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THE
INDIAN RAILWAY ENGINEER

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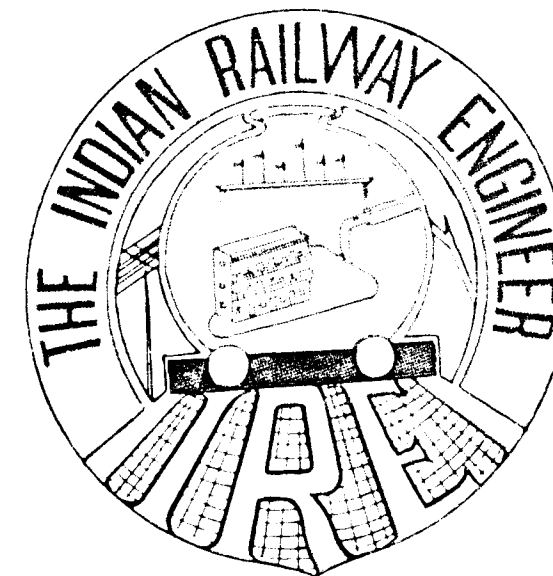


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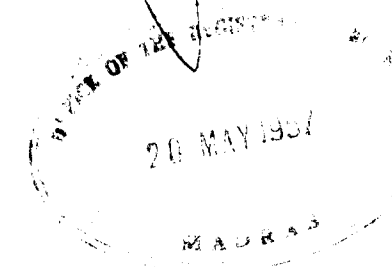
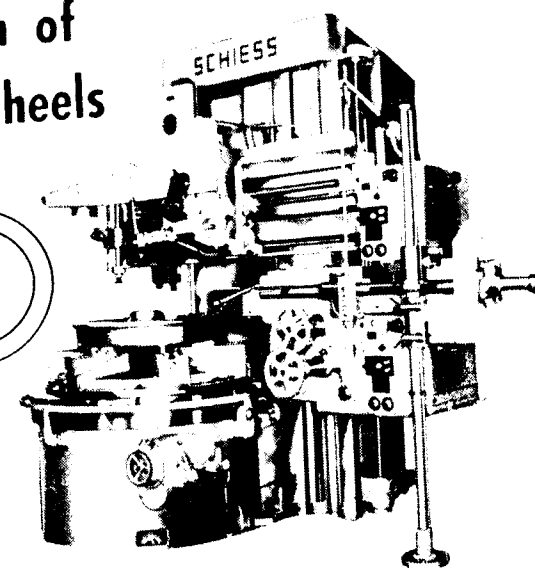
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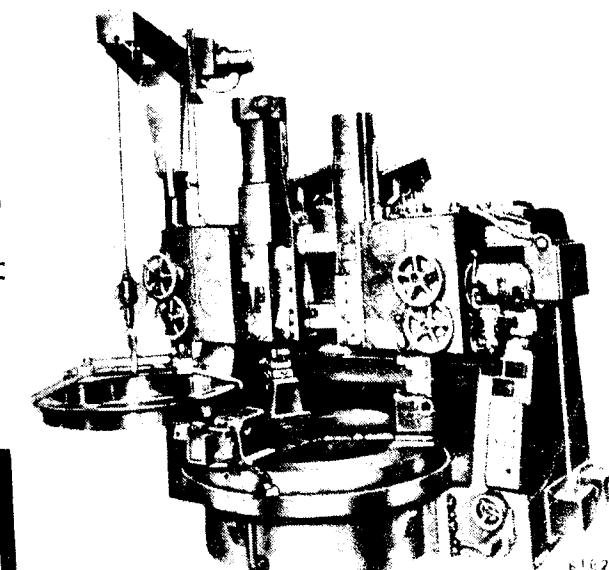
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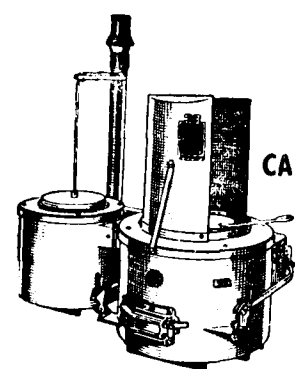
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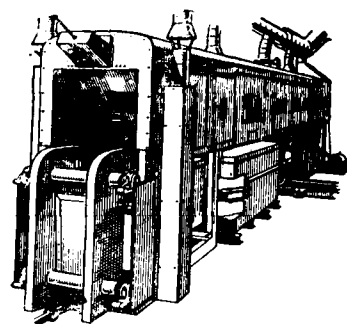
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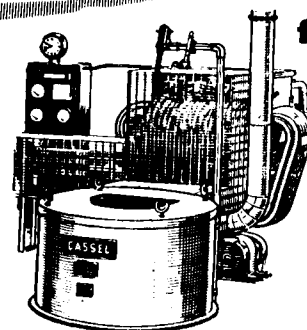
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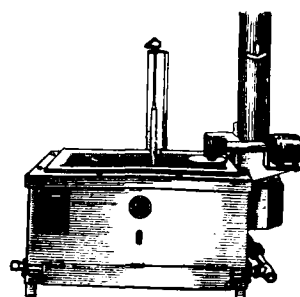


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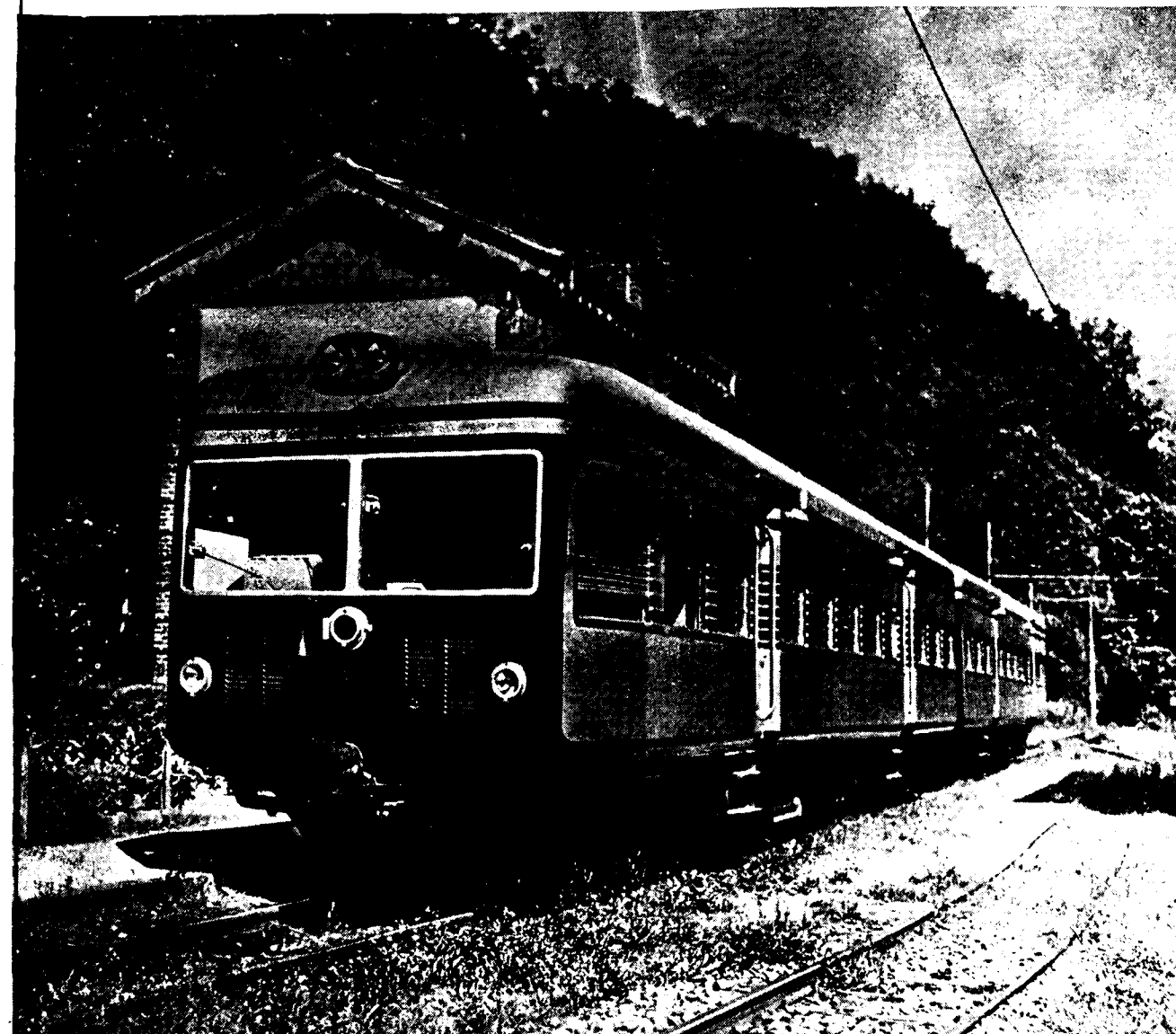


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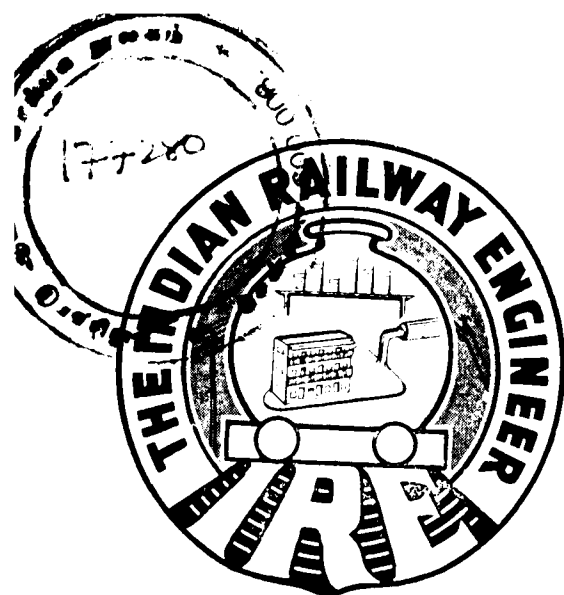
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Managing Editor

T. S. N. Rao

Advertisement Manager

B. Amruta

April 1957

THE INDIAN RAILWAY ENGINEER

3

Railway Labour Past and Present

DURING the nineteen-twenties and thirties Railway Labour was at its best both in regard to discipline and efficiency.

The leading workmen in those days could deliver the goods. They had a sound sense of discipline and took to their jobs as a duck to water. All of them, practically without exception, whether in the workshops or on the open line served a rigid apprenticeship and because of their innate railway sense and tradition turned out to be excellent workmen.

The European Officers and Senior Subordinates of those days ruled their labour with iron discipline. Punctuality in attendance and working round the clock if the necessity arose was extracted from all workmen, and the best of them were encouraged to do a good job of work.

When the time came for a father to retire on superannuation or illhealth, provided he was a good worker, his son or sons were taken into service as Apprentices and in this way a railway traditions was created and fostered in predominantly Railway Families.

After the First World War, which had given a filip to many new railway techniques, the Indian Railways still under European Control decided to introduce them on the Railways in India and round about 1925 or so many reorganisations were taken in hand.

Experts in many fields were imported to India, and Indian Railway personnel for the first time heard of such terms of Production Planning, Mass Production, Scheduling of Locomotive and Carriages and Wagons Repairs, the Progress System of chasing work, Job Analysis, Workshop layouts of machinery for production etc.

The targets given to these foreign experts to put into effect their specialised organisational and production knowledge and show results was a matter of two years. It may be said to their credit that within this period they did show outstanding results.

With the same amount of Labour force as before, the manufacturing production output nearly doubled itself, and the number of locomotive, carriages and wagon repaired and turned out of shops in a specific period in some cases went as high as three times.

On the open line electrification was introduced on certain railways with colour light signalling and the lock and block system. Doubling and quadrupling of lines was effected in order to handle denser suburban traffic and generally it could be said that years between 1920 and 1930 were a period of Renaissance of the Indian Railways. Railway labour rose to great heights in absorbing and putting into effect these new techniques.

New and better types of machines, more intricate in construction but making for a greater production were mastered by the younger and more intelligent of the workmen. The introduction of mass production methods in shops such as jigs and fixtures, tooling and gauging were all mastered by literate workmen and by demonstration and time setting the production figures went up, while costs came down.

On the transportation side pooling of locomotives were introduced whereby the existing procedure of one driver with one engine wholly allotted to him was eliminated and one locomotive was handled by many drivers. The result of this was the more intensive usage of locomotive power reducing thereby the number of locomotives on each railway. Because of the disciplined workmen in the driver, firemen and locomotive staff class pooling became a success. Engine mileage per engine went up, while cost of shed repairs per mile of service rendered went down.

Labour unions were in the early stages of formation, and were certainly not looked with favour by the Administration of Railways, but had to be tolerated, because of a world trend in collective bargaining approved by the more advanced countries of Europe and America.

Then came the World War II and Labour knowing how much the "War Machine" depended upon it for the prosecution of hostilities particularly on the Burma Front began to show its strength.

The war departments wanted to have their munition production according to the targets fixed and strikes naturally upset planned production. The slogan introduced by the War department was "half loaf is better than no bread".

Confidential instructions were sent down from the highest source to placate labour at any costs and give in to their demands. A strike of even a few hours duration was frowned on by the Railway Administration. Special reporters from the Police wired Defence Headquarters, Railway Board, Government of the Province of the slightest stoppage of work whether on day or night shifts. Irrespective of who was right and who was wrong Executive Officers had to tender lengthy explanations for the cause of the strike, and often as not were reprimanded, while labour got away scot free. If workmen slept on duty at night during working hours the matter was to be overlooked. If the outturn dropped below target figures the lapse had to be condoned.

In these circumstances, discipline was sacrificed and labour batted on the weakness of the unsupported Executives. Costs of production, efficiency and discipline were permitted to go by the board as long as labour could be kept at work and free from strikes and threats of strikes. Executives, helpless in their weakness were compelled to placate labour at all stages of their demands and lost interest and initiative.

The war finally came to an end when executive control over labour was at its lowest and shortly afterwards the National Government took over the reins of administration from the Britishers. Labour legislation was drastically revised, somewhat in favour of labour. Railway rules were modified that the disciplinary powers of Senior Subordinates ceased to exist, and the machinery of disciplinary rules was made so complicated that even Executive Officers lost all interest.

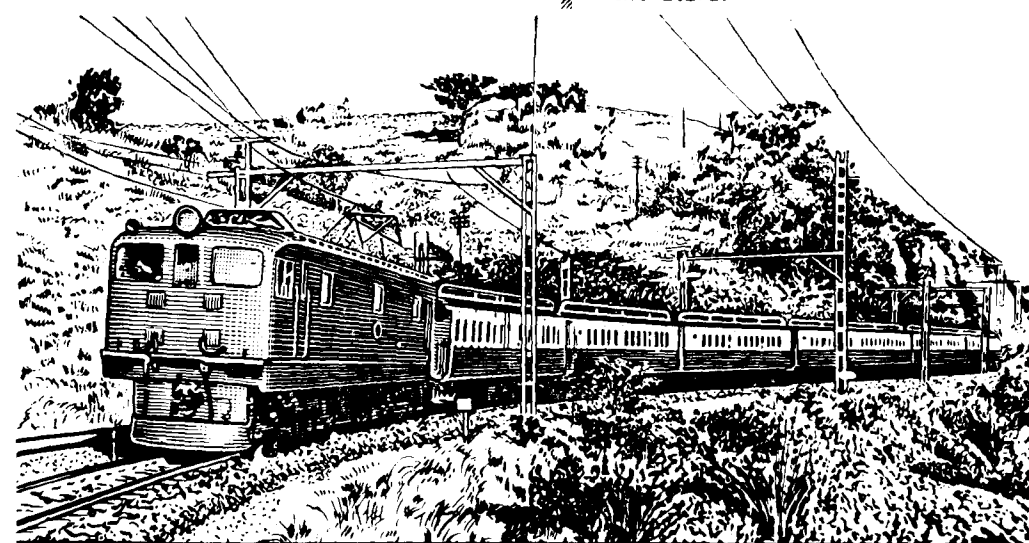
A man in the lowest rung of the labour ladder was now given so much protection that he could "cock a snook" at his chageman, flout the authority of his foreman and ignore the Executive Officer and yet get away with it. Men removed from service or even dismissed were re-instated after months, much to the chagrin of Executive Officers who were responsible for his removal from service.

The power of the Unions became stronger as days went by and in compliance with instructions from the Railway High Command they had to be given priority for interviews with

(Continued on page 20)

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Origins of Civil Engineering in Britain

INTRODUCTION

CIVIL engineering—the design and construction of such works as railways, roads, bridges, water-works of various kinds, docks and power stations—is of fundamental importance to every country's social and economic progress. Britain was first in the field in the modern development of civil engineering as a major industry and the first country to provide techniques, finance and equipment on a large scale to carry out civil engineering projects throughout the world. Thanks to its long experience, its persistent tradition of innovation and its high degree of flexibility the British civil engineering industry is now well-equipped to tackle every type of project whatever the locality. This paper provides a short sketch of some of the principal British contributions to civil engineering technology and of projects undertaken outside Britain by UK engineers and contractors.

Engineering has a long history in Britain, as in certain other countries. The Romans built many fine roads, harbours and bridges, though most of these later fell into decay and the relatively advanced techniques associated with them were lost. In the Middle Ages and sixteenth and seventeenth centuries numerous stone bridges were erected and some land drainage schemes brought into operation. Much of this early constructional work was, however, undertaken primarily to meet military and political need and the term 'engineer' denoted someone who designed and constructed engines of war, military highways and systems of fortifications.

Engineering in the modern sense as a major industry catering for civil needs really dates in Britain from the late eighteenth century when the UK economy was undergoing the momentous changes associated with the early Industrial Revolution. Radically improved techniques led to a greatly expanded output of iron, coal and chemicals, the invention of the steam engine revolutionized the outlook for power-driven machinery and a rich harvest of mechanical inventions helped to make Britain the leading world producer of cotton textiles and other consumer goods. At the same time, and partly as a consequence of the above changes, UK domestic and overseas trade showed a marked expansion in volume and variety, and the size of the population, after remaining fairly static for hundreds of years, began to rise rapidly.

Some of the changes completely transformed engineering techniques. Thus, the development of iron technology gave the British iron industry a strong lead over those of all other countries and provided an essential foundation for a large-scale engineering industry. Again, the invention of the steam engine by James Watt in 1765 not only led to a demand for engineers to design power-driven machinery and plant for factories, but also provided the essential motive power for the subsequent development of railways. Furthermore, the great increase in the number of mechanical inventions included some notable aids to engineering techniques, such as steam and pneumatic hammers, screening and washing plants, drilling machines, tower cranes and derricks.

The Industrial Revolution also touched off a vigorous demand for engineers who could effect improvements in transport. The unprecedented expansion of production and trade called for new and better roads, bridges, waterways and (later) railways, and for men who could apply to such constructional works the skill hitherto confined largely to the military engineers. This need was met by a number of engineers of remarkable ingenuity and enterprise. Some of these, e. g. James Brindley the canal builder and John Metcalf the blind road maker, had little technical training but great natural gifts, while others, such as John Smeaton and Thomas Telford, combined practical ability with considerable scientific attainment. These men were employed, not by the Government, but by individual employers or firms.

The task of training the large number of engineering craftsmen needed was undertaken by a number of big employers, such as Matthew Boulton, who were in the van of industrial progress. In London and other large towns machine tools were invented and manufactured which overcame some of the last obstacles to accurate workmanship. Thus, the difficulties of working with iron were overcome by the invention in 1794 of Henry Maudslay's slide rest, which holds and guides the cutting tool along the iron. In 1800, Maudslay introduced the screw-cutting lathe, which made possible a universal thread in screws. Joseph Bramah (1748—1814) was noted for the invention of patent locks, hydraulic presses and many other mechanical devices. Joseph Whitworth (1803—1887) inaugurated a system of standardized screw threads and machine parts. James

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- (i) supply "portions" suitable for 90R Medium Manganese Rails for 50 joints and
- (ii) make the joints with the "portions" supplied in accordance with item (i) above with their own equipment and staff at Chittaranjan.

Further details can be obtained from the Director Research, Railway Testing & Research Centre, Lucknow free of charge.

2. Firms desirous of supplying the "portions" and making the joints with the help of their "portions" are requested to make their offers by post to the Director Research, Railway Testing & Research Centre, Lucknow, before 14/30 hrs. on 10th April, 1957 after which further offers may not be accepted.

3. In case the firms want to make a token charge for the "portions" and for making the joints with the help of their "portions", their terms separately for the supply of "portions" and for making the joints with the help of their "portions" should be mentioned in their letter.

4. If it is desired to make the token charge, it will be for the finished job. If any assistance is required from the Railway administration, the same shall be clearly brought out.

5. The work shall be done at Chittaranjan under the supervision of the Joint Director Research (M&C), Railway Testing & Research Sub-Centre, Chittaranjan, or any of his assistants deputed by him for this purpose.

6. The welding technique to be followed shall be explained by the firm in a detailed note attached with the letter.

7. Only those firms and/or contractors who have sufficient experience of the work may offer to make this supply and submit complete particulars of work they have carried out in the past or are carrying out at present.

8. The Director Research, Railway Testing & Research Centre, Ministry of Railways, Alambagh, Lucknow, reserves the right to accept or to reject any or all offers without assigning any reason and does not bind himself to accept any offer.

9. The site of the work will be:

Railway Testing & Research Sub-Centre,
Ministry of Railways,
CHITTARANJAN.

Nasmyth (1808-1890) invented a steam hammer (1839), a nut-shaping machine, hydraulic punching machines, and machines for cutting key ways in metal wheels of any diameter.

The technique of surveying had already made great strides through such developments as the introduction of the transit-theodolite, invented about 1550 by Leonard Digges, of a slide rule invented by Edmund Gunter (1581-1626) and of logarithms by John Napier (1550-1617) and Henry Briggs (1561-1630). During the Industrial Revolution many surveying instruments were perfected and used much more extensively than hitherto.

By the early nineteenth century Britain already possessed several thousand skilled and semi-skilled civil engineers. The importance of the new profession was signaled in 1818 by the establishment in London of the Institution of Civil Engineers, which was incorporated in 1828 by Royal Charter.

At first "civil engineering" denoted all engineering that was not military, but after the early nineteenth century it has found convenient to specialize. Civil engineering came to mean the kind of engineering associated with public works such as railways, docks, harbours, water storage and supply and drainage, while other branches of the profession came into existence to specialize on mechanical, electrical, mining, marine, chemical and aeronautical aspects of the subject.

Some of the outstanding early British achievements in civil engineering are described in the following section.

EARLY BRITISH ACHIEVEMENTS

Canals

During the late eighteenth century and early nineteenth century a system of canals and navigable waterways was constructed in Britain to enable the rapidly growing output of industry and its raw materials to be transported cheaply and smoothly. The constructional work often entailed considerable engineering feats, including the provision of tunnels, aqueducts, reservoirs, locks and hydraulic lifts.

Most of this arduous work was carried out by physical human labour. Mechanical aids, however, soon made their appearance. As far back as 1770 steam-powered pumps were already in operation and horse-driven mechanical excavators—forerunners of the 19th century steam excavators—came into use.

Prominent amongst the early canal engineers was James Brindley (1716-72)—who acquired his very thorough engineering skill by extensive practice—and John Smeaton (1724-92) who was also responsible for building the famous Eddystone Lighthouse off the Cornish coast and for designing steam engines for pit drainage purposes. The completion in 1761 of Brindley's first important work, the Bridgewater canal, was a notable event in early canal engineering. Constructed to enable coal to be conveyed from the Duke of Bridgewater's collieries at Worsley to the great commercial town of Manchester, the canal was carried over the river Irwell by an aqueduct and through the hillside by a tunnel a mile long. The Bridgewater canal was followed by the Manchester-Runcorn canal, the Trent and Mersey Canal and many others, built by Brindley and other great canal engineers, including Thomas Telford (1757-1834), John Rennie (1761-1821), Sir Edward Banks (1769-1835) and John Pinkerton (1761-1821). By 1830 there were 1,927 miles of canals and 1,312 miles of navigable waterways in England and Wales, 183 miles of improved waterways and canals in Scotland and 848 in Ireland. After 1830 canal building in the United Kingdom slowed down owing to the competition of railways, and by 1840 had almost ceased, but the Manchester Ship Canal, completed in 1893, was of great commercial importance. Its construction required the excavation of 53 million cubic yards of earth which was carried out with the aid of 97 steam navies, 173 steam locomotives, 6,300 railway trucks and over 200 miles of specially laid railway track. It was the first example of the use of large-scale mechanisation in earth-moving.

The experience gained by its engineers on internal canal construction enabled Britain to provide the skill and resources for the building of canals in several other countries. One of the earliest examples was the Middlesex Canal connecting the tidewater in the River Charles at Boston (USA) with the Merrimac River; it was constructed between 1794 and 1803 by Weston, a British engineer.

In Canada, British engineers built the Welland canal connecting Lake Ontario and Lake Erie, completed in 1829. One of the most important ship canals in Northern Europe, the Gotha Canal in Sweden linking the Baltic with the North Sea, was constructed in 1807 by Thomas Telford. The Amsterdam Ship Canal, which is 15 miles long and has one of the world's largest locks was constructed in 1862 by Sir John Hawkshaw.

Roads

Many of the early developments in the scientific construction of roads took place in Britain. Amongst the pioneers was John Metcalfe (1717-1810) who, despite blindness, built many roads in Lancashire and Yorkshire using heather as a foundation where there was a soft subsoil, and digging ditches to drain away the water. Later developments are associated with the names of Thomas Telford (1757-1834) and John Loudon Macadam (1756-1836). Telford stressed the importance of strong foundations and studied the problems of gradient and road shape. Macadam devised a greatly improved method of road construction and maintenance, and evolved the 'Macadamized' surface—consisting of a thin layer of small angular fragments of stone, laid on a thoroughly drained subsoil.

By the methods ushered in by these pioneers a large number of roads were laid down in the late eighteenth century and early nineteenth century under the 'turnpike' system, i.e. a system of levying tolls on all users of particular roads, except pedestrians, in order to help to pay for the costs of construction and maintenance. By 1840 Britain, with over 22,000 miles of reasonably good roads, enjoyed a highway system which was then superior to that of any other country in Europe. After this period road construction and maintenance languished owing to the much greater transport opportunities offered during the golden era of railways.

After about 1860 there was, however, a partial revival in the importance of road transport owing to the new vogue for bicycling and the introduction of horse-drawn trams. The electrification of tramway systems and their extension to all major cities in Britain and many overseas countries was an important development of the late nineteenth century and one in which British civil engineers played a major part.

The new era of motor cars, which gathered strength after 1900, induced a vigorous demand for new and better roads. This led to intensive experimentation on the subject of road surfaces and the problem of preventing dust. Research with tar and bitumen led to the introduction of asphalt and coated macadam surfaces with a surface dressing to make roads cleaner and safer. Later, additional improvements were introduced with all-concrete roads.

Many of the techniques evolved by British civil engineers, from Macadam onwards, have been widely adopted in road construction and maintenance throughout

the world. British engineers and contractors have, in fact, been responsible for the building of road networks in many countries. In East Africa, for example, they built 35,500 miles of roads, in West Africa 29,300 miles, in Malaya over 6,000 miles and in the West Indies 9,000 miles.

Railways

Britain was the birthplace of railways. It was the country in which railways were first developed as a public means of transport and the country which pioneered railway construction in every continent.

In a sense, the invention and construction of railways was the technical culmination of the Industrial Revolution and Britain's greatest gift to peaceful economic progress in the nineteenth century. Railways provided transportation with regular services at much higher speeds than anything previously available, and they could handle extremely large volumes of traffic, whether passenger or freight. In many countries the building of railways opened up vast areas which had previously been barren wildernesses. In all countries railways, perhaps more than any other single factor, brought about a tremendous expansion of trade and production and appreciably higher living standards.

Epoch-making events in the early history of railways were the invention of the steam engine by James Watt in 1765, of the steam carriage by Richard Trevithick in 1801 and of the railway locomotive by George Stephenson in 1814. The Surrey Iron Railway, opened in 1803 by William Jessop for horse-drawn freight trains, was the earliest-known railway open to public charter. The Stockton and Darlington Railway, opened in 1825, was the first public railway to use steam locomotives. The Liverpool and Manchester Railway, opened in 1830, was the first railway to use steam locomotives for regular passenger services as well as for freight. The opening of the London and Birmingham Railway in 1838, marked the debut of the world's first major trunk line.

Soon after the completion of the Liverpool and Manchester Railway British engineers and contractors were at work constructing networks of railways at home and abroad. Railway constructional work involved difficult excavations of tunnels and cuttings and the erection of numerous bridges, viaducts and embankments. It called for technical and managerial ability of a high order to plan and estimate on a large scale and to take risks. And it enabled Britain's civil engineering industry to attain full stature.

In Great Britain the mileage of lines of open to traffic rose from 1,857 miles in 1842 to 6,621 miles in 1850 and 8,954 miles in 1854. In one year, 1846, the number of persons employed on building railway in Great Britain was as high as 500,000 while another 50,000 were engaged on the operation of lines already open.

Abroad, British engineers and contractors extended their operations to Continental Europe and to every corner of the globe.

Joseph Locke (1805—1860) constructed some of the earliest lines in France (e. g. the Rouen-Paris Line), the Netherlands and Spain. George Stephenson (1781—1848) planned the railway network in Belgium, and his son, Robert Stephenson (1803—1859) constructed the railway between Cairo and Alexandria and advised on certain lines in Belgium, Scandinavia and Switzerland. Sir William Cubitt (1785—1861) was consulting engineer to the Sambre and Meuse Railway in Belgium and the Amiens and Boulogne Railway in France. Isambard Kingdom Brunel (1806—1859), the famous engineer to the UK Great Western Railway, was consulting engineer to various continental lines, including the Genoa-Turin railway in Italy. Sir Morton Peto (1809—1889) was responsible for the construction of several of the earliest lines in Scandinavia. Charles Vignoles (1793—1875), the inventor of the Vignoles rail, laid down railways in Germany, the Netherlands, Poland, Spain, Switzerland and Brazil. Sir John Hawkshaw (1811—1891) laid down railways in Germany and Russia and was consulting engineer to railways in India (Madras).

Most remarkable of all railway contractors was Thomas Brassey (1805—1870). With the help of his "industrial army", which sometimes amounted to 80,000 navvies in addition to technicians and administrators, Brassey and his partners carried out 170 different railway contracts involving the construction of nearly 8,000 miles of railways in five continents. These railways included several in continental Europe (Austria, Denmark, France, Hungary, Italy, the Netherlands, Norway, Poland, Spain and Switzerland) and in Argentina, Canada (the Grand Trunk Railway), India and Mauritius.

After about 1860, with most of the United Kingdom and European continental trunk lines already laid down, British engineers and contractors turned their attention increasingly to projects in more distant lands and tens of thousands of miles of line were built by new generations of contractors including Thomas Walker, Sir John Aird, Viscount Cowdray, Sir Ewen Jones, Sir John Norton Griffiths and many others.

In India and Pakistan British engineers and contractors laid down, from 1853 onwards, over 40,000 miles of railways. The training and bridging of some of the mightiest rivers in the world, e. g. the Ganges and the rivers of the Punjab, through lofty mountain fortresses were great engineering feats. In some areas the lines had to be taken up exceedingly severe gradients, and construction had to be carried out of long tunnels, difficult viaducts, deep cuttings and high embankments. Other formidable problems confronting the early engineers were extremes of temperature ranging from 10 F to 125 F in the shade, as well as earthquakes and floods. An early example of difficult railway construction was the Bombay-Thana railway, which was opened in 1853; this involved the construction of two lines over the formidable barrier of the Western Ghats to the Deccan. One of these lines rose about 1,200 feet in nine miles while the other rose 1900 feet in 14 miles.

The construction of the Burma railways included the building of the Ava Bridge over the River Irrawadi near Mandalay and the remarkable Gokleik viaduct.

For many of the overseas railways built by British engineers and contractors Britain supplied not only the skill, enterprise and labour, but also the necessary finance and the locomotives, rails and other equipment.

The completion of railway networks made radical differences to the internal economy of many countries.

In Argentina, for example, the rapid development of the meat industry was made possible because UK engineers and investors, encouraged by the Argentine Government, had opened up the interior with thousands of miles of railways. The railways enabled the national authorities to maintain law and order and facilitated the transport of livestock and crops, on a large scale, to the port of Buenos Aires for shipment overseas. The United Kingdom furnished the greater part of the technicians and equipment. The first railway—a six-mile line from Buenos Aires was laid down in 1857. By 1890 nearly 6,000 miles of railway were in use, by 1900 10,000 miles.

In Brazil British capital and technical ability played a predominant part in early railway construction. The first line was built by James Brunlees in 1867. British engineers were responsible for the first line in China (from Shanghai to Woosung) and were associated with the building of many of the important early lines, including those from Shanghai to Nanking, Soochow to Hangchow, Hangchow to Ningpo, Canton to Kowloon and Peking to Tientsin.

In East Africa British engineers built 3,000 miles of railway, in West Africa 2,750 miles and in Malaya 1,000 miles.

British engineers and contractors also built many of the lines in Australia, South Africa, New Zealand, Siam and many other countries.

Bridges

The Industrial Revolution led to great increase in the demand for bridges and at the same time made available new materials, e. g. iron and concrete, in place of wood, bricks and stone for their construction. Britain produced many bridge engineers of genius in this period, including Telford, George and Robert Stephenson, John Rennie and I. K. Brunel, who pioneered the use of new materials and initiated new methods of construction.

The world's first cast iron bridge was constructed over the River Severn, at Coalbrookdale, in 1777—79 by the English ironmasters, Abraham Darby (1750—91) and John Wilkinson (1728—1808); this bridge with its 100 foot span carried by a series of semi-circular ribs, is still in use. It was followed by the construction of several more cast iron bridges in Britain and overseas.

The first iron railway bridge, completed in 1824, was built by George Stephenson to carry the Stockton and Darlington Railway over the river Gaunless at West Auckland.

Many of the earliest suspension bridges were erected by Samuel Brown (1776—1852), who was responsible for several improvements in the design of such bridges. Thomas Telford's famous Menai Suspension Bridge in North Wales, built in 1826, was the world's largest span up to that time; the distance between the points of suspension was 579 feet, and there were 16 chains, each link made of five wrought iron bars. It is the prototype of all suspension bridges.

The first railway suspension bridge was built for the Stockton and Darlington Railway in 1830.

The first wrought-iron bridge is believed to have been a road bridge constructed over the Pollock and Govan Railway, in 1841. In 1846 Wm. Fairburn built a plate-girder bridge with a span of 60 feet to carry the Blackburn and Bolton Railway over the Leeds and Liverpool Canal.

The Britannia Railway Bridge over the Menai Straits, built 1846—50, was a successful early experiment in the

use of wrought-iron tubes. The two main spans, each of 460 feet, were by far the longest railway spans at that time. The Conway Bridge—another tubular bridge, with a span of 480 feet, was being built at the same time. Both bridges are still in use.

The success of these two erections led to the building of many other tubular bridges at home and overseas, including the Victoria Bridge over the St. Lawrence River at Montreal. With a length of 6,600 feet (9,084 feet including the abutments and embankments) this bridge, which was designed by Robert Stephenson and opened in 1860, was the longest tubular bridge ever built.

In 1850 construction was completed of the first Warren Truss Bridge, which was built to carry the Great Northern Railway over a branch of the River Trent near Newark, Notts. Two notable truss bridges designed and constructed by I. K. Brunel (1806—1859) were the Chepstow railway bridge (built 1852) and the Saltash railway bridge over the river Tamar in Cornwall (1859)—which has two spans of 455 feet each, with lenticular trusses.

Steel and concrete were employed extensively in the construction of bridges by UK engineers in the second half of the nineteenth century. An impressive example is the Firth of Forth Bridge, which was opened in 1890 and was for many years the heaviest steel constructional work in the world. Designed by Sir John Fowler and Sir Benjamin Baker, the bridge has two spans of 1,710 feet and the bridge proper, exclusive of approaches, is over a mile long. The cantilever arms were constructed with tubular compression members, some of them 12 feet in diameter.

British engineers have also erected many important bridges overseas. Nearly all the railway bridges in India and Pakistan for example, were built by British engineers and contractors. Several were built of wrought iron or steel, with many spans supported on brick walls which were sunk in sand. In Canada, at first timber trestle bridges and afterwards steel and concrete bridges were put up to carry the railways. In Australia and New Zealand most of the early bridges for railways and highways were constructed chiefly of timber and several of them are still in use. The great Sydney Harbour bridge designed by Sir Ralph Freeman was completed in 1932 by the firm of Dorman Long. It embodies a steel arch 1,650 feet long and carries four railway tracks, a 57 foot roadway and two foot-paths; its total length is 3,770 feet. In South America some hundreds of railway bridges have been

built by British firms. Amongst outstanding bridges erected by British engineers in Europe have been the suspension bridge over the river Dnieper built by Charles Vignoles at Kieff, the Vila Franca bridge over the Tagus near Lisbon and the Storstrom bridge in Denmark. The Storstrom bridge, the longest in Europe, provides a through route for railway and roadway over two miles of water between Copenhagen and the continent of Europe, that is, between Zealand and Funen.

The many notable bridges built by British engineers in Central Africa include the Victoria Falls bridge completed in 1905, with a 500 feet span over the Zambesi River 400 feet below, the Birchenough Bridge over the Sabi River, the Otto Beit Bridge over the Zambesi and the Lower Zambesi Bridge in Portuguese East Africa (the third longest bridge in the world).

Tunnels and Subways

British engineers gained considerable experience in the boring of tunnels when the canal system was inaugurated. The early English canals were taken through some 45 tunnels, with a total length of more than 40 miles. One of these, the Marsden tunnel on the Huddersfield canal, is over 3 miles long and is believed to be the longest canal tunnel in the world.

The longest of these early tunnels still in use takes the Grand Union Canal $1\frac{3}{4}$ miles through Blisworth Hill in Northamptonshire.

The coming of railway greatly increased the demand for tunnel construction. Notable early railway tunnels were: the tunnel on the Liverpool and Manchester Railway completed in 1831 (the world's first railway tunnel); the Kilsby tunnel, nearly $1\frac{1}{2}$ miles long, built by Robert Stephenson on the London and Birmingham Railway; and the two Woodhead tunnels, each three miles long, constructed on the Manchester, Sheffield and Birmingham Railway.

The oldest under-water tunnel in the world is M. I. Brunel's Thames tunnel in London, completed in 1843 after attempts extending over 40 years. It is 1,200 feet long, was lined with brick laid up in Portland cement and is still in use; it was used at first for vehicles and pedestrians and later for electric trains.

The first underwater tunnel of importance attempted through solid rock was the Severn tunnel, $4\frac{1}{2}$ miles long, carrying the main railway line from England into Wales. It was constructed by Sir John Hawkshaw and opened in 1886.

A notable example of the application of British experience in overseas countries was the construction of the first railway tunnel through the difficult mud of the Hudson River, New York. This work was undertaken by a company headed by Weltman Pearson (later Viscount Cowdray) in 1890—91. While the work was being carried out one of the firm's directors invented a medical air lock still used to alleviate certain illnesses arising from working under high pressures.

Tunnel construction techniques were greatly improved by Thomas Cochran, who in 1830 invented a method of using compressed air to sink shafts and tunnels under water, and by Barlow (1809—85) and Greathead (1844—96) who invented the 'Greathead Shield'. In combination with compressed air this apparatus made under-water tunnelling not only possible but relatively safe. It was first employed in 1869 on the Tower Subway (London).

Credit for the first underground railway system goes to the Metropolitan District Railway in London. Work was started in 1860 and a portion was completed in 1863 and another part in 1868. This system was, however, built by digging deep trenches and covering over. Tube railway tunnels, driven at great depth through the London clay, using the Greathead Shield in conjunction with compressed air, were begun in 1886, and the main system was completed by 1907. London now has the largest and best equipped underground system in the world with 250 double or twin track miles (ninety of them below the surface) serving 277 stations.

The first cable-operated underground railway in the world was constructed in Glasgow between 1891—97; in 1935 it was electrified.

Docks, Harbours and Lighthouses

The building of docks, harbours and lighthouses has for long held an important place in British civil engineering owing to Britain's maritime traditions. In the eighteenth century the demand for these works received a tremendous impetus from the rapid expansion of UK overseas trade and of the size and number of trading vessels.

The world's first wet dock, the Howland Dock, was constructed at Rotherhithe, in the Thames, as far back as 1690—1700. It was 1,070 feet long, 500 feet wide and 17 feet deep. Soon after 1700 several docks were constructed at Liverpool, Hull and Bristol. Between 1789 and 1828 London was equipped with an extensive dock system enabling it to cope with nearly two-thirds

of UK overseas trade, which already constituted a high proportion of total world seaborne trade. The London dock area was nearly doubled by additional construction between 1850 and 1886, and by the end of the century London possessed 26 miles of docks, extending from Tower Bridge to Tilbury. An important addition in the twentieth century was the George V Dock, completed in 1921. Commensurable dock systems were built at other British ports. At Liverpool, for example, the dock area was extended from 27 acres in 1816 to over 500 acres in 1900. Harbours and docks were also built on a large scale at Naval centres such as Portsmouth and Chatham and at coaling centres like the South Wales ports.

Power-driven appliances—in the form of steam pumps and piling frames—were used in dock construction as far back as 1800. Later on, British engineers initiated many other innovations in techniques, including the use of screw piles (1838), and pile-driving by steam hammers (1846) and by jets (1850).

The boom in shipbuilding, the change from sail to steam and from wood to iron and to steel, led to much new civil engineering work and gave scope for ingenuity and enterprise in the building of berths, shipways, graving docks, wharves, piers, jetties and breakwaters.

Beginning with Thomas Telford (1757—1834), Britain established a heritage of great dock engineers. They contributed to dock and harbour building in many overseas countries. Amongst the nineteenth century examples were the large Callao dock in Peru, built in 1870 by Thomas Brassey, and the docks at Singapore, Colombo and Tampico (Mexico).

The technique of modern lighthouse construction owes much to the pioneer work of John Smeaton (1724—1792), who rebuilt the famous Eddystone Lighthouse, and of John Rennie (1761—1821), who, in conjunction with Robert Stephenson, built the Lighthouse on Bell (Inchcape) Rock opposite the mouth of the Tay.

Land Drainage and Irrigation

After the Roman occupation, land drainage received little attention in Britain until 1630 when a vast scheme, initiated by Sir Cornelius Vermuyden (1595—1683) for the Earl of Bedford, was carried out to drain the Fens and thus convert marsh, bog, and waste land into highly fertile arable land and pasture. Hundreds of channels were cut, sluices were built, to hold back the tides, rivers were changed in course and several

highways and bridges erected. In the early nineteenth century many new systems were introduced by famous canal engineers and contractors, including John Rennie, Sir Edward Banks, William Jolliffe and Sir Morton Peto.

More recently, a great deal of civil engineering work has been carried out on Britain's main rivers and this has considerably increased agricultural yields. The work has required the construction of weirs, sluices, embankments, extensive dredging work and the widening and straightening of river courses. An outstanding example is the Great Ouse flood relief scheme, at present nearing completion.

Overseas, British engineers and contractors have carried out some projects of outstanding importance. In Egypt they introduced modern methods of irrigation into the Nile valley, and in 1898—1902 built the Aswan dam, $1\frac{1}{4}$ miles long and 130 feet high, with 180 large sluice gates. Together with the Asyut barrage (completed in 1902) and the Esna barrage (completed in 1912) these works, which were undertaken by Sir Murdoch Macdonald and other British engineers of outstanding ability, made possible the irrigation of 400,000 acres in Middle Egypt, in addition to a large tract in upper Egypt. Supplementing these works were several other major schemes and the Aswan dam has been twice heightened and strengthened, thus increasing its storage capacity five-fold. In India and Pakistan the immense irrigation projects carried out by British engineers resulted in the construction of 80,000 miles, of canals, providing for an annual irrigated area of over 70 million acres.

Gasworks

Gas lighting was invented by a Scotsman, William Murdock. In 1802 he staged a public exhibition to show the value of gas lighting in factories and the following year a gas lighting system was in operation in Soho, London. By 1819 London possessed over 51,000 street lamps, supplied by 288 miles of gas mains, and similar developments were occurring in other parts of the United Kingdom. The expansion of the gas supply industry, particularly after 1850, called for some civil engineering constructional work of a varied type including gasholders, pipelines, roads, railways and jetties. The Beckton works in Essex, built by Sir John Aird had a capacity of 10 million cubic feet a day in 1870 and was then the largest in the world; since that time its capacity has been expanded sixteen fold.

As a result of continuous research gas manufacture has become much more efficient and this has involved

the use of complex installations, including conveyors, bunkers, crushers, carbonisation plant, purification and storage plant and cooling and grading plant. Extensive and complicated excavation work is required as well as specialized structural work. Gas production in Great Britain rose from 349,000 million cubic feet in 1938 to 521,000 million cubic feet in 1954.

Constructional Materials

The development of such vital constructional materials as iron, steel and cement for use in the civil engineering industry owes much to the work of British pioneers.

Although iron has been known and used in many countries for nearly 10,000 years it was not until the eighteenth century that it became possible to produce it relatively inexpensively and in large quantities. This great advance was mainly attributable to the work of Abraham Darby (1711—63), who discovered a method of smelting iron with coke instead of charcoal, John Wilkinson (1728—1808)—the “iron-mad master”—who, in 1755, greatly developed the use of coke blast furnaces and Henry Cort (1740—1800) who patented grooved rolls in 1783 and in 1784 produced wrought-iron in coal-fired furnaces by the puddling process.

The production of steel made great strides forward through the work of such pioneers as Huntsman, who succeeding in melting steel in a crucible and then casting it. In the nineteenth century steel production was revolutionized by the work of Henry Bessemer (1813—98), who in 1856 announced a new and inexpensive process—the Bessemer converter—of converting molten iron into steel, and Gilchrist Thomas (1850—85), who discovered a method for using phosphoric ores in the Bessemer process and thus made possible its widespread adoption on the continent of Europe. A further notable advance was the invention by Sir William Siemens (1823—83, naturalised as a British subject in 1859) of the open-hearth process.

Britain was responsible for most of the important discoveries in the development of the cement industry. The first major advance was in 1756 when John Smeaton (1724—1792) carried out research to find a mortar which would set under water and which he needed for building the Eddystone lighthouse. Smeaton's observations led him to the discovery that hydraulic lime made from limestone which contained clay set in water better than a pure lime, and he used for the erection of the lighthouse a cement produced from a blue lias lime together with pozzolana, from Italy.

A further discovery came in 1796 when James Parker introduced ‘Roman’ cement made from certain clay pebbles which were burned in a kiln and afterwards finely ground.

Portland cement was patented in 1824 by Joseph Aspdin (1779—1855) after experiments lasting since 1811. Other pioneers in the manufacture of hydraulic cements in the early nineteenth century included Charles Pasley (1780—1861), who undertook some of the earliest-known mechanical tests of the properties of cement mortar and concrete, and James Frost, who patented what he called ‘British’ cement in 1822.

One of the earliest edifices made with Parker's cement was the Chirk Aqueduct which carries the Ellesmere canal across the river from Shropshire to Denbighshire. Constructed by Thomas Telford, this aqueduct is 710 feet long and 22 feet wide and has 10 arches of 40 feet span; it was completed in 1801. Aspdin's cement was used by I. K. Brunel in 1828 in constructional work on the Thames Tunnel. The first work of great magnitude on which Portland cement was used was the London Main Drainage Scheme, designed in 1859 by John Grant.

Early pioneers in methods of wood preservation included William Burnett (1779—1861), who developed the use of zinc chloride, and John Kyan (1774—1850), who patented the ‘Kyanising’ (corrosive sublimate) process in 1832. Experiments in the use of creosote for wood preservation were carried out in Britain as early as 1756 and developed by John Bethel in 1838.

RECENT AND CURRENT CONTRIBUTIONS

This section touches upon some British achievements in civil engineering in recent years, at home and abroad.

Technology and Materials

Perhaps the most outstanding development in civil engineering technology in recent years has been the greatly increased mechanisation of constructional work, thus enabling the available labour forces to be used to much greater advantage and large-scale contracts to be executed in much shorter time than hitherto. Credit for much of this development goes to the United States, but Britain has also made some important contributions, especially as regards conveyor belt and coal handling machinery.

Particularly important advances have been made in the techniques of earth excavating and site clearance

which frequently constituted the largest single item in costs. In this sphere there have been two significant inventions—of commercially successful compression ignition oil engines and of track-laying machines to enable work to be carried out on soft and water-logged ground. Patents for early oil engines were taken out in Britain in 1890 by H. A. Stuart and R. C. Binney, three years before those taken out by Dr. Diesel in 1893. The first successful track-laying tractor was introduced by D. Roberts in England in 1905; it could pull heavy loads over boggy ground or loose sand or up a gradient of 1 in 2 on slippery clay. Since those pioneer achievements there have been considerable developments, and engineers in Britain and other countries have evolved some powerful devices with versatile capabilities. Examples of modern excavating plant produced in Britain include a range of diesel-electric grab dredgers and walking drag lines.

UK welding techniques for civil engineering are being improved by the use of such devices as electronically controlled oxygen cutting machines, by electric arc welding and automatic stud welding.

Similarly, UK road-making techniques have been revolutionized by a wide range of new machines for excavating, laying down foundations, concreting and surfacing. Other examples are power graders and automatically controlled concrete mixing plants, with mobile spreading and finishing machines. With this new equipment it is now possible for a small team of men to lay down about 350 yards of concrete road 24 feet wide in one day. Road making has also been assisted by the application of research findings on soil mechanics, and on methods of stabilizing soil foundations.

Mechanisation has also been advanced by the close links between the civil engineering industry and the mechanical and electrical engineering industries. This has been particularly fruitful in the production of new types of powered hand tools. One example is the development, mainly for rock drilling, of a means of absorbing dust at the very source of its generation at the tool tip.

Another recent development in civil engineering technology has been the extensive employment of unit construction processes in projects where economy of time, materials and labour are of first importance. In bridge building, one example is the Callender Hamilton unit construction material developed before the second world war and used extensively for civil and military purposes, in the United Kingdom and the Middle

East. Another example is the Bailey Bridge introduced by Sir Donald Bailey during the second world war. This bridge, which is of steel, can be assembled by hand to meet varying conditions of span and load. It is already proving of great value in under-developed countries as it can, for instance, be rapidly erected across deep ravines or fast-flowing rivers. Another unit construction bridge is that made by the Butterley Co. It consists of five standard units which are built into a series of isosceles triangles. This bridge has been used extensively in South America and Africa for development work.

Concrete manufacture in Britain in recent years has been improved by the wide-spread use of methods of mix design based on new scientific data and by the application of quality control. In the use of concrete, notable developments include large concrete roofs, in the form of domes or vaults, so designed that they can be safely supported on thin columns or on thin walls. Pre-stressed concrete, the output of which has steadily increased, is employed for several notable large structures, e. g. the new hangars at London Airport, as well as for small erections.

British civil engineers have also made extensive use of new metallic alloys and of synthetic materials, e. g. of polythene for carrying corrosive industrial wastes.

Research into various aspects of civil engineering is carried out by the Ministry of Works, the Department of Scientific and Industrial Research, the Admiralty, various Universities and by individual firms and trade associations. One example is the research work on concrete manufacture which has been carried out over the past twenty years by the Building Research Station and the Road Research Laboratory in conjunction with UK universities and the Cement and Concrete Association. Another is the research carried out at the National Physical Laboratory into the effect of wind-pressure on bridges. This work has been carried out since 1946, with the aid of wind-tunnels for the scale models. The research led to the discovery of two types of aerodynamic instability—an up and down motion of the whole platform and oscillations of a twisting character. Methods were evolved to modify or eliminate this instability.

At the Imperial College of Science and Technology important research has been carried out to discover the manner in which waves exert shock pressure on walls—a matter of considerable importance to civil engineers, especially for maritime structures.

Recent Work in the United Kingdom

Within the United Kingdom British civil engineers and contractors have, in recent years, undertaken an immense volume of constructional work, including projects in entirely new fields, such as atomic power stations.

Constructional Work in Second World War. The constructional work undertaken during the second world war can only be referred to very briefly in this paper. It included the construction of 440 airfields with runways, taxiways and hardstandings equivalent to 3,000 miles of double carriageway roads, and a large number of military docks, harbours, roads, bridges, railways and bombproof buildings and repairs to essential services, which were severely damaged by enemy action. A great deal of research work on the properties of materials and structures under various adverse conditions was undertaken. The many striking innovations included 'Mulberry' and 'Pluto'. 'Mulberry' was the name given to an artificial prefabricated harbour which was towed across the Channel in sections and used in the early stages of the Anglo-American invasion of Normandy in 1944. 'Pluto' (popularly translated as: 'pipe lined under the ocean') referred to a system of cross Channel pipe lines which were laid down to maintain supplies of petrol to the Allied forces during the invasion.

Transport. Since the war, civil engineers have been occupied with much reconstruction and modernization work. On the British Railways, for instance, which today comprise some 19,060 route miles of permanent way, 63,100 bridges, and 1,050 tunnels, track is being relaid at a rate of over 1,800 miles a year, and an extensive programme of bridge repairs and renewals has been undertaken. Railway electrification schemes planned before the 1939-45 War have also been completed, including the Manchester to Sheffield route. This work involved a notable engineering feat in the construction of a double line Woodhead Tunnel through the Pennine Range to replace the existing one. This new tunnel which is over three miles in length, is the third longest in the country, and it took $5\frac{1}{2}$ years to build owing to the treacherous nature of the rock through which it was driven.

In January, 1955, the British Transport Commission published an outline of a 15 year modernization and re-equipment plan, costing about £1,200 million. This plan includes the introduction of diesel traction on a large scale, the electrification of some 1,210 route miles of trunk and suburban lines on the high voltage A. C.

system at a standard frequency, as well as many more reconstruction projects and bridge renewals.

Between the wars there was a considerable amount of constructional work on road improvement and on the building of arterial roads throughout the United Kingdom. In and around London, for instance, some 260 miles of arterial roads were completed, in addition to several by-passes and new roads in other industrial centres. A notable road tunnel built in this period was the Mersey tunnel, opened by King George V in 1934. The underwater section was driven over 5,000 feet through red sandstone; it was lined by 44 feet diameter cast iron rings across which the roadway was supported.

The United Kindom's public road system amounts to about 200,000 miles and is one of the densest in the world. Economic difficulties since the war restricted expenditure on major improvements and new construction, but in November 1954 the Government announced an expanded programme of road construction, and improvement designed to increase safety on the roads and to relieve congestion, and in February 1955 announced its intention to spend £147 million on these projects between 1955 and 1959. Of the more notable post-war contracts mention may be made of the Neath road in Glamorganshire. Three-quarters of a mile long, with dual carriageways each 22 feet wide, it was completed in 1955, and reduced the road distance between the two major towns of Cardiff and Swansea by six miles.

Modernization and extension work on British docks and railways has continued. It has taken account of such new developments as the rapid expansion of the UK oil refining industry the increasing size of oil tankers, the siting of power stations on the coast the growth of car transport by sea and the need for more, dry dock facilities for repair and maintenance of shipping.

At the port of Liverpool the value of the reconstruction and development work now in hand is of the order of £25 million. On the Manchester Ship Canal an important new oil dock has been completed at Eastham and several improvement projects are being carried out. On Tyneside a number of new dry docks have been built, some of them by novel constructional techniques, including the use of 10-ton precast ribs. The extensions at Southampton, which was developed before the 1939-45 War into Britain's principal passenger port, capable of handling vessels of over 80,000 tons, include new cargo and passenger terminals. At Dover twin leading

berths for the new car ferry terminal were opened in 1953. At Preston a new ferry terminal has been built to connect with both Northern Ireland and the Irish Republic, and able to carry very heavy loads.

These are merely a few examples of the considerable volume of civil engineering work on docks and harbours which is being carried out throughout the United Kingdom.

Air transport has added a new facet to civil engineering. Before 1939 most civil airports had grass landing strips and the principal constructional problems were the provision of adequate drainage and levelling the ground. The steady increase in size and weight of aircraft was, however, rendering such grass strips obsolete, and in 1937 Royal Air Force airfields began to use concrete runways. During the war some hundreds of service airfields were constructed with concrete runways. In more recent years concrete airstrips have been constructed of greater depth to support airliners of up to 140 tons, and with heat resistant surfaces to cope with jet aircraft.

Amongst the great civil airports built in recent years pride of place must go to London Airport. Its runways, tracks and parking places cover about 1,000 acres. Constructional work included the excavation of 16 million cubic yards of earth and the laying of $1\frac{3}{4}$ million cubic yards of concrete, 91 miles of drainage pipes and 145 miles of ducts for airfield lighting. The airport was first brought into use in 1946 and the first stage of permanent terminal buildings in 1955. The main access tunnel for road traffic, under the London-Bath Road, is over 2,000 feet long, 86 feet wide and 22 feet high. It provides footpaths, cycle tracks and twin carriage ways, each twenty feet wide.

Water Supply. Britain's water supply system, steadily improved over the past 150 years, now brings purified water on tap to 97 per cent of the population, a higher proportion than in any other country. Since the war, many further improvements have been introduced and entirely new local systems have been constructed for satellite towns. The civil engineering works carried out have often been on a large scale, requiring the laying down of thousands of miles of mains and the provision of long pipe lines, dams, reservoirs, aqueducts, pumping stations and filtration beds. For example, at Hemel Hempstead—a satellite town designed to contain 60,000 people—the new supply system called for the construction of a reservoir to hold 3 million gallons, a 200,000 gallon water tower for high-level supply, and a pumping and booster station in addition to 11 miles of track and

72 miles of distribution mains. The new water supply system for the city of Manchester (population over 700,000), opened in 1955, includes a system of steel syphons which convey 25 million gallons of water a day to Manchester from Lake Haweswater, 82 miles away.

Drainage and Sewerage. Progressive improvements in public drainage and sewerage systems have been a major factor in raising the general expectation of life in Britain from about 40 years at the beginning of the nineteenth century to the present figure of about 70 years. Today, about 90 per cent of the UK population are served by piped drainage and sewerage system and over 60 per cent by sewage treatment plants.

Civil engineering work in this field includes the construction of sewers for domestic and industrial waste, drains for surface water, outfall installations and sewage treatment plants often of a very complex character. Often the tunnelling work has to be carried out in very difficult water-logged ground.

Notable amongst recent constructions is the treatment plant at Mogden in West Middlesex. Occupying an area of 50 acres, this plant has a total tank capacity of 100 million gallons and is capable of handling a normal daily flow of 75 million gallons with a maximum of eight times that quantity in wet weather. It serves a population of 1,400,000.

Oil Refineries. The construction of a petroleum refinery makes exacting demands on both the civil engineer and the chemical engineer. In addition to the highly complex chemical installations it is frequently necessary to provide roads, railways, power stations, oil wharves, cooling and drainage systems on a very large scale. Since the war, a major refinery industry has been built up in the United Kingdom with the result that actual production of refined products rose from about 5 million tons in 1948 to about 27 million tons in 1955.

Electricity Supply. The expansion of the United Kingdom's electricity supply system has made considerable demands on the civil engineering industry. Following the opening of the first public power station at Godalming in Surrey in 1881, a variety of independent power stations were built throughout the country. In the inter-war period, a notable achievement was the development of the 'Grid' system which linked together the most efficient power stations regionally. This entailed the use of 3,600 miles of lines and cables and the construction of tens of thousands of steel supporting towers (pylons). After 1945 a vast new development

programme has been inaugurated. Over fifty new power stations (coal or oil-fired) have been completed, over 1,400 route miles of cables and pylons added to the Grid System and work has begun on a 1,200 mile super grid to transport power economically in bulk from coalfields to points supplying the existing grid. This work has necessitated the construction of foundations (chiefly on piles), cooling water systems, tunnelling in compressed air and marshalling yards and jetties to handle coal and oil supplies.

Over 95 per cent of Britain's electricity is at present obtained from coal-fired steam generating stations. This is attributable to the fact that Britain has for long enjoyed plentiful supplies of coal, together with good railway and water transport for coal, whereas water power resources are relatively remote and scattered. Nevertheless, hydro-electric works (for the production of aluminium) were established in Scotland as far back as 1896 and in the inter-war period some sizeable hydro-electric projects were completed both in Wales and in Scotland. More recently the shortage and increasing cost of coal have encouraged hydro-electric developments of outstanding importance under the auspices of the North of Scotland Hydro-Electric Board.

By the end of 1955 the Board had 22 post-war hydro-electric stations in operation and 18 were under construction. Total installed capacity of stations in operation (including 84,750 kilowatts of the pre-war Grampian scheme) was 558,795 kilowatts, with an average output of 1469 million units per annum. Hydro-electric schemes under construction had a capacity of 310,900 kilowatts and schemes in course of promotion and survey accounted for a further 418,450 kilowatts.

The constructional work carried out on the Board's hydro-electric schemes has made exacting demands on civil engineering techniques. It has involved the building of strong and secure dams and reservoirs for catchment and storage of water, the laying down of pipelines to withstand strong pressures and the driving of tunnels through difficult mountain rock and considerable road construction. Dam building has included the following examples of different designs and forms of construction: concrete gravity, massive concrete buttress, round-headed concrete buttress, diamond-headed concrete buttress, rock-fill, earth fill and pre-stressed concrete. The pre-stressing at Allt-na-Lairige (in Sutherland) was provided by groups of steel rods and cables which held the dam down to the rock.

In 1955 over 24 miles of tunnels were driven in rock. This brought the total mileage of rock tunnel driven

under the Board's schemes up to 110 miles, and a further 30 miles were in hand. The mileage of roads which the Board had built, rebuilt or were under construction totalled 279 miles; of these 102 miles were public roads and the remainder were for access to the Board's works.

Atomic Energy. Britain is among leading countries in the development of atomic energy, and here civil engineering has an important part to play, entailing the exercise of special skills. The unusual size and shape of the necessary structures, the need for very elaborate safety measures for personnel and the need to avoid 'contamination' of the atomic reactor by elements which would interfere with the chain reaction present new problems.

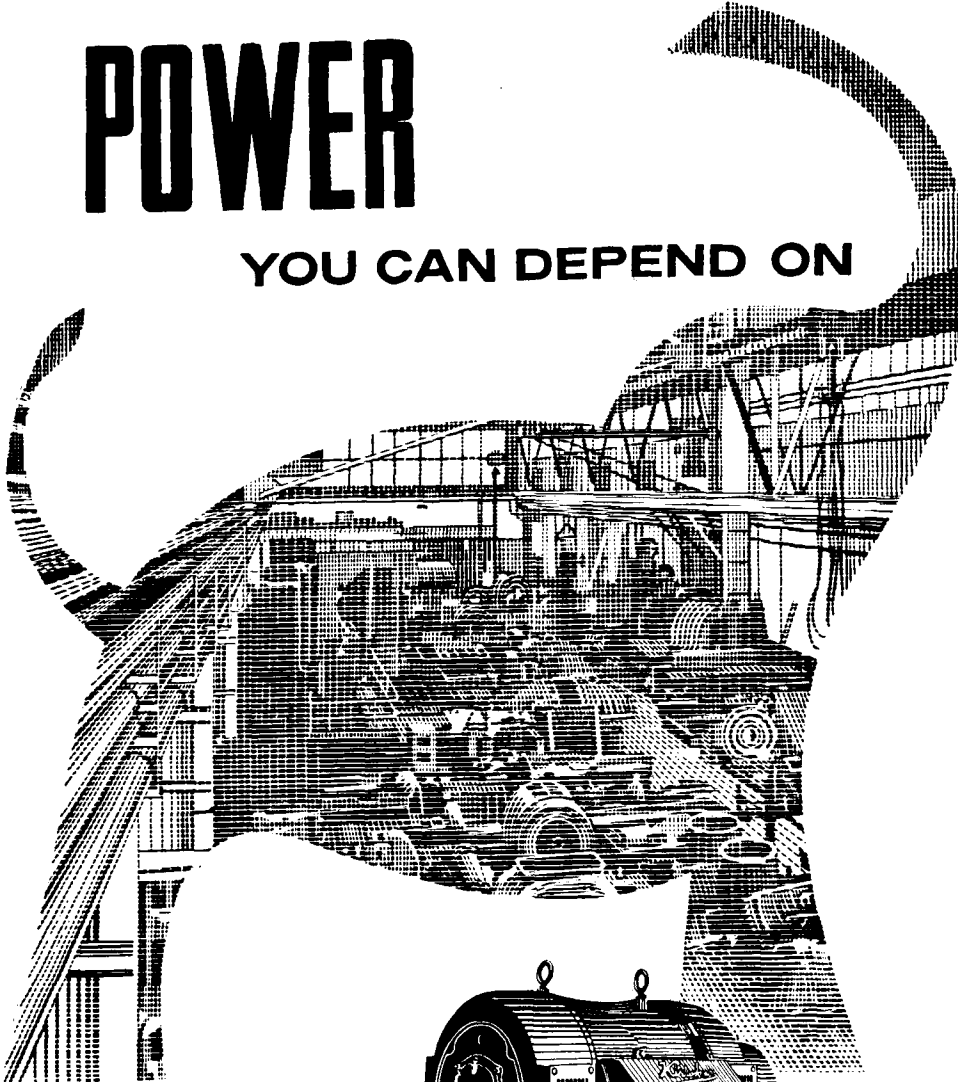
So far, four main installations have been set up by the UK Atomic Energy Authority. At the Springfields factory, near Preston, uranium metal and uranium hexafluoride are extracted from uranium ore. At the Capenhurst factory in Cheshire, uranium is separated into its isotopes by gaseous diffusion. At Windscale, in Cumberland, plutonium is manufactured from irradiated uranium metal and refined. Adjacent to Windscale is Britain's first atomic power station—Calder Hall—In addition to the new problems mentioned above, associated with all atomic structures, each of these installations posed some special problems of its own. At Windscale, for instance, the total weight of the two atomic piles is about 60,000 tons and they are supported on a concrete raft 20,000 feet in area and 10 feet thick. The structure had to be designed on a precision basis, with exceptionally fine tolerances. Special problems had also to be tackled in the disposal of radio active effluents. At Calder Hall there have been constructed two reactor buildings, each containing a relatively large atomic pile which is enclosed in a huge concrete 'biological shield', to protect operators from nuclear radiation.

In 1955 foundations were laid for a fast reactor type of station at Dounreay in the North of Scotland. Although the reactor core is small exceptionally heavy foundations are needed for the protective shielding. This type of reactor creates more fissile material than it actually uses up.

The Central Electricity Authority's ten-year development programme for atomic power, announced in February 1955, envisages an expenditure of £300 million on the construction of 12 atomic power stations which by 1965 will be capable of generating between 1,500 and 2,000 megawatts of electricity.

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(Continued from page 4)

District Officer's, when they brought up cases of even of individuals for discussions. It was as much as the Executive Officer's position was worth if he did not give the highest priority to the redressing of Union complaints. The District Union Officials then brought complaints against the Executive Officers to the notice of Administrative Officers to whom they had easy access and the Foremen were quite often made to eat the humble pie.

In these circumstances, can the Executive Officers and the Senior Subordinates be blamed if they have lost their hold on the workmen and inefficiency had to be condoned for fear of repercussions from higher level.

As for punctuality there has been a set back in Railway Workshops in this respect. If men start work half an hour late and close half an hour earlier at each half session, giving thereby six hours work for the eight hours per day for which they are paid that is considered satisfactory.

If men sit down to take rest during working hours or are likely to be caught sleeping or wasting their time, well it is much easier for all concerned from the highest to the lowest to look the other way rather than ask for trouble by interference.

With regard to skill in workmanship this too is at its lowest ebb, because during the War, for fear of strikes, unskilled workers were promoted to the skilled category and given promotion over lads who had served an apprenticeship. There are many fitters, carpenters, boiler makers etc., in Railway Workshops today who during the war were coolies, peons and office boy and have hardly any knowledge of their trade because they were never trained correctly. They are a dead weight on a shop because they are beyond the stage of learning or acquiring skill. They have got to be carried because rules do not permit reversion for lack of skill but on the contrary make them eligible for promotion when their turn comes on the basis of seniority only. No Chargeman dare gives them an adverse report for fear of his skin.

It is for this reason that the Labour Bill of the Railway is very much higher in proportion to the work turned out.

The labour pendulum has now swung in the opposite direction with even a greater swing and it is hoped that the Congress Government once it is in power for another five years will restore the disciplinary powers to the hands who are expected to exercise control over labour and curb the power of labour Unions who are doing a definite disservice to the country; otherwise all talk of higher efficiency and greater outturn from labour would be of no avail.

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RIDING QUALITIES OF RAILWAY COACH

By A. C. Bhattacharya, A. M. I. P. E.

THE trend to higher standards of ride quality of Railway Rolling Stock is as gradual as it is inevitable. The Railway Engineers throughout the world are realising that amongst the amenities which are being provided for the passengers, the best riding condition is one of paramount importance. Its value lies not only in increased passenger comfort and reduced damage to freight but also in reduced maintenance costs resulting from diminished vertical and horizontal movements.

In India, where long journeys are performed by rail, the need for good riding Coaches is still greater. Apart from comfort of rail travel, this condition engenders a sense of well-being and security. It has been seen from experience that it is neither the amplitude of displacement nor its velocity, that produces a sensation of discomfort. Neither is it the acceleration; for a journey when performed at high speeds over curves of constant radii of curvature is not uncomfortable. In fact, it is the rate of change of acceleration, a phenomenon commonly known as jerk, which produces uncomfortable sensations.

EVALUATION OF RIDING QUALITIES

The term "Riding Quality" denotes, in the general sense, a measure of comfort. All vibrations that emanate from the movement of a vehicle and their reactions in regard to physical comfort form the basis of riding quality.

There is however no wholly quantitative basis for measuring the physical sensations and no specific universal standards as such by which the riding qualities can be assessed and evaluated, but a reference standard, called the "Ride Index", has been adopted by the Association of American Rail Roads to compare the riding qualities of their passenger Coaches.

Experimental investigations initiated by Meister of Germany and developed by several other authorities formed the basis of this standard. The experiments were carried out by subjecting groups of persons of various ages and temperaments to a series of vibrations and tests on a shake table and their reactions in regard to physical comfort were classified and numerical values laid down for each "Threshold" of sensation. A set of comfort curves derived from these experiments is shown in FIG : 1.

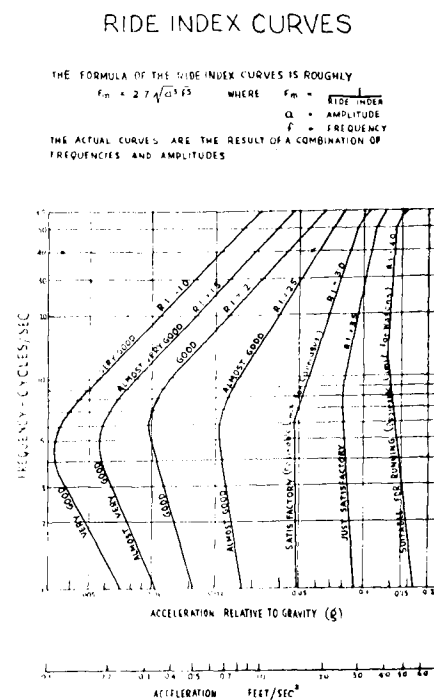


Fig. 1.

The problem of riding has been attacked from different angles in bogie designing since it is mainly governed by springing and its disposition. Good riding not only depends on the mechanical engineer but also on the civil engineer and may involve the electrical engineer as well.

The Mechanical Engineer is responsible for evolving a suitable design for the bogie while the civil engineer can help by providing a suitable track and maintaining it in good condition. For example it has been found that unevenness over rail joints and lateral track irregularities can both be reduced by butt-welding the rails. The effects of the lateral forces resulting from the swing of a carriage underframe carrying an added weight of dynamo and battery boxes, while negotiating a curve, cannot also be left out of consideration.

Another contributory factor, which often goes uncared for but is responsible for poor riding is the manner in which the stock in the train is marshalled. Coaches in a train with varied assemblies comprising light and heavy coaches, long and short, do not ride well. To obtain the best results, the stock should have similar characteristics such as bogie centres, overall length and weight. In this respect, the operating staff enter into the field

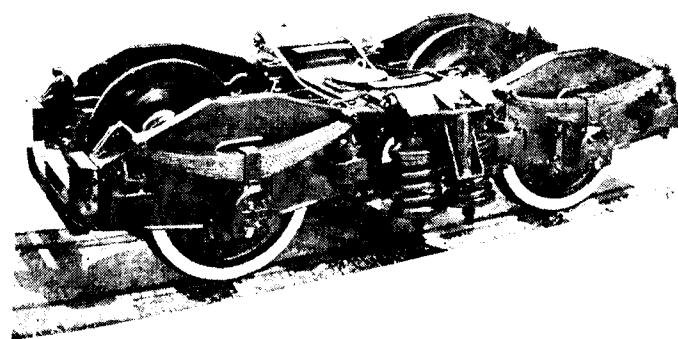


Fig. 2. A typical British bogie.

with the work, which is although non-technical nevertheless important.

DISTURBING FORCES

The disturbing forces which a coach is subjected to while in motion, are :—

- (1) **Pitching**, i. e. the front and back ends of the vehicle alternately rising and falling about a transverse horizontal centre line.
- (2) **Rolling**, i. e. transverse oscillation of the Coach on its springs, about a longitudinal centre line.
- (3) **Nosing**, i. e. transverse oscillation on the track about a vertical axis, pursuing a sinuous path along the track.

The two movements viz: rolling and nosing rarely occur separately, but are generally found acting together in varying proportions. The resulting oscillation is termed hunting.

- (4) Lurch -- one semi-amplitude of movement in the action of hunting, viz., an individual deflection from the centre line towards one or other of the running rails.
- (5) Shuttling — Oscillation of the coach in a fore and aft direction paralld to the track.

Pitching is generally caused by unevenness of track, hammering at rail joints by wheels, eccentric wheels and flat spots. If the period of disturbing force coincides with the natural frequency of the suspension spring, a condition of resonance is set up with resultant rough riding.

The vertical irregularities of track are mainly responsible for causing a tendency for a coach to roll and this is particularly noticed when the coach is at traversing points and crossings. Vertical irregularities are consti-

tuted by the conditions arising from wear of the rail head, unevenness at rail joints and the vertical variations in the travel of the wheel caused when traversing points and crossings.

Nosing is generally induced by the lateral irregularities of the track amplified by the natural motion of the wheel sets along a sinusoidal course when travelling over a straight track. Inaccuracy of bogie assembly and excessive play between the hornchecks and axle boxes and between the bolster and its rubbing blocks are other factors which cause nosing.

The fundamental causes that induce lurch are (a) defects in the alignment of straight tracks and irregularities in radius of curvature and (b) lateral shocks caused by variations in track gauge. The sinusoidal movement of the wheel set due to conal wheel units is another important factor responsible for inducing side lurch in a coach while in motion. Axle box clearances and clearance between wheel flanges and rail gauge faces, provided for in consideration of other factors, are additional causes which attribute to the lateral oscillations or side lurch in a vehicle.

Shuttling forces on a vehicle are generally produced by (a) variation in draw bar pull, (b) unbalance in wheel axle assemblies, and (c) varying accelerations of the vehicle. While movements due to items (a) and (b) periodic, the disturbances due to item (c) are irregular and mostly of a random nature. The frequency of oscillations caused by item (a) is equal to the frequency of the rotation of the coupled wheel of the locomotive and that due to item (b) is equal to the coach wheel rotation. It is obvious therefore that the coaches

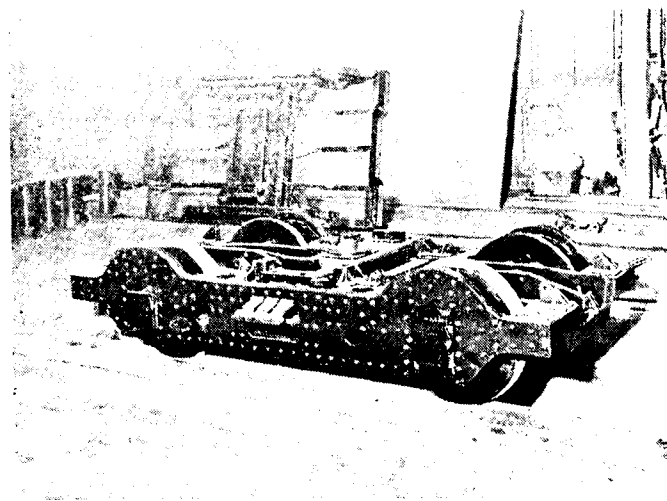
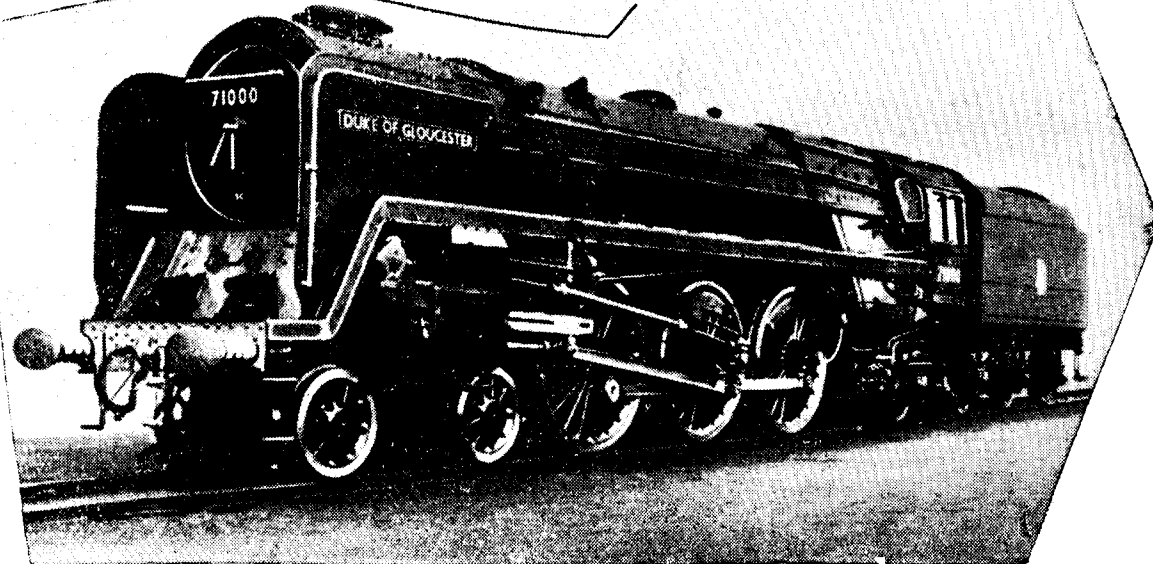


Fig. 3. A bogie showing the laminated elliptic springs under the bolster.

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nearer the locomotive are subjected to greater shuttling effects induced by item (a) caused by the unbalanced reciprocating mass of the locomotive.

CONTROL OF DISTURBING FORCES

In designing the bogie, attempts to control the known disturbing forces have been generally on the following lines.

As an answer to the problem of pitching, the bogie has been designed with a spring-borne floating bolster sustaining the superimposed load on a central pivot and side-bearers. Further resilient liners of adequate thickness of vibration—absorbing material are interposed at bogie pivots, side-bearers and under-spring seats to insulate the underframe from the transmission of vibration emanating from the track and bogies.

The wide spring-base bolster and provision of two sets of springs, one consisting of spiral springs and the other of laminated springs contribute largely to control the rolling. The use of nests of coil springs mounted outside the bogie frame, as first devised by Kreissig and employed in a railcar built for I. G. Farben has been an attractive solution to control this movement, since when the body tends to roll, the springs on one side must control the roll by their compression action and the nearer the springs are to the longitudinal axis of the bogie, the stiffer they must be to control rolling and the less contribution can they make towards good vertical riding. It has been observed that a coach over bogies with the bolsters extended beyond the side frames and their springs disposed correspondingly farther outward, rides well.

Rolling is also controlled by the provision of side-bearers so that a part of the load could be transferred to an appreciable distance from the theoretical centre of rotation. The design of IRCA bogies in India may be quoted as an instance in point.

Where, however, this has not been done, a wide bearing in the middle round the bogie centre pivot is provided to distribute the weight from that centre over the axle boxes. This principle has been employed in designing IRS bogies adopted as standards by the Indian Railways.

The India Rubber body pads interposed between the carriage body and the underframe also serve the purpose of damping this movement while the coach is in motion.

It is not possible to eliminate nosing and lurch altogether as sinusoidal movement is fundamental to the bi-conal wheel unit designed principally to compensate to such extent as possible for the curvature while

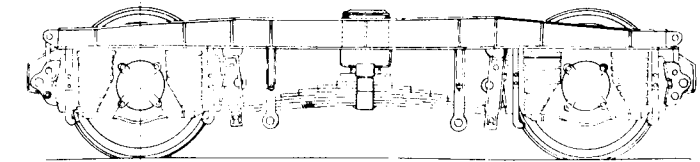


FIG-4 BOGIE OF SCHLIEREN COACH

running along the curves. Cylindrical-tread wheels or altering the wheel to a 1 in 100 cone instead of the 1 in 20 are although possible solutions and experiments carried out according, no finality has been reached in this connection due to following disadvantages associated with such proposals.

- With Cylindrical-tread wheel, if the flange gets against the rail it stops there until it strikes points. There is a tendency for it to run crab fashion. Turning a cylindrical-tread wheel accurately and no compensation for curves are the other disadvantages.
- With the coning of 1 in 100, the wheels under heavier stocks, will require more frequent tyre turning to maintain the effect as it has been found from trial that the treads wear very rapidly.

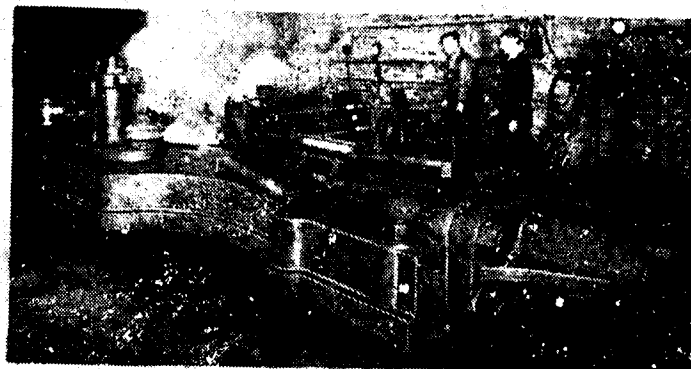
A much attractive solution lies in the reduction of the freedom of yaw of the axle. This was observed for some years in Britain in tramcar bogies. The reduction in the clearance between the axle box and the bogie frame to the bare minimum is another satisfactory proposition to arrest this movement in the type of bogie which has the axle boxes moving in horns.

Some people advocate the use of inclined bolster hangers to control hunting as with the inclination (as from top to bottom) provided, the bolster with its associated parts tends to return to a central position after deflexion. This inclination is also of advantage in counteracting body roll on entering curves. Others are of the opinion that inclined hangers set up oscillations and keep the coach body bouncing, causing excessive side movement, while straight hangers of a correct length will induce less side movement with a quicker, smoother return to the central position.

The reduced flangeway clearance, experiments in connection with which, were carried out in India during 1941, offers another satisfactory solution in this connection.

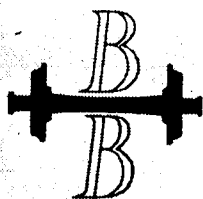
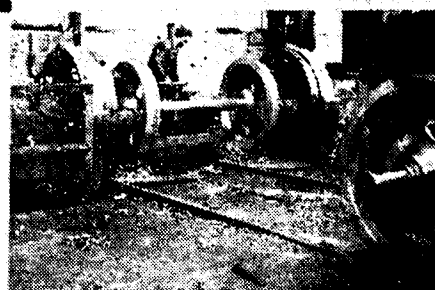
To improve riding qualities, the modern practice is to employ hydraulic shock absorbers for damping both vertical and side movement of the bogie and these have characteristics worth examining.

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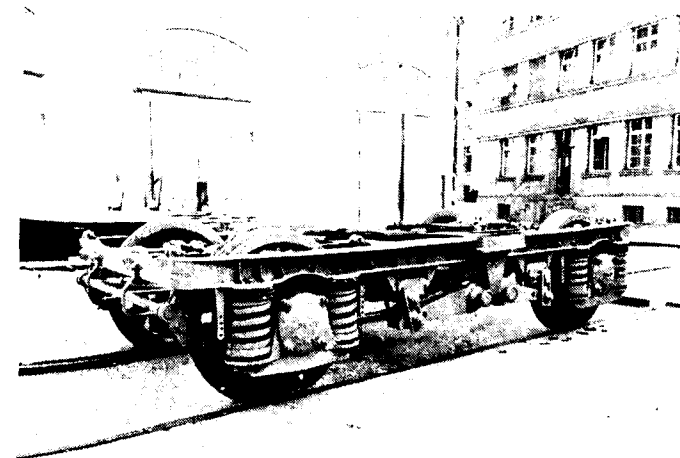


Fig. 5. Bogie springing arrangement according to the current Swiss practice incorporating lateral bolster torsion bars with helical axle-box springs.

BOGIE SPRING SYSTEM

From the mechanical point of view, two factors are vital which govern the riding qualities of a bogie, one is the form of tyre profile and the other is the springing and its disposition. The former has already been discussed in the preceeding paragraphs.

In practice it has been found that two sets of springs on a bogie, one consisting of spiral springs and the other of the laminated springs, yield good results. Spiral springs oscillate more readily than the laminated springs, as the friction of the plates in laminated springs helps to minimise rapidly any oscillation which may be set up.

There are two main practices in regard to the arrangement of such differentiated springs. The normal British practice (Fig. 2) is to support the bogie frame on laminated half-elliptic springs over the axle-boxes with spiral or rubber auxiliary springs at their ends and the bolster rests on spiral springs. The standard I. R. S. type bogie used on Indian Railways is related to the normal British practice.

In the other arrangement (Fig. 3), laminated elliptic springs are provided under the bolster and the bogie frame is supported by spiral springs on equalising beams resting on the two axle boxes.

TORSION BAR

A new line of bogie design, adopting a very simple element from automobile construction has been developed currently in Switzerland incorporating the torsion bar arrangement.

In this arrangement a bar of square or circular cross section is fixed at one end while the other end can rotate in a bearing and has a lever. Pressing on the end of that lever, the bar is distorted according to the force. When the force is omitted the bar turns back to its initial position. This elastic distortion of the bar material constitutes an excellent springing.

The first application of the torsion bar for body springing was made in 1938 with the double-motor-coach BCFZe 4/6 Nr. 681 of the Bern-Schwarzenburg—Railway. Then followed in 1939—40, eight lightweight cars of the R  tlian Railways (Flying R  tlian) with torsion bar body springing. Seeing the good riding qualities, other railways in Switzerland gradually followed suit.

In the Schlieren type coaches recently placed on lines by the Indian Railways, the cross beam of the underframe rests on laminated springs which are in turn supported by swing links fixed to the bogie frame with freedom of lateral and longitudinal movement. The axle boxes are connected to the bogie frame by cylindrical guides surrounded by helical springs. The cylindrical guides are oil-filled and constitute a well lubricated guiding surface as well as being constructed as dashpots to control vertical oscillation of the springs. Fig. 4 depicts this arrangement.

In the latest construction as shown in Fig. 5, the functions of the laminated spring are taken over by two torsion bars secured at the bolster centre and connected at their ends to arms corresponding to the halves of the laminated spring. In this case there is considerable simplification in the bolster since the whole weight of the body is taken at the ends through rubbing pads leaving the centre pivot to be used only for centring. Adjustment is provided at the fixing points.

Although numerous attempts have been made to evolve a satisfactory design of the bogie incorporating different features, it can safely be stated without any fear of contradiction that finality in the matter of design has yet to be reached.

There is considerable room for further research in connection with the design of a bogie in general not to speak of in relation to its riding qualities only, although the course followed has been in the direction of better riding. The whole question appears to be in a state of flux throughout the world and it tends to advance slowly by evolution rather than by revolution.

Specially Designed Powerful New Beyer-Garratts for the 2 ft. 6 in. Gauge Sierra Leone Government Railway

IN 1949 the Sierra Leone Government Railway celebrated its fiftieth anniversary of providing the Colony and Protectorate with its main means of internal communication.

The railway runs from Freetown, the capital and principal port, eastwards for 227½ miles to Pendembu, an important trading centre in the extreme east of the Protectorate, whilst a line branches off at Bauyo, 64½ miles from Freetown, and runs North East to Makeni, another trading centre 82¾ miles from Bauyo, making a total route mileage of 310½ miles.

The gauge of 2 ft. 6 in. was decided on after the respective merits of this gauge and metre were discussed, it being necessary to build the line as economically as possible, bearing in mind the amount of traffic which would be offering, and time has shown that this choice of gauge was the correct one. It is for this reason that the line has been built so many curves and switchbacks, in fact in the first 139 miles from Freetown to Bo, the line climbs up the equivalent of a mountain 1500 ft. high and down the other side whilst at the same time making the equivalent of 75 complete turns.

The line is single throughout, except at passing loops, and was originally laid with 30 lb. rail, but during the last few years, extensive improvements have been made to the permanent way including the commencement of relaying the line with heavier rail. The maximum axleload is 5 tons, and the ruling gradient 1 in 50, while the maximum curvature on the main line is 5 chains.

The first 22 miles from Freetown are the most difficult and abound in curves and grades, so the Beyer-Garratts are an ideal choice for operating under these adverse conditions.

This type of locomotive was first supplied in 1926, when its introduction allowed greatly increased train loads without the necessity for double heading, whilst at the same time giving improved fuel consumption figures per gross ton-mile as compared with the ordinary types of locomotives hauling their rated loads. The first three 2-6-2 + 2-6-2 Beyer-Garratts were followed with three repeat orders, two for two each, and the third for six.

In order to cope with increasing traffic which consists principally of palm kernels, together with chrome ore from Hangha and rice from Magburaka and Mano, a new design of Beyer-Garratt locomotive has been specially produced for this railway, which will give a 35% increase in tractive effort, whilst still retaining a maximum axleload of 5 tons.

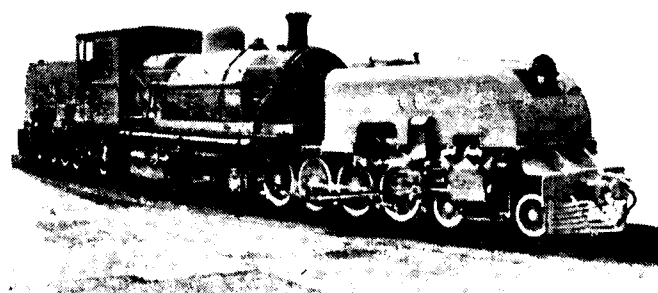
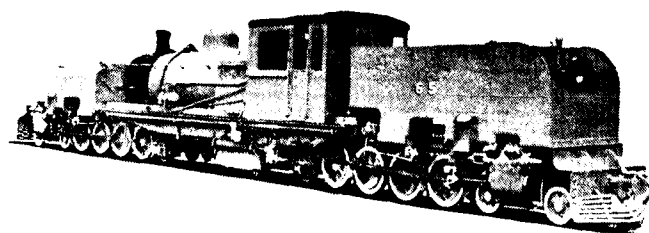
With these fourteen new engines, the Railway have twenty-seven Beyer-Garratts in service. Those previously supplied have proved themselves reliable in service under the exacting conditions of West Africa.

These fourteen Beyer-Garratt locomotives are among the most powerful locomotives ever built for 2 ft. 6 in. gauge, bearing in mind the maximum axleload of 5 tons. They have been designed to the requirements of the Chief Mechanical Engineer, Sierra Leone Government Railway and have been built under the supervision of the Crown Agents for Overseas Governments and Administrations. The locomotives have a tractive effort of 22,990 lb. at 85% boiler pressure and weigh in working order 66.3 tons, when loaded with 4 tons of coal and 1,600 gallons of water.

THE BOILER UNIT

The Belpaire boiler is constructed from steel plates to B. S. S. 24 No. 16 with a drumhead type of smokebox tube plate. The inner firebox is of copper to B. S. S. 24 No. 11 and is stayed with copper stays to B. S. S. 24 No. 12. The grate is of the fixed type except for a "drop" portion at the front centre, which can be operated from ground level. The ashpan is fitted with front and rear dampers and side doors to assist in ash disposal.

The regulator is mounted in the dome and is of the slide type. The Superheater Co. supplied the Melesco superheater header, mounted in the smokebox, which is fitted with an anti-vacuum valve, and the twenty-one



1¾" o. d. × 9 s. w. g. superheater elements. The large tubes are 5½" o. d. whilst the 132 small tubes are 1¾" o. d. The smokebox is fitted with a self-cleaning type of spark arrestor and an ash ejector.

Washing out the boiler is facilitated on Beyer-Garratt locomotives, since access to the plugs at the foundation ring is not impeded by the axles and stretchers of the orthodox locomotive, and even on this narrow gauge locomotive, the washout plugs are easily accessible and a blowdown cock is conveniently mounted at the front of the firebox above the foundation ring. The boiler is lagged with blue asbestos mattresses supplied by J. W. Roberts Ltd. with mild steel clothing plates.

The boiler is fed by two Gresham and Craven No. 8 R. C. W. injectors, located below the footplate on either side, which supply the boiler through a double top feed clackbox. A steam turret is mounted on top of the firebox in front of the cab with a main shut-off valve and valves for auxiliaries with extension spindles into the cab. Two Ross "pop" safety valves are fitted.

THE ENGINE UNITS

Plate frames are used for both the engine units and the boiler unit. They are effectively stayed with cast steel and plate stretchers forming a rigid structure.

The coupled wheel axleboxes are steel castings with bronze bearings lubricated by "Ajax" patent hard grease lubricators. Phosphor bronze liners are used on the axlebox faces to reduce wear of the wheel hubs and gunmetal liners are fitted to the hornfaces. The coupled hornblocks are of one piece steel castings, fitted inside the frames, with class "D" steel liners and wedges. The outer bogie is of plate construction with a cast steel centre, and is fitted with Timken split cannon type roller bearing axleboxes. The inner pony truck, which has outside Timken roller bearings, is a steel casting incorporating the radial arm and check spring brackets. The bearing springs for both the bogie and the pony truck are identical helical springs of

"Timmis" section, whilst helical springs are also used for control. The spring gear for the coupled wheels is underslung with laminated springs, and is not compensated.

The pivot centres between the engine units and the boiler unit are of the well proved Beyer Peacock patent self adjusting type, working in an oil bath, with spring loaded friction side bearers. This design of pivot centre has materially assisted in lowering the cost of maintenance for Beyer-Garratts due to the automatic adjusting for wear and has been applied to several hundred locomotives.

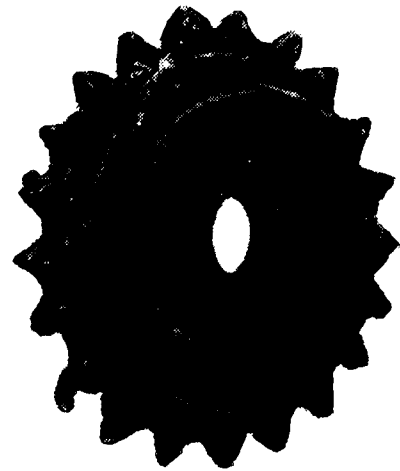
The cylinders are of cast iron, whilst the inner cylinder covers are steel castings, incorporating lugs for carrying the ends of the slide bar, and housing the U. S. metallic packing for the piston rods. Wota N. C. by-pass valves are fitted. The cylinders and main steam pipes are asbestos lagged, and the cylinder cocks are actuated by a steam servo motor. The crosshead is of the Laird type with the arm cast integrally with the body. The slippers are cast iron with gunmetal liners on the top, bottom and sides, and slidebars are lubricated from two oil cups attached to the top bar. The Walschaerts valve gear is so arranged that the die blocks are in the bottom or direct half of the expansion links when running chimney first. All the motion pins are of Class A steel, case hardened, and work in gunmetal bushes.

The connecting rod has gunmetal bushes at both ends, the large end one being whitemetalled. The coupling rod bushes are similarly of gunmetal, whitemetal lined; the knuckle pins being of Class "D" steel. Oil lubrication is used for all the motion and the rods.

A feature of this design is that in spite of the narrow gauge, all points requiring attention are readily accessible, the various cut outs in the front and rear tanks give access to the main steam and exhaust joints. These tanks are strongly built with rivetted construction, being fastened to the engine frames by means of the Beyer Peacock patent spring-loaded fastenings, the tank water fill hole is located on the front tank.

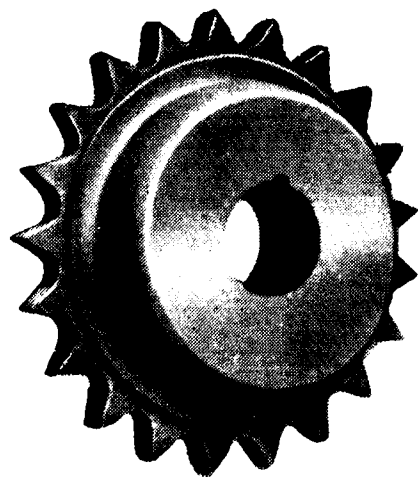
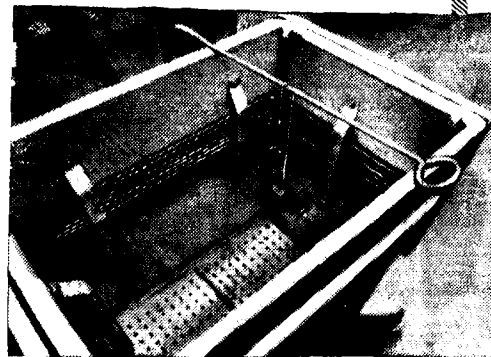
Vacuum brake is fitted, and a Gresham & Craven S. S. J. ejector, type G, is fitted on the right hand side of the boiler. Two 21" diameter brake cylinders are accessibly placed beneath the boiler, together with the reservoirs. They control the brakes on both engine units, the brake rods leading to the units being fully compensated. The handbrake is coupled to the brake

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cross shaft beneath the brake cylinders, and thus can apply the brakes on both units.

Gravity sanding is provided with sand boxes at both ends of each unit, the sanding being controlled by steam servo motors, similar to those used for the cylinder cocks.

The railway's standard drawgear is fitted, which, as can be seen from the illustration, is of the centre buffer type, being self-contained with a screw coupling on top.

LUBRICATION

A Wakefield three feed mechanical lubricator is provided on each engine unit, supplying oil to the steam pipe ball joint and the pivot centre.

Two British Detroit 6 feed hydrostatic sight feed lubricators are mounted in the cab, each supplying an engine unit through Dorman's Flexstel flexible steel joints, the feeds being led to the cylinder barrel, inlet to steam chest and piston rod packing on each cylinder. The coupled wheel hub faces are grease lubricated.

CAB AND FITTINGS

The cab, considering the gauge, is of large proportions and is 7ft. wide, with a double roof, an essential in the tropics. There is also ample ventilation; louvred side shutters are fitted together with roller blinds over the doorways for use during the tropical rain storms. Dunlopillo seats, which are adjustable for height, are provided for the crew. The Stones electric lighting is fed from a turbo-generator mounted alongside the boiler on the left hand side, and fourteen inch "Tonum E" headlights are mounted at each end of the locomotive. Various gauges in the cab are well lit for night operation; and provision is also made to plug in an inspection lamp. The Stone-Smith's

electrical speedometer is fed by a generator driven by the right hand inner coupled wheel of the rear unit. A combined blower elbow and tube cleaning cock is mounted alongside the smokebox.

The locomotives were shipped complete, painted in the Railway's colours of orchard green with signal red buffer beams. These fourteen Beyer-Garratts, numbered 63 to 76 inclusive, will provide useful additional motive power, and are no doubt proving worthy modern additions to the Beyer-Garratts already in service in the Colony and Protectorate.

THE PRINCIPAL DIMENSIONS ARE AS FOLLOWS

Cylinders (4) dia. × stroke.	12 5/8 in. × 16 in.
Coupled wheel dia.	2 ft. 9 in.
Bogie wheel dia.	1 ft. 9 in.
Axleload.	5 tons.
Length over buffers.	63 ft. 7 1/2 in.
Total weight in working order.	66.3 tons.
Boiler pressure.	175 lb./sq. in.
Heating surfaces :—	
Tubes.	829 sq. ft.
Firebox	95 sq. ft.
Total evaporative.	924 sq. ft.
Superheater (inside)	178 sq. ft.
Total.	1,102 sq. ft.
Grate Area.	22.5 sq. ft.
Tractive effort @ 85% B. P.	22,990 lb.
Tractive effort @ 75% B. P.	20, 290 lb.
Coal capacity.	4 tons.
Water capacity.	1,600 gal.

LIMITS AND FITS FOR ENGINEERING

The Indian Standards Institution has prepared and circulated Draft Indian Standard Recommendation for Limits and Fits for Engineering. The system of limits and fits recommended in this Standard comprises suitable combinations of 16 grades of tolerances, or, in other words, grades of accuracy of manufacture and 21 types of fits for both hole and shaft, ranging from fits of extreme interference to those of extreme clearance. It covers almost all the engineering requirements from very coarse to very fine gauge manufacture. It also defines many terms falling within this field and includes suitable figures to elucidate the point.

The Committee responsible for the preparation of this draft Standard is representative of important machine tool manufactures and consumers as also interested Government Departments.

Heavy insulated refrigerator vans

SCANDIA A/S, Randers, Denmark, founded in 1861, builders of railway carriages and wagons, have during the past 90 years been manufacturing railway carriages and wagons of various types.

One of the most modern wagons is a new type of welded all-steel refrigerator van, built in accordance with the UIC-specifications (International Railway Union) and especially intended for export from Denmark to the southern European countries of frozen and cooled fish, meat and vegetables.

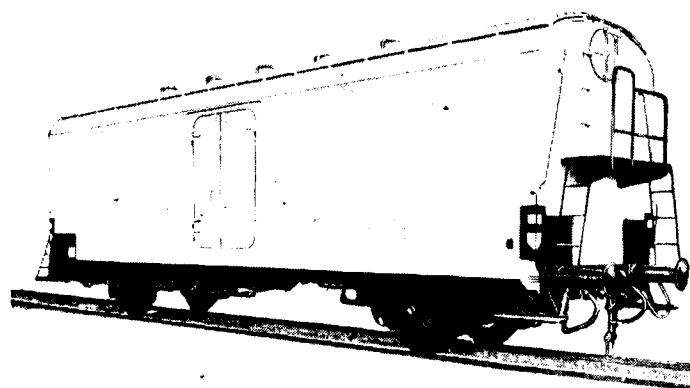
These wagons are especially built for use in fast goodstrains and in passenger-trains with a maximum speed of 75 miles per hour.

The wagons are heavily insulated, and SCANDIA has built 90 wagons of this type for the Danish State Railways.

Denmark is a typical insular country surrounded by sea on all sides, and fishing has therefore always been one of the marked trades in this country. For that reason it comes natural that there is exported fish in great quantities from Denmark to southern Europe, in which districts it is difficult to procure fresh fish.

For the rest Denmark is a distinct agricultural country with among other things a methodical worked cattle breeding, and fresh meat is therefore also a great commodity.

Danish State Railways have for that reason decided to render farming and fishing a service as good as possible by having built these 90 new refrigerator vans



which will possibly be followed by more, and there is further the advantage by procuring such heavily insulated cars that they can be used on the way back to Denmark for the transport of southern fruit rich in vitamins for the Danish market so that there is established an interaction on behalf of the railways and the countries they attend.

The photo (fig. 1) shows the all-steel refrigerator van made for the Danish State Railways with the following data :

Capacity: 38,500 lbs., 1430 cub. ft. including 5,500 lbs. ice.

Tare weight: 35,000 lbs.

Length over buffers: 38' 5"

252 meat hooks.

Distance between axles: 21' 8".

Refrigerant: Water-ice or Solid Carbon Dioxide.

Before the actual manufacture was started a van used for thorough-going experiments was built. The Danish and the Italian State Railways have for that reason carried out comprehensive transmission experiments.

On the basis of the experiments which were achieved with the first van various improvements were made on the subsequent vans, while at the same time the weight was reduced in accordance with the international claims.

The vans are built according to a proposal stated by the Food Transport Council established by the Academy for the Technical Sciences, in which council the various ministries and the people taking an interest in these transport problems are represented. Furthermore the vans are built in conformity with the claims which the International Railway Union makes to the standard refrigerator vans, and according to the judgment of the council these types of vans should be most suitable for inland transport as well as transport from Denmark to the southern countries of both cooled and frozen commodities.

According to the council's proposal the van has been constructed for a heat transmission coefficient of 0.082 BTU/sq. ft. °Fh, whereas the International Railway Union allowed a coefficient of 0.102 BTU/sq. ft. °Fh for a similar standard refrigerator van.

The inside lining is made of galvanized steel sheets in order to make a thorough cleaning as well as removal of any bad smell from fish transport and the like

possible, before the van is going to be used for other commodities which might be damaged by the smell. It has been our endeavours to make the construction of the van as tight as in any way possible by using strong rubber tightening stripes at the doors and devices in order to prevent the outside air from intrusion through outlets of the iceboxes, and thus the 10 rotors placed on the roof serve to circulate the air in the van, whereas the admission of the air from outside does not take place.

The rotors absorb the air from the van and blow it down through the iceboxes, from where the cooled air streams into the van, partly through the space between the floor of corrugated sheets and the chequer plates above, some of which have drilled holes. In each end of the van an icebox is placed, the partition wall of which is adjustable so that each box holds a maximum weight of 2,750 lbs. of ice. The partition can be placed close against the inside end of the van. Thus there will be an increased space of floor to be used for commodities requiring no ice-cooling.

The way in which the partition is constructed allows it to be turned round and kept in this position during the cleaning of the ice-box.

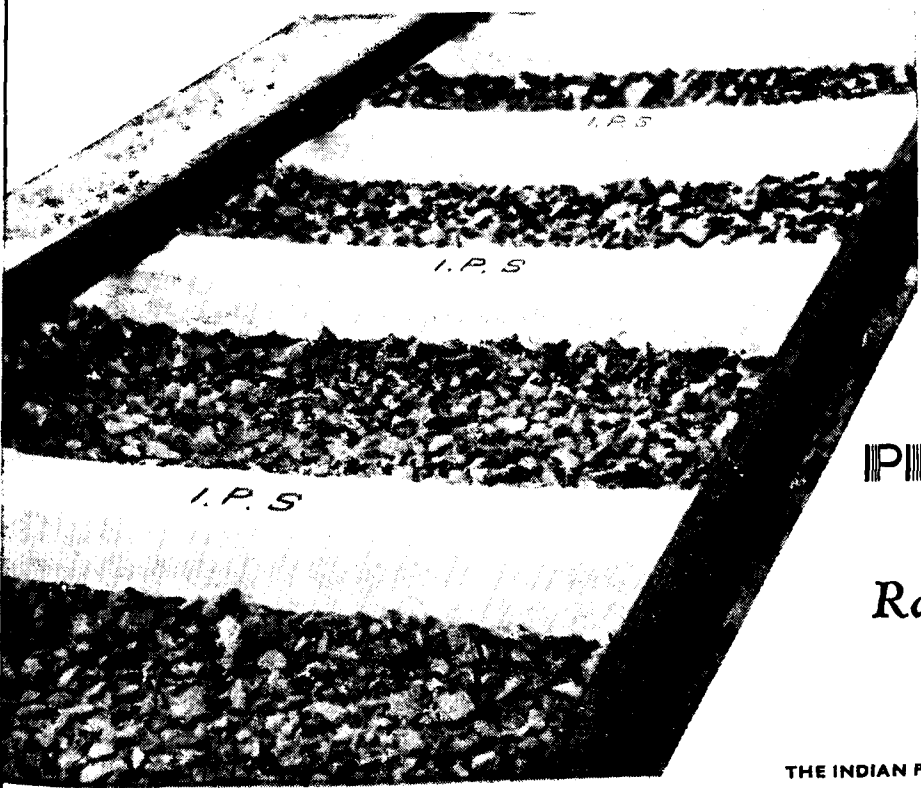
The iceboxes are filled from an outside platform at each end of the van through a circular filling opening with a conical cover.

Inside the filling opening there is in each end of the van room for packages of 650 lbs. of carbonic acid ice.

From one of the platforms the screw brake of the van is also worked, and it is connected with the braking appliance for the air-brake of system "Hildebrand-Knorri Hikep" with SAB brake-block slack adjuster.

Furthermore the vans are equipped with SAB brake governor rendering the normal manual settling of the brake "empty" or "loaded" unnecessary as the braking varies automatically according to the size of the cargo.

Between the outside and inside sheeting of the van the insulation consisting of ISOFLEX is placed. In one of the vans, however, experiments are made with IPORKA as insulation material. Both the sheetings are made absolutely tight in order to prevent invading water from damaging the insulation material and thus reducing the heat insulating power.



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A CAST BOGIE FRAME AND ITS TESTING

By *Dehalu*, Chief Engineer.

Société Anonyme Usines Emile Henricot, Belgium

The prototype of a large number of cast-steel frames for four-wheel one-motor bogies has been tested intensively and strain-gauge measurements made.

STRESSES throughout bogie frames are rarely susceptible to exact calculation, particularly if there is anything unusual about the shape of the bogie and its suspension. The lack of complete knowledge of the stress distribution can be important as it is known that this distribution is not constant as time goes, and variable stresses are responsible for much failures observed in moving structures and also if a large number of bogie frames are to be needed to one standard design.

Some years ago the Belgian National Railways initiated a programme of construction of electric multiple-unit trains, in which it was visualised that use might be made of the same two-axle one-motor bogie for new construction over a period of a good many years. Therefore, a decision was made to supplement the closest possible calculations by a fatigue test and a comprehensive series of strain-gauge stresses measurements on the first cast frame, so that any weak points, stress-concentration areas, or unusual factors might be brought to light before series production was begun, thus giving opportunity for any slight alterations which might be desirable from either design or production points of view.

From these aspects the bogie frame itself was of interest on three main counts:

- (1) It was to be a one-piece steel casting;
- (2) Normal guides and thrust surfaces at the axleboxes were to be replaced by the Alsthom link and Silentbloc arrangement.
- (3) Only one axle of the two was to be driven, by a nose-suspended motor, and this would lead to an asymmetrical arrangement of the bogie and layout of the bogie frame.

The decision to use a single steel casting in preference to welding, though due in part to economics, as several hundred bogie frames would be required ultimately, was undoubtedly influenced by the presence in Belgium of the well-known Henricot foundry at Court St. Etienne, which for long has specialised in such castings, and which for long had specialised in such castings, and which incidentally in the final event also cast the axleboxes for the SKF roller bearings. As regards the type of axlebox suspension, this was chosen to give good riding and

cushioned transmission of tractive and braking stresses and also transverse forces. Finally, one motor per bogie was selected as two motors per car were sufficient and the railway company wanted to have only one type of bogie.

Disc wheels of 1,010 mm. (39 $\frac{3}{4}$ in.) dia. are used, and the wheelbase is 2,500 mm. (98 $\frac{1}{2}$ in.), but this is not symmetrical about the pivot, the distances between pivot and axles being 1,335 mm. (52 $\frac{3}{4}$ in.) motor side and 1,165 mm. (45 $\frac{3}{4}$ in.) carrying-axle side. The normal d.c. motor used is of 250/265 h.p. and top track speed is 120 km.p.h. (75 m.p.h.) for inter-urban coaches and 140 km.p.h. (87 m.p.h.) for express sets. Maximum super-imposed load on the bolster from the body weight is about 21 tons.

General arrangement of the bogie frame from which the points of asymmetry can be appreciated clearly, in particular the middle longitudinal beam between centre and end transoms at the non-motor end, this being a very convenient means of combining extra frame stiffness with suspension of the brake rigging, which in general is of conventional type applying two blocks per wheel.

A particular term in the specification laid down by the Belgian State Railways was that a machined weight of 1,325 kg. (2925 lb.) was not to be exceeded for the frame casting. The Henricot foundrymen thus had very strict tolerances put upon them in regard to core thicknesses and surfaces, for the designed wall thickness had to be observed closely, on the plus side so that the specified weight should not be exceeded and on the minus side so that the casting walls would not be weakened. The tolerance fixed was ± 0 and -2 mm. on the unmachined walls, except for the central parts of the beams where the tolerance was reduced to ± 0 and -1 mm. To get ample torsional rigidity all the main members of the bogie frame have been made as hollow box sections.

The small thicknesses of the walls obliged the foundry to study every detail, in particular to avoid any heat cracks, and to ensure there was no undue cooling of the molten metal before it reached the farthest points of the mould. Therefore, even a more careful study and preliminary testing than usual was given to the location

and proportions of the risers and coolers, and to the strict maintenance of the specified molten metal temperature. The steel itself is of a carbon type of 50 to 60 kg. per sq. mm. (31 to 38 tons per sq. in) ultimate tensile strength, with a minimum elongation of 20 per cent on a test piece five diameters long, and a Charpy resilience value of 6 to 9 kg. meters per sq. cm. This steel is easy to weld; and actually on these bogies one or two small brackets have been welded, where casting them in would have involved cost and procedure out of proportion.

The dynamic tests stipulated by the Belgian National Railways had as their objects the application of actual forces at the points where they would be encountered in service, and to apply these continuously at a frequency which would give in a comparatively short time the number of stress cycles equivalent to many years of service life, and so, as said above, find out in advance if the bogie frame casting had any weaknesses in design, material or casting procedure which could be corrected before series production was begun. The number of cycles fixed was 2×10^6 , and at 250 cycles a minute the test extended for 133 hr., or 5 $\frac{1}{2}$ days of uninterrupted day-and-night testing.

Testing was undertaken in the laboratory of an independent body. The Association des Industriels de Belgique, who sometime ago acquired a very modern fatigue plant to test under variable loads of all kind of large structures as girders, concrete beams, tress joints etc. Horizontal and vertical test loads were applied at the same frequency so that the diagonal forces would be at a maximum at the same time. The test procedure was that these loads should be applied at the given frequency until the moment when any crack, or flaw, or other sign of weakness appeared; but if no such signs appeared the tests were to be carried only to the number of cycles detailed in the preceding paragraph, as it would then be obvious that the endurance limit of the metal had not been reached, and that the casting would withstand the loads encountered in service.

In arranging the magnitude of the forces to be applied, the extreme vertical loads that would be applied to the bolster in service were considered to be 9 tons as a minimum and 24 tons as a maximum. The first would correspond to the vehicle running empty, with the springs partially free under the effect of upward vertical acceleration and transmitted to the body after a shock. The second loading would be attained with a fully-laden vehicle running, and with the body impelled by downwards vertical acceleration

compressing the suspension springs to the utmost. However, for reasons connected with the testing facilities available the minimum test load applied was 4 tons.

Among other vertical forces less important than the superimposed weight on the frame, only the reaction of the traction motor torque acting through the bearings on one of the centre transoms was taken into account. It was considered as a constant unfluctuating load, and for the tests was fixed at 2,800 kg. (6,200 lb.) which figure is sensibly greater than the actual load found under normal working conditions.

Horizontal effects on the bogie frame are numerous, and those from the traction and braking forces are longitudinal in direction. But laterally there are the forces, often severe, arising from flange pressure, not merely on rounding curves at speed, but coming from the sinusoidal motion of a pair of coned wheels along straight track, and from hunting on straight track. Though such flange forces cannot always be accurately measured it is known that they can be greater than the traction and braking forces. The resultant of a flange force and a longitudinal force is oblique; and as the flange forces originate at diagonally-opposite wheels, the bogie frame finally is subject to horizontal forces, tending to distort it as a parallelogram, additional of course, to the bending effects of the vertical forces.

On the test stand the frame was supported vertically at four points corresponding to the axleboxes, and was fixed laterally by two supports corresponding in position to the points of suspension of bolster from the centre transoms. These last two supports resist the couple resulting from the horizontal forces. Nine hydraulic jacks were needed to apply the necessary loads, two for the vertical forces, at the bogie pivot and at the motor-nose bracket, and seven for the horizontal forces. Two of these horizontal jacks, at diagonally opposite corners, applied longitudinal loads varying between 0 and 5.6 tons on the outer posts of the axlebox carrying system. In the two other diagonal corners two more jacks applied constant loads of 2.8 tons to the other posts of the axlebox supports, and by these each main longitudinal of the frame was given an eccentrically-applied load of $+2.8$ to -2.8 tons. Diagonal loads from 4.8 to 0.8 tons were applied by two more jacks located near the axlebox pieces, and another diagonal load of 2.8 tons was applied by the ninth jack. The reactions of all these jacks were taken up by steel members solidly bedded in the floor of the test house. In those jacks which had to provide variable load the variations were obtained by two Amsler pulsators to feed the oil. Those jacks applying

a permanent steady load were fed with oil from a separate circuit.

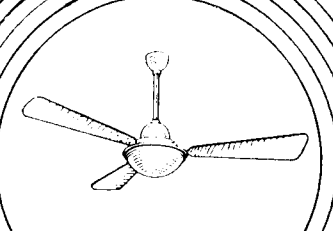
Stresses in the frame under the static and dynamic loads were checked by 14 strain gauges, these 14 points being chosen to give a good idea of stress distribution and to check all points which, after calculation and study, might have chances of being over-strained. Under vertical static load representing the body weight applied to the bogie bolster the stresses shown in Table I were measured.

Under the full range of dynamic horizontal and vertical fixed and variable loads as detailed above, the stresses in the frame casting at the same points are gather in Table II. At first sight it appears that maximum stresses are lower than when only the single static vertical load is applied, the maximum being 5.35 kg. per sq. mm. as against 6.3 kg. per sq. mm. This arises from the horizontal loads originating in the

main longitudinal moments of opposite sign to those produced by the vertical loads.

Gauges Nos. 3 and 4, and 8 and 9 placed diagonally on the frame near the ends of the two centre transoms, recorded stresses, particularly those due to traction forces, which vary less than those checked by the corresponding diagonal groups of gauges 6—7 and 11—12. Amplitudes of stress variation, rising to the maxima at strain gauges 1 and 13, are, at 3.15/3.35 kg. per sq. mm. considered to be more than those the frame structure will have to withstand in service.

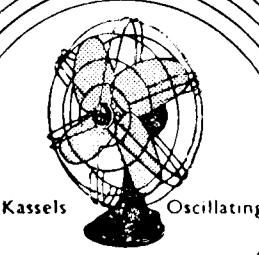
During the test the prototype frame casting withstood the 2×10^6 cycles without the least flaw or rupture becoming visible. There are now more than 500 of these bogie frame castings in service, and from the test result and their performance up to the moment it is believed they will complete the economic life of the bogie as a whole without any serious troubles.



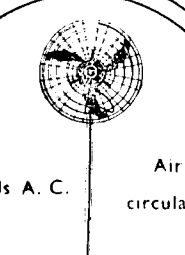
Kassels Airmaster A.C.
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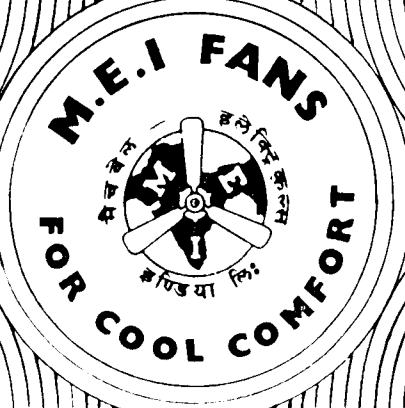
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TABLE I—STRESSES UNDER LOAD OF 24 TONS ON CENTRE PIVOT

No. of strain gauge.	Stress kg. per sq. mm.	Stress tons per sq. in.
1	+6.3	+4.0
2	+6.1	+3.87
3	+5 }	+3.18 }
4	—5 }	—3.18 }
5	+0.98	+0.62
6	—4.1 }	—2.6 }
7	+4.6 }	+2.92 }
8	—4.4 }	—2.8 }
9	+4.6 }	+2.92 }
10	+0.21	+0.13
11	—4.4 }	—2.8 }
12	+4.8 }	+3.05 }
13	+2.75	+1.75
14	+0.84	—0.535

TABLE II—STRESSES THROUGHOUT CAST STEEL BOGIE FRAME UNDER VARIABLE LOADS (contd.)

No. of strain gauge	Minimum stress kg. per sq. mm. (tons per sq. in.)	Minimum stress kg. per sq. mm. (tons per sq. in.)	Amplitude of variation kg. per sq. mm. (tons per sq. in.)
11	—1.97 (—1.25)	—3.65 (—2.31)	1.68 (1.13)
12	+1.68 (+1.13)	+2.94 (+1.86)	1.26 (0.80)
13	+0.95 (+0.605)	+4.30 (+2.73)	3.35 (2.12)
14	—3.35 (—2.12)	—3.98 (—2.53)	0.63 (0.40)

(Courtesy: "Diesel Railway Traction")

TABLE II—STRESSES THROUGHOUT CAST STEEL BOGIE FRAME UNDER VARIABLE LOADS

No. of strain gauge	Minimum stress kg. per sq. mm. (tons per sq. in.)	Maximum stress kg. per sq. mm. (tons per sq. in.)	Amplitude of variation kg. per sq. mm. (tons per sq. in.)
1	+2.20 (+1.40)	+5.35 (+3.4)	3.15 (2.0)
2	+3.05 (+1.95)	+4.41 (+2.8)	1.36 (0.86)
3	+1.83 (+1.16)	+2.52 (+1.60)	0.695 (0.44)
4	—1.27 (—0.85)	—2.32 (—1.47)	1.05 (0.665)
5	—0.82 (—0.52)	+0.28 (+0.18)	1.1 (0.698)
6	—1.76 (—1.11)	—3.34 (—2.12)	1.58 (1.0)
7	+1.66 (+1.05)	+3.34 (+2.12)	1.68 (1.13)
8	—1.37 (—0.87)	—2.52 (—1.60)	1.15 (0.73)
9	+2.38 (+1.5)	+2.90 (+1.84)	0.52 (0.33)
10	—0.22 (—0.14)	—0.42 (—0.27)	0.20 (0.126)

INDIAN FACTORY FOR CONSOLIDATED PNEUMATIC

A programme of expansion in overseas markets is evident in the announcements which have been issued over the past few months by the Consolidated Pneumatic Tool Company Limited of London and Fraserburgh. This receives further emphasis with a statement just released advising the formation of a new company under the title of the Consolidated Pneumatic Tool Co. (India) Private Ltd.

The new company which came into being on February 28th 1957, has a Directorate comprising Mr. G.J. Coffey, Mr. Norman Readman and Mr. V. Nimbkar (Managing). It will operate in Bombay where new factory premises will be constructed.

The primary purpose behind this development, is the manufacture of CP products within the country, and it is expected that operations will be in full swing by the end of this year.

Consolidated Pneumatic products scheduled to be made in India are pneumatic tools, rock drills and demolition tools, pumps, and air compressors.

The new Company will be complementary to the Consolidated Pneumatic branches in Bombay and other Indian cities, as the entire sales and service organisation will continue without change, and will handle CP products of the British, Indian and U.S.A. factories.

Some considerations about single line control

By J. H. Giskes,

Netherlands Machine-works "Alkmaar" Ltd., Holland

INTRODUCTION

AN important problem in the field of railway signalling systems is the control of single line traffic. It is quite understandable that in the beginning with a small number of trains running each day the railways started with single track. But even at present it will require considerable investigation whether it will be economically justified to build a double track. Railway companies will have to find an answer to this question not only for new railway connections, but also for existing lines on which increased frequency of train-movements has to be met with adequate measures.

For distances with a very dense local railway traffic double track might be necessary. But especially for larger distances the costs of doubling the track will mean very high investments. From practical experience it appears that building a double line means an increase of 100% as regards the costs of the railway with super-structure and an increase of 80% as regards the costs of preparing the road compared with a single line lay-out. Further the maintenance costs are about 60% higher for the double line compared with the single line. The decision to be taken will depend upon the maximum capacity of the single line. It is practically impossible to give an exact formula for line capacity. The difficulty is to introduce in the calculations the irregular intervals at which the trains are running actually and how the different types of trains (normal and fast passenger trains, goods trains a.s.o.) are incorporated in the timetable. In the literature some formulæ are given. The different methods will not be discussed here. But for a schematic case a simple formula is given for the number of crossings on a single line.

CALCULATION OF THE NUMBER OF CROSSINGS

Suppose that on a certain single line at regular intervals two types of trains are running in both directions all day long. The two types of trains are e.g. passenger trains and goods trains, characterised by their different speeds: namely V_p and V_g m.p.h. Further it is supposed that the trains are running continuously with constant speeds, that there is a possibility for crossing at each point where two trains meet each other and that the crossings occur without time-delay. The number of crossings can then be evaluated as follows.

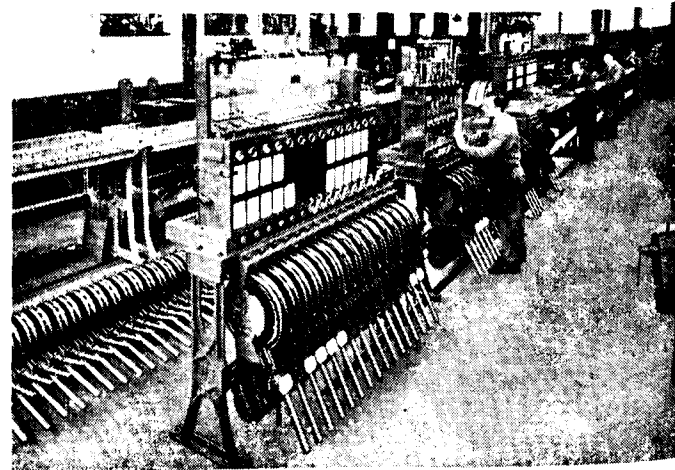


Fig. 1. Mechanical Lever Frame.

The passenger trains moving "up" are travelling at a time distance of t_{p1} hours; the goods trains moving "up" at a time distance t_{g1} hours. The passenger trains moving "down" are travelling at a time distance of t_{p2} hours; the goods trains moving "down" at a time distance t_{g2} hours.

First the number of crossings between the passenger trains moving "up" and the goods trains moving "down" are calculated.

The distance between the passenger trains is:

$$W_p \cdot t_{p1} \text{ miles.}$$

Relatively the pattern of passenger trains each goods train moving in the opposite direction has a relative speed of $(V_p + V_g)$ m.p.h. This means that per hour one goods train crosses the following number of passenger trains:

$$\frac{V_p + V_g}{V_p \cdot t_{p1}}$$

Actually the goods train has passed in one hour a distance of V_g miles. Thus per hour and per mile each goods train crosses with:

$$\frac{V_p + V_g}{V_p \cdot V_g \cdot t_{p1}}$$

passenger trains.

Averaged per hour 1 goods trains pass any given part of the track. Thus the total number of crossings between passenger trains moving "up" and goods trains moving "down" per hour and per mile is:

$$\frac{V_p + V_g}{V_p \cdot V_g} \cdot \frac{1}{t_{p1} \cdot t_{g2}} \quad (1)$$

In the same way the following formulæ can be derived.

Total number of crossings between goods trains moving "up" and passenger trains moving "down" per hour and per mile:

$$\frac{V_p + V_g}{V_p \cdot V_g} \cdot \frac{1}{t_{p2} \cdot t_{g1}} \quad (1a)$$

Total number of passings between passenger trains and goods trains moving "up" per hour and per mile:

$$\frac{V_p - V_g}{V_p \cdot V_g} \cdot \frac{1}{t_{p1} \cdot t_{g1}} \quad (2)$$

Total number of passings between passenger trains and goods trains moving "down" per hour and per mile:

$$\frac{V_p - V_g}{V_p \cdot V_g} \cdot \frac{1}{t_{p2} \cdot t_{g2}} \quad (2a)$$

Total number of crossings between passenger trains moving "up" and passenger trains moving "down" per hour and per mile:

$$\frac{2}{V_p} \cdot \frac{1}{t_{p1} \cdot t_{p2}} \quad (3)$$

Total number of crossings between goods trains moving "up" and passenger trains moving "down" per hour and per mile:

$$\frac{2}{V_g} \cdot \frac{1}{t_{g1} \cdot t_{g2}} \quad (3a)$$

The overall total of all crossings and passings can be obtained by adding the formulæ (1)–(3a).

The six formulæ contain all the same factors. Assuming a fixed ratio between V_g and V_p it is clear that the total number of crossings is inversely proportional to the speed of the trains and directly proportional to the square of the frequency of the train movements (the frequency is inversely proportional to t_p and t_g and it is assumed that the frequencies for both directions are altered in the same ratio).

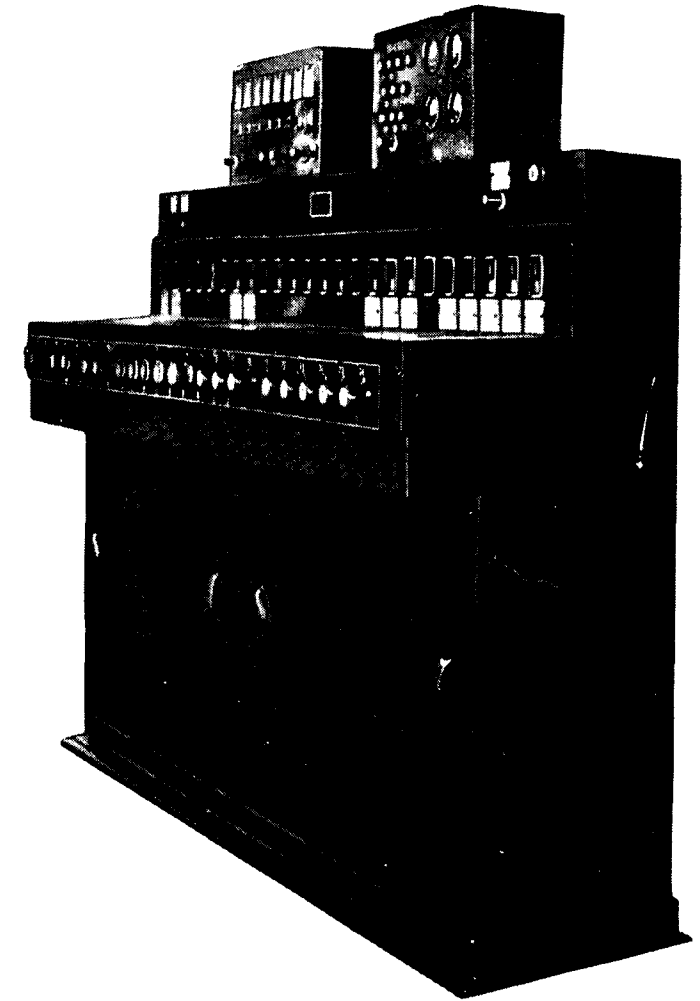


Fig. 2. Electrical Power Frame.

From the formulæ (1)–(3) can be derived the maximum distance between two crossing stations in order that no train needs to stop. This maximum distance can be calculated by putting into the formulæ the condition that only one crossing occurs during a space of time equal to the maximum time distance of the relative series of trains. Thus e.g. from formulæ (3) can be calculated, assuming that $t_{p1} = t_{p2} = t_p$:

$$1 = \frac{2}{V_p} \cdot \frac{1}{t_p^2} \cdot D_{\max} \cdot t_p$$

This can be reduced to the evidential result:

$$D_{\max} = \frac{1}{2} \cdot V_p \cdot t_p \quad (4)$$

In the same way a more general result can be derived from formula (1):

$$D_{\max} = \frac{V_p \cdot V_g}{V_p + V_g} \cdot t_{\min} \quad (5)$$

in which $t_{\min}$ is equal to the smallest value of the actual time-distances t_p and t_g .

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April 1957

THE INDIAN RAILWAY ENGINEER

41

From the formulæ (4) and (5) it is clear that the maximum possible distance between two crossing stations is inversely proportional to the frequency of the train movements. However, this influence can be completely or partly compensated by increasing the speed to which the distance is directly proportional.

For the above given calculations it is assumed that the crossings occur without time delay. In the actual case one of the trains will lose time due to stopping and handling of the signalling system. However, this time delay can be incorporated in the so-called block-speed of a train, which is the averaged speed calculated from the distance between two stations and the time elapsed between entering station 1 and entering station 2, thus including e. g. the delay due to stopping and operating of the signalling system at station 1 to let pass an opposite train.

If from a given time-table these block-speeds are calculated for the trains then with these speeds the above given formulæ can be used and will it be possible to get an approximate impression about the actual status and possibilities of a given line.

From the above given conclusions drawn from formulæ (1) — (3) and from formulæ (4) and (5) it is clear that increasing the block-speed of the trains is an important point to increase the capacity of a line and increasing the block-speed means besides increasing the running speed decreasing time-delay necessities for handling the signalling system at the crossing stations. Therefore it is very much worth while to pay close attention to the signalling system when a decision has to be taken regarding the possibilities of certain single lines.

SIGNALLING SYSTEMS FOR SINGLE LINE CONTROL.

Besides the requirements of quick operation every signalling system has to fulfill the requirements concerning the safe controlling of train movements. These latter requirements will be more severe with faster and busier railway traffic. In the earlier years these requirements could be met by introducing communication between the cabin men at the ends of the lines by telegraph or telephone. With increasing speed and frequency it is more stringent to eliminate the possibility of human errors. This is the aim of every signalling system.

Different systems were developed. At first token-systems were introduced, which still are in use in some countries. However, the token-system is only correct

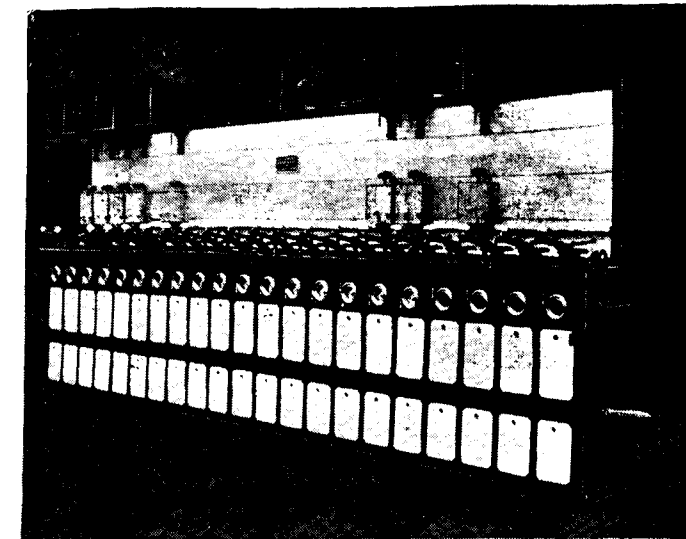


Fig. 3.

on principle in its original form, with one token (staff or tablet) available for each track of a single line to which this token relates. In that case this token is an incontestable indication to the driver who receives it that the relative track is clear and that he is authorized to enter that track. As soon as more tokens are used for one and the same track the safety of the line control depends upon the reliability of the cooperating token instruments at each end of the track that at any moment only one token can be out of the instruments. If this type of token-instruments is accepted, it is reasonable to think over whether it will be possible to use other type of electric interlocking instruments, using no tokens.

An argument that often is raised to indicate an advantage of using tokens is a juridical point. The token can be used to prove that a driver has passed a starting signal in stop position, when driving on a given track he has not in his possession the corresponding token. However, the token itself does not prove anything in that case as regards the position of the signal. For that purpose an interdependency should exist between the token-instrument and the control of the starting signals. In that case again the reliability of the multiple-tokens instrument is the decisive point in order that only a token can be released from the instrument if the signal is cleared. However, it will be difficult to prove that the driver did not start after the signal was cleared, but before the token was handed to him.

The principle difficulty with the latter type of questions is the fact that it is untenable to use signals and tokens beside each other as equivalent means to authorize the driver for certain actions. When leaving a station a token must be handed to the driver and the starting signals must be cleared. But approaching the

next station the token which the driver has in its possession does not prove anything as regards the question that might arise, whether the driver did pass the home signal in "cleared" or in "danger" position.

The following facts are clear :

- (a) an interdependency can be introduced between the position of the starting signal and the release of a token for a given track ; practically it is impossible to achieve that the moment at which the signal is cleared coincides with the moment the token is handed to the driver.
- (b) when driving on a given line there is no relation between the token the driver has in his position and the position of the home signal he approaches ; and especially with the train running the chance to neglect a signal is greater than with the train at stop before a starting signal.

From these points the conclusion is justifiable that it is advisable to use only one type of indications by eliminating the tokens and instructing the drivers that they have to mind categorically the signals as the only indications regarding the movements of their trains.

In that case there must be an interdependency between the block instruments and the signals. These so-called token-less lock and block systems are in use in many European and other countries. Such a system is also manufactured by the Netherlands Machine works "Alkmaar", which system is in use in the Netherlands already over tens of years without any reported accident due to failure of the block instruments. A brief description of this system is given in the following paragraph.

TOKEN-LESS LOCK AND BLOCK WORKING FOR SINGLE LINE CONTROL

The present lock and block system is of the so-called closed type. This involves that in the normal position of the block apparatus at both ends of a certain section of a single line with no train in the section the starting signals at both stations are locked up in the danger position.

To guarantee a safe control of single line traffic the signalling system must fulfill the following principles :

- (a) it must be impossible to admit trains from opposite directions into the same section simultaneously ;
- (b) a train must have left a section before a train from the opposite direction can receive permission to enter the section.

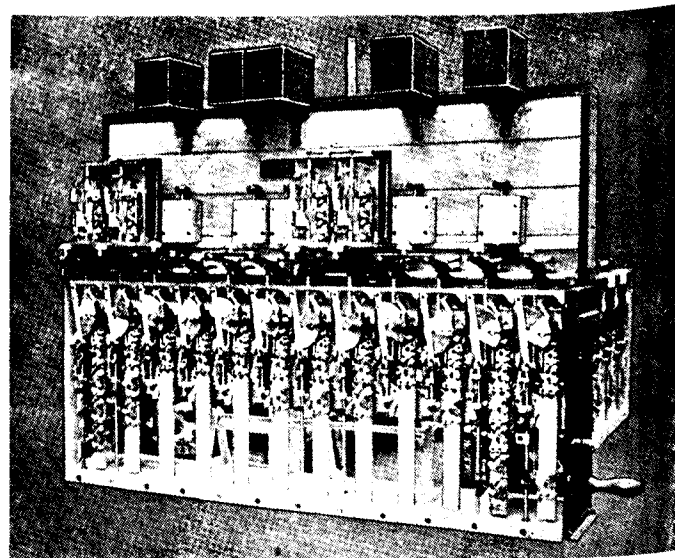


Fig. 4. Lock & Block apparatus (Front cover removed)

These requirements can be met by introducing in the operation of the lock and block system the following features :

- (1) the starting signal at station A can only be cleared once after receipt of permission from station B and this permission can only be given after the previous train has left the section (A and B are the stations at the ends of the considered section) and inversely ;
- (2) when station B gives permission to A the starting signal at B is locked up in the danger position, and inversely ;
- (3) a second permission for the next train can only be given after the first train has left the section ;
- (4) the necessary release of the block instruments to make possible a new permission is only effectuated by direct intervention of the train itself when leaving the section.

The above-mentioned principles (a) and (b) are the special requirements to be fulfilled for single line control beside the normal requirements to be fulfilled for trains running in the same direction on either single or double line.

The possibility to enter a station for trains moving in the same direction depends upon the signalling lay-out of the considered station. The condition that no train can enter the preceding section before the preceding train has left this section is already incorporated in the above-mentioned features of the present lock and block system.

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When a train has left the station the cabinman has to block behind the train; to be able to perform this operation it is required that the starting signal is reset to danger. This will also be required by the interlocking in the lever frame when other operations (resetting of points, clearing of highway crossings a.s.c.) must be done after the train has left the station. If no such additional operations have to be performed and it is wanted to prevent that the cabinman would wait too long to reset the starting signal it is possible to install a special device at the track near the starting signal by which this signal is automatically reset to danger as soon as the train has passed.

It is clear that the lock and block instruments have to be installed and operated in connection with the mechanical lever frame or electrical power frame used for the signalling lay-out of the relative stations. A great advantage of the lock and block apparatus built by "Alkmaar" is that it can be mounted on top of the lever frame of the same make. Thus the complete control apparatus requires a very limited space and the connection between lock and block apparatus and interlocking frame is maintained under all circumstances. Fig. 1 shows the assembling of mechanical lever frames with lock and block apparatus mounted on top of the frames. Fig. 2 gives an example of the type of electrical power frame as built by "Alkmaar" in connection with which the lock and block apparatus also can be used.

The lock and block apparatus can be assembled according to the specifications of every typical set of rules. An overall view of a complete lock and block apparatus is given in Fig. 3. Another apparatus with the front cover removed is shown in Fig. 4. The lock and block apparatus consist of several units, so-called "locks". The locks comprise a relay, contacts, interlocking pins, an operating knob and a visible indication. The arrangement of the contacts and pins can be adapted to the required type of mechanical or electrical interlocking with the lever frame, and to the cooperation with the lock and block apparatus of other stations. The locks can be in two positions, either free or locked shown by the position of the visible indication. This visible indication is a metal flag with one part of its surface coloured white and the other red; one of these parts is visible from the outside behind a glass.

To operate the locks an alternating current (18 cycles) is used, generated by a hand-generator built-in in the lock and block apparatus. Due to this hand-generator the system is completely independent from any local power supply. By pressing the operating knob of a lock typical circuits are closed; then by generating current

the relative locks of the lock and block apparatus at both ends of a section are made free or locked according to the installed system.

For the electrical connection between the lock and block apparatus of two stations only two wires are required besides the earth as return. The same wires and the hand-generator can be used to exchange bell-codes by pressing special bell-contacts mounted on the panel of the lock and block apparatus without any possibility to disturb the position of the locks.

The simplest lay-out of lock and block apparatus to control a single line section between the two stations A and B is shown in the schematic drawing of Fig. 5. Each lock and block apparatus consists of three normal locks, according to their function indicated as: line clear, line blocked, train on line. Above the "train-on-line" lock is mounted a special lock: the treadle-lock. This lock cannot be operated separately: the treadle-lock is electrically connected with the treadle near the home signal and mechanically connected with the "train-on-line" lock. The knobs of the "line-clear" lock and the "line-blocked" lock are mechanically interlocked in

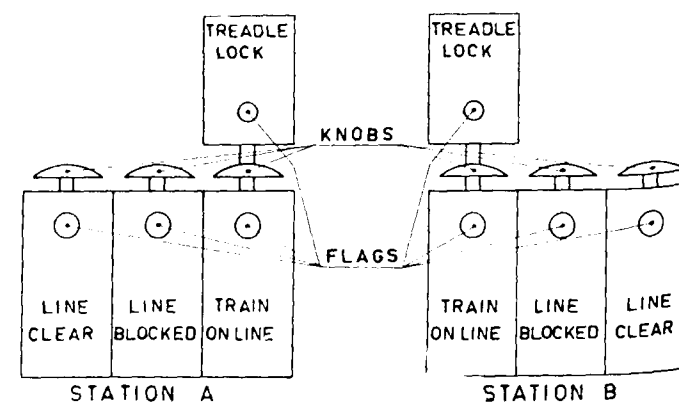


FIG. 5

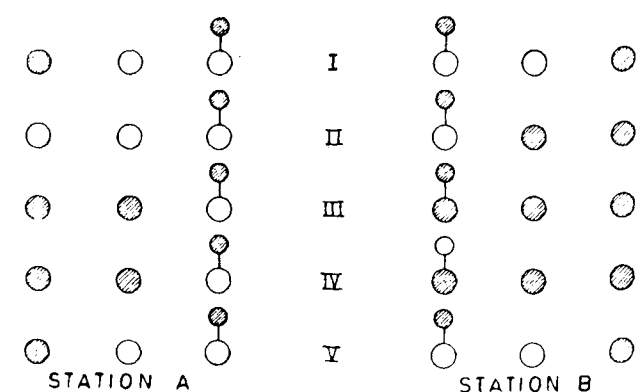
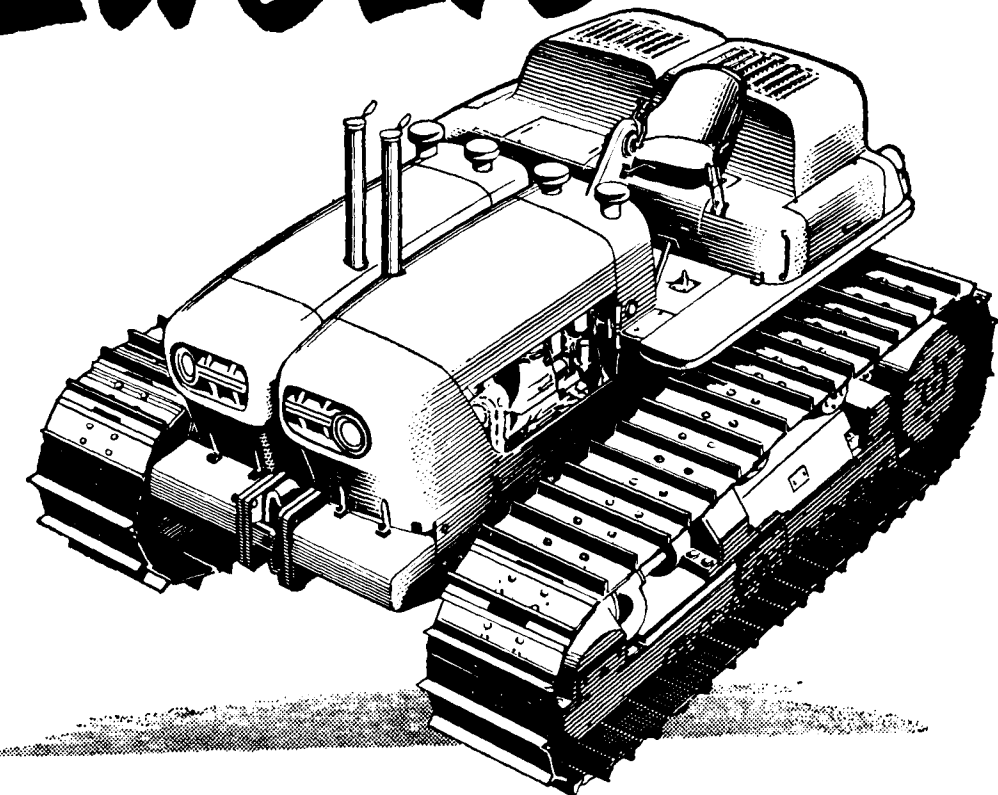


FIG. 6

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such a way that the "line blocked" knob is pressed too if the "line-clear" knob is pressed, but *not* inversely.

Finally the sequence of operations to let a train run from station A to station B will be described. In Fig. 6 the positions of the lock and block apparatus are shown for the different stages by means of the positions of the flags of the locks.

Stage I: normal position. There is no train in the section and the starting signals at both stations are locked up in the danger position due to the fact that the "line-clear" locks are locked. If the cabinman at A wants to send a train to B he asks by bell-code the permission of the cabinman at B.

Stage II: the cabinman at B gives his permission to the cabinman at A to let a train go by pressing the knob of his "line-blocked" lock (besides this the cabinman has to turn the hand-generator of course, which is the case with every "lock"-operation to be mentioned hereafter). By this operation the "line-blocked" lock at B is locked and the "line-clear" lock at A is made free. Now the starting signals at A are released and the train can be authorized to enter the section. But it is worthwhile to note that in the lever frame is incorporated a device which guarantees that once and only once *one* of the starting signals can be lowered. After resetting this signal to danger all starting signals at A are locked up in the danger position again. Further it is impossible to give a second permission from either side to let a train enter the section.

Stage III: after the train has left station A the cabinman at A blocks behind the train by pressing the knob of his "line-clear" lock to indicate to B that the train is on its way. However, this blocking is only possible if the starting signal is reset to danger. By giving this indication the "line-clear" lock and the "line-blocked" lock at A are locked and the "train-on-line" lock at B is locked.

Now a train is on line from A to B. Not any operation can be done now before the train has left the section. For the present case this involves that the train must have entered station B.

Stage IV: the train can only enter station B when the home-signal is lowered. When the train has passed the home-signal and enters the station the treadle is operated, which causes the "treadle" lock to be released.

Stage V: the cabinman at B has to inform the cabinman A that the train has entered at B in order that the normal position of the lock and block apparatus is restored again and a new permission from either side might be given. However, the indication that the train has entered at B can only be given, if these two conditions are fulfilled: one of the home signals at B must at least once be lowered and reset to danger again (checked by a special device in the lever frame) and the train must have passed the treadle (checked by the "treadle" lock). Then the mentioned indication can be given by the cabinman at B by pressing the knob of his "train-on-line" lock. By this operation at A the "line blocked" lock is released, at B the "treadle" lock is locked and the "line-blocked" lock and "train-on-line" lock are released, in which way the original normal position of both lock and block apparatus is restored again.

CONCLUSION

The described scheme to control single line railway traffic is only an example. The constructive principles of the mentioned lock and block apparatus and the lever frame of the corresponding make are such that the interlocking scheme to be incorporated in the machines can be adapted to every type of signalling lay-out, which uses signals as the only means to instruct the drivers of the trains.

The discussed lock and block system has the big advantage compared with the token-system that much less time is required to let a train enter, stop and leave again a certain station.

For instance if a crossing has to take place at a given station. In case of the token-system the stop-train has to arrive at the station in due time before the through-train comes in order that the token from the stop-train can be brought to the token exchange-post for the through-train. This may require 6 to 10 minutes. After the through-train has passed the station a delay-time of the same magnitude will appear before the token of the through-train is handed to the driver of the stop-train and the starting signal is lowered. Thus the total delay for the stop-train will amount to at least 12 to 20 minutes.

On the other hand in the case of the described lock and block system only $2\frac{1}{2}$ minutes would be the necessary delay for the stop-train to let a through-train pass. This is mainly due to the fact that with this equipment all signals, points and lock and block instruments can be

(Continued on page 47)

Rail Traction for India—Steam, Diesel or Electricity?

By R. Vanchinathan

Chief Electrical Engineer, Northern Railway

The U.S. Railways switched over to diesel-electric traction from the traditional steam traction as early as 1940, and they now seem quite satisfied with the change. The reasons which promoted the change, were diesel's ability to haul heavier loads faster; and its better brake-thermal efficiency and concomitant economy in fuel consumption.

THE hauling capacity of a diesel loco is much better at low speeds and the starting pull is over double that of a steam loco of equal horse-power rating. Therefore, for shunting purposes, particularly, the diesel loco is admittedly the most effective type in view of its high accelerating ability and greater availability for service.

Even for main line service, a diesel loco is more economical than its steam counterpart. Statistics indicate that about 35 to 70 diesel-electric locos can do the work of 100 steam locos, depending upon utilisation.

As a result of standardisation and mass production methods the cost of a diesel-electric loco for American service is now only 1 to $1\frac{1}{2}$ times that of a corresponding steam loco as against 3 times in the early days.

Another advantage of a diesel loco over the steam loco is the absence of water supply problems. This is particularly valuable in arid regions.

Further, the diesel loco is comparatively easily manoeuvrable and needs fewer men to man it.

Electric supply for train lighting in the case of passenger services can be conveniently given from the

diesel-electric loco itself, whereas with a steam loco-driven passenger train a more expensive arrangement is necessary for train lighting.

The only item which calls for a higher expenditure in the case of diesel locos, as compared to steam, is in respect of repairs, maintenance and depreciation. The normal life of an oil engine may be taken at about 15 years or so, whereas a steam engine with suitable repairs to its boiler, may be expected to carry on for 30 to 35 years without losing much of its efficiency and service reliability. The repair charges are somewhat higher for diesels, particularly in the later years of the machine. However, the exact data is not yet available as diesel locos now functioning in America are still new.

Nevertheless, on the whole the American railways are quite satisfied with the diesel-electric locos. In fact the cost of the changeover was recovered in the first six to eight years through operational economy. In the case of shunting locos, diesels have shown even better financial returns by paying for themselves within three to five years.

But this excellent financial result in favour of diesel is mainly due to the very low cost of oil in America as compared to coal.

(Continued from page 46)

operated from one central point and without great effort. Three minutes is the actual crossing time with which time-tables are scheduled in Holland if necessary.

The influence of this difference in delay times can be calculated as follows. For a given distance corresponding to a riding time of one hour the same type of trains would have averaged per train a block-speed (see above) 7 to 12% lower in case of the token system than in case of the lock and block system. According to formula (4) this means that the time-distance between successive trains has to be greater in case of the token system. The result is that for the considered distance the

frequency could be increased by 7 to 12% if lock and block system was used instead of the token system.

This difference increases considerably with smaller distances and in case the actual delay time due to exchange of tokens would appear to be greater than the assumed values.

Only some considerations are given in the preceding paragraphs concerning the problem of single line control. Every particular case will require a more detailed study, but possibly some points may be of any use in further discussions regarding this subject.

CHOICE FOR INDIA

Conditions in India are, however, somewhat different owing to scarcity of oil and its high price. High speed oil costs about 20 annas per (imperial) gallon while coal, which is available in plenty, costs anything from Rs. 20 to Rs. 50 per ton, depending upon the load from collieries.

It will not pay us in India to switch over as a general policy from steam to diesel traction unless the oil cost can be brought down. However, diesel may be quite a sound proposition in cases such as: (i) shunting in large marshalling yards; (ii) railcars; (iii) hill or other sections with high gradients; (iv) in arid regions; (v) in areas far away from collieries, etc.

For India with increasing traffic density, the future lies in straight-electric traction and our endeavour

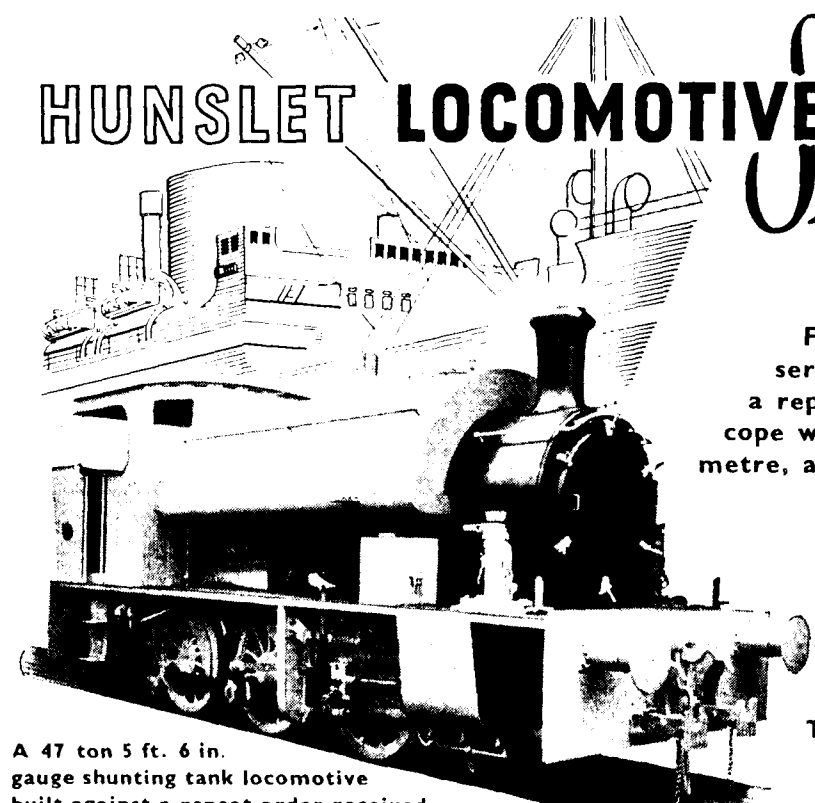
should be to obtain reliable supplies at as low a rate as possible and also try and adopt the latest techniques in electric traction (for example A. C. traction) with a view to effect further economies. Next in importance comes both steam and diesel-electric traction system as a close tie, and the matter of selection, therefore, requires careful scrutiny and consideration.

Here, a note of caution is necessary. Our objective should not always be confined to financial savings only. Emphasis should also be laid on better transport service (by way of safety, reliability, quickness and comfort) to our customers and better working conditions for the operating staff. Even if it costs a bit more, it does not matter, provided the traffic can bear it and the service rendered to all is better and with indigenous materials and labour as far as possible.

(Abridged from *Indian Railways magazine*)

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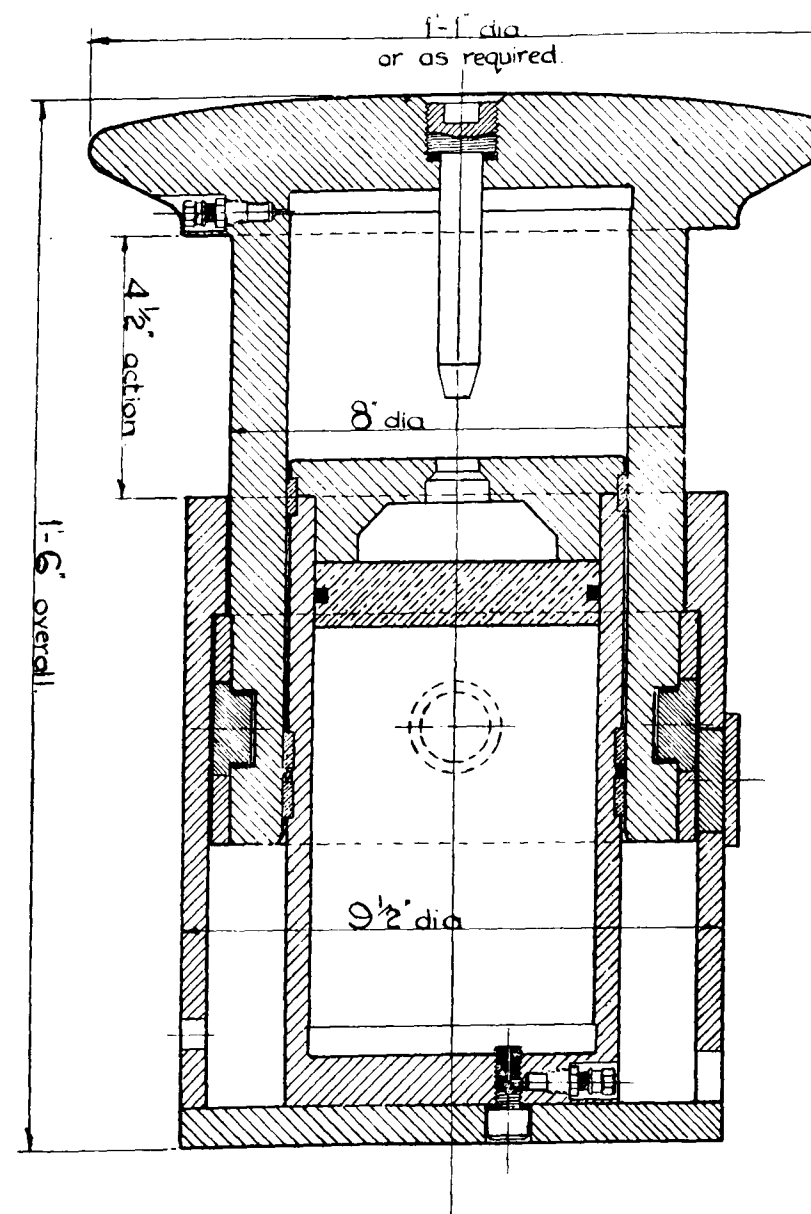
Demonstration & Testing of Hydro-Pneumatic Buffers

It is questionable whether the travelling public give much thought to the comfort which is afforded to them by the use of reliable types of buffers on Railway rolling stock.

The function of a buffer is to absorb shock and thus minimize as far as is practically possible damage which may be caused to the vehicles and their

contents—passenger comfort and safety being of prime importance.

There has been a gradual evolution in buffer design over the past 100 years. Uptil comparatively recently buffers have been fitted with Steel or India Rubber Springs and it has not been possible to obtain a buffer which with such springing elements was capable of



Sectional drawing of Buffer undergoing test.

absorbing within its springing capacity the energy transmitted by moving vehicles at rates exceeding three or four miles per hour.

The advent in recent years of the greater application of Pneumatic and Hydraulic equipment in engineering fields has demonstrated that by the use of devices on these principles far greater shock absorption is possible—sufficient in fact to absorb all shocks on rolling stock likely to be encountered during normal running.

Messrs. George Turton Platts & Co., Ltd., of Wincobank, Sheffield, one of the famous manufacturers of buffers, have devoted considerable study and research to the problem of carrying out extensive tests on a specially constructed test rig with electronic recording apparatus and achieved complete success in designing a buffer capable of meeting all normal requirements.

The following information fully describes these new types of buffers which we venture to suggest will be extensively used on future rolling stock.

Programme arranged to demonstrate developments in high energy absorbing Hydro-pneumatic Buffers and electronic equipment to provide measurement of buffer performance and basic design data.

Type of Stop Block 240 tons concrete mass

Testing Bogey Fabricated steel on roller bearing wheels

Net weight 7½ tons

Gross weight 13 tons to simulate 26 tons moving mass.

Speed Range 0–25 m.p.h. approx.

Rail Track Incline of 20°, levelling out 3 feet before buffer impact

Electronic measurement of:

1. Bogey Speed M. P. H.
2. Buffer Stroke Inches
3. Reaction Load at intervals of stroke and Maximum Tons
4. Energy Absorbed Inch tons

Part 1. Tests on two H-Pn buffers (each 4½" stroke), one mounted on bogey and one mounted on stop block.

RECORDED RESULTS OF TESTS

TABLE I. January 11th, 1955. Temperature 27.8° Fah.

Run No.	M. P. H.	Re-active Load Tons	Energy Absorbed Inch Tons	2 × 4½" Available Stroke Effective Stroke	Buffers
1	3.74	14.3	73	7½" plus	2 H-Pn
2	6.00	29.1	187	8" plus	"
3	8.20	52.5	350	8½"	"
4	10.30	80	552	8½" plus	"
5	12.00	109	750	8½"	"
6	13.66	136	970	8½"	"
7	3.74	36.4	73	8½"	1 H-Pn & 1 IR Spring
8	6.00	89	187	8½"	" "
9	7.20	121	270	8½"	" "
10	1.62	within	13.6	9" bare	2 IR Spring
11	2.25	10	26.3	9" bare	"
12	2.60	tons	35.7	Full metallic contact	"
13	2.88	100	43.2	" "	"
14	3.44	223	61.5	" "	"

FIG. 1

TABLE II. January 12th, 1955. Temperature 28.9° Fah.

1	3.54	12.2	65.2	8"	2 H-Pn
2	5.86	27.4	179	8" plus	"
3	7.90	51.2	325	8½"	"
4	10.00	81.0	520	8½"	"
5	11.64	114	705	8½" plus	"
6	13.66	134	970	8½"	"
7	14.20	159	1040	8½"	"
8	3.62	31.9	68	8½"	1 H-Pn & 1 IR Spring
9	5.77	87.7	174	8½"	" "
10	7.00	121.0	257	8½"	" "
11	2.60	30.7	35	9" metallic contact	2 IR Spring
12	3.44	198.0	61.5	"	"

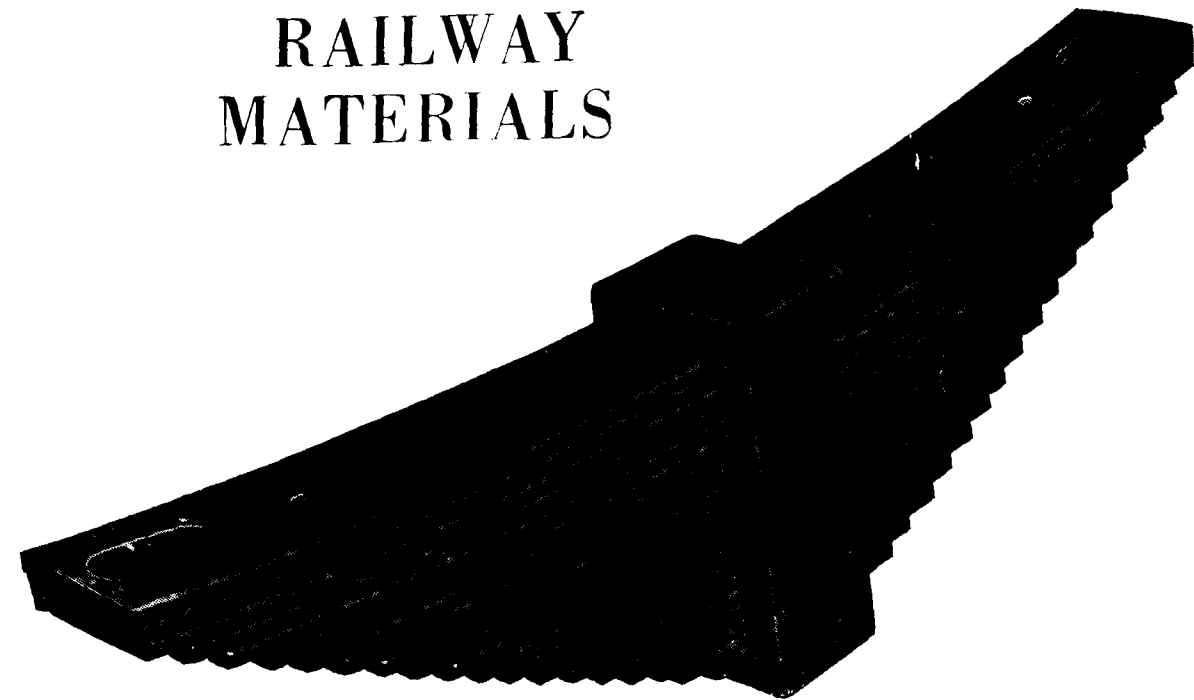
FIG. 2

TABLE III. January 13th, 1955. Temperature 26° Fah.

1	3.54	14.1	65.2	8"	2 H-Pn
2	5.96	29.5	185	8½"	"
3	8.10	51.9	341	8½"	"
4	10.20	80.0	538	8½" plus	"
5	12.00	107.5	750	8½"	"
6	14.70	172.0	1060	8½"	"
7	3.58	33.4	66.5	8½"	1 H-Pn & 1 IR Spring
8	5.96	96	185	8½"	" "
9	7.90	151	325	8½"	" "
10	3.09	160	49.5	9" metallic contact	2 IR Spring

FIG. 3

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Part 2. Tests with one buffer fitted with No. 471 standard IR Springs on bogey and one H-Pn buffer on stop block.

Part 3. Tests on two buffers fitted with No. 471 standard IR Springs (each with $4\frac{1}{2}$ " stroke), one mounted on bogey and one on stop block.

Points to which interest is particularly directed :

1. The extremely low recoil energy of H-Pn buffers, only six inch tons, irrespective of impact energy when charged at 60 lbs./sq. inch pressure.
2. High energy absorption capacity of H-Pn buffers compared with spring buffers.
3. Low maximum reaction load of H-Pn buffers even at high speeds, as compared with high maximum reaction load of spring buffers at comparatively low speeds.

Upon completion of the tests at site Mr. A. P. FITZJOHN, the inventor of our Pneumatic and Hydraulic Buffers, described the design, functions and some applications in a short paper as follows :

After proving the preliminary designs were a practical proposition, the object was to produce a buffer of variable capacity that would absorb energy within the effective stroke right up to its maximum physical strength. Very early in the research work two vital features were discovered, quite distinct from the positive sealing against loss of both air and oil.

1. The orifice head of the cylinder must be strong enough not to deflect under the heavy loads imposed by the oil under pressure; any deflection would affect the area of the orifice and the load characteristics. Even .003" difference in the control stem diameter makes a difference of several tons in the final load.
2. The air or buffing cylinder must not only have sufficient strength to withstand the final air pressure when fully compressed, but it must also be capable of sustaining the load imposed by the oil under a pressure much higher than the designed capacity of the buffer, such as would be the case in the event of a collision at 20-30 m. p. h.

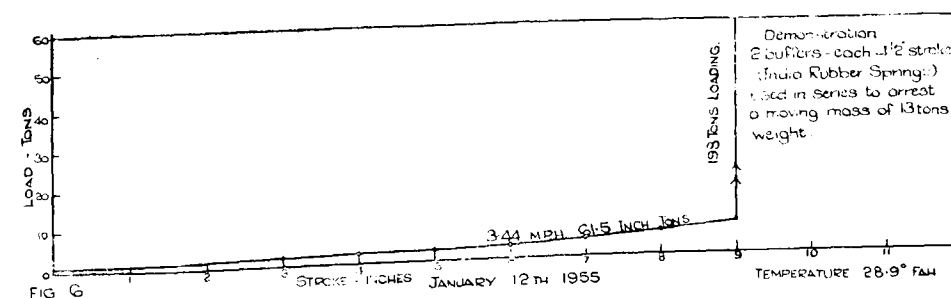
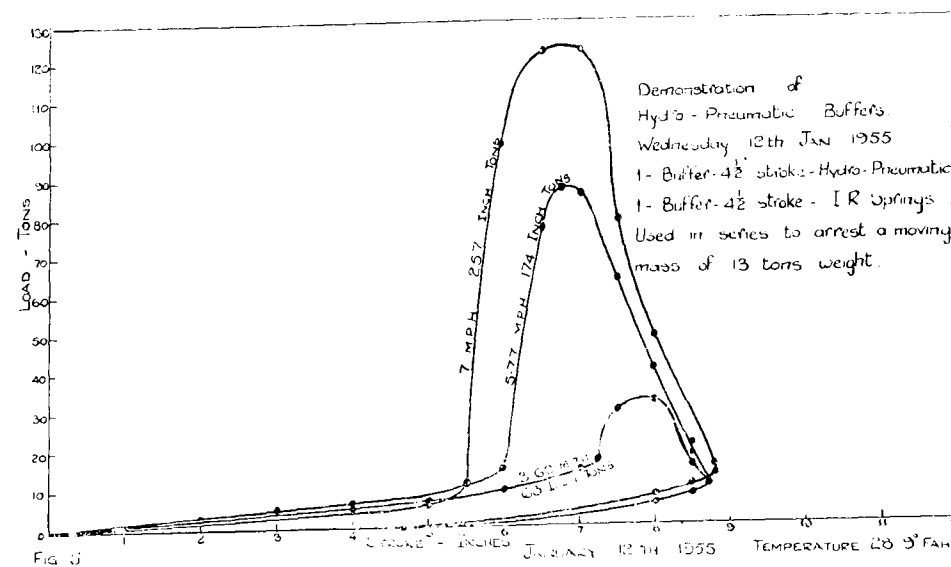
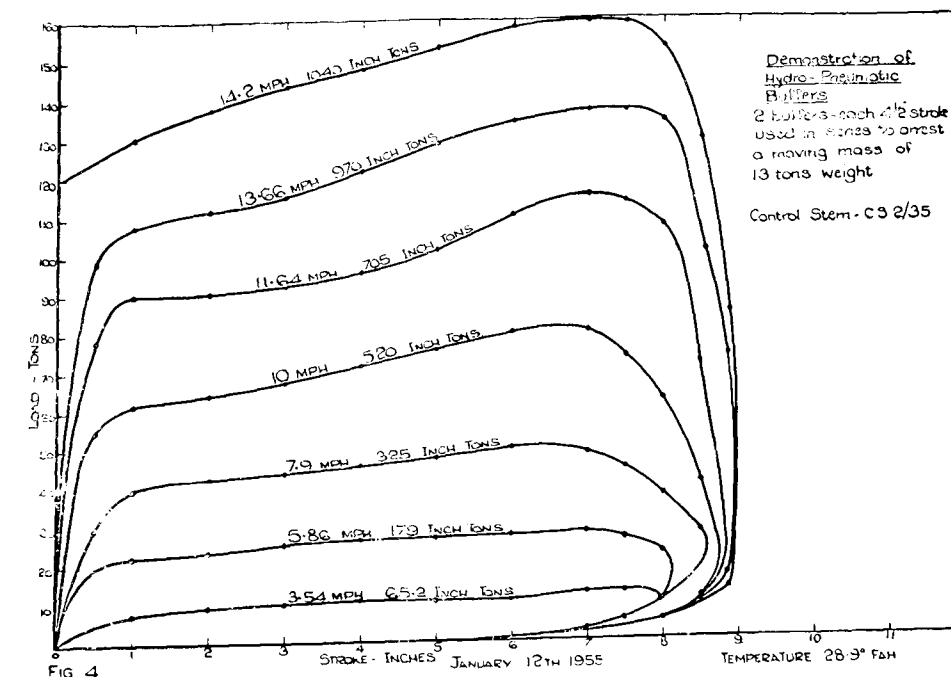
Please refer to the drawing. Inward movement of the plunger is retarded by the oil which must pass through

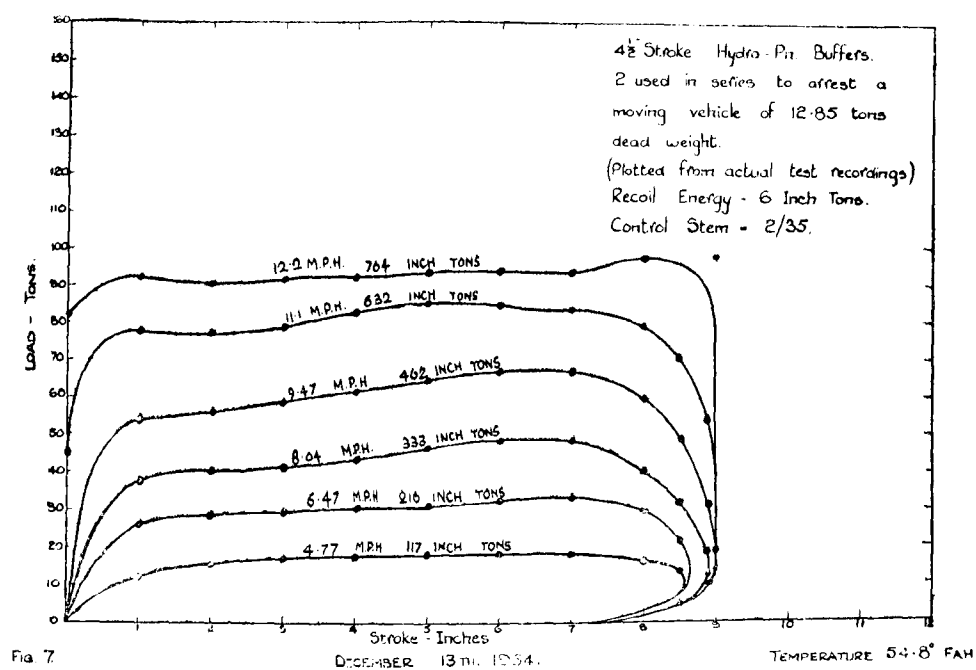
the orifice and the reluctance of the oil to flow through the orifice generates a pressure build-up in the oil cylinder. This pressure over the area of the cylinder bore shows itself as a retarding force to the moving vehicle; conversely, it appears as a load on the vehicle and the body opposing change of motion. The magnitude of the load is proportional to the flow of oil through the orifice and is controlled in practice by careful design of the control stem for the duty the buffer has to perform, i. e., energy to absorb. As the oil flows through the orifice, the floating piston is forced further into the buffing cylinder, thus compressing the air. After the flow of oil has ceased and the moving vehicle has been brought to rest, the air load in the cylinder returns the buffer to the extended position by forcing the floating piston to return the oil back through the orifice into the oil chamber.

The orifice head is secured to the buffing cylinder by means of hollow rivets, which serve the dual purpose of securing the orifice head and providing communication between the buffing cylinder and the annular chamber formed by the clearance between the buffing cylinder and the bore of the plunger. This communication with the annular chamber ensures that the pressure head across toroidal seal is not materially greater than the air pressure in the buffing cylinder, thus the seal is not subjected to the high pressure generated in the hydraulic cylinder. The guiding of the buffing cylinder in the plunger takes place on three automatically lubricated resinoid plastic rings. This assembly permits of generous sliding clearance of the plunger in the buffer case without affecting the necessary close surface contact of the piston and pressure seal. It may be noted that the buffer conforms to the dimensions of the standard R. C. H. hollow plunger buffer, and having the usual clearance between the case and plunger, is free to telescope when buffing on curves.

PERFORMANCE

The graphs, Figs. 4 and 7, show a series of curves obtained from actual electronic test recordings of a pair of $4\frac{1}{2}$ " stroke hydro-pneumatic buffers in series. (Note: The tests and recordings can be repeated on any occasion.) It will be seen that the greater the speed of impact for a given mass, the greater is the load upon the vehicle and opposing structure. It has been proved that the load is approximately proportional to the square of the speed of compression, and since energy is also proportional to the square of the speed, the load-stroke characteristic is approximately rectangular as opposed to the progressive energy curve of all other types of buffers. Likewise, the pressure to which the oil is





The tests were carried out in the adverse conditions of a freezing atmosphere following nights of severe frost, on one night the thermometer registered 20° Fah., as recorded by the Sheffield Meteorological Department. The oil used in the buffers has a pour point of minus 20° Fah. and the variations in viscosity are reflected in the reactive loads at varying rates of compression. Comparison of graphs, Figs. 4 and 7, show that for a fall of approximately 30° in temperature, i.e., from 55 to 26° Fah. there is an increase in the reactive load of about 10%.

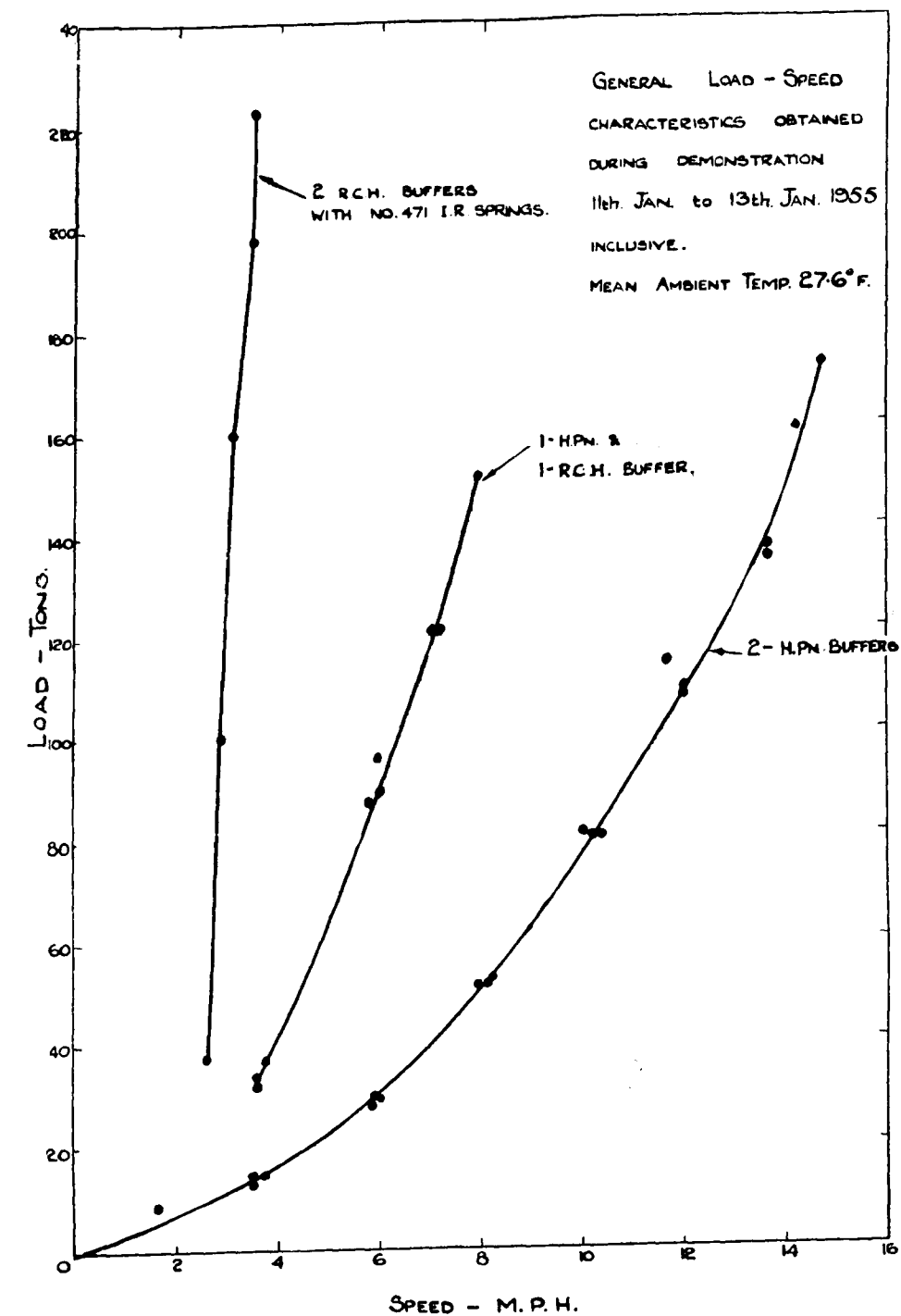
The electronic amplifier and pen recorder employed are regarded by the University Physical Laboratories as being the best and most efficient available, but it might be mentioned that under violent impulses resulting from high speed impacts, the moving pen in the recorder can, due to the inertia of the pen arm, overswing and indicate up to 6% in excess of the actual load. Also, the load cell carrying the strain gauges was calibrated statically on a load testing machine (A.I.D. approved), whereas in testing service it is subject to dynamic loads; the latter at high speed being of the order of 5% higher than the static loads. It is, therefore, safe to assume that the actual reactive loads, due to these two factors, are 10% less than shown in the tables and graphs.

subjected is also proportional to the load. The buffer is nominally a constant stroke unit and above some particular speed full stroke is always achieved. However, depending upon the pressure of air in the buffing cylinder, full stroke is not reached below that speed, and it is obvious that during the stroke the air load is increasing, also to obtain full stroke the applied load must always exceed the air load plus hydraulic and frictional losses. Hence, at very low speeds the hydraulic reactive load is small and the characteristic becomes an adiabatic compression curve. Under very light loads the buffer is only compressed to a point along the stroke where the pneumatic load balances the applied load.

It may be seen on the graphs that the pneumatic slow closure curve intersects each hydro-pneumatic

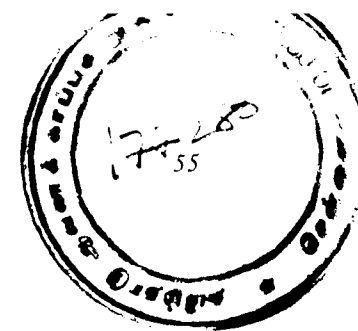
curve along its maximum stroke, and incidentally the pneumatic curve represents the recoil energy given back. The curves do show quite clearly that a hydro-pneumatic buffer designed for a given speed will accommodate any load and energy below its designed maximum capacity. In the event of a buffer being struck at a higher speed than that for which it is designed, it is still capable of absorbing the energy; the load, however, will increase proportionately with the square of the speed and adequate factors of safety should be allowed in designing the various parts, since only the physical strength of the buffer and mountings will decide the upper limit of the range of use.

This type of buffer is a development of our hydraulic dock buffers which are giving unqualified satisfaction in the berthing of large ships. Their great and



exceptional strength is proved by the fact that in over the 1,000 full buffer strokes required in the research to establish accurate data and formulae for the design of buffers for any particular duty, only one pair of buffers were employed. The component parts are as new, notwithstanding that over 750 impact loads between 150 and 200 tons have been sustained.

The science of hydraulics is not one of exact mathematics and, as so often happens, there is a difference between theory and practice. We are continually being called upon for buffers for a variety of applications, i.e., some of the buffers now in hand are for E. O. T. cranes of 1,080 tons gross weight, travelling at 3 m. p. h.; ingot chariots 125 tons gross weight and



maximum speed 12 m. p. h.; 30-cwt. mine cars at 1½ m. p. h. with practically no recoil; and often a low rate of deceleration is specified. With machines and vehicles such as these the weight is unsprung, also the end stops are rigid and unyielding. It will be obvious that heavy masses at low speed require different treatment to light weight bodies at high speeds, and it was to solve such problems by testing and analysing the performance of buffers under dynamic loads, that we were induced to install the test and recording equipment to-day witnessed. The equipment has been used to great purpose in the establishment of empirical formulæ to enable control stems for hydraulic buffers for any particular purpose to be designed with accuracy, and so eliminating trial and error methods. Size, accuracy and form of control stems are vitally essential to ensure that the flow of oil at extremely high pressure through a small orifice is continuous throughout the buffer stroke for the designed impact speed, and to avoid high peak or indeterminate reaction loads.

As buffers are our principal business it is natural that we should take notice of anything appertaining to them. It has been observed that a number of run-in accidents on passenger platforms occurred last year in which passengers were injured, and we feel that much could be done to minimize the effect of such accidents by fitting adequate buffers that would absorb the energy of trains of 3-400 tons running in at speeds up to 7 or 8 m. p. h. without violent rebound or recoil. The platform space in a great many instances is so restricted as not to permit of the installation of long stroke buffers on the stops and it may be interesting to learn that there are hydro-pneumatic buffers which will absorb 3,000 inch tons with 12 inches stroke and an overall length of 44 inches, viz., twice the length of a standard loco. buffer. If a pair of such buffers were installed on the stop and a pair of 4½" to 5½" stroke hydro-pneumatic buffers on the front of the loco., there would be capacity for absorbing upwards of 8,000 inch tons energy and we are confident a large measure of safety would be achieved.

With a train running into stops with existing buffers at 5 m. p. h., the deceleration cannot be less than 325 feet per sec./per sec. or $10 \times g$. at the loco. end of the train, but with hydro-pneumatics the deceleration would be of the order of 20 feet per sec./ per sec., viz., $0.66 \times g$.

On these remarks and the tests witnessed, comments and criticism are warmly invited.

DISCUSSION

Mr. Gammon (British Transport Commission) opened the discussion and in the course of his remarks said that it had not been possible to keep pace so far as shock absorption is concerned with the increased capacity of wagons during the past 30 to 40 years. An increase in the capacity of springs used for buffing purposes had, however, been made, but had been limited due to the restricted space available in the underframe for spring mechanism, but Railway Engineers realized it was not possible to absorb the full energy of high speeds and heavy impacts. He felt that the job was being tackled in the right way, that the trials witnessed were admirable and gave quite a lot of technical data of a comparative character.

The tests witnessed were, however, of a static nature approximating the shocks encountered when running into terminal and siding stops and did not quite convey what could be expected from a test under normal working conditions, fly shunting in marshalling yards, etc., and he stated that arrangements for carrying out shunting tests would be made. The full worth of hydro-pneumatic buffers could only be assessed by testing under such conditions which simulated those encountered in service; it was also emphasized that it would be necessary to have an appreciation of the initial cost set off against maintenance both of the buffers and of the wagons, due to the additional protection which the buffers would afford as compared with existing types of buffers, before the full value to the Railways could be demonstrated.

Mr. Gammon also raised the question of shock absorbing wagons, and pointed out that if hydro-pneumatic buffers were fitted in addition to a central pneumatic shock absorbing unit, it would make an expensive set-up. He therefore asked the author if it was considered 4½" stroke hydro-pneumatic buffers alone would achieve the same results as are now obtained with shock absorbing wagons having sliding bodies and ordinary type buffers. Further, if the stroke was increased to, say, 9", would it answer the same purpose?

He also mentioned that with heavy impacts a buffer of the type under test would act very satisfactorily, but he suggested that at slow speeds and the normal light impacts imparted when trains are started or stopped the buffer would be rather "dead".

Mr. Rock (Southern Region) stated that he and his associates were particularly interested in the test from

the buffer stop angle, they were impressed by the high rate of energy absorption, and in particular the extremely low recoil energy given back after full compression of the buffers. This feature is a distinct advantage for passenger trains.

Mr. Shorter (North-Eastern Region) in his remarks referred to the question of diesel and electric locomotives running into terminal stops, and expressed the opinion that there was a great future for a buffer stop capable of retarding and efficiently arresting this type of locomotive. He had observed that there was no metallic shock at the end of the stroke, even at the higher speeds of impact, and he thought this feature would be effective in safeguarding delicate mechanisms.

Mr. Chidlow voiced the great interest in which he and his colleagues from the London Midland Region had witnessed the demonstration, and in referring to the remarks of a previous speaker said it would be helpful to have results of tests and the performance of hydro-pneumatic buffers in service conditions.

Col. Read (British Transport Commission) referred to the possible loss of air pressure after buffing had occurred, and the effect any loss may have on the resistance by the buffer, as apparently the resistance was partly a result of the air pressure—what in fact would result if the original (initial) air pressure were reduced from 60 to 30 lbs. per square inch?

Mr. Chanter (London Transport Executive) asked if any recoil at all was necessary in buffers, and expressed the opinion that for passenger work the elimination of recoil would be an advantage.

Mr. Bingham (London Transport Executive) asked if the "sleeve lock" plugs could cause jamming of the plunger in the case. He also asked what would occur if the buffers were compressed when a quantity of oil had escaped from the oil reservoir, or in the event of an insufficient quantity being charged in the first instance.

Mr. Oaten (*Railway Gazette*) asked for details of the comparative cost of maintenance of hydro-pneumatic buffers as compared with the standard types at present in service. He also asked for the symptoms that indicate servicing of the buffers is necessary, and later he asked if in the design of this buffer it would be possible to achieve simultaneous metal-to-metal contact at the front and rear of the plunger.

Mr. Roper (*The Engineer*) requested information on the effects of side loads on the buffer.

Mr. Turner (Southern Region Research) said that as the hydro-pneumatic buffer is a high duty buffer he considered that the buffer guides would probably be compelled to take greater loads during operation than the conventional spring buffer, in so far as the latter type goes solid at a comparatively low load. Mr. Turner also suggested that the low recoil energy characteristics might be of considerable advantage in shunting, as at the present time in fly shunting when two wagons collide, the driven one moves on and the driver usually stops. He did feel it was likely that after impact two wagons would probably progress together if fitted with hydro-pneumatic buffers.

Mr. Collins (Eire) referred to the possibility of charging too great a volume of oil into the buffer and asked what the effect would be as presumably the floating piston would be forced further into the buffing cylinder and so restricting the air space.

Mr. Greenhill (Appleby Frodingham) stated that in regard to vulnerable electrical equipment he was happy to say that since the installation of pneumatic buffers some months ago on their self-propelled ingot chariot 53 tons gross, maximum speed 10 m. p. h., considerable saving had been effected in maintenance costs, running into several hundred pounds, and that saving apart from curtailment in the rolling mill production.

In response, the author extended his sincere thanks for the warm terms of appreciation expressed by all those attending the demonstration. It was indeed a great pleasure to confer with such an appreciative gathering of engineers so well versed in the subject. The many questions and comments were warmly welcomed and it is regretted that time did not permit detailed answers owing to so many having to depart for their return trains. Replies would, however, be incorporated in the report of the proceedings.

REPLIES TO DISCUSSION

In reply to Mr. Gammon's comments it is agreed that attempts have been made on railways throughout the world to increase the energy absorption capacity of buffers, space for and the length of the buffer, however, are not the only restricting factors. Springs of greater capacity could be made but would they entail a greater initial load, which in addition to rendering the buffer unresponsive to light or slow speed impacts would, on a full buffing stroke, give

back a recoil energy that would outweigh the advantage of greater energy absorption. These essential features were of first consideration in the design of the hydro-pneumatic buffers seen to-day and the tests witnessed prove that they are sensitive to the lightest impacts, resistant to the heaviest impacts encountered in "fly" or hump shunting, and have a recoil energy of only 6 inch tons, regardless of the input energy. The method of testing was adopted for several reasons, viz., the elimination of as many variables as possible such as deflection of the buffer mountings that could absorb energy; to prove the ultimate strength of the buffer, and that the design, load and energy characteristics could be based on known factors, also to establish formulæ that could be applied to the design of a buffer for any particular duty. The opportunity would be gladly welcomed of sending buffers for the British Railways to test in any manner they may deem fit. In noting that before the Railway Executive can assess the full worth of hydro-pneumatic buffers it is necessary that they should know the initial cost and maintenance costs; it is presumed that the damage to goods in transit and to wagons will not be overlooked.

Mention of one item of railway transport of which the author has considerable experience might be worthy of note is that of rolled steel billets. These are indestructible, but of the 60 wagons received in the works sidings per month, it is safe to say that at least 10% of the wagons have the ends burst out, due to endwise movement of the billets. Since hydro-pneumatic buffers were fitted on the siding end stop over three years ago there has not been an instance of a wagon end knocked out on the works siding.

With regard to shock absorbing wagons, it is freely conceded that no matter how efficient a 4½" stroke buffer can be made, it cannot of itself achieve the results obtained by the 13" stroke of the sliding body as such movement affords a much lower rate of deceleration, but hydro-pneumatic buffers would relieve the underframe of indeterminate damaging loads. Hydro-pneumatic buffers having 9" action would more than likely answer the purpose, but how they could be mounted on the wagon with the existing type of couplings is a matter Mr. Gammon may himself have in mind. Buffers having such a stroke could be produced and the author's Company would be pleased to co-operate in any trials.

Replying to the opinion that the buffer would be rather "dead" when buffing at low speeds and normal light impacts, the ultra-slow recoil witnessed following

heavy impacts and high energy absorption certainly gives rise to this impression. The buffers, however, proved that they were resilient and responsive to slow speed—light impacts when the bogey was pushed in at ¾ m. p. h. and that they recoiled promptly. The buffers under review are charged at 60 lbs. per square inch air pressure, providing an initial load of 15 cwt. and the speed of recoil may be either decreased or increased by adjusting the initial load. The load to pressure ratio is 1 cwt. in load equals 4 lbs. per square inch pressure and the maximum permissible initial load is 25 cwt.

Many of the other questions are inter-related, therefore, in answering collectively the indulgence is claimed of those who helped to complete the success of the discussion by their questions and comments.

MAINTENANCE

Pneumatic buffers have been in service only 4½ years and hydro-pneumatics three years, so it cannot be said with certainty how long they will go without servicing. Records up to June, 1954, of those in service at Liverpool Street Station show there has been no replenishment of air or oil since installation in May, 1950, and the same applies to many others at steel works and quay sides installed later. At a siding end stop under continuous observation, hydro-pneumatic buffers have not been serviced since fitted three years ago. With such reliability it is but reasonable to anticipate the buffers will go at least five years, the usual time for wagon overhaul. The symptoms shown that servicing or maintenance is required are external. Loss of air is indicated if the plunger does not return to the extended length which is measured between back of head and front of the case, which should equal the original length of stroke; the sealing, however, is a case of "fit and forget". The initial air pressure is primarily to return the plunger after buffing, but it also governs the recoil energy and the flexibility of the buffer under light impacts.

Loss of oil is indicated by the fact that the buffer head can be rotated easily by hand owing to loss of pressure on the oil (not loss of air pressure) and the correct oil volume can be restored by a few strokes of an oil gun. The buffer head is immovable by hand when sufficient oil is charged, care should be taken not to continue pumping after the head and plunger become rigid in the case. The buffer is operative with a deficiency of oil up to 20% but with a proportional loss in efficiency. The oil and air valves are housed

in recesses out of harm's way and a special spanner is required to gain access.

With regard to cost of maintenance, at this early stage a definite figure cannot be given, but it will be seen from an examination of the design that the valves and sealing members are not vulnerable to external damage. The plunger, case, buffing cylinder and sleeve lock are all steel forgings, designed with a high factor of safety against shock loading, and stronger than the hollow cylindrical buffers now in service. The buffer functions with a piston-like motion, and if 100,000 reciprocations are accepted as a reasonable life for other spring elements, this represents only 75,000 surface feet piston wear, against 1 to 1½ million that could be expected with an efficiently lubricated bearing. Hence, the maintenance cost could be much less than that of standard types now in service whilst retaining all the advantages of increased capacity.

The answer to the question if the sleeve lock plugs could cause jamming is: they have been a standardized fitting on British Railways locomotive buffers since the war. The plugs fit closely to the case and plunger

walls, and the faces being in the form of a saddle cannot turn when in position.

Regarding the load imposed on the buffer casing when buffing, undoubtedly the lateral load on the casing will be greater when the buffer is absorbing much greater energy than that of spring-type buffers, but the lateral load on the casing of the latter type when the plunger is home solid is infinitely greater, also the stress on the bolts securing the buffer to the wagon headstock. In shunting operations there may be a slight difference in the movement of the wagons due to the low recoil feature of hydro-pneumatic buffers. This is a very interesting question and one that involves complex mathematical calculations. These will be gone into and the results passed on to Mr. Turner in due course.

In conclusion, it will not be out of place to here mention that these buffers have been in public service nearly five years and have been the subject of many experiments and trials going back for 30 years. They are therefore, not prototypes, but a successful development based on research.

The highly successful Laidlaw Drew system of

OIL FIRING of LOCOMOTIVES

*is the result of many years of
technical research and design*

Our "C" type steam jet burner is centrally disposed in the base of the combustion chamber and fires vertically upwards. A special wide angle nozzle is employed and steam is used for atomisation. The combustion chamber is formed by a baseplate attached to the foot of the firebox and combustion air enters through air tubes arranged

circumferentially in the baseplate. The oil flows to the burner by gravity from the oil fuel tank situated in the tender and this tank is provided with a heating element to keep the heavy fuel in a fluid condition and also with an outlet flow heater to raise the oil to the correct burning temperature.

Many hundreds of these installations are in operation, all over the world.

FULL PARTICULARS ON REQUEST

LAIDLAW, DREW & CO. LTD.
Sighthill Industrial Estate, Edinburgh, Scotland.

Record Railway Casting

ENGLISH Steel Castings Corporation, Ltd., Sheffield, one of the E. S. C. subsidiaries, recently despatched the largest railway casting of its kind ever made outside the United States.

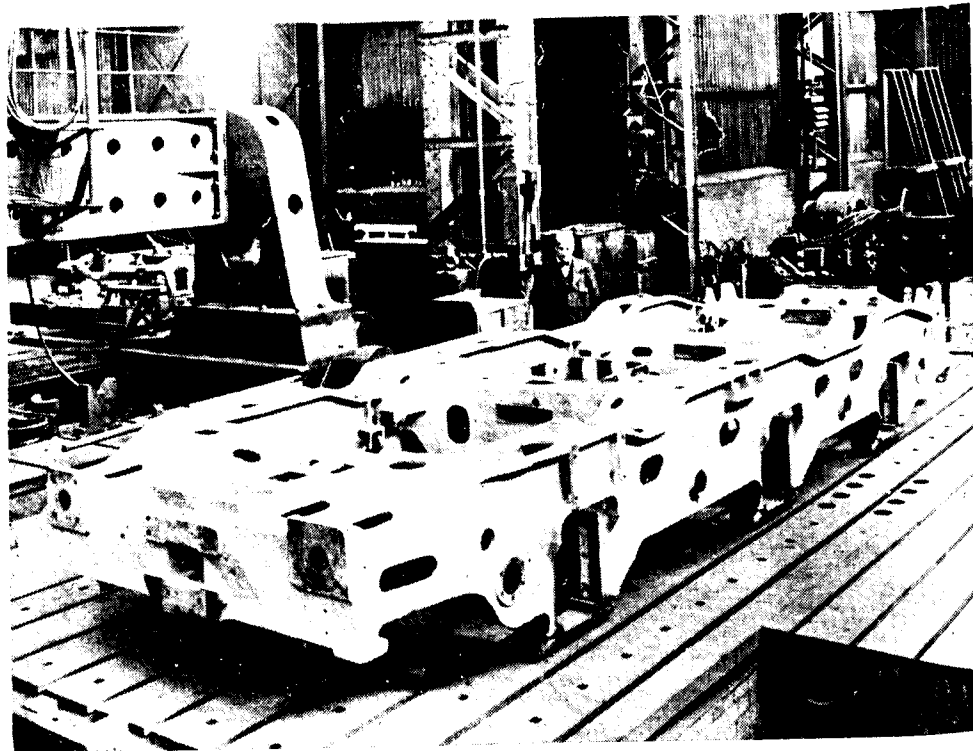
It was the first of a series of one-piece cast steel three axle driving truck beds for New South Wales Government Railways' 3820 H. P. 0-6-6-0 electric locomotives, which Metropolitan Vickers-Beyer, Peacock, Ltd., are building at their Stockton Works, and for whom English Steel Castings Corporation are sub-contractors.

Measuring almost twenty-five feet in length by eight feet in width, and weighing approximately $7\frac{1}{2}$ tons, the truck beds, which are of heat treated steel equivalent to A.R. specification M. 201-52 Grade 'A', are designed to carry three 1,500 volt force ventilated motors mounted on each axle.

The locomotive superstructure is carried on a pair of truck beds, joined by means of a special articulation coupling which permits spring controlled lateral movement, whilst the locomotive is traversing a reverse curve. To compensate for the shortening of truck centres on curves, one of the pair is allowed one inch of longitudinal movement at the centre of the casting.

The rail load per axle is 18 English tons, whilst a notable design feature is the mounting of the draw and buffing gear on the truck headstocks.

The locomotives, forty in all, which are for lifter goods or passenger traffic, will be used on lines running over the Blue Mountains, where the track rises from



One piece cast steel three axle driving truck bed for New South Wales Government Railways, made by English Steel Castings Corporation Ltd., Sheffield.

sea level at Sydney to 3,500 feet, with ruling gradients of 1 in 33. Their maximum operating speed is 70 m.p.h.

RECORD PRODUCTION AND EXPORT OF U.K. DIESEL LOCOS.

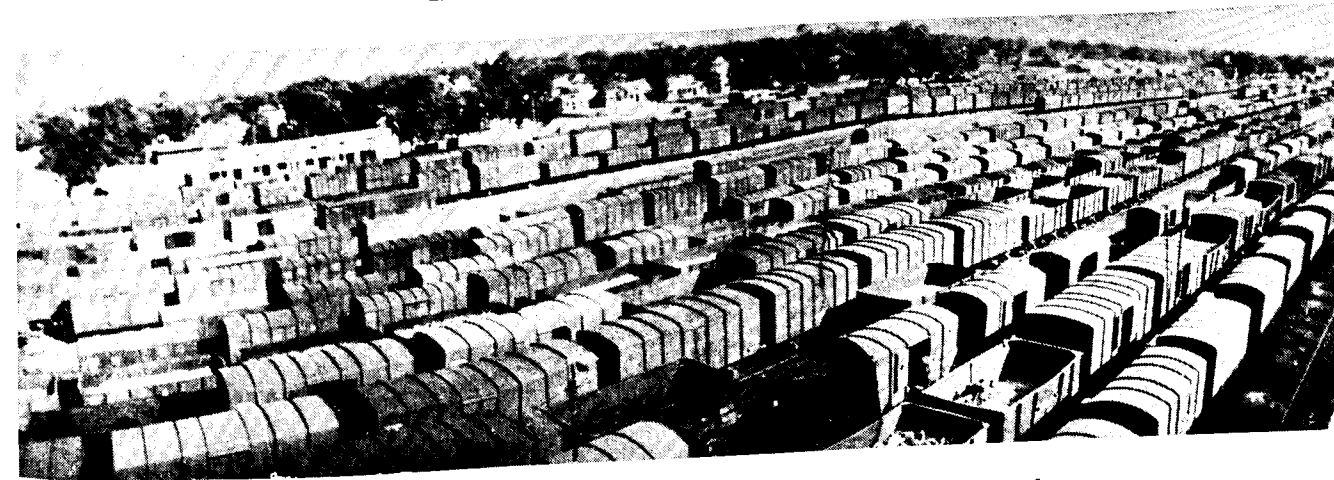
The production and export of Diesel locomotives built in the United Kingdom have broken all records last year.

In the first half of last year, the combined output of British firms making Diesel and Diesel-electric locomotives was 501. This is a rise of 50 per cent. compared with the same period in 1955.

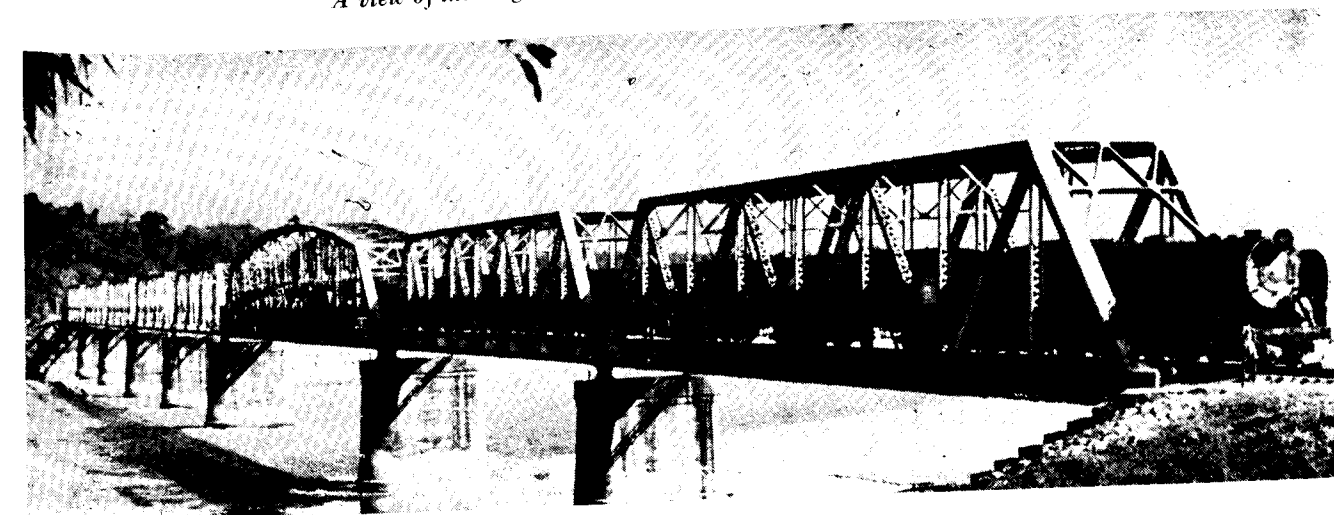
The English Electric Co. recently completed delivery of 23 2,000-hp. Diesel locomotives for Rhodesian Railways and 42 mixed-traffic units for New Zealand. These orders are in addition to those for Netherlands Railways, British Railways, and others. Diesel locomotives built by English Electric are also operating in the Calcutta area.

At present, British builders of Diesel locomotives are executing orders from Malayan Railways, East African Railways, Netherlands Railways, and Irish State Transport, as well as from the British Transport Commission.

RAILWAY WEEK



A view of the wagons assembled at the Manduadih Railway Yard.



A train emerging out of the Tists bridge between Sevoke and Bajrakote on the North Eastern Railway.



Railway construction work in progress near the site of the Rourkela Steel Plant.

A NEW DIESEL-ELECTRIC LOCOMOTIVE

"A description of the Yorkshire Engine Company's 'Janus' 400 H.P. locomotive was published in the January issue, and this is now followed by a description of the new 200 H.P. locomotive manufactured by the same firm."

FUEL ECONOMY

THERE is usually a saving of 75% on the fuel cost of steam locomotives on shunting duties when replacing them by diesel-electric locomotives. This is due to the overall improvement in thermal efficiency and the elimination of lighting up and standby losses.

NO SMOKE OR DIRT

The exhaust of a diesel locomotive is clean and free from smoke, soot or ash. Elimination of smoke and other causes of air pollution is becoming a necessity. Driving of a diesel locomotive is a clean job.

AVAILABILITY OF HORSE-POWER

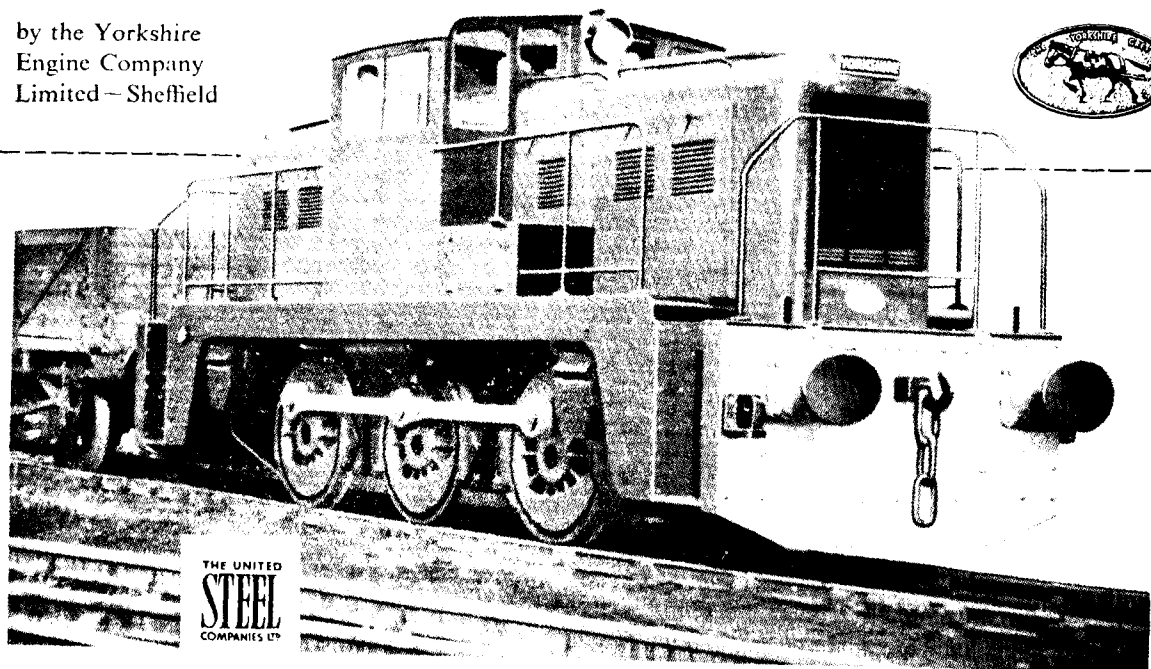
The nearly constant efficiency of electric transmission at about 80% over a wide range of rail speed with the diesel engine running at optimum speed provides the best utilisation of power and the diesel engine cannot under any circumstances be overloaded.

CONTROLS

The driving of a diesel-electric locomotive is a very simple matter. For example, it can be learned by a man in less time than it would normally take to learn to operate an electric crane.

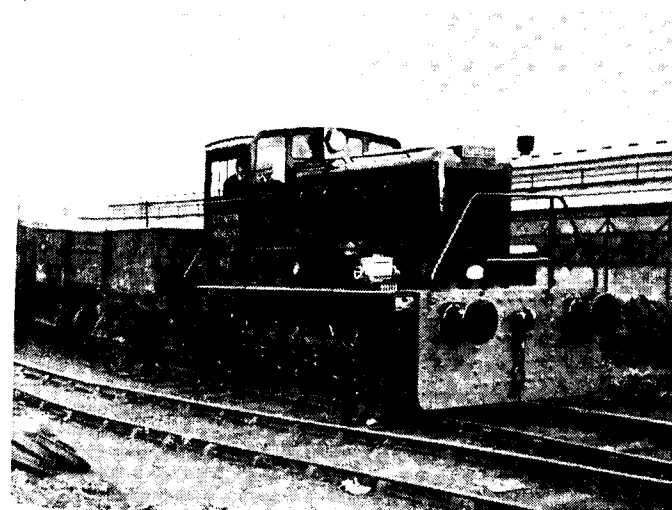
400 H.P. 'JANUS' DIESEL-ELECTRIC SHUNTING LOCOMOTIVE

by the Yorkshire
Engine Company
Limited—Sheffield



THE UNITED STEEL COMPANIES (INDIA) PRIVATE LTD.

Himalaya House, Hornby Rd., P. O. Box 673, Bombay 1.
P-13 Mission Row Extension, P. O. Box 119, Calcutta 1.



Yorkshire Engine Company and its sub-contractors responsible for the design and maintenance of the power equipment have a service organisation and carry spare parts.

GENERAL

The general appearance of the 0-6-0 version of this type of locomotive is illustrated. The diagrams and particulars for both 0-6-0 and 0-4-0 versions are given.

Both versions are identical so far as power equipment and weight are concerned, but for the 0-4-0 the overall length is reduced in proportion to the shorter wheel base.

The locomotives are of the rigid frame type with axles coupled together. The single traction motor is hung on the trailing axle and drives this axle through a gear box containing a right angle spiral bevel and single spur reduction totalling 22.85 : 1.

FRAMING

As the engine generator set is compact and independent of the undergear most of the weight is used to provide a rigid frame built up of rolled steel plates to B. S. 24, part 6, spec. 17, placed inside the wheels with fabricated stretchers all bolted together. Massive buffer beams are employed with good support and these are brought down to 5½" from rail level in order to cover the gear box in case of derailment. The whole structure is designed to withstand heavy traction and buffing shocks and has the necessary weight to provide the adhesion required.

There are no gears to change or clutches to operate. The controls can be grouped most conveniently to suit two driving positions.

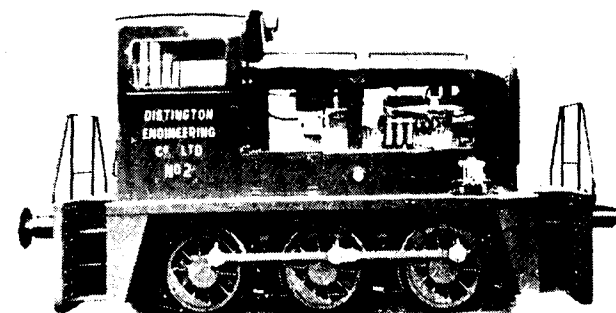
AVAILABILITY AND MAINTENANCE

Experience has shown that a fleet of steam locomotives can be reduced by 20 to 30% by substituting diesel locomotives. This is because the short and long term availability of diesel locomotives is better. The time saved in coaling, watering and fire cleaning improves short term availability, and reduced time under repairs improves long term availability.

With electric transmission the locomotives need only a few hours at intervals of 200/300 hours for change of oil etc., a few days at 2500/3000 hours for top overhaul and no more than this at between 15000/20000 hours for complete overhaul of the engine and turning of tyres etc., if a spare engine/generator set is available and facilities exist for attending to wheels near at hand.

The power unit is resiliently mounted on the frame and there is no rigid connection of any sort between it and the wheels so that the engine is completely protected from shock. The traction motor is axlehung and free to float in any direction with a flexible nose suspension to absorb shock through the gears.

Electrical maintenance is very simple, particularly as the generator is motored for starting thus eliminating auxiliary electrical or compressed air starting equipment.



for the high starting tractive effort and brake power available.

The axle box guides are steel castings of heavy proportions fitting closely into the frames and secured with driving fit bolts.

GENERAL PARTICULARS

Locomotive weight	30 tons.
Locomotive maximum tractive effort	18,000 lb.
Tractive effort at continuous rating	7,400 lb.
Speed at continuous rating	7 m. p. h.
Maximum permissible speed	20 m. p. h.
Oil Engine Supercharged	Rolls Royce C. 6.SFL
Total installed diesel engine rating at 1,800 r. p. m.	200 h. p.*
Horsepower available for traction at 1,800 r. p. m.	185 h. p.*
Generator	B. T. H. Type RTB. 6032
Traction motor	B. T. H. Type RTA. 5041
Gear ratio	22.85 : 1
Minimum rail clearance	5 $\frac{1}{4}$ "
Radiator	Rolls Royce
Battery	D.P. Lead acid 24 cells, 24/48 volts. 77 amp./hrs. at 5 hour rate of discharge.
Track gauge	4' 8 $\frac{1}{2}$ ", 5' 3" or 5' 6"
Length over buffer beams 0—6—0 version	19' 4 $\frac{1}{2}$ "
Length over buffer beams 0—4—0 version	18' 2 $\frac{1}{2}$ "
Length overall (1' 6" buffers) 0—6—0 version	22' 4 $\frac{1}{2}$ "
Length overall (1' 6" buffers) 0—4—0 version	21' 2 $\frac{1}{2}$ "
Width overall, standard gauge	8' 4 $\frac{3}{4}$ "†
Width over cab, standard gauge	7' 10"†
Height over cab, standard gauge	11' 3"†
Number of driving positions	Two
Wheel arrangement	Six or Four
Wheel base 0—6—0 version	9' 0"
Wheel base 0—4—0 version	6' 0"
Wheel Diameter	3' 3"
Can negotiate curves 0—6—0 version	100 ft. radius
Can negotiate curves 0—4—0 version	60 ft. radius
Type of buffers	Optional
Type of couplers	Optional
Type of axlebox	Plain leaded phosphor bronze or roller bearings.
Brake Equipment	Westinghouse straight air brake. Rolls Royce compressor mounted on engine and belt driven. 15 cu. ft. per min. swept volume.
Fuel tank capacity	200 galls.

Notes:

* Rating would be reduced for altitude and temperature.

† Width and height of cab and fuel capacity can be reduced or increased to suit loading gauge.

The decking, which is combined with the platforms form a continuous cover over the frames and eliminates any possibility of oil or water from the power unit above seeping through on to the traction motor. The decking is provided with bearer plates on which the three point supports of the power unit are carried.

The stretchers are positioned to give the maximum support to the power unit and for the nose suspension of the traction motor. There is a strong brace between the frames below the motor provided with a heavy pin linkage so that it can be readily removed when dropping this pair of wheels.

AXLEBOXES

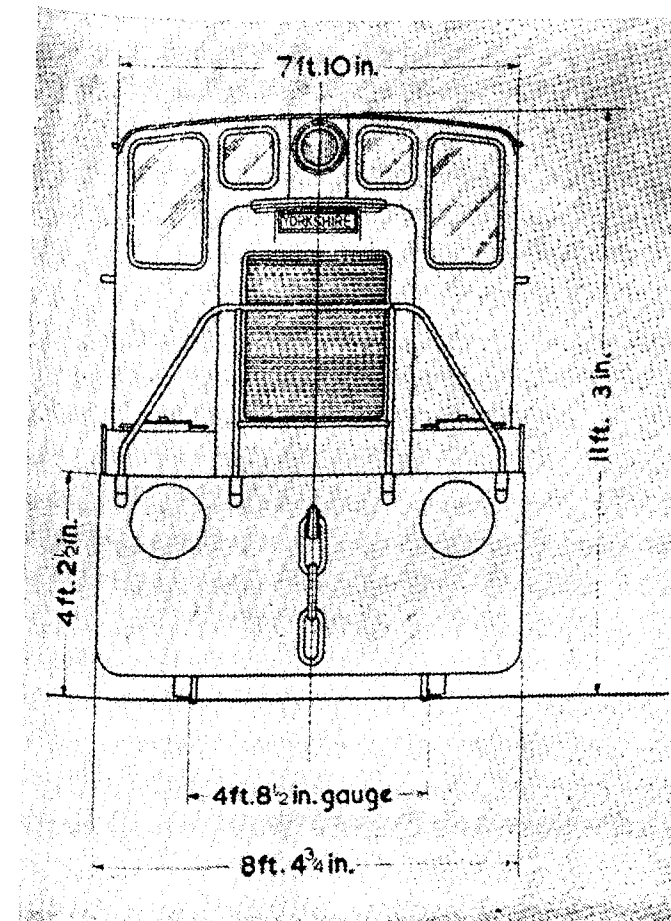
Steel cast axleboxes to B. S. 24, part 4, spec. 10 are fitted as standard. These are provided with renewable leaded phosphor bronze bearings and collar liners. Manganese steel side liners are also provided. The axleboxes are fitted with cast iron keeps containing Armstrong oiler pads. The axlebox bearings are lubricated from a mechanical lubricator mounted on the platform and driven from the leading wheel axle. Alternatively roller bearing axleboxes with manganese side liners can be fitted. These are grease lubricated and therefore the mechanical lubrication is not fitted.

SPRING SUSPENSION

Laminated bearing springs with adjustable sword type hangers rest on the axleboxes and can be readily changed if necessary from underneath. The springs are manufactured from acid or basic water hardening spring steel in accordance with B. S. 24, part 3, spec. 6X.

WHEELS AND AXLES

Cast steel wheel centres to B. S. 24, part 4, spec. 10 are keyed and pressed on to solid forged axles to B. S. 24, part 1, spec. 2, and fitted with forged pins to B. S. 24, part 4, spec. 9, pressed into the wheel centres. The revolving masses are fully balanced in the design of the wheel centres.



TYRES

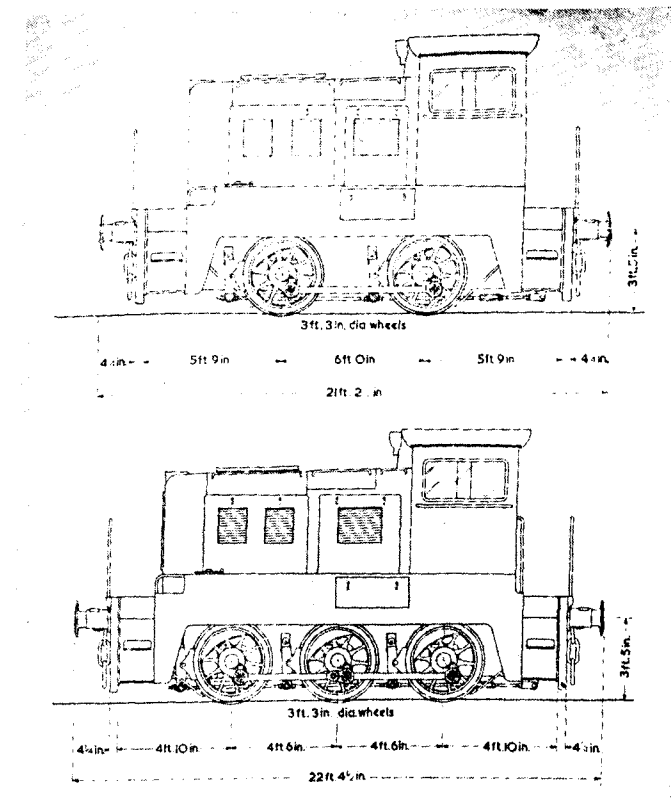
Tyres of steel to B. S. 24, part 2, spec. 4, for class 'D' are shrunk on to the wheel centres.

COUPLING RODS

The wheels are connected by coupling rods forged and machined from acid steel class 'C' and in accordance with B. S. 14, part 4, spec. 8, and are provided with solid leaded phosphor bronze bushes.

POWER BRAKES

The locomotive is equipped with Westinghouse straight air brakes. Provision is made for adjustment. The brake pressure at the cylinders is 50 lbs. per square inch. The compressor, as standard to the Rolls Royce C6S diesel engine having a capacity of 15 cu. ft. swept volume of air per minute, is driven by Fenner vee belts from the engine. The air reservoirs have a capacity of 10 cu. ft. The unloader and safety valve are mounted adjacent to the reservoirs. The feed



valve, driver's valve and Duplex gauge are mounted in the cab and the brake can be applied from both sides.

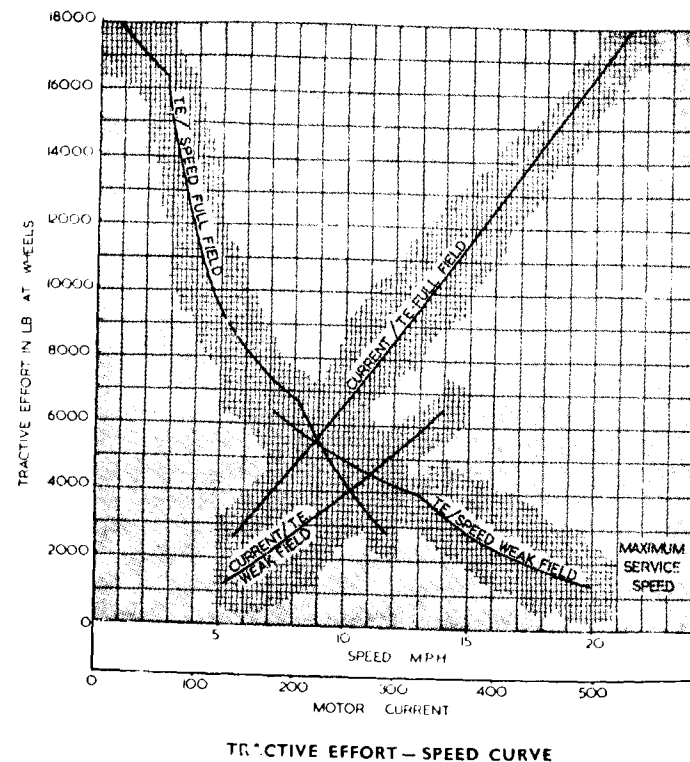
DRAWGEAR

Turflat forged side buffers and Gedges hooks and three link chains are fitted as standard. Any special buffer and drawgear can be fitted if required.

CAB

The driver's cab is constructed of steel plates welded together to form a totally enclosed structure provided with a door at the back. The windows in the front and back panels are fixed with rubber sealing strip, but the side windows and the windows in the side doors are fitted with sliding and drop windows. The control desk, containing contactors and other switch gear and on which are mounted the control levers and instrument panel, is located against the front bulkhead. The control levers, consisting of the throttle, reverser, brake, sanding and whistle levers are duplicated on either side within easy reach of the driver. The throttle and reverser are mechanically interlocked to prevent the reverser being thrown when the throttle is open, or the throttle opened when the reverser is not in either the

PERFORMANCE OF 200 H.P. DIESEL-ELECTRIC LOCOMOTIVE



forward or back position. The instrument panel is provided with 'Start' and 'Stop' buttons, fuel pressure, engine R. P. M., oil pressure, water temperature, battery charge ammeter, speedometer and air brake Duplex gauges. A separate panel on the bulkhead has switches for the head and tail lights, cab light and heater switches and a pilot switch. An earth leakage relay is mounted on the bulkhead. On the control cabinet is also provided the battery changeover switch. In the 'Start' position, the 24 cell battery is in series, to give 48 volts to motor the generator, and in the 'Run' position the batteries are in parallel to give 24 volts for lighting and heating. The hand brake is located on the rear bulkhead. A Servis recorder is included as standard, and also mounted on the bulkhead. The floor is covered by wooden boards. The height and width of the cab can be modified to some extent to suit running dimensions, or for customers' special requirements. A toolbox is provided combined with the desk on the left side. A platform is provided behind the cab, approached by step-ins on either side. Windscreen wipers are supplied.

BATTERY

The 24 cell battery is contained in two battery boxes mounted on the platforms.

POWER UNIT

The power unit comprises the Rolls Royce C6-SFL supercharged oil engine direct coupled to the single bearing generator which is spigot mounted to the engine frame. The radiator is connected to the front of the engine and the whole unit carried on three point resilient suspension mounted on the engine deck. The radiator, auxiliary generator and compressor are driven from the free end of the engine with Fenner vee belts. The complete power unit and control equipment are supplied by The B. T. H. Co. Ltd., Rugby and a detailed description of this equipment follows.

BONNET

The bonnet enclosing the power unit is built up of two sections which are easily detachable for maintenance purposes. The forward portion includes the front moulding on which is mounted the radiator grill and encloses the diesel engine and its auxiliaries, while the rear portion encloses the generator and switch gear mounted on the front of the cab bulkhead. The engine air filters and exhaust silencer are mounted on the roof of the rear portion as it is only necessary to remove the front portion to attend to any major repair on the engine or its auxiliaries. As the weight of the locomotive required is provided mainly in the form of a strong frame, the bonnet sections have been fabricated mainly by welding from the lightest steel mouldings, and consistent with the necessary strength. Doors and covers are arranged for access to the power unit and these are provided with louvres with such air space as is necessary to provide for ventilation. The exhaust pipe and front head light are combined in a neat moulding on the front of the cab above the bonnet.

LIGHTING

The locomotive is provided with forward and rear headlights and a cab roof light.

CAB HEATING AND VENTILATION

A Clayton Dewandre heater with ventilating fan of the latest type is provided in the cab.

MATERIALS

All materials, bolts, rivets and nuts are to British Standard Specification.

PAINTING

The locomotive will be painted to suit the customer's requirements.

TESTING AND TRIAL RUN

If required arrangements can be made for customers or their Consulting Engineers to examine the drawings or materials and visit the works to see the locomotives under construction. The power equipment is tested at the maker's works and the locomotive undergoes extensive trials before delivery. An acceptance test before the customer's representative can always be arranged.

TRAINING CUSTOMER'S STAFF

It can be arranged for customer's fitters and drivers to attend courses of instruction during the final stages of construction of their first locomotive.

ENGINE SPECIFICATION

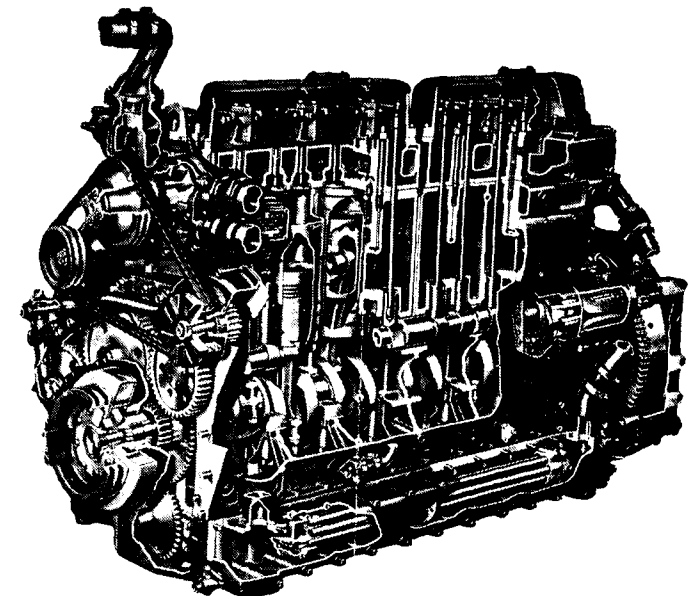
Type	4 stroke, direct injection, liquid cooled
Bore	5 1/8" (130.175 mm.)
Stroke	6" (152.4 mm.)
Capacity (swept volume)	742.64 cu. in. (12.17 litres)
Compression ratio	14 : 1
B. H. P.	200 at 1,800 r. p. m.
Rotation	Anti-clockwise viewed on flywheel
Fuel system	Direct injection governed at all speeds.
Lubrication system	Dry sump with heat exchanger. Full flow filters.

CONSTRUCTION

The cylinder block is integral with the crankcase. The crankshaft main bearing caps are supported by deep webs and the more heavily loaded centre and end bearings are additionally secured by transverse bolts. The main bearings are of pre-finished steel backed copper/lead type with Indium flash to ensure satisfactory life. Replaceable 'wet' type cylinder liners are fitted; the bottom seal being made effective by heat and oil resistance rubber sealing rings and the liners are nipped in position by the cylinder head.

CRANKSHAFT AND CONNECTING RODS

The crankshaft is nitride hardened and has at the front end an externally mounted viscous torsion damper, which effectively reduces the crankshaft oscillations over the full running range.



Internal construction of the 6-cylinder dry sump engine.

tions over the full running range. The connecting rods are drilled longitudinally for pressure lubrication of the gudgeon pins, and for splash to the cylinder walls.

PISTONS AND VALVES

Each of the light alloy pistons is fitted with three compression rings and one oil scraper ring and is recessed in the crown to form a toroidal combustion chamber. The overhead valves are push rod operated and both inlet and exhaust valves have stellited seat faces and stem tips to minimize wear.

SUPERCHARGER

The supercharger is of the Roots positive displacement type, mounted on the crankcase and driven by a gear train and spring drive from the timing gears at approximately twice crankshaft speed; this gives about 8 lb. per sq. in. boost at an engine speed of 1,800 r. p. m. Pressure lubrication is provided from the main engine lubrication system.

AIR CLEANERS

Multiple air cleaner units have been developed for this engine by Rolls Royce Ltd. to ensure the highest practicable degree of air filtration. These comprise centrifuge primary and heavy duty oil bath secondary filters.

OIL HEAT EXCHANGER

To bring the engine oil rapidly to its most efficient working temperature and to maintain it at that temperature under all conditions, a heat exchanger is used. Maintenance of correct engine temperature, apart from increasing the efficiency shortens the warming up period and so reduces wear.

On starting the engine the coolant radiator is by-passed, the warming coolant then re-circulating through the heat exchanger chamber and engine. When the coolant reaches 73 °C. the automatic thermostat control opens and allows the coolant to circulate through the radiator.

LUBRICATION SYSTEM

A dry sump is fitted which reduces the overall height of the power unit and ensures efficient lubrication of the engine on any railway gradient. This sump incorporates an oil to water heat exchanger together with an oil reservoir. Two scavenge pumps return the oil to the reservoir and a pressure pump supplies the main feed to the engine.

Oil is pumped through the heat exchanger and full flow filters to the main feed gallery for distribution to the crankshaft main bearings, crankpins and gudgeon pins, and through drillings in the crankcase to the camshaft bearings and the bearings of the wheelcase gears. Smaller drillings feed oil to the valve rocker shaft bearings, the push rod ball ends and the end of the valve stems at a lower pressure. Twin oil relief valves are fitted; one valve maintains the main oil pressure at 40 to 60 lbs. per sq. in. and the other provides a by-pass in the event of the oil filters becoming choked.

COOLING SYSTEM

The coolant is circulated by a belt driven centrifugal pump through the oil heat exchanger, engine and radiator. Provision is made for fitting a cooling fan, and a thermostatically operated valve causes the coolant to by-pass the radiator until it reaches a predetermined temperature.

Whilst water can be used as a coolant, a correctly inhibited anti-freeze mixture is recommended for use all the year round, as this not only provides protection against frost but prevents corrosion within the cooling system.

FUEL SYSTEM

A fuel injection pump mounted on the side of the engine supplies fuel to the injection nozzles on the cylinder heads. The injection pump is driven from the engine wheelcase, and includes a lift pump for supplying fuel from the main tank to the injection pump through paper element filters. The injectors are easily accessible for servicing. A mechanical compensated speed control governor forms part of the injection pump unit and ensures close governing at all speeds within the running range.

ELECTRICAL UNITS

A Simms dynamo of 960 watts output, is mounted on the crankcase and is belt driven in series with the coolant pump. The belt tension is adjusted by moving the dynamo. This dynamo provides the charging current for the twin lead-acid battery which is in two sections rated at 77 A. H. at the five hour rate of discharge.

The engine is not fitted with a normal type of axial starter as starting in this installation is through the generator and operates on a forty-eight volt circuit requiring a series parallel battery switch described later.

ENGINE SERVICE COUNTER

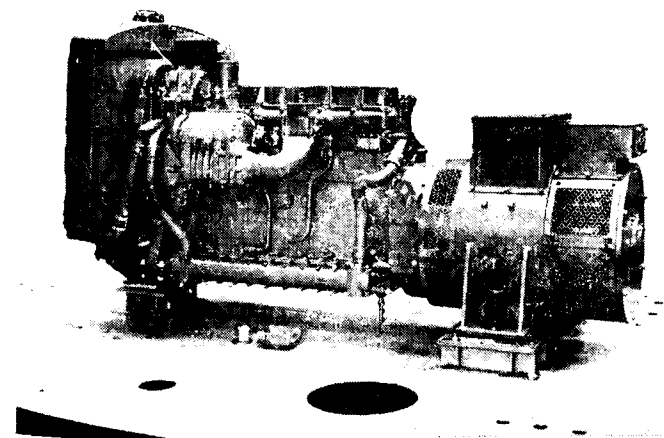
An engine service counter is fitted to provide an accurate means of determining the correct time for servicing.

MAIN DRIVE

The engine is designed for coupling direct to a single bearing generator. The engine-generator set is able to run indefinitely at any speed within the running range without incident of critical speed of torsional vibration. A viscous type vibration damper is attached to the free end of the crankshaft.

FUEL OIL RECOMMENDATIONS

It is recommended that Rolls Royce engines should be operated on fuel oils conforming to B. S. S. No. 209 (1947) Class A, but engines can also be operated on fuel conforming to B. S. S. 209 (1947) Class B. The makers will be pleased to give their recommendations for any fuel that does not meet the Class A specification and they should be consulted in every case.



Engine and Generator Set.

TRACTION GENERATOR TYPE RTB 6032

CONTINUOUS RATING—(Self Ventilated)

kW	Volts	Amps.	R. P. M.
124	500	248	1800
113	378	300	1660

Ratings in accordance with BS. 173/1941.

WEIGHT

Approximately 2,200 lb.

CONSTRUCTION

This machine is a single bearing, 6 pole, commutating pole traction generator specially designed for direct coupling to a diesel engine.

FRAME

The magnet frame is of the fabricated, barrel type with adequate opening for ventilation and access to the commutator and brush gear.

ARMATURE

The armature punchings are of thin electrical sheet steel and are secured on arms welded to a cylindrical spider by means of a heavy interference fit obtained by shrinking. A flexible coupling on the end of the spider is bolted direct to the engine flywheel. The armature windings are held in place by wedges of bonded material which retains its mechanical strength at high temperatures. Mica, glass and asbestos are used exclusively for coil insulation and all connections are brazed. The commutator is of the conventional Vee

clamp ring design with hard drawn copper segments insulated with mica.

FIELD COILS

Self and separately excited field coils are provided. These are wound on the same former and are "Mummified." The compole coils consist of edge wound strip copper. A starting winding consisting of strip copper is also fitted on each main pole.

Mica, glass and asbestos are used exclusively for all coil insulation.

BRUSH HOLDERS

The brush holders are mounted on arms attached to a fabricated brush yoke and are adjustable radially. Split brushes are used with equalized pressure on each brush.

BEARINGS

The single bearing at the commutator end is a single row ball type arranged for grease lubrication.

VENTILATION

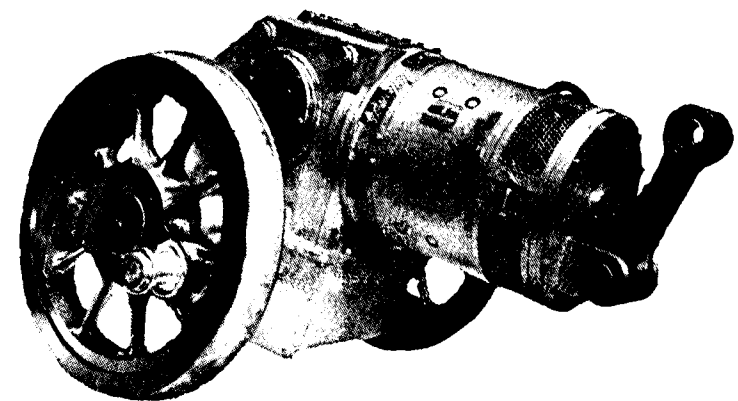
The fan is of fabricated steel construction and provides adequate ventilation of armature and field coils.

TRACTION MOTOR TYPE RTA 5041

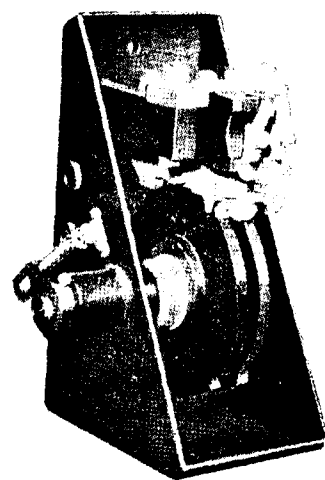
CONTINUOUS RATING ON FULL FIELD
(Self Ventilated)

SHP	Volts	Amps.	R. P. M.
143	440	270	1330

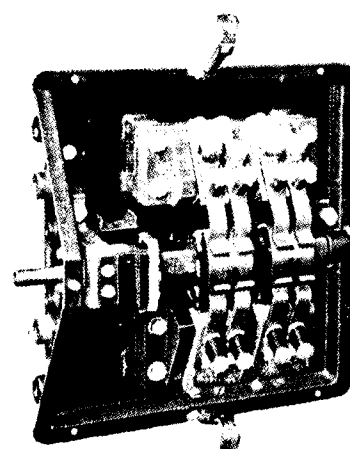
Ratings in accordance with BS. 173/1941.



Traction Motor and Gearbox.



Power Controller.



REVERSER

WEIGHT

Complete with gearbox, approx. 3,800 lb.

MAXIMUM SPEED	GEAR RATIO
4000 r. p. m.	22.85 : 1.

CONSTRUCTION

This machine is a 4-pole commutating pole traction motor which is spigot mounted on an axlehung gearbox.

FRAME

The magnet frame is of the fabricated, barrel type with adequate openings for ventilation and access to the commutator and brushgear.

ARMATURE

The armature punchings are mounted directly on a very substantial shaft and are hot stacked under pressure. The windings, consisting of rectangular copper conductors, are insulated entirely with glass and mica and all connections are brazed. The armature windings are held in place by wedges of bonded material which retains its mechanical strength at high temperatures. The commutator is of the "Pollock" type in which the segments are retained against centrifugal force along their entire length. The spiral bevel pinion has a taper shank which is a very heavy press fit in a corresponding taper bore in the armature shaft.

FIELD COILS

These consist of edgewise wound strip copper insulated with asbestos and mica.

BRUSH HOLDERS

The brush holders are mounted on arms attached to a fabricated brush yoke and are adjustable radially. The brushes are split and are fitted with stranded copper shunts.

BEARINGS

The armature is carried on anti-friction bearings. A plain roller bearing is used at the commutator end. A pair of bearings is used to take the thrust and journal loads at the pinion end.

VENTILATION

A cast aluminium radial type fan provides adequate ventilation of armature and field coils.

GEARBOX

The gearbox is of fabricated steel construction and is split on the axis of the road axle. The lay shaft, which carries a spiral bevel wheel and spur pinion, is mounted on anti-friction bearings, cartridge mounted. The gears can be thrown out of mesh by external adjustment of the cartridges so as to allow the locomotive to be towed safely at speeds above the normal maximum.

The gearbox is carried on the road axle in split type oil-lubricated sleeve bearings.

CONTROL EQUIPMENT**GENERAL DESCRIPTION**

The control equipment consists of a power controller, reverser, contactor panel and battery series-parallel switch.

POWER CONTROLLER

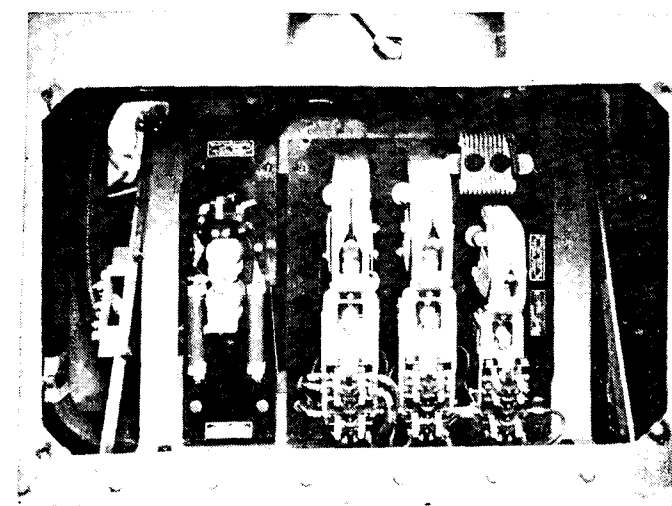
This is a cam operated unit with two silver tipped contacts through which the two contactors supplying power to the motors are energised. The lever of this power controller is mechanically linked to the governor and is used to control the engine speed. Mechanical interlocking is provided to ensure that this controller can be operated only when the reverse lever is fully in either the forward or reverse position.

REVERSER

One standard single motor reverser is operated mechanically by the reverser lever. It has four pairs of copper contact fingers which engage with segments on drum. Electrical interlocks ensure that the motor contactor can close only when the reverser is fully in either the forward or reverse position.

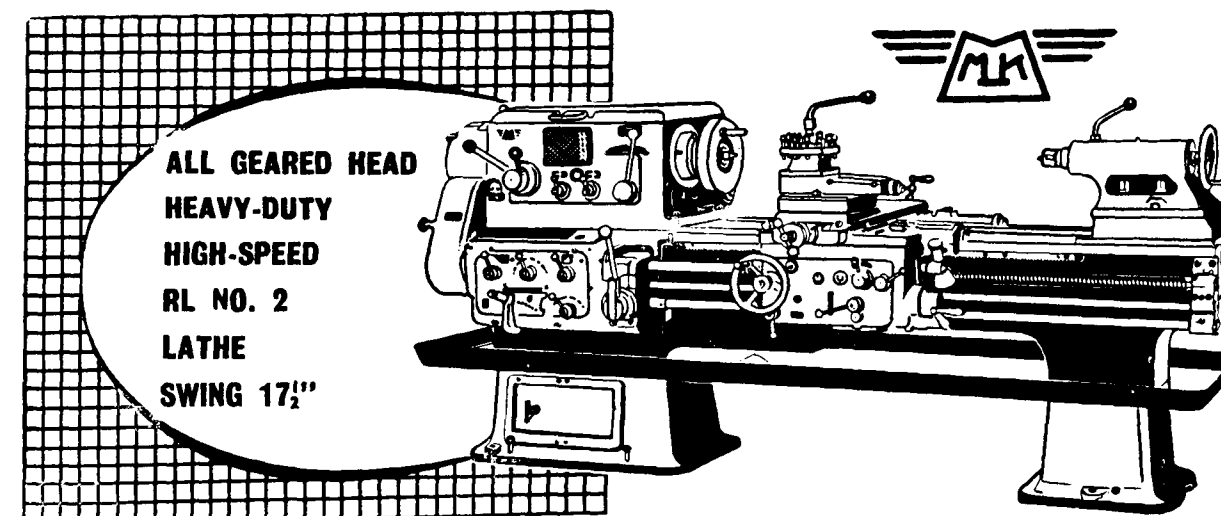
CONTACTORS

One contactor is in the main motor circuit and one provides a divert resistance to give field shunt above predetermined speed. The third contactor is in the generator circuit for engine starting purposes. These



Contactor Panel.

contactors are electrically interlocked to prevent the motor contactors and the starting contactor being closed at the same time. They are single pole, magnetically operated and are of simple and robust design. The construction includes a straight armature with rocker bearings. Blowout coils and arc chutes are provided to assist in rupturing the arc.

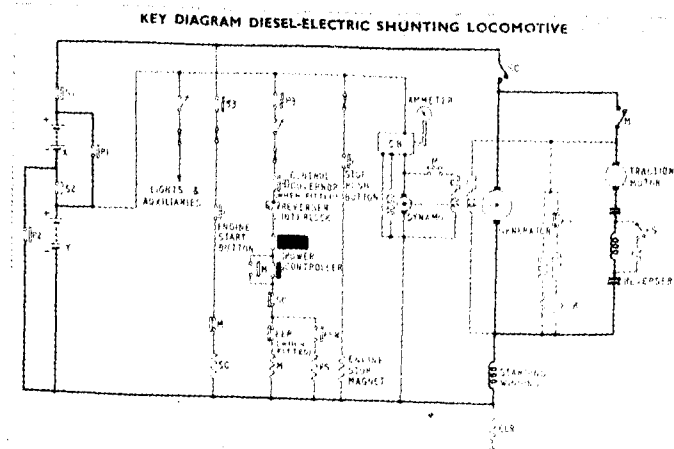


Its special features are: Main Spindle with 18 Mechanical speeds — Sliding gears of Nickel Chrome Steel Hardened and ground by Maag Process — Norton Box to cut all types of threads — Heavy construction for slides to take Carbide tools — Oil pump incorporated in Headstock for lubrication. This lathe is in great demand among Railways and other Production Workshops.

Manufacturers:

THE MYSORE KIRLOSKAR LIMITED

Yantrapur P. O., HARIHAR, Mysore State.
Distributors: Batliboi & Co., Forbes Street, BOMBAY 1.



M = Motor contactor. CB = 24 volt. voltage regulator.
 SC = Starting contactor. Pr, 2 & 3 = Battery series parallel
 FS = Field shunt contactor switch-parallel contacts.
 FSR = Field shunt relay. S1, 2 & 3 = Battery series parallel
 ELR = Earth leakage relay. switch-series contacts.

FIELD SHUNTING EQUIPMENT

Field shunting equipment consists of a field shunting contactor, resistor and a relay. The relay is connected across the generator and operates to introduce the field shunting of the traction motor automatically when conditions are suitable.

EARTH LEAKAGE RELAY

A hand reset, indicating earth leakage relay is provided in the driver's cab.

SYSTEM OF CONTROL

The fundamental traction circuit consists of a reverser and a contactor to connect the traction motor to the generator. The contactor is operated from a 24 volt battery and the reverser is mechanically operated by a link from the driver's reverse lever.

The traction contactor is closed by the throttle switch which is linked, together with the governor speed lever, to the driver's power controller. The locomotive power is varied by variation of the engine speed so that, once the traction contactor has closed, no further change takes place, and the movement of the controller lever serves only to increase the speed of the diesel engine by altering the setting of the governor. Traction motor field shunting takes place automatically at a predetermined generator voltage.

The control system is based on a self-excited shunt wound generator coupled to the diesel engine. When using a diesel engine for traction duty it is essential to introduce some means of employing the full engine horse power over a wide range, if the tractive effort of the locomotive is to be prevented from falling off



Control desk.

rapidly at higher speeds. The scheme adopted by BTH on this locomotive is designed to give the widest possible use of engine horse power with the simplest of equipment.

The series wound motor is connected by a contactor through a reverser to the main generator which is designed with a steeply drooping characteristic. A light separate shunt field is provided to give a fixed short circuit current. This short circuit current is chosen to correspond to a suitable "stall" tractive effort of the motor and thus is self-protecting.

The generator also has a series winding which is provided in order that the engine may be started by motoring the main generator from the supply available from the battery.

The characteristic of the machine is also very sensitive with speed, and advantage is taken of this to prevent overloading of the diesel engine in the manner now described.

The maximum output of the diesel engine is determined by a fixed stop on the fuel injection pump control rack. As the generator increases its loading upon the engine, fuel is increased by the governor until this maximum is reached, after which further loading on the engine will cause a reduction in engine speed. This reduction in speed, however, rapidly reduces the generator voltage and hence its loading upon the engine until a balance point is reached. The reduction in speed is never sufficient to cause serious loss of available engine power.

This system of control provides continuous and entirely smooth variation of locomotive speed and tractive effort between standstill and full horsepower simply by varying the engine speed.

For further information apply to:

THE UNITED STEEL COMPANIES (INDIA) PRIVATE LTD.
 P. B. 673, BOMBAY P. B. 119, CALCUTTA

FRENCH RAILWAY ENGINEERING NOTES SECTION

The Locomotives in Service on the Valenciennes-Thionville Line

DIFFERENT SOLUTIONS—ROLLING-STOCK

THE rolling stock of the Valenciennes-Thionville line consists of four families corresponding to 4 principle solutions: the mono-phase motor for 50 Hz, conversion of mono-phase into direct current by rotating sets or by rectifiers, conversion into three-phase current.

The wide choice of solutions proposed by the industrial current electrification device is not sufficient to explain the appearing of 4 types of locomotives at the origin of the first large scale realization. It is necessary to add that the electrification of the Valenciennes-Thionville line required an entirely new problem of traction. In fact it was required to trail on a line of which the profile is hard long inclines of 10 o/oo) very heavy trains; trains which in steam traction reach 1,350 tons, i. e. scarcely surpassing the loads allowed in direct current electric traction for the 6-driving axles locomotives. A figure of 1,800 tons has been even foreseen on the opportunity of the electrification.

New problem, not solved in 1,500 V direct current, and which was put at the occasion of a new electrification device. The difficulty was not increased. On the contrary, the new device had some expedients. But it has been necessary to group all these technical expedients and, in particular, to utilize the different means of current conversion on the locomotives. It was known by this time that locomotives fitted with three-phase induced current motors, or locomotives powered by direct current motors but permanently fed in parallel under a progressively variable tension obtained by rotating sets or by rectifiers, should be capable to start with loads definitely greater than that required in the other devices.

In these current conversions, the device of rectifiers was seductive. Its simplicity of principle, its high slightness are important advantages. Its innovation

chiefly was not an obstacle. The French National Railways have already experimented on the Annecy test line a locomotive and a motor-coach with rectifiers. Nevertheless it has been judged prudent to do not overreach the little number of such type locomotives, before being able to solve in the practice an entirely unknown problem, this of repercussions on the primary wirework of the harmonics involved by some mono-phase rectifiers engines.

Besides the other conversion devices, i. e. the mono-phase direct current and mono-phase three-phase rotating set locomotives, have the advantage to propose very simple solutions to a problem of which the economical importance is interesting on a rough line, the question of braking by recovery at the descent of slopes.

The "mono-direct" solution was the most suitable for these rotating set machines.

These different considerations explain the composition of the Valenciennes-Thionville line rolling stock, adopted in 1952, and which is the following:

- 65 CC type locomotives (mono-direct set)
- 20 CC type locomotives (mono-three-phase set)
- 15 BB type locomotives (collector mono-phase motors)
- 5 BB type locomotives (rectifiers)

The exceptional proportion of CC type locomotives in this stock corresponds to the exceptional character of the line's traffic regarding only the goods.

THE CC LOCOMOTIVES

The principle of rotating set CC locomotives is the following:

The locomotives of "mono-direct" type (series 14 IOI to 14 I65), designed and built by Alsthom, comprise

a depressor-transformer at constant tension which feeds a synchronous motor, this last drives two direct current generators of which the voltage may be tuned by an appropriated excitation. As in a electric Diesel locomotive, these generators feed the direct current traction motors. The excitation in series of motors is completed by a separated excitation which plays a similar part to this of shuntage in the direct current machines. The feeding of progressive tension motors, their constant coupling in parallel, the special scheme of their excitations, are so many factors of electrical character which enable to develop, without slip risk, traction stresses corresponding to very high adherent coefficient.

The CC type locomotives (mono-three-phase type), of a series 14 001 to 14 020, designed and manufactured by Oerlikon, include first of all a constant voltage depressor-transformer which supplies a synchronous machine playing the part of a diphase; the last one transforms the mono-phase current into three-phase

current of same frequency. The speed of frequency converter (which directs the traction motors speed) is continuously set by a Ward-Leonard drive. As mentioned above, the mutual frequency of motors feeding is a strong bound between them and avoids the individual slip of an axle.

The load of 1.800 tons on a 10 o/oo incline / (which has been the experimental target for the two CC types (mono-phase) / , overreached 50% of the starting load by locomotives of a similar weight in direct current.

By the fact, the experimentation showed that the "mono-direct" and "mono-three-phase" CC locomotives of the Valenciennes-Thionville line are perfectly able of starting with a load of 1.850 t. on a 10 o/oo incline. This is their permissible load.

THE BB LOCOMOTIVES

The 20 locomotives of BB type have been ordered for the traction of passenger, freight or ordinary goods

trains. In compliance with their specification, these machines must draw at a continuous rpm. a 900 tons passenger trains on a level at 65 mph. and a 750 tons goods-train on a 10 o/oo incline.

For the 15 mono-phase locomotives (or direct current motors), the French National Railways placed the order with the Forges et Ateliers de Constructions Electriques de Jeumont in order to take up the study and the construction of motors. The specification laid down the two following qualities: the "insensibility" on starting and the possibility of slow acceleration. Thanks to these data achieved by the manufacturer, the locomotives of the No. 13001 to No. 13015 series with "direct" motors on the Valenciennes-Thionville line have a permissible load of 1050 tons.

For the 5 locomotives with rectifiers, the French National Railways have choiced the "Ignitron" as type of rectifier, produced by the Material Electrique S. W., the same which already fitted the test motor-coach on the Annecy line and which is largely used in the United States in many mono-phase locomotives or motor-coaches for 25 Hz. The result was successful. The locomotives with Ignitrons on the Valenciennes-Thionville line start normally hauling 1,400 tons goods-trains on a 10 o/oo incline.

with ignitrons were also designed to look alike, including, except some simplifications, the type of bogie which has been successfully utilised on the BB 9003 and 9004 direct current locomotives.

It has been standardized on the Locomotives of the four types the pantograph, the main compressed air cut-out, the ancillaries driving system by cage motors provided with three-phase by an Arno converter set. This system had proved its value in service on the Annecy line.

The two types of locomotives with converter sets possess the similar principle of group starting by means of a generator driven by Arno set, although the two types dispose with entirely different converter sets.

Meantime, the locomotives of the two BB types, which include a voltage-timing at the main transformer, are fitted with the same regulator, a robust apparatus which has proved its efficiency in mono-phase traction for 16 2/3 Hz.

At last a lot of unification details has been brought up in the accommodation of cabins, in the controlling organs, in the protection relays and in the numerous components which are found in an electric locomotive: connecting box, thimble, electro-valve, auxiliary contactors, etc.

STANDARDIZATION OF THE EQUIPMENT

Placing their orders for 4 types of locomotives, the French National Railways did not wish that these machines were different in their details although they were different in their principle. They laid special stress on the following point: to standardize all that may be standardize, i. e. all that which did not concern the originality of every type. Such Plan has been obtained in co-operation with the builders.

Regarding the mechanical part, it has been adopted in all the cases the single driver's cockpit, with good visibility ahead and to the rear. This is of considerable economy in the construction and enables to group near the driver all the control devices.

With a view to uniformity, the two types of CC locomotives have the same mechanical part; this study has been based mainly on the rusticity, as concerning locomotives of which the maximum speed is limited to 37 m.p.h. The mechanical parts of the BB locomotives with "direct" motor or the BB locomotives

MAIN DATA

CC LOCOMOTIVES WITH "MONO-DIRECT MOTOR"

Rated horse-power	..	2490 HP at 17 mph.
Corresponding traction stress	..	23,2 t
Maximum traction stress	..	42 t
Braking stress (electric recuperation brake)	..	16 t
Maximum speed	..	37 mph.
Weight of the electric part	..	48 t
Weight of the mechanical part (with transmission)	..	78 t
Total weight	..	126 t
Length (out buffers)	..	approx. 59 ft.

Traction motors:

6 "direct" motors of 415 HP (600 V, 550 A).

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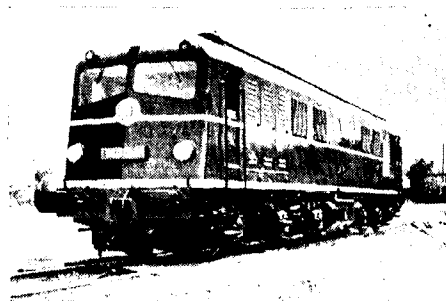
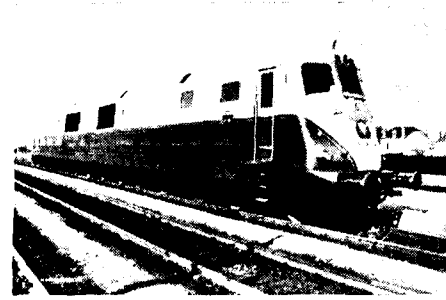
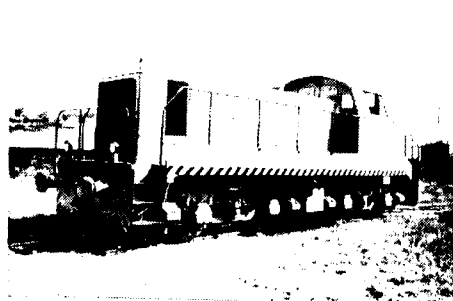
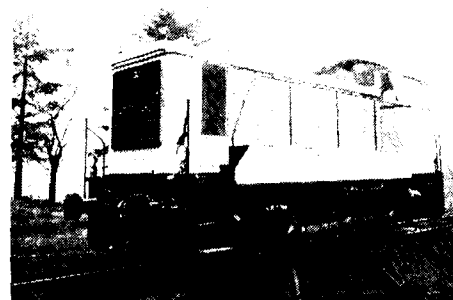
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with electric, hydraulic, hydro-mechanical transmission.

All configurations and all usual extensions. Traction problems design.

CC "MONO-THREE-PHASE" LOCOMOTIVES

Rated horse-power	.. 3600 HP at 25 mph.	Weight of the mechanical part (with transmission)	.. 70 t
Corresponding traction stress	.. 23, 2 t	Total weight	.. 124 t
Maximum traction stress	.. 42 t	Length (out buffers)	.. approx. 59 ft.
Braking stress (electric brake by recuperation)	.. 30 t	Traction motors :	
Maximum speed	.. 37 mph.	6 cage three-phase synchronous motors of 600 HP (930 V, 340 A)	
Weight of the electrical part	.. 54 t		

BB LOCOMOTIVES WITH MONO-PHASE MOTORS

	Valenciennes-Thionville line's locomotives	Locomotives of following electrifications
Rated horse-power	.. 2720 HP at 32 mph.	2720 HP at 37 mph.
Corresponding traction stress	.. 13,5 t	12 t
Maximum traction stress	.. 28 t	25 t
Maximum speed	.. 68 mph.	74 mph.
Weight of the electrical part	.. 38,1 t	
Weight of the mechanical part (with transmission)	.. 46,9 t	
Total weight	.. 85 t	
Length (out buffers)	.. approx. 49 ft.	
Traction motors :	4 mono-phase motors with collectors of 680 HP (250 V, 3000 A)	

L'ALUMINOTHERMIQUE

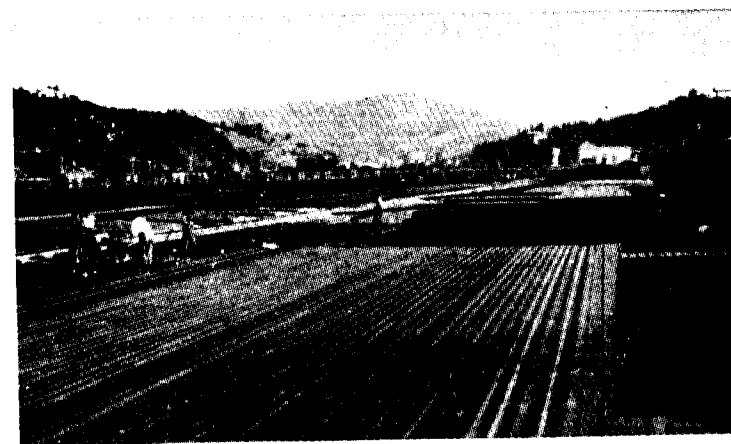
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BB LOCOMOTIVES WITH IGNITRONS

	Valenciennes-Thionville line's locomotives	Locomotives of following electrifications
Rated horse power	3360 HP at 32 mph.	3360 HP at 30 mph.
Corresponding traction stress	17 t	19 t
Maximum traction stress	30 t	33.5 t
Maximum speed	74 mph.	74 mph.
Weight electrical part		37.5 t
Weight mechanical part (transm.)		47.5 t
Total weight		85 t
Traction motors	4 motors of 840 HP (675 V, 1000 A).	

LOCOMOTIVES WITH RECTIFIERS

These locomotives are hauling high speed trains similar to those of the Paris/Lyons direct current line. Therefore their characteristics may be compared to those of our high speed 1500 Volts BB locomotives: normal speed 86 mph. with a power higher than 4000 HP. They are divided in two types:

(a)—the new high speed BB locomotives with ignitrons

15 are under construction for the Paris/Lille line: 155 miles

Terminal speed: 99 mph. A 700 tons-faster train will cover Paris/Lille at an average speed more than 74 mph. with 2 intermediary stops.

With a freight-train of 600 t. and a voluntary limited speed of 62 mph, the achieved schedule will be of 164 minutes at an average speed of 57 mph.

With a 2000 tons goods-train running at a 62 mph. terminal speed, the achieved schedule will be of 228 minutes at 41 mph.

This machine is absolutely terrific and has no equivalent in another system that the 50 periods; even our new Paris-Lyons 1500 Volts BB locomotives, which are well-known remarkable machines, are inferior in regard to the goods service.

The weight of the electrical part will be 38.7 tons.

The progresses achieved in the weight are very important in respect with the Valenciennes-Thionville BB locomotives: the power-to-weight per ton passes from 39, 3 to 48 HP.

(b)—the new high-speed BB locomotives with exitrons

This type, ordered in two units, includes a motor only per bogie. Its possibilities will be somewhat lesser than the former type.

Weight of the electrical part: 36 tons.

The following reasons are given in regard to the realization with two motors only:

1. Lightening and reduction of cost of motors.
2. Better position of motor (in the centre of the bogie).
3. Simplified ventilation.
4. Maximum utilization of adherence by appropriate mechanical and electrical devices.

These machines will be able to haul easily 1600 tons-trains on 10 per 1000 incline.

It is necessary to mention that this type meets entirely the requirements of 2.300 Tons-trains programme of the Eastern Indian Railways.

Regarding the comparative prices between 50 Hz and 1500 Volts direct current, the difference between the orders placed in the same time is less than 5% for machines of same weight, whilst the traction capability is as far higher in the field of heavy loads regarding the 50 Hz.

It is possible to ascertain that the 50 Hz. locomotive with rectifier is cheaper than the other types, as at equivalent weight, its performances are absolutely superior.

(c)—Tendency for a light BB locomotive with rectifiers.

The above mentioned locomotives are of full service only on the lines of big traffic; consequently, the French

National Railways has studied another type of lower weight, less than 80 tons.

They are machines with 2 or 4 motors of which the performances are the following:

Goods	: 1350 t on 8,8 o/oo	
	1050 t on 10 o/oo	
Freight	: 800 t in level at 55 mph	
Passengers	: 550 t in level at 74 mph	
either:		
	With 1 motor per bogie	With 2 motors per bogie
Motors.....	8	10
Electrical part	18	18
Mechanical part	31	32
Total weight	57	60
	Mechanical part, wheels of 1m10	
	Single driver's cockpit casing	
	2 pantographs.	

DIRECT CURRENT ELECTRIC LOCOMOTIVES SPEED AND DURATION RECORDS

It is known now all over the world that 2 French highpower electric locomotives, the CC 7107 Alstom and the BB 9004 M. T. E. have reached the record speed of 206 m. p. h. on March 1955.

In addition, another Alstom locomotive, of the same series, the CC 7147, has won in July 1955 the record of the distance covered in a month, with 39.410 miles, hauling regular trains between Paris, Lyons and back. The distance, which has been covered in 7 months, overreached 273.400 miles; the maintenance has been effected only after 372.000 miles. Such performances show largely the exceptional qualities of duration and security of these French locomotives.

EAST MOTOR-COACHES FOR THE MOROCCO'S RAILWAYS

This convoy has been showed on 12th October 1956 on the range Paris/Strasbourg. It consists of 2 motor

coaches framing 5 coaches of which 3 of 2nd class and 2 bar-coaches of 1st class. It carries 228 sit passengers.

Eventually, one 1st class coach may be replaced by a sleeping car.

The seats are rotary in the 1st class, with reversible backs in 2nd class; all are of variable inclination.

The meals are presented on removable tablets by mean of special waiters distributed by the stewards. Hot meals may be prepared thanks to butane gas ovens.

All the cars are air-conditioned. The installation of conditioned-air has required very special disposals of casing; in particular in order to make not heavy the construction: 1st class carriages have a weight of 29 T. 900 and the 2nd class carriages 30T. 800, that is not very important if we consider that the air-conditioning takes 4 Tons.

Regarding the bogies, the axles driving is realized accordingly 2 carefully studied devices which reduce the maintenance et secure the constancy of the initial qualities of the suspension.

The compartments' lighting is secured by a general lighting (fluorescent), a night lighting with removable individual lamps, and a safety lighting.

The motor-coaches include two motors:

- one MGO motor, of 1000/1200 HP. and 1500 rpm. which secure alone the traction.
- one auxiliary motor, of 200 HP, 1500 rpm. for the different auxiliaries.

The convoy with 286 tons makes a speed of 49 mph on incline of 15mm per meter. In level, a 87 mph speed is normal and it would be possible to reach 93 mph in changing the multiplying of the gears.

The speed of 37 mph is accomplished in 1 minute, this of 62 mph in 2' 5", this of 74 mph in 3' 10" and this of 87 mph in 4' 45".

Some facts regarding the World Speed Record on Rail in March 1955

It is universally known that two French locomotives won in March 1955 the world speed record on rail, reaching a speed of 206 mph. with trains of 100 tons.

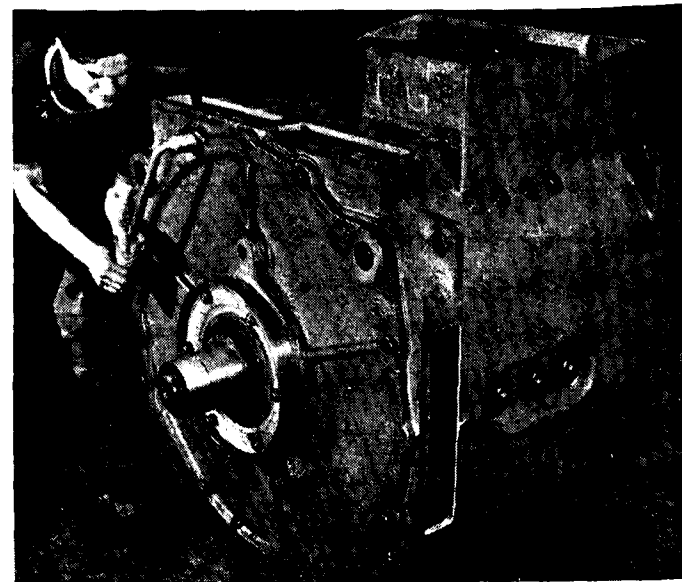
However the minute preparations preceding these performances are generally unknown, although that concerns two locomotives of a series—one of the C.C. type, another of the BB type.

We propose to reveal in the scope of this write-up some typical details regarding, more particularly the locomotive BB—No. 9004 (1)—demonstrating that everything has been foreseen in order to achieve this performance.

TEST OF TRACTION ENGINES

The realization of high speeds is first of all a problem of power. In fact, it is necessary to overcome the resistance to run, including the locomotive, and particularly the air-resistance which quickly increases together with the speed. That is why the electric locomotive, which does not carry its own energy production plant such as the steam engine or the Diesel locomotive, is among the motor engines, the most suitable to attain very high speeds.

In the test, although the train was formed with normal vehicles but carefully faired by means of special coupling heads of carriages, obstructing the entrance of air between them and terminated with a rounded appendix, the calculation and the wind-tunnel tests have showed that the necessary power would overreach 10,000 HP.—then the locomotive was foreseen for 4,100 HP. Thus, it has been necessary to test the 4 traction engines, one by one, on testing platform in order to verify their impeccable deportment at this increased power. Such a power could be obtained only in increasing the voltage feed of the line; thus



Traction Engine—Type 4326-SW.

forcing the engines to work at an intensity more than 30% to the normal one and with intensities relatively higher than these required by the usual operation.

Obviously the platform test have been more exacting than it was necessary, in order to prevent in line a welding melting or an engine flash or still, for instance, a section shrinkage. Thus, the overheatings has been carefully measured, the switching closely watched, the deportment of brushes verified etc. during very severe working cycles.

TESTS OF THE TURNING MASSES AND OF THEIR DRIVE

Centrifugal forces exercising with unusual way on the all turning masses: wheels, gears, drive-rings and the parts driven by them: crank-pins, rods, etc. it has been necessary to verify dynamically the balancing.

(1) The locomotive BB 9004 has been built by the Société "LE MATERIEL DE TRACTION ELECTRIQUE" grouping in the traction field the following firms:

- La Société des Forges & Ateliers Du Creusot (Usines Schneider),
- La Société des Forges & Ateliers De Constructions Electriques de Jeumont,
- Le Materiel Electrique S.W. (Schneider-Westinghouse).

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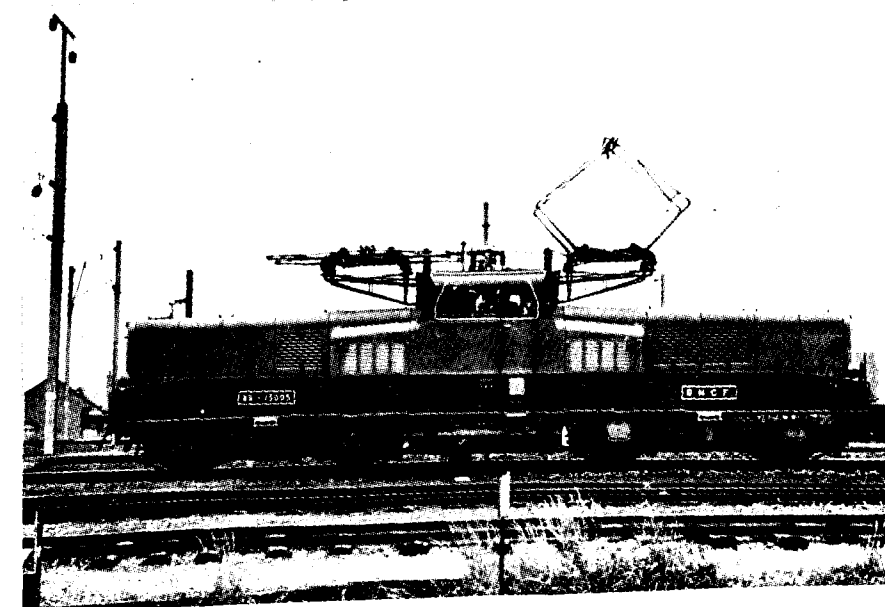
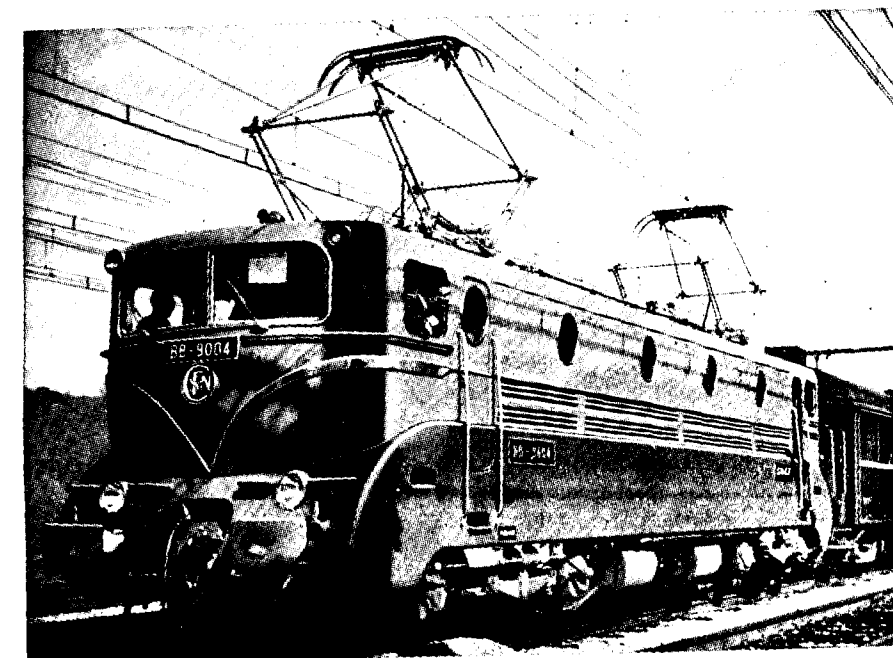
BB 9004

High speed direct current
locomotive.

March 29th 1955—331 Km/h.

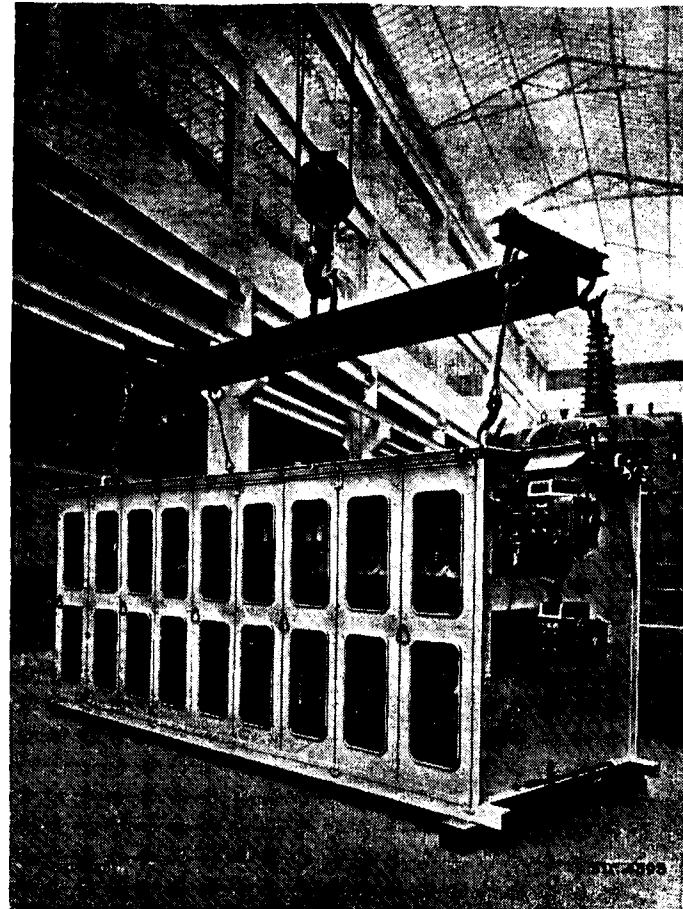
i. e. 206 m. p. h.

World Record



Monophase current on indus-
trial frequency locomotive
—with Ignitron rectifiers
or
—monophase collector motors

TWO RENOWN TYPES OF "M.T.E." LOCOMOTIVES



Complete Block of Electric Equipment. (J.H.)

For instance, regarding the wheels and their driving devices, the tests consisted in the putting in the hole of the whole bogies in the best conditions of security where they worked at speeds frankly by passing these which have been foreseen. They exactly reached the speeds corresponding to 279 mph.

The axle boxes of smooth bearing type have been submitted to very severe tests at similar speeds.

DIESEL ELECTRIC LOCOMOTIVES

It is learnt that the Indian-Railway Board has placed orders for 100 diesel electric broad-gauge locomotives of 2,000 H. P. each, as a major step towards meeting the heavy goods traffic demand during the second plan period at a cost of Rs. 10.7 crores. The first lot of 20 is expected to be shipped to India in June 1957. These powerful engines, which will be able to haul bigger train loads faster, compared to the conventional steam locomotives, will help relieve pressure on traffic.

BRAKING

When the foreseen speed was achieved, it was out of question to utilize without precautions the brakes of the train in order to stop it. This would have provoked redeemings of heat particularly noxious for the material.

The inquiries made by the S. N. C. F. (French Railways) enabled it to value the maxima energies which it was possible to disperse in the braking organs without damage for the material and to regulate these in order to enable a braking since a certain speed, valued to 124 mph.

Better to study a special braking, the S. N. C. F. has preferred to slacken the train in increasing its resistance to run, till the moment when the normal braking became possible. The simple opening of carriages windows by the accompanying personnel at an advance agreed kilometric point, should be sufficient following its calculation to quickly reduce the speed of 205 mph. to this speed of 124 mph. This was very successfully performed.

CONCLUSION

We do not pretend in the scope of this short article to describe, neither to mention the very minute preparatory tests preceding the March 1955 achievement—tests regards as well as the rolling stock as the fixed installations: gauge, plug socket line, energy feed of the last etc. But it is seemed that in drawing the attention of reader on one or three amongst them regarding the M. T. E. locomotive, it would be possible to underline the minute care brought to the preparation of these tests

Everything has been foreseen at all events. The materials proved their good quality even before the attack was launched and the performance proved thoroughly the meticulous care taken by the manufacturers in respect of each minute detail true to their tradition and thus earned for themselves the world's renown.

EDITORIAL NOTICE

CONTRIBUTIONS are invited from the Engineering Profession in India and abroad in the form of original articles, research write-up, Summary of papers read before Technical institutions etc. relating to Civil, Electrical, Mechanical, Signal & Interlocking and Telecommunication Engineering sections and of particular interest to the Railway Engineers. Besides, suggestion for the technical improvement of various aspects of Railway Engineering Practice are also invited with suitable write-ups and photographs wherever possible.

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EDITOR



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I, S. Sundaram hereby declare that the particulars given above are true to the best of my knowledge and belief.

(Sd.) **S. Sundaram**
Signature of Publisher.

LORRAINE — ESCAUT

LORRAINE-ESCAUT was formed, in 1953, by the amalgamation of the Mines and Plants of the ACIERIES DE LONGWY, the Societe Metalurgique de SENELLE-MAUBEUGE and the Societe d'ESCAUT-et-MEUSE.

Some figures will enable us to appreciate the importance of such an integrated industrial group whose range covers all steel and iron products; semi-finished products, railway sleepers and rails, merchant bars, section and steel piling, wire rods, strip and sheets, also steel pipes.

During 1956, LORRAINE-ESCAUT has extracted or manufactured:

- | | |
|--------------------------------------|--|
| — 4,500,000 Metric Tons of iron ore, | } entirely utilized
in the company's
own plants. |
| — 860,000 Metric Tons of coke, | |
| — 1,320,000 „ „ of cast iron | |
| — 307,000 „ „ of pipes. | |

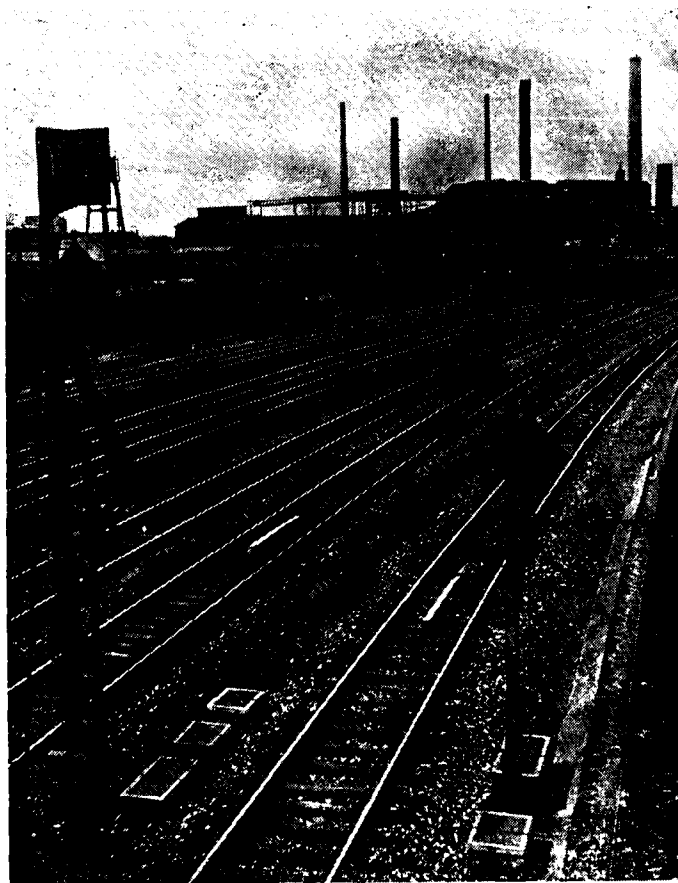


Photo by courtesy: Cliché "La Vie du Rail"

LORRAINE-ESCAUT groups 14 iron mines and plants. More than 27,000 workmen, employees, executives and engineers are employed.

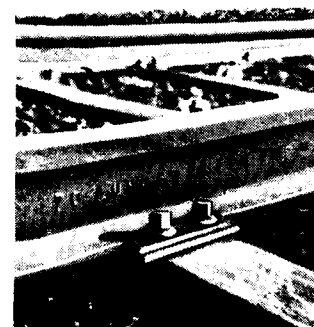
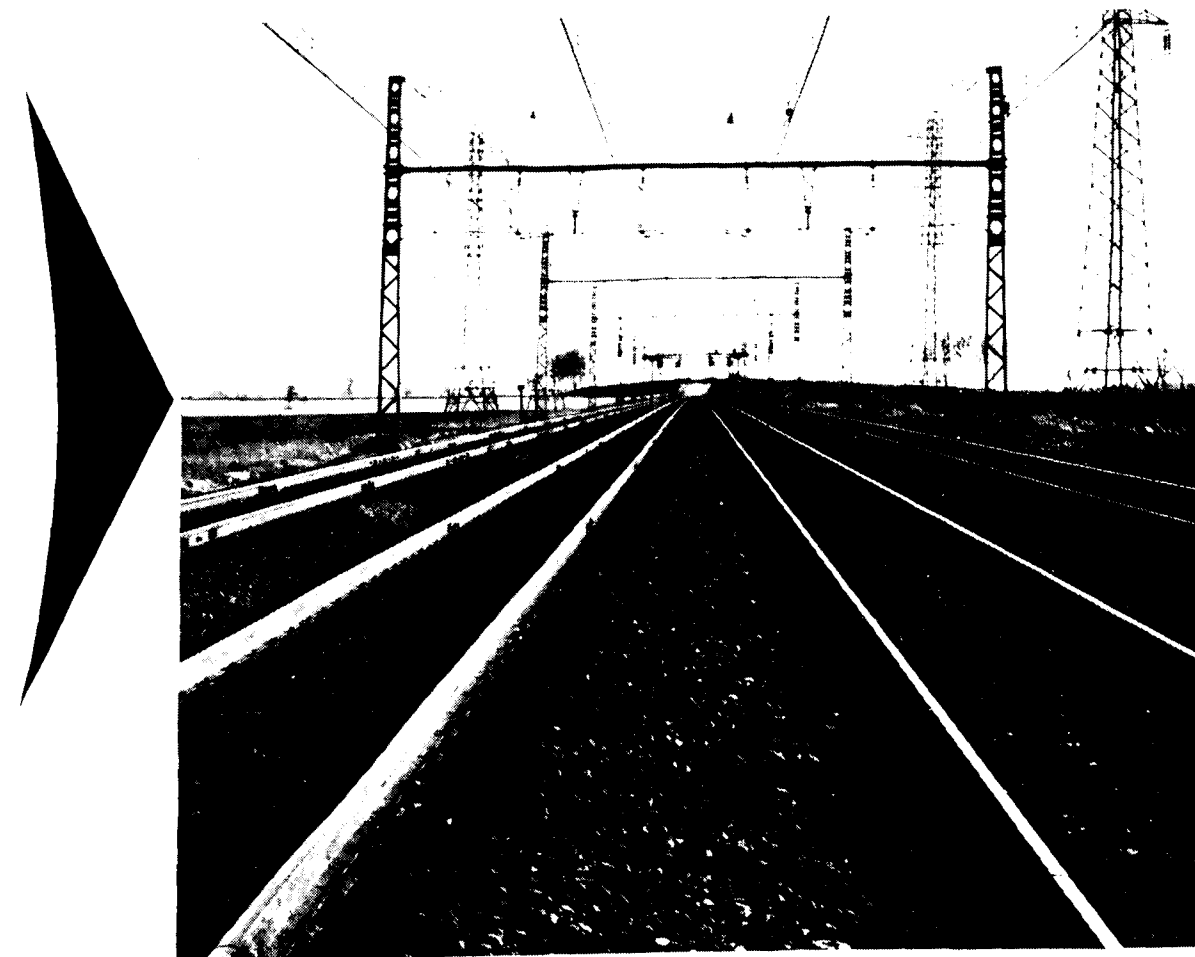
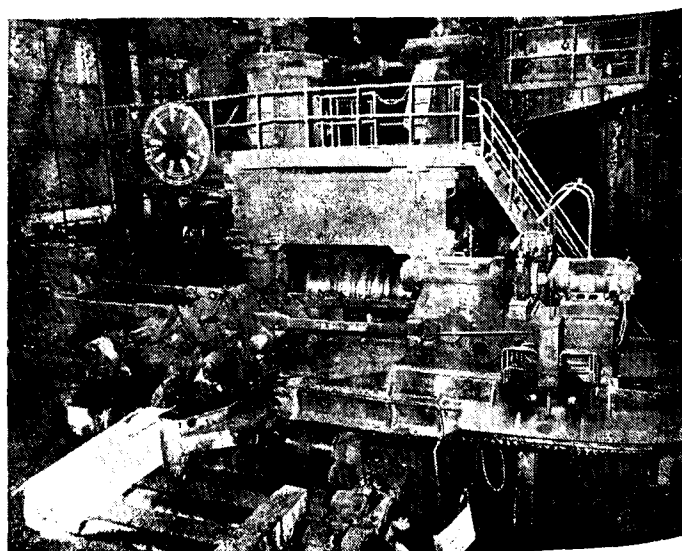
The plants, which are at present amalgamated under the title of "LORRAINE-ESCAUT" have acquired since long a very important rank among the French producers of gauge material. LORRAINE-ESCAUT supply about 20% of rails, sleepers and fish plates which are made in France.

Every day, thousands and thousands of trains run in Europe, India, Bolivia, Australia, South-African Union etc. on the railways fitted with material produced by LORRAINE-ESCAUT.

It is mentioned that this firm is one of the main suppliers of the Indian Union regarding the railway material.

In addition to the properly so called railway material, LORRAINE-ESCAUT deliver important quantities of ancillary products to constructors of locomotives and carriages. For instance, the locomotive which has won the world's speed record has been made with iron sheets produced by LORRAINE-ESCAUT.

In another field, the plants in charge of the fabrication of pipes are well-known in the international market for their excellent quality.



rails, sleepers, fish-plates

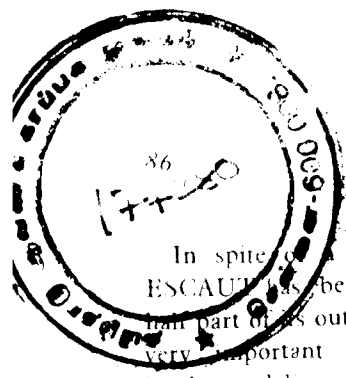
**all iron and steel products
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In spite of a very keen competition, LORRAINE-ESCAUT has been able to sell abroad more than the last part of its output of locomotives pipes. In 1956, a very important tonnage (approximately 1,300 tons) has been delivered to the main departments of Indian Railways:

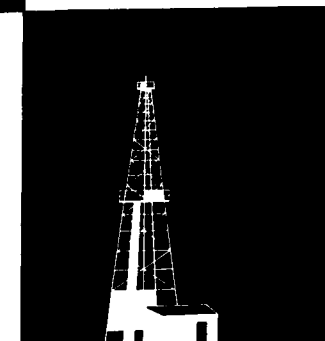
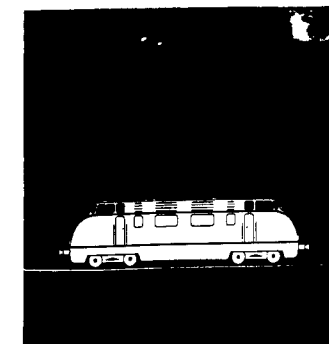
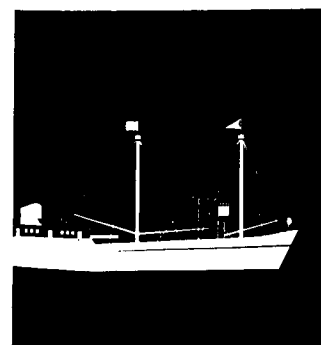
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Northern Railways — North Eastern Railways—
Southern Railways — South Eastern Railways—
as well as to the Chittaranjan Locomotive Works.

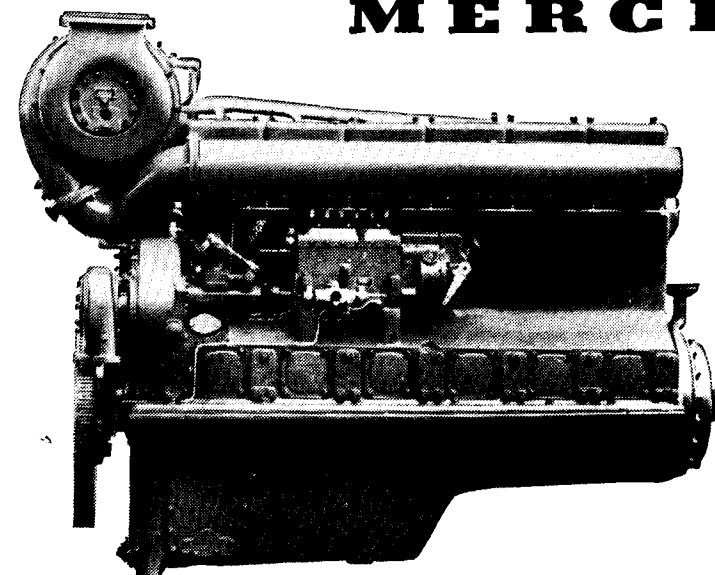
Although the LORRAINE-ESCAUT is the last born of the leading French firms, it possesses an illustrious past during which it has always been esteemed and entrusted by its clients.

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