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LIGHT METALS

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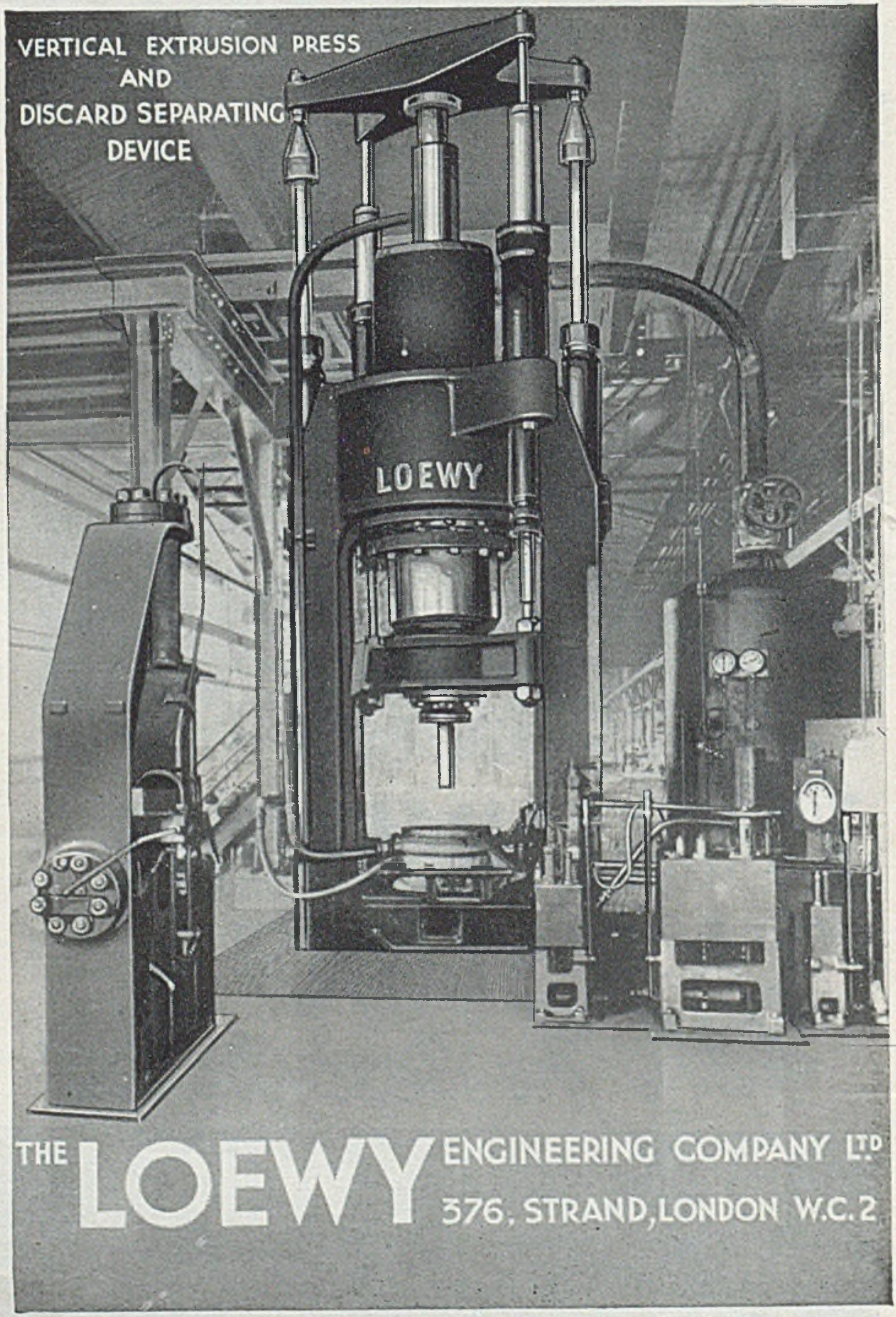
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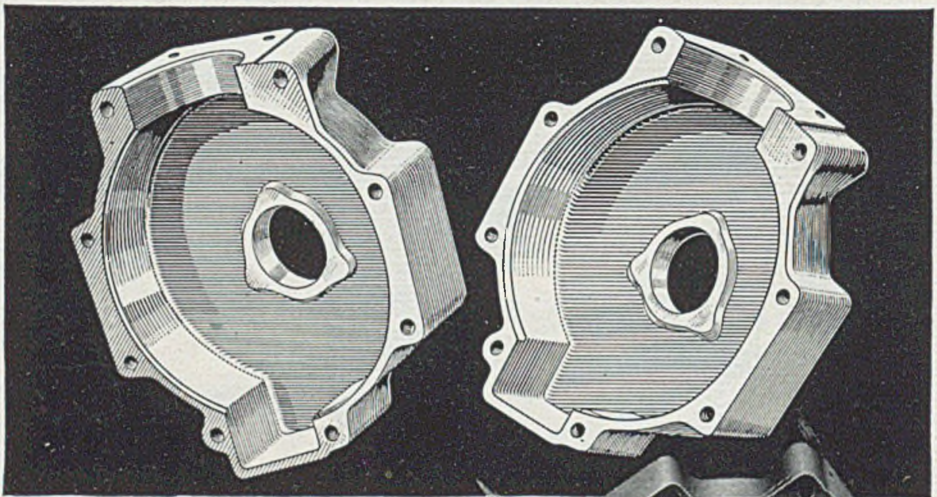

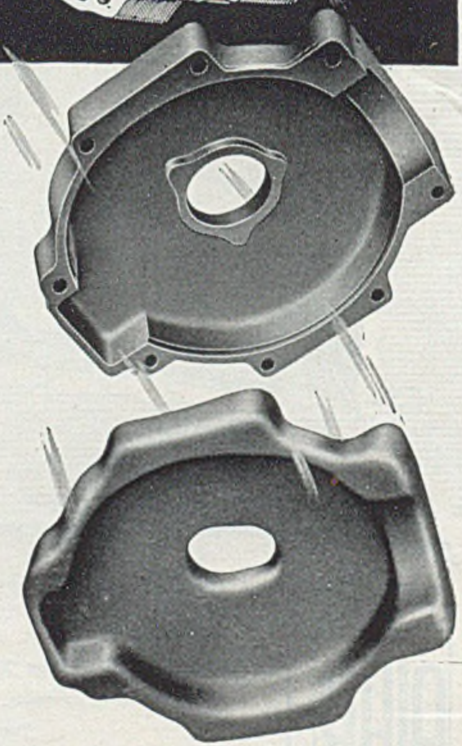

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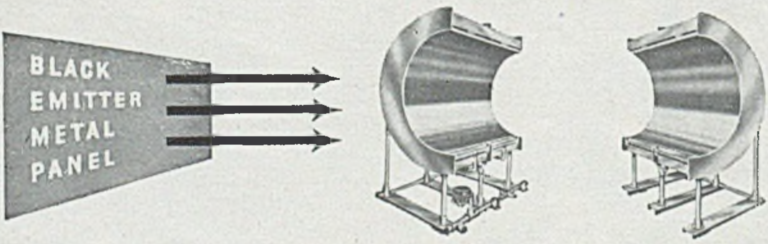

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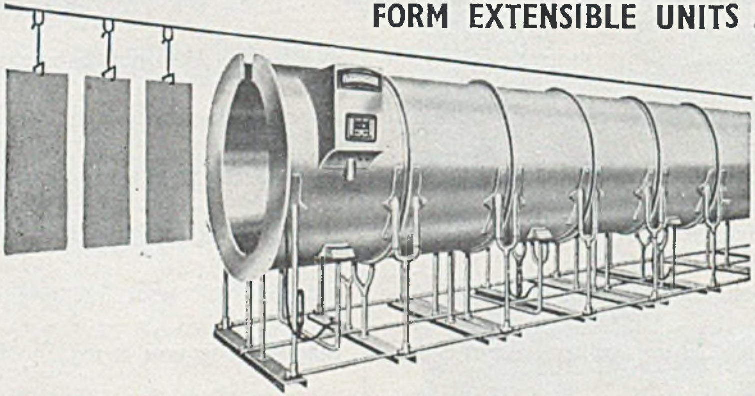

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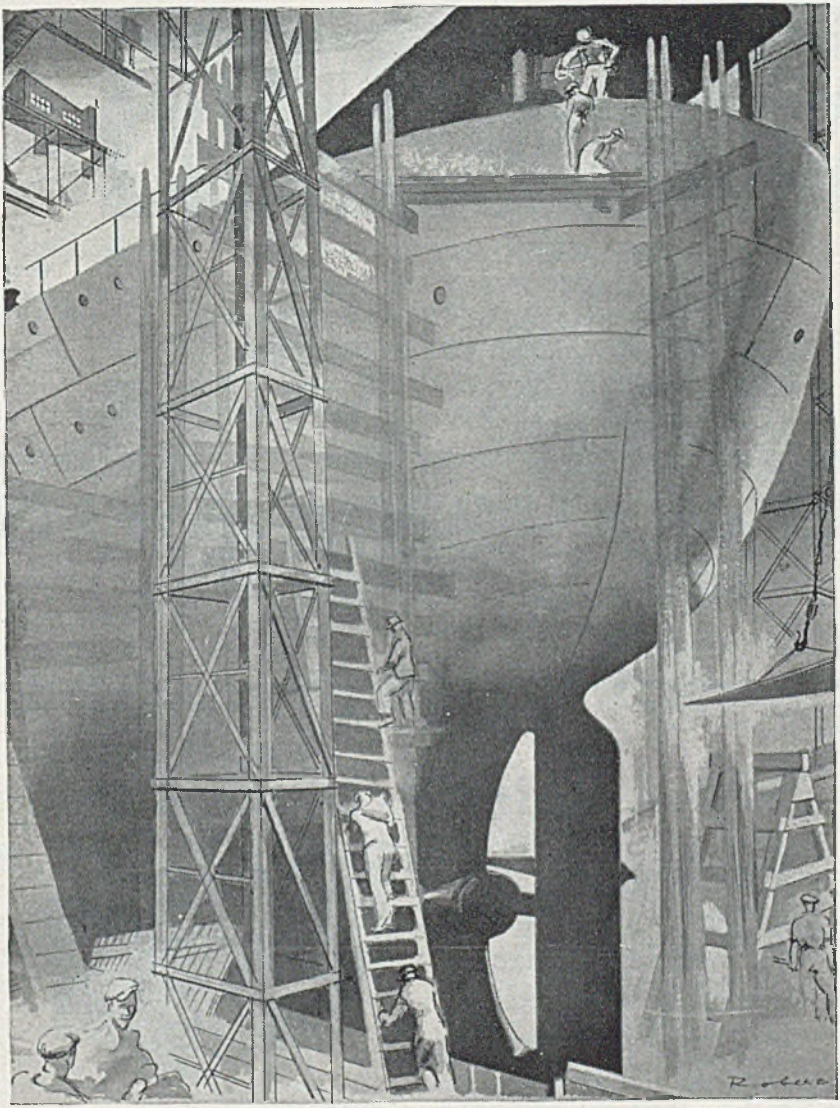
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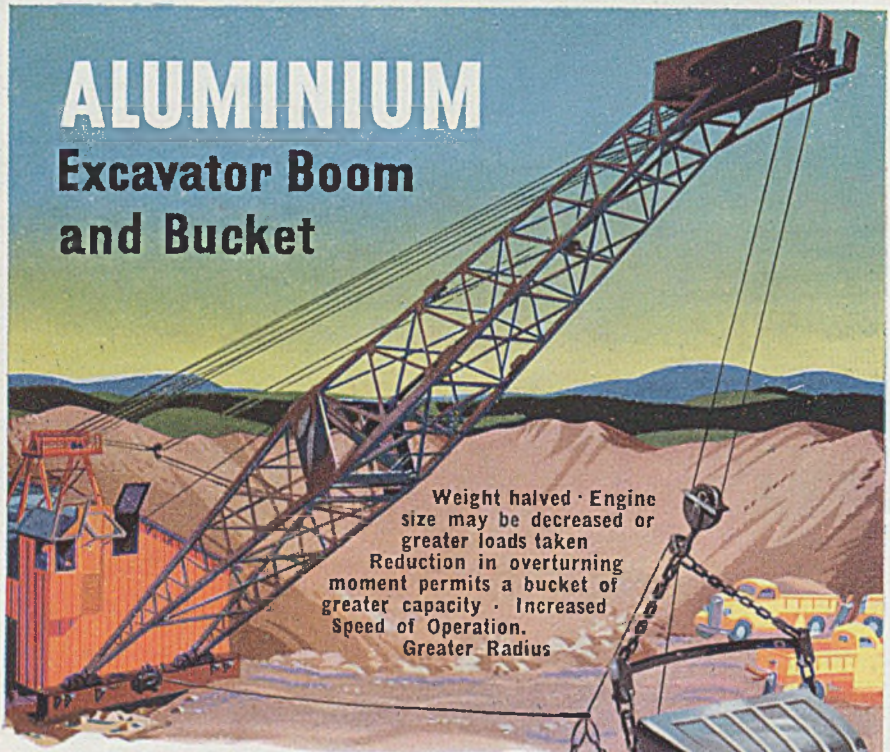

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LIGHT METALS

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

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EDITORIAL OPINION

That Glazed Look

FOR many years past, now, surface coatings of a protective and decorative nature have been available in many forms for application to light alloys. Time has seen certain changes in outlook both on the part of the aluminium industry itself, as well as on the side of the user or customer. One notable instance in this regard, perhaps, concerns the more or less general acceptance of electro-deposited coatings on light metal as a valuable aid for conferring special mechanical properties at the surface and for achieving particular eye effects. Too little attention, we believe, however, is still paid to the potentialities of decorative stoved finishes on cheaper lines of household goods. Quite recently, when discussing this matter with a representative of a merchanting house, we were told that frying pans and kettles provided with red-lacquered handles sold at rates three to four times as great as those for equivalent items in natural metal or with black plastic coatings.

One of the most promising of newer developments consists in the use of sprayed pigmented Polythene, which, applied by means of the powder pistol to the surface of aluminium suitcases, creates not only a very pleasing effect, but confers also very high scratch- and wear-resisting properties.

But just as Japanese cat-fish are capable of detecting threatened earthquakes some 24 hours or more before the event, so those in the metal-finishing trades seem to have an uncanny knack of pre-indicating, by growing signs of uneasiness, the dawn of momentous changes in their own particular world. Admirable as are all the available techniques for finishing aluminium, the light-metal user has long envied the sheet-steel fabricator his vitreous enamelling process. Ten years or more ago tentative efforts were made to produce glass-like coatings on light alloy, mainly by the use of high-lead frits. None really succeeded.

The problems encountered in developing a vitreous enamel for aluminium are weighty in quality and many in number. The immediate difficulty is obvious, namely, that of the low temperatures which must be employed; nothing above about 450 degrees C. is likely to be of much value. Next in order of importance (superficially at all events) comes the question of balancing out the high thermal expansivity of aluminium against that of the glass constituting the vitreous coating. Actually this last problem is more apparent than real, and is, in fact, the symptom of an even graver difficulty underlying the whole technique.

The physics and chemistry of the adhesion of the ground coat of vitreous enamels for steels are complicated in the extreme, but are, nevertheless, well understood. They may best be considered in terms of counter diffusion between the basis metal and the cobalt oxide in the ground mass. In its finished state, the vitreous-enamel coating on steel is virtually integral with the metal itself, this by reason of the inter-diffusion process to which we have referred. To date, we believe, no glass has been developed suitable for application to aluminium, which will permit of the operation of a similar mechanism at the enamel/light-metal interface. Ground coats so far developed for use with aluminium consist, in one form or another, of low-temperature transfer glass, the function of which is to promote purely *mechanical* adhesion of the finished coat, which latter, by the way, usually carries the pigment, if any, which gives the enamel its decorative value.

Here, more troubles arise. If it be granted that the possibility of effective colouring be desirable, and if it be recalled that low-fusion temperature is essential, then the base most clearly meeting both these requirements is litharge. Now, quite apart from the health hazards involved in the use of high-lead frits, such materials usually fail in two other important respects, namely, low immunity to acid attack and relatively poor resistance to abrasion. So far, it would appear, no successful general solution has yet been found to this problem, in spite of the fact that many important interests have for some while been engaged upon it.

No reference has been made to the problem of overall resistance to thermal shock, to crazing, or to the other specific problem of edge effect in the case of aluminium.

Mechanically, the results achieved have been promising. Specimens have stood quite a considerable amount of knocking around without spalling or cracking. From the purely decorative aspect, most delightful results have been achieved, with the high-lead enamels at any rate, and these, if the lead hazard can be tolerated, would seem to commend already their limited commercial use.

One further final point, again probably associated with the mechanical nature of the metal/enamel bond, lies in the difficulty so far encountered in attaining very massive thicknesses in the enamel coating. Heavy layers of glass postulate the existence of stress gradients of an order sufficient to endanger adhesion between the glass and the metal.

Contents

"LIGHT METALS" is published in London, England, on the first Wednesday of each month.

Housewarming in Grosvenor Street

"The year, although a difficult one owing to the many problems involved in moving to London, has resulted in placing the Association on a firm foundation which will allow the aims and activities outlined in the brochure published during the year to be pursued vigorously."—Extract from Report submitted to the Annual General Meeting of the Aluminium Development Association for the year ended December 31, 1946

ON Monday, April 14, a lively housewarming marked the official inauguration of the new headquarters of the Aluminium Development Association at 33, Grosvenor Street, W.1. It was one of those all-too-rare occasions when the visitor might have seen, shoulder-to-shoulder, in social harmony, well-known figures representative of almost every major producer, fabricator and user of light metals in this country.

The retiring President, Mr. Horace Clarke, delivered the following short, but heartening, speech:—

"The immense growth of the aluminium industry for the services of the country in war has been followed by a considerable increase in its peace-time activities in all branches of engineering.

"Now that the industry as a united body has firmly established its own Development Association with headquarters in London, it is able to look forward to still further development in the wide fields of structural, marine and transport applications for which, together with light engineering, aluminium and its alloys are ideally suited.

"In addition to a large number of long-term development projects, the Association has initiated specific research investigations into a number of fundamental problems—for example, the weldability of aluminium alloys; the properties of aluminium-alloy structural sections, including beams and struts; large riveted joints; the buckling of ships' plates, including the effect of riveted joints, and tests of scale model ships' superstructures.

"These development researches are part of the Association's long-term development programme, which ultimately aims at the construction of prototypes of aluminium ocean-going ships, all forms of rail transport, and the far wider use of aluminium in road transport vehicles.

"In structures, apart from purely scientific and technical developments, not only have there been new applications in temporary and permanent houses and other buildings, but, as already announced in the Press, a contract has been placed by the River Wear Commissioners for the construction of a large aluminium-alloy bridge at Sunderland. This is the first British bridge to be constructed in aluminium, and is a double-trunnion bascule giving a clear span of 90 ft. Discussions are taking place in regard to other similar structures, thus opening up a new field of expansion and usefulness for the industry.

"The Association is actively pursuing its policy of publicity for aluminium through the medium of the Press, its own technical brochures and bulletins, film shows, lectures and participation in exhibitions.

"In handing over the Presidency of the Association to Mr. Geoffrey Cunliffe, I can look forward with confidence to its continued progress and so to the growth and prosperity of the industry."

Metallic Joining of Light Alloys

The Fifth Section of this Account, Continued from "Light Metals," 1947/10/209, Deals with the Application of Electrical Fusion to the Joining of Aluminium Wire and Strip and Includes a Survey of the Patent Literature on Some Typical Apparatus

JOINING light-alloy sheet and structural forms by fusion welding is well known. The methods employ a gas flame or electric arc, a filler rod of the same composition as the base material being joined, and a flux of high chemical activity. These processes have limitations in exactly the same way as do all commercial methods. The more obvious of these come immediately to mind, namely, those concerned with the lower limit of thickness of the material to be joined; design of junction for accessibility in the correct manner by torch or electrode for satisfactory welding; the essential need for a flux and the need for its complete removal immediately after welding. Such shortcomings preclude the employment of these forms of flame welding in many cases.

A technique is needed that is satisfactory for fine gauges of wire and thin sheet and foil materials, a process that does not require the two materials to be of the same composition, one that can be operated without the use of a flux, and a method that preferably dispenses with a filler rod. Actually, techniques have been developed to incorporate all these features and they have been extensively operated, with success at both the manufacturing stage and with respect to subsequent service life of the equipment so fabricated.

The type of fusion welding referred to here embraces the joining of wires by electrical fusion, similarly the joining of tapes, or of wires to tapes, or of either to metal tags, lugs or other projections. Numerous metals can be joined in this way, including similar combinations of light alloys, copper, bronze, nickel-chrome, ferrous alloys, etc., as well as combinations of dissimilar metals. The junction obtained is homogeneous, dense, free from oxide inclusions or porosity, free from objectionable grain growth or embrittlement, and it is at least as strong as the two materials joined. No additional bimetallic or multi-metallic combination is introduced to complicate matters by superimposing new electrochemical differences; either the two materials joined are compositionally identical and the joint is likewise similar, or they are different and the joint itself is electrochemically the same as one of the two metals or falls between them. Above all no flux is involved.

The technique for producing fusion welds without using flux is by no means new. The situation caused by the war with respect to material conservation, greater speed of production, and more assured reliability of product, however, created a more intense interest in development in this direction, and gave the necessary impetus to the perfecting of methods and of fool-proof apparatus for carrying out such work on a commercial basis. Many of the applications of electrical fusion welding have been in the electrical industry. They include the jointing of cable in the field, conductors being aluminium to aluminium and aluminium to copper; the jointing of various compositions of wire and tape materials in the wiring of vehicles such as tanks and aircraft; the terminating of the windings of electrical resistances and of resistance elements of various types of hot plate; the fixing of leading-out wires to wound coils, and the joints at breaks during winding, especially in relay coils, transformers, magnet coils, and the like; the jointing of the winding wires of electrical coils directly to terminating tags on spool cheeks, terminal plates, etc.

The field that can be satisfactorily catered for in this manner is by no means limited to the electrical industry. It embraces any industry concerned with the joining of wires and tapes, and there are good prospects for the method when a fused junction is desired, and one in which the heat of fusion must be localized and closely controlled. The fixing of what might be termed "fine-gauge" components or fittings to more massive articles is included. The following can be cited as examples: all categories of instrument making, including meters and clocks; all light frames, such as those for spectacles; many forms of jewellery; fastenings for cases such as cigarette cases and compact sets; fuses of numerous types; metallic fixing of springs, such as wire and tape coil springs, particularly of very fine gauge. The minimum size of material that can be processed in this way is of very low order; wires of a few tenths of a millimetre in diameter can be dealt with quite satisfactorily. Naturally each proposition has to be dealt with upon its own merits, and limitations do arise. These will be referred to again later.

The tools and equipment developed for making these fusion welds by electrical means are covered by quite a wide range of patents. It is probably true to say that development was first concentrated upon giving satisfactory junctions in copper-wire conductors, and that studies then extended to other materials. These included plain and anodized aluminium wires and tapes as used in various coils. Also included would be the resistance wires such as the various nichromes or nickel/chromium alloys, the copper/nickel alloys, the radio valve materials such as nickel and tungsten, each to be joined to copper-clad nickel/iron alloy wire.

For electrical fusion welding, the two elements that have to form the junction must be reasonably clean. Thus coil winding wires that are either enamelled or textile covered, or both, must have this covering removed, in common with all other joining processes, if optimum results are to be achieved. On the other hand, it is not essential to remove slight oxide tarnish, an advantage obviously, and one not associated with other processes, for example, soft soldering. Thus it follows that in the case of very fine-gauge windings, aluminium wires and tapes can be joined quite efficiently in the anodized condition.

The process comprises the precise positioning of the two elements to be joined, precise in so far as they must be firmly and rigidly held, and must be in contact with one another; then a controlled quantity of electricity is discharged through the junction. This may be provided from an electrostatic capacitor or from a step-down transformer with appropriate tappings.

The mechanism of the fusion is similar to that occurring in an electric fuse wire. When a circuit is overloaded, the fuse wire rapidly rises in temperature due to the heating effect of the current, this being proportional to the square of the current, to the resistance of the wire, and to the time of current flow. The fuse wire rapidly rises under overload conditions to a temperature above its melting point, melts, "runs back" from the centre to the two fixed ends, at each of which a bead is formed. If a stranded wire is used instead of a single wire, these beads fuse weld the strands firmly together.

A little consideration reveals that the finer gauges of wire are more of a problem than the heavier gauges for this technique of welding. Nevertheless, the process can be designed and controlled to give close reproductivity. For these fine gauges, even when the diameters of the two elements are markedly different, or one or both of them comprises a stranded conductor, the two elements can be lightly twisted together in order to locate them in close electrical contact with one another.

Fig. 16 illustrates the operations for welding fine wires by electrical fusion. First, the insulation is removed from a few inches of the wires in the orthodox manner. Next, the bared wires are lightly twisted together, then the twisted length is inserted in the welding tool. The essential feature of the latter is two contacting

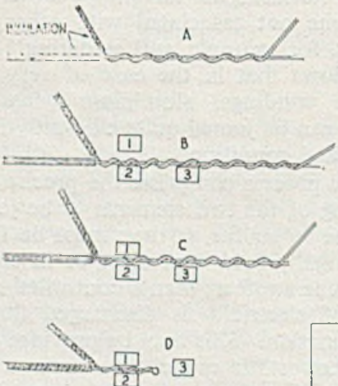
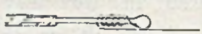


Fig. 16 (above).—The operations for welding fine wires by electrical fusion. The wires are bared and lightly twisted (A), the twisted end is next placed between the clamping electrodes 1 and 2 and in contact with the electrode 3 (B). The wires are then clamped (C) and the circuit made. The electric current heats the wire to fusion, a head is formed and the circuit broken (D).

Fig. 17 (left).—A, cross-section of an electrical fusion weld joining a 10-mil. copper wire to stranded tin-coated wire size 4/37 s.w.g. Magnification × 50. B, a cross-section of the bead showing the merging of the wires and some porosity. Magnification × 100. Fig 18 (below).—Electrically fused junction in which the wires have been pulled longitudinally, bringing the turns as convolutions against the fused head.



blocks placed side by side but spaced a short distance apart (marked 2 and 3 in the diagram), forming the electrodes proper. One of them (3) is rigidly fixed, and the other (2) is spring loaded. The twisted wires are inserted to lay across these electrodes. The lever of the tool is operated; this first brings a third block (1) on to the wires, clamping them firmly against block 2. It next depresses block 2 against its spring pressure and makes electrical contact. Immediately, current passes through the twisted wires which fuse, and a molten bead of metal forms, which runs back along the wire. It solidifies, fusing the wires into a strong junction. Immediately fusion occurs, the electrical circuit is interrupted. The complete operation is very speedy, the current flow being momentary.

If the welding is performed with the wires in a horizontal position, which is usual, the weight of the molten bead may cause it to solidify in a lop-sided position, which, of course, is no real disadvantage. A.C. or D.C. may be employed, and the operating voltage transformed down to a safe level for hand operation of the tool, e.g., 15 to 24 volts.

The nature of the beaded junction is illustrated in a general way in Fig. 17. The upper illustration gives an overall picture of the merging of the wires into the bead, which, in effect, is a cast mass. The lower illustration is taken from representative sections, polished and etched. It shows the wires leading into the bead with some dark cavities between the wires, as would be expected. Over the area in which the boundary lines of the individual wires could be discerned, the grain was directional, still showing the longitudinal arrangement of fine crystals in the length of the wires. In the bead proper, of homogeneous cast metal, the grain was exceptionally fine, and a few dark spots, due to porosity, were revealed.

The two wires can be " pulled " longitudinally, for example, to continue the winding or to terminate it. This pulling is done without untwisting, and the weld and the wires on either side of it withstand the stress. This pulling is demonstrated in Fig. 18.

Compared with soldering, the fusion-welded junction has many advantages. With soldering, the strength of the join is that of the solder, which is relatively low; it becomes even lower if operating temperatures are rather high. There is an electrical difference in the join at the solder interface, and if the soldering is inefficiently executed a high-resistance joint, or even a dry joint of no permanent value, is obtained. Mechanically, a rough joint is often made in which sharp points of solder protrude. These may cut through insulation and may, under service conditions of vibration, abrade other turns of the windings. The aluminium alloys, when used as fine wires for windings, cannot be rapidly soldered, and the additional time and patience for fluxless friction soldering must be allowed.

Electrical fusion welding overcomes all these shortcomings. Speed, no additional metal, no flux and a small, smooth bead free from "points" are its primary advantages. On vibration tests, the electrical fusion welds are superior to any soldered joints, showing, on the average, three times the serviceability and, on individual values, 10 times the life before failure by breakage. "Dry" joints can be eliminated, the cost of solder saved, and the power required is lower than with soldering because it is only consumed during the actual fusion operation, whereas soldering irons constantly dissipate heat.

It has already been stated that the electrical fusing of fine wires is more difficult than heavy gauges. This is particularly so when the fine wires are not of the same gauge, and when using the tool described. This is probably associated with contact at the instant of fusing, and could be more assured by complicating the tool with a second clamping block, with spring pressure, operating on electrode No. 3. Failures are probably associated with the fusion starting in the fine wire and forming a separate bead, and this running ahead of the main bead, the two never coalescing. Even so, in the most difficult cases the failures are only a fraction of 1 per cent., which is no greater, and generally not so great, as faults with soldered junctions.

This shortcoming can be overcome by condenser-discharge methods, as described later, and using a rather different tooling technique. This, however, is not so generally applicable in commercial practice.

With heavier wires, the electrical fusion welding problem is simpler because they can be laid or twisted together to provide a more rigid combination that can be contacted against an electrode. The latter can be stationary and the twisted wires inserted through an orifice to contact the electrode; or the wire combination may be stationary, and the electrode, sleeved for protection, in a hand tool, advanced to contact the wires. In both cases the supply leads are taken, one as a permanent connection to the electrode tool, and one to a clip or pair of insulated pliers in which the wires to be joined are held. The power conditions of current and voltage need to be determined for optimum results for each particular case, with special reference to the size of the conductors involved.

The electrically fused joint can also be made by supplying the necessary wattage by instantaneous discharge from an electrode pencil which is contacted by hand. Tungsten wire and small-diameter carbon rod are the usual electrode materials. Such an arrangement is suited to very fine-gauge wires and thin tapes as well as to heavier gauge materials. It is evident that the two materials to be joined must be rigidly held in the area of the proposed junction. This can be achieved by twisting, as a wire around a terminal tag; by the wire passing through a tube as in the case of a coil winding and tubular terminal; by taking the wire through a hole or loop, or by actual jig clamping or eyeleting. With a fine-pointed electrode, intense heat can be located in a very limited area, and with many classes of work it is not only a question of predetermining the best wattage conditions, but of developing the necessary dexterity to use this type of welding tool.

A number of tools have been standardized for electrical fusion welding and modifications can be made to meet specific requirements. The basis of this range of welding equipment can be well understood from some very fine illustrations and constructional data that are given in the patent specifications. Some of these are extremely informative and they warrant a close study with a view to determining how far the processes can be applied to light alloys, and especially to the thin gauges.

The following is a summary of abstracts from various British Patents:—

B.P. 558,472/1944

This refers to the joining of wires and, particularly, the joining of fine wires such as are used for electrical coils in relays, transformers, telephone receivers and similar instruments. The present invention covers the joining of electrical conductors rapidly without the use of solder flux and neutralizing gas. Further, the joint is formed automatically and simultaneously with the interruption of the circuit caused by the fusion of the wires. The process is convenient for operation by unskilled labour in the factory, or on site.

The process covered comprises the joining of wires by fusion, by placing the wires in contact with one another, for example, by twisting them together and arranging them to form a fusible connection in an electric circuit. A current is passed through the latter of sufficient intensity to fuse the wires and, at the same time, to so interrupt the circuit. Thereby a joint in the form of a molten globule is produced on the fused ends of the wires.

The invention also includes the joining of wires, for example, twisted together, when placed in parallel across a pair of high resistance electrodes (e.g., carbon) in a manner to provide that the junction of the wires forms a fusible connection across the electrodes. The current is applied across the electrodes of sufficient intensity to cause the wires to fuse, thus breaking the circuit and automatically forming a fused joint between the wires.

The apparatus required preferably comprises a set of spaced carbon electrodes between which the wires are connected; the circuit includes an impedance to prevent a too rapid rise of current through the wires. The apparatus and process are illustrated diagrammatically. Fig. 19 thus shows the circuit with the wires in position before and after applying the current. In these diagrams, blocks 1 and 2 are the electrodes, suitably spaced, bridged by the wires to be joined. Block 3 is a clamp which, by means of a spring, serves to hold the wires against block 1. Blocks 1 and 2 are connected to a transformer, the circuit including an impedance 4 and a switch 5. The wires to be joined are 6 and 7, they may be of the same or different diameters and they may be bare or insulated, in which case the insulation is stripped before they are twisted together. They are laid across electrodes 1 and 2, clamped by 3 and the switch 5 is closed, causing the current to flow through the wires between electrodes 1 and 2. The wires melt between the electrodes, the short ends of the wires falling away and the molten

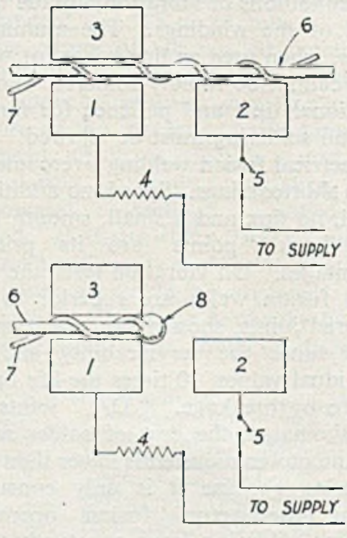


Fig 19.—Electrical circuit showing the wires in position before and after applying the current (B.P. 558,472). The key to the diagrams is given in the text.

section forms the bead 8, which securely welds the wires together.

B.P. 560,500/44

This also relates to the joining of wires, being a modification of the previous patent. It covers improved forms of apparatus for performing the process.

One apparatus for joining wires by fusion consists of a casing, two spaced electrodes mounted and insulated from the casing, a slot in the casing through which the wires can be introduced to bridge the electrodes, and a clamping piece carried on the lid, so that when the latter is closed the wires are clamped in the bridging position. This arrangement shields the eyes of the operator from the flash that occurs when the circuit is closed. The closing of the lid may operate the electric circuit, or a separate press button can be provided.

Fig. 20 illustrates a bench apparatus for joining fine wires. The upper illustration shows the apparatus ready for the insertion of the pair of wires, and the lower shows this apparatus with the lid closed. The boxlike casing 11 is of insulating material with a hinged lid 10, held open by the retaining spring 9. The casing can be screwed to a

bench through the lugs 14, the lid extending beyond the casing, as shown, for easy manipulation by the operator's finger.

On the bottom of the casing the carbon electrode 2 is connected through a resistance element 8, to a contact block 15. Adjacent to the electrode is the contact block 4, which is connected to a contact block 12 through a metal connection 7. On the contact block 12, but insulated from it, is a spring metal blade 6, on the lower side of which is a contact 5 and on the upper side a carbon electrode 1. The lid 10 carries the block 3, which, in the closed position, clamps down on the electrode 1.

The slots 13 in the sides of the casing permit the insertion of the wires for welding. The electrodes 1 and 2 are in correct position in relation to these slots, so that the wires lie across the two electrodes. The contact blocks 1, 2 and 15 are connected to the appropriate electrical supply.

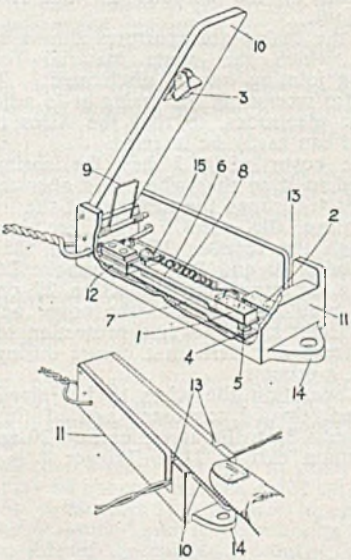


Fig. 20.—Bench apparatus for joining fine wires described in B.P. 560,500/1944. The key to the numbering is given in the text.

It is stated that this apparatus is suitable for wire diameters from 30-50 s.w.g. For fusion welding a pair of wires is twisted together, but it is not necessary to cut the ends. The twisted pair is inserted in the slots across the electrodes and the lid of the apparatus is closed. Block 3 thereby clamps the wires against the electrode 1 and the pressure on this electrode closes the circuit through the contacts 4 and 5. The current flows through the wires which are melted with the production of a globule or bead which welds the wires and breaks the supply circuit. For the electrodes 1 and 2 and block 3, carbon is stated to be the preferable material, with the possibility of using tungsten and other high melting-point metals.

Fig. 21 shows an apparatus for the electrical fusion welding of wires of larger diameter and suitable for gauges from 30-16 s.w.g. In this the handle 39 carries two contact blocks 42 which are connected to a suitable electric supply. One of these blocks carries a metal blade 19, extending towards the front of the tool, with a button 46 which extends outside the handle, and a contact 44. Under the contact is mounted an insulating block 18 to which is fitted a metal member

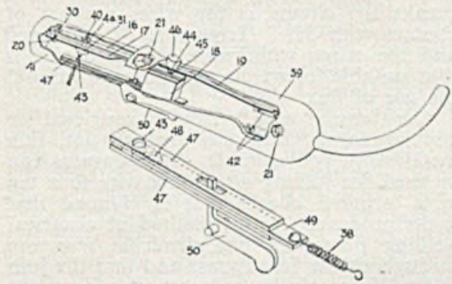


Fig. 21.—The same patent (B.P. 560,500/1944) describes an alternative apparatus for joining wires of thicker section.

16 carrying a spring blade 17. The member 16 carries a contact 45 immediately below, but not normally touching, the contact 44.

The block 18 also carries a wire clamp which is shown enlarged in the lower illustration. This clamp consists of two fixed members 47 with a sliding member, 49, between them. Apertures 43 are formed in the members 47 and an aperture 48 in member 49, this being normally out of alignment with those in 43. The trigger 50 is attached to member 49 so that when actuated to move member 49 against a spring 39 it brings the apertures 43 and 48 into alignment.

The spring blade 17 carries a carbon electrode 31 opposite the apertures of 43. The blade 17 tends to move away from member 16, but movement in this direction is restrained by the screw 20 which is screwed into member 16, passing through an aperture in blade 17 and is held by nut 30. The movement of blade 17 towards member 16 is restricted by screw 40 which screws into member 16 and is held by nut 4a. The lower contact block 42 is connected inside the handle to member 47. A shroud 41 is carried by the handle 39 and surrounds the members 16 and 47. The handle is made in two halves, secured by screws and nuts 21, fitting into recesses.

It is preferable to twist the wires together and trim them level. Alternatively, they may be placed parallel and close together. The trigger 50 is operated to bring aperture 48 in line with aperture 43, and the wires to be joined are inserted until they make contact with electrode 31 and push it back as far as it will go. The trigger is then released whereby member 49 grips the wires against 47. Next button 46 is pressed, thereby connecting the electric circuit, through the carbon electrode 31 and the pair of wires and the members 47 and 49. This causes the weld to be made, because the ends of the wires against the carbon electrode 31 fuse together and melt, allowing the electrode 31 to move away from member 16 until it is stopped by the screw 20. This breaks the circuit as the wires are out of contact with 31. Trigger 50 is depressed and the wires withdrawn. The device is thus suitable for welding conductors, without the use of flux.

The term "wire" is not restricted to circular forms, but may include flat, thin metal strip; for example, the apparatus can be used for joining a winding wire to a tag in a terminal cheek. It is claimed that joints produced by this method of electrical welding possess a fine dendritic structure throughout the fused mass and that the join is free from voids, and that this contrasts with the results from gas welding, in which it is found that the fused mass may be coarse and crystalline and include voids or gas pockets.

B.P. 564,617/1944

This relates to an improvement in construction of the hand tool, embodying the principles in the two foregoing specifications. The new tool is intended for joining wires by electrical fusion and it comprises a handle in the form of a casing. There is a recess in one end to receive the wires to be joined, a pair of electrodes adjacent to this recess, so that they can be bridged by wires, a pivoted trigger lever which operates in conjunction with a shield covering the recess, the shield carrying a clamping piece for fixing the wires to be joined and for pressing them into contact with the electrode. A switch is also included, arranged to be closed by the operation of the trigger lever, whereby the circuit through the electrodes and wires becomes closed.

Electrodes can be of carbon, in the form of blocks secured to metal slide members which are detachable. One or more openings in the casing permit the discharge of any waste material formed during operation.

Fig 22, from left to right, shows the tool, as described, from the side position, and the arrangement with the two moulded parts separated so as to display the internal assembly.

The two moulded parts of the casing are shown at 1 and 2 and they are clamped together by screws with nuts embedded in recesses. When assembled, these mouldings secure the cover plate 3 and trigger lever 4 at their pivots 5 and 6 respectively. The link 7 connects the trigger lever and cover plate through the pins 8 and 9. The extension of the trigger lever at 10 operates the contact springs 11 and 12, while a spring 13 restores the lever to its normal position. This spring is located in the slot 14 of the boss 15.

The feed cable 16, contact springs 11 and 12, resistance 17, springs 13, 18 and 19 are located by being suitably formed to fit in recesses or slots in one of the mouldings with corresponding projections or stops in the second moulding to secure them in position when assembled.

The carbon electrodes 20, 21 and 22 are held by grooved slide members which fit over springs 18, 19 and 23 and these springs are indented and shaped so that they give a frictional grip and a stop for the effective location of the carbons in their correct positions.

In the casing are apertures shown at 24, from which the waste material formed during jointing can be discharged. There are also recesses in the casing at 25 adjacent to the electrodes, so that the wires to be joined can easily be inserted.

The cover plate 3 has the spring 23 riveted to it so that when it is operated by trigger 4, through the medium of the link 7, it clamps the wires, which are inserted through the recesses 25, between the two electrodes 20 and 22. The groove 26 fits over a corresponding projection 27 on the main mouldings so that the cover acts as an efficient shield to give protection to the eyes from any flash that occurs during the welding process.

In operation the wires to be joined are cleaned, twisted together, inserted through the recess 25 to lie across carbon 20 and to rest upon carbon 21. Trigger 4 is then

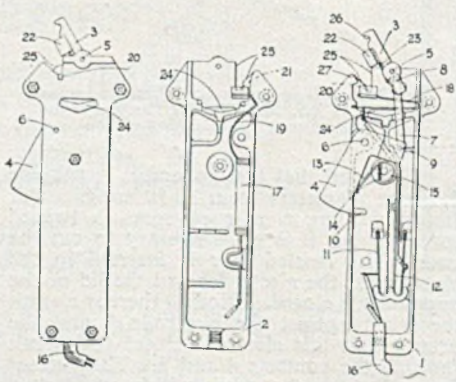


Fig. 22.—Three views of the tool described in B.P. 564,617/1944. From left to right, side elevation of the casing and the internal arrangements.

operated and carbon 22 clamps the wires on the resiliently mounted carbon 20, the contacts on springs 11 and 12 become closed and the wires become fused from carbon 21. This results in the circuit being opened and trigger 4 is then released and the joined wires withdrawn.

The supply circuit from cable 16 is connected one side to electrode 20 through the switch springs 11 and 12 and the other side of the electrode 21 through the resistance 17.

B.P. 570,681/1945

This is an extension of the subject as covered by the preceding patent specifications and specifically covers an improved method and equipment for the electrical welding of metals, with particular applications to wires, strands, tapes, tags or any combination of these forms of conductor used in electrical circuits.

One object of the invention is to provide more precise control of the process by using a predetermined amount of electrical energy from a capacity discharged through the work. The preferred electrode is one of carbon which provides a high resistance contact and ensures maximum heating. It also avoids the tendency for the electrode material to alloy with the work.

One form of the invention places the conductors to be joined side by side in contact with one another and preferably twisted together, forming a fusible connection between a pair of electrodes in a circuit through which a capacity can be discharged of sufficient magnitude to fuse them. Thereby the circuit is interrupted and a fused joint is formed between the conductors.

The patent covers the equipment for joining in this manner. It consists of an electrical condenser or bank of condensers, a switch or contacts for connecting the condensers to the electric supply in order that they may be charged, provision for supporting the conductors side by side in contact with one another and for connecting them to one side of the condenser, and a second electrode for contacting the work to be welded. This second electrode can be spring mounted so that it is normally out of contact with the work and so that it may be used as a switch alternately to charge the condenser or to discharge it through the conductors.

Again, a preferred arrangement is also provided for charging the condenser from a circuit independent of the conductors to be joined. This comprises a rectifier connected to a variable voltage power transformer and thereby control over the energy discharged through the work to be welded is provided. An alternative is to provide tappings on the bank of condensers.

The invention is illustrated by Figs. 23 and 24, which assumes A.C. mains supply. Fig. 24 gives the circuit diagram for this welding equipment and Fig. 36 a perspective of the preferred arrangement of connecting a bank of condensers in parallel, to provide the source of capacity. 1 is the primary winding of a mains transformer, 2, connected across the supply mains 3 and in series with a switch 4 from which the supply can be connected or disconnected. 5 is a variable secondary winding with an adjustable switch 6 and an indicator lamp 7. It is bridged by a rectifier 8, which is in circuit with the appropriate capacity 9. One terminal 10 of this capacity is connected to a clamping device 11 which holds the work to be welded and the other terminal 13 is connected to the carbon electrode 14. The latter is spring mounted to be movable towards the work 12. The contacts 15 are arranged so that with the electrode at rest and the mains switch 4 on, the capacity is charged from the rectifier so that the contacts are opened when the electrode is advanced to the welding position. The capacity terminals 10 and 13 are also connected through leads 16 and 17 and a resistance 18 to a pair of back contacts 19 on the mains switch 4. This ensures that when the mains switch is off any residual charge in the capacity is discharged through the resistance and it prevents any possibility of a spark or a shock when the equipment is switched off. A fuse 20 is included in the circuit between the secondary 5 and the transformer and the rectifier 8, so that should one of the condensers break down by an internal short circuit, overload on the rectifier or transformer is prevented.

The capacity 9 may range from a few to many thousand microfarads, depending upon the size and composition of the wires to be joined. It consists preferably of a bank of condensers 21 assembled so that the busbars 22 and 23 connect them in parallel. These busbars end in terminals 10 and 13, to which the welding fixtures can be connected. The terminals can be socket type mounted on a front panel of the apparatus, thus enabling a variety of fixed or portable welding tools to be plugged in for use as required.

The capacity 9 is charged through the contacts 15 with the electrode 14 in its normal position of rest and then the electrode is moved into contact with the wires 12 and the capacity discharged through them. The surge of current causes the wires to fuse and the bead to form on the wires to give the joint.

B.P. 572,324/1945

This patent covers an improved construction of hand tool based on the principles of B.P. No. 560,500. The tool comprises two castings or mouldings clamped together to form a handle. These two components are recessed to accommodate two side plates at

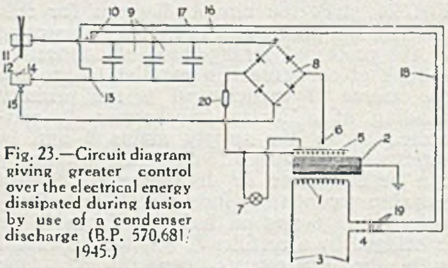


Fig. 23.—Circuit diagram giving greater control over the electrical energy dissipated during fusion by use of a condenser discharge (B.P. 570,681/ 1945.)

the top, and a trigger pawl and restoring spring in the centre, and a contact spring at the bottom. One side plate is insulated from the handle and has an aperture through which the wires to be joined are passed and pressed against a carbon electrode which is carried on a spring support on the other side of the plate. The wires are pressed until the carbon block recedes to the maximum extent. The trigger carries a clamping spring, a quick release pawl for the contact spring used in the lower part of the handle, a contact screw and a restoring spring. When the trigger is depressed it first clamps the wires between the clamping spring and an anvil, which is at one side of the aperture of the side plate. By means of the pawl it then releases the movable contact spring which makes contact with the contact screw in the trigger and completes the circuit. The ends of the wires against the carbon block are thereby fused. The circuit then automatically opens, the trigger is released and the wires welded into a bead, are withdrawn.

B.P. 575,883/1946

This particularly covers electrical welding apparatus for the joining of wires with special reference to the condenser discharge welding referred to in B.P. No. 570,681. It provides a tool for the electrical fusion welding of conductors, including the means for clamping them with their ends in a fixed position with respect to a welding electrode, a shutter normally interposed between the conductors and the electrode and means for advancing the electrode to contact the ends of the conductors. During the latter, the shutter is withdrawn from the path of the electrode.

The invention is explained by Fig. 25, which shows the front and side views of a welding apparatus for use with condenser discharge fuse welding.

The tool comprises a box built up from panels and side pieces 1 of thermo-setting moulding material carrying two busbars 2 and 3 on the underside of the top panel. They have circular ends provided to enter circular sockets on the fuse welding equipment. Busbar 2 is connected by screws and nuts to a metal bracket 4. The latter carries

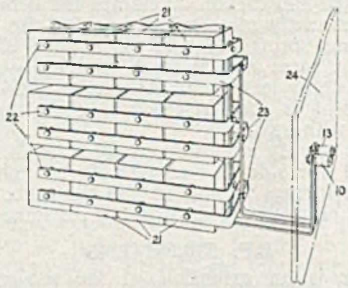


Fig. 24.—The bank of condensers connected in parallel as described in the text.

a fixed metal vice jaw 5, a movable metal vice jaw 6, an operating handle 7, a cam 8, which controls the movement of a slide 9, and an extension 10, which carries the moving vice jaw 6 and is controlled by the spring 11. The cam 8, the slide 9 and the extension 10 are mounted between the bracket 4 and a front plate 12 in such a manner that when the handle 7 is in a vertical position, the vice jaws 5 and 6 have a suitable opening for the insertion of the wires to be welded. The handle 7 is pivoted on the back of the bracket 4 and carries a roller 13, which, when the handle 7 is restored to the vertical position after welding, depresses the caging shutter 14 so that it lies behind the welding aperture and is retained in position by the catch 15. The wires to be joined are inserted in the aperture until they make contact with the shutter 14. The handle is then depressed to a 90 degrees position, which clamps the wires firmly between the vice jaws.

The other busbar 3 is connected to the copper block 16, which is drilled for the push button stem or plunger 17. A plate 18 mounted on the front of the push button stem 17 carries the carbon electrode 19 in a spring holder 20, a pin of insulating material 21 and a contact 22. Good electrical contact with electrode 19 is ensured by the copper braid 23 connected between the copper block 16 and the contact plate 18. The push button stem 17 has under its head 24 a spiral return spring 25. The contact 22 on plate 18 engages the contact 26 on the spring 27 which is mounted on the top of box 1 and is intended to be flexibly connected to a loose plug, not shown in the diagram, which is inserted in a socket on the welding equipment when the tool is fixed for use.

The cover 28 completely covers the working parts of the tool, prevents hot fragments of metal flying out during welding and provides a shield for the operator's eyes. The busbars 2 and 3 can be connected to the two terminals of a source of supply which may be a charged welding condenser. In that case the contact 26 is connected to one terminal of the charging source for the condenser. This maintains the condenser charged because contact 22, which is engaged in the unoperated position of the plunger 17, is through block 16 to busbar 3.

When the plunger 17 is operated, the contacts 22 and 26 are opened, disconnecting the condenser from the charging source and making it ready to fuse weld the wires to be joined. Having clamped the wires as described, the push button head 24 is depressed, opening contacts 22 and 26. The insulating pin 21 depresses the catch 15, releases the shutter 14, which is lifted by the spring 29. Advancing the press button further, carbon electrode 19 makes contact with the wires, causes them to fuse weld to a bead by discharging the condenser. Upon releasing the press button, the latter is restored by spring 25 and contacts 22 and 26 re-engage, thus recharging the condenser. The handle 7 is then restored to the vertical position to release the welded wires and to restore the shutter 14 to its gauging position, ready for the next operation.

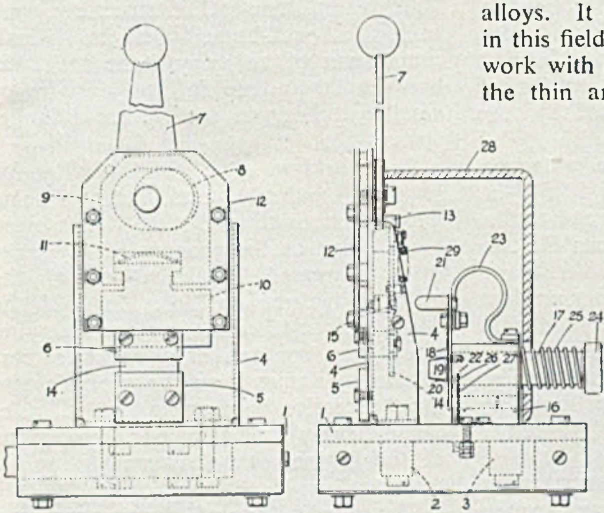


Fig. 25.—Front and side elevations of a machine for electrical fusion welding employing the condenser discharge circuit (B.P. 575,883/1946).

A study of the patent information in the foregoing few selected patents shows that much thought and development work has been expended in this technique of electrical fusion welding. Nevertheless, the position with regard to design of tools and equipment for the process is in its infancy. It is natural that most work has been done with copper as the basic material for joining, this being due to the obvious advantageous applications in the electrical field, where, in this country, copper is still the principal conductor material. It has been applied to copper in the form of wire, tape and tube, including stranded wire, and to combinations of these. Again, it has been applied to the nickel/chromium and nickel/copper resistance wires and tapes, and to phosphor bronze, nickel and tungsten. With respect to aluminium, it has been used for this material in wire and tape form, to anodized wires, and for joining aluminium to copper and phosphor bronze. The process is very promising for study with respect to thin gauges of aluminium and aluminium alloys. It would seem that the problem in this field involves simple but extensive work with respect to methods of holding the thin and light materials firmly in close contact, and to the means of obtaining sufficient wattage in the junction for a very minute fraction of time. Techniques of folding, crimping or eyeleting may assist in these directions.

For aluminium to copper junctions some thought has to be given to the nature of the alloy formed as a result of the fusion. This particularly applies to the welding of fine gauges of material when flexibility is required or when vibration is a service factor from which fatigue failure may occur. With these fine gauges it will be found desirable to arrange the relative masses of aluminium and copper at the junction to be such that the aluminium content in the fused junction cannot exceed 9.8 per cent., i.e., below the limit at which the hard brittle delta constituent can be present in the resultant aluminium bronze alloy.

(To be continued.)

THE NEW WEAR BRIDGE

By F. J. Walker,* A.M.I.C.E., A.M.I.M.E.

The Author Sketches the Development of Bridge Design and Construction from the Time of the Earliest Timber Assembly to the Latest Project—and, in Great Britain, the First—in Light Alloy†

THE world's first moving-span bridge to be constructed of aluminium alloys is being put in hand for the River Wear Commissioners. Its weight will be only 40 per cent. of an equivalent steel bridge yet it will be quite as strong, far less susceptible to weathering and more economical in the power used by the lifting mechanism.

Over a 90-ft. span of the waterway this unique bridge will carry a 4-ft. 8½-in. gauge railway track, besides road traffic, and allow a clear width between the two movable "pony trusses" of 18 ft. 6 ins.

The first use of a 20th-century product for this purpose emphasizes how the story of bridge building is that of adapting to the demands of successive ages the most suitable materials obtainable, and an increasing concern with securing greater strength and durability.

In earlier times, communications were effected by felling a suitable tree over the dividing channel, and from this the primitive "clam" bridge, the timber bridge, evolved. In districts where stone was plentiful, early bridges were made by laying large flat stones across piers built up from small blocks of stone, the stones over-lapping and held in position by friction alone. These were known as "clapper" bridges and may still be found in some parts of Britain.

In Roman times and during the Middle Ages many stone-arched structures were built as "pack-horse" bridges. Maximum span of an early stone arch was between 20 and 30 ft., and a series of smaller arches was used to cover longer spans.

Such bridges gave good service for several hundred years, many being widened from time to time as the need arose. But as the amount of vehicular traffic increased the limitations of the material became obvious. In 1621 the use of four-wheeled wagons carrying more than one ton of goods was forbidden by James I on the grounds that the "excessive burdens so 'falled' *(sic)* the highways and the very foundations of the bridges that they were a public nuisance."

The practicability of adapting cast-iron was demonstrated by the bridges erected in the latter half of the 18th century. The comparatively great strength of this material, and its amenability to production in large units, gave a new direction to bridge building, allowing the architect more liberty in design and making it possible for the engineer to sweep over greater stretches in a single span.

Many of these early cast-iron bridges are still in service, including the first, erected at Ironbridge in Shropshire in 1779. The River Wear, which is to be the first British river associated with the latest bridge-building material—aluminium alloys—was spanned by a cast-iron bridge in 1796.

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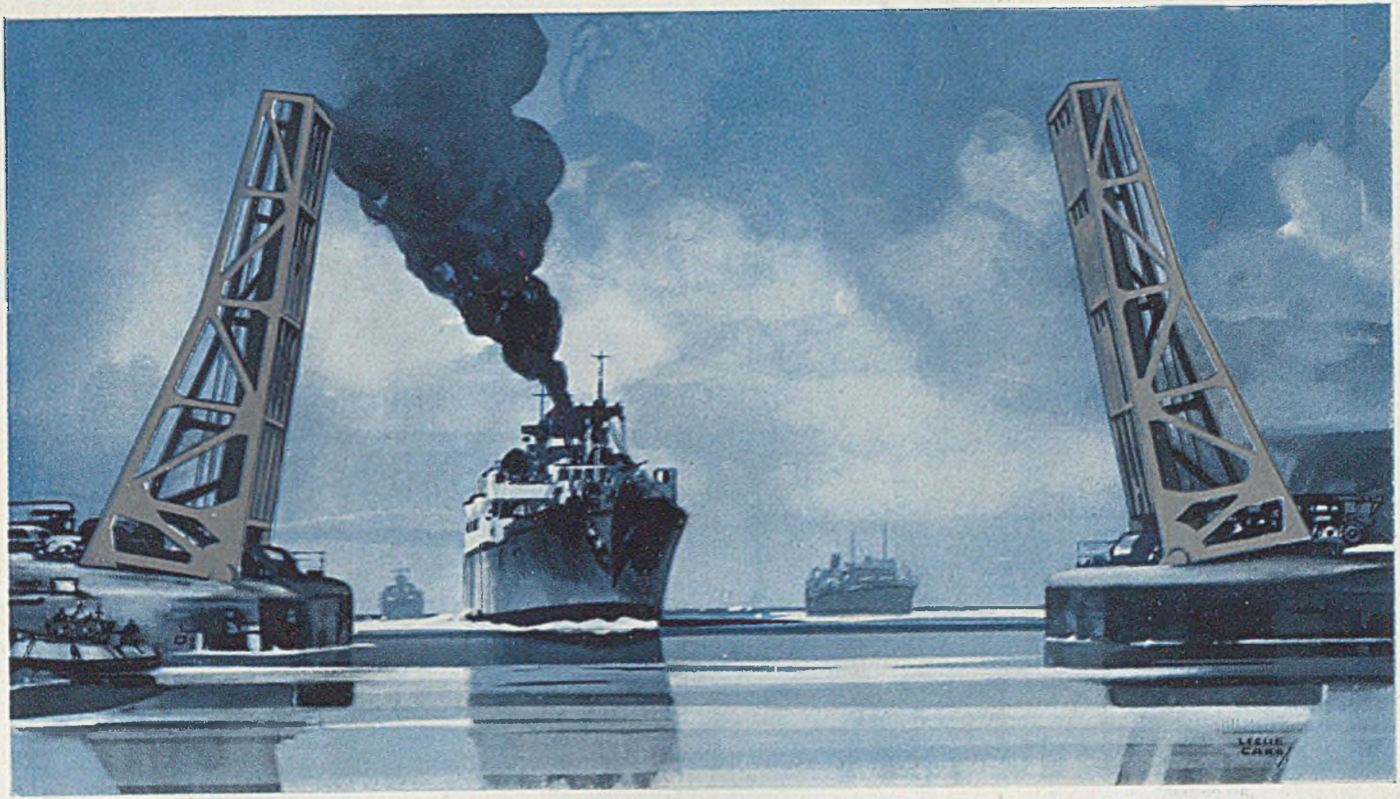
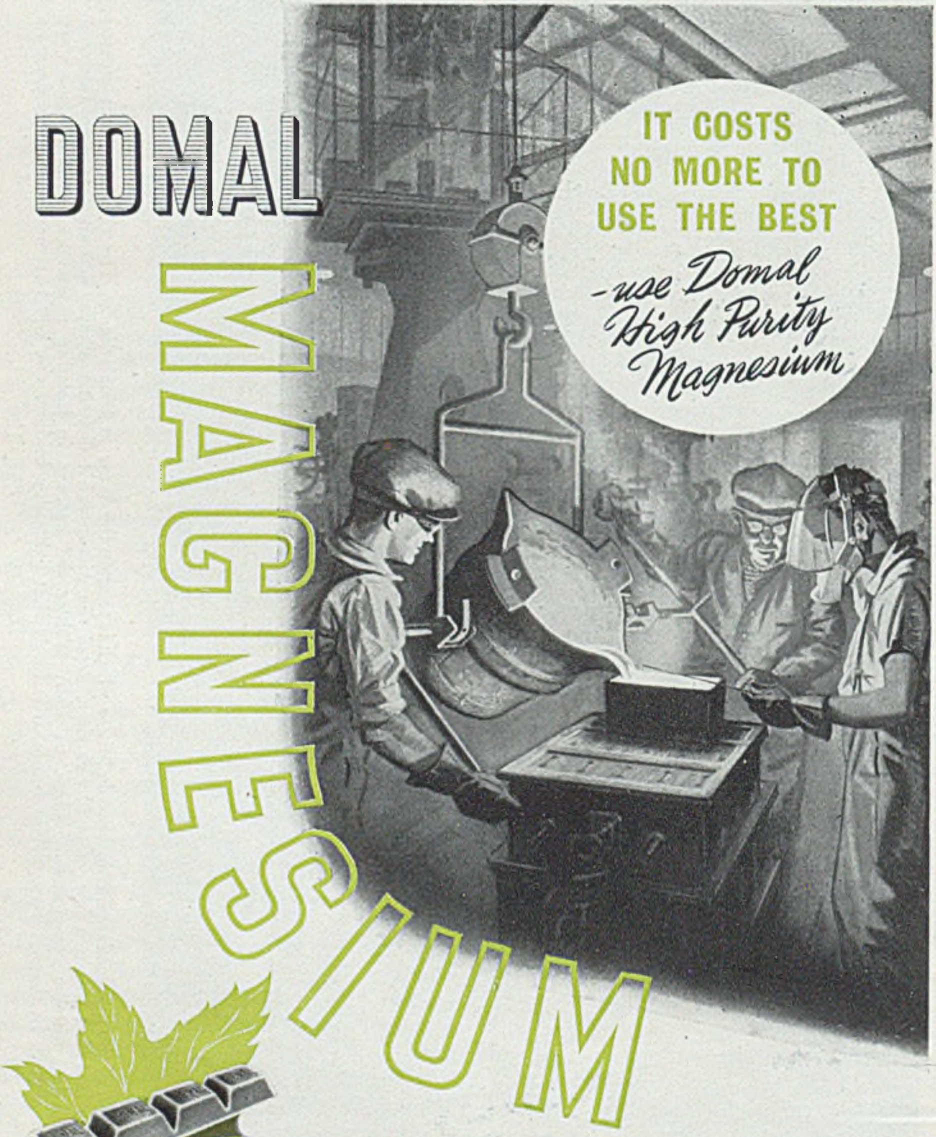
* Chief Civil Engineer, Head Wrightson and Co., Ltd., Thornaby-on-Tees, England. During the war Mr. Walker designed and built the first experimental drum for the unreeling of the steel pipe-line for PLUTO—the line under the ocean conveying petroleum from Britain to the Normandy coast. Other important projects of which he has been in charge include the lock gates and swing bridges of the Mahommed Ali irrigation barrage on the Nile.

† In the selection of alloys, etc., Head Wrightson Light Alloy Structures Ltd., have, from the outset, received the full advice and co-operation of the Aluminium Development Association.



ARTIST'S conception of the all-aluminium twin-bascule bridge which is to span the Wear at Sunderland. The river was first crossed by an iron bridge in 1796; within a few years of this date, arose the widespread belief that alkalies and alkaline earths (alumina amongst them) were in fact metallic compounds. When, in 1827, Wöhler did succeed in isolating aluminium, metal bridges were still something of a novelty. In the not very distant future, it is likely that light-alloy bridges, too, will become as commonplace as did those in iron.



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Quickly following the development of cast-iron to structural uses came the commercial production of wrought iron in forms sufficiently massive for structural application. The strength/weight ratio of wrought iron stimulated the imagination of bridge designers, especially as, for the first time, a material strong enough to take up tensile stresses was available. The result of this advantage over earlier materials was the construction of bridges of wide spans quite impracticable before, in which this high tensile property was well exploited. In place of arches wholly under compressive stresses the girder bridge in all its variations, and the suspension bridge with its slender lines, came into the picture.

Steel was well known when wrought iron was developed for constructional purposes, but production of mild steel on the scale required was impossible at the time. In 1855, however, Bessemer patented his Convertor for the production of mild steel, which allowed a tremendous step to be made in quantity production, size of bar and reduction in price. The stronger and cheaper metal gradually superseded iron and even the greater corrosion resistance offered by wrought iron was insufficient to offset the advantages of higher strength, lower price and more abundant supplies offered by the newcomer in this field.

TYPICAL of some of the old timber bridges still in use—Bont Fawr Tafolwern, Wales. (Courtesy E. Jervoise, Esq., and Architectural Press, Ltd.)

One of the earliest examples of steel in bridge building later became one of the first examples of the use of aluminium alloys. The former was used in conjunction with wrought iron in the construction of the Smithfield Street Bridge at Pittsburgh, Pa., erected in 1882 over the Monongehela River, and the latter was used in the same bridge in 1936 to replace the whole of the wrought iron of the flooring system.* Because of increased traffic it was decided, in 1936, to reduce the weight of the wrought iron flooring girders by introducing aluminium alloys, so reducing the dead load by one ton per linear foot of the bridge length.

This is an important point. In a large steel bridge, such as that over Sydney Harbour, the weight of the material may itself account for about 70 per cent. of the stress on the members—in other words, about 70 per cent. of the material used in building the bridge is merely carrying its own weight and not doing useful work.

By using aluminium alloys the dead-weight can be reduced by about two-thirds. By having only a third of the weight to erect there is a saving in original cost, in the cost of transport to site, in handling and erecting, and in foundation costs due to reduced load—to say nothing of the convenience and ease of handling lighter materials from the point of view of the physical fatigue of the workers.

Reinforced concrete has challenged steel during the past 20 years, mainly on account of maintenance costs, but also because, in certain cases, concrete is æsthetically a more suitable medium. It is not suggested that either of these

* See "Light Metals," 1944 7/582.

materials is the better for any unspecified bridge application, for all the circumstances involved have to be considered when choosing the most suitable material. For example, although reinforced concrete requires less maintenance than steel, it puts greater loads on the foundations and also requires skilled labour on site.

It appears from a comparison of these two modern materials, steel and reinforced concrete, that a material having the chief advantages of each—lightness and corrosion resistance—deserves very careful consideration.

The design of the double leaf bascule bridge for the River Wear Commissioners, Sunderland, by Head, Wrightson and Co., Ltd., is a unique departure from standard methods in that it embodies, for the first time anywhere in the world, the use of aluminium alloys for the moving span.

There is evidence that such applications of aluminium alloys will be extended in the near future, particularly where lightness is to be combined with great strength and minimum maintenance. Where heavy transport and erection charges have to be met, such as occur in connection with bridges in comparatively inaccessible places, economics may well be very favourable to these metals.

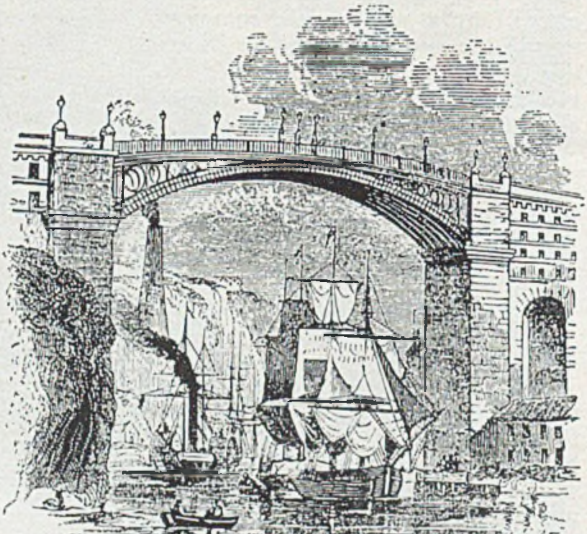
In the particular case of a moving bridge, the reduction in weight of the material used permits a reduction in the size of the lifting mechanism, and daily savings in the power consumption required to lift the leaves.

The weight of the Wear bridge will be about 40 per cent. of the weight of an equivalent steel bridge.

The Wear bridge is a twin leaf, trunnion bascule type, the movable spans consisting of two pony trusses with flooring for the roadway. This roadway is designed to carry a 4-ft. 8½-in. gauge railway track and also to permit modern road traffic to traverse the bridge without hindrance.

The clear span of the waterway is 90 ft., and the clear width between trusses is 18ft. 6 ins.

Machinery for operating the bridge is placed below ground level, where a pinion engages with a curved rack at the tail end of each truss. When the bridge is opened the curved tail end of the trusses descends into water-tight pockets in the abutments. These pockets are spanned by the approach girders and flooring.



THE cast-iron span of the first metal bridge to cross the Wear at Sunderland was designed by Rowland Burden and erected in 1796. (After a print of 1852.)

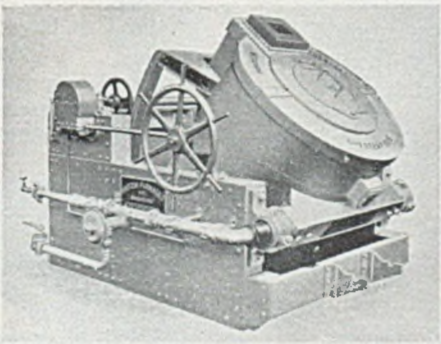
The operating gear for each leaf is driven by two electric motors, and hand gear is provided for use in case of failure of the electricity supply.

Aluminium alloys are available in great variety, each with different properties, and special study is necessary to select the correct alloy for a given application.

Crucible Melting Furnaces

Describing the Melting and Holding Furnaces Installed in an Aluminium Foundry for the Production of Gravity-die-cast Window Frames

ALUMINIUM and its alloys, which contributed so greatly to the war effort in the aircraft industry, are now playing a very important role in the housing programme, and the following article describes a recent installation of melting furnaces in a Midlands factory engaged in the production of light-alloy window frames, both for temporary and permanent houses, the frames being supplied complete with windows and all the necessary fittings ready for the builders on site to fit into position. The factory is in operation for 120 hours per week and the average weekly output is 4,000 complete windows (i.e., 20,000 frames).



TILTING crucible furnace with a maximum capacity of 10 cwt. aluminium. The axis of tilting is just below the pouring tube. This arrangement simplifies the pouring operation by minimising the movement of the metal stream. (Courtesy British Furnaces, Ltd.)

Aluminium is delivered in "prepared" ingot form and, after melting down in two 10-cwt. capacity crucible tilting furnaces, is poured into a refractory lined ladle, slung from an electrically operated lifting and travelling hoist.

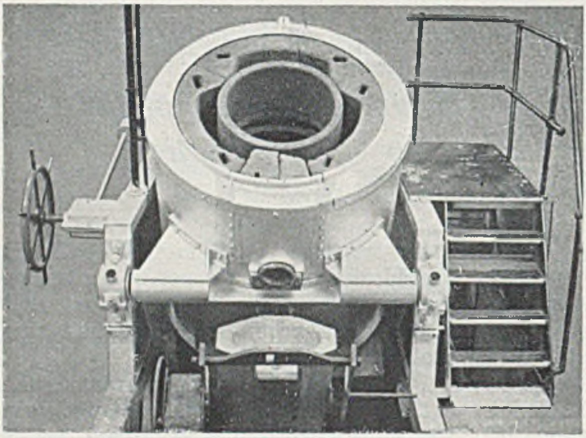
The charge is next transferred to twelve 150-lb. capacity holding furnaces, in which the molten metal is maintained at the desired pouring temperature. Two further 150-lb. capacity crucible furnaces are used primarily for casting the fittings, consisting of tees, hinges, handles, mullions and transoms.

Automatic temperature-control equipment is fitted to all fourteen bale-out crucible furnaces, as constant control of metal temperatures is virtually essential in the gravity-casting system, upon which production is organized.

Die design is a very important factor in the successful production of aluminium window frames and, in the factory under discussion, there have been carried out exhaustive experiments and tests in order to obtain the most satisfactory design and construction of die to give maximum life with an absolute minimum of distortion. Furthermore, in order to obtain a uniform run of metal, it is necessary, first, for the dies to be heated prior to the metal being poured into them. After a few castings have been run off, the dies tend to assume an equilibrium working heat. The temperature of the dies is automatically controlled, and measured with special permanent-contact-pattern thermocouples.

After the frames have been dressed they are placed on an overhead chain conveyor, dipped into a paint tank and conveyed to a continuous drying oven. Next they are completely assembled for inspection before dispatch.

The whole of the installation of melting and holding furnaces was designed and installed by British Furnaces, Ltd., Chesterfield, and the following is a



The 10-cwt. melting furnace in the pouring position and with the cover removed showing the refractory lining. Note the position of the ladle with respect to the pouring tube. (Courtesy British Furnaces, Ltd.).

description of this plant, together with auxiliary equipment.

10-cwt. Capacity (Aluminium) Crucible Tilting Furnaces

Each of the tilting furnaces consists essentially of a crucible with tube pour, preheat ring and stand, all of which are enclosed in a cylindrical mild-steel casing lined with first quality Scottish firebrick, backed up with lightweight insulating refractory in order to reduce radiation losses through the walls to an absolute minimum. The combustion chamber of each furnace is designed in such a manner as to bring the products of combustion into intimate contact with the crucible for the whole of its height.

Each tilting furnace is of the lip-axis type, i.e., the fulcrum or centre line of tilt is as near as possible to the spout. The lip-axis type was chosen because the movement of the spout is very much less than with the central-axis design, and it has been found possible to fix the ladle into a small pit for pouring purposes.

A further feature of this form of furnace is the ease and smoothness with which tilting can be accomplished with only a minimum of effort on the part of the operator. Tilting is carried out by means of a large capstan handwheel connected by mitre and worm gearing to the chainwheel shaft at the back of the furnace.

Counterbalance weights are arranged in guides in such a manner that, when tilting begins, the full load of the counterbalance weights is utilized; as tilting proceeds, counterbalance is reduced by means of a " pick-up " device which acts as a compensator, so maintaining even motion.

150-lb. Capacity (Aluminium) Bale Out Furnaces

Each bale-out or holding furnace consists of a crucible and stand, housed in a refractory lined combustion chamber

One of a battery of twelve 150-lb. "holding" furnaces which are operated in conjunction with two 10-cwt. melting furnaces.

constructed of lightweight insulating refractory backed up with diatomaceous earth insulating bricks. The hot face of the lightweight insulating refractory has a protective wash of sillimanite cement.

A mild-steel cylindrical casing houses the whole of the refractories, except at the top, where a sectional heat-resisting iron plate is fitted.

Each furnace is also provided with a heat-resisting iron drip ring for the purpose of preventing drippings of aluminium entering the combustion chamber during baling periods.

Burner Equipment

The burner equipment on the whole of the melting furnaces was, originally, of the low-pressure automatic-proportioning type by British Furnaces, Ltd., but owing to the temporary shortage of town's gas it was found necessary to fit oil burners in place of gas burners on the two tilting furnaces.

GENERAL view showing the arrangement of the furnace equipment. On either side of the gangway are two sets of three holding furnaces with a melting furnace between them. The electrically operated ladle travels along and across the gangway.

Each bale out or holding furnace is equipped with a heat-resisting steel non-blow-off tip burner arranged to fire tangentially to the refractory lining through a specially designed burner block. A correctly proportioned gas-air mixture is supplied to the burners by automatic proportioning low-pressure inspirators.

In this equipment, gas is induced by the flow of air through a venturi throat and the quantity of air flowing automatically induces the correct amount of gas. The entire operation of the furnaces is, therefore, controlled by the air valve on each inspirator, and an increase or decrease of the air supply automatically increases or decreases the gas, so that the mixture proportions remain in a constant fixed ratio.

The water gauge indicates the rate of consumption and enables the operator to reproduce accurately each day the most advantageous rate of operation.

As mentioned previously, the two tilting furnaces now operate on oil, the burners being of the unsealed type, arranged to fire tangentially to the refractory lining to impart a rapid swirling motion to the products of combustion and thereby obtain uniform heating, which is essential for good crucible life.

The gas-burner equipment uses air at a pressure of 1 lb. per sq. in., along with town's gas at ordinary mains pressure of 3-in. W.G., whilst the oil burners use air at a pressure of 1 lb. per sq. in., along with oil under a head of about 10 ft.

Air Supply

As this factory has a high-pressure air supply available in the form of a ring main system at a pressure of 80 lb. per sq. in., British Furnaces, Ltd., supplied its patent high-pressure inspirators to reduce the high-pressure supply down to 1 lb. per sq. in. on each of the crucible furnaces. These inspirators only take about 10 per cent. of the air required for combustion from the high-pressure supply, the remainder being entrained from the atmosphere.

Ladle-heating Equipment

It is essential that the ladles be heated prior to receiving the hot metal and, for this duty, equipment has been installed for heating the interior of the ladles.

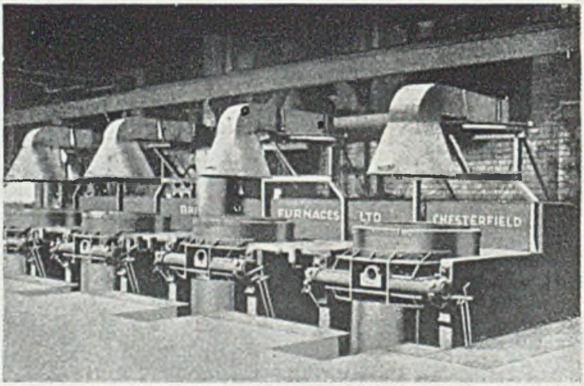
Automatic Temperature-control Equipment

The whole of the temperature-control equipment throughout the plant is of Electroflo Meters Co., Ltd.'s, manufacture and, in the case of the holding furnaces, consists of an indicating control pyrometer for each furnace, which actuates a motorized control valve in the high-pressure air line to each burner.

Each thermocouple is of the right-angular type, the leg immersed in the molten metal being covered with a Meehanite protecting sheath, coated with whitewash every eight hours; very satisfactory sheath life is obtained with this dressing.

An immersion thermocouple measures the temperature of the metal in each tilting furnace and this is indicated on a wall-mounting indicating pyrometer.

In addition to the installation previously described, British Furnaces, Ltd., has designed and constructed crucible furnaces of varying capacities of the bale-out type, central-axis-tilting type and lip-axis-tilting type.



A BATTERY of lip-axis-tilting crucible furnaces. (Courtesy British Furnaces, Ltd.)

NEW SPRAY-TRAPPING DEVICE

The Spray from Chromium Plating Baths is Undesirable both Financially and on Medical Grounds. A Solution to the Problem in the Form of Floating Plastic Tubes Suggests a Wide Field of Application for the Idea

AN outstanding example of a war baby that has become a peace-time giant are "Chrome-Lock" tubes extruded in Styron (Dow polystyrene) for use as a protective blanket over chromium plating tanks to suppress "fume."

Many and costly were the problems which the plating industry faced before the war—loss of chromic acid in a fine spray, which was sucked up by the ventilating system and discharged outside the building; loss of heat from the bath; and oft-times complaints from nearby residences and industries against the fumes.

The Udylite Corporation, of Detroit, Michigan, manufacturers of supplies and equipment for electro-plating and similar operations, approached the Dow Chemical Co. for guidance in working out an idea. Together with Dow engineers they developed "Chrome-Lock" tubes.

These plastic tubes, closed at each end to resemble miniature pillows, are floated on the chrome solution in sufficient depth to blanket the bath and thereby lessen considerably the escape of the fine spray. The lightweight tubes move apart easily when a rack of objects which are to be plated is lowered into the solution; they move back into place around the rack spine, completely covering the acid bath while the objects are being plated.

The simplicity of the blanket is shown by the accompanying pictures, which were taken at Electro-Finishing Industries, Incorporated, Detroit, Michigan, one of the many users of this technique. The tubes are simply dumped into the chrome plating tank in sufficient number to form a blanket of the desired thickness. The thicker the surface blanket of "Chrome-Lock" tubes, the less the acid loss. Tests showed that with no tubes on the surface of the plating bath, 330 milligrammes of chromic acid were present in each 10 cubic metres of air taken a few inches above the surface of a chromium plating bath in operation over a 30-min. period. In a 30-min. test with a 1-in. blanket, only 11.9 milligrammes of spray were present per 10 cubic metres of air, whilst with a 2-in. blanket the quantity was cut further to 8.0 milligrammes. In all cases the blower system was turned off completely, and the plating current was between 440 and 460 amperes. About $1\frac{1}{2}$ lb. of the tubes are necessary for a 1-in. blanket over 1 sq. ft. of solution surface, and 3 lb. per sq. ft. for a 2-in. blanket.

FLOATING on the electroplating solution these small plastic "pillows" (see inset illustration) considerably reduce the spray from the bath. They part and re-form when a new work-piece is introduced, do not break and are resistant to chromic acid.

Whilst the Styron tubes save from 50 per cent. to 75 per cent. of the chromic acid ordinarily lost, the protection given by the system to plating-room employees is also an immense advantage. Experiments and utilization have proved that additional compensations to the user of these tubes include a need for less heat to keep the bath at the correct operating temperature, and a saving of heat and electric power in the plating room by cutting down on the quantity of air withdrawn by the blower.

Styron was chosen as the plastic material from which the 3-in.-long "Chrome-Lock" tubes are extruded because of its exceptional resistance to acids and alkalis, and because, like most plastics, it is lightweight and smooth textured. The tubes are not changed in size, weight, appearance or chemical composition by immersion for days in the highly acid chrome plating bath. In addition, Styron is shatterproof, thereby preventing loss of the tubes by breakage. Replacement is necessary only when the tubes are lost by drag-out, for Styron itself will stand up indefinitely in the acid.

The "Chrome-Lock" tube is another example of a shortage-inspired idea that has proved its peace-time practicality, one that is even now continuing to be an important product in the field of electro-plating.

It seems likely, furthermore, that these polystyrene spray inhibitors may find extended uses. Thus, for example, in pickling baths, whether sulphuric, nitric or hydrofluoric acids be used, the gases evolved inevitably carry over traces of these dangerous fluids in bubble form.

For the first time, a device, which is simple to install, is available to trap the spray without hindering production.

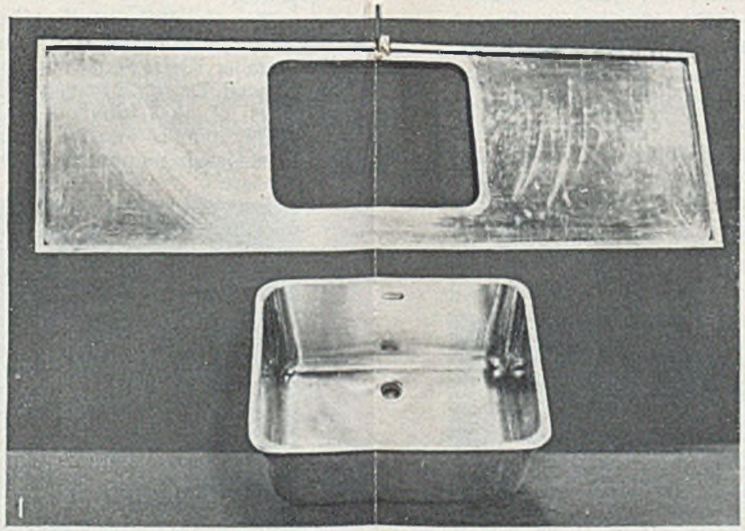
The GLUING of LIGHT METALS

Production of Metal-to-metal and Non-metal Joints by Synthetic Resin Adhesives Underwent Great Development During the War Years and Found Extensive Application in Aircraft Construction.—

—Now, During the Post-war Period, this Technique, of Proven Serviceability, Promises to Solve Many Awkward Problems in the Design and Assembly of Many Types of Domestic Metalware

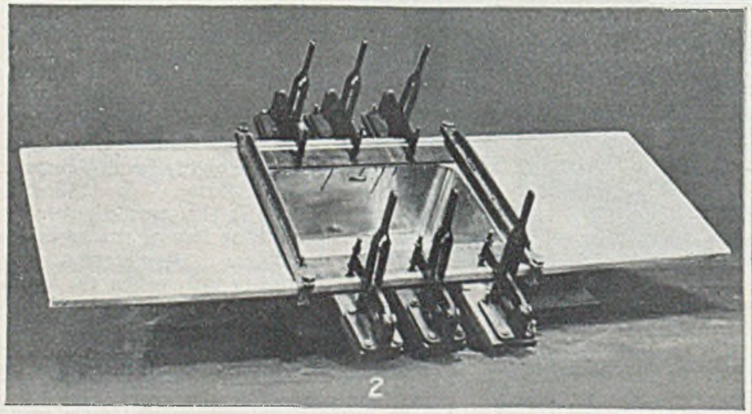
THE joining of light alloys has always presented difficulties. Whilst welding and riveting have been used for many years both suffer from disadvantages, and riveting is often undesirable for æsthetic, if for no other, reasons. Brazing and soldering of light alloys, although sometimes practicable, are hardly as simple and reliable as they are for steel, and soldered joints have a poor resistance to corrosion.

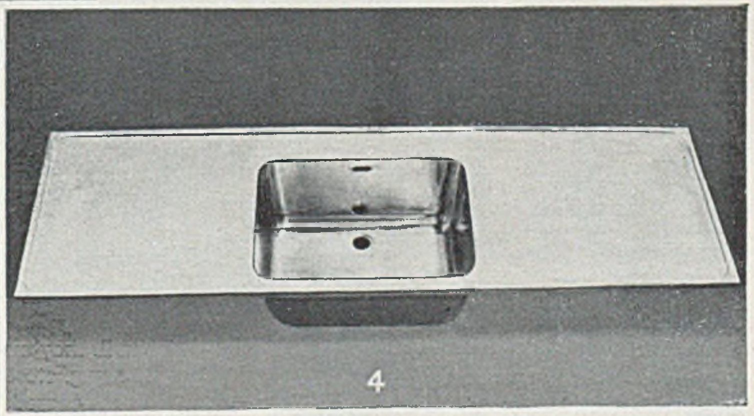
These difficulties explain the interest shown in the Redux process for "gluing" metals developed by Messrs. Aero Research, Ltd., Duxford, Cambridge.



APPLICATION of the Redux process to the manufacture of an aluminium sink and draining board is illustrated by the four pictures on this page. At the top is shown the 18-gauge sheet draining board and the cast sink prepared for gluing (1).

THE two parts are treated with the adhesive and clamped together ready for curing (2). After baking the clamps are removed and the joining is complete (4). Proof of the strength of the bond is given in the lower illustration (3). (Courtesy Messrs. Rubery Owen, Ltd.)





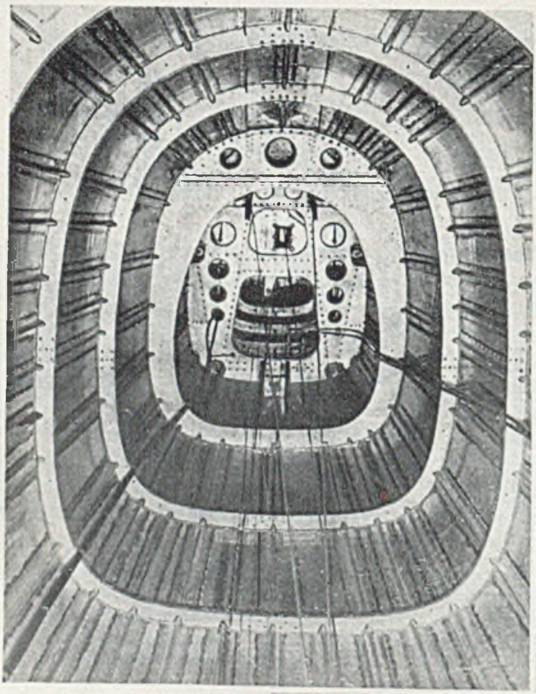
Joints made by the Redux process have a number of striking advantages over the conventional methods for joining metals. Compared with riveted joints between thin sheets, they are stronger, "cleaner" in appearance and often cheaper.

Comparison of Redux With Conventional Methods of Joining

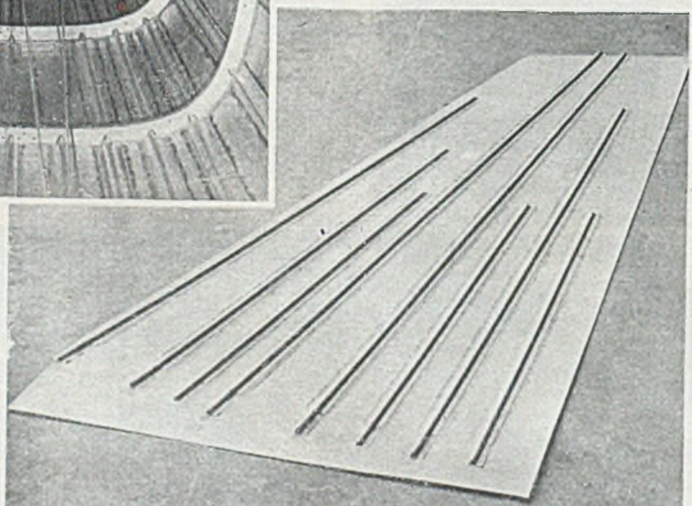
Spot welding has similar drawbacks to riveting. In addition, it is a fairly critical process to carry out because of the good electrical conductivity of aluminium and its alloys. Heavy currents and an accurate control of current, pressure and time are necessary. Furthermore, spot welding is only applicable to the joining of sheets of approximately the same thicknesses. No such limitation occurs in "Reduxing," which can be used to bond thick extrusions, forgings or castings to sheets of any thickness.

Amongst the disadvantages of gas and arc welding are the risk of distortion, the amount of hand work frequently required to clean off surplus weld metal, and the need to wash in boiling water so as to prevent flux remaining on the welded point and thus causing corrosion. Finally, welding has a very bad effect on the mechanical properties of all alloys, in many cases reducing their strength to that of aluminium itself.

It will be seen that all the methods of joining light alloys practised at present suffer from many disadvantages, and this has been one of the factors retarding the growth in their use. We feel confident that the introduction of the Redux process will help to overcome many of these difficulties.



turer's own works, and much of the process can be carried out with unskilled labour. The type of plant required largely depends upon the parts concerned. For the quantity production of small parts, it is most economical to clamp them together and put them in an oven, preferably on a conveyor belt. Electrical heating can also be used, sometimes in the form of compact elements, which are wound with resistance wire (such as are used in flat irons or soldering irons), or where larger areas are involved and the weight of metal to be heated is



THE fuselage for the de Havilland "Dove" (above) shows the duralumin stringers and skin bonded together. At the right is a wing panel for this all-metal air liner immediately after removal from the press. This method of joining has eliminated a large number of rivets and drilled holes.

The Conditions for Bonding

There are three points about the process which are of fundamental importance:—

(1) The metal surfaces must be free from grease.

(2) The parts to be bonded must be firmly clamped together.

(3) A temperature between 140 degrees C. and 190 degrees C. is necessary to "cure" the Redux liquid resin.

These conditions can usually be fulfilled without difficulty in the manufac-relatively small, they may consist of strips of about 22 s.w.g. steel, through which a heavy current is passed. Another alternative, which, in the aircraft industry, is extensively used, is the hydraulic press of the steam-heated type used for plywood manufacture, which, although expensive to install, will bond a large quantity of work

The Process

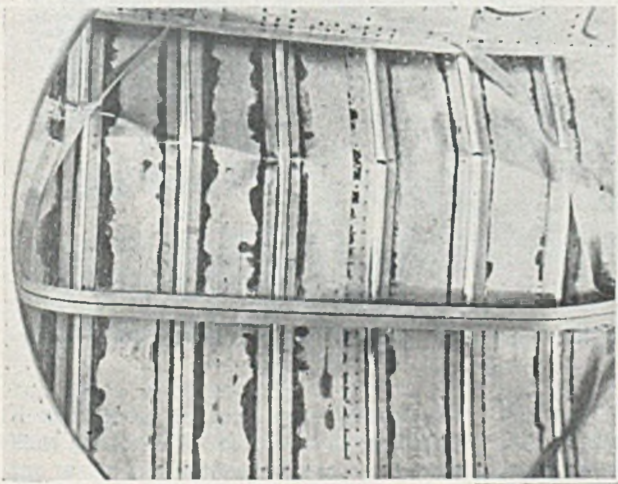
To get the best results, all metal surfaces should be bright and clean. Quite good joints can be made without cleaning with emery, steel wool, or a chemical dip, particularly if the metal is freshly machined, but for the best results it is desirable to ensure that the film of oxide which forms so rapidly on the metal is removed by one or other of the above methods. Then the parts must be degreased thoroughly. For this there is nothing better than the trichlorethylene-vapour baths now common in industry, and which are used so often as a preparation for painting. Other methods may, of course, be used, provided that they ensure a thorough degreasing action.

After degreasing, a liquid resin is brushed on to the metal, and then a white powder is sprinkled on to the resin or the metal dipped into a tray of the powder. The parts (castings, forgings, extrusions or sheet) are then clamped together and put in an oven, so that the resin is at 145 degrees C. for 15 minutes. If quicker production is required, a higher temperature is necessary, and 190 degrees C. for 3 minutes may be used. The appearance of the joint shows whether it has been properly "cured." If it is a light colour it is "under-cured," and if it is very dark and almost black then it is "over-cured." A good joint is a dark reddish-brown colour, and a little practice is sufficient to judge whether a joint has been correctly treated. In a similar way, it is easy to tell from the edges of the joint whether it has been subjected to pressure, because if it has a little of the resin will have squeezed out.

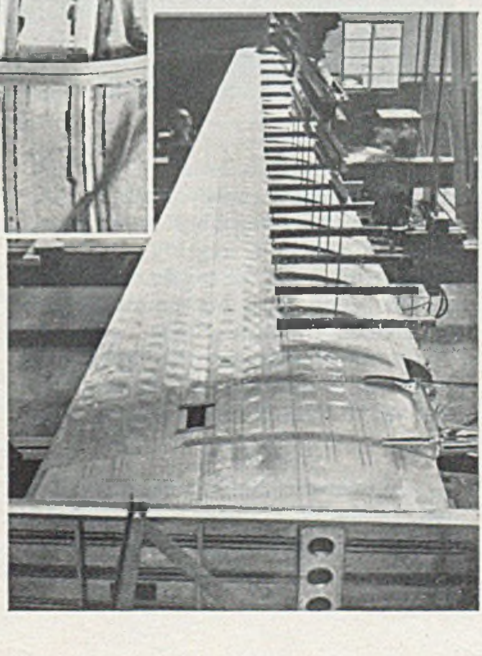
The following are some examples of how the process is applied.

Sink and Draining Board

Redux can be used to join materials of different compositions and, as we have already mentioned, different thicknesses. In their design for a combined sink and draining-board assembly Rubery Owen, Ltd., of Darlaston, specified a ¼-in. thick cast aluminium-alloy sink and an 18 s.w.g. aluminium-alloy sheet draining board. Redux is used to bond the two parts



RESULT of test to destruction (left): although some of the stringers have fractured the bond is still intact. The wing of the "Dove" (below) was subjected to a very drastic series of tests and it was shown tha the stringers hold over their entire length, but if rivets are used the buckles pass through all the rivet heads.



together, and pilot production was commenced in an electrically heated oven and with operators who had no previous experience of metal bonding.

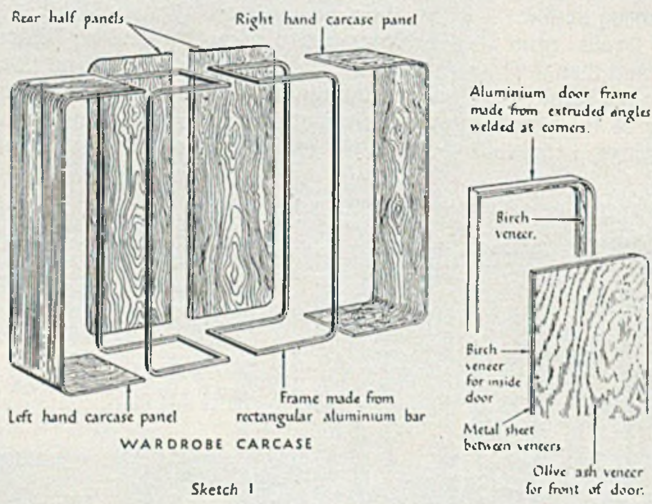
The surfaces of the sink and draining board to be bonded are first cleaned with emery and then degreased. The reddish-brown Redux liquid resin is brushed on the metal and the white granular Redux powder sprinkled on. The parts are then clamped together and put in the oven at 200 degrees C. for an hour. Ultimately, it is expected that a conveyor oven will be used. When the assembly is removed from the oven it quickly cools to 90 degrees C. when the toggle clamps are removed. The steps in the process may be seen from the illustrations.

Another advantage for this application is that the joint between the draining board and the sink is not only structurally strong, but also waterproof.

Aluminium Window Frames

Aluminium extrusions are first degreased in a trichlorethylene-vapour bath and then pickled in a mixture of chromic and sulphuric acids (to Specification D.T.D.915). They are placed in a jig, small angle pieces placed outside each of the four corners, and pressure applied to them by mechanical clamps. Built into each of these clamps is an electric heating element, which quickly " cures " the resin in the joints. After a few minutes the current is turned off, jets of air played on each corner, and then the pressure is released and the completed frame removed from the jig. All four corners are bonded simultaneously, and there is no danger, as there is with welding each corner separately, of distortion or of ending with a frame which is not quite rectangular because too much metal has been burnt off one of the corners. There is no surplus weld metal to be cleaned off, and the small angle bonded to each corner cannot be seen when the window frame is fixed into position.

The Aluminium Window Co., which is producing a range of windows for factories and houses, claims that, as a result of adopting Redux, it has halved the man-hours for assembling the frames and, in addition, has obtained a much more robust article.



WARDROBE CARCASE

Sketch 1

WARDROBE DOOR

Sketch 2

HERE, and on the following page, is illustrated an example of wood-to-aluminium bonding. The furniture, designed by Clive Latimer for Heal and Son, Ltd., is constructed in aluminium sheet, faced and backed by wood veneers on a framework of aluminium-alloy extruded sections.

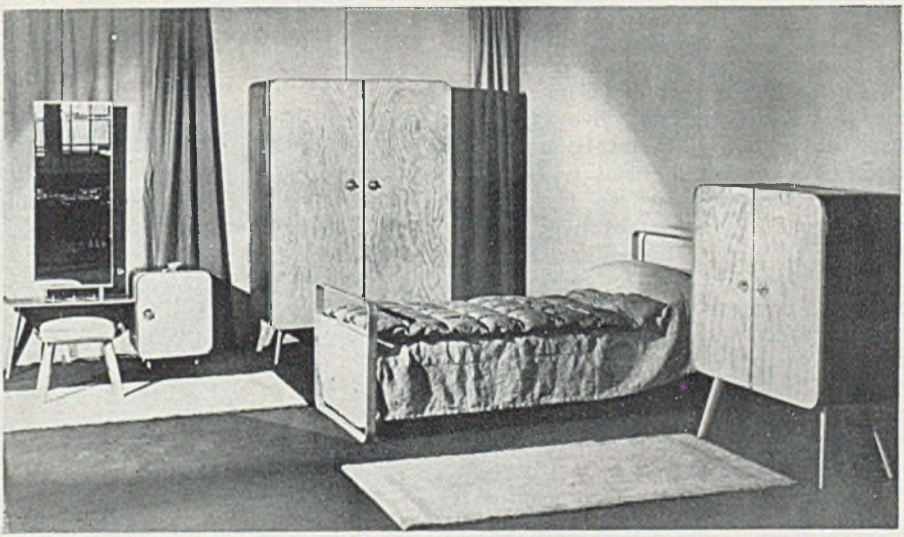
Aircraft Production

In aircraft production "Reduxing" is usually carried out (after the usual degreasing and pickling) in a steam-heated hydraulic press. An account of its uses and advantages was given in an article, "Bonding by Redux," in "The Aeroplane,"[8] and we will confine ourselves here to a brief statement only.

This method of joining is used on the "Dove" air liner to attach 24 s.w.g. stiffeners to the 24 s.w.g. wing and fuselage skins. The bonding is carried out in 4-ft. by 12-ft. panels in one short, carefully controlled operation, which takes the place of hundreds of rivets, for each of which the skin and stiffener would have to be jig drilled. Hence, there is a worthwhile economy in production costs. The other advantage is a saving in weight, because the de Havilland Aircraft Co., Ltd., is quite satisfied that a skin-stiffener panel of Redux construction will take not less than 25 per cent. more load than a similar one of riveted or of spot-welded construction.

Redux is now being used in the construction of high-performance aircraft to obtain smooth wing skins. This is of vital importance to the aircraft designer, and metal-to-metal bonding makes it possible to avoid the thousands of rivet heads which usually cover the fuselage and wing skins of aircraft, with serious effect on the aerodynamic properties.

The other use on aircraft is for bonding aluminium alloys to wood, so that each material may be used where it is most efficient. Such a rational use of wood and metal was impossible before the invention of Redux, and the structural advances resulting from it were striking. Here we can only mention the main spars of the "Hornet," in which wood takes the compression and aluminium-alloy extrusions the tension loads; the "Naval Mosquito," in which the loads concentrated at the metal hinges of the folding wings are distributed over the thin plywood-wing skin, and the "Viking," in which a plywood floor is strengthened by bonding underneath it aluminium-alloy stiffeners.



Furniture

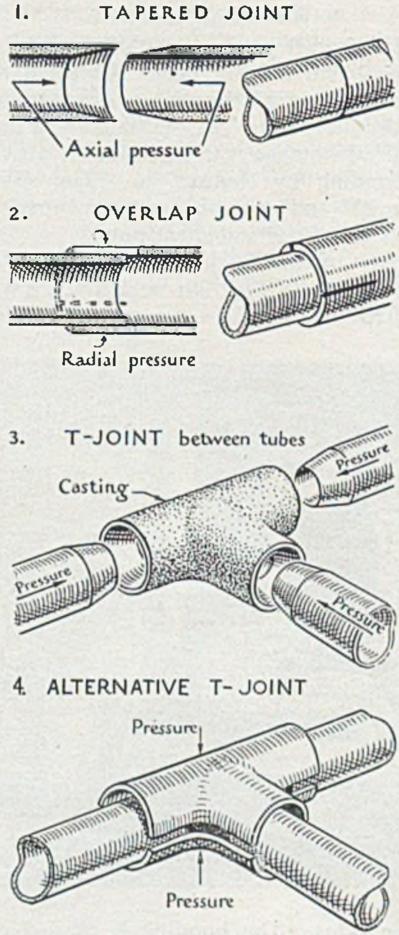
At the recent "Britain Can Make It Exhibition," Heal and Son, Ltd., exhibited suites of furniture, designed by Mr. Clive Latimer, consisting of aluminium frames to which were Redux sheets of veneered aluminium. Thus, the whole construction was based on the use of Redux, first for bonding the veneers to the aluminium sheets, and then for bonding these composite panels to the frames. The group of annotated sketches on page 238 illustrates this method of construction.

At the present time the shortage of wood makes this combination of the good appearance of wood and the strength of metal of special interest, but we believe that its advantages are such that it will always find uses. The panels used in this design had a centre core of 18 s.w.g. duralumin sheet with a veneer Reduxed to each side. In the prototype suites, the veneers used were walnut, olive ash and masur birch, with pleasant contrasting effects. The veneered metal is a very stiff material which is free from the "drumming" characteristics of unsupported metal sheets. It is resistant to the humidity of tropical climates and it does not warp. It is non-inflammable and has a useful property by virtue of the excellent heat conductivity of the aluminium; if a lighted cigarette is placed on veneered aluminium it will not burn the wood veneer because the heat is carried away too quickly by the metal.

The construction of the furniture was quite straightforward because the panels could be curved to shape. In this furniture it was necessary to obtain a radius as small as 3 ins., using 18 s.w.g. (.048 in.) duralumin with 1 mm. (.040 in.) veneer on each side. Such bending, which would have been quite out of the question with plywood, was carried out by soaking the panel in hot water and then rolling it in the usual sheet-metal rolls.

Cycle Frames and Similar Structures

A good example of the disadvantages of welding and of the advantages of Redux is in making duralumin cycle frames. If duralumin tubes were welded to sockets, their strength would fall off sharply, but when they are Reduxed the joint between the tube and socket is stronger than the tube itself, and the



SKETCHES of four typical Reduxed joints between aluminium tubes illustrating alternative methods of applying the pressure during curing.

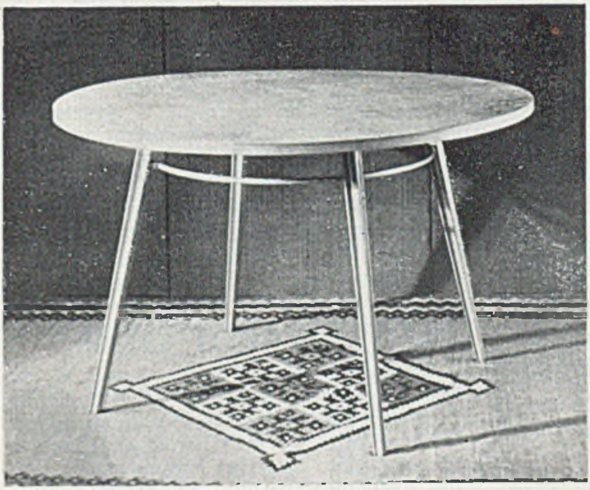
effect of its heat treatment is not destroyed.

To make a joint between a socket and a tube, they are both turned so as to have mating tapers (as in a ground-glass joint between a glass stopper and bottle), and the material is applied to the tapered surfaces. The tube is pressed into the socket and passed through an oven on a conveyor. By such an arrangement complete tubular frameworks for cycle and other structures may be clamped together and bonded in one operation. When frameworks of this kind are bonded by passing them through an oven, it is possible to combine the operation with the final heat treatment, and thus to obtain another useful economy.

Before concluding we should like to mention the more important properties of Redux joints. They are suitable for joining aluminium and its alloys to one another, to plastic materials, such as Bakelite, Tufnol and Delaron, and to wood. It is possible to bond aluminium and its alloys to other metals without danger of electrolytic corrosion because the glue film is a good electrical insulator. The joints are thoroughly resistant to water and solvents, such as alcohol, petrol, engine oil and hydraulic fluid. Redux does not deteriorate with age and maintains its full strength from −40 degrees C. to +60 degrees C. At higher temperatures the strength does fall off gradually, but no tests have been carried out at lower temperatures. Anodized surfaces may be bonded without in any way disfiguring the finish.

The strength of the joint, as with riveted and spot-welded joints, is greatest in sheer, and whenever possible designs should take this into account.

We hope that this brief account will enable users of light alloys to form some idea of the way in which "Reduxing" is carried out and the advantages which it offers. It is not expected that it will solve all the problems involved in the jointing of aluminium and magnesium alloys, and that it will be suitable in every design, but it is believed that Redux has a large contribution to make to the future development of the light engineering industries. There are many applications in which one of the forms of welding or riveting is much more suitable than Redux, but, in the same way, there are many applications in which the opposite is true; the disadvantages are that it requires a clamping pressure and the use of an oven to "cure" the resin. Development work is proceeding on the process, and it is believed that improvements will be made in reducing either the time or temperature of bonding. In addition, a new resin, Aerodux 185, is already in production, which gives quite good adhesion between aluminium alloys and wood at workshop temperatures and with the use of only very light clamping pressures.



DINING-ROOM table with aluminium legs and frame. Here again the gluing process provides a simple method of manufacture (Courtesy Heal and Son, Ltd.)

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NEWS—General, Technical and Commercial

Foire de Paris

THE thirty-sixth Paris International Trade Fair will be held from May 10 to 26, 1947. This year the Fair will occupy 125 acres—that is, 25 acres more than last year.

It is interesting to note that the organizers have decided against the national grouping of British exhibitors. Last year the bias of opinion in the trade Press was against this practice on the grounds that, as the Foire de Paris is a trade fair where actual business is transacted, and not merely a display exhibition, it is much better to have clear divisions of exhibits, based on the type of goods displayed, rather than other methods of grouping which confuse the buyer and diminish the overall appeal of a particular trade section.

Sheet for Can-making

A NEW handbook, "Wrought Aluminium and Aluminium Alloys," has been published by The British Aluminium Co., Ltd. This deals with the sizes, weights, and other relevant data of various wrought forms, including sheet, strip, circles, foil, round rod and bar, hexagon bar, tubes, wire and rivets. Silhouettes of sections are also included.

An interesting feature is the section dealing specifically with sheet for can making. This shows thickness, size, and equivalent tinplate rating in tabular form.

The address of The British Aluminium Co., Ltd., is Salisbury House, London Wall, London, E.C.2.

Engineering Institutions Amalgamate

IT was announced in the early part of 1946 that the Institution of Mechanical Engineers and the Institution of Automobile Engineers were considering an amalgamation and that the application for the necessary powers had been made to the Privy Council. It can now be announced that authority has been given and that the day appointed for the amalgamation was April 13, 1947. On that day, the Institution of Mechanical Engineers created an Automobile Division to focus its activities with respect to automobile engineering, and also on that day an Agreement between the two Institutions came into force whereby the corporate members of the Institution of Automobile Engineers became corporate members of the Institution of Mechanical Engineers in appropriate classes, and simultaneously were placed on the register of its Automobile Division as the first members on the register.

This important step is the result of long and detailed deliberations by the Councils of both Institutions, followed by the necessary approach to the respective memberships, and throughout the stages of the consideration, certain fundamental principles have been kept in mind, namely:—

(a) Automobile engineering is essentially mechanical engineering — mechanical engineers should have their interests promoted by one powerful Institution.

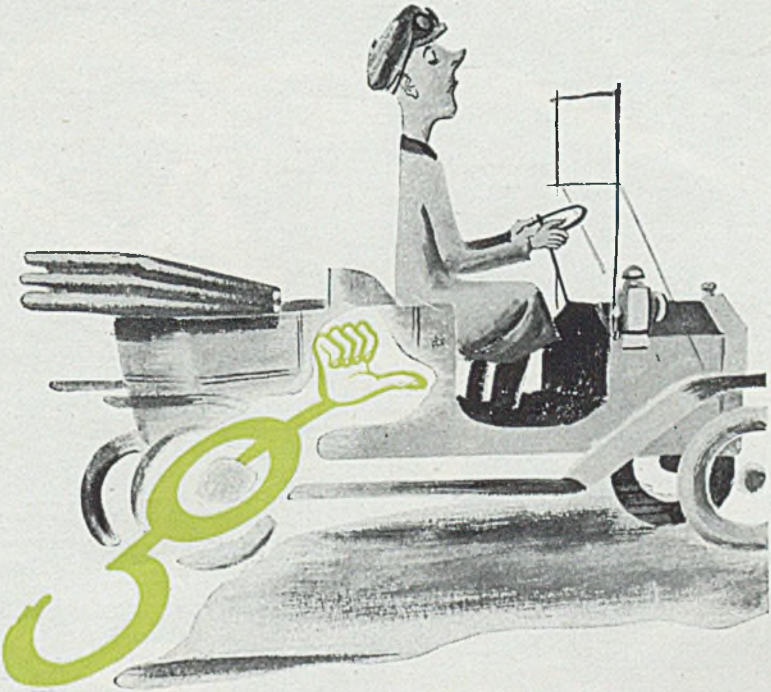
(b) The technical education and practical training of engineering aspirants would be better fostered by an amalgamation of Engineering Institutions which would provide a recognized national qualification in place of a number of specialized sectional qualifications. It would follow that the student would enter the profession through one broad entrance and subsequently specialize.

Since all meetings and activities of the I.Mech.E. are naturally available to all members of the Institution, it readily will be appreciated that a broadening of the professional life will be effected by the amalgamation.

Under the terms of the Agreement to Amalgamate, the Institution of Automobile Engineers has undertaken to take all proper steps to surrender its Charter and dissolve the Institution after the appointed day, but the amendment recently authorized permits corporate members of the Institution of Mechanical Engineers who are registered members of the Automobile Division to describe themselves as "Chartered Automobile Engineers."

Subsequent to the amalgamation, additions to the Automobile Division will be made solely from those who are members of the Institution of Mechanical Engineers, and applications will be reviewed by the A.D. Council, who will make recommendations to the Council of the I.Mech.E. respecting those considered to have the necessary experience to qualify for registration.

It is of great interest to note that this important stage in the development of engineering Institutions has been reached in the year in which the Institution of Mechanical Engineers celebrates its Cen-



tenary. The Institution was founded in 1847, George Stephenson being the first President, and was granted a Royal Charter in 1930. The Institution of Automobile Engineers was founded in 1906, Colonel R. E. B. Crompton being its first President, and it was granted a Royal Charter in 1938.

It is confidently anticipated that this amalgamation will prove of ever-growing benefit to the promotion of the science and art of Mechanical Engineering.

"Hufford" Stretch Former

IT is announced that A. C. Wickman, Ltd., Coventry, have been appointed sole agents in this country, the British Empire and Europe (excluding Russia) for "Hufford" hydraulic stretch-forming machines (Hufford Machine Works Incorporated, California).

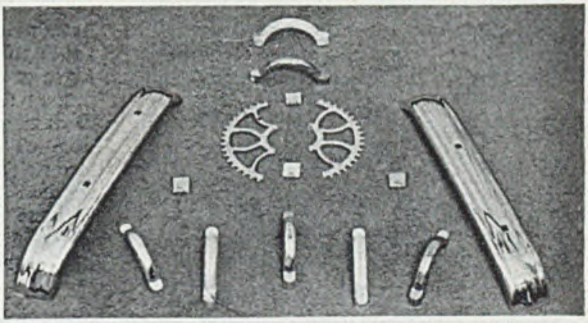
This plant is designed for the stretch-forming of narrow, extruded or rolled sections and mouldings, or narrow sheet metal strips such as are extensively used in aircraft, bus and trailer frames, railway carriage frames, and in general industry and shipbuilding for window frames, conveyor tracks, curved ornamental parts, and so on.

The only tooling involved is a male former corresponding to the finished form of the component the straight, extruded or moulded section being stretched and wrapped around the former so that no subsequent hand truing work is required.

Angles, channels, hat, U, I and T sections, as well as more complex shapes with varying amounts of curvature can be dealt with with equal facility either on edge or in the natural plane. The speed of operation is variable to suit various types of mouldings, and the cycle time for a component ranges from less than one minute up to three minutes, according to the size and shape of the component being handled.

The scope of the machine is very wide and is comparable. There are three standard sizes which will handle lengths of section from 0 in. to 100 ins., 0 in. to 180 ins., and 30 ins. to 266 ins. respectively.

SHOWN at the right is a group of wrought and cast aluminium components electroplated by A.E.R. Ltd., with nickel, chromium and silver. Indoor exposure tests carried out on some of these have demonstrated their serviceability. Particular interest attaches to the chromium-plated aluminium bumper bars.



HOME FRONT SURVEYED

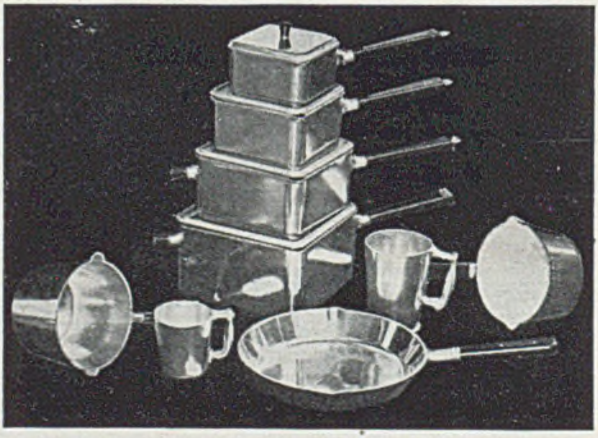
DURING the past seven years aluminium has suffered some strange changes of fortune on the kitchen front. Hardly had we got well into the stride of our war effort when there came from the Government an urgent call for more light metal, and we were exhorted by Lord Beaverbrook to contribute our aluminium pots and pans to an emergency stockpile. Thereafter, for the next four years at least, we had to do as best we might with substitutes; even the tinplate kettle became difficult to obtain, and more than one of us was forced to press into service blackplate cans or biscuits-tin lids in place of the more orthodox forms to which civilization had accustomed us.

With the cessation of hostilities the urge which had impelled us to devote our hollow-ware to aeroplane construction was reversed, and a movement commenced for the conversion of redundant aircraft into domestic ware of all types. Some measure of the success attending first efforts was given by the overwhelming reception accorded to the "Aluminium—War to Peace" Exhibition, first in London, at Selfridges, and later at various provincial centres—but how far have we gone since then? The results of a brief survey are summarized pictorially in the following pages.

A visit to any hardware store will show that, with few exceptions, aluminium kitchen ware is no longer in short supply. Saucepans, in particular, are to be found in impressive piles and the housewife is, at last, once more able to exercise her discretion between one make and another, and so to influence the trend of future design. There are at present two main types of pan on the market; those pressed or spun from sheet metal, and the cast form. Each can, in one respect or another, claim advantage, whilst both have certain disadvantages.

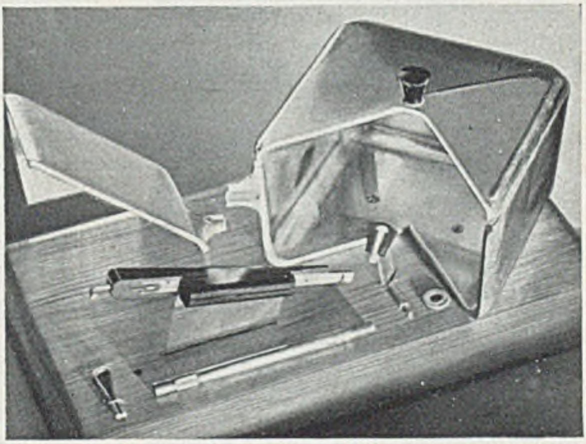
First, the saucepans formed from sheet; these may present opportunity for cheaper production, and, in the lighter gauges, cost less in the shops. They were generally fabricated of unalloyed metal, and, although small additions are now made, they tend to have a brighter appearance, and to be less liable to staining than the cast (alloy) job. Light-gauge pans are easy "on the arm," but, at the same time, are more susceptible to damage by denting and eventual perforation. To those accustomed to cooking by electricity, thin metal, and considerable residual stresses developed in forming, mitigate against such ware remaining perfectly flat on the bottom. Thick metal should be insisted upon.

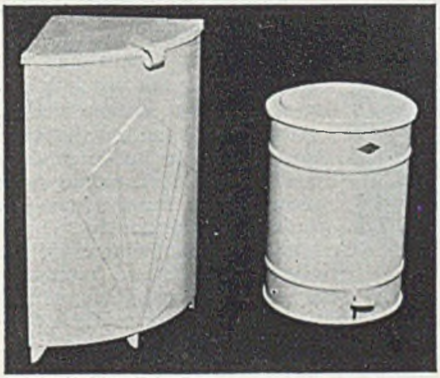
Even with specially thickened and ground bottoms, certain saucepans, unless carefully designed and made, may tend to develop.



ON this page are shown some of the "Daleware" products. At top right are the two parts of a double saucepan which can be used separately, and above are two casseroles (both courtesy New Era Domestic Products Ltd.). At the right is a set of the now familiar square saucepans, together with two milk saucepans, two tankards and a frying pan. (Courtesy John Dale Ltd. and Guy Ward Limited.) The "Daleware" cast utensils are given a special finishing treatment which produces an attractive "hammered" appearance and a good, lasting, bright surface.

ROBUSTNESS of Daleware is illustrated at the right. The plastic-covered rod screws into the boss cast on to the corner of the pan, forming a firm, rigid handle. (Courtesy John Dale Ltd. and New Era Domestic Products Ltd.) Illustrated immediately below are a corner bin for laundry and a small sanitary bin (incorporating receptacle for disinfectant), both in sheet aluminium enamelled in several attractive colours. (Courtesy Guy Ward Limited.) At the bottom is a cocktail set comprising a shaker, bowl and tray in aluminium, with a coloured opaque anodic finish. (Courtesy The Rushton Organisation.)

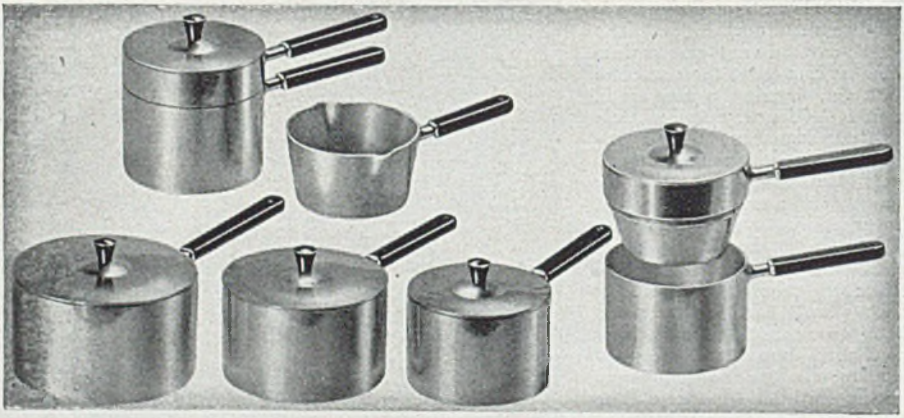


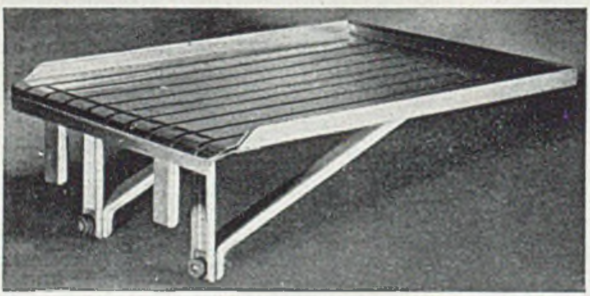


after about twelve months, slight irregularities, which are sufficient considerably to reduce the efficiency of heat transfer from the hot plate. It pays to buy utensils of proven worth!

Before the war, handles on spun and pressed saucepans were usually fixed by riveting. This often limited their useful life, because, sooner or later, the handle loosened due to the rivet holes becoming enlarged. Some improvement may be expected by using spot welding or a similar method in place of riveting.

Cast pans can claim advantages due to method of manufacture. They have substantial side walls and bottoms, are very robust, and can be expected to enjoy very long life. The difficulty of the handle has been countered very simply, either by casting a stub to which an extension is screwed, or by casting the handle complete with the bowl and covering it with a plastic sheath. This has not only overcome the weakness of the riveted joint, but has also eliminated the crevice round the rivet heads, where stale food and bacteria accumulated. The bottom of these saucepans is perfectly flat and tests have, so far, shown it to be exceptionally stable; saucepans in use for twelve months show no signs of any buckle or warp.

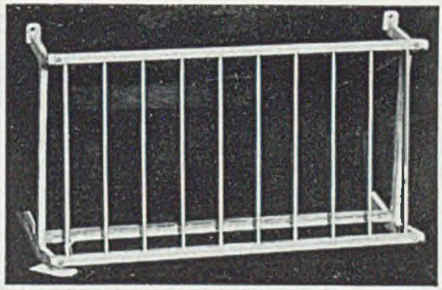


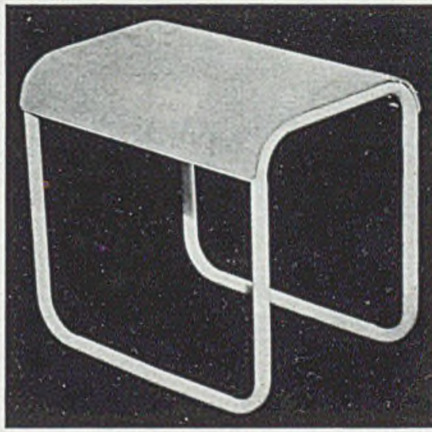


Now for the other side; the cast saucepan tends to be more expensive, and although the buyer when confronted with the foregoing favourable aspects may feel justified in paying just that little extra, yet there is further sales resistance to overcome.

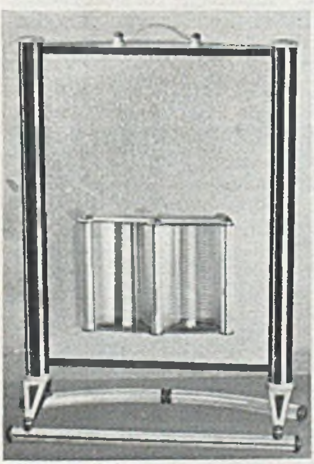
The casting of saucepans was undertaken in the first instance, as a rapid production method which would utilize the then existing surplus of secondary metal, and, at the same time, provide work for the foundries during the change-over from war to peace. Of necessity the alloy had to be used for casting purposes and, for rapid production, silicon was the addition element chosen. This confers a dull bluish appearance to the casting, which may prove unattractive to those

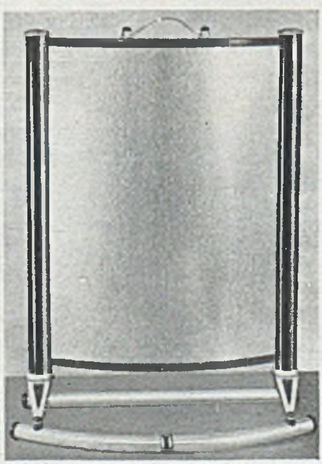
AT the top a range of cast aluminium saucepans including six, seven, and eight inch normal type, a six inch double saucepan and a milk saucepan. Notable features of this range are the mirror finish and the handle. The complete handle is cast on and finally covered with a plastic sleeve anchored with a ferrule through the end. (Courtesy H. J. Maybrey and Co., Ltd.) Centre, a detachable draining board in spot-welded sheet aluminium. (Courtesy The Rushton Organisation.) At the right is an egg-cup stand with egg-cups in polished cast Birmabright by Magnal Products Ltd., Warmley. The egg-cups are of a novel open-bottom design.





accustomed to the pure metal. Moreover, the alloy is softer than wrought forms and, perhaps, more susceptible to scratching. It should be noted that one manufacturer has overcome this objection by the application of an ingenious finishing-cum-surface-hardening treatment. The final and perhaps most troublesome criticism of the cast saucepan is its slightly greater tendency to develop a blackened surface under certain conditions. It is a strange turn of fortune that has caused aluminium to become known as the metal that goes black. This transcription of a current popular opinion is admittedly vague and certainly not scientific. It nevertheless is a fact that the opinion is strongly held. Pre-war domestic utensils were popularly noted for their untarnishing qualities, and confirmation is doubtless provided in most kitchens of the kingdom. Yet, at present, sellers of aluminium ware, especially cast sinks, are frequently confronted with the statement that aluminium





TOP left, a domestic weighing machine largely constructed in aluminium, and operating on the pendulum principle. This item is only manufactured for export. Top right is a plate-rack in aluminium rod and angle for wall fixing. Centre a tubular grained stool. (All courtesy Guy Ward, Limited.) Pictured at the left are front and rear views of an electric fire. As is demonstrated, the reverse position forms an attractive fire-screen. The whole assembly is surprisingly light yet rigid. (Courtesy The Rushton Organisation.)

AT the left: a selection of Falconware products and other domestic utensils in aluminium, including saucepans, kettles, deep-frying pans, egg poachers, a sink-tidy, a colander, a soap dish, cabinet, and various ladles, all fabricated from sheet. (Courtesy Guy Ward Limited.)

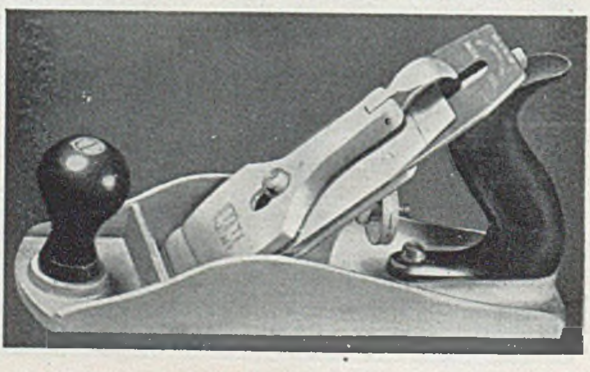
does so soon discolour. How has this situation arisen?

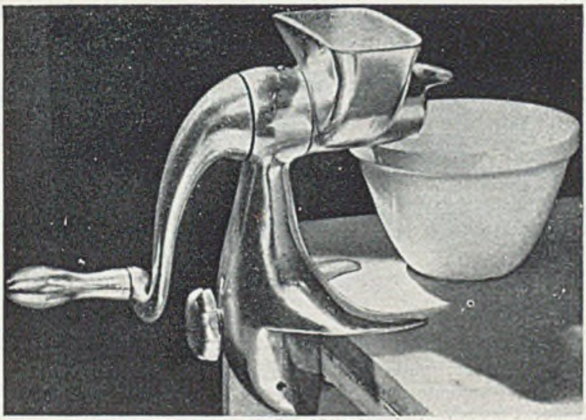
Most pre-war pots and pans were fabricated by spinning commercially pure aluminium sheet. In the present circumstances of material shortage, less suitable materials have been pressed into service. Due to the present position also of general shortage of goods, many founders, having cast their eyes upon a temporary market, are producing kitchen equipment by gravity-die-casting methods, which provide opportunity for the use of alloys which *may* not give untarnishing service; or if this last statement be not strictly correct, then economic alloys of a suitable tight specification are difficult to come by.

It is not easy to produce castings in commercially pure aluminium, and the general consensus of opinion is that an alloy containing up to 5 per cent. silicon may be used. The casting properties of this alloy are good and corrosion resistance is high. Impurities should be kept low when the material is to be finally used in domestic conditions where the washing-up process will be encountered. Copper content should not exceed 0.1 per cent.,* and it is suspected that those cast-alloy utensils which blacken even upon boiling water within them, contain appreciably more copper than the desirable maximum. In theory, therefore, the remedy is easy, but in practice the production of secondary alloy to meet the specification is extremely difficult. The use of virgin alloy is beyond consideration on economic grounds. No blame should be placed on the founders, for they have assisted in the national recovery in providing work and, further, in the supply of goods

* Current U.S.A. practice admits up to 0.2 per cent. copper without detriment, it is claimed.

SMOOTHING plane by Dialoy Ltd., of Cardiff. The body and wedge are cast in aluminium alloy, components being assembled by screwing into cast-in brass inserts. Tests carried out on light-coloured hardwoods (maple and magnolia) have shown that, under normal working conditions, no significant marking or staining is to be feared. The sole of the plane soon acquires a bright, hard finish.



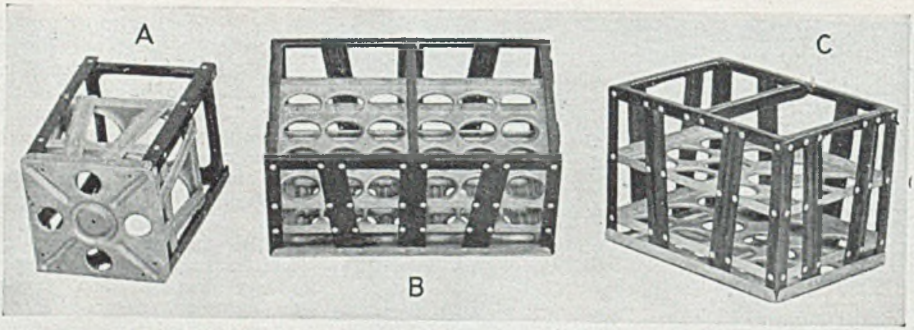


SURPRISINGLY little aluminium ware was to be seen at the recent "Daily Herald" Modern Homes Exhibition, principally because the main exhibits were rooms furnished to price limits where ancillary equipment was not shown. In one corner, however, was the light-alloy mincer by Healacraft Ltd., specially designed for easy cleaning. The laundry exhibit (below) featured several examples of light alloys, especially in certain parts of the washing machines.

otherwise in very limited availability. It is, indeed, unfortunate if such initiative only produces future sales resistance to aluminium products.

A brief discussion is therefore presented on the problem of discoloration of aluminium-alloy goods, together with a word or two on an allied subject.

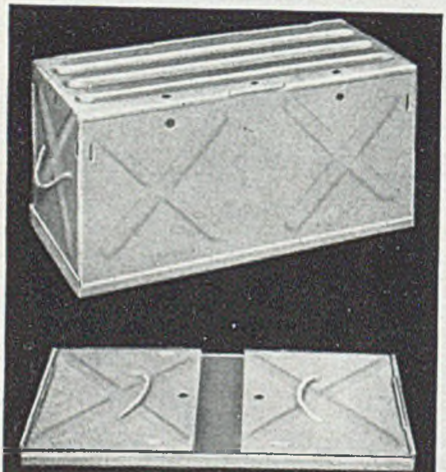
The fundamental fact is that aluminium of normal commercial purity does not become discoloured in the ordinary domestic process of cooking and cleansing. As previously noted, some of the cast pans become stained the first time water is boiled in them and, similarly, darken during washing up in the usual alkaline solutions used by the house-



BOTTLE-CRATES which are astonishingly robust yet weigh approximately fifty per cent. of the conventional design in steel due to the extensive incorporation of magnesium in their make-up. The "Magcrates" pictured above are (A) 4-bottle type; (B) 24-bottle design; (C) 12-bottle model. (Courtesy Essex Aero Ltd.)

wife. No amount of propaganda, it seems, will prevent alkaline solutions being used in the kitchen and, indeed, as long as aluminium, and not alloy, is being cleansed, it is doubtful if the use of alkaline cleansers matters very much. In the low concentrations used, little attack takes place on either metal or alloy, but in relation to influence upon discoloration, the use of alkalies assumes new importance.

As an example. A piece of polished cast



COLLAPSIBLE containers in aluminium alloy have obvious advantages over wooden crates. This container weighs 7 lb. 9 ozs. and the inside measurements are: length 25 ins., width $11\frac{1}{2}$ ins., height $11\frac{7}{8}$ ins. When collapsed for return the height is only $1\frac{3}{8}$ in. (Courtesy Ideal Packagings Ltd.)

alloy, having the composition required by D.T.D.424, was immersed in warm, soapy solution for a short period, at the end of which it had taken on an appearance midway between that of pewter and duralumin anodized by the chromic-acid process. This discoloration is probably due to film formation, related in turn to alkali attack and precipitation of calcium salts, for if the alkaline solution be suitably "inhibited" darkening does not occur.

In this connection, the use of the complex phosphate known as Calgon is of great interest. It is manufactured and sold by Albright and Wilson, Ltd., who describe it as a pure sodium metaphosphate of a high degree of polymerization, very soluble in water. Detergent solutions containing Calgon may be used for cleansing aluminium-alloy utensils without fear of discoloration, providing they have not previously been allowed to discolour by treatment in uninhibited solutions. The efficacy of detergents containing Calgon would appear to depend upon its property of forming a soluble complex with the metallic ions of hardness salts, so that they do not react with soap or alkalies, or, possibly in the case of metals, with the surface. In any case, the formation of a surface film of insoluble calcium compounds is prevented. The importance of avoiding insoluble calcium-salt contamination in electroplating processes has been emphasized in American reports, which showed fairly conclusively that the mysterious staining with which every plater is from time to time concerned is due to hardness-salt residues which are not removed in rinsing operations. American work showed that, if distilled water was used for making up the alkaline detergent solutions and for rinsing stages, staining disappeared. Alternatively, an inhibited rinse after the alkaline degreaser could be used with equal success, the inhibitor presumably being Calgon or similar compound.

It was shown above that aluminium-alloy to D.T.D.424 specification speedily became discoloured in a representative domestic solution. A piece of similar material was immersed in boiling distilled water for a long period; no darkening took place. At first sight it seems safe to argue that the presence of alkali is necessary for discoloration to occur, but experiment shows that alkali, together with Calgon, does not give discoloration. The question may be asked, therefore, if the salts contained in most waters are not an important factor in the problem.

The factor of alloy composition must not be overlooked, however. There is evidence that alloys containing copper in any quantity greater than a trace are prone to discoloration. In addition to pure aluminium, 5 per cent. silicon alloy with specified maxima of impurities, magnesium alloys, such as Birmabright and D.T.D.300, do not discolour in domestic processes. A rough parallel may be drawn between proneness to discoloration and the result of anodic oxidation of these materials; it will be seen that those alloys which give the lightest film by the chromic-acid process are those which are least discoloured. One is tempted to ask if the hardness of the water used in making up the electrolyte has any bearing on the surface colour produced, but it is doubtful if the answer would be known.

One point on which we can be certain is this, that the composition of domestic waters is a governing factor in the discoloration of saucepans. In the course of some experiments on this problem three cast saucepans, each made from the same metal, were tested in three different localities. The first, in North London, was slightly darkened after plain tap water had boiled in it for ten minutes; the same treatment with a softened water from Sidcup produced an attractive amber coloration; the unfortunate saucepan that went to Hammersmith was returned as black as an old coal scuttle. Distilled water and a synthetic hard water were then tried, but no blackening was experienced. It has been suggested that this effect is at least aggravated by the chlorine content of some domestic waters, and although no experiments on this have been recorded, it would account for the fact that plain tap-water is the worst stain producer of all the liquids used in cooking.*

Most housewives are aware that an aluminium saucepan, stained in this manner, can readily be cleaned by cooking in it acid foods such as apple or rhubarb. Food thus inadvertently used to clean the saucepan is, more often than not, later eaten with no ill effects, and it may indeed be asked, whether a dark interior to the saucepan is any real drawback; after all, a brown-enamelled pan suffers no criticism. Again, the golden translucency, or light blue clouding, imparted to magnesium pans by boiling apples, is of uncertain origin, but is easily removed and has no harmful properties. Magnesium,

ILLUSTRATED here is a lorry-load of "Magcrate" bottle-crates about to leave the works of Essex Aero Ltd., Gravesend, Kent. These crates are made in a variety of sizes and forms for bottles of different types.

* For "optical" explanation of black stain on aluminium see "Light Metals," 1938/1/381.

by the way, tends to acquire a matt-white film when subjected to attack by aggressive domestic waters.

The cleaning and descaling of kitchen ware are two problems frequently confronting the user—problems which, for some reason or other, appear to have become magnified unduly in the case of light metal, probably as a result of misguided propaganda on the part of well-meaning technicians in the early days of aluminium. Domestic equipment, provided it be not anodized, is best cleaned with steel wool in conjunction with soap. This combination not only exerts a rapid scouring action, but, furthermore, leaves a brightly polished surface behind it. Where an even more vigorous effect is desired, the effect of the steel wool may be reinforced by a liberal application of "Vim" or "Glitto," or some other proprietary cleansing agent. The use of any of these media should be followed by thorough rinsing with warm water. They may be applied with equal effect to the wrought metal or to any forms of casting alloy; aluminium sinks, for instance, are preferably cleaned with steel wool in conjunction with an abrasive powder.

The descaling of aluminium kettles and the like, which may frequently prove necessary in districts where the water supply is of a hard nature, is best carried out with 33 per cent. acetic acid (suitably dyed, we would suggest, to indicate to the casually curious that the kettle probably contains something other than water). It may sometimes prove possible to remove scale by thermal shock, that is, by leaving the kettle or pan on the hot plate without water, in which circumstance the deposit will usually fly off, after a short while, with a series of smart explosions. In using this method, however, care must be taken that vessels for contact heating do not become distorted.

It might be pointed out here, incidentally, that recommendations made for cleaning aluminium cooking utensils can, with the exception of the acetic-acid descaling treatment, be applied with equal success to those in magnesium or magnesium-base alloy.

The fact must be accepted that wrought and cast utensils have been sold in the period in which such goods were acutely short. It is suggested that the unfortunate result should be honestly faced and guidance given to the public in order that its opinions do not operate against the fair name of aluminium. Instructions, it is suggested, should be given that every care has to be taken with aluminium and the brightness of the surface maintained with vigorous application of fine steel wool and abrasive cleansers. This treatment will restore the original bright appearance, while darkening is minimized by washing with a compound suitably inhibited as indicated above.

Metallurgy and Atomic Energy

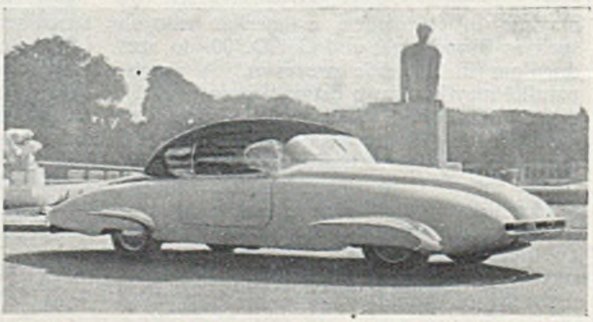
THE thirty-seventh Annual May Lecture of the Institute of Metals will be delivered by Sir Wallace Akers, C.B.E., at 6 p.m. on Wednesday, May 21, in the Hall of the Institution of Civil Engineers, Great George Street, Westminster, S.W.1. The title of the lecture will be "Metallurgical Problems Involved in the Generation of Useful Power from Atomic Energy."

Admission by ticket only, obtainable from K. Headlam Morley, 4, Grosvenor Gardens, Westminster, S.W.1. We recommend early application, as this year the lecture should prove even more popular than usual.

Aluminium Price Increase

ON March 24 last the Minister of Supply announced an increase in the price of virgin aluminium in ingot or notch-bar form from £72 15s. to £80 per ton.

The British Aluminium Co., Ltd., state that these new raw material prices and certain additional changes in production costs have necessitated a general increase of 1d. per lb. for their fabricated products. The new prices dated from April 21, 1947.



THE "402" Peugeot Tourer. This model is notable for its all-aluminium bodywork, by Paul Arzens, 89, Rue de Vangirard, Paris.

Letters to the Editor

Correspondents are reminded that a stamped and addressed envelope should be enclosed in all cases where a personal answer is desired.

Cartridge Cases

"In 'Light Metals' 1947/10/174 we find an interesting mention made of the impact extrusion process which has caught our attention. Quite recently we switched over to this process for the manufacture of our 'Metalix' all-aluminium cartridge cases, and are extremely interested in all possible information and literature about this type of extrusion.

"If you have published any really interesting articles in 'Light Metals' during the past years we should be greatly indebted to you if you would give us the necessary references; we could then order the necessary copies, through our local booksellers. We should like to point out that only technical articles, with full data and information of a character bearing directly on our problem, are of interest to us.

"If besides this, you have any references to books or monographs on the subject, would you favour us with the publishers' name and address.

"Really good information on the subject is scarce, and we should, therefore, appreciate it if you could assist us in this matter."—G. Fromont, France.

We are not aware of any detailed general study published on impact extrusion in English or in any other language. References to the process in "Light Metals" concern mainly particular applications. Press capacity and die design are both coped with, still on a largely empirical basis, any specific information in these regards and with respect to the relationship between extrusion dimensions and power requirements being maintained as carefully guarded secrets of the concerns operating the process.

The use of aluminium for cartridge cases has raised several awkward problems. For cartridge cases for shot-gun ammunition, where explosion pressures in the breech do not exceed about 2 tons/sq. in. unalloyed aluminium impact-extrusions are capable of meeting all requirements. For rifle ammunition, however, where breech pressures of 18 tons/sq. in. or over are encountered the soft nature of the unalloyed metal tends to cause binding in the breech and ejection difficulties. Correspondingly the flow properties of the strong light alloys are such that, even in the heated state, great difficulty has been encountered in impact-extruding these. Certain pre-war German patents covered the use of specially shaped (flat conical) slugs in an attempt to overcome this trouble.

Painting Yacht's Decks

"I am building a yacht, 2½ tons displacement, 280 sq. ft. of sail, with full lines, in aluminium, and should like to use an aluminium paint applied directly to the metal, for the freeboard and deck, provided that it would give effective protection against salt-water corrosion, which would, of course, require that it adhere firmly to the metal, itself resist salt water, sun, wear and tear.

"My reasons for preferring an aluminium paint applied directly, rather than the usual zinc-chromate ground, are:—(a) Economy (one coat of paint instead of two or more); (b) better appearance and easier repair with regard to knocks and scratches, which would reveal a yellow surface if a zinc-chromate ground is used, whereas if the single coat of aluminium paint is injured, only the underlying aluminium is revealed, and can be easily repainted; (c) the aluminium paint will repel heat in the summer; (d) the boat will look like what it is—made of aluminium.

"The chief question is, of course, exactly what should be the composition (with proportions) of the most suitable aluminium paint.

"Subsidiary questions are:—What should be added to the paint to make it usable as (a) a non-slip deck covering, and (b) to hold granulated cork for interior insulation?

(This last, however, is less important.)

"I have already purchased a transparent synthetic finish, but have some doubts as to its protective qualities, and more as to its easy repairability, seeing that it is to be sprayed on.

"If you cannot favour me with the answers to these questions, perhaps you will kindly forward this letter to a quarter that can."—L. C. S. Barber, Oslo.

It will be agreed, we think, that the demands made here for a paint film of such specialized qualities are likely to prove far from easy to meet. There is no difficulty in formulating an aluminium paint suitable for direct application to the metal without the prior application of the zinc chromate ground coat. At the same time, in spite of its highly protective nature, no film of aluminium pigmented paint can be expected to possess the same corrosion inhibiting powers as a zinc chromate primer. We rather feel that the problems raised here constitute a matter for the Paint Research Association of Teddington.

It is possible that many of these requirements could be met by the use of a sprayed-on film of Polythene pigmented with aluminium powder, and inquiries in this regard should be addressed to Schori Metallising Process, Ltd., Brent Crescent, North Circular Road, London, N.W.10. If this should prove possible to carry out on a ship's deck, it gives every promise of yielding, not only a highly protective finish, but one which at the same time possesses good non-slip properties. Granulated cork could, if necessary, be incorporated in the charge prior to spraying.

Metallization

"Being at the present time establishing a firm for metallizing with metal spray guns, I wish to increase my knowledge of the subject by learning what is actually done or recommended in industrial countries such as Britain and the United States who have improved their techniques during the war.

"For this purpose I went to the British Embassy, seeking books or magazines referring to the subject, and to manufacturers of metallizing equipment. Together with the addresses of a few industrial magazine publishers with no special references to metallization, I was lucky to find your issue of 'Light Metals' dated March, 1947 (Vol. X, No. 110), which contains the interesting survey upon 'Metallization with Aluminium,' by C. R. Draper.

"I am not only interested in metallization with light metals such as aluminium, but also with zinc, copper, lead, bronze, and steel. Would you be kind enough to let me know whether you have published any similar study on metallization with the above-mentioned other metals, or if the author has written something as complete in another magazine or book which would not deal solely with light metals."—Robert B. Lasnier, France.

No omnibus review of the complete art of metallization for all metals has yet been attempted, either in English or in any other language. Metal spraying by means of the wire, powder, and molten-metal pistols is adequately covered for all metals in certain of the sources referred to in Draper's bibliography, and in numerous trade publications. Similarly the author's review of citations deals with metals at large, aluminium being covered merely inter-alia.

Repairing a Cylinder Head

"I have a motorcar with a slight crack in the cylinder head. It is an alloy head, and the crack is in the water jacket; it has been there for two years. Can you tell me if there is any possibility of soldering the crack, and what flux, if any, would one use?

"In 'Light Metals' 1946/9/356 a description was given of a method of joining aluminium tubes together by applying some non-metallic solution: in other words, the tubes were stuck or welded together without the application of any heat. Please advise me if this new method of connecting aluminium would be of use to me in stopping the water leak in my car and give particulars of how to use it and where it can be obtained."—E. B. HOOPER, Agricultural Engineer, Heaycastle, Pem.

We do not consider it wise to attempt to solder the cracked head. The corrosion-resistance of suitable grades of soft solder for aluminium would not commend itself for the use of these materials in contact with heated circulating water, whilst with the high-zinc type (Fry's Metal Foundries, Merton Abbey, S.W.19) although resistance to chemical attack may be adequate, great care would be necessary to avoid distortion of the head at the relatively high fusion temperatures employed. The use of synthetic-resin adhesives such as are referred to elsewhere in these pages is not likely to be possible, as their application generally requires positive pressure, and they are not to be regarded as gap glues.

It is suggested that the use of Bakelite sealing compound (Bakelite, Ltd., 18, Grosvenor Gardens, London) as adapted for sealing porous castings, might prove of value.

Metal Adhesives

"I am making a study of metal adhesives, and would appreciate your assistance. In the first instance, I would appreciate a copy of 'Light Metals' for March, 1940, concerning the first account of this subject. In further articles on bonding metals, namely: 'Joining Light Alloys with Adhesives' (1943/6/219), 'Plastic Bonded Light Alloys' (1946/9/356), the Redux process and Araldit are mentioned. Are further details of these processes available and are they marketed by any manufacturing concern in this country?

"I have in mind the bonding of two dissimilar metals (brass and copper) .004 thick. I would appreciate your assistance and help.—W. G. MANN, Bolton.

Araldit is manufactured by the Ciba Co., Basle, Switzerland, and is, at present, not generally available in Great Britain. For details of the bonding technique by the Redux process (Aero Research, Ltd., Duxford, Cambs.), see p. 234 of this issue of "Light Metals." Alternatively certain metallic naphthenates might adequately meet the case if creep under load may be neglected, and if resistance to heat be not called for.

Special metal-to-metal adhesives have also been manufactured by Cellon, Ltd., Kingston-upon-Thames, Surrey, and metal-to-non-metal adhesives by Leicester, Lovell and Co., Ltd., Stroud, Gloucester.

Chemical Analysis of Aluminium Alloys

"Considerable progress has been made in recent years in the methods used for the chemical analysis of both ferrous and non-ferrous alloys, especially in respect to accuracy and simplicity of manipulation. A number of new or modified methods for aluminium alloys has appeared from time to time in this Journal.

"As an indication of the excellent agreement which is obtained by the use of present-day methods, readers may be interested to see the results of the analysis of a standard sample of 'Y' alloy prepared by the Light Metal Founders' Association and analysed independently in the laboratories of a number of the members of that association and of the members of the Association of Light Alloy Refiners. The compositions found are as given below.

"The very close agreement shown by these figures surely reflects credit upon both the aluminium ingot producers and founders and is an illustration of the high standard of technical skill of their laboratory staffs."

F. H. SMITH, Development Officer,
ALAR LTD.

	Cu	Mg	Si	Fe	Mn	Ni	Zn	Pb	Sn	Ti
L.M.F.A.	4.25	1.775	0.30	0.225	<0.01	2.04	—	0.07	—	0.07–0.08
ALAR	4.24	1.77	0.31	0.23	<0.01	2.04	0.01	0.07	0.02	0.07

ALUMINIUM AS A REFLECTOR

Study by C. R. Draper Embracing the Use and Value of Light Metal as a Reflector Material for Infra-red, Visible and Ultra-violet Radiation. To be Presented in Two Parts

FROM time to time in this journal mention is made of the fact that aluminium is of value in this or that application because of its high reflectivity. So scattered are these references and so varied are the applications that it is sometimes a little difficult to visualize just how important is this characteristic of reflectivity and exactly how does the reflectivity of aluminium compare with that of other materials. It seemed to the writer that it might be well worth while to collate some of these mentioned applications, and whilst the result viewed as a catalogue, is not more than fractionally complete, it does constitute a representative collection of relevant facts and figures.

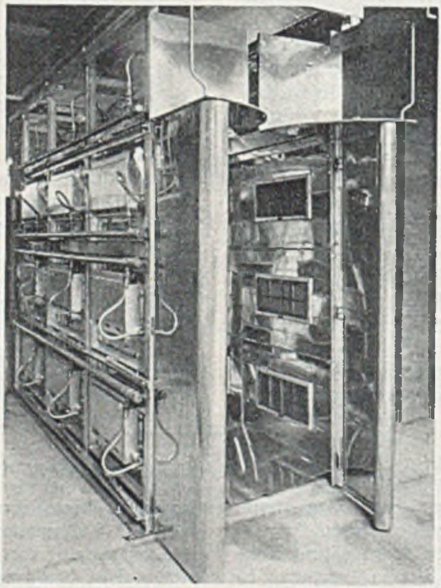


Fig. 1.—Infra-red heating tunnel for drying painted articles. The highly reflective interior lining is polished aluminium sheet. This tunnel can be seen in the British Gas Council's exhibit "Gas in Industry" at the British Industries Fair, Birmingham (Courtesy the Ray-Heating Co., Ltd.)

Reflection of Visible Light

In dealing with the reflectivity of aluminium it is essential to specify the type of radiation under consideration and the condition of the metal surface. Aluminium can be obtained in a variety of reflecting finishes. As far as visible light is concerned, a bright matt surface will exhibit high diffuse reflectivity and low specular reflectivity, whereas a polished aluminium surface exhibits the reverse characteristics, the specular reflectivity being high and diffuse reflection rather less. A dull aluminium surface is naturally low in both specular and diffuse reflection. Unless otherwise qualified, the term reflection is here used to mean total reflection.

With a suitable polishing technique the finish which can be given to aluminium is excellent in quality. The total reflectivity of such a surface is generally considered to be around 73 per cent., which compares with 89 per cent. for lacquered silver and 63 per cent. for chromium plate, but the results obtained by different observers vary considerably, possibly owing to variations in polishing technique. Some reflectivity values of certain common materials for radiation of various wavelengths are given in Table I. As stated previously, the absolute values obtained by different

Table 1.—Reflection of Light by Metals.

This table gives the percentage of normally incident light which is reflected by the polished surfaces of various materials.

Wavelength, μ		Bronze (68% Cu, 32% Sn)	Copper	Gold	Iron	Magnalium	Aluminium	Magnesium	Nickel	Platinum	Speculum	Silver	Silver-backed glass	Mercury-backed glass
U.V.	0.251	30	26	39	—	67	80	—	38	34	30	34	—	—
	0.305	—	25	32	—	72	83	—	44	40	42	9	—	—
	0.357	—	27	28	—	81	86	—	49	43	51	75	—	—
Violet and blue ..	0.420	—	33	29	—	83	87	—	57	52	56	87	—	—
Green, yellow, orange	0.500	63	44	47	55	83	87	72	61	58	63	91	87	71
Red	0.600	64	72	84	57	83	87	73	65	64	64	93	88	70
	0.800	—	89	95	—	84	87	—	70	70	—	97	—	—
Infra red	2.0	80	96	97	78	87	—	77	84	81	77	98	—	—
	9.0	93	98	98	94	91	—	93	96	95	92	99	—	—

observers vary widely, but the relative values for different polished surfaces show much less vibration.

The important point to be observed in this table is the irregularity of the relation between wavelength and reflectivity; for example, the sharp drop in the reflectivity of silver surfaces at wavelengths between 0.251 and 0.357 μ. In the visible region, the reflectivity of aluminium and magnalium (the exact composition of this sample is, unfortunately, not known) is consistently high, nickel, platinum, magnesium, speculum and bronze being much lower in the scale.

Fig. 2 demonstrates the total reflectivity of polished aluminium and of specially selected reflector metal brightened by one of the special anodic finishes for reflectors, in comparison with gold, chromium electroplate, copper, nickel and silver, for the visible and the more important infra-red wavelengths.

From the point of view of reflectivity alone, it is clear that aluminium is one of the best materials to employ, but this is not the only factor in the case and other advantages have contributed to the success of aluminium as a reflector material for visible radiation. Of great

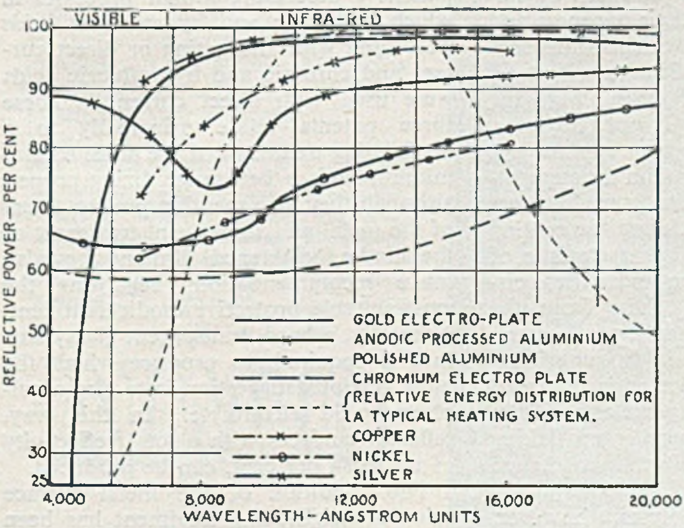


Fig. 2.—Curves showing relative reflective powers of polished and anodically treated aluminium in comparison with those for electro-deposited gold, chromium, copper, nickel and silver at various wavelengths.

importance is the fact that aluminium does not readily tarnish and therefore tends to retain its initial high reflectivity during reasonable periods of exposure under normal conditions. Regular cleaning with soap and water is essential to maintain the surface in good condition; in its absence, local attack or pitting commences in small areas where corrosion products have accumulated and the surface soon becomes irreparably damaged.

Strengthening the Surface

The resistance of aluminium surfaces to tarnishing and further corrosion is due to the presence of a natural oxide film at the metal-air interface and means are available for thickening and toughening this oxide film which result in an improvement in the tarnish and corrosion resistance of the metal surface which is particularly welcome under conditions of outside exposure. This is carried out by the process of anodizing in which the metal is made the anode in a bath of suitable electrolyte. Many substances will give satisfactory results in this capacity, but of the three basic electrolytes in use, namely, sulphuric, chromic and oxalic acids, only the first is capable of giving the transparent colourless films which this application demands.

One of the outstanding service characteristics of anodic films produced by sulphuric acid process is their hardness and resistance to abrasion, which means that anodized aluminium reflectors will stand a lot more cleaning than will the untreated metal. It will not, however, withstand the highest pressures since the thin oxide film is harder than the supporting metal and when the pressure becomes too great the metal yields and the coating cracks. It is, however, characteristic of the anodic film that even under these circumstances it does not flake from the metal. This fact is mentioned because it is an important point in favour of aluminium that if the reflector is damaged or deformed in any way the anodic film is only cracked and there is no flaking such as occurs with vitreous-enamelled iron reflectors.

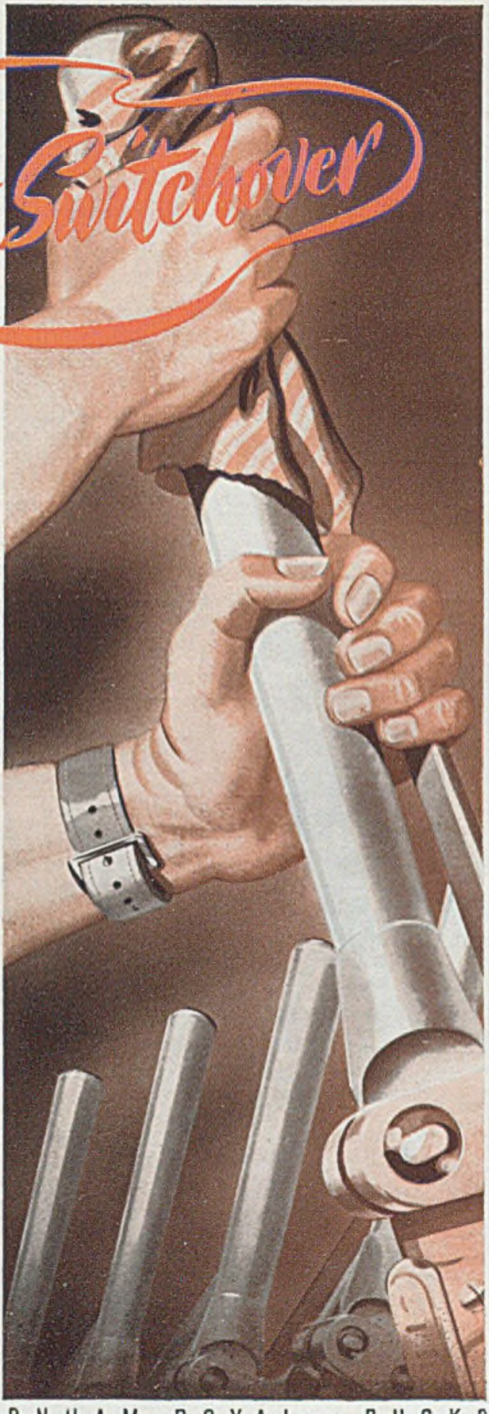
With certain electrolytes, however, whilst an oxide or passivating film is formed on an aluminium anode, the important effect is not so much film formation as controlled solution and removal of the surface. Thus, if aluminium be anodized in a solution of fluoboric acid under the appropriate conditions some solution of the metal takes place, but this is so much more rapid at the high spots that these become levelled before the indentations are appreciably attacked so that an electrolytic smoothing action takes place. In addition, this treatment results in the removal of surface contaminants such as metallic constituents, dirt, buffing agents and the like which produces a substantial increase in the brightness of the surface.

Suitable Anodic Processes

In recent years, these processes by means of which the reflectivity of aluminium, and especially of selected and high purity metal, can be increased, have been widely investigated. The history of this development dates back to 1933 when the basic Alzac patent was granted in America.[1] This dealt with the brightening of polished aluminium articles by making them the anode in an electrolyte containing hydrofluoboric acid, using either alternating or direct current. Very shortly afterwards followed two further patents[2, 3] describing similar processes in which sulphuric and hydrofluoric acids were used with alternating or direct current and chromic and hydrofluoric acids were used with direct current. These three patents relate principally to a brightening treatment of the polished aluminium surface before anodizing proper, although they also mention pre-treatment of the metal and subsequent treatment of the anodic (brightened) film and they also make recommendations regarding the most suitable protective anodic treatment. Naturally, a hard, transparent glassy surface is required, to produce which the most obvious suggestion is to use a sulphuric acid electrolyte: In this way, reflector surfaces with a total reflectivity of up to 84 per cent. can be produced.

The condition of the metal surface prior to brightening treatment has been

The Great Switchover



Throughout industry, engineers are in the grip of a great switchover. Almost overnight, Light Metals have become a great factor for speed in production. They offer a combination of high strength with lightness which *cuts deadweight from* 40% *to* 60%. Incorporated in machinery this property lends " wings " to moving parts and always conserves power and saves fuel. The brewer, baker, dairyman and chemist find Light Metals indispensable—because they are rustproof, non-toxic and highly resistant to a wide range of chemicals. In housebuilding and house-making from prefabricated house units to pots and pans the demand is widespread. *These bright, clean and good-looking metals are in abundant supply at less than pre-war prices.* And it is so easy to switch to Light Metals. ALMIN is ready to advise; to help you to fit Light Metals into your products.

SOME FACTS ABOUT *Light* METALS

Aluminium is cheaper than pre-war, and in certain forms, is readily available. Light-weight, long-lasting aluminium alloys have the strength of steel but cannot rust. Aluminium is easy to work, easy to machine, easy to weld.

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found to be of the utmost importance. Grain size and structure, alloying constituents and trace impurities all have an effect, sometimes very considerable, and the best results are obtained only by using the purest and structurally most perfect metal.

The fourth patent in this series taken out by Alcoa[4] has this fact in mind when it claims the method of producing a composite metal article for use as a reflector. The surface layer of this composite article is of high purity aluminium, the allowable impurities and alloying additions being specified, and a considerable amount of working is recommended to avoid structural markings. This working amounts to a reduction in overall thickness of the composite article by 99.5 per cent.

Brightening involves the formation of a very thin oxide film, the presence of which is undesirable owing to its tendency to smudge. It can be removed, according to a fifth patent, with a solution containing 1-8 per cent. sodium or potassium carbonate and 0.5-3 per cent. sodium or potassium chromate at 70-95 degrees C. applied immediately after brightening.

Just over a year after Alcoa took out its first Alzak patent, the British Aluminium Co., Ltd., was granted a patent in this country for achieving a similar brightening and anodizing effect, which patent forms the basis of its Brytal processes. According to this patent[6] the polished metal, after degreasing, is immersed in an aqueous solution of sodium carbonate (three parts by weight) and sodium orthophosphate (one part) at a temperature of 75-85 degrees C. and pH 10 or more until uniform attack sets in after about 10 seconds. A direct current of 5-6 volts is then applied, the aluminium being made the anode, for about 10 minutes, initial current density being about 30 amps./sq. ft. After this brightening treatment, anodizing is carried out in a 25 per cent. sodium bisulphate solution, which may contain additions of sulphuric, chromic, boric, acetic or phosphoric acids or their salts or chromium oxalate, at 30-40 degrees C., using 6-12 volts D.C. or A.C. and a current density of 5 amps./sq. ft.

In a later patent,[7] the alkaline bath and its technique are varied. The bath may consist of 3-20 per cent. aqueous sodium carbonate with or without additions of sodium tribasic orthophosphate and containing additions of ammonia or ammonium salts, or ammonium substituted organic compounds or of the bicarbonates or monohydrogen orthophosphates of sodium or potassium, and having a pH of 10 or more. In a further variant, the bath consists of an aqueous solution containing 0.1-3 per cent. sodium or potassium hydroxide with or without additions of the carbonates, phosphates, fluorides or molybdates of sodium, potassium or ammonium.

Technique consists in immersing the article until uniform attack is observed, after which a direct current of 10-14 volts, initially 10-15 amps./sq. ft., is applied for about 10 minutes.

Some idea of the success of these brightening treatments for aluminium and the position which the brightened metal holds in comparison with certain other reflector metals can be gained from Table 2, which is taken from the British Aluminium Co.'s publication on Brytal finishes and which, presumably, refers to normal daylight:—

Table 2.—Comparative Reflectivity of Anodically Brightened Aluminium and other Metals.

Specimen	Total Reflectivity %	Specular parts in 100	Diffuse parts in 100
Polished commercial aluminium	73.1	93.1	6.9
Brytal on commercial aluminium	76.8	86.2	13.8
Brytal on "A" Reflector aluminium..	82.4	96.25	3.75
Brytal on super purity aluminium	84.1	99.4	0.6
Stainless steel	59.5	97.0	3.0
Chromium plate	63.0	99.7	0.3
Rhodium on nickel plate	69.1	99.55	0.45
Lacquered silver plate	89.8	96.5	3.5

It will be noted that the main effect of Brytal treatment on aluminium of commercial purity is to cause a considerable increase in the diffuse reflection and a smaller decrease in the specular reflection, the total reflectivity being slightly increased. In other words, the metal surface is brightened but not polished. With grade A reflector metal, however, and still more with super-purity aluminium, diffuse reflection is diminished and specular and total reflection are considerably improved.

Dyed Anodic Films

One very important property of the anodic film is that when it is first produced it is highly absorptive in character and capable of taking up dyestuffs and similar materials. Subsequent treatment is capable of sealing the pores of the film and the absorbed dyestuff is then retained securely and cannot be removed by exposure to the atmosphere or by the ordinary processes of washing. This at once opens up possibilities of colour correction of sources of illumination by the use of coloured anodized reflectors, and, in fact, there are at least two British patent specifications which have this object in view. One of these,[8] taken out by Benjamin Electric, Ltd., relates to colour correction of artificial light by means of fluorescent dyes absorbed in the anodic film which is afterwards sealed with lanoline or whale oil. The reflector and light sources are so arranged that direct illumination from the light source and modified light from the reflector are evenly blended, for example, by a diffusing globe.

The second patent[9] achieves the same object by using a non-fluorescent dye and provides auxiliary reflectors so that all the light is colour-corrected.

It is therefore apparent that aluminium is of value for the manufacture of reflectors for visible light because:

(a) The polished metal naturally possesses a high reflectivity.

(b) Suitable grades of metal can be treated to produce an increased reflectivity coefficient which approaches that of silver.

(c) The metal is resistant to corrosion and tarnishing under mild conditions of exposure and in fact can be rendered largely immune from deterioration from these causes by anodic oxidation.[10] In this condition, the metal surface is very hard and will withstand considerable abrasive cleaning.

(d) The anodized metal offers the possibility of achieving colour correction through the use of dyestuffs absorbed in the pores of the anodic film.

One further point remains to be discussed and that is the ease with which light-metal reflectors may be fabricated. Where the quantity required warrants the production of the necessary tools, reflectors may often be produced by pressing or drawing of sheet metal. In other cases they may be spun. Some stages in the production of spun anodized aluminium lighting reflectors at the Cleveland (Lighting) Division of the Westinghouse Electric Manufacturing Co. have been illustrated in previous pages of this journal.[11] Sheet about $\frac{1}{16}$ in. thick is employed for this purpose. In yet other cases the casting process may be employed.

Fabrication

Whatever method of production is chosen, however, the result is an economical one and it is not surprising, therefore, to find a growing popularity of aluminium reflectors in widely differing branches of industry. In the home and in offices and factories, spun aluminium reflectors may be employed with or without component lighting fittings. They may be arranged to give diffuse or specular reflection, while in the case of those intended for the office or the home, striking effects may be produced by anodic oxidation and colouring of the metal surface. Aluminium reflectors have been employed for such purposes as architectural lighting, for highway illumination, and for the floodlighting of buildings. In the last application, the ease with which aluminium reflectors can be pressed or spun with accuracy to the desired contour is a real advantage. A plane circle of polished and anodized aluminium shown at the exhibition "Aluminium—From War to Peace" proved that the polished metal is capable of forming a very effective mirror without the fragility which necessarily accompanies silvered or mercury-backed plate glass. Small plates of super-purity aluminium anodically treated by one of the reflector processes have proved very popular with the ladies, who found that they could maltreat these new additions to their handbags without the disastrous consequences which attach to the careless handling of ordinary handbag mirrors.

Aluminium has also been used to advantage in large photometric spheres employed for comparing the intensities of sources of light. An interesting example of the adaptability of aluminium is the use of commercial satin-finished sheet for reflecting screens where a wide horizontal spread and narrow vertical angle are required. The effect is similar to that of plain sheet scratched vertically by hand, but it is, of course, much more uniform.

Dr. C. G. Abbot, speaking before the Third World Power Congress in Washington, 1936, described a proposed solar engine in which parabolical cylindrical mirrors of sheet aluminium would be employed to reflect and concentrate the sun's rays on to a blackened surface of chlorinated diphenyl (Arochlor resin), the heat produced being used to generate steam.

Some aspects of the design of aluminium reflecting units have been dealt with in three patents granted to P. King-Morgan in 1937 and 1938.[12, 13, 14]

Electroforming

In the "Metal Industry," November 29, 1940, is given an account[15] of the preparation of 62-in. searchlight reflectors by a process of electroforming. The starting point is a nickel-surfaced electroformed metal mould held in a metal frame, which is coated on the back with a non-conducting lacquer or mask to prevent the building up of metallic deposits. The nickel surface is passivated to prevent adhesion of subsequently applied nickel, and nickel plate is then deposited in a layer about 0.0035 in. thick. This is followed by a slightly heavier coating of copper, the fitting of a preformed bronze ring and the deposition of a heavy deposit of copper. The three layers of nickel and copper, firmly bonded together, are stripped from the mould, the copper is given a protective mask and, after polishing of the nickel concave surface, the latter is given a flash coating of rhodium—a tolerably expensive metal, even for flash coatings. One wonders how much more simple and cheaper it might have been to form aluminium sheet to the required shape, polish, brighten and anodize, at the same time obtaining a reflector of greater efficiency than the rhodium-plated composite nickel-copper article.

Reflectivity to U.V. Rays

It is apparent from Table 1 that, as the low-wavelength end of the spectrum is approached, the total reflectivity of polished surfaces diminishes. The important point to note is, however, that, of the range of metals for which reflectivity values are recorded in this table, two alone retain their high reflectivity in the visible range, all other metals showing a big drop in reflectivity in the U.V. region, so much so that, with these two exceptions, none of the surfaces has a total reflectivity exceeding 39 per cent. at a wavelength of 0.251 μ. These two exceptions are aluminium and its light alloy, magnalium, which, with total reflectivities of 80 and 62 per cent. respectively at 0.251 μ, offer an enormous increase over the reflectivity possible with other materials. It must be admitted that the figures given in Table 1 are insufficient, both in quantity and range of surfaces examined, and also in their accordance with the results obtained by other observers, to justify a conclusion that, of all practicable reflecting surfaces, aluminium is the most efficient for U.V.

radiation, yet, nevertheless, this fact has been proved in practice. The reflection of U.V. light is of importance for photographic purposes, and it is not surprising, therefore, to find that aluminium has found application in the production of mirrors for precision photographic work.

One further characteristic of aluminium which requires emphasis at this stage is the possibility which it offers for the fabrication of front-surfaced mirrors, the use of which is essential in precision work. The multiple images produced by mirrors of glass backed with silver or mercury make precision work with these mirrors quite impossible. Front-surfaced mirrors of silvered glass have been used for many years in optical apparatus, but the inevitable tarnishing and softness of the silver film prevent them from giving lasting satisfaction. Aluminium, however, is much less susceptible than silver to tarnishing, and after only three weeks' indoor exposure in the absence of sulphurous fumes silver has usually tarnished sufficiently to bring its reflectivity below that of ordinary polished aluminium exposed alongside it. The big mirror at the Mount Wilson observatory, for instance, used to be resurfaced every six months; aluminium front-surfaced astronomical mirrors, on the other hand, have been in use under similar conditions for upwards of three years with hardly a trace of loss in reflectivity. The high reflectivity of polished aluminium for U.V. light, and its excellent retention of this high reflectivity during use, are matters of real practical importance when dealing with the very low light intensities which the astronomer so frequently encounters.

Two main processes are in use for the surfacing of reflectors with aluminium, namely, evaporation and cathode sputtering, of which the evaporation technique is better suited to the production of mirrors. The possibility of evaporating certain metals, including aluminium, in a vacuum and condensing them in thin films on glass surfaces was discovered in 1912 by Pringsheim and Phol. They used a magnesia crucible for melting and vaporizing the metals, and produced a number of polished reflecting surfaces. It is an obvious disadvantage to employ crucibles in high vacuum work owing to the excessive outgassing which takes place, and in 1928 R. Ritschl successfully used coils of tungsten wire for melting and vaporizing silver in the preparation of half-silver interferometer mirrors. This change in technique overcame the disadvantages of the crucible method, but the earlier attempts to use it with aluminium failed owing to the fact that the tungsten dissolved in the molten aluminium and the vaporizing coils soon burnt out. It was left to John Strong[16] to ascertain that tungsten has only a limited solubility in aluminium, amounting to about 3 per cent. by volume, so that it was possible, therefore, to obviate the burning-out of the tungsten wire coils by making them sufficiently thick to satisfy the solubility of the tungsten in the aluminium without dangerously reducing the diameter of the wire.

The sputtering process is also effected in a rarefied atmosphere, but takes place between two electrodes where the cathode is the material to be deposited.

The evaporation and cathodic sputtering techniques have been fully explained in a recent issue of "Light Metals."[17]

(To be continued.)

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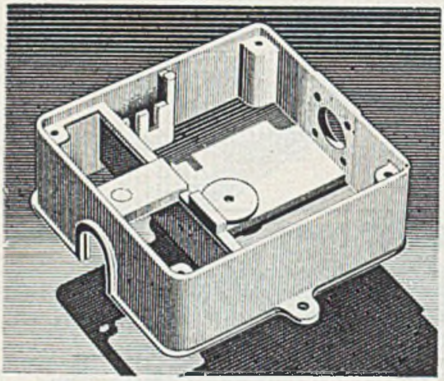
(1) *See Brit. Pat.* 433,484. *Aluminum Co. of America.* (2) *See Brit. Pat.* 436,154. *Aluminum Co. of America.* (3) *See Brit. Pat.* 436,481. *Aluminum Co. of America.* (4) *See Brit. Pat.* 440,287. *Aluminum Co. of America.* (5) *See Brit. Pat.* 489,169. *Aluminum Co. of America.* (6) *Brit. Pat.* 489,162. *British Aluminium Co.* (7) *Brit. Pat.* 513,530. *British Aluminium Co.* (8) *Brit. Pat.* 479,220. *Benjamin Electric Ltd.* (9) *Brit. Pat.* 494,376. *V.A.W. (Germany).* (10) "*Atmospheric Weathering tests on Anodized Aluminium Reflectors,*" *W. E. Harper and P. Smith,* "*Trans. Ill. Eng. Soc.*", 1946/11/*No.* 8. (11) "*Light Metals,*" 1942/5/254. (12) *Brit. Pat.* 499,643. *P. King-Morgan.* (13) *Brit. Pat.* 500,115. *P. King-Morgan.* (14) *Brit. Pat.* 513,149. *P. King-Morgan.* (15) "*Metal Industry,*" 1940/57/436. (16) *John Strong,* "*Phys. Rev.,*" 1934/45/769; "*Astro-physical Journal,*" 1936/83/401. (17) "*Light Metals,*" 1947/10/124.



EDITORIAL AND BUSINESS ANNOUNCEMENTS

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A perfect Casting . . .

"You made the acquaintance of my son at his office I expect?" asks stone-deaf Aged Parent (O. B. CLARENCE) meeting young Pip (JOHN MILLS) in the home of Wemmick (IVOR BARNARD). A homely scene from "GREAT EXPECTATIONS". This Cineguild production (G.F.D. Distribution) has fulfilled great expectations—due to a perfect casting by David Lean and Ronald Neame.

"*Great Expectations*" are not fulfilled by leaning back in an armchair, hoping for the best . . . but by working for the best. How true this is of our high-grade aluminium alloy die-castings — one of which you see here. It combines lightness with strength, corrosion resistance and freedom from porosity — making it a perfect casting.

A perfect Casting by

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