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LOUIS W. KEMPF, OF CLEVELAND, OHIO, ASSIGNOR TO ALUMINUM COMPANY OF AMERICA, OF PITTSBURGH, PENNSYLVANIA, A CORPORATION OF PENNSYLVANIA

ALUMINUM SILICON ALLOY

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This invention relates to aluminum base alloys which contain silicon as the principal alloying element and to certain novel alloys of such nature.

Aluminum base alloys containing silicon are, as regards lightness, especially suited to uses in which light weight is a factor of importance, for, because of the flow specific gravity of the silicon, an alloy of aluminum and silicon is even lighter than most of the well known "high strength" aluminum alloys. In some cases, however, aluminum-silicon alloys for construction material do not possess the necessary strength and hardness, and in other cases the hardness alone is inadequate. It is well known that when aluminum-silicon alloy is used in the form of castings, particularly when the alloy contains high amount of silicon such as 5 to 25 per cent, castings with superior physical properties are usually only obtainable when the structure of the alloy is "modified" in some manner. The so-called modification processes involve either casting the metal in a chill mold or adding to the metal some substance which has in itself the desired modifying effect. The modifying substance may be a metal such as sodium or it may be a salt such as an alkali fluoride. The discovery that these alloys might be modified and that increased strength and hardness might be obtained has called attention to the inherent possibilities of aluminum base alloys containing silicon and the more or less extended use of these alloys is the result of the discovery of such modification. However, the aluminum-silicon alloys so modified do not possess the strength, hardness, or fatigue resistance desired for some purposes. Moreover, in the unmodified state, the alloys do not readily machine, and in the modified condition, considerable care is sometimes necessary to avoid dross inclusions in casting.

The alloys which are the subject of the present invention not only do not have the disadvantages enumerated above, but they retain all of the advantages which have hitherto made the aluminum base alloys containing silicon a desirable material for use in many varied applications.

I have discovered that a small amount of magnesium added to aluminum alloys containing more than about 5 per cent of silicon produces an effect in those alloys which, in view of the amount of constituent added, is entirely out of proportion to what might be expected. The addition of magnesium imparts to the alloy a hardness which is high as compared to the aluminum-silicon alloys heretofore produced, and give to the alloys properties which are much more conducive to satisfactory machining than the older aluminum-silicon alloys. Furthermore, the small amount of added magnesium produces an alloy which responds to heat treatment to a marked degree and permits the production of aluminum-silicon alloys of high strength as compared with those previously known.

Hitherto, in order to produce such strength and hardness and machinability as I have produced in the aluminum base alloys containing silicon by the addition of small amounts of magnesium, it was thought necessary to add comparatively large amounts of other alloying elements, such as copper. Because of the amount of alloying constituent which was necessarily added, the characteristic advantageous features of the aluminum-silicon alloys, such as lightness and corrosion-resistance, were to some degree changed and the resulting alloy was for many purposes not as desirable. The present invention eliminates these difficulties in that the inherent defects of the aluminum-base silicon alloys are overcome without changing essentially the nature of those alloys, and the beneficial properties imparted by the silicon to the aluminum are not diminished.

To obtain these effects, I have added from 0.02 to 3 per cent of magnesium with good results. I have found that the addition of as little as 0.02 per cent of magnesium will produce appreciable improvements over the entire silicon range, the lower limit of which is about 4 or 5 per cent. (The upper limit is for practical reasons about 25 per cent, because of the extreme difficulty of machining the alloys when the silicon content is materially greater than the amount named and the alloys are quite brittle and difficult to cast.) The magnesium may be added to the alloy by any well known metallurgical alloying method, and the aluminum-silicon-magnesium alloy may be made into castings of any nature in practically any type of mold. I have found, however, that the best results are obtained when the metal is modified at the time of casting either by the use of an added agent or by the use of a chill mold.

It is a feature of my new alloy that while the hardness of the alloy in the "as cast" condition, i. e., before solution heat treatment, is increased by the addition of the magnesium, the tensile strength is not increased, and in fact, there is a slight decrease in tensile strength caused, I believe, by the effect of the magnesium on the particular modification process used in casting the alloy. However, this decrease is slight and any disadvantage resulting from it is entirely overcome by the large percentage increase in hardness caused by the magnesium.

Thus in the aluminum-silicon eutectic range in the neighborhood of about 13 per cent of silicon where modification has its most pronounced effect, I have found that increasing amounts of magnesium have a tendency to interfere with this phenomenon and consequently there is little or no increase in tensile strength but a decided increase in hardness. Taking as an example an aluminum alloy of about 12 per cent of silicon which has been cast in a chill mold to obtain a suitable modification effect, the following table clearly shows the results of increasing quantities of magnesium:

TABLE No. 1

Aluminum alloys containing 12 per cent silicon

Alloy	Per cent of magnesium	Tensile strength lbs. per sq. in.	Brinell hardness
A	0.00	30,180	57.7
B	0.08	31,420	72.8
C	0.14	31,570	73.0
D	0.32	30,670	77.6
E	0.47	31,500	82.6
F	1.08	29,500	87.1

It will be observed from these figures that as little as 0.08 per cent of magnesium produced an increase in Brinell hardness amounting to over 25 per cent of the Brinell hardness of the alloy which contains no magnesium. This increase in hardness is, as has been hitherto mentioned, of great importance for many purposes, and the value of aluminum-silicon alloys in the "as cast" condition is thus greatly enhanced.

I have also found that such alloys have machining properties which are notably better than those of the aluminum-silicon alloys containing no magnesium. Another important feature of the alloys represented above is their relative resistance to corrosion. Aluminum-base alloys containing silicon are in themselves, on a comparative basis, corrosion-resistant to a considerable degree, and as between alloy A and alloy C of the above table, for instance, I have found but little to choose from in point of corrosion-resistance, but in respect to this property my new alloys are advantageously superior to aluminum-silicon alloys in which equal properties are obtained by the addition of copper or similar alloying elements, such as zinc and nickel.

It is also an advantageous feature of my new alloys that their strength and hardness are capable of further increase by the application of thermal treatments which are used in connection with other aluminum alloys for effecting that purpose. The aluminum-silicon alloys as hitherto known presented their greatest hardness in the cast and modified condition, and the application of solution or aging heat treatments, such as are regularly practiced in connection with other alloys, did not increase but on the other hand decreased the tensile strength and hardness. Thus, for instance, a casting of such an alloy as alloy A, if heat treated for about 2 hours at 565° C. and later aged for about 20 hours at 150° C. will actually undergo a decrease in tensile strength and Brinell hardness. On the other hand, if 0.4 per cent of magnesium is added to this alloy, the same thermal treatment will increase the tensile strength to about 51,000 pounds per square inch and the Brinell hardness to about 114.

The effect of heat treatment on other properties than the ones above mentioned is also pronounced. For example, a heat treated casting of alloy containing 10 per cent of silicon and 0.2 per cent of magnesium has an endurance limit to fatigue of 9,000 pounds per square inch, whereas without the magnesium the same alloy in the modified condition but without heat treatment has an endurance limit of 6,000 pounds per square inch, which value represents the limit for aluminum-silicon alloys of this composition unless the alloy is made susceptible to heat treatment. Furthermore, between the two alloys just mentioned, the one containing magnesium and in a modified and heat treated condition has a yield point of 16,000 pounds per square inch; while the other, without magnesium but in the unheat treated and modified condition, has a yield point of 14,500 pounds per square inch. If this latter alloy is heat treated by substantially the same heat treatment which produced a yield point of 16,000 pounds per square inch in the aluminum alloy containing both silicon and magnesium, the yield point will decrease to about 12,000 pounds per square inch.

TABLE No. 2

Aluminum alloys containing 5 per cent silicon

Per cent of magnesium	Tensile strength lbs. per sq. in.	Brinell hardness
0.13	29,680	58.8
0.20	31,220	71.5
0.33	33,720	86.0
0.45	47,580	101.0

Because of the lower amounts of silicon in the above alloys, the results are not equal to those set forth in the preceding table but they afford striking evidence of the marked effect of small amounts of magnesium on aluminum-silicon alloy castings containing relatively small amounts of silicon.

It is known in the art that specimens separately cast under commercial conditions which are tested without machining off any of the metal of the outer skin develop more favorable properties than specimens machined out of heavier sections of commercial castings, this because heavier sections solidify more slowly and are more susceptible to internal shrinks and defects than the more rapidly cooled and more satisfactorily fed specimens, a goodly portion of which is in closely proximity to the cool walls of the mold. I have discovered it characteristic of this particular series of alloys that the divergence between separately cast specimens and those cut from the interior of the heavier sections is not at all as marked as it is in the case of other commercial alloys. It is, of course, recognized in the case of all alloy castings that such a drop in strength and elongation must and does progress towards the heavier sections but efforts are being made to cut this variation to a minimum and in the alloys within the scope of this invention I believe that I have succeeded in effecting a distinct advance.

As an illustration of the superiority of aluminum base silicon alloys to which has been added a small quantity of magnesium, I have taken a casting of commercial design and cut test specimens from the interior of one of the heavier sections to be compared with other similar test specimens of the same alloy which were simultaneously cast to test size in separate molds. One alloy was made up with 10 per cent silicon and 0.2 per cent magnesium in an aluminum base. The separately cast bars had an average tensile strength of 29,890 lbs. per sq. in. and an elongation of 8.3 per cent in 2 inches and the bars machined out of the casting had an average tensile strength of 26,800 lbs. per sq. in. and an elongation of 6.3 per cent. This represents only a 13 per cent decrease in tensile strength and a 25 per cent decrease in elongation. Another casting was made from a widely used aluminum base alloy containing copper and bars were separately cast as before. After heat treatment so as to develop the most favorable properties, the separately cast bars had a tensile strength of 30,000 lbs. per sq. in. and an elongation of 7.8 per cent in 2 inches. The bars cut from the heavy section had an average tensile strength of 23,300 lbs. per sq. in. and an elongation of 2.7 per cent in 2 inches. This represents a 22 per cent decrease in tensile strength and a decrease in elongation of 65 per cent. Significantly, the separately cast bars of the latter alloy had higher tensile strengths than those within the scope of our claims, and whereas in the commercial aluminum base copper alloy the loss in tensile strength amounted to 6800 lbs. per sq. in. and the difference in elongation amounted to 5.1 per cent in 2 inches, in the alloy made under the provisions of this invention the loss in tensile strength was only 3090 lbs. per sq. in. and the differences in elongation only 2 per cent.

This superior strength in heavy sections is an indication of improved casting properties and it is interesting to note that a large foundry devoted to the casting of aluminum base alloys found it impossible to make castings from a pattern of rather unusual design by the use of certain standard commercial alloys and it was only by utilizing an alloy made according to the precepts of this invention that a satisfactory casting was produced.

Aluminum base silicon alloys to which have been added small quantities of magnesium are corrosion-resistant to a very high degree. In a comparative test extending over a period of a year, I have subjected a series of aluminum base alloys, widely known and commonly used, to the action of a salt corrosive agent. Along with these standard alloys, I subjected to the test two aluminum base silicon alloys with a silicon content of about 10 per cent with added quantities of magnesium, in one of which alloys the iron impurity was held below 0.15 per cent, the other having slightly more than the usual iron content, say about 0.7 per cent.

The effect of the corrosive agent was measured by determining the loss in tensile strength suffered by the alloys by reason of the corrosion, and obtained by subtracting the average tensile strength of the corroded specimens from the average tensile strength of specimens from the same melt which had been retained for simultaneous testing and which had been protected from corrosive influences by a protective coating.

The four standard commercial alloys representing probably the four most widely used aluminum base casting alloys suffered a depreciation of strength about as follows:

Table A

Alloy A	19.1 per cent loss in strength
Alloy B	17.1 per cent loss in strength
Alloy C	12.5 per cent loss in strength
Alloy D	10.1 per cent loss in strength

The two alloys which I have especially devised and compounded gave these following results:

Table B

Alloy E (with higher iron)	7.4 per cent loss in strength
Alloy F (with lower iron)	2.4 per cent loss in strength

In connection with this test, it should be noted that the corrosive influence was an artificially aggravated case and that such conditions would conceivably never be encountered in the great majority of uses to which the alloy might be put. In specific instances as, for example, when alloys of my invention are used along the sea coasts as parts of seaplanes, ships, etc., conditions approximating those of the test will be encountered and the almost negligible corrosion effects on my alloys will be particularly in demand when considered in conjunction with the high endurance limit and the retention of satisfactory physical properties with increasing section.

Castings of aluminum-base alloys containing silicon and small amounts of magnesium are also susceptible to increase in hardness and strength by the use of low temperature aging processes without previous high temperature solution treatment, and such alloys respond readily to any of the well known heat treatments which have been hitherto described for use in connection with aluminum alloys in general.

I have found it characteristic of my alloys that the physical properties are not varied by previous changes in pouring temperature to the extent of the ordinary commercial aluminum base alloys. It is well known in the art that when the molten metal, through inadvertence or necessity, is poured at temperatures higher than usual for that particular alloy, the physical properties suffer a decrease which in some alloys is especially marked.

As a basis for comparison, I took a commercial aluminum base heat treated alloy containing copper and poured test specimens from the same melt at 3 different temperatures, with the results given in Table C. The test specimens were given a heat treatment which is standard for this alloy.

Table C

Pouring temperature	Tensile strength lbs. per sq. in.	Percent elongation in 2 inches
760° C	26,880	6.4
724° C	30,700	6.2
675° C	32,010	9.1

I also took an aluminum base alloy containing about 11.68 per cent silicon and after adding 0.17 per cent of magnesium performed a similar experiment to determine the variation of properties caused by increasing the pouring temperature. The test specimens were heated for 2 hours at 551° C., and quenched. The results are given in Table D.

Table D

Pouring temperature	Tensile strength lbs. per sq. in.	Percent elongation in 2 inches
787° C	29,350	6.0
734° C	30,240	6.7
675° C	31,650	7.5

It will be observed that although I have used a higher pouring temperature for one of the tests on my alloy, the effect on tensile strength is much less than in the alloy of Table C, as is also the per cent elongation.

My new alloys are also marked by low thermal expansivity thus showing that they retain this advantageous property of aluminum-silicon alloys to which no magnesium has been added.

The term "aluminum base alloy", as used herein and in the appended claims comprehends, for the purpose of avoiding undue details and prolixity, not only the alloy as cast in sand or in chill molds or in any combination of these casting methods, but also the alloy in the normal as well as in the modified condition.

While certain percentages and limits of silicon and magnesium content have been stated, within which limits my best results were obtained, and although certain particular well known heat treatments have been described, it will be understood that these factors may be varied without departing from the invention.

I claim—

1. An aluminum base alloy consisting of from about 5 to 25 per cent of silicon, from about 0.02 per cent to 3 per cent of magnesium, and the rest aluminum.

2. An aluminum base casting alloy consisting of about 12 per cent of silicon, between about 0.02 and 1 per cent of magnesium, and the rest aluminum.

3. As a new product, a casting of an aluminum base alloy consisting of from about 5 to

25 per cent of silicon and from about 0.02 to 3 per cent of magnesium, and the rest aluminum, characterized by high hardness and relatively high corrosion-resistance in the "as cast" condition.

In testimony whereof I hereto affix my signature.

LOUIS W. KEMPF.

CERTIFICATE OF CORRECTION.

Patent No. 1,908,023. May 9, 1933.

LOUIS W. KEMPF.

It is hereby certified that error appears in the printed specification of the above numbered patent requiring correction as follows: Page 1, line 8, for "flow" read "low"; page 2, line 57, in column 3 of the boxed table, for "31,500" read "31,550"; and that the said Letters Patent should be read with these corrections therein that the same may conform to the record of the case in the Patent Office.

Signed and sealed this 18th day of July, A. D. 1933.

M. J. Moore.

(Seal) Acting Commissioner of Patents.

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