REPORT No. 34.

ALUMINUM AND ITS LIGHT ALLOYS.

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This is the subject of a recent circular issued by the Bureau of Standards.[1] It contains information compiled from various sources, including the published literature, manufacturers of aluminum and its alloys, Bureau of Standards test reports and miscellaneous correspondence on the physical and mechanical properties of aluminum and its light alloys, with chapters included on the corrosion and deterioration of the metal and its alloys.

A summary is given of the research work which has been done here and abroad on the constitution and mechanical properties of the various alloy systems with aluminum. The mechanical properties and compositions of commercial light alloys for casting, forging, or rolling, obtainable in this country are described.

The circular is completed by a bibliography of sources of data and information. A table of contents follows:

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[1] Circular No. 76 of the Bureau of Standards.

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In addition to the information contained in Circular 76 of the Bureau of Standards, attention may be called to the series of reports issued by that Bureau during the year 1918, on the general subject of aluminum alloy investigation. Some of the important conclusions of these reports are:

I. REPORT OF THE PREPARATION AND TESTS OF MAGNESIUM ALUMINUM ALLOYS.

This work consisted in the melting and casting of some 16 alloys at the bureau, tests of some of these alloys as cast, the forging at the navy yard and the rolling at the New Kensington plant of the United States Aluminum Co. of others, and the testing of these alloys as rolled and as heat treated.

Although the work was not extended enough in character to admit of very far-reaching conclusions, the following may be regarded as established:

1. For forging and rolling alloys the magnesium content may apparently not go above 3 per cent since, without exception, it was impossible to forge the 6 per cent magnesium alloy and those containing only 3 per cent of magnesium forged and rolled quite badly.

2. Magnesium aluminum alloys of magnesium content higher than 3 per cent are of no value for rolling or forging and have questionable value only for casting, for the reason that they react most readily while hot with air, nitrogen, and water. The exact limits of composition for magnesium aluminum casting alloys have yet to be determined, however.

3. The tensile strength values obtained upon these alloys in no case were superior to those of standard duralumin.

II. REPORT OF THE PREPARATION AND TESTS OF ROLLED ALLOYS—ALUMINUM-MAGNESIUM-NICKEL, ALUMINUM-MAGNESIUM-COPPER, ALUMINUM-MAGNESIUM-MANGANESE.

The results of these tests on the three ternary systems indicate the following important conclusions:

1. The alloys of aluminum-magnesium-manganese are not affected by heat treatment; the alloys of aluminum-magnesium-nickel only very slightly; the alloys of aluminum-magnesium-copper show a decided improvement in the physical properties after heat treatment, amounting to as much as 50 per cent increase in the tensile strength. (See Report III.)

2. Even in the rolled or the rolled and annealed condition the manganese and nickel ternary series are inferior to the copper series as far as physical properties are concerned; arranged

according to strength, the copper series come first, then the manganese series, and finally the nickel series.

3. In the aluminum-magnesium-copper series it is advantageous to have the copper content larger than the magnesium content, preferably twice as great.

The general conclusion then from this investigational work is that from the standpoint of physical properties, tensile strength, and hardness, the aluminum-magnesium-manganese and aluminum-magnesium-nickel series are not to be considered, since they are quite inferior to the aluminum-magnesium-copper series. It should not, however, be assumed from this that for all purposes the former two series are not useful, since for some applications it is more desirable to have an alloy which is resistant to corrosion or which retains its strength at higher temperatures rather than to have merely a strong alloy. For such purposes these series may prove to have a value more nearly equal to that of the copper series.

III. REPORT OF INVESTIGATION OF THE HEAT TREATMENT OF ALLOYS OF ALUMINUM AND MAGNESIUM WITH COPPER, MANGANESE, AND NICKEL, RESPECTIVELY.

It is known that the highest physical properties of aluminum alloys containing magnesium and copper are not obtained without heat treatment either immediately previous to or subsequent to the final forming operation. Wilm has shown that the tensile strength of the alloy of magnesium and aluminum is increased by quenching the alloy from approximately 500° C. and allowing it to age for several days, and has patented this heat treatment process. Curiously enough the hardening effect in aluminum alloys is not obtained by quenching alone; an alloy immediately after quenching is not harder than originally, but increases in tensile strength and hardness with time, such that after a period of several days an increase of from 10 to 30 per cent in hardness may be obtained.

Until the present investigation the status of the heat treatment of aluminum alloys has remained as Wilm left it, with no further attention to the effect which variation in heat-treating conditions, quenching temperature, time and temperature of "ageing," temperature of quenching medium have upon the physical properties produced.

Of the many interesting facts which have been disclosed by this investigation, the following seem to be the most important from the practical standpoint:

The physical properties which are obtained from heat treatment, consisting of quenching and ageing, are dependent upon the conditions under which this heat treatment is carried out. The general method described originally by Wilm and patented by him is not the most satisfactory method of heat treatment of aluminum-magnesium-copper alloys. A much better heat treatment consists in the quenching of the material from a temperature varying from 510° C. to 520° C. in a bath at a temperature of from 100° C. to 150° C. and ageing preferably in this bath at the same temperature for from 10 to 15 hours, or at ordinary temperature for three or four days. By this treatment better physical properties are secured and with less loss of time during ageing. The tendency of such alloys to crack during quenching is also lessened by quenching to 100° C. instead of to 20° C.

IV. FURTHER INVESTIGATION OF THE HEAT TREATMENT OF THE DURALUMIN TYPE OF ALUMINUM ALLOY.

The object of this work was to establish further the laws of the effect of varying heat treatment conditions—quenching temperature, time and temperature of ageing, on the physical properties of duralumin, and to determine the best practical conditions for this heat treatment. The results justify the following conclusions:

(1) There is not in the case of the duralumin type of alloy, as there is in the case of steel, a definite quenching temperature which marks the limit of the property of the material to harden; duralumin may be hardened by quenching (followed by ageing) from temperatures varying from 250° C. to 520° C., and the hardness obtained by quenching from these temperatures increases uniformly as the quenching temperature increases, reaching a maximum at the latter temperature.

(2) Duralumin, on the other hand, is similar to steel in the fact that the tempering of it or aging after quenching is determined by two factors: time and temperature. A temperature of 150° C. marks what may be called a critical temperature with respect to the ageing of duralumin; i. e., above that temperature continued ageing may cause a decrease in hardness after the maximum hardness is attained, whereas below that temperature no such subsequent decrease of hardness occurs. The lowest temperature at which the maximum hardness may be obtained s approximately 125° C.

(3) The rate of increase of hardness with time upon ageing is roughly proportional to the temperature of ageing.

(4) The period of time of holding the specimen at the quenching temperature before quenching has but an inappreciable effect on the properties obtained; on the other hand, an improvement in the hardness of specimens quenched from temperatures below from 500° C. to 520° C. is obtained by preheating them before quenching to the latter range of temperature. Specimens held for 21 hours at the higher quenching temperatures before quenching (515° C. to 525° C.) were blistered with consequent decrease in hardness.

(5) Heating the material above 520° C. is generally detrimental; the material usually blisters and an oxide layer is formed on the surface.

(6) The following tensile properties have been obtained on rolled sheet of the above composition:

Tensile strength.	Proportional limit.	Elongation in 2 inches.
Pounds per sq. in.	*Pounds per sq. in.*	*Per cent.*
60,000	40,000	6
60,000	30,000	20

These properties may be obtained by quenching from 515° C. followed by ageing for one week at from 125° C. to 150° C., depending upon whether a high proportional limit with low ductility is desired (ageing temperature of 150° C.) or the converse.

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