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LIGHT METALS

FEBRUARY
1945

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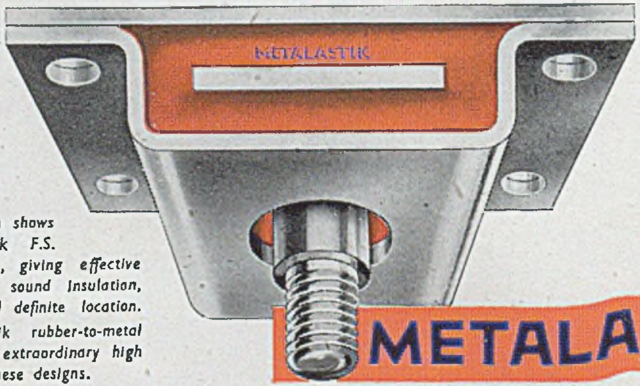

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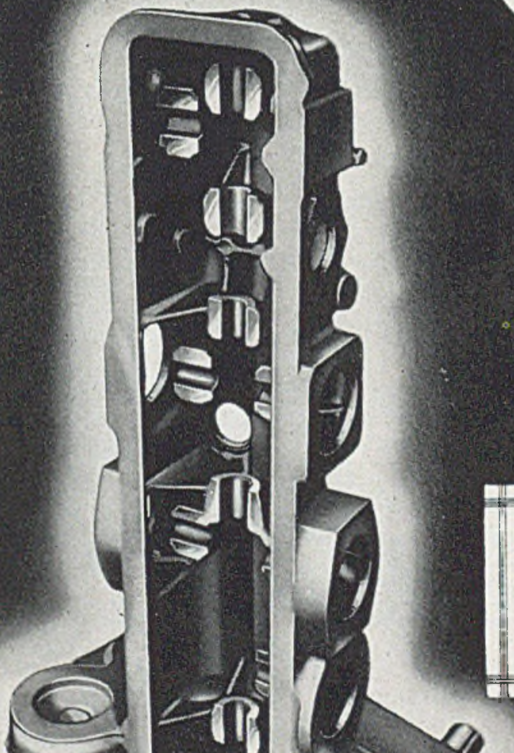

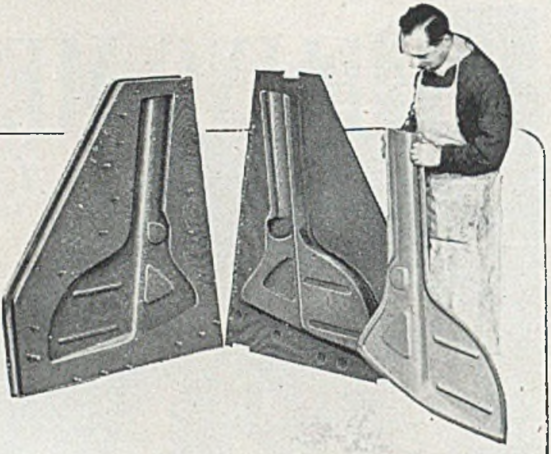

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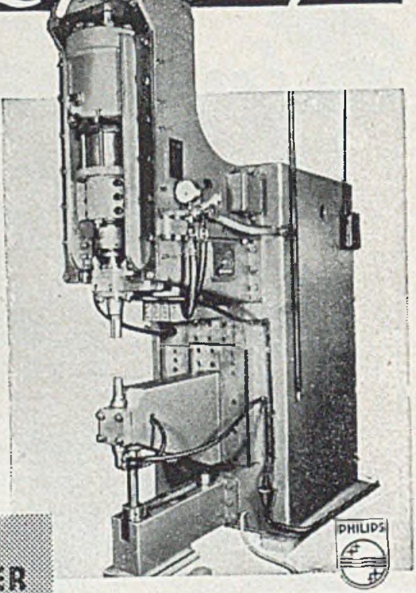

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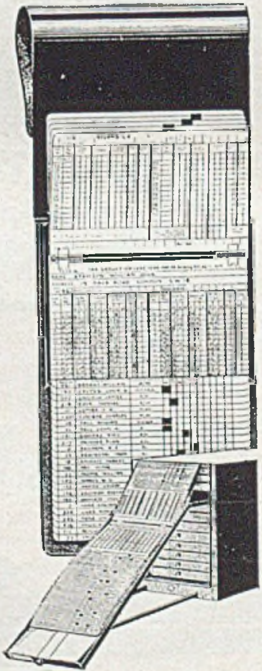

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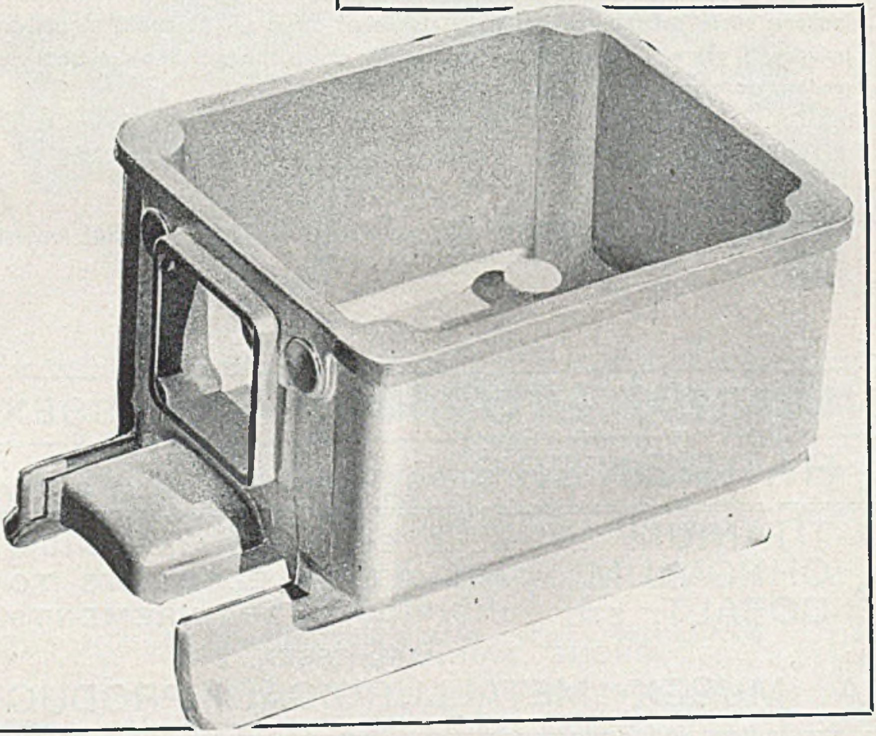

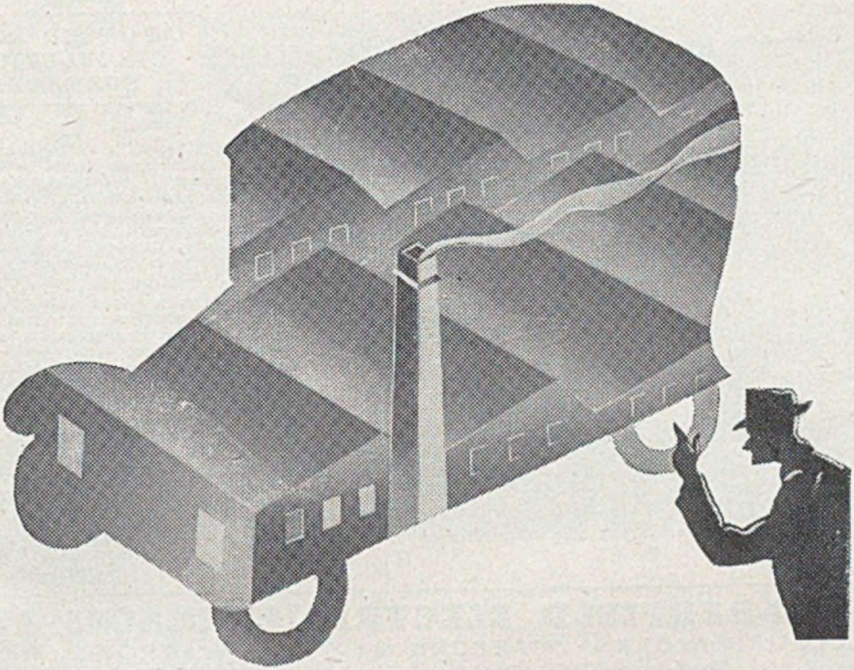

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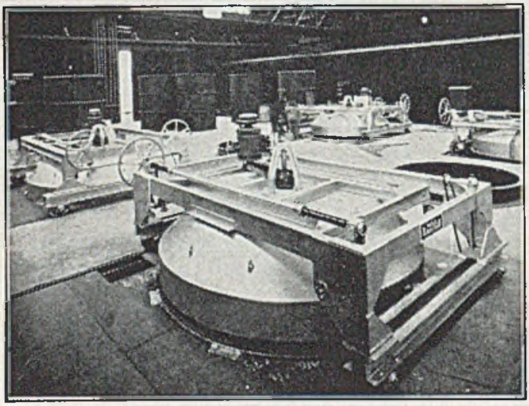

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M-W.96

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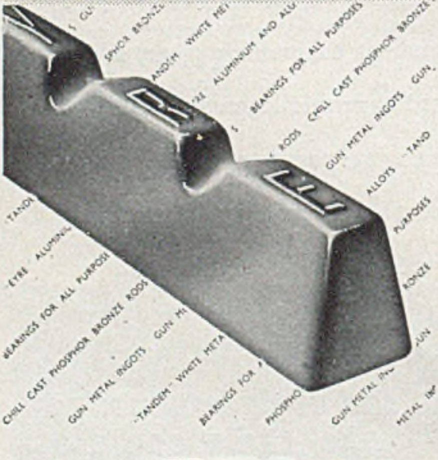

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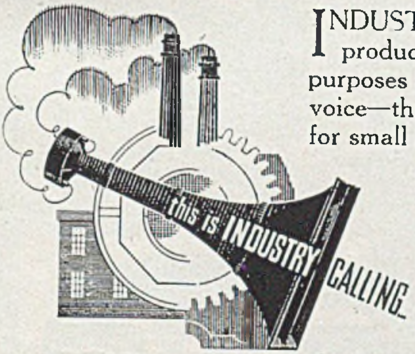

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G.D.4

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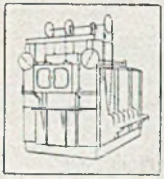

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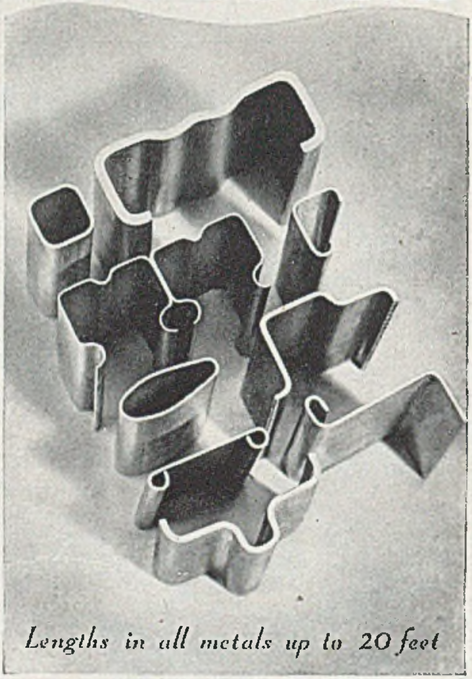

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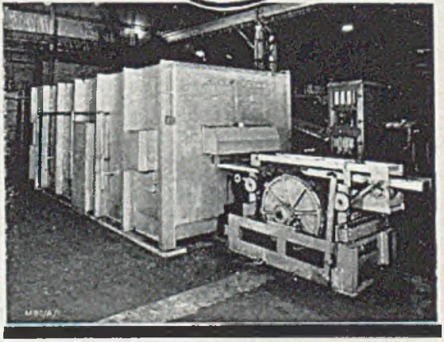

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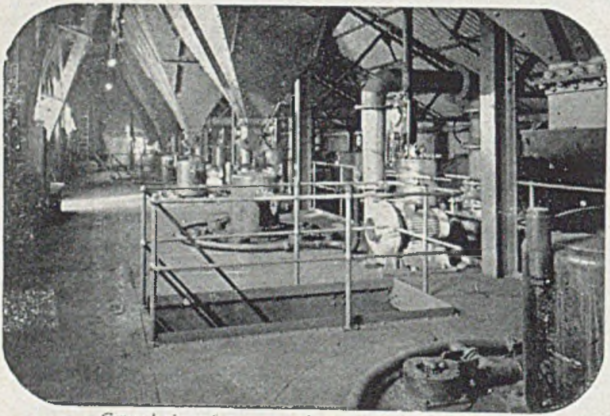

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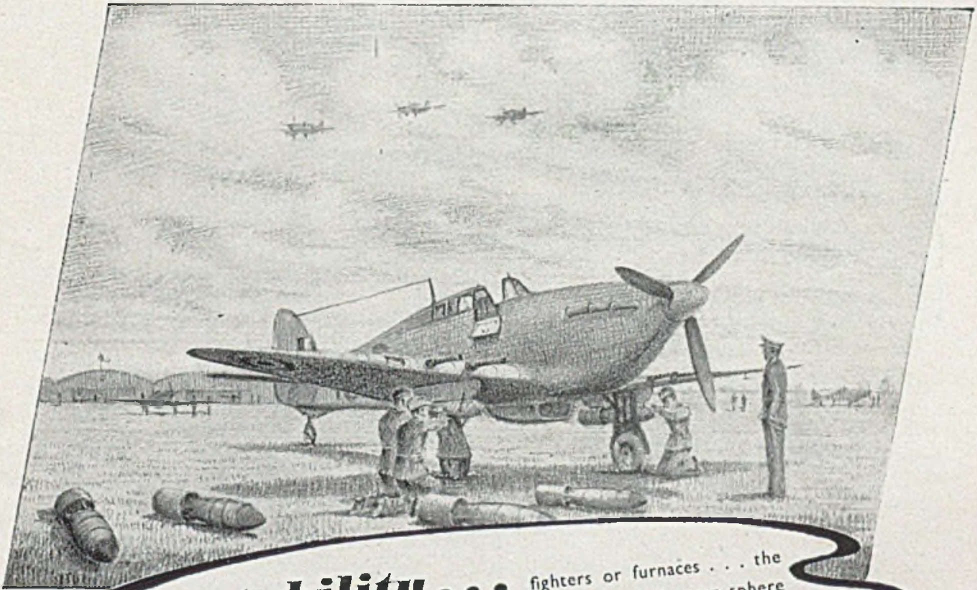

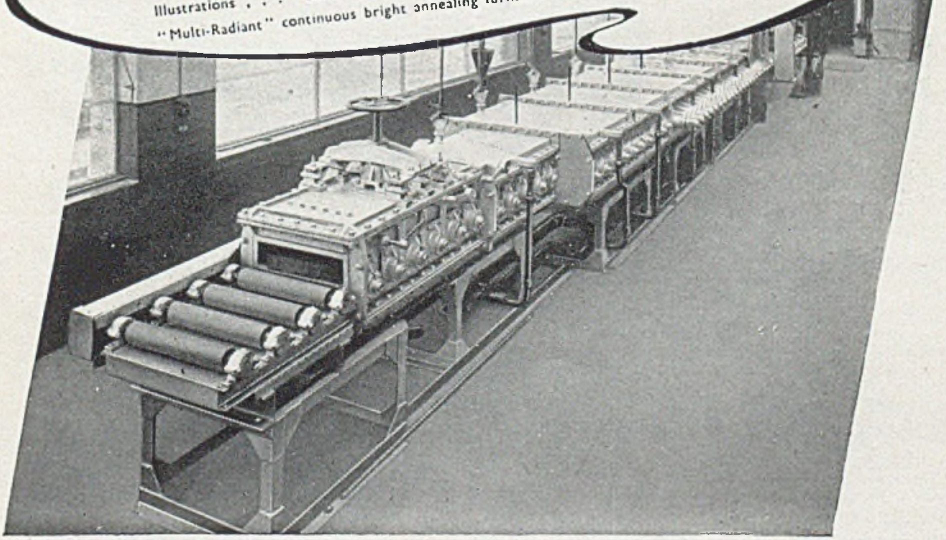

VOL. VIII. No. 85
FEBRUARY, 1945

LIGHT METALS

Proprietors:
TEMPLE PRESS LTD.

Managing Director:
ROLAND E. DANGERFIELD

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

Shape of Things to Come

UNDER the title "Design and the Designer in the Light Metal Trades," the Stationery Office has presented us with a report drawn up by the Committee of the Council for Art and Industry, and completed in May, 1940. The contents of this document are no less depressing than its appearance and mode of presentation. We look in vain for any element of design in its pages, with its authors we lament the scarcity of first-rate creative artists with industrial leanings, and, finally, the "light-metal trades" referred to are those specializing in the production mainly of fancy domestic equipment in the thinner gauges of non-ferrous alloys, some four or five pages alone being devoted to aluminium, and these to hollow-ware only.

If space permitted we would love dearly to quote certain of the literary gems contained in this part of the book; one prophetic phrase, however, we must repeat: "To-day aluminium is still in process of replacing *all* other materials in the trade." (The italics are our own.) This, we fervently hope, will ultimately prove to be true.

Study of the general contents of the book led us, in an idle moment, to consider, in comparative fashion, some foreign publications dealing with the use of, and designs for, aluminium, as projected in other countries. We have it on the authority of a Dutch contributor to a recent issue of "The Commercial Motor" that, even whilst the country was under German domination, the Renault works in France were preparing to use large quantities of aluminium in their new motor vehicle designs. Translated in this issue of "Light Metals" is an account from Switzerland exemplifying the continuous progress that the application of light metal has made in Swiss rolling stock.

It is true, of course, that to some extent economic factors may govern the use of a given structural material for these purposes, but it is apparent, on closer study, that the use of aluminium has been contemplated, not in the light of a substitute material for overcoming difficulties in the supply of steel, but because it represents the logical outcome of a rational evolution.

Another publication which we inspected came from France and was particularly interesting in so far as it did, in fact, cover the somewhat vague field classified under the title " the light-metal trades," in the report forming the subject of our opening paragraph. Interest was caught principally by the obvious " drive " behind the publicity here being given to aluminium, and by the fact that the sponsors of the brochure, again, were recommending the metal with the full assurance that it could meet an urgent public need. Close inspection of much of the work illustrated showed that, from the standpoint of design, many weaknesses exist.

A somewhat paradoxical situation frequently arises when a designer or manufacturer is called upon to transcribe a concept from one material into another. In general, it is not possible satisfactorily to do this, and some modification of form, section or treatment is usually necessary, either on the grounds of facilitating production, or simply because of the different surface qualities of the new material as compared with those of the old. However, it is often by no means easy to uproot tradition, thus, the creator of new designs in, shall we say, the pot-and-pan trade, is likely to meet with somewhat unexpected sales resistance unless he be both very sure of himself and of his material. We ourselves, however, even in this very difficult field, believe that something can be done to raise the artistic level of the more utilitarian side of kitchen life, and, in this thought we believe we can command the attention of the retailer if sufficient publicity of the right sort be given in the right quarter. In this country we do not lack designers of the calibre required for realizing, in part at least, the dream of the " Light-Metal Age," and most certainly we are not short of fabricators and founders with the ability to translate into substantial form the artist's creation.

It is our earnest wish to see passing from Great Britain to the mainland of Europe and to America, publications dealing with every aspect of the use of light metals so illustrated, and couched in such terms, that they may appeal to the public, as well as to the technical, mind. When this comes about we shall feel happier and less disturbed in conscience by the flood of printed matter in this regard which, when the wheels of industry are speeded up for peace-time production, will soon break upon our shores from across the Channel and the Atlantic.

Contents

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SPECIAL ARTICLES

REGULAR FEATURES

Light Alloys in HEAVY ENGINEERING*

An Exhaustive Survey is Presented of Realized Applications of Aluminium-base and Magnesium-base Alloys in the Sphere of Heavy Engineering. Some Indications are Given as to Lines of Future Development

LIGHT alloys and heavy engineering may seem curious partners, but in numerous instances the alliance has demonstrated remarkable serviceability. It is a fact that there are a number of applications in the iron and steel industry, in coal and ore mining, and in the construction of crane jibs and dragline booms in which light metals can be, and have been, utilized to unique advantage. Moreover, all reports appear to indicate that the performance of the light metal and composite light-metal/heavy-metal components has been satisfactory and that anticipated economies in the working of the new plant have come entirely up to expectations. Post-war changes in light-metal economies are likely to tip the scale still further in favour of aluminium.

Although, in recent years, little publicity has been given to this side of light-metals technology, it is by no means a new application, for Alcoa installed its first crane containing aluminium-alloy structural units as early as 1930, whilst giant aluminium dragline booms were at work on the Mississippi embankments by 1931. Since 1933, however, there has been scarcely any mention of these applications in the technical Press. That this is not due to any disappointment in the performance of the light metal or, indeed, to any slackening of interest in these aluminium- and magnesium-alloy components, has been established by inquiry; light-alloy components in heavy engineering are no longer regarded as freak applications and, in consequence, often fail to receive the commendation they deserve. Because of this, the writer is deeply conscious of the inadequacy of this review of published literature on the subject as an indication of the true state of affairs. Nevertheless, as an introduction to the subject both for the metal producer and for the consumer, it is hoped that it will serve its purpose.

Very little attempt is made here to deal with the theoretical approach to the design of these structures. Valuable though it might be, it would, after all, largely duplicate the information which is already available in the handbooks issued by the various aluminium and magnesium producers and factors both in this country and abroad. Moreover, as structures of the type dealt with here are seldom duplicated, but are most often designed individually to do a specific job, stereotyped recommendations are scarcely apt and cannot possess the same value as that practical experience which is, after all, placed freely at the disposal of would-be consumers by the light-metal concerns and engineering fabricators. No special departure from standard engineering practice appears to be called for, except, where necessary, to make allowance for the lower modulus of elasticity of the light metal; the formulæ derived by Dudley in the series of papers published in this

Table 1.—Weight of Composite 175-ft. Aluminium-steel Boom Compared with 150-ft. All-steel Boom

Composite Boom, 175 ft.	
Aluminium:	lb.
Peak plates	1,000
Main-boom structure, except lower 35 ft.	9,000
	10,000
Steel:	
Peak sheaves, etc.	4,000
Lower 35 ft. of main-boom structure	8,000
Guys, walks, etc.	7,000
	19,000
Total weight, fully rigged	29,000
All-steel Boom, 150 ft.	
Peak sheaves, plate, etc.	7,000
Main-boom structure	32,000
Guys, walks, etc.	7,000
Total weight, fully rigged	46,000
Weight saved by aluminium	17,000
Per cent. of weight saved	37.0

---

* The bulk of illustrations pertinent to the structures described in this part of the account will be included, together with a list of references, in the concluding section appearing in the forthcoming issue of "Light Metals."

journal[1] are, therefore, immediately applicable to the design of light- and ultra-light-metal structural components, both mobile and immobile, for use in the heavy engineering field.

The value of light metals in these applications lies usually in one or more of the following factors. First, and most important, is the possibility of reducing weight whilst maintaining adequate strength. This is important in any mobile structure because it enables economies to be effected in power consumption, inertia losses are smaller, braking mechanisms are less critical and speed of operation can be raised, mainly by increased acceleration and deceleration. In the case of overhanging machinery, such as jib cranes and draglines, a welcome reduction in overturning moment can be achieved, and this may be exploited to advantage either by increasing the length of the boom or jib, or by increasing the load on the end of the structure. It is equally important in immobile structures because it enables the use of lighter supporting members and foundations. Where alterations are made to plant, the use of light alloys may be the only means by which the weight of the new machinery can be reduced to a value at which it can be accommodated by the existing structure.

In other cases, the resistance to atmospheric corrosion or to attack by certain chemical environments may be important. Yet again is the practical possibility of converting machinery, such as small hoists, and appliances, such as large foundry patterns, into truly portable equipment which can be handled by a half to a third of the labour required for similar items constructed in steel.

The main structural unit involved in the applications discussed in this review is the "H" beam. This, and other forms of beam, have been built up from plates and angles riveted together, but there is an increasing tendency to make use of extruded or rolled sections, which are both lighter and cheaper for the same strength. Castings and forgings are utilized where applicable, but, in view of the lack of repetition in this field, components are more often built up from available shapes where there is a choice. Fortunately, a very wide range of structural shapes is made, whilst tubing, rod, flat sheet, circles, matting, and expanded metal are available in many different sizes and alloys.

Jointing is usually performed by welding or riveting. The former can be extremely satisfactory and is growing in popularity. A number of articles on the welding of light alloys has appeared in the pages of this journal.[2] Where corrosion resistance is important, it is advisable to use aluminium rivets which may be driven by hand or pneu-

Table 2.—Comparative Performance of 150-ft. All-steel Boom and 175-ft. Composite Aluminum-steel Boom in construction of Vicksburg-type Levee[1]

Levee Height, ft.	Net cubic yds. in Levee per station	150-ft. All-steel Boom			175-ft. Composite Aluminium-steel Boom			Advantages of Longer Boom		
		Cubic yds. handled per station	Cubic yds. rehandled per station	Maximum stations per month[2]	Cubic yds. handled per station	Cubic yds. rehandled per station	Maximum stations per month[2]	Increase in construction speed, per cent.	Increase in monthly income[2,3]	Saving per net cubic yd.[4]
10	2,130	2,660	—	56.40	2,660	—	56.40	—	—	—
15	4,510	7,260	1,610	20.65	5,650	—	26.60	28.8	$4,020	1.78c.
20	7,780	17,120	7,390	8.76	15,520	5,790	9.65	10.2	1,040	1.03c.
25	11,900	30,915	16,025	4.85	27,510	12,620	5.45	12.4	1,080	1.43c.
30	16,920	56,640	35,460	2.65	48,060	26,880	3.12	17.7	1,190	2.53c.

[1] Figures based on Vicksburg-type levee. Swell, 25% ; waste, 10%.
[2] Based on ability of machine to handle 150,000 cubic yds. per month.
[3] Based on contract price of 15c. per cubic yd. of net levee section.
[4] Based on handling charge of 5c. per cubic yd.

matic punches, but which are better driven by pneumatic squeeze riveters. In the larger sizes, however, it is by no means uncommon for steel rivets to be employed. They have the advantage of being cheaper and of higher shear strength, but are only satisfactory from the corrosion point of view if kept well painted; otherwise, corrosion at the iron-aluminium junction is accentuated. Aluminium wood screws, bolts and nuts are less frequently employed, and less information regarding them is available. Whilst their weight is considerably less than that of steel bolts and nuts, there is surprisingly little difference in the strengths of similar components in the two metals. The possible disadvantage of the light-metal bolt and nut is the danger of seizing and distortion of the thread if they be loosened and tightened at all frequently. Anodizing confers little advantage in this connection. A résumé of the work of Bollenrath, Cornelius and Siedenburg on the fatigue strength of light-alloy bolts has been given in this journal.[3]

Aluminium and its alloys require little protection against atmospheric corrosion due to the naturally occurring film of oxide on the metal surface. This protective layer may be thickened and toughened artificially by chemical (M.B.V.) or by electrolytic treatment (anodizing). In this condition the metal also exhibits a peculiarly receptive surface for the subsequent application of protective paints. Details of the M.B.V. and anodizing treatments will be found in other pages of this journal.[4]

Drag-line Booms and Buckets

The first major application of aluminium alloys in drag-line booms and buckets resulted from the severe flooding of the Mississippi river in 1927. Extensive damage and grave loss of life made it imperative to take steps to prevent a repetition of the disaster, and one measure which was adopted consisted in the building of levees or embankments for many miles along the banks of the river. A section of one type of levee employed, the Vicksburg type, will be shown, from which it will be seen that the work involved the fitting of large quantities of surface ground and dumping it to form a bank of height varying from 10 to 30 ft., according to the local conditions. A number of different systems can be employed for the construction of earthworks of this type. In the case of the Mississippi river project, drag-line excavators were employed and, because of the magnitude of the task, some exceptionally large machines were put to work on the job, some with booms 150 ft. long. These structures in steel are excessively heavy.

In an efficient drag line, the various factors of loading, reach, speed and mobility are balanced. The output is a product of these four factors, and any improvement in one without corresponding detriment to the other three factors results in an increase in overall efficiency. It was not long before the Mississippi engineers came to realize that such a condition could be made to exist by the substitution of aluminium alloys for much of the steel work in the boom and bucket. This was done, and in 1931 the first aluminium booms made their appearance on the Mississippi. They appear to have given complete satisfaction and, by the time the levee work was drawing to a close, the number of light-metal booms in operation had increased to over 30. Between September, 1931, and September, 1932, 15 aluminium booms had handled more than 6,000,000 cubic yds. of earth, and, although they were idle for part of this time as the result of unfavourable weather conditions, they showed definite advantages over other existing types of booms, particularly in operating speed and output.

Table 3.—Weight of 2-cubic yd. Steel Buckets and 2-cubic yd. Composite Aluminium-steel Buckets.

(All Weights in Pounds.)

Heavy duty		
Weight of steel bucket		5,650
Weight of composite aluminium-steel bucket		
Aluminium applications	1,600	
Steel teeth, chains, etc.	960	
		2,560
Weight saved		3,090
Per cent. of weight saved		54.7
Medium duty		
Weight of steel bucket		5,000
Weight of composite aluminium-steel bucket		
Aluminium applications	1,250	
Steel teeth, chains, lip, etc. ..	1,300	
		2,550
Weight saved		2,450
Per cent. of weight saved		49.0

The idea consisted primarily in the substitution of a structure built up from strong aluminium alloys for the major portion of the steel boom, and it was found that aluminium booms could be constructed of the same length as steel booms at a saving of 40 to 50 per cent. in weight without sacrificing the strength and rigidity of the heavier boom. This reduction in weight could be used to enable the capacity of the bucket to be increased by 20 to 25 per cent. In the work on the Mississippi, however, it was found more satisfactory to take advantage of the reduced weight to increase the length of the boom and thereby to increase the reach. In the average drag line, this permissible increase amounts to 15-20 per cent. and, in practice, it was found possible to replace the 150-ft. steel boom by a composite aluminium-steel structure 175 ft. long.

As the elimination of dead weight is of the greatest value at the upper end of the boom, the application of aluminium should, therefore, extend from the peak towards the base until the desired weight reduction and stability have been attained. For economy, steel members can be used at the lower end of the boom, where excessive weight does not have so great an effect on the stability or swing speed of the machine, and it was found that the ratio of steel to aluminium depends in a large measure on obtaining the desired performance at the lowest initial cost.

Table 4.—Weight of Completely Loaded 1½-cubic yd. Steel Bucket and 2-cubic yd. Composite Aluminium-steel Bucket.

(All Weights in Pounds.)

	2-cubic yd. heavy-duty composite aluminium-steel bucket	1½-cubic yd. heavy-duty steel bucket	2-cubic yd. medium-duty composite aluminium-steel bucket	1½-cubic yd. medium-duty steel bucket
Weight of bucket	2,560	4,540	2,550	4,000
Weight of dirt	6,000	4,500	6,000	4,500
Total load	8,560	9,040	8,550	8,550
Increased payload	1,500	—	1,500	—

Comparison of All-steel and Composite Aluminium-steel Booms

(1) Stability. Fig. 2 and Table 1 compare the overturning moments of two booms, one in steel 150 ft. long and the other in steel and aluminium 175 ft. long. In the latter case, the lower 35 ft. of the main boom structure, the peak sheaves, guys and walks are of steel and the rest is of aluminium alloy. The figures show that with the same bucket capacity, the overturning moment of the composite steel-aluminium boom is 853,000 ft./lb., or some 9 per cent. less than that of the 150-ft. steel boom. This interesting result naturally brings up the effect of this reduction in overturning moment on the balance of the revolving section of the machine, and, in fact, it was found necessary to reduce the counterbalance by 25,000 lb. in order to restore the balance of the structure. Adding this to the 17,000 lb. difference in weight between the 175-ft. composite boom and the 150-ft. all-steel boom, it will be seen that by making use of aluminium alloys the boom may be increased in length by 25 ft., whilst, at the same time, the total weight of the rotating parts is reduced by 42,000 lb.

(2) Swing Speed. This total weight reduction is important from a number of points of view. In the first place, it affords a welcome reduction of load on the roller bearings, simplifying their design and making for economy both in first cost and in maintenance. At the same time, mobility of the whole machine along the ground or over the water is improved. But of greater consequence is its possible effect on swing speed. The swing cycle of a drag-line boom divides naturally into three parts, acceleration, uniform speed and deceleration. The speed of acceleration and deceleration varies directly with the power available and with the swing inertia of the moving parts, and since the first and third phases of the cycle are of the same order of magnitude as the second phase in a 180-degree swing, and of larger moment in swings through smaller angles, acceleration and deceleration become factors of major importance influencing the swing speed of the boom. A decreased swing speed naturally results in a decreased output and, with normal all-steel construction, an increase in the length of the boom without corresponding increase in the power available results in a decrease in swing speed.

With the composite aluminium-steel boom, two opposing factors are at work. The increased length of boom contributes to the inertia of the system and the decreased weight reduces it. Actually, the reduction in weight does not fully compensate for the increase in length when the bucket is loaded, although it more than does so when the bucket is empty. The swing inertia of the longer composite beam is 8.6 per cent. more than that of the shorter heavier boom when the bucket is loaded, and 4.1 per cent. less when the bucket is empty, but, in practice, these small differences in inertia are found to be without practical effect, and on both types of boom the speed of operation is actually the same.

(3) **Performance.** Drag lines are usually operated with the boom at an angle of 20 degrees to the horizontal. Thus, the 25-ft. increase in length resulting from the use of aluminium alloys gives the operator a 44.4-ft. increase in working diameter and a 6.6-ft. increase in dumping height. This makes it possible to reach more earth without the necessity for rehandling and to use a higher stock pile when rehandling is necessary, the advantages of which are shown in Table 2.

From these figures it becomes evident that the increased reach of the composite boom allows a reduction in the cost of excavation amounting to from 1 to 2.5 cents per net cubic yd., and increases speed of construction by from 10 to 30 per cent., which, in itself, results in further economy on interest, overheads and labour charges. The cost of aluminium structural shapes and plates is greater than the cost of similar steel sections: the cost of fabrication is about the same for both materials. It is obvious, therefore, that the composite aluminium boom represents a greater initial investment than the shorter all-steel boom, but it has been demonstrated that the economies in operation are usually sufficient to write off this extra charge in only a few months of normal working, after which the longer boom can only be considered a distinct asset to the operator. It has been stated that, in one particular contract where the bank was 15 to 30 ft. high, the substitution of a 175 ft. aluminium boom for a 150 ft. steel boom resulted in a saving in operating costs varying from 1 to 2.5 cents per cubic yd. of earth deposited, and, as the cost of the aluminium boom was some $3,500 greater than that of the steel boom, the substitution was paid for out of the extra profits after only three to five months' working. How far these figures apply to other cases it is impossible to say, but it appears to be quite definite that the substitution of aluminium has invariably proved to be economic and satisfactory from the technical point of view.

Table 5.—Effect of Cage Weight Reduction on Power Consumption in the Case of a Vertical Shaft Handling 78,000 Tons/Month.

	Steel cage	Aluminium-alloy cage
Weight of cage, lb.	15,280	10,980
Rope diameter, inches	2	1.875
Factor of safety (men)	7.75	7.8
Peak horse-power	3,800	3,540
R.M.S. horse-power	2,050	1,935

Power cost saving	£174 per annum
Saving in rope cost	£50 per annum
Total	£224

Estimated extra cost of three duralumin cages, £2,200.

Table 6.—Effect of Skip Weight Reduction on Power Consumption in the Case of a Vertical Shaft Handling 52,000 Tons/Month in Seven-ton Skip.

	Steel skip	Aluminium-alloy skip
Weight of skip, lb.	6,900	5,300
Rope factor of safety	6.38	6.73
Peak horse-power	3,019	2,997
R.M.S. horse-power	1,773	1,769

Saving in power cost would be £42 per annum.

Drag Line Buckets

The use of aluminium in drag lines has been extended to include the bucket. It has been proved that dead weight is not essential for fast digging except in rock or very hard ground, and that the digging ability of the bucket depends instead on the relative location of the drag hitches and cutting edge. The ratio of dead weight to pay load may, therefore, safely be reduced with a consequent increase in economy of operation. For a 2-cubic-yd. steel bucket this ratio of dead weight to pay load ranges from 0.83 for the medium duty type of bucket to 0.94 for the heavy duty type, but with composite aluminium-steel bucket it may be as low as 0.43 for both medium and heavy duty types of buckets, and this without any sacrifice of strength and ruggedness. The application of aluminium has been carried further in the heavy duty type of bucket, so that, although there is more metal in it than in the medium duty type, the ratio of dead weight to pay load remains the same in both cases.

Table 3 compares the weights of 2-cubic-yd. buckets in steel and in composite steel-aluminium. From these figures it will be seen that the composite bucket weighs only half as much as the steel bucket, empty, of the same capacity. A further confirmation is provided by Table 4, which shows the weights of 2-cubic-yd. composite buckets of heavy and medium duty types, both empty and loaded, in comparison with steel buckets of only 1½ cubic yd. capacity. It will be seen that, in spite of the increased capacity, the total weight of the composite steel-aluminium bucket loaded is not greater than that of the all-steel bucket with its smaller load.

Although some doubts might be felt about the suitability of aluminium alloys for arduous service of this nature, both booms and buckets of composite steel and aluminium construction have been in operation for a sufficient length of time to demonstrate their practicability and durability. Buckets that have handled more than 200,000 cubic yds. of earth in levee construction conclusively indicate that the composite steel and aluminium bucket is strong enough to resist battering by rocks, stumps and hard earth, and tough enough to resist the abrasive action of the earth.

Their use has not been limited to the Mississippi or to the giants of the species described above. From the Western States comes news of the use of aluminium booms working on highway and irrigation projects, and of the construction of nine 60 ft. booms in a two-year period. In 1938, the Harnischfeger Corporation (U.S.A.) produced an excavator with an aluminium boom 110 ft. long carrying a bucket of 2 cubic yd. capacity which gave a working radius of 15 ft. greater than that obtainable by previous models of the same weight.

A later development of the Mississippi river scheme produced a dredger, reputed to be the largest in the world. The boom, which was capable of swing through 180 degrees, was 240 ft. in length, and incorporated two 75 ft. aluminium sections.

An aluminium boom, 75 ft. long, is in use in Philadelphia stripping the overburden and mining anthracite coal from open pits. The aluminium boom weighs 3,655 lb. less than the equivalent steel boom and is operated with a 1½-cubic-yd. bucket, as compared with a 1¼-cubic-yd. bucket on the steel boom. The actual overturning moment of the aluminium boom plus 1½-cubic-yd. bucket was 787,000 ft.-lb. and for the steel boom plus 1¼-cubic-yd. bucket it was 823,000 ft.-lb. Thus, the aluminium boom is actually more stable than the steel boom, though dealing with a 20 per cent. greater load. Such cost figures as are available have suggested that this increased capacity was sufficient to wipe off the extra cost of the aluminium boom in approximately one month's working.

In 1935, the Marion Steam Shovel Co. of Ohio announced the construction of a steam shovel of 32 cubic yd. capacity. Weighing 34,170 lb., its construction involved the production of a single plate of aluminium alloy weighing 2,400 lb. and claimed to be the largest single plate produced at that time.

Jib Cranes

In England, aluminium booms do not appear to be in operation, so far as the writer has been able to ascertain. This may be due mainly to the absence of work requiring the use of long booms in which, after all, the advantages of aluminization are most evident. There are, however, other types of machines which are structurally comparable and in which the advantages of aluminization would apply equally in this country and abroad. We have most in mind the large jib cranes used in building construction which may have booms as long as 95 ft. and which, in addition, must often be mounted on temporary structures of considerable height. Curiously, there is no mention at all in the technical Press of light alloys having been applied to this purpose, although it is obvious that not a few benefits would result from such an application. The direct benefit of weight reduction in the jib would be supplemented by a much greater lightening of the balance weights, from which could follow a lightening of the supporting structure and simplified erection. The fact must not be overlooked that this type of crane is essentially temporary in character. When it has finished the job on hand, it must be dismantled, transported to a new site and re-erected. Problems of erection, dismantling and transport would be much facilitated by a reduction in the weight of the structural components, and this may be accomplished with no loss in the strength of the assembly.

Table 7.—Effect of Skip Weight Reduction on Power Consumption in the Case of an Inclined Shaft Handling 24,470 Tons/Month.

	Steel skip	Aluminium-alloy skip
Weight of skip, lb.	9,000	7,000
Rope factor of safety	7.06	7.66
Peak horse-power	1,177	1,126
R.M.S. horse-power	694	676

Saving in power costs would be £24 per annum.

Travelling Cranes

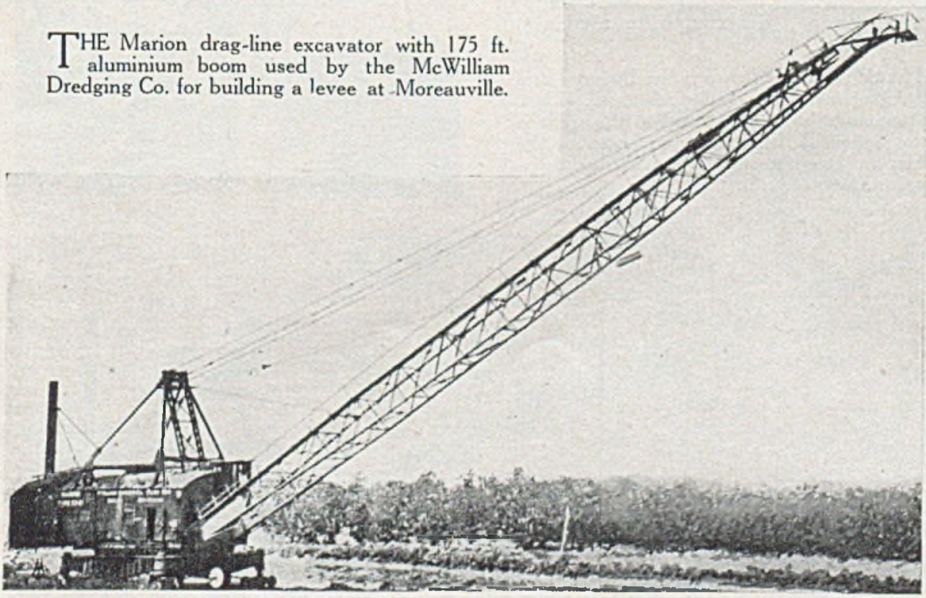
In the construction of travelling cranes, however, the advantages of aluminium construction have not been overlooked, perhaps because of the example set by the Aluminum Co. of America in one of their own factories in 1930. A reduction in the weight of the movable portion of a travelling crane is beneficial in permitting a reduction in the size of the driving motor, in increasing acceleration and deceleration and in simplifying the design of bearings and operating mechanisms generally. It also allows the supporting girders to be reduced in size and, when these, too, are constructed in strong light alloys, the net result is a considerable easing of the load on the supporting structure and its foundations. This is an important factor, particularly where long runways, perhaps 700 to 1,000 ft. long, are involved. Particularly is this important where travelling cranes have to be installed in buildings which were not designed for the purpose and which are capable of supporting only a strictly limited load. In such cases, apart from all other considerations, the economy due to the avoidance of substantial structural alterations to the building may more than compensate for the increased initial cost of the aluminium components.

It was for this reason that aluminium construction was employed for the four 2-ton cranes of 35 to 40 ft. spans which were installed in the incinerating plants in the City of New York. The low weight of the aluminium cranes permitted them to be installed without alterations to the columns and foundations of a building in the original construction of which no provision had been made for such machinery.

As already stated, the initial work on the practical utility of aluminium alloys in travelling cranes was undertaken by Alcoa, which, during the years 1929 to 1930, installed three 10-ton 72-ft. span cranes in its Messina works, two of which incorporated aluminium components. The first was a steel crane of conventional box girder type, weighing 40 tons; the second was similar in design, but the girders, gangway and cage were in the American equivalent of duralumin, the other parts being in steel. The total weight of this crane was 30 tons; the third crane was of the truss type and was constructed entirely of aluminium alloy. Its weight was 21½ tons. It was urgency of requirement that prevented full advantage being taken of the possibilities of aluminium in the second example, but the final result was a series of cranes incorporating light alloys in various ways and to various degrees from which most interesting comparisons may be drawn. The data obtained are of the utmost value from the standpoint of heavy engineering.

Extensive tests under average operating conditions showed that, in comparison with the all-steel crane (No. 1), the composite aluminium-steel crane (No. 2) used 25 to 30 per cent. less power and the all-aluminium crane (No. 3) used 50 to 60 per cent. less power. Crane No. 2 was 15 to 20 per cent. faster and crane No. 3 about 30 per cent. faster than crane No. 1 on average duties.

Details of the construction and performance of the composite steel-aluminium crane (No. 2) have been given,[5] and it will be instructive to recapitulate the main features. The crane was a three-motor single-hook machine with a lift of 22 ft. The design was based largely upon the usual practice followed in building steel cranes, although some departures were necessary in the bridge girders to allow for certain differences in mechanical properties between aluminium alloys and steel. In particular, to compensate for the low modulus of elasticity of the light alloy, the girders were made somewhat deeper, wider and of greater area and were given approximately twice as much camber as would ordinarily be used in a similar steel girder. The aluminium bridge was fabricated from two double web girders spaced 7 ft. on centres and spanning

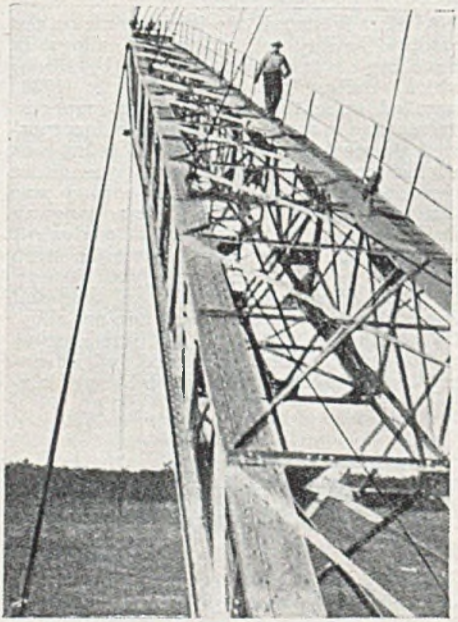

THE Marion drag-line excavator with 175 ft. aluminium boom used by the McWilliam Dredging Co. for building a levee at Moreauville.

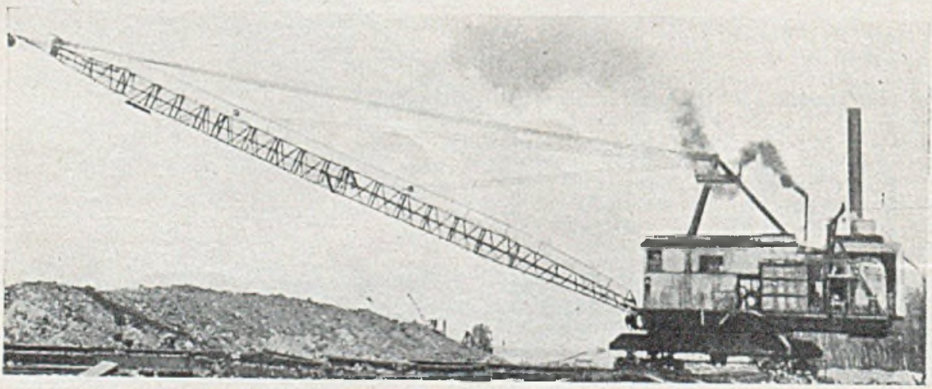
72 ft. 2 ins. The web plates were 46 ins. by $\frac{5}{16}$ in. Flange angles were 3½ by 3½ by ½ in. and cover plates, top and bottom, were 24 by ⅜ in. The bridge girders were attached to cast steel carriages at their ends, and a one-piece cast-steel trolley carrying the hoisting mechanism was mounted on the girder rails. In addition to the girders, aluminium alloys were also used in large amounts for the walkway, hand rail and operator's cage.

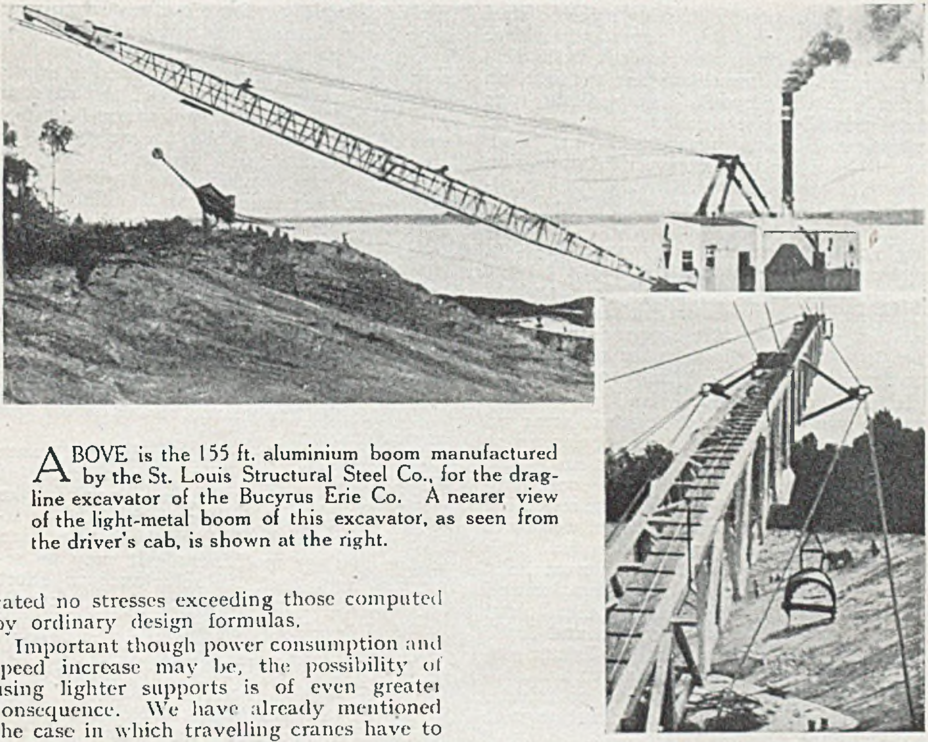
This crane was built by the Alliance Machine Co., of Alliance, Ohio, and it speaks well for the excellent working qualities of light alloys that, although this concern had had no previous experience with aluminium alloys, no fabrication difficulties were encountered. The web and cover plates were flattened and sheared on the same equipment as was ordinarily used in the construction of steel girders. The rivet holes were sub-punched and then reamed to size in the usual manner. Hot steel rivets, ¾ in. in diameter, were used throughout, driven with air-operated squeeze riveters, except for some of the more inaccessible ones, which required pneumatic hammers. No difficulty was experienced in riveting the girders, although a few special precautions were taken. For instance, excessive rivet temperatures were avoided, to decrease the possibility of heating the aluminium plates sufficiently to draw their temper. Also, the rivets were driven at random during the assembly of the box girders in order not to concentrate the heating effect of the rivets and in order to help in keeping the girder straight.

In comparison with the all-steel crane of similar design, the composite aluminium-steel structure was found to give every satisfaction. A total of 10 tons was saved, mostly in the girders. It was found easy to handle and quick to spot, whilst economies due to decreased power requirements were immediately obvious. The aluminium alloy crane was found to deflect 1.8 times as much as the steel crane under the same load at the centre of the span. The maximum deflection measured on the aluminium alloy crane was 1.09 in. under a load of 34,500 lb., which represented an overload of 72.5 per cent. based on the rated capacity of the crane. No measurable permanent set was found in the girders after the removal of this load and strain gauge readings taken at the centre of the span indi-

ILLUSTRATED below is the Bucyrus Erie Company's excavator with its 175-ft. aluminium boom. Pictured at the right is the actual 175-ft. aluminium boom of the Marion drag-line excavator shown on a preceding page.







ABOVE is the 155 ft. aluminium boom manufactured by the St. Louis Structural Steel Co., for the drag-line excavator of the Bucyrus Erie Co. A nearer view of the light-metal boom of this excavator, as seen from the driver's cab, is shown at the right.

cated no stresses exceeding those computed by ordinary design formulas.

Important though power consumption and speed increase may be, the possibility of using lighter supports is of even greater consequence. We have already mentioned the case in which travelling cranes have to be installed in buildings which were not designed for the purpose, but even where this difficulty is not encountered, the provision of lighter runways is also important, and may result in no mean economy. In this country, a duralumin towing carrier has been installed over the seaplane testing tank at the R.A.F. Experiment Station at Farnborough. Duralumin was chosen for this construction because of the greater ease of control of a lightweight moving mass.

An instance in which there is made particularly obvious the increase in payload which can result from the use of light alloys to reduce dead weight is illustrated. It shows a carrier employed in the handling of long steel rails in a large steel dockyard. In this, the gantry and main traverse are of standard construction in steel, but the rails are handled by a carrier traverse in the form of a box girder in aluminium alloy, some 60 ft. long, having a carrying capacity of 4½ tons. With all the rigidity necessary to prevent distortion of the rails lifted, the weight of this carrier was only 1,800 lb. The lifting capacity of the crane itself was 5 tons; with the steel carrier originally used, this lifting capacity was fully occupied in lifting two long rails only. The substitution of the aluminium carrier enabled the useful load to be more than doubled. The aluminium girder was built up from $\frac{3}{16}$ in. aluminium-alloy plate with 2 by 2 by $\frac{1}{4}$-in. angles at the corners, that is, in quite the normal method of construction employed with steel.

Colliery Engineering

We have already referred to the use of a 75-ft. aluminium drag-line boom which has been in operation in Philadelphia in stripping the overburden and mining anthracite coal from open pits. Actually, this is only one of many uses to which light alloys have been put in colliery engineering. Perhaps the most important application is in the reduction of dead weight in mine skips and cages. This is what might be described as a universal application of light alloys in colliery engineering since examples are to be found in every big mining country in the world, probably because the factors which call for the adoption of light alloys are common to the majority of coal and ore mines, irrespective of their location. These factors are numerous and, as they are sometimes misunderstood, it will be advantageous to deal with them in some detail. The factors involved are both technical and economic.

Let us consider the case of an underground working with existing steel or steel and wood cages and skips, ropes and haulage machinery. Reducing the weight of the skip or cage has two immediate results: first, an increase in the factor of safety of the rope and, secondly, a reduction in power consumption. Dealing with the second factor first, this reduction in power consumption may take place in one of two ways according to the design of the haulage plant, and its influence varies accordingly. If the whole of the weight of the suspended system is taken by the friction between the rope and the winding drum, then it is clear that power reduction is proportional to the reduction in weight of the suspended system, that is to say, of the cage or skip and its accessories together with the rope.

In most cases, though, and particularly in deep mines, cages and skips are arranged in pairs or else they are counterbalanced so that a reduction in weight of the suspended system has less effect on power consumption. There is, however, still some reduction in power consequent on a reduced weight of the suspended system, since the peak demand for power and the maximum hoist pull come during periods of acceleration and deceleration, when the entire mass of hoists, motors, cables, skips or cages, and load, must be started or stopped. A lighter suspended system possesses less inertia and consequently less power is required to achieve the same acceleration and deceleration with the structure.

Tables 5, 6 and 7 show the saving in power consumption which was effected in three cases by the substitution of a lighter composite aluminium-alloy-steel cage or skip for a similar all-steel appliance. In one case, advantage was taken of the reduced weight of the suspended system to make use of a thinner rope, and the saving in rope cost and the estimated extra expense of the duralumin cage are also given. Whether the saving in power is sufficient to justify the extra expense of light-alloy cages and skips is a moot point: many colliery engineers believe that the use of light alloys is not justified on these grounds. But it can be said straight away that this is not the manner in which lightweight construction can best assist the colliery engineer. This results from the first factor given above, namely, the increase in the factor of safety of the rope.

This increase can be utilized in a number of ways. Ropes are expensive items and inevitably deteriorate with use. If the rope has worn until the factor of safety reaches the minimum safe limit, reducing the dead weight of the cage or skip offers the possibility of prolonging its life. If, on the other hand, advantage can be taken of the increased safety factor to employ a thinner rope, then the total advantages begin to multiply rapidly. For the use of a thinner rope itself lightens the suspended system, again increasing the factor of safety, so that an actual weight saving is achieved in excess of the reduction in weight of the cage or skip alone. This is very important in the case of deep mines, where the weight of the rope is considerable. Thus, in the case of a particular cage, which weighed 5 tons loaded, it was found that a reduction in weight of 1¾ tons (3,920 lb.) allowed the weight of the rope to be reduced by 3,100 lb. if the maximum distance of descent was to be 2,000 ft., and by 6,500 lb. at 4,000 ft. That is to say, at depths in excess of about 2,400 ft., the weight of rope saved was greater than the reduction in weight of the cage. When it is considered that some of the Rand gold mines descend to below 6,000 ft., the importance of this factor will be obvious.

Alternatively, instead of using a thinner rope, the mining engineer can use more of it: in other words, he can increase the depth of the shaft and maintain the capacity of the cage or skip without alteration to the haulage machinery. It may be remarked here that the reluctance to effect any alteration to the power plant is conditioned not only by the actual cost, which may be heavy, but also by the inevitably prolonged time during which the shaft must be out of action.

Another possibility is that, without increasing the total loaded weight of the skip or cage, its capacity may be increased by the use of lightweight construction. This may be utilized either to increase the tonnage from the shaft or to provide more time and opportunity for necessary shaft repairs and maintenance.

To sum up, the employment of lightweight construction for the skip or cage without increasing its capacity enables a worn or thinner rope to be used with safety or a greater depth to be reached. There is some economy in power consumption. If, on the other hand, the dimensions of the cage or skip are increased, then one is enabled to handle a greater capacity without alteration to the haulage gear. In practice, of course, these factors are intermingled, and it is just this combination, varied in its details to suit particular requirements, that makes light weight of value in this branch of mining engineering. The trend towards lightweight equipment has been influenced by the fact that, in the majority of mines, the sizes of shafts and the power and speed of hoists were determined many years ago, and were based on operations at normal depths. In mining at increasingly greater depths, however, maintenance of daily output has necessitated modification of hoisting equipment. Ever-increasing depths need heavier section ropes

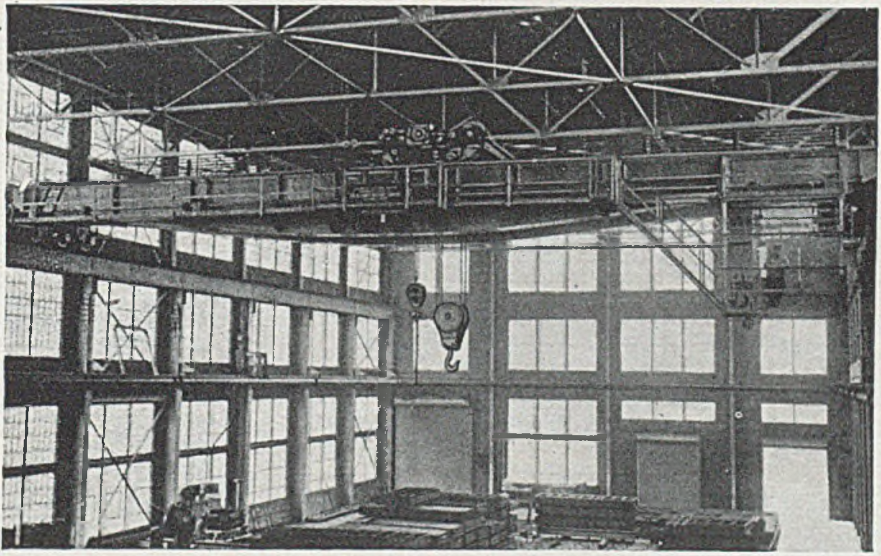

ANNOUNCEMENT

and correspondingly larger winding drums and more powerful engines. Both increasing depths of working and increased consumption require the use of larger skips. In an existing installation in which it becomes desirable to hoist an increased load, it is usually inconvenient, if not impossible, to increase the size of the rope in order to retain a given safety factor with the heavier load, and in most cases it is doubtful whether the existing engine would pull away the load thus imposed upon it. By the use, however, of lighter construction, it is possible to retain the original rope, and at the same time to increase the useful load per trip. The economic implications here need no emphasis.

Light-metal Construction

The next question that arises is the manner in which weight reduction in the cage or skip is to be achieved. One method is to make use of the high-tensile steels. In this way some 15 to 30 per cent. reduction can be achieved. More advantageous, however, is the employment of light alloys in certain positions, by means of which it is possible to achieve a weight reduction in excess of 50 per cent. without sacrificing strength or safety. The equipment is not built entirely of aluminium, but many important parts are constructed of the light metal in order that the weight for a particular installation should be kept below the desired maximum. Cages are frequently built up from riveted aluminium-alloy sections, sheets and gussets. Skips may be lined with manganese steel or rubber, but this is by no means always necessary, and bare aluminium-alloy surfaces have given good service in contact with abrasive, and even corrosive, ores which caused trouble with steel.

Main frameworks can be designed from known characteristics of loading and acceleration, with suitable allowances for impact and fatigue effects to ensure absolute safety. The thickness of side and floor plates, of course, depends on the nature of the ore handled. For the more highly stressed plates and shapes, the aluminium alloy 27ST (4.5 per cent. Cu, 0.8 per cent. Si, 0.8 per cent. Mn, rem. Al) has been recommended, and is said to be in general use in America. Its high strength combined with good resistance to abrasion and corrosion render it very suitable for the purpose. Alloys 52S½H (2.5 per cent. Mg, 0.25 per cent. Cr) and 4S½H (1.2 per cent. Mn, 1.0 per cent. Mg) have been recommended for the sheet employed for the cage side panels and as covers for mechanical parts. Forged parts may be in 14ST (4.4 per cent. Cu, 0.8 per cent. Si,



SHOWN here is the 50-ton, 80-ft.-span aluminium crane in a machine shop of the Aluminum Co. of America. This equipment was constructed by the Alliance Machine Co.

0.8 per cent. Mn, 0.4 per cent. Mg) and castings in 220-T4 (10 per cent. Mg).

Whilst the service record of aluminium alloys has been excellent in mining work, nevertheless special precautions must usually be taken against corrosion. Many mine waters contain chlorides or sulphates in solution, and, consequently, adequate protection must be provided. It has been found that combinations of dissimilar materials are best insulated by a heavy coat of bitumastic or similar paint applied to the surfaces of both materials before assembly. In certain cases, a priming coat of zinc-chromate/iron-oxide paint is applied, followed by two coats of aluminium paint. This has been found to provide a highly satisfactory form of protection. Where conditions of extreme exposure are encountered, however, paints of the bitumastic types are preferred. A plain bitumastic coating is used for priming, whilst the finish coat is a bitumastic-type vehicle pigmented with aluminium powder, this giving excellent protection and, at the same time, conferring a pleasing appearance on the finished job.

It is interesting to note that aluminium trucks have given good service in the haulage of a high-sulphur-content coal which had played havoc with the steel trucks formerly employed.

Illustrated is a four-decker duralumin man cage made by Vickers Armstrongs, Ltd., for use in the South African gold mines, and a double-deck cage for 50 workmen constructed at the Lake Shore Engineering Co.'s works at Marquette, Michigan. In this case, the use of aluminium alloy 27ST plates and shapes with 4S sheets resulted in a saving of 5,200 lb. dead weight over the cage previously used. The only components not constructed in aluminium alloys were the head transom, safety dogs and rails, which were fabricated in steel. Another example is a three-deck cage designed for a total load of 17,100 lb. and consisting chiefly of riveted aluminium-alloy sections, plates and gussets, the total weight of the aluminium used amounting to 3,500 lb. It was stated that the ½-in. rivets used for the assembly were driven cold and that, before assembly, all contacting surfaces were painted with zinc chromate or bituminous paint to prevent possibility of accelerated corrosion effects.

The 7-ton duralumin mine skip also illustrated is another product of Vickers Armstrongs, Ltd. By the substitution of duralumin for steel in the body plates and fittings, these skips provide a very appreciable economy in working costs. The reduction in weight may be used to increase the burden in the skip, to reduce the duty of the engine, or to increase the factor of safety of the ropes, according to circumstances. Skips of this type are being used extensively in the South African and Indian gold mines. They are lined with renewable plates of manganese steel, and the base is sometimes fitted with rubber to reduce impact and to give self-clearing properties. A gold mine in the Philippines has, within recent years, installed a light-alloy skip weighing 2,800 lb. and having a capacity of 60 cubic ft. of ore.

In America, the use of aluminium for skips and cages and of coal- and ore-handling plant has proceeded apace since 1937, but even before that date there were a number of notable examples in existence. The U.S. Smelting, Refining and Mining Co. installed three aluminium skips at their Bingham mines which weighed only 47 per cent. as much as the steel skips they replaced, thereby enabling the effective depth of operation to be increased from 1,600 to 2,500 ft. Three aluminium cages for man haulage were also installed. The Hollinger Consolidated were using a light-alloy cage with a capacity of 60 men. In 1937, the Pittsburg Coal Co. installed aluminium clamshell buckets on two of their coal bridges and, at the same time, they replaced the man and control cabins by light-alloy structures, with the aim of increasing the capacity of the plant. Altogether, the new aluminium bucket weighed 22,500 lb. and the cabin, trolley, motor cradle, gear covers, bearing caps and retainers amounted to another 4,600 lb. The reduction in weight was sufficient to enable the useful load to be increased from 6½ tons to 12½ tons—very nearly double. Since 1937, considerable developmental work on the aluminization of colliery equipment has been undertaken by the Lake Shore Engineering Co. of Marquette, Michigan. This concern operates in the great Michigan and Minnesota areas, from which about 80 per cent. of the annual production of iron ore in the United States originates. Much of the equipment in use in these areas is, naturally, of appreciable age, although well maintained, since mining operations in these areas date back to 1845 in the case of copper and to 1882 in the case of iron. Beginning with comparatively shallow workings, operators have driven continually deeper, this constituting the factor leading to the use of aluminium alloys.

The mines are almost all of the vertical-shaft type, operated from several levels to depths of up to 4,000 ft. In practically all of the mines ore is extracted in a moist or wet condition. In addition, water drips constantly down the shafts, so that the cages and skips are covered with a slime which is rich in minerals and iron. This necessitates specially resistant coatings on all equipment, including that constructed of aluminium. In the eastern section, near

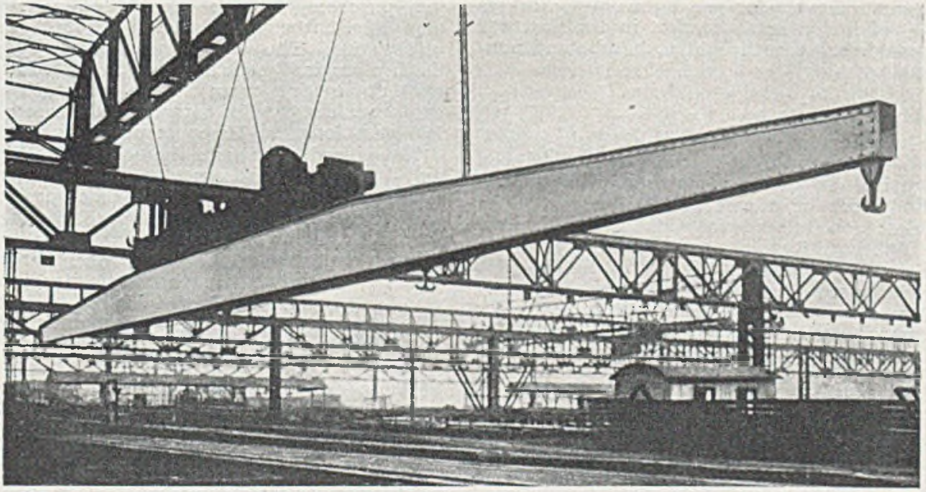
Marquette, the water is nearly neutral and not excessively corrosive to metal, but, in the western section, the water has, owing to its high mineral content, a markedly corrosive action on steel.

In the iron mines ore is hoisted in skips which dump their charges into a hopper set 50-100 ft. above the surface. Steel or timber trestles are constructed between the head frame and the stock piles, the cars being operated on these trestles, and dumping various grades of ore in stock piles below them. It is common practice to stock ore in winter for summer shipment when the Great Lakes are open to shipping.

In the copper-mining country mine shafts are frequently inclined, vertical depths being of the order of 6,000 ft. Many of the mines are wet and the water carries high concentrations of chlorides and heavy-metal salts, so that protection from corrosion is again an important factor. Ore is usually dumped direct from the skips into railroad cars for transport to the smelting plant.

Such are the conditions existing in an area in which the use of aluminium equipment is making rapid progress. Light-alloy skips and man cages are becoming increasingly popular, and, although their initial cost is greater than that of similar steel equipment, this is soon offset by the advantages of increased output, thinner ropes, or one of the other factors discussed above. In the case of new installations, light-alloy skips and cages are said invariably to reduce the total cost of the equipment.

Particularly interesting is the application of aluminium alloys in the ore cars operated by the Cleveland Cliffs Iron Co. These cars are used for the transport of ore from the head of the shaft along the trestles under which the ore is dumped in stock piles. The operation is entirely automatic, each car being self-propelled by an electric motor and fitted with self-dumping mechanism. The use of aluminium has permitted the loading of the trestle system to capacity, thus obtaining an increase in the amount of ore handled with a saving in power costs. The saving actually amounts to about 2 tons dead weight, this, of course, being added to the pay-load of the car. Each car handles about 6 tons of ore, or about 50 per cent. more than would have been possible with all-steel cars. No concomitant technical disadvantages are incurred.



THE crane traverse in Lautal alloy pictured here is designed for use in a steel stockyard and demonstrates admirably the dimensions of elements of this type which may, with perfect satisfaction, be constructed in strong wrought light alloys.

Winding Drums and Inserts

Pithead hoists usually incorporate a wheel or drum which controls the hoisting cables by means of the friction between the cable and the facing of the wheel. The most common materials used for facings are wood, leather, compressed cotton, and similar organic materials impregnated with various substances. These are not entirely satisfactory, however, being liable to excessive wear and overheating; they have been known to catch fire when the cable runs out very quickly and overheats the grooves. For these reasons, die-cast aluminium inserts have been experimented with and are said to have given excellent results (6). The use of aluminium inserts permits a higher loading of the frictional surface, so that drums of smaller diameter may be used without excessive wear. In one case, in a period of six months, 164,000 hoistings from a depth of 140 ft. produced a groove 19 mm. deep in the aluminium bearing surface, leaving three-quarters of the metal facing unaffected.

The " Alcoa News " of 28.6.1937 reports that aluminium coal shovels have been made for use in a coal mine. Weighing 2 to 4 lb. less than the steel shovels they replaced, these lightweight shovels make the work of coal-shovelling a little less arduous, and it is particularly interesting to note that this innovation resulted from a suggestion from the miners themselves. We have not heard of any further applications of this idea, nor is there any evidence to show how successful these shovels were in practice. We would, however, advance the suggestion that lightweight shovels for use by women workers would find a ready market in the post-war period, being both light to handle and non-rusting.

Miners' Lamps

Another direction in which light alloys, and the ultra-light alloys, too, have been applied in colliery engineering is in the bodywork of miners' safety lamps. The First Schedule of the Coal Mines General (Lighting) Regulations of 1934 lays down certain minimum standards of lighting for underground working. Among the safety lamps appearing in the first list of designs approved as meeting Schedule A for use in any type of pit are a number in which the bodywork is of aluminium.

Frequently this type of construction is supplied as an alternative to cadmium-plated steel, and not infrequently the lamps are given the designation of lamps suitable for the use of officials! Nevertheless, the advantages of lightweight construction are real, and there is every reason to anticipate an extension of interest in this field in the early post-war period. Flame-type lamps appear most generally to be constructed of cadmium-plated steel with cast-brass fittings. It is the electric-battery lamps which incorporate aluminium alloys, and no doubt the good resistance of the light alloys to battery fumes and the absence of red rust and green corrosion products have had something to do with the choice of light alloys for this purpose.

Illustrated is an electric safety lamp in which the main castings are in magnesium alloy. By the use of the ultra-light alloys an even greater reduction in weight can be achieved.

The popularity and proved superiority of front silvered mirrors in safety lamps suggests at once the applicability of anodized reflector-finished aluminium in this connection.

A light-duty hoist or power windlass for use in the mining industry and manufactured by the Maschinenfabrik A. Beien, of Herne Germany, just prior to the war, was constructed almost entirely in light alloys. It weighed about 100 lb. and could be handled easily by one man. In use it could be readily stapled into any desired position, and by means of fast and loose pulleys could be used for such purposes as moving excavating machines during the driving of galleries. It was capable of drawing an excavator weighing 775 lb. up an inclination of 55 degrees. Conveyors, motors, skips and other apparatus employed in mines were quite easily handled by it.

By reason of its small bulk and light weight it could, where necessary, be attached to a small lorry. Used for drawing purposes, it was capable of pulling along the flat eight tubs with a total load of six tons. The winch was powered by a 2.5 h.p. engine operating on compressed air at 28 lb./sq. in., or an electric motor. The drum was designed to carry a 5/32-in. rope, 165 yds. long, in 10 consecutive layers.

Introduced at about the same date by an American concern, the Aluminum Ladder Co., Tarentum, Pa. (which specializes in the manufacture of light-alloy portable equipment), was the aluminium conveyor, which will be illustrated subsequently. The total length of this structure was 10 ft., its width being 14 ins. At 4-in. intervals along its length were mounted ball-bearing steel rollers of 1⅞-in. diam. It was constructed of 61 S.T. alloy.

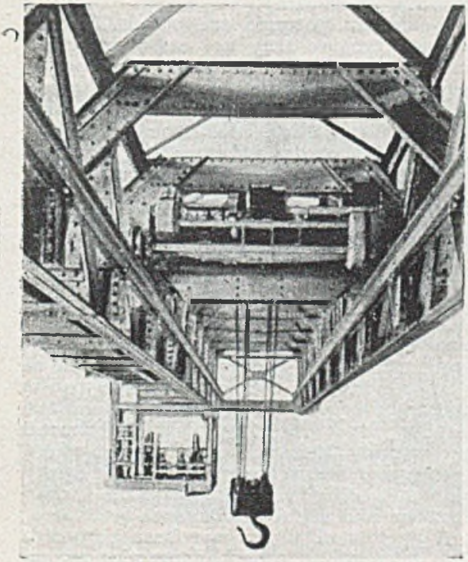
The conveyor was supplied with or without an eccentric axle and wheels. With these latter in the lowered position the whole conveyor could quite readily be moved into any desired position. With all fittings its weight was 51 lb. It could be supplied, on order, in lengths up to 20 ft. and 14 ins. wide.

Aluminium in System of Forepoling

In the Pittsburgh district, the extensive application of mechanical loading equipment was at one time retarded by difficulties in the handling and holding of draw slate which averaged 8 ins. in thickness but was of varying hardness. A system of forepoling was, therefore, devised and put into operation by the Pittsburgh Coal Co. with the object of keeping up this draw slate until the coal had been removed, thereby permitting the loading machine crew and the clean-up men to work safely underneath. It did, moreover, help to keep the slate out of the coal and it made it possible to manœuvre the loading machine without incurring the risk of being hit by falling slate.

The shaft at the coal face was 21 ft.

wide, and it was usual practice to undercut to a depth of 8 ft. Three holes, each 2¼ ins. in diameter and 5 to 6 ft. apart, were, therefore, drilled into the coal face immediately under the draw slate to a depth of 9 ft., and, in these, were placed steel pipes 10 ft. long by 2 ins. in diameter. Immediately under these was placed an aluminium "H" girder 4 ins. deep, which was supported on vertical steel columns. The girder was made of duralumin. It was 20 ft. long and weighed only 4.85 lb. per foot, that is, a total of 97 lb., so that it was easily handled by two men. In fact, this was the reason for the adoption of duralumin, since it was only intended to give temporary support and, having to be erected in a somewhat confined and hazardous position, the need for additional appliances to assist erection was obviously most undesirable.



BUILT by the Northern Engineering Works, the 10-ton 76 ft.-span aluminium crane shown here is in use in a rolling mill of the Aluminum Co. of America. (See following illustration.)

In the South African gold mines, vertical drill columns have been made in aluminium in replacement of wrought iron or steel tubing for the same reason. The columns form the support on which the pneumatic hammers are mounted for work on the ore face. Tubes for loading dynamite into 17 ft. deep columns are also made of aluminium. The reason here is not only the question of reduced weight, although this is important since it reduces the risk of a mishap in handling the loaded tube, but also because the chemical characteristics of aluminium and its freedom from sparking make it a safer material than ferrous or copper-base materials in which to handle such explosives.

The Aluminum News Letter of April, 1937, illustrates a set of large turbine-type fans for use in mines. Aluminium was chosen for this application because of its resistance to water and to sulphur-containing atmospheres, reasons for which the light alloys have been chosen for the construction of fans and ventilating equipment in many branches of industry and in public life, in hotels and so on.

We would close this section with a reference to the use of aluminium in a different type of mining activity, namely, the winning of high-grade clays. The H. C. Spinks Clay Co. (U.S.A.) mines clays of various kinds, including high-grade ball clay, sagger clay and wad clay, and supplies a large number of clays used in the production of high-grade pottery, bathroom fixtures and insulators. Specifications applied to such clays with regard to quality and uniformity of colour are naturally very rigid. Iron particles and iron rust were found inevitably to be picked up from iron and steel wheelbarrows and to contaminate and discolour the clay, ruining it for the purpose intended. As a result, aluminium, which introduces no such defects, has been adopted universally by the company for the construction of the wheelbarrows used in its mines. An added advantage is the low weight which is achieved, enabling the capacity of the barrow to be increased without imposing any extra burden on the operator.

There is no doubt that light alloys can be of considerable assistance in certain directions in the mining of coal, ores and clays. With present difficulties focusing attention on to the coal mines and forcing the issue of increased efficiency, we look to the aluminium and magnesium producers and associated fabricating concerns to make their own peculiar contribution towards placing the mining industry once more on a sound and successful footing.

Light Alloys in Steel Works

We remarked at the outset of this article on the apparent incongruity of light alloys and heavy engineering, and it may come as a surprise to many to learn that light alloys have already carved a niche for themselves in the steel foundry and related works.

Tuyeres have been made in aluminium alloy and are said to offer decided advantages over those made in copper, which is the usual metal of construction.

Aluminium tuyeres are claimed to be cheaper, only one-third the weight of their copper counterpart, more readily repaired, in addition to which they have a life 30 per cent. greater than that of copper, and when they finally have to be replaced, their scrap value is higher.

Aluminium has also found application in the cooling of blast-furnace refractory walls, being the material of construction for the inner cooling boxes used in the form of inserts on a modern all-welded blast furnace built at Bochum. The cooling units proper consisted of conical boxes made in two halves. The outer casing was fabricated from 20-35 mm. steel sheet by welding and was built into the brickwork of the furnace. The inner cooling box fitted inside this steel casing and was constructed of 99.5 per cent. aluminium sheet 2 mm. thick, again by welding. The outer narrow side of the box was reinforced by means of circular indentations and carried welded-on connecting pieces for the lead-in and lead-out cooling water pipes. The pipe through which the cooling water was supplied was carried right through to the opposite side of the box so that the coldest water came into contact with the hottest part of the box. Twelve of these cooling boxes were connected in series. The outflow pipe was of " X " section and was constricted so that the water in the boxes was under pressure. This caused the boxes to expand and the comparatively thin aluminium walls were forced into close contact with the internal surface of the outer steel casing, thus ensuring good heat transmission. Some of the outer steel casings had openings in the middle leading through into the interior of the furnace to enable the temperature to be measured and gas samples to be taken. In these cases, two aluminium cooling boxes were fitted, one on each side of the opening.

One advantage of these cooling boxes was their small height, as a result of which 12 rows could be set in the place formerly occupied by six similar cooling boxes in cast iron, the net result being a more uniform cooling of the refractory wall. Although no corrosion was observed on untreated aluminium boxes, it was considered a wise precaution against unforeseen troubles to submit the aluminium to M.B.V. treatment.

Moulding Equipment

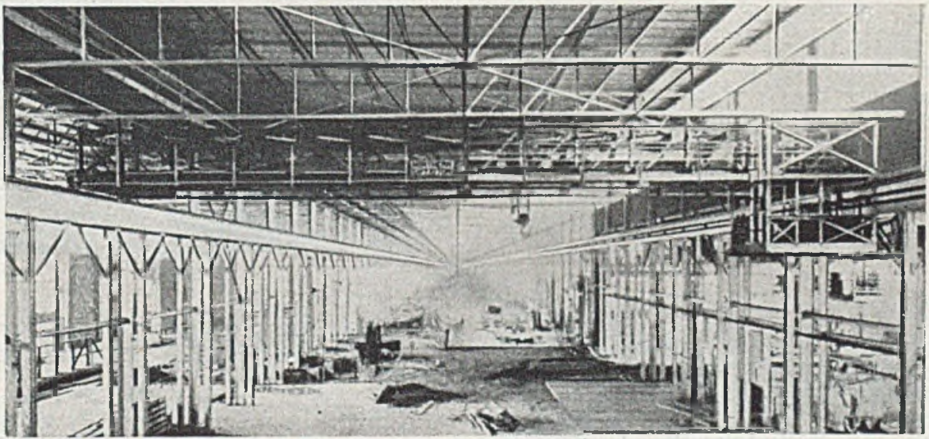
An established application of the light alloys in foundry practice is in the construction of moulding and core boxes, patterns and plates. The advantages result from the low density and corrosion resistance of the light alloy. Flasks are light in weight compared with similar tools in iron or steel, a factor which is of considerable importance in the case of large boxes and also where machine moulding is employed. The maximum size of casting which can be machine moulded by one man or by a team comprising a given small number of men is mainly dependent on the weight of the necessary flask or pattern, together with the sand the former contains and, consequently, any lightening of the flask or pattern increases the maximum weight of sand and, therefore, the maximum dimensions of the casting which can be handled. Lightweight flasks and core boxes are easier to transport to the storage shed, and there is less danger of accidents whilst handling or stacking.

Aluminium patterns are popular in the foundry because they are easily produced and they stand far more wear than wooden patterns. They are, therefore, often made when long runs in either hand or machine moulding are anticipated. The light metal possesses adequate resistance to corrosion and does not pit during normal service in the foundry. Consequently, its surface remains unimpaired and good castings are obtained from it long after wooden patterns would have lost their shape and iron patterns been robbed of their smooth surface and true profile through corrosion. Where particularly arduous service is anticipated, projections can be reinforced and protected against undue wear by the use of steel inserts. An alternative idea, which is said to have been put into operation by one leading firm, is to protect light-metal patterns by means of a heavy coat of chromium plate, in the same way that heavy chrome is being used to increase the surface hardness and useful life of machine tools.

A number of alloys have been proposed. One reference to American practice recommends the use of an alloy of 6-8 per cent. Cu, 2½-3 per cent. Si, and remainder aluminium. In this case trouble had been experienced due to pin-holing as the result of overstirring, bad pouring or bad adjustment of the flame when using an oil-fired furnace, and degassing with zinc chloride or magnesium chloride was recommended. Shrinkage was reckoned at 5/32 in. per ft. Another suggested alloy consisted of 3 per cent. Si, 5 per cent. Cu, and remainder aluminium. In this case, the cast pattern must be aged for six hours at 550 degrees C. to obtain maximum hardness. In at least one works known to the writer, mixed scrap aluminium is melted up and cast into patterns and flasks; scrap magnesium alloy is even more popular for the latter purpose. It is probable that most concerns make use of their low-quality scrap in this way, whilst only a few take the trouble, probably unnecessary in many cases, to employ an alloy of known composition. In casting aluminium flasks, corners should be well radiused and the sections should be as nearly equal in thickness as possible and should not be too thin. The suggestions follow normal foundry practice.

Because of its good resistance to a number of chemicals, aluminium has given good service in ventilation equipment in conditions under which other materials have rapidly deteriorated. Thus, in a Pittsburgh steelworks, the combined effects of high temperature and corrosion caused roof vents on the top of the benzol building in the by-products plant to fail rapidly when made in plated steel. Aluminium, on the other hand, was found to give very satisfactory service. There were nine of these ventilators along the roof and the diameter of each was 36 ins. because of its inherently high corrosion resistance.

The metal has found application in boilers and steam-raising plant. Thus, a Swiss concern describes a number of boilers it has built with bottoms of peraluman (aluminium-magnesium alloy) 7 mm. thick. These replaced copper bottoms 5 mm. thick and were found to give much better service in conjunction with oil burners for use at temperatures not greater than 350 degrees C. In one boiler installation in an oil refinery, considerable trouble was experienced through high-temperature oxidation of the tubes in the water-cooled walls of boilers in the power plant. This was entirely eliminated by the application of a coat of aluminium 0.013 in. thick applied by means of a special spray pistol using powdered aluminium as raw material. Sprayed coatings of aluminium are easy to apply on most surfaces and are finding increasing application wherever high temperatures and corrosive atmospheres of certain types are encountered. There are three chief methods by means of which the aluminium may be sprayed on. Of these, the most popular uses aluminium in the form of powder. In other cases molten aluminium or metal in the form of wire is employed.



SHOWN here is a view of the aluminium rolling mill referred to in the preceding illustration. The giant proportions of the 10-ton crane, a close-up view of which has been given, are made very apparent.

A pamphlet published by Kershaw Brassington and Co. in 1936 refers to a 6-in. flue pipe constructed of welded aluminium sheet. It was 40 ft. long and showed satisfactory resistance to atmospheric corrosion and to condenser steam.

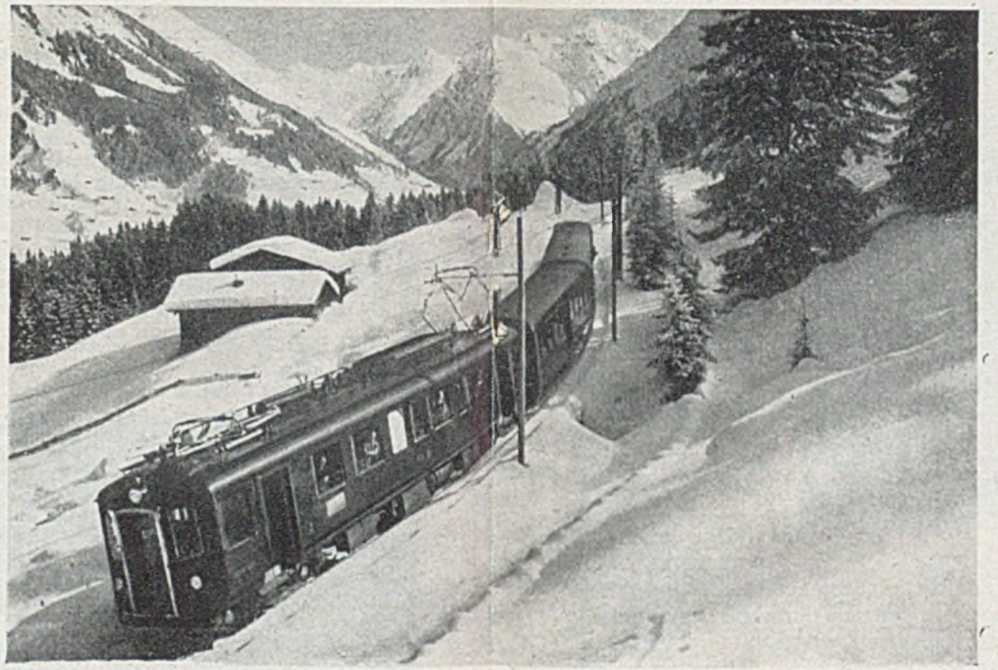
Miscellaneous Applications

In addition to the above, there are a number of instances scattered through other sections of the field of heavy engineering in which light alloys have been applied to advantage.

Aluminium has been used for the casing of an air-line filter. This filter, which was designed for filtering oil, water, dirt, rust, pipe scale, etc., from compressed-air transmission lines, contained a felt pad in a cylindrical receptacle made of aluminium sheet perforated by suitable louvres for the transmission of air. Aluminium was used

Aluminium-cased thermometers are in use in a number of branches of industry. The metal has been employed for the containers and pipe guard at the top of the Kirkham sight-feed lubricator. A large centrifugal pump of German origin, composed entirely of aluminium-alloy sand castings, will subsequently be illustrated.

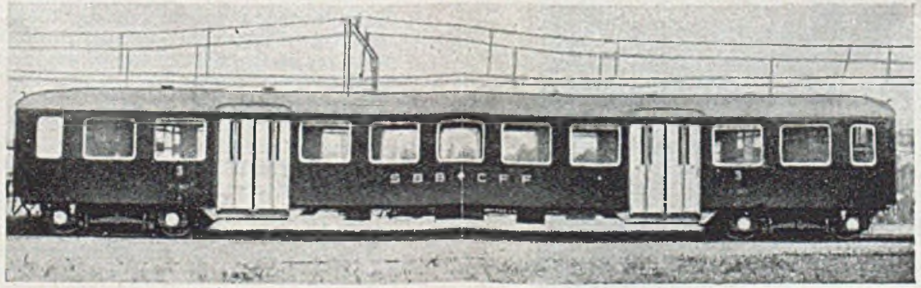
(To be concluded)



NEW-TYPE ROLLING STOCK IN SWITZERLAND*

Account, after Halm and Koenig, from Enlarged Reprint in Technical Supplement to Die Neue Zürcher Zeitung No. 233, Jan. 12, 1944

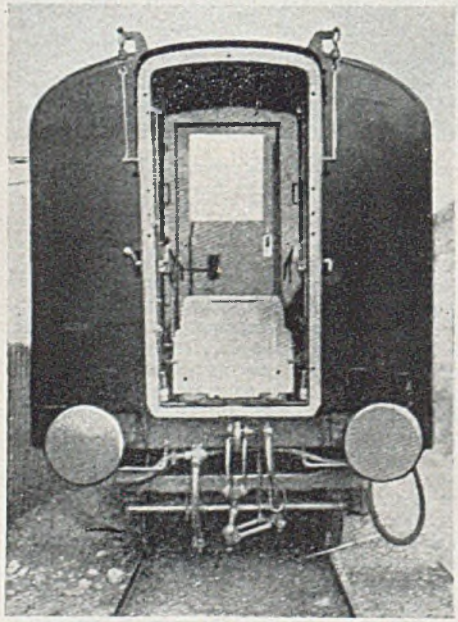
ILLUSTRATED above is the light train on the Unterhalb-Cavadürli section of the Rhätischen Bahn. Pictured below is a lightweight electric passenger coach with aluminium doors and other fittings.



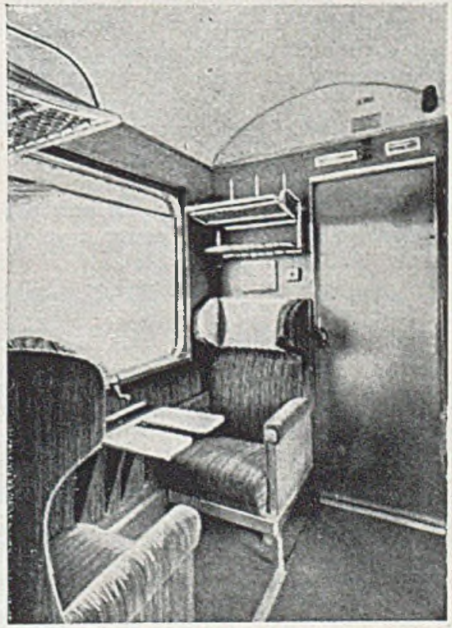
EVEN prior to the outbreak of the present war, aluminium had already found in Switzerland extensive application as a structural material for road and rail transport vehicles and in marine construction. The Swiss aluminium industry devoted great pains to problems of metallurgical development, to the formulation of specifications, to the elucidation of design and methods of working, and to the standardization of various forms in which the material could be delivered to meet the needs of practice.

The results achieved by these efforts have been highly satisfying, more particularly, as during the difficult war period metal importation into Switzerland has been rendered very uncertain, if not directly threatened with extinction. In no small measure, success has been due to the initiative of the State Railways, privately owned railways and tramway companies, together, of course, with the magnificent teamwork of our industry. It is true that, at the moment, light metals are not available in unlimited quantities for random applications of relatively minor importance; their use, moreover, is subject to official control. In this way, supplies are on hand to meet all the demands of war and of the more important industries, and, furthermore, to combat effectively any dangerous situations which may arise from a shortage of heavy metals, particularly copper. Light metals are, with the provisos stated, still available for quick delivery, at prices little above those obtaining in pre-war days. Price stability, and even greater assurance in production possibilities, promise quite definitely to further the expanded use of aluminium in the post-war period.

As regards light alloys for structural purposes, particularly in transport, wartime requirements have intensified their



VIEW of S.B.B. coach with buffers, telescopic connecting corridor and fold-up tread plate, all in strong wrought light alloy.



INTERIOR view of lightweight passenger coach with doors, window frames, luggage racks and other fittings in aluminium alloy.

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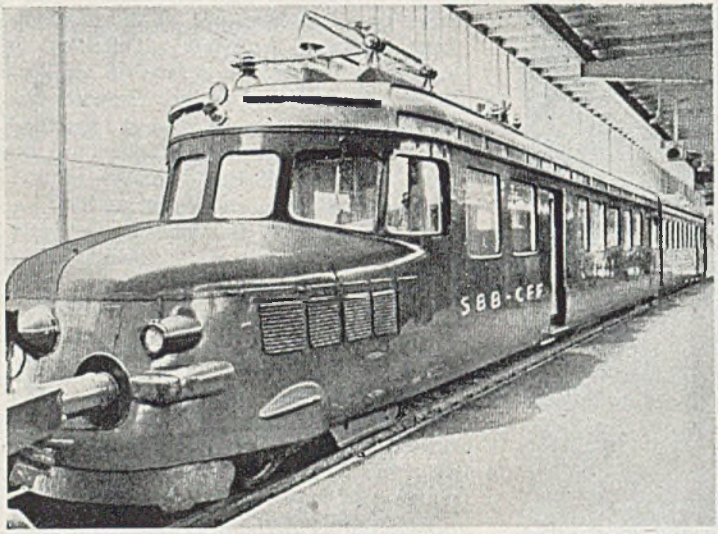
* For further details regarding uses of aluminium in railway engineering, see "Light Metals," 1942/3/280, also 1943/6/521.



MOTOR traction unit on electric passenger train. This features a light-alloy roof, whilst the "bonnet" of the motor house is also in light metal.

use and, as a result of that, development has forged ahead. It is not the purpose of this account, however, to discuss the greatly increased employment of light metals in general transport engineering, as exemplified, for instance, in the equipment of the State postal service, and by Swiss tramways, trolleybus and motor-delivery services. These spheres of use, together with motorcycles, military pontoons and patrol boats, all bear evidence of the growing popularity of the metal. It is proposed to limit this account to an outline of newer developments in connection with State and non-State-owned railways in Switzerland.

Interest in lightweight construction for railway vehicles may be said to have begun in earnest about the year 1930, although its roots may be traced back to an earlier date. The course of evolution was such that attention became focused more and more on the structurally valuable high-strength aluminium-base alloys.

The Swiss National Exhibition in 1939* demonstrated current development by appropriate examples in the Aluminium Hall and in the Transport Salon.

The earliest instance of the use of this metal was in the form of commercially pure sheet employed for the covering of coaches and the like. There were, for example, coaches on the Visp Zermatt line in 1911 covered in aluminium sheet. These coaches, and those used on the Brünig line in 1924, are still in good order. Furthermore, aluminium castings have been used for many years in railway structural work; thus, before the war, the Signum automatic electric safety

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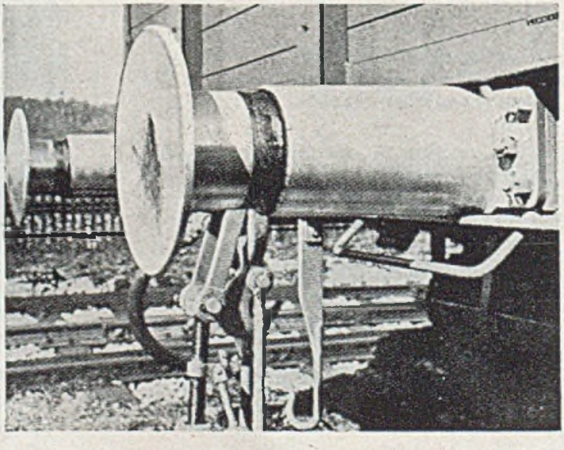
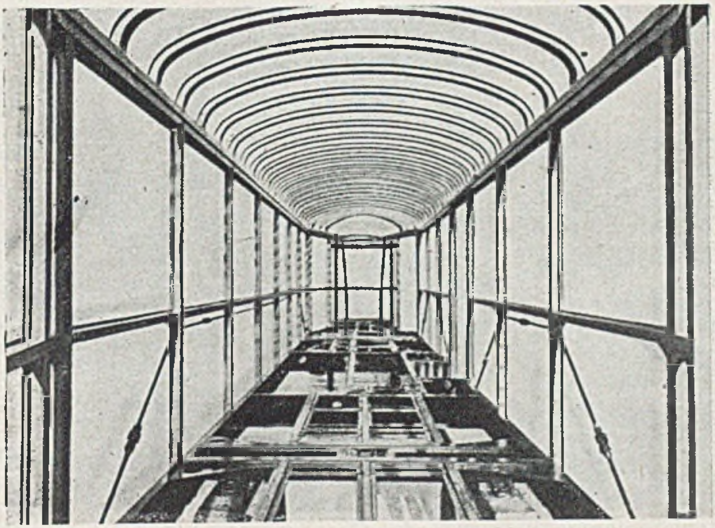
*See "Light Metals," 1939 2/278



LIGHT-METAL buffer unit. The flat-plate type shown here, and the domed-plate type, are produced in wrought high-strength light alloy.



FRAMEWORK of a new tramcar to be used in Zürich. This vehicle, which has very high seating capacity and very low deadweight per passenger, features in its assembly large quantities of light alloys.

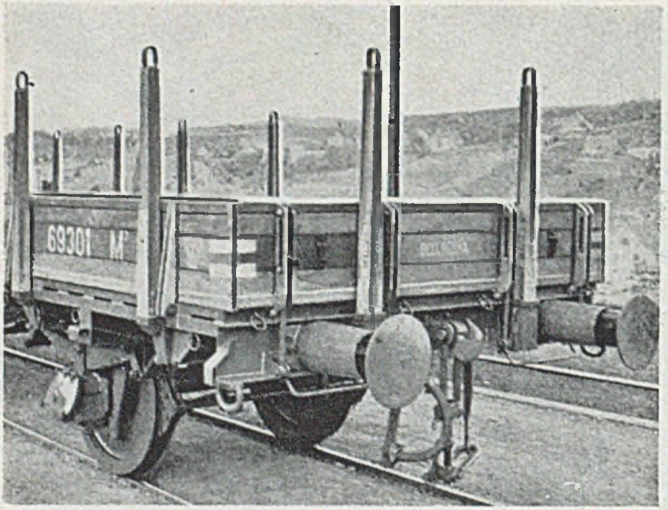
system employed them in considerable quantities. The telescopic connecting corridors between coaches were constructed on frames in heat-treated light alloy, such as Anticorodal, in order that the necessary high strength might be obtained, whilst the hinged tread plate attached to this unit was in the same alloy. Fully heat-treated Anticorodal sheet likewise satisfied all the requirements demanded by the K2 and K3 goods-truck doors.

This stage of development having been accomplished, railway-vehicle constructors began to interest themselves in light-metal doors, window-frames and fittings, for which purpose aluminium extrusions presented an ideal solution to many awkward production problems (see Figs. 5 and 6). It is characteristic of these semi-manufactured forms that they may be turned out to almost any required shape at relatively low cost, hence the surprising readiness with which they were accepted for the purposes we have described.

The increasing application of welding, and the growing trust placed in welded structures generally, ensured that this technique made rapid headway with aluminium as with other metals. Thus, welded light-metal elements soon found their way into railway vehicles. For example, luggage racks, seat frames, ventilating channels, cover plates, and detachable units on the motor coach were all produced as welded assemblies. The plain roof plating of motor coaches was still, in general, of conventional riveted construction.

Applications of this type, which had been proved in service for a period of upwards of 10 years even before the outbreak of war, embraced railway transport vehicles of all types, such as passenger vehicles running both in Switzerland itself and abroad, traction units, goods trucks, electric locomotives, tankers, and so on. A notable instance of light-metal construction of this period is exemplified by the observation car used on the Brünig line, namely, the B4 model, which was fully described by Keller in "Bulletin des Arbeitgeberverbandes der Schweizerischen Transportanstalten," No. 93, 1939.

This recapitulation of pre-war developments will serve to introduce an account of some of the newer applications of light metals in Swiss rolling stock. The low specific gravity of aluminium alloys provided a new solution to the problem of the roofing of goods trucks. In place of the earlier canvas and wood coverings, or the somewhat unsatisfactory thin-copper or galvanized-iron roof, there was introduced the self-supporting type constructed in light metal sheet 2.5-3 mm. thick. During the year 1935-6 trucks



THE M.7-type goods truck with light-alloy side boarding and pillars. The buffer unit is in a strong wrought light alloy.

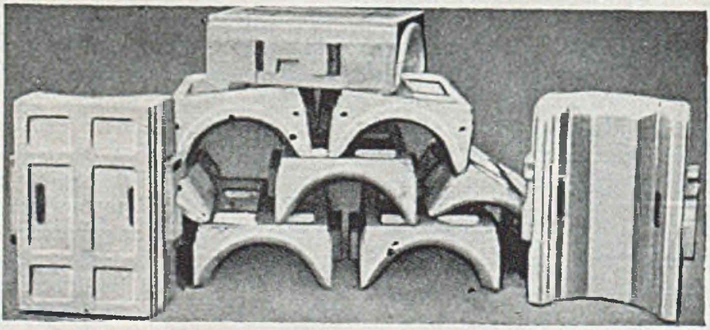
with roofing consisting of 3-mm. Anticorodal sheet were put into service; at the same time the older K2 type was also modified to embody this feature.

As these 3-mm. Anticorodal sheets could be delivered in very large sizes, it became possible to roof-in the complete truck with the minimum number of sheets; thus, any need to guard against leakage at joints was largely eliminated, and the earlier practice of covering junctions with protecting sections (as adopted with good results for many years in the case of buses, trams and trolleybuses) could, in most cases, be safely abandoned.

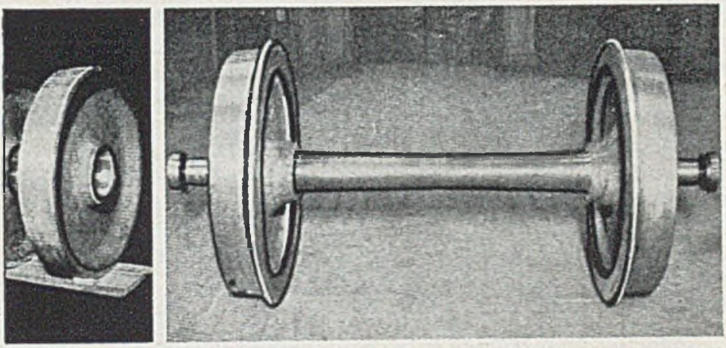
The Swiss State Railways have proceeded in a scientific manner in their adoption of light metal for constructional purposes, the materials being used only where their properties render them desirable and suitable; thus Anticorodal C (cold-rolled finish) has been found to answer all mechanical requirements in service.

Some particular trouble was taken in the attainment of a satisfactory surface finish, and in methods for the application of appropriate descriptions and notices to coaches and wagons. For permanent inscriptions the anodizing and dyeing technique was found to be most satisfactory. The substitution of heavy-metal identification plates on tankers and goods wagons proved somewhat simpler, Aluman being used for the purpose. The pressed-steel ventilating discs used before the war have been successfully replaced by others in Peraluman, also in the form of pressings.

Light-metal buffers at once enabled great weight saving to be achieved. Steel buffers of the type cited weighed 128 kg. as compared with 58 kg. for an Avional forging; the use of the strong



LIGHT-METAL axle box and bearings for rolling stock. Alloys of suitable composition and bearings of satisfactory design in aluminium-base alloy have now been perfected to meet the arduous demands of railway service.



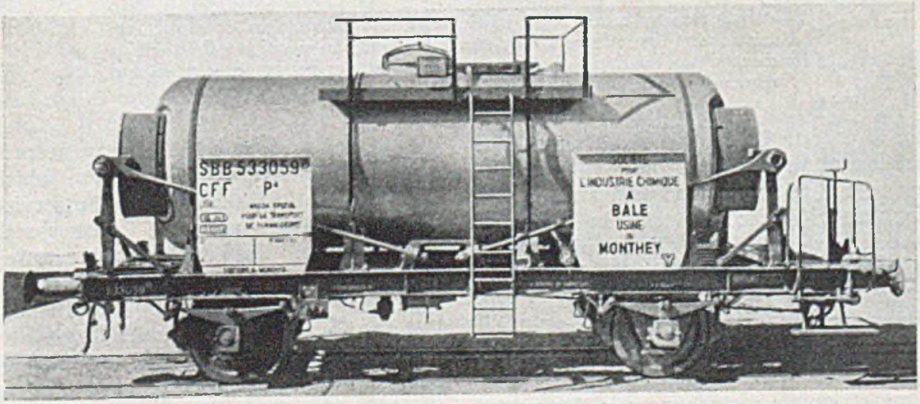
ALTHOUGH strictly in the experimental stage, the light-alloy wheel disc (shown here in side view and mounted on axle) already promises to give successful service and to enable the achievement of even still greater weight reduction in rolling stock.

wrought light alloy results in a saving of about 280 kg. per wagon, with the additional advantage of easier assembling and taking down. Technical advances in mass production and an increasing body of experience have, in the course of the past few years, resulted in such perfection in plant and forging processes that, to-day, these buffer units, which possess very great energy-absorbing capacity, may be turned out in quantity to very close limits. Economies effected in use of material by precision forgings, and the elimination of all unnecessary machining, have made it possible to produce light-metal components of this sort at very greatly reduced cost.

Two basic types, with dome and flat buffer plates respectively, are made. Service experience with these buffers extend now over several years' normal running. Wear resistance of the buffer plate surfaces and sliding action of the movable unit have both proved satisfactory. Under impact, their behaviour has been, on the whole, very satisfactory.

As a result of experiences gained with these buffers consideration might be given to research on light-metal wheels for railway vehicles. Work in this direction has been conducted for several years and the results have been so encouraging that we may look forward to their being mass-produced for new rolling stock in the near future.

If, at first sight, some amelioration of the unsprung wheel mass, with its pronounced deadweight and its reaction on the already heavy live load of the vehicle, structure seems desirable, yet, on the

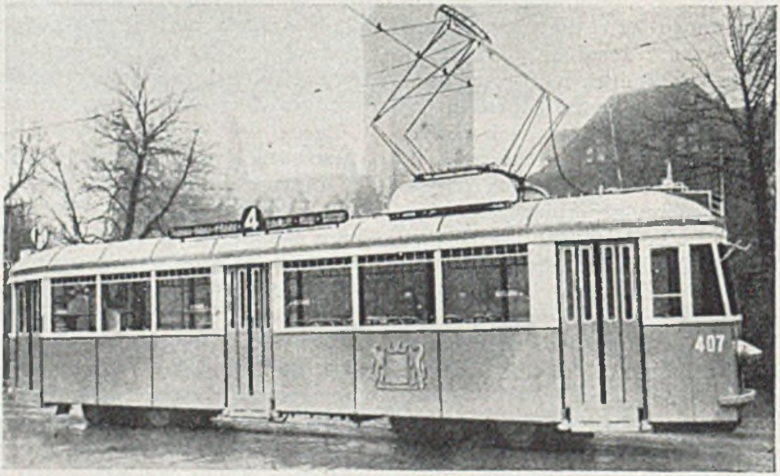


THE S.B.B. tank wagon; the container is constructed entirely in light alloys. Designs of this type have long been in use both for road and rail transport and have given excellent service over a number of years in numerous industries handling the most diverse range of fluids.

other hand, it is also rather natural that, on the other side, doubt should arise regarding the efficacy of tyre and wheel fixing, as well as complications due to temperature and stress under running conditions and especially when braking. However, tests and examination of service and metallurgical requirements, together with trials simulating ordinary running operations, have indicated satisfactory solutions to these problems.

Naturally enough, this particular development is still in its very earliest stages; so far examination has been confined to the basic possibilities of the scheme, and no attempts have yet been made to determine the octimum design for the light-metal wheel in question. Broadly, difficulties in the supply of steel wheels during wartime have provided a strong incentive for the bigger Swiss railway interests to examine the possibilities of light alloys in this connection.

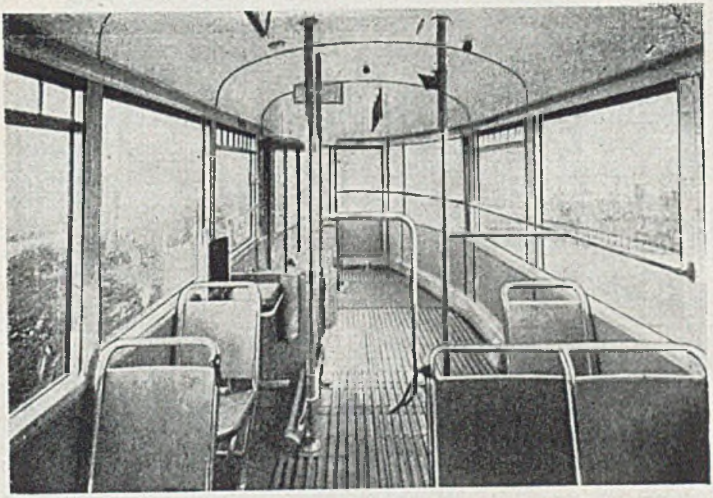
Even more strongly influenced by wartime economic disturbances is the matter of bearings for use in rolling stock, and, here, the effect has been to speed up the introduction of aluminium-base compositions. A shortage of white metal, with a simultaneous need for economy in tin, nickel and the bronzes, has led to some very intensive testing of systematically developed aluminium-base bearing metals well known even before the war. So much work had, in fact, already been done by certain concerns (above all, the Saurer A.G., Arbon), thanks to their own research and development and to their practical use of this type of bearing in road vehicle construction, that they were at once enabled to put forward concrete suggestions.



EXTERIOR view of tramway vehicle in light-alloy construction. In light-railway work more particularly, the advantages of aluminium become very pronounced; they result, not only in positive gain such as increased pay load and decieased deadweight per passenger carried, but furthermore, reduce road loading.

Let it be said, in general, that, according to the nature of the material which is to run in the bearing, and the service demanded of this material, together with shaft loading, lubrication and running speed, so, then, must a specific type of light-alloy bearing metal be selected. Exhaustive investigation extending to the extremes of dry and almost-dry running have yielded valuable data for extending the use of bearings of this sort.

Furthermore, research is in progress in connection with special aluminium alloys designed for shoes running in contact



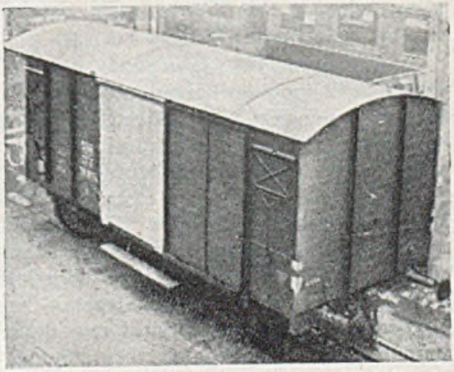
SHOWN here is the interior of a tramway car constructed predominantly in light alloys which confer numerous advantages both of a practical and aesthetic nature.

with the conductor rails of electrified systems; this work has been undertaken in an attempt to eliminate the excessive wear of the older alloys which takes place at high running speed, and, more especially, when the conductor rails are covered with hard abrasive frost or ice.

Attempts to line steel-bearing housings by simply casting-on an aluminium alloy (very much after the practice adopted for white-metal or lead bronzes) soon began to give rise to difficulties owing to the fact that differences in thermal expansivity between the aluminium alloy and the steel interfered with good adhesion. This circumstance had already been encountered in the general engineering industry, which had adopted aluminium bearings at an early date. Here it had been overcome by the use of complete light-metal shells and, in certain cases, by the application of thin shells sprung into position. For rolling stock, however, where heavy impact stressing is encountered, the use of massive light-metal bearings provides the only solution. Investigation by the State Railways on this type of bearing assembly, at first without load, then under full load, and finally under hot-running conditions on a K.3 goods truck, showed that the aluminium alloys recommended for the job were perfectly satisfactory.

The value of these investigations, which, as in the case of the aluminium wheels already cited, provide some solution to the problem of alternative materials in times of shortage of those traditionally employed, cannot be over estimated where big consumer interests of the type we are discussing are concerned. In the first place, such work assures the well-being of the country's transport. Moreover, in taking this course, the railway system not only does a service to itself, but, furthermore, assists participating industries.

The M.7 goods wagon of the State Railways provides an excellent example of the way in which extruded sections have been applied in railway construction technique. These long trucks,



THE K.2-type goods wagon with light-metal roof, light-metal doors, and light-metal ventilating shutter. Especially noteworthy is the fact that the bearings of this vehicle are also in an aluminium-base alloy.

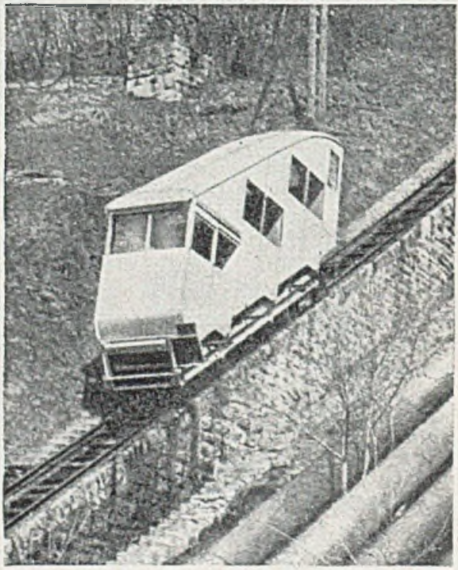
with their low build, are capable of carrying massive loads. It should be made clear that the developments which have been described apply equally to subsidiary services and mountain railways. On every line in Switzerland there are series of coaches, the skins of which consist of light metal; we may quote the Montana Vermala and the Gurtenbahn.

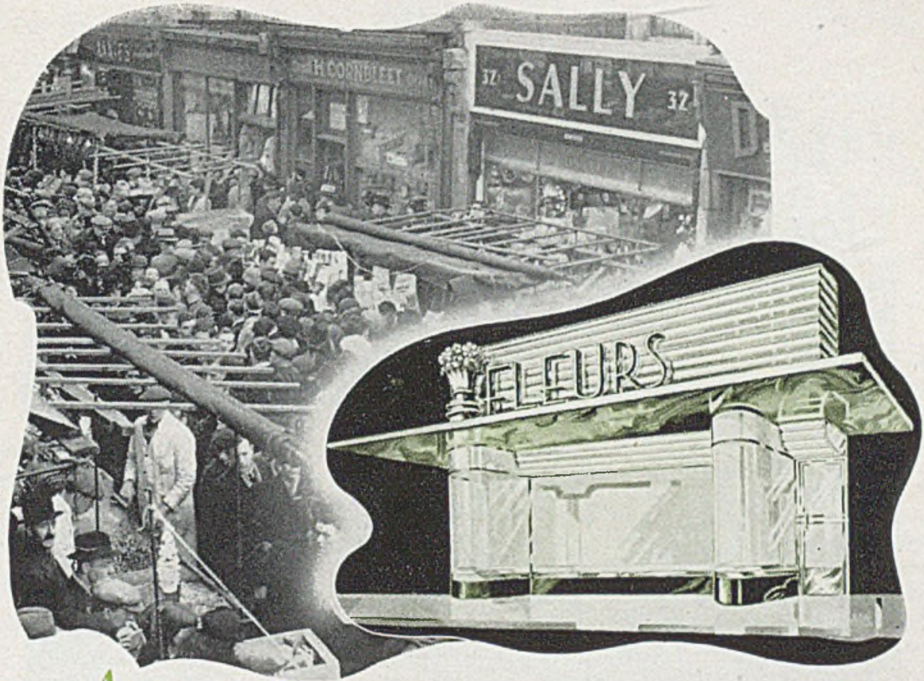
As instances of special constructions may also be cited light-alloy trolleys employed by the State Railways for maintenance staff engaged in the repairing of trolley wires. When the work in hand is finished, these wagons and trolleys must be readily removable from the track, as may be well understood.

To illustrate the increasing tendency manifested for some years by tramway companies to go over to light-metal skin construction, we may cite the case of Zürich, which has recently put into operation a passenger street car with very large seating capacity. The whole structure of this vehicle is in light metal. The section supporting the roof was finished entirely to shape in the works and delivered to the assembly shops in one piece. As a result of the use of light metals, deadweight has been reduced to a figure of 120 kg. per passenger, and there is a possibility that, by the use of forged light-metal buffer-coupling units, together with the application of light-alloy wheels, this figure may be still further reduced.

To conclude this account, a brief sketch will now be given of the more recent tendencies in structural technique for light metals. These are based, principally, on the development within the past few years of satisfactory electrical spot-welding systems for light alloys. The evolution in the period 1938-39 of a seam-welding technique for the complete sheeting of coaches in light metal has resulted in sufficient practical experience being gained to take a further step forward and to justify the assembling of these structures by means of spot-welding. A necessary condition for this to be satisfactory was the development of suitable spot-welding machines which could handle material up to 2 metres long and in thicknesses of 2-3 mm. Plant of this calibre by various manufacturers is already in existence in Switzerland and work has already commenced on the construction of large coaches, the system employed entailing as a first operation the spot-welding of the shell to the light-metal framework.

In these assemblies notable use has been made of extruded sections, and in many cases it has become possible to build up massive sections by the "spotting" together of various appropriate smaller extrusions. In this way spot-welding has permitted the attainment of new and better designs of box structure for the coach flooring, the product being very light and yet highly resistant to buckling or excessive deflection. Because of the extraordinary decrease in deadweight achieved, it is anticipated that these trams (which have already gone into mass production) may prove suitable for use in conjunction with the light-alloy wheels previously referred to.


COACH on the Rifomwerk wire-rope railway. In this and similar instances where reduction of deadweight is all-important, extensive use is made of light alloys.



In the market again

Tastes will always vary regarding WHERE people purchase commodities. Some prefer Street markets—others a really attractive shop.

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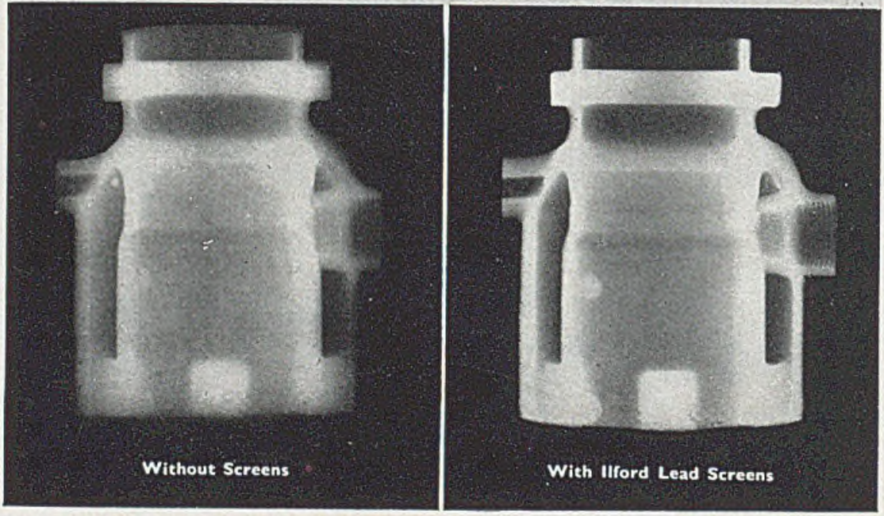

200 kVp 10 mA 5 min. 36 in. *200 kVp 10 mA 3 min. 36 in.*

ILFORD LEAD SCREENS IMPROVE RADIOGRAPHIC QUALITY

Every discerning industrial radiographer is aware of the beneficial action of lead foil placed in contact with each side of the film in overcoming the harmful effects of scattered radiation.

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1. **Maximum reduction of scattered radiation reaching the film giving the greatest possible improvement in contrast.**
2. **Reduction of exposure times up to 50 per cent.**
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4. **Definition indistinguishable from that obtained with non-screen exposures.**
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Inspection of Light-alloy Forgings

Reviewing, Briefly, the Duties of Inspectors in the Stamp Shop and Associated Departments, and the Organization of an Inspection System

TO produce sound light-alloy forgings it is essential that an efficient inspection organization be in operation. Inspection of such work is by no means an easy task; only those with a complete knowledge of forgings manufacture should be employed on specialized work of this kind.

JOB CARD

Date

Works Order No.

Cast No.

Description and Part No.

Material Supplier

Advice Note No.

Customer

Quantity on Order

Material Specn.

Fig. 1.—Illustrating layout of typical job card.

Raw Material

On receipt of the raw material, the inspector must first establish cast identification. Failure to do so at this stage may result in serious consequences later on, not only during the manufacture, but after the finished articles have left the works. The cast number and material specification should be stamped on each bar or billet, together with a standard colour marking; although the latter is not absolutely necessary provided that the former identification is legible and correct. Documentations accompanying the material should contain all information regarding identity, and also the recommended heat treatment and temperatures as specified by the raw material manufacturers.

After the establishment of identification, the material should be inspected to prove freedom from defects. This may be done by a fracture test and visual examination, after which a sample should be analysed to check chemical composition. Owing to the number of specifications being worked to nowadays, it is of paramount importance that all material be kept well segregated in order to prevent any possibility of mixing.

Inspection in the Stamp Shop

When heating light alloys for forging, it is the responsibility of the inspection department to see that the correct soaking times be given at the temperatures recommended by the material manufacturers. All heating furnaces must be equipped with a pyrometer, which is checked at regular intervals to ensure that the temperatures shown are correct.

Mistakes often occur when heating metal for forging. Overheating may occur if a careful watch be not kept on the temperature of the furnace; overheated metal can always be detected by large grain size or " blistering " on the surface. Too low a temperature will also give trouble.

The first few forgings made at the hammers should be checked dimensionally and visually by the inspector, who must determine whether production be continued or stopped pending some alteration to dies, temperature, or wherever the discrepancy may lie. If the forgings be considered satisfactory after this check, production may continue.

Immediately after leaving the hammers

BATCH CARD

Date

Batch No.

Cast No.

Works Order No.

Material Supplier

Customer

Specification

Part No.

Advice Note No.

FINAL INSPECTION

Satisfactory	Rectified	Scrap	Inspector's Stamp

Passed to Despatch Stores (Date)

Signed..............................Inspector.

Fig. 2.—Batch card (front).

the forgings are "clipped" and then returned to the hammers for a light "tapping" to serve as a final setting operation. It is the duty of the inspector to see that all clippings be kept segregated in bags, securely fastened, with a tally attached bearing the correct identification.

In order to ensure that the correct identification of the forgings is maintained, a job card should be raised immediately prior to stamping (Fig. 1); this will accompany the work up to the heat treatment stage and will then be replaced by a batch card (Figs. 2 and 3). A batch of forgings is defined as the number required to constitute one heat-treatment-furnace charge.

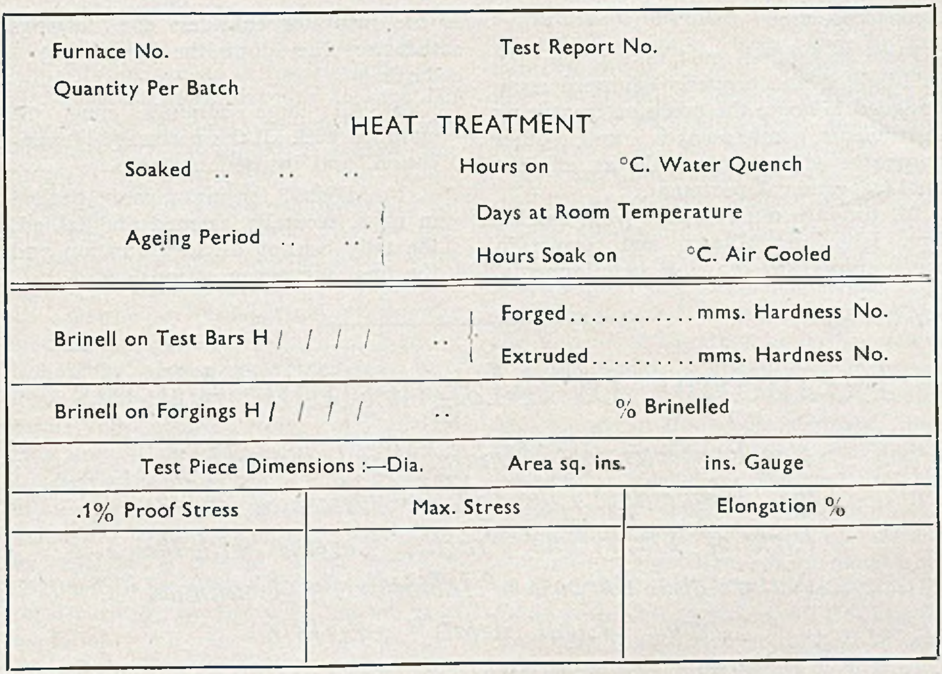
Heat Treatment

In general, light-alloy forgings are required in the heat-treated condition, although there are occasions when they may be used in the "as-forged" condition. Complete heat treatment takes place in two stages:—

(1) Solution treatment.
(2) Ageing.

Solution treatment must be carried out within the range of temperature stipulated by the material manufacturer, and it is the duty of the inspector to see that this is done. Rapid cooling by quenching in water follows unless otherwise stated. Quenching, following solution treatment, renders the material quite soft. Should the latter process be carried out either below or above the ranges specified, the result may be failure to meet the mechanical requirements. Ageing treatment may be performed in two ways, either naturally, that is at room temperature for a period of about five days, or artificially, by heating at a temperature for a given time as laid down by the material manufacturer.

Solution treatment may be carried out in hot-air circulating furnaces or salt bath. Whichever method be employed, the inspector must satisfy himself that the correct treatment temperatures and soaking time be given; any divergence from this stipulation is to be made only by his authority. Pyrometers recording the temperatures of the heat treatment furnaces should be checked regularly at



Furnace No. Test Report No.

Quantity Per Batch

HEAT TREATMENT

Soaked .. .. .. Hours on °C. Water Quench

Ageing Period .. .. Days at Room Temperature
Hours Soak on °C. Air Cooled

Brinell on Test Bars H / / / / .. Forged............mms. Hardness No.
Extruded..........mms. Hardness No.

Brinell on Forgings H / / / / .. % Brinelled

Test Piece Dimensions :—Dia. Area sq. ins. ins. Gauge

.1% Proof Stress	Max. Stress	Elongation %

Fig. 3.—Batch card (back).

the inspector's discretion to ensure their accuracy.

Pickling

All forgings are required to be pickled before final inspection. This may be done in a number of ways, the most common being:—

Sulphuric acid, 12 per cent. (by volume).

Sodium fluoride, 1.5 per cent. (by weight).

The parts should be immersed in this solution for a period of 10 mins. at a temperature of about 20 degrees C.

After this treatment the parts are rinsed in water and then in a solution of 50 per cent. nitric acid for about one minute, and finally in hot water not exceeding 50 degrees C., and dried. It is advisable to carry out final inspection as soon as possible after this process, as the brightness of the metal tends to assist in the detection of any surface defects and also gives an idea of the grain size of the metal.

Test Pieces

Prior to pickling, the heat treatment must be proved. Each heat-treatment batch should be accompanied by three test pieces, which may be either "as forged" or in the extruded condition. Forged test pieces usually give better mechanical figures than the extruded bar, this being due to the extra work applied to the metal. The inspector must see that all test pieces are correctly identified, and made from the same material as the forgings, and truly representative of the latter. After satisfying himself that the correct heat treatment and ageing have been given, he may order one test piece to be machined and pulled. If it meets specification demands, the batch may go forward for final inspection. Should the test piece fail, however, the batch may be re-heat-treated with the two remaining test pieces and re-tested, after which, if all requirements are met, the batch may be passed to final inspection, otherwise the work must be rejected.

Final Inspection

Final inspection must take place in a well-lighted and properly equipped room designed to house the precision measuring instruments, microscopes and other apparatus which go to make an efficient final-inspection department.

All forgings must be free from cracks, laps, folds and blisters, and correct in every respect to drawing requirements. If the inspector considers the forgings satisfactory, he adopts the following procedures:—

(a) All large forgings must be stamped with all the necessary identification, and inspection stamp.

(b) All small forgings must be packed in bags, securely fastened and tallied, the tally bearing all identification and the final inspection stamp.

Founding of Magnesium Alloys

The Properties of Moulding Sands Suitable for the Magnesium Foundry are Discussed in the Light of Theory and Practice, Together with the Nature and Purpose of Inhibitors. (Continued from "Light Metals" 1945/8/6)

MAGNESIUM alloys, of low specific gravity when solid, are, of course, even less dense when fluid. At about 700 degrees C., the specific gravity of molten magnesium is no more than 1.5; it has, therefore, little hydrostatic pressure. This fact, and the fact that magnesium at elevated temperatures is explosively reactive with water, govern the physical and chemical requirements of sand to be used for ultra-light-alloy moulding.

The low density value of the material means, in practice, that air or gas pockets will present comparatively great resistance to the flowing metal, and lack of definition on sharp corners would tend to be produced if steps were not taken to see that back pressure was minimized. Venting, as practised in the moulding of other metals, is, for reasons which will appear later, not sufficient. The first requirement is, then, that the sand chosen shall be "open," or permeable, to a sufficient extent to present no resistance to the passage of air or gas from the mould cavity to the outside atmosphere.

It will be appreciated that the plasticity of a moulding sand depends upon the moisture, either loosely held by, or chemically combined with, the clay that gives the sand its bond or coherence. In a natural moulding sand, this moisture may amount to 10 per cent., which seems, on the face of it, to be a large amount of water to have about where molten magnesium is concerned. Moisture in magnesium moulding sand must, then, be kept to a minimum, and even this minimum must be prevented from reacting with the molten metal. How is the combination of properties thus indicated to be achieved?

Special sand mixtures, elaborated on the basis of washed silica sand and so-called "synthetic," are used. The selection of silica sand of suitable uniform grain size provides maximum permeability, but such a sand does not, of course, contain any bond material, and moulding, other than of the sea-shore variety, is an impossibility. Bond is provided by the addition of bentonite, or an English china clay, these substances having the property of absorbing water to form a plastic clay. Although only a small amount of clay is added, its influence spreads throughout the mass of sand, transforming a heap of free-running silica into a plastic mass that may be moulded into more or less permanent shapes. Only sufficient water is added to achieve this object.

But, as we have said, reaction with even this small amount of water must be prevented. The normal methods for preventing air and water attack on metals offer an instructive comparison with the methods adopted in magnesium foundry technology. Iron is prevented from rusting by red-lead painting, steel by certain forms of electro-plating, and bright annealing is accomplished by heat treating in absence of oxygen or in the presence of an inert gas (inert, because it does not react with the metal being treated). Protection, in a general sense, may be obtained by putting on a blanketing film or, negatively, by removing the source of oxidation.

Historically, the latter method was applied to magnesium-alloy moulding. Early attempts at sand casting involved the use of moulds heated until all the moistures had been driven off. Such moulds, as might be expected, were very liable to damage, and the resultant castings had not, therefore, a good surface appearance. To-day, protective-film-formers are incorporated in the sand. Many substances have been proposed, but it can be said that the three chemicals, sulphur, boric acid and ammonium hydrogen fluoride are now used the world over for the purpose, either singly or in combination.

The whole subject of oxidation-prevention of magnesium, whether in the solid or liquid states, is so important that some space may well be devoted to a consideration of the theoretical background. Surprisingly little information is available on the problem. It used to be stated rather vaguely that sulphur dioxide somehow diluted the air and hence aided in preventing burning of molten magnesium, but the fact that magnesium, once ignited, would continue to burn in sulphur dioxide with decomposition of the gas was often conveniently forgotten. The substances mentioned—sulphur, boric acid, ammonium hydrogen fluoride—are now recognized as inhibitors, and the only satisfactory theory explaining their action was put forward in 1936 by Delavault.

Delavault built upon the work of Pilling and Bedworth, who showed, in a paper to the Institute of Metals in 1923, that oxides formed upon the surface of metals may be greater or less in volume than the metal taking part in the reaction. When the volume of the oxide so considered is less than that of the metal, the film formed is porous and gives no protection; when the volume of the oxide is greater than the metal, the film is continuous and is protective. Pilling and Bedworth further demonstrated that a numerical factor could be evolved connecting the volume of oxide and the volume of the metal from which it was formed; when protection by oxide was obtained, this factor was greater than one, but where no protection was given, the factor was less than one.

This idea was extended by Delavault to magnesium in the molten state, and he showed that, whilst the oxide of magnesium gave no protection, films of certain other compounds of magnesium did, in fact, give protection. He worked out the Pilling and Bedworth factors and obtained figures indicating results that are confirmed by experience. For example, the factors for films formed on molten magnesium by the following agents, oxygen, nitrogen, sulphur, fluorides, are in ascending order, fluorides producing a factor well above unity. This film, then, provides maximum protection. All inhibitors are, to some degree, film formers. The best protection is given by those that form the most continuous films.

Practically, it may be understood that whilst all inhibitors give a similar ultimate result on molten metal—that of isolation of the metal from air or moisture—the surface conditions resulting are strikingly different. Magnesium-alloy castings produced from sulphur sand are silvery and bright and may be pickled without difficulty in dilute nitric or sulphuric acids; it would appear that the film due to sulphur is either temporary or has little protective value on the solid casting. On the other hand, castings produced from ammonium-hydrogen-fluoride sand have a distinct blue sheen, and are only etched with difficulty to a bright finish. The fluoride film appears to be persistent, and indeed has value as a corrosion-resistant medium. It has been noticed also that misruns on thin sections due to imperfect mating of two or more molten metal streams are much more common when ammonium-hydrogen-fluoride sand is used. In this case, the tenacity of the inhibiting film actually becomes a disadvantage.

It may be mentioned in passing that alloying additions have been proposed to restrict the oxidizing tendency of magnesium alloys. Calcium and beryllium have been used in small amounts with some evidence of success in cutting down oxidation of the molten metal, but progress has not yet been made to obviate the necessity for the addition of inhibitors to magnesium moulding sand.

In the absence of an adequate inhibitor content, molten magnesium alloys are attacked with the production of a dirty, scar-like appearance on the surface of the casting. With the use of sand with a falling inhibitor control, this defect will first be seen on thick sections and, of course, frequently on the risers, as these are the biggest volumes of the casting considered as a whole.

The use of sulphur and boric acid together as inhibitors has become associated with the technique originating in Germany, whilst ammonium-hydrogen-fluoride is associated with that known as the English system. It appears that the Americans adhere less rigidly to one or the other system, but often use the three widely known inhibiting substances together at one time.

Because of the low moisture and clay content and maximum permeability of magnesium moulding sands, they tend to dry out quicker than naturally bonded sands. The moulder has to get used to the dry touch of the sand, and foundry organization has to be such as to allow frequent pouring so that the moulds do not dry sufficiently to cause crumbling of thin sections of sand. American sand compositions often include 1 per cent. of di-ethylene glycol which is added, presumably, to combat the speed of drying.

It has been seen that the oxidizing properties of molten magnesium alloys are held in check, during filling the mould, by external conditions created by sand additions and control. Attempts have been made, as we have said, by alloying additions, to produce alloys that do not oxidize so readily as the normal magnesium compositions and thus would not require such strict observance of inhibitor control. Additions of calcium in the proportion of 0.1 per cent. definitely reduce speed of oxidation to some degree, but not to an extent sufficient to eliminate the necessity for inhibitors. Beryllium is added in some foundries in the United States; there does not, however, appear to be any reliable published data.

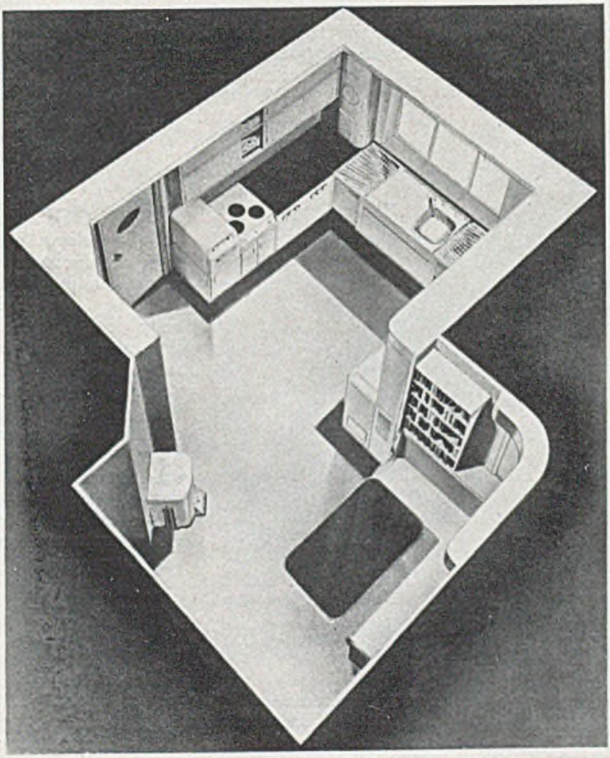
The use of calcium-bearing magnesium alloy in metal for gravity die casting results in castings of a clean, silvery appearance.

From what has been said, it will have been concluded that careful analytical control of sand is a necessity, in order that this most important indirect material is a constant, and not a variable, factor.

Now for practical, as distinct from theoretical considerations. Silica sand consists of practically pure silica. The type used for magnesium moulding should be washed and grain graded; washed to remove foreign organic matter which would form carbonaceous gases at the temperature of molten magnesium, and graded in order to achieve a high permeability value. Sand received into the foundry should be dry, or should be dried before use. It has been found that when 80 per cent. of the sand is retained by adjacent larger sized seives, with the smallest proportion of fines, the permeability will be adequate. For guidance, it may be noted that seives 44 and 60 may be used as the adjacent test seives. The practical requirement is that the sand shall be of uniform grain size.

(To be continued.)

NEWS—General, Technical and Commercial



SHOWN here is a view of the all-aluminium kitchen designed by E. R. Gilbert. Planned for functional efficiency, this assembly also meets the requirements of modern taste and the needs of changing social habits.

A Planned Kitchen in Aluminium

DESIGNED by E. R. Gilbert, the model kitchen in aluminium illustrated here is intended for those who want something more than the Government's "minimum standard" in housing accommodation and equipment.

This kitchen is roomy, airy and cheerful and labour-saving to a degree, and has been laid out to meet the new conditions under which resident maids will either be non-existent or will each cost at least £150 a year for wage and board. Facilities for eating in the kitchen have, therefore, been provided in a delightful alcove or recess. Anodized aluminium is suggested for the jacketing of the various appliances, such as the cooker, refrigerator, washing machine and work bench, and for the cupboarding and sink unit. Standard size units are used and these can be adapted for existing kitchens.

Interesting features are incorporated in the cooker; it has a raised oven; which can be quickly dismantled to facilitate cleaning. There is also a combined sink and electric dish-washing unit with a telescopic swivel tap.

Aluminium is an ideal material for kitchen appliances, cupboarding and kitchen furniture. It lends itself to assembly-line production, is easily kept clean, and can be anodized and dyed in a wide range of attractive colours. Cost should compare favourably with vitreous-enamelled cast iron for appliances, and with timber for cupboarding.

Birmid Industries' Record

TRULY it has been said that "an institution is the lengthened shadow of one man," and when Mr. H. J. Owen, oldest director of the Birmid Industries Group, looks back over the years it must give him great satisfaction, for he has seen aluminium raised from an almost unknown quantity to first place among the strategic metals of war and to be the serious challenger of older metals in the post-war field of transportation.

It was in 1901 that Mr. Owen happened to see a perspiring man pushing a broken-down motorcycle along New Street, Birmingham, and so characteristically went to his assistance. That motorcyclist proved to be a certain Mr. Clement, founder of the Clement Talbot Motor Co., and it was this chance meeting that provided Mr. Owen with his very first order for aluminium castings for motor engines. From this romantic beginning the Birmingham Aluminium Casting Co. (1903), Ltd., was founded.

At a recent gathering of workers, Mr. Percy Pritchard, managing director of the Birmid Group, paid tribute to the latest recipients of the company's long service award, who now total no fewer than 300. Mr. H. J. Owen, looking nothing like his 80-odd years, was there to make the presentations.

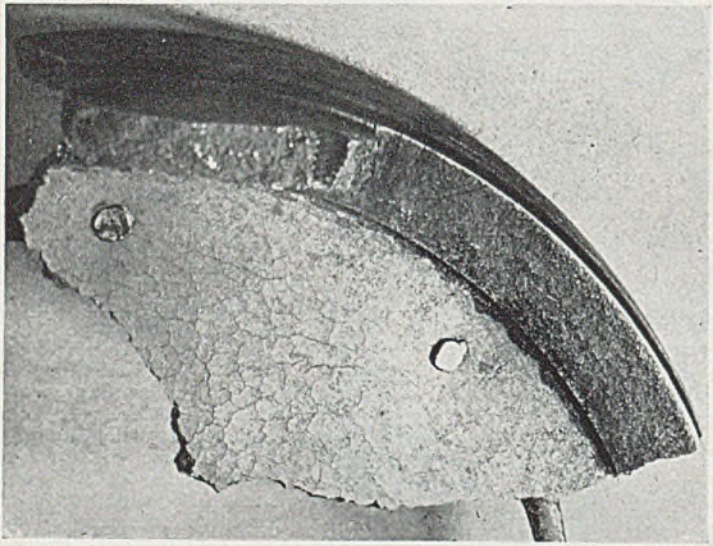
Current Light-alloy Specifications

WITH reference to the summary of current light-alloy specifications presented on pages 576-581 of "Light Metals" for December, 1944, we wish to draw attention to the following corrigenda and modifications:—D.T.D. 133B is now replaced by D.T.D. 133C, the composition of which remains the same excepting that the silicon figures now read 0.05-0.20. In the case of D.T.D. 361, total impurities (Ni., Mg., Mn., Zn.) should read 0.2 per cent. max. The copper content for D.T.D. 364A should read 3.0-4.8. Silicon content for D.T.D. 423A should read 0.75-1.25. The iron content of L.45 should read 0.5-1.5; and in the case of D.T.D. 197 there should have been indicated the presence of 4.0-6.0 per cent. iron.

Fishing Story!

WHILST it must by no means be assumed that errors of the type we are about to note are committed solely by users of aluminium, or that the consequent catastrophes can overtake light alloys alone, the accompanying illustration of part of a fishing reel does emphasize the potential danger of debasing these materials.

Aluminium alloys, no less than those of the heavy metals, have been developed along highly scientific lines and, in general, uncritical tampering with composition leads to danger. The analysis of the metal of which the fishing reel shown is made is as follows:—Copper, 2.52 per cent. Tin, nil or tr. Manganese, nil or tr. Iron, < 0.05 per cent. Silicon, 0.09 per cent. Lead, 1.12 per cent. Nickel, nil or tr. Zinc, 38.92 per cent. Magnesium, Trace. Aluminium, 57.30 per cent. Titanium, ——.



MACROGRAPH (equivalent magnification in reproduction = 2) showing phenomenon of intercrystalline corrosion in the substance of a fishing reel. This article was produced in a debased aluminium alloy high in zinc, and illustrates a danger inherent to the uncritical use of nondescript compositions.

It will be seen that it does not conform to D.T.D. 598 and is of a most inferior and undesirable composition.

The reel itself, which had been little used, was stored under quite normal conditions for a few years, and when, recently, it was taken out and examined, was found to have been rendered entirely useless by intercrystalline corrosion; this is indicated by the tesselated appearance of the surface in the macrograph, from which, also, it will be seen that no obvious surface corrosion is present.

We would stress, as we have done so often before, the fact that, for no matter what purpose, or in what connection, a light metal is required to be used, proprietary or standard alloys of proven value are available. If any doubt exists as to the best composition for a given application, suppliers of the raw material are at once able and willing to give the necessary information.

Light Alloys in
Rectifiers, Photocells and Condensers

In this Section Consideration is Given to the Theory and Practice of the Formulation of Electrolytes for Electrolytic Condensers, and to the Design and Production of such Condensers, Typical Examples and Applications Being Given

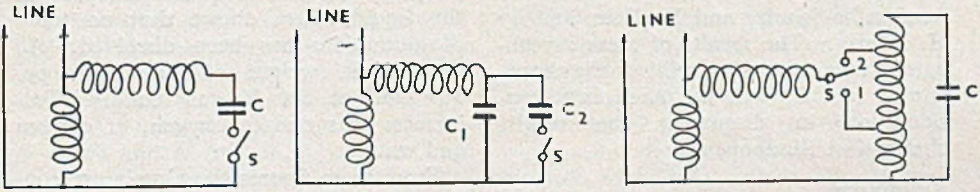


Fig. 134 (left).—Circuit arrangement for condenser-start motor in which the condenser is in circuit in series with the starting phase. Fig. 135 (centre).—Circuit including two condensers in parallel. Fig. 136 (right).—Circuit embodying a single condenser used in conjunction with an auto-transformer to give the same results as the two condenser circuits.

THE concluding paragraph of the previous section of this account ("Light Metals," 1945/8/41) directed attention principally to research and data in connection with the electrical characteristics of the oxide film on the aluminium anode of the electrolytic condenser. Much, however, still remains to be clarified regarding the physical and chemical properties of the film.

In "Zeitschrift für Physik," 3.3.32, 74, 9 and 10, a communication appeared from the research laboratories of N. V. Philips's lamp factory, Eindhoven, Holland, entitled "The Chemical Nature of the Oxide Layers Formed by Anodic Polarization, on the Metals Aluminium, Zirconium, Titanium and Tantalum," by W. G. Burgers, A. Claassen and I. Zernike. A very brief abstract of this is given because the work was carried out in direct relation to electrolytic condensers.

From a combined chemical and X-ray investigation of the oxide film, which is formed by anodic polarization on the metals aluminium, zirconium, titanium and tantalum, the following information was derived with respect to the chemical nature of this film:—

Metal and Oxide Film

Aluminium. By forming in borax/boric-acid solution, almost pure Al_2O_3, with low water content. The Al_2O_3 is found in one of the cubic forms related to γ-Al_2O_3. Reference will be made to the possible effect of forming conditions on the chemical and crystallographic nature of the film.

Zirconium. Monoclinic ZrO_2 (Baddeleyite modification).

Titanium. Tetragonal TiO_2 (Anatase modification).

Tantalum. Ta_2O_5.

In the previous work, the results of a combined chemical and X-ray investigation of the oxide film formed by anodic polarization on the metals aluminium, zirconium, titanium and tantalum were reported. Work concerned with the same subject has recently been published by

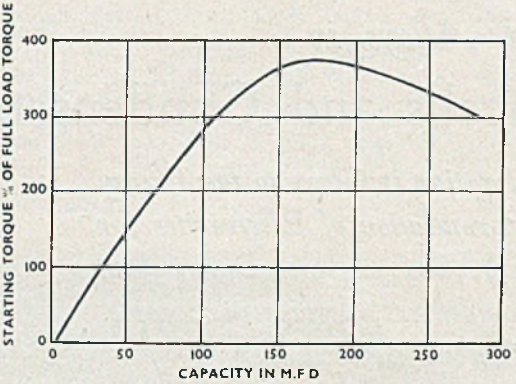


Fig. 137.—Curve for starting torque against capacity (Aerovox Corporation).

A. Günthe-Schulze and H. Betz, and by H. Röhrig. The results of these investigators, in so far as they relate to the above-named metals, will be taken into consideration in discussing the results obtained at Eindhoven.

Aluminium

The anodic oxidation of aluminium takes place in water solutions, containing 2 g. borax and about 100 g. boric acid per litre, at a temperature of about 100 degrees C. At this temperature and concentration of the solution, the sparking pressure amounts to about 530 V. In the experiments to be described, 500 V oxidation was employed for such time until the residual current amounted to only several mA per µF measured at 100 degrees C. The aluminium used was polished rolled sheet 50 mm. thick and 99.6 per cent. pure. Previous to oxidation, it was pickled in KOH and H_2SO_4, and well washed with hot water. After oxidation was completed, the oxide film could be isolated by itself, by dissolving the metal in fairly dilute hydrochloric acid or lye. If the dissolving of the aluminium be not carried out too briskly, the oxide film is obtained in the form of large coherent scales, which, after careful washing, may be filtered off, dried (at about 80 degrees C.) and weighed. As the result of many determinations, the weight of oxide-film yielded thus at 500 V from an aluminium sheet of about 150 cm.² (300 cm.² total surface area) was found to be 16.8 mgm. per 100 cm.² This weight remains constant after many hours' drying at 120 degrees C., within 1 or 2 per cent. Again, aluminium sheet was weighed before oxidation, and the increase in weight after oxidation determined. If care be taken that the aluminium be dipped under potential in the oxidizing solution, there is no danger of metal going into solution; subsequent analysis of the liquid, then, shows that no trace of aluminium has been dissolved. An increase in weight of 7.8 mgm. per 100 cm.² at 500 V was found. This increase was due to oxygen, or oxygen and water.

From these figures the aluminium content of the oxide film was found to be $\frac{(16.8 - 7.8)}{16.8} \times 100$ per cent. = 53.6 per cent. Comparing this with the aluminium content of Al_2O_3 (52.9 per cent.) and $Al_2O_3H_2O$ (45.0 per cent.), it is clear that the oxide film is almost pure Al_2O_3. Gunthe-Schulze and Betz have also come to this conclusion from the behaviour of borax - boric - acid - solution - anodically-oxidized aluminium on heating. A

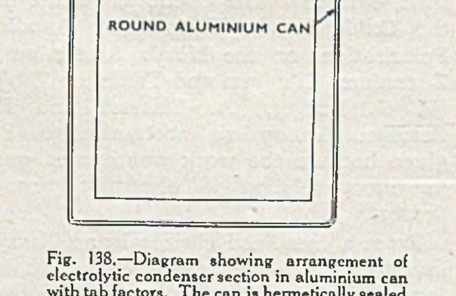


Fig. 138.—Diagram showing arrangement of electrolytic condenser section in aluminium can with tab factors. The can is hermetically sealed and bimetallic junctions are avoided.

certain water content is, however, present; for a direct heating of the film dried at 100 degrees, in the neighbourhood of 1,000 degrees C. (by which its appearance is unaltered), produces a loss in weight of about 5 per cent. ($Al_2O_3 1H_2O$ contains 15 per cent. water). X-ray examination shows that, after this heating, only partial transition to corundum has occurred.

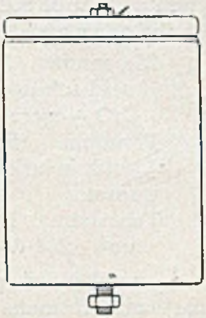


Fig. 140 (Right).—On the underside of the electrolytic condenser shown here is seen the nut-and-screw attachment for fixing.

Fig. 139 (Left).—Ring mounting for aluminium electrolytic condenser.

These conclusions are referred to *thin* films. To *thick* films (formed in oxalic acid), which also differ in other properties from thin films, are ascribed the formula $Al_2O_3.1H_2O$ (20 degrees C.) by S. Setoh and A. Miyata. J. A. M. Van Liempt ascribes the latter formula to films formed in potassium-dichromate/sulphuric-acid solution.

Günthe-Schulze and Betz found that at 570 V the increase in weight was 6.7 mgm./100 cm.^{2}, which should be in agreement with $\frac{500}{570} \times 6.7 = 5.9$ mgm./100 cm.^{2} for 500 V. Over this voltage range capacity is inversely proportional, and the thickness of the oxide film thus proportional to the voltage. This figure is much lower than that of Burgers, Claassen and Zernike, and may be due to slight dissolving of the aluminium in the forming solution.

The specific gravity of the film may be very well determined by the suspension method, with $BaI_2 + HgI_2$ or CH_2I_2 in benzol solution. Both agree in giving 3.10 ± .05. From the weight of 16.8 mgm./100 cm.^{2} and the density of 3.1, it follows that the film thickness formed at 500 V is 0.54 μ. For a capacity of 1.35μ F. per 100 cm.^{2} at 5,500 V the dielectic constant must be 8.2. This figure is considerably lower than that which would be expected (about 12), assuming the film to consist of Al_2O_3 (i.e., corundum). The value 6 to 8 given by H. Rohrig belongs, obviously, to thick oxalic-acid-formed films.

By oxidation in a boric acid solution, which, instead of 2 gm., contains about 30 gm. of borax, we obtain about 21 per cent. higher capacity than with the more dilute solution. At 400 V the weight of oxide film is then 16.7 mgm./100 cm.^{2}, with S.G. 3.3. The dielectric constant is thus almost equal to 11. X-ray examination of these films shows the same dia-

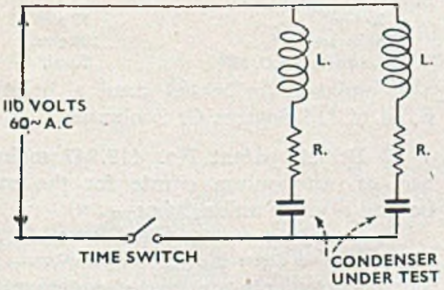


Fig. 141 (Above).—Artificial load circuit for testing electrolytic condensers for capacitator motors.

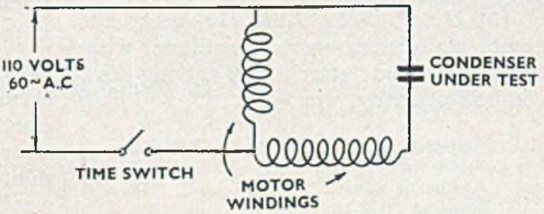


Fig. 142 (Right).—Testing circuit for electrolytic condensers for capacitator motors using actual motor circuit.

gram as that of S.G.3.1. Results obtained on the other metals are as follow:—

Zirconium. Formed in phosphoric acid solution at 550 V—monoclinic ZrO_2—more or less brown colour.

Titanium. Formed in phosphoric acid solution at 200 V—anatase form.

Tantalum. Borax-boric acid solution—200 V—tantalum pentoxide.

A number of patents cover particular formulæ for the electrolyte of electrolytic condensers; others relate to treatments for the electrodes. Some of these for aluminium electrolytics are quoted below:—

Electrolytic Condenser Electrolytes

(1) An American patent cites the following composition in which the weak acid radicle is that of stearic acid, viz.:—

	Per cent. by wt.
Sodium stearate	15.4
Diethylamine stearate	7.7
Glycerol	73.0
Water	3.9
	100.0

(2) U.S.P. No. 1,999,408 covers the tartrate radicle as the weak acid ion, viz.:—

	oz.
Potassium (or ammonium tartrate) ..	1
Gum arabic	24
Glycerine (chemically pure)	104

(3) U.S.P. No. 2,028,775 uses the usual ammonium borate constituent with agar-agar and starch for giving the desired viscosity, viz.:—

	oz.
Agar-agar	1
Potato starch	7
Ammonium borate..	56
Glycerine	36

(4) U.S.P. No. 2,036,669 utilizes an organic amino borate instead of the ammonium salt, and ethylene glycol instead of glycerol, viz.:—

Diethylamine borate	80 gms.
Ethylene glycol	1 litre

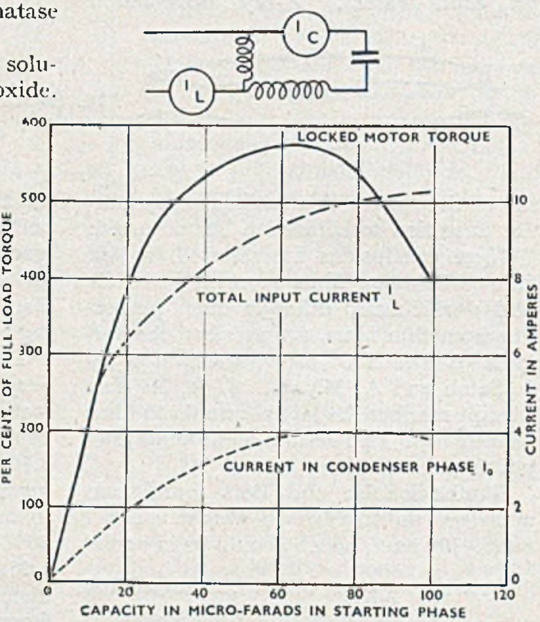


Fig. 143 (Right).—Starting-torque characteristics of 1/6 h.p. motor operating at 220 V a.c.

(5) British patent No. 448,830 prepares a mixture using sorbitol instead of glycerol, viz.:—

Sorbitol	50 gms.
Boric acid	100 gms.
Ammonia (S.F.O. 880)	20 ml.

This mixture is heated until a boiling point of 115 degrees C. is obtained.

(6) British patent No. 449,947 makes use of ammonium citrate for the salt having a weak anion, viz.:—

Ethylene glycol	From 90-10 oz.
Ammonium citrate	From 10-90 oz.

These ingredients are heated together to a temperature of 120 degrees C.

Etched Electrodes

British patent No. 449,947 covers the electrolytic etching of the aluminium electrode. The electrolyte is either an aqueous solution of sodium chloride or a dilute solution of mixed acids comprising a mixture of 8 ml. of concentrated hydro-

INTERNATIONAL RECORDS

THE foot race owes its origin to earliest Grecian times as recorded in the Iliad and the Odyssey. In modern records distances from 100 yards to 1 mile have regularly called forth the greatest powers of athletes, both amateur and professional. The World's record for 100 yards in 9⅜ seconds was set up by John Donaldson of Australia when he won the professional 100 yards championship at Johannesburg in 1910.

The record of International Alloys Ltd. in supplementing the nation's supplies of essential light metals cannot be fully published till after the war. Meanwhile, for post-war developments, please note the name—'INTAL' are and will be makers of aluminium alloys for every conceivable purpose.

International Alloys Ltd INTAL

INTERNATIONAL ALLOYS LTD., SLOUGH, BUCKS.
Phone: SLOUGH 23212. Grams: INTALLOYD, SLOUGH

IA/344A

chloric acid (S.G.1.16), 1.4 ml. of concentrated nitric acid (S.G.1.42) and 0.7 ml. of concentrated sulphuric acid (S.G.1.84) per litre of water. This is operated at 70 degrees C. and a carbon cathode is employed. The aluminium strip, connected anodically, is passed through this bath in continuous fashion. Thence it is passed through very dilute alkali in order to remove any oxide coating, using 2 per cent. of caustic soda or potash at 70 degrees C. Next it traverses a bath of 5 per cent. sulphuric acid to clean up residual alkali and finally it is cleaned by means of glycerol at 100 degrees C.

Thorough water washing between each of these chemical processes is, of course, to be assumed.

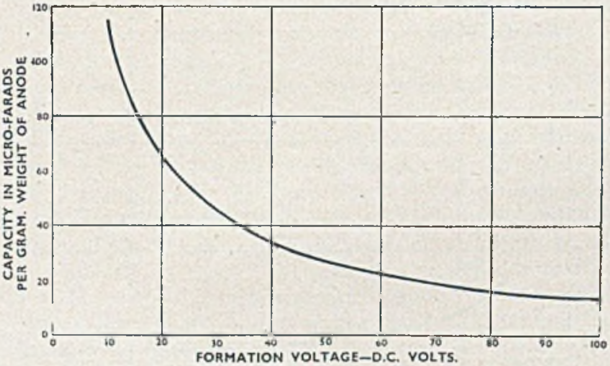


Fig. 144.—Voltage/capacity characteristics of porous-tantalum electrolytic condensers. Electrolyte - sulphuric acid, S.G. 1.100; cathode weight equal to half anode weight.

Electrode Coating

A conducting coating for aluminium for electrolytic condensers is described in British Patent No. 419,927. It is as follows:—

Acetone	137.8 ml.
Amyl acetate	125.0 ml.
Phenol-formaldehyde resin ..	39.9 gms.
Graphite (99 per cent. purity) ..	42.5 gms.

The mixture is applied to the surface of the aluminium and stoved for a period of 24 hours at 100 degrees C., followed by a further period of 2 hours at 170 degrees C.

Production Aspects

From the abstracts of scientific papers presented here, it will have been quickly appreciated that the production of electrolytic condensers is an intricate business and that something special is demanded with respect to materials and process. The general procedure can be seen from the following description of the salient features entailed in one process used for the manufacture of semi-dry condensers of about 8 microfarad capacity, 500 V d.c.

Aluminium foil is required for anode and cathode, and cotton gauze fabric or absorbent paper as separator to carry the electrolyte and chemicals for preparing the electrolyte. Other essentials which do not cause such difficulties with respect to purity are the container and connectors.

The aluminium for the anode is used in the form of foil of thickness 0.005 in. and width 3 ins. The purity of this material is important, a minimum of 99.80 or 99.85 per cent. being specified, and entire freedom from copper is desired. For a unit of 8 microfarad capacity, the length of such foil required for the anode is about 26 ins. This is on the basis of about 20 sq. ins. of active anode surface, including both sides of the film, per microfarad of capacity.

For the cathode foil, purity of the aluminium is less important, a maximum of 99.4 per cent. being stipulated; usually 99.0 per cent. minimum is specified. Higher purity foil can be used, but is unnecessary, and, further, the 0.6 to 1.0 per cent. of impurities is desirable. This, of course, is in accord with the observations already made to the effect that impurities in the cathode are beneficial in helping it to resist film formation under conditions of a.c. leakage. A thickness of 0.002 in. is used, and width of about $3\frac{1}{4}$ ins.; the length required is about the same as that for the anode foil. Both the foil materials must be clean, but the anode foil is further cleaned before use.

The gauze cloth is a good quality cotton sheeting or cheese cloth, having about 40 to 50 threads per inch in the weft and warp. This material must not contain sizing or dressing, must be neutral in reaction, and free from chemicals, and especially free from any trace of chlorides.

The chemicals used for the forming process and for the electrolyte (ammonium borate, ammonia, boric acid and glycerol) should be chemically pure and free from all traces of chlorine compounds. Even cleaning chemicals and water used in forming and for washing after forming must be chloride-free.

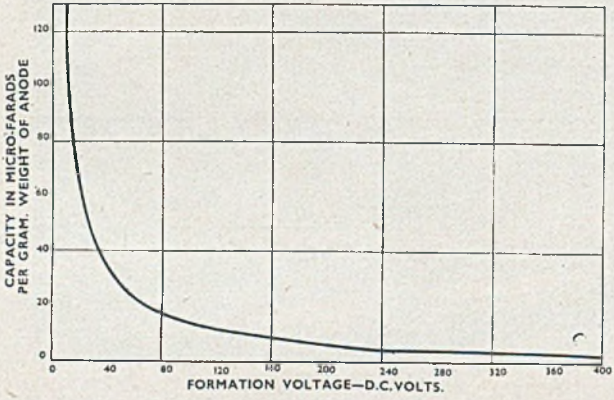


Fig. 145.—Voltage capacity characteristics of porous-tantalum electrolytic condensers.

The aluminium anodes are cleaned in a hot, mild alkali detergent. A solution containing 1 oz. of anhydrous sodium carbonate (soda ash) and 1 oz. of trisodium phosphate per gallon of water is satisfactory when operated short of boiling, e.g., 90 degrees C. (± 3 degrees C.). Cleaning time is about 30 secs. Water rinsing follows, and then an immersion in dilute hydrofluoric acid solution of about 5 per cent. concentration at ordinary temperatures. The usual commercial acid of about 50 per cent. strength is used for this operation, at a dilution of 1 part by volume to 9 parts of water. Water rinsing again follows. The anodes are then passed to a sulphuric acid solution of 7 per cent. concentration. They are connected in pairs and subjected to an alternating current potential of 22 volts for 10 mins. It has to be ensured that the initial current does not rise above 50 amperes, the normal maximum being 12 to 16 per sq. ft. of anode surface. Resistance in series to safeguard this point may be included. Again, the electrolyte must be kept cool, below 38 degrees C., using cooling coils if necessary. The tank for holding the forming solution may be of aluminium or of stoneware. After forming, the anodes are thoroughly washed in water and dried off in a clean air without allowing them to touch one another during drying.

The next step is the winding of the unit, using ordinary condenser winding machines and mandrels. The cathode between two layers of gauze is fixed in the mandrel, then the anode is clipped in, care being taken to see that no sharp corners or edges of the anode can cut through the cotton fabric; especially at the end of the anode which is folded back as a connecting tab. The cathode is usually made about half a turn longer than the anode. The windings are checked on low voltage (about 110 V a.c.), with a protective load of about 0.1 ohm in series to eliminate any that are faulty for short circuits for any reason before proceeding.

The electrolyte is prepared from glycerol and ammonium borate, incorporated under controlled heat in an aluminium tank. Pure chemicals are used, except that the glycerol will contain water, the amount of which must be determined and allowed for in the weights of material used. Proportions used are 100 lb. of glycerol (water free basis) and 67.5 lb. of ammonium borate. The glycerol is carefully heated to 110 degrees C., the borate then stirred in, and heating continued until evaporation to give a weight of 153 lb. has been achieved. Viscosity measurements are sufficient for control purposes.

This solution is maintained at 110-120 degrees C. for the impregnation of the units, and is kept stirred as far as possible, but without breaking the surface or whipping in air. The units are immersed vertically for the first five mins., only the lower half of them being submerged, total immersion time being about two hours. Upon withdrawal they are drained for half an hour to remove surplus electrolyte. Every care must be taken in the impregnation process to ensure complete treatment, with no bare patches, unwetted areas or air locks, because such faults will certainly cause electrical breakdown. Vacuum impregnation is probably to be preferred, using two chambers. In this case the lower one holds the electrolyte, and is connected by pipe line to the impregnating chamber above it. The condensers are loaded vertically in the latter, and the temperature raised to 110-120 degrees C. by indirect heating, such as a steam jacket. The chamber is evacuated, and the electrolyte is raised by the vacuum by opening the valve in the pipe-line which connects the two chambers. It is allowed to rise slowly over the condensers, a soaking period of 30 mins. to two hours permitted, and then the electrolyte is allowed to fall by gravity by breaking the vacuum on the upper chamber. The draining period follows.

The units are then ready for electrical formation. They are arranged on racks provided with drip gullies of aluminium, in which to catch any electrolyte that is forced out during the forming operation.

Forming is carried out with the units arranged in parallel at 510 V d.c., but in such a manner that the forming current (which rapidly falls as the condensers form) does not exceed 10 milliamps across any unit. One procedure is to raise the voltage in steps as the current decreases; another one is to protect each unit with a resistance of appropriate value in series. Another factor that has to be controlled is the forming temperature, which is not allowed to rise above 48-50 degrees C. It is kept down to this level by air cooling from a fan-draught system. The forming is carried on until the current through the unit falls to 1 milliamp. or less, and may require up to 24 hours.

Units from the forming racks next have the surplus electrolyte, if any, carefully wiped off the surfaces, and then they are wrapped in paper of the hydrated or glascine type about 0.001 in.-0.002 in. thick. They are ready for assembling in their containers of card, Bakelite or metal. Special care is exercised in making the terminal connections. Leads are of aluminium tape riveted with aluminium rivets to the folded-over tabs of the anode and cathode. These areas are kept free from electrolyte and are varnished to protect them from corrosion. The leads are mechanically connected to the terminals of the container.

The canned assembly is given a final forming operation at 510 V d.c., with protective resistances in the circuit to limit

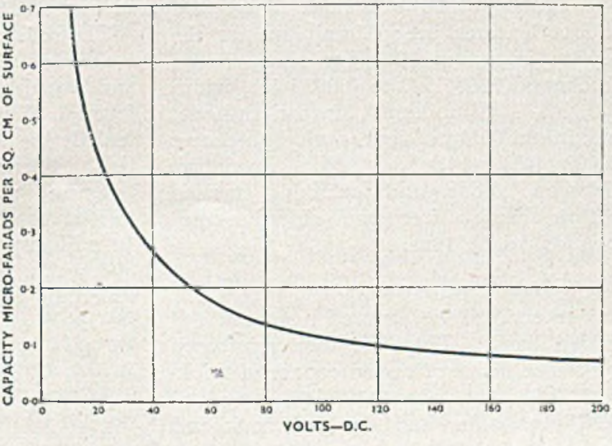


Fig. 146. — Voltage capacity characteristics of smooth-sheet tantalum electrolytic condenser.

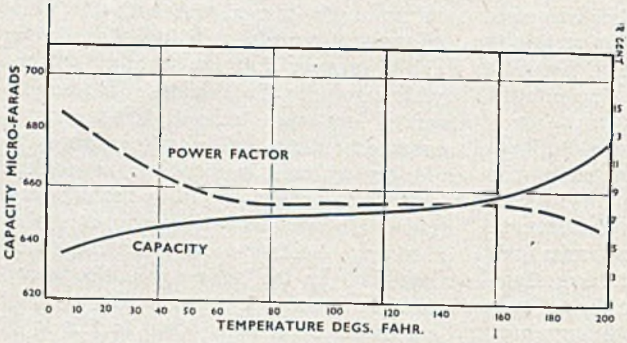


Fig. 147.—Temperature coefficient of capacity and power factor of porous-tantalum electrolytic condenser. Anode formed at 26 volts and tested in sulphuric acid, S.G. 1.100.

the current to a maximum of 5 milliamps., and this formation period is continued until the leakage current at ordinary temperatures is less than 0.10 milliamps. per microfarad.

Inspection tests on the finished condensers include leakage current on all, and capacity and power factor on a percentage of the condensers made from each batch of electrolyte. The leakage current is measured at 500 V d.c. across the condenser terminals, and it must be less than 1 milliamp. at 20 degrees C. for an 8 mF condenser. Capacity is measured at 60 V o.c., 50 cycles, superimposed on 120 V d.c., and values are expected to be within plus 30 per cent. minus 20 per cent. of the nominal value at 20 degrees C. Power factor measured by the bridge method at 100 cycles is about 10 per cent.

A practice for the dry type of electrolytic condensers of the same order of magnitude, say up to 8 mF capacity and 400/600 V, follows similar lines, and salient features are: Aluminium for the anode, minimum 99.8 per cent. purity, thickness 0.0030 in. to 0.0035 in., width 3.5 ins. Aluminium for the cathode, maximum 99.4 per cent. purity, thickness 0.002 in., width 3.5 ins. Insulation between anode and cathode, unsized cotton sheeting free from chlorine compounds, width 4 ins.

Termination

The ends of the electrodes are cut and folded back. They are then reinforced by folded strips of tinned copper of thickness 0.002 in., about 1.5 ins. long and 0.375 in. wide, and doubled back and held by means of tinned-steel riveting clips. A lead is soldered to the tinned copper and taken through the case, the lead being double-cotton-covered stranded copper and coloured to indicate positive and negative. This system is shown in Figs. 126 (cut foil), 127 (first fold), 128 (second fold), 129 (assembly, side view), and 130 (assembly, end view showing rigidity of soldered join).*

The wrapping paper for the units is 0.004-in. wax-impregnated paper, seams being sealed with strips of the same material. The container is wax-impregnated cardboard about 0.020 in. thick, rectangular in cross-section.

Both electrodes are cleaned in alkali and acid exactly as stated for the other procedure. The anode is given the preforming in sulphuric acid. The next stage is quite different. The electrodes and the cotton cloth are carefully coated with the electrolyte without contamination. The electrolyte contains glycerine, boric acid, ammonia and starch. They are then wound, avoiding creasing and ensuring uniformity of pressure. The arrangement of the foils and separating cloth is shown in Fig. 131.*

The rolls are pressed to shape to fit the container. Terminal strips are mounted and varnished to avoid their becoming formed. The units are then wrapped and sealed, the lead wires soldered into position. Forming is then done under d.c. potential, raising the voltage gradually to keep the leakage current always below 10 milliamps. per unit. Finally, the full 500 V d.c. is maintained until the current leak falls below 1 milliamp. Throughout the forming the temperature is kept to 40 degrees C. maximum. The forming requires a time period up to 24 hours.

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* Figs. 126 to 133 will be found in the previous section of this account.

The formed unit is fitted into its cardboard container, the leads brought out in an appropriate manner, and the case sealed. In this form the completed condenser is given a final electrical forming process at the full voltage for a short period. Ultimate inspection covers capacity and current leakage measurements.

Another commercial process for dry electrolytic condensers specifies an aluminium of 99.85 per cent. purity for the anode, and a thickness of only 0.0025 in., this being used for various capacity values and peak voltages in the range 100 to 550. A borate-base solution is employed for the forming prior to winding, this being prepared from the following ingredients:—

Sodium borate	0.046 oz.
Boric acid	1.60 oz.
Water	1 gallon

The sodium borate employed is chemically pure, crystalline $Na_2B_4O_7.10H_2O$. The boric acid is extra purity crystal form free from all traces of chlorides or sulphates. Distilled water is used in the preparation of the solution, and its suitability is checked by electrical conductivity measurements. The container for this electrolyte can be of pure nickel, monel metal or of pure aluminium loosely lined with plates of glass, and in each case of welded construction. Before introducing any solution into it, the vat has to be thoroughly cleaned to remove all traces of foreign matter, and is finally rinsed in distilled water. Provision of means of heating the solution to boiling is necessary, double jacketing for steam, hot water or electrical immersion heaters in water or oil medium being preferred. In making up the solution, the water is raised to the boil, the boric acid added, dissolved and boiled for about 5 mins. to expel carbon dioxide, and finally the borax is added and stirred in.

Preforming is carried out at boiling point using strips of aluminium anode cut to length or continuously fed from the roll. The heat of reaction has to be considered, and if the amount of work treated in relation to the volume of the solution be high, means of cooling must be provided to prevent unnecessarily excessive boiling and evaporation losses.

When forming the actual condenser lengths, these are held in special racks consisting of glass hooks suitably spaced and suspended from glass rods. (Fig. 132).* Sufficient length of aluminium beyond the actual length required to cut connector tags to take from each end to the anode bus bar, as shown in Fig. 133,* is allowed. The anode is immersed with its length horizontal, and width vertical, but only sufficiently below the surface to ensure uniform forming. Cathodes can be of nickel, and nickel wire gauze is often used, two cathodes being employed, one on each side of the anode. The forming time is of the order of 5 to 7 mins. It is controlled by resistance, with voltmeter and ammeter instruments provided, but the resistance is set at the beginning of the job to suit the size of anode being formed and the working voltage of the condenser. Temperatures of 90-100 degrees C. are used.

As a guide the following values are given:—

D.C. voltage of condenser	Initial preforming voltage	Final forming voltage
75-100	80	124
250-300	220	350
450-550	375	600

It will thus be seen that, in this procedure, the final preforming voltage is greater than the working voltage of the condenser.

Every care must be exercised when forming to avoid contamination or physical damage to the anodes. They are assembled in the bath with the current off, the resistance set to the predetermined value, and the circuit closed. Visual note is taken that the voltage starts initially at the anticipated value, that the current falls off and the voltage rises. Final conditions are checked and the anode removed before switching off the current. It is rinsed thoroughly in distilled water and oven dried at 100 degrees C. Excessively large baths are avoided, and the solution may need a little working in on a few anodes to eliminate any impurities.

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* For Figs. 132 and 133, see previous section of this account.

Operating the pre-forming on a continuous basis is obviously possible and, although not simple, is quite practicable. From the reel, the aluminium foil has to be run through the processes with width and length directions horizontal. The anode contact can be a nickel or heavily nickel-plated rotary cylinder over which the material is fed at the entrance to the forming bath. Rotary cylinders for guiding the material in the bath can be of phenolic plastic, e.g., paper or fabric laminated rod, machined to shape. No contact can be provided at the exit end because the aluminium is then formed. It can pass over phenolic-resin rollers through washing processes, which can be small and simple sprays, or immersion, or both. Finally, it can pass through a hot-air tunnel, or dried by means of infrared heating.

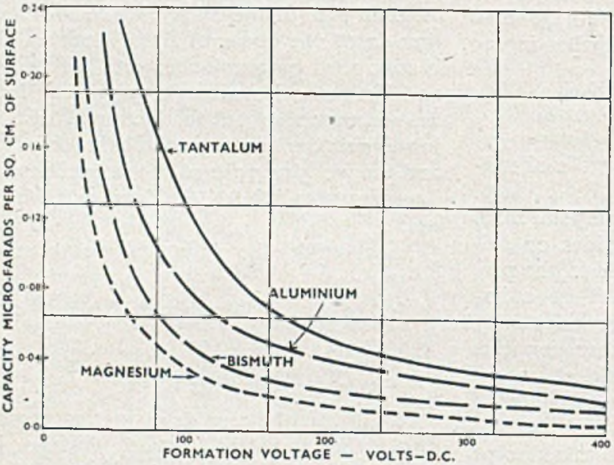


Fig. 148.—Relative characteristics of film-forming metals: capacity per sq. cm. of surface in relationship to formation voltage.

Winding of the condenser rolls is carried out as before described, using paper or fabric as the separating medium. The cathode has to be degreased. If pre-coating is adopted, a starch-bodied electrolyte is applied, the following being a representative composition:—

Ammonium borate (dried at 100° C.)	24%
Boric acid (dried at 100° C.)	10%
Starch	18%
Glycerol	48%

Alternatively, impregnation as previously described can be used. The units are quickly dipped in ceresin wax of melting point about 50° C. before forming. This gives protection against the absorption of water vapour by the glycerine. The forming racks are arranged to maintain a temperature of 35 to 40° C. Voltage is raised gradually to the nominal peak working voltage as the leakage current falls—allowing the temperature fall to the ambient value as the final voltage is reached. Terminating, assembling in cases, and final forming are as previously described.

The Aerovox Corporation developed special electrolytic starting condensers for use with high-quality fractional-horse-power motors such as those in demand for operating such domestic appliances as refrigerators and oil burners, and gave the following information concerning them in a bulletin dated 1932. Motors for these purposes must obviously possess excellent operating characteristics and high starting torque, they must create no radio interference and must be silent or as near silent as possible. The capacitor motor is claimed to be the superior of all types of single - phase fractional - horse - power motors, because, apart from possessing the desired characteristics, it is the simplest and most reliable. The commercial development of this type of motor awaited the availability of suitable capacitors, and the appearance of the specially designed Aerovox electrolytic condensers answered this shortcoming.

Of the many circuit arrangements that can be used with capacitor motors, three generally employed are shown in Figs. 134, 135 and 136. In each, S represents an automatic switch which automatically operates when the motor speed attains a sufficiently high value. Fig. 135 shows the condenser start type of motor in which the condenser is in the circuit in series with the starting phase with the object of providing a high starting torque. In this way starting torque values as high as 400 per cent. of the full load torque can be attained. Besides this characteristic, high starting efficiency, simplicity and reliability are obtained. Power factor under running conditions is low because the condenser is cut out of the circuit at running speed.

The circuit shown in Fig. 135 includes two condensers in parallel. With the switch S closed for the start, the total capacity of the condensers is sufficient to give the high starting torque desired. The condenser C2 is automatically cut out when high speed is reached, whilst the other condenser C1 is so designed to allow the motor to run at almost unity power factor and to operate virtually as a two-phase motor, the condenser functioning to convert the single-phase supply into a two-phase supply.

Fig. 136 shows how a single condenser can be used in conjunction with an autotransformer to give the same results as the two condenser circuits. The switch S is in position number 1 at the start, and the effective capacity for starting is that of the condenser C multiplied by the square of the turns ratio of the transformer. At running speed or slightly lower, the switch S automatically changes to position number 2 and thereby the effective capacity becomes reduced to that value appropriate to afford high efficiency under running conditions.

Regarding the types of condenser used in these circuits, that in Fig. 134 is an electrolytic starting condenser, and it is only in circuit during the starting period. In Fig. 135, condenser C2 may be an electrolytic, but C1, which is in circuit during running, must be an oil-filled oil-impregnated condenser. The circuit in Fig. 137 uses one oil-filled oil-impregnated condenser.

The circuit in Fig. 134 is used when the most important criterion is high starting torque. If additionally high efficiency under running conditions is required, those in Figs. 135 and 136 are advocated.

Again, in the circuit in Fig. 134, maximum starting torque is usually obtained when the impedance of the starting phase is approximately equal to the reactance of the starting condenser. Under such conditions, partial resonance exists in the starting circuit, and the voltage across the starting winding and that across the starting condenser may rise above the line voltage. This excess generally is of the order of 30 or 40 per cent. maximum.

The voltage across the starting condenser depends upon the design of motor, especially the turns ratio between the main phase and the starting phase. The standard line of Aerovox starting condensers are rated for use with 110 V motors, and if used for motors at other line voltages, attention must be given to ensure that excessive voltage cannot develop across the condenser. This voltage should not be greater than 130 to 135 volts during the starting period. The condensers for 110 V motors are designed to give service where the number of starts does not exceed 20 per hour and the duration of each start does not exceed 3 secs. The power factor measured at 110 volts 60 cycles is 12 per cent. max.

Fig. 137 is the Aerovox Corporation's curve for starting torque against capacity. The values for this were determined using a typical ¼ h.p. capacitor-start-type motor with electrolytic condensers in the starting phase. It will be seen from the curve that the particular motor used gives maximum torque at a condenser capacity of 175 microfarads and that at this capacity the torque is approximately 380 per cent. of the full load torque. The variation in capacity that is tolerable is dependent upon the maximum torque desired. Thus the curve shows that for 350 per cent. torque the capacity may range from 140 to 230 microfarads. Consequently, manufacture of the condensers to close tolerances is not normally required.

Briefly, the Aerovox Corporation give the following constructional data appertaining to their electrolytic condensers. High-purity aluminium foil is used, anodically filmed. Two of these foils are wound into a roll, the foils being separated by a layer of gauze and one of 0.0004-in. thick linen paper. The roll is then impregnated by immersion in an electrolyte heated in order to obtain complete saturation of the gauze-paper combination which separates the foils. It is then sealed in a can, aged and tested at 120 V a.c., 60 cycles.

The electrolyte is a viscous fluid, chemically balanced and homogeneous in nature. It is preferred to have a fluid electrolyte for use with a.c., because it best permits of expansion and contraction and dissipation of heat. A parallel is drawn with the case of fixed paper condensers; here it is generally accepted that oil-impregnated, oil-filled designs are better for severe service conditions of a.c. than are wax-impregnated, solid-filled types.

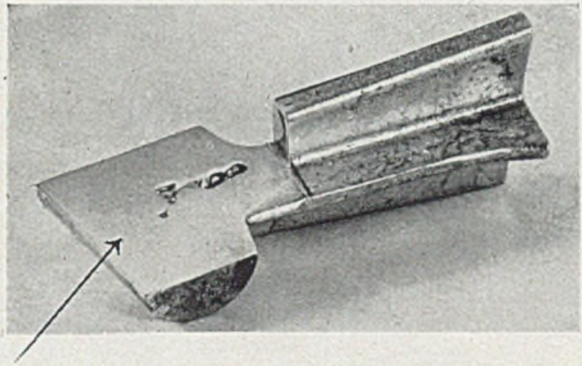
Again, a metal container is advantageous to assist in heat dissipation, and Aerovox condensers are housed in hermetically sealed aluminium cans. Semi-dry condensers are said to be less satisfactory because they do not dissipate heat well enough. Card or non-conducting containers likewise do not dissipate heat quickly from the roll, and aluminium is an obvious choice for maximum conductivity. Again, aluminium is considered essential so as to eliminate the possibilities of stray currents from bi-metallic effects. Aluminium and non-metals are the only materials employed in the construction of these condensers, and they are also mounted in outer containers of aluminium to make certain that no undesirable reactions can occur.

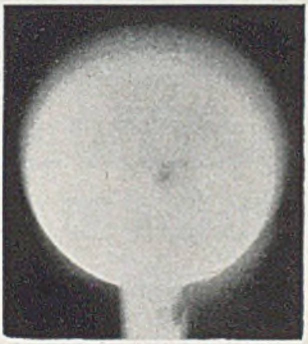
Fig. 138 sectionally shows the construction of the Aerovox condenser. From one foil of the condenser, a tab is taken and spun to a terminal which is mounted in the centre of a hard rubber cover. The tab from the other foil of the condenser is wedged between the hard rubber cover and the side of the can. For sealing, a rubber gasket is placed in the seating provided around the periphery of the cover. The mouth of the can is spun over on to the gasket to yield a hermetic closure. The latter is important for the preservation of a constant electrolyte, i.e., to prevent loss or gain of moisture. If the latter evaporates, power factor increases and capacity decreases. The greater the moisture loss the greater are these changes. On the other hand, in humid atmospheres water could be absorbed in the absence of a hermetic seal, and then proper film formation on the anodes cannot be maintained, corrosion of the electrodes may result, and electrical breakdown can occur.

Table 31 gives some standard sizes of these condensers, from which it can be seen that compactness is a feature. In all of them the can itself serves as one connection, the other being to the central terminal. To isolate the can, it would have to be insulated by means of a cardboard tube and sealed with pitch, and still hermetically sealed in a metal can. Such insulation is not permanent, and, further, it mitigates against good heat dissipation. When mounted in the apparatus, the metal container can be insulated from the frame by mounting on an insulating material, such as Bakelite. They can be mounted in a ring fixing, as illustrated in Fig. 139, or they can be provided with a screw connection, as shown in Fig. 140.

The testing of electrolytic starting condensers is performed with them in series with a motor winding or in an equivalent circuit, such as those shown in Figs. 141 and 142. The artificial load circuit in Fig. 141 includes a reactance L and a resistance R, approximately equal to the inductance and resistance of the starting phase of the motor with which the condenser is to be used. A relay time switch enables the circuit to be closed for a few seconds at intervals to correspond to the number of starts per hour required. Fig. 142 shows the condenser under test in the actual motor circuit.

Special Aerovox condensers are manufactured for higher voltages, for example, for 220 V d.c. motors. Typical of such condensers are the results shown in Fig. 143. The curves show the starting torque characteristics of a $\frac{1}{8}$ h.p. 200 V a.c. motor. It will be seen that a starting





The radiograph which showed the defect to be present.

torque of over 500 per cent. of full-load torque is obtained, using a 60 microfarad condenser in series with the starting winding. Under these conditions the current in the starting phase was nearly 4 amps., and the voltage across the condenser approximately 160 V. In other 220 V motors this voltage developed has been as much as 230 V, and the condensers produced have operated satisfactorily. Their design is essentially the same as for the 110 V a.c. condensers, except for the consideration given for the dissipation of the additional energy per microfarad.

The Aerovox claims for these condensers include the following:—

(1) The use of a special viscous electrolyte, a homogeneous solution, in contrast with a mere paste-like mixture.

(2) No free, unabsorbed electrolyte in the case of the condenser, but sufficient absorbed in the gauze and paper for proper functioning. No leakage in service.

(3) A fluid electrolyte sufficiently mobile for diffusion throughout the condenser. In contrast with past electrolytes, no drying out which would cause lowering capacity and increased losses in the condenser.

(4) Low freezing point and high boiling point to the electrolyte and, therefore, satisfactory performance over a wide range of temperatures.

(5) A stable anode film, negligible deterioration during idle periods, rapid regain of initial characteristics as soon as the unit is placed in service.

(6) Rapid and effective dissipation of heat generated during service periods.

(7) Hermetic sealing and, therefore, evaporation or absorption of moisture in service prevented.

The foregoing illustrates a specific application of electrolytic condensers specially designed for the purpose, one design having been briefly discussed.

Besides the orthodox tantalum electrolytic condensers already recorded, porous tantalum condenser elements have been produced. These use electrodes from elemental tantalum in powder form pressed and sintered into shape by powder metallurgical processes. Excellent porosity is claimed, as well as uniformity throughout the mass, and upon immersion in an electrolyte, saturation throughout the mass is secured. Upon applying a formation voltage, the dielectric film forms upon the walls of all the small pores throughout the mass. In consequence, a condenser of extraordinarily high electrostatic capacity can be obtained from an anode of small dimensions. For some purposes, this factor may ultimately offset the disadvantage of tantalum electrolytic condensers made from sheet material, namely, dimensions and high cost of the electrode material.

The porous tantalum is a product of the Fansteel Metallurgical Corporation of Chicago. By uniform control of this porosity, this concern ensures that the voltage-capacity characteristics of the porous tantalum are determined entirely by the weight of the tantalum in the electrode. This contrasts with the area basis, which, of course, is characteristic of the orthodox electrolytic condensers.

The Fansteel Metallurgical Corporation, in their bulletin 1038-B, give a number of curves to show the characteristics of these condensers. Figs. 144 and 146 show voltage-capacity characteristics of a porous tantalum anode at various d.c. voltages for film formation, and it is claimed that uniform capacity characteristics can be produced within plus or minus 5 per cent. of these curves. The latter apply to the anode only. In d.c. applications, the cathode needs to be at least 50 per cent. of the anode weight, and in a.c. applications the two electrodes should be of the same weight.

Tantalum has an advantage over aluminium in being markedly more corrosion resistant. It can, therefore, be operated in stronger electrolytes which are lower in electrical resistance than is normal with aluminium electrolytics. Sulphuric acid of specific gravity of 1.200 or higher is one recommended, whilst ammonium chloride and calcium chloride are the second and third best electrolytes, dependent upon the nature of the application in question, ambient temperature variations and other factors.

A satisfactory metal container has not been found for tantalum electrolytic condensers using these strong chemical solutions. Consequently, glass vessels with hard rubber covers are employed.

For the smaller sizes of porous tantalum electrodes, film formation is achieved merely by applying the operating voltage. Film formation up to about 250 V is very rapid and the final current leakage value is attained in a matter of a few minutes. For the larger electrodes formed to higher voltages, several hours of formation at high current rates may be required. Both shape and size of the electrode have some bearing upon formation time.

Generally, it is stated that excellent properties with respect to power factor, resistance, and d.c. leakage are obtained from porous tantalum electrolytic condensers, in most cases superior to those given by smooth electrode condensers. Both development and applications have been with respect to d.c. applications and for wet electrodes. No doubt further advances have been made since these initial announcements were made.

The tantalum condensers are claimed to be practically indestructible and to maintain their characteristics through wide variations in temperature and during severe operating conditions, over periods of many years.

For comparison, with the porous tantalum electrode, the voltage/capacity curve in Fig. 146 is given for a smooth tantalum anode. Fig. 147 shows the temperature coefficients of a porous tantalum anode for power factor and for capacity. Fig. 148 gives the capacity/forming voltage relationships for tantalum, aluminium, bismuth and magnesium. ("Trans. Electro-chem. Soc.," Vol. 61, p. 515, April, 1932).

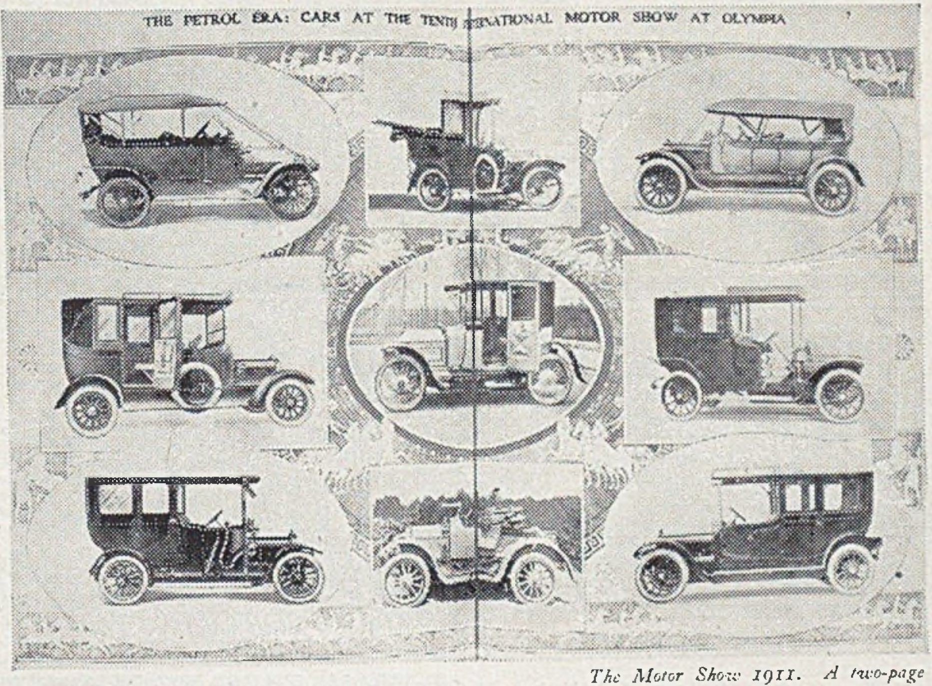
It is evident that the tantalum condensers have more than mere possibilities and that they can command an important field if fully developed. On the other hand, the cost of this element, its availability in quantity and the relative lack of ease with which it can be produced, rather indicate that the general field will still be supplied by aluminium.

Although not directly related to the subject of this account, it might be noted here that the use of porous tantalum in electrolytic condensers, and, in fact, that of metals generally in a coherent but not "solid" form in other technical fields, has recently begun to attract attention. Only during the past few years has the technique of powder metallurgy, as applied to metallic substances generally (apart from those of the platinum group and of the commoner refractory metals), become sufficiently advanced to indicate important commercial applications for metals in this form.

Until recently, as is well known, the principal objective of those turning out metals in the cast form or as sheet, etc., was to obtain maximum consolidation, all porosity being regarded as a defect and likely to exert harmful influences. Now, however, that the mechanical and physical properties of metal-powder compacts are better understood, and now that their quality may be controlled with regard to type and degree of porosity, advantage is being taken of the specialized properties of such masses. In particular, the first and most obvious feature of a porous body lies in its ability to possess a surface area very great in proportion to its bulk. Nowadays, when so much practical application is being made of physical and chemical reactions depending on surface forces, it is clear that the porous metallic compact offers a valuable field for experiment and exploitation. Less well understood, perhaps, too, in relationship to metals, is the fact that the creation of very extensive surfaces in a smaller unit of space results in the real or apparent enhancement of any surface activity which may exist.

(To be continued.)

WHEN WE WERE YOUNG



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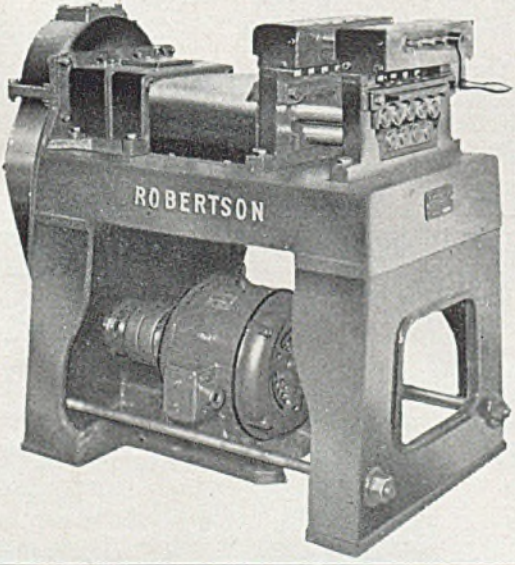
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