ALUMINIUM FROM WAR TO PEACE

LIGHT METALS

JUNE
1945

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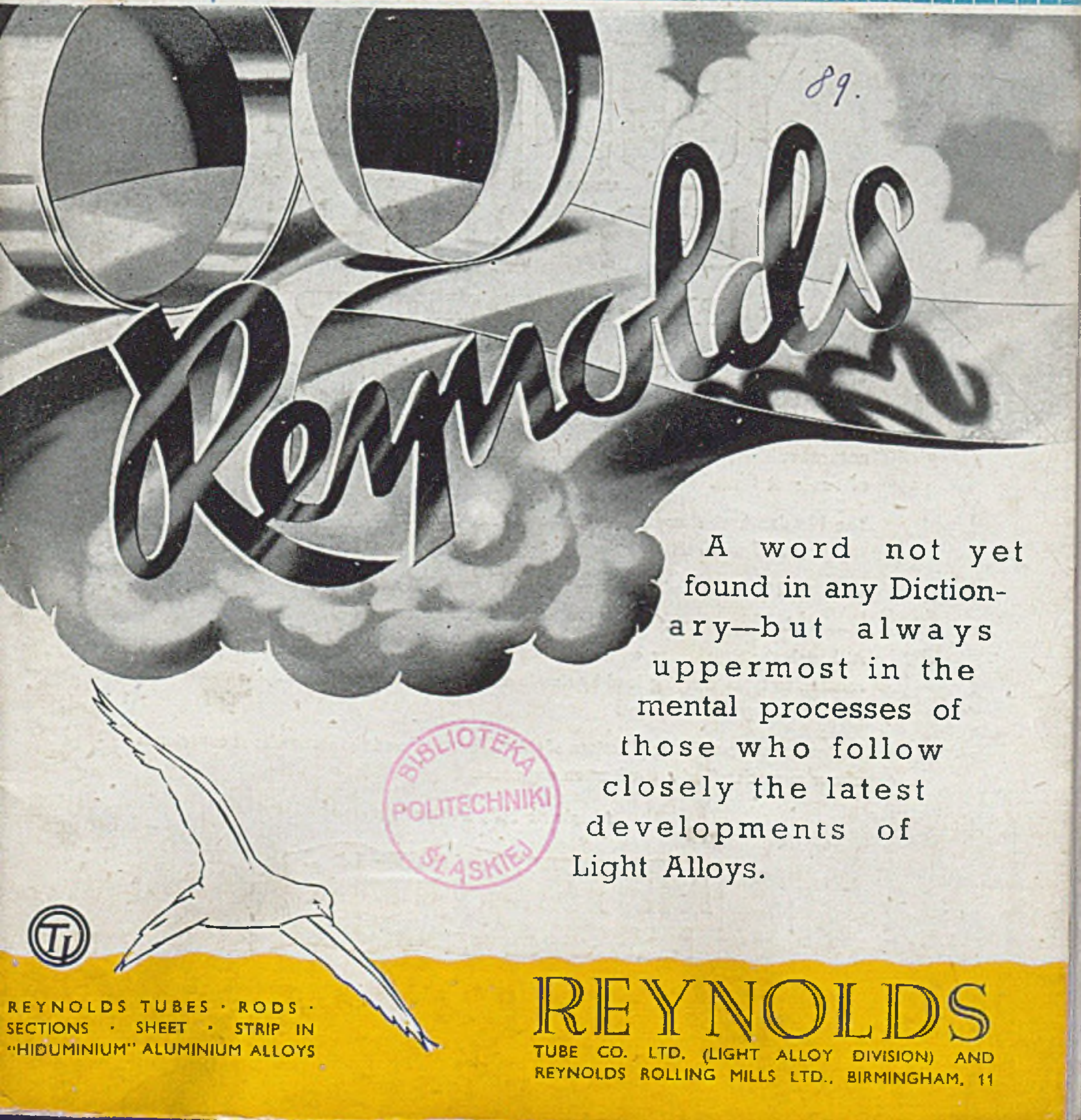

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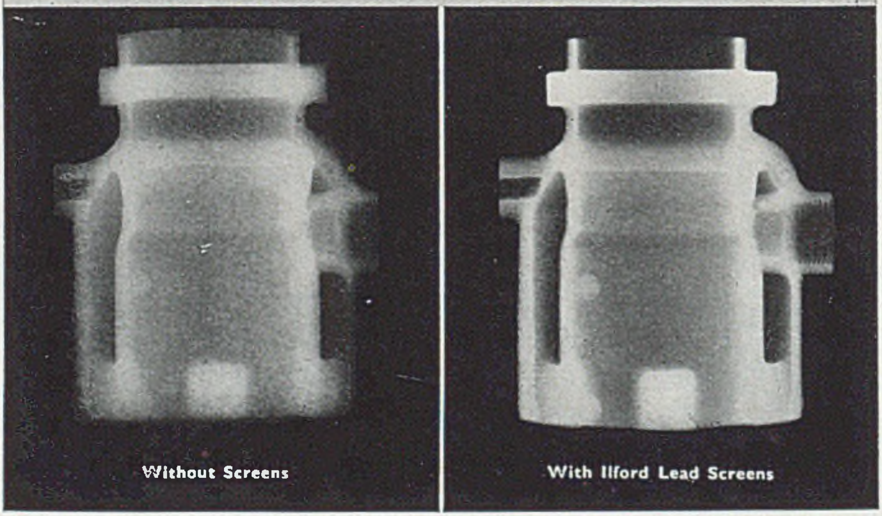

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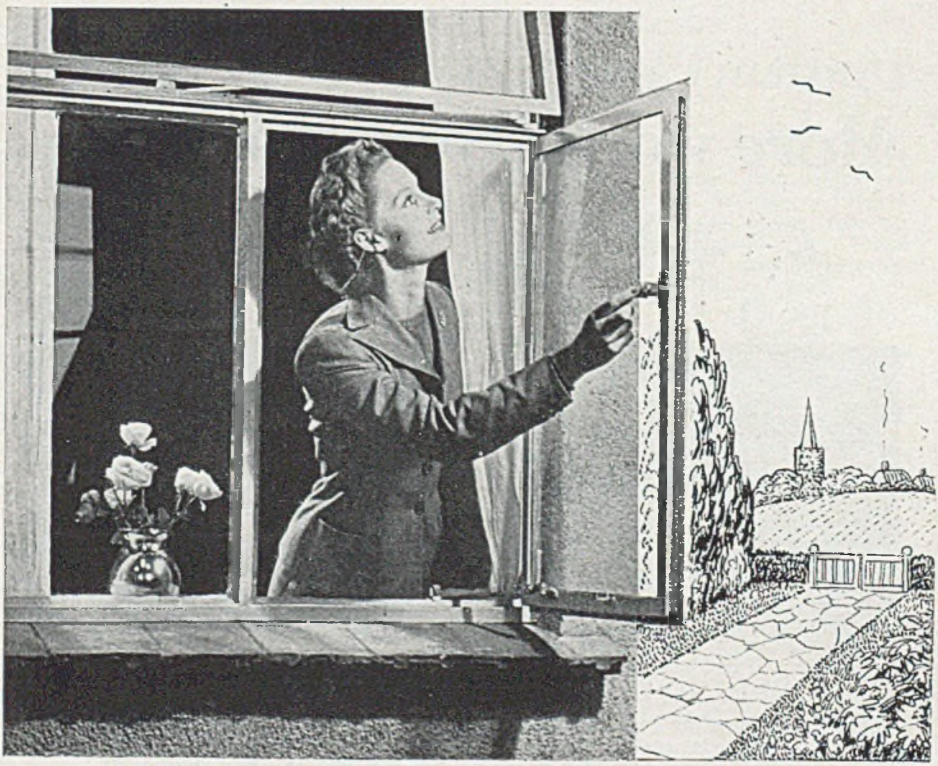

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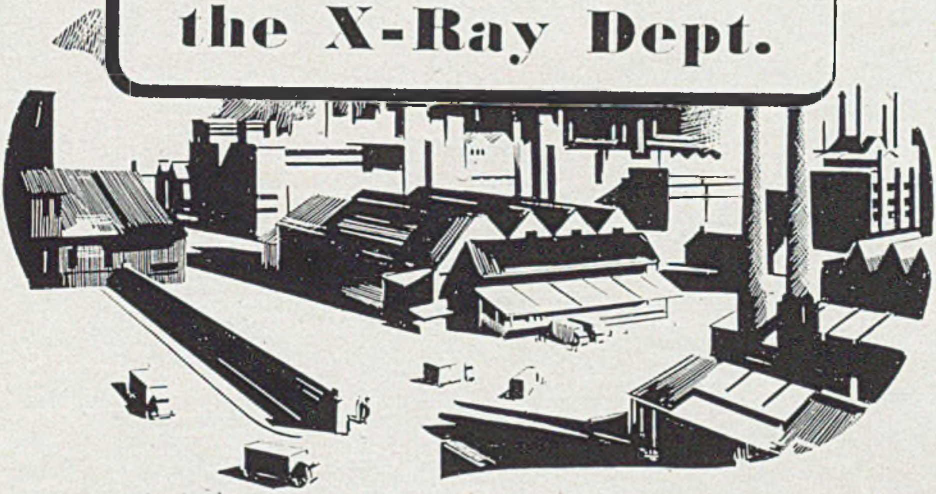

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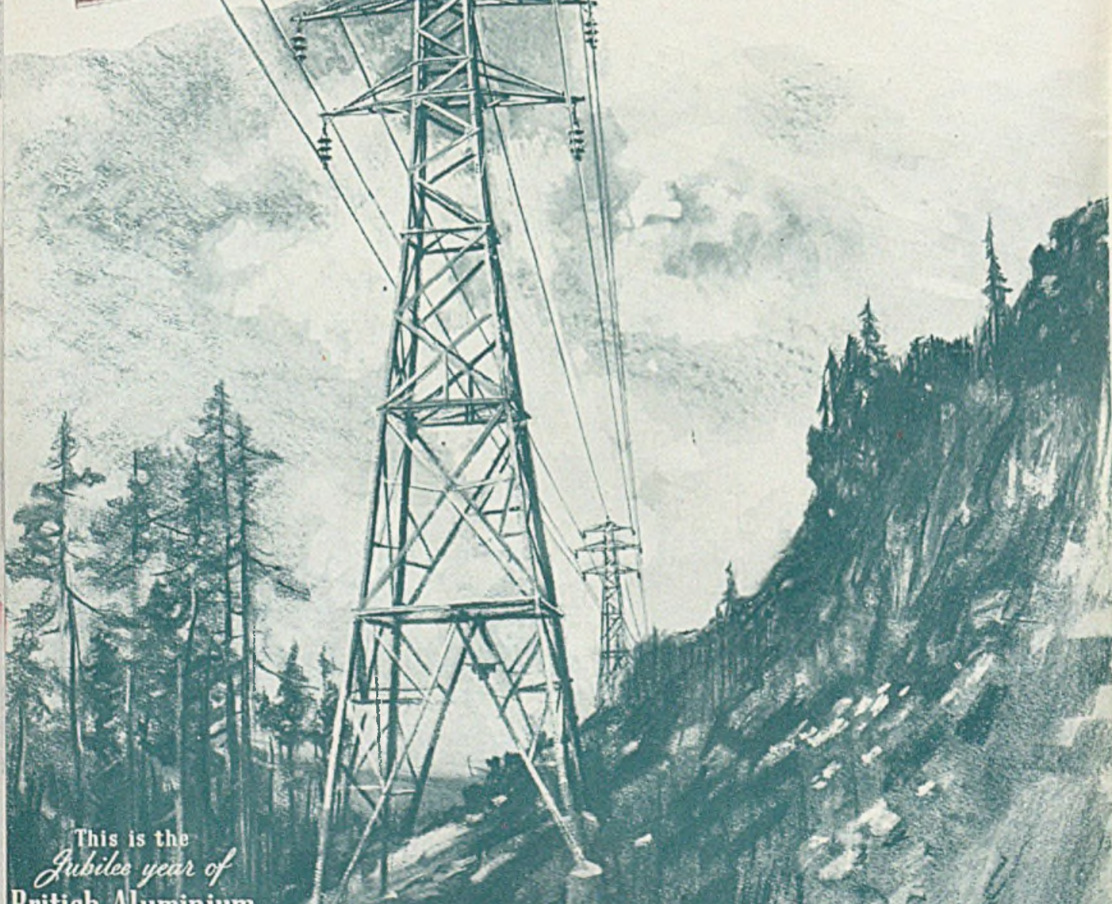

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LIGHT METALS

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

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

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

EDITORIAL OPINION

Introducing A.D.A.

HARD on the news of the official termination of the war in Europe, comes that announcing the inauguration of the Aluminium Development Association. For our own industries, the implications of these two events are of the utmost importance. There is little need to recall the loss sustained by the civil-consumer field when light metals were totally mobilized for total war. From the termination of hostilities in the West, we may infer that, in a comparatively short while, aluminium will once again be free for general use; indeed, already, an earnest of this has been granted by the release of limited supplies for more essential domestic uses.

The formation of A.D.A. represents the crystallization of projects, some of which were initiated many years before the war began, others just prior to 1939, and yet again others which came into being actually during the war years. The value of these early efforts is not to be underrated. We well recall our harmonious relations with, and the good work done by, the Aluminium Information Bureau. We have pleasant recollections of a lunch to which were invited many members and prospective members of the Light Metal Founders' Association, our object being in this case to devise some approach to that body in order to see whether it would consider broadening the scope of its activities. With the Wrought Light Alloys Development Association we have co-operated since its inception.

Seven years' experience preaching the aluminium gospel, long ago taught us that a central body embracing all the principal aluminium interests of the country, consumers and fabricators alike, would sooner or later become a vital necessity if the application of the metal was to be expanded as fully and rapidly as its merits demanded. Contacts with members of the groups to which we have referred, and external inquiries addressed to ourselves and afterwards passed on to these groups, all showed a keen desire for unified effort, and for an intensification in development and research. By current standards aluminium was, in those seemingly far-off times, still a comparatively rare metal. Much, however, had already been achieved in every field of engineering, applied science, and art; everywhere was manifested a praiseworthy impatience to do more. In A.D.A., we believe this desire to be implemented.

There were present at the Inaugural Luncheon of the Association: the Hon. Geoffrey Cunliffe, President of A.D.A., the Rt. Hon. Sir Stafford Cripps, P.C., M.P., Minister of Aircraft Production, the Rt. Hon. Hugh Dalton, P.C., D.S.C., M.P., President of the Board of Trade, and the heads of numerous industries, at present either users of aluminium in heavy tonnages, or prospective big consumers. H. G. Herrington, chairman of the Aluminium Development Association, responded to the toast proposed by the Rt. Hon. Hugh Dalton.

After such an auspicious initiation ceremony, we have every reason to expect great things from the new organization, and it will perhaps be pertinent to forecast, in brief, some major activities and lines of approach soon likely to become evident. Those who, over the period of the past 10 years, have studied the foreign trade and technical Press must be only too painfully aware of the tardiness exhibited in this country in the adoption of new ideas. So, for example, in the heavy engineering field, light metals have, here, made less headway than some of us had hoped to see. In our Editorial pages we have had frequent occasion to voice complaints in this regard; not that we consider we have done industry anything but a service in reproducing accounts and illustrations, exemplifying advance practice, either from across the Atlantic or on the European mainland. Too often, however, pioneer work carried out in this country by our own countrymen has been either on too small a scale to attract the attention it deserved, or for some obscure reason has not been given the notice with which it would have been honoured elsewhere. The primary difficulty, we believe, lay in too great a subdivision of labour and in the absence of a central co-ordinating body capable of visualizing intense, continuous, widespread publicity in all its aspects.

We ourselves have every reason to realize this state of affairs. Campaigning by the printed word in the form of advertisement, essential as it is, is, alone, insufficient to carry the full burden imposed by a desire to exploit to the full the potentialities of a new material or product. It has been demonstrated amply that, even after years of propaganda, many branches of industry will still remain largely ignorant of the resources available to them. Not once or twice, but a dozen times from this office have we informed inquirers that there exist such bodies as the Tin Research Council, the Zinc Development Association, and the Copper Development Association. We have, too, passed on the address of the Wrought Light Alloys Development Association, with indications as to the nature of its activities.

So far we have inferred that the printed word and the central body to which inquiries may be directed are essential. A third factor must also be introduced, namely the ready availability of a widely known centre from which personal contact may be made. Here again, for the past seven years, we have been putting this element into effect from this office. At informal gatherings convened once a month or sometimes more frequently, meetings have been arranged between various representatives of the numerous aluminium interests in this country, and prospective users of the metal, or interested inquirers as to the possibility of its utilization in specific production fields. As often as possible a representative of the Wrought Light Alloys Development Association was invited. We here can bear ample testimony to progress achieved in this way, and to the need which will be satisfied by the establishment of a branch office of A.D.A. in London.

We see in the Aluminium Development Association the answer to the various business and technical problems we have indicated here. Those in the former class we have dealt with somewhat fully; the latter group deserves some examination. Hitherto, for a variety of reasons, the two fields embracing, respectively, wrought alloys and cast alloys, have been segregated, a state of affairs of no material significance during the war years. With the coming of peace, however, and the broadening of the civil-consumer field, such a division could no longer be tolerated with safety, for in exploiting new fields we are dealing, first, with aluminium, irrespective of the form in which it is used. Inquiries, too, from prospective new users, centre principally on the metal itself, and, as likely as not, bear on its application in the foundry and the stamp shop together. From now on we are assured of balanced technical and developmental representation for cast and wrought products.

The field to be covered by A.D.A. is both extensive and complex. Two primary aspects are involved: that of pure research, and that covering new or broadened applications of aluminium and its alloys. Obviously neither side is, in itself, capable of standing alone, and success must ultimately depend on close co-operation between both. For some seven years now, we ourselves have explored fields of use already established, seeking, in so doing, to make possible the use of still greater quantities of metal in tried spheres, and to induce by force of example and precedent, its employment in related but untried directions.

The formation of the Aluminium Development Association is to be interpreted as a sign of the coming assertion, by light alloys, of rights proved now by half a century's successful effort in peace and war, in field and home, in the giant bridge and the micro-balance. Only the future can say to what limits their progress will extend.

Contents

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

THE FACT that goods made of raw materials in short supply because of war conditions are advertised in this journal should not be taken as an indication that they are necessarily available for export.

SAVE PAPER.—More than ever is paper waste required for our war industries. Waste paper makes munitions in a hundred forms—from shell cases to aeroplane parts.

ON Wednesday, May 30, at Selfridges, Ltd., Oxford Street, London, at an exhibition arranged by Messrs. Selfridge, sponsored and assisted by the aluminium industry in this country, the public will, for one month, be given an opportunity of seeing, for the first time, the part which light alloys will play in the home of the future and post-war industry.

For five years light metals constituted priority requirements for our war-time activities: one of the major aims of the exhibition will be to show, in brief, the role of the metal and its alloys in the field, and the transition from this sphere to that of more cultural and domestic needs.

Perhaps, for the first time, there has been achieved an educative unity of presentation so arranged that the layman may, at a glance, grasp the story of the birth of aluminium, its place in the history of our metal civilization, and the intricate techniques which have been evolved to make it serve the countless needs of mankind, in battle, in the home, in leisure and at play. The subject is so vast, and presents so many aspects, that it must at once be realized that no more than a "synopsis" is possible in the space at our command.

An artist's impression of the entrance hall of the exhibition forms the heading of this page. Prominent amongst the exhibits, and a masterpiece of creative art, are the murals which will tell the aluminium story. They are themselves designed for, and executed in, light metal. In close proximity may be seen examples of modern aero engines, themselves consisting largely of light alloys, without which they could have no existence. Step by step the visitor will see how the skill of the light-metal technologist, which made possible the development of the Sabre engine, makes possible also the modern light-metal kitchen.

No matter what interest may predominate it will find its satisfaction here: the colourful bathroom and bay window assembly show how, by various surface treatments and integral colouring, the most stringent requirements of service and art may be combined; delicate scientific instruments, where the important factor of rigidity is achieved without the encumbrance of weight by the skilled use of light-metal castings and forgings; modern surgical instruments and fittings, where the permanence of aluminium, the ease with which it may be fabricated, and its strength, are turned to account for humanitarian ends. The ability of light metals to team up with other structural materials will be exemplified, notably by a few selected assemblies of aluminium employed in conjunction with transparent plastics.

Finally, the exhibition will demonstrate, not only what can be done with light alloys, but also the skill and adaptability of our engineers, technologists and craftsmen. The foreign buyer, seeking in this country goods to satisfy his own market, will derive no less benefit than the housewife, the architect, and the sociologist.

Development of Stereoscopic Photography and Radiography*

By LESLIE P. DUDLEY, D.F.H., A.M.I.E.E., A.I.Struct.E., A.R.Ae.S.

SUMMARY

A brief outline is given of the more important phases in the history and development of stereoscopic photography and radiography. Certain processes for the production of stereoscopic pictures which do not entail the use of individual viewing devices are discussed in greater detail. Some new processes, whereby stereoscopic radiographs of the parallax panoramagram type are produced, are described for the first time.

MANY books and film scripts have had for their central character a professor who, by some highly unorthodox and spectacular method, is able to create living beings. Sometimes his creations take the form of large, sub-human robots, and at other times they are fascinating little replicas of our species, to a scale of an inch or so to the foot, which he stores under bell jars or in pickle bottles. Invariably the worst possible motives are attributed to the professor. This is good " box-office " but poor psychology, for the professor's achievements merely represent the fulfilment of an ambition or desire which, to a greater or lesser degree, is latent in all of us. Sculpture, painting and so on are expressions, in sublimated form, of this same creative instinct. The appeal of the beautifully made scale-model cannot be denied; the fascination of the " peep show " is something which most of us never outgrow, which no doubt accounts for the great popularity of the stereoscope in the Victorian era.

A diligent search of the Patent Office files and other recognized sources of scientific information reveals no clue to how the human species may be reproduced, either full size or to a reduced scale, by other than biological methods. This is scarcely surprising. What may, however, come as a surprise to some is the enormous amount of interest which has been displayed, throughout the ages, in optical methods of producing what may be termed three-dimensional reconstructions of ourselves and other subjects.

So far as the author has been able to trace, Artemidor, in the year 100 B.C., was the first to comment on the three-dimensional nature of the image produced in a plane-reflecting surface. Since that time, plane and concave mirrors have been used by numerous workers for the production of three-dimensional effects, a few references being: Ptolemy (200 A.D.), Porta (1589), Kepler (1604), Horstmann (1899), Sallé (1907) and Kögel (1934). Porta, Kepler and, subsequently, Rohr (1909), Bostock (1910), Schallopp (1935) and various other workers also proposed the use of large lenses for similar purposes.

Although the stereoscope has been known for little more than a century, the underlying principle appears to have been known for much longer. A pair of minute Italian paintings, several hundred years old, were discovered a few years ago; it was found that when the two pictures were magnified and viewed binocularly so as to fuse them into a single image, a stereoscopic effect resulted.

The invention of the stereoscope is usually attributed to Wheatstone (1838), but it is to be noted that the instrument which bears his name was preceded four years earlier by a stereoscope devised by Helioth. This instrument, however, incorporated no optical elements to assist convergence, and was, consequently, inferior to that of Wheatstone or those of Brewster (1848), Wenham (1860) and others. Numerous forms of stereoscopic viewing devices were subsequently designed, amongst which may be mentioned those of Corbin (1861), Dubosq (1894), Miethe (1896), Bellieni (1904), Lumière (1899), Gillette (1905), Leitz (1905) and Busch (1912).

The principle of stereoscopic photography involving the production of homologous views tinted in complementary colours, and subsequent viewing of the pictures through spectacles tinted in the same colours, is well known and need not be described here. It may not, perhaps, be so generally known that a subtractive process embodying this principle was applied to still photography as far back as 1853 by Rollman. This was followed five years later by an additive process due to D'Almeida. Soon afterwards stereoscopic pictures printed in complementary colours were featured in several magazines, a small pair of viewing spectacles being provided with each copy.

With the advent of the kinematograph, complementary colour processes were adapted to the production of stereoscopic motion pictures, largely as a result of the

* Reprint of a paper read before The British Institute of Radiology, March 15, 1945, and reproduced by courtesy of the Institute.

work of Herring (1901), Weinberg (1909), and, more recently, Lumière (1934). Such processes are now generally known as *anaglyphic* processes. Various polychromatic anaglyphic processes have been proposed from time to time, notably by Schestakoff, Gurewitschu and Wiener (1910), Lehmann (1917) and by Schallop and Lumière (1934).

Although methods of producing stereoscopic still and motion pictures with the aid of polarizing prisms are now well known, here again it is interesting to note that the basic principle involved is by no means novel. The earliest proposal, within the author's knowledge, for the projection and viewing of stereoscopic pictures by means of polarized light was that due to Anderton (1890). The development of a commercial process, however, was delayed for nearly half a century by the high cost of natural polarizing crystals. This difficulty was overcome in 1934 by Land with his invention of a method of producing synthetic polarizing materials, now known under the trade name of Polaroid. Additive processes utilizing these materials in the projection of stereoscopic pictures were devised by Land (1934), Bernauer (1935), Ardenne (1936), Käsemann (1938), Walus (1939) and others. The chief subtractive processes are those of Land (1939) and Zeiss-Ikon, Ltd. (1940). In accordance with a recent development due to Land, photographic prints embodying two homologous views in superposition are now obtainable. The plane of polarization of the light reflected by one view is at right angles to that of the light reflected by the other view. Hence, when such a print is viewed through a pair of Polaroid spectacles, the lenses of which have their planes of polarization suitably arranged at right angles to each other, a stereoscopic image is seen. Prints of this type are known as Vectographs, and are useful for various commercial and scientific purposes.

Part I—The Parallax Stereogram

Our professor of screen and fiction fame, however, would never be satisfied if, in order for his creations to come to life, it were necessary for his awed public to don special goggles. If we interpret the phrase "come to life" as meaning, in the photographic sense, the conversion of relatively unnatural, two-dimensional views of material objects into much more natural, three-dimensional views, then we find that the general public, no less than the scientific worker, is on the side of the professor. This fact is exemplified by the lack of success which has attended the numerous attempts to introduce anaglyphic processes into the public cinema. The necessity for wearing spectacles does much to destroy the illusion of reality which it is the very purpose of stereoscopy to create. As one would expect, therefore, a great deal of scientific effort has been expended in the development of photographic and kinematographic processes which do not entail the use of any individual viewing devices. The search for the ideal method has been in progress for some half-century and still continues.

Although the problem has been approached from many different angles, it is an interesting fact that all the most promising processes make use of grids of some form or other, that is to say, either line grids composed of a large number of alternate opaque and transparent strips, or grids composed of a multitude of cylindrical or spherical lenticulations. The number of such processes is very great indeed, and it is impossible here to do more than give brief descriptions of a few of them. We will, moreover, devote our attention mainly to those processes which offer the greatest promise of successful adaptation to radiography.

September 25, 1902, is a date of great importance in the history of the development of stereoscopic photography, for on that day Frederic Ives filed in the U.S.A. his classic Patent Application describing the "Parallax Stereogram and Process of Making Same," which Application was subsequently granted on April 14, 1903. Quoting from the Specification (No. 725,567), Claim 1 reads: "A photograph consisting of a composite image, in juxtaposed lines, of the elements of an ordinary double stereogram, exposed to view through a screen of alternate opaque and transparent lines, so adjusted as to give a stereoscopic effect by the parallax of binocular vision, substantially as specified."

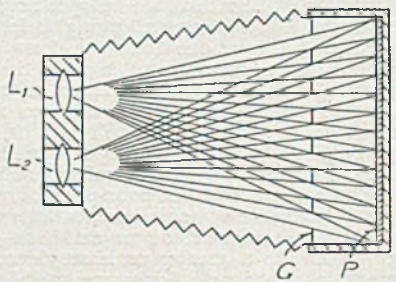

Fig. 1.—Principle of parallax stereogram camera.

It seems likely that Ives's invention had its genesis in a proposal put forward in 1896 by Berthier. The importance of the invention lies not so much in the merits of the parallax stereogram itself, which is subject to somewhat severe practical limitations, as in the influence which the idea has undoubtedly exerted on the minds of subsequent workers. The principle of the parallax stereogram has been explained on many previous occasions, but, for the benefit of any who may be unfamiliar with this type of photograph, a brief description will be given here.

The sketch, Fig. 1, is a diagrammatic sectional plan showing the essential elements of a camera suitable for the production of parallax stereograms, L_1 and L_2 being lenses forming images on a photographic plate or film P. The distance between the axes of L_1 and L_2 is approximately 2½ ins. and consequently, the disparity between the two images is substantially the same as that between the images produced by the two eyes in the human visual system.

A grid, represented by the broken line G, is arranged a short distance in front of P. This grid consists of a large number (usually between about 50 and 100 to the inch) of vertical and parallel opaque lines or strips separated by transparent spaces or strips having the same width as the opaque strips. As will be understood, without this grid in position, the picture produced on the photographic plate would be blurred owing to the superposition of the two images due to L_1 and L_2. Consider, however, the effect of making an exposure through only one of the lenses, the grid being in position. It will be evident that only half of the area of the plate will be exposed, the exposed portions consisting of a number of narrow, parallel strips interleaved by unexposed strips of equal width. Now, by correctly proportioning the distance between the grid and the plate relative to that between the grid and the lenses, it is possible to arrange matters so that, with both lenses in operation, those strips of the plate which are shielded from the light transmitted by one lens are exposed to that transmitted by the other lens. If, then, we imagine that the exposed strips are numbered consecutively: 1, 2, 3, 4, 5, etc., one series, say that bearing the numbers 1, 3, 5 and so on, will carry an image representing a "left-eye" view of the subject, while the other series, bearing the numbers 2, 4, 6 and so on, will carry an image representing a "right-eye" view. From simple geometrical considerations the required distance between the grid and plate is given approximately by the relationship—

$$\text{Grid} - \text{plate distance} = \frac{\text{Lens} - \text{plate distance x width of one strip}}{\text{Distance between axes of lenses}}$$

Referring, now, to Fig. 2, P represents a diagrammatic plan view of a transparency of the parallax stereogram type produced with the aid of a camera such as that in Fig. 1. A grid, G, is arranged in front of the transparency, and the stereogram is illuminated from the rear by diffused lighting. Picture strips carrying the "left-eye" view are indicated by the letter *l* and those carrying the "right-eye" view by the letter *r*. It will be observed that, as shown, the opaque and transparent strips of the grid are of equal width, but, as we shall see a little later, it is customary in practice to employ a viewing grid in which the transparent strips are somewhat narrower than the opaque ones.

Considering the observer whose eyes are shown bracketed at C, it will be evident that if the distance between the stereogram and the grid be correctly chosen, as in the diagram, his left eye will see only the "left-eye" strips or elements of the stereogram

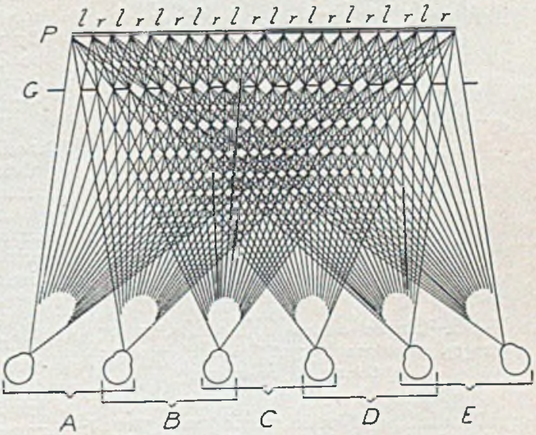

Fig. 2.—Viewing parallax stereogram.

(the "right-eye" elements being obscured by the opaque strips of the grid), and his right eye will see only the "right-eye" elements. Consequently, a stereoscopic view results. Similar conditions prevail if the observer moves laterally through twice his interocular distance to position A or D, a stereoscopic view being obtained from either position. In practice there are a number of positions, such as A, C and E, from which a parallax stereogram may be seen in stereoscopic relief, adjacent positions being separated by twice the interocular distance. Only three such positions are shown in the present diagram.

Let us now consider the case of an observer whose eyes are at some intermediate position, such as B or D. As will be noted from the diagram, from such a position the observer's left eye sees only the "right-eye " picture elements, and his right eye sees only the " left-eye " picture elements. Thus, a pseudoscopic view is obtained. It is an experimental fact, however, that except in rare instances, when the eyes are presented with a pseudoscopic view, considerable difficulty is experienced by the brain in appreciating an effect of complete perspective reversal in all parts of the scene. Partial obscuration of one object by another, knowledge of the relative sizes of familiar objects, and various other factors, all tend to contradict the evidence provided by the unnatural angles of convergence, and confusion results.

With a parallax stereogram there are an equal number of orthoscopic and pseudoscopic viewing positions. These positions are sharply defined, and a very slight lateral movement of the observer's head from one of the orthoscopic viewing positions is sufficient to destroy the stereoscopic effect, as such movement brings portions of both the " left-eye " and " right-eye " images into the view of each eye. This is one of the main disadvantages of the parallax stereogram. In order to minimize the effect, it is customary to employ a viewing grid which, whilst retaining the same pitch as that of the grid used in the camera, has considerably narrower transparent strips. Satisfactory values for the ratio: opaque strip width/transparent strip width lie between about 3 and 5 to 1.

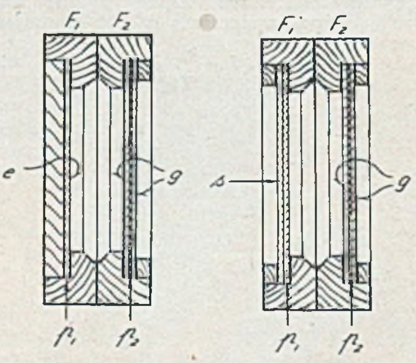

Fig. 3.—Simple camera and projector for integral photography: at the left, camera; at the right, projector.

We must next consider the effect of viewing a parallax stereogram from different distances. In view of the fact that the separation between the grid and the stereogram is negligible in comparison with that between the observer and the stereogram, it will be appreciated that the width of the visible portion of every picture strip is substantially constant at all viewing distances. Consequently, a stereoscopic effect is obtainable at all distances beyond the minimum at which binocular fusion of the two components of the stereogram is possible.

Numerous systems of stereoscopic kinematography, based on the principle of the parallax stereogram, have been proposed from time to time, those due to Noaillon (1927), Dudley (1935) and Ivanoff (1938), being among the most recent, but a discussion of such processes is outside the scope of the present paper.

Part 2—Integral Photography

We come now to a consideration of some highly interesting photographic methods, which methods are among those comprising the fascinating subject known generally as *integral photography.* This branch of photography had its origin in an idea conceived nearly 40 years ago by Lippmann. By way of introduction, an experiment will be described by means of which a simple form of integral photograph may readily be produced.

We will require an anti-halation plate of medium rapidity, a pair of old photographic plates from which the gelatine has been removed, a piece of ground glass, a piece of opaque paper such as that used for wrapping photo-sensitive materials, and two printing frames clamped face to face. The size of the plates and other accessories should be quarter-plate or larger.

The first step is to make, with the aid of a fine needle, a series of punctures in the opaque paper. The punctures should be distributed fairly evenly, and should number about 25 or 30 per sq. in. of the paper. When this has been done, place the paper between the two clear plates and insert the whole into one of the printing frames. This " sandwich " must be held flat in the printing frame by narrow, marginal strips of wood, as the back of the frame is to be discarded. Next, in the darkroom, load the sensitive plate into the other frame, the emulsion side being nearest the punctured paper, and then replace the back of the frame in the usual manner. We now have the simplest form of camera for taking an integral photograph, and are ready to make an exposure. A sectional side elevation of the device is represented by Fig. 3 (left). The printing frame F_1 contains the photographic plate p_1, the emulsion side of which is denoted by e, and the other frame F_2 contains the sheet of punctured paper p_2, sandwiched between the two clear glass plates g.

For our subject, a pair of carbon-filament electric lamps is one of the most suitable. One should be arranged directly opposite the centre of the punctured paper, say 18 ins. away, and the other being placed a few inches nearer to the paper and slightly to

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one side of the first lamp. It is preferable for the lamps to be so arranged that the loops of their filaments are parallel to the plane of the paper.

In order to make the exposure, switch on the current to the lamps for about four or five minutes. The light from the lamps can reach the photographic plate only via the punctures in the opaque paper, and thus produces a large number of minute images of the lamps on the sensitized surface. Each image differs slightly from the adjacent ones, due to the parallactic effect resulting from the different positions which the pin-holes occupy relative to the subject.

Upon the completion of the exposure, the plate should be developed in normal amidol, rinsed in water for a few minutes, and then, without fixing, exposed to the light from 3 ins. of magnesium ribbon held at a distance of about 18 ins. Next, the plate must be given a reversing bath consisting of 3½ oz. water, 8 grs. potassium bichromate and 10 drops of chemically pure sulphuric acid. After a further brief wash, transfer the plate to a 5 per cent. solution of anhydrous sodium sulphite for about 3 mins. Upon removal of the plate from this solution, give it another rinse, and then redevelop it very fully in the amidol first used. To complete the process, fix and wash the plate in the usual manner. The foregoing operations convert the negative into a positive, and must, of course, be conducted in non-actinic light.

When the plate is dry, replace it in the printing frame F_1, the emulsion side being nearest the punctured paper as before. It is important that the orientation of the plate should now be the same as it was during the exposure, so that all the minute images occupy their correct positions relative to the pin-holes by which they were formed. Hence, it is as well to make a reference mark near one edge of the plate, before development, and a corresponding mark on the printing frame. Insert the piece of ground glass into the frame behind the photographic plate. The back of this frame also is now to be discarded, so the ground glass and photographic plate must be held in position by means of marginal wooden clamps similar to those used with the other frame. The modified device will appear as represented by Fig. 3 (right), in which s denotes the ground glass screen.

We now require a lamp box, such as an electric dark-room lamp from which the safety filter has been removed. Insert a lamp of, say, 60 watts capacity, and fix the modified "camera" (which is now going to be used as a "projector") to the front of the box in such a way that the ground glass is nearest to the lamp, and so that no light can escape except through the punctures in the opaque paper.

Take up a position in front of the device, at a distance of about 10 ft. Endeavour to focus the eyes on a plane in space a short distance in front of the device, rather than on that of the pin-holes, meanwhile moving the head slightly from one side to another. Suddenly, and with a startling semblance of realism, the glowing carbon filaments will apparently materialize in the positions which they occupied relative to the photographic plate at the time of making the exposure. This occurs when accommodation is so adjusted that the projected reconstitution of the miscroscopic images is focused on the retinæ. From some viewing positions one filament will appear to overlap the other; a sideways movement of the head will cause them to separate, just as in viewing the original subject. The parallactic effect is two-dimensional, as may be seen by raising or lowering the head. If you move towards the images, they will increase in size until they become blurred as the near point of accommodation is passed. Finally, to quote Lippmann, to whom this experiment is due, "they will be behind your head."

Much research has been undertaken, particularly during the past decade or so, into the development of photographic systems embodying principles similar to those involved in Lippmann's simple experiment. Amongst the modifications which have been dictated by practical considerations, a few of the more important are: small spherical lenses or lenticulations as a substitute for pin-holes; cylindrical lenses or lenticulations for use in cases where parallax about only one axis is required, and lenticulated screens, grids and networks to enable three-dimensional pictures to be viewed without the disadvantages attendant upon the utilization of aerial images. Of these systems, those proposed by Zafiropulo (1934), de Lassus Saint Genies (1934) and Walus (1940) are amongst the most interesting, and were evolved primarily with the object of their application to stereoscopic kinematography.

The type of integral photograph which appears to offer the greatest promise of successful adaptation to radiography is that known as a *parallax panoramagram*, the nature of which we will therefore consider in some detail.

The principles involved in producing photographs of the parallax panoramagram type were first described by Kanolt in his U.S. Patent No. 1,260,682 (Application date, January 16, 1915). In the method favoured by Kanolt, a camera having a single objective of the normal photographic type is caused to move relatively to the subject or scene during the period of the exposure. The effect of this movement is to cause a continuously changing aspect of the subject to be presented to the camera lens. The movement takes place in a horizontal direction, at right-angles to the optical axis of the camera, and preferably in an arc the centre of curvature of which coincides with the "centre of interest" of the subject.

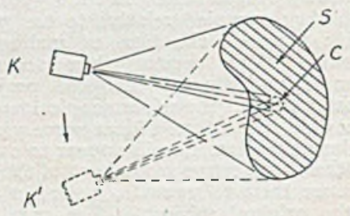

Fig. 4.—Photography by parallax panoramagram principle.

This is illustrated diagrammatically in Fig. 4, in which the "centre of interest" of the subject S is assumed to occupy the position denoted by C. At the commencement of the exposure, the camera is in some position such as K, and, while the shutter is open, the camera moves in an arc about C as centre, reaching a position K' by the time the shutter closes.

As will be appreciated, if an ordinary, unmodified camera were employed, this movement would result in the production

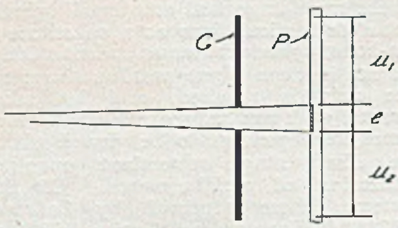

Fig. 5.—Production of parallax panoramagram.

of a blurred picture on the plate or film due to the superposition of an infinity of different images corresponding to the different positions of the camera. A grid, however, is interposed between the lens and the plate, in close proximity to the sensitized surface. This grid is of the same type as that used for viewing parallax stereograms; that is to say, it consists of a number of narrow, substantially vertical and parallel opaque strips, separated by transparent strips of considerably smaller width. During the period of the photographic exposure, relative movement is caused to occur between the grid and the plate, this movement being at right-angles to the longitudinal axes of the grid strips and to the optical axis of the camera. The total extent of the movement, during the making of one complete exposure, is equal to the width of a single opaque strip of the grid. Thus, as the camera moves continuously from one position to another, successive portions of the sensitized surface which have been exposed become shielded from light by the advancing opaque strips of the grid, while the adjacent unexposed portions become progressively uncovered. In this way the whole of the sensitized surface is exposed by the time the movement of the camera and the relative movement between the grid and the plate have been completed. Reference to Fig. 5 will make this more clear. The diagram represents the conditions existing at the commencement of the exposure, and shows, to a greatly exaggerated scale, the narrow, wedge-shaped beam which reaches the plate P through a single gap in the grid G. The

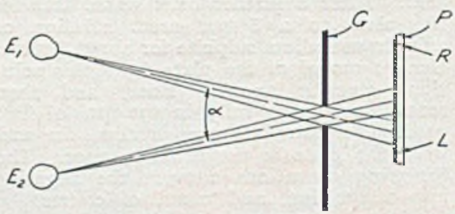

Fig. 6.—Orthoscopic viewing of parallax panoramagram.

portion of the plate which is being exposed at this instant is the narrow strip denoted by e, the adjacent unexposed portions being denoted by u_1 and u_2. Let us assume that relative movement between the grid and the plate is produced by causing the plate to move downwards in the plane of the diagram through a distance equal to the width of one opaque strip of the grid. Clearly, this will cause progressive exposure of the whole of the strip u_1 of the plate as a result of its passage through the light beam. In the same way u_2 and all similar strips will become exposed due to their movement through beams transmitted by the other gaps in the grid. This result may, of course, be achieved by imparting movement to the grid instead of to the plate. The latter method possesses certain practical advantages, and is the one usually adopted.

The photographic record on the plate may now be regarded as consisting of a series of vertical strips, each of width equal to the pitch of the grid, and each corresponding to a plane projection of a particular vertical element of the original subject. One edge of each strip represents the view of the corresponding element recorded at the commencement of the movement of the camera, and the other edge represents the view of that element recorded at the termination of the movement. Thus, each strip represents a view which changes progressively across its width from a "leftwards" aspect to a "rightwards" aspect, and is, therefore, a panoramic view of a narrow, vertical element of the scene.

Transparencies produced in accordance with this method exhibit both a panoramic and a stereoscopic effect when viewed through a grid of the same nature and pitch as the grid employed in the camera. The reason for this will be followed more easily with the help of Fig. 6. As in the previous diagram, G represents a much enlarged plan view of a small section of the viewing grid, showing a single transparent gap; P represents a small portion of the photographic transparency, and R and L denote respectively the extreme "rightwards" and "leftwards" edges of a single panoramic strip of the transparency.

Consider an eye in the position E_1 viewing the transparency P through the gap in the grid G. Let the eye move gradually from E_1 to E_2, and it will be evident that the view of the panoramic strip seen through the gap must change progressively from a "leftwards" to a more "rightwards" aspect. Assume, now, that E_1 and E_2 represent respectively the left and right eyes of an observer, and let α denote the angle of convergence of the optic axes. The disparity between the images seen by E_1 and E_2 will be the same as that between the images recorded by the camera at the opposite ends of an angular transverse equal to α. Hence a stereoscopic view results.

In practice, it is customary to arrange for the camera to traverse a distance somewhat greater than the interpupillary separation. A photograph is thus obtained which changes in aspect with lateral movement of the observer's head. This is an advantage not enjoyed by the use of any system in which the subject is photographed from only two viewpoints. If, for example, the observer in Fig. 6 moves his head to the left, that is, upwards in the plane of the diagram, we can see that the view presented to each of his eyes will become more "leftwards" in aspect, whilst the requisite disparity between the two separate images will still be maintained. The aspect of the view will, of course, change in the opposite sense if he moves his head to the right.

This brings us to a discussion of a further great advantage of the parallax panoramagram. Referring to Fig. 7, let us suppose that the observer moves his head laterally so far, say to the left, that his left eye sees a portion of a different picture strip to that seen by his right eye. The extreme "rightwards" and "leftwards" edges of the strip, a portion of which is seen by the left eye, are indicated in the sketch by respectively R′ and L′. This strip corresponds to a vertical element of the scene immediately adjacent that represented by the strip RL. Now, as we can see, the view presented to the observer's left eye E_1 is a "rightwards" aspect of the element R′L′, whereas that presented to his right eye E_2 is a "leftwards" aspect of the element RL. Consequently, the view obtained is now pseudoscopic. If the observer moves his head still farther to the left, the view will remain pseudoscopic until he moves so far that the line of vision of his right eye is also directed on to the element R′L′, whereupon the view will again

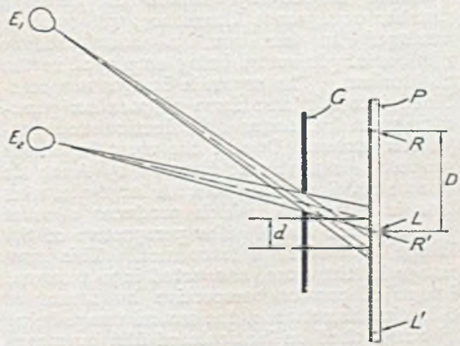

Fig. 7.—Pseudoscopic viewing of parallax panoramagram.

become orthoscopic. However, as will be seen, the distance through which the observer can move his head whilst still retaining an orthoscopic view is much greater than that over which a pseudoscopic view is obtained.

Let D denote the width of one picture element, and d the distance, measured in the plane of the transparency, between the observer's two lines of vision. Then the distance, again measured in the plane of the transparency, over which an orthoscopic view is obtainable is given by $D - d$, whereas that over which a pseudoscopic view results amounts only to d. Now D is equal to the pitch of the grid, and d, owing to the very small distance between the grid and the plate, may be taken as equal to the width of one transparent strip of the grid. Hence, if the grid has a ratio of, say, 5 to 1, we see that $D - d = 5d.$, or $D = 6d$. This means that the orthoscopic viewing zones are six times the width of the pseudoscopic viewing zones, instead of being of the same width as in the case of a parallax stereogram. In actual fact the mathematical relationship between the widths of the orthoscopic and pseudoscopic viewing zones is much more complex than this, but the foregoing simplitailing the photography of screened images —i.e., loss of definition and the necessity for lengthened exposure or increased intensity of radiation. Moreover, cameras of the parallax panoramagram type are somewhat costly instruments. Thus, whilst the photographic method is useful for special purposes, it cannot be regarded as ideal for general radiographic work.

We come, finally, to a discussion of radiographic methods. As in the case of photographic methods, simplification of the equipment and avoidance of image distortion are factors which favour the adoption of the moving-subject principle. Moreover, as we shall see presently, there is a further reason why, with high-intensity radiation, movement of the tube in radiographic methods is prohibited by practical considerations.

The sketch (Fig. 10) shows the essential details of a radiographic method of producing paraliax panoramagrams. Radiation from the source T, after passing through the subject S and the transparent strips of the radiographic grid G, impinges on the film or plate P. The grid is of the parallax panoramagram type; that is to say, the opaque strips are considerably wider than the transparent strips, a ratio of 4 or 5 to 1 being found satisfactory in practice. It is undesirable that the pitch of the grid should be coarser than about 1/50th of an inch. Unless the grid is very thin and, consequently, suitable for use only with radiation of low intensity, it must be angled in accordance with the usual practice, as indicated in the sketch. We can see right away, therefore, that in the general case where a comparatively thick grid is employed, production of a parallax panoramagram by movement of the tube is not possible because, as a result of such movement, the angles of incidence of the X-rays would no longer correspond with the angles of inclination of the grid strips.

Digressing for a moment, it may be mentioned that Snook's two-tube parallax stereogram arrangement is restricted by similar considerations to cases in which a thin grid can be employed. Snook suggested various forms of grid cross-section with a view to providing thick grids which would transmit an equal quantity of radiation from each of the two tubes, but it is extremely doubtful whether such grids could be manufactured with a sufficiently fine pitch to be of practical use.

Reverting to Fig. 10, it is necessary that the image of the subject formed on the film should change progressively in aspect by an amount corresponding to movement of the tube from some initial position T_1 to a final position T_2. This is achieved by causing the subject to move angularly from the position denoted by the broken line S_1 to that represented by the dotted line S_2. The angular movement of the subject is synchronized with lateral movement of the grid, the latter moving through a distance equal to the width of one opaque strip during the time taken by the subject to move from S_1 to S_2. An image of the parallax panoramagram type is thus produced on the film by direct, radiographic means. The same apparatus may be employed for the production of parallax stereograms if the grid be replaced by one having opaque and transparent strips of equal width. In this case, of course, two separate exposures must be made, as already described in connection with the photographic method.

The method of producing parallax panoramagrams which we have just discussed is evidently the most suitable for general radiographic work; the major disadvantages of the photographic method are absent, and there is no distortion due to tube movement.

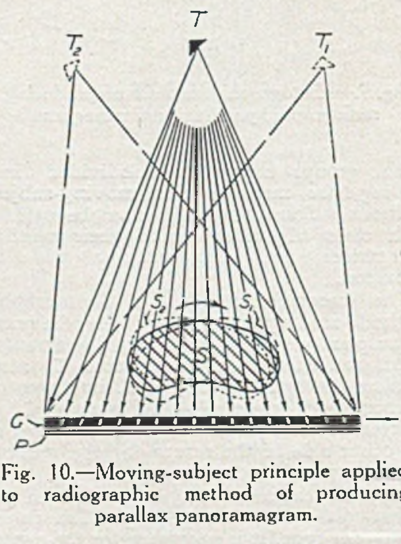

Fig. 10.—Moving-subject principle applied to radiographic method of producing parallax panoramagram.

The value of the information provided by stereoscopic radiographs may be greatly enhanced in many cases by the incorporation of stereoscopic scales. In medical radiography, for example, it is frequently necessary to determine the depth within the subject at which an affected bone or tissue is located, or the position of a radium needle. Suitable scales may be provided for use with any type of stereoscopic radiograph, such scales being viewed in superposition with the radiographs. The scale divisions appear to pass through different planes of the subject, thus enabling them to be used as reference marks for estimating the distances between objects in different planes. We are primarily concerned here, however, with radiographic parallax panoramagrams, so we will confine our attention to the use of scales with radiographs of this type.

There are many different forms which the scale may take; it may, for example, be so designed that, when viewed stereoscopically, it takes the form of a series of rings, each ring being at a different apparent distance, or a helix the axis of which is parallel to the viewing direction. We will assume in the present instance that the scale adopted is of the former type. The easiest, and at the same time the most accurate method of producing the scale is as follows:—

A three-dimensional model is constructed of fine wire or other material which is opaque to X-radiation. It is preferable for the rings to be of different diameters and so arranged that, when viewed radially, the shape of the model is approximately conical, as in Fig. 11 (left), and when viewed axially, the rings appear as a series of concentric circles, as in Fig. 11 (right). The distance between the centres of each pair of adjacent

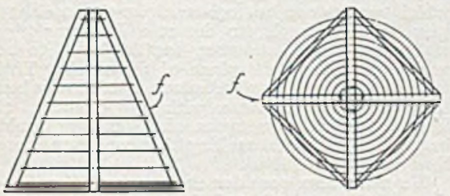

Fig. 11.—Model for use in making stereoscopic scale.

rings may be any convenient fraction of an inch or centimetre, according to requirements. The rings are supported in position by means of a framework composed of a material, such as a plastic, which is highly transparent to X-radiation. This framework is denoted in Fig. 11 by f.

Assuming that the moving subject method is to be adopted, the model is placed on the moving platform or carrier normally used for supporting the subject, and so positioned that the axis of the " cone " will coincide approximately with the central rays from the tube when the platform is at the mid-point of its traverse. A radiographic parallax panoramagram of the model is now made in the usual manner. The resulting negative is used for the production of a number of positive transparencies by direct contact printing.

The subject in connection with which a scale is to be used is now placed on the platform in the position formerly occupied by the wire model, and a parallax panoramagram is produced The tube-film distance adopted in radiographing the subject must, of course, be the same as that adopted in radiographing the wire model. Finally, the radiograph of the subject and one of the positive transparencies are superimposed and mounted behind a suitable viewing grid, whereupon both subject and scale are seen in stereoscopic relief.

The author desires to thank, first, Major R. L. Mansi, R.A.M.C., for the invaluable assistance which he rendered the author in his early experimental work connected with stereoscopic radiography. Of the numerous concerns which have assisted him by producing experimental equipment, sometimes under extremely difficult conditions, the author is particularly desirous of recording his appreciation of the painstaking work carried out by Mr. A. H. Compton, of Messrs. E. R. Watts and Son, Ltd., and by the Research Department of Messrs. Kodak, Ltd., in providing him with radiographic grids, and by Messrs. Cambar Engineering Products in producing the mechanical parts of his apparatus. Finally, he wishes to thank Drs. H. Foy and A. W. J. Houghton for their generous help and encouragement, but for which it would not have been possible to bring the subject of this paper to the attention of the Institute at the present time.

N.B.—Attention is drawn to the fact that the newly developed methods of stereoscopic radiography and the use of stereoscopic scales described in Part 3 of the above paper are covered by various British and foreign patents owned by the author.

Views of an Industrial Radiologist

L. R. Carr, Radiologist, John Dale, Ltd., analyses the technical and economic significance of Dudley's invention from the standpoint of the metallurgist and foundryman.

The techniques of stereoscopic radiography developed by Dudley and described in the preceding paper were evolved primarily with a view to their application in the medical field. It was realized at once, however, that they might prove no less valuable to the industrial radiologist; we therefore owe thanks to " Light Metals " and to the British Institute of Radiology for enabling these developments to be brought to the attention of the light-metals industry. It is believed that some comments by a metallurgical radiologist may be of assistance in assessing the value of these new stereo-radiographic methods in the latter sphere.

The problem of the location of defects is one which is constantly confronting the radiologist. In normal practice he attempts to solve it by taking a number of shots from different angles. This is often not wholly satisfactory, and it may be necessary to supplement radiographic evidence by cutting and polishing sections—a tedious process and one of rather a " hit or miss " nature. If one is looking for a fine defect, a single stereoscopic view could give more useful information than two or even more ordinary radiographs. It is true that a multiplicity of shots is often made necessary by variations in section thickness, and not only by the need for locating defects, but there can be no doubt that, on the whole, the number of shots required could be reduced by the use of a good stereoscopic technique.

In view of the fact that, in Dudley's method, the stereo radiograph, corresponding to a multiplicity of shots from different angles, is produced on a single film, an important economic advantage in the saving of film results, quite apart from the fact that such radiograph provides better information.

Radiological examination serves two purposes in a foundry: first, the development and control of casting techniques, and secondly, the inspection of finished castings. Of these, the first is the more fundamental, and in the future is likely to increase, relatively to routine inspection, in both quality and importance. In this development work the emphasis is on quick, accurate diagnosis and location of defects, and stereoscopy should be able to help the radiologist greatly in achieving this. There is, too, another advantage. Development and control obviously involve close co-operation between radiologist and foundryman. It is a good thing for the latter actually to see the radiographs, but with castings of complicated shape, it may be quite difficult, even for the radiologist himself to see whether defects are occurring and to piece together the evidence of shots taken at several angles. To be able to show the foundryman a clear stereoscopic view would be a big help in making this co-operation easy and effective.

Similarly, in the field of routine inspection, there are useful advantages to be gained. The sentencing of a casting often depends, not just on knowing whether a defect is present, but also on knowing its position. For example, blowholes are usually unimportant unless they will be broken into when the casting is machined. It is frequently difficult, however, to judge this without taking extra shots, and it may be more economical to scrap the casting than to do this. Stereoscopic radiographs could give much help in such cases, particularly if the suggested use of stereoscopic scales be adopted.

Enough has been said, although in rather general terms, to show the potential advantages inherent in the use of stereoscopic radiography. The technique, however, must produce radiographs of high sensitivity and definition; it must be adaptable to routine operations, and it must be economical. It is in these respects that the new method described by Dudley seems potentially so important. It has, of course, been possible for a long time to produce stereoscopic radiographs, but all the methods hitherto available which are known to the writer have been cumbersome and, in his opinion, certainly not suitable for large-scale application, as they involve two exposures on separate films taken with two different tubes or casting positions, and needing special viewing apparatus.

Dudley has described four main methods of producing the parallax-panoramagram type of stereo radiograph. A photographic method may be well worth developing for special cases. Examples which come at once to mind are the routine checking of the alignment of assemblies such as valves, and the replacement of screening by a process of stereoscopic "mass radiography." Screening is a fatiguing process, and with complicated castings can be very slow owing to the need for rotating the object into all possible positions relative to the X-ray beam. The tendency at the moment is to dispense with screening as much as possible, but there might well be great scope for a process which produced stereoscopic radiographs of the images produced on a fluorescent screen. It would give much more information than ordinary screening, and at the same time be more economical and rapid than orthodox radiography.

Of the four methods described, however, the moving-subject radiographic one seems much the more suitable for general application. The simplicity and economy of this technique compared with previous systems is most impressive.

The viewing of the film, too, is simple. It is placed on an ordinary viewing screen, together with a radiographic transparency of a grid of the same dimensions as that used in taking the radiograph. Seen through this grid the radiograph presents to the observer an image which stands out at once in its three-dimensional character. An interesting point is that a magnification of the stereoscopic effect can be produced by varying the distance between the grid and the radiograph.

The radiographic grid used in this process should help greatly to cut out scattered radiation, and this is a most important consideration in obtaining a high-quality radiograph. Furthermore, the continuously changing angle of the beam relative to the casting throughout the exposure may help in resolving fine defects which would not be registered in the ordinary way. For example, to detect a fine crack by radiography it is necessary for the beam to be nearly parallel to the plane of the crack. This is obviously rather a fortuitous condition when the radiograph is taken with one direction of beam only, but the rotation of the casting would help considerably in making this condition more likely to be satisfied.

We must also consider the economic implications of the method, and there seems to be one disadvantage in this respect. The use of the grid will certainly increase the exposure time required. It is estimated that about four times the normal is needed. In the case of light alloys where exposure times are short, this should not be a serious disadvantage, particularly in view of the other advantages to be gained. In the case of the heavier metals, where exposures are measured in minutes or even hours rather than in seconds, it is a more serious matter. In any case, this effect is minimized by the fact that instead of two or more exposures, only one may be necessary. Thus we have to balance the time taken for several exposures involving the delay in changing the film and resetting the casting, against that needed for a single exposure of four times the ordinary length. As an additional offset, there is the probable economy already mentioned, in the saving of film; a stereoscopic radiograph on a single film may replace several radiographs on separate films.

To sum up, it can be said that the use of stereoscopic radiography offers great potential advantages, and that the technique described and demonstrated by Dudley is a most important development. It provides the opportunity of using stereoscopic radiography to a degree which before has not been possible. It must be remembered that this judgment is founded on theoretical considerations and that only by practice can the real merits of the system be fully assessed. It is certain, however, that the method holds great possibilities, and recent news that the development of commercial models of the apparatus is shortly to be commenced is regarded as being of the utmost importance.

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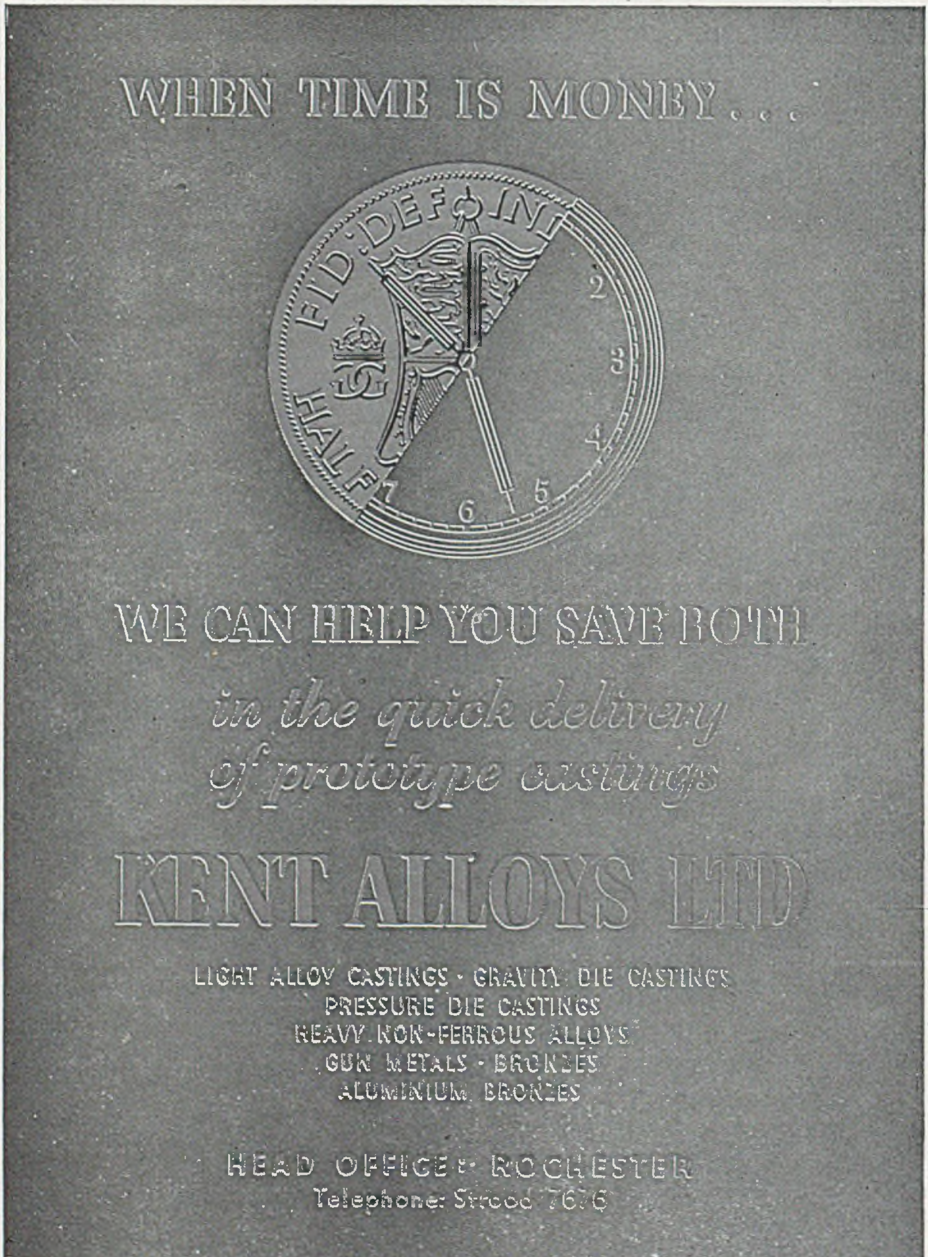
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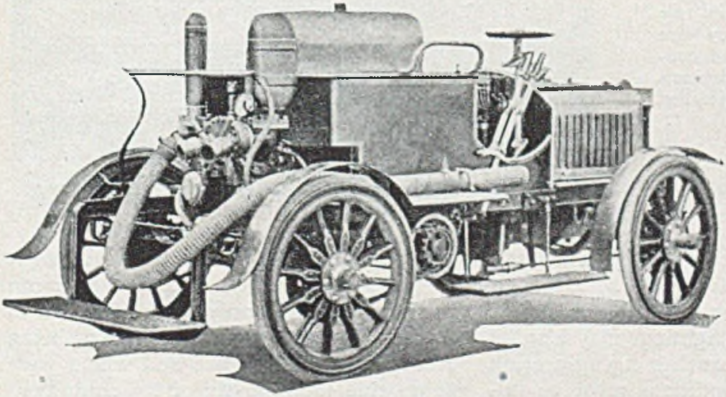
Light Metals in FIRE-FIGHTING EQUIPMENT

A Survey of the Theory and Practice of Applications of Light and Ultra-light Alloys in the Construction of Fire Escapes, Pumps and Miscellaneous Equipment

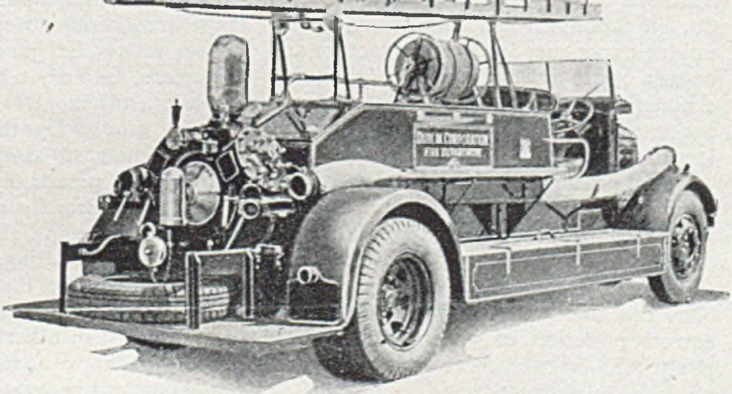
ALTHOUGH it is now over 40 years since light metals made their first appearance as constructional materials for fire-fighting equipment, their use in this connection is still not widely known. This may be due in part to the specialized character of this field, as a result of which technical advances which do not radically affect the appearance of the equipment are not likely to be brought to the notice of the public at large.

There are, however, at least two reasons why this state of affairs should be corrected, at least, in so far as engineers are concerned. The first reason centres on the fact that many of the applications



THE serviceability of light metal in fire-fighting equipment is demonstrated by the early petrol-driven outfit shown at the left. The pump body was cast in an aluminium alloy, and the apparatus was in regular use for 30 years.

(Courtesy, Merryweather and Sons, Ltd.)



CONSTRUCTED in 1937 for the fire department of Dublin Corporation, this fire engine features numerous aluminium-alloy components, amongst which may be noted the cast superlumin pump body.

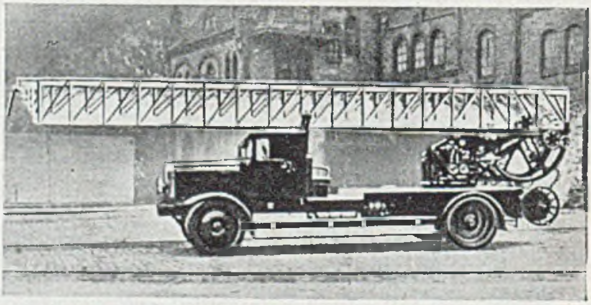
(Courtesy, Merryweather and Sons, Ltd.)

in fire fighting for which light metals have been developed with great success can be translated more or less directly into other fields of engineering practice, or, at least, can provide additional data on which to base the design of other light-weight constructional units. Long fire-escape ladders, for instance, possess a similarity of design to crane jibs and drag-line booms, and, although the first differ in so far as the full length must telescope into transportable divisions and also in that it is impossible to relieve the stresses in the fully extended structure by the use of guy ropes, nevertheless, proved designs may assist materially in the evolution of light metal booms and jibs.

However, the value of Superlumin and of other aluminium-base casting alloys has been proved by long-time service tests; specimens of equipment in aluminium casting alloys which have been in constant use for 18 or 20 years are in the possession of the Merryweather Co., and even the most rigorous examination has failed to detect any untoward deterioration due to corrosion or to the abnormally heavy service which many of the components are called upon to withstand.

The motive which prompted the commercial use of a metal, the properties of which were by no means so well known 40 years ago as they are to-day, was primarily that of reducing the deadweight of parts such as gearboxes and pump bodies, which had previously been cast in gunmetal, but which were then being greatly increased in size and which were hampering the mobility of the equipment by adding so much to its deadweight. Whilst an excellent material for the purpose in most other respects, gunmetal possesses a specific gravity of 8 and may, therefore, be unsuitable for use in highly mobile equipment. Superlumin has a specific gravity less than 3; it can be sand cast or die cast, and its mechanical properties are practically equal to those of gunmetal. Broadly speaking, the weight of components in light alloy is a third of that of similar fittings in gunmetal; occasionally it is less than a third, as in the case of the dividing breeching referred to later, whilst in other cases the ratio may be slightly more than 1:3 owing to minor modifications in design due to the different

SHOWN here is the aluminium - alloy fire escape designed and constructed for the Brussels Fire Brigade. It weighed 1,300 kg.



The second reason is that a special alloy has been evolved which, although designed primarily to satisfy the stringent requirements of fire fighting, may also be of value in other branches of engineering in which similar conditions must be fulfilled. Known as Superlumin, this alloy has been developed by the Merryweather Co. in London, which profited by its unique experience in the manufacture and upkeep of fire-fighting apparatus to evolve a material combining the qualities of corrosion resistance, mechanical strength and low density.

The operating conditions of fire-fighting equipment are generally beyond the control of the user, and the apparatus may be called upon to face not only the comparatively mild influence of mains water, but also the uncertain,. but usually highly corrosive, action of water drained from peaty soil, or even mine water, which is notoriously destructive.

casting properties, etc., of the light alloy. Table 1 compares the weights of typical Merryweather components in gunmetal and in Superlumin.

Table 1.—Comparison of Weights of Typical Components in Gunmetal and Superlumin.

Component	Gunmetal	Superlumin
Key and bar	—	4¼ lb.
Instantaneous coupling	6¼ lb.	2 lb. 6 oz.
"Brigade V" coupling	5 lb. 0.5 oz.	1 lb. 12.5 oz.
Branchpipe	5 lb. 1 oz.	2 lb. 6 oz.
Standpipe	23 lb.	7 lb.
Breeching	13 lb.	4 lb. 11 oz.

Evolution of Light Alloy Components

The earliest forms of fire-fighting equipment were constructed of wood, leather and riveted sheet iron, the pumps being hand operated and capable of delivering a quart or so of water per stroke to the height of a few feet. Extending escapes were unknown, and, indeed, rarely necessary, as tall buildings were then few in number. With the need for increasing the power and adaptability of the equipment came also the even greater necessity of increasing its speed of movement and, with the evolution of the petrol-driven motor pump and its displacement of the old horse-drawn steam-driven equipment, came a realization of the need for light weight.

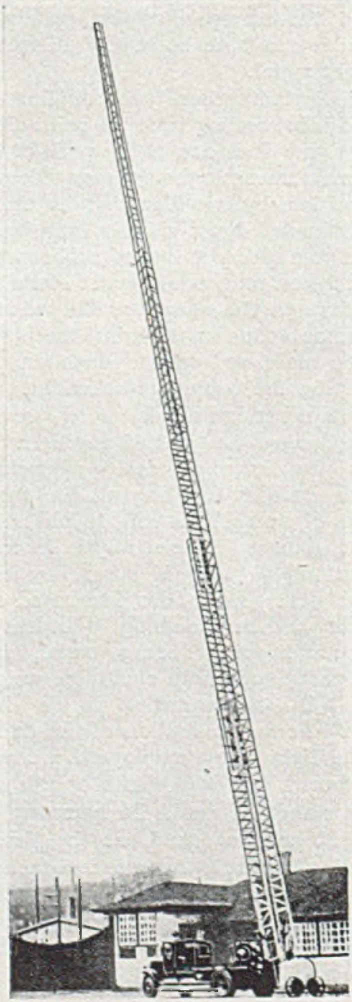
In 1904, the Merryweather concern constructed one of the new motor fire engines for Lord Rothschild, and included a gearbox and a pump body sand cast in aluminium-copper-zinc alloy. As the pump body normally formed one of the heaviest individual components in the structure, the saving in weight was very considerable. Performance was excellent, and this machine saw 30 years' service before being broken up.

From this beginning, numerous successful experiments have shown the value of producing many different components in light alloys. Some of these are illustrated. Light-alloy couplings and dividing breeches of various types are easier to handle owing to their reduced weight, and their use reduces the time taken in assembling the lines. Components such as these are generally produced by die casting. Particular interest attaches to the male member of the coupling, which is die cast complete with thread and is not machined in any way whatsoever. In cases where comparatively fine threads are employed, or where the component is of relatively small size, there is a danger of seizing when both male and female members are made of light alloy, due to distortion of the thread as the result of constant heavy use, and, in such instances, the smaller attachment is preferably made of gunmetal suitably threaded to screw on to its aluminium alloy counterpart. Large-threaded components or those provided with the special round thread specified by certain fire brigades can both be made satisfactorily in light metal.

The instantaneous type coupling illustrated is interesting from the point of view of design. It is one of the push-in type, the male member being engaged, when in position, by two diametrically opposed spring-loaded brass catches, and bearing down on a specially shaped rubber washer so designed that, when water starts flowing through the coupling, the washer is forced outwards tight against the junction of the male and female members, thus rendering the coupling watertight.

Certain fittings consist of two or more parts flanged and bolted together. The bolts are of heat-treated duralumin, which, besides fulfilling all the requirements of strength, is said to obviate the slight danger of electrolytic corrosion which might occur if other non-ferrous alloys were used. Also illustrated are a turnkey and bar weighing 10 lb. less than its counterpart in heavy metal, and a sand-cast Superlumin standpipe weighing only 7 lb., as against 23 lb. in heavy alloy. As an illustration of the ductility of the light alloy employed, it may be mentioned that the barrel of this light-alloy standpipe could be hammered flat without splitting, and, at the threaded coupling to which the hose is attached, it could be squeezed oval in a vice without rupture.

Pump bodies, which formed one of the earliest applications of light alloys in fire-fighting equipment, continue to be constructed in light alloy. Illustrated is a modern fire engine constructed in 1937 for the fire department of Dublin Corporation. The applications of aluminium alloys in this machine include the pump body, which was cast in Superlumin. Also illustrated is a motor fire engine constructed by Ferd. Schenk, Worblaufen-Berne, in which the pump body and the four outlet cocks are all of cast aluminium alloy. Aluminium alloy castings were principally employed for the pump of a portable pumping unit supplied for the use of the U.S. Forest Service and State Forestry Departments. This machine was capable of delivering 63 gallons of water per minute at a pressure of 100 lb. per sq. in., or 40 gallons at 200 lb. per sq. in. A portable pressure pump of German origin intended for use by the fire services incorporated several housings in cast magnesium alloy, whilst the carrier itself was made of welded tubes of Elektron AZM.



ILLUSTRATED above and at the left is the light-alloy fire escape of the Brussels Fire Brigade, shown in the elevated and fully extended positions respectively. The height of the escape, in the latter case, is 42 metres.

Ladders and Fire Escapes

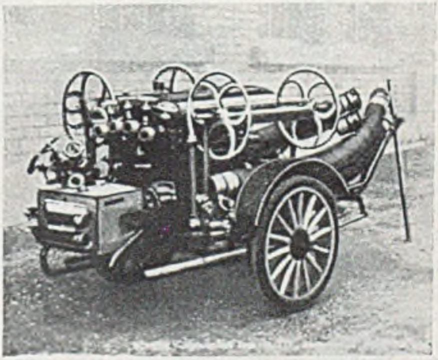
The use of light alloys for such appliances as fire escapes and ladders is, of course, of more recent date. The direct transference of designs adopted for steel to the fabrication of similar work in aluminium alloys was not possible and considerable research was necessary before really satisfactory designs were evolved.

Once achieved, however, the result revealed a striking combination of lightness and strength.

As an example may be considered the aluminium alloy fire escape illustrated which was supplied to the Brussels Fire Brigade. This particular ladder, in its fully extended position, was 138 ft. high, and while this was not as great as some of the longer crane booms which have been constructed in light alloy, the design presented some interesting problems owing to the necessity for the full length to telescope into transportable divisions, and to the impossibility of relieving the stresses in the extended structure by the use of guy ropes. The total weight of the ladder was 2,700 lb., of which 2,250 lb. was of aluminium alloy, the rest covering such steel items as operating equipment, wire cable, guiding rollers, and so on. The weight of an equivalent ladder entirely in steel was put at 4,250 lb., or 58 per cent. more. The advantage of lightweight construction in equipment of this type is obvious. In this case, a reduction of nearly three-quarters of a ton in the load to be transported by the truck was achieved, which very greatly contributed to the average speed and manœuvrability of the vehicle itself and to the speed of erection and manœuvring of the ladder. The lower weight also permitted it to be operated at a much greater angle of tilt, thus providing a substantially increased overhang without fear of overturning.

In the design of the ladder, a factor of safety of 10 was provided in the lowest section under the permitted load of 715 lb. at the top with the ladder inclined at 75 degrees, plus a transverse pressure due to a wind velocity of 22 m.p.h. For the upper sections, progressively higher stresses were considered permissible until, for the top section, the factor of safety was reduced to 6. Such factors of safety were considered sufficiently high to permit the occasional use of a temporary extension ladder, bringing the total height to 158 ft.

The behaviour of light-alloy ladders at elevated temperatures is not really relevant, as, if the temperature exceeds about 70 degrees C., the ladder cannot be gripped in the hands and is, therefore, unclimbable. Nevertheless, when the Brussels Fire Brigade ladder was being planned, it was considered desirable to investigate the behaviour of the light alloy under heat. A series of experiments was carried out which showed that, up to 200 degrees C. at least, there was no substantial reduction in strength, and this was considered as ample justification for the assumption that there would be no bending or collapsing of the ladder under reasonably severe conditions.



TRAILER pump auxiliaries, with pump body and four outlet cocks in cast aluminium alloy. (Ferd-Schenk, Warblaufen-Berne.)

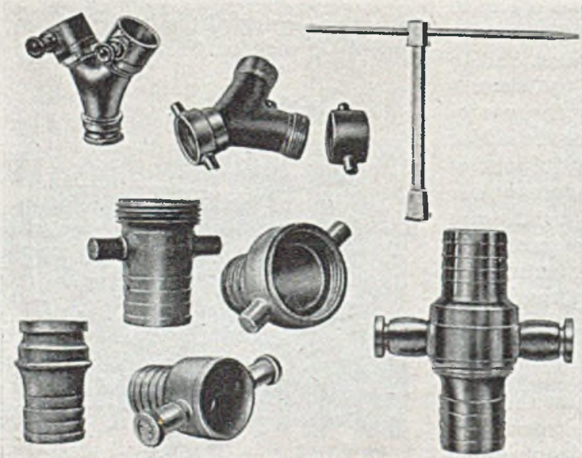
Further testimony was provided when the Stockton, California, fire brigade fought a vicious fire in the Washington Street Garage on January 31, 1940. This garage was a three-storey brick building, the upper stories of which were used as an auditorium. The hottest part of the fire was in the third storey, and aluminium ladders, made by the Duo-Safety Ladder Co., were used in removing scores of people. The chief officer reported that the fire provided ample demonstration of the superiority of the aluminium ladders over similar wooden equipment. The former were handled more easily with less manpower, and, at times, were loaded from top to bottom. They were not harmed by the fire, although one was badly twisted by a falling wall, but, in sharp contrast, a wooden ladder not far from the aluminium ladders had its top burned completely off.

The "Aluminium News Letter" of May, 1940, makes brief reference to the aluminium ladders used on the fire engines at Edgewater, New Jersey. The largest fire engine, with a pump delivering 1,500 gallons of water per minute at 120 lb. pressure, in addition to being equipped with aluminium alloy ladders, had a number of aluminium accessories, such as portable floodlights, nozzles, deck pipes, foam generators and fittings. Aluminium alloy was also used for the hydraulically operated ladders.

Three truck-mounted 100-ft. high aluminium alloy fire escapes have been supplied to the Washington District Fire Department. The factors which led to the choice of light metal for this application included freedom from splinters and from charring, elimination of the need for varnishing, and the fact that lower weight enabled the use of a smaller truck.

A pompier ladder used for scaling buildings under conditions where the use of an escape was not possible demonstrated the remarkable lightness with strength which can be achieved by properly designed light alloy-wood combinations. This ladder consisted of two wooden side members with wooden rungs. At the upper end was a toothed hook, made of duralumin, for engaging on window ledges or other suitable protuberances. The length of this ladder was 13 ft. 6 ins., its weight 17 lb. and its strength sufficient to carry two men.

Whilst interest has so far centred on the use of the aluminium alloys for this type of construction, it is significant to note that fire-escape ladders have been constructed by Messrs. Merryweather in magnesium alloy which, with a specific gravity only two-thirds of that of the aluminium alloys, is the lightest of all commercial structural metals.



Pictured in this group are: a "Brigade V" threaded coupling in Superlumin, weighing 1 lb. 12½ oz. as compared with 5 lb. for a similar unit in bronze; threaded and instantaneous types of dividing breeching in Superlumin; instantaneous - coupling assembly, weighing in all 2 lb. 6 oz.; light-alloy turnkey. (Cowling Merryweather and Sons, Ltd.)

Lightweight Helmets

Light alloys have met with official approval for the fabrication of firemen's helmets in at least one country within recent years. Writing in the German journal "Aluminium" (1939/21/531), Brinck gave the following requirements as being officially laid down with regard to Norwegian firemen's helmets: "The headgear should afford protection to the wearer against falling masonry as well as against possible electric shocks, and should be resistant to the effects of extremes of temperature and moisture." Tests were carried out by the Oslo Municipal Authorities on a number of materials, including steel, brass, leather, fibre, cork and light alloys. The last was found to be the most suitable, the choice finally falling upon an aluminium-manganese-magnesium alloy known as alloy 4S. The helmets were anodized, painted black and provided with interior fittings of leather.

An earlier reference ("Aluminium," 1937/19/417) refers to the fabrication of light-alloy helmets which were enamelled on the outside and padded with leather and cork inside.

In America, in 1938, the Cairn Corporation were producing a helmet of conventional design as a one-piece stamping from aluminium sheet. A lightweight ambulance for the use of firemen was also exhibited in America in March, 1938.

Amongst other miscellaneous applications of the light alloys in fire fighting may be cited an aluminium ramp, which was constructed in the U.S.A. in 1937 for use by fire brigades. The device was intended for placing over fire hose in streets so as to enable traffic to pass over the hose without damaging it. By this means it was hoped to prevent much of the congestion which prevails anywhere in the vicinity of a fire. The ramp itself was constructed of aluminium-alloy sections and formed a complete wheel track 8 ft. 6 ins. in width. It was articulated to allow any section to adjust itself to the camber of the road or to any unevenness of the surfaces.

Alloys of the Al-Mg-Si type have been used in the construction of portable liquid fire extinguishers intended for use in railway carriages and buildings of the German Reichsbahn. The container, which was of 8-litre capacity, consisted of a cylindrical vessel drawn in one piece from the light-alloy sheet. This was protected against corrosion by anodizing and subsequent coating with a stoving varnish. The cylinder contained the fire-extinguishing liquid together with air under pressure. Aluminium was also used in the actuating device, the striking of a knob resulting in the piercing of a thin aluminium sheet, allowing the liquid to escape. The use of light alloys in these applications allowed a weight reduction of 11 lb. to be achieved. Weight reduction is obviously of the utmost importance in the case of the larger types of portable fire extinguishers. Aluminium alloy pipes in 5 m. sections have been employed on the Continent for pouring foam on to oil fires.

Certain of these general applications are actually of considerable significance in so far as they concern apparatus not merely for use on land, but, conceivably, in the future, such types as may be embodied into civil aircraft. It is merely a truism, now, to refer to the value of weight reduction in this last connection; however, certain of the giant passenger-carrying aeroplanes now envisaged will incorporate equipment radically different from that needed for the smaller models with which we are acquainted to-day. Perhaps self-breathing apparatus, used in conjunction with aluminium-alloy oxygen bottles, represents one aspect of more modern advances.

Although originally developed some years ago, and investigated in detail on the mainland of Europe, less has been heard of light-metal bottles in this country than should have been the case. It is true the actual production of the bottles to the standard required to render their general use safe has not proved at all an easy task, but, here again, even prior to the outbreak of war, ample experience and the results of long-term field tests were available.

Rather unconventional is the employment of the heat generated by chemical action on aluminium to thaw out frozen hydrants. Caustic soda and aluminium chips in the proportion of 25 per cent. alkali and 75 per cent. aluminium by volume have been used for this purpose in America, as, in the presence of a small amount of water, a chemical reaction takes place which liberates quite a large amount of heat. From 2 to 4 lb. of the mixture is sufficient to thaw the ice in a frozen hydrant in less than five minutes. As used in Evanston, Illinois, the hydrant cap is unscrewed and the material is poured in on top of the ice. Flushing the hydrant immediately after it has thawed avoids the danger of chemical corrosion of the metal. The cost of materials has been reckoned between 60 cents and 1 dollar per hydrant.

Aluminium and Magnesium in the Electrical Industries

From "Light Metals," 1945/8/211, B. J. Brajnikoff Continues his Discussion on Light Alloys in Electrotechnology. Russian Work on Soldered Joints in Aluminium is Here Reviewed

THE adoption of aluminium as a conductor material in place of copper, has, naturally, given rise to a number of specific problems, the satisfactory solution of which should be considered as of primary importance to the growth of the aluminium utilization in electro-technology. From the preceding sections of the present survey it may readily be appreciated how, as a result of intensive research, many of the difficulties associated with certain peculiarities of aluminium and its electrically suitable alloys have been either mitigated, or wholly overcome, thus testifying to the fact that the main handicap is due not so much to shortcomings of the metal itself, as to inadequate familiarity with methods and technique in application.

Most of the early troubles experienced by the electrical engineer in this connection were centred on the problem of aluminium joints, whether in uniting exclusively aluminium components, or aluminium with some other metals, such as copper, effected by means of soldering or welding. The term soldering is understood to mean the process of joining metals with the help of any alloy fusible at a reasonably low temperature.

For a long time there was prevalent the view that aluminium was not amenable to soldering on account of the fact that the oxide film on the surface of the metal obstructs intimate metallic contact, and thus prevents effective inter-alloying in the process. This difficulty was aggravated by the circumstance that many of the substituents of the solder compositions suggested for the purpose proved to be unsatisfactory. Again, difficulties were experienced in connection with a certain unreliability of the electrical contact between the two aluminium surfaces, due to the interposition of the same oxide film, and owing to the liability of aluminium to electrolytic corrosion under the action of moisture in those systems, where it forms a galvanic couple on account of the contact potential difference of two dissimilar metals, as, for instance, in conjunction with copper.

Under these conditions, in an endeavour to do away with the operation of aluminium soldering, there was developed the mechanical joint, made with either twisted sleeve connectors (for joining small aluminium conductors), or clamps (for taps), and special aluminium clamps with copper bushings for joining aluminium to copper conductors. However, mechanical joints cannot be regarded as always entirely reliable, due to a great plasticity of aluminium, in consequence of which the contact may, in time, be destroyed.

Fig. 1 (above).—Soldered aluminium strip, 1 mm. × 24 mm. cross-section, after fracture in tension under a stress of 11.2 kg./mm.²

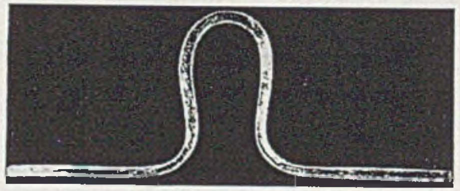


Fig. 2 (above).—Soldered aluminium bus bar, 4 mm. × 8 mm. cross-section, bent in the region of the joint around a 10-in. loop. Fig. 3 (above, right).—Photomicrograph of—soldered copper/aluminium junction.

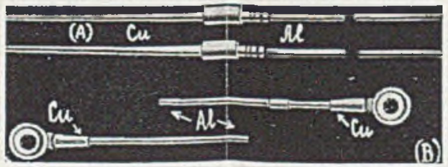


Fig. 4 (left).—Sleeve-soldered Al/Cu wire and Al wire with Cu ring terminal, before fracture in tension (A), and after fracture (B).

Bearing in mind these considerations, it is evident that the soldering and welding of aluminium occupy quite a special position in the technique of joining metals, as in this respect the decisive factors for aluminium are (i) the peculiar properties of the surface tending to hinder soldering or welding, that is, the formation of a thin but very dense film of oxide enveloping the aluminium in air, and its almost instant reappearance after initial removal; (ii) the degree of strength of the joint in regard to the influence of air, water, humidity, i.e. the stability to agents responsible for corrosion of an electrolytic nature.

Depending on the method of removing the oxide film, and the duration of service of the joint, there may be distinguished the following six methods for joining aluminium components: (1) soldering by means of rubbing with a low-melting, heavy-metal solder with or without admixture of aluminium (customarily known as a "soft" solder); (2) hard soldering or brazing with the aid of a high-melting solder with a large content of aluminium; (3) hammer welding (i.e., the jointing effected by means of a hammer); (4) autogenous welding, various types of electrical welding; (5) recrystallization welding; (6) reaction soldering.

In the soldering process by rubbing, and also in hammer welding, the layer of aluminium oxide is removed mechanically, whereas hard soldering and autogenous welding are characterized by chemical removal of the oxide film effected with the aid of a flux.

Historical

The oldest method for soldering aluminium was by means of rubbing. During the past two decades there has appeared a great variety of patent compositions for application by rubbing, under the designations of easy-fusible, pasting, casting, alloys, etc., but all suffer from this common defect, that the soldered joint is subject to corrosion in air or in

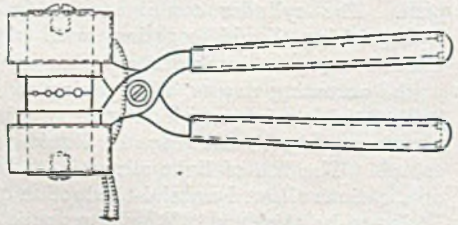


Fig. 5.—Hand-operated electrically heated pliers for effecting sleeve joints by soldering. Note provision for lines of various diameters.

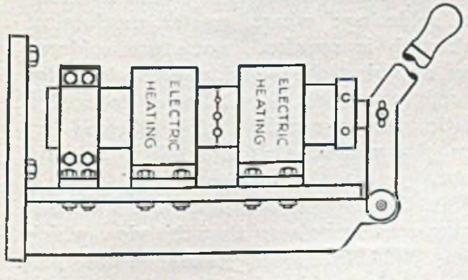


Fig. 6.—Hand-operated electrically heated portable press for effecting sleeve joints by soldering in aluminium wire. (See Fig. 5.)

the presence of moisture. A further drawback of soldering by rubbing is that it can be applied only to conveniently shaped and readily accessible parts.

To obviate these defects, attempts have been made to find a substance capable of dissolving the film of aluminium oxide and to act in a manner analogous to that of borax or " killed spirits " in the case of other metals. Such fluxes were employed in the U.S.A. in the late 19th century, for making joints with the help of a solder consisting of a large proportion of aluminium. However, the quality of joints produced was so poor that the process was largely abandoned.

The next notable development for joining aluminium came in 1900, when a hammer-welding technique for aluminium was patented by the Heraeus concern at Hanau, in Germany: the aluminium components (mainly in the form of sheet) were heated and united by means of hammering. Although this system proved to be quite effective as far as the strength of joint and its non-corrodibility are concerned, yet its practice required so much experience on the part of the operator that its application has found but little favour in industry.

Following this was worked out a method in which use was made of existing aluminium fluxes for soldering, but applying them to the process of welding. The process thus developed, and designated as autogenous welding, was patented by Schopp in Paris, with the subsequent transfer of his patents to the German manufacturing concern, Griesheim-Elektron. The advantages of autogenous welding are: in comparison with hammer welding—an appreciable simplification of the operation, and compared to soldering by rubbing—great strength of the joint and its anti-corrosion stability.

The drawback of the autogenous welding process is that it involves a high working temperature, as the parts to be joined must be heated up to the melting point of aluminium, in consequence of which, in bulky objects, there may be produced critical stresses leading to the formation of cracks, whilst thin sheet material can readily be burnt. Most important of all, it can be used on high-strength, heat-treated alloys to only a very limited extent.

The development of new, improved compositions as, for example, those patented by Rostosky, again attracted attention to the process of soldering and to the advantages that lower temperature working offers. However, the temperatures required are still rather high, for satisfactory fluxes begin to act only when strongly heated. It may be stated that, as a general rule, the soldering of aluminium by means of rubbing is permissible only in those cases where a strong and durable joint is not imperative. Mention should be made of the availability of special aluminium solders designed for special spheres of application. To this group belongs, for instance, compositions distinguished by their particular fitness to casting, whilst another grade is able to ensure minimum of discoloration and darkening at joints, etc. In joining aluminium to a different metal (e.g., copper, brass, iron), the customary practice is to employ the rubbing solders.

It is instructive to draw a parallel comparison between the soldering of aluminium by the application of a rubbing solder and joining it by means of the usual flux-containing process, the relative characteristics of which are presented in Table 7.

In repairing aluminium castings, it is frequently of practical advantage to employ the combination of both methods of soldering: where greater mechanical strength is required, parts are soldered by applying the standard technique for hard solder and then allowed to cool a little, lesser repairs being effected by rubbing while the object is still sufficiently hot.

In the light of what has been said, it may readily be seen that the view which was held for so long that aluminium cannot be soldered is, even now, not devoid of some foundation. Notwithstanding the notable successes achieved in this field during recent years, it should be borne in mind that even the present-day techniques for soldering light metals are still beset by complexities. Indeed, in the considered opinion of many cautious workers, the areas of soldered joints may be regarded as thoroughly dependable only on the following provisos: (1) purity of the metal itself (i.e., the aluminium sections to be joined), which should be free from admixtures of particles of foreign matter and local inclusions of other metals; (2) high quality of the solder composition; (3) the utmost care in the performance of the soldering operation; and (4) the subsequent absence of factors inducing corrosion of the soldered joint due to the electrolytic action. For these reasons, it is advisable to protect the soldered area by a coating of some appropriate varnish or other media neutral to aluminium and stable to weathering.

Aluminium Soldering in Electrical Engineering

From the preliminary analysis it is obvious that if aluminium soldering be considered a matter of consequence to industry in general, its technique of application to electrical-conductor materials might become an important problem. We have in view its use in connection with bus-bars, wires, cables, strip and sheeting stock and the like.

Whilst the utility of aluminium in these forms is gaining constantly increasing recognition, its rate of progress is still hindered to some extent by jointing problems. The various welding techniques do, of course, ensure perfectly dependable results, but cannot always be employed. Having regard to the difficulty under which the union of conductor materials has often to be effected, a great deal of attention and study has been devoted to the general problem of joints. Such difficulties, as typified, for example, by the cable splicing, are inevitable, due to the necessity of working in cramped positions, in moist manholes, and the lack of positive control of the workmanship in making joints. Analogous conditions are encountered in many other operations, whether done in the workshop, in the field, or, in fact, wherever the need of efficiency in the work of handling, jointing and installing the conductors themselves is the governing consideration. A chain can be no stronger than its weakest link, and the weakest links in a cable system are apt to be the joints, unless the latter are made with the greatest possible care. It is obvious, therefore, that the standard of reliability of the joint must be equal to that of any part of the conductor itself.

For all these reasons we will now consider more fully the problem of aluminium soldering with special reference to its applications to the electrical industry.

Table 1.—General Properties of Soft and Hard Solders for Aluminium according to Kostorky and Luder.

No.	Properties	Soft solders	Hard solders
1	Composition of solders	Zinc and tin, plus easily fusible heavy metals; often aluminium up to 20 per cent.	Larger proportion—aluminium, other metals up to 30 per cent.
2	Melting temperature	From 150 degrees to 450 degrees C.	From 540 degrees to 630 degrees C.
3	Specific gravity	From 5.5 to 9.0	From 2.7 to 3.0
4	Method of soldering	Using no flux, by rubbing of the solder for removing the film of aluminium oxide	With the application of specia fluxes
5	Method of heating	Naked flame, soldering bit	Soldering furnace or lamp
6	Stability of soldered areas of the joint	Stable in the absence of corrosive agents (e.g., air, water solutions)	Mechanically strong, stable to corroding agents (at par with the stability of aluminium)
7	Colour of the soldered joint	Darkening on account of corrosion	Stable

Selection of Solder and Flux

As pointed out before, the soldering of aluminium is attended with specific difficulties associated not only with the selection of a solder sufficiently and easily fusible, and, at the same time, stable to corrosion, but also in the effective removal of the layer of aluminium oxide from the surfaces to be joined. Thus, for example, in the case of soft soldering, the removal of the alumina film is only possible by mechanical means. If such methods are feasible and readily performed on a plane surface which is easily accessible, their use in connection with surfaces of a cylindrical or more complex configuration presents considerably greater difficulties, and in some instances becomes practically impossible of realization.

The present-day position of the soldering technique can best be assessed from the results of recent work on the examination of methods for soldering aluminium conductors, accomplished under the direction of Usoff at the Russian Electrotechnical Institute. As pointed out before, the systems available fall into two principal classes: (1) soft soldering, with the aid of low-melting solders, and (2) hard soldering, by means of solders having a high-melting point. According to Kostorky and Lüder, both classes of solders are characterized by the properties summarized in Table 1.

The advantages of soft solders are: their easy fusibility and the possibility of using the soldering iron for their application, and the relative simplicity of the process requiring no application of flux.

The chief drawback of soft solders lies in their low resistance to corrosion, for which reason the soldered joint must always be protected by a coating of varnish or other medium. In the opinion of Kostorky and Lüder, it is, in general, impossible to obtain easily fusible solders for aluminium without impairing their properties to resist corrosion.

The method selected for jointing operations at the Russian Electrotechnical Institute was that based on the use of soft solders, for the reasons that the soldering of the aluminium conductors in erection or repair work should be accomplished, as far as possible, in an easy and simple way, such as is possible in the case of soldering copper conductors by means of tin compositions without high temperature, and involving the use of no complicated tools.

The number of available soft solders for aluminium is legion, with an equally large variety in their composition. Consisting in most cases, mainly, of zinc and tin, they have, besides, admixtures of one or several other metal constituents added to lower the melting point to facilitate adhesion to, and union with, the surface of aluminium to be joined, and to improve the mechanical and corrosion-resisting properties of the solders.

The constitution of the most known solders for aluminium is given in Table 2.

The multitude of solders available and a mounting number of newly marketed formulations, testify to the fact that, as yet, there exists no really satisfactory and universally accepted alloy, the status of which is comparable to that of the tin/lead series. By inspection of Table 2, we see that the principal base of the soft aluminium solders is, in most cases, a combination of zinc-tin alloys, in which the proportion of tin predominates. It should be pointed out that as a soldering medium for aluminium, tin, taken alone, is one of the worst possible agents, a circumstance still further emphasizing the unsatisfactory position of the aluminium joints.

As may be observed from Table 3, at the Russian Electrotechnical Institute there have been subjected to testing 20 different types of aluminium solders prepared by Usoff and his team of research workers on a zinc-tin base, with the addition of the following metals: nickel, copper, silver, aluminium, bismuth, cadmium, lead and antimony. In the shape of suitable castings, the solders were tested for hardness, breaking strength, nature of fracture and microstructure, with parallel measurements of their electrode potentials and fusion temperatures, accompanied also by determinations of their technological characteristics. These last comprised ability to "tin" aluminium and copper, as well as the possibility of application by means of the soldering iron.

Moreover, soldered joints in aluminium plates, effected with the help of the solders, were subjected to the corrosion tests by immersion in 3 per cent. common salt solution, followed by tests of their resistance to rupture.

Appraisal of the Test Results

The results of the tests demonstrated that solders prepared on a zinc base (viz., pure zinc and its binary alloys with nickel, copper, silver and aluminium) are all distinguished by the possession of a relatively high melting point, starting to fuse only in the neighbourhood of 400 degrees C., great hardness, and a coarse fracture, testifying to their brittleness. These solders are characterized by difficulty of performing the jointing process with the aid of the soldering iron and by their inability to "wet" copper.

Solders on a zinc-tin base, on the contrary, are much more easily fusible, less hard, and have a finer fracture. A binary zinc-tin alloy, consisting of 45 per cent. zinc and 55 per cent. tin, which served as a base for most of the solders subjected to the tests, is characterized by marked ability to wet the aluminium with simultaneous removal of its oxide film, a feature that ensures the strength of the soldered joint. This type of solder is equally well capable of tinning copper, owing to the presence of free tin in the eutectic mixture.

The last-mentioned factor permits the application of compositions on a zinc-tin base to soldering of aluminium with

Table 2.—Composition of Aluminium Solders for Industrial Use.

No. of solder	Tin %	Zinc %	Aluminium %	Lead %	Copper %	Other admixtures to the solder %
1	83.0	—	17.0	—	—	—
2	82.0	—	11.0	—	—	Manganese 2, nickel 5
3	78.3	19.0	2.4	0.3	—	—
4	76.0	21.0	3.0	—	—	—
5	73.0	21.0	—	5.0	—	—
6	70.0	25.0	2.0	—	—	Phosphorus 1.5
7	70.0	16.0	10.0	—	—	Tin phosphide 4
8	65.6	12.2	1.0	17.4	3.1	Phosphorus 2
9	63.0	18.0	13.0	1.0	3.0	Antimony 2
10	63.0	31.0	3.0	—	—	Tin phosphide 3
11	63.0	35.0	0.3	—	1.7	—
12	62.5	12.5	6.3	12.5	—	Phosphide of tin 6.2
13	62.0	12.0	4.0	8.0	5.0	Bismuth 5, cadmium 4
14	61.6	15.2	11.2	8.3	2.5	Antimony 1.2
15	60.0	8.0	4.0	12.0	4.0	Silver 12
16	60.0	25.0	2.0	—	10.0	Cadmium 3
17	60.0	—	30.0	—	—	Antimony 10
18	55.0	33.0	11.0	—	1.0	—
19	55.0	23.0	2.0	—	—	Silver 5
20	49.1	20.3	—	26.0	—	—
21	46.0	23.0	15.0	—	8.0	Silver 9

copper, an operation of great utility in electrical technology, for instance in joining to aluminium conductors terminal contact pieces made of copper and the like.

Performance tests on a zinc-tin solder have shown that additions of bismuth, cadmium, antimony or lead have exhibited no specially marked and beneficial influence upon the final product. It has been observed that bismuth lowers the melting temperature of the solders, and also the larger the cadmium content the poorer the quality of the resulting joint. Finally, lead and antimony play no significant role in the process.

A definitely favourable influence has been revealed by the incorporation of silver, the addition of which noticeably improves the grain structure as shown by the fracture of the specimens and the mechanical properties, particularly ductility, as can be judged from results presented in Table 4. The admixture of copper as a substitute for the equivalent proportions of silver in a zinc-tin solder gave quite inferior results.

Corrosion tests in 3 per cent. salt solution of soldered joints on aluminium plates, made with the help of various compositions, have also demonstrated that the best qualities belong to a zinc-tin-silver mixture. After testing by immersion for 300 hours, aluminium plates united by means of this solder displayed a very slight corrosion in the area of the joint, and, under tension, broke elsewhere than at the joint.

Table 3.—The Composition of the Solders Examined.

No. Ordinal	No. of solder	Composition of solders. Proportion of constituents, %		
		Zinc	Tin	Other metal components
1	7	100	—	—
2	18	99	—	Nickel 1
3	17	99	—	Copper 1
4	19	98.5	—	Silver 1.5
5	16	95	—	Aluminium 5
6	4	45	55	—
7	5	45	54	Bismuth 1
8	11	28	70	Bismuth 2
9	8	75	20	Bismuth 1 Cadmium 4
10	6	39	55	Bismuth 1 Cadmium 5
11	3	40	55	Cadmium 5
12	2	35	55	Cadmium 10
13	1	25	55	Cadmium 20
14	9	43.5	55	Silver 1.5
15	20	43.5	55	Copper 1.5
16	12	36	60	Silver 2
17	14	40	50	Bismuth 2 Lead 5
18	13	40	50	Bismuth 5 Lead 5
19	15	20	50	Antimony 5 Lead 26
20	10	2	96	Silver 4 Aluminium 1 Silver 1

Particularly poor results were shown by aluminium strips united by means of cadmium-containing solder (Cd in proportions from 5 to 20 per cent.) or by a solder very rich in tin (with Sn up to 95 per cent.); some specimens in these cases fell apart along the soldered joint during the course of the corrosion tests.

In the soft soldering of aluminium, and dispensing with the use of flux, removal of the alumina layer is done mechanically under the molten solder by means of a metal brush, or by rubbing with the soldering iron. In this case too, however, the application of flux is also desirable, since the latter, by destroying the film of aluminium oxide, simplifies the operation. It is to be noted that the use of energetic solvents such as mixtures of chlorides and fluorides in the soft-soldering process is impossible, on account of the high melting point of these fluxes, the fusion temperatures of which lie within the range 560 degrees to 600 degrees C. Furthermore, it should be remembered that the application of such reagents necessitates the careful removal of residues after soldering, with a view to averting the corrosion of aluminium. This washing operation is by no means easy, and, in many cases, even impracticable. In soft soldering, the substances employed as fluxes are usually certain organic acids, which, if they do not totally obviate the necessity for mechanical removal of the aluminium oxide film, none the less, do appreciably facilitate it.

According to Usoff's experiments, very favourable results are obtainable by the use of stearine. Corresponding tests performed by this investigator have shown that stearine at temperature levels of 400

Table 4.—Influence of the Addition of Silver on the Properties of a Zinc-tin Solder for Aluminium.

Main composition of the solder: Tin, %	Main composition of the solder: Zinc, %	Amount of addition of silver, %	Resistance to rupture, kg./mm.²	Diminution of the cross-sectional area, %	Brinell hardness	Structural appearance of the fracture
55	45	—	7.0	24.0	17.0	Large-grain
55	44.5	0.5	7.0	23.5	17.5	Large-grain
55	44	1.0	8.0	36.5	20.8	Small-grain
55	43.5	1.5	8.3	48.0	20.2	Small-grain

degrees C. and over effectively assists solder to dissolve the layer of aluminium oxide, without mechanical intervention.

In Table 5 are given the characteristic properties of the zinc-tin-silver solder, which was used at the Russian Electrotechnical Institute for soldering aluminium conductors.

Methods for Soldering Aluminium Bus-bars, Strips and Wires

The joining of aluminium strip with the help of zinc-tin-silver solder is easily accomplished, after a little practice, by means of the soldering iron. For considerations of strength, the specimens were, in the investigations being described, lapped, producing a joint in which the faces of the two pieces are superimposed for a length eight to ten times the thickness of the material.

First of all, the surfaces to be united, previously cleaned by emery cloth, were coated with stearine, followed by application, with rubbing, of zinc-tin-silver solder by means of the soldering iron until they had attained a mirror-like appearance. After firmly clamping the parts in the proper position, final jointing was effected by heat conveyed by the iron. The soldering of aluminium strips to those of copper was performed in an identical fashion, the surface of the copper piece, prior to jointing, being coated with tin.

The soldered joints obtained in this manner proved so strong that, in tension, fracture took place usually in the annealed area near the joint, but not at the junction itself. (See Fig. 1.)

Thin aluminium bars (say, 4 by 8 mm. cross-section), used for the winding of transformers and permitting of no thickening at joints, were butt-soldered by chamfering the two ends by filing to an angle of 45 degrees. The procedure adopted for butt-joining was similar to that described in connection with the lap-soldering of strips, that is, the butts, duly prepared, were united with the aid of the zinc-tin-silver solder by means of a soldering iron.

Fracture of test specimens in tension occurred along the soldered joint, but at stresses very close to those for the clear unsoldered part of the bus-bar, thus:—

The unsoldered aluminium bus-bar, 9.81 kg./mm.²

The soldered aluminium bus-bar, 8.38 kg./mm.²

The soldered joint in aluminium bus-bars was also capable of withstanding bending around a loop of the 5 mm. radius, as indicated in Fig. 2.

It should be noted that proficiency in soldering in this manner, so as to make accurate and uniform joints throughout a continuous run of bus-bars, free from objectionable knots, requires considerable experience on the part of the operator.

It has been found that the soldering of aluminium conductors of circular cross-section by means of the soldering iron is impossible, as the rubbing of the solder on the cylindrical surfaces proved so laborious as to be completely impracticable in the field.

As a result of a number of experiments, Usoff and his team have, in this case, adopted the method of sleeve soldering, in which a connecting aluminium tube is employed to enclose the parts to be joined. Special hand tools were designed to facilitate this operation. (See Figs. 4 and 5.)

The procedure consists of the following stages:—The ends of the aluminium wires to be joined are first carefully cleaned with emery cloth and put butt to butt in the connecting sleeve, made of aluminium tubing, or shaped up from the aluminium sheet. Next, in the sleeve so prepared there is sprinkled a composition containing 95 per cent. of the powdered zinc-tin-silver solder and 5 per cent. of powdered stearine. After this, the sleeve, together with the inserted conductors, is placed in the groove of the soldering tool (see Fig. 4), heated up to 500-550 degrees C., and then subjected to pressure through the handles or hand lever.

Table 5.—Properties of Zinc-tin-silver Solder for Joining Aluminium.

No.	Nature of tests	Characteristic properties
1	Composition of solder	Tin 55%, zinc 43.5%, silver 1.5%
2	Temperature of melting	From 190° to 400°C.
3	Resistance to rupture	From 8 kg./mm.^{2} to 10 kg./mm.^{2}
4	Diminution of cross-sectional area	From 37% to 48%
5	Brinell hardness	From 20 to 30
6	Fracture	Small-grain structure of matt appearance
7	Electrical potential (in 3% solution of common salt)	0.83 volt
8	Potential difference in a couple: Aluminium–solder Copper–solder	 0.282 volt 0.828 volt
9	Resistance to corrosion	Under certain conditions subject to corrosion, but to a lesser degree compared to all examined solders. Requires protective coating with varnish
10	Technological features	Solder readily wets aluminium, also copper, gives strong soldered joints, allowing application of soldering bit
11	Soldering temperature	Within range from 500° to 550°C.
12	Microstructure	Zinc plus eutectic zinc, tin, dendrite-like inclusions (solid solution of zinc-silver)

With a certain amount of practice, a satisfactory soldered joint can be accomplished within 5 to 10 secs. Owing to pressure, the solder (prior to melting) is forced into intimate contact with the surfaces of both the aluminium wires and the sleeve, and, by fusion therewith, as well as by filling all the clearances around the sleeve edges, forms a continuous, integral metal union. This method is applicable for soldering both single wires and stranded aluminium conductors.

Special practical importance attaches to the case, when the aluminium conductor has to be soldered with copper, in which event the latter, prior to joining, should preferably be thoroughly tinned. The soldering of copper terminal pieces to the aluminium wires (in order to ensure perfect electrical contact) is made in the same manner, the role of the connecting sleeve being performed by the tubular stem of the copper end-piece itself.

Microscopic examination of the copper-aluminium joint reveals that the solder is strongly bonded to the aluminium, which fact is testified by the absence of a marked boundary line between them; the union of aluminium with copper is effected through the medium of the Cu_3Sn, which, in the form of a tenacious layer, is produced in the process of soldering by tin-containing solder. Table 6 summarizes data on the electrical and mechanical performance of the composite aluminium and copper conductors thus soldered.

The results of these tests indicate that, although in most cases the conductivity of the united material is somewhat lower than that for the corresponding individual metal segment of the same length, yet the mechanical strength of the joint is sufficiently great, as rupture invariably takes place not along the seam, but at an integral area of the metal, as illustrated in Fig. 3.

Analogous results have been displayed by soldered joints in stranded aluminium conductors, such as cables, etc. Besides those indicated, soldered wires have been subjected to alternating-bend fatigue tests, and have been examined for breaking strength at elevated temperature, and for resistance to corrosion. These tests

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Table 6.—Electrical Conductivity and Resistance to Rupture of Soldered Aluminium and Copper Wires.

Cross-sectional area of wires		Length of test-piece, mm.	Electrical resistance		Breaking strength, kg./mm.^{2}	Region of Rupture
Copper, mm.^{2}	Aluminium, mm.^{2}		The calculated value for continuous (jointless) segment, ohms.	The value for soldered segment, as found by tests, ohms.		
1.56	1.65	200	28.5	26.9	9.9	At an integral area of aluminium conductor
1.56	1.66	200	28.5	25.4	10.1	At an integral area of aluminium conductor
1.9	2.3	200	21.3	19.6	9.1	At an integral area of aluminium conductor
1.9	2.4	200	20.8	19.2	9.9	At an integral area of aluminium conductor
9.9	13.0	200	3.9	3.64	11.9	At an integral area of aluminium conductor
9.9	13.0	200	3.9	4.03	12.0	At an integral area of aluminium conductor

have revealed that in the case of alternating bending loads at frequencies of 100 per second, the soldered joint remains intact, rupture taking place at an integral metal area in the neighbourhood of the seam. A noteworthy feature is that the soldered joints exhibit the ability to withstand rupture up to 200 degrees C., the wire finally breaking at an unsoldered point.

Tests on soldered joints in aluminium wires have confirmed that the resistance to corrosion of the zinc-tin-silver solder is relatively favourable. However, this by no means indicates complete immunity to attack, as by its nature, this solder is not entirely free from such a possibility, and, for this reason, should never be used without an added safeguard in the form of a protective coating of some anti-corrosive medium.

After a series of experimental tests, it has been found that the most suitable composition for the protective coating of aluminium soldered joints proved to be the benzoamylone varnish of the following constitution: benzoamylone resin, 35 per cent.; alcohol (95 per cent.), 22 per cent.; remainder 43 per cent. benzene. This varnish can be either air dried, or stoved at 130 degrees C.

In the light of experimental results, it is clear that the soldering method developed is suitable for joining both aluminium conductors (single and stranded wires) with each other, as well as for soldering aluminium to copper conductors, and other components.

(To be continued)

Table 7.—Technique of Aluminium Soldering.

Soldering by rubbing (earlier method, employing no flux)	Ordinary soldering (newer method, using flux)
The mechanical removal of film of aluminium oxide by means of rubbing with a molten solder	The removal of the layer of aluminium oxide by chemical action of a suitable flux
The soldering is effected with the aid of any rubbing solder (i.e., a composition not freely running), which is fit to be used for pasting, casting, etc.	The soldering process is effected with help of an easy-flowing solder, having a large proportion of a given metal, initially designated as a "hard" solder
Difficult method of operation and aggravated by: Low strength; corrosion phenomena (of electrolytic origin) of the soldered joint; discoloration of joint area and its tendency to darkening	Simple method of operation, offering advantages of: Great mechanical strength; absence of corrosion phenomena in the joint; the colour of the united area is practically identical to that of aluminium and is not subject to changes
Consequently: The application of the method is justifiable only in a restricted number of cases	Therefore: The method can be employed always to advantage

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NEWS—General, Technical and Commercial

Trade and Technical Press

IF the Trade and Technical Press of Great Britain can draw any consolation from the turmoil of the past five years, it surely must be this: that its function as a definite part of the industrial organization of the country has been amply demonstrated. Government Departments concerned with production of every sort have not hesitated to rely for much immediate and valuable assistance on information which editorial staffs alone can give. Equally embraced, however, within the rigid stranglehold imposed upon industry, the technical Press has, with the rest, suffered many needless restrictions.

Periodicals, the primary aim of which is to mirror the desires, aims, and achievements of trade and industry, are no ephemeral growth; their beginnings may be traced back very early on in the uprising of our own commercial expansion. We ourselves cannot, at the moment, recall the precise beginning, but would point out, for example, that a journal devoting its interests to railway engineering was firmly established prior to 1840. As new branches of industry have been established, so, too, invariably, has an organ appeared to establish a link between the new development and the public it serves.

Never before in the history of this country have our national resources been so mobilized to a single end as during the past five years. The transition from peacetime activities to those of war was effected with extraordinary rapidity, for all the tenets of economic law were cast overboard, and the jobs which had to be done were tackled regardless of cost in money, manpower, or wear and tear on plant. Study of war-time issues of trade and technical journals shows well how these assisted towards the fulfilment of what might otherwise have been a well-nigh impossible task.

War, however, is, at worst, a temporary phenomenon, and, even in the midst of battle, an eye must always be kept open for the requirements of an eventual peace—a peace not satisfactorily to be achieved by dignified disregard of all established precepts of profit and loss.

The trade and technical Press, which willingly came forward when its services were demanded for the sterner duties of the field, has an even greater duty to perform in stabilizing our industrial organization for peace. This it can do, however, only if freed from the mass of controls at present encumbering its activities, and by a wholesale removal of the vast body of pettifogging restrictions imposed by a list of ministries too numerous to detail.

Given the necessary facilities, now unhappily lacking, publishers of British technical journals are ready, able, and eager to produce publications which, in content and appearance, may certainly compare favourably, in war or peace, with those of any country in the world.

After nearly four years of extraordinary difficulties, during which it has carried on its work with a basic ration of approximately one-fifth of pre-war consumption, the trade and technical Press require from the Government:—

(1) Additional paper of a quality which will stand comparison with that used, for example, by competitive journals abroad. The actual quantity is not great.

The additional paper is needed so that both editorial contents and manufacturers' announcements can be greatly extended, advertisement pages in a technical or trade journal being an integral part of the whole essential to the reader.

It is further needed, as, at present, publishers are unable to meet the demands of any new readers.

(2) The early release of a small number of skilled operatives for the manufacture of high-grade paper, for printing, and, in particular, for block-making, which constitutes a serious bottleneck. Quality and quantity of illustration and free availability of colour where desired are essential to creating a favourable first impression, particularly abroad.

(3) The early release of experienced technical and trade key men to supplement editorial staffs.

(4) A high priority for the provision of new and up-to-date printing machinery. Labour and material involved are relatively small.

(5) The release of full information on the many new discoveries and inventions that British scientific research has evolved and British technical skill developed during the war.

A policy of etxreme caution on the part of Government departments has on occasion resulted in the release of information abroad ahead of its release in this country. As a result, credit for scientific development and inventive genius has not always been given where it belonged.

(6) The close collaboration with the

Government at home and its commercial representatives abroad, which has long existed in other countries, in particular the U.S.A. and Germany. No consultation with industries should take place without representatives of the trade and technical Press, which is in the best position to review any industry dispassionately as a whole.

Quality Through Statistics

ANY book that seeks to popularize the subject of statistical quality control must needs receive careful consideration. In "Quality Through Statistics"* Mr. Wharton attempts a non-mathematical, practical guide to quality control statistics to demonstrate to those "engaged upon production the usefulness of statistical methods in improving manufacturing quality."

The fundamental theory of statistics is, of course, highly mathematically technical, and the author appears to believe that the production executive, of very limited mathematical equipment, can usefully apply its methods; with this view the present reviewer agrees. It is not necessary to study the academics of harmony and composition to become a workmanlike pianist, although it is quite likely that the intelligent and inquisitive musical amateur will explore the more popular works on such subjects, admittedly becoming in the process a more understanding musician within the terms of his own limitations. Similarly, those desirous of using statistics in industrial production may capture more and more of the mathematician's mind as they popularize to themselves the underlying mathematical theory.

Authors, such as Wharton, have to decide initially to what extent they will simplify mathematical concepts in order that the ideas may be grasped by the non-mathematician. One would have wished that the author had spent more space on distribution curves, for it is on their significance that the whole subject is based. The idea of distribution curves is not in itself difficult to anyone who understands what a graph is. The derivation of the mathematical expressions defining distribution curve-forms is another story, and is not of practical importance for our purpose.

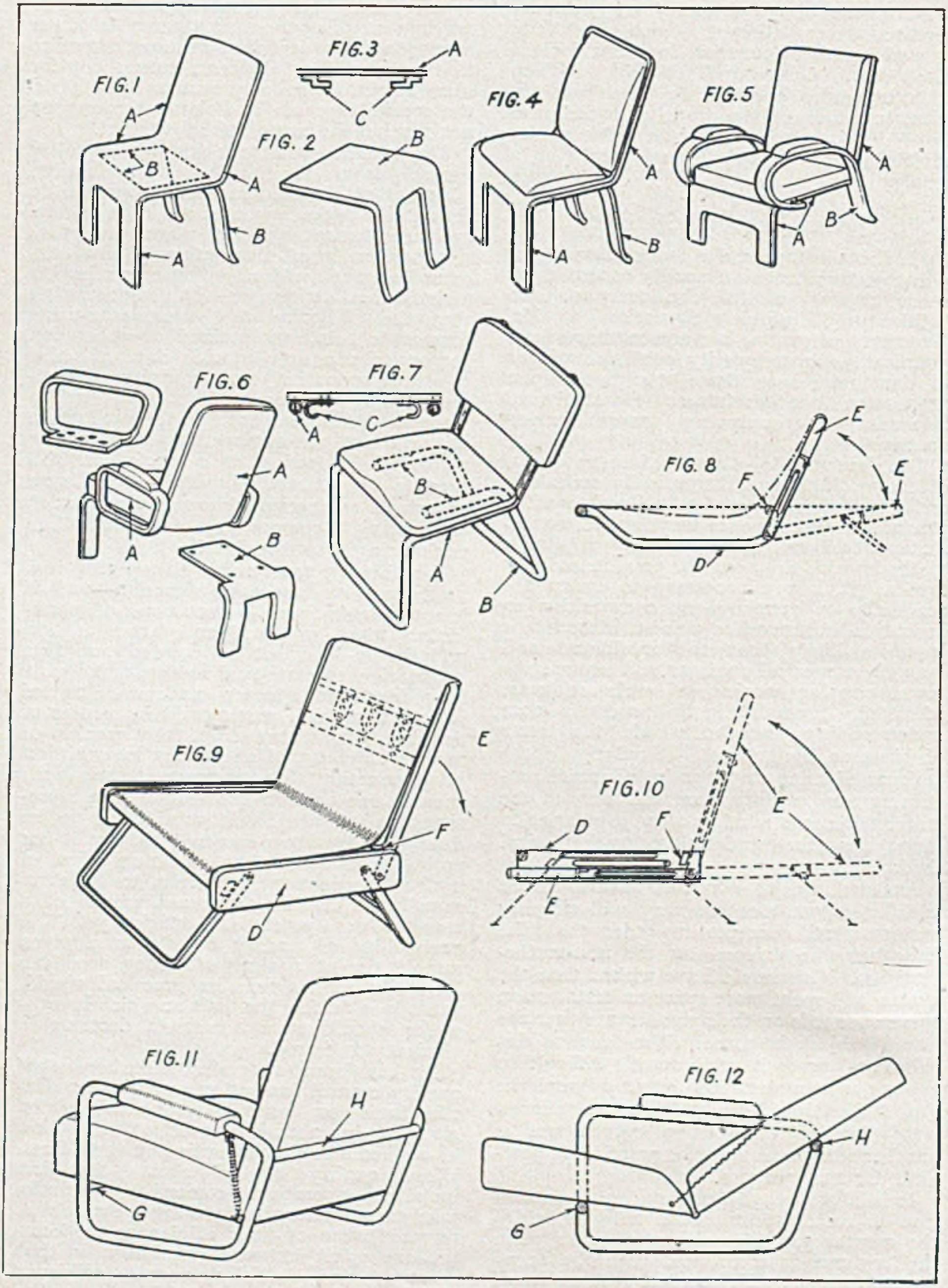
It is suggested that more adequate attention to distributions would help to bridge the mental gap that seems to occur when the beginner is confronted with the apparently distinct quality control systems based upon gauging and on measurement. The system based upon measurement is never even popularly described without reference to the Normal or Gaussian curve, but for some reason probability curves based upon the special case of the Poisson theorem do not receive the same publicity.

The present volume deals with quality control from the angle of production, whereas, of course, the usual approach to the subject is the inspectional. These views are complementary, for when statistical methods are used, inspection is not concerned so much with acceptance or rejection of individual articles as with demonstrating that the efficiency of the manufacturing process is being maintained or otherwise. Inspection can now provide data of value to the production and planning departments, and statistics will in future find a place in the studies both of the production engineer and the engineer-inspector. The status of inspection as a profession will thereby be ultimately raised, and a new branch of engineering known as inspection engineering, comparable to production engineering, can be visualized.

Whether or not quality engineering is a production or inspection function—and it is conceivable that different types of manufacture make any hard and fast allocation undesirable—it must be pointed out that application of statistical methods undoubtedly leads to greater understanding of scientific method, particularly in respect of drawing conclusions from the results of sample batching. Unnecessary interruption of production for process investigation, because one or more individuals in a representative sample batch was found to be defective, has often occurred because it has not been realized that anything short of perfect production is likely to give to samples of the bulk the appearance of a much lower production efficiency. The probability of finding defects in a given sample size at a given efficiency level can be easily ascertained; its practical significance is in setting the limit at which investigation should start because a decrease in efficiency is feared.

It has been suggested elsewhere that quality control inspection provides a scientific basis for bonus payments. Wharton gives an interesting demonstration of how he applied a quality incentive on these lines. When quality control charts are first installed, operatives somewhat naturally take great interest in watching the graphical representation of their efficiency; the competitive spirit between operatives is thus aroused, and initially overall efficiency improves. In the case cited by the author it was considered worth while to maintain operators' interest by making a payment for every plotted point falling below the statis-

* By A. S. Wharton. Philips Lamps, Ltd., Century House, Shaftesbury Avenue, London, W.C.2. Price 6s. post free.



ILLUSTRATED here is a series of designs for chairs in light metal as described on the next page. Each has been evolved to simplify and cheapen production by taking full advantage of readily available semi-manufactured forms such as sheet, strip, tube, and extruded sections.

tical limit on the control chart. The same amount was deducted when the plotted point fell on the control line, a slightly larger amount being deducted when the point came above the control limit. This quality bonus scheme operated separately from the normal production system in use. Rejects were spectacularly reduced by this simple means.

Can quality control methods of inspection or production be applied to light-alloy foundry work: this is a question that is bound to be asked by readers of this journal. A simple method applied to the results of pressure testing has been described recently,* but doubtless many applications can and will be made with the exercise of some ingenuity. It is realized that the successful production of light-alloy castings depends upon the control of many variables: wherever quantitative values can be given to such factors, statistical investigation and charting may follow. Daily correlation of these charts with defectives would possibly suggest the critical factor responsible for lack of success in the production of any part number, and hence in this way the quickest possible remedial steps might be taken.

Wharton's little book, then, is a readable description of quality control methods fulfilling the claim that it is non-mathematical; perhaps its chief value is that it is suggestive of ideas for possible applications. "Quality through Statistics" is therefore complementary to the official handbooks on quality control since they are almost solely concerned with the mechanics of control chart operation.

Light Metal Chairs

PREVIOUS issues of "Light Metals"† have dealt at some length with the design and construction of furniture in aluminium and light alloys generally. In the articles referred to, opportunity was taken to indicate that the nature of these materials and their availability in numerous semi-manufactured forms make possible, in some cases, the creation of new and simplified designs and, in others, enabled the practical realization of what were formerly vague outcomes of wishful thinking.

The extent to which these statements are borne out in practice is illustrated by the patent summary which follows, and by the illustrations accompanying this note.

Figs. 1 to 6 show chairs consisting of two components made of plate or sheeted material: the component A is continuous and forms the legs, seat, and back of the chair, whilst the rear component B is of angular shape and is secured to the underside of component A. Fig. 3 illustrates a front elevation of the seat proper, provided with brackets C, for receiving the top part of the component B, which may extend over the area of the whole seat. This design favours the mass production of formerly constructed chairs, which do not require cross rails interconnecting the two components concerned. Furthermore, the two principal components A and B are so shaped that they can be readily stacked when disconnected, thus facilitating storage and transport. (Patent application No. 7658/44.)

In Fig. 7 is illustrated a chair which, by way of example, is shown to be composed of tubular material; the principles involved are similar to those just described and the front elevation of the seat shows hooks into which the top part of component B is inserted. (Patent application No. 6466/45.) Self-adjusting hammocks are shown in Figs. 8 to 10; they consist of a frame D and a pivoted back E, a canvas strip connecting the front of D with the top of E. The rear of frame D is provided with stops F, which limit the forward angle of E, if the hammock be occupied, whilst the backward rotation of E is limited only by the length of the surface material by unfastening one end of the canvas: the seat and back frame can be folded.

Fig. 8 shows a side elevation of a garden lounge constructed of tube and strip; again, this assembly may easily be taken to pieces by removing the front connecting rod and the back frame, thus facilitating transport and storage.

A metal deck chair with folding front and rear legs is shown in Fig. 9. One end of the canvas is seen to be provided with strips for detaching it from the frame and for regulating the length of material, which, in turn, determines the range of the rearward movement of the back. Fig. 10 presents a diagrammatic view of the deck chair, showing it in the folded and unfolded positions. Besides being of a design making for comfort, considerable space saving is effected and many of these chairs may be packed into a small car for picnic purposes. (British Patent 550,469.)

Figs. 11 and 12 illustrate an adjustable chair in two positions; the upholstered seat and back are hinged together and jointly suspended at the rear of the frame by tension springs, whilst the front of the seat and the back are freely supported on cross-members G and H respectively. If a load be applied to the seat of the chair, the upholstery and suspension springs automatically adjust themselves in a vertical direction, whilst, in addition, the seat and back also take up positions depending on the degree of pressure and the directions from which it is applied.

* "A Method of Statistical Quality Control Inspection of Light Alloy Castings." By F. A. Allen. "Foundry Trade Journal," January 4, 1945.

† See "Light Metals," 1942 5 240; 241; 243.

Light Alloys in
Rectifiers, Photocells and Condensers

Continuing from "Light Metals," 1945/8/254, a Detailed Survey of Fixed Paper Condensers. A Comparative Study is Presented of the Uses of Tin Foils in Various Forms, and of Aluminium Foils

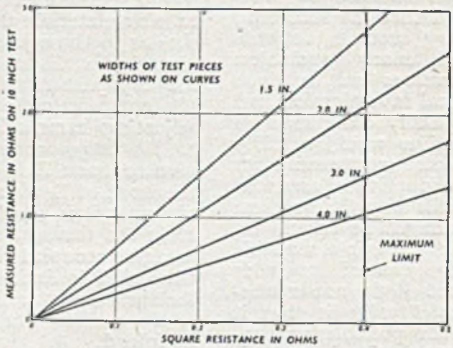


Fig. 176.—Relationship between measured resistance of 10-in. test lengths of tin-foil paper and its square resistance.

THE concluding paragraph of the previous section of this account introduced practical considerations regarding the supply and conditions of delivery of tin-coated papers. Here, over and above general requirements dictated by the delicate nature of metal foils, special precautions must be stipulated by reason of electrical requirements and of condenser - production technique.

The salient features from a typical purchasing specification for tin-coated paper are given below:—

(1) The material required is a high-grade of condenser interleaving tissue paper coated on one surface with metallic tin.

(2) The paper base to be a linen rag stock, the paper to have a smooth surface, free from ragged edges, and to be free from pin holes, slime, spots, crossed fibres, metal particles, carbon spots or other extraneous inclusions.

(3) The metal coating to be pure metallic tin, firmly secured with starch or dextrin base adhesive. The tin coating to be smooth, bright, uniform and continuous, to exhibit no inclusions of zinc, carbon or other impurity, and to reveal no bare patches.

(4) The uncoated surface of the paper to be as free from tin particles as practicable under conditions of good commercial practice.

(5) The adhesion of the tin to the paper to be complete, and such that it cannot be removed mechanically by scraping, scratching or folding, nor under conditions of hot impregnation with wax or oil.

(6) The tin-coated paper to be closely neutral in reaction, showing a neutral reaction to litmus and no evidence of inclusions of carbon or detrimental metals when tested as follows:—Samples of the material, moistened with distilled water and in contact with litmus papers (red and blue), shall be pressed between glass plates for 10 mins. At the end of the period, examination shall show no evidence of colour change in the litmus paper. Further, there shall be no signs of white areas developed in the tin coating.

(7) The pH value of the material to be between 6.5 and 8.5 when tested as follows:—

On a 2 gm. sample of the material shall be poured 100 ml. of pure distilled water, and the mixture shall be simmered for 10 mins. The water extract shall be decanted, evaporation losses made up by adding hot distilled water. The solution shall be rapidly cooled and the pH value measured by indicators or electrometrically.

(8) The water content of the material,

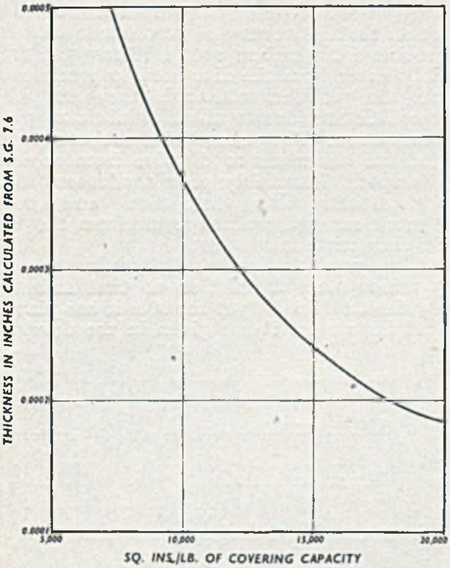


Fig. 177.—Curve showing relationship between covering capacity and thickness for tin/lead-alloy foil.

determined by loss in weight of a sample when dried to constant weight at 100 degrees to 105 degrees C., to be not more than 5 per cent. by weight of the material as received.

(9) The alcohol soluble material extractable with hot alcohol in a Soxhlet apparatus in a period of 6 hrs. to be not more than 0.5 per cent. by weight of the material as received.

(10) The water soluble material extractable with hot water in a Soxhlet apparatus in a period of 6 hrs. to be not more than 1 per cent. by weight of the material as received.

(11) The thickness of tin coating, expressed in terms of lb. of tin per double crown ream (480 sheets, 20 ins. by 30 ins.), to be within the following limits:—

Minimum ... 4.75 lb.
Maximum ... 5.25 lb.

(12) The electrical resistance expressed in terms of square resistance to be not more than 0.4 ohms. It shall be measured on a representative number of rolls, and on three specimens from each roll. At least 2 yds. shall be discarded from the commencement of the roll and from between specimens for the test. The test pieces shall be 12 ins. in length and of the width of the roll. Resistance shall be measured on a 10-in. acting length or on suitable fixture with the specimen clamped between copper strips as the upper members of the clamp and rubber strips as the lower. The leads to the resistance bridge shall be of copper and soldered to the copper clamps. The tin-coated surface of the specimen shall be uppermost, i.e., in intimate contact with the copper clamps. The square resistance is calculated from the measured resistance in ohms from the following relationship:—

$$\text{Square resistance} = \frac{\text{Measured resistance in ohms} \times \text{Width in ins.}}{10}$$

If the measurement be not made at 15.5 degrees C., a temperature correction is necessary.

The square resistance can most readily be computed from charts for the various widths of metallized paper involved. These charts relate the measured resistance in ohms of the 10-in. acting length of the test specimen to the square resistance value in ohms, and show the limiting maximum line. Typical curves are reproduced in Fig. 176.

(13) The tensile strength of the material in the roll direction to be at least 10 lb. per mil. of thickness per inch of width of test piece.

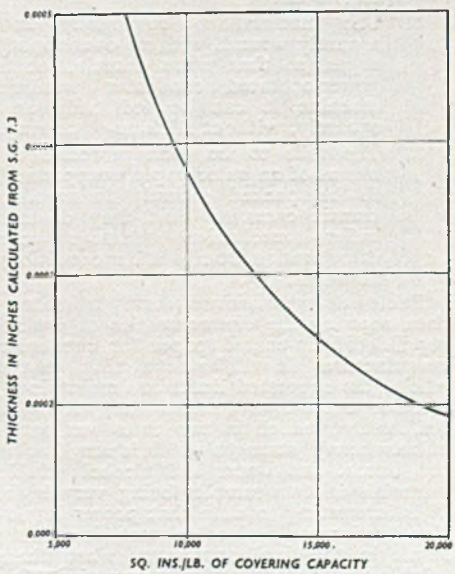


Fig. 178.—Curve showing relationship between covering capacity and thickness for tin/3 per cent. antimony-alloy foil.

(14) The elongation, on a 7-in. acting length, to be not less than 1 per cent.

(15) The substance of the tin-coated paper in the condition as received, and expressed in terms of a weight basis of grams per square metre of area, to be not less than 24.0 and not more than 28.0 gm.

(16) The tolerance on thickness to be plus and minus 10 per cent. of the specified nominal thickness.

(17) The tolerance on width to be plus and minus 1 per cent. of the specified nominal width.

(18) The material on any spool to consist of a single length with no breaks, although a maximum of five joints shall be permitted. Jointing to be achieved without a break in the conductor path, with an inert adhesive in conformity with the other clauses of the specification and without contamination of, or adhesion to, adjacent layers in the roll.

(19) The arbor upon which wound to conform to stipulated requirements, e.g., to be of wood and have a square hole of $1\frac{3}{8}$ ins. side plus and minus $\frac{1}{16}$ in., in order to suit the machine and expanding mandrel upon which used.

(20) To suit the machine upon which used, the overall diameter of the roll not to exceed a limiting diameter, e.g., 8 ins.

(21) The material to be tightly and squarely wound, with no overlapping edges, so that when unreeled on a power-operated condenser winding machine it can be fed truly and squarely, without sticking or tearing.

(22) The rolls to be each protected by means of an outer paper wrapper and to be packed securely in wooden transit cases so that they do not suffer mechanical damage nor deterioration from weather conditions in transit.

Table 34 summarizes some laboratory data showing the characteristics of typical supplies of tin-coated paper for condenser manufacture. It will be noted that, on the whole, the suggested limits are maintained. Notable exceptions concern the weight of tin coating, which in two cases was particularly heavy, strength which is very low in one batch, and water and alcohol soluble materials in two samples being very high. It is interesting to note that poorer insulation resistance values almost invariably result in the final condensers when these soluble extracts are markedly excessive. This is probably due to the retention of moisture and the impossibility of drying so thoroughly in the condenser process under a given set of process conditions. Another point that is worthy of mention is that of trouble from carbon spots. These presumably enter from the zinc used to precipitate the tin powder, although they may be graphitic and due to machine lubricant contamination. They cause local action or cells and the tin tends to dissolve from around the spot. Invariably poor condensers with exceptionally low insulation and poor electric strength values result from the use of such material.

Although this tin-coated paper has to take a minor place in relation to that assumed by the metal foils, yet the rôle it has played and the service it has given in the development and production of paper condensers must not be belittled. It is really a remarkable product, combining features of dimensional accuracy, thinness, chemical purity and, above all, continuity of electrical conductance. Again, the advantages in its use, set against the disadvantages are worthy of record, viz.:—

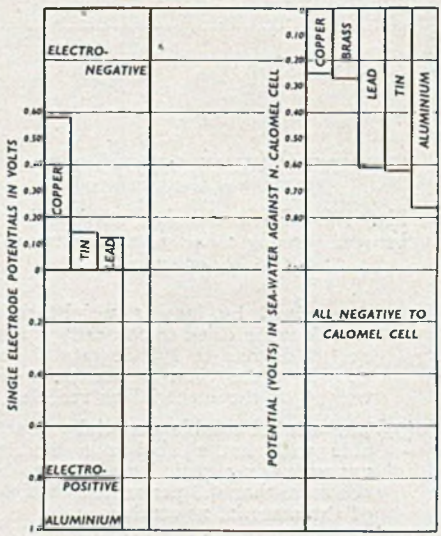
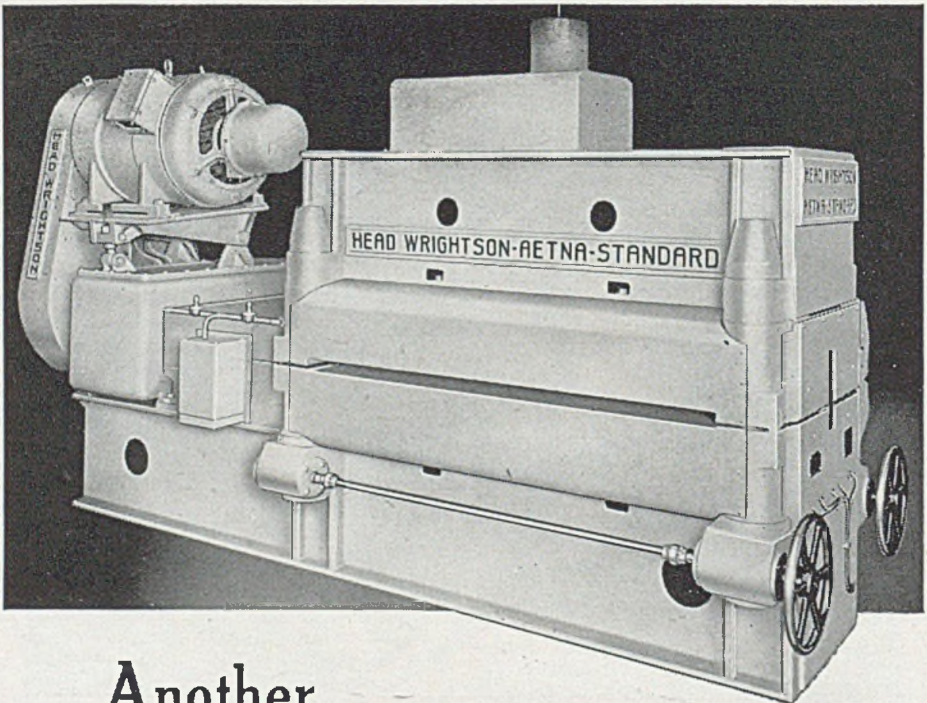


Fig. 179.—At the left: electromotive series. *It should be pointed out that in the absence of practical "field" results and of exact data regarding size, shape, conditions of contact, etc., of various metallic couples, all hypotheses as to type, degree and speed of corrosion must be treated with the greatest reserve.* At the right are graphed potentials in sea-water against a normal calomel cell. The precautions to be taken in interpreting these data are equally as stringent as those authorized above, if misleading conclusions are to be avoided.

Advantages.—(1) A condenser that uses



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the tin-coated paper-type of electrode, upon electrical breakdown, does not develop a dead short circuit, but it still possesses an appreciable internal-resistance value at voltages below those at which arcing occurs.

(2) The tin-coated electrodes enable such condensers to behave more efficiently than metal-foil electrode condensers, when in spark quench circuits. This is accounted for by the lower insulation resistance value of such condensers, and the higher electrical resistance of the tin coating compared with that of metal foil.

Disadvantages.—(1) When tin-coated paper is employed, the insulation resistance of the condenser is relatively low and, moreover, it is difficult to maintain a uniform level of insulation resistance over the product in mass production.

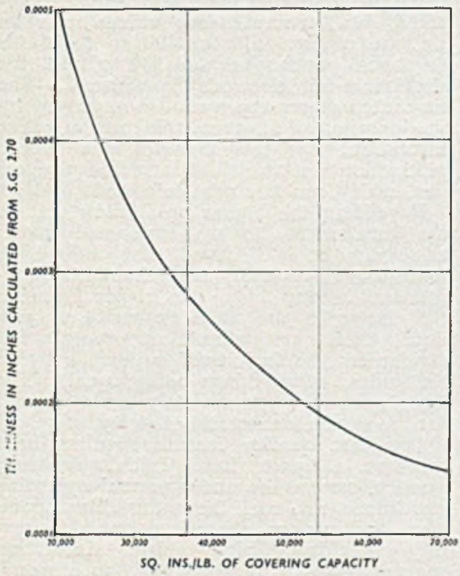


Fig. 180.—Curve showing relationship between covering capacity and thickness for aluminium foil.

(2) The actual electrical breakdown voltage is lower than that which can be obtained with metal-foil condensers; other things, of course, being equal.

(3) Manufacturing costs are rather higher generally when tin-coated paper is used than when metal-foil is employed.

The nature of the electrical breakdown in a tin-coated paper electrode condenser warrants brief consideration in comparison with that occurring in a metal-foil electrode condenser. This is necessary to get this property in its proper perspective and to avoid overrating the value of this characteristic. In a metal-foil electrode condenser, electrical breakdown is simultaneously accompanied by complete fusion of the electrode at the point of area of failure. The structural upset in the neighbourhood is impressed through the thickness of the condenser, so that a number of adjacent layers fuse and weld together. This behaviour is the same for any type of metal-foil electrode, viz., tin or aluminium. As a result, the insulation resistance of the condenser falls immediately from a value of the order of thousands or tens of thousands of megohms to one that is literally nil, i.e., a value that is immeasurable and of the order of a fraction of an ohm. On the contrary, with condensers constructed with tin-powder-coated paper electrodes, the phenomenon is distinctly different, and it is dependent upon the voltage stress at which the rupture occurs. In any case, the breakdown level of these condensers is lower and, in point of fact, breakdown will often occur at quite a low voltage. Such a failure will generally clear itself completely when the voltage is reapplied and, moreover, the voltage can be raised to within the region of the normal breakdown value before breakdown is again experienced. Undoubtedly such breakdowns are due to the individual particles of metal-foil that embed themselves into the paper, thus giving shorter paths through which the voltage stresses are operative. The resealing, it is speculated, is due to the fact that the burnished tin coating still retains the characteristics of tin powder, perhaps with a very thin oxide film surrounding each metal particle. As a result, the period of breakdown is not sufficient for the coalescence of these individual tin particles into a fused and welded mass. Such a property of self-healing is an obvious major advantage in a condenser of this type. On the other hand, there appears to be no disadvantage in the absence of this phenomenon in a metal-foil electrode condenser, because the cause of a failure of this type is not present, and the failure does not occur.

When the tin-coated paper electrode condensers are operated at high voltages, rather different factors enter. When the condenser is broken down under these conditions, the failure is not evidenced by a complete short circuit with an insulation resistance value of a fraction of an ohm. Thus condensers broken down at, for example, 1,000 volts, the insulation resistance value may still be of the order of 100,000 ohms or more, when measured at low voltages. At the high voltage level the condenser continues to behave as though completely short-circuited, this being due to arcing across short distances and the burning of tin particles. The significance of this is important, although the practical application may be specifically limited; nevertheless, the field for exploiting this advantage does definitely exist. It means that the condensers can be operated on low voltage circuits which are subject to periodic surges. The condenser takes the surge and may break down in so doing, but it heals itself and continues to function safely upon its normal operating voltage. Further, it will withstand a number of successive surges of this type without breaking down completely as a condenser under their influence. It must be pointed out, however, that the condenser cannot withstand a severe treatment of this nature without some deterioration. This is revealed by a reduction in insulation resistance and, correspondingly an increase in electrical losses. Again, these are features which may or may not matter, in accordance with the specific application and the nature of the circuit concerned. The self-healing characteristic remains despite this lowering of resistance, and the resistance will be very low even after a single surge effect, however high it was initially.

C. F. Mansbridge, in a paper entitled "The Manufacture of Electrical Condensers" ("J.I.E.E.," Vol. 4, pp. 535-585, 1908), stressed that a condenser having a low insulation resistance value is to be preferred in certain circuits for the quenching of a spark, for example, in induction coils and similar circuits; the resistance in these circuits assists in the same direction of suppressing the surge. Thus the higher equivalent series resistance or the tin-coated paper electrode condensers is beneficial in these cases. The stability of these condensers is backed by confidence that short circuiting will not occur however low the insulation resistance becomes. Unfortunately, these features have become rather obscured, and high insulation resistance values are often specified, despite the impossibility or, at least, extreme difficulty in obtaining them under production conditions. Undoubtedly, misunderstanding has arisen by virtue of the fact that metal-foil electrode condensers enable these values to be attained. In fact, with these types, they are a criterion of correct quality materials and proper processing conditions. The moral to be drawn, therefore, is the fact that the two types of condensers are different commodities. The tin-coated electrode types were at one time essential for all purposes, due, virtually, to the absence of commercial alternatives. To-day they have specific advantages in restricted applications. The metal-foil electrode types are higher breakdown voltage condensers, possessing higher insulation, greater reliability and capable of production to a closer degree of precision. These factors, combined with their more economic production and with developments in manufacturing technique during the past 10 to 15 years, suggest that metal-foil electrode condensers, and in particular those utilizing aluminium foil, can usefully replace their predecessors, with perhaps slight circuit modifications in some cases.

For similar designs, and identical processing conditions, tin-coated electrode condensers will exhibit a maximum insulation resistance value of 5,000 to 6,000 megohms per microfarad of capacity at 60 degrees F., and usually it is much lower, more in the neighbourhood of 3,000 megohms; whereas the aluminium foil electrode type will give 15,000 megohms or more. This is of great practical import and must not be overlooked because high insulation value is one of the chief characterizing criteria of good general purposes condensers. Likewise, breakdown values can be compared, viz., instantaneous values in volts a.c. are of the order of 400 to 6,000 for tin-coated paper types and 800 to 1,600 for aluminium-foil electrode condensers. The tin-coated paper types can be improved by the inclusion of an extra thickness of paper insulation, but this involves still higher production cost as well as increased physical size, which can rarely be tolerated.

Regarding the higher production cost of the condensers having tin-coated paper electrodes, it is believed that it will be found to be generally true that these condensers, having only one paper between the electrodes, are more expensive to produce than are aluminium metal foil condensers having two papers between electrodes, other things being equal. The two types are approximately the same size for the same electrostatic capacity value.

One last quality feature requires brief mention. Apart from initial electrical quality, service life under normal operating conditions, and shelf life under idling conditions and in storage, are important. Generally speaking, high initial insulation resistance value is a good guide to a sound, serviceable condenser. Overload and surges deteriorate any condenser but, apart from these factors and any that may be incorporated under the heading of misuse, insulation resistance always has a tendency to fall. Undoubtedly, this is due to a number of factors, but these can all be grouped within the general statement that an influence is at work to increase the ionizable constituents within the condenser. Improper sealing, even a minute "pin-hole" will permit moisture to enter, and this renders the residual chemicals that may be in the paper or in the impregnating medium conductive. Improper drying of the units or exposure to atmosphere before sealing operates in the same direction. Overheating of the paper or of the impregnant promotes the formation of deleterious organic acids which slowly assert themselves over a period of time. With metal foil electrodes, judicious selection of raw materials and rigorously controlled process conditions, high initial insulation resistance values are obtained, and these show very little deterioration during idling, and very little fall in service. The tin-coated-paper electrode types, however, start life at lower insulation values, fall noticeably in idling and markedly in service. After, say, four years' service, the insulation may be of the order of only a few megohms. The low initial values and fall during storage can only be explained by the greater percentage of ionizable material in the tinfoil paper and the greater practical difficulty in achieving a high degree of drying during processing. The very rapid fall in service is due to the "surge breakdowns" and self-healing phenomenon.

The source of supply of tin-coated paper of condenser quality is probably more restricted than that of the metal foils, and is probably confined to a single manufacturer in this country. It is interesting to note, however, that from 10 to 15 years ago a zinc-coated paper was being developed in Germany for condensers. This consisted of a thin condenser tissue coated on one side with a fine, continuous deposit of metallic zinc, applied by means of a cathode sputtering or vacuum evaporation process. The material had several advantages over the tin-coated paper. It could be guaranteed free from any of the residual chemicals with which the tin powder, chemically precipitated, must be associated. The zinc could be very high purity with no local inclusions, as of carbon, that might set up electrical couples. A smooth, continuously conducting coating could be assured without any subsequent calendering and, therefore, no question arose concerning particles of metal rolled into or through the paper. Consequently, improved condenser qualities would be expected and were, in fact, claimed. These were substantiated by tests made on the material in this country, condensers produced showing a higher breakdown value and better insulation resistance values than are obtained on the tin-coated paper electrode condensers, yet at the same time the self-healing property was retained. This material did not ever become available in this country on a commercial basis, presumably owing to the expensive and complex nature of the equipment required for its production.

The vacuum technique for coating the insulating paper is not merely of scientific interest but it undoubtedly has great technique and practical significance. Aluminium* is just as easy to vacuum evaporate as is zinc, and would probably prove more suitable for this purpose. It would be less reactive chemically than zinc, because of the tendency to form a protective superficial layer of oxide over its surface, and it would possess a higher conductivity value so that thinner films could be tolerated. Another development that seems overdue, at least at first sight, is the substitution of a plastic film such as polythene, polystyrene, cellulose acetate, or similar material, for the paper and thus eliminate much of the moisture and insulation problem. Such a plastic could be metallized by the vacuum process, giving further simplification to condenser manufacture. Ultimately, designs could be smaller and longer life could be assured. Admittedly, much development effort would be necessary to perfect equipments to metallize the film for continuous production

Table 34.—Laboratory Data Appertaining to Tinfoil Paper.

Composition of paper base, linen rag stock; and of metal coating, pure tin in all cases.

Sample No.	1	2	3	4	5	6
Width, inches	3.5	3.5	2.5	2.5	1.25	1.5
Thickness, inches—						
Lowest	0.00046	0.00042	0.00046	0.00044	0.00042	0.00047
Highest	0.00056	0.00050	0.00052	0.00052	0.00051	0.00055
Mean	0.00050	0.00045	0.00048	0.00047	0.00045	0.00052
Weight basis, grams/sq. metre—						
Lowest	25.0	27.0	25.3	24.8	23.5	27.7
Highest	27.0	28.8	28.0	26.7	25.6	28.3
Mean	26.0	27.9	26.6	25.5	24.0	28.0
Water soluble extract, per cent.	1.0	1.0	3.8	3.9	1.5	1.6
Alcohol soluble extract, per cent.	0.2	0.2	0.6	0.4	0.15	0.3
Weight of tin coating, lb./double crown ream (480 sheets 20 ins. × 30 ins.)	4.8	6.1	5.8	4.6	4.55	5.23
Tensile strength, lb. per mil. of thickness per inch of width	10.5	7.1	10.0	10.4	10.7	10.9
Tensile strength actual, oz. on ½ in. strip	21	—	—	—	—	—
Elongation on 7 inches, per cent.	1.2	1.1	1.2	1.2	1.1	1.0
Reaction	Neutral	Neutral	Neutral	Neutral	Neutral	Neutral
Moisture content, per cent.	3.3	2.9	3.1	3.0	3.2	3.3
Square resistance, ohms.	0.18	0.14	0.15	0.21	0.18	0.195
Ph value	7.8	7.6	8.0	7.7	8.2	7.0

* See "Light Metals," 1943/6/56.

processes and large outputs and in the technique of applying it to the production of fixed condensers.

Metallic Tin Foil

It seems that the development of a commercial technique for the production of thin metal foils in continuous lengths, and its establishment for the regular supply of a uniform production, occurred in America and on the Continent, and particularly in Switzerland, many years before they were achieved in this country. Therefore, up to about 20 years ago, metallic tin foil for condensers was all imported. The earliest tin foil used was actually a tin/lead alloy, containing some antimony and the thickness was of the order of 0.0002 in. to 0.00025 in., with rather thicker gauges for special purposes. It is probable that this particular alloy mixture was evolved during the development of processes for rolling the metal to such low thicknesses, and that condenser manufacturers found it suitable, accepting it in the first instance on the basis of availability. When, later, a lead-free alloy became available, namely, pure tin containing from 2 to 4 per cent. of antimony, some users still preferred to adhere to the first alloy. It was claimed to be more flexible and less inclined to crease and split during the processes entailed in producing condenser units. However, it is not felt that any strong claims can be made in this direction, and certain it is that the lead-free alloy was later used in this country with no troubles arising from the influence of alloy composition upon mechanical or physical properties. The two alloys studied over long periods under parallel conditions proved equally good, with condenser quality from the two grades indistinguishable. Further, with the lead-free alloy, it proved a little easier to maintain the thin gauge required, and to obtain, in consequence, the most favourable covering capacity.

One of the early continental specifications stipulated a 90/10 tin/lead alloy containing a minimum of 88 per cent. of tin. Thickness limits were stipulated as 0.005 mm. minimum, 0.0055 mm. maximum, and the substance in terms of a maximum weight basis of 42.0 grams./sq. metre. Strength and elongation were called for on a 7-in. acting length, using a strip 40 mm. wide folded in four lengthwise. A minimum tensile strength of 500 grams. and a minimum elongation value of 3 per cent. were specified. All these requirements could be met with the possible exception of elongation, for which values from 1 to 2 per cent. seemed to be more usual. This seems to be of no consequence provided that the material possesses the strength for handling on power-operated winding machines, particularly with respect to the start-and-stop stresses.

Average requirements of typical specifications for this leaded tin foil are briefly enumerated below:—

(1) Alloy composition to be within the following limits.

	Min. Per cent.	Max. Per cent.
Tin	82.5	—
Lead	12.0	15.0
Antimony ...	—	4.0

(2) Thickness to be assessed by covering capacity, limiting values for which for nominal thicknesses quoted on purchase orders, to be as under:—

Normal thickness. Ins.	Covering capacity. Sq. ins. per lb. Min.	Max.
0.0002	17,500	—
0.0003	12,000	15,000
0.0005	7,000	9,500

Tolerance on width to be plus or minus 1 per cent. on the nominal.

(3) The foil to be free from contamination by oil, grease, dirt, chemicals or other extraneous matter and neutral in reaction.

(4) The foil to be uniform, of smooth surface, free from crinkles, holes, tears or other imperfections, and edges to be clean cut, free from raggedness or turn-over.

(5) Strength. Determined on a 7-in. acting length, tensile strength to be a minimum of 64 oz. per in. of width per mm. of thickness, and elongation to be a minimum of 1 per cent.

(6) Foil to be supplied in one continuous length, free from any type or join and on centres of specified dimensions. To be wound squarely with even tension throughout the roll and capable of being unwound tangentially at right angles to the axis of the spool without tearing. The start of the roll to be made obvious by the insertion of a piece of paper between the first and second layers of the foil.

(7) The centres upon which wound to be of wood, inside diameter 3 ins., outside diameter 4 ins., length exactly equal to the width of the foil. Maximum overall diameter of the roll to be 5 ins.

(8) Rolls to be protected by square wooden cheeks, the side dimensions of which must permit the cheeks to extend beyond the roll diameter. Cheeks to be securely held by screws with flush heads, these screws passing into a suitable loose plug in the core of the centre.

(9) Rolls to be packed securely in wooden cases to prevent mechanical damage in transit, or deterioration from weather conditions.

In actual practice, a range of thicknesses of tin foil were used, but the commonest size was a thickness of the order of 0.0002 in. This gave sufficient strength for use on power-operated machines and the objective was to obtain the maximum obtainable covering capacity or area per unit of weight for economic reasons. In arriving at this small thickness commercially, naturally much trouble was experienced at the outset from tears, holes and other defects in the material, and with torn or ragged edges arising in the slitting operations. Difficulties were also encountered in maintaining reasonable uniformity of thickness throughout the length of the roll. However, the problems associated with these peculiarities were mastered in relatively rapid time and, with an organized production process control acting in co-operation with a sound routine, raw material inspection at the purchaser's end, the condenser manufacturer's needs soon became satisfied to a very close degree indeed.

Table 35.—Laboratory Data on Tinfoil (Tin-Lead Alloy) for Condensers.

Source	A	A	B	C	D	E	D
Sample No.	1	2	3	4	5	6	7
Width, inches	3.5	3.5	3.75	3.5	3.75	3.0	1.5
Thickness, approximate average, ins.	0.00022	0.00022	0.00023	0.00031	0.00022	0.00022	0.00025
Covering capacity, sq. ins./lb.—							
Lowest	16,000	16,300	15,400	13,900	17,200	18,200	15,000
Highest	18,200	18,000	17,100	15,900	19,100	20,400	17,200
Average	17,100	17,200	16,200	14,830	18,000	19,500	16,140
Tensile strength on 1½ ins. width, oz.	27	27	26	38	24	27	32
Elongation on 7 ins., per cent.	1.9	1.8	2.0	2.0	2.0	1.5	1.7
Reaction	Neutral	Neutral	Neutral	Neutral	Neutral	Neutral	Neutral
Composition, per cent.—							
Tin	84.5	83.0	84.4	80.6	86.4	84.4	83.7
Lead	11.5	13.0	13.4	16.3	11.7	12.7	13.5
Antimony	4.0	4.0	2.2	3.1	1.9	2.9	2.8
	100.0	100.0	100.0	100.0	100.0	100.0	100.0

In Table 35 are presented some data recorded on consignments of the tin-lead alloy condenser foil in various widths and from several suppliers. Little comment is called for in relation to the suggested specification limits already given. The compositional values vary a little but not alarmingly. Covering capacities drift somewhat, and some of them are on the low side. All are clean and neutral, and strength and elongation values are of satisfactory order.

The question of measuring the thickness of these very thin metal foils is one that has given rise to much controversy from time to time Uniformity of thickness is essential throughout the length of the roll, this being a stringent requirement for condenser manufacture that does not arise possibly in any other application of these thin metal foils, or at least not to the same degree. Obviously, some latitude must be permitted and, expressed as a percentage, the allowable tolerance appears as quite large. A total tolerance of 10 per cent. or even 12 per cent. can safely be accepted. It is really large fluctuations that have to be guarded against, and it is stressed that these certainly creep in if inspection is relaxed and if a systematic rigorous testing routine is not maintained. Fluctuations as high as 50 to 100 per cent. of the nominal thickness, and always in the plus direction are not uncommon under these lax conditions. It is evident that under such circumstances it is impossible to maintain condenser dimensions. It has to be realized that a condenser roll may contain any number of turns from a few to many score. The accumulative plus error cannot be compensated and, if it is not detected until the units are wound, much scrap may be produced and, in fact, a condition almost approaching chaos may arise. When such units are impregnated and pressed, they are appreciably oversize in thickness. Therefore, they will not enter their containers and, at the same time, capacity is upset so that it is impossible to maintain even quite wide capacity limits.

In taking thickness measurements, therefore, something more than a few readings on a micrometer gauge are both desirable and essential. The material is so thin that, even if measurements are made upon 10 superimposed layers, and a number of such readings taken and averaged only a poorly representative picture, and one that is totally inadequate, is secured. It is for these reasons that a covering capacity test has been evolved, and it is emphasized that this method of inspection is by no means intended for the evaluation of value for money quality alone, but that it is the all-important thickness assessment.

The number of tests made for covering capacity cannot be laid down rigidly, and it must be dictated by circumstances and local conditions. As a general guide, it is recommended that at least 10 determinations should be made, and that these should be taken on samples from different rolls in the consignment. The test piece can be selected from a distance two or three yards inside from the commencement of the roll, and it can be two yards in length by the width of the foil. Further, in making initial purchases, a good practice is to conduct shop trials on a few rolls, and during this procedure to take samples for covering capacity determinations at intermediate positions through the roll. Once uniformity within specified limits has been established by these means, responsibility for hidden defects can be made the onus of the supplier, a close watch upon performance during production maintained and periodic checks made by sampling occasionally from the machines during winding.

If it be necessary to have a knowledge of actual average thickness for any particular purpose, and it may be for design reasons, then this may be derived from the covering capacity figure by calculation, using the nominal density value of the tin alloy involved. In Fig. 177 is given a curve showing this relationship between average measured covering capacity expressed in terms of square inches per pound, and the calculated thickness in inches, the calculation being made assuming a density value of 7.6 for the tin/lead alloy. The information given by graphs of this nature is sufficiently accurate for any purposes that are likely to arise.

Reverting to the data given in Table 35, it is a matter of interest that samples Nos. 1 and 2 represented continental sources, No. 3 an American supply, while the remaining materials illustrate products available at a later date from manufacturers in this country.

A non-leaded grade of tin foil followed and rapidly established itself. It became almost universally adopted, few users only still insisting upon the leaded material. Again, it appeared to be appreciated on the Continent earlier than it did in this country.

This new grade of tin foil was not pure unalloyed tin; but an alloy with antimony, containing generally from 2 to 4 per cent. of this element. The inclusion of this element was to induce hardness and to promote maximum tensile strength. Experience shows over a period of time that rather more favourable covering capacity values and thinness were procurable. Strength and ductility proved quite satisfactory, and the foil met all the requirements with respect to cleanliness and accuracy of spooling. In short, the tin/antimony alloy introduced no shortcomings but, on the contrary, offered some small but definite advantages.

Table 36.—Laboratory Data on Tin Foil (Tin/Antimony Alloy) for Condensers.

Source	A	B	B	A	A	C	C	C	C	C	D	E
Sample No.	1	2	3	4	5	6	7	8	9	10	11	12
Width, ins.	$1\frac{11}{16}$	3.5	3.5	3.5	3.5	1.625	1.0	$1\frac{5}{8}$	1.0	3.5	3.5	3.5
Thickness, approximate average ins. ..	0.00022	0.00022	0.00022	0.00018	0.00020	0.00027	0.00028	0.00032	0.0004	0.00023	0.00029	0.00022
Covering capacity, sq. ins./lb. :												
Lowest	18,100	18,000	18,200	22,500	19,300	13,400	13,000	11,700	9,300	17,730	12,800	18.500
Highest	21,200	20,500	20,300	24,500	20,600	15,600	15,500	15,300	12,100	19,670	15,500	20,000
Average	19,500	19,200	19,000	23,700	20,000	14,700	14,200	13,400	10,700	18,200	14,310	19,500
Tensile strength on 1½ ins. width, oz.	27	32	39	26	27	34	35	31	35	30	40	29
Elongation on 7 ins., per cent. ..	2.3	1.6	1.6	2.0	1.9	2.0	2.0	1.9	2.0	1.7	1.9	2.0
Reaction	Neutral	Neutral	Neutral	Neutral	Neutral	Neutral	Neutral	Neutral	Neutral	Neutral	Neutral	Neutral
Composition, per cent. :												
Tin	97.3	97.1	97.1	96.7	97.0	97.2	97.1	97.3	97.2	97.0	98.2	97.5
Antimony	2.7	2.9	2.9	3.3	3.0	2.8	2.9	2.7	2.8	3.0	1.8	2.5
	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0

Table 36 gives the laboratory characteristics of the tin/antimony alloy foil, covering quite a wide range of samples. The materials numbered 1 to 5 are typical of the earlier continental-produced foil, whilst Nos. 6 to 12, inclusive, illustrate later production in this country. It will be noted that the home-produced material did not show up so well on covering capacity, nor with respect to uniformity in this direction, as did the foreign manufactured foils. Greater attention must, therefore, be paid to the stipulation of requirements and to inspection in order to ensure that they are fulfilled and maintained.

Fig. 178 shows the curve correlating covering capacity in terms of square inches per pound with calculated thickness in inches, and from this it will be seen that there is a small advantage to be obtained as compared with the tin/lead alloy foil. This is to be expected, of course, from the slightly lower density value of 7.3.

Table 37.—Analytical Values for Impurities in Typical Tin Foils.

	Tin/antimony alloy		Tin/lead/antimony alloy	
Sample No. ..	1	2	3	4
Impurity per cent.:				
Lead	0.060	0.065	—	—
Arsenic ..	0.032	0.029	0.017	0.032
Bismuth ..	Nil	Nil	0.002	0.002
Copper ..	0.020	0.020	0.060	0.050
Iron	0.045	0.052	0.055	0.058
Nickel	Traces	Traces	Nil	Nil
Zinc	0.016	0.020	0.050	0.045

The specification clauses proposed for the tin/lead alloy condenser foil can hold good equally well for this alloy, with the one possible exception, that a slightly higher covering capacity may be asked for if it is desired to take advantage of this feature. Thus, the minima might be raised for thicknesses of 0.0002 in., 0.0003 in., and 0.0005 in. to values of 18,500, 12,500 and 7,500 sq. ins. per lb. respectively.

Regarding impurities in these tin alloys, both of them can be considered high purity metals. This fact is demonstrated by two sets of typical analytical values for each alloy shown in Table 37.

Aluminium Foil

Pure aluminium metal foil has now been used in the manufacture of fixed paper condensers regularly for 20 years or more. Naturally, its commercial development involved the same or closely similar problems and difficulties, as did the successful manufacture of tin foils of the very thin gauges required. The same faults were initially met in bulk consignments, namely, irregular thickness through the length, holes and tears, ragged and turned-over edges, and the like. These difficulties gradually effaced themselves, and an aluminium condenser foil became regularly available to a guaranteed covering capacity, and in all other respects in a quality that satisfied the condenser manufacturers. Its use was firmly established on the Continent before it was in this country, and its manufacture likewise was several years ahead there, particularly in Switzerland.

One of the first points to be given consideration when using aluminium foil for condensers is, of course, its electrical conductivity or resistivity. In microhms per centimetre cube at 20 degrees C., the resistivity of aluminium is 2.8 as compared with 11.3 for pure tin. This signifies that aluminium foil can be employed in a thickness only one quarter of that of tin for the same results if, of course, it were practicable to roll the aluminium to a gauge that is safely handable as thin as this. In practice it is not, and a value of the order of 0.00020 in. is the thinnest used for this application. Therefore, higher electrical conductivity is obtained, and from what has been discussed under tin-coated papers, it will be adduced that this is an advantage, with the possible exception of the case of condensers for spark quench circuits, and even in this instance the case for a higher conductor resistance is not too soundly established.

Density is a second important quality that has to be given consideration. Aluminium has a specific gravity of 2.7 as compared with 7.3 for tin. This is all in favour of aluminium, and it signifies that for the same thickness three times, or at least two-and-half times, the area per pound is obtainable than with tin. This has an important feature from the cost aspect. A thinner aluminium foil, however, may cost more than one slightly thicker, this being dependent upon a number of manufacturing factors. Therefore, the user has to balance up the pros and cons and select a foil of covering capacity which all round is the most economic proposition. This, in effect, resolves itself into computing the price per pound into one per area. At one time a covering capacity figure of 50,000 sq. ins. per lb. was the most favourable value, but later it lay more in the region of 40,000 sq. ins. per lb. Obviously, this factor has to be under constant review.

With regard to strength, the values obtainable are at least as good for the aluminium foils as they are for the tin foils in these thin gauges. On power-driven winding machines, no difficulties due to breakage are encountered. When material is purchased to specification, which lays down the essential requirements with respect to tightness and axial trueness of winding on the former, no shop troubles arise and very little wastage occurs, and this is largely confined to the short ends at the end of the roll that are too short for the particular condensers being wound.

In Table 38 are given the test characteristics of a number of aluminium condenser foils of continental origin. It will be noted that they are clean, high-purity materials, and that the strength, which is good, depends upon the thickness of the material. Table 39 presents similar data for British materials, and it will be seen that they compare very favourably with the continental foils. Table 40 is included in order to demonstrate that uniformity of thickness or of covering capacity is maintained throughout the length of the roll. The importance of ensuring uniformity, and the method of controlling it, were dealt with in detail in the section on the tin foils.

(5) The tensile strength measured on a 7-in. acting length to be not less than 14 oz. per inch of width, and the elongation to be not less than 1 per cent.

(6) The covering capacity to be within plus or minus of 5 per cent. of the nominal covering capacity stipulated on the purchase order. This tolerance to include any variation that may occur through the roll or rolls. The evaluation of covering capacity to be made on at least 10 samples, each of two yards length; taken after discarding the first two yards of the roll.

(7) The width of the foil to be as stated on the purchase order and the allowable tolerance on the width to be plus or minus 1 per cent.

(8) The foil to be supplied on metal centres consisting of steel tubing, internal diameter 3 ins., wall thickness $\frac{1}{16}$ in. The width of centre tube to be exactly the same as the width of the foil.

(9) The foil to be in one continuous length and without any joins, either chemical or mechanical. The start of the roll to be clearly marked by the insertion of a paper strip.

(10) The foil to be wound on the steel centres with perfectly even tension, and there to be no turn-over of edges. No tearing of the foil to occur when unwound tangentially at right-angles to the axis of the roll. Maximum outside diameter of the roll to be 6 ins.

(11) The rolls of foil to be protected by means of two protecting cheeks. These cheeks to be of wood, square in shape, and fixed by means of screws through a wooden plug in the centre, the screw heads to be fitted flush.

Table 38.—Laboratory Data on Aluminium Condenser Foils, Continental Origin.

Source	A	A	B	B	B	C	D
Sample No.	1	2	3*	4	5	6	7
Width, ins.	3.5	3.5	3.5	3.5	3.5	2.2	3.5
Thickness, approximate average, ins.	0.00040	0.00030	0.00025	0.00025	0.00025	0.00025	0.00025
Covering capacity, sq. ins./lb.—							
Lowest	26,800	35,600	49,500	47,920	48,400	45,900	45,000
Highest	29,300	38,100	51,500	49,500	40,300	51,300	49,900
Average	28,000	36,900	50,700	48,410	49,260	48,100	47,200
Tensile strength on $1\frac{1}{2}$ ins. width, oz.	56	36	21	21	21	21	22
Elongation on 7 ins., per cent.	1.5	1.4	2.0	1.8	1.7	1.7	1.5
Compositional, per cent. impurities—							
Iron	Traces	Traces	0.95	0.64	0.58	0.29	0.19
Silicon	0.30	0.32	0.34	0.33	0.30	0.35	0.26
Reaction	Neutral	Neutral	Neutral	Neutral	Neutral	Neutral	Neutral

* Note.—This material was slightly oily, and on test gave an ether extract of 0.30%, this consisting of hydrocarbon mineral oil.

Commercial purchasing specifications for aluminium foil can closely follow the model already given in some detail for the tin foils. The following brief exposition may be taken as a guide:—

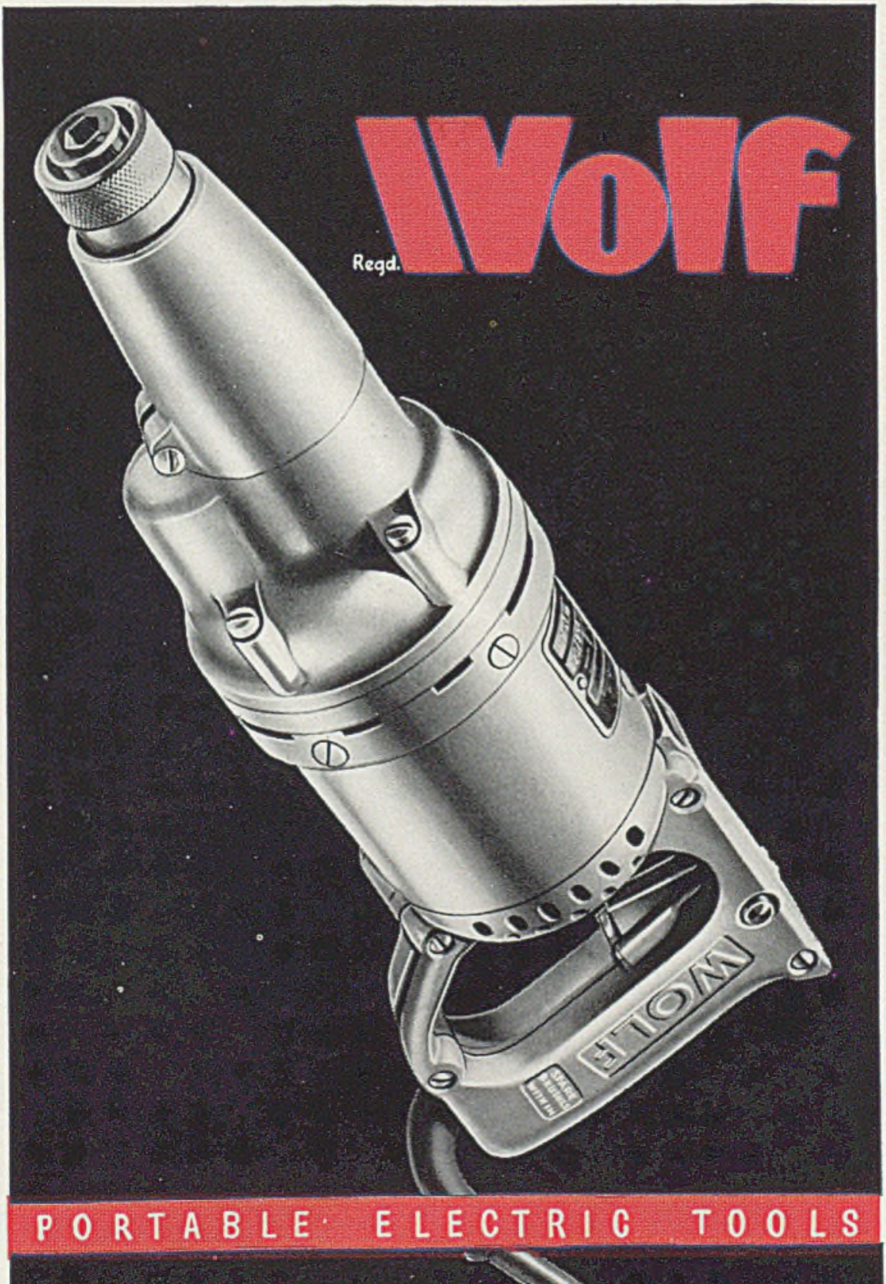
(1) The material to be a high-grade foil of commercially pure aluminium.

(2) The foil to be smooth and bright in appearance, uniform in physical hardness and in chemical composition, free from holes, tears, folds, wrinkles or any other imperfections.

(3) The surface of the foil to be free from any contamination, free from grease or oil, and to be chemically neutral in reaction.

(4) The aluminium to be of at least normal commercial purity, and the maximum impurities allowable to be:—

	Per cent.
Iron plus silicon	1.00
Total other elements, except oxygen	0.10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The cheeks to be fitted squarely, to be easily removable and easily replacable.

(12) The rolls to be packed rigidly in wooden cases in such a manner that no mechanical damage can occur in transit and in such a manner that no deterioration can occur due to weather conditions or exposure during transport or in storage.

It will be noted from these specification clauses that iron or steel centres are permitted. They are an innovation that came after the establishment of aluminium as a condenser foil, and have been a marked success. In fact, they are preferred to the earlier wooden spools which, although they were of wall thickness of about ½ in., their shrinkage during storage was very quickly marked. In consequence, these wooden later section in some more detail, when the comparative little use that is made of the aluminium alloys for this purpose will be examined. For the moment it suffices to state that the bulk of the metal used for this purpose is probably soft copper, and that the next greatest in consumption is probably tinned soft copper. A soft tin/lead alloy is also used considerably, while brass and tinned brass are employed instead of the copper upon some occasions. The electro potential differences between these metals and the foil, either tin or aluminium, with which they may be in contact is of importance. In fact, some engineers are apt to afford this phenomenon more attention than it deserves, and the reason for making this criticism will emerge from the discussion a little below. First, the actual potential differences will be considered.

Table 39.—Laboratory Data on Aluminium Condenser Foils, British Origin.

Source	A	A	A	A	A	A	B	A
Sample No.	1	2	3	4	5	6	7	8
Width, ins.	3.5	3.5	3.5	1.5	1.5	2.5	2.5	1.42
Thickness, approximate average, ins.	0.00020	0.00023	0.00022	0.00022	0.00020	0.00020	0.00026	0.00031
Covering capacity, sq. ins./lb. :								
Lowest	55,650	43,500	45,400	47,400	52,400	51,100	32,100	30,200
Highest	57,900	46,100	52,100	48,600	58,300	59,200	42,400	38,000
Average	56,860	44,300	49,000	48,100	56,100	55,200	39,300	33,200
Tensile strength on 1½ ins. width, oz.	19	21	20.1	21	18	20	33	38
Elongation on 7 ins., per cent.	1.5	1.3	1.2	3.0	1.7	1.5	1.5	1.2
Compositional, per cent. impurities :								
Iron	0.20	0.24	0.16	0.18	0.19	0.31	0.22	0.27
Silicon	0.34	0.37	0.28	0.27	0.27	0.28	0.31	0.26
Other metals	Traces	Traces	Traces	Traces	Traces	Traces	Traces	Traces
Reaction	Neutral	Neutral	Neutral	Neutral	Neutral	Neutral	Neutral	Neutral

centres quickly become loose and cause winding difficulties, or render winding altogether impossible. Therefore, wastage with the wooden formers was appreciable, and this has become significantly reduced by the adoption of the metal centres. They are of very thin wall and, therefore, quite light in weight; they are of iron or steel and, therefore, of ample strength. Generally they are " black " in appearance, i.e., in the condition as the steel comes from the hot drawing and, in consequence, the precautions specified for packing the rolls of foil for transit and storage are quite sufficient for the prevention of any deterioration of the iron centre by rusting. Further, no troubles from rusting in use have been recorded.

A point not so far mentioned, but yet important as far as condenser foils are concerned, involves the behaviour at bimetallic junctions. These junctions do occur at the contacts between the lead-out tapes and the foils. Various metals are employed for this purpose and they will be dealt with in a

The position of these metallic elements in the electromotive series of the metals, that is, their single-electrode potentials expressed in volts and developed when the metal is in contact with a solution of its ions of chemically normal concentration, is given in Table 41, and these values are reproduced graphically for easy comparison in Fig. 179. It will be seen that copper, highly electronegative, and aluminium, highly electropositive, are widely separated, with tin and lead very close together in an intermediate position. From this, one would at first sight regard these characteristics to be too disparent for safe contact between any of these metals except tin and lead, which have virtually the same values. Copper in contact with any of the others would promote or accelerate their corrosion. Aluminium in contact with any of them would be corroded at more than normal rate. On this argument, a tin condenser foil would be preferred, used in contact with tin/lead alloy contact tapes or with tinned copper tapes.

A more practical evaluation of the problem of bimetallic corrosion, although still not a foolproof one, is derived from a consideration of the potentials developed between the metal concerned and a normal calomel cell when an electrolyte, such as artificial sea water, connects them. Such values in volts, and measured at 25 degrees C., are given for the metals in question in Table 42. They are reproduced graphically in Fig. 181. The metals are for all practical purposes in the same relative order as in the previous table. Brass virtually behaves exactly the same as does copper, because their potentials are so close together. For the same reason tin and lead, or an alloy comprising these two elements, will perform the same. Again, a coating on copper or on brass consisting of tin or of lead, or of an alloy of tin and lead, will enable copper or brass to be used just as safely as tin itself, provided that the coating is continuous, non-porous and not scratched through at any point to expose the underlying copper or brass. Viewed on a narrow basis, the same conclusions are drawn as were inferred in the previous paragraph. More broadly interpreted, however, tin coatings are brought into the picture, and these enable the safe, or safer, use of copper and brass. Further, tin and lead on this basis of assessment are seen to be not so disparent from aluminium itself. Therefore, there should be no hesitancy concerning the use of tinned copper tape conductor contacts safely in conjunction with aluminium.

Table 40.—Aluminium Condenser Foil, 2.2 ins. wide by 0.0002 in. thick.
Covering Capacity Checks Through the Roll.
All Values of Covering Capacity Expressed as sq. ins./lb.

Position of sample in roll	Test No. 1	Test No. 2
Beginning	45,500	47,500
Middle	45,000	45,000
End	45,000	47,000
Mean value	45,830	

Some detailed attention has been given here to this question of bimetallic contact problem because it is being afforded more and more thought in practice. Nevertheless, it is not deemed that the foregoing completes the picture in this particular instance. The reason for this view is as follows: The condenser unit, completely wound and its contacting tapes inserted, is ready for immediate processing. This involves a controlled cycle of operations, including thorough drying, vacuum impregnation and sealing.

Table 41.—Electromotive Series of Metals. Single Electrode Potentials in Volts.

Electro-negative—	
Copper	– 0.58
Tin	– 0.14
Lead	– 0.12
Electro-positive—	
Aluminium	+ 1.0

In an efficiently designed process, using correct raw materials, and a combination of conditions such that will produce satisfactory and stable condensers, there will be no influences such as moisture or a combination of moisture and electrolyte, still residing within the condenser to cause corrosion to commence. Also, in circumstances not quite approaching the ideal, the electrical resistance due to wax impregnation under high vacuum, would so suppress any tendency for local action to set in that its influence would be completely negatived. It is contended that under these circumstances, plain copper contacts can be employed entirely safely. Further, long experience in practice proves that this is the case. At the same time, one must not completely ignore all theory.

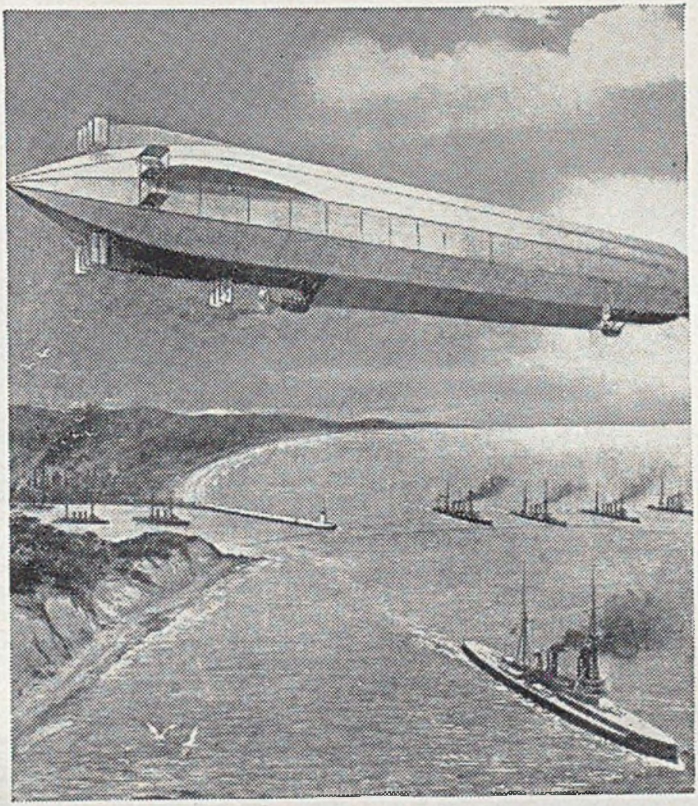
It was pointed out that, in the case of aluminium foils, it is expeditious to purchase on the basis of a combined consideration of price per pound and covering capacity value. A curve relating covering capacity in square inches per pound with thickness in inches calculated on a density value of 2.70 for aluminium is given in Fig. 180.

The use of aluminium condenser foil does not, of course, materially reduce the weight of the unit into which it is introduced in this instance, because, of course, the foil itself is only a small portion of the weight of the potted and sealed condenser. Its main attributes lie, however, in providing a readily available material in a uniform and sound condition, and in enabling condensers to be produced with, if anything, an improvement in quality at a lower cost. It is really amazing how accurately this very thin foil can be manufactured and slit cleanly into narrow widths, frequently of less than 1 in., and how expeditiously this can be handled through the operations of condenser manufacture with very little trouble and loss.

Table 42.—Potentials in Artificial Sea Water Against a Normal Calomel Cell at 25°C.

Copper	— 0.25 volts.
Brass	— 0.27 volts.
Lead	— 0.61 volts.
Tin	— 0.62 volts.
Aluminium	— 0.76 volts.

(To be continued.)



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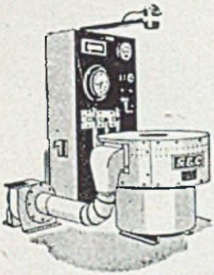

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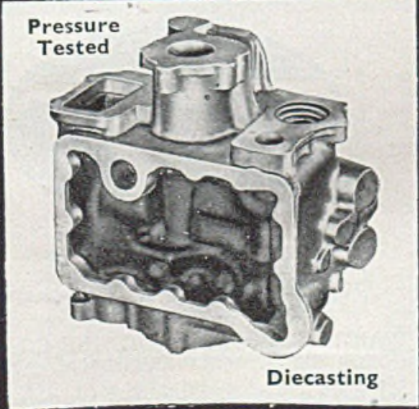

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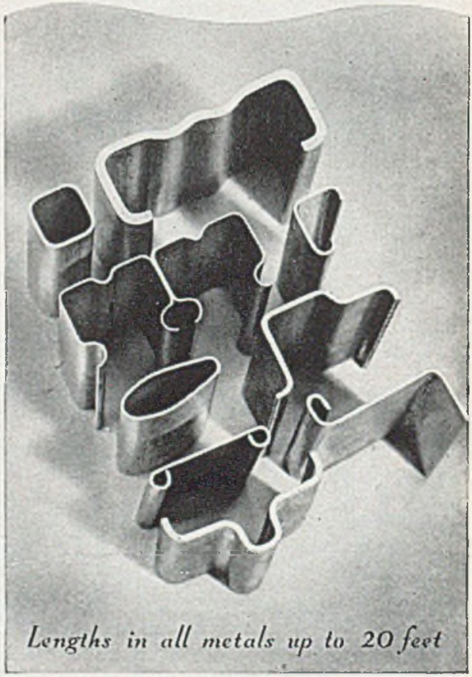

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