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ZINC ALLOY

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This invention relates to a new type of zinc alloy for use either in the cast or wrought form.

The invention has for its object the production of a type of a zinc alloy which has superior physical and chemical properties and stability. Specifically, the invention provides such an alloy which has a fine grain size, and increased hardness, strength and toughness, and increased resistance to softening on heating to elevated temperatures.

Still a further object of the invention resides in treating such alloys to enhance the hardness and creep resistance.

Other objects of the invention will be apparent from the following description and claims.

As is well known, zinc is available commercially in several main types, as follows:

(1) Very pure zinc, i. e. zinc which is 99.90% pure or purer. This metal is very soft and ductile, recrystallizes at room temperature and is very stable.

(2) Common zinc of Brass Special or Prime Western grade. This material is a natural alloy of zinc with varying proportions of iron, lead and cadmium. These impurities make the metal harder, less ductile, but still chemically stable.

(3) Zinc alloys, used usually in die casting, which contain aluminum in substantial amounts (1% or more). These alloys are hard, less ductile than pure zinc and are chemically unstable. Their stability is improved by small additions of other metals and by a painfully rigorous exclusion of all but the most minute traces of lead, tin and cadmium.

(4) Zinc alloyed with about 1% of copper with or without small additions of other metals. These alloys are fairly hard, fairly ductile and are chemically permanent. They are used chiefly in rolled form and are not particularly effective in resisting softening or heating.

My invention, as will be shown, results in an alloy which is superior to any of these four types of available zinc.

Before arriving at the invention, I carried out a great many experiments in an attempt to form zinc alloys of fine grain size and increased strength and toughness and resistance to softening on heating to elevated temperatures. My experiments have involved the addition to zinc of metals of high melting point (i. e. over 3000° F.). It was hoped that the addition of these metals would impart to the alloy the properties recited above. However, most of the metals with which I experimented could not be alloyed with zinc by the usual commercial means and some of them segregated badly after they were alloyed with zinc so as to be of no use commercially. I have discovered that both of these drawbacks relate to the same fundamental property of zinc and that they can be obviated if the alloy is compounded in the manner described herein.

The invention is based on the following reasoning:

Two metals which react to each other to form alloys yield a product which may be characterized by any of three degrees of association. (1) If the affinity of the metals is very great, as in the case of zinc with most metals, the product is an intermetallic compound embedded in an excess of one of the reacting metals. (2) If the affinity is somewhat less, as in the case with copper, silver and gold, the product is a solid solution which appears as homogeneous phase. (3) If the affinity is still less, the melt on cooling has a eutectic structure or one in which discrete particles of both metals settle out in a finely dispersed condition. Zinc forms such alloys with tin, bismuth and, in certain ranges of composition, with cadmium and mercury, for example.

In view of the low melting point of zinc the intermetallic compounds formed by zinc with the high melting metals are all of much higher melting point than zinc. When these metals are added to a bath of molten zinc for alloying, a solid layer of intermetallic compound forms on them and is an effective seal to prevent further alloying action. In this way only a negligible amount of the addition metal reacts with the zinc and under usual conditions this is drawn out of the melt with the unalloyed metal.

An underlying concept of the invention is that if the reacting metals have less affinity for each other, they might form the second above-mentioned class of reaction product, that is, a solid solution or, indeed, a liquid solution at the alloying temperature which would diffuse readily throughout the melt and so expose fresh surfaces of the high melting metal to the zinc for continued alloying action. In accordance with the invention, therefore, the affinity of the molten zinc is reduced by first alloying with it an appreciable amount of copper. I have found that in this way it is possible to incorporate substantial amounts of high melting metals with zinc.

All of the alloys in accordance with my invention are thus made up of zinc and copper with one or more additional metals which have high melting points, that is, melting points above 3000° F.

The effective copper range of the alloys of my invention is 2.00% to 3.00% with the preferred percentage for most purposes about 2.20%. In some cases, however, copper may be employed in amounts up to 5%.

In compounding the alloys it is sometimes advisable to make a master alloy of zinc, copper and a high melting metal in which the two latter elements are present in considerably higher percentages than in the first alloy. The high melting metals which I have found satisfactory and all of which melt at over 3000° F. are zirconium, titanium, vanadium, chromium, columbium, molybdenum, tantalum, tungsten and uranium.

Beryllium is a border line case which confers the advantages of the invention to a limited extent but it is particularly valuable for the special property of prevention of oxidation of the 2.20% copper alloy when heated twenty-four hours at 700° F. in the presence of air.

These high melting point metals are used either singly or in combination in amounts ranging from 0.02% to 0.50% in zinc containing, for example, from 2% to 3% copper.

Elements tested and found inoperative in the beneficial sense described include iron, cobalt, nickel, manganese and antimony.

The high melting metals proposed begin to show their effect at concentrations of 0.02% or thereabout and a gradual improvement in physical properties results with increasing content to about 0.50%. When only one of the high melting metals is used a content of 0.20% is usually satisfactory. It is significant to note that while these high melting metals have a slight hardening effect in zinc or in zinc alloys containing 1% or less of copper, many attempts have shown it to be impossible to disseminate evenly more than about 0.05% of these metals in such alloys, and when greater amounts were added no improvement in physical properties was found with increasing percentage of the high melting metal over 0.05%. These alloys containing 1% or less of copper do not have the superior resistance to cold flow characterized by zinc alloys with 2% or more of copper together with the high melting metals.

It is true that alloys of 1% copper with minute additions of magnesium or lithium have high creep resistance, but these alloys do not maintain their physical properties on re-melting and the proportions of the alkali metals must be very carefully controlled to avoid excessive brittleness. There is some indication that the hardness of these alloys with alkali metals is due to the formation of an oxidized product in the alloy, which is a much harder variable to control than a simple metallic addition. Some specific examples of the invention are as follows:

	Per cent
No. 1:	
Copper	2.20
Zirconium	.05
Zinc	Balance
No. 2:	
Copper	2.20
Titanium	.05
Zinc	Balance
No. 3:	
Copper	2.20
Chromium	.05
Zinc	Balance
No. 4:	
Copper	2.20
Vanadium	.05
Zinc	Balance
No. 5:	
Copper	2.20
Tungsten	.05
Zinc	Balance
No. 6:	
Copper	2.20
Zirconium	.22
Titanium	.22
Zinc	Balance
No. 7:	
Copper	2.20
Chromium	.22
Vanadium	.22
Zinc	Balance
No. 8:	
Copper	2.20
Columbium	.20
Molybdenum	.10
Zinc	Balance
No. 9:	
Copper	2.20
Beryllium	.05
Zinc	Balance
No. 10:	
Copper	2.20
Tantalum	.10
Tungsten	.22
Zinc	Balance
No. 11:	
Copper	2.20
Chromium	.20
Titanium	.10
Zinc	Balance
No. 12:	
Copper	2.20
Chromium	.05
Molybdenum	.12
Iron	.03
Zinc	Balance
No. 13:	
Copper	2.00
Titanium	.04
Molybdenum	.12
Iron	.07
Zinc	Balance
No. 14:	
Copper	2.20
Zirconium	.05
Titanium	.05
Chromium	.05
Vanadium	.05
Tungsten	.05
Zinc	Balance

Alloys in accordance with the invention are much stronger and tougher than pure zinc or zinc hardened with the natural impurities, iron, lead and cadmium. Moreover, they have a much higher softening temperature. They are distinguishable from the aluminum-bearing zinc alloys by the fact that they are chemically stable and are not subject to inter-crystalline oxidation or swelling, even if compounded on an impure zinc base. All of the five grades of zinc set up by the American Society for Testing Materials (see "Zinc and Its Alloys," Bureau of Standards Circular No. 395, page 27) may be used in my

alloys, but for maximum ductility and toughness the natural impurities lead, iron and cadmium should be at a minimum.

When zinc alloys containing copper and a third element, as above described, are cast in iron molds, the alloy has a duplex structure consisting of a ground mass of zinc containing some of the alloying material in solution and a dispersed phase of particles richer in copper than the ground mass and containing zinc and some of the other alloy materials. In this condition, depending on which of the high melting metals are used, the alloys have favorable physical properties, such as hardness, ductility and creep resistance.

With the exception of beryllium, which I have stated to be a borderline case, it will be noted that all of the addition metals I have tried and have found satisfactory, appear in even numbered series of groups IV, V and VI of the periodic table. It would appear, therefore, that hafnium and thorium, which also fall in this category, would likewise be satisfactory.

In accordance with another phase of the invention, the hardness and increased resistance are enhanced, in most cases, by subjecting the alloys to elevated temperatures. For example, alloys using as a third element zirconium, titanium, chromium or vanadium increase in hardness by being rolled at temperatures of 300 to 400° F., and this hardness remains when this degree of heat is used in a subsequent anneal for two hours.

Alloys using columbium or molybdenum as a third element do not develop full hardness on rolling but require an anneal at 400° F. Alloys containing as a third element tantalum or tungsten require heating to 700 to 750° F. and quenching to bring out their full hardness. It will be noted that the reaction to heat varies with the melting point of the alloying metal, the higher the melting point the higher the temperature needed to bring out maximum hardness. This latter treatment evidently puts all of the alloying material into solid solution in the zinc or at least in the form of an extremely fine precipitate. Subsequent anneals with slow cooling at temperatures up to 600° F. cause the precipitation in more massive form of some of the copper and the third alloying element, but the hardness is not substantially reduced except when the amount of the third element is low. For example, an alloy of 2.20% copper and .22% titanium maintained its hardness up to 600° F. but an alloy of 2.20% copper and .05% titanium maintained its hardness to 400° F. only and lost much of it at 600° F.

The fact that subsequent precipitating anneals do not raise the hardness above that obtained with the 700° F. anneal and quench is believed to indicate that there is enough precipitation of the secondary phase at room temperature as a result of this treatment to exert the maximum hardening effect without the need of a subsequent precipitating anneal. This would not be strange in view of the low melting point of zinc.

The table below shows the effect of various heat treatments on hardness of a series of alloys of zinc containing 2.20% copper and a third element as shown in column 1. Columns 7, 8 and 9 show the results of heat treatments performed on alloys previously heat treated as in column 6. All tests refer to alloys rolled to .010 to .030" gauge with the exception of column 2. The values given are Rockwell H numbers (60 kg. load, ⅛" dia. steel ball).

Col. 1	Col. 2	Col. 3	Col. 4	Col. 5	Col. 6	Col. 7	Col. 8	Col. 9
	Cast	Rolled	Anneal 24 hrs. 280° F.	Anneal 2 hrs. 400° F.	Anneal 24 hrs. 700° F. and quench	Anneal 2 hrs. 200° F.	Anneal 2 hrs. 400° F.	Anneal 2 hrs. 600° F.
.22% Zr	92	93.5	93	94	95	96	96	97.5
.22% Ti	95	99	93	94	95	96	97.5	100
.22% Cr	97	101	98	99	97.5	97.5	95	96.5
.22% V	90.5	97	97	97	101	104	102	101
.20% Cb	92	95	86.5	95	101	101	103	101.5
.10% Mo	89.5	87	86	98.5	99	100	101.5	101
.10% Ta	88	91.5	91.5	92	98	97	98.5	98
.22% W	89.5	95	92.5	94	101	101.5	100	101.5

The following table showing changes in Rockwell H hardness resulting from the heat treatment of cast alloys of zinc with copper and other alloying elements as well as zinc with copper alone shows first that copper alone is not satisfactory for maintenance of high hardness on annealing. It also shows that beryllium, although not as effective in increasing hardness on anneal as the elements with melting points over 3000° F. does prevent loss of hardness from the original cast or rolled state. Finally, it shows that the presence of iron in the alloys may result in a drop in hardness at extreme annealing temperature (600° F.) in alloys which without iron maintain their hardness at a 600° F. anneal. The anneals of columns 4, 5 and 6 were done on alloys previously annealed as in column 3.

Col. 1	Col. 2	Col. 3	Col. 4	Col. 5	Col. 6
Analysis zinc balance	Cast	Anneal 24 hrs. 700° F. and quench	Anneal 2 hrs. 200° F.	Anneal 2 hrs. 400° F.	Anneal 2 hrs. 600 °F.
2.20% Cu	91.5	91	93	87.5	85.5
4.00% Cu	97.5	88.5	94	96.5	85
2.20% Cu + .055% Be	92.5	92.5	91.5	94.5	93
2.20% Cu + .10% Mo	89.5	99	100	101.5	101
2.00% Cu + .04% Ti + .12% Mo + .07% Fe	94	94	95.5	100	85.5
4.00% Cu + .04% Mo + .05% W + .41% Fe	100	97	101	101	86.5
2.20% Cu + .20% Cr + .10% Ti	96	99	99	102	100.5
2.20% Cu + .05% Cr + .05% Ti + .03% Fe	91	94.5	95	98.5	97.5

It will be obvious that for some purposes the alloys may contain iron without impairing their usefulness, and this will be an economic advantage with certain of the high melting metals, which are cheap in the form of ferro alloys but more expensive in the pure state or alloyed with cop-

per. The same holds true for moderate incidental contents of nickel or manganese.

The alloys containing copper and beryllium did not lose their original bright metallic sheen in the 24 hour anneal at 700° F. and it is therefore evident that beryllium is indicated as an addition with or without another high melting metal when a bright finish is desired on the alloys after heat treatment.

The following table, shows the changes in Rockwell H hardness on annealing of a series of alloys all containing .05% each of zirconium, titanium, chromium, vanadium and tungsten, with variable copper content, and in one case with an addition of lead and cadmium, the natural impurities of zinc. As before, the treatments of columns 7, 8, and 9 were done on alloys previously treated as in column 6. All alloys are in the rolled form except those in column 2.

Col. 1 Content	Col. 2 Cast	Col. 3 Rolled	Col. 4 Anneal 24 hrs. 280° F.	Col. 5 Anneal 2 hrs. 400° F.	Col. 6 Anneal 24 hrs. 700° F. and quench	Col. 7 Anneal 2 hrs. 200° F.	Col. 8 Anneal 2 hrs. 400° F.	Col. 9 Anneal 2 hrs. 600° F.
1.10% Cu	91.5	100	97	101	91	87.5	88.5	90
2.20% Cu	95.5	102	99.5	102	101	98.5	100	101.5
2.70% Cu	97	100	96	101.5	101	101.5	102	102
2.20% Cu, .10% Pb, .10% Cd	95	111	107	109	102.5	101	103	97

It will be noted that the 1.10% copper alloy loses its hardness on continued exposure to elevated temperatures and the 2.70% copper alloy is no better in this regard than the 2.20% copper alloy. The presence of .10% each of lead and cadmium in the 2.20% copper alloy is shown to result in increased hardness as rolled and at low temperature anneals but reduced hardness at more elevated temperatures. This series establishes the effective copper range as about 2.00 to 3.00% copper.

Further evidence regarding the upper limit for copper for optimum effect is given by the following table which compares the Rockwell H hardness of alloys containing vanadium and chromium with copper contents of 2.20% and 4.00%. As above the treatments of columns 7, 8 and 9 are done on alloys previously treated as in column 6. All alloys are rolled except those of column 2.

Col. 1 Analysis balance zinc	Col. 2 Cast	Col. 3 Rolled	Col. 4 Anneal 24 hrs. 280° F.	Col. 5 Anneal 2 hrs. 400° F.	Col. 6 Anneal 24 hrs. 700° F. and quench	Col. 7 Anneal 2 hrs. 200° F.	Col. 8 Anneal 2 hrs. 400° F.	Col. 9 Anneal 2 hrs. 600° F.
2.20% Cu, .22% V	90.5	97	97	97	101	104	102	101
4.00% Cu, .40% V	99.5	98	97.5	101	89.5	96	95	89.5
2.20% Cu, .22% Cr	97	101	98	99	97.5	97.5	95	96.5
4.00% Cu, .40% Cr	102.5	98	95.5	96.5	102	99.5	97	90.5

It appears that while the same ratio of copper content to content of high melting metal is maintained, the increase in alloying elements has reduced, rather than increased, hardness at elevated temperatures.

Alloys containing 2.20% copper and a third metal as disclosed can be rolled to thin gauges without cracking at the edges, while with higher copper there is more tendency for edge cracking.

While the hardness of the alloys of the invention persists even after heating to elevated temperatures, there is a change in the alloys as shown by the micro-structures. The finely precipitated particles resulting from the solution treatment at 700° F. and subsequent quench coalesce and grow in size on subsequent heating to high temperatures with slow cooling. Some of these particles locate themselves along grain boundaries and cause reduced ductility of the alloys. The heat treating schedules shown are not offered as the optimum treatment for any of the alloys for any special use, but merely show the effect of elevated temperatures in increasing the hardness and creep resistance of the alloys.

In general the maximum hardness is developed by heating the 2.20% copper alloys at 700° F. for a number of hours depending on the mass of the article and quenching. Higher copper contents require higher soaking temperatures. The 2.70% copper alloys must be heated just under the melting point to insure solution of all of the alloying material. For some purposes the alloys will reach a satisfactory condition in the cast or rolled state without further heat treatment.

An important feature of the invention lies in the fact that I have discovered that the higher the melting point of the third alloying element the slower it is precipitated and the finer its particles for a given heat treatment. It is recognized that dispersed elements of large molecular or atomic size diffuse and precipitate more slowly than do those of smaller size. Molecular size of the dispersed material rather than melting point may be the regulating factor here. It is apparent therefore that the alloys of the invention form a continuous series of which each member has its particular value under certain conditions of use. The lower melting point metals are indicated when it is desired to develop the maximum hardness of the alloys merely by the rolling treatment and when either the thermal conditions in use will not be high or when a reduction of ductility in use as a result of high temperatures could cause no difficulty. Similarly the higher melting metals are indicated when difficult forming operations are to be made on the rolled metal which might be difficult or impossible if the full hardness of the alloy were developed in rolling. The formed articles can then be heat treated to develop their full hardness and creep resistance. When the alloys are subjected to high temperatures in use and must retain not only hardness but ductility and impact

resistance, the higher melting point addition metals are indicated.

An important feature of the alloys of the invention results from the fact that severe forming operations such as wire drawing, which develop considerable heat and so soften the heretofore available workable zinc alloys, do not soften the alloys of the invention, and much greater reduction per pass, for example, in wire drawing, can be taken than with other zinc alloys. The high melting metals while fulfilling the same purpose in the alloys are therefore identical or interchangeable in only a qualitative sense. The essence of the invention, therefore, lies in the gradually changing properties provided by a series of alloys which makes them effective over a wide range of applications.

The creep resistance of the alloys of the invention is controlled by variation of the heat treatment just as is the hardness. That is, the alloys formulated with the lower melting metals of the group show greatly improved creep resistance at low annealing or rolling temperatures, while the alloys compounded with higher melting point metals are brought to their best state of creep resistance only by more elevated annealing temperatures. To indicate this effect, a few creep tests are listed in the table below for a number of alloys of the invention in various conditions of heat treatment.

Minutes for 1% elongation under load of 10,000 lbs. per sq. in. of zinc alloys containing 2.20% copper plus additions—shown in column 1

Col. 1	As rolled	Annealed at 280° F. 24 hours	Heated 24 hours at 700° F. and quenched. Then annealed 2 hours at 400° F.
.22% Zr	101	19	Over 10,000
.22% Ti	5,760	Over 10,000	Over 10,000
.22% Cr	Over 10,000		Over 10,000
.22% V	719	218	Over 10,000
.20% Cb	115	23	Over 10,000
.10% Mo	7	15	Over 10,000
.10% Ta	41	28	Over 10,000
.22% W	216	50	Over 10,000
.20% Cr			
+.10% Ti	1,440	Over 10,000	

Because it was not practical to assure exactly reproducible conditions of rolling temperature there is not the gradual change in creep resistance in the as rolled condition that would be expected under uniform rolling conditions.

In the foregoing discussion of the invention, no mention has been made of the effect of a number of well known principles which materially affect the qualities of the alloys. Because of the novelty of these alloys as a class, a discussion of some of these principles as applied to the alloys is in order.

When fine grain size and ductility are important in the use of these alloys, the grain size is properly controlled by the rolling temperature. When a high temperature anneal after rolling is needed, the alloy may be kept in a fine grained condition either by rolling at such a temperature that there is no strain or cold work left in the alloy, or, if this is not feasible by rapid elevation of its temperature through its germinative range, in accordance with the principle described in "The Science of Metals" by Jeffries & Archer, page 111, paragraph 1, and page 114, paragraph 1, published in 1924.

When this method is impossible or undesirable, and when it is not desired to correct grain size by further rolling after the high temperature anneal, the composition of the alloy may be adjusted in several ways to yield a fine grain size as annealed. One simple method is to use a quantity of copper or of the high melting metal greater than will be dissolved by the high temperature anneal contemplated. The undissolved particles tend to restrain grain growth during the anneal. Another method is to incorporate in the alloy a quantity (say .1–.2%) of a metal which goes into solid solution in zinc such as nickel or manganese, etc.

While it is not known how these zinc soluble metals act, it is presumed that they exhaust the solvent power of the zinc and keep it from dissolving as large an amount of copper at elevated temperature as would be dissolved in the absence of the zinc soluble metals nickel, manganese, etc. The undissolved copper rich precipitate would then act to prevent grain growth. This same speculation may account for the failure of these zinc soluble metals to induce the desirable properties of hardness and creep resistance of the alloys of the invention. Their high solubility may prevent the super-saturation of the zinc lattice with copper which may be necessary for the beneficial results secured.

Of all of the high melting metals dissolved, chromium is unique in that it has appreciable solid solubility in zinc, and in alloys of the invention it appears to play a dual role just as it does in steel, that is, part of the chromium is held in solid solution in the ground mass and part of it is present in the precipitate. This is believed to be the reason for the finer grain size of alloys of the invention using chromium as compared with those using any other of the high melting metals under the same conditions of treatment.

The use of chromium in the alloy removes the need of the last mentioned artifice to maintain fine grain size. It is to be noted, however, that for some uses, as for example when high creep resistance is required with minimum hardness, this dual action of chromium may be a disadvantage and the use of some other high melting metal might be preferable.

The use of aluminum in the alloy is not recommended because of its known effect in causing physical and chemical instability in zinc alloys. Tin and bismuth cause intergranular brittleness and should not be present. Alkali metals such as magnesium and lithium are preferably absent because very slight variations in amount of these metals cause wild fluctuations in properties and their effect is not constant on re-melting the alloys.

It will be apparent that the use of two or more of the high melting metals in the same alloy is indicated when favorable properties are required over a greater range of temperature than can be accommodated by an addition of only one high melting metal. This is also in order when it is not known in advance under what thermal conditions the alloy is to be used. By using a metal from both the high and the low ends of the melting point range, an alloy can be produced which has fine hardness and creep resistance as rolled and also when subjected to temperatures well in excess of the rolling temperature.

When die castings of thin section are made

of the alloys of the invention, the rapid chilling of the metal may entrap enough of the copper and third alloying element in solution in the zinc or at least as a very fine precipitate, so that the alloys as cast will have the improved properties described or may be given them by a relatively low temperature precipitating anneal, depending on the thermal conditions of casting and the choice of the high melting alloy metal.

The alloys of the invention are particularly suitable for rolled photo-engravers plates which require permanence of hardness and creep resistance after annealing at elevated temperatures, and must etch smoothly and rapidly in the acid etching solution used (usually nitric acid). The fine precipitated particles of the alloys of the invention are very uniformly distributed and of very fine particle size. They are more noble, chemically, than the ground mass, and cause, in etching, local action cells which lift out the noble particles by dissolving the ground mass adjacent and cause removal of more metal than is actually dissolved by acid, resulting in increased speed of etch and decreased acid consumption. The etched surfaces are very smooth because of the fineness and ubiquity of the precipitate.

When in the claims the phrase "the remainder being substantially all zinc" is employed, it is meant to include zinc of the grades referred to herein and which contain the natural impurities iron, lead and cadmium in limited amounts.

I claim:

1. A zinc alloy containing copper from 2 to 5%, and from .02 to .50% of at least one of the group of grain refining high melting point elements consisting of beryllium, zirconium, titanium, vanadium, chromium, columbium, molybdenum, tantalum, tungsten and uranium, the remainder being substantially all zinc.

2. A zinc alloy comprised of from 2 to 5% of copper, molybdenum from .02 to .50%, the remainder being substantially all zinc.

3. A zinc alloy comprised of about 2.20% copper, molybdenum about .10%, the remainder being substantially all zinc.

4. A zinc alloy comprised of from 2 to 5% copper and from .02 to .50% vanadium, the remainder being substantially all zinc.

5. A zinc alloy comprised of about 2.20% copper, vanadium about .22%, the remainder being substantially all zinc.

6. A zinc alloy comprised of from 2 to 5% copper, and from .02 to .50% tungsten, the remainder being substantially all zinc.

7. A zinc alloy comprised of about 2.20% copper, tungsten about .22%, the remainder being substantially all zinc.

8. The process of forming an article which comprises rolling and fabricating a zinc alloy comprising from 2 to 5%, and from .02 to .50% of at least one of the group of grain refining high melting point elements consisting of beryllium, zirconium, titanium, vanadium, chromium, columbium, molybdenum, tantalum, tungsten and uranium, the remainder being substantially all zinc, to form the article into the desired shape and then increasing at least one of the two properties hardness and creep resistance of the article by heat treatment including heating at temperatures up to 750° F.

9. The process of forming an article which comprises rolling and fabricating a zinc alloy comprising copper from 2 to 5% and from .02 to .50% vanadium, the remainder being substantially all zinc, to form the article into the desired shape and then increasing at least one of the two properties hardness and creep resistance of the article by heat treatment including heating at temperatures up to 750° F.

10. The process of forming an article which comprises rolling and fabricating a zinc alloy comprising copper from 2 to 5% and from .02 to .50% tungsten, the remainder being substantially all zinc, to form the article into the desired shape and then increasing at least one of the two properties hardness and creep resistance of the article by heat treatment including heating at temperatures up to 750° F.

11. The process of forming an article which comprises rolling and fabricating a zinc alloy comprising copper from 2 to 5% and from .02 to .50% molybdenum, the remainder being substantially all zinc, to form the article into the desired shape and then increasing at least one of the two properties hardness and creep resistance of the article by heat treatment including heating at temperatures up to 750° F.

12. An article of manufacture comprised of a shaped zinc alloy comprising copper from 2 to 5% and from .02 to .50% of at least one of the group of grain refining high melting point elements consisting of beryllium, zirconium, titanium; vanadium, chromium, columbium, molybdenum, tantalum, tungsten and uranium, the remainder being substantially all zinc, at least one of the two properties hardness and creep resistance of which article has been increased by heat treatment including heating at temperatures up to 750° F.

13. An article of manufacture comprised of a shaped zinc alloy comprising copper from 2 to 5% and from .02 to .50% vanadium, the remainder being substantially all zinc, at least one of the two properties hardness and creep resistance of which article has been increased by heat treatment including heating at temperatures up to 750° F.

14. An article of manufacture comprised of a shaped zinc alloy comprising copper from 2 to 5% and from .02 to .50% tungsten, the remainder being substantially all zinc, at least one of the two properties hardness and creep resistance of which article has been increased by heat treatment including heating at temperatures up to 750° F.

15. An article of manufacture comprised of a shaped zinc alloy comprising copper from 2 to 5% and from .02 to .50% molybdenum, the remainder being substantially all zinc, at least one of the two properties hardness and creep resistance of which article has been increased by heat treatment including heating at temperatures up to 750° F.

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