EXHIBITIONS FEATURE ALUMINIUM WITH PLASTICS

LIGHT METALS

NOVEMBER 1945

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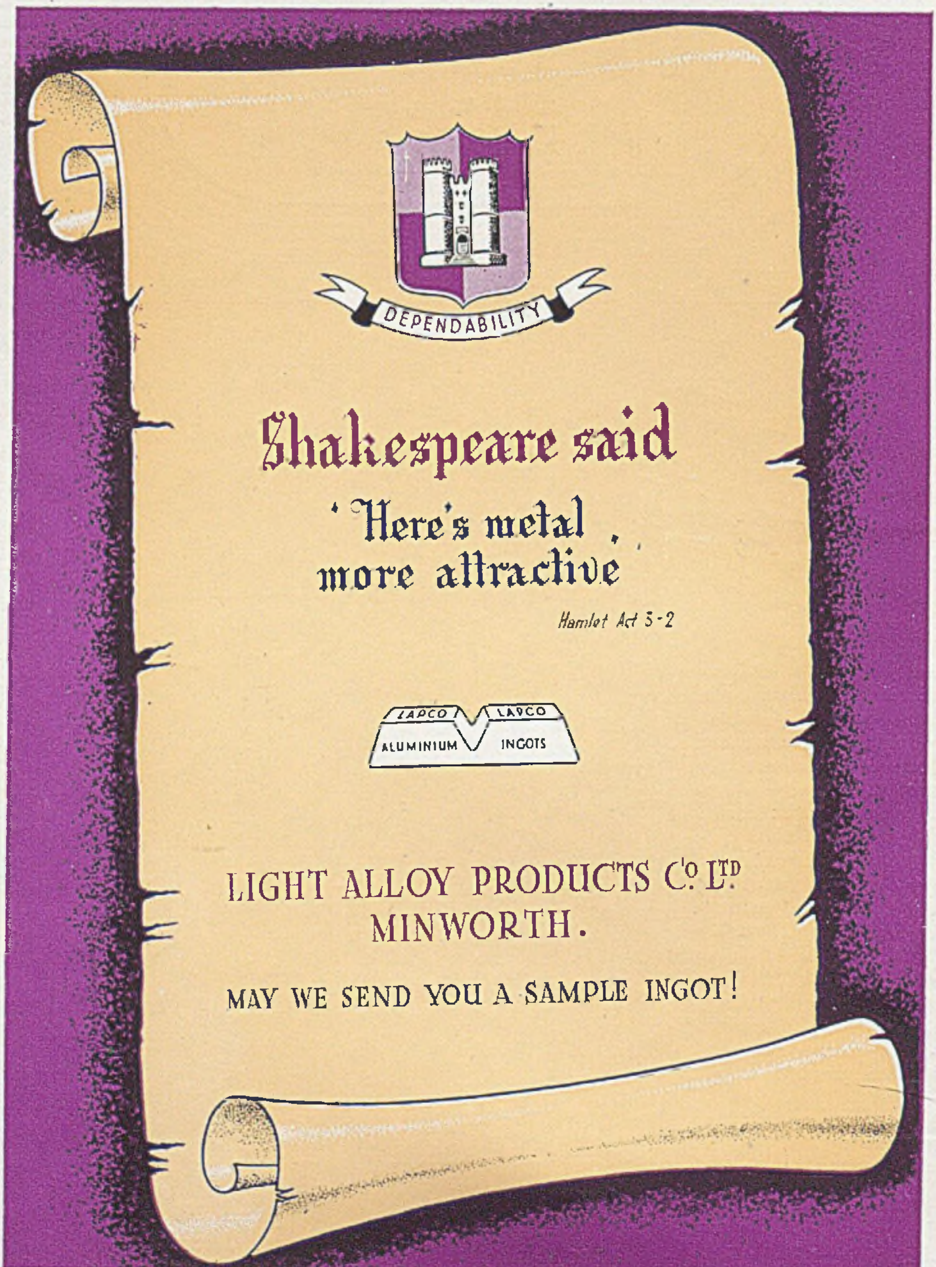
DEPENDABILITY
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'Here's metal more attractive'
Hamlet Act 3-2
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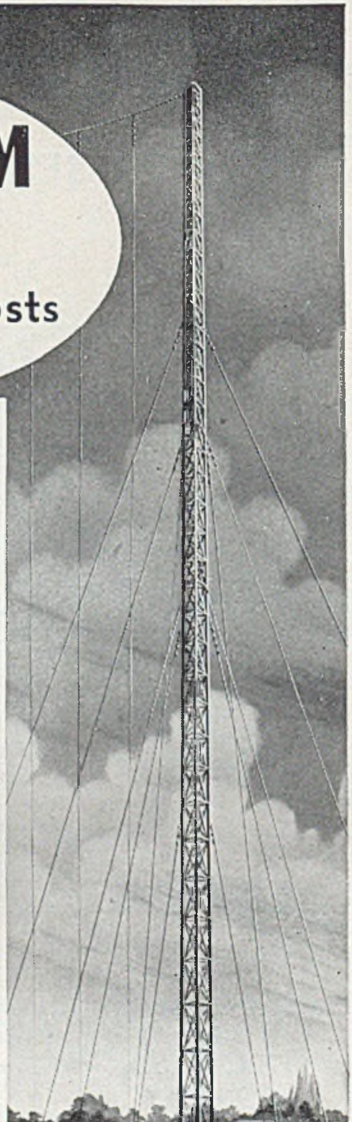

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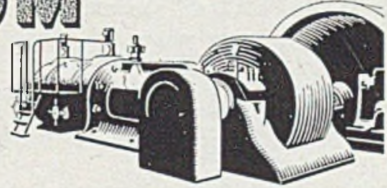

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STEAM FOR PROCESS AND HEATING
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A simple introduction to the properties of steam leading to a more critical understanding of the steam tables.

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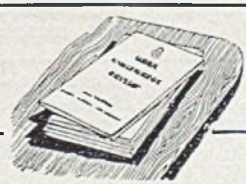
The practical side of steam engine operation : how to get the most power from the least steam. What the indicator diagram is and what it means.

Few people know how interesting steam can be until they have had to learn about it. These bulletins make the learning easy. If you haven't all the copies you require, they can be obtained free on demand from the Ministry's Regional Offices.



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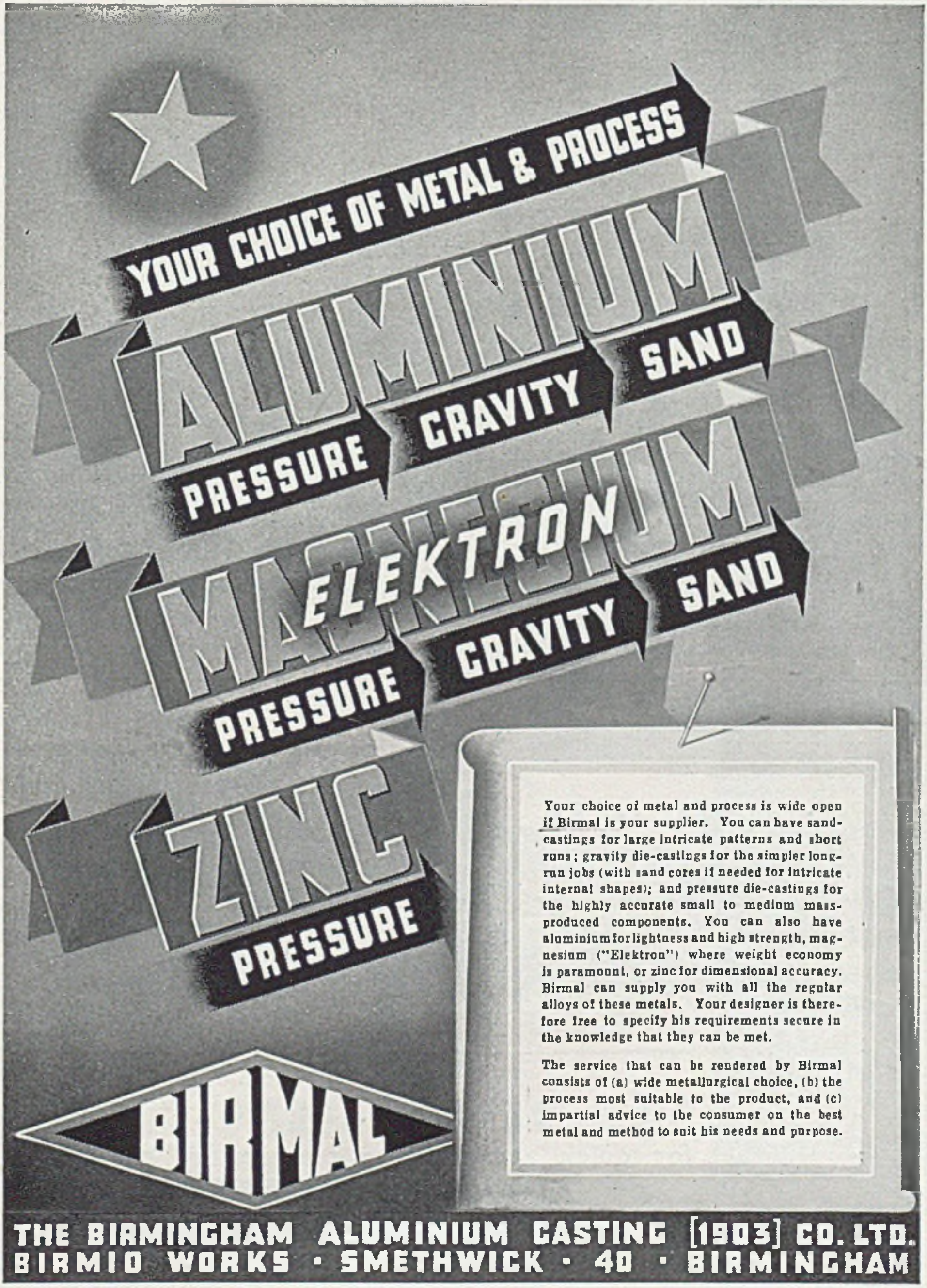
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PRESSURE
GRAVITY
SAND
MAGNESIUM
ELEKTRON
PRESSURE
GRAVITY
SAND
ZINC
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Obviously aluminium alloys which can withstand such high stresses are of great engineering value. What we have achieved indicates clearly that aluminium and its alloys have entered new fields and made new technical advances possible. *You are invited to write to our Technical Development Department for information*, and they will gladly help you with any engineering problem.

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LIGHT METALS

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Dealing Authoritatively with the Production, Uses and Potentialities of Light Metals and their Alloys

Editor:
E. J. GROOM, M.Inst.MET.

Offices:
BOWLING GREEN LANE, LONDON, E.C.1

EDITORIAL OPINION

What is Truth?

JOURNALISTS, to their cost, lawyers, to their profit, know all too well how labile a quality is truth. Roughly handled, or badly adjusted in time and space, it may suffer most unexpected allotropic changes and stand out as the very antithesis of itself.

Students of the humanities are familiar with this potentiality and, to quote but three instances, recognize, as a matter of course, fundamental differences between the historical, religious and scientific aspects. Of these, the last is the most deceitful. "Home truths," popularly considered as a distinguishing type, are not admitted as a distinct class in logic or ethics.

Violent and undignified quarrels arose in the latter half of the nineteenth century between two groups of schoolmen, one faction seeking to sustain the older interpretation of truth, the other doing its level best to torpedo tradition with the, then, newly forged weapons of science. Both sides erred, but, in any case, in spite of oratorical clamour and a shocking waste of ink and paper, the country, as a whole, was not seriously disturbed. Industry and commerce plugged steadily along, growing more powerful as they became more adventurous. Improved plant, novel techniques, and an ever-increasing range of new materials offered themselves for exploitation; there was lots of "rule of thumb" (too much then, perhaps), but the prizes to be gained by speedy satisfaction of wider public demands more than outweighed the losses entailed.

To-day, the struggle has terminated; humanism is vanquished and the age-old dictatorship of letters threatens to be supplanted by that of the exact sciences and their near relative—technology.

Despotism, however benevolent, can, at the last, rarely prove anything but an enervating force. The pinpricking tyrannies of our medical and legal systems (not, be it observed, of the basic sciences themselves) have, for many years, provoked growing irritation, and the latest exploit of atomic physics, whilst inspiring world awe, has not elevated that abstruse cult in public esteem. Only at our peril can we permit this degree of unbalance to grow, for, as it does so, so is the broader spirit of experimentation constrained to follow the dictates of convention; outlook becomes "stylized." Unless duly tempered to meet the various requirements of individuals, scientific and technological truth, so strong a force for good in the hands of a master, may, in the hands of underlings (whatever their qualifications, training and experience), usurp powers to which it can never be entitled. We direct an attack, chiefly, against the plausible and ill-timed use of systematic terminology and scientific generalization.

The bedside manner of the physician and surgeon furnishes a concrete example of the recognition of a human need which might well be catered for by the technologist. Were this so, we might receive fewer anxious inquiries, such as "Do you think I shall damage my aluminium sink if I pour green-water down the drain? You see, I always put soda in my cabbage." Or this one—"Good heavens! a magnesium frying-pan, but the confounded thing will flare up, surely, if you try to fry a kipper in it?" And yet another—"You know, I am quite worried. I listened the other day to somebody giving a lecture, and he said quite definitely that electro-plated aluminium could not be recommended. He spoke some rot about 'bimetallic corrosion.' I'm beginning to wonder whether that chromium-plated aluminium coffee percolator I've been using for the past 10 years won't suddenly drop to pieces."

You've heard it all before, haven't you? Yes, and a thousand other idle neuroses, all the outcome of "careless talk" by well-meaning technicians unaccustomed to dealing with humanity outside the limits of their own laboratories. We had a telephone call the other day from somebody knocking out picture books from scrap duralumin sheet: said he, "I've noticed that the stuff cracks up if I close the book tight. It's all right, I suppose?" To which we replied: "Did you ever hear the story of the old lady who complained to her doctor of singing in the ears when she tried to stand on her head? You know it? Good! Then why close those books up tight?" Next time, too, somebody reads a paper on aluminium before the Fish-slice Makers' Guild, and rambles off about the modulus of aluminium being one-third that of steel, we're going to scream!

Supposing that, in future, moduli be left for the heavy-engineering fraternity, bimetallic corrosion for the chemical engineers and shipbuilders, and absolutely pore-free castings for those who want them? The bulk of the metal users of this world require a material that works easily, looks good, satisfies their customers, and does what they want it to do. In aluminium they've got it! If sheet develops pimples after it has been sold, then let the doctor be sent for, otherwise, good soul, he should be encouraged to pursue the theory and practice of metallurgical eugenics and pathology in decent privacy.

Contents

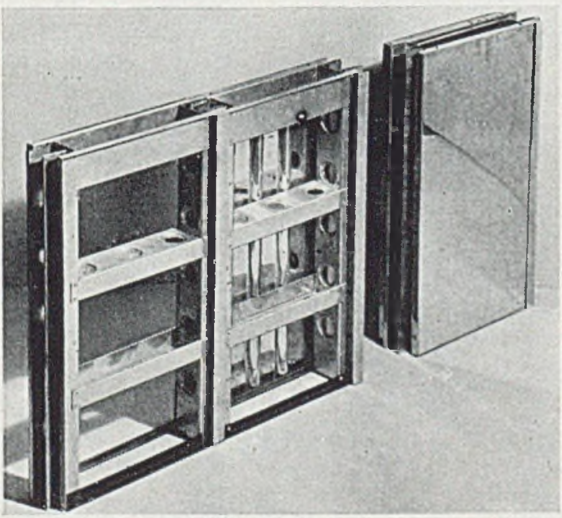
"*LIGHT METALS*" *is published in London, England, on the fourth Thursday of the preceding month.*

SAVE PAPER.—Waste paper is still required to manufacture into a thousand forms for our Navy, Army and Air Force overseas.

Aluminium with Plastics in Building

Presenting a Brief Discussion on Domestic and Building Units Shown at a Recent Exhibition in London. These are Characterized by the Combined Use of Plastic and Light Metal, each Material being Employed in that Capacity to Which it is Functionally Best Suited

DURING the war years, as is well known, production both of light metals and of plastics increased enormously; simultaneously, new and improved techniques for their manipulation were developed. Now, not only raw materials but experience also is available to the building industry.



THE "Alpla" panel wall unit, a prefabricated frame made from plastically coated aluminium alloy and comprising vertical male and female interlocking members. The distinctive features of the locking column are: it is light, extremely rigid and easily and quickly assembled by unskilled labour; it forms an integral part of the framework of a house; although the components can be placed together for assembly at an angle, when locked together; the parts fit in dead alignment; joints are made without the use of any form of studding or bolts; contraction in the complete member due to expansion of the panels can easily take place, as the lock is so constructed that it "breathes" with variations in panel temperature; the member is impervious to weather; the covering strips assure neat and clean locking joints.

At a private exhibition held recently at No. 3, Vere Street, London, W.1, by Runcolite, Ltd., and Industrial Plastics, Ltd., exhibits were staged demonstrating not only the individual potentialities of light metal and plastics, but, furthermore, designs were shown illustrating the most practical and practicable combinations of the two. Each was shown employed in a manner best suited to its own practical range of properties If, here, we concentrate on the light metal aspect, it is merely because that is our immediate concern; the purely plastic exhibits were none the less worthy of closest examination.

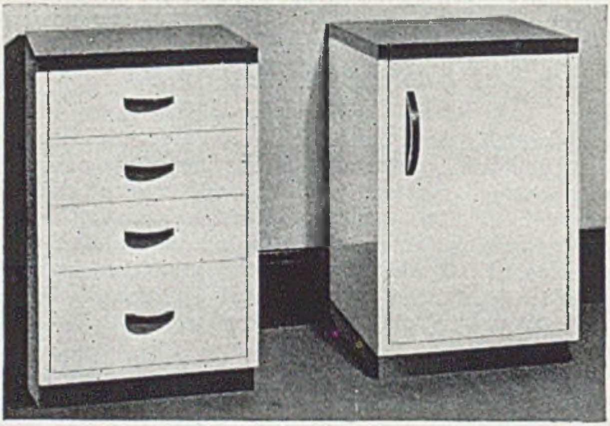
In elaborating a scheme for the metalwork shown at the exhibition, complicated methods of production were eliminated from the very outset. It is interesting to note that the basis of by far the major portion of the work consisted of sheet used as such, or in the form of rolled section. Press tools, at present the cause of one of the chief bottlenecks in the output of aluminium components, were not required.

Simple designs were chosen, easily adaptable to any modern house. For example, panel units for both outer and inner walls, fittings, furniture and equipment were all such as to be capable of mass production at competitive prices. We were given to understand that many of the items exhibited will be immediately available. The design of the exhibition was due to Mrs. G. Schreiber, N.R.D., whilst W. Cookson was responsible for much of the technical development involved in connection with the sheet metal.

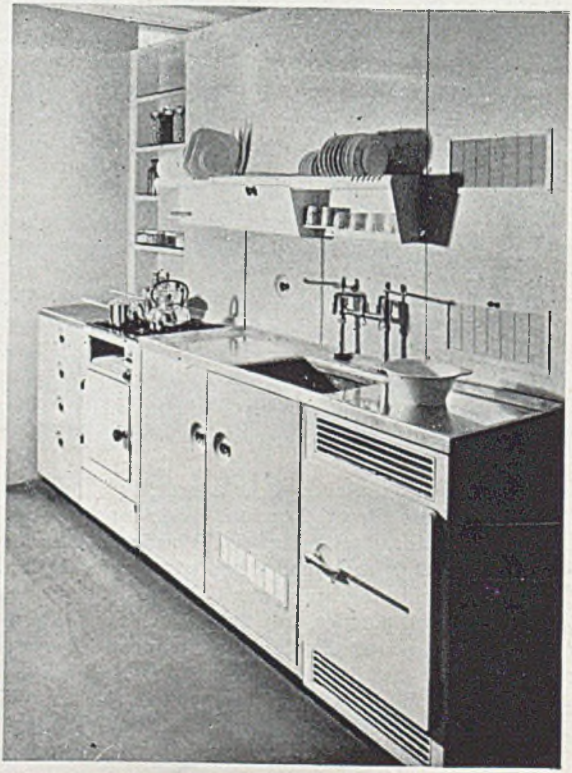
Whilst the exhibition gave special emphasis to the importance of plastics in relationship to housing, the new materials shown were no less applicable to the post-war plans of the shipbuilding industry and railways. For example, prefabricated partition walls are indicated as ideal both to the conversion of war-time transport into passenger liners and for the construction of new railway coaches.

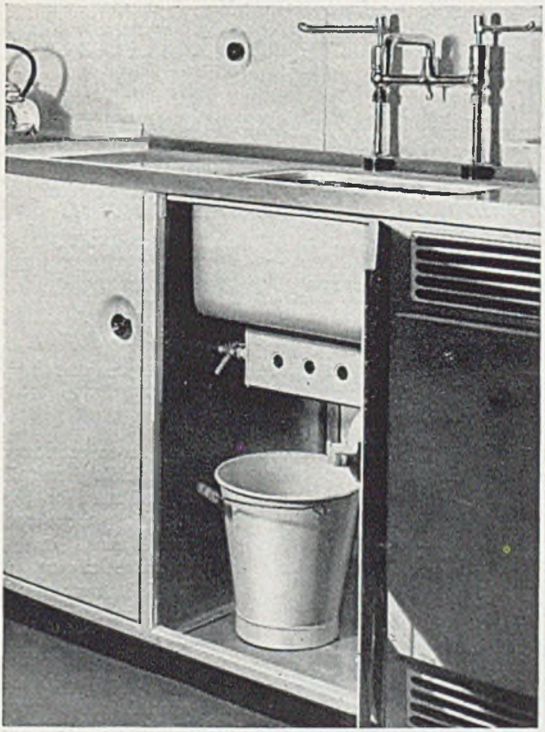
Colour was one of the outstanding features to be observed, and those interested in the surface treatment of light metal found here the answer to many problems not only as regards corrosion protection but also for purely decorative purposes. The new "Plastoglaze" finish and both stoving and air-drying Cerrux finishes (Cellon, Ltd.) were used.

One of the most interesting developments to be seen was the "Alpla" prefabricated wall panel unit (International Plastics, Ltd., Light Metals Division). This panel is made in the form of cavity units with lining on both sides, and a number of them can be clipped together



SHOWN at the left are a small chest of drawers and cupboard, the body of which is, in each case, fabricated from light metal sheet, together, in the first instance, with drawers also made from aluminium sheet. The top consists of a single heavy plastic moulding. Shown below is an aluminium-and-plastic kitchen assembly finished in turquoise blue. The sink, which is of stainless steel, has a heating unit below it, and, with an Ascot water heater, is fitted into an assembly of aluminium panels, cupboards and drawers, etc.





GAS-HEATED sink shown at the Runcolite Exhibition. This unit is so constructed that it may be used as an ordinary boiler for clothes washing, fruit bottling, etc. It is fitted with an extractor and has a close-fitting lid so that, when used for laundering, steam does not escape into the room. A wringer is housed in a wall recess behind the left-hand draining board. Knobs on all the fittings in the kitchen are recessed to avoid accidents to clothes.

by a patented device which unlocks them in a few minutes, thus avoiding the elaborate but usually unsatisfactory systems of studding and similar methods. These panels may be erected by unskilled labour, and are so readily handled that two women can erect a 9-ft. partition wall in two minutes; plumbing units may be incorporated in this system.

An exhibit of special interest was the kitchen and bathroom unit showing the ideal combination of plastic and aluminium, designed for simple and speedy production at a very moderate cost. The walls illustrated the "Alpla" method of construction, specially adapted to allow the installation of a prefabricated plumbing unit which included all the essential services. Panels on the bathroom side could be rapidly removed to give access to the plumbing unit. Minor access doors were similarly constructed.

The kitchen consisted of separate units which are interchangeable and can be chosen to suit individual requirements, and includes double draining boards of aluminium, and a wringer which fits into a wall recess, and is covered by the lid of the sink when not in use.

Other features of the kitchen were—cupboard and drawer units of aluminium covered with plastic skin, rendering them resistant to corrosion and condensation, and very easy to clean; plate racks and hanging cupboards of new and attractive design; a modern gas-cooker and gas-operated refrigerator, forming part of a smooth level working surface; fittings specially designed for speedy assembly and with locking clips to avoid the necessity of fixing nails and screws into the walls.

The base and interim shelves in the plastic kitchen, too, are made from aluminium, and are coated with a coloured plastic skin to match the remainder of the plastic superstructure.

The research department of the British Artificial Resin Co., Ltd., under the direction of Dr. V. Yarsley, has developed building board proved to possess good resistance to moisture and fire, and which can be manufactured with paper veneer and aluminium facing. A skin of "Plastoglaze" renders such boards suitable for use in kitchens and bathrooms. The outstanding advantage of the material is its cheapness and suitability for mass production.

Aluminium in the Coal-gas Industry

Concluding from "Light Metals," 1945/8/522, a Survey of the Theory and Practice of the Use of Light Alloys in Coal-gas Production and Consumption. Special Attention is Directed to the Stability of Aluminium in Contact with the Chemicals Produced during Manufacture and Processing of Coal Gas, and to the Eminent Suitability of Light Metals for those Branches of the Food Industry employing Gas Heating

ANOTHER important feature of the light alloys is the range of alloys and purities of unalloyed metal which are available. Perhaps the most important advance in the field of chemical engineering in recent years has been an appreciation of the importance of using the right material in the right place, and the aluminium industry has catered for this requirement by producing a range of materials each with individual characteristics which ensure the maximum performance under specified conditions. Thus, there are available alloys of high rigidity; those combining strength with corrosion resistance; material particularly suitable for welding or for machining, in the last case, due to the production of brittle chips; unalloyed metal where softness and low mechanical properties can be tolerated, but where resistance to chemical attack or just economy in first cost is desirable; and metal of super purity where exceptional resistance to chemical attack is required. Even in the last case, some choice may still be exercised by the availability of clad materials in which a thin sheet of super purity metal is backed by an aluminium alloy or by unalloyed aluminium of lower purity to combine the exceptional chemical resistance of the super purity facing with those characteristics of strength or economy which are peculiar to the backing metal. However good or however bad may be the results obtained from the indiscriminate choice of material, better results may be achieved only by the careful selection of the best type of material in its most suitable form, having regard to all the conditions of fabrication and use.

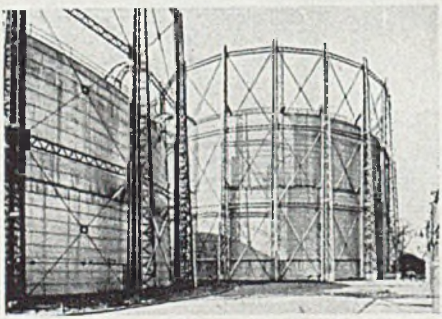


Fig. 1.—The value of aluminium paint for the protection of steel work against atmospheric corrosion in the most adverse circumstances has now been established for many years in practice. Shown here are gas holders treated in this way.

Aluminium and its alloys are among the most easily fabricated of metals. They may be cast in sand or metal moulds, pressed, stamped, rolled, drawn, spun, machined, and welded with ease. These factors alone sometimes dictate the choice of aluminium when complexity of design would make fabrication in another material impossible or, at least, of much greater difficulty. Particularly concrete instances have occurred in the automobile industry where the use of aluminium has greatly simplified the fabrication of experimental cylinder heads of exceptionally complicated design. In other cases, this ease of fabrication may result in lower production costs; automobile cylinder heads for standard motorcars, for instance, have been known to cost less in aluminium alloy than in cast iron in spite of the greater raw material cost of the light alloy.

Another point which must not be overlooked in considering the cost of aluminization is the high scrap value of the light alloy. Thus the initial high cost of raw material for plant constructed in this material is, to some extent, compensated by the high scrap value of the plant after it has come to the end of its useful life.

In many applications in the gas industry, the high heat conductivity of aluminium is of importance. Heat is transmitted through aluminium at a rate which is four to five times as rapid as through an equal thickness of iron or steel. On the other hand, when used for the casing of heated equipment, the low emissivity of the metal reduces radiation losses. Thus, for boilers and ovens, the use of aluminium conserves gas consumption and, in gas illuminating burners, the metal makes for the more rapid dissipation of heat and assists in keeping the appliance cool.

Not the least important attribute of aluminium, at least, in relation to its application in domestic gas-consuming appliances, however, is the facility with which it may be finished in a variety of decorative effects. Polished aluminium is equal in appearance to a plated finish and can be kept bright with little trouble; occasional washing with warm, soapy water is all that is required to keep the surface in good condition. Other decorative effects may be produced by sandblasting, scratchbrushing and by various methods of frosting. The production of dyed anodized finishes which are fast to light, resistant to washing, hygienic and free from chipping and rusting has opened up new vistas which the manufacturers of domestic gas-consuming appliances are now in process of investigating. At the aluminium exhibition, for example, were to be seen a "Renown" gas cooker with aluminium panels and top finished an ice blue. The same colour was used to finish the aluminium shell of the Ewart "New Empire" multi-point gas-operated water heater, whilst other exhibits, notably a gas-heated wash copper, illustrated the pleasing effects to be obtained by the use of polished and frosted surfaces, both in the natural silvery colour of aluminium and in coloured finishes. The modern kitchen is crying out for attractive and coloured finishes which must, however, be permanent and easy to clean, and it would seem that, in this sphere, aluminium has much to offer to the modern home. Incidentally, encouragement in this direction may be drawn from an account, presented in the opening pages of this issue, of a recent private exhibition featuring light metals in combination with plastics.

The Place of Magnesium in the Gas Industry

Before proceeding to a detailed review of the applications of aluminium and its light alloys in the gas industry, it is of interest to pause to consider the place in this industry of the ultra-light alloys. In the matter of availability, they do not fall a long way short of aluminium and its alloys, although there are a few serious gaps in the alloy range yet to be filled and there is nothing comparable to super purity aluminium. Fabrication is also fairly simple, but raw material cost is higher than aluminium. So far as corrosion resistance is concerned, magnesium and its alloys are somewhat loth to form protective films, and although no work appears to have been carried out on the effect of the materials met with in the gas industry on massive magnesium and its alloys, it is unlikely that resistance would be satisfactory. According to Beck,[2] the ultra-light alloys are resistant to sulphur, ammonium sulphide, carbon bisulphide, hydrocarbons and crude tar, but are attacked by aqueous solutions of sulphates, ammonia and nitrous gases.

The density of the magnesium alloys is, however, lower than that of the aluminium alloys, and it is on this score alone that magnesium can make any useful contribution to the efficiency of the gas industry. That they have a potential value in this field is described in greater detail later in this article.

Applications of Aluminium in the Production of Coal Gas

Coal gas is produced by the destructive distillation of coal in fireclay or iron retorts provided with air-tight doors and heated by means of producer gas. Under these conditions the coal undergoes very complex changes and yields a great variety of volatile products which may be gaseous, liquid or solid, together with a non-volatile residue of coke.

In the older method of production these retorts are arranged horizontally in banks and the gas evolved passes by way of vertical ascension pipes to a long, horizontal hydraulic main which serves as a water seal and prevents gas passing back when the retort is opened and the coke is removed. In this hydraulic main, the gases are cooled and partial separation occurs into crude gas, ammoniacal liquor and tar. The crude gas leaving the main is at a temperature of about 80 degrees C. and it is at this stage that massive aluminium comes into the picture.

The crude gas contains as major impurities:—

Tar in fair quantity,

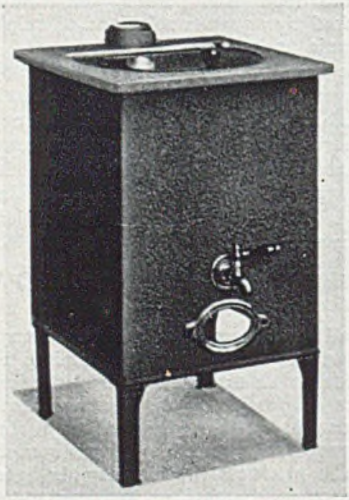
Ammonia, about 1 per cent. by volume,

Sulphuretted hydrogen, about 1.3 per cent. by volume,

Hydrogen cyanide, about 0.1 per cent. by volume,

Carbon disulphide, about 0.03 per cent. by volume,

all of which should be removed. The hot gases pass first through a series of iron pipes or condensers kept cool by immersion in water, by simple exposure to the air or sometimes by exposure to the air supplemented by intermittent or continuous spraying with water. As the temperature of the gas falls, more tar is separated, together with ammoniacal liquor, and the two are collected in the tar well from which they are run into a large tank for further treatment.



The gas next passes through a special tar separator and then on to the washer or scrubber, where the bulk of the remaining ammonia is removed by solution in water The old design of washer comprised an iron tower packed with coke or with wooden sieves down which water slowly trickled. Being countercurrent to the upward flow of gas, the lower concentrations of ammonia were met by a more dilute aqueous solution of the gas and, as ammonia is extremely soluble in water, removal of this gas was substantially complete. Modern plant, however, employs scrubbers of a very different kind consisting essentially of a casing partly filled with water in which is mounted a series of plates in bundles mounted on a slowly rotating shaft. These bundles of plates pick up the washing liquor from the trough of the scrubber while the gaseous mixture is directed across them by means of suitable baffles so that the aqueous surface exposed to the flow of gas is very large and

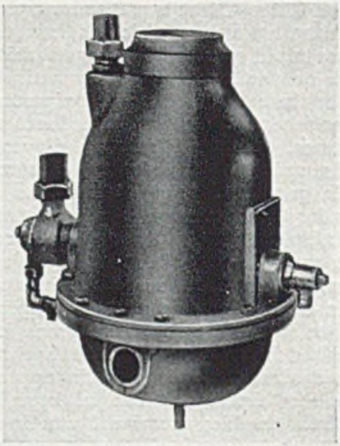


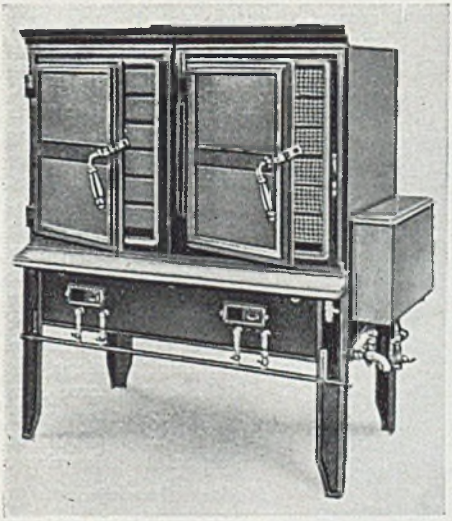
Fig. 2 (left).—The Slackson "Nu-Square" gas copper. The boiler top is of cast aluminium. The copper, as shown here, is not provided with its table top. Fig. 3 (above)—The "Magic Hurro" gas heated hot-water circulator. The heating coils and other components of this unit are fabricated from light alloy.

the separation of ammonia achieved is highly efficient.

Wood or galvanized iron are the usual materials of construotion for these plates, but in modern plant, corrugated aluminium sheet is finding increasing favour for the purpose. The main advantage to be obtained in this way is an increased life for the unit due to the small corrosion of the aluminium sheet, but a further point of importance is that, due to the lower weight of the aluminium bundles, more plates can be packed per unit length of shaft without increasing the power available.

At one or more stages of the purification line, exhausters and pumps are installed to facilitate the movement of the gases. In many plants aluminium alloys have replaced other metals in the construction of these exhausters and compressors because of the superior corrosion resistance of the light metal and the correspondingly longer useful life of the unit. The rotors of these compressors are made completely of light alloy, the hub consisting of a high strength aluminium alloy casting, whilst the vanes are made of a wrought light alloy, generally of the duralumin type. These rotors have been found to resist the action of the gas itself and of the condensates of sulphuretted hydrogen, ammonia and hydrogen cyanide which tend to form in the compressor.

Along the purification line, too, doors and



covers which are exposed to the action of the gases at temperatures up to about 100 degrees C. have been made of aluminium with beneficial results. Schwerber[3] reports that, in long term tests, doors and covers of aluminium remained unattacked, whereas heavy metal doors in comparison tests were completely destroyed after six months' use. It is also confirmed that aluminium is unattacked by ammoniacal liquor and that in experiments on aluminium immersed in ammonia solution of 5 degrees Bé, the metal remained unchanged; it was also unattacked after eight months' exposure to cyanide residues.

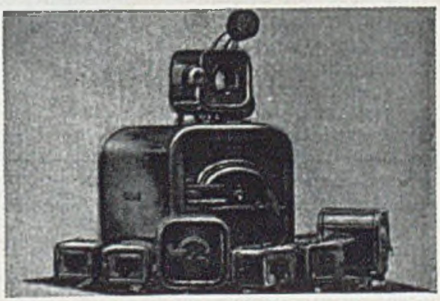
Cyanides, which are of value, are removed by passing the crude gas through a washer containing ferrous sulphate and alkali, when ferrocyanide is formed. In this process, the advantage of using aluminium is doubtful and, in fact, is not to be advised in view of the presence of caustic alkali. An alternative method of removal, however, in which light alloys would probably give better service than most other available materials, involves the use of ammoniacal liquor containing ammonium sulphide and powdered sulphur in suspension (ammonium polysulphide). Under these conditions a solution of ammonium thiocyanate is obtained:

$$(Nh_4)_2S_2 + NH_4CN = (NH_4)_2S + NH_4CNS$$

The Purification Train

The scrubbed gas now contains as major impurities only carbon dioxide and sulphur compounds, chiefly sulphuretted hydrogen and a smaller amount of carbon disulphide, together with benzole and other by-products, and a purification train is installed to recover the by-products and to remove the sulphur compounds which would otherwise form very objectionable fumes of sulphur dioxide in combustion. The gas is accordingly directed into purifiers where it passes over trays or grids packed with hydrated ferric oxide. This oxide of iron decomposes the sulphuretted hydrogen with the formation of ferric sulphide. "Spent oxide" is

Fig. 4 (left).—Double steaming oven with aluminium casing and trays in perforated light alloy. (Courtesy Fletcher Russell and Co. Ltd.) Fig. 5 (below).—Soldering stoves and muffle furnaces with aluminium alloy end castings and sheet aluminium casting. (Courtesy Selas Gas and Engineering Co. Ltd.)



"revivified" by exposure to the air when sulphur separates and the hydrated ferric oxide is re-formed. It has been suggested that beneficial weight reduction and a lighter structure would be obtained by making these grids of perforated or expanded aluminium.

Originally carbon disulphide was removed by passing the gas through "foul lime," that is to say, through lime previously used to remove sulphuretted hydrogen, when a thiocarbonate is formed:

$$Ca(SH)_2 + CS_2 = CaCS_3 + H_2S$$

The sulphuretted hydrogen formed was removed in a second purifier. However, this method is no longer practised and, in view of the small amount of carbon disulphide usually present, it is generally left in the gas. Occasionally it is removed by a catalytic process in which the gas is passed over nickel at 450 degrees C., sulphuretted hydrogen being formed and removed by passing over hydrated iron oxide:

$$CS_2 + 2H_2 = 2H_2S + C$$

In the catalysis chambers, where contamination of the catalyst by heavy metals must be avoided, aluminium is a very suitable material of construction.

The next stage is to remove certain valuable by-products, chiefly naphthalene and benzole, and this is carried out by drawing the gas through oil washers. It is then dried in a calcium chloride chamber and passed through the station meter to the gas holder. For the various parts of the meter, aluminium is a valuable choice of material. Being light in weight, the rotor of the meter revolves more freely on its bearings and the absence of corrosion products ensures that the operating parts are always free to move. In the calcium chloride dryers, aluminium sheets may be used conveniently and efficiently as described above in the case of the ammonia scrubbers.

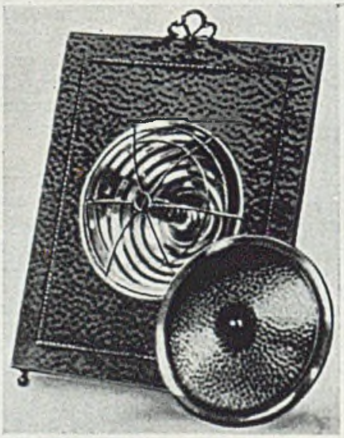


Fig. 6.—Bowl-type portable gas fire incorporating a metal surround. Aluminium, both plain, and anodized and dyed, is very suitable for surrounds of this type, whilst reflectors of polished aluminium maintain their efficiency even under the adverse conditions existing here.

The gas holder is either a counterpoised iron bell sealed below with water or else an iron tower with a movable piston sealed by flowing tar. To prevent re-wetting of the oil, the water in water-sealed gas holders may be covered by a film of suitable oil. So far, the gas holder has not been made of aluminium. Although there is much to be said for this application, the cost would inevitably be high, and it is common practice to use steel which, however, is given a surface as close as possible to an aluminium surface by means of aluminium paint. Aluminium paint differs from ordinary paint in that the colouring medium is metallic and in the form of flakes, which, under the action of surface tension, orientate themselves parallel to the surface of the paint film, thus providing a continuous sheath of overlapping aluminium flakes. The protective effect of such a coating is very much greater than that of an ordinary paint coat, and the bright surface reflects heat and light, thus tending to maintain a uniform temperature of the gas. Of course, aluminium paint has not the corrosion resistance of massive aluminium, but there is no doubt as to its superiority over common organic coating compositions.

The red-hot coke remaining in the horizontal retorts is discharged by machines and quenched in water. Sprayed-on coatings of aluminium have been employed with much success to protect the iron and steel parts of the coke discharging machines and the coke quenching trucks from high temperature oxidation. Schwerber[3] suggests that massive aluminium would prove as suitable for the purpose, but some care would need to be taken in design to ensure that thin sections of metal did not come into prolonged contact with the red-hot coke, or fusion might take place.

Modern Developments

Modern coal gas is often admixed with water gas produced by blowing steam over red-hot coke:—

$$C + H_2O = CO + H_2$$

whereby the percentage of carbon monoxide in the gas is increased. This procedure has been simplified and the batch operation of the horizontal retorts, necessitated by the operations of unloading the coke and recharging with coal, has been converted into a continuous process by the introduction in recent years of large vertical retorts built of silica brick. In these retorts, coal is fed in continuously at the top and coke removed at the bottom, while steam is introduced at the base of the retort to form water gas, which passes through the rest of the plant in admixture with the coal gas. In these vertical retorts, aluminium flue pipes have been found to possess a very long life[3] in spite of the high temperatures involved and the strongly corrosive nature of the fumes. Aluminium may also be substituted with advantage for copper and brass in various small fittings of the retort and its accessory plant, such as the washers and scrubbers. In this connection, its non-sparking properties are of considerable value and assist materially in reducing the fire risks attached to the operation of a gas-producing plant.

Trouble has sometimes been experienced in gas-consuming appliances by the choking up of small orifices by microscopic particles of gummy matter which tend to deposit and slowly build up into resinous masses of fair size. The formation of the microscopic gummy particles has been shown to be the result of polymerization of certain constituents of the gas by a process which is catalyzed by small amounts of nitric oxide present in the coal gas. To overcome this difficulty, the Philadelphia Gas Co. has developed a treatment which consists essentially in submitting the gas to the silent brush discharge. Under these conditions, the nitric oxide is converted into the peroxide, which is then removed by washing the gas with certain oils.

The discharge is obtained between large parallel plates of aluminium sheet, 10 mm. thick, alternate plates being connected together and earthed, whilst the others are connected to a high-voltage transformer. These latter plates carry a large number of sharp steel points (217 points per sq. ft.), from which the discharge takes place to the earthed plates. Aluminium was chosen as the material for the plates as it is capable of being rolled out perfectly flat, and at the same time the metal is not corroded by the coal gas and its impurities. The total equipment, which is designed to treat 24,000,000 cubic ft. of gas per day, involves the use of more than 300 sq. m. of 10-mm. thick aluminium sheet. This, together with other applications of aluminium in the form of sections, castings, etc., brings the total weight of aluminium used at the Philadelphia Gas Works to 12,000 kg.

Among other concerns which have advertised the good use they are making of aluminium in the manufacture of coal gas may be cited the Société Française de Chaleur et Lumiere and the Société Anonyme Representation Industrielle Internationale.

Within recent years an interesting application of aluminium has been made in the process for the recovery of benzene, using activated carbon. Aluminium wires are used to make the fine-mesh gauze on which the activated carbon is supported. In spite of the constant passage of coal gas, water vapour, and benzene, and the maintenance of a temperature of 110 degrees C., no corrosion occurred due to the gas stream and poisoning of the catalyst was avoided. Carbon, activated with zinc chloride, was quite satisfactory, in contact with the fine-mesh aluminium, but carbon activated with phosphoric acid tended to attack the metal and was to be avoided in contact with aluminium equipment. In Belgium, aluminium coils have been used in the distillation of benzene and for the heating of benzene-containing oils.

Coal tar, which is, perhaps, the most important by-product in the manufacture of coal gas, itself consists of a large number of different substances, which are separated or partially separated by fractional distillation. The tar is heated in wrought-iron stills or retorts, the vapours which pass off are condensed in long iron or lead worms immersed in water, and the liquid distillate is collected in fractions. In this way the following main fractions are obtained:—

(1) Light oil or crude naphtha. Collected up to 170 degres C. This separates into two layers, namely, gas liquor (the presence of this is due to its being retained mechanically by the tar) and an oil lighter than water, from which further hydrocarbon fractions, benzene, toluene, xylene, solvent naphtha, pyridine and phenol are obtained by further distillation and other treatment.

(2) Middle oil or carbolic oil. Collected between 170 and 230 degrees C., from which naphthalene and carbolic acid are obtained.

(3) Heavy or creosote oil, collected between 230 and 270 degrees C. This is ordinary creosote and contains such materials as phenol, cresol, naphthalene, and anthracene.

(4) Anthracene oil, collected at temperatures above 270 degrees C. This contains anthracene, which is employed in the manufacture of various dyestuffs and phenanthrene.

(5) Pitch—the residue in the still. This is removed while still hot and used in the preparation of varnish, etc., and for the production of asphalt.

In all these processes of fractional distillation and purification, aluminium has not so far found very extensive application, although it possesses considerable potentialities. In most of these processes, heat transfer is an important operation, and good heat conductivity in the constructional material is a prime necessity. This condition is fulfilled admirably by the light alloys which are, moreover, substantially inert to the chemical substances involved. By analogy with the petroleum industry, where good use has been made of the aluminium alloys in those parts of the distillation apparatus which are not subjected to the highest temperature—for instance, bubble caps—there should be ample scope for aluminium in the design of efficient separating and purifying plant.

Schwerber[3] reports that satisfactory results have also been obtained with aluminium steam-heating coils immersed in tar, with a comparatively high phenol content at 197.5 degrees C. These results are particularly interesting, in view of the fact that tar obtained in the more modern vertical retorts tends to have a high phenol content. Aluminium has also proved suitable for the manufacture of distillation columns used for the fractionation of tar oils at temperatures up to 180 degrees C. Where higher temperatures are employed in conjunction with steel equipment, it is suggested that sprayed-on coatings of aluminium might be employed, as they are in the oil industry, to give protection against high-temperature oxidation.

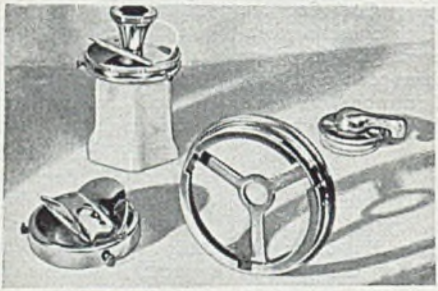


Fig. 7.—Globe galleries, deflectors and rings in aluminium. (Courtesy William Sugg and Co., Ltd.)

Coking Plant

The coke obtained from gas retorts is a greyish-black very impure form of carbon containing the ash of the coal. It is used as a fuel. A hard variety of coke for metallurgical purposes, for example, blast furnaces, is prepared by carbonizing coal in coke ovens. Modern " recovery ovens," for instance, the Otto, Simon-Carves or Koppers ovens, employ fireclay or silica brick retorts 40 ft. long, 14-18 ins. wide and 12 ft. 6 ins. high in which the coal is heated by flues passing between the retorts in which part of the gases evolved, mixed with air pre-heated in a regenerator, are burnt.

The remaining gases evolved contain many valuable by-products and, in their recovery, aluminium has been satisfactorily employed in a number of important roles. The gas as derived from the coke ovens contains tar, hydrogen, carbon monoxide, carbon dioxide, sulphuretted hydrogen, methane, ammonia and aliphatic and aromatic hydrocarbons, including benzene. The hydrogen is generally used for the production of ammonia by the catalytic process, for which purpose it must be pure, and the general principle, therefore, is to remove all other materials present in one way or another. Tar is separated by cooling. Benzene is removed by scrubbing with creosote or other suitable heavy oil in a steam injection-heated tower. Aluminium has been successfully employed in the fabrication of the steam injectors, and aluminium pipes have been used in the construction of the benzene rectifying column.

At the Waziers works of the Société Chimique de la Grande Paroisse, carbon dioxide, derived from coke-oven gas, is conducted a distance of 5,140 yds. through an underground pipe 200 mm. in diameter. This pipe was made of aluminium in order to prevent its corrosion by gaseous sulphide impurities.

The ammonia, which is produced directly from the hydrogen and atmospheric nitrogen, may be converted by oxidation to oxides of nitrogen, which are then absorbed in water to give nitric acid. The hoods of the catalyst chambers in which the oxidation of the ammonia takes place, as well as the pipes through which the nitric acid formed is removed, are made of aluminium. The use of aluminium for the storage and transport of the nitric acid so obtained is now well known.

In the production of pure ammonium nitrate, gaseous ammonia is allowed to react with aqueous nitric acid; the solution is cooled by passing through condenser tubes and then crystallized to obtain the pure, solid ammonium nitrate. In order to avoid contamination of the solution and staining of the product, aluminium pipes are used in the condensing system and the crystallizers, which are of quite large size, are entirely of aluminium construction.

Acetone and glycol are among the substances derived from the hydrocarbons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extracted from the coke-oven gas. Aluminium containers and tanks are employed for the transport and storage of these materials, towards which aluminium is inert.

From the methane separated from the coke-oven gas, methyl alcohol is obtained by oxidation. Further oxidation gives formaldehyde, in the distillation, condensation and storage of which aluminium is much in evidence as it is practically inert to this substance and does not accelerate its decomposition. For similar reasons, aluminium is employed for the manufacture and storage of hexamethylenetetramine derived from formaldehyde and which is used in the synthetic resin industry. Aluminium is also employed in the moulds used in the casting of phenol formaldehyde resins, in which connection it offers advantages over moulds made of other materials.

Related Plant and Applications

Although there is not usually more than a trace of sulphur compounds and gases in the atmosphere inside and in the immediate vicinity of a gasworks, this concentration is quite sufficient to cause gradual attack on wooden, iron and galvanized iron structures, iron nails and steel screws and so on. Aluminium is not attacked in this way, and in consequence it finds ready application in the construction of outbuildings and in plant not directly concerned with the production of coal gas. In workshops, for example, the machines have to be fitted with guards and they may be driven by pulleys. At least one concern has found it worth while to construct these parts of aluminium because of the longer life obtained. No great difficulties are encountered in the fabrication of parts of this type in aluminium alloys and the cost is by no means excessive.

Although gas and electricity producers are, in one sense, competitors, yet in another sense they are complementary to each other. In gasworks, for example, electric lighting is desirable wherever there is danger of gas being present in the atmosphere, whilst electric power is much in evidence for driving the machines, notably the retort charging and discharging machinery. The sulphurous nature of a gasworks is fatal to the use of copper, and the life of copper conductors is always short; often it is limited to two years. In consequence, the choice of conductor metal has fallen on aluminium, either as plain aluminium stranded conductor or as steel-cored aluminium cable, which has given such good service in the distribution of electric power throughout the country. Not only does an aluminium conductor give much better service, but it is invariably cheaper than the equivalent copper conductor. Aluminium conductors have been in operation for more than 15 years under the worst conditions in atmospheres laden with sulphur and sulphurous fumes without exhibiting any signs of corrosion. For similar reasons, busbars should be of aluminium, and, under similar conditions, it is preferable for aluminium fittings to be adopted in switch rooms and similar places.

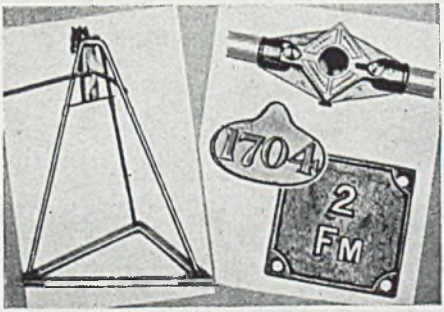


Fig. 8.—Pipe bender, die stock and number plates of aluminium alloy. (Courtesy Gas Light and Coke Co.)

Wheel barrows, shovels and rakes may be constructed of light alloy, not so much because of their resistance to corrosion, but because of their light weight. Being easier to handle than the conventional tools, they reduce fatigue and increase a man's output.

For the main building and for the various outbuildings inevitably attached to a gasworks, many concerns are now using corrugated aluminium sheeting and aluminium nails in place of galvanized iron because of the rapid corrosion of the latter. The higher initial cost of the light metal is justified by the longer life obtained, but it is compensated to some extent by the ease with which the light-metal sheets can be handled. Where the use of aluminium metal is not practical, aluminium paint is a valuable protective which will greatly prolong the useful life of a wooden or metal structure.

This idea of aluminization applies to other structural items such as roof gutters and down pipes, general rainwater goods and fittings of all types—glazing bars, window frames and fasteners, door furniture and kick plates in the offices and the laboratory, and so on. The Pforxheim Gas and Water Works experimented with aluminium gutters and down pipes as far back as 1912, since when there has been a steady replacement of galvanized iron in these works by aluminium goods fabricated from sheet metal 1.25 mm. thick. These items have been found to be quite satisfactory without any additional protection by means of paint. Aluminium glazing bars, door furniture, windows and kick plates are already well known and liked in general architectural practice for their good appearance and permanent finish.

Aluminium also finds application in a related industry, namely, in the plant used to prepare the luminous material with which gas mantles are treated and to impregnate the mantles themselves. The materials employed contain cerium and thorium, collodium (high viscosity nitrocellulose solution), nitric acid and ammonia, and, after considerable experiment, it was ascertained that aluminium was the only suitable material that could be used economically for certain parts of the plant. Aluminium vessels are used accordingly, both to contain the nitro compounds and also for the evaporation of the ammonia with which the nitric acid is neutralized at a later stage in the process.

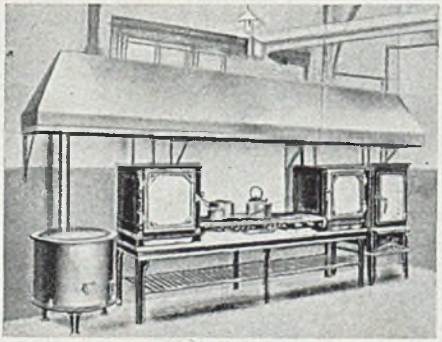


Fig. 9.—Aluminium canopy installed over a gas cooker in a hospital. The corrosion-resisting qualities demanded of a metal for this apparently elementary use are, in fact, most stringent. Light metal has proved to be one of the most satisfactory materials for the purpose.

Testing Laboratory and Development Section

The danger arising from the installation of faulty gas appliances is very much greater than it is with most other types of domestic apparatus and, indeed, with many forms of industrial equipment. In consequence, it is usual for the gas producers to test every appliance before it is installed in a customer's premises. Aluminium in the form of castings, tube or sheet metal is used very largely in the test laboratory for the parts of the test plant because of its low weight, its cleanliness and its incorrodibility, and because of the ease with which it is formed and machined. Aluminium paint is used on woodwork and metal work in the laboratory to a large degree.

The ease with which the light alloys are worked and welded and their reasonable first cost make them ideal for the fabrication of experimental equipment and models and it does, in fact, figure very largely in the list of materials used in the development department of the modern gasworks, where new designs are evolved and improvements effected in existing models.

Installation and Maintenance

The installation and maintenance of gas-consuming appliances is a branch of the gas industry in which aluminium and, indeed, magnesium-base materials, too, are important because of their low density. These services form the connecting link between the gas producer and the gas consumer and they involve a great deal of travelling between the works and its many customers and the carriage not only of the appliances themselves, but also of the tools with which to install and maintain them—tools which are, of necessity, frequently heavy and unwieldy.

Portability, then, is the keynote to the requirements of this particular branch of the gas industry and it has been met by the use of aluminium alloys of various types according to the duty to be performed. Tool partitions and sometimes even complete truck bodywork can be made in aluminium sheet instead of wood or sheet iron. A low-strength wrought-aluminium alloy economical in first cost is quite suitable for this purpose. Assembly may be by welding, riveting or by bolting together, and a considerable weight reduction is achieved compared with wood or steel. Life may be prolonged and maintenance and painting costs are frequently reduced, these factors largely offsetting the higher initial cost of the light alloy. In the same way it is common practice to-day to use cast aluminium alloy parts for number plates, lamp brackets and so on, since these parts are light in weight and easily cleaned and maintained. Alpax aluminium alloy may be employed for this purpose.

Alloys of greater rigidity are called for in the fabrication of tools. Thus, cast light-alloy parts are employed in the construction of the pipe bender illustrated, whilst the whole of the steel die stocks used by one concern have been replaced by a composite stock built up from an aluminium alloy casting and tubing. In this way, weight has been reduced from 6-7 lb. for the steel die stock to under 2 lb. for the light-alloy stock, the result of which has been an increased working efficiency at little extra cost.

A fitter's bicycle was constructed in which the front and rear carriers have been built up from aluminium alloy tubing and sheet. The front carrier, destined to carry light but bulky articles such as bags, etc., is produced in aluminium alloy tube jointed by tee-pieces and cross-overs and it has been found that, because of the reduction in weight resulting from the use of aluminium, the strength to weight ratio is increased so that it is possible to carry heavier articles than with the previous carrier. The rear carrier consists essentially of a small box with a sliding lid destined to carry small tools, and the production of this in aluminium showed a weight reduction of 45 per cent. compared with the same article in steel.

Light alloys have found useful application in certain of the plant and appliances connected with road work involved in the installation and repair of mains and so on. Danger lamps and spot lights have been fabricated with the main castings of corrosion-resistant aluminium alloy. Lamp tripods in aluminium alloy have been found to possess an extended life compared with wooden tripods, which more than balances the additional cost of the light metal. Even meter cases have been made of light alloy to facilitate handling.

In all these applications we suggest that the value of the ultra-light alloys should be investigated by means of practical tests. The main requirement is light weight, and this is an attribute which magnesium alloys possess to an even greater extent than the aluminium alloys. They are, moreover, possessed of adequate strength, sufficient, in fact, to enable them to be used in highly stressed positions in modern aircraft, whilst their corrosion resistance, whilst slightly inferior to that of most aluminium alloys, is still remarkably good. Bicycle carriers, pipe benders, lamp bases, and so on, might usefully be made of magnesium alloy tubing or castings, and would show an even greater reduction in weight than has been exhibited by their aluminium alloy equivalents.

Aluminium in Gas Consumption

We come now to the other side of the gas industry—the consumer side. Here, again, aluminium is employed frequently because of its resistance to the atmosphere and to the products of gas consumption and to unsightly oxidation and deterioration at the temperature of burning coal gas, because of its good heat conductivity, and the attractive range of finishes in which it can be obtained.

In both domestic premises and industrial undertakings, gas consumed is paid for by meter reading. It is, of course, essential that this instrument should be reliable, and it has been found that, because of its chemical inertness, aluminium is particularly suitable for meter drums and similar parts where complete incorrodibility is essential. Aluminium is being used for the meter arms and vanes because its light weight lessens the pressure drop by an amount which may be important when considered over a complete distribution system. This is an application for which magnesium alloy, with its even lower specific gravity and inertia might be considered.

Domestic Uses

Manufacturers of domestic gas-consuming appliances are very alive to the appeal of aluminium in modern hygienic and labour-saving kitchens. For cooking stoves, aluminium sheet has been used for oven linings for several years past, as the result of a strong recommendation by the Committee of the National Gas Council. Tests, which extended over a period of two years, showed that, after polishing, aluminium sheet oven linings were as good as when first fitted and that the material permitted of regular cleaning. In comparison with enamelled steel, which is the only other satisfactory lining material, chipping in service and rusting of the iron surface thus exposed is completely avoided and the surface exposed to the heat of the burners immediately over the flames does not show such definite signs of burning after use. From the price point of view, aluminium sheet is cheaper than enamelled steel in first cost; when the oven goes in for repair the sheets can be cleaned and used again, or, if they become damaged at the fixing holes, they can be cropped and used again in smaller ovens. Moreover, when the lining is finally scrapped, it possesses a higher scrap value than scrap enamelled steel.

Lately, however, stove designers have become bolder in their use of aluminium and have embarked on more ambitious schemes in which aluminium anodized and dyed in various pastel shades forms the casing or main panelling of the appliance and sets the keynote for the decoration of the kitchen. Thus, we have already referred to the "Renown" cooker shown at the Aluminium Exhibition, in which the panels and top were of aluminium sheet coloured an ice blue. The great advantages of this type of finish are that it is permanent, does not chip, is hygienic and easily cleaned, and is of most attractive appearance. This cooker is, however, only one from a comprehensive range which may confidently be anticipated in the better days to come.

Construction is usually by a combination of castings, extrusions and sheet. Die-castings in aluminium alloy are particularly apt, possessing a much cleaner finish than the same casting in iron, and, if properly designed, will have all the required strength.

Die-cast aluminium alloy has been recommended for the production of gas-burner taps, the alloy chosen for this purpose consisting of aluminium, with 5 per cent. nickel.

Cast-aluminium grids and perforated shelves inside gas ovens might be an advantage over those of plain or tinned iron, such as are in use at the moment, which rapidly turn black and may become scaled and unsightly. One disadvantage is that a method other than the current one of soaking in caustic soda would have to be adopted for cleaning off baked grease and residue.

The use of aluminium in gas-fired clothes washers and coppers was, at one time, limited to cast-aluminium tops, lids and bowls, but has now been extended to include panelling and the legs. An example of the old type is the Slackson "Nu-Square" gas copper illustrated, the boiler top of which was of cast-aluminium. Examples of such aluminium tops and lids were exhibited at the B.I.F. in 1936. Although aluminium has been used satisfactorily for the purpose, tinned copper is still the more common material of construction for the bowl. This is, no doubt, due to the danger of marking clothes which rub hard against the aluminium surface; this danger can certainly be reduced and can, possibly, be avoided by anodizing the metal surface. At the aluminium exhibition could be seen a gas copper in which every part except the pan was of aluminium alloy, the pan being of tinned copper. The body was finished in polished, natural-coloured aluminium, and was fitted with a pressed-aluminium top rim, an aluminium lid, and feet in the same metal.

For water-heating, numerous experiments have been made with aluminium coils in place of copper, on the score of lower cost and with plated or anodized aluminium for the outer casing. The "Magic-Hurro" gas-heated hot-water circulator which is illustrated was exhibited at the B.I.F. in 1936, and makes good use of aluminium for the heaters and for the component parts. A more recent example is the Ewart "New Empire" multi-point, gas-operated water heater shown at the "Aluminium from War to Peace" exhibition, in which the outer casing was of aluminium, anodized and dyed an ice blue. Also exhibited was an "Ascot" water boiler, in which the top, deflector, and base were in aluminium alloy.

All these appliances require the use of vent pipes. For the construction of these, aluminium was recommended by the Société de Gaz de Paris in 1937. Its use certainly eliminated the corrosion and formation of loose scale inevitable with the use of iron vent pipes.

Illustrated is a smaller appliance, a portable gas fire, which can be used without any flue. Here, aluminium is suitable for the surround because it is light in weight and amenable to attractive tooling and finishing schemes, and also for the reflector, because of its good reflector properties and the ease with which its polish can be maintained. Bowl gas fires of this type with aluminium reflectors were exhibited at the 1936 B.I.F. by Messrs. W. Parkinson and Co.

Extremely popular among modern gas fires is the type in which the heating radiants are surrounded by a vitreous-enamelled or stove-enamelled cast-iron surround, and are fitted with a plated cast-iron shelf under the radiants. We would suggest that aluminium would be an extremely useful metal to employ for this purpose. Working to a smooth finish would be much easier than with cast iron, and the decorative possibilities are wider, because they embrace not only the enamelled finishes used at present on cast-iron surrounds, but also those produced by anodizing and dyeing the light metal, which are characteristic of aluminium and cannot be matched in other materials.

In the Aluminium House, a coal-burning fire is set in a surround of this type, and the result is most effective.

Gas stoves and heavy fixed appliances of this type are connected to the main gas supply pipes by steel gas barrel. This is of heavy wall thickness and changes in direction are mostly produced by means of right-angle bends threaded on and packed with red lead and hemp. For the connection of gas fires to conveniently located plug points, brass tube of thin section is more frequently employed. Not only is this much more attractive in appearance, but it may also be subjected to a certain amount of bending and forming in situ to follow the line of the wall, tiled surround or skirting, as the case may be. However, brass requires to be constantly cleaned, an operation which, not unnaturally, is looked upon with some disfavour in modern homes, where, for one reason or another, adequate domestic help is not always to be had. An alternative, however, is available in the form of annealed aluminium alloy tubing, which also has the advantage of being available in various finishes as required. Another important point is that the absence of necessary cleaning imposes less strain on the joints and reduces the danger of subsequent gas leakage. Tests have indicated that annealed aluminium is equally efficient from the installation point of view, and it has the added advantage of being some 20 to 25 per cent. cheaper. One point to be remembered is that brass fittings should not be attached to aluminium tubing, or corrosion of the aluminium at the joint is liable to take place in damp weather. Aluminium alloy cocks and other fittings are, however, available. They have passed through many tests and it has been shown that, with careful choice of alloy and by hardening the metal surface through anodizing, a wearing life can be obtained equal to twice that given by a brass cock. Fittings of this type may be produced either as die castings or as hot pressings.

Lighting Fittings

For domestic gas lighting, aluminium globe galleries, deflectors, and other fittings are used to a considerable extent. Such fittings are easily produced as castings or from sheet metal; they are readily given an attractive polished finish, which is retained longer than is the polish on copper or brass, and, moreover, they can frequently be produced at a lower cost than similar articles in yellow metal. Aluminium galleries and gas-burner fittings were exhibited by G. Bray and Co., Ltd., at the 1936 B.I.F.; some examples of aluminium galleries, rings, and deflectors are illustrated.

The modern home prefers the use of remote switches for gas-lighting control sunk in the wall and finished with a flush-fitting concealing plate, rather like the flush-fitting electric switches which are now so popular. This concealing plate may be of bakelite or other plastic, but a stronger job is obtained and more attractive decorative possibilities are opened up by the use of plates of aluminium which may be machine-tooled and finished in colour or otherwise to harmonize with the general scheme of decoration.

In municipal and factory lighting schemes, the weight of large and frequently ornamental lamps creates a problem of its own, necessitating the use of substantial supporting structures and tackle for raising and lowering the lamps. For this reason, aluminium is being employed both in this country and abroad for the purpose, in place of cast iron. In one instance, in a project carried out in Germany, a weight reduction of 5.5 kg. was achieved in the case of a six-burner type of lantern and 6.7 kg. in the case of a nine-burner lantern. The actual weights of these lanterns were: For the six-burner type, 10.7 kg. in cast iron, 5.2 kg. in aluminium; for the nine-burner size, 15.4 kg. and 8.7 kg. respectively. The light alloy is frequently employed in the form of sand castings and the alloy generally chosen is of the Alpax type.

Also of importance is the corrosion resistance of the light alloy. Street lamps are very much exposed to the weather and frequent painting is undesirable, if only because of the palaver of lowering the lamps and, perhaps, interfering with the flow of traffic. Frequent inspection is impossible, and, more often than not, lamp casings are repainted either before their time or when corrosive attack has proceeded too far, so that tedious and expensive surface preparation becomes necessary.

Factory lamps, although generally not exposed to the weather, are frequently in continual contact with fumes which may be of a corrosive nature, whilst inspection and maintenance are as difficult, if not more so, than in the case of street lamps. In addition, lamps of both classes are exposed to attack by gas combustion products, in which respect aluminium is very superior to iron and copper-base materials. These considerations of light weight and simplified maintenance make aluminium an attractive material to use in this connection, particularly since the economies to be effected under these headings may exceed the additional prime cost of the light alloy.

For use with such lamps and for floodlighting and similar applications, aluminium reflectors may be adopted. Aluminium-alloy sheet is particularly suitable for this purpose, being easily formed to any desired shape and being capable of taking and retaining a high polish, giving highly efficient spectral reflection. In this connection, methods of electrolytic polishing and methods of anodizing designed specially for the protection of reflector surfaces are of particular importance. Where diffuse reflection without glare is required, satin or frosted finish metal may be employed with good results.

Other Industrial Applications

Among other applications of aluminium in the industrial consumption of gas may be mentioned industrial cookers and canopies. As in domestic cookers, the main attraction of aluminium in industrial cookers lies in its good resistance to the products of gas combustion and the ease with which it may be kept clean and in hygienic condition. Decoration is usually of less importance and the metal surface is generally left in the polished or semi-matt condition.

Aluminium sheeting is much to be preferred for the construction of canopies over gas cookers. Not only is it light in weight, thus simplifying support and erection, but its corrosion resistance eliminates the risk of scale falling from the canopy and, perhaps, into the food which is always present when iron sheet is used for the canopy. Aluminium-painted iron sheet, whilst infinitely preferable to unpainted iron sheet or to sheet painted with other material, is still a long way from perfect. Brass sheet is, of course, quite out of the question for the purpose, and, in consequence, aluminium is enjoying considerable popularity for the fabrication of this type of equipment. An aluminium canopy installed over a gas cooker in a hospital and a double steaming oven with aluminium casing and aluminium perforated trays are illustrated.

In sugar boiling, sweet-making, and similar industries, aluminium is being adopted to a considerable extent, primarily because of its hygienic nature. However, manufacturers are finding that the reasonable first cost of the material, the ease with which it can be fabricated, its good heat conductivity, and the reduced thermal radiation of polished sheet are points worth considering, and there is every indication of an increased consumption of aluminium in these fields.

Again, in the bakery industry, aluminium conveyor belts have been adopted in gas-fired bakery ovens because of the resistance of the metal to high temperature oxidation and because of the absence of corrosion products which would contaminate the bread. For the latter reason there is also a possibility of the use of the metal in bakery scales and in loaf-forming machines.

Aluminium, both in the form of the massive metal and as aluminium paint, finds important application in the construction of gas-fired furnaces of various kinds. Such furnaces, which may be employed for the heat-treatment of metals, annealing, assay, and other purposes, quite commonly employ casings of aluminium or aluminium alloy and external castings also in light alloy. Not only does this give a strong, yet light, and non-rusting structure, but, in addition, the low emissivity of the metal, particularly in the polished condition, greatly reduces heat radiation and makes for more efficient working of the furnace and for economy in fuel. Where the use of massive aluminium is not possible, aluminium paint is a useful coating, reducing the radiation of other metals and protecting the base against oxidation and corrosion. Illustrated is an assay muffle furnace installation at the Chelsea Polytechnic, in which the casing and the main castings are in aluminium alloy, and a range of soldering stoves and muffle furnaces, in which the end castings are in aluminium alloy and the casings are in sheet aluminium. At the 1936 B.I.F., gas-fired steam boilers, in which heat insulation was achieved by asbestos in conjunction with an outer covering of aluminium sheet were exhibited by J. Brockhouse and Co., Ltd.

Flue Pipes

We have previously made reference to the use of aluminium for flue pipes in domestic gas-consuming apparatus and to the recommendation for aluminium which was made by the Société du Gaz de Paris. Flue construction becomes of all the more importance in industrial plant where infinitely greater volumes of gas are burnt and where correspondingly greater volumes of hot, corrosive fumes have to be disposed of. Some of these industrial flues may be very long, particularly where multi-storied buildings and high factory roofs are involved, and, although aluminium piping has been used on occasion, and with much success, the tendency is to employ iron or tin plate for the job and to protect the metal by coating with a suitable paint.

The requirements of a suitable paint are many. It must be largely immune from physical and chemical change at the temperatures involved; capable of forming and maintaining a coherent, adhesive film which will protect the metal from corrosion by the gas combustion products and from high temperature oxidation; it must itself be resistant to the products of the combustion of coal gas; it must be quick-drying and easy of application, in order that two or more coats can be applied in quick succession without special skill or unusual appliances to reduce the shut-down of plant to a minimum. In addition, it may frequently have to withstand the action of steam, hot cotton-seed and fish-oil vapours, and decomposition products of these oils which may be passed with the burnt gas up the flue.

Although the meeting of many of these requirements is the prerogative of the liquid portion of the coating composition, aluminium powder is undoubtedly the best choice of pigment. Unlike most other pigments, it is practically unaffected by heating to red heat, and it is unique among pigments in that a diffusion or alloying takes place slowly between it and the iron pipe, so that, although the whole of the organic medium may be lost by oxidation and charring, the pipe is still protected by a skin of aluminium, perhaps more adhesive than the original paint. Aluminium paints are recognized as possessing better adhesion on heated iron than are paints pigmented with other materials, and the aluminium skin, being of low porosity, provides highly efficient protection for the iron against oxidation and attack by corrosive agencies present in the fumes; aluminium appears to possess good resistance towards these materials. These facts, combined with reasonable cost and easy application, have made aluminium paint a firm favourite for the protection of gas flues, both internally and externally.

We have already referred to the growing demand for surface coating compositions processing not only high corrosion protective powers but at the same time, decorative properties capable of variation over a wide range. For normal purposes, paints meeting these requirements have been available for many years, but it is only within the last 10 years or so that compositions have been developed which satisfy the many complex mechanical, physical and chemical demands called for in a medium to be applied to metal assemblies of the type discussed here.

It is well known, of course, that the base of most of these more modern types of paint consists of one or the other of the synthetic resins; these, unlike the older drying oils, are, in the cured or hardened state, relatively free from subsequent ageing. They are, in addition, physically inert, being less prone to absorb oil or greasy matter from combustion gases or the surrounding atmosphere. According to the purpose for which they are to be used, they may possess extremely hard surfaces, or, conversely, may maintain a permanent almost rubber-like form.

A point of some practical importance, too, is the amenability of these paints to individual control in one or more properties. Thus, for example, the stoving enamels which were developed many years ago, are both physically and chemically very inert and mechanically strong. They possess the disadvantage, however, that on thin sheet assemblies where it is essential that absolute flatness and freedom from weaving be obtained, their use is limited due to the buckling which may arise during the stoving process. Thus air-drying urea-resin-base paints have been evolved which closely approach the stoving compositions in their general qualities but require no heating after application.

The private exhibition described in the opening pages of this issue of "Light Metals" furnished numerous examples of aluminium domestic gas assemblies built up from relatively thin sheet and treated decoratively with these media.

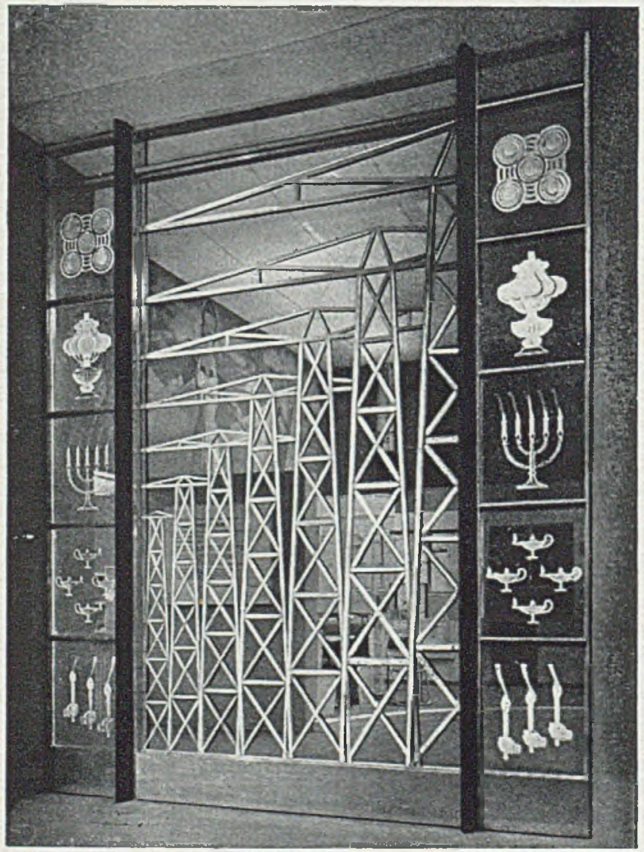
Finally, the combined use of the anodizing process and painting technique should not be lost sight of. Although there is no doubt that, with adequately degreased aluminium sheet, paint (that is priming) can be made to adhere with every satisfaction, nevertheless, adhesion can be strongly promoted by preliminary surface treatments. Of these anodizing is by far the most widely known. The straightforward chemical treatments, such as the M.B.V. process or the Pyalumin method of the Pyrene Co., may also be employed. Pretreatment of the sheet in this way is to be recommended where very severe demands are to be made upon the coating.

REFERENCES

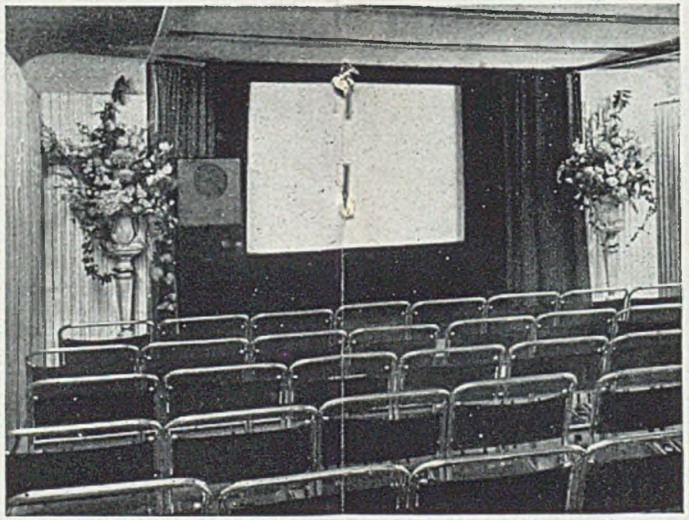
(1) "*Aluminium from War to Peace*," see "*Light Metals*," 1945/8/90. (2) "*Technology of Magnesium and Its Alloys*," *pp.* 300 *et seq.* (3) "*Aluminium*" *(German)*, *XIX*/8/556.

WOMEN'S ELECTRICAL EXHIBITION

Designers, Industrial Artists and Craftsmen Co-operated to Achieve Striking Presentation in Aluminium and Plastics at a Recent "Birthday" Exhibition



GRILLE constructed from extruded aluminium sections and Perspex to the design of Ralph Lavers by J. Starkie Gardner, Ltd. This work, which is some 16 ft. high and 10 ft. wide, adopts as its symbolism, pylons for overhead transmission lines. The Perspex panels are deeply engraved into a massive section of the plastic. The bulk of the metalwork is in natural colour; the mullions and inter-linking expanded metal being anodized and dyed black.



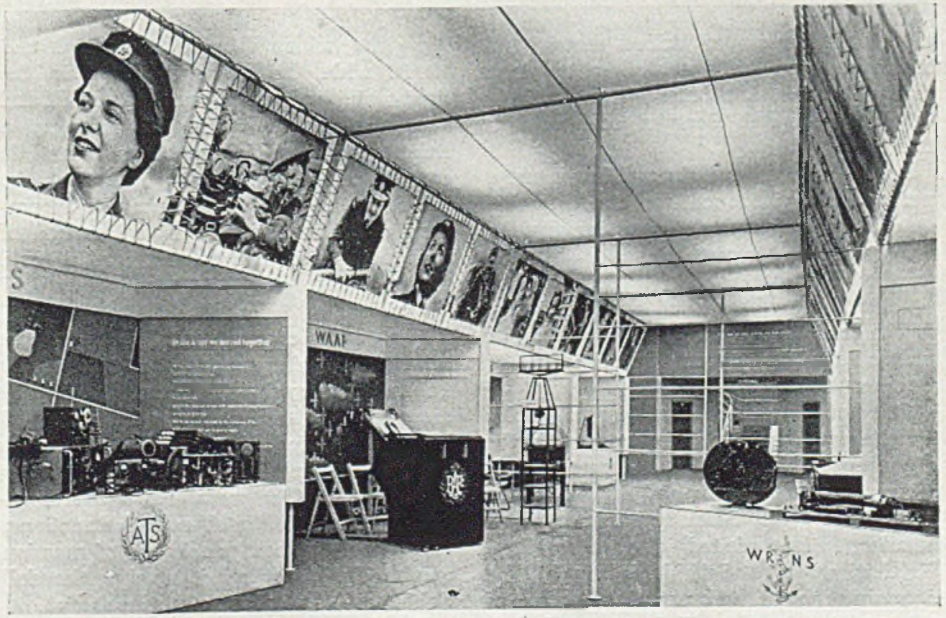
LEFT. View of the cinema. Above the felt wall hangings was a light-reflecting cove in expanded aluminium, anodized and dyed blue.

RIGHT. Hulme Chadwick, A.R.C.A., A.R.AE.S., the designer of the first Women's Electrical Exhibition, recently held at Dorland Hall.

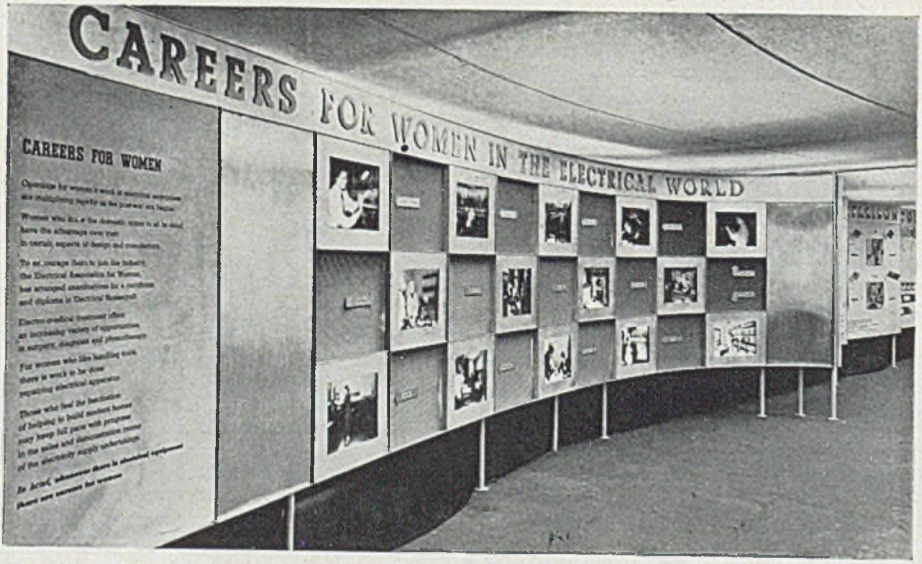
LIGHT alloys need no introduction to electrical science and practice. In every branch of electrotechnology they have, for many years, found wide and ever-increasing application. It must not be assumed, however, that novel fields for their use in this connection no longer exist; particularly is this true with respect to the decorative arts associated with the use of, or publicity for, electricity in the home.

At the first Women's Electrical Exhibition, staged by the British Electrical Development Association for the 21st birthday celebrations of the Electrical Association for Women, the use of aluminium was turned to good account.

In this journal we have for many years stressed the importance of using light metals in conjunction with other modern structural materials in order that the fullest possible value may be educed from it. Hulme Chadwick, A.R.C.A., A.R.AE.S., the designer of the exhibition, has extracted full value from the association of these two complementary aspects, and, side by side with masterpieces of industrial art in plastics, he has brought



VIEW of the main hall of the Exhibition. Here all side panels are in anodized aluminium, dyed blue with white lettering. Letters for panel titles on the individual exhibits are cut in clear Perspex, with edges painted blue. The photographs are reproduced direct on to sensitized canvas.



THE construction of the panel "Careers for Women" entails a curved form, the attainment of which was greatly simplified by the use of aluminium. The bulk of the metal work consists of expanded aluminium, anodized and dyed to a golden colour. The photographic panels are reproduced directly on Perspex, and are illuminated from behind to give very striking effects. The panel was executed by J. Starkie Gardner, Ltd.

together products of skilled design and craftsmanship, the effect of which may justly be said to be due almost entirely to aluminium and Perspex working as a team.

As enthusiasts for light metals, we may, perhaps, be pardoned for concentrating on our own particular subject, leaving the assessment of the part played by women in the electrical industries during war-time to those who visited the Exhibition at Dorland Hall during the period of its public showing from October 12 to October 25.

One of the most striking examples evolved by Chadwick's co-workers is the aluminium grille with Perspex panels which was designed by Ralph Lavers and executed by J. Starkie Gardner, Ltd. Readers who visited the Aluminium Exhibition at Selfridge's will be acquainted with the peculiar genius of this artist, who, it will be remembered, was responsible for the design of the murals there. (See "Light Metals" July insert between pages 336 and 337.) In the grille, which is some 15 ft. high and 12 ft. wide, he has symbolized in the light-metal body of his work the spirit and power of electricity in the form of a balanced composition based on an artistic concept of the grid system. Flanking the grille, as may be seen from the accompanying illustration, is a series of engraved panels in Perspex, symbolizing, again, the multitudinous uses of electricity.

The bulk of the metalwork in the grille is of aluminium anodized in its natural colour; the mullions, of elliptical cross section, are anodized and dyed black. Linking the pylons is a cross webbing of expanded aluminium, also dyed black. The metal structural members of this grille are all extruded sections, whilst the Perspex panels are of massive gauge, finely engraved to give the full light-dispersion effect of the material.

The "careers" panel, of curved form, is also constructed of aluminium and Perspex. The use of the metal here is significant in that, by reason of its easy-working properties, it facilitated the obtaining of the curved shape. The body of the panel consists of expanded aluminium, anodized and dyed to a golden colour. The Perspex panels, $\frac{1}{8}$ in. thick, depicting careers for women in the electrical industry, were produced by photographing direct on to the sensitized material.

The cinema provides a further example of the use of aluminium. Above the lemon-yellow pleated-felt wall coverings is a light-reflecting cove in expanded aluminium, anodized and dyed blue. Incidentally, in contrast to this highly decorative use of the metal for reflective purposes, reference might be made to the shock cradle exhibit in the bay devoted to nursing. This apparatus, manufactured by The Medical Supply Association, Ltd., consists of a light-metal shield of the usual form, into the interior of which are fitted a number of electric lamps for providing warmth, the heat being directed on to the patient by a series of anodized aluminium plane reflectors.

From the standpoint of the designer and constructor, the actual use made of light metals in this exhibition is probably of somewhat less importance than the implications of that use. We have, at all times, stressed the great possibilities and advantages of employing aluminium in combination with plastics: the association is somewhat natural, both being constructional materials of comparatively recent origin, and both, certainly, being at that stage of development when their potentialities are becoming recognized at large.

The problem, however, assumes a somewhat broader form. Light metals can be combined, not only with plastic, but, in one or other of their many available forms, may be used in conjunction with textiles, with wood, and (with due precautions) with many types of plaster board.

The side panels of this particular exhibition can serve to emphasize the special merits of aluminium for display purposes. Its availability in a wide variety of gauges, in sheet form up to the largest sizes, gives the display artist every opportunity to work out his designs unhampered by grosser material considerations. Surface finish, colour, even method of executing lettering and decorative design itself, may all be varied over a very wide range. It is in point of fact, somewhat instructive to compare modes of treatment and design as exemplified by the exhibition at Selfridges, with those adopted here.

The employment of expanded aluminium as a decorative medium is somewhat novel, but, as may be seen in the case of the "careers panel," possessed of great possibilities when handled by designers of talent and craftsmen of experience. The very significant use of the metal in this form in Ralph Lavers's grille, is all the more striking by reason of the fact that it is employed so sparingly.

The use of electrical energy in the industrial and domestic spheres entails, as we have indicated, the employment of large amounts of aluminium in every conceivable form. The overhead transmission lines which distribute the power consist, themselves, of steel-cored aluminium; the bulk of the cooking utensils designed for use with the modern electric stove, again, consist of massive light metal, appropriately formed for efficient contact heating. Squirrel-cage rotors for domestic fans, and the major portion of the bodywork of the electric washing machine furnish instances of the almost exclusive use of light alloy.

On the mainland of Europe, to an even far greater extent than in this country, light metals have established themselves firmly as structural materials in electrical engineering. Thus, in the September issue of "Light Metals" (page 438), will be found a most extensive list of apparatus of all types, mainly for domestic use, employing aluminium in place of the conventional copper or brass. We have recently heard, too, that, in Norway, the use of the metal on an increased scale for such purposes as these is already under active consideration. It is important to note that in electrical engineering aluminium alloys are capable of meeting in full the most stringent physical, mechanical and artistic requirements.

NEWS—General, Technical and Commercial

No Light Metals Here

THE harassed light-metals technologist, seeking diversion in realms of art far removed from aluminium and magnesium, is recommended to visit the exhibition "Le Théâtre de la Mode," which, sponsored by the Continental "Daily Mail," will be open at the Princes Galleries, Piccadilly, until November 15.

We are not accustomed in these pages to lyrical rhapsody, and find great difficulty in doing adequate justice to the beautiful settings in which a multitude of wire figurettes demonstrate in so lifelike a manner the art and imagination of the painters, sculptors, dressmakers, hairdressers and jewellers of Paris.

All profits from the exhibition will go to the R.A.F. Benevolent Fund and to French charities.

ALUMINIUM pack for cod's roe. W. Mohn and Son, Bergen, Norway. This pressed can, which measures $5\frac{1}{2}$ ins. diam. and $2\frac{1}{2}$ ins. deep, is provided with a shouldered body to take a clip and handle for conversion to use as an emergency saucepan.

SMALL saucepan spun in 16 gauge aluminium sheet. This specimen has been in constant use since 1895, and, beyond surface scratching, shows no sign of wear. The handle, which has been removed, is of brass, riveted to the pan with copper rivets. No corrosion whatever has occurred at the contact areas.

Aluminium—War to Peace

VARIOUS references in the September issue of "Light Metals" were made to the Aluminium Exhibition, recently held in Birmingham. This was described as being shown at John Lewis's, Ltd., Birmingham; it should have been, of course, attributed to Lewis's, Ltd., a concern in no way connected with John Lewis's, Ltd., London. We tender our apologies for any inconvenience caused by this misstatement.

New Electrode Holder

FROM A. S. Young and Co., Ltd., we have received details of the new "Press-grip" electrode holder, one model of which is now being supplied with an aluminium core for use with welding currents up to 150 amps.

The aluminium core is claimed to stand up very well to workshop use and is, of course, considerably lighter than a holder of the same size but with a copper core, weighing only $15\frac{1}{2}$ oz. against 1 lb. 12 oz. for the copper-cored holder.

I.B.F. Session 1945-46

THE following programme has been compiled for the 1945-46 session of the Institute of British Foundrymen:—

London Section

November 28.—Professor Shestopal's paper on "The Technological Principles of Casting Design," presented by Mr. C. H. Kain, Director, Lake and Elliott, Ltd., Charing Cross Hotel, 7.30 p.m.

December 14.—Social Function—details later.

1946.

January 9.—An informal discussion on "Patent Laws as Affecting the Metallurgical Industry," Charing Cross Hotel, 7.30 p.m.

January 30.—Works visit to Ealing Park Foundry, Ltd.

February 27.—" Opportunities for the Foundry Technical in India," by Mr. J. Blakiston, M.I.Mech.E., Modern Foundries, Halifax. Charing Cross Hotel, 7.30 p.m.

March 27.—" The Education and Recruitment of Foundrymen," by Dr. Ingall. Charing Cross Hotel, 7.30 p.m.

April 24.—Annual General Meeting, followed by a Short Paper Competition on a special subject to be announced later. Charing Cross Hotel, 7.30 p.m.

May 22.—Works visit to Lake and Elliott, Ltd., Braintree.

F. Arnold Wilson, Hon. Sec., care of William Jacks and Co., Ltd., Winchester House, Old Broad Street, London, E.C.2.

The East Anglian section has meetings and lectures arranged for the following dates:—November 8, February 14 and March 14. Details of the arrangements from the Hon. Sec., A. N. Sumner, Messrs. Reavell Co., Ltd., Ranelagh Works, Ipswich.

The Slough section has meetings and lectures arranged for the following dates:—November 15, December 6, January 17, February 14, March 14, April 11 and May 9. Details of the arrangements from the Hon. Sec., F. J. Pike, Encombe Cottage, Fairfield Lane, Farnham Royal, Bucks.

Business Notices

WE are informed by Kayser Ellison and Co., Ltd., steel manufacturers, Sheffield, that Mr. P. B. Henshaw, joint managing director of this company, has been elected president of the Crucible Steel Makers' Association.

From Charlesworth Bodies (1931), Ltd., we have been informed that, as from September 11, 1945, Mr. F. Walkden has been appointed chief buyer for the Charlesworth Gloucester factories covering supplies for aircraft assemblies, " Charlesworth " aircraft components, and " Charlesworth " kitchen units for land, sea and air.

Following a recommendation by the Board of Short Bros. (Rochester and Bedford), Ltd., the Minister of Supply and Aircraft Production has agreed to the sale of Kent Alloys, Ltd., to Dawnay, Day and Co., Ltd., which concern has purchased the entire share capital. The policy of the company remains unchanged and, under the joint managership of F. H. Hoult, will continue its business of manufacturing and machining high-grade aluminium, magnesium and heavy non-ferrous alloy castings.

The British Aluminium Co., Ltd., the temporary head office of which is at Salisbury House, London Wall, London, E.C.2, announces that its telegraphic address has been changed to " Britalumin Ave London." The address for cables will be " Britalumin London."

ALUMINIUM FOUNDRY ALLOYS

FURTHER to his original account entitled " Selection and Preparation of Aluminium Foundry Alloys," published in " Light Metals," March, 1945, page 103, and to a letter from F. N. Smith, chief metallurgist, Kent Alloys, Ltd. (" Light Metals," August, page 402), E. Carrington, in answer to the latter item, has forwarded the following comments:—

" In reply to Smith's letter in your August issue, I certainly agree that laboratory control is essential in all aluminium foundries if the best castings with the best physical properties are to be obtained, but there is no doubt that the high strength alloys D.T.D. 298-304 and D.T.D. 300 require much more care and technical skill than some of the non-heat treatable alloys.

" On the issue of the use of aluminium dies, Mr. Smith and myself do not appear to agree so well, but some of this disagreement may be due to misunderstanding.

" I ought, perhaps, first to point out that I have not claimed better physical properties as one of the advantages given by aluminium dies. Actually, I did not know whether they were better or not until I read Mr. Smith's letter; but in view of the fact that iron dies give better properties than sand moulds because of higher conductivity, one might perhaps expect aluminium dies to give somewhat better properties than iron dies for the same reason. Smith rather stresses this effect of higher conductivity on physical properties, but this is not necessary, as all founders will agree that the higher figures for die-cast test bars given on all B.S.S. specifications are actually obtained. His experiments with different die materials are very interesting, and it is hoped that he may think them of sufficient general interest to merit publication.

"Before leaving this question of thermal conductivity, I would draw attention to Smith's first letter in your April issue. He says: '. . . . the thermal expansion of the die materials is almost a negligible factor in determining the constraint to the contraction of the casting in the die provided the thermal conductivity of the die material is of a relatively high order.' I take this to mean that with high conductivity there is very little constraint. In Smith's second letter in your August issue he says: 'By means of an externally applied coolant, as suggested by Carrington, the rate of heat transfer through the die could, of course, be increased.' We therefore have a 'relatively high conductivity,' as mentioned above; but, later, Smith says, 'To return to the use of an external coolant, this would result obviously in a lower die temperature and could, therefore, be expected to increase the constraint under which the casting would cool, since the cooling range would be greater. Far from being eliminated, cracking would be expected to increase.' These two statements do not appear to agree.

"In discussing the question of thermal expansion, Smith states that when a die has become worked in, it has a constant temperature with a fluctuation range of only ± 10 degrees C. Admittedly, a thermocouple could be inserted in any die which would give a reading of this order, but that would only indicate the temperature of the mass of metal surrounding the thermocouple. Information about such a temperature is quite useful, but results obtained would depend upon the position of the couple.

"The actual thermal conditions during casting are not by any means so simple. Nicholson[1] has taken records of die temperatures. The chart which he reproduces shows very little variation in temperature, and is placed in sight of the die caster to show him how the die is working; but Nicholson gives a time-temperature diagram which shows the temperature variations at four different places in the die. The one near the casting shows a far greater variation than the others, and Nicholson says, 'Any die at work is a complex of pulsating temperature gradients.' This, I think, very aptly describes the conditions. Again, Mickel,[2] in an article on die stresses (in pressure dies), says, 'Immediately before the injection of the metal the temperature of the die steel, considered over the whole of the die, is undoubtedly irregularly distributed, and the die is consequently subjected to thermal stresses. At the instant when the molten metal comes into contact with the surface of the die the temperature of the surface is suddenly raised by a very considerable amount. Even though the temperature of the metal, say, 600 degrees C., has no effect on the micro-structure of the steel, it does produce a very steep temperature gradient between the surface of the steel which, almost instantaneously, assumes the temperature of the metal, and the underlying metal. . . . The surface layer expands, temporarily, a very appreciable extent. . . .'

"Mickel placed thermo-couples of a special type very close indeed to the surface of the die which came in contact with the molten metal, and recorded the temperature during a number of shots. He found that the die temperature increased by more than 300 degrees C., the maximum temperature being 30 to 70 degrees C. higher than the casting temperature of the metal. This he attributes to the friction of the molten metal against the ingate, but a large proportion of the increase will be due to simple conductivity and would be obtained in a gravity die. Mickel says, 'The other remarkable result is the rapid rate at which the temperature increases, rising by more than 300 degrees C. in less than one thousandth of a second. . . . Only after about 15 secs has it fallen to the steady die temperature at about 300 degrees C.'

"Whilst both Nicholson and Mickel were experimenting with pressure dies, it is obvious that similar contacts and similar conductivities occur in gravity dies. If, then, we have a die which has to cool in a few seconds from a temperature approaching the melting point of the aluminium alloy to a temperature at which the casting may be removed, the tendency for the casting to crack will depend upon the difference in coefficient of expansion between the aluminium alloy used and the die material. If that of the die material is only half that of the casting, and if the casting is very hot short, it is difficult to see how it can fail to crack, even though the structure and physical properties of each portion which does not contain a crack are quite good. If, on the other hand, an aluminium die is cooling through the same range as the aluminium casting which it has produced, there should be little danger of cracking, and it is a fact that castings are being made in aluminium

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1 "Metal Industry," 1945/67/305.
2 "Metal Industry," 1945/67/276.

dies which could not possibly be made in iron dies.

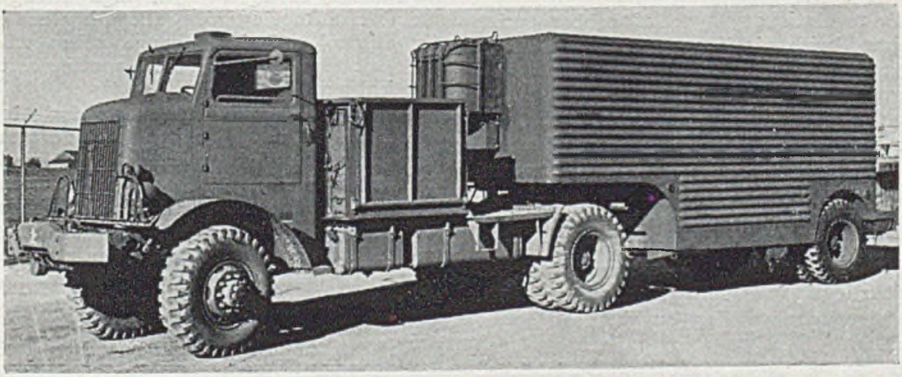
" As regards the working temperature of aluminium dies, so many factors are involved, such as thermal conductivity, specific heat, surface colour and form, radiation, etc., that I would not like to express an opinion as to which has the most effect. This could only be found by careful experiments, and it is hoped that such experiments will be carried out. I can only say that, in actual production, lower temperatures are used for aluminium dies than for iron dies. I quite agree that high die temperatures for any particular die material are to be preferred, but only experience can show whether higher or lower temperatures can be used with a new die material. Admittedly, too, a low die temperature gives, in normal practice with iron dies at any rate, rounded corners and lack of detail, but it seems reasonable to expect a greater range of temperature variation at the die surface of aluminium dies owing to the greater conductivity of aluminium, and thus sharp corners could be obtained although the average die temperature was low."—E. Carrington.

NEW LIGHT-WEIGHT TRAILER

WILL war-time-stimulated aircraft design be applied to the post-war automobile, truck, and trailer?

First indication of what may be a trend in automotive design is the new experimental revolutionary lightweight refrigerated auto-trailer designed for contributed to its structural strength. The engineers used the monocoque construction principles as applied to aircraft.

The new trailer was intended primarily for military use—for transporting frozen meats, and presented several advantages for Army use. It could be easily loaded aboard ship,

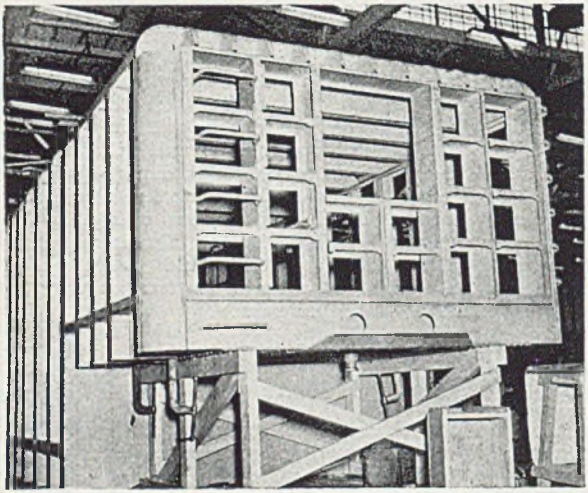


EXPERIMENTAL refrigerated trailer, designed on aeronautical engineering principles and built of aluminium alloys, weighs only half as much as standard refrigerated trailer now used by the U.S. Army. Here the semi-trailer, painted khaki brown, is shown attached to an Army tractor. It was designed and constructed for Quartermaster Corps by Fairchild Aircraft.

military use. Though in operation for almost a year, details of this model had been kept secret for security purposes.

Following well-established aircraft precedents, engineers of the Fairchild Co. cut 51 per cent. off the weight of the typical automotive trailer. Light weight, high strength aluminium alloys made for much of the reduction in weight. Other factors that contributed to a lighter unit were a new lighter refrigerating unit and redesigning the trailer in such a way that every part

added little to the ship's cargo weight, and could even be transported by air if necessary. Weighing only 7,118 lb., it has almost the same cubic capacity as the 14,700-lb. trailer formerly used as standard equipment by the U.S. Army. The unit will easily do 50 m.p.h. over good roads. It has an unusually low centre of gravity which contributes to road stability. There is no chassis, body and chassis being integrated, and the chassis channels forming part of the trailer's floor. Stresses are



SKELETON of experimental refrigerated trailer shown on preceding page is constructed entirely of aluminium alloys in order to save weight. Design and fabrication of the trailer followed aircraft production principles rather than standards of truck manufacture.

distributed throughout the entire framework. Even the skin of corrugated sheet aluminium contributes to the strength of the whole unit.

A revolutionary type of rubber spring inflated with air like an automobile tyre was the substitute for the usual heavy steel springs, with a saving of 300 lb. Engineered by the Firestone Tire and Rubber Co., the air springs are about 8½ ins. in diameter, convoluted, and also serve as pneumatically controlled shock absorbers. Air pressure within the four shock absorbing springs is maintained precisely as pressure is maintained in auto and truck tyres, but at a higher level. The springs hold 55 to 80 lb. of pressure depending on the load to be carried.

These principles follow well-established aircraft precedents. Pneumatic or hydraulic shock absorption systems in contrast to the metallic springing used on automobiles or trucks have long been standard on heavy aircraft. And an aeroplane fuselage—the aeronautical equivalent of a trailer's body—is an integral stress bearing unit. The application of lightweight, high strength metals such as aluminium alloys in place of the original trailer's 14 gauge carbon steel and oak timbers also reflects routine aeronautical practice.

Insulation, a major problem in designing a refrigerated trailer, was solved by attaching an interior shell of aluminium to wood stringers and filling the void between the exterior and interior shells with fibreglass. Rubbatex, a light cork-like insulating material of synthetic rubber, was used for flooring with additional strength provided by a top covering of corrugated aluminium sheet.

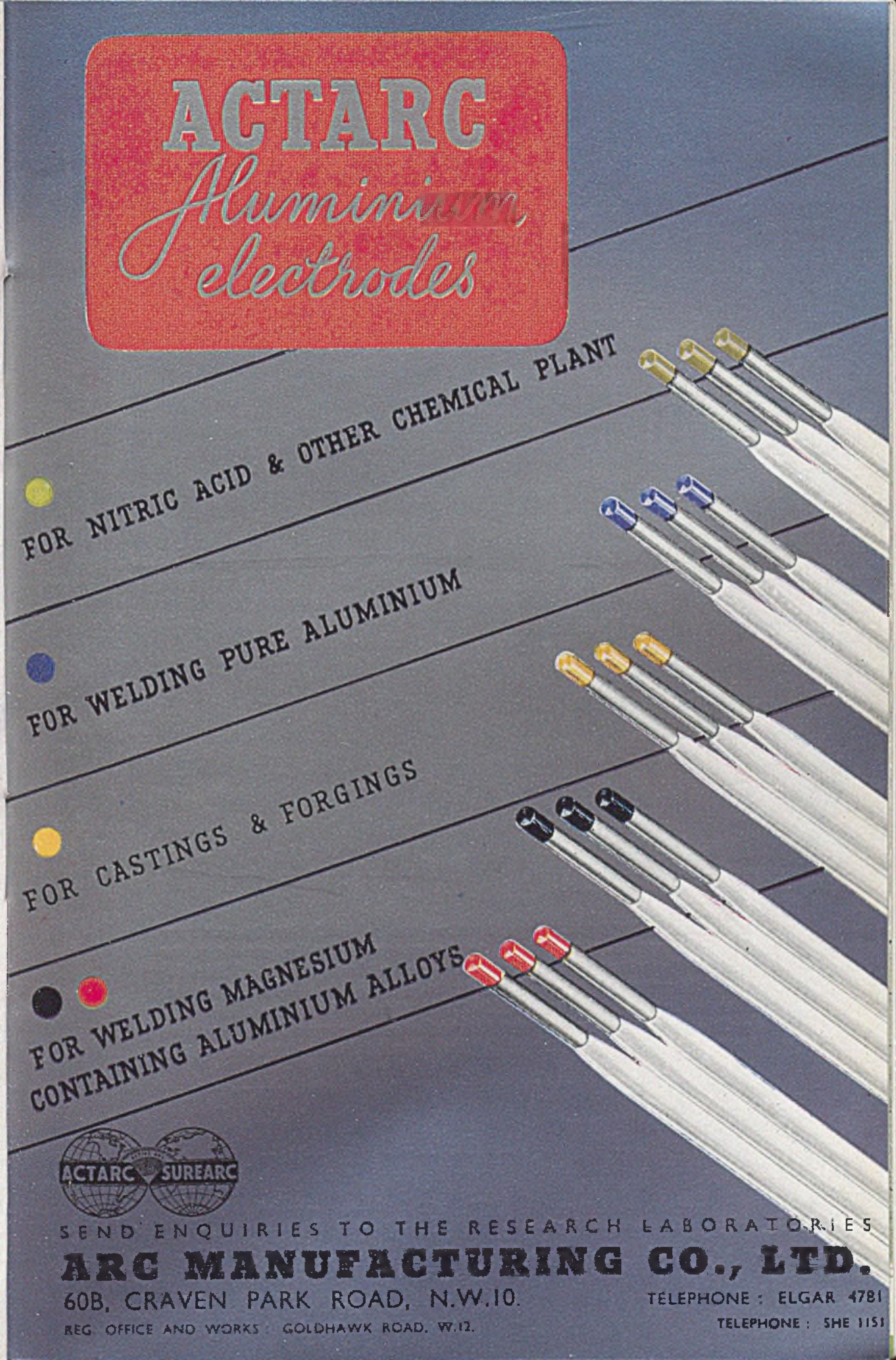
About 2,000 lb. was eliminated by installing a 700-lb. refrigerating unit recently developed by the United States Thermo Control Co. Placed in the front of the trailer, this unit forces a large quantity of cold air to the rear across the cargo of food.

Aluminium Production in Mexico

THE Reynolds Metals Co. announces that construction of a new Mexican aluminium fabricating plant will start within a few days. Operations are expected to be commenced by the middle of 1946.

The new company, namely, Internacional de Mexico, has a paid-in capitalization of 7,545,000 pesos or 1,509,000 dollars. Of this sum, 51 per cent. is held by Reynolds Metals and the balance by the Banco Nacional de Mexico and Inversiones Latinas.

The new aluminium plant will initially produce aluminium sheet and aluminium, tin and lead foil for the Mexican and Latin-American market. It is also planned in the near future to construct an aluminium powder plant and at a later date activities will be expanded to cover nearly every phase of aluminium fabrication.



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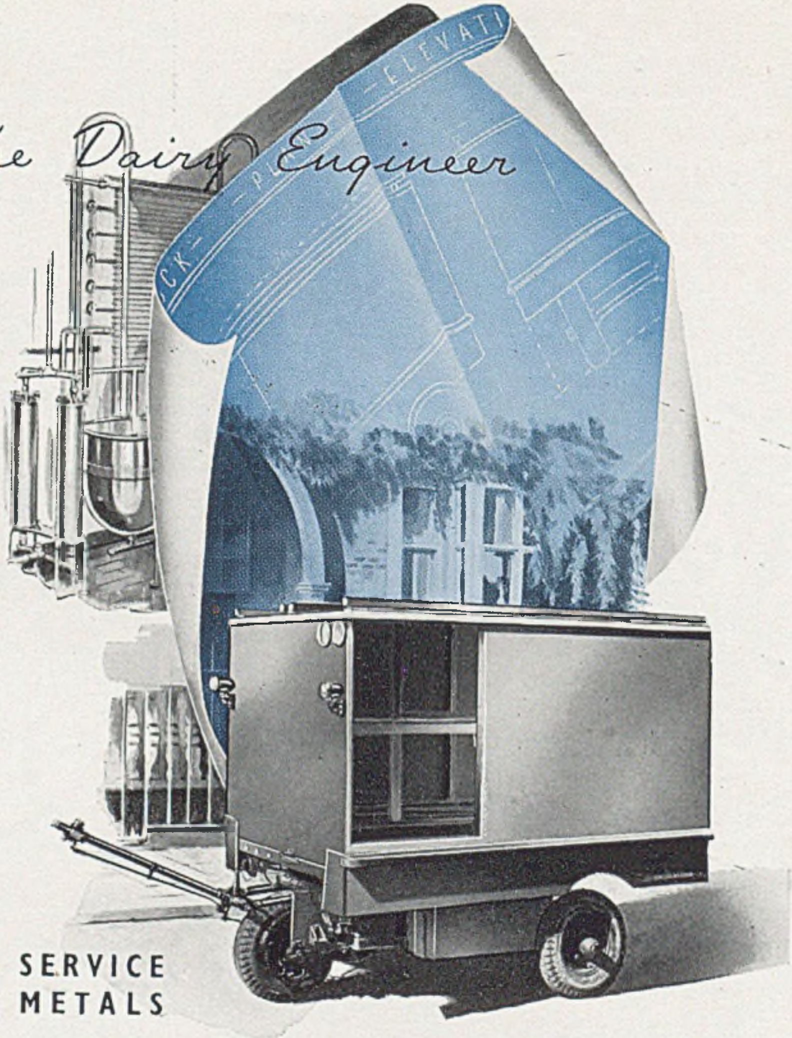

A DESIGN SERVICE IN LIGHT METALS

It is stimulating even to speculate on the rehabilitation in our new highly competitive world, of the most commonplace structure or product in terms of Light Metals. To give an idea form, to quicken the pace of attaining the full functional value of a mechanical product, Hiduminium Applications Ltd. (*designers to great organisations in the light metal industry*) invite manufacturers and others to share their experience and facilities in design and consultation. Further information on request.

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Bauxite and Lend-Lease

AS the world's largest producer of bauxite, British Guiana believes it can help Britain in the Lend-Lease negotiations if Washington acts on an interim report by the Senate sub-committee on surplus war property.

The committee recommended the State Department and Foreign Economic Administration to negotiate for bauxite deliveries in partial payment for Lend-Lease.

British Guiana exported $40 million worth of bauxite between 1939, and August, 1945, and has huge reserves.

" Game and Play of Chess "

CONSIDERABLE interest was aroused by the reference to total chess on page 509 of " Light Metals " for October, and we have been asked whether the rules for this are yet available. By permission of Mr. Charles Beatty and the British Chess Federation we have been permitted to reprint them here.

These Rules are drawn as far as possible in logical extension of the F.I.D.E.* Laws of Chess (British Edition) as drafted under the copyright of the British Chess Federation to whom grateful acknowledgments are made.

It is understood that, where applicable, the laws of Flat Chess apply to Total Chess, except in so far as they are modified in the following Rules.

1. DEFINITION AND OBJECT

(i) Total Chess is played by two persons on a square similar in all respects to the orthodox Flat Chess board, above which are superimposed at suitable intervals three boards, gridded on transparent material, to correspond with the 64 squares of the orthodox Flat Chess board. Each person shall play with a series of 16 men similar in all respects to orthodox Flat Chess men.

(ii) The object of the play is to checkmate the opponent's King as in Flat Chess.

2. THE TOTAL CHESS BOARD

(i) The Total Chess Board shall be so placed between the two persons that the nearer corner square at their respective right hands shall be light coloured.

(ii) The four superimposed boards are termed respectively, level one (bottom level), level two, level three, and level four (top level).

(iv) Every perpendicular sequence of four adjoining squares is called a tier.

(v) The words " file," " rank," and " diagonal " have the same definitions as in Flat Chess.

3. DESCRIPTION OF THE MEN

The men in each of the two series are the same as in Flat Chess.

4. INITIAL POSITION OF THE MEN

The men shall be arranged before the commencement of the game as follows:—

Level	*Men*	*Position*
IV (top)	King and Rooks	On the squares in tier to the squares they would occupy in Flat Chess
III	Knights	Ditto
II	Bishops	Ditto
I (bottom)	Queens and Pawns	On the squares they would occupy in Flat Chess

5. NOTATION

The same systems of recording chess moves may be used, with the addition, when necessary, of the Roman number II, III, or IV written before the usual designation in order to indicate the level.

6. CURRENT EXPRESSIONS

As in Flat Chess.

7. MOVEMENTS OF THE MEN IN GENERAL

(i) There are three types of move:—

(a) *Flat Move:* The move of a man to a square on the same level.

(b) *Tier Move:* The move of a man to a square in the same tier.

(c) *Total Move:* The move of a man to a square on a different level and not in the same tier.

(ii) (a) A Pawn is held to project a shadow to all squares in the same tier: such squares are called shadowed squares.

(b) When a Pawn occupies a square in the same tier as a square occupied by a piece, the shadow projected by such a Pawn is thereby neutralized.

(iii) The move of a man shall be to an unoccupied and unshadowed square, or to a square occupied by an opposing man.

(iv) The move of a man shall not:—

(a) In a flat move cause such a man to pass over any occupied square, or through any shadowed square, except in the case of the move of the Knight.

(b) In a tier move cause such a man to pass through any occupied square.

(c) In a total move cause such a man to pass through any shadowed square, except in the case of the move of the Knight.

(v) Notwithstanding anything contained in these Rules, a piece, other than a

* Fédération Internationale des Echecs.

Knight, shall not command a square occupied by the opponent's King if any square in a tier between it and the opponent's King is occupied by a piece.

(vi) A legal move of a man to any square occupied by an opposing man requires the removal of that opposing man by a player from the Total Chess board.

8. MOVEMENTS OF THE INDIVIDUAL MEN

(i) The King can be moved:—

(a) In a flat move, as in Flat Chess.

(b) In a tier move, up or down one level.

(c) In a total move, up or down one level to a square being in the same tier with a square he may occupy in a flat move.

(d) In castling the laws of Flat Chess apply.

(ii) The Queen and the Rook can be moved:—

(a) In a flat move, as in Flat Chess.

(b) In a tier move, up or down any number of levels.

(c) In a total move, up or down any number of levels to a square being in the same tier with a square either may occupy in a flat move.

(iii) The Knight and the Bishop can be moved:—

(a) In a flat move, as in Flat Chess.

(b) In a tier move. The Knight and the Bishop cannot be moved to a square in the same tier.

(c) In a total move, up or down any number of levels to a square being in the same tier with a square either may occupy in a flat move.

(iv) A/The Pawn, when not making a capture, can be moved:—

(a) In a flat move, as in Flat Chess.

(b) In a tier move, up one level, or two levels in the case of the first tier move, and afterwards one level only at a time.

(c) In a total move, up and forward one level and one square.

B/Capture with a Pawn can be made:—

(a) In a flat move, as in Flat Chess.

(b) In a tier move, a Pawn cannot capture in tier.

(c) In a total move, when the opposing man is on a square being in the same tier and one level above a square on which he could be captured in a flat move.

C/EN PASSANT

(a) In a flat move the laws of Flat Chess regarding capture *en passant* apply.

(b) In a tier move, a Pawn making a tier move of two levels cannot be captured *en passant*.

(c) In a total move, a Pawn making a total move cannot capture *en passant*.

D/PROMOTION

Each Pawn which is moved to the eighth rank of any level must be exchanged for a piece in accordance with the laws of Flat Chess.

9. CHECK

The laws of Flat Chess apply.

10. CHECKMATE

The laws of Flat Chess apply.

NOTES ON TOTAL CHESS OPENINGS

Total Chess openings differ from those of Flat Chess chiefly because of the following considerations:—

1. Owing to the King being on level IV and out of range, pawns on the second rank are more vulnerable. The King's Bishop's Pawn at KB2 is unguarded.

2. By moving on levels III or IV, pieces are immune to immediate attack by pawns. They also lose the benefit of defence by pawns.

3. The development of a piece need not be hindered by that of another. For example:—

After 1. P—K4
2. Kt—KB3

the Queen can move to KB3, Kt4, or R5 on another level.

4. An attack on a piece, other than a King, is not parried by the interposition of another piece (unless all three pieces are on the same level or in the same tier).

5. Either Rook can be moved to K1 or Q1 without the necessity of castling previously.

6. An open file or a diagonal can be captured and reinforced more quickly by moving pieces in tier to each other; for example, two Rooks and a Queen in the tier of K1.

7. In addition to the ways in which a file can be opened in Flat Chess, a file can be opened by neutralizing the shadow of the pawn.

In spite of these differences the principles of Flat Chess still generally apply.

It seems to be a principle of Total Chess that pawns should stay on the bottom level except for a good tactical reason.

Note.—To distinguish between the two kinds of Chess in the Rules given here, ordinary Chess is called Flat Chess, and three-dimensional Chess is called Total Chess when played as directed.

INDUSTRIAL FUTURE OF ALUMINIUM

"Aluminum—An Industrial Marketing Appraisal." By Nathanael H. Engle, Homer E. Gregory and Robert Mossé Published by Robert D. Irwin, Inc., Chicago, 1945. Price: 6 dollars.

IT is doubtful if such a comprehensive review of any other industry has ever been made as contained in this book by American professors, who are severally specialists in some aspect of commerce. The book is one of an "Industrial Series" of the Bureau of Business Research connected with the College of Economics in the University of Washington, Seattle. Prepared with the co-operation of the United States Department of Commerce and the Washington State Planning Council, the authors were further assisted by about 200 company officials, who gave advice and criticism during the survey of the industry.

All aspects of aluminium production, industrial structure and markets, together with the authors' recommendation for public policy are exhaustively treated in the 500 pages of the book. Although the review is essentially American, Part 3, dealing with aluminium markets, can be read with interest and profit by aluminium executives in this country. For, in the authors' own words, the "purpose in this volume (is) to provide the basis for charting the economic future of aluminum, so that our findings may serve to guide those in business and government who must make policy decisions. Can the aluminum industry face transition from war to peace with confidence? Can it hope to continue into the years of peace at war-generated levels?" These questions are answered on the findings of the authors' investigations in all aspects of the industry. They point out that one is not justified in talking of *the* aluminium industry, because they found a number of closely integrated industries all combining to give end products, such as pots and pans, automobile pistons, and transport and war planes; so that although the book ends by being nothing more than an economic survey, its actual content consists of a mass of technical and commercial data which would appear to be of great value to technicians and business men alike.

The present reviewer has been amazed at the penetration of thought which the authors have impressed upon their subject. As an example, they say that "aluminum is not aluminum, but rather an array of special-purpose metals which may be expected to give maximum satisfaction only when selected functionally"; again:—"*magnesium faces substantial sales resistance arising from ignorance about its qualities and uses.*" [The italics are ours.—Ed.]*

As indicated, it is to the chapters on past and future markets that the British reader will turn, as other sections of the book are dealt with from the aspect of American national economics. True, the chapters dealing with markets and uses are based upon the same American survey, but

Pre-war Consumption of Aluminium by Industries, United States, 1935-39, Average.

Industry	Sales	
	Million Pounds	Per Cent.
Total	257	100.0
Transportation	57	22.2
Automobile	25	9.7
Air	23	8.9
Rail	3	1.2
Other	6	2.3
Metal and metal products, non-ferrous	41	15.9
Electric light and power companies ..	35	13.6
Cooking utensils	31	12.0
Electrical machinery, apparatus, appliances	26	10.1
Iron and steel and their products, except machinery	22	8.6
Blast furnaces, steel works, rolling mills	10	3.5
Architectural, structural, ornamental	8	3.1
Other	4	1.6
Machinery, except transportation ..	9	3.5
Air-conditioning, refrigeration, etc.	2	0.8
Business machines	1	0.4
Engines, gas, Diesel, steam	1	0.4
Other	5	1.9
Chemical and allied products ..	7	2.7
Paints and varnishes	5	1.9
Sales to metal jobbers..	15	5.8
Miscellaneous industries	14	5.6

The remaining 17 or 18 per cent. included sales to metal jobbers, to manufacturers of machinery of various types, to the paint and varnish industry, and to miscellaneous users.

a careful reading of these chapters can give ideas and suggestions to all who at present are struggling to find the maximum output for swollen war-time productive capacity.

Basically, the marketing limits for aluminium are defined by technological factors and costs; it is suggested that the first rule of the man who wants to sell aluminium is to "ask the technician," whilst the cost accountant must be consulted for the ultimate decision, which must be based upon some sort of economic discussion. These considerations, technical and accounting,

*See "Editorial Opinion," "Light Metals," Sept., 1944, p. 461.

are considered in some detail. The competitive materials, steel, magnesium and plastics are briefly studied and, as a conclusion, the statement by Mr. T. O. Richards, of General Motors Research Laboratories, is quoted: " The United States will need twice its present steel capacity by 1960 and a great deal more aluminium than the war peak capacity. If full employment and high level consumption can be achieved by the people of the world, in the years ahead, the big problem will be where to find enough materials of all kinds, not where to look for markets." The foregoing statement contains, indeed, an assumption that is foundational in the survey: that is, that full employment and, therefore, high level consumption can be achieved, if not by the people of the world, yet by the United States. The level of consumption was postulated as that given by a national income of $100,000,000 at 1940 prices.

The technique of market estimating is adequately described and is perhaps too long to detail at this place, but for our purpose the following brief description may be instructive:—

Market estimating may be the result of either direct or indirect methods. The former consists of field interviews with a statistical sample of potential customers, while the indirect assessment is based upon past relationships and trends of related values.

Two hundred companies, past or potential consumers of light alloys, were interviewed. In the questionnaire submitted verbally or by correspondence, firms were asked to show the influence of price per pound by giving figures of anticipated utilization at the two price levels of 15 cents and 10 cents a pound. The answers demonstrated that the demands of some industries were inelastic, and would not alter if either price ruled. The following industries were indicated as inelastic:—Railroad, blast furnaces and steel mills, aircraft, aluminium foil, road transportation, radio, engines (gasolene, Diesel, steam), and hardware. These industries

Estimated Annual Post-war Consumption of Aluminium, by Industries,* Pounds.

Industry	Price of Aluminium Metal	
	At 15 cents per pound	At 10 cents per pound
Total, all industries	1,428,629,000	1,890,300,000 †
Transportation	845,500,000	1,053,500,000
Automobiles	400,000,000	600,000,000
Buses	12,500,000	12,500,000
Truck trailers	—	8,000,000
Railroads	368,000,000	368,000,000
Aircraft	65,000,000	65,000,000
Iron and steel and their products	350,000,000	450,000,000
Steel industry	250,000,000	250,000,000
Architectural, building construction	100,000,000	200,000,000
Electrical Industries	93,644,000	135,450,000
Transmission lines	15,000,000	18,000,000
Electrical goods, manufacturing appliances and general equipment	48,165,000	64,525,000
Communications and related equipment	7,500,000	15,000,000
Floodlight and other lighting equipment	2,500,000	5,000,000
Radios		
(a) Low estimate	600,000	6,000,000
(b) Medium estimate	5,000,000	5,000,000 †
(c) High estimate	24,000,000	27,000,000
Regulators, switches, etc.	154,000	10,500,000
Washing machines	15,000,000	35,000,000
Miscellaneous electrical items	325,000	425,000
Non-ferrous metal casting and stamping	50,000,000	100,000,000
Metal stamping	3,500,000	10,000,000
Cooking utensils	45,283,000	67,925,000
Machinery and related equipment	28,702,000	49,925,000
Air conditioning and refrigerating equipment	18,500,000	31,000,000
Business machines	2,200,000	2,750,000
Derricks and cranes	20,000	700,000
Engines, gasoline, Diesel, steam, etc.	2,420,000	2,420,000
Mining machinery	250,000	300,000
Tyre making machinery	2,000,000	5,500,000
Miscellaneous machinery	3,312,000	7,255,000
Miscellaneous industries		
Aluminium foil	15,000,000	15,000,000
Hardware	500,000	500,000

* Based upon field interviews with 135 consuming companies. The assumptions were made of complete conversion to peace with full employment in American industry and national income of $110 billion at 1940 prices. The totals may be reached by the fifth post-war year.

† Medium radio estimate used in totals and sub-totals.

took 50 per cent. of the estimated usage. Influence of price was more or less marked in the remaining industries:—Automobile, architectural and building construction, electrical appliances, non-ferrous metal castings, cooking utensils, air-conditioning and refrigerating plant, transmission lines, washing machines, communications equipment, non-ferrous metal stamping, miscellaneous machines, flood-lighting and other lighting equipment, business machines, tyre making machines, miscellaneous electrical items, mining machines, regulators, derricks and cranes, and truck trailers.

The figures derived from field survey checked well with those obtained indirectly.

The authors' survey of the post-war market in the United States gives the estimate that a total demand for 1,500,000,000 pounds may result five years after the war. This demand is on the further assumption that virgin metal continues to cost (in U.S.A.) 15 cents a pound. If, however, the price of virgin be reduced to 10 cents a pound, a total demand of 2,000,000,000 pounds is possible. The total requirements include virgin and secondary metal the proportions given for the 1,500,000,000 pounds demand being given at 900,000,000 for virgin and 600,000,000 for secondary. The tables reproduced, numbered 88 and 89 in the book, show, first, the increase in consumption anticipated industry by industry, and, secondly, the distribution of the forecast demand at the two price levels.

Each of the user markets noted in the tables referred to is considered in further detail in three chapters. Since the transportation market is the largest field, one chapter of 27 pages is devoted to considerations of the views expressed to the authors during their survey. In the automotive industry possible requirements vary widely from company to company, but a general conclusion was that potentialities for light alloys in this industry was decidedly dependent upon price. While as much as 40 lb. weight per car was used in some cases before the war, estimates by some automobile specialists gave up to 500 lb. for a post-war product. Much depends upon the enthusiasm, or otherwise, of the engineer for light alloys. The influence of war-time experience in aluminium is exemplified in the case of a Detroit firm that had converted an iron foundry completely to aluminium casting for war production. It was felt that this experience would be transferred to post-war operations. The same foundry, however, thought that the price for virgin ingot would have to be 9 cents before any large use could be expected. Another executive wanted aluminium at 7 cents, while one saw little hope for large consumption until the price was as low as 4 cents a pound.

Difficulties in fabrication were mentioned several times; there appears to be ignorance on welding processes for aluminium, although it is pointed out that the war has again given many operatives the necessary "know how." A second limitation of the material was due to the difficulty of deep drawing.

The authors' conclusions of market appraisal for aluminium in this field is given as 400,000,000 pounds using aluminium at 15 cents a pound, for a production of 5,000,000 cars having an aluminium-alloy content of 80 pounds each. This market is somewhat elastic, so with a price of 10 cents a pound, it is estimated that 125 pounds might be used in each car, and for an output of 5,000,000, 600,000,000 pounds of aluminium will be required. It is noted that these quantities should not be anticipated until three or four years after the war.

The position is very different when trucks and buses are considered, for weight saving means reducing operating costs and increased pay load. Extracts from engineers and executives of truck and bus producers are given here because of their interest and divergency of view. The chief engineer of a large company states that his "consumption of aluminium was about 1 ton per bus in the pre-war period. At 10 cents a pound for aluminium we estimate an increase of about 50 per cent. in our consumption. On the technical side we find that aluminium extrusions offer a great advantage over steel. Also, cast aluminium wheels are fairly satisfactory, but pressed aluminium wheels can also be used now that a good hub cap can be made. Axle housings and similar parts could be made of aluminium if the techniques for repairs by truck-operating companies can be developed. The successful use of aluminium in truck and bus production depends to a large extent on getting the right alloy for the particular use."

Another engineer of a large truck and bus producer said: "The use of aluminium in trucks is very competitive, hence price is a factor. Most of the use of aluminium in buses and trucks has been in the construction of bodies. A large bus which holds 37-41 passengers may use 5,200 pounds of aluminium. We anticipate an increased use of aluminium in running gear and rear-axle housings; wheels may also be made of aluminium, but more research is necessary to develop them. Aluminium brake shoes have failed, and cast and malleable iron are used instead. Pistons can be made of secondary aluminium provided the same physical specifications can be met . . . it is preferable to rivet rather than to weld, but advancement is being made in the welding process . . . difficulty is that there is not a wide enough understanding to weld aluminium . . . riveting is better understood." This statement concludes by stating that this company is not prepared to take the risk of welding, as a failure of 2 per cent. of the welds made would put them out of business.

The president of a moderate-size truck-body plant stated that " a price of 10 cents a pound is low enough to make aluminium a preferred material."

A small truck company stated that they had not found aluminium to be a particularly satisfactory material because of atmospheric corrosion. Use after the war would depend upon what advances had been made in corrosion protection.

Each of the opinions quoted contains some interesting information, and the reviewer's difficulty is to know when to stop quotation. The opinions quoted serve to indicate the wealth of valuable technical and commercial information to be found in this book.

In consideration of the railroad and railway-car building industry, it was found that with but few exceptions the railroads were not convinced of the superiority of aluminium in rolling-stock construction. Another opinion that aluminium was definitely superior to other materials for passenger and freight cars from the technological and economic aspects; again, one car builder advocated the superiority of stainless steel. The president of a large car-building company stated, among other things, that design considerations must be carefully considered, particularly with respect to the low modulus of elasticity of aluminium, but because of the lightness and strength of the alloys used, it was possible to hold deflections within the range of that of a structure using light alloy, still effecting weight saving, but also actually providing greater strength. He mentioned again that welding of aluminium is not without its difficulties but expected that they will be overcome as research develops methods.

Of interest is the statement of another authority that aluminium could be used to increase the water capacity of locomotive tenders, so eliminating stops for water pick-up, reducing overall time and operating expenses. Another official of a car-building company stated that the rapid developments of plastics has given reason to consider the replacement of aluminium by plastics in some conditions, but that no definite conclusions had been reached.

A definite engineering problem in the use of aluminium in railway cars is mentioned in another reply as follows:—" . . . brake shoe capacity. A standard rule is that brake-shoe pressure has to be 60 per cent. of the weight of the car, in order to be able to stop the train. If the weight of a freight car is lightened by 10,000 pounds from its original 40,000 pounds, the brake-shoe pressure must still be 60 per cent. of the weight of the car. But when the car is loaded the braking equipment is insufficient to do the job. On the other hand, heavier braking equipment on a lighter car would slide the car wheels when the engineer tried to stop the train. Thus, a different solution must be sought which adds to the cost of the brakes. Railroads think a long time before they will pay extra for both aluminium and brakes. It is argued also that there is not much saving in coal for locomotion, even if freight cars are lightened by the use of aluminium. As coal and fuel oil are both cheap, railroads have not been interested in arguments in lighter equipment."

The authors' met a difficulty in appraisal when they considered the aircraft industry, because the industry itself remains doubtful of its own future. Aluminium and magnesium will undoubtedly remain aircraft materials, but the amount of aeroplane production in post-war years is so uncertain that difficulty was experienced.

Turning to architecture and building construction, the authors evolved an estimate for the post-war market of 100,000,000 pounds' weight at 15 cents per pound to 200,000,000 pounds at 10 cents. In the words of one interviewee: " a large use was anticipated for window frames and other structural parts as well as for decorative effects. A new electro-plating process for chrome-plating on aluminium is expected to open up new uses for decorative purposes in building."

In passing, it is worth noting that 17 per cent. of the surface of the Rockefeller Centre in New York is aluminium, the total amount in the building amounting to 1,500 tons.

Another building opinion is that aluminium has very definite advantages over steel for casement windows in dwelling houses, for aluminium alloys do not stain and do not require frequent painting for upkeep.

In a comprehensive review of the possibilities of light-alloy application to plumbing, the official of a large company specializing in the production of such requisites made the point that the public, having been educated to glass-like cleanliness of enamelware and pottery, is not likely to take kindly to aluminium sinks and plumbing fixtures in general, unless a finish for aluminium is developed to give equal or better surfaces than the accustomed finish of the usual materials.

Saving in freight charges is mentioned several times as a further inducement for the consideration of aluminium in such goods as heating radiators, valves and fittings, and soil, sewer and water pipes.

The electric light and power companies have been important users of aluminium in the form of overhead cables, but future demands depend upon post-war conditions. Given full employment and industrial prosperity, new power lines may have to be erected; should serious unemployment follow the war, new lines may be installed as part of a public-works programme. An official of the U.S. Department of Commerce stated that in the choice of cables for transmission lines " weight and price become the deciding factors." The demand, therefore, is elastic to some extent. Final computation gave aluminium sales of 20,000,000 pounds at 15 cents per pound, and 24,000,000 pounds at 10 cents for an annual construction of 10,000 miles.

A manufacturer of electric fixtures was enthusiastic about aluminium, writing in the following terms:—" The company appreciates aluminium now that they cannot get it. When the company had to change over to steel for lighting it found that steel was more expensive than aluminium. In the case of aluminium, all that the company had to do was to form it, then alzate it and that was all. In the case of steel, the company had to form it, clean it, electro-plate it and paint it. Steel may just be plated, buffed, and polished and then lacquered but this is still more expensive. For fluorescent lighting, aluminium is just right. It should be used for industrial lighting, but the industry has built up porcelain enamel steel and it is hard to change over to aluminium. The company was unsuccessful in spot-welding, but it got around this by riveting its aluminium products."

The authors of this exhaustive market appraisal rightly consider the influence of aluminium's " little sister," magnesium, on post-war markets. A long chapter deals with the history, production, processes and markets of magnesium alloys. First in the authors' conclusions is the difficulty of assessment of magnesium's post-war place, for the large war-time production has been utilized in plane construction and pyrotechnics, including incendiary bombs. The public, therefore, has had little chance to become familiar with the metal. It may be interpolated that the population of the big cities of the United Kingdom would confirm the statement that " the emphasis on incendiary uses has not allayed the widespread fear of magnesium."

The present (U.S.) price of 20½ cents per pound makes the material economically comparative with aluminium and, for some uses, with steel and copper, but a lower price would encourage experimentation. A price as low as 10 cents a pound is envisaged by some enterprising concerns shortly after the war.

Over 100 reports of the field survey gave definite answers to questions relating to probable consumption of magnesium. Of these, 77 reported that no use of magnesium was contemplated in post-war years, reasons being a frank admission of " no knowledge," together with detailed reasons why magnesium was unsuitable for specific industries. Fire risk and corrosion were mentioned several times; nevertheless, with certain reservations, 28 companies said they would use greater or less amounts of magnesium after the war.

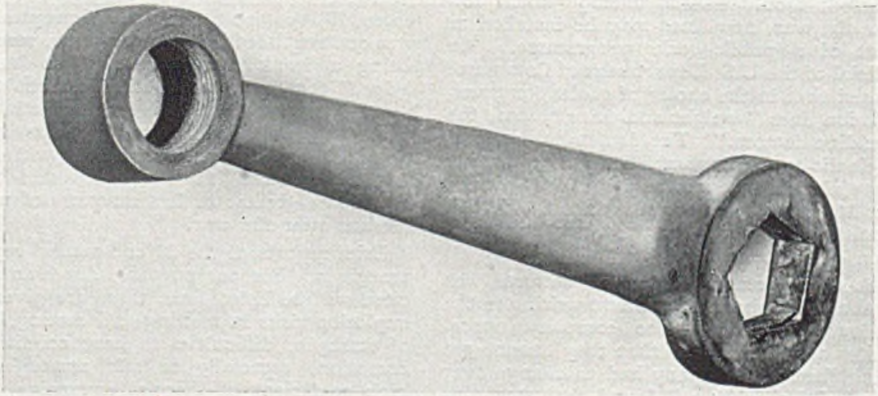
Brief reports of the 28 companies' replies are given. For our purpose, disadvantages cited will be listed first: these are given as explosion risks in melting and casting, lack of strength, difficulties in heat conditions, corrosion, especially in salt atmospheres, high coefficient of thermal expansion, and poor machineability. Favourable factors encouraging increased use of magnesium were given as follows:—Good machineability, strength at high pressures, low specific gravity and corrosion resistance to some chemicals. Many replies stated that no technical limitations had been found with respect to a particular job; others, again, cautiously stated that experience was limited.

It may be objected that the replies abstracted above show a rather marked lack of knowledge on the subject. Similar ignorance was apparent in some of the aluminium replies and, therefore, it may be suggested that the first task confronting the aluminium industry, both here and in the States, is technical propaganda conceived and executed in the broadest possible terms. True, we have a Development Association that has done valuable work in providing information to all who ask. However, anyone who has been in attendance at the recent aluminium exhibitions will agree that it is not very wide of the mark to say that engineers in general do not know even the A B C of light-alloy materials. Development associations must beware of assessing their work on the number of queries received and answered, for often questions will come from present users of light alloys. The yardstick, no doubt extremely difficult to apply, must be the responses from firms to which aluminium alloys are still unfamiliar in practice. The task is one to be shared by associations and individual firms. In this connection, one last quotation may be made. Although the statement was made as the outcome of conference at one works, the purport of its message surely applies in a general sense and might well be taken to heart in this country:—

"Emphasis was placed by the officials interviewed upon the necessity for an educational programme covering developments in production of aluminium and magnesiums (alloys) . . . of particular importance in such a programme is information on methods of fabrication."

LEAD-PLATED ALUMINIUM

IN view of the many erroneous and too-general statements which have been circulated regarding the efficacy and advisability of electrodeposits on aluminium as a means for protection or decoration, the illustration reproduced above is of some interest. The component shown consists of an aluminium-alloy gravity die-casting designed for use in what amounts virtually to a constant spray of sodium sulphate with weak sulphuric acid.



DESIGNED for experimental use in connection with a complex chemical-engineering process, this light-alloy permanent-mould casting was lead-plated as a protection against the spray of weak sulphuric acid, plus sodium sulphate, with which it comes into contact when in operation. As shown here, the component had been in continuous use for one month—no surface attack of any kind is visible. A deposit in the threaded portion (at the left) proved to be sodium sulphate which had crystallised out, and, on analysis, indicated the absence of both lead and aluminium. (Courtesy of A.E.R. (1938), Ltd.)

In current practice the component has hitherto been made as a plastic moulding. It is essential that, in operation, when once positioned and centred, no distortion should occur. Unfortunately, quite apart from the fact that the plastic component absorbs fluid and, as a result, alters in shape, this distortion varies with changes in humidity and with time; for, in use, it may be subjected to somewhat rough handling which removes the more or less impervious resin skin.

The assembly, into which the part shown fits, is of quite a massive nature, however, and the use of any heavy metal is ruled out. An aluminium arm, therefore, was made and lead-plated to protect it against the acid spray. No sign of attack is visible after one month's continuous operation.

Light Alloys in

Rectifiers, Photocells and Condensers

Continuing from "Light Metals," 1945/8/491, a Discussion on the Relationship Between Impregnated Media and the Service Characteristics and Life of Fixed-paper Condensers

THE influence of temperature upon the electrical characteristics of fixed-paper condensers having various impregnating waxes as dielectric media is worthy of note. Regarding breakdown voltage, it is logical to anticipate a negative coefficient, that is, a fall in electric strength as temperature rises, in any case because this is usual with all dielectrics. Further, some complication may be expected as the melting point of the wax is passed, depending upon how sharply this change in phase occurs, and upon the volume change that accompanies it.

Results are given for a number of condensers having a different wax impregnant, but otherwise identical in construction and manufacture. All were of 1 mF capacity, using two aluminium-foil electrodes, with two papers of 0.0004-in. thickness between the foils. One batch used a low melting point paraffin wax as dielectric, one a high melting point paraffin wax, and one a high melting point mineral wax. All the units were dried and vacuum impregnated in exactly the same manner, and sealed with bituminous compound into metal cans.

These condensers were tested for electric strength at three temperatures, the highest being just above the melting point of the highest melting wax. For this purpose they were held at the temperature overnight (18 hours) in a large electric oven, thermostatically controlled. The tests were made with the condensers actually in the oven at temperature. This was achieved by taking leads from the condenser terminals through insulating tubes in the oven wall. On each condenser the voltage was raised from zero at a rate of approximately 100 volts per second until breakdown occurred.

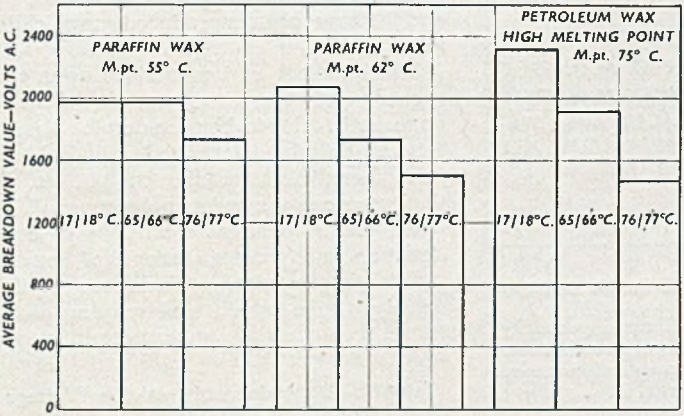


Fig. 183. — Breakdown voltage of fixed-paper condensers at various temperatures for different impregnating media. Condenser construction system consisted of two papers between aluminium foils (see Tables 80, 81, 82).

The results for the low melting point paraffin wax are given in Table 80. It will be seen that the electric strength at

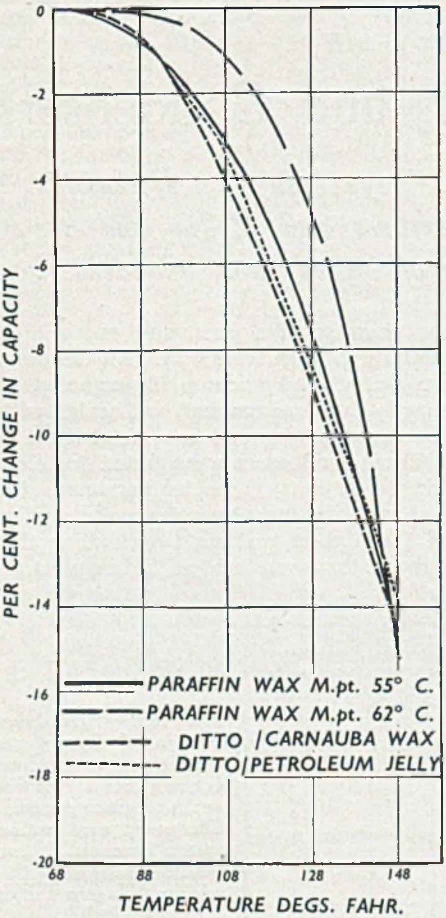


Fig. 184.—Percentage change in capacity with temperature for fixed-paper condensers with various types of plain and compounded paraffin wax.

the intermediate temperature, which is above the wax melting temperature, is of the same order as that at ordinary temperatures, while that at the highest temperature is only 10 per cent. below this value.

Table 81 gives the results for the high melting point paraffin wax. The electric strength starts at the same order of level as for the low melting wax, drops about 15 per cent. just above its melting point, and another 15 per cent. at the highest temperature.

Table 82 deals with the high melting point mineral wax. At ordinary temperatures the electric strength is about 15 per cent. above that for the paraffin waxes, falling about 15 per cent. at each temperature increment, the highest temperature being just above the wax melting point.

A very much larger number of test values would have to be employed for formulating a finite conclusion. These few values indicate, however, that the higher melting paraffin wax has no advantages with respect to electric strength over the lower melting one, and that the high melting mineral wax is superior at normal temperatures but of the same order of quality at more elevated levels. These conclusions are in general borne out in practice.

To give a concise picture of the influence of temperature upon electric strength, and its dependence upon the nature of the wax, the mean values from Tables 80, 81 and 82 have been reproduced graphically in Fig. 183.

The influence of temperature upon the capacity of the condenser is another important factor to be considered. Again, this can only be determined on individual condensers, and for the comparison of various waxes the test samples must all be made under identical conditions of construction and process, except, of course, for the impregnant. Variations in the quality of the paper, and varying efficiencies in processing, have some influence

Table 80.—Dependence of Breakdown Voltage upon Temperature.

Fixed-paper condensers, aluminium-foil electrodes, 2 × 0.0004-in. papers, impregnated with paraffin wax, melting point 55°C., capacity 1 mF.

Sample No.	Breakdown Voltage, V.A.C. at		
	17/18°C.	65/66°C.	76/77°C.
1	800	1,500	1,200
2	1,600	1,800	1,200
3	1,900	1,900	1,500
4	2,000	2,000	1,600
5	2,000	2,000	1,700
6	2,100	2,100	1,800
7	2,100	2,100	1,900
8	2,400	2,100	1,900
9	2,400	2,100	2,200
10	2,500	2,200	2,400
Mean	1,980	1,980	1,740

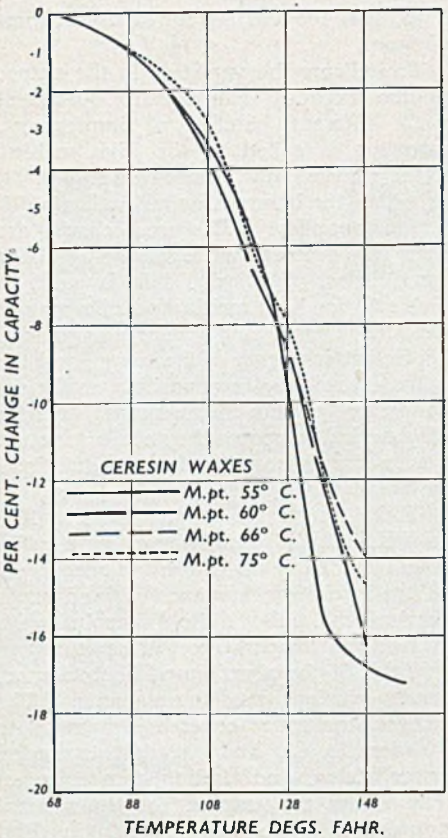


Fig. 185.—Percentage change in capacity with temperature of fixed-paper condensers with ceresin wax impregnating medium.

upon the change in capacity with temperature.

In general, fixed paper condensers have a negative temperature coefficient, but the drop in capacity with temperature rise is not necessarily linear. Further, appreciable variation in the magnitude of the change may occur from condenser to condenser, and the change may not follow quite the same path for different waxes. Nevertheless, the average temperature coefficient is a characteristic of the wax that is quite marked, as can be seen from the data presented.

Table 83 summarizes information on the capacity/temperature relationship for condensers having various impregnants. All were made with aluminium foil electrodes and with two papers between foils. The measurements were made very carefully by holding the condensers at temperature for a period, using either a thermostatically controlled hot air oven or oil bath. The temperature of 68 degrees F. (or 20 degrees C.) was taken as normal for the basis of expressing the percentage change, and readings were taken at increments of 10 degrees F. Several condensers were tested for obtaining an average value.

The tolerable capacity change, naturally, varies with the closeness of the tolerance on capacity allowable. A plus or minus limit of 5 per cent. really needs the plus or minus change in capacity over the operating range to be as small as possible, preferably not more than 5 per cent.

Impregnant No. 1 is the commonly used low melting point paraffin wax. It shows a high capacity temperature coefficient, dropping 5 per cent. in 40 to 50 degrees F. rise, and 12 to 15 per cent. for a 70 to 80 degrees C. rise. Impregnant No. 2 high melting paraffin wax is appreciably better up to about 140 degrees F., i.e., for small increases in operating temperatures it is advantageous, but not for large increments.

Impregnant No. 3, the high melting point petroleum hydrocarbon wax, is markedly superior, and exceptionally good for operating temperatures up to about 140 degrees F.

The ceresins (Nos. 4, 9, 10 and 11)

Table 81.—Dependence of Breakdown Voltage upon Temperature.

Fixed paper condensers, aluminium foil electrodes, 2 × 0.0004 in. papers, impregnated with paraffin wax, melting point 64°C., capacity 1 MF.

Sample No.	Breakdown voltage, V.A.C. at		
	17/18°C.	65/66°C.	76/77°C.
1	900	1,500	900
2	1,700	1,600	1,000
3	1,800	1,700	1,000
4	1,900	1,700	1,300
5	1,900	1,700	1,400
6	2,100	1,800	1,700
7	2,100	1,800	1,800
8	2,600	1,800	2,000
9	2,700	1,900	2,000
10	3,000	1,900	2,000
Mean	2,070	1,740	1,510

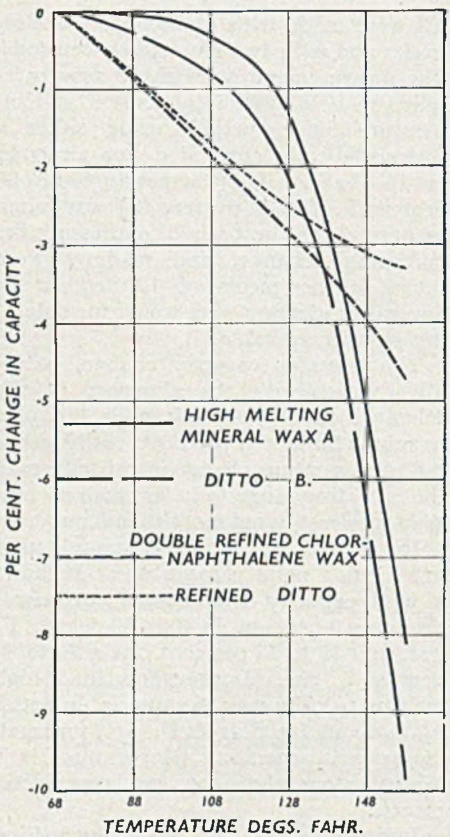


Fig. 186.—Capacity temperature characteristics of fixed-paper condensers with high-melting-point mineral and chloronaphthalene waxes.

have no particular merit over the low melting paraffin wax. Nor have the paraffin carnauaba wax or petroleum jelly mixtures (Nos. 7 and 8) in this particular respect.

Both the chlorinated naphthalene waxes (Nos. 5 and 6) are very good, being superior to the high melting mineral wax over the whole range, but not quite so good over the first portion of the range (up to about 140 degrees F.).

As before stressed, these temperature coefficients should only be regarded as a typical guide representing the order of the change. The average values from Table 83 are reproduced graphically in Figs. 184, 185 and 186 for clarity of comparison.

To indicate the variation in the nature of the capacity temperature coefficient with different batches of impregnant, attention is called to the high melting point mineral wax, impregnant No. 3, in which the letters A and B indicate different supplies. The coefficients are definitely different while still being of the same order. Similarly, data is given in Table 84 for high melting paraffin waxes. One of them has a marked positive coefficient over part of the range, and the other a tendency to a positive coefficient over short portion of the range. Yet for all practical purposes they conform to the general trend shown for impregnant No. 2 in Table 83.

These results are graphed in Fig 187, in which the high melting point paraffin wax from Table 83 is also included.

The insulation resistance of fixed paper condensers falls quite sharply with increase in temperature. This is shown in Table 85 for aluminium foil condensers having various wax impregnants. The temperature range covered is from 20 to 40 degrees C., and the tests recorded cover rising and falling temperatures. The values are graphed for the mineral petroleum hydrocarbon waxes in Fig. 188, and for the ceresins in Fig. 189. The path of the curves may be regarded as typical, although the actual insulation resistance values depend also upon the paper portion of the dielectrics.

Table 82.—Dependence of Breakdown Voltage upon Temperature.

Fixed paper condensers, aluminium-foil electrodes, 2 × 0.0004 in. papers, impregnated with high melting point mineral wax, melting point 75°C., capacity 1 MF.

Sample No.	Breakdown voltage, V.A.C., at		
	17/18°C.	65/66°C.	76/77°C.
1	1,700	1,500	900
2	1,700	1,600	1,000
3	1,800	1,700	1,300
4	2,000	1,700	1,600
5	2,400	1,900	1,700
6	2,500	1,900	1,800
7	2,700	2,100	1,900
8	2,700	2,200	2,000
9	2,700	2,200	2,100
10	3,200	2,400	2,400
Mean	2,320	1,920	1,670

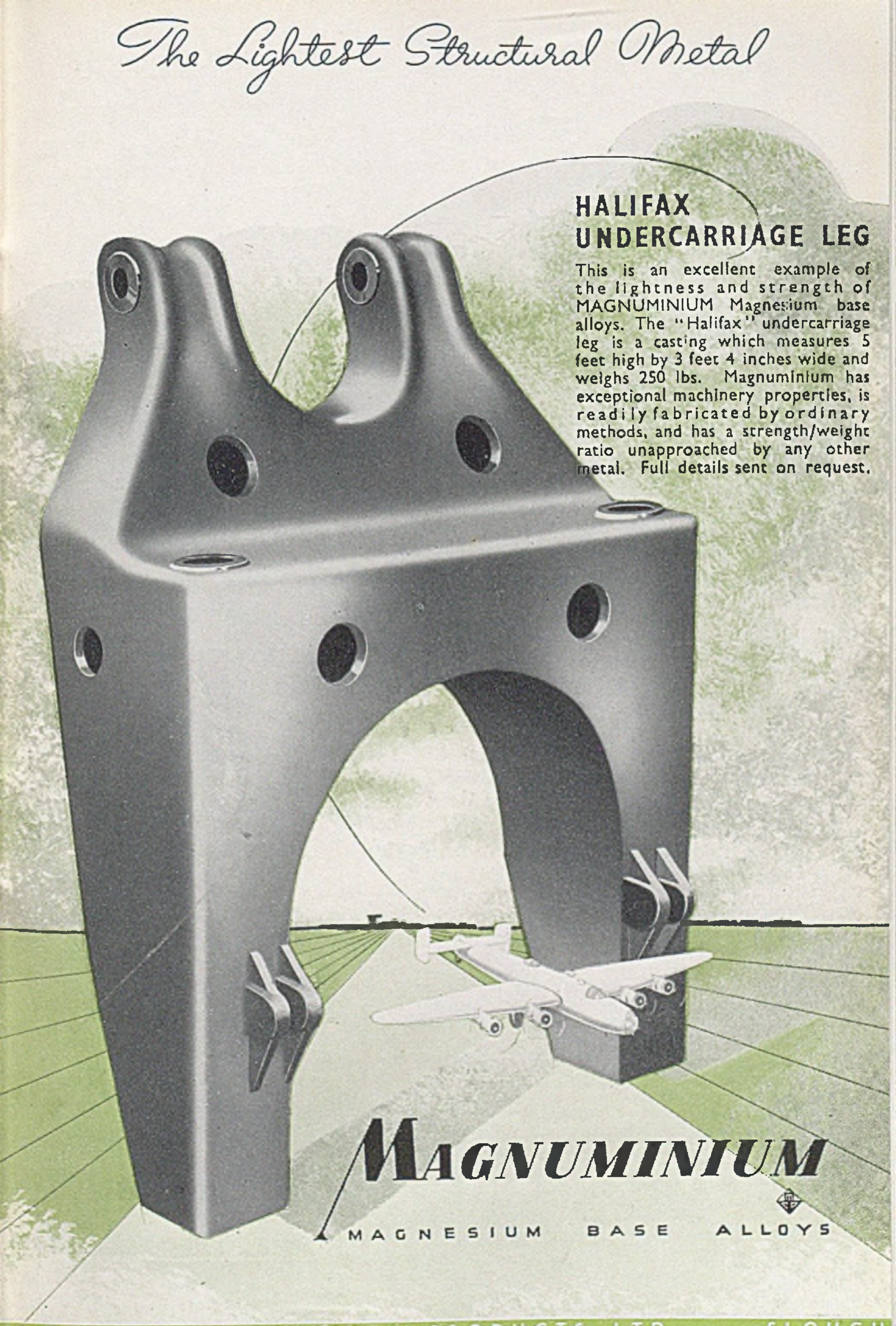

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Table 83.—Dependence of Capacity on Temperature.

Fixed paper condensers, two papers between aluminium foils.

Impreg-nant No.	Type of impregnant	No. of test condenser	Nominal capacity MF.	Per cent. decrease in capacity from capacity at 68°F. at temperature °F.									
				68	78	88	98	108	118	128	138	148	158
1	Paraffin wax, melting point 55°C.	1	1.0	0.0	0.1	0.6	1.6	3.5	5.9	8.6	12.0	15.2	—
		2	1.0	0.0	0.1	0.8	2.3	4.4	6.6	9.0	11.5	14.0	—
		3	1.0	0.0	0.1	0.7	2.5	4.3	6.5	8.7	11.3	14.1	—
		4	1.0	0.0	0.1	0.4	1.5	3.3	5.7	8.4	11.5	14.8	—
		Mean	1.0	0.0	0.1	0.63	1.98	3.88	6.18	8.68	11.58	14.52	—
2	Paraffin wax, melting point 62°C.	1	1.0	0.0	0.04	0.09	0.3	1.2	2.7	5.5	10.2	17.3	—
		2	1.0	0.0	0.10	0.25	0.5	1.4	2.7	5.3	9.4	16.5	—
		3	1.0	0.0	0.00	0.05	0.4	1.3	2.8	5.5	9.2	13.6	—
		4	1.0	0.0	0.00	0.08	0.2	0.5	1.2	2.8	5.9	13.2	—
		Mean	1.0	0.0	0.04	0.12	0.35	1.1	2.4	4.8	8.7	15.2	—
3	High melting mineral wax, melting point 75°C.	1A	1.0	0.0	0.03	0.09	0.2	0.4	0.6	1.4	2.7	5.1	8.0
		2A	1.0	0.0	0.02	0.07	0.2	0.4	0.6	1.3	2.9	5.2	8.2
		3B	1.0	0.0	0.10	0.30	0.5	0.8	1.3	2.1	3.5	6.5	9.8
		4B	1.0	0.0	0.10	0.43	0.6	1.0	1.4	2.3	3.8	6.7	9.9
		5B	1.0	0.0	0.10	0.20	0.4	0.7	1.1	2.0	3.4	6.4	9.6
		Mean	1.0	0.0	0.07	0.27	0.38	0.66	1.0	1.8	3.3	6.0	9.1
4	Ceresin wax, melting point 55°C.	1	1.0	0.0	0.45	1.1	2.0	3.3	5.5	9.5	16.0	—	17.5
		2	1.0	0.0	0.22	0.9	1.9	3.3	5.3	9.2	16.4	—	17.7
		3	1.0	0.0	0.34	1.0	2.0	3.2	5.3	9.0	14.2	—	15.6
		4	1.0	0.0	0.37	1.0	2.0	3.3	5.3	9.3	16.0	—	18.0
		Mean	1.0	0.0	0.35	1.0	2.0	3.3	5.3	9.3	15.7	—	17.2
5	Double refined chlorinated naphthalene wax, melting point 88°C.	1	0.75	0.0	0.40	0.84	1.30	1.75	2.1	2.6	3.2	3.8	4.6
		2	0.75	0.0	0.40	0.86	1.32	1.77	2.3	2.8	3.3	3.9	4.8
		3	0.75	0.0	0.45	0.86	1.37	1.86	2.4	3.0	3.4	3.9	4.7
		4	0.75	0.0	0.43	0.85	1.35	1.80	2.3	2.9	3.3	3.8	4.8
		Mean	0.75	0.0	0.42	0.85	1.34	1.80	2.3	2.8	3.3	3.9	4.7
6	Refined chlorinated naphthalene wax, melting point 94°C.	1	0.75	0.0	0.28	0.7	1.1	1.6	2.0	2.4	2.5	—	3.1
		2	0.75	0.0	0.40	0.9	1.3	1.8	2.3	2.8	2.9	—	3.5
		3	0.75	0.0	0.42	0.8	1.3	1.7	2.1	2.6	2.7	—	3.3
		4	0.75	0.0	0.37	0.8	1.2	1.7	2.1	2.5	2.6	—	3.2
		Mean	0.75	0.0	0.37	0.8	1.2	1.7	2.1	2.6	2.7	—	3.3
7	Paraffin wax, carnauba wax mixture, melting point 61°C.	1	1.0	0.0	0.20	0.7	1.7	3.0	4.9	7.5	10.5	14.2	—
		2	1.0	0.0	0.22	0.8	1.8	3.1	5.0	7.6	10.7	14.5	—
		3	1.0	0.0	0.20	0.9	1.8	3.1	4.9	7.6	10.6	14.4	—
		4	1.0	0.0	0.21	1.0	1.9	3.2	5.0	7.7	10.8	14.9	—
		Mean	1.0	0.0	0.21	0.9	1.8	3.1	5.0	7.6	10.7	14.5	—
8	Paraffin wax, petroleum jelly mixture, melting point 54°C.	1	1.5	0.0	0.20	0.75	2.3	3.2	5.9	8.6	11.1	14.3	—
		2	1.5	0.0	0.19	0.68	2.2	3.1	5.7	8.3	10.7	13.8	—
		3	1.5	0.0	0.13	0.57	2.1	3.0	6.0	8.5	10.9	14.0	—
		4	1.5	0.0	0.12	0.56	2.1	3.0	5.6	8.2	10.5	13.5	—
		Mean	1.5	0.0	0.16	0.64	2.2	3.1	5.8	8.4	10.8	13.9	—
9	Ceresin wax, melting point 60°C.	1	0.70	0.0	0.43	1.2	2.2	3.9	6.5	9.0	13.0	16.7	—
		2	0.70	0.0	0.29	0.8	1.7	3.4	5.9	8.0	10.9	15.3	—
		3	0.70	0.0	0.42	1.1	2.1	4.0	6.6	8.9	12.7	16.3	—
		4	0.70	0.0	0.34	0.9	2.0	3.5	6.0	8.1	11.7	16.4	—
		Mean	0.70	0.0	0.37	1.0	2.0	3.7	6.3	8.5	12.1	16.2	—
10	Ceresin wax, melting point 66°C.	1	0.65	0.0	0.47	1.1	2.2	4.2	6.7	9.0	12.1	14.7	—
		2	0.65	0.0	0.44	0.9	2.1	4.0	6.5	9.0	12.3	14.8	—
		3	0.65	0.0	0.22	0.7	1.3	2.6	5.9	8.0	11.5	12.8	—
		4	0.65	0.0	0.27	0.7	1.2	2.8	5.7	7.9	10.8	13.1	—
		Mean	0.65	0.0	0.35	0.9	1.7	3.4	6.2	8.5	11.9	13.9	—
11	Ceresin wax, melting point 75°C.	1	0.70	0.0	0.47	0.9	2.0	3.2	6.2	8.6	13.0	15.1	—
		2	0.70	0.0	0.42	0.8	1.9	2.9	6.1	8.2	12.3	14.7	—
		3	0.70	0.0	0.28	0.8	1.2	2.1	5.7	7.8	11.9	14.4	—
		4	0.70	0.0	0.23	0.6	1.3	2.2	5.3	7.0	12.0	13.8	—
		Mean	0.70	0.0	0.35	0.8	1.6	2.6	5.8	7.9	12.3	14.6	—

A brief reference can be made to power factor. This is usually found to be higher with the chloronaphthalene waxes than with the hydrocarbon types. This applies even if the necessary higher impregnating temperatures and/or times, necessitated by the higher melting points of the former, are used. Again, the power

Table 84.—Dependence of Capacity on Temperature.

Fixed-paper Condensers, Two Papers Between Aluminium Foils, High Melting Point Paraffin Wax as Impregnant, Melting Point 62°C.

Number of test condensers	Nominal capacity mF	Per cent. change in capacity from capacity at 68°F. at temperature of °F.:—												
		58	68	78	88	98	108	118	128	138	148	158	168	178
1	0.5	—	0.0	1.0	1.7	1.9	1.3	−0.25	−2.5	—	—	—	—	—
2	0.5	—	0.0	1.0	1.6	1.7	1.2	−0.50	−3.2	—	—	—	—	—
3	0.5	—	0.0	0.8	1.5	1.8	1.4	−0.45	−3.9	—	—	—	—	—
Mean	0.5	—	0.0	0.9	1.6	1.8	1.3	−0.40	−3.2	—	—	—	—	—
4	1.0	0.14	0.0	−0.07	−0.10	−0.04	−0.25	−1.1	−2.6	−4.6	−6.5	−8.8	−10.9	−13.1
5	1.0	0.06	0.0	−0.03	0.0	0.12	0.50	−1.6	−3.0	−4.8	−6.9	−9.0	−11.2	−13.4
Mean	1.0	0.10	0.0	−0.05	−0.05	0.04	0.37	−1.4	−2.8	−4.7	−6.7	−8.9	−11.1	−13.3

factors are to some degree dependent on capacity, being smaller the lower the capacity value. There is no obvious explanation for this other than suggesting that the smaller units are easier to impregnate more perfectly.

To illustrate these points, power factor values expressed in terms of minutes at 15.5 degrees C. are given in Table 86 for a range of paraffin and for chloronaphthalene-impregnated aluminium-foil condensers, produced as efficiently as practicable.

The foregoing has dealt with what are virtually solid dielectrics, and reference has been made to the petroleum jellies as representing a semi-solid class. These materials are generally easier to handle through the production processes of unit making, assembling into containers, and sealing, than are liquid dielectrics, especially for mass producing small condensers. Again, they are more suitable in assembly and service, for mounting in any position, with no possibility of spillage or leakage. At the same time, they are not always suited to the temperature range to be encountered, especially at low temperatures. Another feature that has to be considered in some instances is heat dissipation. This is particularly the case with large-capacity condensers, perhaps of several hundred microfarads, such as power factor correction condensers. These are usually made by the assembly of a multitude of small units of 1 or 2 mF into a single tank. A suitable liquid impregnant is very useful, the tank being filled with the same medium, and the liquid serving as coolant. Often the individual units include a serrated paper throughout the individual units to augment cooling (a patented feature).

Again, in some equipments, a transformer or switch may be housed in the same container as the condenser. Transformer oil is required for the first of these items and is, therefore, convenient for the condenser, and must be of suitable high grade to satisfy this purpose. The same can apply to oil-immersed rectifiers combined in circuit with condensers. Meticulous care is paid to the manufac-

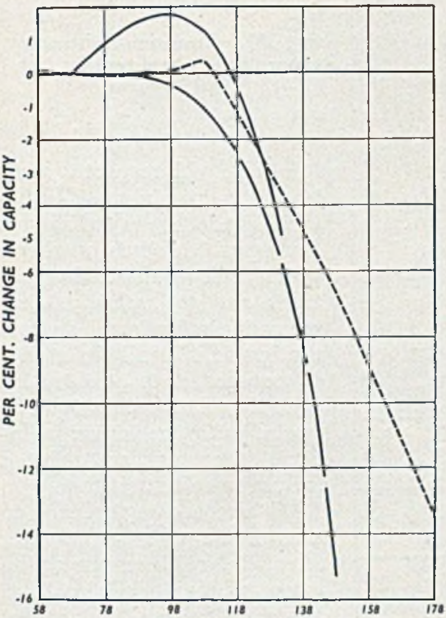


Fig. 187.—Capacity/temperature characteristics of fixed-paper condensers impregnated with paraffin wax of melting point 62 deg. C. obtained from different sources.

ture of transformer oils and other high-grade electrical oils for these purposes. Particular attention is given to freedom from moisture, and to packing in sealed metal drums for transport and storage for the prevention of ingress of moisture. British Standard Specification No. 148 covers a range of lighter oils, and several manufacturers specialize in these as well as in heavier grades of mineral oils and jellies.

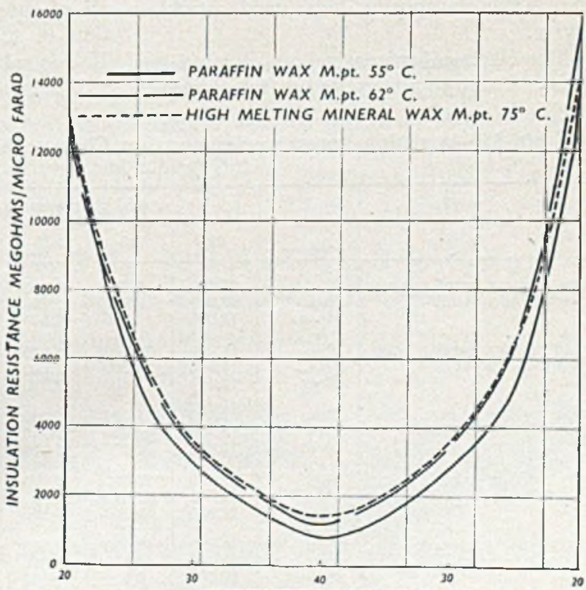
Tabulated data are presented to show typical laboratory characteristics of these oils, tests being based on the methods of B.S.S. No. 148. They are self-explanatory and amply illustrate the claim of high purity and cleanliness. Table 87 refers to several of the grades of transformer oil covered by B.S.S. No. 148. The marked difference in sludge values between the grade A and grade B oils is clearly demonstrated. This is considered to be a very important feature in favour of the grade A oils, especially where condensers are concerned.

Table 88 refers to several oils that are closely similar to the grade A materials, and which are marketed specially for condenser and transformer purposes. They are clean and of high purity. It should be noted that these factors are principally of importance in connection with the purely electrotechnical aspects of condenser manufacture.

Further, in Table 89 two of the heavier electrical materials are shown. It will be noted that they correspond to the grade A standard of purity, but they are, of course, very different with respect to heaviness.

All these oils respond to the same basic

Fig. 188 (below).—Insulation-resistance/temperature characteristics for paraffin and high-melting-point mineral waxes.



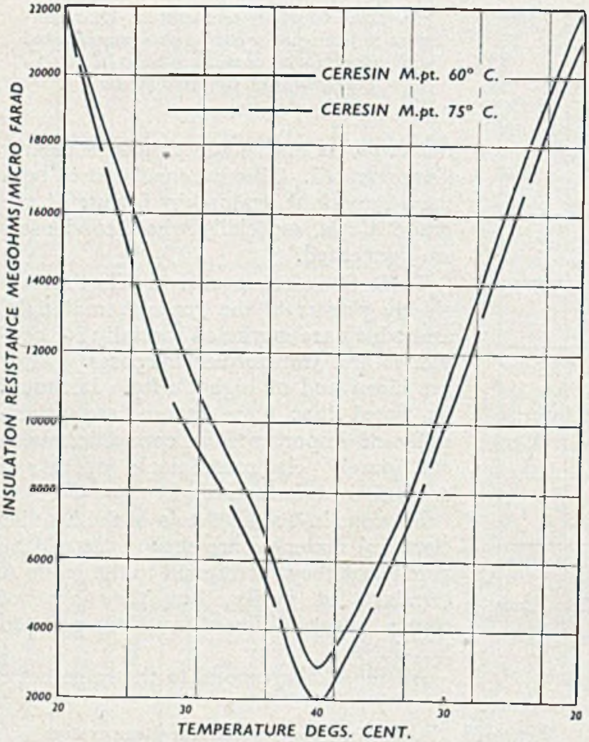


Fig. 189.—Insulation-resistance/temperature characteristics for ceresin waxes.

methods of condenser impregnation, and can serve its specific field very satisfactorily.

The electrical insulating oils covered by B.S.S. No. 148 are graded in two groups, A and B, with respect to their tendency to sludge. Within each grade are subdivisions distinguished by numbers, which indicate the cold test or tendency to solidify, expressed in minus degrees centigrade. In all six grades are covered, namely, A0, A10, A30, B0, B10 and B30. The grades with the higher numbers, of course, are selected for use in cold locations.

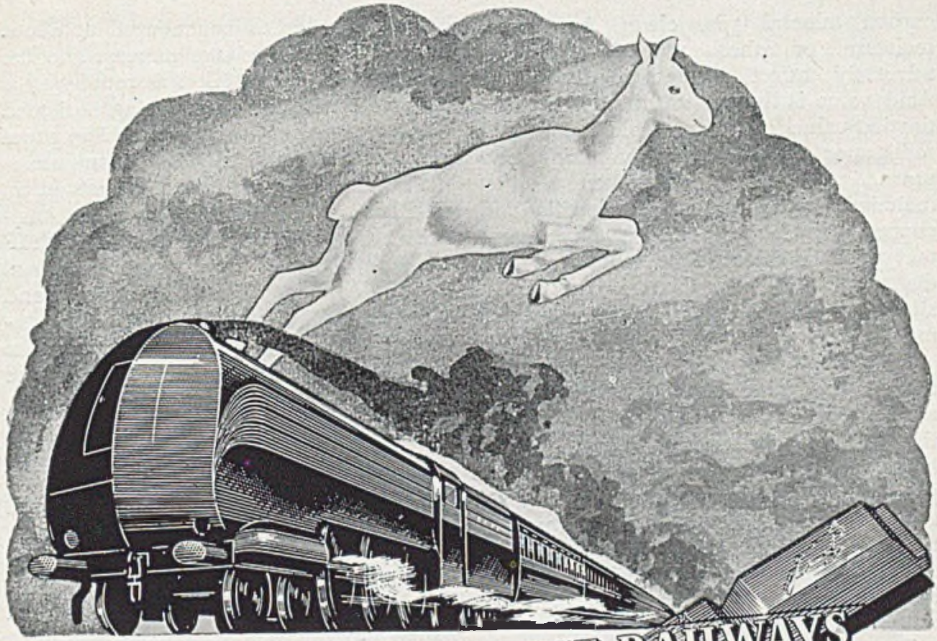
With regard to tendency to sludge, the class A oils are selected for higher operating temperatures, especially those above 80 degrees C. or where higher current-carrying capacity is involved. The class B oils, in general, would be used where lower service temperatures are entailed.

A schedule of the physical properties of all of these oils is given in the specification in tabulated form (see Table 90). This is self-explanatory.

The oils specified must be pure hydro-

Table 85.—Insulation Resistance/Temperature Characteristics of Fixed Paper Condensers for Various Impregnants.

Impregnant		Insulation resistance, megohms/MF at temp. °C. :—						
		20	30	35	40	30	25	20
Low melting paraffin wax (melting point 55°C.)	Min. ..	12,300	2,700	1,450	700	2,700	4,500	12,500
	Max. ..	13,200	2,900	1,950	1,200	3,100	6,000	14,000
	Mean ..	13,000	2,800	1,630	850	2,900	5,200	13,500
High melting paraffin wax (melting point 62°C.)	Min. ..	11,900	3,200	1,800	1,050	3,100	6,000	13,000
	Max. ..	14,500	3,500	2,200	1,450	3,550	7,000	17,000
	Mean ..	12,600	3,400	2,000	1,200	3,350	6,350	15,500
High melting mineral wax (melting point 75°C.)	Min. ..	12,500	3,300	2,000	1,200	2,500	6,200	12,800
	Max. ..	13,500	3,850	2,150	1,700	3,600	6,700	14,700
	Mean ..	13,000	3,600	2,100	1,420	3,300	6,450	14,000
Low melting ceresin wax (melting point 60°C.)	Min. ..	21,000	10,000	6,000	2,400	10,000	—	20,500
	Max. ..	23,000	12,500	9,000	4,000	13,000	—	24,000
	Mean ..	21,800	11,300	7,500	2,900	11,500	—	22,000
High melting ceresin wax (melting point 75°C.)	Min. ..	16,500	7,000	4,000	1,000	7,200	—	17,000
	Max. ..	23,000	12,000	8,500	3,000	12,500	—	25,000
	Mean ..	20,200	9,500	6,000	1,800	9,800	—	21,000



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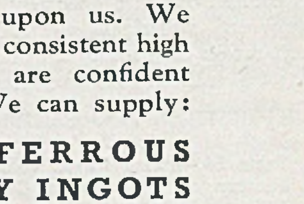

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carbon mineral oils, clean, free from moisture, or other material, likely to adversely affect insulating properties. Acid value is limited to 0.2, and saponification value to 1.0, expressed in terms of milligrams of potassium hydroxide per gram. A copper discoloration test is included, stipulating no discoloration of copper when heated for 12 hours in contact with the oil on a water bath at 100 degrees C. The packing of the oil is stipulated in steel drums sealed to exclude moisture.

Of the tests included in the schedule, the one requiring most comment is the method for tendency to sludge. Briefly, the test is made on 100 grams of oil, heated in a glass flask in contact with a piece of pure copper sheet, with slow passage of air through the oil at a temperature of 150 degrees C. for 45 hours. The sludge precipitated is separated by removing the oil with petroleum spirit and weighing the residue.

The method for loss by evaporation virtually consists of subjecting 20 mls. of the oil in a flat-bottomed glass vessel to a temperature of 110 degrees C. for a period of five hours.

The cold test is determined from the temperature at which the oil "clouds," due to the separation of particles of solid paraffins and fluidity at the limiting specified temperature. Electric strength test is carried out in a specially designed cell between spherical electrodes with a separation of 4 mm. The temperature of the test is from 15.5-20 degrees C.

Alternating current of 25-100 cycles is used. The test is commenced at about 10 kv. and the voltage increased to the full test voltage of 40 kv. as rapidly as is consistent with its value being indicated by the measuring instrument. The proof test voltage is maintained for 1 minute.

Table 86.—Phase Angle Values for Condensers of a Range of Capacities and Different Impregnants.

Wax impregnant	Average capacity mF at 15.5°C.	Phase angle, minutes at 15.5°C.		
		Min.	Max.	Mean
Double refined chlor-naphthalene wax (melting point 94°C.)	(a) 1.514	25	40	30½
	(b) 0.702	19	24	21½
	(c) 0.725	18	26	20.5
	(d) 0.250	14	18	16
Paraffin wax (melting point 55°C.)	(a) 1.250	18	19	19.5
	(b) 0.600	17	19	18.0
	(c) 0.600	12	16	14.5
	(d) 0.250	11	12	11.7

The following analytical details of an oil-filled power factor correction condenser are of interest. It was of 100 mF capacity, made up from units of 2 mF capacity, the impregnant and filling medium being grade AO transformer oil. Electrical test values on the individual units in the assembly gave the following results:—

Capacity at 68° F., 2.015 mF.

Power factor at 68° F., 6 minutes.

Breakdown voltage, 6,000 volts d.c.

Constructionally, the unit comprised three papers between aluminium foils, the paper being linen base of 0.0004-in. thickness and the foil being 0.0003-in. thickness. The edge clearance between paper and foil was ¼ in., the widths of paper and foil being 3¾ ins. and 3¼ ins. respectively. Contact with foils employed tinned copper tapes, 5/16-in. wide and 0.0015-in. thickness. The unit was supported on a former consisting of a synthetic resin-bonded paper tube, rolled and moulded quality, ⅜ in. in outside diameter and 1/16-in. wall thickness. Also, a corrugated paper separator was included through the centre of the winding, presumably to promote uniform cooling.

Table 91 summarizes the quality characteristics of a number of oil-filled condensers. It will be seen that special features are low-power factor, good insulation resistance and high breakdown voltage. In making these condensers, normal condenser processing conditions were employed. Thus, the wound paper units were pre-dried for 10 hours at 250 degrees F. in a current of dry air, and then vacuum dried in the same oven, at the same temperature, for 4 hours at 3.5 mm. pressure. The oil was preheated for 15 hours at 250 degrees F., and fed to the units without breaking the vacuum. The impregnation period was two hours at 250 degrees F. An alternative procedure used a modified pre-treat-

Table 87.—Laboratory Test Results on Typical Commercial Transformer Oils to B.S.S.148.

	Grade			
	A0	A10	B0	B10
Cold test degs. Cent.	0	−10	−1	−12
Sludge, %	0.008	Nil	0.76	0.90
Viscosity (Redwood) secs. at 15.5°C.	133	137	190	172
Electric strength, volts A.C.	45,000	41,000	40,000	42,000
Flash point, degs. Cent.	168	182	174	170
Evaporation, %	1.1	0.2	0.5	1.8
Acid value mgms. KOH/gm.	Nil	Nil	Nil	Nil
Saponification value, mgms. KOH/gm.	Nil	Nil	Nil	Nil
Discoloration of copper	None	None	None	None
Specific gravity at 15.5°C.	0.840	0.848	0.860	0.878
Ash on incineration, %	Nil	Nil	Nil	Nil
Total sulphur, %	Nil	Nil	0.08	0.09
Appearance and colour	Clear, colourless	Clear, colourless	Clear, pale yellow	Clear, pale yellow

ment of the oil, i.e., it was vacuum dried at 3.5 mm. of pressure for one hour at ordinary temperature instead of hot dried.

Oil is easy to use, lending itself readily to a variety of process techniques, and condenser results are consistently good.

H. Warren, in a lecture entitled "Insulation" ("Jour. Inst. Elec. Eng.," December, 1940, Vol. 87, No. 528) refers to the adoption of mineral oils for insulating and cooling as a major development in electrical engineering, but points out their shortcomings from the angles of inflammability, sludging and explosive nature of arc-formed gases. He, therefore, stresses the importance of the commercial availability of the chlorinated diphenyls because they are electrically satisfactory and non-inflammable, although price is higher.

The chlorinated diphenyls are prepared by the direct chlorination of diphenyl, and the resultant product is fractionally distilled and separated in groups upon a basis of chlorine content and distillation range. The liquid products boil between 300 degrees C. and 400 degrees C. and have a specific gravity of about 1.5. Materials of this class are marketed in this country as Permitol, in America as Pyranol, and in Germany as Clophen. With increase in the degree of chlorination, viscosity tends to increase and solvent action to decrease. For transformers, where cooling is required and the same requirement can hold good for oil-filled condensers, low viscosity and low solvent action are desirable properties. A mixture of 60 per cent. of hexa chlor diphenyl with 40 per cent. of trichlor benzene satisfies this requirement. The permittivity of this mixture is 4 as compared with 2 for mineral transformer oil. This permittivity value of the diphenyl compound is of similar order to that of the associated insulation materials, consisting of impregnated paper, woods, shellac-bonded products and the like, in transformers and condensers, and it, therefore enables a more uniform distribution of electric stresses to be obtained in the insulation. Further, the liquid is stated to be non-sludging and non-inflammable; any gases formed as a resultant of arcing are non-explosive, and the material is of similar breakdown strength to transformer oil.

With regard to expense, design has to ensure that a minimum of the chlorinated diphenyl material is employed. This is achieved so far as is practicable by minimizing the size of the container.

Warren states that in condenser applications, the high permittivity chlorinated diphenyl is eminently suitable as the impregnant for paper condensers, particularly as it enables higher electric stress to be worked at than is permissible with any other impregnant. A suitable grade of Permitol has a permittivity value of 5, and in the form of impregnated paper or kraft condenser tissue it

Table 88.—Laboratory Test Results on Typical Special Condenser Oils.

Sample No.	1	2	3
Cold test, degs. Cent.	−12	−1	−14
Sludge, %	Nil	Nil	Nil
Viscosity (Redwood) secs. at 15.5°C.	205	175	160
Electric strength, volts A.C.	47,000	45,000	46,000
Flash point, degs. Cent.	168	175	196
Evaporation, %	2.2	1.1	2.3
Acid value, mgms./KOH/gm.	Nil	Nil	Nil
Saponification value, mgms./KOH/gm.	Nil	Nil	Nil
Discoloration of copper	None	None	None
Specific gravity at 15.5°C.	0.898	0.860	0.838
Ash on incineration, %	Nil	Nil	Nil
Total sulphur, %	Nil	Nil	Nil
Appearance and colour	Clear, colourless	Clear, colourless	Clear, colourless
Viscosity (Redwood) secs. at 70°F.	135	120	90
140°F.	44	44	42
212°F.	32	32	32

has a permittivity of 6. This is nearly three times that of mineral oil.

Electrical engineers are naturally and justifiably critical of chlorinated compounds, however stable they may appear to be in normal circumstances and however pure their initial condition. They are sceptical of the formation of traces of hydrochloric acid under conditions of condenser processing or in subsequent service. Such acid development would cause loss in insulation resistance, increase in power factor, and the possibility of electrolysis or the corrosion of the aluminium foils. Engineers are, therefore, sceptical, and much work has been done to offset any deterioration from this possibility.

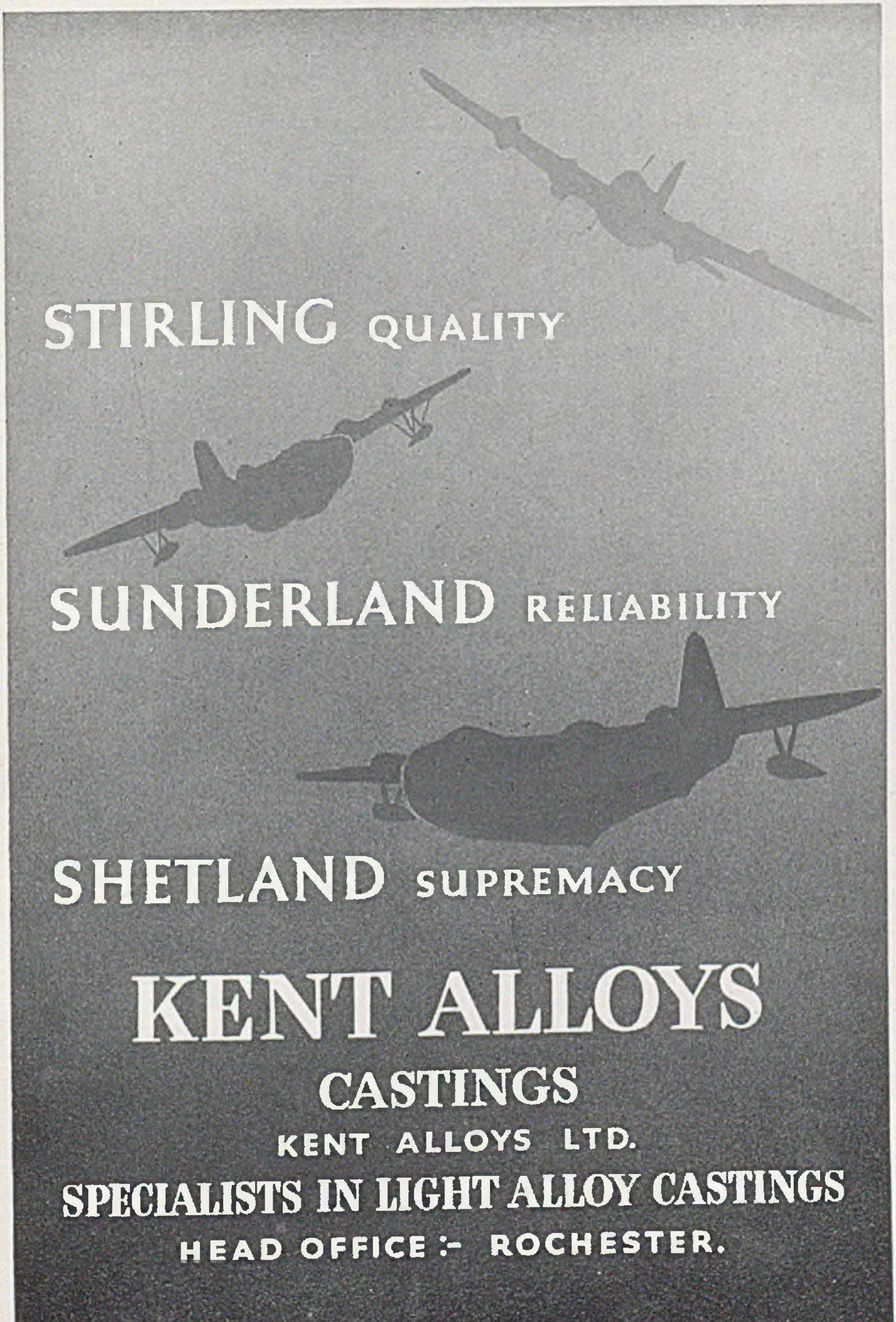
Much information is available on the chlorinated diphenyls. H. W. Bowron contributed an article, "Chlorinated Diphenyl," to "Paint Technology," November, 1936, p. 401. This deals with the history, development and production of these compounds. The information given in Table 92 is taken from this source. This shows the increasing viscosity of the product as the degree of chlorination increases.

The Monsanto Chemical Co. of U.S.A. has issued a brochure entitled, "Physical Properties of the Arochlors." It presents concisely the properties of this company's range of chlorinated diphenyls, ranging from water-white mobile oils and pale yellow viscous oils to light amber resins and opaque crystalline solids. The tabulated summary of properties is reproduced from this in Table 93.

Fire hazard reduced or eliminated is a primary reason for using the chlorinated diphenyls, but reduced size of otherwise bulky components results from its high dielectric constant (or permittivity), and this has to be taken advantage of in many applications. Even so, usage is not so straightforward as at first sight may appear. The inclusion of an anti-oxidant or inhibitor to prevent hydrochloric acid from being formed to a dangerous degree has evidently proved to be a necessity. Further, special mixtures have proved advantageous for retention of the electrostatic capacity of paper condensers within reasonable limits at very low temperatures.

These practical facts are evident from published data from the Westinghouse Electric International Co. and from the Western Electric Co., both of U.S.A. Abstracts from these are included in the following:—

In the section "Stories of Research" of the "Westinghouse Engineer," Vol. 4, No. 5, September, 1944, recent developments by the Westinghouse Electric International Co. on impregnation media for fixed paper condensers are briefly given. These developments have been short-term ones for the improvement of paper condensers for Services' requirements. One of the qualities that had to be quickly improved upon concerned loss of capacity at low temperatures, this loss being 25 per cent. or more, and also shortened life at elevated temperatures. Condensers are now produced that per-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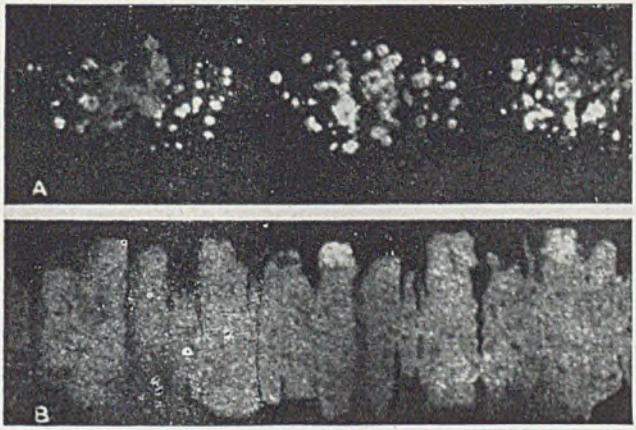

Fig. 190.—Fluorescent areas in paper taken from condensers next to the cathode after accelerated ageing tests using chlorinated naphthalene impregnating media and two layers of 0.4 mil. unbleached linen paper: upper figure, no stabilizer, aged at 100 deg. C., 120 volts d.c. for 245 hours; lower figure, no stabilizer, aged at 100 deg. C., 120 volts d.c. for for 670 hours.

form with increased efficiency and longer life whether in the heat of the tropics or the intense cold of the stratosphere.

Direct-current impregnated paper condensers are used in filter circuits, tuned audio frequency circuits, and circuits requiring blocking and by-passing elements. Any great deviation from the rated capacity is important, particularly in tuned circuits. Again, in many applications these condensers are subject to d.c. voltages accompanied by a.c. voltages, which may not be inconsiderable. Therefore, the a.c. characteristics of the condenser are of considerable importance, as well as the d.c. characteristics.

The condensers referred to are impregnated with a chlorinated liquid which is a polar substance. The molecule of this liquid can be visualized as a dumbell-shaped unit with a positive charge at one end and a negative charge at the other. When a voltage is impressed across the condenser, the molecules align themselves by rotation, presenting the negative end to the positive side of the applied voltage and the positive end to the negative side. The reversal of the voltage causes the molecule to rotate through 180 degrees to reverse its polarity to correspond to the new conditions. It is evident, therefore, that when an a.c. voltage is imposed, the

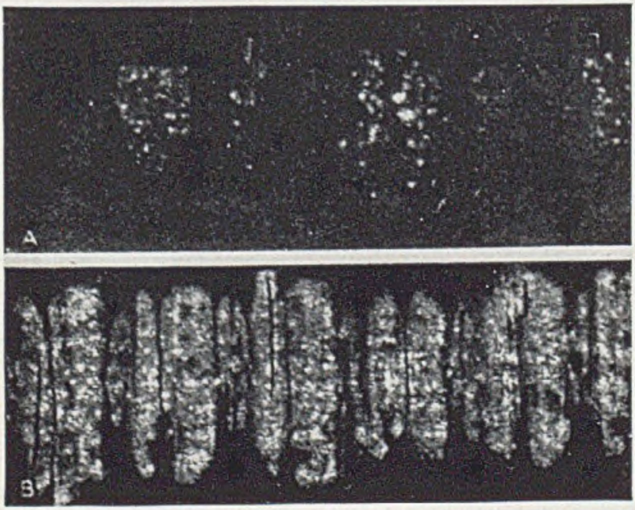

Fig. 191.—Corrosion pattern on aluminium anodes taken from condensers after test (see Fig. 190 above). Taken with artificial light which struck the aluminium on an oblique angle. These anodes showed marked corrosion, whilst those from a stabilized sample showed only slight attack despite the greater severity of the test.

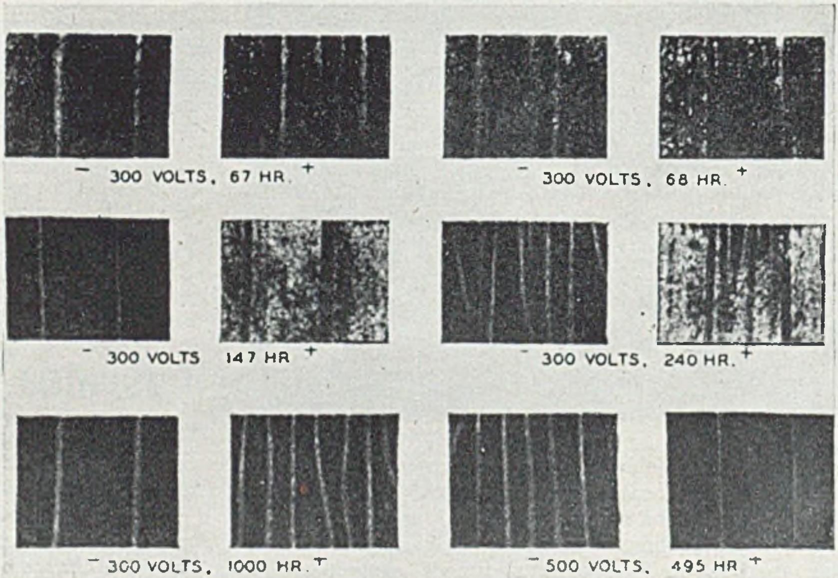

Fig. 192.—Prevention of deterioration of evaporated aluminium electrodes by anthraquinone. Reproduced from photographs taken by transmitted light. The electrodes are intact in stabilized samples, despite the greater severity of the test.

frequency of this reversal corresponds to the frequency of the applied voltage.

This physical action of the molecules is thus a movement by a discrete particle, and, therefore, any increase in viscosity of the medium, such as would be induced by exposure to low temperatures, tends to retard the movement of the molecules during this reversal. The higher the frequency the more will this be noticeable. At extremely low temperatures the ability to reverse freely may be lost entirely. Consequently, on account of the fact that polar materials depend upon the rotation of the molecules for part of the dielectric constant, only part of the rated capacity is effective at low temperatures.

Westinghouse developed a new chlorinated liquid composition that maintains its dielectric constant to considerably lower temperatures than is the case with chlorinated diphenyl, which is the material normally employed for impregnation. The material is called Special Inerteen, and it possesses physical and electrical characteristics quite comparable with those of the ordinary Inerteen fluid, except that it has considerably lower viscosity and lower freezing point. This difference makes possible unrestricted rotation of the dipoles at a frequency of 60 cycles, down to about −40 degrees C., whereas the dielectric constant, which is a measure of dipole rotation, of standard Inerteen falls off sharply at about −5 degrees C. From the practical angle of impregnated condensers, the standard condensers rated for 60 cycles and 25 degrees C. exhibit a sharp falling off in capacity at 0 degree C., and at −40 degrees C. the value is only 70 per cent. of the rated capacity. When the Special Inerteen is used as impregnant, the capacity at 60 cycles does not begin to drop below the rated figure until after −35 degrees C. has been reached, and at −40 degrees C. the capacity is still 95 per cent. of the rated value. At higher frequencies, although the gain in capacity at low temperatures with the new liquid is somewhat less, it is still appreciably marked, even at 1 megacycle. It is pointed out, however, that paper condensers are not particularly suited for

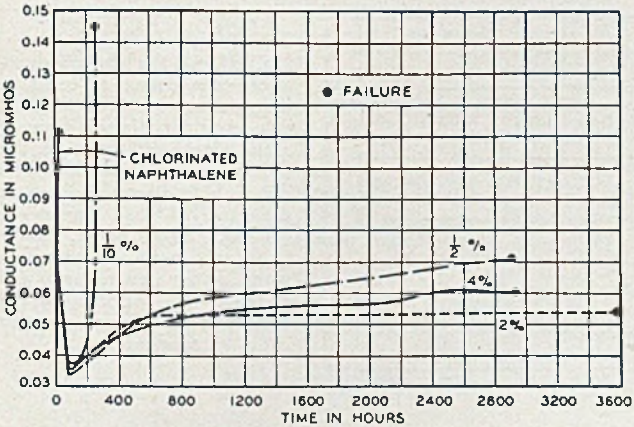

Fig. 193.—Effect of various concentrations of anthraquinone on the leakage current and life of paper condensers impregnated with chlorinated naphthalene: 100 deg. C., 350 volts D.C., two layers of 0.4 mil. linen paper.

application in circuits involving such high frequencies, because of the inherent high dielectric loss in the paper at these frequencies, independent of the impregnant employed.

It is admitted that special mineral oil as the impregnant exhibits a practically flat dielectric constant curve from + 85 degrees C. to −70 degrees C. at 60 cycles, and even at 1 megacycle at −40 degrees C. the capacity is still 86 per cent. of the rated value. The reason for using the chlorinated hydrocarbon is its high dielectric constant, so that if mineral oil were employed the condensers would have to be half as large again.

The chlorinated hydrocarbon liquids are stated to have excellent electrical characteristics for the purpose of impregnating paper condensers. Nevertheless, under sustained d.c. voltage, there is evidence that hydrogen chloride is formed, and this attacks the condenser foil with the formation of aluminium chloride. Once this is formed it catalyses further decomposition of the impregnant and even of the paper. Service life under a.c. voltage is considerably longer than under d.c. stress, because undoubtedly some phenomena of electrolysis occur. To counteract this shortcoming, stabilizing chemical compounds have been developed and are found to be very effective. For example, a new stabilizer added to the standard or to the Special Inerteen shows up very favourably on accelerated life tests. Thus at 85 degrees C., and a voltage stress of 1,000 v. per mil., the average life proved to be 120 hours without the stabilizer present. By inclusion of the stabilizer the units withstood 3,000 hours satisfactorily and have still not failed. The value of the stabilizer is, therefore, established without doubt.

The Bell Telephone Laboratories have likewise made extensive researches on the subject of stabilizers, not only for the chlorinated diphenyls, but also for the chlorinated naphthalene wax impregnants. Informative data on the subject are given by D. A. McLean in the "Bell Laboratories Record," March, 1945, Vol. 23, No. 3, under the heading of "Chemically Stabilized Paper

Table 89.—Laboratory Test Results on Typical Heavy Electrical Oil and Jelly.

	Oil	Jelly
Melting point, degs. Cent.	—	54
Cold test, degs. Cent.	0	—
Sludge value, %	0.07	Traces
Viscosity (Redwood) secs. at 70°F. ..	7,500	—
140°F. ..	390	280
212°F. ..	78	90
Electric strength, volts A.C.	45,000	48,000
Flash point, degs. Cent.	208	200
Evaporation, %	Nil	Nil
Acid value, mgms./KOH/gm.	Nil	Nil
Saponification value, mgms./KOH/gm.	Nil	Nil
Discoloration of copper	None	None
Ash on incineration, %	Nil	Nil
Total sulphur, %	0.09	0.08
Colour	Light Brown	Light Brown
Contraction during solidification, % ..	—	4.8

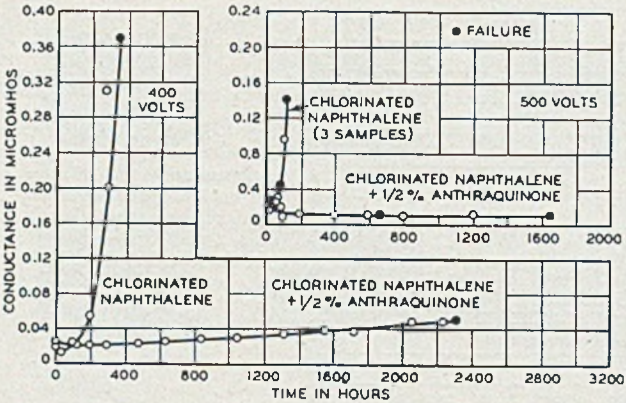

Fig. 194.—At the left: conductance—time curves at constant d.c. potential at 100 deg. C. The lower curve in this diagram at the left is for 400 volts d.c., the upper curve being for 500 volts d.c. In both cases the dielectric consisted of two layers of 0.4 mil. Kraft paper. Kraft-paper condensers, when fortified with anthraquinone, are superior in performance to stabilized linen-paper condensers.

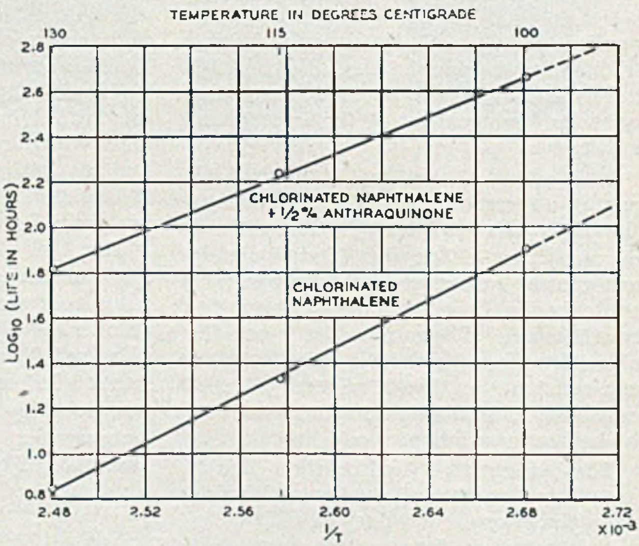

Fig. 195 (right).—Temperature life relationship of stabilized and unstabilized condensers at 400 volts d.c., two layers of 0.4 mil. Kraft paper. (T = absolute temperature.) The improvement obtained by adding anthraquinone is somewhat greater the higher the operating temperature.

Capacitors.'' This indicates that the subject was given attention long before the outbreak of war, foreseeing that extended service life of capacitors would be essential under the more severe operating conditions of temperature and voltage encountered with military equipment, as compared with those of telephone communications installations.

Two impregnants extensively used are chlorinated diphenyl and chlorinated naphthalene, the first a liquid and the second a wax-like solid. Their merits lie in that they resist oxidation and thermal decomposition, possess high dielectric constants compared with that of mineral oil, and have good electric properties. McLean states that paper condensers using these synthetic chlorine-containing chemicals have a satisfactory life when operated at room temperatures. At high direct-current potentials and at temperatures from 50 to 100 degrees C., such as are met with in Services equipment, rapid degradation of these dielectric materials occurs. The Bell Laboratories have discovered a number of compounds which, when added in small amounts to the chlorinated impregnant, substantially increase the life of condensers, as shown by accelerated direct current tests. Further, in the tests, these stabilizers were found to maintain the leakage current through the condensers at low and relatively stable values, this contrasting with

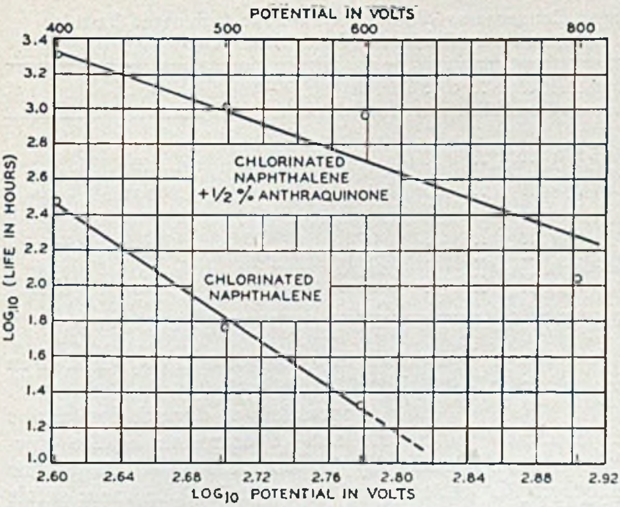

Fig. 196.—Voltage life relationship at 100 deg. C. over the range 400-800 volts d.c. (two layers of 0.4 mil. Kraft paper). Dependence of the life of condensers on voltage is as important to the engineer as its dependence on temperature.

rapidly the increasing leakage currents in unstabilized condensers.

Quinones were the most satisfactory of the stabilizers used. Anthraquinone was chosen for commercial use for various reasons, viz.: high effectiveness, ready availability in a pure grade, low volatility, and absence of toxicity.

In the tests, linen-base paper was generally used, because its very poor performance with unstabilized impregnants makes it a sensitive indicator of the effectiveness of the stabilizer. In practice, Kraft wood paper is almost exclusively employed for paper condensers in America.

Figs. 190 and 191 refer to condensers having two 0.0004-in. unbleached linen papers between aluminium-foil electrodes, and chlorinated naphthalene impregnant without stabilizer after ageing by direct-current voltage at high temperatures. In Fig. 190, A shows the paper taken from next to the cathode foil after ageing the condenser for 245 hours at 100 degrees C. under 120 volts d.c. The photograph was taken using ultra-violet light, which is known to cause the decomposed areas to fluoresce, after freeing the paper from wax by solvent extraction. B is a similar photograph on a sample after 670 hours of the ageing test. The progressive development of the decomposed areas is apparent in the papers from these unstabilized condensers.

Similar samples taken from condensers in which 0.5 per cent. of anthraquinone was included in the chlorinated naphthalene wax impregnant showed no visible deterioration even at a voltage twice as high and test time twice as long. Again, the papers shown in the fluorescent photographs had become visibly browned and embrittled in the fluorescent areas,

Table 90.—Schedule of Physical Properties after B.S.S. No. 148 for Electrical Oils.

Class of oil	Sludge (maximum).	Viscosity at 15.5°C. (60°F.) (maximum). Redwood secs.	Electric strength (minimum). Volts.	Flash point (minimum).	Evaporation (maximum). Per cent.	Cold test (maximum).
A.0 ..	0.1	200	30,000	145°C. (293°F.)	1.6	0°C. (32°F.)
A.10 ..						− 10°C. (14°F.)
A.30 ..						− 30°C. (− 22°F.)
B.0 ..	0.8	200	30,000	145°C. (293°F.)	1.6	0°C. (32°F.)
B.10 ..						− 10°C. (14°F.)
B.30 ..						− 30°C. (− 22°F.)

Table 91.—Aluminium Foil/Paper Condensers, Wound on Phenolic Laminated Tubular Formers, and Impregnated in Grade A0 Transformer Oil.

Type No.	1	2	3	4
Construction:				
Number of papers between aluminium foils	3	2	3	3
Thickness of paper, inches	0.0004	0.0004	0.0005	0.0005
Type of paper	Linen	Linen	Linen	Linen
Electrical values:				
Capacity MF. at 68°F.	2.72	1.10	1.63	2.25
Power factor, minutes	9	11	9	6
Insulation resistance at 68°F., megohms/MF.	12,600	11,000	10,000	10,000
Breakdown voltage, V.D.C.	3,500	1,600	5,600	6,000

whereas that from the stabilized condenser was not perceptibly different in colour or flexibility from unused paper.

In Fig. 191 at A and B is shown the corresponding corrosion of the positive aluminium foil electrodes, the photographs being taken in artificial light at a glancing angle. The marked corrosion, and its progressive nature, is evident from the two pictures. In contrast, the positive aluminium foils from the stabilized condensers, despite the doubled voltage and doubled ageing period, showed only a slight haze.

Reference is also made to further delicate tests made on condensers produced from Kraft wood paper on which very thin electrode films were made by depositing an aluminium layer by vacuum evaporation. This was possible because a small amount of corrosion entirely consumed the thin aluminium film. The condenser windings were made from this aluminium-coated paper by winding, drying and impregnating in the orthodox manner. They were subjected to voltage at 100 degrees C. The impregnating compound was then extracted with solvent and portions of the paper photographed by transmitted light to reveal holes produced by corrosion. Results are given in detail in Fig. 192. Summarizing, the positive electrodes were rapidly attacked in unstabilized condensers, and eventually even the negative electrodes showed some deterioration; under test for 240 hours at 300 volts, the positive electrodes was largely destroyed. In stabilized condensers under the same test condition, no detectable attack occurred in either electrode in 1,000 hours at 300 volts, or in 495 hours at 500 volts.

The suppression of degradation of the dielectric and of corrosion of the electrodes by the presence of anthraquinone is reflected in longer life and more stable leakage current.

It was shown in the "Bell Laboratories Record" for February, 1943, p. 136, that Kraft wood paper exerts its own stabilizing action, and, in consequence, this paper, used in conjunction with an anthraquinone stabilized impregnant, can be expected to yield condensers of superior performance to those constructed with linen paper.

This subject of stabilizing paper condensers impregnated with chlorine-containing impregnants is also dealt with in "Ind. and Eng. Chem. (Ind. Edn.)," Vol. 37, pp. 73-79, January, 1945.

(To be continued.)

Table 92.—Influence of Chlorine Content on the Properties of Chlorinated Diphenyl.

No.	Percentage of Chlorine	Properties of Chlorinated Diphenyl
1	18.30	Light mobile liquid
2	27.19	Light oil—less mobile than No. 1
3	42.11	Light oil—S.G. 1.375 at 29°C.
4	42.86	Heavier oil than No. 3
5	52.15	Viscous oil
6	57.19	Semi-solid—pitch-like
7	59.73	Semi-solid—softening point 49.5°C.
8	65.26	Non-crystalline solid—softening point 61.5°C. Shows conchoidal fracture.
9	65.40	Semi-crystalline solid
10	66.21	Crystalline solid

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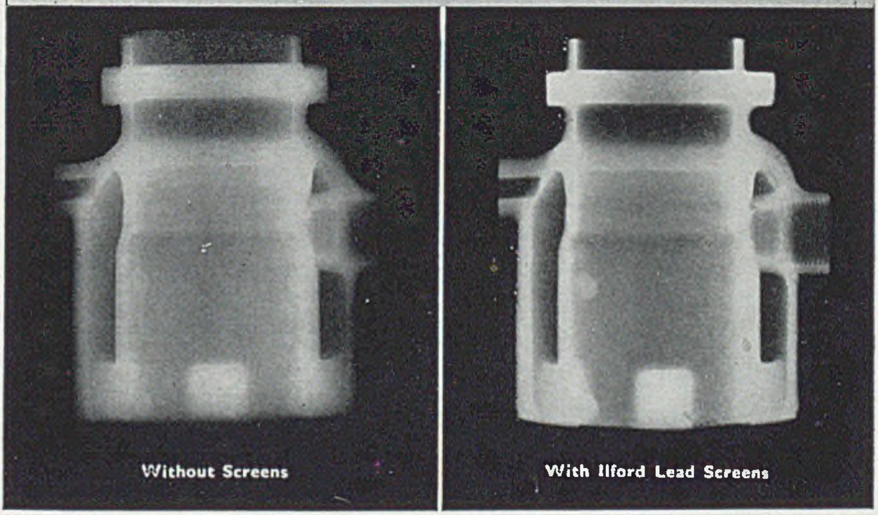

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