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ALLOY

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1 Claim. (Cl. 75—134)

This application is a division of my application Serial No. 58,163 filed January 8, 1936.

My invention relates to alloys and particularly to alloys having especially high resistance to attack by various corrosive media. It also relates to alloys particularly adapted for making prosthetic articles such, for example, as dentures.

So far as I am aware there are no commercial alloys at present available which are not subject to attack by lactic acid.

Chrome-nickel steels of the so-called 18—8 type, for example, while highly resistant to atmospheric corrosion and to various other media are easily corroded by lactic acid, as are also the high nickel-chromium alloys of the so-called "Nichrome" type, and the high cobalt-chromium alloys of the so-called "Stellite" type.

It is well known that lactic acid is formed in the mouth, and recent investigations have shown that individuals whose teeth are subject to rapid decay and who by reason of this fact must provide themselves with artificial teeth generate lactic acid to a greater extent than do individuals whose teeth remain sound for many years. Lactic acid is also present in milk and milk products, and is encountered in fermentation processes involving other substances.

Hence, it is particularly desirable that alloys to be used in the manufacture of dentures, and in apparatus and equipment for use in the dairying, ice cream, brewing, pasteurizing and other industries should be as resistant as possible to the corrosive influences of this acid. In many of these industries the alloy should be capable of satisfactorily withstanding attack by lactic acid at comparatively high temperatures such as those encountered in pasteurizing, sterilizing, etc., as well as at normal atmospheric temperatures.

In my copending application Serial No. 738,816 filed August 7, 1934, of which application Serial No. 58,163 aforesaid is a continuation in part, I have disclosed a base alloy comprising nickel, chromium and cobalt to which minor quantities of molybdenum, titanium and silicon may be added and which exhibits remarkable resistance to attack when submerged for long periods in a 12% solution of lactic acid in temperatures of the order of 180° F. to 190° F.

In that application the base alloy disclosed contains the following ingredients:

	Percent
Ni	32 to 40
Cr	27 to 35
Co	24 to 30

This base alloy in and of itself, as pointed out above, shows extremely high resistance to lactic acid which is substantially enhanced by the addition of up to about 7% or 8% of molybdenum, the preferred molybdenum content being in the neighborhood of about 6%. Molybdenum also increases the resistance of the alloy to hydrochloric acid.

Alloys for the purposes which I have in mind should be readily workable, and hence I prefer to keep the molybdenum content in the neighborhood of about 6%. Additions of molybdenum up to as high as 16% do not deleteriously affect the corrosion resistant characteristics of the composition, but a molybdenum content in excess of about 7% or 8% markedly decreases the workability of the alloy and it approaches the class of alloys adapted for high speed tools. Particularly where small quantities of other elements are present such as silicon, manganese, titanium or beryllium, which may be added to enhance certain characteristics of the alloy, such as its hardness, fluidity, etc., molybdenum within the preferred ranges stated above seems to offset the marked reduction in corrosion resistance of the alloy which follows the addition of these elements alone or in combination. Experiments have shown that slightly lower percentages of chromium, lower percentages of nickel, and both lower and higher percentages of cobalt may be advantageously employed than are disclosed in my said copending application provided, certain preferred ratios between the nickel and the cobalt and between the total of the nickel and cobalt and the chromium are maintained. In other words, my base alloy may contain the following ingredients—

	Percent
Ni	20 to under 50
Cr	20 to 33
Co	from 20 to 50

The following examples of my composition are illustrative of my invention.

Nos.	Percent Ni	Percent Co	Percent Cr	Percent Mo	Percent Mn Ti	Percent Si	Percent Be	Percent W	Percent Cu Be
21	35.8	29.3	27.9	4	2.0	1.0			
25	35.4	29.0	27.6	6	2.0	1.0			
27	31.7	25.9	24.7	16	2.0	1.0			
31	37.2	30.6	29.2		2.0	1.0			
33	36.0	29.3	27.9	6			0.8		
51	38.1	31.2	29.7						1.0
57	38.5	31.5	30.0						
58	36.2	29.6	28.2	6					
60	20.0	45.3	27.9	6			0.8		
61	34.8	28.4	27.0	9			0.8		
62	33.7	27.4	26.1	12			0.8		
63	33.4	27.2	32.6	6			0.8		
64	20.0	40.6	32.6	6			0.8		
65	36.0	29.3	27.9				0.8	6.0	

In the above table Mn Ti indicates manganese-titanium containing 30% of titanium, while Cu Be is copper-beryllium containing 80% of beryllium.

Highly polished specimens of all of these compositions were tested by immersion in a 12% lactic acid solution maintained at a temperature of from 180° F. to 190° F. In addition, stainless steel containing 18% of chromium and 8% of nickel, "Nichrome" containing 80% of nickel and 20% of chromium and "Stellite" containing 69.3% of cobalt and 29.7% of chromium and 1% of copper-beryllium were subjected to the same test for comparative purposes.

At the end of 200 hours, specimens Nos. 21, 25, 27, 58, 60, 61, 62, 63, and 64 of my alloy were not discolored. The nichrome and stellite compositions were badly corroded in 1½ hours, and the solution containing the stainless steel was badly discolored in 7 hours, indicating that the alloy had been attacked.

Certain elements, such as tungsten and beryllium when added alone or in combination to the base alloy exert a deleterious influence upon its resistance to the lactic acid test. The effect of beryllium in this respect can be overcome by incorporating molybdenum in the base alloy within the limits above set forth but this is not true of tungsten. Other elements such as the copper, manganese, titanium and silicon also lower the general resistance to corrosion when molybdenum is not present. This is substantiated by lactic acid tests, as above described, on specimens 31, 33, 51, 57, and 65. Specimens 31, 51 and 65 corroded in 1½ hours. Specimen 33 corroded in 19 hours while specimen 57 which is the base alloy withstood the test for 72 hours without discoloring, indicating that the base alloy itself has extremely high resistance to attack.

As an example of the corrosion resistant characteristics of my alloy when subjected to other media, specimen No. 58 was tested in a tincture of iodine solution using a "Nichrome" specimen containing 80% of nickel and 20% of chromium as a control. The nichrome was badly attacked in two days and the iodine solution in which it was submerged had decomposed, but specimen 58 was not visibly attacked.

Specimens 57 and 58 were immersed in phosphoric acid at a temperature of 212° F. for 8 hours without attack. In boiling phosphoric acid both specimens were attacked, but specimen 58 showed the best resistance to this medium.

A solution of ammonium poly-sulphite $(NH_4)xS$ is recommended by the Bureau of Standards as a proper test for the inertness of nickel alloys. Specimens Nos. 25 and 33 when subjected to the fumes of this solution were not discolored. Nichrome, however, was discolored in two days.

Comparative tests of 18—8 steel and a specimen of my alloy containing approximately—

	Percent
Ni	38
Co	32
Cr	26
Mo	4

in a hot 20% salt spray for 30 hours showed that the steel became appreciably coated with rust while my alloy maintained its initially bright appearance and was not visibly affected in any way.

All of my alloys are characterized by extremely high resistance to lactic acid and to the corrosive action of most other media, but changes in the proportions of the ingredients or the addition of other elements may somewhat affect the corrosion resistance as against these other media. For example, specimen 25 is attacked by a 20% sulphuric acid solution at 212° F., and by a boiling solution of caustic soda, while specimen 33 is not. On the other hand, specimen 25 is more resistant to lactic acid than specimen 33.

For certain specific uses such as casting, molybdenum is a desirable element because it lowers the melting point of the alloy, increases its fluidity at casting temperatures and improves the melting characteristics in general. Where the casting includes attenuated portions such as in dental bridgework, the addition of small quantities of manganese-titanium as a deoxidizer and denitrifier will be found advantageous. The manganese-titanium aids in keeping the alloy clean upon recasting. In some cases, if desired, small portions of calcium, about 0.1% may be added to the melt before casting to further deoxidize the metal.

My alloy is easy to form and cast, has a tensile strength greater than the ordinary nichrome alloys, is quite ductile and yet its yield point is sufficiently high so that in use as a denture it successfully resists the normal forces tending to cause deformation. Its hardness reaches a greater degree than that of nichrome alloys of the ordinary form containing about 80% nickel. The hardness varies from about C—10 to C—25 on the Rockwell scale which places it intermediate in hardness between the ordinary casting gold used in making dentures and alloys of the cobalt-chromium type such as are used for this purpose. This intermediate hardness gives it a particularly desirable position as a sort of compromise between quite soft and very hard alloys and so is most satisfactory to the majority of dentists who desire an alloy which, while having the most desirable properties, is of sufficient ductility to allow desired adjustments

upon partially finished dentures without danger of breaking by reason of too great brittleness which usually accompanies excessive hardness.

My alloys are, generally speaking, malleable, forgeable and otherwise workable. Where an especially easily workable alloy is desired, it will be found advisable to keep the chromium below 30% and the molybdenum under 6%.

It is to be understood that the percentages of the various elements stated above are percentages by weight of the total alloy.

In general, the cobalt is present in the higher portions of its range when the nickel is present in its lower portions and vice versa, and the total of the chromium, nickel and cobalt will be between 90% and substantially 100% of the total alloy. Hence, the term, "substantially all cobalt" as used in the claim is to be understood as including cobalt and incidental impurities.

While my invention is in no sense limited to chromium, cobalt and nickel in the following ratios as will be apparent from a consideration of the examples given above, very excellent results are obtained if the ratio of the nickel to the cobalt is between about 0.45 and 1.25 and the ratio of the sum of the nickel and the cobalt to the chromium is between about 1.85 and 2.35.

What I claim is:

A workable alloy having high resistance to lactic acid in solutions of the order of 12% at temperatures of the order of 180° to 190° F., and containing as essential alloying ingredients chromium, nickel, cobalt and molybdenum; the chromium content being from 20% to 33%, the nickel being from 20% to under 50%, the molybdenum being from 1% to under 7%, and the balance being substantially all cobalt and within the limits of 20% to 50%.

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