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**BERYLLIUM STRENGTHENED IRON
BASE ALLOY**

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This invention relates to and has for its principal ob-
ject the provision of a beryllium strengthened iron base
alloy which retains high strength characteristics at tem-
peratures as high as 1400° F.

Iron base alloys such as chromium, cobalt and/or
nickel steels that may additionally contain effective pro-
portions of tungsten, vanadium, tantalum, columbium,
aluminum and other alloying elements are extensively used
in industry. On the basis of cost, it is highly advantageous
to consider the use of such steel alloys for many indus-
trial applications when the properties of the steels are ade-
quate to withstand the forces and other conditions en-
countered in use. Steels of this type are used in the manu-
facture of automotive engine parts, aircraft structural
members, high temperature bolting, bearing and spring
articles and the like. For example, there are over one
hundred specific steel alloys that are proposed to be suit-
able for use as wheels and hardware in turbine engines.
Obviously, constant improvements are avidly sought in
this class of iron-base alloys. Especially desired are new
alloys with a favorable strength-to-density ratio.

Broadly stated the alloy of the invention comprises a
low density chromium-cobalt-nickel iron-base alloy which
has been strengthened with effective amounts of beryllium
and molybdenum.

For ease of reference, the range in weight percents of
the various constituents which are or may be included
in alloys which fall within the scope of the subject inven-
tion are set forth below in Table I.

TABLE I

	Broad	Preferred	Optimum
Chromium.....	20-23.2	20.1-23.2	About 21.0.
Cobalt.....	10-16	10.12-15.45	About 13.0.
Nickel.....	10-16	12.44-15.52	About 13.0.
Molybdenum.....	2.3-5	2.65-4.6	About 3.25.
Beryllium.....	.5-1.1	.62-1.03	About .80.
Carbon.....	Up to 1.2	.05-1.12	.30-.60.
Silicon.....	Up to 1.0	.01-.92	.10-.85.
Carbon and Silicon.....	.25-1.5	.27-1.23	.40-1.0.
Tungsten.....	Up to 2.0	.5-1.93	.75-1.5.
Manganese.....	Up to 2.0	.46-1.80	About 1.5.
Aluminum and Nitro- gen.....	Up to .6	Up to .5	Up to .3.
Boron.....	Up to .025	Up to .02	Up to .017.
Columbium and Tan- talam.....	Up to 1.0	Up to 1.0	Up to 1.0.
Iron and Impurities....	Balance	38-53	40-50.

In addition the following formulae must be satisfied
by an alloy within the scope of the invention.

	Broad	Preferred	Optimum
I.....	$42 > Cr + Co + Mo > 33$	$40 > Cr + Co + Mo > 35$	$39 > Cr + Co + Mo > 37$
II.....	$Co \cong Ni = 13 \pm 3$	$Co \cong Ni = 13 \pm 2$	$Co = Ni = 13$

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The importance and relationship of the various con-
stituents of the alloy invention will be fully discussed
below.

The chromium content is very critical in the alloy of
this invention. It was found that alloys with less than
about 20 percent chromium did not have adequate cor-
rosion and oxidation resistance. Alloys containing more
than about 23.2 percent chromium were difficult to hot
work and had low room temperature ductility.

Both cobalt and nickel must be present in the subject
alloy to provide a critically proportioned matrix consist-
ing essentially of iron, cobalt, nickel and chromium.

It should be particularly noted that both nickel and
cobalt are required in the alloys of this invention. These
elements are not equivalents in the subject alloy as is
sometimes the case in various alloy steel families. On the
contrary, it is essential in the alloy of this invention that
both nickel and cobalt are present in the alloy in about
equal amounts, each within the range 10 to 16 percent
and preferably each at about 13 percent. This relationship
may be stated by the expression:

$$Co \cong Ni = 13 \pm 3$$

Where: The values represent weight percent each in the
alloy. The symbols represent the respective element
present in weight percent.

Test results have indicated that every deviation from
this range yields alloys that do not have the desirable
combination of physical and mechanical properties and
good working characteristics that are possessed by the
alloys of the invention.

Beryllium must be present in the alloy in the amount
indicated to provide a strengthening effect to the alloy,
and the molybdenum constituent optimizes this effect.

The specific strengthening mechanism of the subject
alloys is not completely understood. It appears that the
novel combination of the essential elements results in a
variety of strengthening and hardening mechanisms, i.e.,
(1) principally the formation of intermetallic compounds
containing beryllium, (2) compounds containing, as
present, carbon, silicon, aluminum and/or nitrogen, (3)
solid solution strengthening (Cr-Co-Ni-Fe) and/or
other possible mechanisms. The desirable high-tempera-
ture properties of the alloy of this invention appear to be
provided by the presence of chromium and the proper
combination of cobalt (balanced with nickel) and molyb-
denum together with beryllium. Chromium provides oxida-
tion and corrosion resistance; cobalt provides high tem-
perature stability, hardness, and strength; and molyb-
denum provides strength. It has been determined that the
combined chromium, cobalt and molybdenum content
must total not less than about 33 percent nor more than
about 42 percent of the alloy. This relationship may be
stated by the expression:

$$42 > Cr + Co + Mo > 33$$

Where: The values represent total content in weight percent. The symbols represent the respective element present in weight percent.

Although molybdenum and tungsten are at times considered as equivalents in some alloy systems, this is not the case for the alloy of this invention. It was discovered that molybdenum is essential within the range from about 2.3 to about 5 percent in the strengthening and hardening mechanism of the alloy. Tungsten is usually associated with molybdenum in commercial raw materials and therefore, tungsten may be tolerated in the alloy up to about 2.0 percent.

Surprisingly, it has been determined that the alloys of this invention do not require carbon as an essential or critical element. Further, silicon is not required in the alloy. The data in Table II and Table V (set forth below), relating to Alloys 7, 9, 10, 18 and 20 show that

percent. Boron when present has been found to improve the high temperature stress-rupture properties of the alloy. The rupture life of a given alloy improves with increasing boron content within the permissible range. Alloys 21-23 of Table II which are identical except for increasing boron content were found to have a rupture life in hours at 1200° F. and 60,000 p.s.i. of 127.7, 154.8 and 267.0 hours respectively.

Less than about 0.5 percent aluminum may be tolerated in the alloy as a residual of the deoxidizing step. Nitrogen may be present in the alloy up to a maximum of about 0.2 percent, although the aluminum plus nitrogen content should not exceed about 0.6 percent. Nitrogen is often added to alloys of this class to stabilize the austenitic structure.

A representative number of alloys which are within the scope of the subject invention are set forth below in Table II.

TABLE II.—COMPOSITIONS OF IRON-BASE ALLOYS OF THE INVENTION
[Weight percent]

Alloy	Cr	W	Fe	C	Co	Ni	Mn	Mo	Cb/Ta	Be	Si	Al	N	B
1	20.94	1.47	44.70	0.33	11.60	13.80	0.88	4.02	0.78	0.79	0.35	0.16		
2	21.33	1.38	43.10	0.32	11.64	13.60	1.32	4.56	0.69	0.62	0.66	0.24		
3	21.22	1.54	43.30	0.31	11.93	13.28	1.52	4.43	0.76	0.82	0.76			
4	21.21	1.44	42.36	0.34	12.14	15.62	0.54	4.43	0.67	0.65	0.56	0.14		
5	21.69	1.55	39.38	0.32	15.45	12.44	1.60	4.43	0.76	1.03	0.49	0.10		
6	21.41	1.56	45.32	0.23	11.81	13.60	0.46	4.52	0.66	0.69	0.34	0.05		
7	21.69	1.51	44.40	0.26	11.94	13.22	0.56	4.60	0.75	0.84	0.01			
8	21.69	1.51	43.80	0.31	11.62	12.04	0.64	4.60	0.84	0.77	0.92			
9	21.69	1.48	44.60	0.27	11.94	13.44	0.56	4.60	0.65	0.63	0.01			
10	22.06	1.50	44.25	0.34	11.82	13.52	0.62	3.52	0.33	0.94	0.10			
11	21.47	0.94	46.75	0.26	10.75	13.44	1.44	3.82	0.65	0.63	0.28			
12	20.51	0.75	46.38	0.23	10.12	13.76	1.48	4.20	0.78	0.65	0.32			
13	20.57	1.02	44.75	0.29	12.80	13.32	0.80	3.32	0.70	0.70	0.58	0.47		
14	20.10	1.29	44.75	0.32	13.32	13.68	1.32	3.42	0.71	0.84	0.41	0.05		
15	20.38	1.92	44.37	0.29	13.20	13.72	1.44	2.65	0.71	0.88	0.40	0.10		
16	20.87	1.03	44.87	0.30	12.34	13.60	1.36	3.68	0.66	0.75	0.29		0.17	
17	20.40	0.60	47.10	0.22	11.50	13.00	1.60	3.34		0.76	0.32	0.06		
18	21.63	0.63	45.90	0.09	12.06	13.12	1.80	3.34		0.87	0.35		0.05	
19	20.60	1.08	44.13	0.48	11.61	13.60	1.60	3.49	0.78	0.81	0.33	0.17		
20	20.11	1.05	44.75	0.05	12.34	13.40	1.76	3.64	0.14	0.89	0.44	0.12		
21	23.18	1.04	43.63	0.53	12.00	13.40	0.56	3.20	0.76	0.84	0.54			0.005
22	23.18	1.04	43.63	0.53	12.00	13.40	0.56	3.20	0.76	0.78	0.54			0.011
23	23.18	1.04	43.63	0.53	12.00	13.40	0.56	3.20	0.76	0.77	0.54			0.017
24	20.71	1.02	45.38	0.45	11.50	12.94	1.76	3.71	0.76	0.85	0.38			
25	20.60	1.08	44.13	1.14	11.61	13.60	1.60	3.49	0.78	0.81	0.33	0.17		

either carbon or silicon may be present only as impurities in the alloys of this invention provided that the total content of carbon plus silicon equals at least 0.25 percent. Thus, it appears that carbon and silicon are interchangeable in any proportion within the range, 0.25 to 1.25 percent. This is completely unexpected for iron-base alloys of this class. The carbon content in various iron-base alloys (especially steels) is usually extremely critical. However, when alloys are prepared within the composition ranges of this invention, the alloy retains excellent physical, mechanical, and chemical properties, although, as shown in the tables, the carbon content varied from about 0.05 to over 1.0 percent. As stated above, it is believed that, within the specified ranges as set forth in Table I, the various hardening elements are combined with beryllium to yield a desirable balance of intermetallic compounds in a cobalt- and nickel-rich iron-base matrix. Thus, the alloy of this invention does not depend upon precise stoichiometric proportions of metals and carbon to form carbides as the principal strengthening mechanism of the alloy.

Manganese may be present in the alloy up to about 2.0 percent to provide certain metallurgical characteristics and other benefits known in the art. Columbium plus tantalum may be present in the alloy up to 1.0 percent to provide stable carbides for strength at higher temperatures. However, as shown in Table II and Table V, Alloys 6, 17, 18 and 20, columbium plus tantalum may be omitted from or present only as an impurity in the alloy for service in general applications.

Boron may be present in the alloy up to about .025

The alloys of this invention attain the maximum strength and hardness after a solution heat-treatment and an aging or precipitation heat-treatment. Various heat-treatment parameters were tested, as shown in Tables III and IV.

TABLE III.—HEAT-TREATMENT OF TESTED ALLOYS—SCHEDULE NO.

[See Table IV for schedule]

Alloy No.	Tensile Test Temperature			
	Room Temperature	1,000° F.	1,200° F.	1,400° F.
55				
1	12			18
2	17		12	18
3			12	18
4		11		12
5	15			10
6	15		16	10
7		15	11	14
8		11	11	13
9		11	12	10
10			10	10
65				
11	7	7	7	7
12		4	5	6
13	7	7	9	7
14	7	7	9	7
15	7	7	7	7
16	3	3	3	3
17				2
18				2
70				
19	1	1		1
20				
21	7			7
22	7			7
23	7			7
24	7			7
75				

TABLE IV.—VARIATIONS OF HEAT TREATMENTS

Schedule	Solution Treatment			Aging Treatment				
	Time, min.	Temp., ° F.	Cooling	Time, min.	Temp., ° F.	Cooling	Time, hr.	Temp., ° F.
1	15-60	2,075	WQ	2	1,200			
2	15-60	2,075	WQ	8-16	1,000	AC	2	1,200
3	10	2,100	WQ	16	1,000			
4	20	2,050	WQ	8	1,000			
5	15	2,100	RAC	2	1,200			
6	15	2,100	RAC	1	1,400			
7	15	2,075	WQ	2	1,200			
8	15	2,075	WQ	2	1,200			
9	15	2,125	WQ	2	1,200			
10	15	2,050	WQ	1	1,400			
11	15	2,050	WQ	2	1,200			
12	15	2,125	WQ	1	1,400			
13	15	2,050	WQ	24	1,200			
14	15	2,125	WQ	1	1,400			
15	15	2,050	WQ	4-8	1,000			
16	30	1,950	WQ	1	1,400			
17	15	2,125	WQ	3	950			
18	15	2,125	WQ	2	1,400			

WQ—water quenched; RAC—rapid air cooled by fan; AC—air cooled.

TABLE V.—TENSILE PROPERTIES OF THE ALLOYS

Alloy No.	Room Temperature			1,000° F.			1,200° F.			1,400° F.		
	Ultimate Strength, K s.i.	Yield Strength, K s.i.	Elongation, Percent	Ultimate Strength, K s.i.	Yield Strength, K s.i.	Elongation, Percent	Ultimate Strength, K s.i.	Yield Strength, K s.i.	Elongation, Percent	Ultimate Strength, K s.i.	Yield Strength, K s.i.	Elongation, Percent
1	214.3	178.2	8.5							127.5	102.4	3.0
2	206.0	160.0	4.2				183.0	129.0	1.7	105.8	83.2	4.8
3							137.0	86.0	2.7	82.8	56.0	5.0
4				160.8	126.0	2.6				112.6	86.1	7.8
5	205.3	171.7	* BOGM	186.5	124.3	4.0				81.1	74.9	4.2
6	186.6	129.1	14.0	152.0	103.0	13.0				103.0	77.8	12.0
7				193.6	142.2	3.2	115.6	86.9	4.1	99.2	72.1	10.6
8				128.8	97.6	6.7	159.7	117.9	10.7			
9				137.5	104.6	3.8	110.6	81.1	10.3			
10							127.9	98.5	13.0	104.6	79.3	16.8
11				131.9	95.1	9.6	139.1	96.2	4.8	88.5	60.2	17.9
12	169.4	152.2	11.4	160.1	124.2	15.4	119.1	88.8	14.2	93.4	74.6	13.6
13	198.2	196.6	3.3	168.1	130.7	6.4	133.2	96.1	2.8	81.6	52.9	11.2
13A	120.8	67.7	30.1				126.0	106.6	10.6	114.7	88.6	14.7
14	193.9	185.5	6.2	170.3	132.8	5.2	166.5	129.5	9.1	123.0	98.7	4.4
14A	115.2	66.8	26.7									
15	203.3	199.3	3.2	176.3	126.8	7.1	157.9	124.1	6.0	112.5	79.5	9.3
15A	125.0	68.9	23.9									
16	158.2	71.1	14.0	121.0	89.3	12.3	137.0	113.1	5.1	89.5	77.3	2.7
17							154.8	123.0	7.1			
18							139.7	112.6	9.5			
19	218.5	183.3	6.9	188.7	154.0	8.3	168.8	139.5	3.4	123.6	100.1	13.8
19A							172.6	133.7	5.5			
20							164.3	114.2	11.5			
21	205.8	164.1	2.3				155.4	122.3	6.5			
22							154.4	115.9	6.1			
23	204.8	169.6	2.3				155.8	119.8	8.4			
24	216.1	180.8	4.8	189.5	158.9	6.1	177.6	143.3	5.2	132.0	106.9	5.0

* Broke outside gage mark used for measuring.

As seen in Table IV, the solution treatment temperature was varied from about 1950 to about 2125° F. and the time at temperature from about 10 minutes to about 60 minutes. As more fully discussed below, best results were obtained with the solution heat-treatment at the higher temperatures, as shown by the data; therefore, the range of about 2050 to 2125° F. for about 15 or longer minutes is preferred.

Following the solution heat-treatment, the alloys were water quenched, except when Schedule Nos. 5 and 6 were employed wherein air cooling with a fan was the cooling medium. Satisfactory results were obtained with both cooling methods.

A very broad range of precipitation heat-treatments was used during the testing program as shown in Table IV. Temperatures ranged from about 950 to 1400° F. for times from 1 to 24 hours. All yielded good results. The precipitation heat-treatment parameters do not appear to be particularly critical; however, the best practice to fit a specific condition may be determined within the skill of the art. The broad range of effective heat-treatment

parameters is desirable in the processing of commercial products on the basis of production costs.

Table V presents the tensile properties of the alloys listed in Table II after they were worked into sheets about .063 inch thick and heat-treated according to Tables III and IV.

As seen from the data of Table V, the alloys of the subject invention have excellent tensile strength through 1400° F. In addition, welding tests have been conducted which show that the alloys can be welded in the annealed condition and repair welded in the aged condition without difficulty. Strips were welded in the aged condition and subsequently reaged without any cracking occurring. In addition, the hot forgeability of the preferred composition has been found to be outstanding.

It was further discovered that the alloy of the invention is equally useful in the form of castings. As an illustration Alloy 25 of Table II was prepared in the form of a number of cast-to-shape articles. The as-cast articles were heat treated for eight hours at 1000° F., followed by air cooling, to enhance their physical and mechanical properties

by means of solid solution and precipitation strengthening mechanisms. The as-cast articles were found to have an average Rockwell "C" hardness of 16 to 18 while the average hardness of the precipitation strengthened articles was about 32 to 35.

Another particularly attractive feature of the alloy of the invention is its low density. A preferred alloy composition has a density of 0.281 lb./in.³. In aircraft or rocket applications, a severe penalty is paid for excess weight caused by high density alloys.

Specific preferred alloys of this invention exhibit superior strength-to-density ratios when compared to even the best of the nickel-base superalloys currently in use.

A useful and presently widely used alloy (19 Cr, 4.5 Fe, 0.10 C, 0.5 Si, 11 Co, 3.2 Ti, 10 Mo, 1.5 Al, 0.008 B, bal Ni) at 1200° F. has a yield strength-to-density ratio of 454,000 inches. Specific preferred alloys of this invention have been shown to have a yield strength-to-density ratio of about 510,000 inches.

Further, the alloys of this invention have a significantly superior strength-to-density ratio to other iron-base beryllium-hardened alloys known in the art which cannot be heat-treated above 2000° F. without fear of adverse effects (as is more fully detailed below). For example, an alloy known in the art containing nominally 13.0 Ni, 0.3 C, 17.0 Cr, 2.0 Mo, 1.0 W, 0.5 Si, 1.5 Mn, 0.8 Cb, 1.0 Be, 63.0 Fe plus normal impurities has an ultimate strength-to-density ratio of 433,000 inches at 1200° F. compared to 630,000 inches for a preferred alloy of this invention; this is a 45 percent superiority.

Furthermore, it should be pointed out that the alloy of the subject invention is not merely an equivalent or alternative to other beryllium containing iron-base alloys which however, do not meet all the critical limitations of the inventive alloy. For example, it is known in the art that iron-base alloys containing nickel can be strengthened by the addition of beryllium which causes precipitation hardening. Because of the low incipient fusion temperature and other metallurgical reactions which occur in these nickel containing alloys near 2000° F., the maximum temperature of heat-treatment is limited to about 2000° F.

Alloys within the scope of the subject invention wherein the critical cobalt-nickel relationship is satisfied have been heat-treated at temperatures as high as 2125° F. (as seen in Table IV) without serious adverse effects. The discovery that cobalt in conjunction with the critical amounts of chromium and molybdenum as well as nickel, as noted, yields alloys with significantly higher incipient fusion temperatures than those for similar alloys of this type which are known in the art, permits the alloy of this invention to be heat-treated at higher temperatures.

Further, it has been found that annealing temperatures of approximately 2075 to 2100° F. better prepare the alloys of this invention for subsequent strengthening by precipitation from solid solution. For example, Alloy No. 15 of this invention when annealed at 1900±25° F. and then aged 2 hours at 1200° F. had 0.2 percent offset yield strengths of 64.0 s.i. and an ultimate strength of 99.5 K s.i. at 1200° F. Material from the same heat of Alloy No. 15 when annealed at 2075 to 2100° F. and then aged 2 hours at 1200° F. had a 0.2 percent offset yield strength of 124.1 K s.i. and an ultimate strength of 157.9 K s.i. at 1200° F.

Thus it can be seen that cobalt stabilizes the alloy of this invention, thereby, permitting higher heat-treatment temperatures to endure exposure of the alloy at the maximum temperature levels (about 2100° F.).

The alloys of this invention have superior high temperature strength/to density characteristics compared to those incapable of being heat-treated at these higher temperatures.

As a final example of the uniqueness of the alloy of the invention, a prior art alloy containing 20.36 Cr, 1.55 W, 43.10 Fe, 0.26 C, 24.26 Co, 3.69 Ni, 0.54 Mn, 4.10 Mo, 0.69 Cb+Ta, 0.01 Si and 0.78 Be plus impurities was

shown to be capable of age hardening. This hardening reaction caused ultimate tensile strengths as high as 153.8 K s.i. at 1200° F. Such an alloy could be used at room temperature for such application as where wear resistance was of importance, but unfortunately the oxidation rate of the alloy and the tendency to overage at service temperatures was excessive and rendered the alloy unacceptable for high temperature use.

Thus it will be seen that alloys with the optimum properties of high strength-to-density ratio, oxidation resistance, and aged stability must conform to the Formulae I and II noted previously.

What is claimed is:

1. A beryllium strengthened iron base alloy consisting essentially of in weight percents from about 20 to about 23.2% chromium, from about 10 to about 16% cobalt, from about 10 to about 16% nickel, from about 2.3 to about 5% molybdenum, from about .5 to about 1.1% beryllium, and from about .25 to about 1.5% carbon plus silicon, balance iron and impurities, said alloy being further characterized in that the chromium plus cobalt plus molybdenum content is at least about 33% but not more than about 42% of said alloy, and said cobalt and nickel contents are approximately equal to one another and equal to about 13%±3% of said alloy.

2. A beryllium strengthened iron base alloy consisting essentially of in weight percents from about 20 to about 23.2% chromium, from about 10 to about 16% cobalt, from about 10 to about 16% nickel, from about 2.3 to about 5% molybdenum, from about .5 to about 1.1% beryllium, up to about 2% tungsten, up to about 2% manganese, up to about .6% aluminum plus nitrogen, up to about .025% boron, up to about 1.0% columbium plus tantalum, up to about 1.2% carbon, up to about 1.0% to about 1.5%, balance iron and impurities.

3. A beryllium strengthened iron base alloy consisting essentially of in weight percents about 21% chromium, about 13% nickel, about 13% cobalt, about 3.25% molybdenum, about .8% beryllium, from about .75 to about 1.5% tungsten, about 1.5% manganese, from about .3 to about .6% carbon, from about .10 to about .85% silicon, balance iron and impurities.

4. A beryllium strengthened iron base alloy consisting essentially of in weight percents about 21% chromium, about 13% nickel, about 13% cobalt, about 3.25% molybdenum, about .8% beryllium, about 1% tungsten, about 1.5% manganese, about .35% carbon, about .4% silicon, about .7% columbium plus tantalum, balance iron and impurities.

5. A beryllium strengthened iron base alloy consisting essentially of in weight percents about 20.1% chromium, about 13.3% cobalt, about 13.7% nickel, about 3.4% molybdenum, about .84% beryllium, about 1.29% tungsten, about 1.32% manganese about .32% carbon, about .41% silicon, about .71% columbium plus tantalum, about .05% aluminum, balance iron and incidental impurities.

6. A beryllium strengthened iron base alloy consisting essentially of in weight percents about 20.6% chromium, about 11.6% cobalt, about 13.6% nickel, about 3.5% molybdenum, about .81% beryllium, about 1.08% tungsten, about 1.6% manganese, about .48% carbon, about .33% silicon, about .78% columbium plus tantalum, about .17% aluminum, balance iron and incidental impurities.

7. A beryllium strengthened iron base alloy consisting essentially of in weight percents about 23.2% chromium, about 12.0% cobalt, about 13.4% nickel, about 3.2% molybdenum, about .77% beryllium, about 1.04% tungsten, about .56% manganese, about .53% carbon, about .54% silicon, about .76% columbium plus tantalum, about .017% boron, balance iron and incidental impurities.

8. A beryllium strengthened iron base alloy consisting essentially of in weight percents about 20.6% chromium, about 11.6% cobalt, about 13.6% nickel, about 3.5% molybdenum, about .81% beryllium, about 1.08% tungsten, 1.6% manganese, about 1.14% carbon, about .33%

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silicon, about .78% columbium plus tantalum, about
.17% aluminum, balance iron and incidental impurities.

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