METALLURGY

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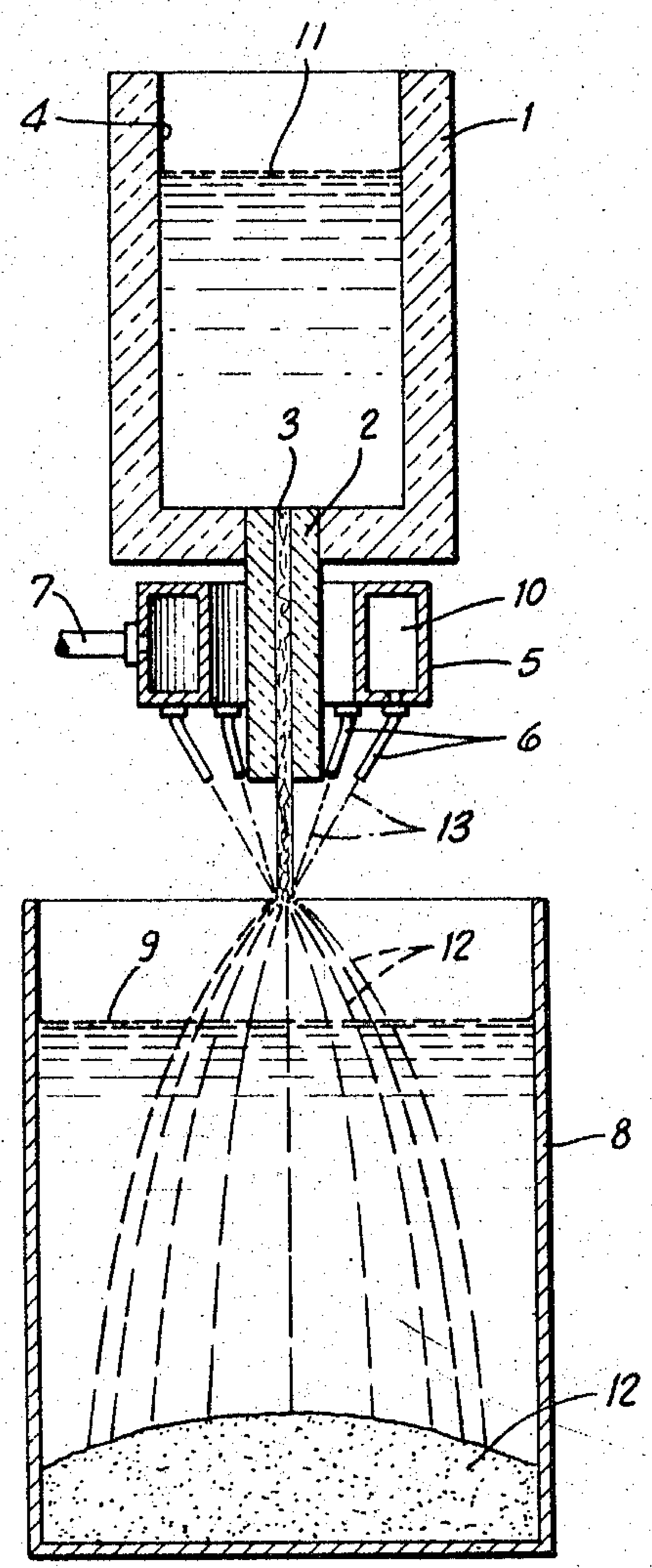

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ABSTRACT OF THE DISCLOSURE

Aluminum base alloys having superior elevated temperature properties when formed into articles from powdered metal containing alloying additions in amounts exceeding that which can be satisfactorily added by ordinary casting techniques.

This invention relates to alloys characterized by superior elevated temperature properties. More particularly this invention relates to aluminum base alloys and to aluminum base alloy articles characterized by superior elevated temperature properties, said alloys containing alloying additions in amounts exceeding that heretofore possible in the production of sound and workable cast bodies.

This application is a divisional application of our copending application Ser. No. 628,297, filed Dec. 14, 1956, now Patent No. 2,967,351.

By the term "workable" as used hereinafter is meant that the cast body can be subjected to metal deforming operations such as rolling, forging, and extruding.

The design of present and future aircraft and air weapons for operation at high unit stress levels and at speeds where considerable aerodynamic heat occurs has created a critical need for better light weight aircraft structural materials having higher strength, higher modulus of elasticity and greatly improved elevated temperature properties than those heretofore attainable.

It is well recognized that possibilities for obtaining such improved properties with prior art aluminum base alloys are quite limited. This is especially true insofar as elevated temperature properties are concerned.

The high strength aluminum base alloys fabricated under conventional procedures are limited to those alloy systems in which there is an appreciable equilibrium solid solubility of the alloying elements in aluminum. As the alloying elements have appreciable rates of diffusion in aluminum at elevated temperature, the high temperature stability of these alloys is seriously impaired. Consequently, exposure of the conventional precipitation hardened aluminum base alloys to high temperature service results in rapid overaging and attendant decreases on mechanical properties.

The development of aluminum base alloys which would have sufficiently high elevated temperature properties for present aircraft uses has been hindered by the fact that most alloying additions, which have low diffusion rates at elevated temperatures and consequently could yield stable alloys, form coarse primary crystals of intermediate phases with aluminum or other alloying additions, and cause severe chemical segregation during solidification from the molten state when added in amounts greater than a few atomic percent, or in many cases a few tenths of an atomic percent. These alloying additions upon solidification of the casting tend to concentrate in large coarse intermediate phase particles which have negligible or very limited solubility in solid

aluminum and in this form such alloying additions make a minimum contribution to the mechanical properties of the alloy. Thus the presence of large amounts of such alloying additions generally result in cast bodies which are unsound and difficult or impossible to process.

Accordingly, it is an object of this invention to provide novel aluminum base alloy compositions and articles from these compositions which are characterized by superior elevated temperature properties.

It is a still further object of this invention to produce aluminum base alloy articles, characterized by superior elevated temperature properties, containing alloying additions of metals in amounts which under conditions of production heretofore known would form coarse primary crystals of intermediate phases with aluminum or other alloying additions and would cause severe chemical segregation during solidification.

It is a still further object of this invention to produce aluminum base alloy articles characterized by superior elevated temperature properties, containing alloying additions of at least one other metal such as chromium, manganese, iron, zirconium, titanium, vanadium and molybdenum in amounts exceeding that heretofore possible in the production of sound and workable cast bodies.

These and other objects and advantages of the invention will be apparent from the ensuing detailed description of the invention.

In accordance with this invention, a melt of the desired composition is first heated to a temperature at which it is a homogeneous liquid solution. The liquid solution is then comminuted at this temperature by one of several methods whereby the individual particles formed are solidified and cooled at a rate sufficiently rapid to eliminate or substantially eliminate formation of coarse crystals of intermediate phases. For example, atomizing or shotting is satisfactory. In the resulting aluminum alloy particle, the undesirable characteristics outlined above as resulting from the presence of relatively large additions of certain alloying elements have been found to have been eliminated or greatly minimized. The solidified particles are then subsequently consolidated by working into larger bodies which are suitable for direct application or subsequent wrought metal fabrication procedures, such as extruding.

The rapid cooling rate of the comminution process greatly extends the amounts of the alloying additions which may be beneficially contained in aluminum alloys. Many compositions may be prepared in accordance with this invention which have received little, if any, consideration in the prior art of aluminum alloy development because it is well known that when such alloy compositions are prepared by conventional casting procedures sound and workable material is not produced.

According to this invention, it has been found that aluminum base alloys containing alloying additions of at least one of the elements, chromium, manganese, iron, zirconium, titanium, vanadium and molybdenum in amounts exceeding that heretofore possible in the production of sound and workable cast bodies can be produced. These alloys are characterized by superior elevated temperature properties. One such alloy consists essentially of, by weight, from 4.5 to 13% copper, 1.5 to 5.0% manganese, 0.2 to 2.0% zirconium and 0.1 to 1.0% vanadium, balance aluminum and impurities in normal amounts. Superior elevated temperature properties have also been obtained with binary aluminum base alloys containing one of the following alloying additions in the recited amounts: from 3 to 10% manganese, 1 to 6% zirconium, 3 to 12% iron, 2.5 to 5% molybdenum, 1 to 6% chromium, 0.5 to 4% titanium, or 0.1 to 2.5% vanadium.

Specific examples illustrating these and other alloys which have been produced according to this invention but not constituting a limitation thereto are given in Table I.

solidified particles will be substantially the same. The resulting article may then be further worked by conventional methods and means into the desired shape or form.

TABLE I.—CHEMICAL COMPOSITION OF ALUMINUM ALLOY POWDERS IN PERCENT BY WEIGHT

Alloy Nos.	Fe	Cu	Mn	Cr	Ti	Zr	V	Mo	Al
1		6.2	2.5			0.2	0.1		Balance.
2		6.2	5.0			0.2	0.1		Do.
3		6.2	2.5			2.0	0.1		Do.
4		11.0	4.5			0.35	0.2		Do.
5		4.5	3.5			1.5	0.8		Do.
6		6.2	1.5			0.2	1.0		Do.
7		6.2	0.3	1.5		0.2	0.1		Do.
8			5.0						Do.
9			7.5						Do.
10			10.0						Do.
11	5.0								Do.
12	7.5								Do.
13	10.0								Do.
14						2.0			Do.
15						4.0			Do.
16					2.0				Do.
17							2.5		Do.
18								2.5	Do.
19								5.0	Do.
20				1.5					Do.
21				3.0					Do.
22	1.5	6.2				0.2	0.1		Do.
23			5.0		0.5	1.0	0.5		Do.
24			5.0			2.0			Do.
25			5.0		2.0				Do.
26	2.0		5.0						Do.
27	7.5		3.5						Do.
28			5.0	1.0	1.0	1.0	1.0		Do.
29	7.5					2.0			Do.
30	7.5				2.0				Do.
31	7.5			2.0					Do.

The alloys of Table I were prepared by first comminuting a homogeneous liquid solution of a melt having the final desired alloy composition by atomization with an apparatus illustrated with reference to the figure.

This apparatus consists of a graphite crucible 1 having a 1" diameter graphite rod 2 affixed to the lower portion thereof. Graphite rod 2 has a longitudinal tubular passage or hole 3 provided therein in open communication with the interior 4 of graphite crucible 1. Positioned about graphite rod 2 is provided a ring type header 5 having a plurality of gas nozzles 6 connected thereto and in open communication with the hollow interior 10 of header 5. Nozzles 6 are directed downwardly at an angle such that lines drawn through the axes of nozzles 6 intersect at a point below graphite rod 2. A suitable hose or pipe 7 is connected to header 5. Pipe 7 is connected to a source of gas (not shown), for example air, under pressure. Immediately below rod 2 may be provided a container 8 containing a chilling liquid such as water 9.

The molten metal 11 to be atomized is contained in graphite crucible 1 from which it passes through hole 3 in rod 2. By passing a gas such as air under pressure into header 5 jets 13 of such gas will issue from nozzles 6 forming a cone of jets intersecting at a point below hole 3 in rod 2. The molten metal issuing from the bottom of the hole 3 is thus atomized by the cone of air jets whereby the resulting particles 12 are rapidly solidified and collected in container 8. While the atomization provides sufficiently rapid cooling to solidify particles 12 the added cooling provided by liquid 9 prevents the particles from sticking together.

It is to be distinctly understood that the apparatus above described is but one means for comminuting the molten metal and is given by way of example only and it is to be distinctly understood that the invention is not to be limited to the use of such a specific apparatus or means for comminuting the metal. For example, the container 8 and liquid 9 could be eliminated if a sufficient distance is provided for the atomized particles to fall whereby the particles 12 are cooled sufficiently in air to prevent sticking together.

The solidified particles 12 are then consolidated by working into an article, said working being of sufficient amount such that the densities of the article and of the

Some of the alloy powders illustrated in Table I were treated by the successive steps of (a) cold compacting, (b) hot compacting, and (c) extrusion. The cold compacting was accomplished by placing the powder in a .638" ID hardened steel die and successively pressing this charge from each end under a 25,000 p.s.i. pressure. Prior to charging the powder to the die, the rams and die walls were lubricated with a thin film of stearic acid and aluminum flake pigment in carbon tetrachloride. Upon completion of the cold compacting operation, the green billet was ejected from the die. The hot pressing of the green compacts was effected by replacing the normal extrusion die in the extrusion apparatus with a blank plug. The green compact was then placed in the heated chamber and subjected to a light load for approximately three minutes until the compact had reached the desired extrusion temperature. Pressure was then gradually applied until a load of 80,000 pounds per square inch was reached. This load was maintained for five minutes before being released. Upon completion of the hot pressing operation, the blank plug was removed and replaced with the desired extrusion die. After the extrusion die had reached temperature, the hot compacted billet was extruded at a rate of approximately 1.5 feet per minute. The extruded samples were subsequently straightened by means of a straight pull through a wire drawing die, the wire drawing die being sufficiently smaller than the extrusion to effect a small reduction in area.

The remaining alloys of Table I employed an alternative fabrication procedure which provided a more rapid fabrication technique whereby the cold compacting step prior to hot compacting was eliminated. This procedure consisted of charging the powder to a hot extrusion apparatus having a blank plug in place of the extrusion die, placing the ram immediately on top of the cold charge and subjecting the powder charge to a load of about 20,000 p.s.i. while the powder is heated up in the extrusion chamber. After the powder had reached the extrusion chamber temperature, the load was increased to approximately 100,000 p.s.i. to effect consolidation. The blank plug was then removed, replaced with the desired extrusion die and the consolidated material extruded as described above in connection with the first procedure.

Nonheat treated extrusions of all the alloys of Table I were tensile tested at 600° F. after being exposed to this temperature for 48 hours. The results of these tests are given hereinbelow in Table II. It will be noted that three subheadings, 13D, 8D and 4D appear under "Percent Elongation." These subheadings indicate the gauge length for measuring the elongation in terms of the diameter of the specimen. For example, 13D means that the gauge length prior to testing was thirteen times the diameter of the specimen. The elongation is then expressed as a percentage of this length.

For purposes of comparison the properties of two conventional wrought aluminum alloys, e.g. 7075–T6 (nominal) composition, 1.6% copper, 2.5% magnesium, 5.7% zinc, 0.25% chrominum, balance aluminum) and 2014–T6 (nominal composition, 4.5% copper, 0.9% silicon, 0.8% manganese, 0.5% magnesium, balance aluminum) are given in Table IV below when measured at 600° F. and when measured at room temperature after exposure to a temperature of 600° F. for the designated period of time.

TABLE II.—TENSILE PROPERTIES AT 600° OF EXTRUSIONS OF POWDERS

[Short time tensile tests after exposure to 600° F. for 48 hours]

Alloy No.	Extrusion temperature, (°F.)	TS (p.s.i.	YS (p.si.	Percent elongation			Percent reduction in area
				13D	8D	4D	
1	800	17,900	12,700	12			66
2	800	18,700	12,000	18	24	39	69
3	800	19,000	12,100	28	40	63	72
4	800	19,000	14,100	18	26	40	58
5	800	18,800	13,000	20	27	40	56
6	800	17,100	11,700	17	23		78
7	800	18,400	13,800	15	22	35	77
8	800	17,400	11,700	16			73
9	850	15,900	9,700	25			67
10	850	17,000	8,700	19			26
11	850	18,800	14,600	14			47
12	900	23,000	17,300	12			48
13	900	22,400	14,300	6			4
14	800	13,000	8,400	19			52
15	800	13,700	9,000	23			48
16	800	15,300	12,100	19	26	35	61
17	800	12,900	8,000	18	24		79
18	800	11,800	8,500	11	16	21	72
19	800	13,600	10,200	12	18	26	58
20	800	12,600	9,500	11	15	22	64
21	800	17,100	12,800	11	15		50
22	800	12,100	7,500	20	28	40	84
23	900	24,300	16,200	15	20.8	40	54
24	850	19,400	12,200	22	30	44	55
25	850	21,200	14,500	15	17	15	
26	800	13,800	8,500	20	28	26	
27	850	22,600	14,200	3	8	13	3
28	900	23,400	17,300	8	10	8	21
29	900	24,500	16,100	11	14		25
30	900	23,800	16,500	15	22	29	65
31	900	27,600	19,500	10	20	20	36

Non-heat treated extrusions of all alloys of Table I were also tested at room temperature after being exposed to a temperature of 600° F. for 48 hours. The results of these tests are given in Table III below and the high properties obtained demonstrate the elevated temperature stability of these alloys.

TABLE IV.—PROPERTIES OF CONVENTIONAL WROUGHT ALLOYS AFTER EXPOSURE TO 600° F.

Alloy	Time at 600° F. (hr.)	Measured at 600° F.			Measured at room temp., YS (p.s.i.)
		TS (p.s.i.)	YS (p.s.i.)	Elong. (4D)	
7075–T6	½	19,500	7,000	55	
7075–T6	100	8,500	6,500	80	16,000
2014–T6	½	10,000	9,000	30	
2014–T6	100	8,000	6,500	50	14,500

TABLE III.—ROOM TEMPERATURE PROPERTIES OF EXTRUSIONS OF POWDERS

[Extrusions were exposed to 600° F. for 48 hours prior to tensile testing]

Alloy No.	Extrusion temperature, (°F.)	TS (p.s.i.)	YS (p.s.i.)	Percent elongation			Percent reduction in area
				13D	8D	4D	
1	800	48,400	35,400	6	8	14	16
2	800	62,200	43,900	5			17
3	800	72,300	62,400	3			4
4	800	71,300	47,000	4			11
5	850	73,200	62,500	7			12
6	800	49,300	37,400	7			34
7	800	49,600	38,700	8	11	18	43
8	800	35,600	27,100	13			66
9	850	42,800	34,400	10			30
10	850	56,200	31,200	3			11
11	850	38,600	28,800	11			61
12	900	47,700	36,500	9			56
13	900	52,400	38,100	7			23
14	800	50,200	44,400	7			21
15	800	61,600	48,300	6			25
16	800	34,800	29,800	10			65
17	800	30,700	25,700	12			68
18	800	25,300	21,200	13	19	29	74
19	800	30,400	22,100	12	17	26	64
20	800	25,100	19,700	14	19	31	71
21	800	32,200	25,500	11	16	26	67
22	800	42,400	30,100	9	12	19	45
23	900	63,200	55,700	6			25
24	850	69,200	60,000	6			25
25	850	50,700	41,700	9	14	20	45
26	800	41,600	33,900	11	18	24	56
27	850	63,100	40,200	2	7	3	5.6
28	850	63,300	40,900	3	3	5	8.8
29	900	67,500	54,000	8	12	19	30
30	900	49,400	33,500	10	14	22	59
31	900	55,900	41,800	7	11	16	36

As can be seen by comparison of the results shown in Table II, with Table IV, the improvements obtained in the 600° F. tensile properties by the additions of alloying ingredients in amounts exceeding that heretofore possible in the production of sound and workable cast bodies are very significant. From the results obtained with these alloys it can be seen that the new alloys containing such large amounts of alloying additions produced by the method of this invention have significantly higher tensile strengths and yield strengths at 600° F. than prior art aluminum base alloys produced by conventional methods, typical examples of which are given in Table IV.

Table II illustrates a large number of alloys exhibiting properties measured at 600° F. significantly superior to prior art alloys, the lowest properties being a tensile strength of 11,800 p.s.i. and a yield strength of 7,500 p.s.i. Tensile strengths as high as 27,600 p.s.i. and yield strengths as high as 19,500 p.s.i. were exhibited by alloys containing the large amounts of alloying additions illustrated in Tables I and II produced by the method of this invention. In addition, from Table II it can be seen that more than two-thirds the alloys produced exhibited tensile strengths measured at 600° F. in excess of 15,000 p.s.i. and yield strengths measured at 600° F. in excess of 10,000 p.s.i.

In general, from reference to Table II, it may be seen that the various alloys set forth fall into the following groups with the recited mechanical properties when tested at 600° F. after exposure to 600° F. for 48 hours.

(1) Alloys consisting essentially of 3 to 10% manganese, balance aluminum and impurities in normal amounts having a tensile strength from about 15,000 to about 18,000 p.s.i., a yield strength from about 8,000 to 12,000 p.s.i., and an elongation from about 16 to 25% in a length 13 times the diameter of a cylindrical test specimen.

(2) Alloys consisting essentially of 1 to 6% zirconium, balance aluminum and impurities in normal amounts having a tensile strength from about 13,000 to 14,000 p.s.i., a yield strength from about 8,000 to 9,000 p.s.i., and an elongation from about 19 to 23% in a length 13 times the diameter of a cylindrical test specimen.

(3) Alloys consisting essentially of 3 to 12% iron, balance aluminum and impurities in normal amounts having a tensile strength from about 18,000 to 23,000 p.s.i., a yield strength from about 14,000 to 18,000 p.s.i., and an elongation from about 6 to 14% in a length 13 times the diameter of a cylindrical test specimen.

(4) Alloys consisting essentially of 2.5 to 5% molybdenum, balance aluminum and impurities in normal amounts having a tensile strength from about 11,000 to 14,000 p.s.i., a yield strength from about 8,000 to 11,000 p.s.i., and an elongation from about 11 to 12% in a length 13 times the diameter of a cylindrical test specimen.

(5) Alloys consisting essentially of 1 to 6% chromium, balance aluminum and impurities in normal amounts, having a tensile strength from about 12,000 to 18,000 p.s.i., a yield strength from about 9,000 to 13,000 p.s.i., and an elongation of about 11% in a length 13 times the diameter of a cylindrical test specimen.

(6) Alloys consisting essentially of 0.5 to 4% titanium, balance aluminum and impurities in normal amounts having a tensile strength from about 14,000 to 16,000 p.s.i., a yield strength from about 11,000 to 13,000 p.s.i., and an elongation from about 18 to 20% in a length 13 times the diameter of a cylindrical test specimen.

(7) Alloys consisting essentially of 0.1 to 2.5% vanadium, balance aluminum and impurities in normal amounts having a tensile strength from about 11,000 to 13,000 p.s.i., a yield strength from about 7,000 to 8,000 p.s.i., and an elongation of about 18% in a length 13 times the diameter of a cylindrical test specimen.

(8) Alloys consisting essentially of 4.5 to 13% copper, 1.5 to 5% manganese, 0.2 to 2% zirconium, 0.1 to 1% vanadium, balance aluminum and impurities in normal amounts having a tensile strength from about 17,000 to 19,000 p.s.i., a yield sterngth from about 12,000 to 15,000 p.s.i., and an elongation from about 12 to 28% in a length 13 times the diameter of a cylindrical test specimen.

(9) Alloys consisting essentially of 7.5% iron, an element chosen from the group of 2% chromium, 2% titanium and 2% zirconium, balance aluminum and impurities in normal amounts having a tensile strength from about 23,000 to 28,000 p.s.i., a yield strength from about 16,000 to 20,000 p.s.i., and an elongation from about 10 to 15% in a length 13 times the diameter of a cylindrical test specimen.

(10) Alloys consisting essentially of 3.5 to 5% manganese, one or more of the elements chosen from the group 2 to 7.5% iron, 1% chromium, 0.5 to 2% titanium, 1 to 2% zirconium and 0.5 to 1% vanadium, balance aluminum and impurities in normal amounts having a tensile strength from about 13,000 to 25,000 p.s.i., a yield strength from about 8,000 to 18,000 p.s.i., and an elongation from about 3 to 22% in a length 13 times the diameter of a cylindrical test specimen.

The room temperature tensile properties of the extrusions of alloys produced in accordance with this invention after exposure to 600° F. can be seen by comparison of Table III with Table IV to be superior to those found in conventional wrought aluminum alloys after a similar exposure to 600° F. Several of these compositions were outstanding in this respect and exhibited tensile strengths in excess of 60,000 p.s.i. and yield strengths in excess of 50,000 p.s.i. The lowest yield strength shown in Table III is 19,700 p.s.i., which is substantially higher than that exhibited by alloy 7075–T6 of Table IV.

It was also found in accordance with the present invention that the alloys exhibited substantially high modulus of elasticity values. For example, alloys 9, 12 and 15 as designated in Table I had the following values for modulus of elasticity:

	Psi.
Alloy No. 9	12.5×10^6
Alloy No. 12	11.8×10^6
Alloy No. 15	10.8×10^6

It will be understood that various changes, omissions and additions may be made to this invention without departing from the spirit and scope thereof as set forth in the appended claims.

All percentages in the claims are by weight of the total alloy.

What is claimed is:

1. An article of manufacture fabricated from aluminum base alloy particles each consisting essentially of 1 to 6% zirconium, balance aluminum and impurities in normal amounts, said article being characterized by possessing elevated temperature properties at about 600° F. after 48 hours of exposure of a tensile strength from about 13,000 to 25,000 p.s.i., a yield strength from about 8,000 to 17,000 p.s.i., and an elongation of from about 11 to 25% in a length 13 times the diameter of a cylindrical test specimen.

2. An article of manufacture fabricated from aluminum base alloy particles each consisting essentially of 3 to 12% iron, balance aluminum and impurities in normal amounts, said article being characterized by possessing elevated temperature properties at about 600° F. after 48 hours of exposure of a tensile strength from about 18,000 to 23,000 p.s.i., a yield strength from about 14,000 to 18,000 p.s.i., and an elongation from about 6 to 14% in a length 13 times the diameter of a cylindrical test specimen.

3. An article of manufacture fabricated from aluminum base alloy particles each consisting essentially of 0.1 to 2.5% vanadium, balance aluminum and impurities in normal amounts, said article being characterized by possessing elevated temperature properties at about 600° F. after 48 hours of exposure of a tensile strength from about 11,000 to 13,000 p.s.i., a yield strength from about 7,000 to 8,000 p.s.i., and an elongation of about 18% in a length 13 times the diameter of a cylindrical test specimen.

4. An article of manufacture fabricated from aluminum base alloy particles each consisting essentially of 4.5 to 13% copper, 1.5 to 5% manganese, 0.2 to 2% zirconium, 0.1 to 1% vanadium, balance aluminum and impurities in normal amounts, said article being characterized by possessing elevated temperature properties at about 600° F. after 48 hours of exposure of a tensile strength from about 17,000 to 19,000 p.s.i., a yield strength from about 12,000 to 15,000 p.s.i., and an elongation from about 12 to 28% in a length 13 times the diameter of a cylindrical test specimen.

5. An article of manufacture fabricated from aluminum base alloy particles each consisting essentially of 7.5% iron, an element chosen from the group of 2% chromium, 2% titanium and 2% zirconium, balance aluminum and impurities in normal amounts, said article being characterized by possessing elevated temperature properties at about 600° F. after 48 hours of exposure of a tensile strength from about 23,000 to 28,000 p.s.i., a yield strength from about 16,000 to 20,000 p.s.i. and an elongation from about 10 to 15% in a length 13 times the diameter of a cylindrical test specimen.

6. An aluminum base alloy consisting essentially of 1 to 6% zirconium, balance aluminum and impurities in normal amounts, said alloy characterized by possessing elevated temperature properties at about 600° F. after 48 hours of exposure of a tensile strength from about 13,000 to 14,000 p.s.i., a yield strength from about 8,000 to 9,000 p.s.i., and an elongation from about 19 to 23% in a length 13 times the diameter of a cylindrical test specimen.

7. An aluminum base allow consisting essentially of 3 to 12% iron, balance aluminum and impurities in normal amounts, said alloy characterized by possessing elevated temperature properties at about 600° F. after 48 hours of exposure of a tensile strength from about 18,000 to 23,000 p.s.i., a yield strength from about 14,000 to 18,000 p.s.i. and an elongation from about 6 to 14% in a length 13 times the diameter of a cylindrical test specimen.

8. An aluminum base alloy consisting essentially of 0.1 to 2.5% vanadium, balance aluminum and impurities in normal amounts, said alloy characterized by possessing elevated temperature properties at about 600° F. after 48 hours of exposure of a tensile strength from about 11,000 to 13,000 p.s.i., a yield strength from about 7,000 to 8,000 p.s.i., and an elongation of about 18% in a length 13 times the diameter of a cylindrical test specimen.

9. An aluminum base alloy consisting essentially of 4.5 to 13% copper, 1.5 to 5% manganese, 0.2 to 2.0% zirconium, 0.1 to 1% vanadium, balance aluminum and impurities in normal amounts, said alloy characterized by possessing elevated temperature properties at about 600° F. after 48 hours of exposure of a tensile strength from about 17,000 to 19,000 p.s.i., a yield strength from about 12,000 to 15,000 p.s.i., and an elongation from about 12 to 28% in a length 13 times the diameter of a cylindrical test specimen.

10. An aluminum base alloy consisting essentially of 7.5% iron and an element chosen from the group of 2% chromium, 2% titanium and 2% zirconium, balance aluminum and impurities in normal amounts, said alloy characterized by possessing elevated temperature properties at about 600° F. after 48 hours of exposure of a tensile strength from about 23,000 to 28,000 p.s.i., a yield strength from about 16,000 to about 20,000 p.s.i., and an elongation from about 10 to about 15% in a length 13 times the diameter of a cylindrical test specimen.

11. An article of manufacture fabricated from aluminum base alloy particles each consisting essentially of 4.5–13% copper, and at least one element chosen from the group consisting of 0.3–5% manganese, 0.2–2% zirconium, 0.1–1.0% vanadium, 1.5% iron and 1.5% chromium, balance aluminum and impurities in normal amounts, said article being characterized by possessing elevated temperature properties at about 600° F. after 48 hours of exposure of a tensile strength from about 12,000 to 19,000 p.s.i., a yield strength from about 7,500 to 15,000 p.s.i. and an elongation from about 12 to 28% in a length 13 times the diameter of a cylindrical test specimen.

12. A hot worked aluminum base alloy powder article free from aluminum oxide except as an incidental impurity and having a maximum iron content of 1%, said hot worked alloy powder article being formed from atomized powder of an aluminum base alloy containing at least 70% by weight of aluminum and from 5–10% by weight of manganese as the essential component, the amount of said component exceeding the total quantity of any hardening elements present in the alloy, said alloy being substantially free from elements which form a solid solution with aluminum, except as they occur as impurities, said hot worked article being characterized in the as-worked condition by a tensile strength at 600° F. after a 48-hour exposure of not less than 15,000 p.s.i. and a yield strength of not less than 10,000 p.s.i.

13. A hot worked aluminum base alloy powder article free from aluminum oxide except as an incidental impurity and having a maximum iron content of 1%, said hot worked alloy powder article being formed from atomized powder of an aluminum base alloy containing at least 70% by weight of aluminum and from 3–10% by weight of manganese as the essential component, the amount of said component exceeding the total quantity of any hardening elements present in the alloy, said alloy being substantially free from elements which form solid solution with aluminum except as they occur as impurities, said hot worked article being characterized in the as-worked condition by a tensile strength at 600° F. after a 48 hour exposure of not less than 15,000 p.s.i. and a yield strength of not less than 10,000 p.s.i. wherein the alloy also contains at least one hardening element selected from the group consisting of 1–6% chromium, 0.5–4% titanium, 1–6% zirconium and 0.1–2.5% vanadium, all percentages being by weight, the total not exceeding 10% by weight, the manganese content of said alloy exceeding the total amount of hardening elements added thereto.

14. A hot worked aluminum base alloy powder article free from aluminum oxide except as an incidental impurity and having a maximum iron content of 1%, said hot worked alloy powder being formed from atomized powder of aluminum base alloy containing at least 70% by weight of aluminum and from 3.5–6% by weight of zirconium as the essential component, the amount of said component exceeding the total of any hardening elements present in the alloy, said alloy being substantially free from elements which form a solid solution with aluminum, except as they occur as impurities, said hot worked article being characterized in the as-worked condition by a tensile strength at 600° F. after a 48-hour exposure of not less than 13,000 p.s.i. and yield strength not less than 9,000 p.s.i.

15. A hot worked aluminum base alloy powder article according to claim 14 wherein the zirconium content is 5–6% by weight.

16. A hot worked aluminum base alloy powder article free from aluminum oxide except as an incidental impurity and having a maximum iron content of 1%, said hot worked alloy powder article being formed from atomized powder of an aluminum base alloy containing at least 70% by weight of aluminum and from 5–10% by weight of manganese as the essential component, the amount of said component exceeding the total quantity of any hardening elements present in the alloy, said alloy being substantially free from elements which form a solid solution with aluminum, except as they occur as impurities.

17. A hot worked aluminum base alloy powder article

free from aluminum oxide except as an incidental impurity and having a maximum iron content of 1%, said hot worked alloy powder article being formed from atomized powder of an aluminum base alloy containing at least 70% by weight of aluminum and from 3–10% by weight of manganese as the essential component, the amount of said component exceeding the total quantity of any hardening elements present in the alloy, said alloy being substantially free from elements which form solid solution with aluminum except as they occur as impurities wherein the alloy also contains at least one hardening element selected from the group consisting of 1–6% chromium, 0.5–4% titanium, 1–6% zirconium and 0.1–2.5% vanadium, all percentages being by weight, the total not exceeding 10% by weight, the manganese content of said alloy exceeding the total amount of hardening elements added thereto.

18. A hot worked aluminum base alloy powder article free from aluminum oxide except as an incidental impurity and having a maximum iron content of 1%, said hot worked alloy powder being formed from atomized powder of aluminum base alloy containing at least 70% by weight of aluminum and from 3.5–6% by weight of zirconium as the essential component, the amount of said component exceeding the total of any hardening elements present in the alloy, said alloy being substantially free from elements which form a solid solution with aluminum, except as they occur as impurities.

19. A hot worked aluminum base alloy powder article according to claim 18 wherein the zirconium content is 5–6% by weight.

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UNITED STATES PATENT OFFICE
CERTIFICATE OF CORRECTION

Patent No. 3,462,248 Dated August 19, 1969

Inventor(s) S. G. Roberts, M. C. Fetzer and J. B. Hess

It is certified that error appears in the above-identified patent and that said Letters Patent are hereby corrected as shown below:

Col. 1, line 57, "on" should be --in--. Col. 5, Table III, column entitled "Percent Reduction In Area", Alloy No. 1, "16" should be --41--; Alloy No. 2, "17" should be --11--; Alloy No. 3, "4" should be --7--; Alloy No. 4, "11" should be --12--; Alloy No. 5, "12" should be --14--; Alloy No. 6, "34" should be --33--; Alloy No. 7, "43" should be --46--; Alloy No. 8, "66" should be --60--; Alloy No. 9, "30" should be --31--; Alloy No. 11, "61" should be --66--; Alloy No. 12, "56" should be --53--; Alloy No. 13, "23" should be --21--; Alloy No. 14, "21" should be --25--; Alloy No. 16, "65" should be --68--; Alloy No. 17, "68" should be --64--; Alloy No. 19, "64" should be --61--; Alloy No. 20, "71" should be --77--; Alloy No. 21, "67" should be --65--; Alloy No. 24, "25" should be --22--; Alloy No. 25, "45" should be --46--; Alloy No. 27, "5.6" should be --5.8--; Alloy No. 28, "8.8" should be --8.0--; Alloy No. 29, "30" should be --39--; Alloy No. 30, "59" should be --56--. Col. 6, line 3, "nal)" should be --nal--. Col. 8, line 1, "sterngth" should be --strength--. Col. 9, line 34, "allow" should be --alloy--.

SIGNED AND
SEALED
JUL 14 1970

(SEAL)
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