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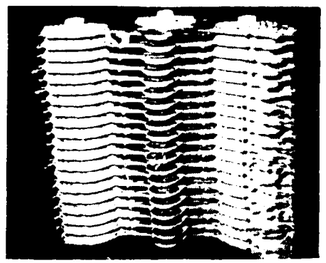

METALS & ALLOYS SUPPLEMENT

J.O.I.E.

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Manufacturing Development Research

RESEARCH. can be defined as the search for new knowledge representing creativ activity that generally leads to change. It is considered as the source of funda mental knowledge on the one hand and of technical development on the other, th latter being the application of the former to practical problems. Being a *sine qua non* i the fields of modern technology, the value of research in industry is fully recognise to-day.

All researches can be carried out in two distinct directions, viz., fundamental an industrial. Fundamental research refers to one undertaken in natural science and is lik exploration—delving into the unknown in the hope of finding something whereas i industrial research, a clear objective is necessary at the start, not just to save time, bu to make it possible to use the powerful scientific methods which have achieved suc successes elsewhere. Industrial research is usually carried out more or less on similar line as the work study, except that it goes into very much wider fields and with a greate rigidity of scientific methods.

Through research it has been possible to translate countless dreams into concret form and to provide many of the comforts of the present age. The manifold uses to whic metals and their alloys are being put to-day, have only been possible through researc and investigations carried out at various levels.

To-day when everyone is exhorted to do his best to produce more, emphasis i rightly laid on the extra effort that must be made by every individual worker in industry but it must also be recognised that every aid that modern science and technical ingenuit can devise must be utilised to obtain maximum efficiency from the operators, and so assis them in the common task.

It is in this field that manufacturing development research or "Shop Floor' research, as it may precisely be termed, can play its full part. This new conceptio in the application of science to industry with a view to basing conclusions as far a possible on quantitative facts scientifically obtained, aims to provide the answer to an manufacturing problem, before the problem arises, and in many cases, actually succeed in doing so.

Its principal aim is service to industry—in production and quality control and fo this Keynote of service it has earned a very important place in to-day's industrial set-up Every progressive management in other Countries has accepted the need and value of suc research in industry.

Manufacturing Development research is not new but probably its immense valu was not realised and exploited before. Further no systematic records of such researc results maintained as guides for the future follow-on as a result of which much of th labour spent on this score has been lost.

It is rather unfortunate that quite a number of industrial undertakings in this country have not yet introduced such research in their workshops and in many cases where it has been introduced, no arrangement has been made for the interchange of informations with their colleagues in similar industries. The result is that there is every possibility of investigations proceeding along parallel lines simultaneously in several organisations. Further it leaves no scope to find an answer immediately with consequent saving of much time and eliminating repetitive preliminary study.

The solution is that there should be free interchange of knowledge as it can do much to raise the level of efficient production and so add to the effectiveness of the nation-wide effort. The position can be further improved if industrial units group together and carry out such research piece-meal on problems of special interest to them.

The importance of maintaining proper records in this connection cannot be over emphasized. The records should be in narrative form to include difficulties encountered, their solution with the details of experiments carried out, reasons for accepting or rejecting one or the other method, details of jigs and fixtures used with their drawings, etc. In facts records should be maintained for all case studies undertaken, irrespective of the fact if success has been achieved or not, as it is in these records that all researches made, live on to form a substantial stepping-off point for others to follow.

A separate record should show the development reports received from associated organisations so as to build up a valuable dossier of manufacturing information.

It is true that the picture of research and development work as discussed is not fanciful as it appears to be in popular mind. But in the practical field, it has its immense value since research and development, may not be a phenomenal affair in every case but consist of small things as well.

A country must have to depend ultimately on the efforts of a large number of people and not on the geniuses alone. These people, selected for their talents in their own spheres should work as a team, feeding and inspiring each other with new ideals and methods usually insignificant or small in themselves but in the aggregate building into something useful and carrying the process of development a step forward.

———

GLANDLESS CIRCULATORS

An English firm, Hyward Tyler & Co. Ltd., of Bedfordshire, which has been making pumps since 1815, has received a £ 430,000 order for 176 special glandless circulators. These are to be used in circulating hot water in the heat exchangers at Britain's nuclear power stations at Bradwall, Berkeley and Hunterston.

Chosen for their leak-proof quality, the circulators are designed to run for long periods without maintenance and have features which give them special value where space is limited and as working pressures and temperatures rise. Similar equipment has been installed at Calder Hall and is on order for Chapelcross and Dounreay atomic energy establishments. The firm claims to be the first in Britain to have developed circulator units which can be used either as main coolant pumps or for secondary circulation uses in nuclear power plants.

Deuterium Fusion investigated in ZETA at Harwell

(From an Overseas Correspondent)

ON Friday last the United Kingdom Atomic Energy Authority and the United States Atomic Energy Commission simultaneously made announcements regarding the investigations which they are making into the possibilities of establishing controlled thermonuclear reactions. Encouraging results have been obtained in both countries, so much so that the use of controlled thermonuclear reactions for the generation of electricity is now a distinct possibility for the future. It must be emphasised, however, that although striking advances have been made the practical application of this experimental work is still a long way off.

The reports issued last week deal with a challenging field of research in which work has been under way in both the United Kingdom and the United States for some time. Research workers in the two countries pursued independent lines of research until 1956, but since then the two programmes have been the subject of close co-operation including exchange of results and information as a means of more rapidly reaching the common goal. Papers prepared by leading workers in both countries and describing the results achieved so far were published in *Nature* of 25th January.

To put the present work into perspective it should be understood that the operation of existing atomic power reactors is based on the fission (or splitting) of atoms using heavy elements such as uranium or plutonium. The possibility which is now being explored is the harnessing of power from the fusion (or joining) of atoms of light elements such as hydrogen. It is this fusion reaction which provides the heat of the sun and the stars. The results obtained with the experimental rig at Harwell known as ZETA (zero energy thermonuclear assembly) suggest that thermonuclear neutrons have been obtained, but further work will be necessary before this can be proved conclusively. However, the temperatures which have been achieved in this apparatus have been as high as 5×10^6 deg. C, higher than the measured surface temperature of any star.

Many major problems have still to be solved before a practical power producing version of ZETA can be seriously considered, and the work must be

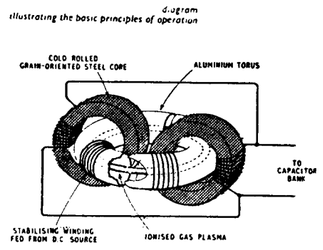


Diagram illustrating the basic principles of operation

Part of the 1,600 μF 25 kV capacitor bank which is capable of storing up to 500,000 joules.

expected to remain in the research stage for many years. As Mr. Lewis L. Strauss, chairman of the U. S. Atomic Energy Commission, said last week, in the field of fusion we are unfortunately not yet at a point comparable to 2nd December, 1942, when the first self-sustaining fission reaction was obtained. If it does ultimately prove possible to construct a power station operating on the fusion of deuterium (heavy hydrogen, which is written either as H^2 or D), the oceans of the world will provide virtually inexhaustible sources of fuel. The methods of extracting deuterium from water are comparatively simple and well established and it is likely that a thermonuclear power station would be sited near the sea or some other suitable expanse of water and contain its own deuterium production plant.

EXPERIMENTAL APPARATUS

On 12th August last year, ZETA, a large experimental apparatus for studying the controlled release

Part of the auxiliary electrical control equipment showing the capacitor room to the rear.

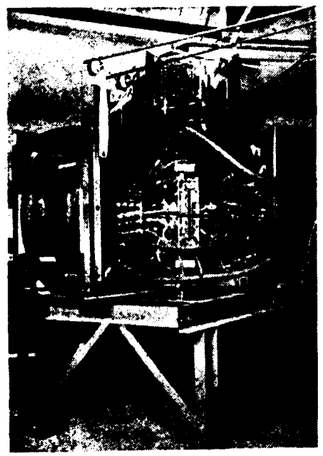
of energy from thermonuclear reactions was started up at Harwell. On 30th August this apparatus was first operated under conditions that produced nuclear reactions. Neutrons emitted in these reactions were observed when deuterium gas was heated electrically to temperatures in the region of 2 to 5 × 10^6 deg. C. The hot gas was isolated from the walls for periods of 2 to 5 millisec. The heating process was repeated every 10 sec. The high temperatures achieved, and the relatively long duration for which the hot gas has been isolated from the tube walls are the most important experimental results obtained so far. Although much longer times (perhaps several seconds) are required for a useful power output there appears to be no fundamental reason why these longer times, together with much higher temperatures, should not be achieved.

The source of the observed neutrons has not yet been definitely established. There are good reasons to think that they come from thermonuclear reactions, but they could also come from other reactions such as a collision of deuterons with the walls of the vessel, or from bombardment of stationary ions by deuterons accelerated by internal electric fields produced in some forms of unstable discharge. In the ZETA apparatus the number of neutrons produced by each pulse of energy as the current was doubled was roughly that which might be expected from a thermonuclear reaction at the measured temperatures. These temperatures have been definitely established.

To fill in the background to the present work it should be recalled that the U. K. A. E. A. have stated in their last two annual reports that research has been in progress for some years to investigate the possibility of reproducing energy in a controlled manner from thermonuclear reactions. Over two years ago the design of ZETA began and just over six months ago this large-scale experimental installation was started up, with the results described above. The reaction being studied in ZETA is that in which deuterons (the nuclei of the heavy hydrogen isotope deuterium) collide with one another and fuse to form heavier nuclei, releasing energy and some neutrons in the process. For fusion to be possible the deuterons must have enough energy to overcome the initial electrical forces of repulsion between them. This necessitates heating the deuterium gas to temperatures of millions of degrees centigrade. The hot gas must be kept away from the walls of the container, otherwise it falls in temperature.

The principle adopted in ZETA is to pass a large electric current through the deuterium gas. This current sets up an electric discharge in the gas which heats it and also produces an intense magnetic field around the column of hot gas. This magnetic field causes the discharge to become constricted and hence heated still more. Since it also causes the discharge to wriggle about, this field by itself is not enough to keep the discharge away from the walls. The wriggling has been suppressed by applying an additional steady magnetic field parallel to the axis of the tube. The discharge chamber is a ring-shaped aluminium tube or torus of one metre bore and three metres mean diameter, containing deuterium gas at low pressure. The gas, usually at a pressure of about 10^{-4} mm. of mercury, is made weakly conducting by a radio frequency discharge. The tube is linked by the cold-rolled grain oriented steel core of a large pulse transformer so that the toroidal ionised gas plasma forms what is, in effect, a short-circuited secondary winding. The ring-shaped discharge chamber itself is divided into two electrically insulated sections so that it has no current induced in it. A condenser bank capable of storing up to a maximum of 5 × 10^6 joules is discharged into the primary winding of the transformer and produces a unidirectional current pulse in the gas up to a maximum of 200,000 A. The current pulse in the gas lasts for about 4 millisec and is repeated every 10 sec. A steady axial magnetic field is generated by current-carrying coils wound on the torus and facilities exist to enable this to be varied from zero to 400 gauss. A vacuum spectrograph connected to the body of the torus is used to measure the temperature of the gas discharge. Throughout the current pulse the emission of neutrons is observed regularly in routine operation of ZETA with deuterium; up to 3 × 10^6 neutrons are emitted per pulse.

Equipment for determining the source of the neutron emission.



In "Sceptre III" the A.E.I. research team have achieved temperatures of nearly 4 × 10^6 deg. C.

TEMPERATURE MEASUREMENTS

The temperature of gas discharges may be determined from measurements on the light emitted by the gas atoms, but measurements of this kind in these experiments present problems because, at the temperature of the discharge, the hot deuterium atoms are completely stripped of their electrons and therefore do not emit a line spectrum. One method of solving this problem is to mix with the deuterium a small quantity of some heavier gas, such as oxygen or nitrogen, the atoms of which are not stripped of all their electrons under these conditions, and to study the spectral lines emitted by this impurity; the random motion of the high-energy impurity atoms, which make many collisions with the deuterium atoms and so reach the same energy, causes the spectral lines to broaden, owing to the Doppler effect, and the amount of broadening is a measure of the ion energy. Many measurements by this method have indicated temperatures in the region of 2 to 5 million degrees centigrade. Whilst temperatures in this range are required to explain the observed rate of neutron production on the basis of a thermonuclear process, electric fields in the gas arising from instabilities can also accelerate deuterium ions and lead to nuclear reactions. Such a process was described by Academician Kurchatov in his lecture at Harwell in 1956. Therefore, it is not altogether certain that the observed neutrons come from a thermonuclear reaction. Experiments are continuing to study the details of the neutron-producing processes.

In order to obtain a net gain in energy from the reaction it would be necessary to heat deuterium gas to temperatures in the region of 100 million degrees centigrade, and to maintain it at this temperature long enough for the nuclear energy released to exceed the energy needed to heat the fuel and that lost by radiation. Lower temperatures would suffice for a deuterium-tritium mixture.

The work on ZETA has been done in the General Physics Division at Harwell which is under the direction of Mr. D. W. Fry. The group responsible for the work has been led by Dr. P. C. Thonemann and senior members concerned with ZETA have been Mr. R Carruthers and Mr. R. S. Pease, with Mr. J. T. D. Mitchell of the Engineering Division, and Dr. W. B. Thompson of the Theoretical Physics Division. The principal contractors for construction were the Metropolitan-Vickers Electrical Co., Ltd. (who also collaborated in the design), British Insulated Callender's Cables, Ltd., and Telcon, Ltd.

Research work in the field of controlled thermonuclear reactions is also being carried out at the A. E. I. Research Laboratory (director, Dr. T. E. Allibone) on behalf of the U. K. A. E. A., and with

(Continued on page 8)

On Getting Things Done

By Dr. S. C. Dholakia, B. Sc. (Hons.), B. Sc. (Tech.), Ph. D. (U.S.A.), A. M. I. I. Chem. E.
Works Manager, Calcium Carbide Factory, Birlapur, West Bengal.

FOR us in India, the present age may well be called an Age of Planning. Nationally, we have realized that our needs are large, our resources immense and our potentialities vast. At the same time we have also concluded that without planning we will not be able to co-ordinate our potentialities, resources and needs—primarily because we have little time to lose in raising our standard of living. Planning however, by itself is not enough. Execution is equally important and one can say without hesitation that efficiency and rapidity with which a nation executes her plans can serve as an index of progress.

Execution which means getting things done must be preceded by comprehensive planning which however is only an end of the beginning. The ways and means by which plans are harnessed depend upon the sphere of activity which may relate to domestic, scientific, social, political and industrial problems. The methods have to be carefully selected to correspond with the emotional and material needs of the sphere involved. Our primary interest here lies in the industrial field of human endeavour which if properly applied promises to change the face of our Country.

Why do some projects fail to materialize at an anticipated rate while others are reported to be proceeding ahead of schedule? Why certain industrial concerns turn into gold whatever enterprize they undertake as against some others who miserably fail even in apparently simpler undertakings? It is customary to point out to some fortuitous events or some unsurmountable difficulties or to circumstances beyond one's control as reasons for failure when in reality the boot is on the other leg. It is the scientific method of handling problems at all levels and ranks from top to bottom of the organization that really matters.

Getting things done is an art which however has to be rationalized by scientific analysis. The following factors have to be clearly understood before the art and science of execution can be mastered.

1. Organization
2. Study of Human Reactions
3. Professional Talents
4. Incentives and Motives
5. Comprehensiveness of the Plan
6. Inter-relationship of efficiency, cost, legality and ethics
7. Analyses of Specific Situations in a job
8. Personal contact—Balance of Condemnation and Appreciation

Let us imagine a large concern has just finalized a plan for expansion. The job requires co-ordination of the following parties for carrying out the various stages of the plan :

(a) Departmental Staff, Skilled and Unskilled workers.
(b) Inter-departmental help—under Common Head
(c) Technical service from an Independent Organization
(d) Contractors and Suppliers
(e) The Government Officials.

(Continued from page 7)

the advice of Sir George Thomson. Experimental work was started at the Imperial College by Sir George Thomson in 1947. It was moved to the A. E. I. Laboratory in 1951. The senior members of staff engaged are Mr. D. R Chick and Dr. A. A. Ware.

This work has recently culminated in a device which looks like a small edition of ZETA. This is known as "Sceptre III" and is an aluminium 12 in. diameter toroidal tube, the mean torus diameter being 45 in.; and it is threaded by an iron core weighing 4 tons. About three weeks ago temperatures of about 4×10^6 deg. C were achieved with this apparatus and neutrons were observed. The work is being continued to see how far temperatures can be increased with smaller and less expensive systems.

(Courtesy—"Electrical Review")

All the above categories represent different groups of people with one thing in common however. They are all human beings and the dealings will have to be on a person-to-person basis. This fact is often overlooked and leads to troubles most of the times. The various means employed commonly are authority, force, payment of money, consultation and persuasion. The historic approaches of 'divide and rule', bribery, threats and opportunistic humility also find place in these affairs. These means and approaches do not always work smoothly if the primary factors listed above are not attended to. For instance, if human reactions are hostile to a certain order or talents and incentives are insufficient or motives are not understood and appreciated, there is very little a person in authority can do in a positive direction. He can of course use his authority in imposing dismissals and disciplinary actions but this is after all a negative action and by itself does not lead to furtherance of the objective of getting things done.

Within a department, where authority can be used most effectively, clarity of instructions, practicability of the order, consideration of the difficulties involved, and putting one's own shoulder to the wheel play significant role in supplimenting the cut-and-dry approach of authority. While the pen might be mighter than the sword, the soft words expressed in prompt response to psychic demands are the mightiest of all.

When inter-departmental help is required, simply getting instructions passed on through the common head may not get the things done as smoothly and quickly as a direct person-to-person approach might. At these levels and at all levels for that matter, the problem of satisfying egoistic needs of the human nature is important and cannot always be handled through a rigid framework of the institutional system of assigning work.

The procedures involved in handling independent parties which are not under the direct control of the local executive have to be carefully developed. As a first step it is absolutely essential to clarify right at the start the details of responsibilities, specifications, schedules and terms of spheres of work and materials involved and the negotiating machinery in case of differences. The rest will have to be tackled on a person-to-person basis at the site of work. Here will come into play the technical competence of the local persons involved in reconciling different alternatives propose and in finding solutions so as to adopt the available materials and tools for the job rather than insisting only on the recommended components. The efficient means of communication and transport have to be available for speedy decisions and steady supply of the materials and tools. The local organization of all the parties involved should be so constituted talentwise and so authorized as to handle day-to-day problems successfully without frequent references to their superiors far away to avoid delays and bottlenecks. Personal qualities such an initiative, aggressive attitudefor the sole object of getting work done, courteous but firm handling, ability to work according to the spirit rather than the letter of the mutual agreements, and capacity of helpful co-ordination are highly essential in this connection.

Nowadays the governmental controls are getting increasingly important and hence a thorough understanding of the legal and procedural aspects in dealing with the officials is required. Even in general, the governmental machinery is rather lengthy, of course for valid reasons sometimes and it can be a serious handicap to progress if matters are not handled rightly at the start. As elsewhere, personal approaches work very well here as well. If the official is approached as a helpful representative to assist the executioner to complete his plans at the earliest—not as an unavoidable nuisance to put up with—the affairs would be greatly simplified.

Thus one finds that if basic factors are interpreted and acted upon properly, the normal reactions arising in practice can be successfully dealt with. While one may have to deal with a superior, a subordinate, an equal, a Government Official, or an independent person, the basic needs of a person-to-person relationship have to be satisfied in order to get work done.

Let us take an instance of an executive who comes across some of the following flat reactions in his normal work.

1. I can't do it—No time.
2. This way is hopeless—I do not agree with it hence I won't do it.
3. If you take the responsibility—I'll do it otherwise let me do it my way.
4. This is not my work—You better wait until Mr. so-and-so comes back.
5. I would like to do the easier way although it is more expensive—why should I not do the more convenient way?
6. I thought you meant that way—hence I have done so.
7. I had done it alright. I don't know who spoiled it afterwords.
8. How can I do it? Mr. so-and-so did not supply me the materials/instructions.
9. Either he does it or I do—Both can't work.
10. I told my assistant to do it—but he forgot—what can I do?
11. Alright—I shall do it. (After sometime—no progress) Oh—I forget, will you explain me what is to be done?
12. Only one hour left to-day—I will start it tomorrow (Postponing attitude).
13. You told me this way, Mr. so-and-so ordered me the other way—I am confused and have not done it.

From the above, it will be observed that the reactions—expressed or implied—have to be properly handled in order that the work is done. Sometimes the explicit reactions serve only as excuses to cover up the intrinsic reactions which have to be discovered and remedied. For example, the excuse of 'No time' may not always be genuine unless the organization is defective. The real reason may be lack of incentive, inappreciation of motive, or conflict of personality. Similarly the other reactions can be analysed and counteracted.

Once the writer had come across the following list of factors which contribute to the idle time at any working place, which would be found instructive:

1. Not enough rest after fatigue
2. Insufficient directions
3. Discontinuities in work
4. Group bigger than required
5. Delay in receiving materials
6. Ill health of the workman
7. Extreme weather conditions
8. Inadequate ventilation and lighting
9. Dislike of the Supervisor
10. Simply Laziness.

Most of the above are subject to control resulting in improving the efficiency of getting things done.

Besides developing generalized approaches to a group, the importance of psychic reactions of the individual should not be overlooked. Authority has to be intrinsically respected instead of forcibly imposed in order to be effective. The political keynote of Lord Acton—Power corrupts and absolute power corrupts absolutely—applies with no less force in industrial organizations. Untimely overuse of authority can derail a smoothly working execution of a plan. At times, one has to be autocratic while at other times democratic and co-ordinating spirit has to be applied. This can only be judged if the basic urges of human nature are respected to at all levels of an Organization.

A famous story comes to mind. Sir Christopher Wren had undertaken to repair an ancient Church in England. While he was moving among the masons at site, he asked one whether he knew what he was doing. The mason replied "I am Chipping off the Stone". The other answered to the same question —"I am earning my bread", and the third one remarked—"Sir, I am helping Sir Christopher Wren in repairing this great Church"—This shows how much important it is to develop outlook among all concerned so that each one of them takes pride in becoming the partner in the great art of getting things done.

Heavy-Weight Roller Bearings

At the European Machine Tool Exhibition, Hanover, Germany (Sept. 5 to 24), bearings for a wide variety of applications were shown by British Timken Ltd., of Northamptonshire, one of the world's leading manufacturers and exporters of tapered roller bearings. The majority of the exhibits comprised bearings for work and cutter spindles, including grinding spindles which are usually met by bearings from the precision ranges. There were however, also bearings from the standard ranges suitable for pumps, controls, drives and gear shafts.

Two features of these bearings are of special interest. First, they use the entire length of the rolling element to sustain load. And additionally, roller bearings by this firm are made from case-hardened nickel alloy steel. When these bearings are used in pairs, the fact that the rollers are set at an angle means that the loads can be carried in all directions. Some of these bearings used in machine tool construction are machined to tolerances as fine as 0.00075 in.

A New Fork Lift Truck

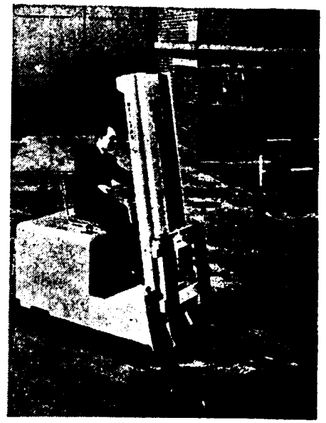
A new fork lift truck has been added by Matling Ltd. to their wide range of mechanical handling equipment. Known as model RFLT2 it is rider controlled and has a maximum lifting capacity of 3,000 lbs. at a load centre of 20 inches. In common with all other Matling units it has been designed to provide maximum manoeuvrability in restricted spaces.

The truck is powered by a 24-volt battery which operates a heavy duty constant speed reversing motor. Transmission to the single rear wheel is through a multiplate clutch and a gear box providing three speeds. The advantage of this arrangement is that it dispenses with the use of complicated electrical control gear equipment.

Lifting and tilting are effected hydraulically by means of a separate 24-volt series wound motor direct coupled to a gear type pump which supplies pressure to the lifting and tilting jacks operating the telescopic mast assembly. The hydraulic tank is placed under the driver's seat and incorporates a pressure relief valve which prevents the operator from lifting a load of excessive weight.

The layout of the truck controls has been carefully studied with a view to eliminating operator fatigue. The controls are of the motor car type, light in action and consist of a conventional steering column, a 'dead man' pedal on the right of this and a foot brake pedal on the left. A parking hand brake is provided close to the operator's left knee. The three gears are selected by means of a lever on the steering column. Reverse of any gear can be obtained by pressing a foot switch next to the 'dead man' pedal. A green light on the facia panel shows when forward speeds are engaged and a red light indicates reverse motion.

Various safety devices have been incorporated to ensure foolproof action. A key switch must be turned and the 'dead man' pedal actuated before the equipment can be operated. The electrical circuit is broken when the brake pedal is depressed and when the charging plug is left open. Mechanical interlocks are provided on the tilting and lifting control levers. Positive stops inside the jacks ensure that neither load carriage nor mast can over-travel.



Rider controlled Fork Lift Truck.
Model RFLT2. Matling Limited.

Heights of lift ranging from 54 inches to 144 inches can be provided. Mast tilt is 2° forward and 10° backward. The cast steel lifting forks which are laterally adjustable from 13 inches to 27 inches are supplied in lengths to suit customers' pallets. Every truck produced is tested with a 25% overload.

Working parts are easily accessible for maintenance purposes, the weather-proof panels covering the battery and power unit compartment being quickly detachable. For charging all that is necessary is the removal of the charging plug socket cover and the insertion of the charger lead and plug.

A comprehensive selection of ancillary attachments such as squeeze clamps, rotating heads, jibs, booms, pole forks etc. is available for use with this model.

An interesting feature of this new fork truck is that wherever possible standard components have been incorporated in its construction. These are interchangeable in all trucks in the Matling range, thus ensuring maximum serviceability for Matling fleet owners.

The Boilermaker in Nuclear Engineering

How manufacturing and testing facilities for nuclear equipment have been integrated with the rapidly growing output for other industries.

IN the manufacture of heavy engineering plant for the current design of nuclear power stations employing gas-cooling of the reactor, the part which departs most from established practice is that played by the maker of boilers and pressure vessels. The departure is not only a matter of scale but also involves the development of techniques and machinery for fabricating and welding the types and thicknesses of steel used in nuclear power generation. These problems are not confined to the boilermaker's works because Class I vessels too large for transport as a complete unit must be assembled on site and the work must be to a standard at least as high as the best works practice. These reflections are prompted by a recent visit to the John Thompson Group's works at Wolverhampton, Britain. John Thompson is the "boilermaking" partner of the nuclear power consortium of A.E. I.-John Thompson Nuclear Energy Co., Ltd. The Wolverhampton works are producing for the commercial nuclear station the reactor vessels and the complete heat-exchangers, together with gas ducting and thermal shielding, and are, in addition, manufacturing the fuel loading and discharge machines, using special facilities developed by one of the group companies in precision engineering work for Admiralty contracts. The way in which the necessary adaptation and extension of facilities has been carried out is also of particular interest, because of its integration with rapidly expanding output in other fields of manufacture. For example, the value of output of the John Thompson Group in 1956 was more than double that for 1952 and more than three and a half times that for 1949. From 1949 to 1953, output increased yearly by almost equal steps, then went ahead by greater bounds in 1954, 1955 and 1956. While this output included some work for nuclear projects (in particular for the Dounreay fast reactor in 1956), the major part of it has been due to increase of the group's more conventional manufacture of power station and industrial boilers, process plant and other products.

Integration of nuclear work with other manufacture in this way produces two important values. First, it permits economical full operation of certain heavy and specialized equipment; and secondly, it maintains high standards of quality in the manufacture of conventional products by the use of high-grade machines, skill and conditions necessary for nuclear plant manufacture. Whereas the skill and facilities developed for conventional manufacture have made possible the engineering of nuclear plant, the nuclear work in turn raises and maintains quality and economy in the more conventional products. And full employment of costly plant and skilled labour provide availability of large manufacturing resources, capable of undertaking the largest projects economically.

Manufacturing resources now available at John Thompson's works are adequate to undertake the work for one commercial nuclear power station of the Berkeley type, or of larger output, per year. Considered alongside the U. K. Government's nuclear programme of 6,000 MW by 1965, and estimating the possible share of each of the manufacturing consortia in this programme, it is clear that production capacity at John Thompson's works can cater for some overseas contracts for nuclear plant in the same period. This work need not necessarily be for complete heat-exchangers and reactor vessels as at Berkeley. For some parts of the plant, manufacturing facilities closer to the site might be used.

The heat-exchanger vessels for Berkeley nuclear power station (275 MW) are now being made and may be taken as an example of the use of the facilities now available. These vessels are 18 ft. (5,486 mm.) dia., fabricated from steel plate $1\frac{1}{8}$ in. (28.6 mm.) thick. They are made up of five cylindrical sections forming the body of the vessel, and a domed section top and bottom. The cylindrical sections are fitted with a large number of inlet sleeves for connection to pipework and tube headers. The domed end sections are fitted with 5-ft. (1,524-mm.) dia., 6-in. (152.4-mm.) thick compensator rings to make up the necessary steel thickness and strength at the connection to gas ducting from and to the reactor vessel. Each of the seven sections is completed so far as possible in the works and afterwards transported to Berkeley for assembly and welding into a complete 70-ft. (21.3-m.) high heat-exchanger. The whole of the welding must be to Class I requirements, and the fabrication must be stress-relieved after welding. The cylindrical body sections of the vessels are each fabricated from two steel plates, roll-formed cold to shape in the large roll-bending machine in the heavy bending and welding shop. This machine serves the works with roll-formed shells up to 6 in. (152.4 mm.) thick (thick plates are first heated in a furnace, alongside) for chemical and petroleum vessels, water-tube boiler drums, shell boilers, mill bodies, and so on.

Construction of reactor vessels for the gas-cooled stations is largely site work, using pressed petal plates from the boiler press shop for the domed end sections, and roll-formed plates for the cylindrical sections. The Berkeley reactor vessels are made up of dome-shaped top and bottom sections and five bands of plates forming the cylindrical portion. Plate thickness is 3 in. (76.2 mm.) and the vessel is 80 ft. high and 50 ft. dia. (24.4 × 15.2 m.). Special pendulum flame-planing equipment has been developed and installed by John Thompson for edge preparation of the petal plates, so that no machining is necessary. This operation is carried out after pressing the plates to shape, which is curved in two planes. Trial assembly of the reactor vessel plates is carried out before despatch to site. In the case of the domed end sections, this is done on a large 50-ft. (15.2-m.) dia. jig in the newly-equipped fabricating shop, and for the cylindrical section, the bands of roll-formed plates are assembled on a circle of plinths. Site welding of the reactor vessels has had certain effects upon the provision of facilities at the works. Welding research and development, always active at Thompson's, including their pioneering work in fusion welding in Britain, has been further enlarged.

Production of stainless-steel vessels which have included the complex reactor vessel for the Dounreay fast reactor, is carried out by a special section of the shops devoted to the completion of vessels and steam drums using cylindrical shells from the heavy bending and welding department. The stainless-steel section employs techniques evolved from their experience of producing vessels for the chemical industry. Other sections of the department are producing steel drums for the nuclear power station heat-exchangers. This is quite normal work for them. Chemical and petroleum vessels 100 ft. (30.5 m.) long have been produced, and there are high-pressure

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"Circuit-Printing" Techniques and their Place in Radio Industry

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THE First Five Year Plan had envisaged a production target of radio receivers and components amounting to 350,000 sets per year. But the target could not be achieved and the total annual production during 1955—56 was estimated to be about 130,000 sets only i. e., not even 38%. It is in view of this that the Second Five Year Plan has conservatively set a lower production target of only about 200,000 to 225,000 sets by the year 1960—61. In order to achieve this, the Planning Commission has gone further to formulate and licence various schemes of development and production of radio components. From this scheme of things, it appears that one of the basic bottlenecks in this industry is the procurement of components, their manual assembly and individual wiring. This serious short fall in our schedule targets is no doubt due to various factors, but one of the most important is the non-application of the mass-production techniques which have become available owing to advances made in fields of "circuit and component printing" and have already been adopted in other countries. These techniques lend themselves to mass production in the easiest and speediest forms; for, in addition to wiring net-works, efforts can be directed to successfully print some components also, such as, low value capacitance, resistance and inductance. The importance of 'circuit-printing' will be clear from the saying that if simply wiring network and low-value, low precision (± 20%) resistors and capacitors could be printed then the operations and work of the radio industry would be reduced by more than 50%. In fact, a reference to circuit-printing has been specifically made on page 127 of the draft Second Five Year Plan. It is in view of this that the meaning and the methods of circuit-printing are discussed below in brief outlines.

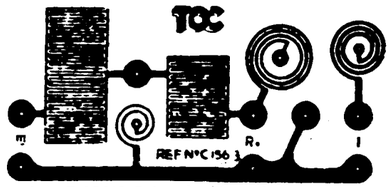
Circuit-Printing is a production technique of achieving miniaturization of assemblies. In this technique, circuit wiring and elements such as inter-connections, resistors, capacitors etc., are printed on or are made integral parts of the mounting base chasis itself, thereby avoiding all external wirings and complications and also resulting in tremendous reduction in the size of the finished assembly. The art of circuit-printing may be developed to various stages of perfection, depending on the component availability and manufacturing techniques and skills procurable. A brief description and discussion of some of the known techniques is given below.

(Continued from page 15)

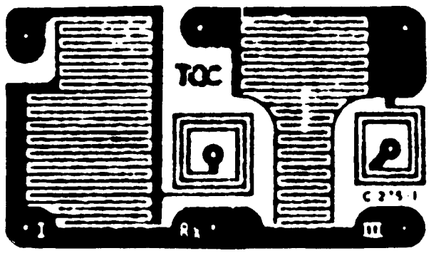
steam drums now in production for large conventional power stations, some of which are 4¼ in. (114.3 mm.) thick and weigh 65 tons (66,040 kg.).

Machining and fabrication to close limits are required in substantial quantity for many nuclear projects. This was especially so for the Dounreay fast reactor project, where tolerances required were very much stricter than normal boiler making practice. In fabrication of the reactor vessel, limits measured in thousandths of an inch were met by skilled workmanship, and calculation of distortion due to welding and machining.

The centralizing of all John Thompson research facilities in order to provide the best possible service to each company from combined resources, was a natural step forward in group development, quite apart from the needs of research in connection with manufacture for nuclear power. Many sections of the centre serve all group companies in the investigation of problems existing in their widely varying fields of conventional manufacture: and, as with many of the factory extensions, the need for expansion and development to meet conventional manufacturing progress coincided with the need for additional resources for nuclear power.



(a) C 156/3 Printed coils and two printed condensers.

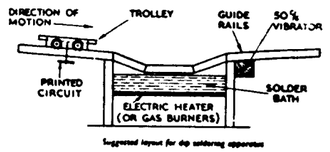


Front of panel showing printed inductors and condensers.

A metal foil such as electrolytic copper or silver is bonded to a sheet of silicon resin or "teflon"-impregnated fibre glass. With the exception of the desired circuit pattern, all the metal surface may then be removed by various methods such as stencil screen process, sand blast process, photographic acid-resist process etc. Instead of fibre glass or silicon, steatite or ceramic plates may also be used as a base after proper firing. In this case, the connecting networks may be printed with fused metallic silver. Holes in such panels can then be drilled or punched for plugging in separate miniaturised components after which the complete assembly is fluxed and dipped in a solder bath so that all soldered connections are made in one operation. In this way, the dangers of incorrect wiring and dry solder joints are eliminated.

To improve the space factor, three dimensional wiring may also be produced by arranging for the base material to be flexible and therefore foldable, or alternatively by suitable treatment of the laminated phenolic base, enabling it to be bent and folded to shape after printing.

A further improvement in the 'circuit-printing' techniques has been the adoption of the "unit-line heated die pressing process" which provides flexibility for easy change in circuits. In this system, a metal



Suggested layout for dip soldering apparatus

block with a raised pattern is used as the die, similar to the printers' line-block. Silver powder is spread evenly over a laminated plastic panel and the heated die pressed on the surface. The compressed silver powder is bonded to the surface and becomes a conducting layer while all the surplus powder is brushed off and used again.

Another system of circuit printing depends on a basic stage module roughly cylindrical in shape, say ½" in diam. and 2" in length, and composed of ceramic of high dielectric constant. The inner surface of the cylinder may be completely silvered and the outside surface silvered in required patches. These patches may function as the high-potential electrodes of by-pass capacitors and the inner silvered coating functions as the common ground electrode. Thus, not only the capacitors but the silver inter-connections and tape resistors may also be printed and located on the cylinder. A special silver paint may also be used for circuit-printing. This paint may consist of finely divided electrolytic silver powder, low m. p. glass powder, volatile carrier etc., and may be made of required viscosity, bonding strength and resistance by varying the proportions of various ingredients.

Due to large surface area of printed wiring in comparison with its cross-section and the fact that bright copper or silver, having a high radiation efficiency are used, relatively heavy currents can be carried with safety in the printed networks. For example, 1/32" line width of 1.5 mil thick copper can easily carry currents upto about 2 amperes and a similar 1/8" line width would carry about 4 to 6

amperes. Silver wiring would give more than 20% increase in the current carrying rates. Also, as the surface resistivity of the base material is always high, there is an insulation resistance of about 50,000 M. Ohms between two printed wirings spaced by 1/16" at ordinary temperatures.

In practical details, the first stage is to make a drawing several times full size in which the complete wiring pattern to be printed is shown to scale. A black and white drawing is necessary with the conductor pattern in black, if the photographic process is to be used to prepare a printing plate. The width of lines and spacing in between should be considered with care.

Similarly, resistors may also be printed, if required, by using proper techniques. For example, they may be of cracked-carbon-type which are produced by "cracking" carbon on a smooth ceramic surface, the thickness etc., being governed by the resistance required. Alternatively asbestos paper strips with uncured silicon resin bond resistance film on one side may be used as tape resistor. Lengths of this adhesive resistance tape are laid down on the printed plates when heating the entire plate simultaneously cures and permanently secures the resistance element.

Work has also been carried out on deposing resistors using "aspect-ratio" techniques. Instead of attempting to place resistors of different values in the correct circuit positions on the panel, the whole plate is evenly covered with a resistor material to start with. The correct amount of resistor material required is then determined by the 'aspect-ratio principle' i. e., by means of a rectangle having an aspect-ratio of 10 : 1 (width to length or length to width) with two values of ohms per square (1 & 100 K), the range from 100 to 1 M can be covered. The remaining unwanted material is finally removed by sand-blasting.

As already mentioned before, condensors may also be printed consisting of thin metallised discs of various dielectric mediums. The simplicity and reliability of "circuit-printing" techniques show an appreciable saving in cost, in addition to other economic advantages, for example, elimination of inspection and later "trouble shooting" during service. It also affords better designing, greater reliability and reproducibility of networks. These tremendous practical advantages have resulted in the mass scale adoption and development of these techniques in the foreign countries to such an extent that now even transformers, potentiometers and other components are being increasingly printed. It is only with the adoption by the industry of these modern and upto date techniques of mass scale production that we can ever hope to make up and attain the standards of production obtaining in some advanced countries.

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Thanks are due to Telegraph Condensor Co., London from where some of the illustrations have been taken.

NEW DIESEL DUMPER

Chaseside Engineering Company, Ltd., of London, have produced a new one cubic yard diesel dumper, designed primarily for strength and simplicity. It can take heavy shock loads and be driven over rough sites by an unskilled operator without fear of damage, it is claimed. A specially built heavy duty gear-box, incorporating constant mesh gears, provides three forward speeds of up to 4, 8, and 15 m.p.h respectively and 4 m.p.h. in reverse.

Open centre track tyres and correct arrangement of weight distribution between the two axles give remarkable traction with or without load-all; machines must climb a one in four ramp unladen as part of the normal working test. It has high ground clearance at both axles and even greater clearance in the centre of the machine. The skip is of all welded construction with base and back of 1/4 in. and 3/16 in. steel plate. It is tipped by means of a hand tipping lever and the balanced design resets it automatically when empty. The struck capacity of the skip is one cubic yard and the payload on uneven ground can be as high as one-and-a-half tons.

Some Aspects of Commercial Refrigeration

By G. Keith Drew and C. M. Marks

THE subject of commercial refrigeration is at once so wide and all embracing that, in a relatively short article of this nature, a problem is presented as to how, adequately, to deal with all of its very important aspects.

In its widest aspect, and certainly one of its major ones, it has been one of the greatest factors in raising living standards by making possible a wider distribution of food stuffs through preservation of foods at all stages of production, manufacture and handling. Beyond this, it has helped in many industrial fields to improve and speed up certain processes and in providing stabilised conditions of temperature and humidity, so essential in many important manufacturing spheres.

The need for refrigeration is universal and this fact is fairly generally accepted. Its importance in the economy of every country and its effect on living standards is not always, however, fully appreciated.

The very lifeline of any country is its system of food production and distribution. Many countries sustain a low standard of living, mainly because of poor conservation and distribution of food. For the widest possible distribution of foodstuffs, refrigeration is essential. For the hygienic and healthful handling of food, it is essential. No country can build up its economy and support a large population without refrigeration. Modern living and the move to higher living standards demand the wide use of refrigeration.

Despite the growth in the acceptance and uses of refrigeration the loss of food from spoilage is still tremendous. It is calculated that the world's annual losses from improper storage alone is 18 thousand million tons! This stupendous waste underlines the still vast need for refrigeration. Refrigeration can prevent most of this waste and thereby make more food available more cheaply.

Because refrigeration helps to promote a higher standard of living—because it saves food and therefore money and because it ensures hygienic storing and handling of food, it is not only a necessity, but its use is essential, too, in the national interest of any country.

The important and fundamental need for refrigeration in every community is briefly outlined above. This need exists throughout the whole field of food production and handling.

The food producer needs refrigeration to safeguard his produce whilst awaiting shipment or processing, or in the course of processing. The transporter of food needs refrigeration to preserve it during shipment. The whole-saler needs refrigeration to safeguard the produce in his warehouse whilst awaiting distribution. The retailer has need for safe and hygienic storage of his supplies to preserve quality and again to prevent waste; also to ensure that all foods he sells are pure, in prime condition and uncontaminated.

WHAT IS COMMERCIAL REFRIGERATION?

For the precise purpose of this article it is, perhaps, now desirable to have a clearer picture of what exactly is meant by commercial refrigeration. Various definitions have been applied in the attempt to clearly differentiate between the three main refrigeration functions, namely domestic, commercial and industrial. For various reasons, usually of convenience or because of fiscal necessity, these definitions have more often than not been based either on the size of the actual box or cabinet or on the capacity of the condensing unit. Neither of these methods affords a proper means of distribution as they might well tend to over-ride the main factor, which is the question of usage. Identification of domestic—that is of self-contained refrigerator cabinets used mainly in the home—is fairly clear. The difference between commercial and industrial is not, however, so easy to define because these classes tend to overlap. A more or less arbitrary definition has been made by the British Refrigeration Association, which classes as "commercial" refrigeration plant requiring a prime mover up to and including 10 h. p. to drive the compressor.

Taking this definition as a basis, one finds that the need for commercial refrigeration falls under four main headings:—

1. In the process freezing of various commodities, either to make them more palatable or to preserve them for sale on a later and possibly more profitable occasion.
2. In the storage of perishable goods so as to cut down wastage and also to reduce the risk of financial losses due to day to day price fluctuations.
3. In the display of perishable foodstuffs so as to attract more customers and thereby increase trade.
4. Applications for industry outside the food trades and including air conditioning.

Obviously, the next stage is to take the above headings in turn and examine them more closely and in greater detail.

Processing by freezing is by no means new and perhaps the best known and more obvious form of it is the making of ice-cream. This has undergone many changes since the day of the freezing salt and simple rotating can or blade.

An important and more recent development of commercial refrigeration is quick freezing. Meat was, of course, first commercially frozen many years ago, and indeed the advance of refrigeration techniques which made it possible was another great contribution by the industry to wider distribution of that staple food and therefore better living. Through it, meat supplies became available at economic prices in countries which were unable to home produce adequate quantities.

Freezing techniques have now gone very much further and to-day many varieties of frozen foodstuffs are available, both to the caterer and to the housewife. The advantage of this in the case of seasonal foodstuffs is very obvious—it helps the grower and producer by providing a market for all of his crop and at fair prices, whilst giving wider choice to the user all the year round.

Quick freezing as a means of food preservation has a very great deal in its favour. Since the process of freezing quickly at very low temperature only arrests development of the food, it preserves its natural character and most frozen foods are indistinguishable from their fresh unfrozen counterpart. The popularity of quick frozen fruits, vegetables and fish is growing tremendously with the appreciation of their cleanliness, freshness and relief from the work of preparation.

Beyond this, there is the development of frozen precooked foods whereby complete meals already prepared and cooked need only to be heated to be ready for the table. To the many housewives of today who are unable to get domestic help, or who continue their working careers, these quick frozen meals are an inestimable boon.

Quick freezing is now coming to the aid of the bakery trade, several plants for the freezing of bread already having been installed in this country. The bread is frozen immediately after baking and can be kept for long periods. After thawing out, quick frozen bread is equal to the newly baked product. In this way does refrigeration help to solve labour problems by eliminating night baking or by enabling existing plant and facilities to be more fully utilised.

REFRIGERATED STORAGE

The second main heading, that of storage, has provided to date what might be called the bread and butter of the commercial refrigeration industry and covers a vast field from the small household type cabinet and the small ice-cream conservator, either or both of which might be utilised by the shopkeeper, up to farmers' fruit stores and huge dock storage chambers.

It is impossible in a short survey such as this to cover the whole scope of this range which is developing all the time. As an indication of its variety, however, some of the following examples may be of interest. Most firms dealing in perishable foodstuffs, whether on the wholesale or the retail side, regard a storage coldroom as being essential to their business and equip themselves accordingly.

Fruit growers extend the 'season' for many fruits by refrigerated storage, so giving availability over longer periods and avoiding waste due to seasonal gluts. In the case of some soft fruits, great advantage can be gained by taking the natural heat out immediately after picking. Fruits treated this way will retain fresh conditions longer, travel better and further and so widen the market.

Hospitals and institutions—apart from their position as caterers utilise refrigeration for blood, drug and serum storage, for mortuary cooling and for operating theatre conditioning. There are hosts of

other general storage applications, but the few instances recorded above will serve to give some idea of the variety.

The third of the main headings is the one which has, perhaps, made the greatest proportionate increase in the last decade in the whole field of commercial refrigeration, although it must be understood that, as yet at all events, its volume does not approach that of the other two headings already discussed.

The idea of increasing the sale of highly perishable goods by exhibiting them to customers whilst at the same time preserving them in good condition by surrounding them with cool atmosphere is by no means new either in conception or physical fact.

DISPLAY CABINETS

Almost exactly 50 years ago in the U. S. A. the first of such display cases was produced. It was very primitive in operation in that it employed ice and was based on the ice-box which was then in common use as the most up-to-date and practical form of storage. The cabinet however, incorporated glass windows which, when free from moisture, did permit of the goods being disclosed in a fresh, firm condition and uncontaminated by flies. A few years later a glass fronted counter was developed, with concealed ice bunkers at either end, which would fit in as part of the retailer's counter and which he could serve over but at the same time, his customers were enabled to view the perishable goods he had for sale being shown off to their then best advantage.

It is interesting to note that by regularly employing crushed salted ice in these display counters, a temperature of 36° to 38° F. was maintained. Naturally, with the inception of automatic refrigeration a condensing unit and evaporator coils took the place of ice and freezing salt.

With very slight modifications in height and visibility etc. the design of the case itself remained much the same for the next 25 years or so; in fact, the closed type refrigerated case still being sold to-day is of very much the same design.

This glass-fronted enclosed type of display case, varying in length from, perhaps, 4 to 10 ft. has until the last couple of years represented the main bulk of sales in the display market. Another variation which enjoys a limited sale is the coldroom which has a glass display window let into one side, or another form of this is the ordinary service cabinet with a glass front, but owing to the need to keep all the goods stored attractively arranged all the time, this variation is not usually considered highly practicable.

A more popular form of enclosed display of this type is the method by which the actual shop window itself is either partly or wholly insulated on the back and sides, extra glazing inserted on the front, and the resultant space refrigerated. This is naturally more expensive, and there are limitations as to use; none the less, under suitable conditions the window can be made very attractive and well worth while.

To-day, however, the position remains that the most popular amongst closed type refrigerated display cabinets is the counter height case about 6 ft. long which it is easy to accommodate in the average small shop. Although a lot of these closed cases are still sold, it is the open type case which is responsible for the vast increase in the amount of business which is being done in refrigerated display.

With the development of self-service in the U. S. A. which started to take place in the late '30s and early '40s open refrigerated cases, from which the public could themselves select milk, fats, sausages, bacon etc., and other perishable foods, became an essential part of a food shop. With the extension of this method of retailing by the development of the 'one stop store' or 'supermarket' open type refrigerated counters providing the correct temperature and conditions for the attractive display and preservation of fresh meats, cooked meats, fish, ice-cream, frozen foods and various other commodities, became additionally necessary and these were duly produced.

Because of its economy in the use of staff and the way in which it fosters impulse buying plus the time saved by the customer, this method of merchandising has inevitably started to take hold in Great Britain and Europe and is steadily expanding; consequently the demand for open type refrigeration has spread and is increasingly growing. This demand is now being met by the manufacture in Great Britain of all types of open cases similar to those originally supplied in the U. S. A. and in some cases improved versions.

These refrigerated cabinets are now manufactured in very many shapes and sizes; some are free standing and have several refrigerated tiers, others

stand on existing counters. Some have canopies and superstructures and stand against walls, others can be served over or are so constructed as to be available for self-selection from all sides. In many instances cabinets can be multiplexed together to give any required length and so, if necessary, fill one side of a store.

There is already a big volume of display business being done; it is very rapidly growing and will without doubt so continue for many more years.

INDUSTRIAL APPLICATIONS OF REFRIGERATION

Dealing with the fourth heading, commercial refrigeration meets essential needs in other fields, too. In industry it can speed up, processes, thereby increasing production and plant capacity. Products cooled rapidly by mechanical refrigeration are ready more quickly for the next process, for handling, for tinning or packaging. It provides correct temperatures and humidities, so preserving the condition of products before manufacture and during processing. This ensures a uniformly high quality and minimum waste.

In many branches of the engineering industry, refrigeration is giving valuable assistance in research, development and production. By reproducing varying climatic conditions, tests are carried out on materials, instruments and processes. The benefit of this to the aircraft manufacturer, for example, can well be imagined when refrigeration can produce in the laboratory the conditions to be experienced in the stratosphere and thus enable designers and metallurgists to know exactly how metals, fabrications and instruments will behave in, or stand up to, those conditions. On the production side, refrigeration again contributes; examples in this field are the use of low temperatures for components such as rivets, cylinder liners and the like, where shrink fits are necessary.

AIR CONDITIONING

Refrigeration is an essential component of most air conditioning systems. Air conditioning has made very rapid strides in recent years and is a field in which still further and much wider development will take place over the next year or two.

Originally used primarily in large public buildings and in some factory processing and storage rooms, the application has gone far beyond this, and in the realm of 'comfort' conditioning is invading the appliance market in the shape of self-contained unit conditioners as well as becoming more extensively used for ensuring maintained conditions of clean air with controlled humidity and temperature, where necessary in industry.

The refrigeration industry has done much to make these developments possible by the design and production of higher efficiency, more compact and lower cost units, especially, perhaps, in the design and development of the 'hermetic' type of condensing unit.

There is no doubt at all that but for these units, room conditioners of the self-contained type would never have reached the practicable stage. The hermetic unit with its built-in, self-contained motor, its relatively small size and its comparative silence in running enabled air conditioning engineers to design complete units which would condition a room yet occupy little space and emit no distracting noise.

So in this sphere, too, commercial refrigeration plays an important part in improving and raising living standards.

At a recent refrigeration and air-conditioning exhibition held at Atlantic City, U. S. A. it was said that "Refrigeration is just as important as, and is fast becoming no less essential than heat in some metal working processes. In a dozen other industries it has been found that refrigeration is one of the most effective cost reduction methods available to engineers." This statement in no way exaggerates the position of refrigeration in relation to industry generally.

An aspect of modern commercial refrigeration which also is of the utmost importance to the user is its extreme economy of operation, both in respect of electrical current consumption and of maintenance.

It is difficult to give precise figures relating to current consumption, as this will obviously vary, not only with the type and size of the plant, but also according to its usage. In this connection it is of course necessary to ensure that the refrigeration plant is of fully adequate capacity, since if it is underpowered, the running time will be substantially greater, which will not only increase current consumption, but may also tend to induce more wear in the components of the machine. With a properly designed plant, the operational cost in current consumption is quite nominal.

The modern commercial refrigeration plant is fully automatic and requires no staff in attendance, either qualified or otherwise. With periodic checks and maintenance adjustments, the plant will give many years of service with little expense.

The principal maintenance requirements are regular oiling of the motor, inspection of and cleaning of the condenser to ensure that there is freedom from obstruction of air flow due to accumulation of fluff, dirt etc. Controls should be checked and where automatic defrosting is not employed, then the cooler should be regularly defrosted manually.

The British refrigeration manufacturing industry is well founded and has a long history of continuously successful development and progress. It is comprised of a number of specialist firms with modern plant and equipment, producing the widest possible range of products for all applications of refrigeration and air-conditioning. Apart from supplying the big home market demand, products of the industry are shipped to practically every country of the world, these exports forming a very high proportion of the industry's output. All manufacturers provide expert application engineering and advisory services, and the technological quality of the industry is of a very high order, worthily following Lord Kelvin, that great British Scientist who contributed so much to the development of refrigeration techniques.

(*Courtesy:* "ELECTRICAL INDUSTRIES EXPORT")

IRON ORE DEPOSITS IN ANDHRA PRADESH

THE total iron ore reserves in Andhra State are estimated to be about 430 million tons. The best quality of iron ore having 50 to 65 per cent of iron content is found in district Kurnool which is estimated to have a reserve of 3.7 million tons. The quality of iron ore found in Hyderabad district with 37 to 43 per cent of iron content is estimated to be of the order of 37 million tons. The largest deposit has been traced in Guntur district—296 million tons—with an iron content of 33 to 37 per cent. Of the total reserves in the state, the poorest quality of iron ore with 25 per cent iron content only, is found in the district of Nellore which has 93 million tons of reserve.

A Practical Approach to Efficient Machine Buying

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

INDIAN industry has before it a great potential of engineering developments. A number of new plants are being constructed in a wide range of industries to maintain and improve high levels of gross national production, income and employment. This represents increased productivity with which to meet competition, productivity which will keep our national economy strong, productivity with which to insure our national security—in fact, our very existence.

Machine tools are the key to modern industry. There is hardly a single product that does not owe its size and shape—its very existence—to machine tools that cut or form metal.

The fundamental solution of all economic problems lies in an increased output of commodities such as can only be achieved by supplementing manual effort by machine power on a scale never before contemplated. To that end good machinery and especially good tools are essential, for without good tools even the best workman with his best efforts and intention cannot achieve the desired result.

A host of improvements have taken place during recent times in the construction, appearance finish and performance of the generally accepted types of machine tools and many revolutionary designs with applications of electronic methods of control and measurements, fitting of automatic copying and profiling devices, use of tungsten—carbide tools have been introduced as special features of modern machine tools. The increased use of hydraulic systems for machine motions and control has also become a normal practice now.

In addition to the mechanical efficiency of the machine itself, safety and comfort of operation have received careful attention as these are not merely humane, but also help in obtaining increased production.

MODERN TRENDS IN DESIGN

The modern trends in the design of machine tools are in developing them in two divergent directions. On the one hand, the aim is towards automatic operation, maximum utilization of horsepower, the ultimate in speeds and feeds and all other features which contribute to the highest possible productivity in mass-production operations.

At the same time, the tendency is also towards the development of machine tools which are adequate yet of more simple design.

Usually the mechanical efficiency and other advantages of the machine tools are judged by the following factors :—

1. Provision of increased speed and feed range with easier and quicker control and rapid power traverses.
2. Greater power and rigidity to permit tungsten carbide and other high speed cutting alloys to be used.
3. The use of improved materials, alloy steels in spindles, gearing and transmission shafts and the extension of ball and roller bearing applications.
4. Solidity, rigidity and freedom from vibration particularly in large heavy duty machine tools and in that way the weight of the machine tool, is, in many ways, directly related to the performance which can be expected. There is however no particular virtue in weight for its own sake : in fact, superfluous weight in moving reciprocating parts is detrimental for producing accurate and high grade finish. It is not the dead weight but the weight distributed carefully in the right proportions and in the right places, is what really counts.
5. The use of pneumatically, hydraulically and electrically operated chucks and work holding fixtures.
6. Accuracy, better lubrication and chip disposal arrangements, since life and accuracy of any machine is very much dependent on the type of lubrication system fitted.
7. Versatility of the machine specially for factories where there is no fixed manufacturing policy and a large variety of different components to be manufactured.
8. Increase ease and safety of operation by the provision of push button control and the efficient guarding of rotating parts.
9. Application of copying devices—either in form of attachments or as an integral part of the machine.
10. Incorporating fixtures designed to reduce the loading and unloading times.
11. Mechanical and electrical size gauging devices.
12. Power Consumption.

Since the buyer of machine tools in any factory or project should see that the most suitable one is supplied to his shop, it is in his own interest to keep himself posted with current trends in design and methods and to retain a receptive mind.

CORRECT PROCEDURE

In order to ensure that the capital is spent wisely, an efficient machine buying routine, is of paramount importance. A purchase must be justified by a saving of cost in performance or improved quality of product. This extends beyond the mere removal of metal and must be regarded from a standpoint of investment. The basic idea should be to cut production cost.

The correct procedure comprises three main steps :—determination of what is required, comparison of obtainable machines with the machine that is required for the purpose of selection, and finally placing the order and preparing for delivery.

Determination of what is required will be dependent on the type of work to be handled in the factory and the quantities involved. If the quantities are of one-off type or small multiples of one, universal type of machine will be the general choice. In case of factories dealing with batch production, general purpose machines are used—to allow ready adaptation to changes of programme. In conjunction with simple jigs and fixtures this equipment produces work economically, although not as cheaply as is possible with specialised plant. Where it is a case of mass or line production, specialised plant such as automatic machines can be purchased with advantage.

Based on these factors, the first step in buying machine tools will be to collect first hand detailed information about what is required. The buyer must be in touch with the practical operations in the shops and ascertain their needs specially with reference to jobs proposed to be put through or which are already being handled in the existing machine proposed to be replaced by a new one. This will enable him to collect datas as regards working capacity, handling devices required, range of speeds and feeds etc., so as to draw out the specification of requirement for issuing enquiry letters.

The Specification should give, as far as possible, the complete picture of what is required and is generally compiled giving informations against the following heads: Specification Number, Machine, Capacity, Description, Dimensions, Purpose for which required, Nature of drive and power and Special equipments and spare parts. Shown in Appendix 'A' is an example of a typical specification made out for a Radial Drilling Machine.

ESSENTIAL DETAILS

It is worth indicating here the essential details, which should be incorporated in the Specifications for describing the different types of machine tools. Such details in respect of some of the machine tools are mentioned below by way of examples :—

a) *Centre Lathe* :

(i) Type : General purpose, Production or Tool Room.

(ii) Capacity : Height of centres, Distance between centres swing over bed, swing over saddle.

(iii) Gap : Yes or no. If yes, diameter of swing in Gap and width to be swing in Gap are to be indicated.

(iv) Screw Cutting :— Yes or no. If yes, British, Metric or Special threads to be cut should be stated.

(v) Speed Range :— Maximum and Minimum.

(vi) Feeds :— Number and Rates.

(vii) Hole in Spindle :—Diameter to be given.

b) *Shaping Machine* :—

(i) Type : Mechanical or Hydraulic. Fixed or travelling head.

(ii) Capacity :— Length of Stroke, size of table and Maximum height between table top and underside of ram.

c) *Milling Machine* :—

(i) Type : HORIZONTAL : Plain, Universal or Production

VERTICAL : Plain, Universal or Production.

(ii) Table :— Size of the table.

(iii) Feed Length : Longitudinal, Cross, Vertical. Hand or power (say whether mechanical or hydraulic).

(iv) Speeds :— Maximum and Minimum.

(v) Spindle Height :— Maximum and Minimum heights of Spindle centre above table for horizontal type; and maximum and minimum heights of spindle nose above table for the vertical type.

(vi) Throat :— In vertical Machine the distance from spindle centre to face of column should be quoted.

(vii) Arbors :— Length and Diameter.

d) *Capstan Lathe* :—

(i) Type : Bar, Chuck or both.

(ii) Capacity :— Height of centres, swing under support Bar, Swing over Cross Slide, Maximum distance between spindle flange and capstan.

(iii) Screw Cutting :

(iv) Speed Range : Same as for Centre

(v) Feeds : Lathes.

(vi) Hole in Spindle :

N. B.— In all cases where production types are required, the enquiry should be accompanied by drawings or details of the job to be done and the rate of production is also to be quoted.

The specification on completion should be sent along with the enquiry to the different machine tool dealers for their quotation, with costs, delivery terms and carriage.

COMPARISON CHART

On receipt of the quotations from the various firms offering their machines, a comparsion chart should be prepared giving the main features of the different makes of machines offered.

A tabular form of the chart with the details of price and delivery shown at the bottom will prove very useful in this connection. In its first column should be the details of the machine specified and in subsequent columns the details of the offers received from each firm against different heads of the specification.

This will provide the opportunity of making direct comparisons of the machines offered and seeing their main features at a glance.

It is sometimes advantageous to mark the salient features of the machines in red to make them prominent with regard to the advantages and disadvantages of the machine to facilitate selection.

After making the final choice, the final stage of the procedure should then be completed. This consists of making out the order giving particulars of all the features and requirements desired as well as the price and delivery dates and terms.

A note of caution will not be out of place here. Price alone should not be the guiding factor in purchasing the machine. This policy when adopted would react to the detriment of the production costs. It has been found in many cases that the economies made possible by buying and using the best machines procurable, have more than justified the difference in price, and more often than not proved the lower-priced product to be " dear at any price ".

It was Ruskin who wrote long ago. " There is hardly anything in the world that some man cannot make a little worse and sell a little cheaper. People who consider price only are this man's lawful prey ".

(APPENDIX—' A ')

Name of the Company : .....

Address :— .....

1. *Specification No.* .....

2. *Machine* :—Radial Drilling Machine.

3. *Capacity* :—(a) Drilling 2″ dia. from solid in mild steel.

(b) Tapping whitworth $1\frac{1}{4}$″, Gas 2″.

(c) Boring upto 5″ dia.

4. *Description* :—Radial Drilling, Boring and Tapping Machine with elevating arm, 4′—6″ radius fitted with box bed.

Spindle Datas :—

(i) Length of feed—I4″.

(ii) No. of Speeds—8

(iii) No. of Feeds—4 with 40 to 165 cuts/inch.

(iv) Range of speeds—1000 to 53 R. P. M.

(v) Spindle bore—Morse taper No. 4.

The machine should have centralised control with all controls conveniently grouped on the lower part of the saddle, be equipped with combined locking to saddle and column, adjustable auto-trip to feed for depth drilling recessing etc., fine and quick adjustments to spindle, safety device to prevent damage by over-running, quick reading dial giving speed and feed for all holes with the machine capacity and oil sight glass indicating that saddle lubrication pump is working.

Dimensions :— (a) Radius of drill spindle—4′—6″ Max.

(b) Traverse of saddle along arm—3′—$4\frac{3}{4}$″

(c) Spindle to top of box bed—3′—0″ Max.

(d) Vertical adjustment to arm by power—2′—5″.

5. *Purpose for which required* :— For drilling general engineering fittings.

6. *Nature of drive & power* :—

(a) *Motors*—The Motors shall be suitable for operation on 400 V, 3 Phase, 50 Cycles A.C. Supply, Drip Proof, continuously rated, tropically insulated and shall comply with the I. S. Specn : No. 325/1951.

The relevant items of Appendix ' G ' of the said Specification must be submitted with the tenders duly filled in. The H. P., make, type and speed of the motors shall also be specified. No tenders will be considered unless the above particulars are furnished.

(b) *Control Gears*—The control gears shall be push button operated automatic contactor type complying with the I.R.S Specn : No. E--11—39 in all respects with provision of ammeter, one no-volt and three adjustable overload releases, single phasing preventor, interlocked isolator as specified therein. The make and type of the starters shall also be clearly stated. The appendix ' A ' of the above Specification must be submitted with the tenders duly filled. No tenders will be considered without the above particulars.

The control gears above 10 H. P. should be of floor mounting type.

7. *Special equipments & Spare Parts* :—

(a) Necessary spares for electrical gears for 2 years normal maintenance.

(b) A separate motor-driven pump and necessary fittings for cooling arrangements.

(c) Lamp to facilitate night shift working.

(d) Drill sockets as per details below.

(i) Morse Taper (1) No. 3 inside × No. 4 Outside = 3 Nos.

(ii) No. 2 inside × No. 4 outside = 2 Nos.

(iii) No. 2 inside × No. 3 outside = 3 Nos.

(iv) No. 1 inside × No. 2 outside = 4 Nos.

Standard Series of Czechoslovak Power Valves TESLA

From A Technical Correspondent

IN each technical field there exists a body of materials and components considered generally as standard and which permit the application of proven working methods. Equipment prepared from standard components is reliable in operation, requires minimal maintenance and service. For every-day use this is more important than higher power, if the latter is obtained by the choice of materials and components developed specially for the given purpose in agreement with the latest technical achievements, i. e. completely new and more powerful but less reliable.

According to experience gained in the use of varbus types in different equipments, in the course of time there arose a number of types which are universally applicable for practically all applications which may arise in transmitter engineering or in industrial high-frequency applications. The standard series of Czechoslovak power valves TESLA contains three types with anode losses 2, 5 and 20kW. This series will be supplemented in the near future with a further type with anode loss 85 kW.

The standard valves TESLA are air cooled. Types RD 2 XH and RD 5 XH have conventional fin-type radiators as used by all manufacturers. Type RD 20 XH is fitted with a coiled radiator which enables perfect cooling of the valve at full rated anode loss and is very advantageous from the points of view of material consumption and dimensions.

The basic characteristic in the design of the standard series of valves is the use of modern technology and the use of new vacuum materials. The seals between the metal and glass are made of "Kovar" and low-loss hard glass; the cathodes in all types are of thoriated tungsten; perfect vacuum is maintained by the use of zircon and zircon alloy getters.

The characteristics of the tubes are designed to permit their substitution for hitherto employed similar but less economical types in existing equipment without changes. It was also taken into account that the tubes should be able to be used as substitutes for foreign types in equipment of other than Czechoslovak origin. The operating data of the valves of the TESLA standard series do not deviate from the values customary in other products of the same category. For these reasons the valves, although mainly intended for use in new equipment, may be used for modernisation of existing transmitters and industrial generators in which they may replace older types with pure tungsten cathodes. This introduces large savings since the use of thoriated tungsten permits the same power with much lower heater power.

Basic characteristics of standard series of valves TESLA

Type	
Heater voltage	V
Heater current	A
Anode tension	kV
Anode current	A
Grid current	A
Anode losses	Kw
Useful emission (min.)	A
Amplification factor	u
Max. frequency	Mcs
C_{ag}	pF
C_{gk}	pF
C_{ak}	pF
Height	
Diameter	
Weight	

Valve RD 2 XH may be used as an oscillator, RF power amplifier with anode or grid modulation or as an audio-frequency power amplifier and modulator. When employed as an RF oscillator or unmodulated RF amplifier it may deliver RF power of 3.5 kW at full anode tension up to 110 Mcs. At 150 Mcs the anode tension is reduced to 3 kV and the RF power drops to 1.95 kW at 140 W driver power. With grid modulation at 110 Mcs and anode tension 5 kV the carrier frequency power will be 0.82 kW. As an audio-frequency amplifier a push-pull class-B connection gives a useful power of 5.6 kW with 5 kV on the anodes. From these examples it may be seen that the valve is of universal application with relatively high efficiency.

Valve RD 5 XH is also universally applicable. For example, in operation as an unmodulated RF power amplifier or oscillator at 45 Mcs it gives 10 kW output power in class-C with anode tension 7.5 kW. Grid drive will be about 430 W under these conditions. Raising the frequency to 100 Mcs requires the anode tension to be reduced to 5 kV and the useful output power to 5 kW. With anode modulation, e. g. for a broadcast transmitter on 40 Mcs, the anode tension may be 6 kV. The carrier frequency power in this case will be 4 kW and grid-drive will take about 160 W. When used in class-B push-pull connection for audio-frequency amplification one pair will give an output of 15 kW at anode tension 7.5 kV.

The largest valve of this standard series is the RD 20 XH (a larger type is under development) intended for use up to 30 Mcs. At this frequency it gives 32.8 kW RF power (unmodulated RF amplifier or oscillator) and at 5 Mcs 51 kW. It is thus particularly suitable for telegraph transmitters, the efficiency of which is increased by their use due to their economical operation. When used as a class-C RF amplifier with anode modulation in broadcast transmitters, it can supply 20 kW carrier frequency power up to 20 Mcs, with 10 kV anode potential. With grid modulation and 30 Mcs, the anode tension may be 10 kV and the carrier power 6.9 kW. At 20 Mcs this power rises to 10 kW with increased anode tension 12 kV. The valve may also be used as an audio-frequency amplifier in push-pull class B with an output of 50.6 kW per pair with anode tension 12 kV.

These valves were displayed at last year's third Czechoslovak Engineering Exhibition in Brno and aroused great interest among foreign visitors for their characteristics and their possibilities for wide application.

Manufacture of Waterproof Abrasive Papers in India for the first time

With technical help from their Associated Companies in U. K. & U. S. A., Carborundum Universal Ltd., Madras, have commenced production of Waterproof Abrasive papers, strictly following most exacting technique and rigorous standards of quality control.

Three different qualities of papers which are used as backings are specially treated to make them thoroughly waterproof. The abrasives are manufactured under the latest "Electro Coating" method wherein Silicon Carbide abrasive grains are coated in an upright position in a high voltage Electrostatic field so as to make them absolutely uniform and very sharp.

Waterproof paper is used for wet rubbing down of sealer, primer, under coat and finish coats of paints, lacquers, enamels etc.

*** *** ***

Welding Copper Vessels

In the fabrication of a large cylindrical copper vessel, destined for use on a liquid weighing machine, the Hull firm of W. Broady and Sons have employed a double operator vertical method of welding.

The vessel was constructed of 3/16 in. thick copper, and saffire oxyacetylene hand welding blowpipes, supplied by British Oxygen Gases Limited, were used to carry out the work.

The double operator vertical method of applying butt welds can be employed where seams can be placed in a vertical position and where there is access to both sides of the metal.

Advantage can be taken of the Higher welding speeds and the greater economy of gas and rod which are obtainable with this technique, which achieves sound penetration with build-up on both sides. Thicker metal can be welded without specially prepared edges.

*** *** ***

Plastic Coated Steel

Plastic coated steel is being produced at British Iron & Steel Research Association's South Wales Laboratories for trial distribution to Industry. Polyvinyl coated strip called "Plasteel" combines the strength of steel with the durable finish of plastics. The strip can be folded, crimped, sheared and deep-drawn without damage to the coating.

HOW RESEARCH AIDS BRITISH INDUSTRY

BOOKLET DESCRIBES SUCCESSES OF CURRENT PROJECTS

A cotton fabric which is exceptionally waterproof and windproof and yet permeable to air and resistant to tearing; fireproofed jute hessian and acid-fume-resistant jute cloth; better methods of dyeing leather —these are some of the results of current research being carried out in Britain by industrial research associations and research councils which are linked to the Department of Scientific and Industrial Research (DSIR).

Other projects in hand include a process for producing soles of leather shoes which combine maximum flexibility with a reasonable degree of waterproofing; a cheaper method of dyeing felt; and the more effective use of coal in railway engines.

Progress in these and many hundreds more fields of research is described in the booklet *Research for Industry*, just published in London by H. M. Stationery Office.

There are now 39 industrial research associations and seven research councils which receive grants from DSIR. They are voluntary bodies set up by groups of firms to study their common scientific and technical problems.

ALUMINIZED FABRIC

The British Cotton Industry Research Association, for instance, reports that at its Shirley Institute nearly 200 major research projects are in progress, as well as many smaller investigations arising out of members' inquiries.

In addition to the cotton fabric mentioned above, another product recently developed by the institute is an aluminized fabric which, having aluminium on the surface, protects the wearer from radiant heat and, being porous, permits the body to "breathe". This, says the report, should make the fabric specially suitable for protective garments for firemen. The surface of the fabric also has unusual light-reflecting properties which should render it suitable for cinema screens.

Mill trials have been completed of the institute's "pressure point" system for card-dust extraction. This device, which is now being introduced to industry, removes 90 per cent. of the dust emitted by cards—a major cause of disease in card-room workers. The institute is also embarking on fundamental investigation into the causes of flame propagation in textile materials.

Among projects of the British Jute Trade Research Association's laboratory at Dundee, Scotland, is investigation into the effect of different spinning conditions on the hairiness of the yarns. A major item of chemical research completed is clarification of processes underlying the degradation of cellulosic materials in contact with rusting iron. In research into the chemical constitution of jute, evidence has been obtained for the existence of a new ester linkage in jute hemi-celluloses. Following success in evolving a process for anti-corrosive jute wrapping for bright steel parts, the work has been extended to the protection of a mass of small steel articles.

"ANTI-STATIC" RUBBERS

The Research Association of British Rubber Manufacturers at Shrewsbury, Shropshire, reports that an important stage has been reached in studies on "anti-static" rubbers—rubbers specially made to conduct electricity sufficiently to remove static charges. These rubbers are being used increasingly in bus tyres, driving and conveyor belts, flooring and other equipment for hospital operating theatres, and in other situations where fire hazards are present.

Other development work described in the report included research into the reduction of noise in motor-vehicle bodies, which is said to have yielded promising results through the use of specially placed damping materials. Research in another field is expected to lead to a major reduction in the failure of the life of coil springs in engines and other types of industrial plant.

The booklet also includes a description of processes for applying automation to the manufacture of knitted stockings, and tells of research into the more efficient use of oxygen in electric furnaces used for steelmaking and into the efficient and greater use of iron in foundries.

During the year covered by the report—1956-57—research associations received grants from DSIR of £ 1,500,000, and had a total income of £ 6,000,000.

TEXTILES SECTION

Manufacture of Latch Knitting Needles for Outerwear Machines

Highly Skilled Personnel and Specially Developed Machines Employed

By E. F. Didier
General Works Manager
Knitting Machine & Sewing Machine, Needle Division of The Torrington Co.

THE latch knitting needle, invented in 1847 by Matthew Townsend, is the fundamental loop-forming element used in a wide variety of flat-bed and circular weft knitting machines for manufacturing the whole range of knitted outerwear products, as well as underwear and hosiery. It is also a component of the highly complicated Raschel units in the warp knitting field, and in specialized types of machines for manufacturing rugs and carpeting.

TYPES OF LATCH NEEDLES

Approximately 12,000 different varieties of latch needles have been made to date. The Torrington Company carries between 7,000 and 8,000 various needles in stock at all times, of which some 4,000 types may be constantly in demand, while the balance are ordered at periodic intervals. Monthly production schemes can include as many as 275 different needles, varying in length from 13/16th in. to about 8 1/2 in. and in thickness from 0.0105 in. to 0.116 in.

Needles can be classified in five ways: (1) by needle gage; (2) by the type of hook, including the gage of the hook; (3) by the position of the hook; (4) by the type of latch; and (5) by the kind of butt.

Needle gage refers to the thickness of the needle. A 42 gage needle, for example, has a thickness of 0.024 in. The gage of the hook is a measure of the diameter of the hook in inches. It is possible for the gage of the needle and of the hook to be different.

Three basic types of hooks are used in latch needles; the common or regular is the general purpose type; the Excelsior hook is most frequently employed on needles for machines making plaited fabrics. The T. P. A. hook is somewhat more exaggerated than the Excelsior and has specialized uses.

There are two fundamental types of latches: the straight and the concave. Practically all latch needles have the same type of spoon. The wire butt, the solid butt, and the flat stock butt latch needle each has its particular advantages in terms of needle design and end use requirements.

An experienced person who knows "where to hit the needle and how hard" to correct heat treating distortion.

PROCESSES IN LATCH NEEDLE MANUFACTURE

At least 40 operations are involved in the manufacture of a simple type of latch needle. In addition, there are such quality control operations as inspection between operations, weighing and counting, and washing for removal of oil and chips.

Latch needles may be produced either from wire or cold rolled flat steel. Which form of raw material is used depends, in general, on the needle design. The steel must be the finest quality obtainable.

The first step in the drawing of wire is a generous cropping of the ingot end to remove the unstable or piped portion of the stock, which would develop segregation in the wire after it is drawn. After the steel is hot rolled, the rods are ground to remove pits and seems; the rods then undergo a series of cold drawing and annealing operations which impart a proper tensile strength and good surface finish. When the wire has been drawn to proper size and treated to obtain the physical requirements, the actual manufacture of needles can begin.

Wire from the coils is straightened, cut and formed on special four slide machines. Points and cheeks of the needle are swaged to size on rotary swaging machines that exert approximately 4,000 blows per minute. The front cheek taper is developed during this operation and, in most cases, must be held within a tolerance of 1/2 deg. The location of the taper in relation to the butt of the needle is important because all subsequent operations are controlled from these two points.

When the needles are pressed to proper thickness, the points are clipped the correct distance from the butt of the needle. Center punches make precisely located impressions on both sides of the cheek which guide the drills to make the rivet holes.

Battery of furnaces used in heat treating needles.

There are two methods for making the latch and assembling it to the needle. The most spectacular method employs an automatic machine to make the latch and the rivet and also complete the assembly. A skilled technician requires from two days to a week to change this machine from one needle type production to another. Obviously, the method is economical only on large volume production requiring a long run.

When the production quantity is too small to warrant the automatic machine set-up, the latch is produced and also assembled to the needle by hand. Skilled hands match the hole in the latch with the drilled hole in the cheek; the rivet hole is tapped, the rivet screwed in place, clipped and riveted over, ready for grinding.

Final inspection of needles. Each needle is individually inspected.

After assembling the latch to the needle, the latch is ground along the top surface and on the end. This operation gives shape to the latch and provides for smooth casting off of stitches during the knitting cycle.

Strange things happen during the heat treating operations. Most needles increase in overall length by 0.004 in. to 0.006 in. after hardening, depending on the size and shape of the needle. During the tempering operation which follows, this expansion is reduced by approximately one-half. Distortions will vary in accordance with strains that have been set up during previous operations.

An experienced person who knows where to hit the needle and how hard soon corrects the distortions resulting from the heat treating operations. A straightening hammer and a polished steel block are his working tools.

The needles, now in final form, undergo a few beauty treatments, followed by a series of inspections and tests, before being counted and placed in black tucks for packaging in the red boxes with the green labels for distribution to the world's knitting mills. This is a dramatic new package, completely redesigned to give full protection against damage and to provide easy access to the 50 needles in each package.

DEVELOPMENT OF PRESSED RIVET LATCH NEEDLES

There have been literally thousands of improvements in needle making methods, materials, and handling techniques since the invention of the latch needle.

Among the most notable advances are the development of the plain rivet, its subsequent replacement by the screw rivet, and the more recent development of the improved pressed rivet. Because of its longer service qualities the pressed rivet latch needle is becoming increasingly popular and will gradually replace the screw rivet needle.

There is a fundamental difference in the construction of the increasingly popular new pressed rivet needle and the older screw rivet. In the pressed rivet, the sides of the needle cheek are pressed inside to form two trunnions on which the latch rides as a bearing.

Comparison of screw-rivet needle (top) and pressed-rivet needle (bottom). Note badly worn condition of rivet hole in latch at the top.

Grinding is unnecessary and therefore the original strength of the needle cheek is retained. The screw-type needle has a hole drilled and tapped in each cheek to take the threaded rivet which then provides a bearing for the latch. The threaded rivet must be found flush with the cheek after assembly—usually about 10 per cent of the cheek is ground away.

The screw-rivet needle ties the cheeks together rigidly so that when something strikes the latch, there is no flexibility to cushion the blow and the latch either breaks or bends. The cheek walls of the pressed-rivet needle are not so rigidly tied together and thus are capable of flexing somewhat to cushion the force of the latch striking. In other words, latches in the pressed-rivet type of needle have the ability to "roll with the punch," and do not break or bend so readily.

A test run at Shawmut, Inc. indicated that the pressed rivet needle finished the test with still a perfectly round latch hole, and showed relatively little wear. The screw rivet, in the same test, showed excessive wear on the end of the hook and latch hole.

The test was run on a circular machine operating at a speed of 22 r. p. m. Pressed and screw rivet needles were alternately placed in the machine to eliminate variables in other knitting conditions. There were 47 screw rivet needles and 25 pressed rivet needles removed from the machine due to breakage or other damage. The machine produced 1,408 stitches per minute and 45,290 pounds of cloth. There were 23½ latch reciprocations per second, for a total of 164,904,960 during the test.

HOW TO PROLONG NEEDLE LIFE

The problem of needle care is receiving greater attention today than ever before. Because it is one of the smallest and probably the most inexpensive elements in a knitting machine, many knitters do not exercise sufficient care in the selection of needles and in determining the cause of needle breakage.

Fortunately, there is a growing realization that modern maintenance practices probably are more essential to the prolongation of needle life than any other factor.

The majority of needle failures are not caused by the needle itself—rather there is some other factor in machine operation, such as improper yarn size for the gage of the machine and needle, poorly wound yarn, improper tension in knitting, inaccurate adjustment of yarn guides, worn or damaged needle beds or slots, worn or steep cams, and unnecessary build-up of lint on the needle bed.

Greater care and attention to these potential trouble sources not only will greatly reduce needle failures, but will pay additional dividends better machine operation, less down-time and maintenance expense, and a much finer product.

Stainless Steel Has Many Advantages in Textile Mill Operations

By W. E. McFee
Armco Steel Corporation, Middletown, Ohio, U. S. A.

TEXTILE mills in the United States report to us that they have saved many thousands of dollars through the use of stainless steel processing equipment.

Some typical comments from representive users follow.

Ten years ago a southern piece-dyeing mill bought six new machines for acid-type dyeing and bleaching operations. The equipment was made of Type 316 Armco Stainless Steel. At the end of one year the record showed $ 9,447.50 in operating costs saved.

This is how the money was saved:

The six dye vats made of Armco Stainless produced more than the 12 wooden vats they replaced. Electric power and steam costs were halved. 24 loadings and unloadings of material—96 needed before. The new equipment cut cleaning costs more than half. Man-hours saved: 120 a day.

Today these same machines are still in good condition..still producing true-color fabrics. The original cost was "written off" by the savings years ago. Yet annual savings are much greater now because of higher labor costs all along the line.

A chemist in an Eastern dyehouse said that dyes and bleaches have no effect on two 500-pound Armco Stainless kiers installed in 1939. Each kier has it associated pumps, piping, expansion tanks, and dye cans fabricated of stainless steel. The kiers and tanks are made of Type 304 Armco Stainless.

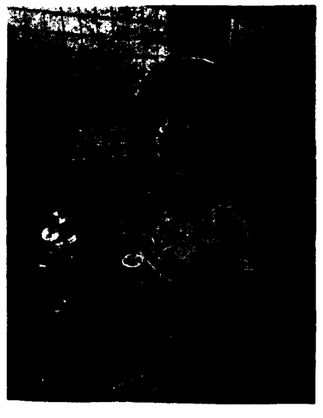
For more than 10 years the kiers have been in constant operation and have shown no signs of corrosion. Bleaching and dyeing operations are performed interchangeably.

This is a typical "day-to-day" cycle:

BLEACHING SOLUTIONS

Yarn is immersed in a solution containing 0.03% sodium carbonate, 0.06% sodium silicate and 0.3% sodium hypochlorite. The solution is drained, the fabrics are given a 10-minute cold water wash, and a new bath containing 0.23% sodium carbonate, 0.09% sodium silicate and 0.13% hydrogen peroxide is prepared.

At various times as much as 2% of a detergent consisting of 50% sulfonated fatty higher alcohol and 50% pine oil is used.



Armco Stainless Steel sheets and strip are ideal for processing equipment used in bleaching and dyeing operations.

DYEING OPERATIONS

As many as five hours may be required to complete the dyeing cycle.

After a detergent is added to the water, color is added in two parts, half while the solution is flowing from outside the yarn to the inside and half when the flow is reversed. After a 10-minute run a saturated sodium chloride solution is added. Dark shades require as much as 1.4% sodium chloride, light shades as little as 0.2%.

After another cold water wash the yarn is diazotized in a cold bath with 0.24% sodium nitrite and 0.40% sulfuric acid. A sixth cold water wash is started, followed by a wash in a lauramine soap solution. The tank is emptied again and the fabric is given a warm water wash at 100°F.

WOOLLEN MILL'S EQUIPMENT IN SERVICE 15 YEARS

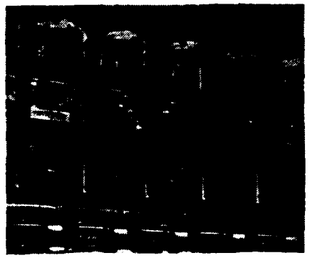
Records in one of the country's largest woollen mills show that some of the dyeing and finishing equipment has been in service more than 15 years and is still in excellent condition. Both Types 316 and 317 Stainless Steel were used in the construction of these vats.

Sulfuric, acetic and formic acid in the concentrations used in the dyeing processes have no injurious effect on the stainless equipment.

BLEACHING, DYEING EQUIPMENT

Another wool processor has standardized on Type 316 Stainless Steel for bleaching bowls and dye vats. Some of the machines have been in service about seven years; a new group of stainless vats were added less than a year ago.

"Acid" colors containing acetic and sulfuric acids in concentrations under 1% are used in the majority of operations.



Stainless Steel is used for centering eyes on this unit called an "uptwister." Top corrosion resistance is needed here.

"BRIGHTER, LIGHTER SHADES"

"Stainless steel allows the dyer to obtain brighter and lighter shades than when the dyeing is carried out in iron equipment," the chief chemist in this mill said. "It also makes the machine more versatile; thus hydrogen peroxide bleaching can be carried out where it could not be used in iron.

"In carbonizing work, we find that conditions are too severe for the economical use of Type 304; in such conditions we use higher alloys such as Type 316."

Stainless Steels have helped textile manufacturers solve three major problems: Costly maintenance of machinery working under severe corrosive conditions; loss of finished fabrics because of stain and discoloration; and deterioration of processing solutions by reaction with equipment materials.

MAINTENANCE SAVINGS

CLEANING COSTS DOWN. Even after long service the hard, smooth non-absorbent surface of Armco Stainless Steel is easy to clean and keep clean.

FEWER REPAIRS. Stainless Steel is a solid, corrosion-resisting metal and naturally has no plating to chip or wear off. This means no relining, no discarding of equipment because of surface damage.

NO RUST SPOTS. Armco Stainless resists acids, bleaches, soaps, dyes and other chemicals. *When the correct grade is used with proper fabrication and care no rusting occurs.*

LOWER OPERATION COSTS

NO BOIL-OUTS. Stainless Steel puts an end to costly equipment boil-outs. A quick rinse with a hose removes all traces of color — light or dark. This permits quick color changes, leaves all machines on "open schedule" for shifts from dark colors to pastels.

No caustic or reducing chemicals are needed. You get more output with less equipment.

TRUE COLORS. Colors run true every time. There is no need to use dyes "corrected" for reaction between dyes and metal.

LONG SERVICE LIFE. Cost per year of service is less because with proper care stainless equipment lasts indefinitely. It eliminates down-time for repairs because of its strength and corrosion resistance.

FEWER REJECTS

NO SNAGGING. There is no place for fabrics to snag on smooth surfaces of well-designed stainless equipment.

NO SPOTTING. Armco Stainless eliminates off-colors, color saddening, and spotting of fabrics and yarns. In many cases this alsc makes possible much longer use of solutions.

Use The *Correct* Grade of Stainless Steel

No rule-of-thumb can be applied to selecting the correct grade of stainless steel for textile equipment because of wide variations in processing and operating procedures. But the decision is always important because maintenance and the service life of equipment may depend on the grade used.

In general, stainless steels have been found entirely satisfactory for dyes in alkaline solutions, even though they may contain small percentages of reducing acids and free chlorine. They are also highly resistant to the effects of oxidizing acids.

Some stainless grades are also resistant to the corrosive attack of such chemicals as sodium chloride, sodium sulphate, sodium carbonate, sodium sulfite, acetic acid, sodium hydroxide and sulfuric acid at temperatures and concentrations commonly used in the textile industry.

Armco Stainless Steel types frequently used in textile equipment are produced in sheets, strip, plates, bars and wire.

NEW "ELC" TYPES SAFEGUARD WELDED AREAS

Three new types of Armco Stainless Steels are ideal for welded equipment exposed to corrosive conditions at service temperatures below 800°F. They are Type 304 ELC, Type 316 ELC and Type 317 ELC.

These special stainless grades prolong service life and slash maintenance costs because they are as corrosion-resistant adjacent to weld areas as elsewhere.

The reason is the Extra-Low Carbon (.03% maximum) in Armco ELC grades. This eliminates intergranular corrosion adjacent to the welds as no harmful carbide precipitation occurs during welding.

These grades can be used to advantage in such welded equipment as agers, kiers, bleaching and fulling machines, carbonizing equipment and dye kettles. They do the same job as corresponding grades stabilized by the addition of columbiam or titanium—at less cost.

ARMCO 18-8 (TYPES 302, 304, 304 ELC)

If solutions are alkaline, or if they contain only oxidizing acids, these grades give a good account of themselves in various textile applications.

Type 302 has normal carbon content: Type 304 has maximum carbon content of .08%; Type 304 ELC has a maximum of .03% carbon.

ARMCO 18-12 MO (TYPE 316)

ARMCO 18-12 MO ELC (TYPE 316 ELC)

ARMCO 19-12 MO (TYPE 317)

ARMCO 19-12 MO ELC (TYPE 317 ELC)

These chromium-nickel-molybdenum types offer the greatest resistance to corrosive media of all the grades of Armco Stainless Steel. Dye manufacturers and textile mills have learned that they are the best over-all grades for bleaching and dyeing operations.

It is also the experience of the textile industry that Type 316 is the most suitable of the stainless steels for handling dye solutions containing chlorides and other reducing agents. Types 316 or 317 have been found *necessary* for carbonizing equipment.

ARMCO 17 (TYPE 430)

This is the most popular of the chromium grades. It is excellent for such parts as reeds, heddles and drop wires because it strikes a good balance between necessary hardness and adequate corrosion resistance.

To achieve the exact shades desired, experimental dyes are placed in stainless steel beakers for testing at various temperatures. The beakers are set into stainless steel dye bath tables.

HOW TO CARE FOR STAINLESS STEEL EQUIPMENT

Give it reasonable care and your stainless steel equipment will return many years of thrifty, efficient service. Here are a few suggestions to help you get the best results from your investment:

1. New stainless steel equipment should be thoroughly cleaned before using to assure utmost corrosion resistance. Foreign matter may accumulate on the surface of the metal during shipment and installation.

Scrub with a warm 15 to 20 per cent solution of nitric acid, or a warm solution of orthophosphoric acid at about 50% concentration. When all foreign matter is removed, be *sure* to follow *immediately* with a thorough water wash. Otherwise the acids may etch the polished surfaces of stainless steel, or get into your bleaching and dyeing solutions.

(Note: Nitric acid will not remove iron oxides, but orthophosphoric acid will do so.)

2. All units should be drained and cleaned once a week if possible, regardless of the nature of solutions used. Wash with hot water and dry with an air hose, or brush the bottom as free of water as possible and then allow to dry.

3. During cleaning, all lint, pieces of brush bristles or other solid particles should be removed.

Stainless Steel has many advantages in slasher exhaust hoods. Because this metal resists corrosion it is not affected by high humidity. There are no rust spots to drip on woven cloth. Lint that collects on wet hoods is easy to remove with a brush or cloth.

4. After cleaning and drying, the equipment should be exposed to the air for two or three hours. If this is not possible, the use of alkaline or oxidizing cleaning solutions will be helpful.

5. If scum, lint or other solid particles still cling to the stainless steel after washing, the unit should be thoroughly scoured. Any of the popular brands of common household cleaners should do a satisfactory job.

6. Ordinary steel wool should never be used. Steel particles are likely to cling to the stainless steel and start superficial rusting, which in turn may cause a local condition favorable to corrosion. This applies to all other metallic scouring materials except stainless steel wool.

7. If superficial rust spots or any other discolorations appear on the surface of stainless steel, they usually can be readily removed. Apply a 50 per cent solution of warm orthophosphoric acid to a lint-free cloth and rub it on the discolored area. Be sure to remove the acid by washing thoroughly with water afterward.

8. Occasionally particles of rubber will break away from a hose, especially when steam or hot water is used. When these particles stick to the stainless steel, they should be removed as outlined under suggestion No. 5.

9. The proper grades of stainless steel offer excellent resistance to hypochlorite bleach solutions. However, it is not recommended that this type of solution be kept in the equipment longer than 3 to 4 hours at a time. After draining, the unit should be cleaned and dried as outlined in No. 2.

10. It is good practice to rinse a unit with water immediately after a solution of *any* type is drained from it.

11. In cyclical work, where the unit is cleaned between operations, suggestion No. 2 need not be observed.

12. Should it become necessary to change service conditions, such as the types of solutions used, make certain the grade of material is suitable, for the new conditions.

How Stainless Steel Stands Up in Textile Processing Equipment

PROCESS	MATERIALS	TEMP. ° F.	DURATION OF TEST	AERATION	AGITATION	ALLOY	AVG. CORR. RATE, IPY	PITTING, INCHES DURING TEST
Dye operations for wool	2-4% sulfuric acid, 4% glaubers salt, aniline dyes (Per cent based on weight of wool)	212	10 hrs./day 6 days/wk. 37 day test			302 316	∠ .0001 ∠ .0001	none none
Dyeing of piece goods	Algosol and Indigasol Dyes, Sulfuric acid, nitric acid, sodium nitrite	105—175	171 days	Slight	Slight	302 316	∠ .0001 ∠ .0001	* *
Dyeing operations	Dye solutions of basic, acid and direct colors used with acetic, formic, sulfuric acids	120	251 days			302 304	.00006 .00002	.001, .002 .005, .007
Dyes and developer baths	Dye solutions and developer baths—250 hours, and sodium hydrosulfite and caustic—5 hours		11 days			302, 304 316	.00001 ∠ .00001	none none
Preparation of sodium hydrosulfite	40% sodium hydrosulfite plus free sulfur dioxide (133 batches)	86—122	42 days			302 316	∠ .00001 ∠ .00001	etched none
Dyeing of cotton fabric	Solutions of (1) hydrochloric plus acetic acids at 50° F–57 hrs., (2) acetic acid plus sodium dichromate at 130° F. —41 hours, (3) sulfuric acid at 120° F. —37 hours, and (4) sodium perborate at 120° F—17 hours. Total time in use, 152 hours		28 days			302 316	.00004 .00002	none none
Vat Ageing	Hot water carrying CF dyes and other agents from the Vat ageing of printed goods	212	378 days	Good	flowing	302 316	0 0	none none
Vat Ageing	Steam and hot water with reagents from vat ager of printed goods	212	268 days	Vapors & air		302 316	.00011 ∠ .00001	.002-.003 none
Rapidogen ager	Formic acid—12.9% plus Acetic acid, 48%	212—220	300 hours	Vapors & air		302 316	.0007 .0001	badly pitted none
Dye Plant	Splashes and fumes in miscellaneous dyeing operations	Room	1 year	—		302	0	.004-.018 (few in number)
Rayon sizing bath	Gelatin, vegetable oil, softeners, penetrants, glycerine	160	208 days			302 304 316	∠ .00001 .00004 ∠ .00001	.001-.002 .003-.005 none
Fur washing, dyeing, bleaching	Alkalis, organic and inorganic acids, oxidizing and reducing agents—usually at 0.1 to 1.5%	70—100	25 days			304 316	.0001 .0001	none none
Acid ager	45% acetic acid plus 17% formic acid	212—220	600 hours			302 316	.0005 .0001	.007-.012 .008

Data not available.

How Stainless Steel Stands Up in Textile Processing Equipment

PROCESS	MATERIALS	TEMP. ° F.	DURATION OF TEST	AERATION	AGITATION	ALLOY	AVG. CORR. RATE, IPY	PITTING, INCHES DURING TEST
Wool Carbonizing	6.4% by weight H_2SO_4, full immersion	75, ave.	144 days			304	.00001	*
Wool Carbonizing	31.5% HCl Vapors and air in air duct	220	37 days	Yes		302 316	.0065 .0036	Slight Slight
Wool Carbonizing, mixing tank	H_2SO_4, 66° Be to 10% by weight		473 days			302 316	.0070, .0018 .00046. .0098	Perforated .003
Dyeing of wool skeins	Sulfuric acid dye solution with 0.5% Pallatine dyes	Boiling	13 months			316	.0002	*
Wool dyeing solution	Miscellaneous wool dyes	212	71 days		by steam	302 347 316	∠ .0001 ∠ .0001 ∠ .0001	* * *
Rug dyes	Acids salts, boiling water, caustic soda, chloride of lime	212	60 days			302 316	.000011 .000011	∠ .001 etched ∠ .001 bright
Miscellaneous dyeing operations	Vat, sulfuric, direct, dyes, acetic acid, bichromate and copper sulfate colors. Also caustic scouring with 7.5% NaOH at boiling point	Boiling	5 months			302 316	∠ .0001 0	.002 0
Liquor heating compartment of dyeing	Sulfuric acid + formic acid = 0.75 gpl.	120–212 (275 hours at boiling)	330 hours	none	by steam	302 316	.00007 .00006	* *
Dye machine	Typical wool dyeing operations	Boiling	365 days	none		321 (cast) 302	∠ .0001 .0001	none none
Vat dye machine	Miscellaneous dye liquors, etc., containing at times: (1) brine, (2) pyrophosphate, (3) soap, (4) formaldehyde and formic acid, (5) chlorine bleach, (6) sodium bicarbonate, (7) formic acid, (8) sodium nitrite plus hydrochloric acid, (9) soda ash, (10) caustic soda, etc.	45–202	64 days			302, 304 316	∠ .00001 ∠ .00001	none none

* Data not available.

Note: Tests on stainless steel textile equipment exposed to various dyestuffs and chemicals were made by The International Nickel Company. Although the results tabulated on these pages do not imply recommendations, they may be helpful to the mill and its fabricator in determining the correct grade of Armco Stainless Steel for your equipment.

Temperature Without Touching

By B. B. Ritchey

Textile Department, Industrial Division of Minneapolis - Honeywell Regulator Co.

How to get temperature measurements of moving textile materials without contact with the fabric with a low range radiation pyrometer.

BECAUSE today's dryer temperatures are higher, because new curing type resins require goods to be held at a specified temperature for a fixed time and because nylon must be properly heat set to obtain some of its most saleable qualities, the danger of tendering goods by excessive heating has become more real. Thus, close measurement and control of the temperature of moving materials becomes most important to assure proper processing with efficiency that will yield a profit.

But measurement of moving fabric temperatures is not a simple matter. Several complications arise if moving cloth heat is measured by a contact element. First, the motion of the cloth may generate false heat by friction against the sensing element tip, to give an inaccurate reading. Second, a lack of stiffness of the cloth prevents a good contact between the measuring element and the fabric. Last, the relatively small mass of the element cannot measure enough cloth area for true accuracy since the cloth is constantly in motion. But, if the thermocouple were made large enough to measure a sufficient area, it would conduct heat away from the cloth faster than the cloth could conduct it to the contact point, lowering the temperature and yielding an inaccurate measurement.

However, temperatures of moving textiles need not be measured by a contact element. Actual cloth temperature can be measured without contact with the work through a radiation pyrometer. This device converts the heat radiated from the fabric to a minute electrical signal proportional to fabric temperature.

WHAT'S A RADIATION PYROMETER?

To understand the operation of a radiation pyrometer, some discussion of radiant energy and its properties is necessary. All objects which are warmer than absolute zero (minus 459°F) radiate heat energy. Conversely, all objects are capable of absorbing radiant energy from other bodies at higher temperatures.

The quantity of energy which is radiated from a body is dependent upon its temperature, its composition, and the condition of its surface. In general, the more reflectance shown by a boby, the lower will be the quantity of heat emitted—as it will reflect rather than absorb heat. Thus, an object with minimum reflectance will emit the greatest quantity of energy. Such an object is known as a *blackbody* and is said to have an *emissivity* of 1.0. Since most common materials are not blackbodies, and show emissivities of less than 1.0, emissivity is usually defined as the ratio of radiant energy emitted by a body to that which is emitted by a blackbody at the same temperature. This measurement is often expressed as "percent emissivity".

The radiant energy emitted at the relatively low temperatures encountered in the textile industry is

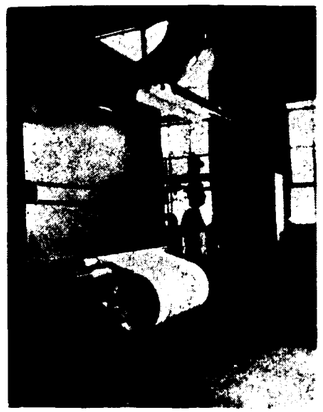


Fig. 1. In this nylon heat setting operation, temperature of the moving material is measured by a low range radiation pyrometer, and indicated and controlled through the recording potentiometer on the wall behind the operator—all within several degrees and without contact with the cloth.

quite different from that emitted at high temperatures, including the visible spectrum (light). Fig. 1 shows the wave length distribution of energy at various low temperature levels. The radiant energy at these temperatures is entirely outside the visible range. Unlike the radiant energy from a red hot iron bar. Personal experience demonstrates this, since radiation at such temperatures can be felt but not seen. To confirm this and mark a difference between low and high temperature radiant energy, let us take the case of a *Pyrex* baking dish. The *Pyrex* is transparent to both light and high temperature radiation (and therefore has a very low emissivity *in that range*). But, if that dish is heated to 350°F during baking, though visible radiation cannot be traced to it, a person can definitely feel heat radiating from it. In this range, *Pyrex* is actually opaque and absorbs radiation readily. Thus, at comparatively low temperatures, transparency to light is not a criterion of emissivity.

Transparent films of cellulose derivatives are somewhat similar to glass in their opacity to low temperature radiation. Fig. 2 shows that a clear lacquer is far

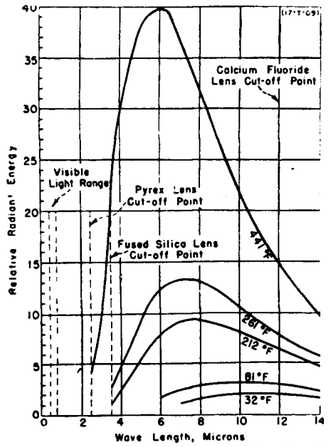


Fig. 2. Visible light waves fall considerably below the wavelengths encountered in low range temperature measurements. Thus, though pyrex may be transparent to light, it absorbs and re-radiates heat in the lower ranges.

less transparent to low temperature radiant energy than it is to visible light. In fact, the emissivity of this material is rather high, as shown by the fact that two thin coats of the lacquer on bright copper raises the emissivity from less than 0.1 to approximately 0.6.

Further, the visible color of a surface is obviously not an indication of its relative emissivity at low temperatures. Fig. 3 shows the emissivities of several paints and refractory materials—and it is to be

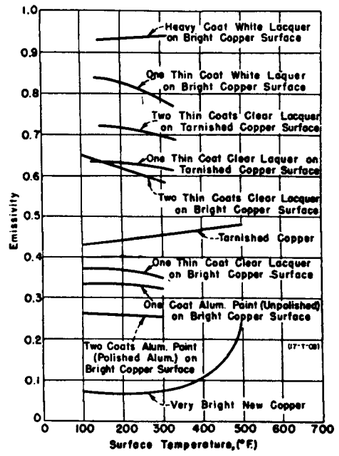


Fig. 3. Emissivities of copper, uncoated, coated, and tarnished, versus temperature.

noted that the black paint used actually has a lower emissivity than other colors in the 200° to 400°F temperature range. However, dull or flat black paint is still a good "emitter" and is actually used as a reference standard in some cases.

RADIATION CHARACTERISTICS OF TEXTILE FIBRES

Some data has been collected on the emissivity of sized cotton yarn while it is passing over a stainless steel cylinder. The sets tested were 2300 ends of cotton 9's at 260°F, 4500 ends of cotton 30's and 5000 ends of cotton 45's; the latter two at 250° F. The tests were made by sighting the radiation pyrometer first at a *stripe* of dull black paint on the cylinder and then a sheet of warped yarn. In all instances the recorded temperature dropped less than 5° as the sighting of the unit was changed from black paint to cotton yarn. The color of the yarn made no apparent difference to the reading. Further, as was expected, the results were the same whether the yarn was moving or stationary.

Tests have also been conducted on various nylon fabrics with the result that close woven nylon fabrics

show an emissivity of approximately 0.9, and should lend themselves very well to use with a radiation pyrometer. However, such open weaves as nylon net have yet to be found accurately measurable, as some 50% or more of their actual area is open space which does not emit radiation.

THE BROWN *RADIAMATIC* UNIT

The only radiation pyrometer currently available for measuring relatively low temperatures is the Brown Low Range *Radiamatic*. It will produce satisfactory results on a number of textile fabrics if the following 6 conditions are met:

1. Work temperatures must lie between 100 and 600°F.
2. Emissivity of the surface sighted upon is reasonably high and remains relatively constant.
3. The temperature around the sensing element is below 120°F and is not subject to sudden extremes of variations.
4. The target area sighted upon is ample in accordance with the values given in Table I.
5. The pyrometer "sees" the work only—that is, the reflected radiation is eliminated by shielding if necessary.
6. Excessive dust, smoke or water vapor is kept out of the pyrometer line of sight. (Where these things are present in the line of sight, they can sometimes be eliminated by air purging).

Even where all these conditions are not met, it is possible in some cases to use the pyrometer. For example, some users are measuring temperatures as low as 32°F.

COMPONENTS OF THE RADIAMATIC MEASURING SYSTEM

The Brown Radiamatic Pyrometer system comprises three basic components: A low range *Radiamatic* unit, a reference junction temperature controller, and an *Electronik* potentiometer. The last may be any of the conventional strip or circular chart recording models, with or without pneumatic or electric control, depending on the application.

Operation of the system is as follows: radiation of heat from the object whose temperature is to be measured is focused by a calcium fluoride lense upon a group of small thermocouples which create a minute voltage. A potentiometer receives this voltage and amplifies it in the conventional manner to operate the recording pen and, if control is included, to actuate the controlling means—such as a mercury switch. In the case of the most popular application to date, control of nylon heat setting, one of several electric control forms is used depending on the setter employed. These control units direct a proportioning of electricity to the heater rods to maintain a constant tenter temperature within one or two degrees.

To eliminate the effects of ambient temperatures on the thermopile, (the small cluster of thermocouples in the *Radiamatic* pyrometer) a temperature-sensitive resistance winding and a heating element can be included in the detecting unit. The reference junction temperature controller operates from a resistance winding to control power to the heating

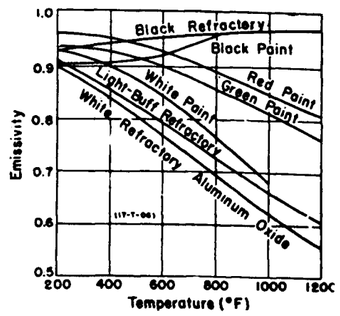


Fig. 4. Emissivities of several paints and refractories versus temperature. At low ranges, black is not necessarily the best "emitter".

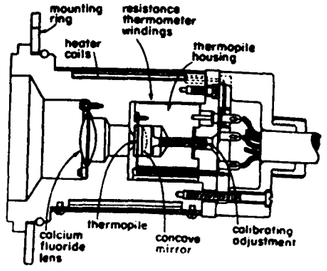


Fig. 5. The internal parts of the Brown Low Range Radiamatic unit used in textile applications.

(Continued on page T.13)

Preliminary Report on Service Uses of Cyanoethylated Cotton Products

By Jack Compton
Technical Director, Institute of Textile Technology, Charlottesville, Va.

(Continued from JOIE / March 1958–Vol. 2, No. 3)

Cyanoethylated Sewing Twine in Outdoor Use. Comparative weathering tests were made on 12/4 cyanoethylated cotton, cotton, and phenyl mercuric salicylate (0.01%) treated cotton sewing twine. The twine samples were all exposed to full Georgia sun during the summer months. Samples were tested for tensile strength at various intervals of time with the results obtained shown in Table VI.

TABLE V

Fresh Water Reservoir Submersion Tests on ¼-in. Diameter Marine Rope Constructed of Various Types of Chemically Treated and Modified Cotton and Manila

	Breaking strength		
		After	
Cotton product	Orig.	23 weeks	% Loss
Untreated	441	138	68
Acetylated	312	312	0
Azoton	468	540	15(gain)
Proofed cotton*	345	394	14(gain)
Manila	596	160	73
Cyanoethylated manila	518	536	3(gain)
Proofed manila**	615	407	3
Nylon	not tested		

*Copper naphthenate (1.8% Cu).
**Copper naphthenate (0.15% Cu)–G-4 (0.15%).

Seam tests made on cotton duck sewn with cyanoethylated cotton, Dowicide treated cotton, and Orlon[2], sewing twine after 14 weeks outdoor weathering showed that the cyanoethylated cotton twine seam was equal to or better than, the proofed cotton twine

TABLE VI

Weathering Test on 12/4 Cyanoethylated Sewing Twine and Mercury-Treated Cotton Twine

	Breaking strength, lb.		
Time, weeks	Untreated	Azoton	Mercury*
0	6.9	7.9	6.9
4	6.4	7.7	5.8
9	5.1	6.9	4.4
14	3.8	5.2	3.6

*0.01% Phenyl mercuric salicylate.

[2]Du Pont acrylic fiber.

(Continued from page T.12)

element so that a constant temperature is maintained. These elements can be seen in Fig. 4. Thus, the unit is responsive only to radiation focused upon its thermopile. If cooling is required instead, a water jacket to keep the unit at a stable reference temperature can also be provided.

The recorder is offered only with an arbitrary calibration of 0-100 in even divisions on the chart and scale. Any attempt at temperature calibration would, of necessity, be based upon blackbody conditions and would be of little value in the majority of low temperature applications, where such conditions do not exist. Furthermore it is usually more important to be able to reproduce a predetermined optimum temperature level from day to day than to maintain an actual calibrated temperature reading.

Today, the majority of applications of the low range radiation pyrometer have been made on nylon heat setting and resin curing operations. But, because of the many applications in the textile industry where temperature of moving fabrics, should be measured, and because of the adaptability of a radiation pyrometer to this service, it is believed that there are many places where this measuring system will be very useful. Although general rules can be given for its adaptation to various measurement and control problems, specific application data will usually require a brief survey by a trained instrument engineer.

seam, and both were better than the Orlon twine seam, Table VII. It will be noted that the predominant type of seam failure for the Orlon twine seam was fabric failure at the stitch due to cutting, whereas fewer of the seam failures were of this type on the proofed and chemically modified cotton twine seams. The seam failures of both of the latter yarns were largely twine failures and these were at a definitely higher level than the failures at the seam when Orlon twine was used. It will be noted also that the fabric breaking strengths at the stitch for the cyanoethylated and proofed cotton twine seams were at a higher level than those sewn with the Orlon twine.

Cyanoethylated Cotton Tobacco Shade Cloth. Cyanoethylated cotton tobacco shade cloth was put into several service tests in Florida. The breaking strengths of the cyanoethylated cotton shade cloths after exposure for one season, in two of these tests, are shown in Table VIII. It will be noted that the cyanoethylation of the cotton shade cloth decreased the original breaking strength in the warp from 21.7 to 16.6 lb. but increased the strength of the filling from 20.2 to 27.4 lb. In Test No. 1 the average losses in strength of the fabrics in the warp-and filling-wise directions were 60% for cotton and only 37% for the cyanoethylated cotton after one season's exposure. In Test No. 2 these losses were 74.1 and 7.8%, respectively.

In other tests cyanoethylated cotton tobacco and seed bed cover fabric lost more strength than cotton during service use. A partial explanation for this may lie in the fact that in most of these instances the fabrics were kiered and bleached prior to cyanoethylation, whereas in the above-cited examples greige fabric was cyanoethylated. At the present time, studies are underway with the objective of determining the cause for the poor weatherability of some cyanoethylated cotton fabrics and with the development of treatments to minimize deterioration in outdoor uses.

2. *Acid Resistance*

Filter Fabric. In comparative tests with 8-oz. cotton filter twill, cyanoethylated cotton fabric was found to give three to four times longer service, Table IX. In this instance a hot mineral acid solution was filtered

Tests similar to those earlier reported showing the acid resistance of cyanoethylated cotton fabric were made on an 8.8-oz. cyanoethylated cotton twill fabric containing 3.35% nitrogen. In this test a 40% sulphuric acid solution was used at 75°F. After standing in the acid solution for 24 hr. the cotton and cyanoethylated cotton fabrics were removed, neutralized, rinsed, dried, and after conditioning, 1-in. raveled strip breaking strength determinations made in the warp- and filling-wise directions. The results obtained, expressed in percentage breaking strength loss, are given in Table X. This experiment was repeated after washing both the cotton and cyanoethylated cotton in a commercial home laundry machine. It will be noted that the average loss in strength after washing the cotton was less than before washing, whereas the reverse was true for cyanoethylated cotton. The effect of prewashing the

TABLE VII

Seam Tests on Duck Sewn with Various Types of Thread after 14-Weeks Exposure

12/4

Azoton, lb.		Proofed cotton, *lb.		Orlon, lb.	
Orig.	Exp.	Orig.	Exp.	Orig.	Exp.
154T**	122T	137S	132T	125S	114S
142S	130S	130S	116S	119S	110S
142T&S	1-5S	112S	118T	122S	110S
117T	130S	116T&S	121T	109S	105S
127T	134T	146T	132F	100S	110S
123T	110S	150T	118F	103S	118S
	132S		130T		110S
	122S		130S		110S

*Dowicide G.

**T, twine failure; S, fabric failure at stitch; F, fabric failure away from seam.

TABLE VIII

Cyanoethylated Cotton in Tobacco Shade Cloth

	Breaking strength, lb.			
	Cotton		Azoton	
	Warp	Fill	Warp	Fill
Original	21.7	20.2	16.6	27.4
Field Test No. 1*	7.9	6.4	11.6	16.1
Field Test No. 2*	5.6	5.2	15.4	21.2

*One-season exposure in Florida.

TABLE IX

Cyanoethylated Cotton Filter Twill for Filtering an Acid Solution at 120°F.

Product	Average life, hr.
Cotton	24
Azoton	72 to 96

fabrics may be of no significance, but the lower loss in strength experienced by the cyanoethylated cotton is real.

3. *Heat Resistance*

Laundry Press Cover Fabric. A large number of service tests were conducted in commercial laundries using cyanoethylated cotton fabric (3.5 to 4.0% nitrogen) in place of cotton on both ironer rolls and presses. A large number of variables enter into such a full-scale service evaluation, which will not be mentioned here. The data summarized in Table XI are sufficient to show the superior performance of cyanoethylated cotton press fabrics with relation to similar cotton fabrics in this case. More complete details concerning the tests can be furnished those interested.

Comparative tests of cyanoethylated cotton fabric were also made with nylon and Dacron[3] laundry press fabric. From these service tests it was possible to determine the relative cost of using cotton, cyanoethylated cotton and nylon or Dacron fabric. The data shown in Table XII are based on the cost of cyanoethylated cotton fabric (7.25 oz./sq. yd.) being 20c per yard greater than for a similar cotton fabric. This is, of course, only an approximation based on pilot plant studies.

It would appear that on a cost-per-day basis cyanoethylated cotton press fabric could easily gain favor in laundry use. However, in the service tests it was found that the sticking of starched goods to cyanoethylated cotton press cloths was as great as to cotton. This resulted in a buildup of starch on these covers so that it was necessary to wash them after a week or 10 days use, whereas this was not found to be the case for nylon and Dacron covers. The labor required for removing and replacing the covers after washing, together with the laundering of the covers, reduced the savings resulting from the lower initial cost to a point where it was questionable that the cyanoethylated cotton press cloth was the better buy. It is possible that laundry press covers produced from cyanoethylated cotton fabric with a nitrogen content in the range of 4.5 to 5.0% would give longer life in service than those used in the tests described. If this is found to be the case, there is little doubt that this product would be favored by commercial laundries over both cotton and nylon or Dacron press covers.

[3]Du Pont polyester fiber.

In laundry roll covers the service life of 29 oz./yd. cyanoethylated cotton fabrics was found to be about one third that of the Dacron fabrics ordinarily used. In this case, however, the cost of the Dacron fabric was $5.60 per square yard, whereas the cyanoethylated cotton fabric was estimated to be $1.90. It is thus evident that cyanoethylated cotton roll covers are competitive with Dacron covers.

Enameling Duck. Cyanoethylated cotton enameling duck, 37 × 45, 9.2 oz./sq. yd., was put into a typical fabric coating use where it was subjected to a temperature of 195°F. for a period of 6 weeks. It will be noted in Table XIII that the losses in both tensile strength and tear strength were considerably less for the cyanoethylated cotton fabric than for the cotton fabric. Particularly outstanding are the low tearing strength losses.

When the enameling ducks were given a preshrinking treatment of the sanforizing type prior to service

TABLE X

Cyanoethylated Cotton Fabric for Overalls, 8.8-oz. Twill 3.35%N

(% Loss in tensile strength after 24 hr. in 40%H_2SO_4*)

Original		Washed	
Cotton	Azoton	Cotton	Azoton
70(W)	46(W)	67(W)	55(W)
80(F)	56(F)	73(F)	53(F)

* Temperature 75°F.

TABLE XI

Cyanoethylated Cotton Laundry Press Fabrics

Test No.	Type work	Average life, days	
		Cotton	Azoton
1	Towels, aprons	10–15	22–27
2	Aprons	15–20	24
3	Sheets	25–30	55
4	Cases, towels	10 and less	22
5	Family flat	15	20
6	Family flat	15	30

TABLE XII

Comparative Cost of Cyanoethylated Laundry Press Fabrics with Other Press Fabrics

Fabric	Average use, days	Cost per yd.	Cost per day, cents
Cotton	15	$1.00	5.5
Azoton	30	1.20	4.0
Nylon	50	3.65	7.3

use, the results shown in Table XIV were obtained for tensile and tear strength in both the warp and filling directions.

It will be seen that tensile strength loss of both the cotton and cyanoethylated cotton was less after preshrinking except for the latter in the filling-wise directions, whereas the tear strength loss was greater for both the cotton and cyanoethylated cotton fabrics. Again, however, the latter fabric was found to have deteriorated to a lesser extent in service, as determined by the tensile and tear strength losses, than the former fabric.

Conveyor Belt Duck. It was proposed to put a rubber conveyor belt reinforced with 28-oz. cyanoethylated cotton duck into a high temperature service use and compare the performance with a similar belt reinforced with cotton duck. Breaking strength tests were thus made on the 7.5/3 cotton and cyanoethylated cotton yarn after treating under simulated service conditions as follows: (*a*) after 15 hr. at 320° F.; (*b*) after heating for 4 hr. at 220° F.; (*c*) fully wet out, and the per cent change in strength calculated with relation to the tensile strength of the yarns conditioned at 65% RH and 72° F. The effect of weaving the 7.5/3 yarns into the 28-oz. fabrics was also determined for each of these properties by removing the yarns from the woven fabrics. The results obtained are shown in Table XV.

It will be noted that both the cotton and cyanoethylated cotton were apparently damaged as a result of weaving, although the relationship between the two types of fibers after subjecting to various tests was essentially unchanged. The heating of the yarns at 320° F. for 15 hr. caused a loss in strength of the cotton (34.5%) about six times as great as for the cyanoethylated cotton (6.7%) after reconditioning at 65% RH and 72° F.; whereas heating for 4 hr. at 220° F. and testing immediately, cotton (26.4%) lost about five times as much strength as cyanoethylated cotton (5.4%). When the yarns were fully wet out and tested for tensile strength, the cotton (20.0%) increased in strength to a lesser extent than the cyanoethylated cotton yarn (29.0%).

In tests made on the fabric it was found that the breaking strength of the 28-oz. cyanoethylated cotton duck was 10% lower than for 28-oz. cotton duck. When heated for 4 hr. at 220° F., however, the former fabric was 10% stronger than the latter. Since the fabric is cured in rubber in a dry condition, the cyanoethylated cotton duck should produce initially a stronger conveyor belt than cotton duck of the same weight and retain this strength under high temperature use conditions for a longer time.

4. Abrasion Resistance

In some service uses the abrasion resistance of cyanoethylated cotton fabric has been found to be greater than that of cotton fabric, whereas in other uses the reverse is true. An example of the former is shown in the case of cyanoethylated cotton chafer fabric used in V-belt covers.

TABLE XIII

Loss in Tensile and Tear Strength of Cotton and Cyanoethylated Cotton Enameling Duck After 6 Weeks Service Use at 195°F.

(37×45, 9.20-oz. duck)

Product	% Loss tensile strength	% Loss tear strength
Cotton	24.2 (W)	42.4 (W)
	16.7 (F)	32.0 (F)
Azoton	16.8 (W)	8.2 (W)
	11.4 (F)	0.0 (F)

TABLE XIV

Loss in Tensile and Tear Strength of Pre-shrunk Cotton and Cyanoethylated Cotton Enameling Duck after 6 Weeks Service Use at 195°F.

Product	% Loss breaking strength	% Loss tear strength
Cotton	11.2 (W)	65.6 (W)
	15.0 (F)	45.1 (F)
Azoton	6.6 (W)	10.0 (W)
	15.6 (F)	14.6 (F)

TABLE XV

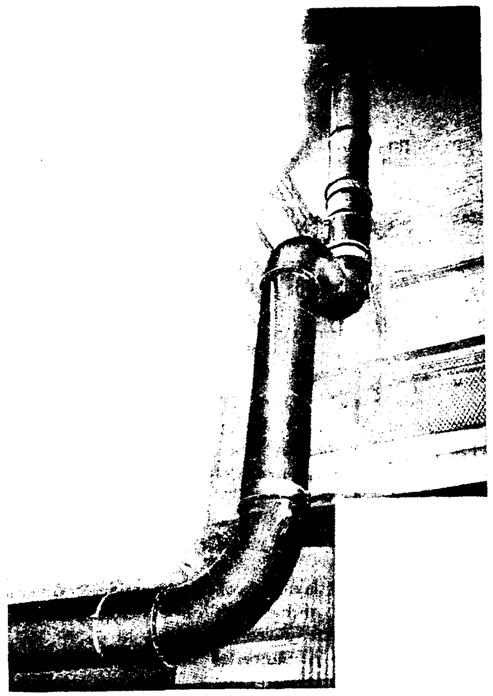
Change in Single End Breaking Strength of 7.5/3 Yarn Taken from 28-Oz. Cotton and Cyanoethylated Cotton Conveyor Belts under Various Conditions Following Testing at 65% RH and 72° F.

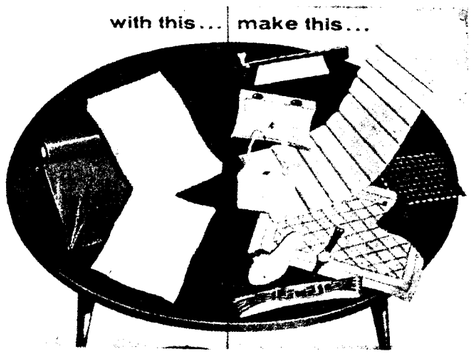
Test No.*	Before weaving		After weaving	
	Cotton	Azoton	Cotton	Azoton
1	−34.5	− 6.7	−39.6	− 3.6
2	−26.4	− 5.4	−28.8	−10.6
3	+20.0	+29 0	+26.9	+18.1

*(1) After 15 hr. at 320°F. followed by reconditioning. (2) Bone dry. (3) Fully wet.

—(To be Continued)

PLASTICS AND CHEMICALS SECTION





CYANOETHYLATION OF COTTON

Findings of the
Institute of Textile Technology
Charlottesville - Virginia - U.S.A.

THE reaction of acrylonitrile with cellulose and other high polymeric materials containing hydroxyl groups was first investigated and patented by I. G. Farben chemists in 1938 (1). As a result of the work of Bruson (2), MacGregor (3), and others (4), it has been shown that acrylonitrile enters into many addition reactions not usually shown by an olefinic bond. The reaction with materials containing hydroxyl groups, such as cellulose, proceeds as follows:

$$\text{Cellulose–OH} + \text{CH}_2 = \text{CHCN} \xrightarrow{\text{Caustic Soda}} \text{Cellulose} - \text{OCH}_2\text{CH}_2\text{CN}$$

In 1945, Houtz (5) confirmed the early work of the German scientists, and defined the conditions for a two-step process for the impregnation of cellulosic fibers with caustic soda followed by treatment with acrylonitrile to give highly substituted cyanoethylated cellulose, soluble in organic solvents.

In subsequent work, Stallings (6, 7) reported modifications in the two-step procedure for the treatment of cotton fiber, yarn and fabric with acrylonitrile to obtain partial reaction products that retain their original form. The reaction conditions described, however, result in: (a) the hydrolysis of some of the nitrile groups in the partially cyanoethylated cotton first formed to carboxyl groups, thereby producing mixed cellulose ether derivatives consisting of cyanoethyl and carboxyethyl cellulose, and (b) excessive formation of the by-product B, B′ – oxydipropionitrile.

In 1952 Compton (8, 9, 11, 12, 13) of the Institute of Textile Technology reported that conditions could be defined for the partial cyanoethylation of cotton fiber, yarn and fabric with acrylonitrile without significant changes in physical appearance or morphological structure responsible for outstanding performance characteristics of cotton as a textile fiber. This is in contrast to other reactions for the chemical modification of cotton, with the possible exception of acetylation (10). The Institute procedure for the cyanoethylation of cotton fiber, yarn and fabric has been adapted to pilo plant operations (12, 16) by the joint efforts o American Cyanamid Company, Monsanto Chemica Company and the Institute of Textile Technology.

Later a simplified one-step procedure was developed in which the caustic solution is dispersed in th liquid acrylonitrile and the cotton cyanoethylated wit the mixture (16, 17). Also, the two-step procedur for the partial cyanoethylation of cotton fiber, yar and fabric without change in physical appearance ha been modified so that, instead of liquid acrylonitril acrylonitrile vapor is used (9, 16, 18). The use o these modified procedures under carefully controlle conditions has led to the production of satisfactor partially cyanoethylated cotton fabric and yarns in a economical manner (16, 17, 18).

PROPERTIES

Partially cyanoethylated cotton fiber, yarn an fabric with a nitrogen content in the range o 3.8 ± 0.5% are similar in appearance, hand an processing characteristics to cotton but differ pri marily and significantly in that they:

1. Are permanently rot—and mildew-proo (12, 13):

Cyanoethylated cotton duck with a nitroge content of 3 0 to 3.5% in soil burial tests (19 for periods as long as nine months lost no tensil strength.

2. Are more stable, or resistant, to degradatio by wet and dry heat (13, 14):

Cyanoethylated laundry roll cover fabric, 9-ounc containing 3.6% nitrogen lost only 3.5% in tensil strength in a standardized aging test at 320°F. fo 15 hours, whereas the untreated fabric lost 38% (13 In the presence of moisture at elevated temperature cyanoethylated fabrics and yarns show about th same resistance to heat degradation as in dr heat (14).

3. Are more stable, or resistant, to degradation by organic and mineral acids (13):

With 20% sulfuric acid solution at 136—140°F. after 20 hours, for example, cyanoethylated cotton print cloth with a nitrogen content of 3.5% lost 44.2% in tensile strength, whereas the untreated fabric lost 86%.

4. Have lower moisture regain, typical data being 5.0 to 5.5% as compared with 7.0 to 7.5% for cotton (11, 13):

5. Have altered dyeing characteristics, being more receptive to many dyes in all classes of dyestuffs, particularly acid and acetate (or dispersed) dyes (11, 12, 20, 21, 22):

6. Have different stress-strain fiber properties with more work required for rupture under tension (11, 13, 14, 15):

7. Have altered electrical properties (18).

The dielectric constant value is increased in proportion to the extent of cyanoethylation.

It should be noted that cyanoethylated cotton is degraded by caustic solutions under certain conditions (15, 20, 21). Accordingly, caution is needed when using such solutions during finishing or dyeing. Cyanoethylated cotton is sufficiently stable in alkaline solution to permit normal laundering and special finishing operations to be performed without difficulty. However, it should not be considered for end uses involving prolonged contact with highly alkaline solutions.

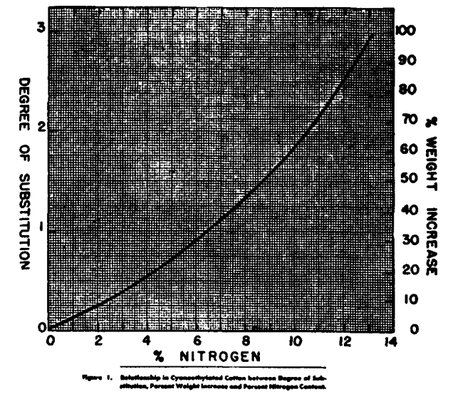
PROCESSING

General Introduction to Processing

DESCRIPTION OF THE REACTION

When cotton reacts with acrylonitrile in the presence of caustic soda as a catalyst under controlled conditions, the hydroxyl groups are partially replaced by cyanoethyl ether groups. The desired extent of cyanoethylation is achieved when, on the average, one hydroxyl group in every other anhydroglucose unit of the cellulose molecule is replaced (or approximately every sixth hydroxyl).

The relationship that exists between percent nitrogen content, percent weight increase by addition of acrylonitrile, and cyanoethyl groups per anhydro-



glucose unit, or degree of substitution, is shown in Figure 1.

The water which is necessarily present when cotton is cyanoethylated with acrylonitrile also reacts to produce oxydipropionitrile. This high-boiling, colorless liquid is the principal by-product of the reaction. Under some conditions of reaction, hydrolysis of nitrile groups occurs to a limited extent. The process conditions described in this report are designed to minimize these side reactions.

PROCESS VARIABLES

The major variables influencing the course of the cyanoethylation of cotton are:

Type of catalyst;

Amount of catalyst and water in the system;

Uniformity of application of catalyst solution;

Temperature of reaction;

Time of reaction;

Physical condition of the cotton.

Proper control of these variables is essential for obtaining uniformly cyanoethylated cotton products with the least losses of acrylonitrile in side-reactions (16, 17, 18).

TYPE OF CATALYST

The reaction of acrylonitrile with cotton is catalyzed by bases. As is characteristic of base-catalyzed reactions, the rate of reaction is dependent upon the

strength of the base, the stronger bases giving greater reaction rates. From a practical point of view, no great difference is observed between the common strong bases, such as sodium and potassium hydroxide. Consequently, caustic soda is recommended because of its lower cost. Sodium carbonate and trisodium phosphate are also catalysts, but, being weaker bases, give very slow cyanoethylation rates. Sodium bicarbonate is virtually ineffective. This latter observation is important and indicates that the caustic soda solution used in the cyanoethylation of cotton must be protected from undue exposure to the atmosphere to prevent the absorption of carbon dioxide with consequent conversion of caustic soda to sodium carbonate and/or sodium bicarbonate. Protection of the cotton from prolonged contact with the atmosphere following application of the caustic solution is particularly important.

AMOUNT OF CATALYST AND WATER IN THE SYSTEM

The base (i. e., caustic soda) is generally used as an aqueous solution, as reaction does not proceed in the absence of water. Since water can also react with acrylonitrile, forming oxydipropionitrile, it is economically important to choose conditions which minimize losses due to side reactions. The competing reactions of acrylonitrile with cotton and water are illustrated below :

$$\text{Cellulose-OH} + CH_2=CHCN \xrightarrow{\text{Base}} \text{Cellulose-}OCH_2CH_2CN$$

Cyanoethylated cotton

$$H_2O + 2\,CH_2=CHCN \xrightarrow{\text{Base}} O(CH_2CH_2CN)_2$$

Oxydipropionitrile

The amount of water must therefore clearly be kept at a minimum consistent with the other operating requirements, such as uniformity of treatment and a relatively fast rate of reaction. The optimum quantity of water will usually lie in the range of 50—100% of the weight of dry cotton entering the reaction.

Closely allied with the quantity of water in the reaction is the amount and concentration of the base. The amount of base may be altered by varying the concentration of the caustic soda solution, by varying the quantity of the solution applied to the cotton or added to the reactor, and, to some extent, by varying the time of contact. The latter variation results from the fact that caustic soda is preferentially absorbed from its solutions by cotton, and the extent of preferential absorption is somewhat dependent upon the time of contact of the cotton and the solution. The greatest variations are observed with the short contact times; little change in the ratio of caustic soda to cotton is observed after ten minutes contact.

Other factors being constant, increasing the caustic soda concentration will usually increase the rate of reaction. However, other effects must be taken into consideration. High concentrations may induce a highly exothermic polymerization of acrylonitrile at high temperatures, and thus constitute a safety hazard. Moreover, there is some evidence that the cyanoethylated product prepared under these conditions is less resistant to microbial attack. Consequently, the use of caustic soda solutions having concentrations in excess of 10% should be avoided, especially at temperatures above 100°F. Thorough laboratory investigation of safety factors and the effect on the product should precede any deviation from this rule.

UNIFORMITY OF APPLICATION OF CATALYST SOLUTION

It is very important for good uniformity of cyanoethylation that intimate contact of the caustic soda solution with the cotton be attained prior to effecting any reaction. This may be achieved in several ways, such as steeping the cotton in alkali solution and removing the excess by padding or centrifugation, or by efficient circulation of a mixture of acrylonitrile and caustic soda solution through the cotton under conditions where the rate of reaction is slow (low temperature). Either of these precautions will result in greater uniformity. The use of an alkali-stable wetting agent will also help.

TEMPERATURE OF REACTION

The temperature of reaction is also an important variable. The rate of reaction increases very markedly with increasing temperature; under conditions giving negligible reaction at room temperature, cyanoethylation to a nitrogen content of 3.5% can be readily achieved in about three minutes at the temperature of boiling acrylonitrile. Under other conditions, excellent results have been obtained at room temperature with low losses of acrylonitrile in by-product formation.

TIME OF REACTION

The time of reaction is likewise a variable. In a continuous process where minimum residence time is essential, temperatures at or near the boiling point of acrylonitrile are recommended. When mild conditions are used (e. g., 2% caustic soda, caustic soda solution to cotton ratio of 1.0, and reaction at 130°F.), the nitrogen content of the cotton reaches an equilibrium of about 3.5% after approximately 30 minutes. Longer reaction times are ineffective in increasing the extent of reaction. Under more severe conditions, it is possible to carry out the reaction to any desired degree of cyanoethylation until complete substitution of the three hydroxyl groups per anydroglucose unit is obtained. The nitrogen content of the cyanoethylated product usually serves as a measure of the degree of substitution, since untreated cotton contains a negligible quantity of nitrogen (Figure 1).

PHYSICAL CONDITION OF THE COTTON

The state of the cotton employed in the reaction is of some importance. Raw cotton and greige yarns and fabrics may present difficulties in the application of caustic solutions. As a result, great care should be exercised with these materials to insure even treatment. Raw and mercerized cottons cyanoethylate faster than either greige or bleached material and milder reaction conditions may therefore be required to obtain equivalent degrees of substitution. In all cases, it is essential that only unsized or desized cotton be utilized in the process, as cyanoethylation of the sizing material may cause poor physical properties of the cotton and create operational difficulties. With plyed yarns of high twist and with heavy ducks and fabrics, there is often a problem of penetration of the reagents with the consequent possibility of uneven treatment. These problems are mechanical rather than chemical, and should present no undue difficulties to experienced textile finishers. These factors must be recognized, however, as variables.

OTHER FACTORS

The amount of acrylonitrile used will generally be considerable excess of that theoretically required for reaction and, with the procedures described in this report, is probably not an important variable. The reactivity of the acrylonitrile with cotton and the rate of by-product formation will vary with its water content. Commercial acrylonitrile contains about 0.6% water. If the water content is higher, it is often possible to compensate for this by applying a correspondingly smaller amount of a more concentrated alkali solution to the cotton.

The use of inert solvents to reduce the amount of acrylonitrile being used results in slower cyanoethylation of cotton and is therefore not recommended.

A factor of considerable economic importance is the quantity of acrylonitrile lost by purely mechanical means, i. e., leakage from pumps, vapor losses from the columns, etc. While such losses cannot be considered as reaction variables, they are mentioned at this point to explain certain cost items appearing in the economic considerations discussed subsequently in this report. This problem arises in part because of the high ratio of acrylonitrile to cotton required in each of the procedures described.

All the variables described above interact in a very complex fashion. Thus, it is possible to obtain cyanoethylated cotton of any given nitrogen content under a great variety of reaction conditions. The conditions described in this report give cotton cyanoethylated to 3.8 ± 0.5% nitrogen with a minimum amount of by-product formation and with no unusual safety hazards. If any substantial changes are contemplated in the procedure, it is suggested that the effect on by-product formation and on the safety of the operation be thoroughly investigated.

Batch Treatment

PROCEDURE

Modified package dyeing equipment has been used successfully in the cyanoethylation of cotton yarns and fibers on a pilot plant scale (13, 16, 17). The essential parts of this operation are shown in the flow sheet, Figure 2. The pilot plant treating units

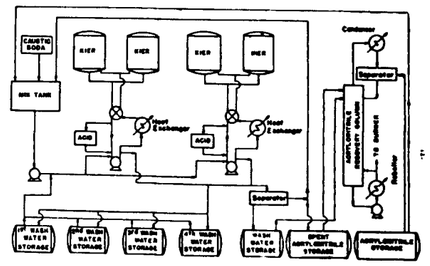


Fig. 3. Interior view of pilot plant showing cotton treating system.

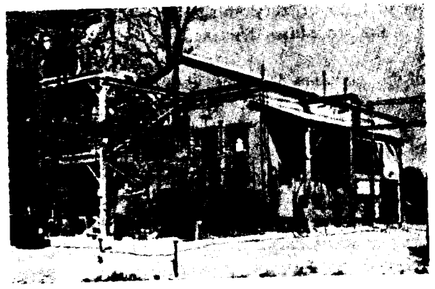


Fig. 4. Exterior view of pilot plant showing acrylonitrile recovery and storage system.

consisted of two kiers each of 25-pounds capacity, which were used simultaneously or individually as desired, Figure 3. To permit the safe handling of acrylonitrile, the kier system was modified as follows :

a. Total enclosure of the system ;

b. Removal of expansion tank ;

c. Added storage tanks for acrylonitrile, caustic soda solution, wash waters, and mixing tank ; and

d. Used of heat exchanger in place of kier jackets.

Since an excess of acrylonitrile was used in the process, a recovery system was necessary. This consisted of a distillation column, condenser, and separator which substantially removed the water and reaction by-product from the acrylonitrile, Figure 4.

Approximately 20,000 pounds of cotton yarn were treated successfully in this equipment.

In the early operation of the unit, cotton yarn was treated for Institute member mills to make yarn, thread and fabric available for field evaluation. A so-called two-step procedure (13, 16, 17) was used in these first stages inasmuch as it was the best method available at the time. In this method, the yarn was wound on conventional dye tubes and placed in the kiers. The packages were treated first with a dilute caustic soda solution (1.0 to 2.0%), which was circulated in the kier system. The direction of flow was reversed every 2 to 4 minutes with a total circulating time of 20 minutes. The packages were extracted to remove the excess solution (to a 60 to 70% wet pick-up). The packages were then returned to the kier and treated with acrylonitrile at 140 to 165°F. for a period of twenty to thirty minutes. This gave 3.5 to 4.5% nitrogen on the cotton and a relatively high amount of by-product formation. At the end of the reaction cycle, the solution was cooled and soured with dilute phosphoric acid solution to neutralize the caustic soda. When a pH of 6 to 7 was obtained, the solution was discharged to the recovery system. The packages were then given four fresh water washes to remove the residual acrylonitrile, the washes also going to the recovery system. The two-step procedure is not recommended for use in the package machine because of its high cost of operation.

This early work led to the development of a satisfactory one-step procedure for the batch treatment of yarns, using the same equipment with the exception of the dye tubes. The conventional dye tubes were replaced by Davidson springs to obtain as much as a 40% increase in the treating capacity of the kier. This change also permitted a more level treatment throughout the yarn packages than was previously obtained with conventional dye tubes.

—(To be Continued)

Effect of Extenders in PVA Paints

By Franklin King, Jr.
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MOST of the published information on polyvinyl acetate emulsion paint systems is concerned with the vehicle, rather than with pigmentation, and in particular, extender pigments. This would seem to belie the fact that extender pigments have a marked effect upon the various properties of the several different types of PVA emulsions. These include pre- and post-plasticized PVA emulsions as well as different types of copolymers. It is the effect of various extenders in these systems which will be discussed in the following paragraphs.

Extenders are truly functional secondary pigments in all paint systems. In fact, instead of thinking of a formulation in terms of prime pigment, inert and vehicles, one should think now of a formulation containing color pigments — i. e., titanium dioxide, carbon black, organic toners, etc., functional pigments, and the necessary additives and vehicles.

It is important for the chemist and purchasing agent both to realize that although new types of materials are required for the newer resin emulsion systems, the proper choice of extender, functional or other pigment, can permit use in both solvent type and water-thinned paints.

The extenders most commonly recommended and used in PVA formulations are those traditionally stocked by the manufacturer for other systems A new extender gaining widespread use in both emulsion and solvent systems is wollastonite, a naturally occurring calcium silicate.

The properties of wollastonite in alkyd flat paints have been published[1] and some of the comparisons noted therein are valid for emulsion systems. Reference will be made to this earlier paper where applicable to polyvinyl acetate systems.

One of the main problems encountered in working with polyvinyl acetate emulsion paint systems is that of formulating in an acid pH range. If the formulator buffers his system originally to make it alkaline, he must anticipate a drift to the acid side since most of the buffers are of a fugitive nature. The difficulties which can ensue and the effects of formulating with different extenders will be discussed below.

Among the most important contributions of wollastonite to PVA formulations is its buffering action, which keeps the pH from drifting downward and holds it at a reasonably alkaline level. This level differs

The Author

Franklin King, Jr.

FRANKLIN KING, JR., manager, paint industry sales for the White Pigments Division, Godfrey L. Cabot, Inc., Boston, is no newcomer to the paint industry. He has been active in paint sales and technical service work since 1946, when he returned from destroyer duty as executive officer of the U.S.S. Wainwright.

A native Bostonian, he attended Noble and Greenough School, then Harvard University, where he was graduated with the degree of B.S. in 1942. Following four years of war service, he joined the chemical sales department of E. & F. King & Company, Boston. He was vice-president of the firm when he left to join the Cabot White Pigments Division in 1952. Since becoming a member of the Cabot force, he has devoted full time to the development and sales promotion of Wollastonite. During the past year he was appointed manager of Cabot paint industry sales for both Wollastonite and Cab-O-Sil. He has given numerous illustrated talks before technical meetings, production clubs and other organisations throughout the country.

Mr. King is a member of the New England Paint, Varnish and Lacquer Association, the Chemical Club of New England, the American Marketing Association, and the Harvard Club of New York City.

with different emulsions, but is generally in the 7.5-8.0 pH range. The graph shown here indicates that one commonly used extender (Extender A) also holds the pH very slightly alkaline, whereas two others (Extenders B and C) do not. The formula is a typical primer sealer using post-plasticized PVA emulsion and 100 pounds of each of the various extenders plus 100 pounds of TiO_2 at 27 per cent pigment volume concentration.

In the above curve the wollastonite formula was buffered with ammonia to an original pH of 8.5. It is now known that this is not necessary, due to the high basic pH that the wollastonite itself contributes. Similar data indicate that as shown here, wollastonite will maintain alkaline equilibrium pH in any PVA system of the copolymer or post-plasticized type.

There are three major reasons why it is important to keep pH stable on the basic side:

(1) Can corrosion will be reduced. Experience with P. V. A. systems in England and in this country indicates that alkaline P. V. A. systems will reduce can corrosion.[2, 3] Moreover, anodic inhibitors like sodium benzoate which are normally added to P.V.A. paints are. in many instances, more effective in alkaline systems.

(2) Alkaline media with pH values of 7.0 to 8.0 are more favorable for the dispersion of colors.[4] This effect can be seen in tints made with phthalocyanine blue. At equal opacity the tints made with wollastonite are brighter, and color development is richer and fuller. Since the trend to tint base systems is continuing, it is exceptionally important that this alkaline condition be maintained. Otherwise the pH may drift and flocculation take place, so that tube tinting colors added in nine months to a year's time will not match the color card standard.

(3) Pigments not normally acceptable in acid media can be used safely if no pH drift from the basic side is encountered. Ultramarine blue is an example of this.

Rusting is another problem often encountered when applying polyvinyl acetate emulsions to substrates where ferrous materials may be present. It can result from a lack of suitable rust-inhibiting primer over nail-heads in dry-wall construction or from a high percentage of tramp iron present in the manufacture of masonry blocks. Most P.V.A.'s today bear a warning on the label that substrate iron must be coated with a suitable metal primer.

Calcium salts have long been known to contribute to rust inhibition, and apparently the combination of wollastonite and polyvinyl acetate produces an ionic distribution favorable for the maintenance of rust resistance.

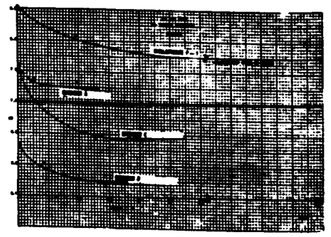


Figure I

Extender C *Wollastonite P-1*

No other extender tested shows this resistance to rusting over cold rolled auto body steel.

	Extender	Extender	Extender
Wollastonite	A	B	C
No Rust	Rusts	Rusts	Rusts

The paints in these panels, prepared by solvent degreasing, were made at equal pigment volume concentrations, substituting only the extenders one for another. In order to show the effect of these extenders in a transparent primer sealer formulation, no hiding pigment was used. After drying for 48 hours, they were then water spotted and the rusting appeared on all but the wollastonite panel. The Extender B panel, in addition to after-rusting at the water spots, showed overall rusting as the film coalesced. Since this is true of all films which are acid in pH when applied, it can be expected that formulations with other extenders which are also in the acid pH range will behave in the same manner.

Wollastonite seems to offer the same advantageous features in polyvinyl acetate emulsion paints as in alkyd flats—superior polish resistance, increased

abrasion resistance, and holdout at high pigment volume concentrations.

Separate scrub tests of films containing wollastonite, and three other extenders were made by the following procedure:

Glass plates 8″ × 15″ were prepared and a blue-gray semi-gloss drawn down over same. After thoroughly drying for 48 hours, various PVA paints were drawn down over the gray and the opacity and sheen measured. The plates were then stained with crayon, ink, grease, etc., and subjected to a scrubbing test using a 5 per cent wetting agent solution and Bon Ami powder and a soft cloth in the Gardner Straight Line Machine.

THREE VALUES FOR EACH WERE OBTAINED

1. Number of strokes to remove various stains or to film break.
2. Opacity after scrubbing.
3. Sheen after scrubbing.

The results of the washability test indicate wollastonite to be superior to two of the extenders in both pencil and grease stain removal.

The results of the test showing resistance to abrasion are shown on the following curves:

In Figure II paints that were identical with the exception of the extender Wollastonite vs. Extender B and C were subjected to the scrub test described above. The initial opacities were all rated 100% for means of comparison, and the drop in opacity measured at 1000, 2000 and 3000 cycles. These results are plotted. The actual changes in opacity at the end of 3000 cycles were:

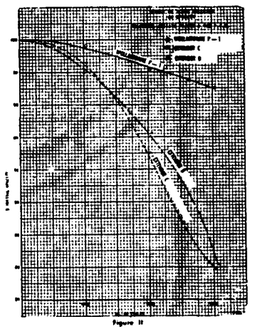
Wollastonite	Extender B	Extender C
1.5	13.0	13.0

This is a definite indication of the superior abrasion resistance of wollastonite films.

The table below shows the change in sheen due to polishing at the end of 1000 cycles. The results for 44 per cent P. V. C. are not given because Extender B formula failed, so comparable results are not available.

A study has been made of holdout qualities of PVA primers with increasing pigment volume concentrations. Again only the extender volume was changed, and it is apparent from the results in Figure III that wollastonite contributes to good holdout at higher loadings than the other materials tested.

Extender B *Wollastonite P-1*



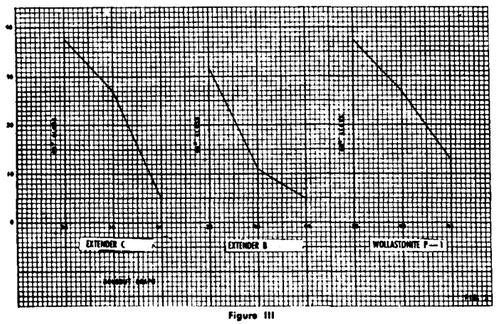


Figure III

Extender A *Wollastonite*

	36% P.V.C.		40% P.V.C.	
	Initial 85° Sheen	After Polishing	Initial 86° Sheen	After Polishing
Wollastonite	4.1	8.0	3.0	7.0
Extender B	8.3	12.0	8.5	16.5
Extender C	7.0	16.5	6 0	15.5

This clearly shows the superior resistance of wollastonite to polish in data presented it is seen that the grind fineness of wollastonite films did not

	44% P.V.C.			40% P.V.C.		
	Wollastonite	Extender B	Extender C	Wollastonite	Extender B	Extender C
N. S. Fineness Before ..	5.0	5.0	5.0	4.75	6.50	6.25
N. S. Fineness After ..	3.5	0	0	4.75	5.25	3.25

Above are the residual gloss values of the semi-gloss enamels applied over the PVA paints at the three different pigment volume concentrations.

A function of the good dispersion characteristics of wollastonite films is freeze-thaw stability at the higher pigment volume concentrations. From the change after 5 cycles of freeze-thaw test, but that the fineness of the other emulsions was appreciably reduced.

At 36 per cent P. V. C. all samples tested showed good freeze-thaw stability.

From the data herein presented, it can be seen that wollastonite holds promise as a functional extender in polyvinyl acetate emulsion paints and that extenders in general do contribute properties to these paints. The selection of the proper extender is therefore of importance equal to that of the selection of other ingredients.

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Extinguisher for Metal Fires

Model PDMU 25 is a new special-purpose fire extinguisher designed to meet the difficult problems of fire outbreaks involving metals such as sodium and calcium, or magnesium and aluminium in the form of powder or swarf. Produced by the Pyrene Company, Ltd., of London, the new extinguisher is charged with 25 lb. of dry chemical powder which is discharged under pressure provided by a cartridge of CO_2 gas.

This dry chemical powder is applied to the burning metal by means of an applicator comprising a long tubuler metal extension terminating in a cone-shaped spreader. The applicator ensures that the discharge of dry chemical powder is delivered lightly on to the fire in order to prevent the danger of scattering which is associated with this class of fire. Speedy operation is effected simply by removing the safety clip, detaching the applicator and striking the top of the extinguisher. A "squeeze-grip" control valve enables the flow of dry chemical powder to be shut off at will and to be used to its fullest advantage.

Jet Black Lacquer from COBLAC Chips in 30 Minutes

NO one denies the economics of chips over paste dispersions per pound of pigment delivered. These economies are often sacrificed for speed of incorporation with pastes. This need not be.

Our laboratory, in conjunction with the laboratory of Morehouse-Cowles, has developed a method of solution for COBLAC Chips, taking only 30 minutes and yielding lacquer having a color improvement of 10—20 shades.

Many are familiar with the Cowles Dissolver which was used for the dissolving of our COBLAC 405 Chips. Those who are not, should become acquainted with this excellent piece of equipment, not only for the preparation of lacquers, but also for the many other uses it has in a paint or ink plant.

For example, 1/2 pound of our new COBLAC 405 Chips was added to 3 pounds of Nitrocellulose lacquer formulation. The Cowles Dissolver was run at 3000 RPM with a 3-inch impeller for 30 minutes. The temperature reached just under 100°F.

This concentrate was diluted with additional lacquer solution under slow agitation to the desired concentration of carbon black.

Linear Accelerator for Industry

Believed to be the first of its kind specifically designed for industrial radiography is a 5-MeV (five-million-electronvolt) linear accelerator which has recently been installed at one of the establishments of Britain's Ministry of Supply. The primary advantage of linear accelerators, it is claimed, is that they give more X-ray output and greater energy than machines previously used for radiography, including Van der Graaf machines, resonant transformers, and cascade generators. The machine also compares favourably with multicurie radio-isotope sources such as Cobalt 60. For example, a half-hour exposure using the linear accelerator will give a radiograph of the best obtainable definition of a steel specimen 9 or 10 in. thick, whereas the same exposure using a Cobalt 60 source of reasonable size would only give about 5 in. penetration.

The 5-MeV linear accelerator has been designed to give extremely good definition. In spite of the high energy and the large output of over 500 roentgens per minute at one metre, the electron beam which creates the X-rays has a diameter of only two millimetres when it strikes the target. Additionally, the polar diagram of the output tends to be flatter than is normally associated with such a high energy beam because of a special new magnetic focussing device associated with the X-ray head. The main part of the machine has been kept small, overall length being only 9 ft. This has made it possible to obtain a high degree of mobility so that the accelerator can be moved into the best position for obtaining a radiograph, instead of moving the specimen, which may be unwieldy and bulky.

The following movements are possible: (1) the whole accelerator can be tilted from vertical to horizontal; (2) the X-ray head rotates; (3) the accelerator turns through 180°; (4) the whole machine can be raised or lowered 8 ft.; (5) the machine is mounted on an overhead rail so that transverse and longitudinal movements are obtainable over the room which houses it. The accelerator was designed and constructed by Mullard Research Laboratories on behalf of the contractors, Philips Electrical Ltd., of London.

Properties of CRYSTOLON R

The properties of CRYSTOLON R are described below :

Composition—Pure silicon carbide (SiC) of dark gray or gray-green color. Crystal form is alpha or hexagonal.

Bulk Density—Density is usually 2.5 gms/cc. It can be varied to give a maximum of approximately 2.62 and a minimum of 2.4.

Permeability—can be made impervious to the passage of water.

Hardness and Abrasion Resistance—Silicon carbide is an extremely hard material having a Knoop hardness at 100 grams test load of 2500. Therefore, the product is hard and abrasion resistant.

Surface Finish—The finish is considered equal to or better than most bonded ceramics.

Strength—The modulus of rupture is approximately 10,000 psi at room temperature. This strength is probably maintained to the dissociation temperature of silicon carbide (above 4000°F.).

Chemical Resistance—CRYSTOLON R has a high resistance to acids or alkalis. Its resistance to oxidation is better than most carbides and borides.

Thermal Shock Resistance—Thermal shock resistance is high compared to other ceramic materials.

Thermal Conductivity—High compared to other ceramic materials.

Electrical Conductivity—CRYSTOLON R is a semi-conductor. Its electrical resistivity is approximately 3 ohm cms. at room temperature. The conductivity increases at higher temperature.

Uses—CRYSTOLON R has been satisfactorily used in filter plates and tubes for acids, also crucibles for melting high temperature materials such as synthetic mica. This material has given excellent service in rocket nozzle applications. CRYSTOLON R can be impregnated with refractory metals e. g. $MoSi_2$, Cr/Si, $MoSi_2$/Ni etc. Impregnation can increase the strength of a body several times and improve its thermal shock resistance as well as render it impervious and a good electrical conductor.

ROKIDE C—CRYSTOLON R COMBINATIONS

For certain applications the good properties of ROKIDE C and CRYSTOLON can be utilized more effectively by combining the materials into an integral article.

Thick coatings of SiC on graphite have been made in this way, providing greater protection to the graphite base. An interesting application of this technique is the fabrication of one piece uncooled rocket motor linings made up of a continuous ROKIDE C lining containing a CRYSTOLON R throat insert.

Super-Cushioned Power Cylinders

The Fluid Power Division of the Baldwin Instrument Company, Ltd., of Kent, are now able to fit "super cushions" to their entire range of pneumatic and hydraulic power cylinders. Cushioned cylinders are in common use today for decelerating the piston rod and associated load thereby obviating mechanical shock at the end of the stroke.

The Baldwin cushioning effect is produced by closing the exhaust port at a point before the piston reaches the end of its stroke, therefore trapping a certain volume of fluid. This trapped fluid is allowed to escape slowly through an adjustable orifice which controls the degree of cushioning. Super cushioning is achieved by arranging for a larger volume of fluid to be trapped than in the case of the standard fitting. This system is found necessary where a large mass, moving at a high velocity, needs to be decelerated without impact. An important feature is that the degree of super cushioning which is built can be chosen to meet the requirements of each job. Because of the system of unit construction which is employed throughout the range of Baldwin fluid power equipment, super cushioning can be fitted at either end or both ends of the cylinder.

* * *

Mathematical Approach toward Proper Pigment-to-Vehicle Ratios

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ARRIVING at proper pigment-to-vehicle ratios in premix bases often involves trial-and-error steps that are both costly and time-consuming. While some paint companies already have satisfactory methods of calculation, it is the writer's observation that others are less fortunate, and would be interested in a dependable method if it were made easily available.

This mathematical approach to the problem is based on checks made of hundreds of examples over a period of years. Many exceptions may be found to any rule given, but this method will prove successful in the greatest majority of cases. It is offered in the hope that it will be found helpful.

To begin with, oil absorption, or oil demand, can be considered basic, and if a standard method of calculation is used we can establish a constant from which to derive our first step. But currently the concise definition of oil absorption is as controversial as grind gauge interpretation. Published tables show figures obtained by more than one method. Some are arrived at by the "Spatula" method, while others appearing right beside them are based on the "Stirring Rod" method.

Here is a typical example : C-400 Talc manufactured by Sierra Talc Company is printed in "Scientific Section" as having an oil absorption of 36-37 and just preceding this with no explanation Asbestine 3X, a product with a similar oil demand, is printed as having 20. Before one can use the mathematical equations within this article one first has to make allowances for the fact that tables show only what the supplier furnishes to the "Scientific Section". When it can be established what method was used by the pigment supplier, conversion of one method to the other may be made with reasonable exactitude.

By the "Spatula" method, oil required is approximately 60% more than by the "Stirring Rod" method. Therefore—

"Stirring Rod" method x 1.6 approximates the "Spatula" method.
"Spatula" method x 0.63 approximates the "Stirring Rod" method.

All calculations must be expressed by one single method of calculating oil absorption. Information herein is based on the "Stirring Rod" method. (Pounds of oil demanded by one hundred pounds of pigment before reaching the "Putty Ball" stage.)

To project this into table form we begin by showing in Table # 1 a method of calculating a satisfactory premix for the Cowles Dissolver.

Table // 1 by not only showing the mathematical method but also by using a definite example is self-explanatory.

We might explain why the 2nd stage of the premix is shown. We feel that if a premix for any given mill, except the ball or pebble mill, is not divided into two stages of vehicle-introduction, the action of pigment agglomerate against pigment agglomerate (which is very advantageous) is almost completely lost. In the low viscosity gained by introducing all the vehicle into the mixer before adding the pigment, one can not expect the necessary energy dissipation or "shear" required to break up the agglomerates. This naturally throws nearly all the load on to whatever type mill is involved. Although this is very elementary, as a resident inspector, the writer witnessed this inefficient method being followed in many plants. Following this high shear approach is particularly important for dispersion units requiring very high horsepower.

The second stage in Table # 1 should point out also the added advantages gained from stabilizing your dispersion (whether gained in the mixing or milling stage) by shearing on a more permanent coating of vehicle solids. There are not ample vehicle solids present in the first stage to adequately complete

TABLE 1

To Figure Pre-Mix "Base" for Cowles Dissolver

1. Compute oil demand of each of the pigments in formulation (using Gardner Coleman oil absorption or pounds of oil demanded by 100 lbs. of each pigment).
2. Add vehicle into mix tank equal to approximately 2 times the sum of the computations above, for first stage of premix.
3. Turn on COWLES and add pigments.

FOR EXAMPLE: The following base for 100 gallons of White Industrial enamel shows how one may derive the proper flowing type pre-mix based on oil demand or oil absorption.

PRE-MIX FOR COWLES' DISSOLVER

	A	B	C	D	E*
Material	Amount of material Lbs.	Oil Absorption or oil demand per 100 lbs. of pigment (Gardner Coleman)	Oil Demand for lbs. shown $\frac{A \times B}{100}$	Multiple of Oil demand for proper mobility—shear on COWLES C×E	Fc = 2.0 - First Stage Fc = Factor for Cowles bases on Oil/Pigment ratio
Tipure R-110	267#	15.5	41.4 #	83 #	
D-65A (70%)	41				
Min. Spirits	42				
	First Stage above—Mix 5 minutes			First Stage above—Mix 5 minutes	
D-65A	93#				
Dipentine	10			Added vehicle necessary for "finished base"	
	Second Stage—Mix 2-3 minutes			Second Stage—Mix 2-3 minutes	

IN ABOVE PASTE for the *Morehouse Mill*, TOTAL VEHICLE equals 4½ times Oil demand.

NOTE: Poor flowing type paints, like raw linseed oil paints, and paints having a false or thixotropic viscosity, may require excess vehicle up to as much as 3 times the oil demand.

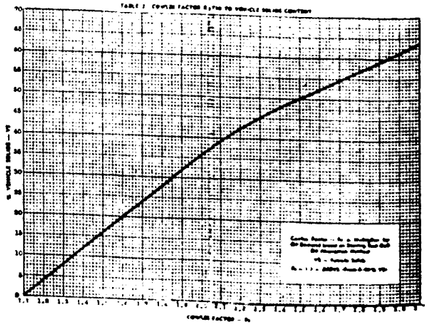
Water systems where pigments are dispersed in almost all water, require as low as 1-¼ to 1-½ times the oil demand.

*Factor on COWLES will vary up and down from the above Fc = 2 in different types of paint, and at different vehicle solids level. Normally, as the vehicle solid level is raised, the factor must be raised or vice versa.

this "coating" action. Herein lies the reason for many bad characteristics in a paint, most obvious of which is pigment settling. Frequent cases of "seed out" can be traced to milling in too low a level of vehicle solids.

Table # 1 can be used to adjust for other type mixers but most often the factor will need to be raised from 2.0 as shown for the Cowles Dissolver up to 2.5 to 3.5 when using common types of mixer.

Table # 2 shows the method of using Table # 1 at all vehicle solids levels from 0 to 40% solids. In almost any given piece of dispersion equipment the heavier the blended premix vehicle the more vehicle required to move a given mass of pigment. This is



especially true of the same vehicle at different levels of vehicle solids.

Alkyd, being one of the most used in the industry, appears in all the examples shown. (As appears on the bottom of Table # 1 many distracting results may stem from the unusual). However we show in Table # 2 how a 70% Alkyd behaves in a non-reactive pigment system, at abnormally low and normal levels of vehicle solids.

Since the self-explanatory curve was calculated for the Cowles Dissolver we quote only one possible reason for the curve's shaping off at 40% solids. Above this point it seems a good deal of energy is required just to move the vehicle upward in solids content as it gets more "tacky". This reduces the energy percentage potential to move a given mass of pigment.

Range for the first stage of premix is all that is shown on the graph and not a "finished premix base". This graph only shows a means of calculating to effect shear in this first stage. Vehicle solids level should be raised in a second stage before milling.

The graph indicative of the Cowles Dissolver more than covers the suggested range for first stage premixing. We feel that 20-35% is a safe and practical range although many successful batches have been made far below and far above these limits. The range on the Cowles Dissolver used as a mixer, is not borderline even to the slightest degree. However the ratio of pigment to vehicle based on oil demand is somewhat borderline in full efficiency is

TABLE 3

Pigment-To-Vehicle Ratios for Equipment in General

Equipment Type	Symbol	Constant	FIRST STAGE Premix Computations		SECOND STAGE Premix Computations	
				Sugg. VS	Raise to	Sugg. VS
COWLES (Factor Fc) Preceding Morehouse Mill	Fc/M	1.1	TV = OD × 1.1 + .025VS	20–35%	ODX 3½ – 4½*	35–50%
COWLES preceding Roller Mill	Fc/R	1.1	TV = OD × 1.4 + .025VS	35–50%	ODX 3–4	45–60%
BALL MILL	FB	1.2	TV = OD × 1.2 + .025VS full schedule grinding time	20–35%	ODX 3½–4½ 45 min. after full schedule grinding time to lessen settling	40–60%
COWLES preceding BALL MILL	Fc/B	1.1	TV = OD × 1.1 + .025VS 15–30 min. on Cowles	20–35%	ODX 3½–4½ ⅛ to ¼ full schedule grinding time	35–50%
PEBBLE MILL	FP	1.25	TV = OD × 1.25 + .025VS full schedule grinding time	20–35%	ODX 3½–4½ 45 min. after full schedule grinding time to lessen settling	40–60%
COWLES preceding PEBBLE MILL	Fc/P	1.1	TV = OD × 1.1 + .025VS 15–30 min. on Cowles	20–35%	ODX 3½–4½ ⅛ to ¼ scheduled grinding time to lessen settling	35–50%
ORTHODOX MIXER Preceding Morehouse Mill	Fo/M	1.7	TV = OD × 1.7 + .025VS	20–35%	ODX 4–5	35–50%
ORTHODOX Mixer Preceding Roller Mill	Fo/R	1.8	TV = OD × 1.8 + .025VS	20–35%	ODX 3–4	45–60%

TV = Total Vehicle
OD = Oil Demand (Stirring Rod Method)
CONSTANT = Factor (Multiplier for Oil Demand)
VS Vehicle Solids

* Heat sensitive, reactive pigments, or pigments subject to drastic viscosity changes on milling, fall outside of most of above limitations.

to be gained. When followed by a Morehouse Mill this borderline is no longer apparent. Here the human element factor is backed up by an insurance policy. Recently the writer reclaimed a "seeded" batch of paint on a Morehouse Mill which a centrifuge failed to clean up. This might be considered the epitome of this insurance policy theory.

The "constant" of 1.1 which is used as the multiplier for oil demand ("Stirring Rod" oil absorption) applies only to the Cowles Dissolver so far as we know. For most other pieces of equipment the constant of 1.1 would need to be raised. The unusually efficient job of concentrating performed by this new type dispersion unit produces free flowing pastes with pigment percentages far beyond imagination. Recently this machine made a thin flowing paste out of 300 #/ 97% Red Lead in 25 #/ of alkyd vehicle. Most people would assume that this approximately 40 #/ per gallon Red Lead would become a solid mass instead of the apparently thin paste the Cowles made out of it.

Table # 3 applies to many types of dispersion equipment.

We use the Fc as meaning "Factor for Cowles". To derive full efficiency in premixes and bases for other equipment this same sort of approach can be used. Generally since most equipment will not concentrate pigment so highly as will the Cowles, the constant of 1.1 applicable to the Cowles should be raised. Table #/ 3 covers the establishment of this constant to many types of equipment.

Table #/ 3 will not fit, especially in stage #/ 2 of the premix, when using Phthalo colors, Iron Blues, Chrome Greens containing appreciable amounts of Iron Blue, and pigments which produced thixotropy. Possibly certain other pigments will react so as to divert the computations outside the limits shown.

It should be noted also that adjustment of the computations may be necessary in line with personal ideas as to proper paste viscosities. Some believe that a good milling paste can be "walked on", while others prefer pastes "thin enough to splash" or "throw". We have tried to strike a happy medium between these extremes.

However, allowing for these and other possible variations noted above, in the great majority of cases the writer has found that the tables will eliminate many trial and error steps, and improve both the efficiency of the equipment used and the quality of the end product. It is hoped that the information will be helpful to others in providing dependable, constructive steps toward easier and better methods for computing proper pigment-to-vehicle ratios.

High Pressure Hose for Aircraft

Silvoflex Type 200 hose units, manufactured by the Flexible Pipes Division of The Palmer Tyre, Ltd., have become the first hose units ever to meet the United Kingdom Ministry of Supply's Specification D. T. D. 3954 in respect of the design, type approval and production of fire-resistant high-pressure flexible hose and end-fittings for aircraft fuel systems. So stringent is this specification that, although issued as long ago as 1951, no manufacturer had hitherto been able fully to meet its requirements.

All test rigs used in this work were specially devised and the exacting tests of D. T. D. 3954, which subject the rubber flexible pipe assemblies in the laboratory to the most gruelling and extreme conditions of temperatures, vibrations and impulse pressures likely to be encountered under operational conditions, are an interesting illustration of the way in which Britain's aircraft industry is maintaining its world-wide reputation for reliability and performance.

VEHICLE AND AIRCRAFT FAN

A new vehicle and aircraft fan has been developed by The General Electric Company, Ltd., Magnet House, Kingsway, London, England. It has 6-in. diameter black rubber blades, giving a compact outline. The fan is silent running and can be operated from the battery system of any vehicle. The motor is totally enclosed and mounted on a backplate by means of a ball and knuckle joint which provides a simple and effective means of controlling the direction of the airflow. Connection to the electrical supply is made by means of a length of cable which is supplied already fitted to the fan motor. The motor body and backplate are finished in white enamel, the ball and knuckle joint is chromium plated. The fan has a speed of 2,500 r.p.m. and is suitable for 6, 12 or 24 volts direct current. It is rated at 14 watts and has a weight of one-and-a-half pounds.

APPLICATION OF VINYL MAINTENANCE PAINTS BY HOT SPRAYING

INTRODUCTION

Paints based on vinyl resins have excellent resistance to a greater variety of corrosive exposures than any other air dried system, particularly if the vinyl paint film is built up to the thickness of at least five thousandths of an inch. With the development of the hot spray technique for applying vinyl maintenance paints, the greatest drawback to the use of these paints—the numerous coats necessary to build the system to the proper thickness—has been removed.

Union Carbide's laboratories have investigated this technique and developed a formulation that may be sprayed hot "as is," or cold by minor thinner adjustments. This composition, Formula Suggestion XE-5404, is shown in Figure I. This formulation and the data on the hot spray technique are not to be construed as a recommendation either to produce a paint for sale or to use this spraying technique. The information is presented solely for evaluation by paint manufacturers and results reported should be confirmed under each manufacturer's specific conditions.

TEST DATA

In addition to the basic formulation XE-5404, the reported advantages of the hot spray technique have been cooroborated. Through the use of this method of applying vinyl paints, more build is attained per coat, thereby requiring fewer passes; there is less likelihood of damaging drift from overspray; less solvent is required; fewer passes mean lower total labor cost per square foot of surface; reduction of overspray loss gives increased coverage per gallon; the finish is better with a noticeable reduction of sagging; there is less tendency for the film to "pull away" from sharp edges because of less shrinkage on drying; the working conditions for spray men are improved by the almost complete elimination of the fog that occurs with conventional spray.

The use of heat as the means of reducing the viscosity of the paint to the proper level for spraying has introduced the problem of maintaining properly controlled heat at the spray gun head. This has been solved to some extent by the use of portable paint heaters. These heaters, which are neither expensive nor cumbersome to operate, can be carried with the spray operator or kept very near the spray gun at all times. Long feed hoses from the paint heaters make controlling the temperature of the paint very difficult, and in some cases impossible, under variable winter weather conditions.

The application of heavy or thick films in a single coat by the hot spray technique means less opportunity for the solvents to evaporate. Any appreciable amount of retained solvent in a vinyl film reduces the resistance and toughness of the film. Hence, the maximum durability of coatings applied by this technique is developed somewhat more slowly than in cold sprayed multiple coat systems. This attainment of maximum durability by a hot sprayed vinyl coating can be hastened or delayed by weather conditions. In addition, certain hot spray formulations contain higher boiling cyclic ketones which can absorb much more water than the straight chain ketones, thereby increasing the penetrability of the coating. These factors must be considered carefully for each individual job before specifying the use of this technique.

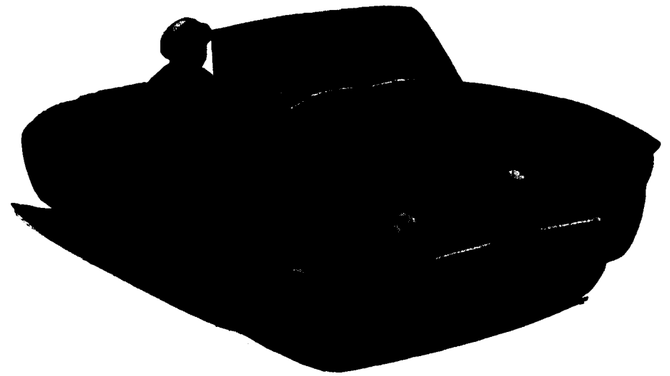
Most straight vinyl paints can be used for either hot or cold spray, with minor thinner adjustments. In the laboratory, Formula Suggestion XE-5404 was used "as is" for hot spraying and was applied using 35 pounds air pressure and 15 pounds pot pressure. The temperature was maintained at 160 deg. F. at the gun. For cold spraying, the paint was thinned 20 per cent with a 1 : 1 mixture of methyl isobutyl ketone and toluene. An ordinary suction cup spray gun was used, with 45 pounds air pressure. Three coats were required to deposit approximately the same film thickness as was deposited in one pass by hot spraying.

FIGURE I

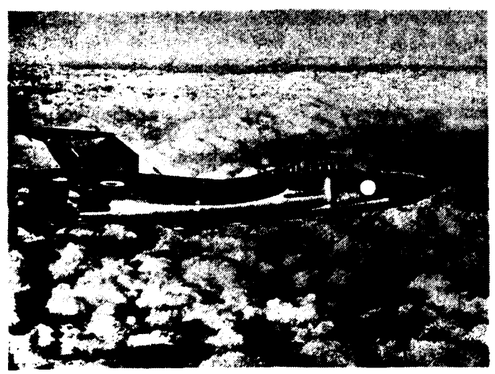
Formula Suggestion XE-5404

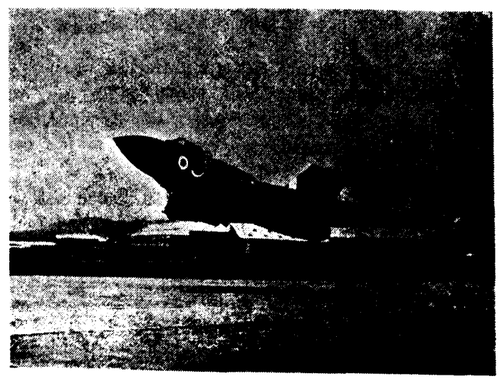
	Parts By Weight
"Mapico" Red N. 387 iron oxide	11
"Metro-Nite" pigment BXXXX	11
VINYLITE vinyl resin VAGH	15
FLEXOL plasticizer DOP	3
Methyl isobutyl ketone	30
Toluene	30
	100

This paint is prepared by dissolving vinyl resin VAGH in the total weight of solvent, adding the plasticizer, and mixing thoroughly. The pigments are then pebble milled into this solution until a good dispersion is obtained. This formula is based on vinyl resin VAGH and therefore is applied over a wash primer based on VINYLITE vinyl butyral resin XYHL. One coat systems based on VINYLITE vinyl resin VMCH can be formulated in a similar manner. However, the usual precautions regarding pigment choice must be observed when using vinyl resin VMCH; basic pigments must be avoided.



AIRCRAFT AND AUTOMOTIVE INDUSTRIES SECTION





The Fairey/Ferranti 3-D Miller

(From Our Overseas Aviation Correspondent)

GENERAL BACKGROUND

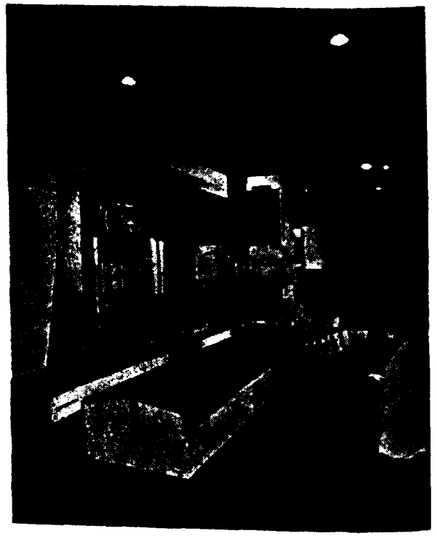
SINCE the advent of the gas-turbine the tendency towards higher and higher speeds for aircraft has led to a considerable amount of re-thinking in the design of aircraft structure. The problem simply stated, is a demand for more strength in less space and at less weight, combined with much greater accuracy of manufacture, in both the aerodynamic shape of the aircraft and in the internal structures where wide tolerances incur severe weight penalties. The main line of development has been towards integral construction; the change from multi-component structures with rivetted or bolted assemblies to single-piece major components.

The original concept, particularly in the U. S A., was for manufacture of these components from light alloy forgings of unprecedented size, and in America, a programme for the installation of heavy forging presses was prepared. The long-term nature of the manufacture of these very large presses created interest in the possibility of the manufacture of relatively small components from solid slab material, primarily as an interim measure, and secondly to deal with prototype work.

The experience gained in the U. S. A. from the performance of the first presses installed soon brought to light the severe limitations of the forging conception of integral construction.

1. Large forging dies are extremely costly and take a long time to manufacture.
2. The introduction of even a minor modification becomes a serious matter, both in time and money.
3. The close tolerances required could not be achieved by forging and more and more machining became necessary after the forging operation.
4. The distortion caused by stresses released during machining, could not be rectified.

The many difficulties encountered caused the U. S. A. to review their policy and the result was a



Fairey/Ferranti 3-D Miller.

drastic pruning of the heavy press programme and an increasing emphasis on machining from slab material. In the United Kingdom the enormous capital outlay necessary for heavy presses was not available and the slab machining technique was recognised as the only possible line of development for the British aircraft manufacturer. This resulted in parallel action on both sides of the Atlantic, but before any real development work could be initiated on shaping components, there were still two outstanding problems to be overcome in connection with the slab material itself.

1. The distortion arising from stresses released during machining.
2. The reduction in transverse elongation properties as slab thickness is increased.

The first problem was resolved by carrying out a stretching operation on the slab in the direction of the grain. This process is not applicable to forgings, since a constant cross-sectional area is necessary in

order to secure even stress stabilisation throughout the material. Large stretching machines of several thousand tons capacity, capable of dealing with the maximum size of slab required, have now been installed both here and in the U. S. A.

The transverse elongation of the slab is a function of the amount and type of working the material receives in the process of manufacture and satisfactory values have now been achieved for even the thickest slabs by carefully controlled pre-forging operations prior to rolling.

Encouraged by the material developments, The Fairey Aviation Company initiated a research and development programme on the manufacture of slab components. The over-riding factor in any manufacturing process is the economic one and, in the case of machining integral components from slab, the governing factor is the enormous quantity of material which must be removed from the slab to produce the finished component, this being in the order of 90 per cent of the initial slab weight. It naturally follows that an investigation into the machining of light alloys was the first step.

Test equipment was assembled to study the effects of cutting at high speeds of up to 12,000 surface feet/minute. An interesting feature revealed in metal cutting at these very high speeds, is that the heat generated in the process is contained in the cuttings produced and is not transferred to either the cutter or the slab material. This is most important, since cooling a high speed milling cutter is extremely difficult, and of course, heating of the slab would cause severe distortion. Metal pick-up and welding to the cutter was the major problem encountered, but this was resolved by injecting oil-mist directly onto the cutting face, from jets embodied in the cutter. With this technique a very high standard of surface finish was achieved.

It soon became evident that existing practice was not nearly approaching the full exploitation possibilities of light alloy machining and work proceeded with the development of a series of self-contained high speed spindles of up to 20 h. p. and 6,000 r. p. m. Provided with suitable traverse movements, these could become economic cutting engines capable of exceeding, by very high factors, the efficiencies of conventional machine tools, which generally are designed primarily for steel cutting, with minor variations to embrace the light alloys.

The next stage in the programme was an investigation of the machine tool problems, in order to achieve optimum utilisation. It was obvious from the results of the cutting test that hand-controlled machines were not capable of utilising the full cutting potential and, since structural components must naturally be of diverse shape, a more sophisticated method of power control was essential.

A comprehensive survey was made of controlled machines in operation or under development both in Europe and in the U. S. A. In the meantime, a production component was selected and re-designed as a slab component, in order that comparative information could be obtained from its manufacture. In parallel with this, a machine was converted for hydraulic tracer control, in order, primarily, to gain actual experience of the control problem.

This machine, known affectionately as the "Green Linnet", has been producing components for the Fairey Gannet anti-submarine aircraft for a number of years.

A large variety of tracer control systems was available at this stage, mainly from the U. S. A. and the European mainland countries. The Massachusetts Institute of Technology in the U. S. A. were also operating a numerical control system which embodied some computer elements. The tracer systems were offered as basically accurate systems, where high accuracies could be achieved providing the machine to which they were applied was capable of utilising the control information. The requirements of such a machine were that it should possess :—

(a) A slide system having the lowest possible co-efficients of static and dynamic friction and free from the stick-slip phenomenon at all speeds.

(b) A drive system of extremely high stiffness, combined with low inertia and free from backlash under all drive conditions.

(c) Structural members of high mechanical stiffness with minimum mass.

(d) An efficient cutting spindle with a high degree of rigidity.

Deficiency in any of these features will bring about a resultant loss of accuracy, the first three items being the primary requirements of any piece of mechanical equipment controlled by a closed-loop servo system. Such a machine tool was not in

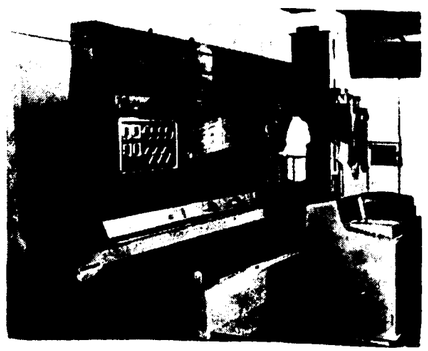
existence and virtually nothing was as yet being made available by the Machine Tool Industry of this country to meet the demands of the aircraft industry for such a machine.

Ball and roller bearing slides to meet the friction problems of the larger machine tools were already a feature of some smaller machines, and attempts to adapt these, and pads of low friction plastic materials, were made notably in the U. S. A. On the drive system problem considerable efforts were made by the oil companies to produce oils of high bulk modulus to overcome the fundamental lack of stiffness of ram systems, while the gearing approach was generally to utilise more accurately cut gears with reduced running clearance to minimise backlash. The structural problem was being met to a large extent by replacing cast iron with carefully designed light weight welded steel structures of comparable rigidity.

It was felt that these efforts fell far short of meeting the requirements and that machine tool design still lagged a long way behind the development of control methods. Theoretical calculations on drive systems indicated that, where relatively large masses are to be moved, a rack drive gearbox system was capable of a higher efficiency and stiffness to inertia ratio than screw systems or hydraulic rams, although the recirculating ball screw correctly mounted is suitable where the load is small and the drive length relatively short. A design study was undertaken of a rack drive gearbox with two gear trains driving in opposition, incorporating a pre-loading device to eliminate backlash independent of gear tooth clearance. Gearboxes of this type have since been built and, under extreme test conditions, have fully met the performance requirements.

Much experimental work was done on slide friction problems where it was found that a form of pressurized oil system affording some measure of load relief would be superior to the low friction material pads and capable of carrying higher loads than the ball or roller system, where irregular surface deformation under load is the major fault. A suitable machine geometry was established to meet the production requirements and the estimated slide loads were plotted for a group of suitably spaced support points. These included all the dynamic and cutter load combinations as well as the static loads, the object being to provide a series of support pockets into which oil would be forced at a pressure slightly lower than that required to balance the minimum load occurring at that point so that the slide friction would be a function of the residual load only and, in addition, slide contact would be maintained under all conditions. During the investigation into the method of controlling the large assortment of pressures required, it was realised that if the oil was allowed to flow continually from the pockets, causing the slide faces to separate, and if the flow was in some way limited, then the small variations in the slide gap could serve to control the pocket pressures and thus form a simple closed-loop servo system. The initial calculations based on a simple form of control showed that a slide system was possible where the sliding members would be completely separated by a control film of oil and yet have a stiffness comparable to that of the structural members when subjected to a varying load. Further test work was then carried out on an experimental rig embodying this system and the results obtained formed a basis for the design of the slides of the machine. The phenomenally low frictional results recorded on a full-scale test bed are quoted later in this report.

While the experimental work and design studies were in progress, research was being made in this country and in the U. S. A. into the electronic control of machine tools direct from programmed information. A programme control system offers obvious advantages over a template following system. Apart from the fact that no templates need be manufactured the programme system is capable of issuing advance information to the machine, the main feature being control of acceleration demands. In the case of a heavy machine tool operating at high speeds following a template, when the tracer reaches a corner or sharp change of shape on the template,



Fairey/Ferranti 3-D Miller.

the machine receives a demand possibly to stop travelling in the "X" direction and start moving along "Y". This constitutes an infinite acceleration demand which cannot be met and the machine overshoots. This means that the tracers speed must be reduced for that operation to the point where the amount of overshoot occurring is within the permissible limits. Under programme control the acceleration demand can be automatically limited so that the machine can operate at full speed throughout the machining operation, decelerating only where a change of shape demands it. In this way the high machining speeds available are utilised economically.

Various programme control systems were investigated, the most advanced of these being the Ferranti digital system in which a computer is used to process the planning information, the machine control equipment being simply a servo system utilising as its input, the magnetic tape recording produced by the computer. The method of measurement adopted was the use of optical defraction gratings which are completely independent of the drive system and measure movement of the slides directly, thereby embracing the complete machine within the control loop. The more common approach was to control the machine up to the gearbox input side or the driven end of the lead screw and disregard inaccuracies occurring beyond that point.

Another outstanding feature of the Ferranti system was the simplicity of the programme information required. This is kept to a basic minimum, the computer handling all the necessary calculations in contrast to the other systems, which entail the laborious plotting of intermediate points, the spacing of which gives an approximate shape related to the accuracy required. It was quite clear at this stage that existing machines which were available, either with tracer or programme control systems, were inadequate to cope economically with aircraft requirements. In some instances speed was available, in others accuracy, but the two fundamental requirements never occurred together on one machine.

Knowing the requirements of the aircraft industry and with a sound background of mechanical development, Fairey's prepared a scheme for a machine tool capable of utilising the full control possibilities of the Ferranti system, a machine to have a high degree of accuracy and which was at the same time an efficient cutting engine, thus making integral construction an economic proposition. This had been made possible through a proposal which had been put before the Aircraft Production Development Directorate of the Ministry of Supply and had received their support; a development contract was issued in late 1955 for the design and manufacture of the machine and included for full-scale testing of the various unorthodox features to be progressively conducted throughout the construction programme and continued until the machine was completed, when it would be subjected to a comprehensive series of performance tests.

THE MACHINE

The machine weighs 50 tons and has a vertical column travelling a distance of 25 feet along the bed, this forming the "X" axis of the machine. Mounted on the face of the column is the head carriage travelling vertically along the "Y" axis with a movement of 7 feet. The cutting head is fixed to a cross-slide on the head carriage and has an infeed movement of 12 inches along the "Z" axis. These "X", "Y" and "Z" movements are servo controlled from the pulse information recorded on the magnetic tape.

The cutter serves the vertical worktable which is 8 feet high and 28 feet long and is formed of four cast iron slabs 15 inches deep mounted on three buttress supports. These stand on base castings fastened to the machine bed and allow the table to be set at a suitable distance from the cutting head, with a range of adjustment of 24 inches. Running along the lower edge of the worktable is the chip conveyor which carries the swarf to one end of the machine to be deposited in containers. A series of hinged deflector plates on the conveyor can be closed to form a walkway along the full length of the table to facilitate component handling. Slide faces and other functional parts of the machine are fully protected by flexible covers against the ingress of swarf.

Hydraulic and electrical power supplies are enclosed in a separate housing away from the machine The operator normally stands in front of the Ferranti control desk and behind him is the contractor panel containing the heavy electrical switchgear. On the platform at the base of the column is the hand control box mounted on a hinged pedestal which can be used for manual operation of the machine and setting up to component datums, two speeds being provided on each of the three movements, a normal operating speed for cutting and a pick-off speed at which single movements of .001 inches can easily be selected. The electrical cables and air supply lines are brought into the column on an overhead boom

hinged from a wall stanchion and the hydraulic oil supply passed through flexible pipes encased in armour sheathing rolling in a metal trough built along the front edge of the bed.

The weight of the head carriage is balanced by means of a hydraulic cylinder inside the column. Two roller chains transmit the load, over pulleys on top of the column and through a double sheave on the end of the piston, the outer ends being anchored to the top of the column. This gives a two-to-one ratio, enabling a cylinder of short stroke to be used. Oil at a pressure of 1,000 p. s. i. is supplied to the upper end of the cylinder from a reducing valve in the hydraulic supply line. On the upward stroke of the piston as the carriage moves down, the oil is exhausted to the return line through a spring loaded relief valve. The traverse speeds on the machine are infinitely variable up to the maximum of 150 inches per minute on "X" and "Y" and 75 inches per minute on "Z". The normal operating range used in production is 100 to 150 inches per minute for the roughing operations and 50 to 75 inches per minute for the finishing operations.

THE SLIDE SYSTEM

The method of slide lubrication used is a unique version of the hydrostatic pressure system in which the moving members are entirely supported on an oil film with no direct metal-to-metal contact between the bearing faces. An automatic metering device controls the pressure of the separating oil film in such a way that external loads applied to moving members cause an opposing force system to be set up in the oil film to completely balance the loads and maintain the rigid location of the slide. The system thus accommodates all the cutting and inertial loads encountered and the frictional forces are entirely viscous and independent of the loads on the slide. The main bed-slide of the machine under test with a 9 ton load gave the following "friction force" to "speed" relationship :—

At 10 inches per minute, force required = 2 lb.
At 100 inches per minute, force required = 20 lb.
At 200 inches per minute, force required = 40 lb.

A reduction of the load from 9 tons to 1 ton caused a slide movement of only .0003 inches from the mean setting, the carriage still floating freely. This system is virtually free from wear, there being no metal-to-metal contact and so the accuracy and efficiency of the slides will be maintained indefinitely.

THE DRIVE SYSTEM

It is quite common in a conventional machine tool drive system to find that the drive motor can be turned through a considerable number of revolutions before the machine begins to move, due to backlash between the mating teeth of the gearing and wind-up or elasticity in the gear shafts and bearings. If a controlled machine tool is to follow the control information with any degree of accuracy, then these conditions must be eliminated. The drive power for the Fairey machine is by high speed hydraulic motors of extremely low inertia coupled to specially designed gearboxes. The Ferranti standard half horsepower type gearbox is used on the infeed movement driving on to a re-circulating ball lead screw engaging with a double-nut system with spring pre-load. The larger gearboxes on the "X" and "Y" movements are of Fairey design and are twintrain boxes terminating in a pair of spur pinions driving on to a common rack. The gear loop is closed at the input end by an axially floating shaft with right and left-hand helical pinions engaging with the first gear in each of the two trains. Pneumatically loaded bellows apply an axial load to the floating shaft which results in a pre-load torque being applied throughout the two trains, equal to 110% of full load torque. Under conditions of no load the pre-load torque is equally distributed through the two gear trains and it is taken up by the driving train as the drive torque is applied. At full load the remaining 10 per cent of the preload exerted on the non-driving train maintains the backlash-free condition. The axial float of the pre-load shaft accommodates any tooth ripple or eccentricity errors in the gearing and, over a period, automatically takes up tooth wear. The gears, shafts, bearings and mountings were designed for optimum conditions of high stiffness with low inertia and it is due to these considerations, combined with the virtual absence of slide friction, that the resonant frequency values recorded on test were: for the "X" drive with an 8¼ ton column, 22 cycles per second, and for the "Y" drive with the 1 ton vertical carriage, 63 cycles per second.

THE CUTTING HEAD

The cutting head is a Fairey designed unit of 20 h. p. running at 6,000 r. p. m. and has been tested on the machine up to metal removal rates of 140 cubic inches per minuts for face milling, 110 cubic inches per minute for end mills of 2 inches and 3 inches diameter. The surface finish obtained at these rates was around 10 micro inches R. M. S.

THE CONTROL SYSTEM

Briefly, the sequence of operations in the Ferranti programme control system is as follows: The designer produces a drawing of the part to be machined, dimension with respect to a datum, each point being given three rectangular co-ordinates, representing distances in the "X", "Y" and "Z" planes from the common datum. Points to be dimensioned are those where the two curves intersect, e. g. where a straight line joins a radius. From the drawing a planner prepares the machining programme specifying the route to be followed by the cutter and inserts information concerning cutter diameter and feed rate and also the shape of the path between the change points, a set of code symbols being used to denote a circle, an elipse, a parabola or any other second-degree curve, the absence of a shape symbol denoting a straight line.

The programme sheet is then copy-typed on a Creed tele-typewriter which produces a typescript check copy and simultaneously a paper taps with a series of punched holes representing the programme information in binary code. This paper tape serves as an input to a digital computer which translates the information into a set of pulse-trains on a magnetic tape, the computer service being provided by Ferranti.

The three pulse channels on the tape control the "X", "Y" and "Z" movements of the machine, each pulse representing a distance of .001 inches and the pulse-train recorded on fourth channel provides a continuous check on the three control channels. When the magnetic tape is played back on the machine control desk, the command pulses are passed through the control equipment which transmits corresponding signals to the machine servos, so that the machine follows the pattern of movements recorded on the tape to produce the shape initially programmed.

Along the length of each axis of the machine is a glass grating, ruled over its full length with a pattern of fine dividing lines spaced with a frequency of 500 lines per inch. On the moving member a reading unit with a small section of similarly ruled grating placed at a slight angle to the long grating sets up a Moire fringe pattern where alternative dark and light bands travel across the screen each time a line is passed. A group of photocells scan this fringe pattern and transmit two pulses for each line counted, so that each pulse, again, represents a distance of .001 inches. In the control equipment the tape signals are amplified and after passing through a direction discriminator are held in a binary store.

Feed back signals from the optical grating on the machine pass through a similar direction discriminator and on to the binary store where the input and the output signals from the tape and grating are then compared and any discrepancy between the two is passed through a mixing network, amplified and passed on to the electro-hydraulic valve which controls the oil flow to the hydraulic motors on the drive gearboxes. The command pulses are also passed through a rate meter which gives a voltage output proportional to the velocity demand. In the mixing network this voltage is compared to the feed back signal from a tacho generator in the gearbox and, here again, the difference in voltage is amplified and fed to the electro-hydraulic valve. This velocity loop provides the coarse position control for the machine, the resultant velocity being maintained within ± 2 per cent of the command velocity. The displacement loop signal is superimposed on the velocity loop signal and gives the fine position control of the machine within .001 inches. Considerable emphasis has been placed on electronic reliability and the circuits are designed to continue functioning correctly even if the value of any of the components varies by as much as 30 per cent. As an additional precaution a daily check drill is instituted where the screen voltages of all the valves in each channel are reduced in turn, so that any component approaching the marginal condition can be replaced before the day's work commences. This marginal check occupies only 10 to 15 minutes but the reliability of the equipment is such that it has never been found necessary so far to replace any components. Checking circuits are provided to ensure that the errors in the machine movements never exceed a pre-set level. The check channel pulses from the tape are compared with the sum of the feedback pulses from the "X", "Y" and "Z" gratings and if the discrepancy between these exceeds 8 digits the machine stops. In addition to this, safety interlocks are also provided to stop the machine in case of failure of any of the services. Several refinements have been added to the control equipment supplied for this machine. The code symbol MCC-F appearing on a programme will automatically switch the control circuits to double pulse scale where traverse speeds of over 75 inches per minute are being used and at the end of each programme the symbol MCC-W is used to stop the tape-deck. A mirror image switch has also been added to the control desk so that right and left-hand components can be produced from the same magnetic tape.

PERFORMANCE

A comprehensive acceptance programme was devised by the Ministry of Supply to test every aspect of the machine performance. A full alignment check was made and a series of test pieces machined and inspected for accuracy and finish. Time trials were conducted under full cutting load and complete functional checks made on all services. Extremely good surface finishes were obtained even under full load conditions, 8-10 micro inch r. m. s. at 110 inches per minute, with a 3 inch diameter end mill on a full face cut at 0.34 inches depth is a typical example. Dimensional accuracies of ± .002 inches were achieved on dimensions up to 18 inches with repeatability within .001 inches over four consecutive test pieces. An elliptical channel section frame 7 feet high, which entailed the machining of four elliptical paths, was produced with every dimension within .005 inches, the part being programmed directly from the curve equations. All the test pieces were machined at the normal traverse rates quoted above.

It is too early yet to quote actual times against conventional method times, as the few components machined have not been produced in sufficient quantity by hand methods to achieve a settled production time. The time saving in relation to these is, of course, fantastically high, but records are being compiled and these indicate so far that our original estimates of production rates between 10 and 30 times faster than normal will be borne out.

FUTURE DEVELOPMENTS

Development work under the Ministry Specification is still proceeding on various features of the machine. Specially designed bearings will soon be ready for test for a 100 h. p. spindle to operate at 12,000 r. p. m. which will raise the cutting capacity to 500 cubic inches per minute or even higher. Various aspects of angular control are being studied, the farthest advanced of these being a spindle adaptor carrying a variable angle cutter which will mill the changing angles normally encountered around the periphery of wing ribs. This can be achieved without any additional control equipment by locking the infeed movement and switching the "Z" channel over to the angular control. Design studies are also under way for a smaller version of the machine, tailored to meet the problems of milling high tensile steel components.

Thrust Boring on Drainage Scheme

The construction of a main drainage scheme at an English town has involved the driving of culverts beneath a number of busy roads and railway lines and, in order to avoid interrupting the normal flow of road and rail traffic while this was going on, the main contractors called on the services of a horizontal thrust boring machine now being operated in Britain by Costain-John Brown, Ltd., of London.

This machine, which is driven by a 50 h.p. petrol engine, consists of a rotary cutting head, driven by a cutter bar and a spiral conveyor which carries the earth displaced at the "face" back through the lining and deposits it behind the machine. The cutting head operates immediately in front of the leading edge of the culvert liner tube. This tube is drawn forward, as the cutter removes the soil, by a winch geared to synchronise earth removal and linear advance. This winch is located on the machine structure and its cable is connected to a dead man anchorage near the culvert entrance. The machine is saddle mounted on the culvert liner and secured to it by twin girths. As the cutter head bores into the earth, the winch pulls the liner into the cavity which has been formed. As a result of this system of close and progressive lining, there is no possibility of subsidence. The thrust boring machine engaged on this drainage scheme has been employed to drive a 130 ft. culvert of 2 ft. diameter under the railway main line near Staines, Middlesex, and a road running alongside the line.

Self-contained teams of operators with all the necessary equipment and transport are able to operate anywhere. The simplicity of the system allows a speedy, convenient and economical method of lined culvert excavation work, eliminating, as it does, the possibility of subsidence, the need for expensive vertical excavation and fill operations, and interference with road, rail or canal traffic.

SEAGOING TARPAULINS

ALREADY widely adopted by the trucking industry, neoprene-coated nylon tarpaulins are being tested as hatch covers by the United States Maritime Administration. After more than two years of evaluation, the nylon tarpaulins are top candidates to replace conventional hatch coverings.

Results of severe exposure tests on ships of a reserve fleet indicate the new covers, coated with elastomers such as neoprene and "Hypalon" synthetic rubber, offer outstanding resistance to weathering and abrasion, and remain watertight. In addition their light weight and flexibility make shipping and handling economical and easy.

The tests were undertaken because materials engineers found conventional tarpaulins were bulky, heavy, and had to be discarded after a year's exposure. Technical experts of the Du Pont Company suggested that tarpaulins made from "Pairprene" synthetic rubber coated fabric might provide a solution for the replacement and handling problems.

Nylon provides a strong, durable base fabric, remains flexible even in sub-zero weather, and resists damage from mildew and other micro-organisms. Neoprene has proven its ability to resist deterioration by sunlight, weather, oils, and abrasion. When Du Pont developed its method of bonding neoprene to nylon, the two synthetic materials produced a tarpaulin which was light in weight, flexible, waterproof, and gave years of service.

The new material promises to last at least three times as long as conventional tarpaulins, amply justifying a higher original cost. This saving alone could be a decisive factor, even without the additional benefits of ease of handling and lower shipping costs.

In March, 1955, the first tarpaulin made of the new material was installed on the reserve fleet. Preservative oil, used to loosen rust, was splashed on the hatch planks. This oil is highly penetrative and would in itself give the material a rugged test.

Detailed inspections have been conducted by Maritime Administration field engineers every three months, and the tarpaulins are as effective today as they were when installed over two years ago.

In April, 1956, a second hatch cover was installed, this one coated with Du Pont's new "Hypalon" synthetic rubber. This new material, like neoprene, offers excellent resistance to sunlight and weathering. In addition, "Hypalon" can be furnished in a variety of fast colors, an appealing feature for passenger ships. After two full summers and a winter, it remains waterproof and shows no wear or distortion.

Plans are now under way to fabricate several more hatch covers for testing on merchant ships in active service. Conventional canvas covers will be used on half of the hatches on the test ships, the new material on the other half. In this way both tarpaulins will face the same conditions, and accurate comparisons can be made. Du Pont engineers feel this phase of the test will confirm the effectiveness of the new materials.

NOTE TO THE EDITOR: The "Fairprene" synthetic rubber coated fabric for the tarpaulins described were made by the Fabrics and Finishes Department of the Du Pont Company at their Fairfield, Connecticut, U. S. A., plant. Here are additional statistics on the material:

Weight: 14 ounces per square yard. Average 25 by 40 foot tarpaulin weighs 110 pounds.

Fire Resistance: Vertical Flame Test (Method 5902 of Federal Specification CCT-191B) after flame, maximum 10 seconds; after glow, zero seconds; char length maximum, two inches.

Tensile: Pounds per inch, 300 plus; grab W × F, 300 plus.

Tear: 22 pounds × 25 (strip W × F).

Width: 42, 54, and 72 inches.

Hydrostatic: Mullens, 200 psi.

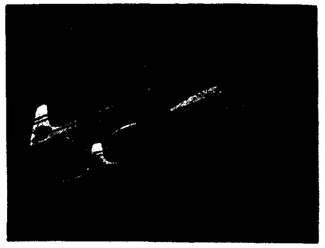
AW 650 FREIGHTERCOACH

Technical Editor
Sir W. G. Armstrong Whitworth Aircraft Limited
Baginton . Coventry . England

A GOOD basic aircraft design, like a good musical theme, is enhanced by the variations which can be played upon it. That so many alternative versions of the A. W. A. Freightercoach should have been put forward at this stage of the project is an indication of the versatility of the initial design. In autumn 1955, Armstrong Whitworth were invited to submit a project study for a multi-purpose military transport with obvious civil applications.

Later, under the M. T. C. A. instead of the M. o. S., the project became a predominantly civil one, backed as a private venture by the Hawker Siddeley Group. The result of an intensive market survey showed that initially four well-proven Rolls-Royce Dart powerplants should be used, but it was decided also to profit from the low installed drag and efficiency of the Tyne to offer another version with this engine for longer stage-lengths. These versions became respectively the AW .650 and 651, both with a twin-boom layout, a wing of well-proven merit and a pressurized fuselage of approximately circular section. Discussions quickly showed the possibilities of the type as a military freighter with an integral ramp for dropping stores (AW .660), a similar version with Tyne engines (AW .661) and a further variant with an enormous unpressurized double-deck fuselage, with a floor-level width of 174 in, on which further changes could be rung. These are a car ferry which would accommodate six cars and 30 passengers, designated AW .670, or a short-range "air bus" with 130 seats, the AW .671. Another variant that has been considered is a fuselage based on the AW .650 configuration but reduced in length.

The project is being tackled with appropriate intensity from the outset. Two complete airframe test shells are being constructed, and work is in hand on three prototypes which are scheduled to fly from Bitteswell in October 1958, December 1958, and February 1959. These will be followed by seven pre-production AW .650s between April 1959 and March 1960. Described below is the basic long-fuselage, four-Dart powered AW .650 now under construction.



AW650 Freighter Coach - Artist's Impression.

STRUCTURE

The twin-boom configuration was a logical choice for the operating role of the aircraft, and the same tail/boom/wing/powerplant arrangement is used to form a basic carrying vehicle for at least three distinct fuselages.

FUSELAGE

The capacity of the long fuselage is 3,680 cu. ft. (that of the shortened AW .650 fuselage is about 3,000 cu. ft.) with a floor width of 10 ft. an area of 426 sq. ft. and a minimum vertical clearance between the floor and wing spars of 6 ft. 8 in. In section, the fuselage has been compared to that of the Ambassador; roof and belly curves are struck from two radii, sides from a third and there is a well-defined chine at the level of the floor and a less prominent one at roof level. The floor is four feet above the ground and both loading doors are at truck-bed height. The fuselage is of conventional stressed-skin construction with I-section frames, generally at 21 in. pitch, backed by doubling strips with intercostal stringers riveted through; two robust additional doubleframes carry loads into the centre-section spars. The interior is pressurized to a dP of 5.5 lb/sq. in. and the end doors are closed on inflatable seals. The front door, which is faced with a bulkhead, incorporates a large baggage compartment and the crew toilet. In addition to the freight loading doors there is a 66 in. by 30 in. passenger door on the port side aft and an emergency exit 48 in. by 24 in. opposite. Four of the 19 windows also function as emergency exits, two 36 in. high by 20 in. wide and two more 26 in. high by 19 in. wide, the latter positioned between frames pitched at 23.5 in.

WING

During the preliminary design it was found that a modification of the Shackleton 3 wing would be very suitable for the AW .650. The responsibility for the wing has hence been invested in Avro at Manchester, where as much of current Shackleton tooling as possible will be used. Fatigue experience with this type of wing is considerable, and a safe life in normal operation of 30,000 hr. can be predicted with confidence. The final wing is in fact now much modified in detail largely because of the tail-boom attachments and different engine spacing. Nevertheless, the basic three-section, two-spar design is retained, with spars (consisting of upper and lower booms with conventionally stiffened webs) at about 13 per cent and 62 per cent chord. The section is modified N. A. C. A. 23018 at the root, tapering to N. A. C. A. 23012 at the tip. The main constructional break occurs 30 in. outboard of the boom centreline, the outer wing having two deg of dihedral. The leading edge is hinged for accessibility. Carried from the rear spar are hydraulically operated, double-slotted flaps extending over 31 per cent of the chord and out to the three-piece ailerons. The linkage is designed to give a large chord-wise extension over the initial range of travel. The mechanism consists of a main and emergency motor, and a worm and wheel gearbox driving a bevel box through an output shaft to give continuous torque-tube operation to the respective chain and sprocket driven flap portions. A smaller flap, 163 in. wide, is set into the centre section between the boom and the fuselage, so that 64 per cent of the total wing span is flapped.

TAIL UNIT

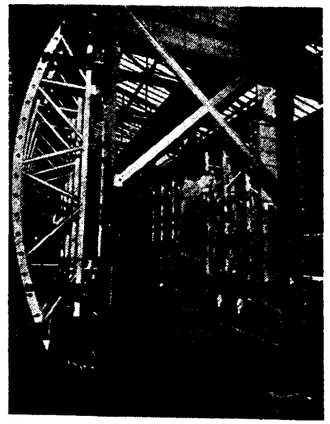
Final design of the complete tail unit is being undertaken by Gloster Aircraft. The tail is supported on long semi-monocoque booms of flattened circular section extending from the rear of the inboard engine nacelles. The tailplane is of conventional two-spar multi torsion-box construction and carries horn-balanced elevators with six sections of tab.

UNDERCARRIAGE

This is the responsibility of Dowty. The main units, somewhat similar to the Friendship geometrically, are hydraulically retracted rearwards into the booms, where they are closed by two doors (one for the leg and one for the wheel) hinged outboard of the centre-line of the nacelle. Twin Dunlop wheels are fitted with Maxaret anti-skid units and Dunlop 15.5 × 20 tubeless tyres inflated to 74 lb./sq. in. The nose undercarriage, which is also retracted rearwards into a box is free to caster through 360 deg. and can be hydraulically steered through a range of ±55 deg. The tyre size is 32 × 10.75-16 and the inflation pressure 70 lb./sq. in.

POWERPLANT

Choice of the RDa. 7/2 (Dart 526) engine of 2,100 e. h. p. was followed-up by A. W. A. obtaining permission from Vickers to allow them to buy Viscount-type powerplants complete back to the



"AW650 in Jig"

AW650—Mock-up.

fireproof bulkhead. A typical cruising speed over medium stages with this engine would be 276 m. p. h. t. a. s. at 25,000 ft.

Tyne versions of the Freightercoach may, under some conditions, be limited in take-off performance with the Tyne RTy .1 (4,695 e. h. p.) installed, but the two-spool turboprop would offer greater fuel economy and lower specific installed weight.

A larger propeller than that fitted to the Viscount is to be used; it will be an 11 ft. 6 in. constant-speed, feathering Rotol propeller fitted to a Friendship-type hub.

SYSTEMS CABIN AIR

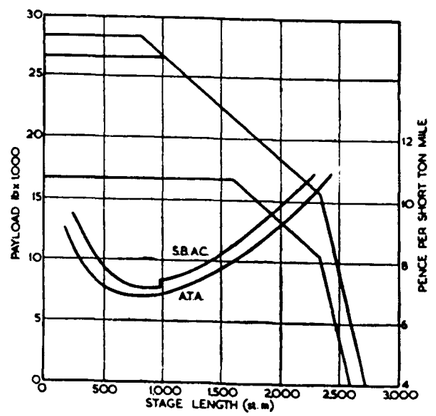
Pressurization air at 5.5 lb./sq. in. is supplied by three Godfrey Type 15 blowers driven through the Rotol gearboxes on engines one, two and four. Air is drawn through filters and then passes through silencers into a pressure-limiting valve, primary and secondary heat exchangers (cooling air for which is ducted from N. A. C. A. scoops aft of the cockpit windows) a secondary silencer and a temperature-control valve. The air-conditioning equipment is installed in a compartment aft of the flight deck and above the freight hold, and provides up to 100 lb./min. of conditioned air through distribution ducts throughout the length of the main cabin, around the crew compartment and into de-misting jets on the side and d-v. windscreen panels.

FUEL

The fuel is contained in ten bag tanks between the wing spars, with a total capacity of 3,300 Imp. gal. The capacities of individual tanks, from root to tip, are 362 Imp. gal, 463 gal, 405 gal, 320 gal. and 100 gal. A pressure refuelling and defuelling system is installed, with filling points on each main undercarriage leg. Normal over-wing refuelling is available as well. The pressure refuelling rate is 150 gal./min. through each point.

FLYING CONTROLS

The manual flying controls are quite conventional. Spring tabs operated through push-pull rods, and tension-compensated control cables are installed. Elevator movement is 25 deg. up and 15 deg. down, rudder movement ± 20 deg. and aileron movement 24 deg. up and 14 deg. down. Trimming is by tabs on each surface.



Payload-range and direct operating costs for the AW.650.

DE-ICING

The wing leading edge is thermally de-iced by ram air heated by exhaust gas tapped from the inboard engines and passed through heat exchangers. The heated air is passed through the hinged, double-skinned leading edge assembly via a double-skinned nose and exhausted through outlets at three stations along the span just aft of the front spar, between ribs 3 and 4, 11 and 12 and 21 and 24. The area protected by warm air extends back to 12 per cent chord. Propellers, engine intakes and tail surfaces are electrically de-iced by both continuous and cyclically heated systems.

HYDRAULICS

Power is supplied by Lockheed Mk 9 pumps mounted on the accessory gearboxes of engines 1, 2 and 3. The system operates on D. T. D. 585 (mineral) at 2,500 to 3,000 lb./sq. in. (except for the duplicated wheel-brakes supply, which operates at 1,500 lb./sq. in.) and serves undercarriage retraction, nosewheel steering and flaps. An Integral emergency power pack supplies the undercarriage and flaps, and a double-acting hand pump is fitted. The Hobson reservoir is pressurized by the cabin blower to 10-12 lb./sq. in.

ELECTRICS

The main generator system comprises four 6-kW 28-V engine-driven D. C. generators, running in parallel and supplying a split busbar. Three 25-amp.-hr. 24-V accumulators are fitted to give engine starting without using ground facilities. The A. C. power requirements for radio and radar are supplied by inverters, and four 22-kVA alternators supply the heavy power needed by the electric de-icing units.

FLIGHT DECK

Normally, the aircraft will be flown by a crew of two, although provision is made for three, and the aircraft can be ferried solo. Pilot opinion has been freely and extensively employed in the design of the cockpit, and the resulting layout should prove exceptionally popular and efficient. Specified equipment includes the Smiths Flight System and S. E. P. 2 autopilot, duplicated controls, and seats mounted on rails on each side of a large central console with plenty of room for access. Roof panel provision is for radio, cabin conditioning, de-icing and generator and invertor control systems. Standard equipment is an I. L. S./V. O. R., two A. D. F.s based on Marconi A.D. 712, an STR. 18-based H. F., twin STR. 12D V. H. F., and Ultra intercommunication equipment. Decca Navigator and weather radar (based on the Ekco E. 120) will be available to special order. H. F. aerials are strung along each boom, A. D. F. sense towel-rail aerials are situated beneath the rear fuselage with tandem loop aerials under the centre fuselage, and two V. H. F. aerials project from above the cockpit and low on the starboard side of the fuselage. The I. L. S. marker aerial is in the fuselage behind the nosewheel fairing, the glide-path aerial is in the nose, and the localizer and V. O. R. aerials are situated halfway up the fin.

PAYLOAD ACCOMMODATION

Conversion between all-freight, mixed passenger/cargo and all-passenger services has been carefully considered. The aircoach version of the standard Freighter provides for 77 passenger seats at 34-in. pitch, with toilet and galley facilities for medium stages, or 74 seats at 36 in. pitch, 77 at 34 in. and 83 at 32 in. The ferry version (AW. 670) carries six cars and 30 passengers, and the AW. 671 can carry up to 130 passengers over short stages.

COMMERCIAL HISTORY

With the sales of all variants in the hands of the Hawker Siddeley Group, and aided by the very widespread Rolls-Royce sales organization, commercial success seem as assured as it can be for a new project. Models of the AW. 650 have appeared in the markings of B. E. A., and the AW. 670 car ferry in Silver City livery.

New Special Purpose Battery

A new type of power battery employing a new design of double sleeve plate construction has been produced by Oldham and Son, Ltd., of Denton. The "Pg" double sleeve, multi-tube battery has, it is claimed, important advantages for uses such as miners' electric cap lamps and in buses, electric vehicles, fork trucks, mechanical handling equipment, underground traction and similar applications. The "Pg" type of tubular positive plate, the firm states, resolves many of the problems which have been engaging battery research engineers for a considerable time. It answers deterioration problems, for all the components are virtually immune to the effects of continuous and long immersion in acid, whilst the mechanical construction is such that shedding of the active material, either through normal cycling or exterior vibration, is eliminated.

The plate consists of a number of thin P.V.C. (polyvinylchloride) tubes each of which by reason of its greater inherent strength, can be perforated to provide a greater accessibility of the electrolyte to the active material than is possible with conventional slitted tube construction. In addition, each P.V.C. tube is lined with a woven glass fibre sleeve, the assembly being centred on a feathered "X" metal spine. The active material is closely packed into the space between the spine and the glass fibre sleeve. By reason of the thinness of the P.V.C. and the glass fibre wall, a greater volume of active material can be packed into each tube. This is an important factor which contributes to greater capacity. In use the glass fibre sleeve becomes securely embedded in the active material which is therefore positively retained, so contributing to considerably longer life. In view of the greater accessibility of the electrolyte to the active material afforded by the perforations in the P.V.C. tube, the high rate of discharge is better than could be expected from a slitted tubular positive type of battery.

DART FOR THE HERALD

By A Special Correspondent

SEVERAL years ago Handley Page realised that it was only the operators of air transports built specifically for local services and operation in undeveloped areas who knew with certainty the qualities such aircraft must possess. Representatives of the company investigated operators' requirements by an on-the-spot study of their needs. Their enquiries took them to most airlines operating short and medium-length routes.

The Dart Herald is a development of the aircraft which was built to the specification thus evolved.

Power for the stressed-skin constructed, high-winged Herald is generated by two Rolls-Royce Dart R. Da. 7 mark 527 propeller turbines. These engines each produce 2,100 shaft h. p. They are an advanced version of the engine which, since its introduction into service in April 1953, has more than four million engine hours to its credit.

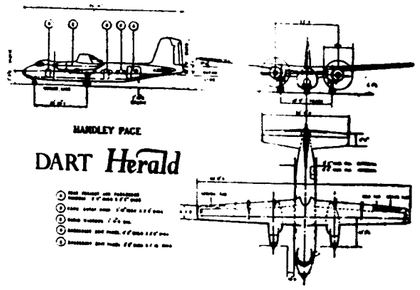
Although the Herald embodies the latest techniques such as spot welding and sandwich construction, the operator bears little of the burden of research expense. This is because the company's considerable experience of the design, construction and development of modern military and civil aircraft has been applied to the Dart Herald.

Versatility is one virtue of the Herald. As a freighter it can carry a maximum load of nearly five tons, whereas in the passenger version it can carry up to 43 people at 1½d a passenger-mile. When mixed loads are carried, movable partitions separate passengers and cargo. The ratio of passengers to freight can be varied simply by moving the partitions to suit traffic at any stage of a journey.

High cruising speed, exceptional range and good airfield performance make the Herald ideal for local-service operation in either developed or undeveloped areas of the World.

The experience of many years' construction of civil and military transport aircraft by Handley Page, coupled with an engine which has proved itself by

HANDLEY PAGE DART HERALD
Medium-range airliner with two Rolls-Royce Dart turboprop engines.



worldwide operation, ensures that operators of the Dart Herald will have a branchliner that is both reliable and economical.

Pressurised, vibrationless comfort is the keynote of the Dart Herald's passenger cabin. With its smooth-running turboprop engines this new airliner will bring mainline standards of luxury travel to the local-service and branch routes on which it will fly.

The size of its cabin will appeal to operators. It is, in effect, a pressurised tube 58 ft. long, stretching from the bulkhead behind the cockpit to the rear pressure-bulkhead. It has a volume of 2,075 cu. ft.

Along each side are oval double-pane windows. The strong cabin floor will carry a load of 150 lb./sq. ft. in the forward and rear freight areas and 100 lb./sq. ft. elsewhere.

Interior layout, furnishings and fittings are arranged to meet individual requirements. For operators who need them, racks can be fitted in the fuselage conveniently for the stowage of luggage carried aboard by passengers.

As a standard arrangement, quickly-detachable, low-weight double seats are used. Attachment sockets in under-floor seat-beams and the cabin walls allow them to face either forward or aft on each side of a central gangway. These sockets are arranged so that changes of seating layout can be made rapidly. This method of attachment is also suitable for the fold-up type of seat used by some operators.

There are two entrance doors. One, on the port side towards the rear, is an outward-opening double door used for passenger entry or freight-loading. The other smaller door gives access to the front of the cabin and is used for crew entry.

All door access-panels lie flush so that they do not obstruct the movement of freight. Loading is simplified by the cabin floor being level and close to the ground.

Crew comfort has been studied at all stages in the design of the Dart Herald.

Two pilots form the flight crew for normal operations, but a radio operator's position can be fitted aft of the flight-deck at the expense of some payload space.

Both pilots have a wide range of vision through five flat windscreen panels and each has a sliding direct-vision panel beside him. When the aircraft is level on the ground, objects less than ten feet ahead can be seen directly over the nose.

Pilots' seats are comfortable; they can be adjusted in flight for height and rake and the position of head and arm rests can easily be altered.

Dual flying controls are fitted.

The layout of instruments and controls varies within limits according to the requirements of individual operators, as does that for radio, navigational aids, pilot-aid and propeller de-icing installations. Care has been taken to ensure that instruments are adequately but unobtrusively illuminated for night flying.

The instrument layout was devised after extensive consultation with aircrew who fly on branchline and local service routes in many parts of the world.

Special attention has been paid in the construction of the mainplane to the effects of fatigue failure; even should failure of a panel occur, the structure would still be safe.

Ease of servicing and maintenance—essential for branch-line transports—has been built into the Dart Herald from the initial stages of its design. The greatest effort has been made to reduce the amount of routine servicing needed and to ensure simplicity of and easy access to all airframe services.

Emphasis has been laid on interchangeability, the use of standard parts and avoidance of the need for special tools.

New Hymatic Hot Air Valve

To the wide range of valves for aircraft pneumatic systems produced by the Hymatic Engineering Company, Ltd., of Worcestershire, is now added type MD. 32, which has been specially developed for the production of Britain's Comet IV airliner. It is a hot air electro-pneumatic stop valve with a thermal range from minus 40°C. ambient to plus 365°C. The valve can be kept continuously energised at the highest temperatures. When the solenoid is energised, air from the upstream side of the valve is allowed to pass through a pilot valve on to the rear piston of a larger area than the valve poppet, thus opening the valve. It is closed by shutting off the flow of upstream air to the piston. Residual air bleeds past the piston clearance to the spring chamber, which is vented to atmosphere.

The MD. 32 is normally used for pressures up to 150 lb. per sq. in. In addition, it can be used as a flow controlling orifice in its own position. When functioning in this manner it has a pressure drop of 7 lb. per sq.in. at 5 lb. per minute flow. Applications for the MD. 32 on the Comet Four jet airliner include control of compressor-bled air for wing deicing and emergency fuel jettisoning. The specification of this new valve also makes it suitable for use to control all types of hot air pneumatic systems, including the remote control and selection of air supplies to pneumatic emergency systems, for airborne guided weapons, and in boundary layer control of flows over aerofoils.

NEW GERMAN DESIGNS AT HANOVER

The aeronautical display set up at Hanover Airport is quite a minor sideshow not only in comparison with the mighty industrial fair but also with other air shows on the Continent. A few items of interest nevertheless deserve notice. For the aeronautically curious top marks go to the Schwan I ornithopter glider, but it has not yet flown.

The designer, Herr Dipl.-Ing. Walter Filter, prefaces his introduction with the words of the great Prandtl, "If any one could find a design by which we could imitate the flight by flapping motion so beautifully performed by our large birds, a great future would lie in store for this design." Professor Proell, of Hanover Technical University, is said to have been a keen adviser and sponsor.

As shown at the exhibition, the Schwan I is a single-seat ornithopter glider. The flapping motion is to be performed by muscular power. It is claimed that short-duration horizontal flight can be maintained without thermals. The glider is to be launched in the manner of an ordinary glider, and, once air-borne, the flier can actuate the flapping motion by operating the reciprocating sliding shoes with his feet. The sliders move longitudinally in relation to the fuselage and cause the flapping motion of the "feathers" through the medium of a rod-and-lever mechanism.

The machine is a midwing monoplane of orthodox shape with conventional disposition of tailplane and fin. Roughly half-way along the span a flapping hinge is arranged, beyond which the wing breaks up into six aerofoil-profiled feathers of a length diminishing from the leading to the trailing feather, roughly approximating an elliptical shape.

During the flapping motion, each feather changes its incidence, cyclically so as to produce lift efficiency. The inventor claims that wind-tunnel measurements have proved the feathers to have an extremely favourable polar curve with almost vanishing induced drag. So small is the induced drag that, according to the inventor, powered flight with 4 h. p. in a two-seater is thought of as a lavish assumption.

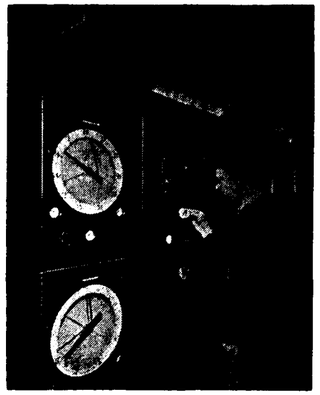
Mechanically, the two flapping feather systems are connected by a rubber spring across the fuselage and the flapping motion is performed at the resonant frequency of the complete system. This is around 20 cycles/min. It is this operation at resonance which has been mechanically tested to the full satisfaction of the designer. The small up-and-down motion of the fuselage is not disturbing because of the low accelerations involved. The controls of the aircraft are conventional.

The construction of the fixed wing portion is based on an aluminium-alloy tubular spar with wooden ribs, reinforced with metal fittings in places, and plywood covering. The feathers are basically of the same type of construction. The fuselage is constructed of wooden formers and it is covered with plywood.

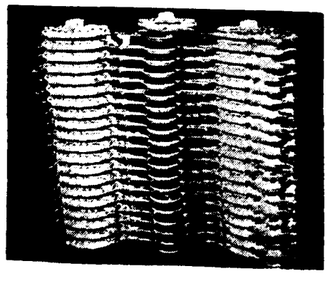
The designer was told that the Russian designer of a powered ornithopter, which is claimed to have been flown and is supposed to be capable of lifting 15 people, was about to visit the Hanover display.

Somewhat more orthodox, yet new enough to attract interest among the exhibits, is the Dutch Kolibrie ramjet helicopter, which demonstrated its remarkable flying qualities. The two-seater embodies the development pursued under the umbrella of the Dutch Aeronautical Institute. After 500 hours of endurance flying and 150 hours' engine type-test it received a Dutch certificate of airworthiness in 1957, and the first deliveries of a batch of 10 started last March.

Several small aeroplanes were displayed which represent the very young German post-War development. Perhaps the most modern in structural detail is the Blume Bl-502 four-seat low-wing monoplane with a 150-h. p. Lycoming O-320-A engine. This machine received its type approval four weeks ago. Of orthodox configuration and layout, it is remarkable for the care taken over the finish and profiling. It is claimed that a laminar-wing profile has been achieved and the use of Redux bonding has made a smooth wing possible, while a specially developed bonding assembly rig in which the skin is pre-stressed ensures, according to the designer, the maintenance of the exact profile under flight loads. The machine has an all-up weight of up to 2,470 lb., a maximum speed of 155 m. p. h., a landing speed of 53 m. p. h. and a take-off run of 1,230 ft.



METALS & ALLOYS SUPPLEMENT



Automatic Metering of Magnesium opens Cold Chamber Die Casting Applications and Markets

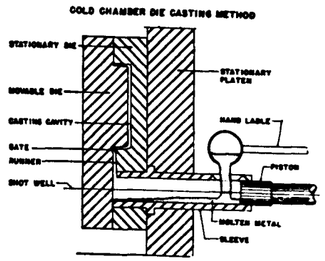
By F. C. Bennett
Chief Die Casting Section, Metallurgical Laboratory,
The Dow Chemical Company, Midland, Michigan

THE pressure die casting industry has grown rapidly in the last ten years because of the mechanized nature of the process and improvements tending to widen its scope. For example, hot chamber zinc die casting has been developed to the point where large castings are regularly produced in an economical manner for and by the automobile industry, among others. Several organizations are operating small, completely automatic, hot chamber machines with excellent results. Magnesium is also being cast by the hot chamber technique as described in previous papers (1) and there is no reason why these machines couldn't be operated automatically for high production of simple castings.

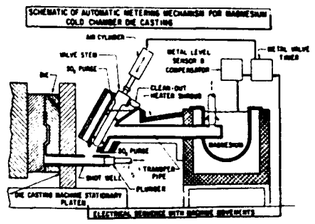
Unfortunately the hot chamber process has certain limitations which tend to restrict its use. The injection pressure is developed by close-fitting mechanical components which must perform under very difficult conditions of temperature, stress, and exposure to molten metal. Permissable maximum pressures must be kept relatively low to avoid failure of the materials used. These problems become more formidable as machine size is increased to handle larger castings.

Aluminum alloys present a much more serious design challenge from the standpoint of the hot chamber machine since the few materials which resist the alloy attack have very low tensive and impact strength. It was necessary for the industry to develop another technique for the economical production of large aluminum and magnesium die castings.

The cold chamber process has become the accepted standard for aluminum alloys and a large portion of magnesium die castings are also made in this manner. The sudden demand for automatic automobile transmission castings caused a phenomenal expansion of the aluminum die casting business. Larger machines became justified, extending the



Schematic of the standard cold-chamber die-casting process. Note that hand ladling of molten metal is required.



Schematic of new automatic-metering process for cold-chamber die casting, in which hand ladling is eliminated.

competitive scope to parts weighing 75 pounds or more. As this field opened up, molten metal handling became a serious problem for several reasons.

Manual ladling to a cold chamber machine involves die lubrication, die closure, ladling the metal into the injection cylinder, making the shot, returning the ladle, opening the die, and removing the cast. Under such conditions there is very little time for inspection of the part without loss of production. The ladle and molten metal surface require a certain amount of attention to maintain the cleanliness of

the charge. Large ladles tax the physical strength of the operator while very large charges must be made by mechanized means.

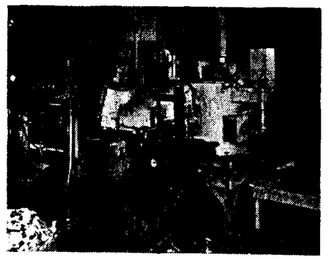
A good automatic metering system would do everything in sequence after the die closure button initiated the cycle, except remove the casting. This would leave the operator time to inspect the product or make process adjustments as required. This goal appeared to be worthwhile and led to the development of the Dow metering system. (2)

Refined molten magnesium alloy is charged into a heated steel holding pot which serves as a reservoir during the recovery period of the melting unit. The flux protected molten metal is fed by gravity through a heated pipe to a control valve over the feed port of the casting machine. Discharge of the metal for each pour is governed by an electric timer which may be equipped with a superimposed compensator to correct for static head variations. Automatic die lubrication is provided.

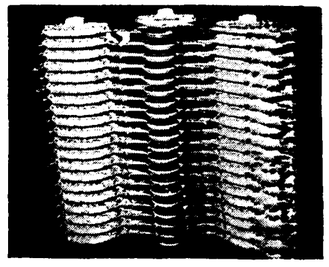
With this system the operator presses the die close button to start the cycle and removes the casting at the end. In the interim the die closes, the metering valve opens and closes to discharge the proper amount of molten metal into the shot cylinder, the injection stroke is made, and the die holding period is followed by opening and part ejection.

Rather startling results have been achieved in laboratory and production tests of this metering system. A small part cast with a shot weight of 0.3 pounds was regularly produced at 330 cycles per hour with little effort expended by the operator. This led to production runs on a convertible die which could be used on either a hot or a cold chamber machine. This multiple cavity die required 1.55 pounds per shot and ran at 240 cycles per hour on the hot chamber machines. The same peak rate was easily reached by the new cold chamber method indicating that it was now possible to run almost any die to the limit of its heat removal capacity using either casting method.

In an effort to demonstrate the process on a faster machine a joint test was arranged with an A. C. Spark Plug die and a Castmaster # 7A machine at Cleveland, Ohio. The maximum production rate achieved here was 550 cycles per hour even though some casting ejection problems were encountered with the 0.3 lb. shot. It was estimated that 600 cycles would be possible under smooth operating conditions.



An automatic-metering mechanism in operation on a conventional cold-chamber die-casting machine. Mechanism is located over shot well, receives molten magnesium from holding pot at right.



Successive shots of automatically-metered magnesium die castings. Note uniform biscuit lengths.

A well known manufacturer of electrical equipment now has two machines operating with the magnesium metering equipment and others are following suit. Their experience checks the previous results in that the ability of the die to remove heat determines the peak production rate.

The quality of the die castings produced by the metering process has been checked using visual, dimensional, and radiographic methods of comparison, and a general improvement has been observed. This is undoubtedly due to the more uniform conditions of production.

The metering system is safer than manual ladling because the operator stands behind the parting line during the cycle. He can regulate the thickness of the cast "biscuit" at the end of the shot piston to minimize the bursting hazard as the die opens. Parting line guards can be used if desired without interfering with the metering cycle. Metal losses are

comparable to those reported with good magnesium hot chamber practice.

Cold chamber metering offers flexibility to the plant where magnesium and aluminum must be processed on the same machines. The feed unit can be moved back to permit handladling of aluminum or it can be temporarily replaced by one of the aluminum ladling devices using similar electrical circuitry.

It is well suited to large parts where hand ladling is very difficult and might otherwise require two men. Examples of such parts would be transmission housings and engine blocks.

Thin walled parts with appreciable area would be easier and more economical to produce with this equipment due to the improved control of casting variables. Some examples are industrial tools and office machinery. Special alloys should prove easier to process for aircraft and missile applications.

CONCLUSION

An automatic metering system for supplying molten magnesium alloy to cold chamber die casting machines has demonstrated production rates equal to those achieved by hot chamber zinc or magnesium machines without some of their limitations. The process is simple in principle, flexible in operation, continuous, safe, easy to run, and produces good castings.

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PURE METALS

By Lawrence P. Lessing

When almost all impurities are removed from a metal, it usually exhibits unexpected properties. Many metals are now purified in the search for new materials to meet the demands of technology

EVER since man first stumbled on nuggets of copper or gold in the bed of some ancient stream, he has been dealing with metals in various degrees of impurity. Even today commercially pure metals contain small but important amounts of foreign elements. So-called pure gold, the buried coin of the realm, is about 0.4 per cent copper and other impurities. Only recently has science or industry begun to approach truly pure metals; *i. e.*, metals in which the impurities have, in some instances, been whittled down to less than one part in 100 million. Since man's history can be written in terms of metals, this foreshadows a new metallurgical age.

The great difficulty, to begin with, was that nearly all metals were found intractably combined with other metals and materials in the earth's crust. For centuries men struggled with fire and crucible to release the more easily separated metals from the ores in which they were hidden. The long Bronze Age gradually gave way to the Iron Age. Then, in the industrial revolution, as iron was rapidly refined on a large scale to steel, and steel was found to acquire a wide range of different properties when alloyed with other metals, more and more difficult metals began to be wrested from their ores. The capture of elusive aluminum and magnesium opened the Light Metals Age.

Beyond these older metals, however, is a range of highly reactive metals, such as titanium, zirconium and hafnium, which are not only difficult to pull from their ores, but, once secured, are the very devil to hold on to. At the temperatures required to melt them, these metals combine furiously with the oxygen and nitrogen of the air and the materials of the vessels containing them to form brittle, spongy masses with no resemblance to metals at all. Indeed, until the last decade they were only theoretical metals. All metals to a greater or lesser degree have the same kind of reactivity, which explains why, under traditional smelting and refining processes, and even with the most advanced techniques, none has yet been secured in an absolutely pure state.

Until a metal is isolated in such purity, its nature and characteristics cannot be fully known. Metallurgy, in fact, is now at a stage that may almost be likened to the prescientific stage of chemistry when the role of pure elements and their combination into molecules were unknown. Large areas in the chemistry of metals remain a mystery. Many physical actions and properties go unexplained. Alloying proceeds by laws not yet entirely known. Though metals literally underpin civilization and constitute more than three fourths of the periodic table of the elements, relatively little in a systematic way has been known about them.

The first impulse to get a pure metal came from the scientific passion for measurement. The atomic weight of silver had to be settled as accurately as possible to provide a key reference in the table of elements. About the turn of the century, after a number of approximations elsewhere, Theodore W. Richards of Harvard University succeeded with great labor in distilling a tiny amount of very pure silver and establishing its weight as the international standard. Later the developments of metallurgical microscopy, the electron microscope and X-ray diffraction plunged research deep into the atomic structure of metals. It was found that a pure metal has a typically tight, crystalline structure in which the atoms are arranged in regular, perfectly spaced polyhedral forms, called a crystal lattice. Alloying materials distort these forms in a regular way, generally adding strength, hardness or other properties to the metal; impurities such as gases, slags or other minerals cause haphazard breaks or discontinuities in the lattice, generally weakening or degrading the metal. From a study of the pure forms, some calculations could be made as to a metal's theoretical strength and other properties, and some of the simplest alloys could be explored.

A few industrial advances were made toward purer metals. Perhaps the most notable was the New Jersey Zinc Company's development in the late 1920s of a fractional distillation process for high purity zinc, containing less than 0.005 per cent of impurities.

This put zinc into the big automobile die-casting market; for the purer metal, unlike ordinary zinc, was corrosion-resistant and made strong, cheap alloys for precision casting. Other metals, such as platinum, were also refined, for special purposes, to fairly high purity on a small scale.

TINY IRON CRYSTAL grown in the General Electric Research Laboratory has a strength of one million pounds per square inch. The crystal is the tiny loop in the center. The heavy bar running from upper right to lower left is a human hair for purposes of comparison.

But there was no great impetus toward pure metals until World War II. Then the accumulated knowledge and curiosity regarding metals became linked to the driving demands of three advancing technologies, each revolving on the development of new or old metals to unheard-of purities. Atomic energy required a purity in metals extending from its base metal, uranium, right up to reactors, which had to be made of strange, new, heat-resistant metals that would not absorb too many neutrons, the particles that make an atomic reaction go. Supersonic aircraft required metals able to withstand tremendous heats, a quality that was soon seen to be related to purity or uniformity, for it led to the development of pure titanium, molybdenum and many new high-purity alloys. Finally, new electronic devices, mainly the transistor but including older electronic and microwave tubes, required ultra-pure metals both new and old in order to function at all. Suddenly, there was a greater range of metals closer to purity than ever before.

The first result was the discovery in metals of many remarkably new properties hitherto veiled by impurities. This was not wholly unexpected. Since the earliest production of hard, bright metals from dull, earthy ores, metallurgists have learned to expect large effects from very small, unlikely sources. The reduction of carbon in iron from 4 per cent to about 1 per cent makes all the difference between brittle cast iron and tough steel. Alloys get all their wide range of effects from tiny additions of metals, sometimes in amounts as little as a fraction of 1 per cent. About 0.2 per cent of impurities, mainly oxygen and nitrogen, is all that stands between ductile titanium metal and its non-metallic forms. The present drive for purity, however, leaves hardly a new or old metal untouched, and the sheer range of new properties is phenomenal.

Chromium, long considered a hard, brittle, almost unworkable metal, used only in plating and in such alloys as stainless steel, is found, in high purity, to be almost as ductile at room temperature as soft wire. Vanadium, another brittle metal used up to now mainly as a toughening agent in tool and spring steels, becomes an unusual ductile metal at high purity.

Even more remarkable properties show up in the laboratory. The General Electric Research Laboratory, which has had a broad hand in this field since developing high-purity tungsten for lamp filaments, is growing and studying so-called perfect crystals or microscopic "whiskers" of metals. These were first discovered at the Bell Telephone Laboratories, growing on cadmium. Crystals of iron, grown at

ZONE MELTING of germanium is shown here in the type of apparatus in which it was developed at the Bell Telephone Laboratories. Bar of metal is slowly being pulled through a gas-filled quartz tube past induction coils which melt only narrow zones of metal. The molten zones sweep impurities to the end of the bar, leaving behind the highest purity metal yet attained by industry.

General Electric, are about a tenth the diameter of a human hair. Under test they show tremendous flexibility, indicating a tensile strength of almost a million pounds per square inch, close to the theoretical strength of iron and far beyond that of any known metal or alloy. The theory is that in such small dimensions crystal structure is continuous enough to approach the ultimate properties of the pure element.

At the University of Virginia a group under Allan T. Gwathmey has been growing huge single crystals

of high purity metals to facilitate their study in another way. The pencil-thick crystals are sectioned and machined into highly polished slices or spheres, so as to cut through or along one or more faces of the crystal. On a large scale these crystal faces are exactly like those found in the tiny crystal "grains" of the regular metal. Various chemical experiments are then carried out on the prepared crystals and the rates of reaction measured on each of the faces. A dozen metals have thus been studied, including copper, silver, nickel and iron. One face of a copper crystal corrodes about five times faster than another at about 400 degrees Fahrenheit. One face of a nickel crystal promotes a catalytic reaction at least 1,000 times more rapidly than another. Friction and wear also vary from face to face of the same crystal. Thus the different crystal faces of a metal behave as if they were entirely different metals.

At the same institution another group under Jesse W. Beams has been whirling thin metal films to destruction in the ultracentrifuge and measuring the forces required. The metals are lightly coated on the tiny rotor of a microscopic ultracentrifuge. This rotor, suspended free in a magnetic field, attains tremendous speeds and forces. Again the results are startling. The thinner the metal film, the tougher and stronger it is.

All this would seem to indicate that if we can get metals pure enough, reintroduce small impurities or alloys in a completely controlled way and learn how to orient their surface crystals in a desired pattern, we may unfold an entirely new range of strengths and special properties. So far few of the new discoveries are explainable, much less practical, but the trend is clear. The ferment of research in universities, government agencies and big industrial laboratories is already felt in commerce. A leading supplier of ferroalloy metals like Union Carbide and Carbon Corporation, for instance, has been investigating nearly all its metals in ultra-pure form. Two years ago it brought in two new closed-furnace processes for producing high-purity ferrochrome and manganese to meet the increasingly tight specifications for jet-aircraft alloys.

The problem of producing high-purity metals in industrial quantities is an entirely different proposition from getting them in small laboratory amounts.

The first stage is to secure them in as pure a state as possible from their ores. Nearly all the basic ways of doing this are more obviously chemical processes than the old metal-smelting techniques. Titanium and zirconium, which are not metals at all except at high-purity, are secured by the Kroll process, named after Wilhelm Kroll, who developed it for the U. S. Bureau of Mines. This is a five-step process pivoting upon the reduction of the metal chloride by molten magnesium in an inert atmosphere or vacuum. It produces a sponge metal which must be further processed. Other basic processes range from hydrogen reduction, one of the oldest, to fractional distillation, solvent extraction and the newest ion-exchange methods. Nearly all these processes are in flux as chemists search for more economical or direct means, such as electrolysis, to get purer metals from ores and thus eliminate some of the further laborious process stages.

The crux of present high-purity metals production is the final stages of refining. The effort required to produce a metal 99.9 per cent pure is as nothing to the care and labor needed to remove any part of

PURE ZIRCONIUM is deposited by the iodide process on the big hairpin filaments above. The base metal and iodine are heated in a vacuum, in which the filaments are suspended white hot. As the iodide vapor strikes the filaments, it decomposes, depositing the pure metal.

the last 0.1 per cent of impurities. Anything with less than 0.05 per cent of impurities is an industrial achievement. In industrial terms, chemical purity is not so important as the structural purity or uniformity of a metal's constituents, for most industrial metals are alloys. The developing techniques may be graphically seen in the growing production of zirconium.

This jewel-like metal is closely associated in its ores with 1 to 6 per cent of its sister metal hafnium. They are so closely related that it is most difficult to separate them. Hafnium differs from zirconium in only one important respect: it avidly absorbs neutrons from nuclear reactions. Hence the hafnium had to be got rid of when it was decided to build the atomic submarine reactor (under contract by the Westinghouse Electric Corporation) out of zirconium. Zirconium is not only a low neutron absorber but is lightweight and highly corrosion-resistant. The Bureau of Mines therefore devised an ion-exchange method which, interposed in the Kroll process, acts upon the metals in solution to pull out all the hafnium atoms. (Pure hafnium, thus made available, is a promising new metal in its own right.)

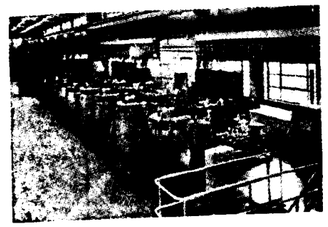
But the zirconium was still not pure enough for reactor purposes. Other slight impurities, which also absorbed neutrons, had to be removed so far as possible. Some years earlier two Dutch investigators, A. E. van Arkel and J. H. deBoer, had devised an ingenious laboratory process for securing ultra-pure samples of titanium, zirconium and other metals. It consists of a glass vacuum still in which a hairpin filament of the metal being sought is heated to well over 1,800 degrees F. The sponge metal, introduced into the still with iodine, forms an iodide vapor which, on contact with the hot filament, deposits crystals of pure metal on the hairpin rods. Westinghouse, finding no more suitable method and no one but itself to do the job, set out in 1950 to adapt the iodide, or crystal-bar, technique to volume production. In 14 weeks it scaled up the process from glass stills to a row of big stainless-steel vacuum tanks, each with clusters of four-foot hairpins. These were soon yielding zirconium in ton lots.

Not long afterwards, however, a more straightforward process was developed by others that produces the metal for less than $15 a pound, against a 1950 price of $250 a pound. Last year high-purity zirconium production was shifted to the new Carborundum Metals Company, using a vacuum method for direct reduction to high-purity sponge metal.

Vacuum methods of one kind or another are the almost universal tool of high-purity metals technology.

Nearly all date from only the last four or five years, at least on an industrial scale. Industry generally has been reluctant to work in vacuums, mainly because of their strangeness, but also because they add costs in production time. In dealing with metals, however, in which a very small part of atmospheric oxygen can act as a contaminant, a fairly high vacuum becomes a necessity. Recently other striking advantages have appeared.

Broadly, there are two levels of vacuum used in the new metals techniques. One is embodied in the vacuum arc-furnace, in which a low-vacuum or inert-gas atmosphere is maintained while a large carbon electrode supplies power and heat to the melting metal. This is the tool for primary titanium



IODIDE PROCESS was taken from the laboratory to this production line of vacuum tanks by the Westinghouse Electric Corporation to get zirconium for the first atomic submarine reactor. Now superseded, it remains an important laboratory process for pure metals.

and zirconium, as well as for high-purity molybdenum, experimentally produced by the Climax Molybdenum Company and under intensive development for advanced jet engines because of its high melting point (4,750 degrees F.). The other level of use is represented by the high-vacuum melting furnace, in which heat is supplied by induction coils around a center crucible and the vacuum maintained is in the region of one 100,000th of an atmosphere. At these pressures, gaseous impurities and other inclusions are literally pumped out of molten metals, while alloying elements may be added with considerable accuracy.

Vacuum metals have had an amazing rise in the past year, mainly through the research of such industrial entities as the Utica Drop Forge & Tool Corporation, General Electric, Westinghouse and two furnace developers, the F. J. Stokes Machine Company and the National Research Corporation. It all started out with the discovery that the vacuum furnace, used to melt uranium in the war program, could melt and conserve high-alloy scrap and, further, could impart improvements in properties to the original complex alloys used for critical jet-engine parts. By this method some special alloys only recently have been shown to have their strength increased by as much as 10 per cent at high temperatures. To get such increments as well as to explore others, nearly all the specialty steel companies and specialists in jet-turbine blades are rushing vacuum-furnace installations. Meanwhile vacuum melting is moving rapidly to other metals for other uses. The theory is that, by drawing out gaseous and other inclusions, a more continuous, cohesive crystal structure is provided for greater strength and other improved qualities. Thus metals for fine-drawn wire are much less subject to breakage after vacuum melting; special bearing steels develop fewer rejects and wear longer, and an experimental automobile-valve spring shows faster recoil for a free increase in horsepower.

Another example of the growth of vacuum melting is the Vacuum Metals Corporation, a 50 per cent interest in which was recently acquired by the Crucible Steel Company of America, with plans for large expansion. Vacuum Metals, a small subsidiary of National Research, built part of its business on the vacuum melting of high-purity copper, iron and nickel. Its copper, for instance, is held to 0.0005 per cent or less of oxygen and nitrogen, 0.0001 per cent or less of sulfur and phosphorus, and similarly small amounts of 13 other trace impurities. Such metals, also made by others, are now widely used for electronic tubes such as magnetrons and klystrons. One manufacturer reports that vacuum metals give such tubes increased performance and a 40 per cent longer shelf life.

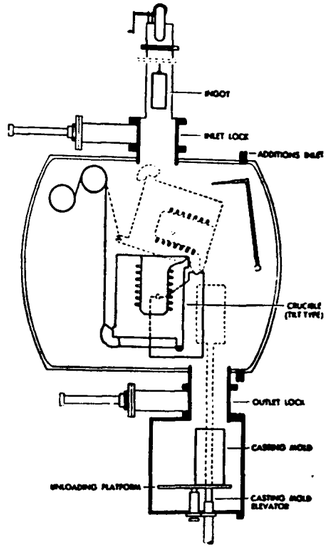
Such purity is nowhere near enough, however, for the metals going into the new electronic transistor devices, invented at the Bell Telephone Laboratories. Bell Laboratories, which has had as basic an interest in metals as any industrial research group, recently announced an entirely new process, developed by W. G. Pfann and K. M. Olsen, that raises the purity of industrial metals to a new frame of reference. By this process, germanium, the semiconducting transistor metal, is refined to a state in which almost no impurities are detectable by present analytical tools; then, by a reversal of the process, a minute impurity (antimony) is reintroduced evenly the extent of one part in 100 million to make it function as a transistor.

In the process, called zone melting, a long bar of the metal is passed slowly through a series of narrow heating zones, formed by induction coils. Only small portions of the bar are molten at one time. These molten zones travel along the bar and carry with them the impurities, leaving the pure metal to cool and recrystallize behind. As the impurities are swept into the last short section of bar, it is cut off and returned for chemical refining. In the reverse process, called zone leveling, a tiny "pill" of the desired impurity or alloy is implanted in one end of the bar and swept evenly through the metal by a single melt zone. Pfann arrived at the process after observing and mathematically analyzing a phenomenon long known to metallurgy: as an ingot or casting of metal cools, its impurities tend to move and segregate toward the top. This fact had been giving transistor men endless trouble as they searched for sections of germanium with the proper uniformity.

Zone melting, which closely controls the solidifying of the metal and the segregation of impurities, is a basically new idea with wide implications. Bell Laboratories is already working it into a number of production forms; it should be possible to use all kinds of heat and even chemical-reaction zones. Bell and others are using it to develop silicon metal for transistors and to explore purity in other metals. Bell hopes to get an answer finally to a question that has bothered it for years: why Chilean copper makes better rectifiers than any other copper in the world. By removing practically all impurities from a metal and then reintroducing them one by one, a new fool is made available for selectively analyzing the nature of primary metals and their alloys.

Still other techniques for handling or getting pure metals are under development. Westinghouse has done much work on levitating or float-melting bits of metal, heated and suspended in a vacuum between electromagnetic induction coils to prevent all contact with furnace walls. Now it is proposed to combine this with zone melting to solve the problem of melting titanium, not yet satisfactorily done, for titanium combines with its container even more rapidly in a vacuum than in air.

The Oak Ridge National Laboratory, interested in exploring new metals for reactor development, has been employing a novel means to get heretofore unavailable rare-earth metals. This is the mass spectrometer or calutron—used in making the original separation of uranium 235—an instrument that literally sorts out minerals atom by atom. By this means the Oak Ridge Laboratory has laboriously secured pound lots of pure cerium, neodymium, samarium and gadolinium.



HIGH-VACUUM FURNACE is rapidly developing as the most widely useful tool for the production of high-purity metals. Ingots, ranging from copper to the latest high-temperature alloys, are charged into the chamber through the inlet lock without losing the vacuum, and are melted in the crucible by induction coils. In the low pressure maintained, gases and other impurities are pumped out of the metal to achieve striking improvements in properties. The molten metal is then cast under vacuum, and removed through the outlet lock.

The physicist is not yet satisfied that he has anywhere achieved an absolutely pure metal, and he will not rest until he has refined metals purer still. It may be that, with the grossness of instruments for analyzing such vanishingly small inclusions in metals, he may never achieve a really pure metal or know that he has achieved it. But the National Bureau of Standards has finally been granted funds for an attack upon this basic problem. About the last thing industry could use would be such impossibly pure metals, for the indication is that they would be too soft for practical purposes. Nevertheless, the striving for purity in metals is already creating a whole new level of industry at the same time that it is expanding our basic knowledge of metals.

Bright Future Predicted for Vacuum Melted Metals in Chemical Industry

* By E. M. Mahla

PROCESSING procedures that can improve the useful property range of steels will be fostered by the chemical industry in order to extend the list of useful products or reduce the cost of existing products. Vacuum melting appears to offer promise by improving many properties of steels and is thus of current interest to the industry.

The benefit that is expected from these steels can be exemplified currently by three principal fields of interest. All appear to be associated with the essentially inclusion-free surface of these materials. They are: A—transverse fatigue properties; B—high quality surface for film casting wheels; and C—corrosion resistance.

It is difficult to say how much these fields of interest may be extended. There are indications that the transformation kinetics of vacuum melted SAE 4340 differ significantly from commercial 4340. It may be that wear resistance, coefficient of friction, or even the quality of welds in some specialized materials can be usefully modified by vacuum melting.

How do transverse fatigue properties enter into the picture? An important line of manufacture at du Pont and the chemical industry in general relates to products synthesized under very high pressures—up to 30,000 psi. The equipment involved in generating such pressures and handling process streams is subjected to severe fluctuating internal stresses. The fatigue failure of such equipment, particularly pump and compressor cylinders, constitutes a high maintenance cost item. The cylinders are expensive, each one representing fabricating and machining costs many times the cost of the base steel, and labor involved in replacement is great. Plants using such equipment are in continuous operation. Down time for replacement involves the loss of valuable production. When an interrupted process is restarted a certain amount of off quality product is unavoidably produced. Considering these factors, it is easy to see that the failure of a single pump or compressor cylinder containing of $ 200 to $ 1000 worth of steel can be expensive.

FATIGUE INVESTIGATION

In a series of fatigue researches[1] carried out in du Pont laboratories, the following was shown:

A—In laboratory fatigue tests on standard aircraft quality AISI 4340 steels failure of specimens cut transverse to the forging direction always nucleate at a surface non-metallic inclusion.

B—Transverse endurance limit, determined statistically by the staircase method on the same commercial AISI 4340 steel, was only 65 pct of the longitudinal endurance limit.

C—The transverse endurance limit of vacuum melted AISI 4340, having the same chemistry, the same forging reduction, and heat treated to the same strength level was 90 pct of the longitudinal endurance limit. In actual numbers, at a hardness of 28 to 29 Rc, the commercial steel had a transverse endurance limit of 0 to 83,000 psi, while the vacuum melted steel had a limit of 0 to 120,000 psi.

This difference in endurance limit of 37,000 psi is significant, particularly when it can mean the difference between infinite life and failure for an operating piece of equipment.

If the laboratory data can be substantiated in actual service tests the chemical industry would be justified in going to vacuum melted steels for high pressure equipment. It would be surprising if similar justification could not be obtained in many other applications for high strength steel where fatigue failure is a problem.

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Consider the case of high quality surfaces for film casting wheels. Film is continuously cast on large revolving wheels, stripped off, further processed, slit to useful widths, and wrapped up prior to use. Since film materials are usually liquid when cast, they rather faithfully reproduce the surface quality of the casting wheel. Any defects on the film decrease salability of the product.

Du Pont Co.'s extensive research on wheel finishing procedures continuously strives toward perfection in wheel surfaces. As an outgrowth of these studies, the laboratories developed techniques for surface finishing where the limiting defects in metal surfaces have become the non-metallic inclusions in the metals used for wheel fabrication. It has been shown that vacuum melted, corrosion resistant steel, essentially free of non-metallic inclusions, is a superior material for casting wheels. Unfortunately, large forgings for 40 in. diam. rolls on which to cast 36 in. film, or wider is still unavailable. It isn't difficult to imagine a large market for rolls having superior surface finish and extreme accuracy. It should be possible to produce superior foils, 0.005 to 0.0001 in. thick of a fairly wide variety of metals and plastics, if roll surfaces were sufficiently good.

Cylindrical surfaces are not the only considerations from the standpoint of surface finish. Many polymeric materials are extruded from flat dies with spaced lips. The manufacture of such extrusion dies is a tedious and costly process, requiring extreme geometric precision and superior surface finish. Imagine how frustrating it is to spend hundreds of man-hours finishing such die lips only to uncover gross non-metallic defects or even microporosity in the last few steps. In a case like this, how important is a cost difference in the base material?

CORROSION RESISTANCE

One of the most insidious forms of corrosion encountered in metal service is pit corrosion. In this type of corrosive action, localized areas on a metal surface are preferentially attacked. Corrosion may proceed until the entire cross-section of the part is perforated. Failure due to pitting is difficult to repair and usually results in discarding the equipment.

Laboratory research on pit corrosion, where the fine structure of stainless steels is studied relative to pit initiation, shows that non-metallic inclusions located in grain boundaries are the most likely sites for the initiation of corrosion pits. Unfortunately, for this discussion of vacuum melted steels, these are not the only sites of pit nucleation. It must be concluded that metals fail by pit corrosion whether or not they contain non-metallic inclusions in their surfaces. How much of an improvement inclusion free metals would afford relative to pit corrosion resistance, is unknown at this time. However, it is safe to expect metals to be measurably better under appropriately defined conditions. If a real tie can be established between surface non-metallics and pit corrosion resistance, the interest of the chemical industry in vacuum melted stainless alloys will be great indeed.

As a major consumer of metals, the du Pont Co. has a real and active interest in vacuum melted steels, based on research already carried out in its laboratories. It is clear that under appropriate conditions the transverse endurance limit of inclusion free, vacuum melted steels is significantly superior to that of aircraft quality steels. Under all conditions, inclusion free steels make superior casting wheels and rolls to those made from standard materials. There is evidence that pit corrosion resistance may be measurably affected by surface non-metallic conclusions.

All these facts, and many more open to speculation, such as heat treatment response and general corrosion resistance that could be affected by trace elements controlled by vacuum melting, make these steels of great current interest in research. Du Pont confidently expects to specify vacuum melting techniques for equipment as soon as the industry is able to supply it. It should not be construed that du Pont feels vacuum melting is the only way, or even the best way to obtain materials having low inclusion counts. Use of appropriate scavengers, coupled with proper processing control, may lead to the same goal by more economical means.

REFERENCE

[1] J. T. Ransom: Effect of Inclusion on the Fatigue Strength of SAE 4340 Steel. *Trans.* ASM (1954) *46*, p. 1214.

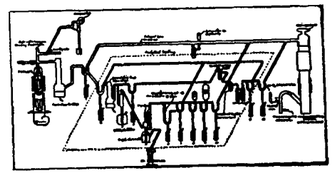
Metals Research Employs Vacuum-Fusion Techniques

A major factor in producing and refining metals is the analysis of gases which are picked up and retained. In some of the newer metals such as titanium, tendency to combine with the atmosphere gases is so great that the metal must be produced and melted under inert gas atmosphere or in a high vacuum. Even the more common metals such as nickel, copper, iron and many ferrous and non-ferrous alloys pick up gases from the atmosphere.

Effect of small quantities of contained gases in metals gains increasing recognition with progress in metallurgical research and development and the increasingly exacting demands of modern technology. In most metals, traces of oxygen, nitrogen and hydrogen produce marked effects on such properties as elevated temperature strength, ductility in tension and bending, general workability and electrical conductivity.

Determination of the gas content of metals, particularly oxygen content, has often been considered difficult. Method generally used now is the "vacuum-fusion" method, a technique dating back to about the mid-1920s. This technique has been modified and improved and its use has increased rapidly during the past few years, due, in a large part, to the concentrated effort being expended on development of titanium alloys. Control of oxygen content is especially critical in titanium metallurgy to determine oxygen content of the metal.

Use of the vacuum-fusion technique in other fields



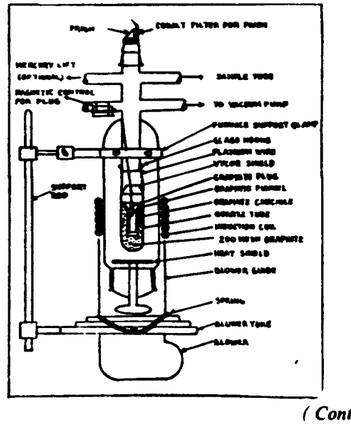
also is expanding in research and development where attempts are being made to relate gas content of metals to their physical properties.

Gas concentrations normally encountered range from less than 0.001 per cent for metals such as vacuum-cast iron, nickel and copper to 0.1 to 0.5 weight per cent for titanium alloys. Refinements in the vacuum fusion technique and apparatus will permit their use for still lower oxygen concentrations. Analysis can be completed in one hour (although average time required is usually greater), is reproducible and is accurate.

The technique, finding increased use for research work, is also being investigated for control and inspection of metal production.

Example of the effects of the vacuum-fusion technique is vacuum-cast bearing steels which have been found to exhibit improved fatigue resistance and can be used to produce high-stress bearings with greatly improved performance. Such steels also are used for the manufacture of precision bearings with fewer rejections due to inclusions and other defects. In the electronics industry, vacuum-cast metals and alloys are being employed in vacuum tubes, particularly power or transmitting tubes, because they offer less outgassing, fewer finished tube rejections and because both used—life and shelf life are increased.

Use of vacuum-cast metals has reached a point where Vacuum Metals Corp., a subsidiary of National Research Corp., Cambridge, Mass., manufactures and sells gas-free, high-purity metals and alloys on a commercial basis.



In most metals, nitrogen, oxygen and hydrogen can be determined from a single sample. For titanium, only oxygen and hydrogen values are presently considered reliable. Oxygen is held chiefly as combined metal oxides of one or more of the metallic elements present; nitrogen is present principally as nitrides, and hydrogen may be present in solution or sometimes as hydrides.

Vacuum fusion technique has come into common acceptance because, in a good vacuum and at temperatures generally above the melting point of the metal, metal oxides can be completely reduced by carbon to yield carbon monoxide; metal nitrides can be completely decomposed to give off nitrogen, and hydrogen can be quantitatively released.

For the vacuum-fusion technique, most widely used apparatus is a development of the National Research Corp. illustrated in the halftone and line sketch below. Apparatus has three essential parts: a pumping system for evacuating the entire system preparatory to conducting analysis; a furnace chamber in which the sample can be heated in the presence of carbon to evolve carbon monoxide, hydrogen and nitrogen and a mercury diffusion pump for transferring these gases to the third part, the analytical section, where the combined carbon monoxide, nitrogen and hydrogen are first measured then separately determined.

Furnace tube, illustrated below, consists of an air-cooled pyrex glass shell containing a suspended quartz tube inside of which is an insulated layer of graphite supporting a graphite crucible. Crucible is both a container for the melted samples and a source of carbon for reduction of oxides and nitrides. It is heated by an induction heating coil located outside the glass shell. Crucible temperatures run as high as 2400C during preliminary outgassing and are held at 1650-1900C during actual operation.

Evolved gases are circulated through an analytical train in the final or analytical section of the apparatus.

(Continued on page M.15)

HEAT FAST . . . BUT SAFE

By H. G. Grim,
Vice-President, Manufacturing, Heppenstall Company

Automatic program control cuts old 20-30 hour cycle of die block heating to 4 hours, maintains product uniformity, and reduces fuel use 20 percent

DIE block heating preparatory to quenching is no longer a critical 20 to 30 hour operation at the Heppenstall Company. A new, completely automatic program control process has cut 17 to 24 hours from the heating time for work loads up to 20 tons. Fuel consumption has been reduced 0 percent per pound of steel heated, and a costly expansion plan eliminated.

Additionally, this radical process has produced other benefits, such as improved overall plant efficiency, the ability to use less-skilled personnel to handle the heating operation, and a reduction of manufacturing costs.

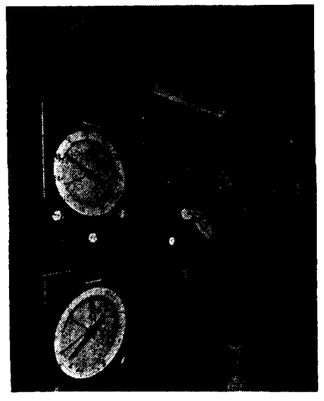
Heppenstall "discovered" quick heating when demand reached a point where existing facilities were no longer adequate. The company believed an expansion of production facilities was needed to keep pace.

As an alternative to expansion, they investigated the advantages of a Selas Corporation furnace using radiant heat regulated by Honeywell automatic controls. After some study, they felt this combination would enable the company to meet production requirements without adding additional furnaces.

PROGRAM CONTROL AUTOMATIC

The company purchased a furnace especially designed for die block heating to replace one of 13 furnaces in the line. The Selas furnace heats 38,000 pounds of die blocks—a work load equal to a single die block 16 inches thick, 36 inches high and 20 feet long—in only 3 to 4 hours. Large gas burners on each sidewall of the furnace assure uniform, safe and fast heating. Automatic program control is provided by Brown *Time-Pattern* transmitters and *ElectroniK* controllers.

There are two basic reasons why die block heating has always been considered a critical process. First,



Operator places required control cam, based on work load, on Brown *Time-Pattern* transmitter program controller at the start of a heat. The cam automatically resets the set point index of the work temperature controller to insure desired work temperature over a given period of time.

(Continued from page M.14)

By passing the gases over hot carbon oxide the carbon monoxide is oxidized to vapor and nitrogen is unchanged. Water vapor is removed with a drying agent or a trap maintained at minus 80C, carbon dioxide is removed in a liquid, nitrogen-cooled trap at minus 196C and the remaining nitrogen is measured in a McLeod-type gage.

Carbon dioxide then is released from the liquid nitrogen-cooled trap and the combined carbon dioxide and nitrogen is measured. Water vapor is carbon dioxide, hydrogen is oxidized to water determined by difference. From the measurements the quantities of oxygen, nitrogen and hydrogen in the metals can be calculated.

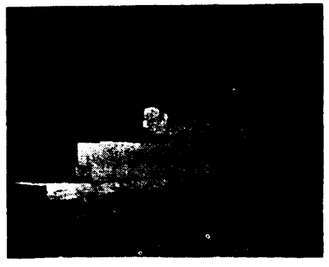
the alloy steels used are likely to crack if not heated uniformly. With conventional methods, uniformity can only be obtained by slow heating and soaking.

The second reason is that the steel sections are relatively large. Blocks processed at Heppenstall range from 8 to 40 inches thick. A block 66 by 24 by 18 inches and weighing 8,100 pounds isn't considered large.

Up to now, long-cycle operations employed heating rates of only 100 to 150° F per hour and soaking times of about one-half hour for each inch of average cross section. A typical heating cycle therefore required 20 to 30 hours based on work load size. All previous attempts to shorten the heating time in conventional furnaces produced cracked die blocks.

After installation, three blocks, 18 inches thick, 24 inches high and 66 inches long, were placed behind each other and put through the furnace on three test heats. These tests were made to determine if the blocks could take the high heat quickly without cracking, and to establish the best furnace and work temperatures and the heating cycle.

The ability of the furnace to cut the heating cycle was shown immediately. The temperature of the work surface was raised to the desired 1,550°F from room temperature in only 45 minutes. The center of the work load reached 1,550° F in only 4¾ hours compared to the usual 20 to 30. Laboratory tests failed to show any signs of cracks or other metallurgical defects.



A load of 15 die blocks, weighing 23,832 pounds, leaves the furnace and is ready for quenching after being heated for only 3¾ hours—a startling slash in the old 20-30 hour cycle. Automatic program control on the Selas furnace gets credit for upsetting an old idea about die block heating.

The heating cycle for full operation was determined by the temperature readings obtained from these test heats. Final adjustment of the set point index on the control instrument was based on readings obtained by six thermocouples—one on the surface and one embedded in the geometric center of each bloc. These temperature readings were co-ordinated with those of a *Radiamatic* unit sighted on the work.

As heat after heat of metallurgically sound die blocks was produced, even higher temperatures were proposed. The heat was increased and the work surface temperature raised quickly to 1,650° F, held there for a short time and then gradually lowered to 1,550° F. Temperature of the work center responded accordingly by reaching 1,550° F in 3¾ hours—one hour less.

BLOCK QUALITY NOT AFFECTED

This cycle has been in use ever since, with no adverse effects on block quality. The exactness with which test temperatures were reproduced permitted the cutting of cams in terms of work thickness to meet the heat cycle requirements.

In full production, the work load is pushed into the car-bottomed furnace. The proper cam, cut for the thinnest section of the load, is placed on the *Time-Pattern* transmitter.

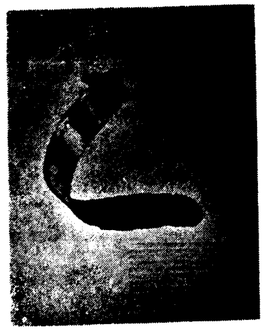
Temperatures throughout the furnace are sensed by the thermocouples and recorded by the Brown *ElectroniK* six-point strip chart recorder.

A 2 psig blower supplies combustion air while natural gas is regulated at 2½ psig. These are proportioned by fuel-air ratio control which operates the gas and air valves simultaneously. Gas pressure is regulated to maintain fuel and air at perfect combustion proportions over a wide range of burning rates. An unusually wide turndown (from maximum to minimum heat input) is provided to meet varying load conditions.

A Brown *ElectroniK* circular chart pneumatic controller records and controls work temperature sensed by the *Radiamatic* sighted on the blocks ; a second *ElectroniK* monitors furnace roof temperature, and functions as a high-limit safety cutoff should the work temperature controller fail for any reason.

When furnace temperature is equalized at the desired point, a back-set switch in the recorder starts

the cam drive motor of the transmitter. The pneumatic signal from the transmitter remotely adjusts the set point index of the work-temperature controller. This controller operates the diaphragm control valve in the gas line to the burners.



Conclusive evidence of the absence of any crack-forming tendencies of fast heating. The crack, previously formed in the die block, was not aggravated by the rapid heating cycle.

If, for any reason, the temperature should go too high, the controller which constantly monitors furnace roof temperature takes over as a safety device and closes the fuel valves until a safe condition is restored.

Overall fuel consumption is low compared to that of the adjoining conventional furnaces. In terms of cubic feet of gas per pound of work heated, the new process uses only 80 percent as much fuel as each of the other 12 units.

Around the clock production at Heppenstall has demonstrated that die block heating with automatic control can be both fast and safe.

The benefits from automatic control are four-fold:

1. Overall plant efficiency is improved because a close production schedule can be set up and maintained. Manpower and crane and quenching facilities are used effectively.
2. Less-skilled personnel can adequately handle the heating operation.
3. Minimum attention is required. Only about 20 minutes of the operator's time is needed over the entire cycle.

Die blocks get a thorough sonic test at Heppenstall to assure product uniformity. Rigid inspection and testing prove that high-speed heating maintains soundness of blocks.

4. Product uniformity is maintained.

In the early stages of production testing, Heppenstall metallurgists were not completely convinced that die block steels could take rapid heating. Their skepticism seemed to be confirmed one day when sonic tests revealed the existence of a crack near the surface in one of the hardened blocks. They machined off a chip and examined it. There was scale formation at the bottom of the crack, indicating that the crack had been formed prior to hardening.

This removed all doubts, because the metallurgists agreed that if the rapid heating method possessed any crack-forming tendencies, it certainly would have severely damaged an already cracked block.

These metallurgists are now convinced that high-speed heating, when applied uniformly and under controlled conditions, obsoletes the generally recognized concept of slow heating rates.

ALUMINIUM WELDING

Benford and Wagner, Associate Professor of Naval Architecture and Marine Engineering and Assistant Professor of Mechanical Engineering, respectively, at the University of Michigan, have tested Norwegian coated aluminium electrodes on standard American aluminium alloys. Tentative results show that (1) they give sound welds, (2) welding in restricted areas is easily accomplished, (3) welders are as easily trained as with mild-steel welding, and (4) welding under field conditions is much more feasible than with other welding methods. Tensile test specimens have shown weld strength equivalent to that of the parent metal.

Tellefsen, agent for ESAB, Oslo, manufacturer of aluminium-welding electrodes, points out that the Norwegian coated-electrode method of metalarc welding takes full advantage of the superior workability features of aluminium—ease of handling, speed of welding, a minimum of joint preparation, and a special finishing routine. This permits labour costs to be cut to the extent that the overall cost differential between aluminium and steel is largely eliminated. He claims that, *in spite of all* the good that can be said for inert-gas shielded welding, Norway is increasing her lead by leaps and bounds. Inert-gas welding equipment is too cumbersome and too expensive to be used for purposes of practice. Coated electrodes used with an ordinary D.C. welding machine are far handier and will as a rule afford the welder more experience in one month than he could get in a year with inert-gas equipment. By this is meant experience with a variety of situations as encountered in ship work which must be done quickly without interfering with other workers.

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