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ALUMINIUM ALLOY HAVING LOW COEFFICIENT OF EXPANSION

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The object of this invention is an aluminium alloy which will have a low coefficient of expansion but will have at the same time a good strength (particularly as regards the qualities of proof stress and creep), have a good hardness, and be easy to cast.

It is known that a high content of silicon in aluminium alloys reduces the coefficient of expansion. Known alloys, however, of this type have certain disadvantages which it is the object of our invention to avoid.

According to our invention we make an alloy of the following elements in the following proportions:

Silicon	per cent of the whole	10.0-15.0
Nickel	do	0.1-0.8
Copper and silver together and including at least 0.05 per cent of each	do	0.35-1.0
Manganese	do	0.15-0.45
Magnesium	do	0.07-0.55
Iron and zinc (as impurities) if any not exceeding	per cent of each	0.6
Aluminium	the remainder	

Iron and zinc may be present as impurities in commercial aluminium or secondary aluminium but each should preferably not exceed 0.35 per cent. Up to a total of each of 0.6 per cent may be permitted but if the iron content exceeds 0.35 per cent the manganese content should be between 0.25 per cent and 0.45 per cent.

The following elements may be added as refiners up to 0.15 per cent of any one and 0.35 per cent of the elements in all: Boron, calcium, cerium, chromium, cobalt, lithium, molybdenum, niobium, potassium, sodium, tantalum, titanium, tungsten, vanadium and zirconium.

Of these the most important is sodium which may be added in known manner just before casting. About 0.1 per cent is the preferred amount. It results in the production of a fine aluminium-silicon eutectic. The amounts given are those added to the alloy of which some may be lost.

Fluxes containing alkaline fluorides and chlorides may be used and have some modifying effect.

The preferred constitution of the alloy is as follows:

Silicon	11.5-13.2	per cent
Nickel	0.25-0.45	per cent
Copper	0.25-0.50	per cent
Silver	0.25-0.40	per cent
Iron	0-0.35	per cent
Manganese	0.15-0.45	per cent
Titanium	0-0.15	per cent
Calcium	0-0.15	per cent
Sodium	0.01-0.10	per cent
Zirconium	0-0.15	per cent
Magnesium	0.07-0.30	per cent for sand castings or 0.07-0.45 per cent for chill castings
Aluminium	the remainder	

Such small contents of thorium and/or beryllium not exceeding 0.1 per cent in total may be added with advantage.

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The alloy can be prepared in a manner familiar to foundrymen, for instance, to molten aluminium are added rich alloys of the various elements. The magnesium, may be added in metallic form, but it may also be added as an alloy of 25-30 per cent magnesium in aluminium which gives a better control of final percentage owing to less variable losses.

When the alloy is to be sand cast the maximum of magnesium should be not greater than 0.3 per cent but for chill castings it should exceed 0.3 per cent and can be up to 0.55 per cent though a maximum of 0.45 per cent is preferred.

Sodium, if present, is added just prior to casting.

For foundry purposes the alloy can be made and ingoted and then remelted for making castings in the normal manner.

An example of our alloy was prepared of the following composition:

Silicon	13.0	per cent
Nickel	0.3	per cent
Copper	0.35	per cent
Silver	0.30	per cent
Magnesium	0.10	per cent
Iron	0.30	per cent
Manganese	0.20	per cent
Titanium	0.025	per cent
Calcium	0.04	per cent
with Sodium and Aluminium the remainder	About 0.02	per cent

This when sand cast, cooled, heat treated by heating for 12 hours at 160° C. and allowed to cool, gave the following approximate test results:

Brinell hardness	73
Maximum stress	12.5 tons per square inch
0.1% proof stress	9.0 tons per square inch
Elongation	2.5%
Coefficient of expansion from 20-150° C.	0.000019" per °C.

The above coefficient of expansion may be compared with that of a well known alloy No. 50 in the R. R. series which for similar temperatures is 0.000023" per °C.

At 200° C. after soaking at that temperature for half an hour the alloy gave the following results:

Maximum stress	12.1 tons
0.1% proof	9.0
Elongation	4.6 per cent

These results indicate that physical properties are well maintained up to 200° C.

The above example of our alloy when chill cast and aged 12 hours at 160° C. gave the following results:

Brinell hardness	87
Maximum stress	14 tons per square inch
0.1% proof stress	10.5 do
Elongation	3.0 per cent

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Tests have also been made on specimens cut from a sand cast cylinder head, cast in the alloy, weighing about 200 pounds including gates, runners and risers. The size of the head measured approximately 42 x 8 x 7½ inches and the one flat face of the casting was formed by a thin metal plate on which was placed the sand mould containing a number of intricate cores.

After fettling the head was aged for 14 hours at 165–170° C.

The composition as determined by chemical analysis was as follows:

	Per cent by weight
Silicon	12.10
Nickel	0.38
Copper	0.46
Silver	0.36
Magnesium	0.20
Iron	0.50
Manganese	0.42
Zirconium	0.12
Sodium	0.03
Titanium	0.03
Calcium	0.02
Aluminium	The remainder

Tensile tests on test pieces cut out of casting:

(a) From thick section ¼" from face:

Maximum stress.....	tons/sq. in..	16.65
Yield point	do.....	10.75
Elongation	per cent..	6.0
Reduction of area.....	do.....	5.5
Brinell hardness		79

(b) From thick section ¾ in. from face:

Maximum stress.....	tons/sq. in..	13.9
Yield point	do.....	10.2
Elongation	per cent..	3.8
Reduction of area.....	do.....	5.0
Brinell hardness		76

(c) From heavy section 4 inches from face:

Maximum stress.....	tons/sq. in..	12.0
Yield point	do.....	8.6
Elongation	per cent..	3.0
Reduction of area.....	do.....	3.0
Brinell hardness		66

Fatigue tests on specimens cut out of a casting:
Rotating cantilever alternating bending tests—

(a) At room temperature:

±4.55 tons/sq. in. for 40×10⁶ reversals

(b) At 150° C.:

±4.30 tons/sq. in. for 40×10⁶ reversals

The following figures for Young's modulus were obtained on specimens from the cylinder head casting:

At 18° C.: 11.6×10⁶ lbs.

At 200° C.: 10.6×10⁶ lbs.

Creep.—The following creep tests were made on specimens cut from a sand casting of similar composition to above. Under 9.0 tons/sq. in. stress applied as a continuous load in bending at 150° C., the rate of creep strain is only 0.3×10⁻⁶ inches/hour between the 400th and 500th hours under the applied load. Under exactly similar conditions, that is 9 tons at 150° C., the figure obtained on a chill-cast modified silicon-aluminium alloy in general commercial use

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was 4.0×10⁻⁶ inch/hour between 400th and 500th hours under load. The presence of silver confers better properties, particularly under creep at elevated temperatures without seriously affecting the coefficient of expansion.

The alloy may be given solution treatment up to 540° C. with or without subsequent ageing at about 160° C. for 24 hours or about 6 hours at 180° C. High temperature heat treatment, however, is not usually advisable for large or complicated castings due to liability to heat stressing and distortion.

When high temperature solution treatment is given the magnesium and copper content should be near the maximum in order to get the best mechanical properties.

The alloy can be used in the forged state in which expression we include all types of mechanical working but in this case the silicon content should not exceed 12.5%. The usual heat treatments may be given.

What we claim is:

1. An aluminium alloy formed of the following elements in the following proportions:

	Per cent of the whole
Silicon.....	10.0 -15.0
Nickel	0.1 - 0.8
Copper and silver together and including at least 0.05 per cent of each.....	0.35- 1.0
Manganese	0.15- 0.45
Magnesium	0.07- 0.55
Aluminium the remainder.	

2. An aluminium alloy formed of the following elements in the following proportions:

	Per cent of the whole
Silicon.....	10.0 -15.0
Nickel	0.1 - 0.8
Copper and silver together and including at least 0.05 per cent of each.....	0.35- 1.0
Manganese	0.15- 0.45
Magnesium	0.07- 0.55
Aluminium the remainder together with the usual impurities including up to 0.6% of iron and up to 0.6% of zinc.	

3. An aluminium alloy formed of the following elements in the following proportions:

	Per cent of the whole
Silicon.....	10.0 -15.0
Nickel	0.1 - 0.8
Copper and silver together and including at least 0.05 per cent of each.....	0.35- 1.0
Manganese	0.15- 0.45
Magnesium	0.07- 0.55
Up to 0.15% of boron, 0.15% of calcium, 0.15% of cerium, 0.15% of chromium, 0.15% of cobalt, 0.15% of lithium, 0.15% of molybdenum, 0.15% of niobium, 0.15% of potassium, 0.15% of sodium, 0.15% of tantalum, 0.15% of titanium, 0.15% of tungsten, 0.15% of vanadium, and 0.15% of zirconium, and up to 0.35% in total of boron, calcium, cerium, chromium, cobalt, lithium, molybdenum, niobium, potassium, sodium, tantalum, titanium, tungsten, vanadium and zirconium.	
Aluminium the remainder.	

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4. An aluminium alloy formed of the following elements in the following proportions:

	Per cent of the whole
Silicon-----	10.0 -15.0
Nickel-----	0.1 - 0.8
Copper and silver together and including at least 0.05 per cent of each-----	0.35- 1.0
Manganese-----	0.15- 0.45
Magnesium-----	0.07- 0.55

Up to 0.15% of boron, 0.15% of calcium, 0.15% of cerium, 0.15% of chromium, 0.15% of cobalt, 0.15% of lithium, 0.15% of molybdenum, 0.15% of niobium, 0.15% of potassium, 0.15% of sodium, 0.15% of tantalum, 0.15% of titanium, 0.15% of tungsten, 0.15% of vanadium, and 0.15% of zirconium, and up to 0.35% in total of boron, calcium, cerium, chromium, cobalt, lithium, molybdenum, niobium, potassium, sodium, tantalum, titanium, tungsten, vanadium and zirconium.

Aluminium the remainder together with the usual impurities including up to 0.6% of iron and up to 0.6% of zinc.

5. An aluminium alloy formed of the following elements in the following proportions:

	Per cent of the whole
Silicon-----	10.0 -15.0
Nickel-----	0.1 - 0.8
Copper and silver together and including at least 0.05 per cent of each-----	0.35- 1.0
Manganese-----	0.15- 0.45
Magnesium-----	0.07- 0.55

Elements of the group thorium and beryllium in total up to 0.1 per cent. Aluminium the remainder.

6. An aluminium alloy formed of the following elements in the following proportions:

	Per cent of the whole
Silicon-----	10.0 -15.0
Nickel-----	0.1 - 0.8
Copper and silver together and including at least 0.05 per cent of each-----	0.35- 1.0
Manganese-----	0.15- 0.45
Magnesium-----	0.07- 0.55

Thorium and beryllium in total up to 0.1 per cent.

Aluminium the remainder together with the usual impurities including up to 0.6% of iron and up to 0.6% of zinc.

7. An aluminum alloy formed of the following elements in the following proportions:

	Per cent of the whole
Silicon-----	10.0 -15.0
Nickel-----	0.1 - 0.8

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Copper and silver together and including at least 0.05 per cent of each-----

Manganese-----	0.35- 1.0
Magnesium-----	0.15- 0.45
	0.07- 0.55

Up to 0.15% of boron, 0.15% of calcium, 0.15% of cerium, 0.15% of chromium, 0.15% of cobalt, 0.15% of lithium, 0.15% of molybdenum, 0.15% of niobium, 0.15% of potassium, 0.15% of sodium, 0.15% of tantalum, 0.15% of titanium, 0.15% of tungsten, 0.15% of vanadium, and 0.15% of zirconium, and up to 0.35% in total of boron, calcium, cerium, chromium, cobalt, lithium, molybdenum, niobium, potassium, sodium, tantalum, titanium, tungsten, vanadium and zirconium.

Thorium and beryllium in total up to 0.1 per cent.

Aluminium the remainder.

8. An aluminium alloy formed of the following elements in the following proportions:

	Per cent of the whole
Silicon-----	10.0 -15.0
Nickel-----	0.1 - 0.8
Copper and silver together and including at least 0.05 per cent of each-----	0.35- 1.0
Manganese-----	0.15- 0.45
Magnesium-----	0.07- 0.55

Up to 0.15% of boron, 0.15% of calcium, 0.15% of cerium, 0.15% of chromium, 0.15% of cobalt, 0.15% of lithium, 0.15% of molybdenum, 0.15% of niobium, 0.15% of potassium, 0.15% of sodium, 0.15% of tantalum, 0.15% of titanium, 0.15% of tungsten, 0.15% of vanadium, and 0.15% of zirconium, and up to 0.35% in total of boron, calcium, cerium, chromium, cobalt, lithium, molybdenum, niobium, potassium, sodium, tantalum, titanium, tungsten, vanadium and zirconium.

Thorium and beryllium in total up to 0.1 per cent.

Aluminium the remainder together with the usual impurities including up to 0.6% of iron and up to 0.6% of zinc.

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