft. per capita may be accepted as sufficient capacity for heated digestion tanks.



SEDIMENTATION IN RELATION TO DIGESTION.

While considering the effect which the condition of the raw sludge has on digester capacity it will not be out of place to review the various types of sedimentation tanks and their efficiency in this respect.

1. Rectangular hand-cleaned tanks will provide thick sludge but will not provide it at short intervals, except where large plants are designed with a great many such tanks. As such tanks are kept in use for several days and more often several weeks the sludge will not be fresh but in most cases will be definitely acid and considerable extra volume in the digester will be necessary for rectifying this and bringing the pH value up.

2. Hopper bottom or inverted pyramid tanks will provide sludge fresh and often, but will not give a sludge of less than 97 per cent. water. Reference to Graph IV, on which quantities of sludge for a given solids content are plotted against percentages of moisture, shows the greatly increased capacity which will be required for such a wet sludge.

3. Mechanically de-sludged tanks, of which there are several types available, provide sludge fresh and often, and, if the mechanisms are properly designed to this end, will thicken the sludge to 92 per cent. or 93 per cent. water. This type of unit therefore affords the best conditions for sedimentation with separate sludge digestion and in addition shows considerable saving in costs over the other types in the larger sizes of tanks.

SCREENINGS, DETRITUS AND HUMUS.

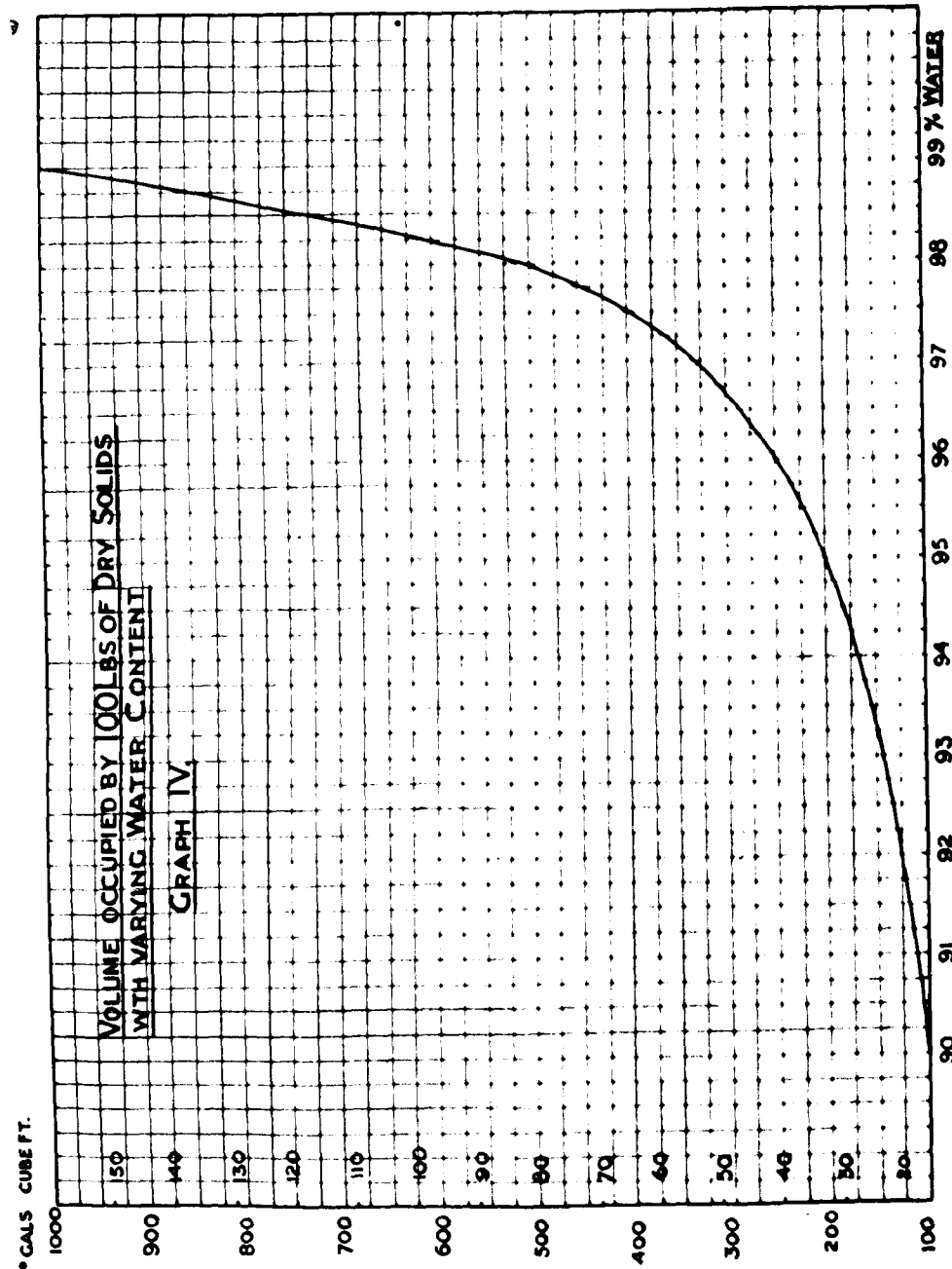
Since digestion prevents nuisance from the sludge it is possible to prevent nuisance from the other notable sources, by a very simple means. This consists in removing all putrescible matter from the detritus and screenings and putting it into the sludge.

Although this may seem difficult at first it is in fact quite easy. In the case of the screenings a high pressure water jet is arranged to play on the material removed by the screens. By this means practically all of the putrescible matter will be broken up and washed back into the sewage flow to settle out in the sedimentation tanks. The disposal of the residue by incineration will be referred to later.

In the case of the detritus, by the use of a suitable elevating mechanism designed also to act as a washing machine, the light organic matter can be separated from the grit and returned to the sewage flow, so that only clean grit is discharged instead of the usual highly objectionable mixture of organic and inorganic matter.

Following up this principle of getting all the organic matter into the sludge for final disposal by digestion, humus sludge or excess activated sludge is returned into the sewage flow to be settled out again with the raw sewage in the settling tank.

In some cases where this has been done it has been found that sedimentation has been adversely affected owing to peculiarities in the sludge or to the method of operation, but in others the sedimentation of the raw sludge has been improved by the



addition of the activated sludge or humus sludge and the principle is now generally accepted as satisfactory.

The effect of this re-sedimentation is not only to get the whole of the sludge to one place without nuisance and well mixed ready for digestion, but also to lower the water content of the activated sludge or humus sludge.

GAS COLLECTION.

Gas collection from the early type of open tanks was by means of a number of floating covers designed so as to trap the gas rising from beneath them and collect it in gas domes from which it was conveyed to a central gas holder.

When cylindrical tanks of the type described in this paper were first considered, a similar method of treatment was adopted, the whole roof being made to float on the liquid contents of the tank. This was done from a fear that if a fixed roof were used air might be drawn into the tank during certain phases of operation and mix with gas forming an explosive mixture.

The floating roof is costly and has many disadvantages where thickening or circulating of the sludge is provided for, while the fixed roof does not involve any danger from explosion where the digester as a whole is properly designed. Where a fixed roof is used the maximum rate of discharge of digested sludge should be fixed at an amount which ensures that in a given time a greater volume of liquid cannot be drawn from the tank than will be occupied by the gas evolved in the same time under normal working conditions. A very small gas holder on the gas line will serve as an indicator of the conditions in the tank, and should this gas holder fall below a certain level, the withdrawal of sludge will be stopped. In most cases, where some use is made of the gas, a gas holder of fair capacity will be in use and the above precaution will be unnecessary, since gas will be drawn back to take place of sludge drawn out, if the rate of withdrawal for any reason exceeds the rate of gas evolution.

Where convenient, the additions of raw sludge are made at the same time as digested sludge is withdrawn so that fluctuations in level in the tank are minimised.

Except when sludge is being withdrawn the level of liquid in the tank is hard up against the under side of the roof, the overflow pipes being carried up above this level outside the tank.

HEAT REQUIREMENTS.

The heat added to a digester is required for two purposes :—

1. To raise the temperature of the added sludge.
2. To make good radiation losses.

The first will, of course, vary with the temperature of the incoming sludge, but the amount of such variation is so small compared with the total heat required that it may be neglected.

The radiation losses vary according to the ground or site conditions of the tank. In a tank having a reinforced concrete wall 12in. thick and which is placed in dry excavation for half its depth, the excavated earth being banked up round the upper half of the tank, the heat lost by radiation may be taken as about 6 B.Th.U. per sq. ft. per hour.

Example III.

A digester serving a population of 20,000 and providing a capacity of 1 c. ft. per capita = 40 ft. diameter $\times$ 20 ft. deep, area of floor, walls and roof = 5,000 sq. ft.

Sludge to be digested at 93 per cent. water, say 28,000 lbs. per day.

Temperature of sludge to be raised from say 55° F. to 80° F. = 25° F.

Therefore heat required to raise temperature of sludge

$$28,000 \times 25 = 700,000 \text{ B.Th.U's.}$$

$$\text{and Radiation losses} = 5,000 \times 6 \times 24 = 720,000 \text{ ,,}$$

$$1,420,000$$

$$\text{Add 25 per cent. for other losses} = 355,000$$

$$\text{Total} = 1,775,000 \text{ B.Th.U's. per day.}$$

Heat available, assuming .8 c. ft. of gas per capita (see Appendix) having a calorific value of 600 B.Th.U's per c. ft. $20,000 \times .8 \times 600 = 9,600,000$ B.Th.U's. or assuming a boiler and heating coil efficiency of only 60 per cent. = 5,760,000 B.Th.U's. or more than 3 times the heat required.

Where the digester is situated in water-logged ground the heat required to provide for radiation losses will be considerably greater and where the production of power from the gas is of great importance, and it is consequently desired to use as little as possible for heating the digester, some form of lagging having a low coefficient of conductivity may be necessary.

Where the gas is employed in gas engines the heating water for the digester may be obtained from the cooling jackets of the engines supplemented by exhaust heaters. In this way about one-third of the heat value of the gas consumed by the engines may be recovered.

When used in this way approximately 400 c. ft. of gas per day will provide 1 B.H.P. continuously at the engine shaft, so that in the foregoing example the power output obtainable from an engine would be :—

$$\frac{20,000 \times .8}{400} = 40 \text{ B.H.P.}$$

and the heat available for the digester 3,200,000 B.Th.U's.

INCINERATION OF SCREENINGS.

It is natural to imagine that power produced from sludge gas is necessarily cheap and in many cases this is so. Where, however, duplicate engines and dynamos have to be provided as stand-by the loan charges on these and their attendant switchgear may bring the cost within very close range of that of purchased power in some districts.

For this reason other outlets for the use of sludge gas are coming into prominence. The chief of these is the incineration of screenings.

Owing to their high moisture content screenings are extremely difficult to incinerate in any of the ordinary forms of destructor. To deal successfully with

them a self supporting flame of considerable intensity and capable of exercising a cutting action is necessary. For this purpose sludge gas fulfils all the requirements. Considerable care is however necessary in designing the incinerator to ensure complete combustion, or offensive odours will be produced. It is also necessary to protect the lining against the high moisture content of the gases of combustion.

COSTS OF HEATED TANKS.

On account of the mechanical equipment involved when digestion tanks are fitted with heating arrangements and thickening mechanisms it is usually assumed that their cost, compared with open tanks, is very high.

For a given population this is not the case when allowance is made for the difference in the capacities necessary with the two types of tanks. To illustrate this Graph No. V has been prepared which shows :—

- The costs of open tanks constructed in concrete to a capacity of 8 c. ft. per capita (the high limit).
- The same costs for a capacity of 5 c. ft. per capita (low limit).
- The costs of closed tanks with heating equipment and thickening mechanisms for a capacity of 1.5 c. ft. per capita.
- The same costs for a capacity of 1.0 c. ft. per capita.

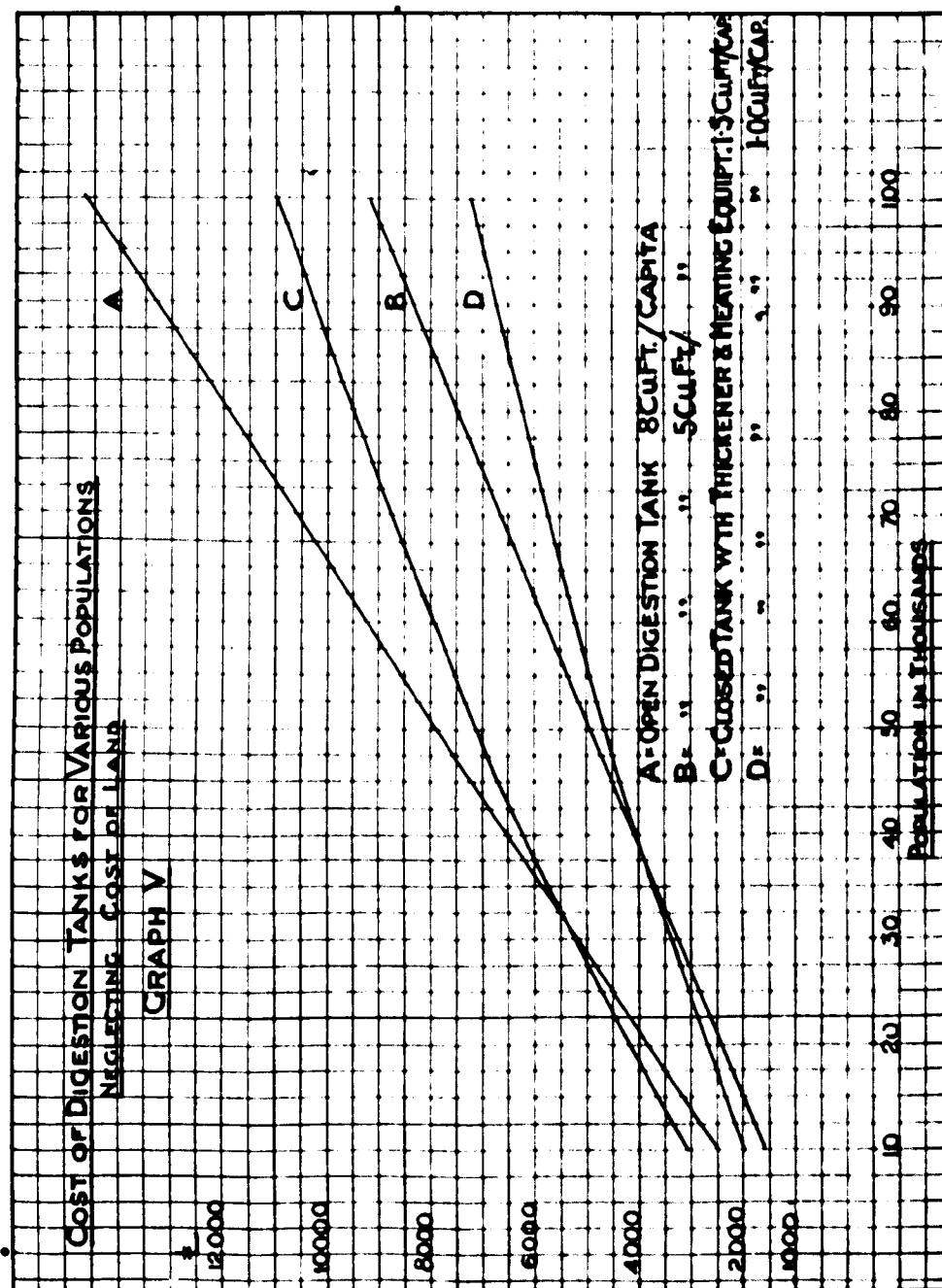
From these it will be seen that for populations over 30,000 the heated digester has definite economical possibilities in first cost apart from the advantages of greater certainty in operation, higher gas production and lower operating costs.

APPENDIX.

Results obtained from 17 digestion plants using heated tanks and thickening mechanisms.

	Average.	Max.	Min.
Capacity per capita	1.5	2.3	0.9
Moisture in raw sludge	95%	98.5%	91%
Temperature of digester	86° F.	96° F.	70° F.
Per cent reduction of volatiles	56%	74%	30%
Gas per head of population	.827 c. ft.	1.25	.5
Calorific value of gas	660 B.T.U's	750	600

NOTE.—Since average results are frequently misleading the maximum and minimum have also been given to indicate the range of variation.



DISCUSSION.

MR. A. S. LOWE (introducing his Paper) said: In preparing this Paper I had three objects in view. The first of these was to put forward a method of calculating digester capacity based on the available data. In order to apply any engineering formula it is necessary to be certain of the properties of the material involved. I have therefore indicated the conditions that are necessary to ensure the sludge behaving in as uniform a manner as possible, and I have endeavoured to outline the method of obtaining these conditions.

The second object was to suggest the desirability of bringing together all the material of the same nature for treatment by the same process. This is a form of rationalising which is appreciated in industrial processes, but I think is rather neglected in sewage treatment.

The third object of this Paper was to stimulate discussion. The technique of sludge digestion has developed and is developing so rapidly that many people with real knowledge and experience of the subject are reluctant to commit themselves to writing a paper, but will come forward in discussion. For that reason while endeavouring not to be dogmatic; I have included as many definite figures and statements as I feel are justified by experience and research, in the hope that these figures and statements may provoke a discussion which will be of some value.

There is one other point; that is the question of the value of the water of digestion both as a seeding medium and as a buffer solution for maintaining alkalinity. I think its value has been appreciated during the last year since the Paper was written, and I hope that point will come up in the discussion.

I have one apology to make, and that refers to graph IV. Since writing the Paper I have had occasion again to consult "A text-book on Trade Waste" by Wilson and Calvert, and I found I had subconsciously, so to speak, lifted the graph from this text-book. My apology is not for producing it again, because I think it is of considerable importance, but for having done so without acknowledgment to Dr. Calvert.

MR. WHITEHEAD, proposing a vote of thanks to the Author, said: I have read

the paper carefully, as it is one which deserves careful reading. My impression is that Mr. Lowe has somewhat laboured the case for digestion in closed heated tanks equipped with stirring devices.

His statements on the second and third pages regarding open tanks are not borne out by our experience at Birmingham, where digestion in open rectangular tanks without the addition of artificial heating has been in successful operation since 1911. Surely the facts are that digestion can be carried out successfully in at least half a dozen different ways, and it is futile to unduly stress the supposed benefits of one method to the detriment of another method, when the results obtained from both methods are achieved with the same freedom from nuisance and at the same cost.

I criticise, too, the suggestion which is implied by graph V. It is not correct to suggest that a closed tank of 1 or 1.5 cubic feet capacity per capita with a thickening and heating equipment will give comparable results with open digestion tanks of from 5 to 8 cubic feet capacity per capita.

The correct proportions for conditions in this country where the whole of the sludge including storm water and humus sludge is digested are probably nearer 3 cubic feet per capita for heated tanks, than 1 to 1½ cubic feet as mentioned by Mr. Lowe.

A cost graph on this basis would show, as we have experienced at Birmingham, that a digestion plant working at an optimum temperature of 75 to 80 degrees F., is more costly to build than an unheated plant of double the capacity per capita. It is true that capacities of digestion tanks of 1 to 1½ cubic feet are in successful operation on the Continent and in the States, but the reason for this is that rivers there are generally sufficiently large to take care of that portion of the sludge which is not arrested in the small sedimentation tanks that are usually provided.

Mr. Lowe's arithmetical examples are interesting, but if they start with an assumption which is incorrect for English conditions, such as the amount of dry solids per capita per day to be dealt with, then their value is misleading.

The remarks, too, on gas collecting are

open to criticism. The floating roof may, or may not, be costly. I have seen designs of some floating roofs which in my opinion are unnecessarily costly, but there is no doubt that a floating roof gives a considerable measure of protection from mishap by explosion, and it is not objectionable from an insulating point of view when a gas space is maintained over the whole surface of the digestion tank.

In conclusion I would say that I share Mr. Lowe's views on the merits of sludge digestion. It is a process which cannot be worked without encountering difficulties. These difficulties can be overcome, but my experience compels me to warn Sewage Works Managers against attempting sludge digestion with insufficient tank capacity, and recommend them to carry out the work in two stages.

The problem is one that has not been solved in the laboratory; the laboratory has assisted, but the works' factors dominate the whole issue.

MR. H. JACKSON, seconding the vote of thanks, said: I would refer to some tanks which have just been put into operation and are now working under the supervision of Mr. Grant at Gravesend. It was necessary for the engineer responsible to ascertain, as far as he was able, reliable figures for estimating; then to put those figures into a material form in the plant.

Mr. Lowe in his Paper has given the impression (I think unwittingly) that this problem is one that is now all cut and dried and can be calculated in the same way, say, as the value of an annuity. Mr. Whitehead has already indicated that that is not so.

There are a number of variables which upset many of the anticipations indicated in the Paper. For instance, capacities are there determined from organic contents of the sludge without indicating at all the degree of margin that would have to be allowed, due to variation in water content and other causes.

In designing the tanks at Gravesend, the first task was to estimate the amount of sludge, its organic matter content, and the amount of that organic matter that might be expected to come away in the form of gas. Having formed such an estimate, and the plant being in operation, it becomes the

task of the engineer to review the bases of his estimate from the point of view of the figures actually obtained in practice. In due course such figures will be available in this particular instance. It would have been of much more value, I suggest, if Mr. Lowe had been able to set out before us some ascertained facts first, had made his deductions, and then had shown us how these deductions were turning out in practice. In other words, the value of the Paper to me is very considerably decreased because of the uncertainty with regard to the statements upon which deductions are made.

For some reason, in the tank Mr. Lowe is dealing with he has provided for no gas capacity at the top of the tank. There must be some reason for this. At Gravesend the tanks are circular. The cover to each is in four pieces, bolted down to the sides of the tanks and having the sides of each cover dipping into a water seal formed in the concrete of the tank. The top of each cover is 2 ft. 3 in. above the normal working level of the sludge, and gas is drawn off from gas domes 2 ft. dia. and 1 ft. 3 in. high, one situated in the middle of each cover. The water level in the seal can be varied at will, and thereby the pressure of gas in the tanks can be controlled. It will be seen that there is a considerable space on the top of the sludge liquor, which is occupied by gas.

I am quite sure that Mr. Whitehead will be pleased to know that in filling the tanks, and even in examination of the tanks from the manholes in the covers, no explosions have occurred. Precautions were taken, and no smoking is allowed in the vicinity.

Another point is that of the heat required to maintain the temperature of 80 degrees F. or thereabouts. It is a difficult matter to obtain reliable information with regard to the amount of heat radiated from the tanks. The problem arose as to whether it would be economical to insulate the tanks to conserve heat in that way. Taking the figures I was able to obtain, mostly from National Laboratory experiments, I came to the conclusion that by lining the outside of the exposed portion of the tanks with two inches of cork the advantage obtained would warrant the capital expenditure. And not only the sides of the main tanks, but the

sides of the pre-heating tanks and the covers with their gas domes have been similarly covered with cork. Such heat insulation by means of cork is impossible below ground. Mr. Lowe has taken for his example perfectly dry ground. This is a condition rarely found on the site of sewage disposal works. At Gravesend the heat insulation below ground is carried out by an annular air space drained to a sump from which any infiltration water can be pumped.

MR. F. R. O'SHAUGHNESSY: The main purpose of sludge digestion is to facilitate disposal of the solids associated with sewage. This implies elimination of offensive odour, with modification of the physical character of the solid matter so that it may be disposed of more readily; and these things must be done so that the cost of doing them shall be reasonable.

Whilst not wishing to minimise in any way the value of the information put forward by Mr. Lowe I would suggest that he does not go far enough because he does not take a sufficiently broad view of the whole problem of sewage disposal, of which this question of sludge treatment is so important a part.

For instance Mr. Lowe tells us nothing at all about some of the most important things, that is the character and the fate of the finished solid product of the process; and the ordinary person is left to infer that, unless we are prepared to introduce all the refinements described in the Paper, separate digestion of sludge is out of the question. This is indeed a most pernicious error, and one of the purposes which Mr. Whitehead and I had in mind when we read our paper on sludge digestion before The Institution of Civil Engineers was to clear up the fog created by this type of statement. My own belief is that there are hundreds of small works where sludge digestion may be carried out by intelligent managers on fairly simple lines, thus securing the great advantages of eliminating nuisance and facilitating disposal. It is a further conviction of mine that with facilities for manipulating the sludge, some of which Mr. Lowe has discussed in the present Paper, the plant will be manipulated not only for obtaining the useful methane, but mainly, when opportunity permits, with a view to

conditioning the resulting solids for use by the farmer as a valuable source of manure.

My own way of looking at this business is that in the mixture of waste materials which are contained in the aqueous complex which we call sewage sludge there are a number of solid materials, such as fats, celluloses, proteins, etc., which are capable of undergoing fermentation in the presence of sufficient water. Experience has shown that certain physical factors, some of which Mr. Lowe has enumerated on the second page of his Paper, influence not only the rate but, even more important, the course of the biochemical reaction. It is literally true that the immediate purpose of the process which Mr. Lowe has attempted to describe is the control of the course of the biochemical changes in a desired direction. As these changes are brought about by living agents it follows that each one of the physical factors must have its limitations, and this is the real meaning of the word optimum which heads this list on the second page.

Mr. Lowe speaks of necessity within the limits of his own experience and implies that it is desirable in practice to attain all of his so-called optimum conditions. I would suggest that wider experience shows that there are other considerations of the greatest importance in everyday work which are not dealt with in this Paper. For instance it has been shown, more particularly by Dr. Rudolfs and Mr. Heukelekian, of New Jersey, that the bacterial complex of the methane ferment is not unduly upset even if the temperature is lowered to the neighbourhood of the freezing point of water, but on the other hand universal experience shows that a very moderate lowering of the pH value is disastrous. It follows from this that the maintenance of pH value at a proper level is of vital importance if stability of the process is to be ensured.

May I next point out how the question of temperature bears on this. It is claimed, and quite rightly, that as the temperature maintained in the digestion chamber approaches what has been called the optimum—that is 75 degrees Fahrenheit to 80 degrees Fahrenheit—the speed of destructive fermentation increases and that the time retention, or in other words the tank capacity needed for this preliminary stage, diminishes.

Quite a number of important things follow from this, but the one point I would draw your attention to is that the amount of reserve alkaline material is inevitably reduced with the reduction in volume, and this means in practice that the process becomes more sensitive and less stable, as anyone with large scale experience is bound to discover.

Mr. Lowe has added his quota of evidence in support of this, but there will be many cases where reasonable stability is much more important than maximum speed. With Mr. Lowe's statement that a reasonably low content of water in the crude sludge put into the digestion chamber is essential, I am in the fullest accord, but I am not at all convinced that this desirable density is to be assured on the lines suggested by Mr. Lowe. In America, where the methods described by Mr. Lowe are exploited to the full, we have witnessed a complete reversal in the last year or more in the attitude of leading engineers and chemists with respect to sludge digestion. No longer is this process held in such favour as formerly and there is a decided turning towards mechanical de-watering of the crude sludge and subsequent incineration as a method of disposal. But one of the reasons given for this surprising change is of the greatest interest in connection with the statements in the present Paper, and that is that the aqueous material pumped back from the digestion chamber to the incoming sewage interferes seriously with the aeration processes. This seems to imply that the amount of water accompanying the crude sludge to the digestion chamber is at times excessive, and this is in accord with my own experience of mechanical sludging devices.

Mr. Cass: I should like to make one enquiry confined to an agricultural area the population of which has dwindled, due to agricultural depression. For 46 years the sewage, amounting to something like 5 gallons per head—not 30—has been dealt with since the days of Dibden's experiments and the Exeter experiment, by gravitation through a septic tank, and under the River Thames and applied to the land. During the 46 years there has been no complaint of river pollution and the Conservancy Authorities have been perfectly satisfied with the results. The cost of

working is negligible. The agricultural depression is great and the people are so poverty stricken that very few of them can afford baths, and hence the very small quantity to be dealt with.

I would like to know if during, say, the last 40 years, or since Dibden's London experiments and the Exeter Bacterial Aerobic and Anaerobic (as we used to call them) treatment, there is any material reason which would justify a poor population paying for pumping back to treat it through sprinkler arrangements in addition to treatment by land—so long as the land is alluvial and contains a percentage of gravel and sand mixed; an excellent media for purification.

If that question is not regarded as too unimportant would Mr. Lowe kindly give us his opinion, because I feel there are many places in this country that would be otherwise forced to pump storm water and sewage that they could not afford to pay anyone to do, because the population is too scarce, who would be very grateful indeed to get out of the Bankruptcy Court by those methods.

MR. A. J. MARTIN: The Author says at the outset of his paper: "Sludge digestion, properly conducted, offers a complete solution of the nuisance problem and very greatly reduces the area required for drying beds."

That statement I whole-heartedly support, but I go further than the Author and I would say to any sewage works manager or engineer who may be considering the adoption of sludge digestion: Do not be deterred by the fear that any expensive or elaborate devices are necessary or that sludge digestion requires management of a higher order than you will find on any ordinary sewage works. If you have sludge digestion plants properly designed and worked with a moderate amount of care you are sure of satisfactory results.

The statement which I should have liked Mr. Hughes to deal with is on the second page—No. 3 in the first series. Among the conditions stated by the Author to be best for methane digestion, he includes "moisture content low." Mr. Hughes has assured me more than once that it is essential to satisfactory results to have a high moisture content, something like 94 per cent.

In his comparison of open and closed tanks the Author states that the temperature

in an open tank cannot be maintained at the optimum of 80 degrees F. I think he is altogether over-stressing the difference between an open and a closed tank in that respect, for the radiation of heat even from an open tank is not very rapid; sludge is not a good conductor of heat, and if you have your tank of a reasonable depth and sunk in the ground I do not think there will be any difficulty in maintaining in an open tank in this country a temperature which will be adequate for satisfactory digestion.

In regard to the capacity of tanks, I have been digesting sludge for a great many years. When I began doing so no data on this point were available, and I had to work out my capacities for myself. The earliest tanks I laid down had a capacity just under 1½ cubic feet per head. Among them were those tanks at Chingford for which Mr. Hughes is responsible. The population has gone up by about 50 per cent. and Mr. Hughes is now working with something like 1 cubic foot per head. I know he would like to have more but at the same time with one cubic foot per head he is able to produce a digested sludge which is free from nuisance, and which does dry readily on the beds. I would like to ask, with great respect, what more do you want? It may be that in order to get complete digestion of our sludge we should have 3 cubic feet per head; but is it necessary to get complete digestion? In my humble judgment what we want to get is a sludge that will not give rise to a nuisance and that will dry freely on sludge beds. If you can get that with from 1 to 1½ cubic feet per head, why go to the expense of putting down larger tanks? I say that with great respect to Dr. Calvert, and I hope to have the opportunity of discussing the point with him later.

I recently laid down some digestion tanks at Southall-Norwood. I had no idea of digesting the whole of the sludge, but the sludge presses were overworked, and I laid down the tanks to relieve them. Mr. Hall, however, has discontinued the use of his presses and he is putting the whole of his sludge through the tanks. Their total capacity is only about 22,000 cubic feet, and he is putting through them the sludge from 40,000 people and from some-

thing like 100,000 gallons per day of trade wastes. That is to say, he is digesting his sludge with a tank capacity of about half a cubic foot per head, and as far as I can see with perfectly satisfactory results.

MR. HICKS (*Gravesend*): Dealing first with these various "optimum conditions," I question the basis upon which they have been stated. In the past in the whole history of sewage development we have shown that if one of our leading lights has suggested something and carried on with it, it has been taken for granted; but in these days when so many scientific minds have gone into the question of both sewerage and sewage disposal, if you can get away with a thing that is unorthodox you become a genius. If you do not get away with it you are finished in the sewage world; and it is a question of whether you can show it is orthodox to maintain these conditions, or whether you can still be orthodox by scrapping some of them; and to my mind from my small experience of sludge digestion, and especially after I have been able to work with low temperature digestion and other kinds of digestion, I have been in the position to question whether some of these working conditions are correct, or whether they are only correct for the particular sludge undergoing digestion.

That brings in the question whether every sludge has its own particular optimum conditions and whether every sludge ought to have its own peculiar design of tank. If you are dealing with a sludge which contains rather a high percentage of organic matter it is my experience, at any rate, that digestion is easier started and easier maintained than if your sludge contains a lower percentage of organic matter. If you work with a sludge containing 80 per cent. organic and you go on to a sludge containing 70 per cent. organic, it is much easier to maintain your digestion. Furthermore, if you bring down your gas production to terms of c.c.s. per gramme of dry organic matter, you will get more gas per gramme from dry organic matter with a higher percentage organic sludge.

I have been connected with this same plant that Mr. Jackson speaks of, and there is one peculiar factor that has some reference to this plant, one that has not been enlarged upon. This plant was designed to be used

as a heated digestion plant, and then for certain reasons we were not able to put heat into it. We found in the course of several months' running that we could start up digestion without any trouble. We added no lime to our sludge. Our pH came on naturally with the store sludge and the store sludge with a fairly high pH was used as a seeding for the rest of the tank. A small quantity of this was put into the tank and further sludge added day by day. In spite of the fact that the moisture content of the added sludge was something like 96 per cent. the pH went up. No heat was added. Furthermore, even when the tank became full the pH did not drop, and the gas produced was actually 1 cubic foot per head of population per day—which is rather alarming in view of the fact that with these pH figures in Mr. Lowe's cases, only 8 cubic feet per person per day was obtained.

As a result of this example, working with a non-heated sludge, simply with the addition of your crude sludge to a mass of sludge which has been kept say a month, to bring the pH up by a fermentation process—is it possible to get more gas?

That brings me to what we mean by sludge digestion; whether we mean it as a method of gas production or whether we simply mean making our sludge more innocuous and more easily dried on beds, or whether we should only reduce our area of drying beds by means of a sludge with a better drainability. Engineers for the last few years have been promising local authorities that the area of drying beds needed can be reduced, for two separate reasons: one that quite a lot of sludge can be sent back to solution as supernatant liquor. Secondly, that the treated sludge is more easily drainable.

Let us deal with this supernatant liquor, which perhaps is a very important part of this sludge digestion. If we can get into solution some of our organic matter and the rest of this matter, turned out from the tank as gas, how much of our trouble has been got rid of? All; because we know it is not very difficult to deal with the inorganic residual.

Then comes the question of the design of tank based upon whether you wish to get digestion, or gas production; digestion to

produce supernatant liquor or digesting sludge to produce drainable sludge. The rectangular tank at Birmingham has very great advantages. Its chief advantage is that the cost of construction is very low; secondly that so many of these tanks have been down since the days of septic tank action which are capable of being used for sludge digestion without any great cost. So they offer a very great solution to the works manager. But unfortunately if you get supernatant liquor formed in the tank it is very difficult to withdraw it.

That brings us to these so-called modern methods of digestion, in which it may be possible to withdraw this supernatant liquor. That brings us to the question of how we are going to get rid of the supernatant liquor formed with the particles of digested sludge.

Then these methods which are so detailed in this Paper are not the only methods of tank construction which operate to withdraw supernatant liquor from the tank. There ought to be quite scientific methods of being able to so treat a sludge as to get your sludge into such a physical and chemical condition that it easily parts with the particles of water adhering to the sludge itself, to form it into a layer and withdraw it. The difficulty is to determine those optimum conditions for each separate sludge, and then to determine the condition of the sludge, and then when we have determined the conditions to maintain them. That has been the object of laboratory experiments and large scale experiments, and I venture to say that probably the greatest function of a digestion tank is to be able to get rid of so much of the sludge there as supernatant liquor; and treat it as a separate thing specially designed to deal with such a material. For if we can only get rid of the organic matter from our sludge, by solution, then we are getting the greatest usefulness from our tanks.

The question then resolves itself really into a method of maintaining that digestion in economical conditions, and if the digestion can be maintained without the use of heat the added advantage of heating, of course, may be questionable, whether you are going to lose more gas from not using the heat. The gas could be collected and used for power production; or is it a question whether

you are still going to get sufficient gas to carry on power production even keeping your sludge at outside temperature? I do think that careful consideration ought to be given by our designers to this vexed question. Certainly, or at any rate more likely, there is a greater flexibility in a plant in which the sludge can be intimately circulated or otherwise kept under inherent control, than in a rectangular tank, in which you have got your masses of sludge which may or may not be intimately mixed. There may be great masses of ripe sludge which are not acting as seeding to the great mass of crude sludge which has been mixed with it, and if it is possible in a closed tank to keep the whole of your seeding in intimate mixture with your incoming crude solution and at the same time be able to withdraw from that tank so much of your organic matter actually in solution, and at the same time having the added advantage of collecting your gas from that tank, then such digestion certainly does offer really wonderful possibilities in its future.

MR. G. T. COTTERELL: This question of sludge digestion, I agree most thoroughly, is only one phase of the treatment of sludge, and I admit that there are many other factors to be taken into account in the treatment of sewage, some of which may give us a better means of treating the sludge than by digestion. I also agree that we cannot lay down any dictum as between open digestion and closed digestion tanks, although for my part I have a preference for the latter.

I think it comes back to the question the last speaker asked us to answer, what is our object in sludge digestion? Well, there is one common object that applies to both open and closed tanks, and in one sense I submit that it is the primary object, and that is that in both cases sludge shall be satisfactorily dealt with without nuisance; that we get a resultant that is without smell, and that is not attacked by flies. Therefore, to that extent we can solve the sludge question.

But there is another object which we must have in view, because we have discovered that this sludge which formerly was such a nuisance contains valuable properties for the production of power, which have been going to waste. When we come to take an open or closed digestion tank, I submit that we

get a higher efficiency from the closed digestion tank for the production of gas than we do from the open one.

I should like to hear Mr. Whitehead tell us what his production of gas per person per day is from his open tanks and compare it with the figures that have been given to us, or the figures stated in this Paper. Both these figures may be over the average. Perhaps I may quote my own experience: we for some years have been interested in putting up large digestion tanks for the treatment of sludge, and in one case in a town of about 24,000 people, for the last year there has been a production of gas from closed digestion tanks certainly .7—not less than and probably more than .7 per cubic feet per head per day. It enables us in that town to carry out pumping, as well as lighting, heating tanks, and other services for which otherwise we should have to use either electrical or other power, and it makes a very considerable saving in expense. Now that is a town of only 24,000 and one does not dare to compare it with a city like Birmingham, where they must have power absolutely running to waste. But I do suggest that if we will but develop along this line there must be many smaller places where they will find power obtainable from sewage gas that will become valuable for pumping purposes and other work.

MR. A. S. LOWE, in reply, said: I know that in this Paper I have taken a course rather the opposite to that advocated by Mr. Whitehead, but I think that does not mean that either he or I think any the worse of one another as engineers.

Coming to the points which Mr. Whitehead mentioned: I think the matter of capacity has perhaps been rather misunderstood. The idea set out in my Paper was not to say that, as the result of the figures produced there, this or that capacity was the correct one per head of population in every case. The object was to indicate a method of arriving at the capacity when you had got the necessary information about the particular type of sludge which you were going to deal with. I think that is clear from the two examples producing quite different results, when the ratio of organic to inorganic matter is varied. In that connection Mr. Whitehead criticised the figure of 0.15 lbs. of dry solids per head. That figure was

intended as an indication on which to base those examples, but it is, I submit, a proper figure, in fact a high one, for domestic sewages.

With regard to my criticism of the floating roof. I believe that we are thinking of rather different things. In speaking of a floating roof I had in mind a roof floating on the sludge; I think Mr. Whitehead had in mind a roof floating on the gas. I agree entirely that a roof floating on the gas is a very excellent thing and offers an easy solution to a number of problems, variations in water level and so on; it does however produce one difficulty, and that is in breaking up the scum. The scum will form under the floating roof and unless you add to the complication of the machine by putting in some stationary arm against which to crush that scum you will find a difficulty in dealing with it.

I am not quite sure what it was Mr. Jackson asked me for when he asked for ascertained facts. The ascertained facts as far as calculations are concerned are contained in graphs I and II, and they are facts relating to domestic types of sludge. They were obtained by means of a series of experiments in small scale digesters, under the conditions of temperature and gentle stirring indicated in the Paper, on a variety of ordinary domestic sludges. They are facts which would have to be ascertained individually for different types of sludge.

Mr. Jackson also asked if gas space is provided in the tank. That again brings us to the question of the difficulties of dealing with the scum if you provide a gas space in the tank. Although this is not an insuperable difficulty, in the type of tank that I have described there would be no gas space; such gas space would be provided in a separate gas chamber.

Mr. Jackson also asked for figures of thermal conductivity. Reliable tables of coefficients for different materials are available. The figure of 6 is a fairly reasonable

figure for 12 inches of concrete under average conditions of temperature difference between tank contents at 80° F. and surrounding ground. Rudolfs published in the *Sewage Works Journal* about 6 months ago some figures of heat conductivity through the earth surrounding the tank which are of considerable interest.

I was so interested in what Mr. O'Shaughnessy had to say that I did not make any notes and I cannot in consequence make any reply, if any reply were possible, except perhaps the general one, which also applies to Mr. Whitehead's criticism of my stressing the necessity for a heated digestion tank with stirring devices, as against doing the same thing in an open tank. We all know that sludge digestion can be carried out in an open tank and without heat, but I submit that it is not a controlled process in the same way that it is if you have heat regulation and gentle stirring. It also takes up a very great deal more room than the same process in a heated tank. The efficiency of the tank, if I may put it in that way, is not so great. I think perhaps the time is coming when large towns will not be able to afford the space necessary for the very large tanks required, and they must have a tank which is not only smaller but is of such a nature that it can be put quite close to buildings.

What Mr. Martin had to say on this question of capacity was of extreme interest to me. I feel that there is some justification for suggesting a method of capacity determination based on experimental data when I hear Mr. Whitehead saying that the proper capacity is 3 cubic feet per head in heated tanks and Mr. Martin saying that a perfectly satisfactory capacity is 0.5 cubic feet in unheated tanks.

The tanks considered in my Paper average about 1.5 cubic feet per head which is nearly the average of the figures given in the discussion and represents a factor of safety of about 2 applied to the results obtained in my examples.

CONFERENCE

Under the auspices of the Institution of Municipal and County Engineers.

FRIDAY, 17th NOVEMBER, at 3.0 p.m.

MAJOR L. ROSEVEARE, O.B.E., M.Inst.C.E. (*President of the Institution*), in the Chair.

The following Paper was taken as read:—

Private Street Works.

BY

A. O. MITCHELL

(*Private Street Works Assistant, West Sussex C.C.*)

(NOTE.—This Paper was submitted for the open competition arranged by the Congress Committee, and was awarded a Special Prize of Five Guineas.)

THE making up of private streets under the Private Street Works Act, 1892, is still a comparatively new procedure to County Councils.

In the preparation of provisional apportionments complications frequently arise, some of those requiring careful consideration being the following:—

- (1) A street in which the premises on one side are not in the Local Authority's district.
- (2) A street which is on the site of an old public lane or footpath.
- (3) A railway or canal fronting on a street.
- (4) A place appropriated to public religious worship fronting on a street.
- (5) Premises not fronting on a street but having direct access thereto.
- (6) Certain works already carried out by the owners of premises on a street.
- (7) The construction of soil sewers in private streets by County Councils.

Assuming the sketch plan to be one of a street in which all the above complications arise, the preparation of the provisional apportionment will be somewhat interesting.

The street is to be made up under the Private Street Works Act, 1892, by the County Council. On the north side, the broken double line A.B.C.D. defines the boundary of an Urban District, which runs, as shown, along the forecourt fences of the premises 1-6 which are the property of the Urban District Council. A railway company's siding fronts on part of the south side of the street, and a hall used for public religious worship fronts on the north side, and is shown on the plan next to premises No. 7.

Along the centre of the street there exists an old public lane.

The premises 11-18 have been set back some distance behind the line of the remaining premises on the north side as the builder wishes to retain the ownership of the land shown in hatched lines on the plan.

The scheme is to include the provision of a soil sewer which is to be connected to manhole No. 1 at the head of the main sewer.

It will be seen on reference to the plan that in front of the hall and premises 7-10, the owners have laid concrete kerbing and flag paving. These materials are in good condition and they are laid to the correct levels of the new road, therefore they will not need to be disturbed when the street works are in operation.

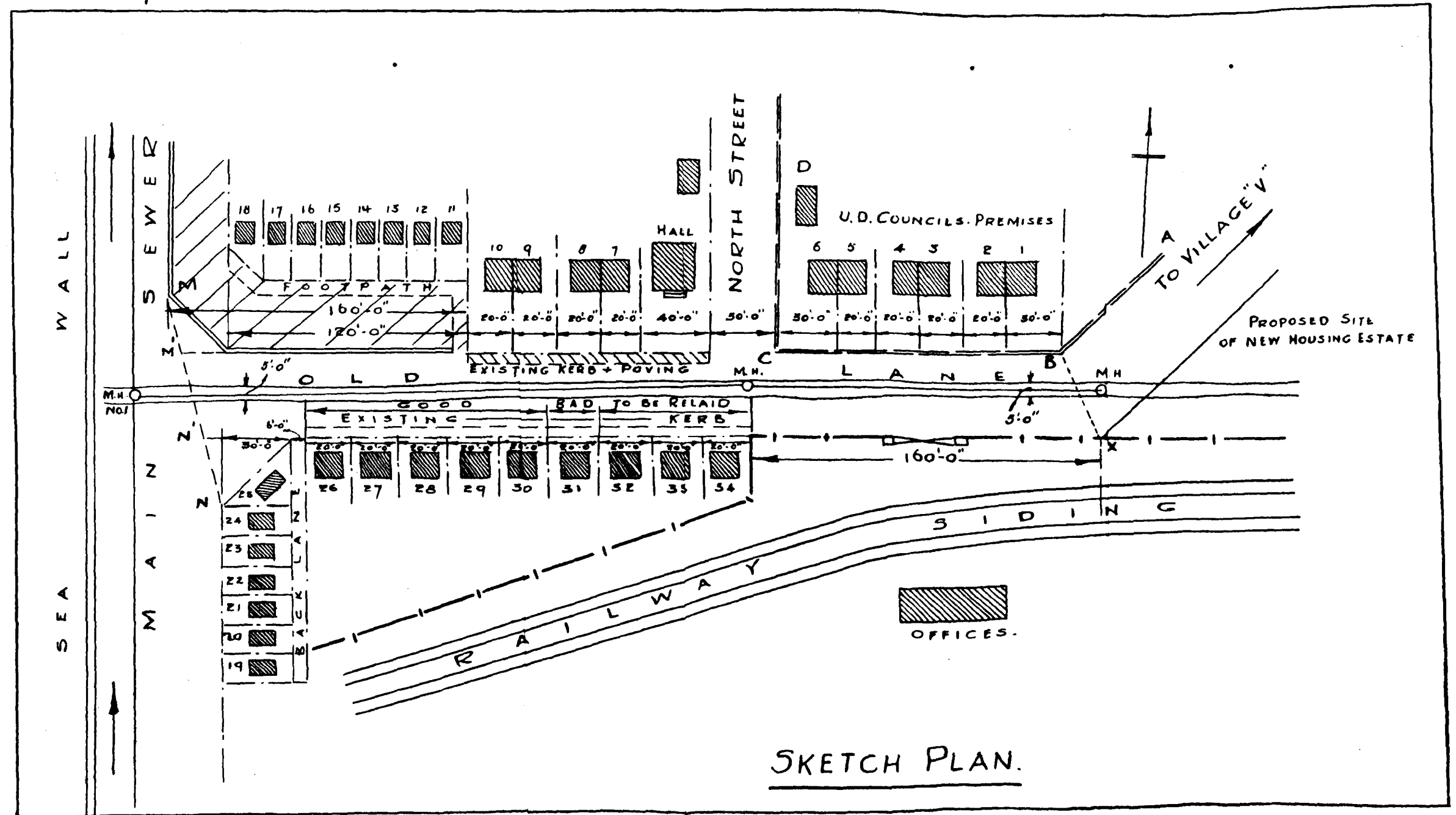
In front of premises 26-34, the owners have also laid concrete kerbing. The length in front of Nos. 26-30 is in good condition and at the correct levels, but of the length in front of Nos. 31-34 the whole of the 20 feet in front of No. 31 is very badly damaged, and will need to be taken up and replaced with new kerbing; whilst that in front of Nos. 32, 33 and 34, though the material is in good condition, will require to be taken up and relaid to the correct levels.

Let it be assumed that the first resolution, i.e., to sewer, level, pave, metal, flag, etc., the street has been passed by the County Council under Section 6 (1) of the Act, and that the Surveyor has been instructed under Section 6 (2) to prepare the necessary specification, plans and sections estimate and provisional apportionment, and in preparing the latter he has to deal with the various complications that exist.

First of all, considering the Urban District Council premises 1-6 which are not situated in the same district as the street, it has been held that the street or that part of it which is to be dealt with must be within the Authority's district, and where the premises on one side of a street are in another district, no expenses can be apportioned on them.

In this case, however, it is anticipated that a revision of boundaries will take place in the near future, and that the Urban District is likely to be extended to take in the whole of the street. Realising that they will then be frontagers on the street within the meaning of the Act, and at the same time being anxious to expedite the works as much as possible, the Urban District Council have agreed with the County Council (prior to the passing of resolution No. 1 by the latter) to their premises being included in the Provisional Apportionment as if they were *now* frontagers within the meaning of the Act.

Section 285 of the Public Health Act, 1875, gives power to Local Authorities to execute works in adjoining districts, and to combine for execution of works,



but it seems doubtful whether or not this Section would be applicable to a case such as the foregoing.

Had not the Urban District Council agreed*to be included in the provisional apportionment, the whole cost of the works would be apportionable on the remaining frontagers, unless the County Council resolved to exercise their powers under Section 15 of the Act, whereby they may, if they think fit, resolve to contribute a portion of the expenses.

Dealing now with the railway company's siding it will be seen that there is direct communication between the railway and the street by means of an entrance, through which are hauled goods, etc., unloaded from the railway wagons. By Section 22 of the Act, railway and canal companies are not chargeable with the expenses of private street works in respect of any land which shall *at the time of the laying out of the street* be used *solely* as a part of their line of railway, canal or siding, station, towing path or works, and *shall have no direct communication with the street*.

A railway company objected to the inclusion of a piece of land belonging to them in a provisional apportionment for a street on which the land abutted, but with which it had no direct communication, on the grounds that such land was at the time of the laying out of the street, used by them solely as a part of their line or works within the meaning of this Section. The land had been acquired by the company solely for the purpose of their railway and works, but they allowed their servants for the time being to use it as a garden ground on payment of a nominal rent. The Justices found, as a fact, that it was not used in any way as a part of the company's railway or works and that, therefore, the company's objection failed.

It seems, therefore, for a railway company to obtain exemption under Section 22 there must be no direct communication between the railway and the street, and even if there is no communication the land, at the time of the laying out of the street, must only be used as part of their railway or works, etc., and for no other purpose.

In those cases in which a railway or canal company obtain exemption under Section 22, it is rather hard on the other owners on a street. The sum which would otherwise have been apportioned to the company is to be paid by the other owners, in proportions settled by the Surveyor.

The whole of the expenses are not to be apportioned in the first instance among all the owners other than the company.

In the event of the company subsequently making a communication, they must pay to the Local Authority their proportion of the cost of the works, notwithstanding that such proportion may have already been paid by the other owners, and such sum shall be repaid to the other owners by the Local Authority.

In the street under consideration, the railway company have direct access thereto, and are therefore liable to be included in the apportionment. If they could not be so included for one of the reasons in Section 22, the County Council

could here again resolve to contribute a portion of the expenses under Section 15, and so lighten the burden of the other frontagers.

Taking next the case of the hall for public religious worship, it is rather interesting to note the difference in the wording of Section 151 of the Public Health Act, 1875, and Section 16 of the Private Street Works Act, 1892.

Section 151 of the 1875 Act provides that the incumbent or minister of any church, chapel or place *appropriated* to public religious worship which is now by law exempt from rates for the relief of the poor, shall not be liable to private street works expenses, as the owners or occupiers of such church, chapel or place, etc., nor shall any such expenses be deemed to be a charge on any such church, chapel or place, etc., and the *Urban Authority may if they think fit undertake any works from the expenses of which any such incumbent or minister is hereby exempted.*

The exemption in this Section only applies to an incumbent or minister, the trustees of a non-conformist chapel are apparently not exempt.

Section 16 of the Act of 1892, which is in substitution of Section 151 of the 1875 Act, in districts where the former Act is in force, exempts not only incumbents and ministers, but trustees also, and the text *requires*, not simply enables, the Local Authority to bear the proportion in respect of which such exemption is allowed.

For the owners of the hall under consideration to obtain exemption under Section 16, it would seem that it is necessary that the hall should be appropriated, i.e., used solely for public religious worship. It is ascertained, however, on making enquiries that the hall is also used for concerts and dances, etc., periodically, and that it is not wholly exempt from rates for relief of the poor. For these reasons it is considered that the owners can be included in the apportionment of expenses.

The case of the old public lane is the next for consideration and it is first of all necessary to ascertain whether or not it is repairable by the inhabitants at large. It does not follow that because a road is dedicated to the public, and becomes a highway, that the highway authority are liable for its repair and maintenance.

Prior to the passing of the Highway Act of 1835, no distinct act of adoption was necessary in order to make a parish liable to repair a public road; if the road was public, the parish was bound to repair it.

Since 1835, however, some formal act of adoption has been required before a highway authority become liable for the repair of a new highway; there are two ways in which a highway which has been dedicated since 1835 may be "adopted" by a highway authority. One is by compliance with Section 23 of the Highway Act 1835 and the other is by compliance with one of the Acts relating to private street works. There is no liability on the part of a highway authority to repair any road dedicated to the public since the Highway Act 1835 came into force unless the procedure laid down in one of the foregoing Acts has been complied with.

An owner may object that part of the width of the street is a highway repairable by the inhabitants at large, and the 1892 Act is silent as to what is to be done if the objection is made out. It is generally assumed that in such a case the Court of Summary Jurisdiction may under Section 8 (1) amend the resolution, plans, etc., by limiting the scheme to the remaining portion of the street.

It is interesting to note that in districts where Section 150 of the Public Health Act 1875 is in force, the procedure in dealing with a case similar to the one now being dealt with is entirely different. Where, for part of its width, a street is a public footpath or repairable by the inhabitants at large, the street may be dealt with under the last paragraph of Section 150, which states that "The same proceedings may be taken and the same powers may be exercised, in respect of any road or street of which a part is, or may be, a public footpath or repairable by the inhabitants at large, as fully as if the whole of such street or road was a highway not repairable by the inhabitants at large."

Apparently the meaning of this paragraph is that in those cases in which the magistrates could properly find the residue to be a street, that power of so finding is not to be taken away in consequence of the fact that there is a public footpath.

In the case of *Evans v. Newport Sanitary Authority*, 1889, where a street was formed by an old footpath repairable by the inhabitants at large and strips of land alongside which had been recently added to widen it, it was held that, having regard to the terms of the Section, the frontagers were chargeable with the expenses of improving the whole street, and not merely such part of it as had been added to the ancient highway.

It has been definitely ascertained that the old public lane now under consideration was public before the passing of the Highway Act of 1835, and the County Council have resolved to contribute the cost of making up that part of the street which embraces the area of the old lane.

Referring again to the premises 1-6 which are situated within the boundary of the Urban District Council, the latter Council, being owners of the premises, and having agreed to be included in the provisional apportionment as if they were and having agreed to be included in the provisional apportionment as if they were and having agreed to be included in the provisional apportionment as if they were frontagers within the meaning of the Act, also the railway company, and the owners of the hall and premises 7-10 and 25-34 being frontagers within the meaning of the Act, the only other premises to be considered are Nos. 11-18 and 19-24.

Under the Public Health Act, 1875, the expenses of private street works *must* be apportioned according to frontage; under the 1892 Act also, the expenses *are to be so apportioned*, unless the Local Authority resolve to exercise one or all of the powers given to them under Section 10 (a) (b) and (c) of the Act, viz:—

- (a) That regard shall be had to the greater or less degree of benefit to be derived by any premises from such works.
- (b) That regard shall be had to the amount and value of any work already done by the owners or occupiers of any such premises.
- (c) That they may also, if they think just, include any premises which do not front, adjoin or abut on the street or part of the street, but access to which is obtained from the street through a court, passage or otherwise, and which in their opinion will be benefited by the works and may fix the sum or proportion to be charged against any such premises accordingly.

If the Local Authority resolve to exercise their powers under Section 10 (a), (b) or (c) it will be the duty of the Surveyor to take these considerations into account in making his apportionment.

The apportionment must be approved by the Local Authority by Resolution under Section 6 of the Act, and may be objected to under Section 7.

The apportionments shall state the amounts charged on the respective premises and the names of the respective owners or reputed owners and shall also state whether the apportionment is made according to the frontage of the respective premises or not, and the measurements of the frontage and the other considerations, if any, on which the apportionment is based.

The apportionment shall be made on each separate house or plot and different premises belonging to one owner should not be lumped together.

If the apportionment is according to frontage, the objection will usually be that the premises do not front, adjoin or abut. An owner cannot object that the degree of benefit principle (Sec. 10 [a]) should have but has not been adopted, his proper remedy for that grievance is by appeal to the Ministry of Health under the Public Health Act 1875 Sec. 268, but if the premises are included in the apportionment under Section 10 (c) on the ground of Benefit of Access, it would seem that an owner of premises so included may object under this head that they ought to be excluded.

Where the Local Authority *have not resolved* that the apportionment of expenses shall be otherwise than according to frontage, the Justices have no jurisdiction to apportion the expenses otherwise than according to frontage.

If premises which have access to a street are included in the apportionment, it is *advisable* but not essential to state in the Resolution approving the provisional apportionment that the Local Authority "think just" to include such premises, but that they do so think just must be presumed from the fact that they have passed a Resolution under Section 6 (3) approving a provisional apportionment which *does in fact include such premises*. Let it be assumed that the County Council, in settling the apportionment have resolved to exercise the powers conferred upon them by Section 10 (b) and the last paragraph of that Section.

As to the meaning of the words Court, Passage or otherwise, apparently they include anything which gives access to the premises in the same way as a court or Passage, but not a Public Street or a road made for a purpose other than that of giving access to the premises in question.

Such a "Passage" need not be the only means of approaching the street, the word here means something in the nature of a "feeder" of the street to be made up. There may be included premises, access to which is obtained through a private road made *primarily* for the purpose of giving access thereto, but not premises access to which is obtained through a road which is or is intended for a Public Street, or premises access to which is obtained from a continuation of a street, a portion of which is being made up.

An appellant's premises did not front or abut on a portion of a street on which works were being carried out, but access therefrom to his premises was obtained through the remaining portion of the street.

It was held that the words "Court, Passage or otherwise" mean a court or passage, or something in the nature of a Court or Passage, but *do not mean* a portion

of street itself and that the section did not empower the Local Authority to include the appellant's premises in the provisional apportionment.

It has already been explained that the land in front of the premises 11 to 18 and shown in hatched lines on the plan does not belong to the owners of these premises. It would seem, however, that the owner "A" of the land having a total frontage of 160 ft. is the frontager on the street within the meaning of the Act and that the owners of the premises 11 to 18 cannot be included as frontagers in the apportionment.

The owner "A" has made a footpath across his land for the purpose of giving the owners of these premises access to the street, and it is considered that they can be included in the apportionment as having access through "a Court, Passage, or otherwise." In what proportion they are to be included has now to be considered.

The frontage of "A's" land directly in front of the eight premises is 120 ft. The frontage of "A's" land included in the plots of the premises, this 120 ft. is the total and had this land been included in the plots of the premises, this 120 ft. is the total frontage on which the eight owners would be apportioned each in proportion to the frontage of the respective plot. Each of the owners has equal benefit of access to the street, which they must use to get to the village "V," therefore it is considered reasonable to divide the frontage of 120 ft. equally amongst them and to include them in the apportionment, as if they each had a frontage of 15 ft., in addition to apportioning owner "A" on his total frontage of 160 ft.

The owners of the premises 19 to 24 have access to the street through a private back lane, 6 ft. wide, and derive equal benefit from the street as the owners of the premises 11 to 18. It is considered therefore that the former premises should be included in the same proportion as the latter.

In the case of the six premises 19 to 24, however, this proportion of frontage of 15 ft. on each of the owners includes a frontage of 1 ft. of the 6 ft. lane on each owner. This lane, as it belongs to the owners of these six premises, and serves them only, could be included, it would seem, in the apportionment, as a frontage within the meaning of the Act, in which case the 6 ft. would be divided amongst the six owners, and would thus make a frontage of 1 ft. to each owner.

It is not considered advisable, however, to include in the apportionment the same premises both as premises fronting, adjoining or abutting on the street and as premises having access, but care must be taken in preparing the apportionment not to include again the 6 ft. lane frontage.

The owners of these premises having access should not be included in the apportionment as frontagers but mention should be made that they are each included in the proportion of a 15 ft. frontage.

The frontages, MN, BX, and that of North Street are now to be considered.

As North Street and the roads of which BX and MN are the frontages, are all dedicated to the public, these three frontages are frontages of land 'extra commercium' and have no owner within the meaning of the Act.

In spite of this it would appear that they should be included in the provisional apportionment, and in this case the County Council as Highway Authority should

bear the cost. In quite a number of districts it is the custom to exclude frontages of this description from the apportionments, and spread the cost over the whole of the remaining frontagers on the street.

In the case of the frontage MN, it is doubtful whether the frontage should be the measurement M to N, or M' to N' which latter is the frontage on the general width of the street throughout practically its whole length.

For this purpose the frontage is measured from M to N and is 70 ft. That from B to X is 40 ft. and that of North Street 30 ft. The width of the old Public Lane is 5 ft. throughout its whole length and as the County Council have resolved to bear the cost of that portion of the carriageway which covers the area of the old lane it would seem that 5 ft. should be deducted from both the frontages MN and BX making them 65 ft. and 35 ft. respectively. For the purpose then, of that part of the street which is to be made up at the frontagers' expense, MN is 65 ft. and BX is 35 ft.

The total actual frontage on the street is 920 ft. made up as follows :—

	Feet
Frontage MN	65
Owner "A's" land	160
Hall and Premises 7-10	120
North Street	30
U.D. Council's Premises 1-6	140
Frontage B-X	35
Railway Company	160
Premises 26-34	180
No. 25	30
Total	920

This figure when divided into the total amount to be apportioned gives a rate per foot frontage.

The total proportion of frontage on which it is proposed to include the premises having access is 210 ft. made up as follows :—

	Feet
Premises 11 to 18 in the proportion of 15 ft. each	120
Premises 19 to 24 in the proportion of 15 ft. each	90
Total	210

Therefore the total of the actual frontage and the proportion of frontage is :—

	Feet
	920
	210
Total	1,130

Which figure when divided into the total amount to be apportioned gives a smaller rate per foot of frontage than the 920 ft. of actual frontage alone would give, so that it will be seen that the effect of the inclusion of the premises having access is to reduce the rate per foot of frontage on all the premises actually fronting on the street.

In the preparation of the provisional apportionment it is necessary to deal with the owners who have carried out certain works on the street.

It is a general belief amongst frontagers on a private street that they pay for a length of paving and kerbing and half width of carriageway on the side of the street on which their premises are situated, according to the frontage of their premises, and, although actually this is how the apportionment works out on many streets, it would not seem to be the correct interpretation of the Act, which does not state that premises shall be charged with the cost of the works on that side of the centre line of the street on which those premises are situated, but states that "the expenses incurred in executing Private Street Works shall be apportioned on the premises fronting, adjoining or abutting on the Street."

One half of the width of a carriageway of a street, owing to a bad foundation perhaps, may have to be made up with a more expensive form of construction than the other half, and the footpath on one side, owing to the levels of the entrance to the premises, may have to be a raised footpath involving the construction of a retaining wall, and it would not seem to be the meaning of the Act, that the frontagers on the one side of the street should pay for the raised footpath and more expensive carriageway construction, whilst those on the other side should pay for the ordinary footpath and cheaper form of carriageway construction.

Again, a street may be made up with a footpath on one side only, but it would seem that the premises on both sides can be included in the apportionment of expenses.

A Local Board resolved to execute certain Private Street Works in a street which had buildings on the north side only, and was bounded on the south side chiefly by land of the Local Board.

The works comprised the making up of the roadway and the paving and kerbing of a footpath on the north side only, no footpath being made on the south side.

By the provisional apportionment the expenses of paving and kerbing the footpath were apportioned amongst the owners of premises on the north side only, all other expenses were apportioned amongst the owners of premises abutting on both sides of the street.

It was held that the expenses of the footpath were properly apportionable amongst the owners of premises on both sides of the street.

It would seem from this that a frontager is not only liable to be apportioned with the expenses of the works on his side of the street, but on both sides, in other words, on the expenses of the works as a whole and that the owners on the street question, although they have carried out certain works of footpaths on the side on which their premises are situated, can be apportioned on the cost of the footpath on the opposite side and should not be excluded altogether from the expenses of

the footpaths, but as the Council have resolved to take into account the terms of Section 10 (B) these owners should be given a credit with regard to the amount and value of the works which they have carried out.

These works consist of paving and kerbing.

Let it be assumed that the three following items appear in the estimate of expenses:—

- (1) Provide and lay as specified new concrete paving (*a*) 5/- sup. yd.
- (2) ditto ditto ditto kerbing (*a*) 2/- lin. ft.
- (3) Take up and relay to correct lines and levels existing kerbing (*a*) 3d. per ft.

The kerbing and paving in front of the hall and premises 7-10 are in good condition and will not need to be disturbed in the works, so it would seem that the owners of these premises are entitled to a full credit value at the rates given in the estimate. For the amount of work they have done, *i.e.* the owners of the hall will be entitled to a credit for 40 ft. of kerbing at 2/- per ft., and each of the other premises 20 ft. of kerbing at the same rate per ft. These owners will also be entitled to a credit value of so many super yards of paving (according to the length of their frontage multiplied by the width of the paving) (*a*) 5/- per super yd.

Similarly the owners of premises 26-30 will each be entitled to a credit value of 20 ft. of kerbing @ 2/- per ft. as the material in front of the latter premises is equally good as that in front of the former.

In front of premises 32-34, however, whilst the material itself is good, it will be necessary to take it up and relay it to the correct lines and levels, which, according to the estimate will cost 3d. per lin. ft., therefore it would seem that these owners are only entitled to a credit value each of 20 ft. of kerbing (*a*) 2/- per ft. (the cost of new kerbing) less 3d. per ft. (the cost of taking up and re-laying) *i.e.* 1/9d. per ft.

Again, in front of premises No. 31, the kerbing is so badly damaged that it will be necessary to take it up and replace it with new kerbing so it would seem that this owner will not be entitled to receive any credit value for the work he has done.

Having decided what credit value is to be given to the owners of the premises concerned, it is assumed, in the provisional apportionment of expenses, that there has been no work of any description carried out in the street; then the total amount to be apportioned on all the owners will be:—The estimated cost of the proposed work plus 5 per cent. *plus* the total value of the works done plus 5 per cent. (the authority is allowed to include 5 per cent. commission in addition to the estimated cost, see Section 9 [2]).

In this way each owner is being apportioned on the cost of the street works as a whole. The total value of the work done plus 5 per cent. which has been included in the amount to be apportioned on all the owners, will then be deducted from the total charge on the premises concerned as a credit in their respective proportions, and the nett total of the apportionments on all the premises will equal the estimated cost of the work.

These credit values will be subject to adjustment in the preparation of the final apportionment after the works have been completed and it has been definitely ascertained whether or not it was necessary to disturb or replace the works for which the credit has been given in the provisional apportionment.

Finally it is necessary to deal with the construction of the soil sewer which is to be included in the scheme.

The County Surveyor when preparing his specification of Private Street Works, under Section 6 (2) shall, if and so far as the works include sewers, consult the Rural District Council. (Local Government Act, 1929, 1st Schedule part 1).

If a requirement were made by a Rural District Council to a County Council to construct a larger sewer than necessary for the street the County Council would no doubt make it a term including the requirements in the specification, that the additional cost should be repaid to them by the Rural District Council.

In the case of the street under consideration the Rural District Council have required the County Council to lay a 9 in. sewer in the street, which sewer will be of sufficient capacity to take also the sewerage from a proposed housing estate to be developed near the east end of the street.

It has been ascertained that a 6 in. sewer would be of sufficient capacity to deal with the premises on the street alone, therefore the Rural District Council have agreed with the County Council to pay the additional cost involved in the construction of the 9 in. sewer. (See Section 40, Public Health Act, 1925).

It would seem, therefore, in the provisional apportionment of expenses, that the cost of a 6 in. sewer only should be apportioned on the frontagers.

The whole of the premises including the Railway Company's offices will be connected to the sewer, and Nos. 19-25 will be connected by means of a combined drain through the private back lane.

Each pair of the Urban District Council's premises 1-6 is to be connected to the sewer by means of a combined drain, and a number of the other premises are to be similarly dealt with.

Apparently a combined drain from two or more houses of the *same* ownership constitutes a sewer, under the Public Health Act, 1875, and the question may arise whether or not these lengths of sewer, between the forecourt walls of the premises and the main sewer (*i.e.* the lengths actually under the street) should be included in the apportionment of expenses on the frontagers.

It would seem, however, that nothing outside the main sewer serving the whole of the street should be included in the apportionment as the specification could otherwise be attacked on the grounds of unreasonableness (Section 7 [d]).

The manner of connecting up the houses with the main sewer is a matter for the owners of the houses and the Rural District Council, who remain the Sanitary Authority for the district, and each frontager should bear the whole cost of connecting his premises with the sewer.

Apart from certain exceptions, all existing and future sewers within the district of a Local Authority shall vest in and be under the control of such Authority (Section

13, Public Health Act, 1875), and every Local Authority shall keep in repair all sewers belonging to them (Section 15, Public Health Act, 1875).

In the case of a combined drain from two premises of the *same* ownership, as this drain constitutes a sewer within the meaning of the Act of 1875, the Rural District Council, before allowing such combined drain to be constructed, would no doubt make it a condition that the owners of the premises concerned should sign an agreement, undertaking to be responsible for all the future maintenance and repairs. On the completion of the main sewer, it will become vested in the Rural District Council who will be responsible for its future maintenance and during the construction of the sewer by the County Council, the Rural Authority's Surveyor would no doubt be required to inspect it from time to time and to apply such tests to it as he would think necessary.

It may happen on a street, that certain premises will derive no benefit from the construction of a soil sewer, for instance on the street under consideration the premises 19-25 may have already been connected to the main sewer running parallel to the sea wall and the Railway Company may have had no offices to be connected. In such a case, as the Local Authority are empowered to do any one or more of the works called Private Street Works (Section 6 [1]) it would almost seem reasonable, if the Local Authority so resolve, to apportion the cost of the sewer on the degree of benefit system, and the remainder of the works on frontage, and access in this case.

DISCUSSION.

MR. A. O. MITCHELL, introducing his paper, said: This paper was written to illustrate a number of interesting and somewhat complicated points which frequently arise in the preparation of provisional apportionments under the Private Street Works Act, 1892. The various points are included in one street, in an attempt to show how interesting the preparation of the provisional apportionment for such a street would be, also to express an opinion as to how they could be dealt with in order to avoid, as far as possible, objections from the frontagers under Section 7 of the Private Street Works Act, 1892, and the upholding of any such objections by the magistrates.

The Private Street Works Act, 1892, is much wider than the sections applying to these works in the Public Health Act, 1875, and, by the inclusion of Section 7 in the former Act, frontagers may object to the proposed works on various grounds. This Section also has the effect of making surveyors to local authorities use considerable care in putting forward provisional apportionments to their Councils for approval.

Referring to the case of the old public lane in the Paper, numerous law cases have arisen over the question of whether a street is a street within the meaning of the Act or is a highway repairable by the inhabitants at large.

Other points on which frontagers often object are "That the proposed works are unreasonable or that the estimated expenses are excessive," also "That any premises ought to be excluded from or included in the provisional apportionment."

The "degree of benefit" system of apportioning lays a local authority open to receive many objections from frontagers, as it is by no means an easy matter to determine what greater or less degree of benefit any premises derive from the making up of a street. This system is often adopted where it is desired to give relief to corner premises. It is also very rightly adopted in the case of a street in which is situated a large factory or warehouse, the remainder of the premises being of the small working class type. This system is referred to in the paper in connection with the apportionment of the cost of the foul sewer.

MR. D. EDWARDS (*Brighton*), moving a vote of thanks to Mr. Mitchell, said: The case as it is presented in the paper appears at the first glance to be hypothetical, but those of us who are accustomed to the working of the intricacies of the Private Street Works Act will appreciate that the points raised are of real practical value.

It will relieve your minds if I say at once, particularly to those who are just coming into the working of these provisions—I am referring mainly to the county surveyor—that in no instance in any one street would you find the conundrums put forward in this paper all arising at one time.

It would be as well to remember, before we come to the discussion of this Paper, that we are dealing with both the Public Health Act, 1875, and the Private Street Works Act, 1892. The first of those, the Public Health Act, 1875, is ordinary compulsory legislation, whereas the Private Street Works Act, 1892, is an adoptive Act. But, once an authority has adopted the 1892 Act, it cannot revert to the former Act. Therefore you might as well ask yourselves the question: "What inducements have I to adopt the Private Street Works Act, 1892, in preference to the provisions of the Public Health Act, 1875?"

The first and foremost which comes to my mind is the fact that you are able to deal with the objections to the work before the work is commenced, whereas it is provided in the Public Health Act that the objections can be dealt with after the works have been completed.

The Brighton Corporation were badly bitten some two years ago. We went boldly forward with works on what we thought was a private street but was afterwards determined by the Justices and on Appeal to be an ancient highway, and consequently the local authority had to bear the whole of the burden of the cost of the works which had been carried out. Of course, it made them think a little more, and they said: "Well, suppose we adopt the Private Street Works Act, 1892; shall we then in future be relieved from this responsibility?" and it was eventually decided to adopt the Private Street Works Act, 1892.

Another important point, in my opinion, is the fact that you are able to have regard to the amount and value of any work already

carried out by the owners or occupiers of any of the premises. If we as individuals owned property in the street, I am sure we should be the first to say that it is only fair and reasonable that the owners should derive benefit from the work they have already carried out. That provision is given in the Private Street Works Act, 1892.

There is also another important point, which the author mentioned in his opening statement, namely, that you have provision for the greater or less degree of benefit to be derived by any premises from the works. As I said previously, the Public Health Act, 1875, allows you to determine the objections to the work after they are finished, and that is a disadvantage of that Act, in my opinion.

Whilst we have touched briefly upon the Public Health Act of 1875 and the Private Street Works Act of 1892, there is another important legislative enactment of recent making which is not referred to in this Paper at all. I refer to the Public Health Act, 1925, Section 30, which empowers the local authority to declare an existing highway to be a new street. It may be considered by many, as it is, to be a very contentious procedure. Take, for example, the case of an existing highway which the owner of land intends to develop for building purposes. Section 30 of that Act empowers the local authority to declare that road, as an existing highway or a road repairable by the inhabitants at large—it does not matter which—to be a new street.

There are two points of great importance to be noted when you are considering this Section. The first is that, if the local authority concerned are working under the provisions of the Public Health Act, they may include the existing highway and the added strip of the widened roadway as a whole cost apportioned on both frontages. If you are working under the Private Street Works Act the interpretation put upon the 1925 Act is that it is only the added strip which you may charge to the one side where building develops or a street is laid out. This is, of course, my opinion.

Now legislation is required upon this point, because I personally, at any rate, cannot conceive any local authority demanding from the owner of property the giving up of the whole of the land necessary to

widen the existing highway to the proposed width, and more if necessary, without some return for doing so, especially if he is also to be charged with the cost of private street works. It may be, of course, in the opinion of some people, considered fair, but to me it does not seem just and proper to compel the owner to give up the necessary land for widening the street and also to charge him with the cost of making up that section of the street. First of all, I have regard to the incidence of traffic existing or developing on the existing highway, and it has been determined by the local authority that the traffic demands a widened road, and, if the incidence of such traffic demands a widened road, I cannot see equity in charging the private individual for the cost of making street works, of such widening, and also giving up his land in connection with them.

As far as the Paper is concerned, I am sure you have all gone through it, but I want to draw your attention particularly to the properties marked on the sketch plan Nos. 11 to 18. Opposite No. 11 there is a court or passageway which leads from the street to the property, and there are two frontages marked there, one of 160 ft. and the other of 120 ft. The passageway is included in both of those frontages, and later in the paper it is suggested that the properties numbered 11 to 18 shall also be measured again for frontage purposes, so that No. 11 really comes in twice for a charge. My view on that point is that the passageway only, being a means of access into the property adjoining the street, should be charged to the street. We will assume that the width of the passageway is 8 ft.; that only should be included as a street frontage. We will assume further that the cost per foot is £1, so that the total charge on that particular frontage is £8, and we will assume further that there are eight houses into which that passageway connects; then the cost for each of those houses would be £1. That is my method of apportionment in this case.

The author does not quite agree with that, but I would not stop there. I would say that I should introduce the degree of benefit for those properties, because they are not actually abutting on the street. You may ask why I suggest that. Well, it is assumed that the land in front of the property is to be retained in private ownership. You

might say that will add to the amenities of the cottages. It may or it may not, because, if there is a different owner of the land in front of the cottages, he may feel disposed to put a large hoarding or a high fence in front of the property where it abuts on the road, so that the amenities of the houses are not increased or enhanced but are reduced. Therefore it is a clear case, to my mind, where the degree of benefit should come in.

It is suggested in the Paper that, in addition to the frontage of the property abutting on the street, the frontage also of other properties not abutting on the street should be taken into consideration for the apportionment, but, if that were so, you would be unable to compare the costs of one street with those of another. You will notice in the paper that, whilst the actual frontage of the property on the street is 920 ft., it is proposed to increase it by another 210 ft. for properties which really do not abut on the street at all, and therefore the total comes to 1,130, with the consequence of reducing the cost per foot of frontage. As an alternative to that, I suggest that the cost per foot of frontage should be based strictly on the actual frontage of the property to the street, that is, 920 ft., and that the other properties should be brought into account by the degree of benefit, deducting in proportion from the other frontages as they are worked out. You get practically the same result. The same principle, of course, applies to properties No. 19 to 25.

Mr. E. H. FORD (*Coventry*), seconding the vote of thanks, said: Mr. Mitchell has not enumerated in it all the conundrums which we get, but he has discovered a good many of them. Quite recently I had a peculiar case put up to me, where, owing to modern methods of transport, certain people went to a church by car, and it was suggested that they should take part of the land in front of the caretaker's house and the minister's house—this was a Nonconformist church and the 1892 Act had been adopted—and turn that land into a garage for the cars that came on Sundays, as the police objected to the cars waiting about in the streets. The question was put to me as to whether it was possible to get out of paying street frontages on the private street alongside the church, on the flanking wall. I said I did

not know and I thought it was a very open question, but we do find, of course, these points arising in connection with churches and chapels. Sometimes the caretaker's house is rated, and sometimes there is a Sunday school, part of which is rated, which may be used as a kind of institute.

With regard to these old lanes and streets, Mr. Edwards mentioned a case in Brighton. We have many cases in Coventry where there are old lanes which have been developed gradually in connection with building estates. When the Committee came to consider how they could get the land to widen these lanes, their attention was called, of course, to the powers under the 1925 Act. I am sure all of you here will appreciate that, when people buy estates for development, they buy the land at a certain price and in that price the back land is worth a comparatively small amount, say £50 an acre, but the frontage on these old lanes has been bought at rates varying from £250 to perhaps £500 or £600 an acre. This has to be averaged over the whole estate, and it may come out to £150 or £200 an acre. If you are going to put in force Section 30 of the 1925 Act in a form in which it might be construed but which, as Mr. Edwards said, is not by any means certain until we have some legislation on the point, you are going to upset the land values in the neighbourhood; that is, you are going to treat the old lane just as if the developer were laying out a new street in the central portion of the estate. He has got to give up the land for the widening, as he does if he makes a new street on the land—not quite so much, perhaps—and he has also got to pay the street expenses, and that, of course, is not possible if you are going to keep the cost of building, especially the cost of building working class houses, down to a reasonable figure. It is not possible if you are going to put those expenses on the old lane. As a compromise, the City Council decided to tell the land owners that we had these powers and that not only should we expect them in future to give us the land free of cost, as had been customary in the past if the local authority undertook the street works, but we should also expect them to go a little further and do any necessary excavation, tree felling, taking down of hedges, etc., down to the new road foundations. We

thought that, for the time being, at all events, that was a reasonable compromise, and we made a number of agreements on that point.

The only other matter to which I want to refer is the question of flanking frontages. Mr. Mitchell referred to that in his opening remarks, and, of course, we do find that, when a man has a corner site in old streets which have not been made up to the satisfaction of the local authority, there is a great hardship very often on people who cannot stand it. These people buy corner houses, entirely ignorant of the possibilities in the future, probably not having been warned by their legal advisers, and they find themselves suddenly faced with a long flanking frontage carrying a heavy portion of the street charges. We have had several cases of that, and our legal departments do not want too much of this bringing in of the degree of benefit. It lays them open to be shot at when the matter comes before the Justices, and they prefer that we should always keep, as far as possible, strictly to frontage. The way we have eased these matters in Coventry is by using the power to allow these people a fair amount of time to pay the charges, in some cases as much as six or seven years; also in some cases we have let them off interest charges. That seemed to be the fairest thing to do.

MR. D. H. PRICE (*Bedwellty*): Our experience is that the Private Street Works Act is a very unpopular Act to work. It is very difficult to get it put into force. Frontagers say that all private street works should have been done by the land owner before the street was completed or as the houses are completed, and it creates a very great amount of bad feeling amongst the frontagers. They say they have already paid to the land owner what he has called a development charge and they think that ought to cover all. Still, in many cases we have put the Act into force.

Taking first the question of the widening of the lane, I had one instance, very many years ago, where an old parish road, about 16 ft. wide, had been widened by building houses on both sides, and the land had been thrown into the road and had been used as part of the road for many years. The Clerk to the Council ruled that we could not put the Private Street Works Act into force in connection with that street, as it was

public highway, and the scheme was abandoned and the Council did the work at their own expense.

With regard to the frontage of the street in the paper, North Street, the system I have always adopted is to exclude all the cross streets from the frontage and simply take the total frontage, the net frontage, of the houses abutting on the street, and I have therefore had the same experience as is described by the Author in the paragraph where he states: "It is a general belief amongst frontagers on a private street that they pay for a length of paving and kerbing and half width of carriageway on the side of the street on which their premises are situated, according to the frontage of their premises," etc. People do not understand why they may be charged more than the actual amount right in front of their houses. With regard to the custom of the greater or less degree of benefit, I have had many cases where there has been a long flanking frontage of a house with a long garden, as much as 100 ft. frontage, and the front part of the house has already paid for private street works. In fact, I knew of one case where the front, side and back came in, three charges on the same property, and it was only a cottage of about 18 ft. frontage. Therefore it is obviously unfair to charge the whole of that work on that one property. What I have known to be done in many cases is this—it may not be strictly regular, but it has never been challenged—that we charge the man with only the actual amount of the side frontage built upon. It is not deducted from the total frontage, but, at the conclusion of the scheme, an allowance is deducted equal to that frontage. The Council have thus made a contribution toward the cost of the scheme, but the contribution is only for that particular frontage.

Referring to the question of access, I had one case which has not been dealt with at all in this Paper. It was the case of a fairly large quarry, with a narrow private road leading to it from the street. The system I adopted was to ascertain the rateable value of that quarry, compare it with that of the cottages, and charge the owner in the same proportion as the rateable value of the cottages fronting the street. With regard to the question of work already done, we take the estimate of the work to be

done and then valued the work which had previously been done by each frontager separately and then adding the total value of work done to the estimated cost, thus getting the estimated total value of the completed work. In estimating the value of completed work, deductions are made for any relaying of paving or kerb and channel that may be necessary. The total value of completed work is divided by the total frontage to get a figure per foot run. This figure is multiplied by each frontage to obtain the gross apportionment and then the net apportionment is obtained by deducting the value of work already done.

MR. H. D. STRANGE (*Dorchester*): I should like to ask whether it is necessary to advertise for contract prices or whether a surveyor can, under his Council, do work by direct labour without having to ask for the special consent of the frontagers.

MR. N. SCORGIE (*Highgate*): The principles enunciated in this Paper are extremely interesting, but I want, if I may, to utter one word of caution to those who intend or think it possible to put into practice the views which have been expressed here by Mr. Mitchell, because I am afraid that if they do they will find many pitfalls, and it will be a very long time before they get the provisional apportionment agreed to by the Justices.

Mr. Price said he was diffident about putting the Private Street Works Act into practice. I do not know whether by that he inferred that the Public Health Act of 1875 was the one preferred, but I want to say this, that the difference and the main difference between the Public Health Act of 1875 and the Private Street Works Act of 1892 is that in the latter you get all your difficulties overcome before you start spending the money in the hope of recovering it from the owners. If you make an apportionment under the 1875 Act you may get the whole thing quashed after you have spent the money, and you will not be able to recover anything, but if you get the initial provisional apportionment approved by the magistrates you have got a stage towards your goal. I realise that, even after you have spent the money, there is an appeal to the Ministry of Health regarding the principles of apportionment, the charges, etc.

I suggest to Mr. Mitchell that, notwithstanding an agreement by the County Council and the Urban District Council, it would be *ultra vires* to include anything as an apportionment, upon the Urban District Council or their property. They are outside the area, and no agreement can go beyond statute law. Therefore the only way he can do what he wants and get over his trouble there, being desirous that the Urban District should make a contribution to this highway which is going to be for their benefit, is by the County Council agreeing to pay such an amount as represents the apportionable sum and the County Council then entering into an agreement with the Urban District Council to repay that amount.

With regard to properties Nos. 11 to 18, and Nos. 19 to 25, I say definitely that to apportion those properties on frontage rates is illegal and if you did that you would get your apportionment upset. You must remember you are apportioning on premises which "bound, abut or adjoin thereto"; those are the words of the statute. You have only got "access to" here. The only way in which those people at Nos. 11 to 18 and Nos. 19 to 25 can have any expense apportioned upon them is in respect of those passages which abut upon the highway in question. I heard Mr. Edwards giving you that arithmetical sum about eight houses and a passageway of eight feet and a cost per foot of £1, so that the cost for each house would be £1—I thought that was rather good for him! He made a suggestion that you might do it by degree of benefit, but I have had conversations with a good many Town Clerks, and they all feel shy of the degree of benefit, because when you are apportioning on frontage you are on a sure foundation but when you are apportioning on degree of benefit and you have to place that in front of lay people as the Justices are in a great measure they may have a very different idea of the degree of benefit which a particular property has on a particular street from the idea which the engineer and the Town Clerk may have, and therefore they would upset your apportionment in that respect.

The old lane question is one which is often in front of us, but I do not think it has ever been decided under the Public Works Act whether you can deal with these streets as

one highway because you have got a highway between two strips of land. There is the old highway. If you deal with that you will have to relieve the frontagers of the expense of making up that portion which has always been a highway repairable by the inhabitants at large.

Notwithstanding experience under the Metropolitan Management Act, the Public Health Act and the Private Street Works Act, I should not like to submit an apportionment to Justices on the lines indicated by Mr. Mitchell. He has given us many conundrums but he has given us many pitfalls, and I should caution very strongly those young men who read what has been said in this Paper to take a note of the cases that have been decided on these points. I do not say this unkindly, but of course the County Councils are only infants in the matter of dealing with private street works, and they cannot become even youths until they have got past their childhood.

THE CHAIRMAN (MAJOR ROSEVEARE): Am I not correct in stating that under the 1925 Act, while a further 20 ft. to be given up from the land can be demanded, the extra width of street works has to be charged to the local Council?

MR. L. L. BALDWIN (*Coalville*): A point has arisen with me recently which I think is somewhat of a novelty, and an illustration of the way in which the authority may get "twisted" under these Acts. We were working under the 1892 Act. There was a corner plot which had a frontage of 40 yards to the street which we were going to make up. During the course of the negotiations and the time of provisional apportionment, etc., the man who owned this corner plot sold off a strip 40 yards long and a foot wide, so that he entirely cut off his land and premises from the proposed street. He had neither frontage nor direct access to the street. Before notices were served he took the precaution to sell this strip of land to a man of straw, from whom it was useless to attempt to recover anything even if we could find him, and the matter has now stood over for some considerable time. We reported the facts to the Ministry of Health and I believe legislation to meet similar cases is in hand. In the meantime we are taking the precaution of assessing a nominal rateable value on this 40 yards strip, which will bring

into the Valuation List, and so keep it before our eyes. We are also entering it in the Land Charges Register, so that if eventually the original owner of the land tries to take possession of this strip again we shall have some chance of recovering our expenses.

Mr. F. READ (*Gellygaer*): It is venture some on my part to disagree with Mr. Edwards and Mr. Scorgie, but I venture to say that there is no simpler way, and no more practical way, of assessing degree of benefit than fixing a frontage to accord with it, and I suggest that Mr. Mitchell, in allowing a frontage of 20 ft. or whatever it was, to each of Nos. 11 to 18, has done exactly what Mr. Edwards would do, only he has done it in an absolutely simple way. Mr. Edwards' result would be exactly the same and it would be, I suggest, more puzzling for the magistrates to approve.

I know of a case similar to the one that has just been mentioned, where a narrow strip of a flank frontage was sold to a man of straw, to avoid street costs, and the owner got away with it.

Mr. Mitchell has told us a good many things, some of which I do not think are safe. For instance, he allows 5 per cent. on the value of the work already done. That seems to me quite outside the Act. In effect, what he has done is to charge the other frontagers with 5 per cent. on what the old works would have cost if they had been done to-day, and handed that over to the present owners. It is not legal.

I missed in this Paper the fulcrum that the whole thing turns on, i.e., the service of notices. If there are any pitfalls anywhere, that is where you will find them. You have got to serve the notice on the owner or the reputed owner, and in our part of the world, where most properties are leasehold, there are leases, sub-leases, building agreements, mortgages in possession and out of possession, agents, rent collectors. It is very difficult indeed to know who is the technical owner of the property, let alone the owner of vacant land. There may be a plot which has been sold or leased; a man takes a plot to build three cottages and builds them on half of it, and there is room for another cottage, and you cannot distinguish that land from the vacant land next door. Therefore the service of notices is a very difficult matter. The way that seems to me to be most safe

is not to serve on the owner at all but to pin your faith to a notice served on the ground. You can send a copy to the owner, and you should do so, but notice on the ground is legal. Even then, however, there are snags. You serve a notice on the ground, on a plot perhaps 50 ft. wide, and by and by that is cut up, perhaps into three plots. One plot had a notice and the other two had not. The new owner says he was never served. The practice I have carried out myself, therefore, is to divide the land up into 15 ft. plots, and then everybody will have at least one notice.

Mr. C. W. DAVIS (*Ellesmere Port*): I am going to mention particularly three points: the value of work already carried out, the degree of benefit derived, and making up a street of less than by-law width.

The street I have in mind is perfectly straight, short in length, and terminating by giving access to a quarry. It contains a public footpath 4 ft. wide, which runs down one side, and, of course, the cost of making up that proportion of the width of the street would not be charged on the frontagers. The owners of the quarry have, almost from time immemorial, carried out certain repairs to the street, in order to render it in such a condition that they could use it. Unfortunately for them, the street is located on clay subsoil of a very soft nature. To my knowledge, during the last three years they have put many tons of broken bricks and loads of ashes on the road, and the only result is that, by the time two or three hundred of their vehicles have gone over, the clay has come through the ashes and the bricks have disappeared beneath somewhere, and there seems to be no possibility of getting any consolidation or any foundation in this way. If my Council make up that street the quarry owners will claim that they have already contributed something of value towards its making up, but I consider they have not. The materials they have applied to the surface are to-day valueless and have been rendered so by the traffic which has passed over it, for which they and they alone are responsible.

Then we come to the degree of benefit derived. Here we have a street which is 75 per cent. built up and, much as I dislike having to make up a street and apportion according to degree of benefit derived to a

certain extent, what alternative is there? The owners of the quarry are alone responsible for the condition of the street. It is a quagmire; it is nothing but mud and it is full of pools of water. Every time a lorry passes down it the water splashes up on the side and pedestrians get dirty. When I come to apportion the expenses, I must apportion a considerable amount of the cost of making up the street on these quarry owners. They are at the present moment using the street to 75 per cent. of its total use. I cannot apportion on frontage alone. Their frontage is merely the end of the street, a width of about 18 ft.

Finally, the street varies in width between 18 ft. and 22 ft. As I have already said, it has 75 per cent. of its frontage made up. I do not know any powers which entitle my Council to widen the street and charge the cost of so widening it on the owners of the property. I do not know of any powers which my Council may have to appropriate the land. If the street were not developed and development were taking place, I believe they could require development to take place in such a way, with fences set back, that there would be a street 36 ft. in width. In the circumstances, they cannot do it. The Council badly want to make up the street. The frontagers want it made up, probably because they are not the owners, and the frontagers should have it made up. They are really living in appalling conditions. Are there any steps which an authority can take to get such a street made up to the full By-law width, or must they proceed, if they are going to proceed at all, to make it up at its present width of between 18 and 22 ft., knowing that some day they or their successors will be compelled to widen it to by-law width at the cost of the rate-payers?

Mr. R. J. JENKINS (*Portsmouth*): I want to ask a question in connection with the houses Nos. 19 to 25. I presume that the builder bought the land on which they stand and the land on which the back lane stands, that is, he bought one big plot and when selling the houses sold with each the plot on which it stood only. The result is that the back lane is still his. Could you still distribute the cost? If you work under Section 150 the builder, who did not convey

any part of the back lane to the houses, would have to pay.

Mr. H. CLIFFE (*Bromley*): I want to refer to the case of *Evans v. Newport Sanitary Authority*, which is quoted in the Paper, where it is given as substantiating the case for widening an old highway and charging the whole cost of the work against the frontagers. I notice particularly in that case that an "old footpath" is referred to, but in the next paragraph of the Paper Mr. Mitchell refers to an "old public lane." There does appear to be considerable difficulty in deciding whether, in the case of an existing public highway, the land can be taken in under the Section to which Mr. Edwards has referred, Section 30 of the 1925 Act, for the purpose of declaring a new street of by-law width and then charging the expenses of constructing the whole width to the frontagers. Mr. Edwards was very definite that this could be done, but I am still in doubt as to whether it can be done. Section 30 states that you may declare the street a new street for the purpose of the application thereto of the by-laws, and of any provisions in a local Act with respect to the width of new streets, the by-laws as a rule state definitely that the street must be a certain width. With regard to construction, they state as a rule, if the road is to be constructed, the way in which it should be constructed. As a rule, however, we find that streets are not constructed by the people laying out the street but subsequently the Public Health Act or the Private Street Works Act has to be put into force in order to get the street made up. Of course, where it is an existing road not repairable by the inhabitants at large, and owing to building development the street is declared a new street, there appears to be little difficulty.

One other point I want to refer to in the Paper, where, taking one case in particular, Mr. Mitchell states that, as North Street is dedicated to the public, its frontage is a frontage of land "extra commercium" and has no owner within the meaning of the Act. Mr. Mitchell states that, in spite of this, he thinks that this frontage ought to be included in the provisional apportionment and that the County Council as Highway Authority should bear the cost. This, of course, is a very unusual practice, and I

should like to ask Mr. Mitchell if he has considered the point that, although the highway abutting is dedicated to the use of the public, they have only surface rights in that highway and some other person still owns the subsoil, and, if anyone should be charged with street making charges, the owner of the subsoil should be charged.

MR. A. W. CURRIE (*Lymington*): There is one point in connection with this subject which I have not heard mentioned. A Council some two years ago started to make up a private street and went before the Justices. The Justices amended the specification to such an extent that the Council thought they would not go on with the work. They therefore rescinded their resolution to make up the street and did nothing. After a period of two years a new specification was prepared, with new apportionments. The case went to the Court, and the Court ruled, taking a case that happened many years ago, that they could not hear the objections at all in this case. The Court admitted that the Council were within their rights in rescinding the resolution, but they said the Council could not go on with the matter again. The point arises, first: What is the actual position of the Council? Secondly, may the frontagers themselves make up the street and call upon the Council to take it over as a public highway?

There is one further point. If the frontagers elect to make up the street, do they make it up under Section 20 of the 1892 Act, which says they must make it up to the satisfaction of the Urban Authority? If they have to make it up to the satisfaction of the Urban Authority, the Authority could then require their previous specification, which was cut down, to be used.

THE CHAIRMAN (MAJOR ROSEVEARE): I quite agree with Mr. Edwards that it is not fair to charge Nos. 11 to 18 on the basis of frontage. There is not the slightest doubt that the man who has retained the land on the front has done so for the purpose of developing it. That means that the rear of those new houses would back on to the fronts of the existing houses. Therefore there must be a small footpath entry to the main road, and without the slightest doubt Nos. 11 to 18 should be charged only for the width of the entry from the private street. With regard to Nos. 19 to 25, their entry

into the new street is only a back lane, and to charge the owner full frontage charges for a back lane, when he has the main street in front and presumably has paid for that when it was made up in the first place, would be definitely unfair.

It would be interesting to obtain a plebiscite of the surveyors in this room to find out how many of them charge for the cross roads and how many do not. One's experience in going up and down the country is that the procedure on that point varies very considerably.

MR. W. H. ELEY (*Newmarket*): I should like to draw attention to the Rights of Way Act, 1932, which comes into force on the 1st January next, and which will probably clarify some of the difficulties which now exist in respect of what are existing highways. A register has to be made and certain things have to be done. It is a very short Act. I think, if it is worked, it will to some extent clarify some of these difficulties which Mr. Edwards has mentioned chiefly in regard to footways and rights of way such as those mentioned in the old Enclosure Awards, or anything like that.

MR. A. O. MITCHELL, in reply, said: With regard to the premises Nos. 11 to 18 Mr. Edwards suggested that they should be apportioned on degree of benefit.

I am of the opinion that the premises cannot be included in the apportionment in this way as they do not front, adjoin or abut on the street.

The Act distinctly states that the expenses incurred in carrying out private street works shall be apportioned on the premises fronting, adjoining or abutting on the street, according to the frontage of the respective premises unless the Local Authority resolve to have regard to one of the considerations mentioned in Section 10, and even if the Local Authority do so resolve to apportion the expenses on the degree of benefit principle that principle can only be applied to premises fronting, adjoining or abutting on the street.

The latter part of Section 10 enables the Local Authority to include in the apportionment, premises having access to a street through a "court, passage or otherwise," and I am of the opinion that this is the only way in which premises which do not front, adjoin, or abut on the street, can be included.

It is left to the Local Authority to decide in what proportion such premises shall be included, and in the Paper it is mentioned that the premises are not included as actual frontages, but each in the proportion of a 15 ft. frontage.

Referring to the question about carrying out private street works by direct labour or contract, this I think is a matter for the Local Authority to decide, as there is no mention in the Act about the adoption of either system.

With regard to the 5 per cent. commission credited to owners of works already done, the total estimated cost of the proposed works plus 5 per cent. commission is ascertained and the total value of the works already done plus 5 per cent. is also ascertained. The two totals are added together and apportioned over all the frontages. In this way it is assumed that no work of any description has been carried out on the street. Each frontager who has already carried out work is given credit for the value of the particular work plus 5 per cent., the reason being this, that those particular frontagers are being apportioned with their share of the 5 per cent. commission of the estimated cost of the proposed new works on the street, therefore it is considered reasonable to credit them with the value of the works which they have already done, plus 5 per cent.

It is rather difficult for me to give an answer to Mr. Davis's questions without seeing the street to which he referred, or having a little more information about it. I shall be pleased to reply to these questions in writing.

With regard to the premises Nos. 19 to 24, and the back lane serving them, perhaps I have not made it quite clear in my Paper, but that lane is the property of the owners of the particular premises. I have included those premises in the same proportion as I have included the premises Nos. 11 to 18, as having access to the street, but in this case the proportion of a 15 ft. frontage to each owner includes a proportion of 1 ft. of the 6 ft. back lane which is a frontage within the meaning of the Act. This, I think, is fully explained in the Paper.

The next question referred to the "extra commercium" frontages which I mentioned in connection with North Street, etc. In

my opinion the frontages of any dedicated highway are frontages within the meaning of the Act, and should be included in the apportionment of expenses. I do not think it is fair to spread the cost of these frontages over the remaining frontagers on the street. Although it is the custom to do so in many districts, I think the cost of these particular frontages should be borne by the Council.

With regard to the question about *Evans v. Newport Sanitary Authority*, I should like to have time to consider that, and I will answer it in writing.

THE CHAIRMAN (MAJOR ROSEVEARE): With regard to the point whether a local authority can carry out work by direct labour or must do it by contract, they can do either, but the point is that, after they have carried out the work by direct labour, they are open to have an appeal made to the Ministry from any of the frontagers, to the effect that had the work been done by contract it would have been done more cheaply.

MR. A. O. MITCHELL has contributed the following reply:—

Having read the full report of the remarks of the various speakers, I have the following observations to add to my replies at the Discussion.

MR. D. EDWARDS.—With regard to premises Nos. 11 to 18 and the two frontages of 120 ft. and 160 ft., I do not quite follow what Mr. Edwards means when he says that premises No. 11 comes in twice for a charge. This is not the case, as it will be seen on reference to page 767 that the whole of the 160 ft. frontage which includes the footpath is charged to Owner "A," whereas the premises 11 to 18 have only been included once, each in the proportion of a 15 ft. frontage, and not as being actual frontages on the street.

MR. EDWARDS suggests that he would include these premises by dividing the frontage of the passageway equally amongst them and then introduce the degree of benefit system for them. I have explained at the commencement of my reply why I do not think that the premises 11 to 18 can be included under degree of benefit, but can only be included under the latter part of Section 10 as having access through a "Court, Passage or otherwise." This passageway, or footpath as I have called it in the paper, has been

made by Owner "A" for the purpose of giving the owners of the premises under consideration access to the street, but it will be seen on reference to the sketch plan that "A" still retains the ownership of this footpath.

The latter part of Section 10 enables the Local Authority to fix the sum or proportion to be charged on premises having benefit of access, which in their opinion will be benefited by the works, and in the case under consideration, as each of the premises 11 to 18 will be benefited by the making up of the street to the same extent as any of the premises actually fronting on the street, it would be unfair, in my opinion, only to charge these premises with an equal share of the frontage of the footpath, which, assuming, as Mr. Edwards does, the frontage is 8 ft. and the rate per foot £1 would only be a charge of £1 on each of the eight premises.

For the purpose of comparing the costs of street works and the rates per foot of frontage, naturally only the premises actually fronting on the streets, i.e., the premises which make up the length of the streets, should be taken into consideration.

Mr. E. H. Ford.—With regard to the case of the Nonconformist Church, I do not think that any buildings other than those devoted exclusively to public religious worship, or any lands other than churchyards or burial grounds attached to such buildings, can obtain exemption from Private Street Works charges under Section 16. It was held in a recent case of Ilford Corporation v. Mallison that a piece of vacant land adjoining a building appropriated to public religious worship, on which land it was intended to erect a Sunday school, is not entitled to be excluded from the provisional apportionment of Private Street expenses.

Mr. D. H. Price.—The method which Mr. Price adopts for dealing with works already carried out, is precisely the same as the method suggested in the paper, and is, in my opinion, a fair and straightforward way of dealing with such works.

Mr. H. D. Strange.—I have already replied to Mr. Strange's question, but I should like to add in reply to the Chairman, Major Roseveare, that if the Surveyor's estimate is less than any of the tenders received

from Contractors, I think that the works could safely be carried out by direct labour without much fear of objections from the frontagers.

Mr. N. Scorgie. With reference to the U.D. Council's premises Nos. 1 to 6, while I agree with Mr. Scorgie that possibly the safest way to deal with these premises would be for the County Council to first of all contribute the amount of the apportionment and recover the same later from the Urban District Council, the same result would be achieved in the end as if the latter Council agreed for their premises to be included in the apportionment.

Referring again to premises 11 to 18 and 19 to 24, Mr. Scorgie says it is definitely illegal, and Major Roseveare says it is unfair to include those premises in the apportionment in the way suggested in the paper, and that they can only be apportioned in respect of the passages through which they have access. I do not agree, for the reasons given in my reply to Mr. Edwards, and furthermore, the Act does not state that premises having access to a street must be apportioned only on the frontages of the courts or passages etc., through which they have access. Mr. Scorgie says that it must be remembered that the expenses are being apportioned on the premises which front, adjoin or abut. These are not the only premises to be included in the apportionment for this street, and in paragraph 6, page 766, it will be seen that the County Council, in addition to apportioning on the premises which front, adjoin or abut, have resolved that in settling the apportionment they will take into consideration the powers conferred upon them by the last paragraph of section 10, which allows them to include premises having access, and, as already stated in reply to Mr. Edwards, to fix the sum or proportion to be charged against such premises.

Proceeding, Mr. Scorgie, states that Town Clerks and Justices feel shy about the Degree of Benefit principle, and prefer the frontage principal as being a sure foundation. In the paper the premises concerned have been included in the proportion of a 15 ft. frontage each, and as Mr. F. Read states, it is, in my opinion also, a simple and practical way of assessing such premises. Instead of including them as if they each

had a frontage of 15 ft., they might have each been assessed with the amount which the 15 ft. produces and then the necessary deductions made from the total amount to be apportioned on the other frontagers. The ultimate result would be the same, but as Mr. Read states, the former method is much simpler and easier for Magistrates to understand.

With regard to Mr. Scorgie's warning to readers of this paper, I would say that the paper was prepared after thorough investigation of various legal opinions on the cases mentioned. The chief point of contention seems to be the premises having access, and I can call to mind a case where such premises were included in a provisional apportionment on precisely the same lines and not one objection was received from the owners of the premises concerned.

I think that in preparing a provisional apportionment a point which should not be overlooked is, fairness to all the premises concerned. Full regard has been given to this point in the paper, and I am fully of the opinion that an apportionment drawn up on the lines suggested would meet with the approval of the Justices.

I am of the opinion that the clauses in Section 10 of the Act should be taken advantage of wherever possible, because it is far too common a practice for Councils to take the easiest way out and apportion strictly according to frontage.

Mr. F. Read.—With reference to Mr. Read's remarks about the 5 per cent. on the value of works already done, I think he must have slightly misconstrued the paragraph on page 770 concerning this point. I hope I have now made it clear by my remarks at the conclusion of the discussion.

In cases where the owner of a plot or plots of land is doubtful, I think it is a very good idea to post notices on the respective plots in addition to serving them on the reputed owners. It is a very safe way of overcoming the difficulty of which Mr. Read speaks, and in my opinion should be done in all such cases.

Mr. C. W. Davis.—Mr. Davis states that the street to which he refers contains a public footpath 4 ft. wide which runs down one side and that the cost of making up that part of the street would not be a charge on the frontagers. Apparently the Council of Elles-

mere Port are working under the Private Street Works Act, 1892, but a point which should be borne in mind is that the procedure under this Act, and the Public Health Act, 1875, is entirely different, and I refer Mr. Davis to the last paragraph on page 764 and the first paragraph on page 765 of the paper, which explains fully the difference in procedure of the two Acts with regard to a street of which part of the width is repairable by the inhabitants at large.

Dealing now with the works already carried out by the quarry owners, these works apparently consist of various loads of hardcore put in the road to secure a foundation for their lorries. If this hardcore has become valueless on account of the lorries using the road, then I do not think the owners are entitled to any credit for the work which they have done. The Local Authority are not bound to take into consideration the amount and value of work already done by the owners of any premises, but they may resolve to do so if they think just. (See Sec. 10, P.S.W. Act, 1892). If the Local Authority do not resolve to do so, I do not think that the Justices could order that such works should be taken into consideration. A frontager may object about the amount and value of work already done under Section 7 of the Act, but I am of the opinion that such an objection could only be considered by the Justices providing the Local Authority had resolved to take these works into consideration. Assuming that during the progress of the works, the existing hardcore was found to be of some use, a credit could be given to the owner concerned in the final apportionment.

With regard to the degree of benefit to be derived from the works, this street seems to be one to which that principle of apportioning should be applied, as the quarry owners only have a frontage of 15 ft., but at the same time use the street to 75 per cent. of its total use; it would obviously be unfair to apportion on frontage alone.

The street apparently is 75 per cent. built up, and presumably the owners of the premises are bound to use the street, and, apart from the owners of the remaining 25 per cent. of vacant land, will all derive equal benefit from its being made up. What that degree of benefit is can only be determined by the Local Authority, but I think

that the quarry owners should be apportioned with a considerable share of the cost of the works. I can remember a street made up some years ago, in which was situated a large works the remainder of the premises being of the small working class type. The degree of benefit system was introduced, and I believe the owners of the works were apportioned with half the cost of the works, the remaining half being equally divided amongst the owners of the other premises. I think that Mr. D. H. Price's method of taking the rateable value into consideration would be exceedingly useful in a case such as this.

If the public footpath which runs down one side actually abuts on the forecourts of the premises on that side, I think it is very doubtful if the frontagers on that side can be included in the apportionment, either on frontage or degree of benefit, as they do not front, adjoin or abut on the private street, but on the public footpath which, presumably, is repairable by the inhabitants at large. I also think it is doubtful, if these premises could be included under the latter part of section 10, as having access to the part which is the private street, as such access must be through a court, passage or otherwise, and not by means of crossing a public footpath. (See page 766). If, however, there is a part of the private street between the public footpath and the forecourts on that side of the street, then I think the premises could be included in the apportionment. (See last paragraph page 764, and first paragraph page 765).

Dealing lastly with the question of making up a street of less than bye-law width, I understand from Mr. Davis's remarks, that it is the wish of his Council to widen the street from its present width of 18 to 22 ft. to a uniform width of 36 ft., and I am of the opinion that under sections 154 and 176 of the P.H.A. 1875, the necessary land may be acquired subject to compensation, to enable the Authority to widen the street, whether the widened portion can be made up at the expense of the frontagers is doubtful. It has, I believe, been held that if a Local Authority purchase land for the purpose of making a new street they cannot afterwards make it up at the expense of the frontagers, i.e., the new street becomes repairable by the inhabitants at large. Also,

if they purchase land for widening a new street already repairable by the inhabitants at large, they must henceforth keep the whole in repair, and the widened part cannot be made up under their Private Street Works powers. Where, however, the purpose is to widen a *private street*, the intention of section 154 may be that the added strip shall merge in and become part of the private street liable to be made up by the adjoining owners. Assuming this to be the case, only the works included in Section 8 (1) of the Act of 1892 could be charged to the frontagers, and the cost of such works as the taking down of forecourt walls or fences and re-erecting same in their new positions, could not be apportioned on the frontagers.

A number of speakers have mentioned Section 30 of the Public Health Act, 1925, but there seems to be some doubt as to whether this section could be applied to the case under consideration, and I think to be on the safe side it would be as well for the Council to acquire the added strip of land, subject to compensation, under Section 154, and contribute the cost of the making up of this added strip under Section 15 of the 1892 Act.

Mr. R. J. Jenkins.—In connection with the premises 19 to 24 and the back lane, this lane is the property of the owners of those premises.

These premises are included in the provisional apportionment in the same proportions as the premises 11 to 18, but in this case that proportion includes an equal proportion on each owner of the 6 ft. back lane. If the builder of the premises still retained the ownership of the back lane, whether the Local Authority were proceeding under Section 150 of the P.H.A. 1875, or the Private Street Works Act, 1892, the builder would in my opinion be liable for the 6 ft. frontage of the lane, but I think that the premises 19 to 24 could still be included in the apportionment as having access through a court, passage or otherwise. This is precisely what happens in the case of the premises 11 to 18 and the passageway through which the owners have access. (See reply to Mr. D. Edwards).

Mr. H. Cliffe.—The case of Evans v. Newport Sanitary Authority, is mentioned as an example of the procedure under the latter part of Section 150 of the P.H.A.

1875. An old footpath *repairable by the inhabitants at large* is quoted in the case.

The definition of the word "Street" given in Section 4 of the P.H.A. 1875, includes lanes and footways, the same definition is extended to Section 5 of the Private Street Works Act, 1892, with the additional words, "and not being a highway repairable by the inhabitants at large."

With regard to the "extra commercium" frontages, I agree with Mr. Cliffe that the public only have the right over the surface of dedicated highways and that some other person or persons own the subsoil. At the same time owners of lands incapable of yielding a "Rack-rent," such as owners of the soil of dedicated highways, are not liable for Private Street Works expenses in respect of the frontages of those highways, and, as stated in the commencement of my reply, I think that the Local Authority concerned should bear the cost of the frontages of such highways.

Mr. A. W. Currie.—The case stated by Mr. Currie is rather a puzzling one. Apparently the Court ruled that once the Council had rescinded their resolution, they could not bring the matter forward again. I think there is a considerable amount of doubt about that ruling, in view of the fact that the Standing Orders recommended by the Ministry of Health stipulate, I believe, a period of 6 months between the rescinding of a motion and the further proposal of a similar motion. I think that the Local Authority could agree with the frontagers under Section 146 of the P.H.A., 1875, to make up the street and subsequently take it over, but no doubt the Authority would require the street to be made up to a specification satisfactory to them in the same way as if they, the Authority, made it up themselves. This would also apply before taking over the street under section 20 of the Act of 1892.

If the frontagers agree to make up the road themselves subject to the Council taking it over, and the Council on their part insist on the previous specification which was cut

down by the Court, the position of the Council and the frontagers would seem to be something in the nature of a deadlock from which it is difficult to see a way out, especially in view of the Court's previous ruling of the case.

Major Roseveare.—In replying to Major Roseveare, it is again necessary to consider the premises 11 to 18 and 19 to 24, and I refer Major Roseveare to the sketch plan in the paper.

When the paper was written, I had in mind the case of an actual street in the County of West Sussex for which a provisional apportionment was prepared. It will be noticed that the forecourt fences on the West side of premises 19 to 24, are set back some way behind the line of the wall of owner "A's" land on the West of premises 11 to 18. This is indicated by the direction of the dotted line MN.

The land on which the sea wall abuts and along which the main sewer runs is beach, not a highway, and there are proposals in the district to extend a promenade along this beach. Owner "A" has retained the land hatched on plan, not for the purpose of building, but for the purpose of negotiating with the Council, when the time comes, for the purchase of his land, to enable the promenade to be constructed of the same width as that between premises 19 to 24 and the sea wall, and also for making the necessary "bell mouth" to the private street. This, perhaps, should have been explained at the commencement of the paper. It will be realized, that as the land abutting on the sea wall is beach, and not a highway, the owners of premises 19 to 24 have had no previous road charges to pay.

In conclusion, with regard to the various statements which have been made about Section 30 of the P.H.A. 1925, this section refers to new streets, and, in my opinion it is doubtful whether it could be applied, even if it were so desired, to a street such as the one in the paper which has been fully developed for a considerable number of years.

The following Paper was taken as read :—

Vibration in Roads and Buildings.

BY

C. H. BRADBURY, A.M.Inst.C.E.

(NOTE.—This Paper was submitted for the Open Competition arranged by the Congress Committee and was awarded a Special Prize of Five Guineas).

VIBRATION, whether in the form of tremor or noise, is probably the biggest curse of modern civilisation. The phenomenal increase in motor traffic together with the increasing use of machinery have gone far towards aggravating the nuisance and it is now becoming realised that serious steps must be taken to protect buildings from vibration and individuals from noise. The recent building collapses in London, for which no explanation could be found other than that they were caused by transmitted vibration, show to what extent the trouble may manifest itself, and it is an open secret that the authorities are gravely concerned regarding the safety of London's more notable buildings.

For some years past, attempts have been made in various parts of the world to cure the bogey of transmitted vibration. Underground and surface railway companies, and contractors for the installation of reciprocating engines, have at various times devoted considerable time to the problem, and in many instances success has been attained. But the fact that there have also been many failures, and that methods which have proved successful in some instances have, for no apparent reason, failed in others, show that the subject is, as yet, only partially understood.

The following paper is therefore an attempt to throw light on the subject generally and to co-ordinate theory and practice in so far as present day knowledge will allow.

THE VIBRATION OF ELASTIC BODIES.

The fundamental condition governing vibration problems is that all elastic bodies from a simple rod to a complicated building have one or more natural periods

of vibration. These natural periods, which in complicated cases may take a multiplicity of forms or modes, normally lie dormant until excited by some external influence.

If now this external influence takes the form of a periodically recurring force and its period happens to coincide with one of the natural periods of the body affected, the latter period is "picked up" and amplified, and the amplitude of the vibration of the body may assume dangerous proportions, even though the recurring force is so small that, if applied statically, its effect would pass unnoticed. This is the important condition of "resonance" and it is the object of the vibration engineer to avoid this condition in roads, buildings and machinery.

If the natural frequency of the body is any exact multiple of the frequency of the disturbing force, resonance is again possible on account of the fact that synchronism is obtained between the natural frequency and a harmonic of the forcing frequency. On the other hand, if the natural frequency is less than the forcing frequency, resonance is impossible as there is no harmonic in the forcing frequency below the fundamental.

In brief, a force of low frequency can excite synchronous vibration in a high frequency body, but a high frequency force will have little effect on a low frequency body.

The intensity of the vibration produced under resonance conditions is dependent upon two factors, viz., it is proportional to the energy of the disturbing force, and inversely proportional to the amount of damping on the body. If the damping is very small, a small disturbing force may produce dangerous conditions, whereas with heavy damping, a comparatively large disturbing force may give resonance conditions so slight as to pass unnoticed.

THE PRINCIPLES OF VIBRATION TRANSMISSION.

To produce resonance it is not necessary that the disturbing force shall act directly on the body. It may be transmitted through some suitable medium, under which condition, if the loss of energy in the medium is only slight, the effect on the receiving body will be the same as if the disturbing force were acting directly on it.

Vibration is transmitted by means of waves. These waves may take several forms, the most important of which, from the point of view of this paper, are what are known as surface and compression waves.

Surface waves are similar to those formed on the surface of a pond when a stone is dropped in. These waves spread equally in all directions, and their amplitude gradually diminishes as the distance from the source increases.

Compression waves are harder to visualise, but they can be demonstrated easily by a simple example. Suppose that a long, light helical spring is suspended horizontally from the ceiling of a room by light threads attached to each coil. The

spring is now given a sharp tap at one end. The coils at that end are momentarily compressed, and, in recovering, they compress their immediate neighbours. These neighbours, in recovering, compress their neighbours and the result is that a compression wave travels down the spring.

In both the above cases, if the original disturbance were periodic, waves of the frequency of the disturbance would be transmitted, and resonance in an elastic body at some point remote from the source would therefore be possible.

This is the basic principle of vibration in roads and buildings. The earth, and on certain occasions, the air, act as the vibration transmitter, and buildings, etc., which have one or more natural periods of vibration, receive the transmitted impulses. Whether the impulses will cause dangerous conditions in the building affected depends on a number of conditions which it is now proposed to discuss.

THE TRANSMISSION OF GROUND WAVES.

Vibration may be transmitted through the ground by the two types of wave already considered. An example on a large scale is that furnished by an earthquake, from which the surface waves travel along the crust of the earth at approximately 300 m.p.h., and the compression waves travel through the body of the earth at approximately 500 m.p.h. The distance of an earthquake from a given point of observation is deduced from the time interval between the arrivals of the two sets of waves.

The distance which a vibration wave will travel in the earth depends entirely on the materials of the earth immediately surrounding the source of the vibration. It is an established fact that when an elastic ground wave passes from a less dense to a more dense strata, part of the energy of the vibration is reflected back into the less dense medium, the amount of reflection depending on the difference between the two densities.

Thus if vibration is set up in a strata of low density, only a small part of the energy will be transmitted to a high density medium in contact with it, whereas if the vibration is set up in a high density strata, the waves may travel indefinite distances in this strata without appreciable damping and may thus affect low density strata a considerable distance away.

Rock is an excellent transmitter of vibration. Cases are on record where vibration has followed a seam of rock underground and shaken buildings some miles away where the seam of rock has outcropped. Buildings between the source and the district shaken have been entirely unaffected.

Vibration is also readily transmitted through clay or wet swampy ground, whereas dry sandy ground is a bad transmitter.

THE PROPERTIES OF VIBRATION INSULATORS.

The methods of curing vibration problems may be broadly classified under three headings, viz. :—

- (a) The cause of the vibration may be eliminated.
- (b) The cause may be isolated.
- (c) The affected body may be isolated.

Isolation is effected by what are known as vibration insulators and these may be divided into two main classes :—

- (a) The resilient types possessing elastic properties. Examples of this type are cork, felt, rubber, etc.
- (b) The non-resilient types such as sand, gravel, etc.

Type (a) function mainly by altering the natural frequency of the vibrating system. In the type of vibration problem under consideration, the system is composed of the vibrating body and, in certain cases, the body transmitting the vibration. If now a layer of resilient insulating material is placed between the transmitter and the body, the natural frequency of the entire system is altered. By judiciously choosing the proportions of the insulating layer, the natural frequency of the composite system may now be made to lie below the frequency of the disturbing force. Great care is, however, required, in determining the proportions of the insulator as, in certain circumstances, the vibration may be intensified instead of reduced.

The task of determining the dimensions of the insulating layer is made doubly difficult by the fact that the load-deflection characteristics of this class of insulator are curves and not straight lines. To amplify this statement, take as an example the natural frequency of a Diesel engine crankshaft. To calculate this frequency, the natural frequency of the material is used and this modulus is obtained from the figure for the modulus of the material is used and this modulus is obtained from the straight line portion of the load-extension graph. Thus, within the limits of proportionality, the natural frequency is independent of the stress in the shaft. This is not so in the case of cork, felt, etc., since on account of the fact that even within the limits of proportionality the load-extension graph is a curve, the "modulus" will vary as the stress varies. The natural frequency therefore depends intimately on the loading placed on the material.

The non-resilient insulators in class (b) function mainly by destroying the rigidity of the system, and absorbing the energy of the vibrations by internal friction. It must be remembered, however, that although both classes of insulator obey the law of vibration reflection mentioned earlier in the paper the resilient type can circumvent this law by acting as frequency changers whereas the non-resilient type are governed solely by this law. Thus if the source of the vibration happens to be in sand or gravel, the energy is absorbed locally and very little vibration is transmitted to the surroundings. If however the vibration originates in a high density medium such as rock, the effect may be recorded in sand or gravel, some distance away.

This point emphasises the fact that this class of insulator is useful only for isolating the source of the vibration and not for isolating the affected body.

THE CAUSES AND PREVENTION OF VIBRATION.

Having considered the principles of vibration and the materials used for insulation, let us now consider some of the causes of vibration in roads and buildings and the methods used for eliminating or minimising the nuisance.

As has already been stated in an earlier part of the paper, the source of any synchronous vibration must be a periodically recurring force, and in the case of vibrating buildings this source can usually be traced to one of the following :—

- (a) Street Traffic.
- (b) Railways.
- (c) Unbalanced Machinery.

The worst offenders in the case of street traffic are heavy lorries, omnibuses and tramways. Contrary to popular belief, the most troublesome part of the vibration caused by heavy road vehicles is not due to riding over the uneven road surface, but is due to what is known as "torque reaction" from the engine. Riding over a rough surface will undoubtedly produce shocks in neighbouring buildings, but unless these shocks are regularly recurrent, resonance conditions cannot be set up.

Torque reaction is caused by the torque of the engine being balanced by the chassis and then, in turn, by the road. Now in the case of an internal combustion engine, the torque delivered by the engine is not constant, but is regularly pulsating. These pulsations are thus transmitted via the chassis and wheels to the road and elastic ground waves are then set up which may synchronise in a building which is being passed by the vehicle.

This type of vibration is probably the most difficult to control. The increasing use of pneumatic tyres and the growing popularity of six-cylinder over four-cylinder engines—giving a lower ratio of maximum to mean torque—are doing much to alleviate the problem, but the advent of the compression ignition engine, with its extremely high ratio of maximum to mean torque, is, from the point of view of road vibration, a retrograde step.

With regard to the roads themselves, very little can be done in the case of the materials used, since the latter are determined more from the point of view of resistance to wear and road holding qualities than from the point of view of vibration. In the case of new and reconstructed roads, however, a great deal of help may be obtained by laying at the base an insulating layer of cork or similar material.

Tramways cause trouble mainly on account of faults in the wheels and rails. "Shock" vibrations are produced by hammering at points, cross-overs, and rail joints, whilst "periodic" or continuous vibrations are produced by corrugated rails and out-of-true wheels.

Shock vibrations are more serious in the case of tramways than in the case of motor vehicles on account of the greater unsprung weight involved, and the fact that there is metal to metal contact with no medium such as a rubber tyre to minimise the shock.

The cure for hammering at rail joints is to use the now popular welded joint. By this means all sections of the rail become virtually one continuous length. Troubles due to rail expansion are practically non-existent in a well designed track, the surrounding road material being successful in keeping cool all but the surface of the rail.

Cross-overs and points may have the shock reduced by allowing the wheel flange to take the load until the intersection is passed. It should be mentioned that this method is successful only where the traffic on the two sets of tracks is approximately equal, since any great inequality will produce greater wear in one groove and the trouble will reappear.

Corrugated rails are probably the greatest curse of a tramway system. The corrugations produce high frequency vibrations which not only damage the rolling stock, but are very prone to synchronise in neighbouring buildings. The cause of rail corrugation is somewhat obscure, but the cure is certain. Rail-grinders should be brought into use as soon as corrugations are noticed, as the trouble, once started, rapidly assumes unpleasant proportions.

Out-of-true wheels, or tyres on which a flat has been formed by violent braking, are also potential causes of synchronous vibration. Although trouble due to this cause is rare, unevenly worn tyres should not be kept in service any longer than is possible.

Where new tracks are being laid, or old tracks relaid, the permanent way itself may be insulated from the surrounding roadway. Great care must, however, be taken in this procedure. An insulating layer under the rail proper has been found to be of scant value, whereas satisfactory results have been obtained by placing the insulating layer under the concrete block supporting the track. The reason for this apparent discrepancy is that a certain amount of mass is necessary to resist shock loading.

Various types of insulator have been used for this purpose, one of the most successful being asphalt-asbestos.

The above remarks regarding the track are also applicable in principle to railways and light railways employing sleeper track. In these cases, however, a dry cinder or broken stone foundation is very effective in preventing vibration transmission.

Tube railways may have an insulating layer similar to that used for tramways, placed under the sleepers. Also, on the principle previously mentioned that vibrations set up in sand are quickly damped out, the tube itself may be jacketed with sand.

To come now to the question of unbalanced machinery. In this class, the most prominent offenders are gas and Diesel engines and reciprocating pumps, in which the principal causes of vibration are :—

- (a) Unbalanced forces in the line of stroke due to reciprocating and revolving masses.
- (b) Unbalanced forces at right angles to the line of stroke due to the revolving masses.
- (c) Unbalanced couples which tend to rock the installation on its foundations.

Wherever possible, these out-of-balance forces and couples should be balanced in the machine itself. In the case of reciprocating forces and couples however, complete balance cannot be obtained by means of simple counterweights, the direction only of the force being changed as more weight is added. The condition of the surrounding subsoil and the possibility of using suitable foundation insulation should therefore be examined to determine whether it would be more convenient to leave the out-of-balance force or couple horizontal or vertical.

A rather ingenious method is sometimes used in the case of engines normally fitted with balance weights so that the best balance is obtained in situ. Balance weights to balance the revolving masses only are fitted and these weights have hollow pockets cast in them. When the engine is installed, a little molten lead is poured into the pockets. The amount of lead is gradually increased until the best balance is obtained, when the pockets are finally sealed up.

To turn now to the question of preventing vibration transmission through the foundation, the cheapest and most popular method is undoubtedly mass or inertia damping. By this is meant the use of a massive foundation block, any increase in the size of which will proportionately reduce the amplitude of the vibrations. Although this method often gives satisfactory results, it is obviously impossible to reduce the vibration amplitude to zero, so that synchronism is always possible between the natural frequency of a building and the small residual vibration.

The most satisfactory method is to use a vibration insulator of the resilient type under or around the foundation block. Now it will be remembered that when describing this type of insulator earlier in the paper, it was pointed out that its action was more that of a frequency changer than a damper. The effectiveness of this insulation will therefore depend on the relationship between a number of factors, the most important of which are:—

- (a) The total mass of the engine (or pump) and its foundation.
- (b) The forcing frequency.
- (c) The specific loading on the insulator.
- (d) The combined natural frequency.

As previously mentioned, an improperly dimensioned insulator may intensify the vibration and steps should be taken to ensure that this condition cannot obtain. Knudsen's formula, given below, is a useful check on this point.

If $w = 2\pi N$ where N is the forcing frequency

M = the total insulated mass.

C = the unit deformation of the insulating material

then if w^2 is less than $\frac{2}{MC}$, the resilient support will amplify the amplitude of the insulated body.

To avoid resonance, therefore, the natural frequency of the combined system should be kept as low as possible. On account of the many factors involved, this frequency is virtually impossible to calculate, but by making provision in the foundation for altering the loading on the insulating pads, it may be lowered to the limit

determined by the bearing capacity of the material, after the installation is completed.

If parallel data are not available when making an installation of this type, it is advisable to determine the correct insulation by experiment.

THE VIBRATION OF BUILDINGS.

The major causes of transmitted vibration have now been dealt with, together with the methods of either eliminating or isolating the cause. These methods of vibration control should be used wherever possible, for a number of reasons, the most important of which are:—

- (a) A whole area may be relieved by dealing with the cause, whereas more expense and less general relief are entailed by dealing with buildings separately.
- (b) Existing buildings, particularly ancient monuments of historic interest, are virtually impossible to isolate.

Nevertheless it is now becoming increasingly common practice to isolate new buildings in districts where traffic or machinery vibration is prevalent, the main object being to guard more against the future than the present day conditions.

It is not proposed to describe in detail in this paper the various methods that have been used for building isolation, as an entire paper would be required to do justice to this part of the subject. The author proposes instead to deal with the principles of building isolation, since, throughout the diverse methods that have been used, the principles remain constant.

Before a building can be successfully isolated, it is necessary to understand the types of vibration that are possible, and, to get a clear conception of these types of vibration, a simple analogy will be helpful. The simplest analogy is a pair of ordinary football goalposts, in which the two uprights represent the walls of the building, viewed in section, and the crossbar an upper floor or the roof.

The types of possible vibration are now threefold. The uprights, if disturbed by a vertical pulsating force, may vibrate as struts, or if disturbed by a horizontal force may vibrate as cantilevers with the fixed points in the ground, while the crossbar, if disturbed by a vertical force, may vibrate as a beam.

The frequencies of a simple system such as that described above can be readily calculated, but unfortunately, even in the case of a single storey building, too many unknown factors are present to render calculation possible, while the adding of further storeys renders the possibility of calculation even further remote. The fundamental modes of vibration as exemplified by the goalposts remain, however, so that with these in mind it is possible to form some idea of the principles of building isolation.

If it is anticipated that vibration will be transmitted to the building through the ground, a layer of insulating material must be placed between the girder feet and the concrete raft forming the foundation.

If vibration is anticipated from machinery installed on the ground floor, the foundation of the machinery must be separated from that of the building by an insulating layer.

If vibration is anticipated from machinery installed on one of the upper floors, it is preferable not to use insulation, but either to arrange the machinery for complete balance, or, after installation, to adjust its speed to avoid synchronism. Of the two methods, the former is preferable, and, in the case of engines, extremely good balance can be obtained by having six or more cylinders.

The insulating material used for buildings is of a similar character to that used for machinery. Adjustment is impossible once the insulation is in place so that steps should be taken in the design stages to keep the estimated natural frequency as low as possible.

DISCUSSION.

MR. C. H. BRADBURY (introducing his Paper): I am employed by a well-known firm of manufacturers of heavy oil engines, and I have investigated a number of vibration problems dealing with these engines, so that, when the particulars of this competition were announced I decided to extend my knowledge of vibration problems by entering a Paper on the subject.

The subject is one about which comparatively little is known. If one searches the available literature on the subject, one finds very little unanimity of opinion on the major issues, and very little agreement in methods of tackling the problem. This Paper has therefore been written with the object of provoking discussion on this important subject. It would be particularly valuable to hear of any experiences you may have had in overcoming vibration, because the subject is not one that is readily amenable to calculation, and it is only by accumulating experience that an ultimate solution may be found, and mathematics adapted to the subject.

MR. M. B. McBERTH (*Bathgate*) moving a vote of thanks to Mr. Bradbury, said: As I live in a mineral area where a great deal of the country is honeycombed, and as my office fronts a main road which carries several thousand tons per day and over which the "giant rudder" from Darlington passed within a few feet of my desk, I might almost say that I live in vibration. Further, a

railway runs within a few yards of the gable of the building, but it was only after road loads became so heavy that gas mantles would not last and electric light had to be introduced. I therefore welcome the investigation of the cure of vibration in roads and buildings.

Speaking as a road engineer, I think the only solution for existing roads is to provide some form of surface which will eliminate or sufficiently reduce vibration to make it at any rate less of a nuisance than it is, and for new roads we must devise some forms of construction which will meet the special circumstances of each case.

MR. R. J. JENKINS (*Portsmouth*) seconding the vote of thanks, said: Under the heading "The Causes and Prevention of Vibration," Mr. Bradbury says: "In the case of new and reconstructed roads, however, a great deal of help may be obtained by laying at the base an insulating layer of cork or similar material." If Mr. Bradbury has any practical knowledge of how that should be used—I should like to know what kind of cork it should be and what shape, whether large or small pieces should be used and how it is laid.

Mr. Bradbury mentions the corrugation of rails in tramways. I have never thought of that myself, but he seems to know something about it, and thinks it is really a cause of vibration. I should be glad if he could give us a few instances.

I believe one source of vibration in roads is the solid rubber tyres. I think it has been said that a solid tyre overloaded 65 per cent. gives over four times the amount of vibration to the road.

I know from experience that roads made in the same way and, as far as I could see, on the same soil, acted differently. In one case I had inquiries made from the people living in the road. The houses were of a very poor character, and the people living in them constantly complained of vibration. When we made a decent concrete road they were quite satisfied. In the case of the other road, on which I think the concrete was an inch thicker, one of my assistants who lives in that road, when I asked him: "How do you find the concrete road?" replied: "Terrible. You can feel the vibration right out in the kitchen." So there we have two roads treated in the same way and producing different results.

In the Paper Mr. Bradbury says that gravel does not carry vibration, but I think he infers that wet gravel would do so. I think it is correct that wet gravel will carry vibration more than dry clay. At Southsea in houses 300 yards back from the sea wall, when we have a heavy sea, the pictures on the wall move and gradually get out of level. I take it that there is a gravel bed all the way into which the sea infiltrates, and that must be the reason.

In one case I had a waterbound macadam road with a tar surface, and I had complaints of vibration. We laid there a modern road with a concrete foundation and four inches of synthetic asphalt, and when I made inquiries as to the vibration I was informed that the trouble had really been met; they had no complaints to make. Therefore I think the greatest contribution we engineers have to make in this matter is the constructing of good modern roads.

MR. W. J. STEELE (*Newcastle-on-Tyne*): It may be of interest if I give you the details of some tests on vibration which were carried out on a street in Newcastle. There was a tramway, and some four years ago, the entire surface was renewed, including the tramway track. The carriageway had been paved with wood for the whole of its width. When the surface was renewed the tramway was re-paved with new wood, but the flanks on

both sides of the tramway, right up to the rails, were entirely paved with rubber blocks. The whole length of the renewal work would be about 130 yards.

The results of the tests for vibration were briefly as follows: On the old wood, which had been down for twenty years and which, as you can realise, was badly worn, the amplitude was very considerable. Having got the result on an old road in a very bad condition, the same tests were carried out on the completed section, both on the new wood and on the new rubber. The difficulty of finding out the truth and making a comparison is shown by the fact that the tests proved that on the new wood there was not a marked difference from the results obtained on the rubber blocks. We were rather hoping that the traffic going over the new rubber would have produced much less vibration than on the wood, but that was not borne out by the tests. The tests did show that there was something in favour of rubber; the vibration was less on the rubber than on the wood, but not much less. There was, however, a very great difference in vibration both on the new wood and on rubber as compared with the old wood the paving.

There is a point that Mr. Jenkins raised to which I should like to refer. I do not think it possible to get rid of vibration entirely on old paved streets by superimposing a thin new surface. It was a common practice fifty years ago in many towns in the north-east of England to form street surfaces with chip or random stone paving. Now it would cost a very large sum to bring these surfaces up to modern conditions by entire reconstruction, and yet the vibration that Mr. Jenkins has mentioned we have in many cases felt very severely, even to the moving of pictures and the falling of plaster ceilings. As a compromise, a new surface of synthetic asphalt was placed on the top of this old chip paving, in some cases only an inch and a-half in thickness, and it has undoubtedly considerably reduced the vibration. It has not entirely stopped it, however, and when the asphalt gets worn, the vibration will probably be as great as it was previously, but there is no doubt that in a simple manner like that vibration can be reduced. I think there is no doubt that the increasing speed of traffic—I think speed in this matter has a

greater effect than load is one of the main causes of vibration, and, if it goes on to an unlimited extent, the question will arise as to how far an owner of property can recover costs if his property is damaged by vibration as a result of traffic. From whom it can be recovered it is very difficult to say, but, if the modern idea for this great speed with these loads goes on, it will be a matter for consideration as to whether the owner will be able to recover from somebody.

All kinds of theories have been put forward as to the cause of the corrugation of tramway rails, but nobody seems to have discovered it yet. I have had several instances of corrugations having appeared within three years of the tramway being constructed. The only method of removing them that I know of is grinding. With regard to their causing vibration, I am not quite sure that the vibration set up by corrugation on a tramway will extend to buildings, but it certainly does extend to vehicles, that is, to the tramcar itself. If there is no vibration, there is at any rate tremendous noise noticed by the people who live in the houses abutting upon a tramway which is badly corrugated.

MR. A. J. NEWPORT (*Building Research Station*): In this very interesting Paper the Author says: "To turn now to the question of preventing vibration transmission through the foundation, the cheapest and most popular method is undoubtedly mass or inertia damping," and he goes on to say that increasing the size of a foundation block will reduce the amplitude of the vibrations. That is perfectly true, but what is important from the point of view of transmission of vibration is not the amplitude of vibration of the block itself but the magnitude of the periodic force transmitted to the ground. Now it is possible to calculate theoretically what might be called the "transmission factor," that is, the ratio of the periodic force transmitted to the ground to the unbalanced periodic force in the engine. If that is done, it will be found that, although the amplitude of vibration of the engine block is inversely proportional to its mass, the transmission factor and therefore the magnitude of the periodic force transmitted to the ground is independent of the mass. That is entirely contrary to the statement made by the Author and entirely contrary to what is usually believed. What

it really means is that, if there are two absolutely identical engines and they both have the same unbalanced force and one is mounted on a small foundation block and the other on a large heavy foundation block, the one on the small block will certainly have a larger amplitude of vibration, but the magnitude of the periodic force transmitted to the ground will theoretically be exactly the same in both cases if the foundations have been correctly designed. Actually it can be shown that the transmission factor depends upon the ratio of the maximum permissible bearing pressure of the material under the foundation to the elastic modulus of that material at the working stress. It does not depend upon the mass at all. In order to reduce transmission to the ground it is necessary that the bearing pressure on the material underneath the foundation block, whether that material happens to be the earth or a special insulating pad, should be the maximum stress which the material is capable of supporting. In order to explain why the periodic force transmitted to the ground is independent of the mass of the foundation block I should first mention that the magnitude of this force depends upon the ratio of the restoring force to the mass of the block. Supposing we design our block correctly, making the area of suitable proportions, then the material, whether the ground or whether an insulating pad, underneath the block, will be carrying its maximum permissible stress. It is necessary to do that in order to make the periodic force transmitted to the ground a minimum. Suppose we decide to try the effect of doubling the mass of the block. The material underneath the foundation block is already carrying its maximum permissible stress, and, if we double the mass of the foundation block, it will be necessary to double its bearing area, and if we double the bearing area we double the restoring force, because this force is directly proportional to the bearing area. If we double the restoring force and the mass of the block, we have not altered the ratio of the two quantities, and therefore we have not altered the periodic force transmitted to the ground.

The problem really is analogous to that of a pendulum. The time of vibration of a pendulum depends upon its length and not upon its weight. If one doubles the mass

of the pendulum bob one will double the restoring force, and the ratio of the restoring force to the mass remains constant.

THE CHAIRMAN (MAJOR L. ROSEVEARE): There is a considerable amount of theory on this question of vibration. It is exactly like its twin sister, the problem of acoustics. The difficulty is to associate the theory with the varying factors on both sides. There are the problems of the cause of vibration and the structure affected. As to the cause of the vibration, the interesting point about the Paper is that it does not refer so much to what Mr. Steele has been mentioning with regard to the roughness of the surface of the road, but the suggestion is that vibration to a very great extent is due to the different periodicity of the engines of passing motors. That is being minimised to a very great extent by increasing the number of cylinders, and a point not mentioned, the present practice of suspending the engine. On the one side there exists the compelling force, or what the Author terms the forcing frequency constantly varying, and on the other the building, with a periodicity affected every time the loading is changed; two factors, one on each side, varying the whole time! Vibration occurs when a particular forcing frequency coincides with the natural frequency of the structure affected.

With reference to machinery in a building, the point just raised by Mr. Newport is an interesting one suggesting increasing the mass and thereby obtaining the same effect, but I think he left out the question of the superficial area of blanketing effect where rubber insulation is used.

The problem is a difficult one, and, as Mr. Steele has said, it gives scope for research for road engineers, with a view to ascertaining the best materials to use in roads to prevent vibration. I do not know whether members have found that with a tarmac road of rather doubtful strength, subject to a service of buses of the same make, and therefore the same periodicity of springing, corrugation in the road surface occurs far more so than with varying traffic of similar tonnage. On the other hand there is no greater distributor of vibration than a reinforced concrete structure, and to that extent concrete roads may be one of the worst kinds of roads possible in setting up

vibration in buildings abutting. I believe in America they are careful that their underground railways have no association with reinforced concrete buildings abutting, because it is found that even with gravel in between, the vibration set up is considerable, and can only be checked by making a complete break.

The whole subject emphasizes the advisability as an elementary precaution of obtaining adequately deep building lines on main roads subject to heavy traffic.

MR. C. H. BRADBURY, in reply, said: With reference to the corrugation of tramways and the question whether it has any effect on buildings, I have in mind one particular case at Lincoln. Just before the tramways were scrapped they were in a very bad condition. A house that I have very often visited adjoined the tramway, which was a single track, so that it was used twice as much as the rest of the track. It was badly corrugated. When you sat in this house you could definitely feel the thud of the cars as they passed over the rail joints. You could also feel the high period vibration from the corrugations. The house was very old and solidly built, but it had a crack down one side and ultimately had to have a steel reinforcing band put round the second storey. I should not like to say whether it was caused by the shock vibrations of trams going over the rail joints or by the high period vibration due to the corrugations, but the vibration due to the corrugations could be felt in the house, which was 20 yards from the tramline.

The question was raised of the surfacing of roads and the improvement caused by putting on a new surface. Obviously a bad surface will produce bad shock vibrations, but, as I have pointed out in the Paper, the torque reaction from lorries, particularly solid tyre lorries, is an important factor. A house in which I once lived stood close up to the road. It was a very old house, and the level of the front room floor was actually slightly below the pavement. The subsoil was very damp. When the Corporation started running buses past the house, the road was not in a very good condition, and we had a lot of vibration. The buses were single-deckers with solid tyres. After about two years the road was re-surfaced with tarmac and there was an improvement in

In 1925, Mr. J. A. Priestley, the Cleansing Superintendent of Sheffield, read a Paper before this Congress. Many interesting facts were brought out and amongst others the point made that "where a load is picked up from point to point and delivered in bulk as in cleansing work it is necessarily costly." He urged, however, that the class of transport employed should be that which "will best combine efficiency with economy but neither aim should be wholly subordinated to the other, particularly as regards the sacrifice of efficiency to economy."

That is axiomatic and really forms the starting point of this Paper.

HOUSE AND TRADE REFUSE COLLECTION.

Historical.—The early types of vehicles employed in Public Cleansing took the form of open top tip carts. These vehicles were similar to those used in the haulage of materials, and very little attempt was made to evolve a design specially applicable to the work on which they were now engaged. Being horse-drawn the scope of usefulness of these vehicles was limited.

With the advent of the internal combustion engine open top bodies on commercial chassis gradually took the place of horse transport for the longer hauls. These bodies were generally fitted with a loose canvas cover which was supposed to be drawn over the load and so prevent the dispersal of dust when the vehicle was filled. In practice, however, the sheet was rarely efficiently secured and but little improvement resulted from its use.

Following the practice of the original cart the load line was high, and in order to deposit the contents of the bins in the body the fillers had to scale a ladder propped against the side of the vehicle.

Mounting a ladder carrying a full and heavy bin involved grave risk of injury to the employees, and there was an added disadvantage in that the loading process was anything but dustless.

It was obvious that modifications in procedure must be effected, and all concerned began to devote serious thought to the evolution of a type of vehicle that should embody as few as possible of the defects of its prototype.

Line of Development.—The first step was to reduce the height of the loading line of the vehicle. This was achieved by re-designing the chassis, and replacing the then current large diameter wheels with solid rubber tyred wheels of smaller diameter. The steering lock was increased and greater flexibility of operation thereby obtained. This was a particularly valuable improvement, since it enabled vehicles to be operated in narrow carriageways, not to mention heavily trafficked thoroughfares.

In the earlier models sectional canvas covers hung from a centre ridge pole were fitted, these being much easier to handle than the one piece sheet previously employed.

There was a practical point, however, in that with continued use the covers became soiled with grease and other matter, and ultimately presented anything but a neat appearance.

They were not altogether successful, for a comparatively large area of refuse remained exposed to view while the vehicle was at work, and but little diminution in the dust nuisance resulted from their use. This was unfortunate, for the lowering of the load line had actually brought the dust cloud nearer to the passer-by and its presence directed attention to the purpose for which the vehicle was being employed.

It was not long before further modifications were made, these in the main taking the form of a permanent type of cover to the vehicle.

There were various designs, the basis of all being some form of sliding metal cover which was opened for the introduction of refuse into the vehicles and closed on completion of the operation.

Some covers were hand operated, working on the roller blind system, while others consisted of sheet metal covers operated either by foot or by hand and so balanced that they returned to place on the pressure of the operating mechanism being released.

For a time it appeared that a wholly satisfactory form had been evolved and that standardisation of principle was in sight.

It was observed, however, that each year the refuse was tending to become lighter and bulkier, and in certain parts of the country these vehicles proved unsuitable for handling the class of refuse produced.

It was but a short time before variations of the original type made their appearance and, speaking generally, the design favoured was one which while permitting of a reasonably dustless operation would allow of a larger load in actual weight being carried.

Among the many may be specially noted those bodies of the covered van type as distinct from the more squat form of vehicle. These were side loading fitted with laminated steel shutters, and served their purpose in that they certainly held a larger quantity and weight of refuse than the earlier design.

They had one major defect, for in order to make the maximum use of the added capacity it was necessary to "trim" the refuse at frequent intervals. This operation naturally diverted the loaders from their normal work, and the increased cost of operation more than offset the advantages gained in other directions.

About this time "end" as distinct from "side" loading received more consideration and the next development of this same van type took the form of a vehicle the roof of which was still higher than that of its predecessor, while the loading was accomplished from the rear of the vehicle.

Within the body itself was a moveable barrier. The men with a bin of refuse on their shoulders walked up a ramp or steps of various designs provided at the rear of the vehicle, entered therein and tipped the refuse over the barrier.

The rate of loading was improved materially, and as, with the use of suitable tools, it was found possible to pack to a good height, greater loads were carried than was possible in its immediate predecessor.

The fact that the men had to enter and work in a dust laden atmosphere probably

operated against the more widespread adoption of this type, for despite the provision of ventilating louvres, fan lights and moveable roof sections of the "sunshine roof" type, the complete elimination of this nuisance would appear to be impracticable.

In passing it may be mentioned that there was a further modification of this same type which permitted of side loading in addition to the end loading above described, the first part of the load being discharged into the vehicle through the side openings.

The rate of filling was improved but this advantage was offset by the fact that the loading operation was visible to the passer-by. Moreover, the moveable shutters employed being of the hand-operated, as distinct from the self-closing variety, it was not unusual to find them left open for a longer period than was necessary for the actual loading process to be completed.

This, of course, defeated the whole object of the provision of covers, and where this practice prevailed the vehicle was but one degree better than the original open type.

Recent Developments.—In comparatively recent times yet another modification of this type of vehicle has made its appearance on the market. The design appears to offer many advantages not shared by its predecessor and if the performance in practice approximates to its theoretical capabilities it would seem that a new era is opening up.

The vehicle referred to is of the end loading van type and is fitted with a moving floor consisting of either rubber or of metal plates. This floor may be either hand or mechanically operated.

The first advantage claimed for this vehicle is that the moving floor entirely replaces the complicated tipping gear hitherto employed. By rotating the floor one direction the refuse is carried within the vehicle, while by reversing the direction of travel the load is discharged either wholly or in part as may be required.

It will be appreciated that this latter is a very valuable provision, especially when the method of disposal is that of tipping, for it is not always convenient or desirable to deposit the whole of the load at one time. Again the absence of under-gear permits of the provision of greater ground clearance which in itself may be a material advantage should the vehicle have to traverse rough ground.

In passing it should also be noted that as the load may be discharged without the need of elevating the body of the vehicle as with the usual systems, the head room to be allowed in entering Destructor premises and Depots can probably be reduced.

Conversely the moving floor can be employed to compact the refuse. Experiments carried out in the Cleansing Department of the Metropolitan Borough of Stepney prove that the claim made in this behalf is easily substantiated. Its value where the refuse is of a light bulky character can readily be appreciated.

The second advantage is that all loading is carried out from the rear, and at no time do the fillers enter the dust-laden atmosphere of the vehicle. The men mount a shallow step or ramp, discharge the bins over the tail board and when the refuse

reaches the top the floor is moved forward, the load carried out of the way and an empty space becomes available for further refuse.

In order that the dust arising in the process of emptying the bins into the vehicle may not be distributed into the open air, a strip curtain, which may be constructed either of canvas or rubber, is hung over the opening between the underside of the roof of the vehicle and the top of the tailboard. This in no way interferes with the fillers emptying the bins, and, moreover, has the further advantage that it screens the operation from the eye of the passer-by.

It will be obvious that this machine is a great advance on the side loading, for in traffic congested streets the vehicle and loaders take up considerably less room than the latter type, while the risk of men being knocked down and injured in the course of their duties is materially reduced.

This completes the general historical survey, and in order to afford a basis for discussion it is proposed to deal now with those points which in the Author's opinion should form the basis of design for vehicles engaged on this particular class of work.

Since the general principles of body and vehicle design are the same whether horse, electric motor, or internal combustion engine provide the motive power, no specific reference is made to this latter.

A moment's consideration will serve to shew that there must of necessity be a diversity in the types of body employed to meet the varied conditions prevailing throughout the country. Nevertheless there are certain salient points to be borne in mind when assessing the merits of a vehicle for use in any given district.

Consideration must first be given to the type of load the vehicle is to carry. In certain districts the refuse may well be of a bulky character. Trade refuse may form a large percentage of the whole, and the presence of a large proportion of one or the other may form the deciding factor in the capacity of body required and the size and type of loading aperture to be specified.

Next will come a survey of the topographical conditions of the district, with special reference to the width of the streets in which the vehicle is to operate.

Lastly, must be considered the facilities at the discharge point, that is to say, whether the existing headroom of established Destructor Plants or Depots will necessitate modifications in the angle of tip, etc., or whether in the case of "Controlled" or other tipping there is sufficient ground clearance for the vehicle to be operated under normal working conditions.

These points being satisfactorily settled, other aspects may be grouped as follows:—

Chassis.—These remarks are obviously more applicable to the forms employing motive power other than horse traction, but the same general principle will apply.

It is essential that the chassis should be of robust construction, economical to operate, and the power unit of such a size as to work with ease and yet at the same time be not so large as to be wasteful.

Adequate and easily operated brakes, preferably of the four-wheel type, are essential.

The vehicle must be easy to manoeuvre and have a turning circle such that it can be operated with advantage in heavily trafficked thoroughfares or in narrow side streets, and that it can be brought into position with the minimum of effort at the point of discharge.

There would appear to be considerable scope for improvement in this direction.

When the vehicle is to be operated in Northern Districts further points must be accorded the most careful consideration.

The type in general use in other counties would be unable to work through the narrow back service roads common to certain parts of the above area. Overall length and width of vehicle become factors of paramount importance and the designer must keep this aspect ever before him.

Wheels.—The size of wheel to be fitted depends on the type of body selected. If kerbside loading is the rule then a low load line is essential. To achieve this, as already noted, manufacturers originally fitted small diameter wheels shod with solid tyres, and these served their purpose though it was found in practice that the chassis was punished in some measure when the vehicle was operated in districts where sett or other paving of a like character was common.

Recent legislation has somewhat forced the issue and pneumatic tyres are replacing the original solids. The changeover has resulted in a reduction in the wear and tear on the chassis, while, generally speaking, a better grip on the road surface is obtained.

The load line may be slightly raised by reason of the change, but the difference is not so great as to interfere with the efficient working of the vehicle.

Body Construction.—The body should be of metal of such a gauge as to be capable of withstanding the rough usage to which these vehicles are almost invariably subjected. Attention should, however, be paid to the weight question, and in this connection it may be noted that improvements in recent years in the science of electric welding permit of the weight of bodies being cut down to limits before unknown, without sacrificing line, appearance or strength.

The body should be shaped to permit of easy discharge of the load. The moving parts on the body itself should be reduced to the minimum, for it is obvious that with a more simple and straightforward design less trouble is likely to arise.

Accommodation for Driver.—The vehicle should be designed to allow the driver to enter and leave the cab very easily that he may assist the loaders to load and trim the refuse as required. His comfort, convenience and safety should be studied, and to this end refinements in the shape of safety glass windscreens, automatic windscreen wipers, direction indicators and full length doors with wind-up windows may with advantage be incorporated.

The extra initial cost of these will be more than offset by the advantages derived during the period the vehicle is in commission.

Accommodation for Fillers.—Definite and adequate provision should be made for the conveyance of the Fillers during the course of their duties. In many vehicles at present in commission there is distinct evidence that such provision has been merely an afterthought, and though the arrangement may be the best possible in the circumstances there exists much scope for improvement in this direction.

So much for the general aspects of the case.

The next point to consider is that of Loading.

LOADING.

General.—The first point to be borne in mind is that the operation of depositing refuse within the vehicle must be capable of being conducted in an easy and hygienic manner. Whether the vehicle be rear or side loading, a low load line is essential.

As has already been indicated careful screening will go far to overcome the objections inseparable from the earlier types of vehicle. This matter of screening has not received the attention which its importance would justify. It is suggested that careful consideration might well be directed to the evolution of a design that would permit of the filling operation being carried out in such a manner that the passer-by shall not be conscious of the character of the material removed, while at the same time the movements of the Fillers shall not be unduly restricted.

Systems in Vogue.—As is well known, several loading systems are in vogue. These may be divided roughly into two main systems, (a) those in which special types of bin are used, and (b) those which permit of the employment of all types of bin.

Type (a)—Special Bins.—In the former category are the machines which are extremely popular on the Continent, and it will perhaps be fitting to devote a few moments to their consideration.

Generally speaking, the refuse produced in the Continental towns and cities differs in character from that of this country, and it is understood that the output is more strictly controlled.

The type of bin employed is one of the hinged cover variety, and used in conjunction with a patented shutter mechanism incorporated in the vehicle the filling process is rendered almost entirely if not completely dustless.

Various methods of a mechanical character are employed to ensure that the maximum load is carried in the vehicle, and there is no question but that under certain circumstances the method of working is, from a sanitary point of view, as near ideal as one can reasonably hope to attain.

This system is operating satisfactorily in certain cities in this country, but the question whether its more general use would be justified is debatable, if only on the grounds that the successful working of this system involves the standardisation of the refuse bins employed.

This in itself is a somewhat heavy handicap, and thought naturally turns to the other form for the operation of which no special type of bin is requisite.

Type (b).—Any Type of Bin.—This may be regarded as the standard practice in this country, and it is but natural that vehicle design should be influenced thereby.

The needs of the district wherein the vehicle is to be employed will determine whether side, end loading, or a combination of both is required. The same factor will largely determine the size and number of openings required, for the vehicle must be capable of universal application.

Packing the Refuse.—Facilities must be afforded for packing the refuse into the vehicle that an economic load may be carried. This packing is generally carried out by the Fillers, assisted sometimes by the driver of the vehicle, tools suitable for the purpose being employed. On no account should it be necessary for the men to have to enter the vehicle to perform this function. The recent development of the moving floor has been used with advantage to supplement though not entirely to dispense with the system of packing by hand labour.

It is suggested that a field for research is opened up here, for it is obviously desirable to entirely eliminate the hand packing, and it may well be that the solution of the problem does not lie in any form of mechanism at present employed.

Unloading.—The factors governing the loading of the vehicle apply in some measure to its unloading, and improvements of the one are generally applicable to the other.

Systems in vogue :—

- (a) The first, and at the moment the more usual, is that which employs some form of mechanism, either hand or mechanically operated, to tip the body of the vehicle to such an angle that the load may be discharged in the minimum of time.

This tipping gear may be arranged for end or side operation as desired, though choice must ultimately depend on the conditions which obtain at the Shoot or Disposal Works.

This system has undergone gradual and general improvement over a number of years, and there is little comment to make thereon.

There are two points to which research might perhaps be further directed. These are :—

- (i) Greater rapidity of operation than has been achieved up to the present, and
- (ii) Introduction of some form of safety device to prevent the body of the vehicle crashing down should the lifting system fail at any point of the upward or downward travel.

- (b) The second type is the later development of the movable floor already referred to.

This is a comparatively new development, but the results obtained clearly shew that it is to be reckoned with. The major advantages may be summarised as follows :—

- (i) The refuse can be discharged from the vehicle as and where required.
- (ii) The strain on the chassis and its component parts is materially lower than that set up when the usual form of tipping gear is in operation.
- (iii) The further points of limited headroom and improved ground clearance have already been noted.

As, comparatively speaking, this form is still in its infancy it may perhaps not be amiss to indicate certain aspects of design to which more detailed attention might with advantage be directed.

It must always be remembered that the wear and tear is extremely heavy, and where it is found essential to introduce mechanism of any type the aim must be to reduce the actual moving parts to the minimum. In any event all moving parts must be sheltered to a high degree from the corrosive and abrasive action of the refuse. Whether the mechanism be hand or power operated is a matter for the individual for each has its respective advantages and disadvantages.

Equally important is the cost and ease of replacement of the mechanism at the end of its useful life, and would-be users should make a point of satisfying themselves that the cost of such replacements does not form too high a proportion of the original cost of the vehicle. This point is stressed for it is one that so many manufacturers, not to mention vehicle users, have been known consistently to overlook.

Application to Rural Areas.—It may be urged that the foregoing remarks are perhaps more applicable in practice to urban areas. It is submitted, however, that the principles are of a purely general character equally adaptable, though perhaps in a modified form, to less thickly populated districts.

The rural user will probably find the vehicle of 7 cubic yard capacity ample for his requirements. In order that it may be operated the more readily within the district, larger diameter wheels than those employed on vehicles used in urban areas may be specified.

There is a further point, but this chiefly concerns the choice of motive power. It not infrequently happens that the houses in rural areas are at some distance one from the other. It is very essential, therefore, that the vehicle should have a good turn of speed to enable it to deal efficiently and cheaply with the work on hand.

General.—No attempt has been made in the foregoing notes to deal with special types of vehicles or bodies, but rather to discuss the forms in more general use. There are, of course, many of the former but, speaking generally, their application is restricted to specified districts or maybe sets of working conditions.

The principles enunciated apply equally to these types, for their design must permit of dustless loading while adequate cover for the load must be provided at all stages of operation.

Without desiring to enter the field of politics reference must be made to the question of vehicle taxation. It is common knowledge that the rates have been amended, and in some instances materially increased under recent legislation.

The point is one that must not be lost sight of when reviewing the position and assessing the possibilities of various machines.

It is submitted that a 3-ton machine is probably the most economical to operate under the conditions which generally obtain throughout this country.

The question is one of great interest both to the manufacturer and user, and it may well be that this factor will materially affect the future trend of vehicle design.

HIGHWAY CLEANSING.

As has already been indicated, the removal of House and Trade Refuse is but one phase of a Cleansing Department's activities.

It is proposed to deal next with an equally important branch, namely, Highway Cleansing, and in order that the improvements made in recent years can be the more readily appreciated a short résumé of past practice appears to be indicated.

There are some of us old enough to remember the days when the crossing sweeper formed an essential part of the daily life, and when the impervious road surfaces of to-day were practically unknown.

The arrival of motor transport, involving as it did the supplanting of the horse, altered the whole problem, and the type of refuse removed to-day differs greatly from that of the last century.

Up to a comparatively few years ago streets were swept by hand labour augmented by the use of horse-drawn rotary brooms. The detritus was picked up and placed in open top hand-barrows, which when full were pushed to a steel container, known as a street orderly bin, situated on the edge of the pavement at various points throughout the streets.

The sweeper shovelled the contents of his barrow into the bin through an opening near the top, and from time to time a horse-drawn vehicle with a high load line visited and cleared these bins. In the process of filling and clearing the street orderly bin a quantity of refuse fell again on and was spread over the carriageway and footway, and on that score alone the system could be condemned as unhygienic.

Where the street orderly bin system did not obtain, a very general practice was to sweep the refuse into heaps and leave it for later collection.

Vehicles passing close to the kerb quickly broke up the dump, while in dry windy weather the disintegration was still further accelerated.

What was left of the dumps was removed periodically by horse drawn vehicles, the loading being carried out in the unhygienic manner outlined above.

The first improvement in procedure was the introduction of a comparatively low load line vehicle mechanically propelled. The new type was fitted with an open steel body, and in order to conceal the character of the load, loose canvas covers were employed.

This was certainly an advance over the high load line, for the vehicle could be filled with far less effort and less risk of the refuse being scattered in the process. The covering, however, was not quite so successful for, generally speaking, it was

only drawn into place when the vehicle was fully loaded and proceeding to tip.

However, a change had been brought about and it was not long before improved types of vehicle made their appearance. The steel body was still retained, but was fitted with a closed top having either sliding steel covers or laminated steel shutters through which the refuse could be loaded.

This was a big step forward, for the refuse was no longer exposed to view when the vehicle was travelling through the streets. It must be confessed, however, that, even with this modification, the loading operation was not entirely dustless.

While this changeover was in progress an earlier link in the chain, the street orderly cart, was itself being overhauled. It was obvious that the open top orderly cart had to go, but considerations of weight and ease of handling precluded the adoption of a complicated design.

Many interesting forms have been evolved. Amongst these may be instanced a steel frame mounted on two rubber tyred cycle wheels and carrying two bins fitted with hinged lids, and another type, which is more in the form of a compromise, involving the conversion of the open top cart to hold two or more steel bins fitted with lids.

The street sweeper places the material collected direct into the bins provided. These bins are of such size and weight that when filled they can be readily handled and tipped into the transport vehicle allocated to his area.

The adoption of this system has three main advantages, (i) that the refuse is not visible to the passer-by, (ii) being covered it is not exposed to wind and weather, and (iii) the bins can be tipped into the collecting vehicle with the minimum amount of spillage.

This system has been further modified, patented bins being provided for the sweeper. These bins are fitted with a hinged lid, an attachment to which serves to open a sliding steel cover on the motor vehicle when clearance is being effected. It is claimed for this system that it is practically, if not indeed completely, dustless in operation. The development is, in the Author's opinion, one that merits the very serious attention of all concerned.

The same points of design instanced in the case of the House and Trade Refuse vehicle apply equally to the collecting vehicle employed on street cleansing. If anything, one might stress the particular advantages of end loading over side loading in view of the fact that these vehicles are operating continually in thoroughfares carrying a large volume of traffic.

The loading aperture must not be too restricted in size, for it may well be that the vehicle will be employed for the removal of refuse in street and other markets where refuse of a bulky character is the rule.

There is, however, just one point that requires special mention. Provision must be made to drain away any water that may come from refuse collected during wet weather. In the old days it was a common sight to see water streaming from the collecting vehicle when it passed along the street, but in these days such procedure cannot be tolerated.

Pump Design.—The method of applying the water has also undergone considerable change, and the earlier type pump has been improved out of all recognition. The present day fitment generally consists of a high efficiency turbine pump constructed of gunmetal, a material with a high resistance to corrosive action.

Pressure Jets.—It was only natural that the actual pressure washing jets should be improved at the same time. The earlier fixed type of jet has given place to one of an adjustable type so mounted that the driver of the vehicle can direct the jet of water in any given direction while the machine is in motion.

One of the greatest advantages derived from this type of fitment lies in the fact that the passer-by is no longer subjected to a spray of water and mud when the machine is working close to the kerb.

Channelling.—Apart altogether from street washing, these machines, by the introduction of suitable jets, can be employed for street watering or for swilling down the channels. This is a most valuable service in the modern town, and one that can hardly be operated without the introduction of some form of machine.

In this connection it may perhaps be of interest to note that the introduction of "one-way" traffic has necessitated modification in the design of the flushing jets for channel purposes. These are now mounted on both sides of the vehicle, whereas previously one jet only (and that on the near side) was considered essential.

General.—With the growth of modern traffic it would appear that the days of hand flushing, efficient though it be, are numbered. There is considerable controversy as to whether the washing of roads by a pressure jet is desirable or otherwise, but it is difficult to see how the work can be carried out efficiently and at a low cost if this method be not employed.

However that may be it will, perhaps, be well for engineers and manufacturers to concentrate on securing those detailed improvements which will render the operation of this machine even more efficient than is at present possible.

GULLY CLEANSING.

It is a short step from the cleansing of the highway to the cleansing of street gullies.

Early Methods.—Here again the practice of the past would not be tolerated to-day in large centres of population.

The method of operation was primitive and consisted in removing the detritus from the gully by means of a scoop with a long handle and either placing it in the gutter to drain away the moisture prior to loading, or, alternatively, dropping it direct into a steel slop cart generally horse drawn.

• Apart altogether from the hygienic aspect of the operation, for which nothing good can be said, there was a further grave drawback in that the gully was generally left unsealed. At some later time a water cart was used to replenish the water content, but in the meanwhile a quantity of evil smelling liquid was left in the pit and in addition the sewer was ventilating through the unsealed gully.

In parenthesis it may be stated that the installation of a double-seal gully of a type common in certain areas would have prevented this. In view of the many advantages possessed by this form it is difficult to understand why it has not been more universally adopted.

LINES OF DEVELOPMENT.

Motor.—The demand naturally arose for a more comprehensive and cleanly system of operation, and a form of vacuum machine mounted on a commercial motor chassis was first employed.

Generally speaking, it consisted of a 750 to 800 gallon cylindrical tank fitted with suitable suction pipe and emptying door. The vacuum pump was driven from the engine.

The method of working was to create a vacuum in the tank and lower the suction pipe into the gully. If the contents were not removed by the time the vacuum was exhausted a pause had to be made while the vacuum was re-established. This was by no means the simple process it sounds, and considerable time was taken thereon. Further than that the raising and lowering of the suction hose required the employment of three men using a hand winch. On that score alone operation costs were heavy.

This machine had a further serious drawback in that no provision was made for draining the water contents in the tank, and in consequence the machine spent a considerable proportion of its time running to and from the tip. The difficulty can be better appreciated when it is realised that probably only 15 per cent. to 25 per cent. of the tank contents consisted of sludge, the remainder being water.

Trouble arose again at the point of discharge, for the whole had to be shot and the water drained off before the sludge could be handled and carted away. In the special case where the sludge was barged away at so much per ton, the cost was materially increased by the fact that about 75 per cent. of the load was water.

There existed a further disadvantage in that the machine was not, so to speak, self-supporting, for a water cart had still to follow to provide the necessary clean water for re-sealing the gullies after clearing.

Despite their deficiencies these first motor vehicles proved a great advance on the old methods, and it is small wonder that intensive research was undertaken and further improvements forthcoming.

Steam Vehicles.—Shortly after the appearance of the early motor machines, steam gully emptiers appeared on the market. These had a stronger chassis and the tank capacity was materially increased.

A very definite step forward was registered, for the tanks were now divided into two compartments, one for carrying sludge drawn from the gullies and the other for clean water for the subsequent re-sealing.

Generally speaking, each compartment had a capacity of about 900 gallons, and it was possible to reduce the number of visits to tip and also the occasions on which the water tank required refilling.

These vehicles were, however, heavy, and on that account incapable of universal application if only on the score that in many places the streets were unsuitable to carry the load involved.

FURTHER DEVELOPMENTS IN MOTOR VEHICLES.

Tank Design.—Needless to say, the motor manufacturers were not standing still, and as the vehicles began to improve so they were fitted with tanks of larger capacity. Tanks holding 1,000 to 1,200 gallons became general, and these, as in the case of the steam vehicle, were divided into two compartments, one for sludge, and the other for clean water.

The proportion of the tank space allotted was approximately two-thirds for sludge, and one-third for clean water, and consequently in the course of the working day numerous stops to replenish its water supply had to be made.

Pumps.—The mechanical parts were still further improved and vacuum pumps produced giving a high figure of efficiency. A further advance was registered in that it no longer became necessary to obtain a vacuum in the whole of the sludge compartment. With the speeding up of this process more gullies per day were emptied.

Suction Hose.—The method of operating the suction hose was also overhauled and by the use of jib and balance weights ease of handling was achieved with a consequent saving in the labour and operating costs.

Draining of Surplus Water.—Perhaps one of the most valuable improvements, however, has been in the making of provision for draining away all surplus water from the sludge.

For the first time it was possible to take to the point of discharge detritus having a remarkably low water content, a feature which naturally exercised a very considerable influence on the ultimate disposal cost, and further materially added to the sphere of usefulness of the machine as a whole.

Modern Practice.—The present day machine is entirely different to its predecessors. Except probably for the Metropolis and like large centres of population where extensive gritting is indulged in, the improved construction of street surfaces has brought about an appreciable diminution in the amount of detritus to be removed from gullies over a given period, while the decrease in the proportion of horse transport has also contributed to this end.

Tank Capacities.—Naturally the design of the tank has required modification, and, generally speaking, the current practice is for this to be divided up in the proportion of one-third for sludge and two-thirds for clean water.

Water Compartment.—As has already been indicated, the performance of the machine had hitherto been slowed up by the necessity to replenish the clean water supply. The modification in design has resulted in a material reduction in the number of visits to the water stand post, and the time so gained has been employed by the machine in its normal function of emptying gullies.

BY J. N. SWINDLEHURST.

The effect on the cost per gully emptied, or whatever other costing unit is employed, can be readily realised.

Sludge Compartment.—The reduction in the size of the sludge compartment permits of vacuum being raised more quickly. Further, an outlet has been provided through which all surplus water may be drained away from time to time during the day into the sewer through the gullies. This improvement renders it possible to obtain greater efficiency from the tank, for the "dead" time previously spent in travelling backwards and forwards from the work to the place of discharge is reduced to a negligible amount.

Tank Design.—Before leaving the question of the tank it will perhaps be desirable to instance what may be regarded as the major improvement effected in its construction.

In the earlier models the chemical action of the water and sludge set up rapid deterioration of the inside of the tank. To counteract this wasting effect, heavy section metal was employed in construction with a consequent material increase in weight. In the modern gully emptier the section of the steel plate is appreciably lighter, the alteration being rendered possible by the thorough galvanising of all exposed surfaces.

Whether this represents the last word remains to be seen, but it is submitted that herein lies a fruitful field for research.

It may be regarded as by no means outside the realms of possibility that a compound steel or an alloy of other metals may be produced that will render even this galvanising process unnecessary, while giving an extended lease of life to this essential part of the mechanism.

Suction Hose.—Reference has already been made to the methods of operating the suction hose. It will be remembered that the original form entailed the use of a hand winch. This was followed by a balanced jib which in turn has been superseded by a swivel arm with a weight at one end to balance the suction hose and pipe situated at the other extremity.

This form is very light and easy to handle and enables operating costs to be reduced. Still further detailed improvements are doubtless possible, but it is difficult to foresee the line they will take.

REMOVAL OF SLUDGE FROM TANK.

Early Practice.—Originally the emptying door took the form of an elliptical opening at the bottom end of the tank.

Though the tank was inclined toward the rear the inclination was generally insufficient to afford complete clearance and hand raking had to be resorted to. Needless to say, this was a lengthy, tedious, and, on occasions, very dirty process.

Improvements Effected.—Various modifications have been tried and at the present day the whole of the rear end of the tank is in the form of an emptying door. In order still further to facilitate discharge, tipping gear is introduced which enables the tanks to be raised to an angle of 45°.

As the load consists of material having a comparatively small water content the operation can be performed very rapidly and it is difficult to see how this method can be improved upon.

Points of Design.—Reviewing the situation generally it would appear that the main points to look for in a machine of this class are :—

- (a) Form of construction.
- (b) Capacity of the tanks and the respective proportions allocated to sludge and clean water.
- (c) Ease with which a vacuum can be obtained and held.
- (d) The amount of physical effort required to operate the suction hose and pipe, paying in addition particular attention to the form of its construction and its ability to withstand the hard usage to which it will undoubtedly be subject.
- (e) The provision made for draining off the surplus water from the sludge and so reducing to a minimum the number of visits to the point of discharge, and whether it is possible to make use of this super-natant water for the purpose of gully sealing.
- (f) The system of clearing the tank of de-watered sludge.

Particular stress is laid on the above, for each and every one of the items mentioned has a very direct bearing on the efficiency factor of the machine as a whole.

It need hardly be added that there are two further factors to bear in mind, which though common to all vehicles are particularly applicable to this heavier type of transport :—

1. The chassis must be of robust construction, adequate for the loads it will ultimately carry, and
2. All moving parts (including motive power) shall be so designed that a margin of power is available even under adverse working conditions.

There is a great tendency to attach all sorts and conditions of gadgets to vehicles of this class, and it is submitted that the utmost simplicity should at all times be insisted upon.

General.—There is, perhaps, one phase to which engineers and manufacturing interests might well devote their attention, and that is to the production of machines of smaller capacity than the larger types to which specific reference has been made.

There is no doubt that such machines would have a very wide sphere of usefulness in that they could operate in narrower thoroughfares than the larger, and, further, would be of the utmost value, particularly for cesspool emptying in rural areas. Such machines should have a great future, if only on hygienic grounds, if the operating costs can be kept sufficiently low.

CONCLUSION.

As stated at the outset, this Paper has been written in an endeavour to help both user and manufacturer.

There are so many types of vehicles and modifications of the same type on the market at the present time, that the choice as between one and the other has become a matter of extreme difficulty.

It is hard to believe that all these variations are necessary or even desirable, and it is suggested that the time has come for a greater measure of standardisation to be effected, with a consequent saving not only in first cost but in ultimate maintenance.

If this Paper should be the means of concentrating thought on Vehicle Design and of bringing about the elimination of non-essentials with a consequent gain in all-round efficiency, the Author's purpose will have been achieved.

DISCUSSION.

Mr. J. E. SWINDLEHURST, introducing his Paper, said : The subject of vehicle design in relation to public cleansing is one that cannot fail to be of great interest to all engaged in municipal engineering. The more one studies this subject the more does it appear that there are, as it were, distinct fashions in vehicles. The change from one fashion to another is not rapid, and in the interim period there are many variations of the same type. When one surveys the whole field for a period of years it is extraordinary to note how various details of design reappear, and it is difficult to understand, without a full knowledge of the working conditions, the various reasons which have necessitated their re-employment. In this Paper I have endeavoured to give a résumé of both past, present, and, to some extent, of what may prove to be future practice.

The Paper does not deal with the very vexed question of motive power, for that is a subject in itself. Many papers have been written on that subject, either wholly or in part, and, so far as I am aware, we are as far from finality, that is to say, we are as far from agreement as to the best form of motive power to-day as we have ever been. There are developments, notably in the tractor trailer system. From the exhibits at this Congress it is evident that there have been great steps forward in the design of tractors. By the use of some of these new types we shall probably achieve greater ease

of manœuvre than is possible with what I might term the self-contained vehicle.

There are several items which I have not specifically mentioned in this Paper. One of those deals with the house and trade refuse collection section : I refer to the container system. I have not dealt with that in any detail, for it is, generally speaking, of a local application. Those of us who have to deal with metropolitan conditions find that system extremely useful when dealing with large blocks of flats, hospitals, and institutions of that character. It may quite possibly happen that the system will be extended to the provinces for use in similar conditions.

There is another point to which I would draw attention, and that is the section dealing with road sweeping machinery. This Exhibition has disclosed a machine working on a principle entirely different from that previously in use : I refer to the suction sweeper. It would appear to be an adaptation of the well-known household Hoover or similar machine. It seems to me that a machine of that type has great possibilities, and it provides a field that may well be further explored, both from the point of view of the user and from the point of view of the manufacturer. For reasons which you will appreciate, I do not want to deal with that machine in detail at this juncture, but the features embodied are so novel in character that I feel it is almost my duty to

bring it forward and so make my Paper more complete in that particular.

The aim of both user and manufacturer is to obtain a vehicle that will perform its work efficiently and economically. I sincerely hope that the discussion will take the line of constructive criticism, and that both sides will air their views. If that hope be realised, then I feel sure that there must arise from this discussion developments on lines that probably up to now have not been explored but which will be of undoubted benefit to both sides.

MR. O. CATTIN (*Lambeth*), proposing a vote of thanks to the Author, said: I have necessarily had to make an intensive study of the vehicle question for at least ten years, and there are certain features in connection with vehicles for refuse collection which come out in that study. The trend of public opinion since the War has undoubtedly been for the concealment of refuse, that is to say, that it shall not meet the eye. The majority of our constituents, I think, have in their minds the house refuse question, and I am afraid attention is concentrated on house refuse, leaving street refuse somewhat trailing behind. I would say here and now, as a Londoner with a professional life of forty years, that London has met this problem well, and I still maintain that London is the best scavenged town that I know. The improvement in the vehicle and in the kinds of vehicles which have been purchased has been very noticeable. We had the period of the German type of machine—I think it is quite safe to call it the "Ees-Em"—but I must say that, having examined it in all its details and having regard to the conditions of the populace we have to serve, I should have hesitated to attempt its installation in my own borough. It has an insuperable difficulty, to my mind, and that is the provision of special bins. We then come to the low loading type of vehicle, which has an advantage for the men who are doing the work. The poor unfortunate man staggering up a ladder under a heavy bin was an object of sympathy; I am not at all sure that it was required, but anyhow the low loading type is adopted, and with its fit-up of course it is very attractive to the eye. It is what in the Army they would call "eyewash" to a certain extent. Many authorities have purchased fleets of these vehicles, and very

handy machines they are. There is really nothing to say against them. I would only say this, that to my mind scavenging is a matter of intensity. You have to deal with a district according to the character of the streets, and I should be the last person to attempt to clear away foul refuse at places where ladies are shopping or where there is a great public assembly. It is quite obvious that you have to deal with special conditions, and I consider that the low loading type of vehicle used in a busy street is no advance on the old high loading fashion. For that reason I have dismissed it from my mind. The automatic flaps are by no means easy to manoeuvre, and I am not at all sure that the workman is much better off with them. That led us up to the end loader. There are two problems in house refuse collection, large capacity and the concealment of the refuse, and I think that the end loading vehicle is going to be very largely used. The concealed entry and that sort of device are, of course, a great advantage. I am sorry to say that I have no experience of the moving floor. I only feel that the more apparatus you have in connection with the vehicle the more trouble there is going to be in the future, and simplicity is a great advantage. I do not know whether I am safe in saying that the moving floor may lead to trouble after a few years' working. The whole subject of the collection of refuse is largely influenced by the skill of the person employed and the care he exercises in collecting, and we must look forward to the time when refuse will be removed from a house in a manner similar to the way in which a funeral is conducted. I do not know when that time will come, but we want sealed vessels and sealed vans. Still dealing with the refuse question, the moving floor has a great advantage in the compacting of refuse. Judging from the few experiments I have made, I think we are only at the beginning of compacting. I believe that if the compacting can be carried out in a sanitary way we shall be able to save a great deal of money. It is really astonishing how the refuse can be compacted. Perhaps my remarks as to the moving floor might be qualified if the moving floor will lead to a sort of fuel brick being taken out, instead of the refuse being shot from the vehicle. I think it is possible to compress the refuse almost enough for that to be

DISCUSSION.

done, though I am not yet sure on the point. The whole question is in the able hands of the makers of the vehicles. We owe a debt of gratitude to them. There is no doubt that there are many vehicles which deserve the utmost credit. There is this to be remembered, however, that when an engineer has to recommend an authority to purchase a large number of vehicles he is not likely to get a new set very often. We must have a certain life for the vehicles, and perhaps the hire purchase or the hire system may be attractive. That brings me to this point, that I am not in favour of trundling about the street, from house to house, a very expensive motor vehicle. I think the horse or the tractor can be adapted to a container which is not so expensive that you could scrap it and have a new one. It may be that the body of the motor vehicle could also be reconstructed, but I think, in the interests of the ratepayers, it is just as well to have a container independent of the means of locomotion.

With reference to street sweeping, as I say, it has rather lagged behind the other subject, but it is one which is very easy to deal with, to my mind. Given the beat system and a suitable motor vehicle, it is quite easy to arrange a body to the motor vehicle which in loading will give no offence to persons using the streets. A covered vehicle with shutters or flaps seems to fulfil this purpose admirably.

So much for the vehicles for street sweeping and house refuse collecting. I have rather taken the sort of lead Mr. Swindlehurst gives in this matter, but it enables me to follow out my own line of thought on the subject. I think that successful scavenging depends on what I call the finer arts, that is to say, you need a fleet of special motor vehicles connected to any system by which you can carry out the "stunt division" work. The sweeper and collector I have persevered with for years, and, although it is a great man displacer, there is no doubt that, used in the early morning, it can make the streets very acceptable to our constituents when they are starting out to business. I think the sweeper and collector should be persevered with. I have heard some people say they cannot use it, but I think that is because they have no permanently paved roads in their particular areas. I think that on permanently paved roads the sweeper

and collector is of great advantage, and I should certainly be inclined to try the suction sweeper, if it can be found to be an economical proposition.

With regard to street washing, I was employed in Central London for seventeen years before the War, and I think that, given asphalt or a similar impervious surface, the street washer is indispensable. It leads to great economy in the lifting of detritus. I was told, when I instituted it elsewhere, that we should block the gullies and send too much water down the sewers, and have all sorts of trouble, but of course, after all, the water used by the street washer with pressure sprays is not as much as an ordinary shower of rain. The amount of water one uses in a 1,100-gallon tank is negligible, and, to my mind, every town should have street washing carried out.

With regard to the gully emptier, I would give great credit to the manufacturer. The multi-purpose gully emptier which I use at the present time is a magnificent machine and fulfils all the purposes for which we require it without any nuisance being caused to the public. I think there is room for more research on the question of the suction hose of the gully emptier and its manipulation. I can foresee the time when it will be used almost without manual control, but what we have at the moment is very satisfactory, and, as far as I know, it has led to no complaint.

There has been a general improvement in scavenging services throughout, and I maintain, as a London surveyor of forty years' service, that nowhere can you see a better example of public cleansing than in the boroughs of London.

We are greatly indebted to the Author for putting forward this Paper to show that we have at our command all the necessary machines, and we are looking forward to more research being done to enable us to do scavenging in a way that will be nothing short of marvellous. The only fear I have in my mind is that all these things are man displacers, which makes their use rather difficult in borough work.

MR. E. J. MUMFORD (*Kenington*), seconding the vote of thanks, said: Reference is made in the Paper, under the heading of "House and Trade Refuse Collection," to the matter of screening the refuse from the sight of the public. There is no doubt that, although

it is possibly a detail, it is an exceedingly important point.

The Paper also refers to the question of end or rear loading. I commenced using this type of vehicle about two years ago, and there is no doubt that it has overcome a large number of objections to the ordinary side loading vehicle. It facilitates loading and it enables larger loads to be carried. When you have to deal with very bulky articles it is easy to appreciate that they may be placed in such a vehicle without difficulty. Further, the first test that was taken with this particular vehicle showed that we actually got an increase of 30 per cent. in our loads conveyed to the disposal points. Then, from the men's point of view, I asked a large number of dustmen who were utilising the vehicle as to how they liked it, and, having regard to the criticism that nuisance arises from the dust in the interior of the vehicle, not one of the men raised any complaint on this particular point. A great practical advantage of rear loading is that it does not obstruct either pedestrian or vehicular traffic.

With regard to the moving floor, I too have not yet had an opportunity of trying it out, but I certainly think that it is well worth trying so as to gain experience with regard to it.

Another important point in connection with refuse collection vehicles is that great care should be taken in selecting a particular vehicle for a particular district. It may be that in a certain district a particular vehicle is giving excellent results, but if that vehicle is used in another district it may be that such good results will not be obtained, because it is not the right type of vehicle for that district.

Another important practical point, which is mentioned in the Paper, is the question of body construction. You certainly require robust construction, but, having regard to taxation, great care should be taken to see that you do not get an excessively heavy body.

The Author refers to the question of the vehicles being constructed so as to convey fillers to the district. With regard to that, if one adopts a relay system I do not think it is of very much importance.

Another advantage of the end loading vehicle is in packing. We know that in the

case of side loading the dustmen have to spread the loads so as to get more in, and not infrequently they suffer from accidents, cut hands and so on, but that is more or less obviated with rear loading.

With regard to unloading, I think another requirement should be added to those given in the Paper, namely, that the load should be discharged in the minimum of time and with the minimum of dust nuisance.

When I read the Paper I noticed that Mr. Swindlehurst had made no reference to the container system, and I was very glad to hear him refer to it in his introductory remarks. The container system is no doubt an excellent system and in particular circumstances it has great advantages.

With regard to costing, one must be exceedingly careful in giving figures, but the figures that have been obtained in connection with the container system show that, where it is satisfactorily introduced, 1s. to 1s. 6d. per ton can be saved in the cost of transport.

A point I want to refer to in connection with street washing vehicles is not so much the pressure type for cleansing the surface as the matter of watering the channels. My experience of the motor driver is that he covers the ground much too quickly and there may be great waste of money when this type of vehicle is used, because so little water is sprinkled that it serves no useful purpose at all. I would throw out a suggestion that a mechanism might be introduced so that the rate of discharge would approximate to the rate of the speed of the vehicle.

With regard to gully cleansing, the experience in Kensington is that the smaller vehicle in the end is more economical to run than the larger vehicle.

There is only one other point in the Paper to which I wish to refer again, and that is a matter of the container system. We have found, on introducing the container system in connection with our street cleansing, that we have again been able to reduce our costs. These containers are placed in suitable positions and, instead of the time of the vehicle having to coincide exactly with the beatman, the beatman takes his bins and empties them into these containers. Therefore I think authorities would do well to consider whether the introduction of the container system would not be an advantage in regard to their street refuse collection.

Mr. A. E. CLOVES (Cleansing Superintendent, Reigate): The Paper gives us an array of statements that may be of considerable use in the very near future. It also gives us details of certain apparatus which other boroughs may operate or try to operate with success.

I notice in the Paper a reference to body construction. I myself have been forced to operate the vehicles left to me, but I think that, taking into consideration the new licensing laws, some of us will have to realize that iron and steel are not the best materials to use for body construction but that there are other lighter materials and that good ash and oak, with their lightness and durability, will, if treated properly, give the same service and satisfaction, with very likely better results, in the very near future.

With regard to loading, in my district I am operating now both the shutter principle and the flap principle. Certain ideas have been carried out in the department, with the close co-operation of the members of the department—we must all realize that we have to take into consideration the men who work the vehicles—and there is no doubt about it that rear loading is not going to suit everybody. I have had trials carried out with rear loading, and I am very much afraid that, in some of the very narrow passages that exist in some boroughs, with rear loading and five loaders on each side of the passage, it must be realized that side loading is more suitable in such places.

A month ago I ran a test to see from a certain number of premises which was the most efficient vehicle, the side loader with the shutters or the side loader with the foot-operated flaps, and, after a careful test over a measured mile, it was found that, with the foot-operated flaps that we used in the department, the amount of refuse collected was more. There were 180 premises on each side of the place, and, by having a foot-operated flap and the loaders not having to trim the vehicle, we cut down our loading time by nearly 17 per cent. That shows that, as far as the vehicle design and construction are concerned, rear loading might not suit every one of us. After a trial I can definitely state that in my area I should not hesitate, if I were buying new vehicles, to go back to the side loading vehicle. In that connection I would say that the men have not

to leave open the shutters. With the foot-operated flap I have noticed in my travels men prop them open, discharge the refuse and go back to the stands with the bins, leaving the flaps open.

With regard to street cleansing, in many districts we are not using the receptacles that could be used with economy to ourselves, and that are already upon the market, but we stick to a certain kind of design. We have a fancy for it, and we are not making any attempt to introduce something else. What I say is this: If you have a light vehicle—we will say a two-ton vehicle—with sliding shutters or something similar, and if your street refuse workers, instead of operating the hand carts that you see even in London in a good many instances, have the bins with the trucks that are so readily adaptable to any kind of borough now, and if the vehicle and the organisation behind the vehicle are as nearly perfect as it is possible to get them, I think you will find that you can operate successfully that system where the refuse is collected from the truck placed right into the vehicle, the vehicle being semi-covered or semi-dustless, and that the object you set out to attain will be readily accomplished.

Mr. E. J. ELDON (Mandsworth): Mr. Swindlehurst has struck out on a somewhat new line which has not, to my knowledge, been dealt with to any very great extent in the past, and his Paper is of much value.

He refers to the fact that refuse is tending to become lighter and more bulky compared with weight. I have found in my Borough that that has been particularly noticeable, and I believe the same has been found in other places. That is evidence that it does not do to dogmatise on these matters. Conditions change—often very rapidly. Therefore we have to keep an open mind and see to it that we are not tied down to any particular ideas.

Vehicles with moving bottoms are certainly very interesting, and I hope that they will be found to be satisfactory in practical operation, because if they are that feature will no doubt be of very great value. Both that form of apparatus and the shutter principle applied to public cleansing have been discussed for many years past, and have been tried out more or less, but have never made any appreciable headway. So far

as the suction principle is concerned, the great difficulty has been the cost of operation. If that can be overcome I think it has a very great future before it, but where the "beat" system is in operation vehicles of that kind often have to travel very long distances to obtain reasonable loads, and I can quite imagine that the maintenance of a suction, covering perhaps 20 miles or more for one loading, would be a very expensive matter.

Then there is the question of wear and tear. Mr. Cattlin said it is desirable, in dealing with matters of this kind, that moving parts should be reduced in number as much as possible, and that wear and tear should be reduced to a minimum. I quite agree with Mr. Swindlehurst in his remark that there must of necessity be a diversity in types of body. We sometimes hear people making the remark that there must be one type of vehicle which is the best, and therefore why on earth cannot we set ourselves to the problem and find out that type and adopt it, and have done with it. That, I think, is utterly absurd. Conditions vary so much in different towns, and even in different parts of the same town, that we must be prepared to adapt the vehicle to the particular local circumstances.

The last speaker rather condemned the use of the rear-loading vehicle. There, again, it is quite wrong to dogmatise. What is suitable in some districts may be quite unsuitable in others. In London this type of vehicle is certainly making very great headway, and I think it is likely to be adopted very generally, but it does not follow that it would be appropriate in other places.

He also referred to the foot-operated flaps. I do suggest that such a trial as that to which he referred—which, after all, was only a single trial for a few hours—should not be taken too seriously. The results may be very different when they are taken on the ordinary practical every-day working of the vehicle. They may be very different also after the men have had them for 6 or 12 months. I have been making inspections in the Metropolitan Boroughs during the last 12 months in connection with a committee making certain investigations, and I have been very much struck by the fact that the foot-operated flap is being abandoned in many cases. I have not been able to find a case where it is still in very much favour. The

men will prop the flap open, and you cannot be on their track all the time. There have also been accidents, and the men complain in some cases that when they have to manipulate the treadle at the same time as they are manipulating a heavy bin it is essential they should prop up the flap. So that personally I am rather doubtful about the value of the foot-operated flap.

There is one point to which I do not think Mr. Swindlehurst has referred. In some cases I have seen horse-drawn vehicles which have been more or less reconstructed on modern lines. An appreciable amount of money has been spent on them, but the wheels have been left as they were—as the ordinary cartwheel. In other cases new horse-drawn vehicles have been adapted with ball-bearing wheels, and I have been assured that there is a difference of from 30 to 50 per cent. in the loads that the horse is able to draw comfortably, compared with the old type of wheel. My own view is that one should hesitate very much before attempting to adapt any old vehicle to bring it more into line with modern requirements. I think in most cases it will be found that it is neither one thing nor the other, and that it will pay very much better to scrap old vehicles and start afresh.

I also think with Mr. Cattlin that too much has been made of the extremely low-loading vehicle. The result has been, in many cases, that in busy streets people have had the stuff tipped out right under their noses. Where this happens I think it might even be much better if the man went up the ladder and the dust was more or less out of the way.

I have been very much impressed also by the mechanical horse trailer system which is being adopted. So far as my personal knowledge is concerned, I think it has very great possibilities.

On the question of bins, I do think that those used with the somewhat complicated continental vehicles which have been tried in this country are suitable for our conditions. Some effort should be made to standardise bins. They might be reduced to about three types, which should tend to lower the cost of manufacture, improve quality, reduce the stocks, and facilitate collection. Then, again, with the continental system of collecting with vehicles requiring bins of

special design, there is always the difficulty that there are bound to be times when people have to put a certain amount of refuse into some other vessel than their bin. This happens especially at Christmas time.

With regard to street cleansing, I feel that the system of collecting by portable bins on trucks and discharging those into vehicles perambulating the district is about the best that has been devised, especially for London. I do not understand the reference to a large quantity of water being picked up with street sweepings. I find that with bins and collecting vehicles we have no trouble of that kind.

THE CHAIRMAN (MAJOR L. ROSEKARE): I should like to thank my former colleague, Mr. Swindlehurst, for writing this Paper, because I do feel that a considerable amount of money has been wasted in the past by manufacturers trying to forestall the requirements of engineers, and also by local authorities using vehicles which do not quite meet what is required. I think it is up to us clearly to define and think out what we do want, and give the manufacturer then a chance of trying to build the vehicle that is required.

There are one or two points I should like to raise in connection with the Paper. With regard to the moving floor, I have tried it and personally I think it is going to be the thing of the future. There is a difficulty with regard to the maintenance and moving parts, but if you can get material compressed up to 60 per cent. it is going to make a considerable difference in the cost of collection. There is one point I would suggest, namely, that in the front of a vehicle of this type there should be a box capable of holding old bicycles and wooden boxes, so that when the pressure is put on, which is sometimes done by machine power and amounts to anything up to three tons, you will not destroy the efficiency of that work by having some hard material which prevents the compression of the lighter material which we are now generally getting.

Then with regard to the gully cleaner, in my Borough and previously in the North, all new gulleys which I put in have double traps, the advantage being that when the gully cleaner goes round it can suck out of the trap and empty it without any danger

of unsealing the sewer. That is a distinct advantage, in that the gully cleaner need not in future have a water container, and the supernatant water can be discharged into the sewer and thereby increase the capacity of the gully emptier by a hundred per cent.

With regard to the suction sweeper, I agree with Mr. Elford that if that can be made efficient it is going to be a big step forward, because it will not be necessary to carry water around to water the road before it is swept, which, as a matter of fact, leaves a slight smear of mud after the brushing, which dries up and blows about afterwards.

With regard to the sweeper, I have found that a little more care is required in covering up the working parts, especially the brush bearings.

MR. SWINDLEHURST, in reply, said: I am in some difficulty to know where to begin, for the remarks made by the speakers have followed rather closely the lines set out in the Paper.

There is a point which I should like to take up on the remarks made by Mr. Clouds, of Reigate. He favoured side-loading as distinct from end-loading where you have narrow passages to deal with. I am not conversant with his local conditions, but on the face of it it would seem to me that a vehicle can be the more readily loaded from the end than it can from the side if your passage-way be restricted. It is difficult on that account to understand the decisions arrived at as the result of that test. One cannot emphasise too strongly the fact that the whole question of public cleansing, whether it be house refuse, street cleansing or the cleansing of gulleys, is a matter of local conditions. I do not think any man can dogmatize, and it is utterly wrong to try to do so. What is perfectly sound in one section of a district may be not so sound in another section of the same district.

The point raised by Mr. Elford with regard to the suction sweeper and the distance it may have to travel to pick up a "paying load" (shall we say?) is a good one. I believe he prefaced his remarks with the statement that they applied more particularly to those districts where the "beat" system of scavenging was in operation or, in other words, where you have the major portion

of the detritus removed from the streets before the sweeper comes along. That is agreed, given certain conditions, but I can visualise conditions in busy thoroughfares where it is difficult for the manual work to be performed without danger to the employee. In this case a mechanical sweeper of this character might be used with great advantage; that is to say, where there is a comparatively large amount of road detritus to be removed. It should be remembered, however, that this type of machine is more or less in its infancy, but as I remarked in my opening statement, it represents a new development. I believe it has been tried out in the North under very severe conditions, and doubtless in the fulness of time there will be an opportunity to try it out under other conditions, both in the provinces and in the Metropolis. When the results of those tests come to hand we shall be in a position better to assess the merits or the demerits of this system. For the moment I submit that it is a most interesting development and one which is worthy of considerable attention by all interested in public affairs.

The question of the loading line of the vehicle is a very vexed one. I agree with the various speakers who have condemned what I call the extreme low loading line. The refuse is brought right under the nose of the passer-by, and although some systems are more dustless in operation than others I know of no system that is entirely dustless, except that in which special bins are employed. I do not want that remark to be regarded, if I may say so, as a boost for that particular type of system. When, however, one has studied the various types of vehicle in use, I think it must be conceded that for one hundred per cent., or practically one hundred per cent., dustless loading, those vehicles which are in use in many cities on the Continent, and which employ the special type of container, are in advance of the vehicles in general use in this country. It must be emphasised, however, that the favourable comparison is in that direction, and in that direction only.

I have not dealt with the problem of the standardisation of bins, for, although it has a material bearing on this question of house, trade and street refuse collection, and is to some extent a matter to be reckoned with in vehicle design, rightly or wrongly I do not

regard the question as having so great a bearing as have other factors.

The point which the Chairman has made with regard to the provision for the storage of hard and bulky materials when using a moving floor vehicle is an extremely good one, particularly if that moving floor be used, as the manufacturers assure us it can be used, to compress the refuse. I know it can be done with Metropolitan refuse of a comparatively light character. The figures which have been obtained from tests in the Metropolitan Borough of Stepney show conclusively that the moving floor has a very great advantage over what I may term the fixed floor type of vehicle. We have yet to see how this floor is going to stand up to service. I know of no worse abrasive than the dust from house refuse, and, when you couple that with the chemical action which undoubtedly does ensue with the repeated carriage of refuse of various descriptions, it is a question to my mind whether there must not be very material modifications in design to overcome those two factors.

Then there is the further point with regard to the moving floor that, whatever type be adopted, it must be capable of repair and replacement not only quickly but at a low cost.

Mr. Messent in his remarks made a very interesting point in the matter of using the gulley emptier or similar machine for channelling. In my experience it is little use giving detailed instructions to the operator that his speed must not exceed x miles an hour, because he invariably does speed up. Traffic conditions on occasion make it necessary that he should speed up, and if the flow of the water is the same at four miles an hour as it is at 12 miles an hour then obviously the work cannot be carried out as efficiently at the higher speed as at the lower. If, therefore, there could be some system—and I do not think there will be any great practical mechanical difficulty in it—of coupling the control of the water outlet with the speed of the vehicle, it would be a very great step forward, and would enable the work to be carried out more economically than at the present moment.

The point has been made also as regards the accommodation for the fillers. I agree that with a relay system that accommodation

is not so necessary. On the other hand, you probably have to get the fillers from your central depot to the point at which they are to commence their work. That again is a matter of local organisation. In some districts, of course, the fillers go straight on to the job and the vehicles meet them there. I said a moment ago that it was not necessary with the relay system. Perhaps I should modify that remark and say that it is not so necessary with the relay system as it is with what I may call the "beat" system. There have been too many instances in the past of the fillers crowding on to the vehicle, hanging on by their eyebrows almost, and even climbing into the driver's cab and by their presence impeding his actions. In these days when the number of road accidents is mounting daily I feel that every precaution should be taken to avoid the driver's attention being diverted from the road while he is in charge of the vehicle. If the driver's cab is cluttered up with coats, boxes and fillers—and you have not got to go far to find many instances of that—then I submit that that driver cannot be working as efficiently as the public has a right to expect. With that in mind I strongly urge that special accommodation be provided for the transport of the fillers and the men operating the machine when proceeding to and from the districts in which they are working.

VOTE OF THANKS.

THE CHAIRMAN (MAJOR L. ROSEVEARE): It would be rather an ingratitude on our part if we did not express our appreciation to the Congress Committee for the opportunity which has been afforded us of perusing, and hearing the discussions on, Papers covering such a large field. It has entailed a considerable amount of work, especially as it has fallen, as it usually does, on two or three men. I believe Mr. Sandford Fawcett, for instance, read through the whole of the Papers. Then the two Secretaries, Mr. Johnson and Mr. Scott-Giles, have done a tremendous amount of work, mostly behind the scenes. They have done their work very quietly and very efficiently, and our very best thanks are due to them. I beg formally to move that our thanks be given to the Congress Committee and to the two Secretaries for their excellent work during the Congress.

MR. BURNS (*Hemsworth*): It is a privilege and a pleasure to second the vote of thanks. I am glad you included the secretaries. I think also the staff should be included.

I regard this Exhibition as the best that has ever been held, and the most advanced in new ideas. I want to pay a tribute to the winners of the prizes, and one of my pleasures is in the fact that the prize-winners are all young men. I should like also to say a word of praise and gratitude to the judges of those Papers.

We should like as ordinary delegates, just members of public bodies and not members of any official staff, to express our pleasure and gratitude to the Congress Committee for giving us the opportunity of coming here for a whole week in order to hear the views of great experts. These views when put into operation will help this country of ours to be more healthy and more prosperous. The women of this country will take sides with their men in order to put these ideas into effect. The Government, urged by public opinion, will be compelled to go on and, because of conferences like these, we can make England the happiest and healthiest country that there is on the face of the earth.

MR. ABBOTT: In associating myself with the resolution I would say that this is the first Congress which I have had the pleasure of visiting, and I unhesitatingly say that I have reaped a great advantage by coming here. Being of a mechanical turn of mind I have been greatly interested in the developments of the mechanical appliances used in municipal work. Further than that, I have greatly benefited by the Papers which have been so ably discussed at the various conferences during this session. I am sure that one cannot go away from this meeting without having realised that he has to some extent received benefit by the discussions which have taken place. We feel that we are on the eve of big developments in the improvement of various machinery and appliances.

I should like, in supporting the resolution, to couple with it an expression of our thanks for the consideration which the Congress Committee has given to the well-being and pleasure of the delegates.

MR. E. J. ELFORD, in acknowledging the vote, said: All I need say is that there are only a limited number of individuals who

really deserve this vote of thanks. The Chairman, Sir Henry Maybury, and Mr. Sandford Fawcett put in an enormous amount of time on the Papers. I have not had any part in adjudicating on the Papers, and I look on that as being one of the heaviest tasks which has had to be performed. When I received my bundle of Papers I looked at them more or less with dismay, because it takes days to go through them, and you can quite imagine the task which the adjudicators had in going through not only these Papers but all the other Papers which were submitted, and coming to a final decision as to their respective merits. Mr. Johnson and Mr. Scott-Giles who have borne the burden of the whole Congress, certainly deserve your thanks. The other members of the Committee have not had

anything like so much to do as the four gentlemen I have mentioned. I have a very great admiration for the voluntary work done in connection with a Congress of this kind, and I look upon these Congresses as being of the very greatest value. We have had a good deal of criticism of congresses lately. We had a Committee that reviewed the whole of the local government of the country in the course of a few weeks, and which came to the conclusion that congresses were of very little value, and that they ought to be discouraged by the Government. Those of us who have been attending congresses for many years have come to appreciate their value, and I am very pleased indeed that that opinion has been voiced here this morning. It will be an encouragement to the Congress Committee to go on.

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