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ALLOY

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My invention is a new alloy having novel characteristics which adapt it for practically all uses where extremely high resistance to corrosion is essential.

One of the objects of my invention is to provide an alloy in which the three principal ingredients are chromium, nickel and cobalt but which, by other additions, is endowed with many novel and desirable characteristics entirely lacking in other alloys containing chromium, nickel and cobalt in the same proportions.

The essential ingredients of my alloy and their percentages of the total composition, by weight, are—

	Per cent
Cr	10 to 35
Ni	20 to 50
Co	20 to 50
Be	0.1 to 5
Ni+Co	55 to 80

In addition to the foregoing, I find that additions of molybdenum in quantities under 8% and preferably in the neighborhood of about 6% are particularly desirable in developing certain characteristics; the alloy with molybdenum additions being specifically claimed in my divisional application Serial No. 83,078.

The preferred ranges of my essential ingredients are—

	Per cent
Cr	20 to 30
Ni	30 to 40
Co	25 to 40
Be	from 0.1% to about 1.4% and from 1.8% to 5.0%.

I find that alloys of this character containing beryllium in the neighborhood of about 1.6% are somewhat less desirable than those containing beryllium either below or above this percentage in that the ultimate strength of the composition with this quantity of beryllium is substantially reduced. In any case the nickel content plus the cobalt content should not be less than 55% nor more than 80%.

In making my alloy the nickel, cobalt and chromium, and molybdenum if molybdenum is to be incorporated, are first melted together, and the beryllium, which has a very low specific gravity and is readily oxidizable is thereafter added. Due to the lightness of the beryllium it should be prealloyed with a heavier metal such as nickel or copper and the addition made by tying the nickel-beryllium or copper-beryllium to a rod and plunging it into the molten mass. Once

the copper or nickel-beryllium is wet it alloys readily. While the beryllium addition alone very greatly increases the fluidity of the material at casting temperatures a small amount of silicon may be added if desired, but this addition should not exceed 1%. Just before the molten mass is poured I prefer to add about 0.05% of calcium as a de-oxidizer.

One of the outstanding characteristics which distinguishes my alloy from a similar chromium-nickel-cobalt alloy without beryllium is its comparatively high yield point. For example, an alloy containing the following ingredients—

	Per cent
Cr	27.3
Ni	35.0
Co	28.7
Mo	6.0
Si	1.0
Ti	0.7
Mn	1.3

showed a tensile strength of 100,000 pounds per square inch with a yield point at 43,000 pounds per square inch. Substantially the same alloy with an addition of 4.0% of beryllium showed a tensile strength of 120,000 pounds per square inch with a yield point at 87,000 pounds per square inch. In other words, the yield point was raised more than 100% by the beryllium addition.

Again, 0.8% of beryllium added to an alloy containing nickel 35.5%, cobalt 29.5%, chromium 28.2% and molybdenum 6% raised the yield point from 45,000 pounds to 53,000 pounds per square inch.

Another very desirable characteristic is the marked improvement in the surface of the material as cast. This feature combined with a substantial reduction in the melting point, a reduction in the specific gravity, and a reduction in the shrinkage of cast specimens makes the composition particularly desirable for cast dentures and the like.

The reduction in the melting point is of particular importance because the melting point of alloys of this character is unusually high. For example, the melting points of some of the alloys containing chromium, nickel and cobalt within the above ranges, but without beryllium, are as high as 2640° F. to 2750° F. The addition of beryllium within the limits contemplated by this invention will reduce the final melting point of most of the alloys to between 2300° F. and 2500° F.

Another desirable characteristic developed by the beryllium addition is a decided reduction in

the specific gravity of the material. This is a very important factor where the material is used for prosthetic articles.

The following series of melts using, for comparative purposes, substantially the same percentages of chromium, nickel, cobalt and molybdenum, show the effect of adding various percentages of beryllium either in the form of copper-beryllium or nickel-beryllium—

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Melt No.	Base	33	34	43	44	45	46	47	48
Co.	28.7	29.5	29.0	27.7	28.2	28.6	29.6	29.2	29.5
Cr.	27.3	28.5	28.0	26.4	27.0	27.2	28.6	28.6	27.8
Ni.	35.0	35.0	34.0	31.9	33.8	34.8	35.3	35.0	35.3
Mo.	6.0	6.0	6.0	6.0	6.0	6.0	6.0	6.0	6.0
Be.		0.8	2.4	4.0	1.6	0.4	0.4	1.6	0.8
Si.	1.0			1.0	1.0	1.0			
Ti.	0.7			0.7	0.7	0.7			
Mn.	1.3			1.3	1.3	1.3			
Rockwell C-scale.	C-13	C-22	C-30	C-42	C-35	C-24	C-22	C-34	C-26
Sp. gr.	8.20	8.15	8.07	7.44	7.84	8.13	8.13	7.61	7.93
Tensile strength	100,000	110,000	130,000	120,000		100,000	89,000	67,000	100,000
Yield point	43,000	53,000	65,000	87,000		55,000	50,000	48,000	55,000
Melting points ° F.			2,450	2,300	2,327	2,480		2,340	

From the foregoing table it will be observed, among other things, that small additions of beryllium effect a remarkable increase in the hardness of the material as measured on the Rockwell C-scale. For example, the base alloy without beryllium has a hardness of C-13 whereas melt No. 43 with an addition of 4% of beryllium shows an increase in hardness to C-42, while heats Nos. 45 and 46 show that the addition of only .4% of beryllium about doubles the hardness reading.

In short, it may be said that the addition of beryllium to the chromium-nickel cobalt alloys herein described substantially changes the characteristic of the alloy in the following respects—

1. Reduces the melting point;
2. Increases the fluidity;
3. Reduces the gravity;
4. Improves the surface as cast;
5. Increases the resistance to high temperature oxidation;
6. Increases the yield point;
7. Increases the hardness;
8. Reduces the elongation;
9. Reduces the tendency of the material to react with the casting crucible; and
10. Reduces the coefficient of expansion.

All additions of beryllium within the limits disclosed above produce a substantial increase in the fluidity of the molten composition, and this characteristic is particularly marked with additions in excess of 2%. For example, when 2.4% beryllium was added to an alloy comprising cobalt 29%, chromium 28%, nickel 34% and molybdenum 6% the fluidity was increased to a point where certain thin sections could be cast which it was impossible to run with the base alloy.

Where a particularly fine surface is desired on articles cast from my alloy, as in the case of dental plates, etc., excellent results are obtained by melting the composition in an atmosphere of hydrogen and, moreover, the toughness of the casting is very substantially increased.

My base alloy set forth in the above table, and which is within the disclosure of my copending application Serial No. 58,163, is not only extremely resistant to corrosive attack by lactic acid but may be said to be practically inert thereto. The addition of beryllium does not in any way appreciably affect this highly desirable characteristic of the base alloy yet it makes possible the casting of lactic acid-resisting articles

from this type of alloy which would otherwise be impossible.

While titanium is not an essential ingredient of my alloy, additions up to say 1% or slightly more, preferably in the form of manganese titanium, may be made. Such additions facilitate the soldering and welding of the composition.

Since the beryllium is incorporated in the composition in the form of an alloy with a heavier

metal such, for example as copper, and the titanium, when employed, is preferably added as a manganese-titanium alloy, and molybdenum and silicon are permissible additions within the limits stated, it will be apparent that in addition to the principal alloying elements, chromium, nickel and cobalt and minor but effective quantities of beryllium, my alloy may contain other elements in quantities somewhat exceeding those ordinarily encountered as impurities but which do not materially affect the desirable characteristics of the composition as above set forth. Hence, the phrase, "the balance being substantially nickel and cobalt," used in the claims, is to be understood as including elements other than nickel and cobalt to the extent aforesaid.

What I claim is:

1. An alloy comprising chromium, nickel, cobalt and beryllium as essential alloying ingredients, the chromium content being from 10% to 35%, the beryllium content being from 0.1% to 5%, and the balance being substantially nickel and cobalt each between 20% and 50% with a combined nickel and cobalt content of from 55% to 80%; said alloy being characterized by a higher yield point, a substantially greater fluidity at casting temperatures, and a cleaner surface in the "as cast" condition than it would otherwise have without the beryllium.

2. An alloy comprising chromium, nickel, cobalt and beryllium as essential alloying ingredients, the chromium content being from 20% to 30%, the beryllium content being from 0.1% to 5%, and the balance being substantially nickel and cobalt; the nickel content being from 35% to 40% and the cobalt content being from 25% to 40%; said alloy being characterized by a higher yield point, a substantially greater fluidity at casting temperatures, and a cleaner surface in the "as cast" condition than it would otherwise have without the beryllium.

3. An alloy comprising chromium, nickel, cobalt and beryllium as essential alloying ingredients, the chromium content being from 10% to 35%, the beryllium content being from more than 1.6% to 5%, and the balance being substantially nickel and cobalt each between 20% and 50% with a combined nickel and cobalt content of from 55% to 80%; said alloy being characterized by a higher yield point, a substantially greater fluidity at casting temperatures, and a

cleaner surface in the "as cast" condition than it would otherwise have without the beryllium.

4. An alloy comprising chromium, nickel, cobalt and beryllium as essential alloying ingredients, the chromium content being from 20% to 30%, the beryllium content being from more than 1.6% to 5%, and the balance being substantially nickel and cobalt; the nickel content being from 35% to 40% and the cobalt content being from 25% to 40%; said alloy being characterized by a higher yield point, a substantially greater fluidity at casting temperatures, and a cleaner surface in the "as cast" condition than it would otherwise have without the beryllium.
5. An alloy comprising chromium, nickel, cobalt and beryllium as essential alloying ingredients, the chromium content being from 25% to 32%, the beryllium content being from 0.1% to 5%, and the balance being substantially nickel and cobalt; the nickel content being from 30%

to 40% and the cobalt content being from 25% to 35%; said alloy being characterized by a higher yield point, a substantially greater fluidity at casting temperatures, and a cleaner surface in the "as cast" condition than it would otherwise have without the beryllium.

6. An alloy comprising chromium, nickel, cobalt and beryllium as essential alloying ingredients, the chromium content being from 25% to 32%, the beryllium content being from more than 1.6% to 5%, and the balance being substantially nickel and cobalt; the nickel content being from 30% to 40% and the cobalt content being from 25% to 35%; said alloy being characterized by a higher yield point, a substantially greater fluidity at casting temperatures, and cleaner surface in the "as cast" condition than it would otherwise have without the beryllium.

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