J. E. HANAFEE

PRODUCTION OF HEAT-TREATABLE ALUMINUM CASTING ALLOY

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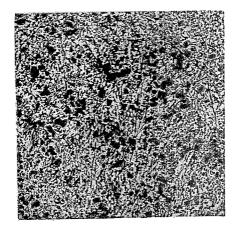


FIG. I

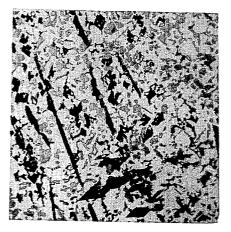


FIG. 2

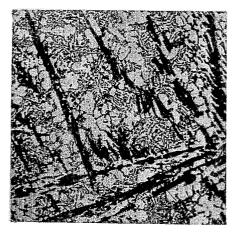


FIG. 3

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3,297,435 PRODUCTION OF HEAT-TREATABLE ALUMINUM CASTING ALLOY James E. Hanafee, Westfield, N.J., assignor to The Inter-national Nickel Company, Inc., New York, N.Y., a 5 corporation of Delaware Filed Mar. 22, 1963, Ser. No. 267,239 10 Claims. (Cl. 75-142)

The present invention relates to the production of 10 aluminum alloys and, more particularly, to the production of cast aluminum alloys.

It is well known that aluminum has gained great favor for many structural applications because of its light weight and fair strength at moderate temperatures. 15 On the other hand, attempts of aluminum promoters to make any serious inroads into the elevated temperatures and/or high strength fields have been largely thwarted since commercially pure aluminum is relatively weak at elevated temperatures as well as possessing relatively 20 poor casting characteristics. Thus, the art has been faced with the dual problem of (1) increasing the strength while (2) improving the casting characteristics of aluminum alloy castings.

problem was to select materials which are known generally to increase the strength of other metals. For example, copper has been added to aluminum to produce alloys having improved mechanical strength; however, copper alone did not afford enough of a gain in casting 30 characteristics to be a panacea for the designer. To obviate the shortcomings of the aluminum-copper alloys, the art turned to silicon additions. The thus-produced aluminum-copper-silicon alloys were adequate for many applications where high ductility, high resistance to im- 35pact loading and/or high strength at elevated tempera-tures are not required. In addition, aluminum-copper and aluminum-copper-silcon alloys have poorer resistance to corrosion than most other aluminum casting alloys.

40 In an attempt to gain greater strength and hardness at elevated temperatures, iron in an amount of 1% was added to an aluminum alloy nominally containing 10% copper and 0.2% magnesium. This alloy is characterized by good resistance to hot-cracking so that it may be 45 successfully produced in a permanent mold as well as in sand. However, its mechanical properties and/or characteristics were such that it became a special purpose alloy, i.e., for pistons, and thus was uneconomical to produce.

50 In the continuing search for still greater mechanical properties and/or characteristics, an aluminum casting alloy that was heat-treatable, i.e., an alloy exhibiting a marked susceptibility to improvement of its mechanical properties, etc., by heat treatment, was developed. It contained about 4% to about 5% copper, but only small castings of simple design could be cast because this alloy exhibited a severe tendency to hot-crack and shrink in the sand mold. Silicon (about 0.8%) was added and this somewhat reduced the tendency to crack. However, 60 invention; this silicon content was not sufficient to permit casting in a permanent mold so that the silicon content was increased to about 2.5%. As in the case of the previously mentioned aluminum alloys, while this addition made the

acteristics), it made it less favorable from another standpoint (mechanical strength).

Still higher silicon additions, e.g., up to 12% and higher, further improved the casting characteristics of the aluminum alloys as well as improving the thermal expansion characteristics thereof. Here again though, the elevated temperature mechanical properties and/or characteristics were inadequate for most elevated temperature applications. Attempts to improve the last-named characteristics by the addition of nickel to aluminumsilicon alloys met with some success where the nickel content was less than about 2.5%. However, the elevated temperature properties, etc., are less than desirable and the attempts to increase them by increasing the nickel content have been unsuccessful since the room temperature properties and/or characteristics were so low as to render such alloys useless. The gain of one beneficial property was only at the expense of another needed

property. Although many attempts were made to overcome the foregoing difficulties and other disadvantages, none, as far as I am aware, was entirely successful when carried into

practice commercially on an industrial scale. It has now been discovered that aluminum alloy cast-One method adopted by the art to solve the complex 25 ings having good mechanical properties and/or characteristics at room temperature and at elevated temperatures in combination with good casting properties, etc., may now be produced.

It is an object of the present invention to provide a novel process for producing cast aluminum alloys having a favorable microstructure.

Another object of the present invention is the provision of a new process for producing unique aluminum alloy castings having good room temperature and elevated temperature mechanical properties and/or characteristics.

It is also an object of the present invention to provide a special process for making heat-treatable aluminum alloy castings which are particularly adapted for use at elevated temperatures and which have good resistance to corrosion and wear as well as having relatively low thermal expansion.

The invention also contemplates providing a new heattreatable aluminum alloy casting having a favorable microstructure.

It is a further object of the invention to provide a unique aluminum alloy, which alloy has good room temperature and elevated temperature mechanical properties and/or characteristics.

Among the further objects of the invention is the provision of an article of manufacture made of an aluminum alloy which, in the heat-treated condition, has good room temperature and elevated temperature mechanical properties and/or characteristics.

Other objects and advantages will become apparent 55 from the following description taken in conjunction with the accompanying drawing in which:

FIGURE 1 is a reproduction of a photomicrograph taken at a magnification of 100 diameters $(100 \times)$ of an etched aluminum alloy within the scope of the present

FIGURES 2 and 3 are reproductions of photomicrographs taken at $100 \times$ of etched aluminum alloys not within the scope of the present invention.

Generally speaking, the present invention contemplates alloy more favorable from one standpoint (casting char- 65 the production of unique aluminum casting alloys having

microscopic aluminide morphologies that are favorable, i.e., the morphology, as viewed under a microscope, is such that the aluminum alloy has good mechanical properties and/or characteristics at room temperature and at temperatures up to about 600° F. or higher. According 5 to this invention, a favorable morphology is obtained by a process in which the massive, coarse aluminides which ordinarily form in aluminum alloys containing, by weight, 5% to 25% silicon, 4% to 9% nickel and up to 1% each of copper and magnesium with the sum of copper and 10 magnesium being 0.2% to 2% are substantially inhibited from forming by delimiting and/or controlling unavoidable iron present to an amount which is correlated to the percentages of silicon (Si), nickel (Ni) and copper plus magnesium (Cu+Mg) such that the amount of iron is 15 less than

$$1-0.1$$
(percent Ni) -0.02 (percent Si)
 $+0.05[2-percent(Cu+Mg)]$

The aluminum alloys produced in accordance with the 20 aforementioned control of iron which contain silicon, nickel, and copper plus magnesium in the previously mentioned ranges and controlled amounts are in themselves novel since these alloys are characterized by a refined aluminide microstructure as well as having some measure 25 of room temperature ductility in combination with good mechanical properties and/or characteristics at temperatures as high as 600° F. or higher.

The alloys according to this invention contain aluminum, silicon, nickel and either copper or magnesium or both, and each of these elements in combination with each other element plays an important role in controlling the properties of the alloy providing the iron is delimited and/or controlled in the aforesaid manner. For example, the silicon content is in the range of 5% to 25% and, advantageously, between 10% and 16%. The inclusion of silicon in the alloys of the present invention contributes importantly to the castability and other foundry characteristics of the alloy, improves wear characteristics, and beneficially lowers the thermal expansion characteristics thereof. However, if too much silicon (more than about 25%) is included, the alloy becomes very brittle, difficult to machine, and the pouring temperature for casting the alloy is much too high for economical practice. On the other hand, too little silicon (less than about 5%) is also 45disadvantageous to the properties of the alloy. For example, the coefficient of linear thermal expansion becomes raised to the point at which the use of the alloy in high temperature applications is inhibited. Furthermore, the wear resistance of an aluminum-nickel alloy containing 50 too little silicon is materially decreased as are the castability characteristics of the alloy.

In general, nickel when present in amounts of 4% to 9%, and advantageously 5% to 7%, improves the high temperature properties and/or characteristics of alumi- 55 num/silicon alloys. However, if the nickel is present in amounts of less than about 4%, there is no appreciable gain in hot hardness properties over nickel-free aluminumsilicon alloys. Moreover, the thermal expansion characteristics of such an alloy are undesirably high. When the 60 nickel is present in an amount over 9% by weight, the foundry characteristics deteriorate, e.g., the feeding rate of the molten alloy to the mold is reduced, the pouring temperature is raised, etc. In addition, castings made of the alloy tend to be much too brittle and it is found that 65 and all commercially practical forms of aluminum and there is a detrimental great volume of aluminides present in such castings.

The casting alloys produced in accordance with the invention may contain up to 1% copper and up to 1% magnesium provided that at least 0.2% of copper plus mag-70 nesium is contained therein. Thus, while neither copper nor magnesium individually need be present at least one or both must be present in a total amount of at least about 0.2% in order to impart strength and hardness to the alloy at room temperature. In addition, copper and 75

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magnesium afford a measure of improved machinability to these alloys. If too little copper plus magnesium (less than about 0.2%) is present, their hardening or strengthening function would be lost. If too much copper plus magnesium, e.g., over 1% each or over 2% in total, is present the room temperature ductility is substantially lowered unless the alloy is subjected to a relatively uneconomical high temperature, long-time heat-treatment. In addition, where the copper plus magnesium exceeds 2%, no significant improvement in high temperature properties is apparent.

The alloys of the invention may optionally contain alloying and/or incidental elements such as titanium, boron, phosphorus, sodium, cadmium, indium, tin, lithium, manganese and chromium. For example, the alloys produced within the scope of the present invention may tolerate up to 1% titanium without adversely affecting the beneficial properties and/or characteristics. As a matter of fact, between 0.1% and 0.3% titanium in the castings has an advantageous effect in that it contributes to grain refinement. Up to 0.05% and, advantageously, up to 0.01%, boron may be included in the alloys of the present invention without adversely affecting their properties and/ or characteristics and may even be advantageously included since it appears to afford some measure of grain refinement. Phosphorus in amounts of up to 0.03% contributes to hard particle refinement of the hypereutectic aluminum-silicon-nickel alloys within the scope of this invention. Sodium, on the other hand, when added to an 30 aluminum alloy melt in amounts of up to 0.05%, aids in the hard particle refinement of the hypoeutectic aluminum-silicon-nickel alloys of this invention. However, ex-

cessive sodium causes overmodification with a resultant coarse microstructure. Cadmium, indium, tin and/or 35 lithium may be usefully present in the age hardenable aluminum-nickel-silicon alloys containing copper plus magnesium since each of these elements improves the aging characteristics. Thus, up to 0.5% cadmium, up to 0.5% indium, up to 0.5% tin and up to 1% lithium may

be incorporated into the alloys of this invention. Advantageously, the amounts of such elements are minimized, and in such cases the alloy may contain, by weight, up to 0.2% cadmium, up to 0.2% indium, up to 0.2% tin and up to 0.8% lithium. With particular regard to lithium, it is important that excessive lithium is not employed as its inclusion may cause the casting characteristics of the alloy to deteriorate. Manganese and chromium may be tolerated in amounts of up to 0.5% manganese and up

to 0.5% chromium. However, each of these elements tends to form undesirable aluminides and should be controlled.

While the aluminum alloys of this invention do contain silicon, nickel, copper and/or magnesium in the controlled amounts and for the reasons hereinbefore set forth and while these alloys may optionally and/or incidentally contain restricted amounts of titanium, boron, phosphorus, sodium, cadmium, indium, tin, lithium, chromium and/or manganese, no combination of such ingredients, even within the aforementioned ranges, produces satisfactory alloys unless the iron content in weight percent of such alloys is less than

1-0.1(percent Ni)-0.02(percent Si)

+0.05[2-percent(Cu+Mg)]

aluminum alloys for ordinary applications contain some iron, i.e., at least about 0.05% by weight of the alloy. From this correlation, it is clear that the maximum iron content is at the minimum levels of nickel, silicon and copper plus magnesium, i.e., 4%, 5% and 0.2%, respec-tively, and is about 0.59%. Conversely, as nickel silicon and/or copper plus magnesium are increased, the lower must be the maximum content of iron. It is also manifest that no useful alloy can be produced in accordance with this invention which contains the maximum amounts

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of nickel (9%), silicon (25%) and copper plus magnesium (2%) since the required iron content would be less than zero. Thus, the compositions of useful alloys within the broad scope of the invention are sensitive to changes in any of its required constituent ingredients and/ 5 or elements. In particular, any change in silicon or nickel or both greatly affects the permissible iron content of such alloys. Copper plus magnesium has a similar but lesser When the alloy contains more than the maximum effect. iron (which depends on the contents of nickel, silicon and 10 copper plus magnesium), the alloy has poor ductility at room temperature and is characterized by having a microstructure of massive, coarse aluminides (an unfavorable morphology). On the other hand, when the iron content satisfies the correlation, the alloys have adequate room 15 temperature ductility and are characterized by having a microstructure of refined aluminides. Since the formation

For the purpose of giving those skilled in the art a better understanding of the invention and a better appreciation of the advantages of the invention, a number of illustrative examples are hereinafter set forth in Table I. Each alloy set forth in the following example was air induction melted and, when adjusted to the required composition with regard to iron, nickel, silicon and copper plus magnesium, cast into a 1" x 2" x 14" permanent wedge mold which was at about 450° F. and which had a bottom aluminum chill plate at room temperature. The pouring temperatures varied between about 1250° F. and 1500° F. depending upon the silicon and nickel contents of the alloy being poured. In addition, each of the alloys was heat treated by heating at about 950° F. for about 8 hours, water quenching and following with a stabilizing treatment comprising heating to about 400° F. and holding at that temperature for approximately 8 hours.

TABLE I

Alloy	Composition, Weight Percent								
	Silicon	Nickel	Iron	Copper	Magnesium	Titanium	Aluminum		
A B D E F	$5.3 \\ 5.4 \\ 5 \\ 11 \\ 16.2 \\ 24.4$	4 4 8.1 4.9 5 4	0.05 0.5 0.04 0.07 0.17 0.1	0. 93 0. 93 1 0. 95 1 0. 95	0.7 0.76 0.96 1 0.95 0.91	$\begin{array}{c} 0.24\\ 0.21\\ 0.2\\ 0.24\\ 0.2\\ 0.25\end{array}$	Balance. Do. Do. Do. Do. Do.		

rates as well as by iron content, the iron content should be at the lower end of the permissible range whenever it is difficult to impress a chill completely through the crosssection of the solidifying molten metal in the mold.

In carrying the invention into practice, particularly un- 35 expectedly good results are obtained when the aforedescribed process for refining aluminides is carried out on aluminum alloys containing, by weight, 10% to 16% silicon, 5% to 7% nickel, 0.5% to 1% copper and 0.5% to 1% magnesium with or without titanium, boron, phos- 40 phorus, sodium, cadmium, indium, tin, lithium, chromium and manganese in amounts not exceeding the amounts heretofore set forth. The alloys produced by such a process have a superior combination of physical, mechanical and/or metallurgical properties and/or 45 characteristics.

The alloys produced within the contemplation of the processes of the present invention are heat-treatable and are advantageously heat-treated to provide castings having superior properties and/or characteristics. Advantageous 50 heat treatments include (1) a stabilizing (overaging) at about 400° F. to 700° F. for about 2 hours to 20 hours, advantageously at about 400° F. to 650° F. for about 3 hours to 16 hours; (2) a solution heat treatment at about 900° F. to 1050° F. for about 3 hours to 20 hours fol-55 lowed by a water quench and a stabilization at about 400° F. to 700° F. for about 2 hours to 20 hours; and (3) a solution treatment and water quench as in (2) followed by an aging treatment at about 300° F. to 500° F. for about 1 hour to 20 hours.

The process of the present invention and the iron-containing aluminum alloys produced thereby may be made by any of the known foundry procedures as those skilled in the art will readily understood. For instance, the alloys may be air induction melted and cast, e.g., into a permanent mold at about 450° F. with or without a chill plate although an aluminum chill plate is advantgeously employed so that the formation of harmful aluminides is abated by the faster solidification rate. As those skilled in the art will readily appreciate, the pouring temperature is a function of the silicon and nickel levels but does lie between about 1200° F. and 1500° F. Standard commercial degassing, e.g., with dry chlorine, and silicon refining and modifying techniques may also be used when appropriate.

of harmful aluminides is promoted by slower cooling 30 The alloys of the present invention exhibit good mechanical properties and/or characteristics, including ultimate tensile strength (U.T.S.), 0.1% offset yield strength (Y.S.) and elongation, at room temperatures, as is illustrated in Table II.

TABLE II

0	Alloy	U.T.S., pounds per square inch (p.s.i.)	Y.S., p.s.i.	Elongation, Percent	Brinell Hardness No.
-	A B C D. E. F.	46, 000 40, 900 48, 400 46, 600 47, 800 32, 500	40, 500 37, 900 45, 500 45, 200 47, 200	$\begin{array}{c} 0.7\\ 0.7\\ 0.2\\ 0.1\\ 0.1\\ < 0.1 \end{array}$	114 104 128 119 146 134

The data in Table II confirms that alloys produced according to the processes of this invention have acceptable room temperature properties and/or characteristics, particularly since there was no evidence of brittle fracture. In addition, these alloys have good elevated temperature properties and characteristics. For example, alloys C, D and E were held at 600° F. for about 100 hours and then mechanically tested. It was found that at 600° F. their ultimate tensile strengths were 10,800, 10,900, 11,800 p.s.i., respectively, and their elongations were 7.8%, 10% and 5.7%, respectively. As an additional demonstration of improved elevated temperature properties, the Rockwell H hot hardnesses of alloys C, D, and E were determined. It was found that after about 24 hours at 600° F. 60 the Rockwell H hardnesses at 600° F. were 57, 60 and 67, respectively. Thus, even after exposure at elevated temperature for extended periods of time the alloys of this invention have ultimate tensile strengths of at least 10.000 p.s.i. together with acceptable ductility at 600° F. and also 65 have high hot hardness of at least 55 Rockwell H at this temperature. At room temperature the alloys of this invention are characterized by ultimate tensile strengths of at least 32,000 p.s.i. together with acceptable ductility.

To illustrate the advantageous properties and/or charac-70 teristics attributable to the novel, non-obvious features of the present invention, a number of alloys similar to the alloys set forth in Table I but not in accordance with the present invention were prepared and compared with alloys prepared in accordance with the teachings of this inven-75 tion. The compositions, in weight percentages, of the al7

loys not in accordance with the invention are set forth in Table III.

8 alloy and the iron components at temperatures as high as 600° F. since the coefficient of linear thermal expansion

Alloy	Composition, Weight Percent							
	Silicon	Nickel	Iron	Copper	Magnesium	Titanium	Aluminum	
Z Y W U T S Q Q O	$5.3 \\ 10.5 \\ 16.1 \\ 19.7 \\ 18.3 \\ 19.4 \\ 24.3 \\ 23 \\ 5.1 \\ 9.8 \\ 16.1 \\ 9.8 $	$\begin{array}{c} 8.3\\ 6.8\\ 6.9\\ 5.7\\ 6.5\\ 6.6\\ 4.2\\ 6.2\\ 10.1\\ 0\\ 2.6\\ 0\end{array}$	$\begin{array}{c} 0.39\\ 0.53\\ 0.3\\ 0.53\\ 0.13\\ 0.57\\ 0.5\\ 0.43\\ 0.09\\ 0.04\\ 0.1\\ 0.56\end{array}$	$1 \\ 1.07 \\ 0.96 \\ 0.8 \\ 0.85 \\ 0.83 \\ 0.98 \\ 0.98 \\ 0.94 \\ 0.95 \\ 1 \\ 0.98 \\ 1.02 $	$\begin{array}{c} 1.\ 02\\ 1.\ 06\\ 0.\ 94\\ 1.\ 02\\ 0.\ 83\\ 0.\ 73\\ 0.\ 92\\ 0.\ 98\\ 1.\ 11\\ 0.\ 86\\ 0.\ 8\\ 0.\ 77\end{array}$	$\begin{array}{c} 0.21\\ 0.2\\ 0.16\\ 0.15\\ 0.18\\ 0.19\\ 0.2\\ 0.13\\ 0.22\\ 0.2\\ 0.21\\ 0.2\end{array}$	Balance. Do. Do. Do. Do. Do. Do. Do. Do. Do. Do	

TABLE III

the invention in at least one respect. For example, alloys Z, Y, X, W, V, U, T, S and R did not satisfy the correlation or iron to nickel, silicon and copper plus magnesium and, when tested at room temperature, they exhibited substantially no elongation and were characterized by brittle 25 fracture. Alloy Q contained no nickel and had an ultimate tensile strength of only 7,100 after 100 hours at 600° F. Alloy P, although low in iron, was outside of this invention in the nickel content. This alloy had an ultimate tensile strength of only 8,700 p.s.i. after 100 hours 30 at 600° F. Alloy O contained no nickel and had a Rockwell H hardness at 600° F. of only 38 after 24 hours at 600° F. Alloys E, X and Y were each etched with 0.5% hydrofluoric acid and examined under a microscope at a magnification of 100 diameters ($100 \times$) and these photo- 35 micrographs are depicted in FIGURES 1, 2 and 3, respectively, wherein the dark (appearing as black in the drawing), constituents are aluminides. The gray constituents, of generally polygonal configuration in FIGURES 1 and 2, and of eutectic-like configuration in FIGURE 3, 40are silicon. A comparison of FIGURE 1 (illustrating an alloy produced within the scope of this invention) with FIGURES 2 and 3 (illustrating alloys not produced in accordance with this invention) clearly demonstrates that the delimiting and/or controlling of iron in aluminum alloys containing controlled amounts of nickel, silicon and copper plus magnesium produces refinement of the aluminides. In FIGURE 1, the aluminides are of a refined configuration. On the other hand, the aluminides depicted in FIGURES 2 and 3 are coarse and massive. Accord- 50 ingly, the mechanical properties of the aluminum casting alloy having a refined microstructure are superior to those having the coarse, massive microstructure as shown hereinbefore.

The process of the present invention permits the use of 55 a commercial form of aluminum and aluminum alloys which contain iron as an impurity. In addition, it allows for the production of aluminum castings which because of their sizes and/or shapes do not allow rapid solidification throughout the entire cross section of the solidifying 60 molten metal. Furthermore, the alloys prepared in accordance with the present invention are particularly useful whenever a strong, lightweight component having good mechanical properties at high temperatures, e.g., about 600° F., as well as at room temperature is needed. For 65 example, the present invention is usefully employed in the materials of construction for pistons, engine blocks and other internal combustion engine parts and components. In addition, since the alloys of the present invention have relatively low coefficients of thermal expansion, their at- 70 tractiveness for use in engine blocks and pistons is considerably enhanced. Moreover, the alloys prepared in accordance with the present invention are particularly adapted to be utilized in conjunction with iron compo-

Each of the alloys itemized in Table III are outside 20 between the aluminum alloys of this invention and iron and iron alloys is quite similar.

> Although the present invention has been described in conjunction with preferred embodiments, it is to be understood that modifications and variations may be resorted to without departing from the spirit and scope of the invention, as those skilled in the art will readily understand. Such modifications and variations are considered to be within the purview and scope of the invention and appended claims.

I claim:

1. A process for refining massive, coarse aluminides present in an iron-containing aluminum casting alloy consisting essentially by weight, 4% to 9% nickel, 5% to 25% silicon and up to 1% of copper and up to 1% of magnesium with the sum of copper and magnesium being 0.2% to 2% and increasing the high temperature mechanical properties and characteristics without sacrificing any of the room temperature properties and characteristics of the alloys which comprises delimiting unavoidable iron present such that the iron content in the alloy to be cast is less than

$$\frac{1-0.1 \text{ (percent Ni)} - 0.02 \text{ (percent Si)}}{+0.05 [2-\text{percent (Cu+Mg)}]}$$

- casting the alloy, and thereafter heat treating said cast 45 alloy at a temperature of about 400° F. to about 700° F. for about 2 to 20 hours to thereby produce an alloy characterized by having an ultimate tensile strength of at least about 32,000 pounds per square inch at room temperature, an ultimate tensile strength of at least about 10,000 pounds per square inch at about 600° F., a Rockwell H hardness of at least 55 at 600° F. and ductility at both room temperature and at elevated temperatures up to about 600° F.
- 2. A process for producing a heat-treatable iron-containing aluminum alloy which comprises preparing a melt consisting essentially by weight, of 4% to 9% nickel, 5% to 25% silicon, up to 1% copper, up to 1% magnesium, the sum of copper and magnesium being between 0.2% and 2%, up to 1% titanium, up to 0.05% boron, up to 0.03% phosphorus, up to 0.05% sodium, up to 0.5% cadmium, up to 0.5% indium, up to 0.5% tin, up to 1% lithium, up to 0.5% chromium, up to 0.5% manganese with the balance essentially aluminum, delimiting unavoidable iron present in the melt to an amount that is less than

1-0.1 (percent Ni) -0.02 (percent Si)

+0.05 [2-percent (Cu+Mg)]

casting said melt and thereafter solidifying said melt. whereby the formation of coarse, massive aluminides is substantially inhibited.

3. A process for producing a heat-treatable, iron-containing aluminum alloy which comprises preparing a melt nents requiring close tolerances between the aluminum 75 consisting essentially, by weight, of 5% to 7% nickel,

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10% to 16% silicon, 0.5% to 1% copper, 0.5% to 1% magnesium, 0.1% to 0.3% titanium, up to 0.01% boron, up to 0.2% cadmium, up to 0.2% indium, up to 0.2% tin, up to 0.8% lithium, up to 0.5% chromium, up to 0.5% manganese with the balance essentially aluminum, delimiting unavoidable iron present in the melt to an amount which is correlated to the nickel, silicon, copper and magnesium contents such that iron is less than

+0.05 [2-percent (Cu+Mg)] 10

casting said melt and thereafter solidifying said melt to produce an aluminum casting alloy substantially devoid of coarse, massive aluminides which is characterized by good strength, ductility and hardness at temperatures from room temperature to 600° F.

4. A heat-treatable, iron-containing aluminum casting alloy consisting essentially, by weight, of 4% to 9% nickel, 5% to 25% silicon, up to 1% copper, up to 1% magnesium, the sum of copper and magnesium being 20 between 0.2% and 2%, iron in an amount which is correlated to nickel, silicon and copper plus magnesium and which is less than

1-0.1 (percent Ni) -0.02 (percent Si)

up to 1% titanium, up to 0.05% boron, up to 0.03% phosphorus, up to 0.05% sodium added, up to 0.5% cadmium, up to 0.5% indium, up to 0.5% tin, up to 1% lithium, up to 0.5% chromium, up to 0.5% manganese, with the balance essentially aluminum; said alloy being 30 characterized by having a microstructure that is substantially devoid of harmful, coarse, massive aluminides.

5. A heat-treatable, iron-containing aluminum casting alloy consisting essentially, by weight, of 5% to $7\bar{\%}$ nickel, 10% to 16% silicon, 0.5% to 1% copper, 0.5% 35 to 1% magnesium, iron in an amount which is correlated to nickel, silicon, copper and magnesium and which is less than

1-0.1 (percent Ni) -0.02 (percent Si)

0.1% to 0.3% titanium, up to 0.01% boron, up to 0.2% cadmium, up to 0.2% indium, up to 0.2% tin, up to 0.8% lithium, up to 0.03% phosphorus, up to 0.05% sodium added, up to 0.5% chromium, up to 0.5% manganese. with the balance essentially aluminum; said alloy being characterized by having a microstructure that is substantially devoid of harmful, coarse, massive aluminides.

6. The process as set forth in claim 1 in which the described heat treatment is carried out at a temperature of about 400° F. to 650° F. for 3 to 16 hours.

7. The process as set forth in claim 1 in which the described heat treatment is preceded by a solution heat treatment conducted at temperatures of about 900° F. to about 1050° F. for about 3 to 20 hours, the solution 15 treatment being followed by a water quench.

8. The process as described in claim 2 in which the cast alloy is thereafter solution treated at about 900° F. to about 1050° F. for about 3 to 20 hours, water guenched, and then treated at a temperature of about 300° F. to about 500° F. for about 1 to 20 hours.

9. The process as set forth in claim 2 in which the cast alloy is thereafter heat treated at a temperature of about 400° F. to 700° F. for about 2 to 20 hours.

10. The alloy as set forth in claim 4 in which both +0.05 [2-percent (Cu+Mg)] 25 copper and magnesium are present.

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HYLAND BIZOT, Primary Examiner.

DAVID L. RECK, Examiner.

+0.05 [2-percent (Cu+Mg)] ⁴⁰ R. O. DEAN, Assistant Examiner.

^{1-0.1} (percent Ni) -0.02 (percent Si)