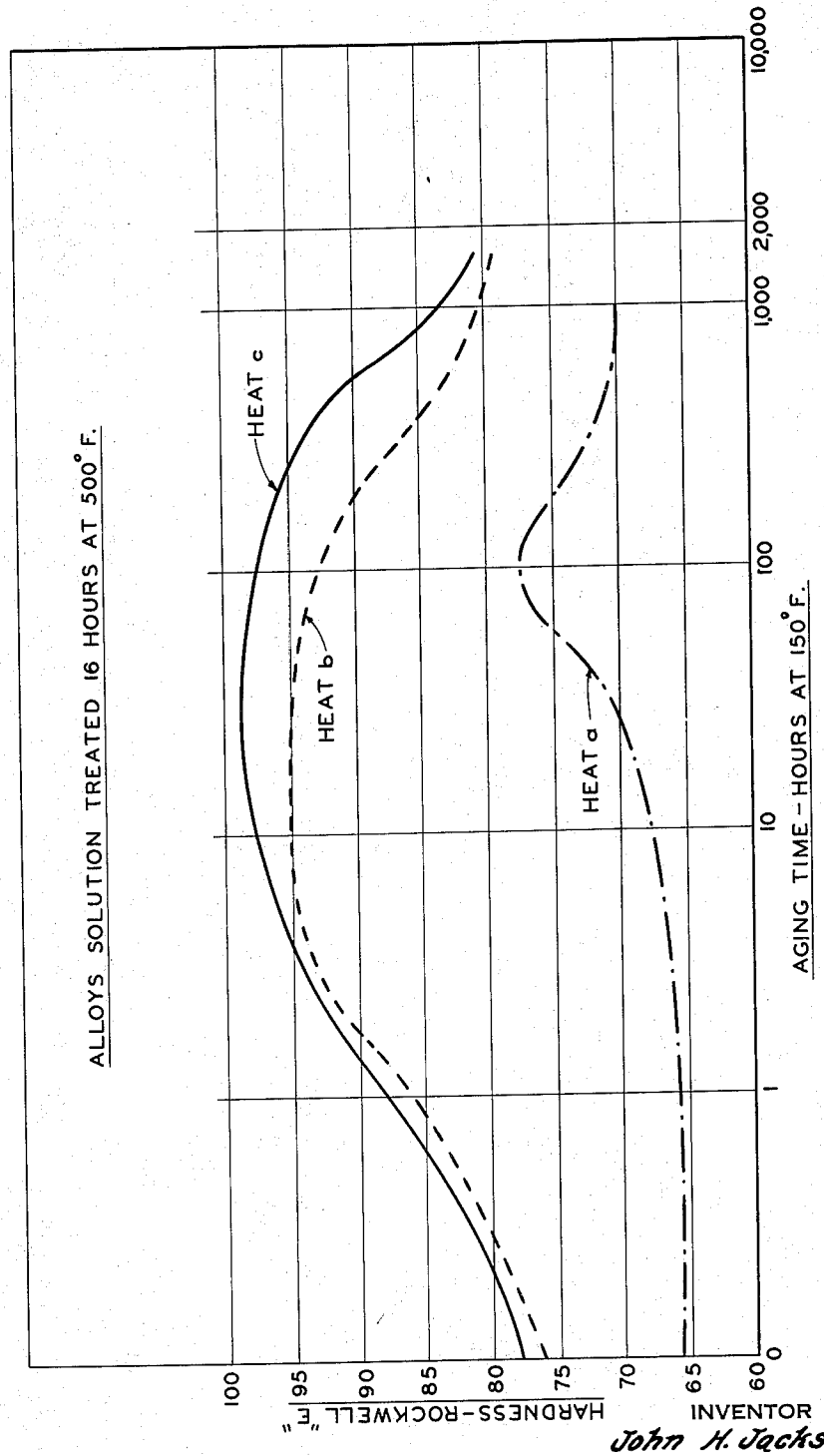
April 17, 1956 J. H. JACKSON 2,742,357

MAGNESIUM-LITHIUM BASE ALLOYS

Filed Aug. 7, 1948 2 Sheets-Sheet 1

FIG. 1



INVENTOR

John H. Jackson

BY

Pennie, Edmonds, Morton and Barrows

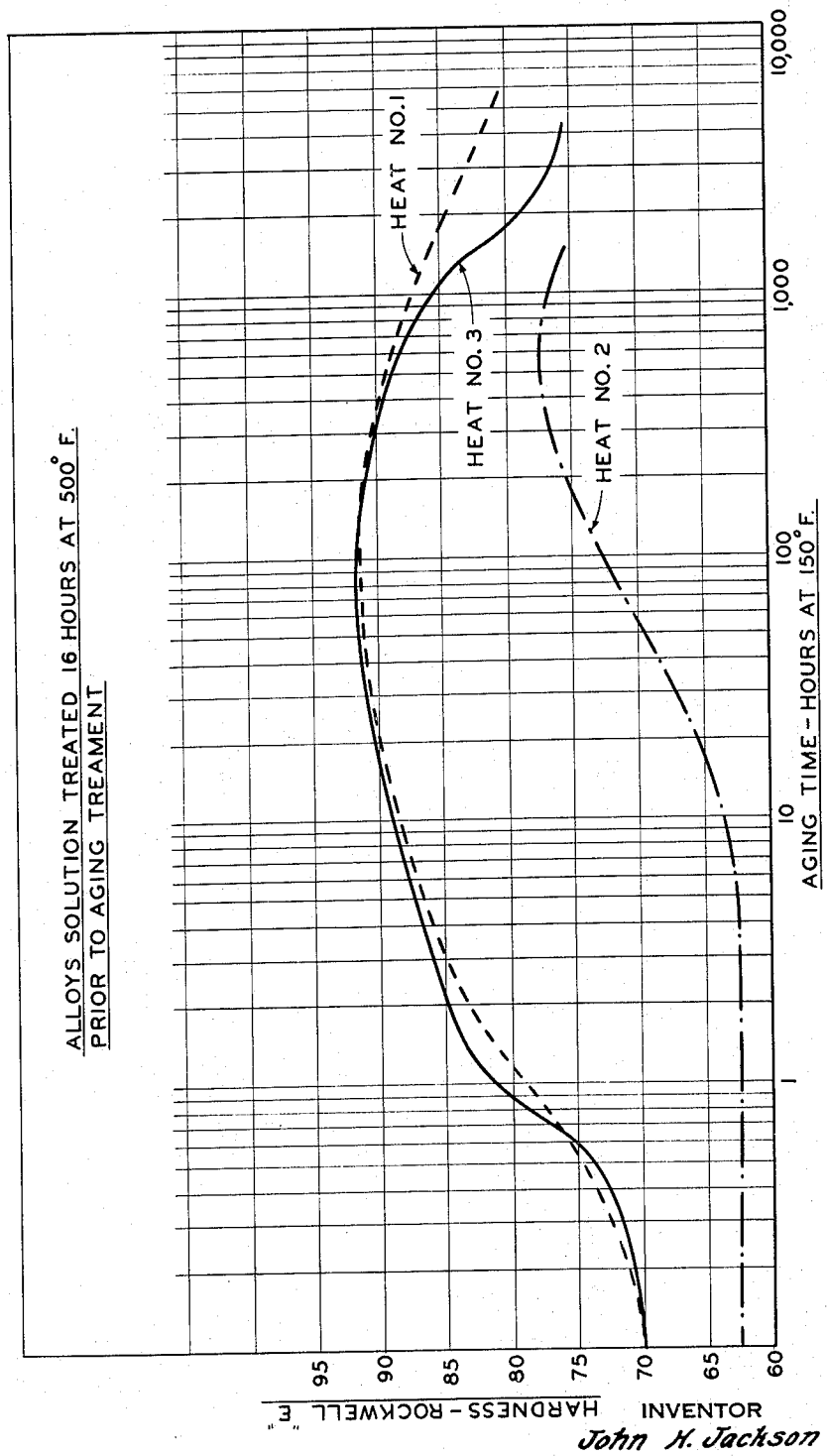
ATTORNEYS

April 17, 1956 J. H. JACKSON 2,742,357

MAGNESIUM-LITHIUM BASE ALLOYS

Filed Aug. 7, 1948 2 Sheets-Sheet 2

FIG. 2



INVENTOR
John H. Jackson
BY
Pennie, Edmonds, Morton and Barrows
ATTORNEYS

United States Patent Office 2,742,357 Patented Apr. 17, 1956

2,742,357

MAGNESIUM-LITHIUM BASE ALLOYS

John H. Jackson, Columbus, Ohio, assignor, by mesne assignments, to Mathieson Chemical Corporation, New York, N. Y., a corporation of Virginia

Application August 7, 1948, Serial No. 43,057

1 Claim. (Cl. 75—168)

This invention relates to magnesium-lithium alloys and has for its object the provision of an improved alloy consisting essentially of a magnesium-lithium base, one or more of the alloying metals aluminum, cadmium, silver and zinc, and one or more minor addition elements.

The alloys of my invention comprise 66% or more of magnesium, from 1 to 13.5% of lithium, and one or more of the aforementioned alloying metals, and one or more of the following minor addition elements in the approximate amounts given:

0.16% Cu	0.01% Ti
0.05% Ca	0.01% V
0.10% Ni	0.01% Zr
0.15% Al	0.01% Cr
0.10% Ba	0.01% Ce
0.50% In	0.01% Mn
0.50% Tl	0.01% Fe
0.50% Hg	0.01% Co
0.01% Sn	0.01% Cb
0.01% Be	0.01% Mo
0.01% Si	0.01% Ta
0.01% Sb	0.01% W
0.01% Te	0.01% Th
0.01% Pb	0.01% Sr
0.01% Bi	

One of the important features of the alloys of my invention is that they are work-hardening alloys which are also creep resistant at room temperature.

It has been found that one or more of the alloying metals are very effective in making the binary magnesium-lithium matrix work hardenable and more creep resistant at room temperature. However, where the alloying metals are added in quantities appreciably greater than their solid solubility limits, at ordinary temperatures, it has been found that the effect is not lasting because of precipitation of the metal or a compound of it at temperatures up to and including 200° F.

In furtherance of the objective concept of the invention, certain of the foregoing elements were added to alloys of the magnesium-lithium base and put into solution by a high-temperature solution treatment and it was found that the matrix was capable of work-hardening

provided the alloy were not used under conditions where the major portion of the solute precipitated. In order to study the effect of such minor additions, test bars were tested for work-hardenability in the solution treated and in the solution treated and aged state. As a result of these tests, it has now been shown that desirable work-hardening properties, which can be retained even after aging at higher temperature, may be imparted to magnesium-lithium base alloys and that the addition of small amounts of one or several elements is decidedly beneficial in providing work-hardenable magnesium-lithium base alloys.

I have also made the amazing discovery that the beneficial effects of one or only a few slightly soluble elements in minor amounts can be enhanced by adding a large number of such elements. An alloy to which twenty-nine minor elements were added was produced with the amazing result of a significant improvement in the stability of the age-hardened alloy as measured by age-hardening tests.

The following are typical examples of alloy compositions including one or more minor elements:

Alloys containing "minor additions"

No.	Mg/Li	Percent Mg	Percent Li	Percent Ag	Percent Cd	Percent Zn	Percent Ni	Percent Cu	Percent Ba	Percent Ca	Percent Al	Percent Mn	Percent Sn
1	6	80.8	13.5	1	4	0.25	0	0.16	0.1	0.05	0.15		
2	6	80.7	13.5	1	4	0.25	0.1	0.16	0.1	0.05	0.15		
3	6	80.8	13.5	1	4	0.25	0.1	0.16	0.0	0.05	0.15		
4	6	81.7	13.6	0	4	0.25	0.1	0.16	0.0	0.05	0.15		
5	8.1	83.8	10.4	1	4	0.25	0.05	0.16	0.1	0.05	0.15		
6	8.1	83.8	10.4	1	4	0.25	0.1	0.16	0.1	0.00	0.15		
7	6	67.8	11.3	5	15	0.25	0.1	0.16	0.1	0.05	0.15		
8	6	67.8	11.3	5	15	0.15	0.2	0.24	0.2	0.10	0.15		
9	6	69.5	11.6	3	15	0.25	0.1	0.16	0.1	0.05	0.15		
10	6	66.2	11.0	2	20	0.25	0.1	0.16	0.1	0.05	0.15		
11	6	76.3	12.7	6	4			0.61			0.13	0.26	
12	6	75.9	12.6	6	4			0.63				0.27	0.60
13	6	76.6	12.8	4	4	0.25	0.1	0.16	0.1	0.05	2		
14	6	77.5	12.7	4	4		0.5	0.25			2		
15	6	73.5	12.2	4	4	4	all elements listed in column 1						

In the accompanying drawings, Figs. 1 and 2 are graphs on semi-logarithmic scales illustrating age-hardening characteristics of the invention.

In Fig. 1 a comparison of the 150° F. age-hardening characteristics of (*a*) a 6 Mg/Li, 4% Zn, 4% Cd, 4% Ag alloy, (*b*) the same alloy with small additions of Cu, Ca, Al and Ba, and (*c*) the same alloy containing small amounts of 29 addition elements is given. The superiority of alloys (*b*) and (*c*) is obvious. It should be noted further that alloy (*c*) represents a marked improvement over alloy (*b*) as is shown below:

	Alloy *b*	Alloy *c*
Maximum Hardness	93	97
Time at maximum hardness, hours	80	140
Time at hardness of 85 Rockwell E or over, hours	350	800
Time at hardness 10 points higher than as-quenched hardness, hours	300	660

Fig. 2 shows the effect of decreasing the silver content as evidenced by the age-hardening characteristics of a 6 Mg/Li, 15% Cd, 5% Ag alloy. Curve (1) shows the characteristic of a 6 Mg/Li, 15% Cd, 5% Ag alloy and the deleterious effect of decreasing the silver content is observable by comparing curve (1) with (2) which shows the characteristics of a 6 Mg/Li, 15% Cd, 3% Ag alloy. However, as evidenced by curve (3), this deleterious effect can be compensated for by small additions of a number of addition elements so as to produce an alloy having the following composition: 6 Mg/Li, 15%Cd, 3% Ag, 0.16% Cu, 0.05% Ca, 0.25% Zn, 0.10% Ni, 0.15% Al, 0.10% Ba. It will be readily seen that the stability of age-hardenable alloys may be achieved at

an elevated temperature even with reduced silver content by adding a number of alloying elements in small amounts.

Several melting procedures have proved satisfactory for producing the alloys of the invention. For example, melting may be done under argon, without flux, and in this event the metals are melted first and the non-metallic compounds added subsequently. In an alternative procedure, the melting is done under a 75% LiCl—25% LiF flux in a single crucible. A third melting procedure which has proved satisfactory requires two crucibles, some of the components being added in a metallic state under the flux with the magnesium-lithium in one crucible, and the other components being added as compounds to a flux in a second crucible and the contents of this second crucible are later transferred to the first crucible for final alloying.

In producing the alloys under argon, it is important that the metals be relatively pure and especially low in sodium because the finished alloy should contain less than 0.1% of sodium as explained in the application of Alfred C. Loonam, Serial No. 602,171, now U. S. Patent No. 2,453,444. When the alloy is produced under the LiCl—LiF flux, it is important that the flux as initially used be free of sodium to the end that it will absorb sodium from the alloy and thus reduce the sodium to amounts less that 0.1% as explained in the application of Alfred H. Hesse, Serial No. 603,749, now U. S. Patent No. 2,507,713.

I claim:

A magnesium-lithium base alloy, containing less than 0.1% of sodium, consisting of at least 66% of magnesium; from 1% to 13.5% of lithium; from 1% to 5% of silver; from 4% to 20% of cadmium; from 0.15% to 0.25% of zinc; from 0.05% to 0.2% of nickel; from 0.16% to 0.24% of copper; from 0.1% to 0.2% of barium; from 0.05% to 0.10% of calcium; and from 0.15% to 2% of aluminum.

References Cited in the file of this patent

UNITED STATES PATENTS

2,376,868 Dean et al. ---------- May 29, 1945

OTHER REFERENCES

Gann et al.: "Magnesium and Its Alloys," reprinted from Industrial and Engineering Chemistry, vol. 19, page 1193, Oct. 1927, published by A. C. S., page 2, table I of reprint.

Hume-Rothery, "Equilibrium Relations and Some Properties of Magnesium-Lithium and Magnesium-Silver-Lithium Alloys," J. Institute of Metals, vol. 71, 1945, pp. 589–601.

Mellor: Inorganic and Theoretical Chemistry, vol. 4, page 255, (1946). Published by Longmans, Green and Co., London.