Magnesium and Its Alloys

Recent Developments in Great Britain

J. L. HAUGHTON
National Physical Laboratory, Teddington, Middlesex, England

THE development of magnesium and its alloys has been considerable all over the world during recent years. In Great Britain it has shown itself in the greatly increased production of the metal from its ore, in a large increase in the use of the existing alloys, and in intensive research into the properties of new combinations of magnesium with other elements.

Increased Production of Metal and Use of Alloys

With reference to the production of the metal, mention need only be made of the new electrolytic extraction plant which has been opened by Magnesium Elektron Ltd. at Clifton Junction, near Manchester, and of a direct reduction process carried out by Murex Ltd. at Rainham, in Essex, which are already producing large quantities of the metal; and of a new plant in course of erection in Swansea by Magnesium Metal Corporation, which is also working on a thermal reduction process. The present annual production of magnesium in this country is estimated at about 5000 tons per year, and this amount will probably be largely increased in the future.

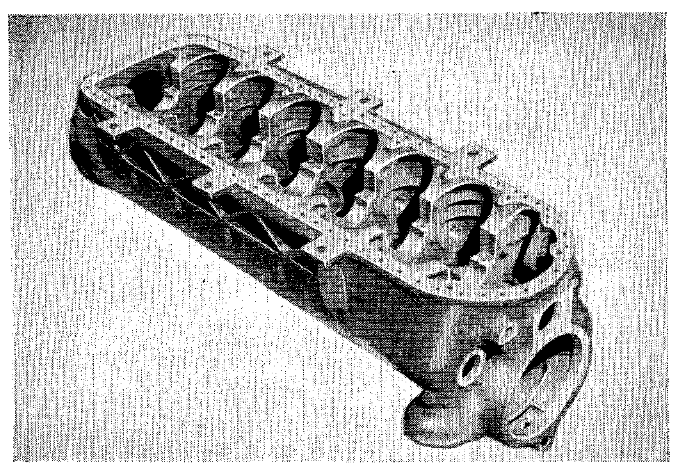
Until comparatively recently no appreciable amount of magnesium was produced in this country, the supplies required being imported from Germany and America.

The use of alloys has also greatly increased. Certain firms have been making small quantities of alloys or selling castings or forgings made from them for several years, but they have all greatly increased their output and other companies have started manufacture. Among the present firms dealing with alloys of magnesium, reference must be made to Sterling Metals Ltd., The Birmingham Aluminium Casting Company Ltd., J. Stone & Company Ltd. James Booth & Company Ltd., and Birmetals Ltd. (all associated with Magnesium Elektron Ltd.), and Magnesium Castings and Products Ltd.

These firms are using existing and well-tried alloys of magnesium, but it is certain that some of them are carrying out research with a view to obtaining better alloys or to improving existing ones. No results have been published as yet. However, work has been carried out for the past five or six years at the National Physical Laboratory on new alloys, and a series of reports has been published (*1*). Most of this paper is a summary of the work already completed there and indicates further work now in progress.

Lines of Research

Two main lines of investigation are undertaken concurrently: (*a*) The effect of the addition of new elements to magnesium and of the different methods of working these alloys is studied. So far, work at the National Physical Laboratory has been concentrated on wrought alloys and cast material has been ignored. (*b*) The constitution of a number of these alloys (mostly binary) has been investigated in order to assist in the study of the mechanical properties. Only a brief reference will be made here to (*b*), since the results are readily available (*1*). Only that part of the equilibrium diagram dealing with magnesium-rich alloys has been studied; the binary alloys with nickel, silver, calcium, and cerium, and the ternary alloys with cadmium and aluminum have been investigated so far, and the diagram of the ternary alloys of magnesium-aluminum-silver is now being studied. The work has involved the introduction of much new technique. In certain cases the metal has been purified by repeated sublimation *in vacuo;* difficulties which have arisen during the thermal analysis of the alloys, owing to the great difference of density between magnesium and some of the added elements, have necessitated the design of a new type of furnace in which the thermal curves are taken (*2*).



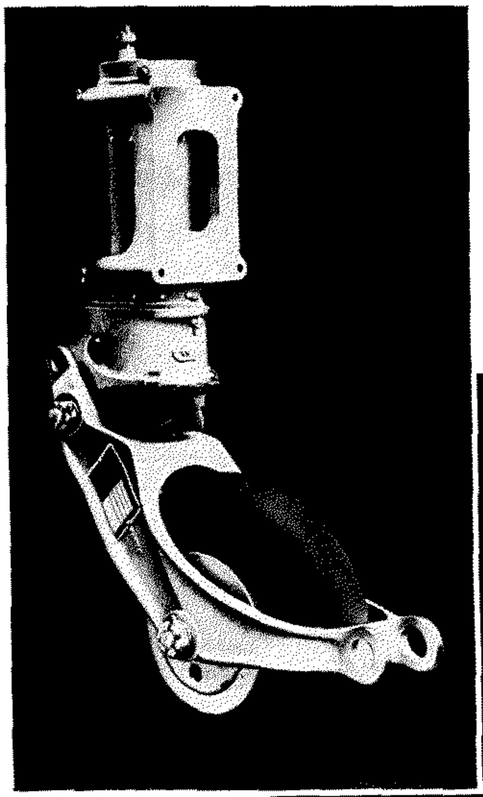
Courtesy, Sterling Metals Ltd.

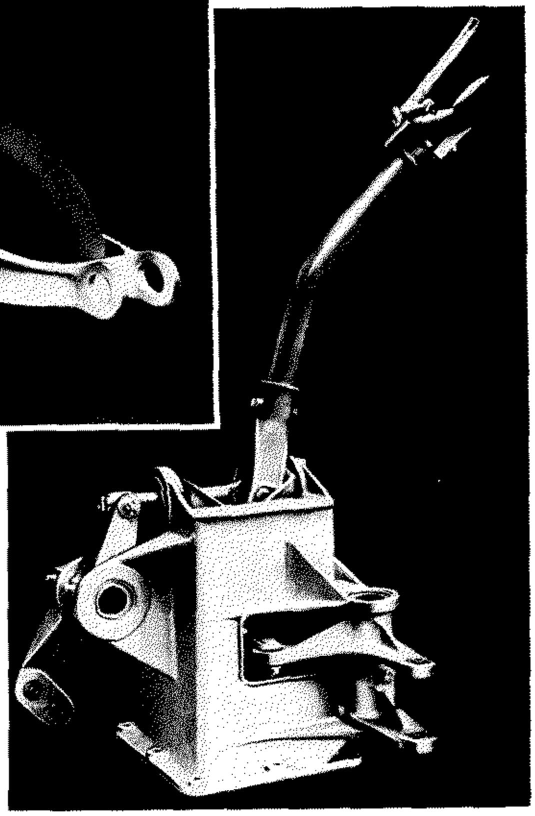
CRANKCASE OF AN AIRPLANE ENGINE, CAST IN A MAGNESIUM ALLOY

As is generally the case in work on the constitution of alloy systems, new methods of etching have had to be found in order to differentiate between various constituents. Almost all the equilibrium diagrams investigated had been previously studied. But this had either been done a long time ago very incompletely and with an imperfect technique, or very impure magnesium had been used. It is not surprising that in every case alterations had to be made in the hitherto accepted diagrams.

Improvement of Mechanical Properties

In the effort to improve the mechanical properties of wrought magnesium alloys, two lines of attack have been followed: (*a*) The effect of the addition to magnesium of various elements, singly and in combination, has been studied; in a few cases this has been done systematically but in general only as a preliminary survey to find out what combinations hold promise of being worth more thorough investigation. (*b*) The effect of various mechanical and thermal treatments on the more promising of these alloys has been investigated. Two different types of alloys have been envisaged—those for use at ordinary temperatures, or at any rate not above about 150° C. (300° F.), and those for use at temperatures in the neighborhood of 300° C. (570° F.) or higher. The first type of alloys will be generally useful in aircraft for propellers, crankcases, angle brackets, etc. (sheet metal has hardly been studied at the National Physical Laboratory); the other type will be useful for pistons of internal combustion engines. The two kinds of alloys present completely different problems. Mechanical deformation, introduction of cold-work effects, thermal treatment, etc., can be invoked to give rise to increased strength in the case of alloys used at room temperature. But the piston alloy must be tested in a completely annealed condition, for no matter what condition it is in when introduced into the cylinder, it will become completely annealed after a small amount of use. All forms of extra strength obtained by working or age hardening are therefore ruled out for such alloys, unless some treatment which will prevent or greatly reduce grain growth can be found. The alloys must also be tested at different temperatures. It was soon found that a knowledge of the properties of alloys at low temperatures was little guide to their properties at high temperatures; as the temperature was raised, material which was excellent at room temperature often decreased in strength much more rapidly than one which would be considered practically useless at room temperature. The latter might be very much stronger at about 300° C. than the alloy which was much better at 50° or 100° C. (120° or 210° F.).





Tail Wheel Assembly (*left*) and Control Column Assembly (*below*), Incorporating "Elektron" Magnesium Castings, for Use in Aircraft

Courtesy, Phillips & Power Ltd.

Alloys for Different Temperatures

Much less work has been done on the alloys for use at high temperatures; the National Physical Laboratory's investigations have shown that the addition of 2 per cent calcium plus 2 per cent silver gives an alloy with a tensile strength of 4.3 tons per square inch (9700 pounds per square inch) and an elongation of 76 per cent at 290° C. (554° F.). This is appreciably better than an alloy containing 4 per cent aluminum. Much better results, however, were obtained with alloys containing cerium. The following table gives the composition, ultimate stress, and elongation of a few of these alloys at 300° C.:

	Composition %	Ultimate Stress *Lb./sq. in.*	Elongation %
1.	Ce 7.0	13,500	120
2.	Ce 2.7, Ni 5.4	13,800	59
3	Ce 9.9, Co 1.5, Mn 1.5	16,700	152

Further work is now being carried out on alloys of this type; alloy 3 is comparable with the aluminum piston alloys but is only about two-thirds as dense.

Much more progress has been made on alloys for use at room temperature. Alloys with aluminum and with aluminum plus silver have been carefully studied, and a preliminary investigation has been made of alloys containing manganese, zinc, and cadmium, either singly or together. These alloys have been examined mainly in the pressed form, although some investigation into the properties of the material in the rolled state has also been carried out.

This work is now being actively prosecuted, together with a more complete study of some of the series mentioned above, and other combinations both in the pressed and in the rolled states. For this purpose the laboratory is equipped with a 120-ton hydraulic press, a set of bar and sheet rolls which can be driven at peripheral speeds varying from about 50 to 120 feet per minute, and a set of bar and sheet rolls which can be driven as low as 2 feet per minute. It has been found that many magnesium alloys which cannot be rolled at ordinary speeds can readily be rolled at very slow speeds.

Magnesium alloys are invariably worked at elevated temperatures, and both the press and the rolls are provided with means for heating the surfaces which come in contact with the metal. This is particularly important in the press and the slow rolls, where the hot alloy may be in contact with a large block of metal for a considerable time. The dies in which the pressing is carried out are surrounded by a number of small gas jets which impinge on them. A hole, bored in one of the dies, carries a thermocouple, and the die is maintained at the temperature at which the metal is being pressed. This temperature is vitally important. In the past it was assumed that as high a temperature as possible should be employed so long as it was far enough below the eutectic point of the alloys being forged to be completely safe. For example, in the aluminum-silver-magnesium alloys, which have been most completely studied, the ternary eutectic melts at 403° C. (754.4° F.) and the alloys were generally forged at 380° to 390° C. (715° to 735° F.). If a much lower temperature was employed, forging was difficult owing to the hardness of the material which frequently cracked during the operation. It was found, however, that if the material was given a preliminary "breaking down" at 380° C. it was possible to finish the pressing at a temperature which varied from 150° to 200° C. (300° to 390° F.), according to the alloy, and to obtain much better mechanical properties. For example, when an alloy containing about 8 per cent aluminum is forged at 380° C., its tensile strength was about 45,000 pounds per square inch; if the material is first broken down in the press at 380° C. and the final reduction is carried out at 200° C., the tensile strength rises to 61,000 pounds per square inch. The effect is even more marked in alloys containing a small amount (1 to 2 per cent) of silver. The silver appears also to have the effect of increasing the proof stress; values of nearly 50,000 pounds per square inch have been obtained for some of these alloys, as shown in the following table:

Composition			Ultimate Stress	Elongation on $4\sqrt{A}$	0.1% Proof Stress	Modulus
%Mg	%Al	%Ag	*Lb./sq. in.*	%	*Lb./sq. in.*	*Lb./sq. in* $\times 10^{-6}$
91.9	8.1	...	61,000	4.0	37,500	6.5
92.0	6.5	1.5	62,000	11.5	48,000	6.5
91.4	4.1	4.1	60,000	10.3	45,000	6.6
94.7	3.8	1.5	55,000	11.7	41,500	6.5

Alloys such as these should have a great future in the production of air screws, etc.

Work is now being carried out at the laboratory on the properties of alloys which have been rolled at 200° C. This work is not yet complete, but interesting results have already been obtained.

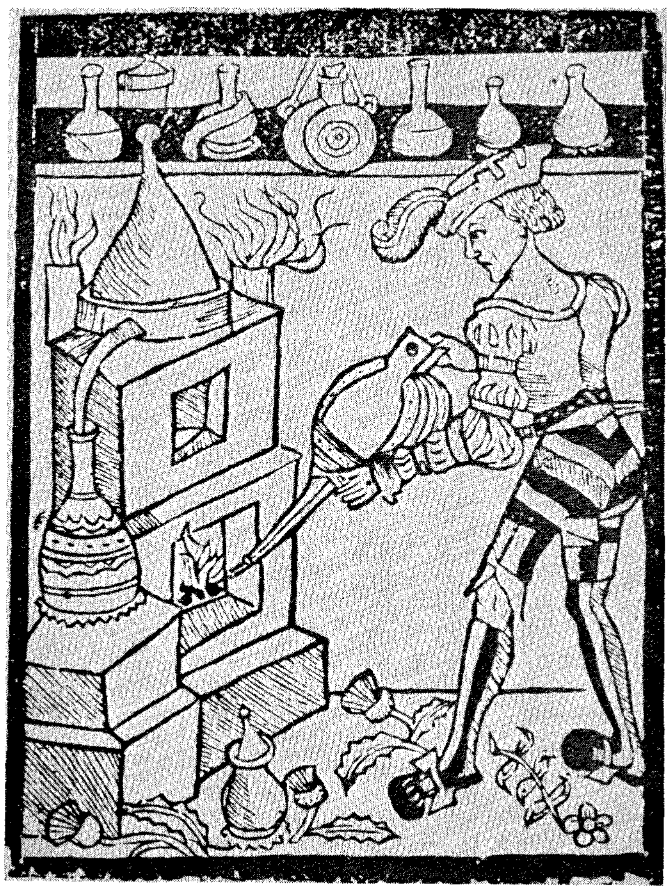
The reactive nature of magnesium has seriously interfered with its much wider adoption; to those who still associate the metal mainly with the ribbon which is burned to give a flashlight for photography, it seems incredible that magnesium can be used for structural purposes. The metal does corrode seriously under certain conditions, but so does steel and this disadvantage has not prevented its almost universal use. Many processes have been tried for reducing the corrodible properties of both metals. Nothing has been found or appears likely to be found, which will produce a "stainless magnesium." But there are several surface treatments which greatly reduce the corrosion of magnesium and, in addition, form excellent surfaces to which paints will adhere. These processes are, in general, either the selenium treatment of Bengough and Whitby or one of the chromate treatments. There are several variants of the latter; the most important is the acid dip, in which the object is immersed in a cold mixture of nitric acid and potassium dichromate, or one of the R. A. E. treatments, which are carried out in hot solutions. (All of these processes are patented.)

Literature Cited

(1) Haughton *et al.*, *J. Inst. Metals*, **54**, 275 (1934); **57**, 287 (1935); **60**, 339, 351 and **61**, 241 (1937); **62**, 175 (1938); Prytherch, W. E., *Ibid.*, **56**, 133 (1935).

(2) Payne, R. J. M., *J. Sci. Instruments*, **11**, 90 (1934).

MEDIEVAL DISTILLING



No. 104 in the Berolzheimer series of Alchemical and Historical Reproductions is, like Nos. 38, 66, 72, and 87 previously presented, from the title page of a XVI-Century book.

Michael Puff von Schrick's "Ein nutzlich puchlein von allen gebrante wassern" was published in Erfurt, Germany, 1500–1592, and covers the production of all kinds of "burnt waters," i. e., potable products obtained by distillation from wines and other fermented fruit juices, and floral waters.

A free translation of the quaint medieval title is "A useful booklet on all brandies."

The original, a woodcut, shows the usual type of still of the period, the forerunner of the "pot still" of Scotland and Ireland. Note the thistles strewn on the floor.

D. D. Berolzheimer

50 East 41st Street
New York, N. Y.

A complete list of the first 96 reproductions appeared in our January, 1939, issue, page 124. An additional reproduction appears each month.