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ALUMINUM-BERYLLIUM ALLOY

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This application is a continuation in part of our copending application Serial No. 462,402, filed June 19, 1930, which, in turn, is a continuation in part of our copending application Serial No. 327,- 176, filed December 19, 1928, and on which Patent No. 1,774,542 was issued September 2, 1930, which, in turn, is a division of our patent application Serial No. 150,141, filed November 22, 1926, and on which Patent No. 1,716,943 was issued June 11, 1929. The claims of this application are directed towards the disclosure, in said last mentioned application, of aluminum base alloys containing beryllium, silicon and magnesium, and also copper in addition to these constituents.

The invention relates to aluminum base alloys containing beryllium, the object being to provide an improved aluminum-beryllium alloy which has substantial advantages without as well as with heat treatment.

Because of its low density, beryllium is a desirable alloying element for many purposes for which light aluminum base alloys are used, but because of its present high cost, beryllium cannot be used in large quantities as an alloying constituent in competition with less expensive alloying constituents. We have discovered, however, that by alloying relatively small quantities of beryllium with aluminum there result inexpensive light aluminum base alloys, which, when heat-treated in a particular manner discovered by us, possess materially higher physical properties than previously known similar aluminum-beryllium alloys. This heat treatment is fully described in our Patent No. 1,716,943, identified hereinabove.

Aluminum-beryllium alloys such as herein contemplated may be variously manufactured. For example, an alloy of low beryllium content may be prepared by stirring metallic beryllium, which melts at about 1280° C., in molten aluminum at about 1100° C. until the beryllium is dissolved. The use of small amounts of a flux such as barium chloride facilitates introduction of the beryllium. By using higher temperatures, rich aluminum-beryllium alloys containing 10, 25 or 50 per cent or more of beryllium may be prepared in this way for use in the subsequent preparation of aluminum-beryllium alloys having lower beryllium content, or for use themselves without subsequent alloying.

The invention will now be further explained with reference to specific examples with the understanding, however, that the examples are given by way of illustrations and not as limitations of the invention.

In the following table there is given in the first

column the beryllium content of a number of aluminum-beryllium alloys, specimens of which were prepared by casting the alloys in iron molds to give chill cast slabs about one-fourth of an inch thick. The Brinell hardness values of these alloys as cast were determined by using a 10 millimeter ball under a load of 500 kilograms, and are given in the second column of the table. The several specimens were then all heated for 24 hours at a temperature of 631° C., and then quenched in water, after which their Brinell hardness values given in the third column of the table were determined in the manner just explained. Thereafter the specimens were all permitted to age naturally for two days at room temperature, and their Brinell hardness values given in the last column of the table were then determined.

Beryllium per cent	Hardness as cast	Hardness quenched	Hardness when aged 2 days at room temperature
0.013	16.8	15.7	16.9
0.025	17.2	17.2	24.3
0.075	19.4	22.7	36.8
0.21	21.2	23.8	37.0
0.40	22.8	24.1	39.1
0.75	25.9	27.3	42.9

This table shows that the Brinell hardness values of the specimen containing .013% beryllium do not vary materially with heat-treatment, the hardness value of the specimen when quenched and aged being substantially the same as when cast. However, the specimen having a beryllium content of .025% when quenched and aged had a Brinell hardness materially higher than as cast or as quenched, and this is likewise true of the several specimens having beryllium contents greater than .025%. From this it appears that aluminum base alloys containing not less than about .025% beryllium are capable of having their hardness and strength substantially increased by heat-treating them.

The invention is applicable not only to chill castings made of aluminum-beryllium alloys, but also to sand castings, as shown by the following example. Samples of sand cast aluminum-beryllium alloys containing .5% beryllium showed in the cast condition an average tensile strength of about 12,000 pounds per square inch and a Brinell hardness of 21. After aging 11 days at room temperature the samples showed no appreciable change in strength or hardness. Other samples of the same alloy after being heated for 30 hours at 632° C. and quenched in water had a

tensile strength of 13,000 pounds per square inch and a Brinell hardness of 23. These heat-treated samples were then permitted to age naturally at room temperature for 11 days, when it was found that their average tensile strength was 17,000 pounds per square inch and their Brinell hardness 36.

The samples thus far given have been of cast aluminum-beryllium alloys, but the invention contemplates wrought, rolled or otherwise worked alloys. As illustrative of this, an alloy containing 0.075% beryllium was forged hot to a bar about five-eighths of an inch square, and after annealing was found to have a Brinell hardness of 16.4. The sample was then heated for 20 hours at 631° C., quenched in cold water, and then permitted to age naturally at room temperature. After so aging for 16 hours its Brinell hardness was 31, and at the end of 72 hours it was 34.

We have found very useful and beneficial effects are produced by the addition of beryllium to aluminum base alloys containing silicon, copper, magnesium, magnesium and silicon, magnesium and copper, and magnesium, copper and silicon. Depending upon the particular alloy in question, the effect of the addition of beryllium to these alloys may, for example, be to confer age hardening characteristics where they did not exist before, to increase the age hardening characteristics already inherent in the alloy, and to increase the total hardness of the alloy.

As shown by the following example, beryllium confers age-hardening properties upon chill cast aluminum-copper alloys. Such an alloy containing 4% copper and no beryllium after being chill cast showed no appreciable increase in hardness after standing several days at room temperature. However, when .05% of beryllium was added to an aluminum base alloy containing 4% copper and the alloy chill cast, the Brinell hardness increased from 46 immediately after casting to 69 after the sample was aged naturally for five days at room temperature. Similarly, the Brinell hardness of an aluminum alloy containing 3% copper and 0.05% beryllium increased from 48 as cast to 64 after aging eight days at room temperature. After heating samples of the last mentioned aluminum-copper-beryllium alloy for eight hours at 589° C. and quenching in water, it was found that the Brinell hardness as quenched was 58, and after aging two days at room temperature it was found that the hardness had risen to 87. Results of the same order were obtained by varying the beryllium as well as the copper content of other aluminum base alloys containing these constituents.

Heat-treated pure aluminum-copper alloys show distinct hardening at room temperature. For example, an aluminum-copper alloy containing 4% copper was heat-treated at 550° C. and quenched. The hardness of the as quenched specimen was 63. After aging twenty-five days at room temperature, the hardness had increased to 79. The addition of beryllium to such an alloy causes an increase in this effect. The addition of 0.05% beryllium to the foregoing alloy caused the hardness to increase from 65 immediately after quenching from 550° C. to 99 after aging twenty-five days at room temperature.

It is shown in the following example that the addition of beryllium to aluminum-copper alloys has the further advantage of reducing the liability of the alloy "burning" during its forging or heat-treatment. The heating curve showing the increase in temperature per unit of time of an

aluminum-copper alloy containing 6% copper normally shows an arrest when the alloy reaches a temperature of about 548° C., this being due to the fusion of the aluminum-CuAl₂ eutectic at this temperature. When .81% of beryllium was added to an aluminum-copper alloy containing 6% copper and the resulting alloy heated, it was found that the first arrest in the heating curve was at 564° C. and that forgings of this alloy heat-treated for two and one-half hours at 554° C. showed no signs of "burning". This indicates that the copper and beryllium had probably combined in some way, because otherwise any free CuAl₂ present in the alloy would have melted at or below the aluminum-CuAl₂ eutectic temperature of about 548° C.

We have found that in some cases heat treating periods much shorter than some of those used in the preceding examples produce equally beneficial results. As illustrative of this, samples of a forged aluminum-copper-beryllium alloy containing 6% copper and .81% beryllium were heat-treated for two and one-half hours at 554° C. and quenched in water. As determined by using a 1000 kilogram load, the Brinell hardness of this alloy as quenched was 69, and after aging naturally at room temperature for twenty-four hours it had risen to 98. At the end of forty-eight hours the Brinell hardness was 99, and at the end of twelve days it was 101. The average tensile strength of forged samples of this alloy after aging twelve days was found to be about 52,000 pounds per square inch, and the elongation to be 25% in two inches.

As to the effects of beryllium on aluminum base alloys containing additional alloying constituents other than copper, we have found by a number of tests that the addition of silicon to aluminum-beryllium alloys results in an increase of their final hardness after quenching. An aluminum base alloy containing .1% beryllium, .5% magnesium and 1% silicon was found to have a Brinell hardness of 42 as cast and of 54 after aging for one week at room temperatures, the latter being materially higher than that of a similar alloy not containing beryllium. After being heated for eighteen hours at 550° C., quenched in water and aged for one week at room temperature the Brinell hardness of the aluminum-beryllium-magnesium-silicon alloy just described was found to be 74. An alloy of the same composition plus 4% copper showed as cast a Brinell hardness of 70, and after aging at room temperature for one week it showed a Brinell hardness of 84. Samples of this alloy, after being heated for fifty hours at 500° C. and quenched in water, showed as quenched a Brinell hardness of 57, and after aging at room temperature for one week Brinell hardness of 97.

We contemplate the addition of beryllium in amounts of between about 0.025% and 1.0% to alloys containing between about 0.1% to 1.0% of silicon, between about 0.1% and 0.5% of magnesium and between about 0.1% and 6.0% of copper. The results of our tests indicate that the advantages of our invention are realized to an appreciable degree with alloys falling within these limits of composition.

The advantages of adding beryllium to an aluminum base alloy containing magnesium and silicon are shown in the following examples. An aluminum base alloy containing .5% magnesium and 1.0% silicon was formed into chill castings, which, after aging for seven days at room temperature had a Brinell hardness of 48.

After heating similar castings of the same composition at 550° C., quenching them in water, and aging them at room temperature for twenty-four hours, they had a Brinell hardness of 69.

- 5 Chill castings of an alloy of the same composition, but to which .05% beryllium was added, had a Brinell hardness of 54 after aging for seven days at room temperature, and after being heated at 550° C., quenched in water, and aged
10 at room temperature for twenty-four hours it had a Brinell hardness of 76.

- Similarly, the advantage of adding beryllium to an aluminum base alloy containing magnesium, silicon and copper are shown in the following examples. An aluminum base alloy containing .5% magnesium, 1.0% silicon and 4.0%
15 copper was made up into chill castings, which, after aging at room temperature for five days, was found to have a Brinell hardness of 80. An
20 alloy of the same composition, but to which .05% beryllium was added, had a Brinell hardness of 84 after chill castings of it were aged at room temperature for five days.

- Throughout this specification, and in the appended claims, the expression "aluminum base alloy" is used to describe an alloy in which aluminum is the predominant constituent regardless of whether the alloy is binary, ternary, or
25 of a more complex order.

According to the provisions of the patent statutes, we have explained the principle and mode of operation of our invention and have described numerous specific examples of the manner in which it may be practiced. However, we desire
80 to have it understood that, within the scope of the appended claims, the invention may be practiced in alloys having compositions differing from those particularly described.

We claim:

1. An aluminum base alloy containing from about 0.025 per cent to 1.0 per cent beryllium, about 0.1 per cent to 1.0 per cent silicon, about 0.1 per cent to 0.5 per cent magnesium, and characterized by high hardness and beneficial age
85 hardening properties.

2. An alloy consisting of from about 0.025 per cent to 1.0 per cent beryllium, from about 0.1 per cent to 1.0 per cent silicon, from about 0.1 per cent to 0.5 per cent magnesium, and the
90 rest aluminum.

3. An alloy consisting of from about 0.025 per cent to 1.0 per cent beryllium, from about 0.1 per cent to 1.0 per cent silicon, from about 0.1 per cent to 0.5 per cent magnesium, from about
95 0.1 per cent to 6.0 per cent copper, and the rest aluminum.

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