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ALLOY STEEL AND METHOD

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My invention is concerned with the chromium-nickel alloy steels and more particularly the heat-hardenable chromium-nickel stainless steels.

One of the objects of my invention is to provide a chromium-nickel-molybdenum alloy steel which readily lends itself to forming, shaping and other fabrication in the annealed condition and which is capable of being hardened from the annealed condition with simple low-temperature ageing treatment to achieve high strength and hardness at both low temperatures and high temperatures.

A further object is to provide a method for conditioning alloy steels of the character described wherein, following shaping, forming or other fabrication, the metal is thereafter quickly, economically and reliably hardened and strengthened by way of a simple and comparatively low-temperature ageing treatment of relatively short duration.

Other objects of my invention and advantages of the same will be obvious in part and in part more fully pointed out during the course of the following disclosure.

My invention therefore resides in the combination of elements, in the compositions of materials, in the several operational steps, and in the relation of each of the same to one or more of the others as described herein, the scope of the application of which is indicated in the claims at the end of this specification.

In order to better understand my invention, it may be noted at this point that the invention is directed primarily to an improvement in the chromium-nickel alloy steels. Of this group of steels the well-known austenitic chromium-nickel grades are defined as having a chromium content ranging from about 10% to 35%. The nickel content may range from something above 0% on up to 25% or more, nickel being included for the dual purpose of improving the stainless qualities of the steel and controlling the structure of the steel and with this the softness, ductility, and magnetic qualities thereof. With nickel high the steel is essentially austenitic. Conversely, with nickel low relative to chromium, the metal is either typically martensitic or ferritic, depending upon the carbon content.

In the known-chromium-nickel alloy steels various alloying metals may be included in small amounts to impart special properties. Typical of these are aluminum, copper, molybdenum, manganese, cobalt, silicon, sulphur, phosphorus, tungsten, vanadium, titanium, columbium and the like. The remainder of the composition is substantially all iron. Usually the steels are of low carbon content, say about 0.03% to a maximum of about 0.20%. For special purposes, however, the carbon content may be substantially higher.

The 18–8 chromium-nickel stainless steel, of course, is characteristically austenitic. And such an austenitic steel is non-magnetic. It hardens upon working by

known forming, working or machining operations at room temperature. Moreover, it work-hardens as by riveting, or like joining treatment. Such a steel, however, with its high values of both chromium and nickel, is virtually immune to phase-transformation when subjected to heating and a subsequent quench. The soft austenitic condition, characteristic of the steel, is retained throughout heat-treatment; the steel is not hardenable by heat-treating methods to improve strength and hardness. In some respects this is viewed as a disadvantage.

A further disadvantage of the austenitic chromium-nickel stainless steels is that upon rolling, drawing, or other work conducted in a single direction, the work-hardening effect essentially is along the direction of working and the mechanical properties transverse of the direction of working are not developed to the same extent as those in the working direction. The disparity is particularly noted in compression. In many applications a difference in the longitudinal and transverse compressive strengths is not acceptable.

Moreover, in the austenitic chromium-nickel stainless steels the tendency to harden in working requires frequent interruption of the working operation to relieve the strains induced by working, as by subjecting the metal to intermediate anneal. And frequently, such intermediate anneal is attended by a loss of the nice dimensionality imparted the products, as through light scaling, or perhaps distortion.

As contrasted with the well-known austenitic chromium-nickel stainless steels briefly discussed above, there are the precipitation-hardenable chromium-nickel stainless steels, that is, the chromium-nickel stainless steels which are hardenable by heat-treatment. Typical of these are the Armco 17–7PH (about 17% chromium, 7% nickel, 1% aluminum, and remainder iron), the Armco 17–4PH (about 17% chromium, 4% nickel, 4% copper, and remainder iron) and the Armco PH15–7Mo (about 15% chromium, 7% nickel, 2% molybdenum, 1% aluminum, and remainder iron).

In their annealed conditions, these steels possess good working and forming characteristics. And in their hardened conditions the steels display many highly desirable physical properties. Illustratively, the steels are hard, durable and of high tensile strengths.

In the past various efforts have been made, as by varying composition and heat-treatment, to accomplish the requisite phase-transformation at reduced temperatures. But, in general, the results leave much to be desired, even where there are employed closely controlled percentages of added hardening agents such as columbium, titanium, vanadium and tungsten and, where time and temperature of treatment have been tried in numerous combinations. And while the precipitation-hardened products possess admirable strength at room temperatures, both hardness and strength rapidly diminish with use at temperatures above about 900° F.

One of the objects of my invention, therefore, is to provide a chromium-nickel alloy steel which, in the annealed condition, lends itself to fabrication into a variety of intricate and complex shapes and which readily lends itself to hardening in substantial absence of scaling and physical distortion, in simple operation under conditions

of comparatively low hardening temperatures of relatively short duration, to achieve strength of high value both at room temperatures and at elevated temperatures as well.

Referring now more particularly to the practice of my invention, I find that with a proper combination of molybdenum, chromium and nickel, I achieve an alloy steel which is subsequently hardenable by heat-treatment from a soluble solution-treated (annealed) condition. And that this hardening is had by way of a single-step hardening operation of comparatively short duration conducted at relatively low temperatures. Where desired, it also can be hardened by double-treatment, this from an even more ductile annealed condition.

The hardened steel is strong and hard both at room temperatures and at high temperatures. The mechanical properties of the steel compare favorably with known and available precipitation-hardened steels.

The alloy steel of my invention essentially consists of about 5% to 15% chromium, about 3.5% to 12% nickel, about 4% to 12% molybdenum, with remainder substantially all iron. Carbon is included in amounts of about 0.005% to 0.15% and nitrogen in amounts up to .150%. Manganese also may be present in amounts up to 2.50%. Phosphorus is present in amounts up to 0.05% maximum, sulphur up to 0.05% maximum, and silicon up to about 2.00%. Where desired, columbium and tantalum are employed in total amount up to about .75%. At times, for specific purposes, aluminum may be used in amounts up to .40% to control delta ferrite. Copper may be present in amounts up to 3.0%, vanadium up to about 1%, titanium and/or zirconium up to about 0.50%, and boron up to 0.010%. In some instances, where extreme hardness is desired and some calculated sacrifice in ductility of resulting steel is permissible, tungsten may be substituted for molybdenum, in amounts up to about 7% tungsten. As more particularly noted hereinafter, the ratio between the sum of the chromium and molybdenum contents of the steel and the nickel content does not exceed about 4.5.

For the single-treatment steel of my invention I employ about .005% to .12% carbon, 5% to 14% chromium, about 4% to 12% nickel, about 4% to 12% molybdenum, up to .150% nitrogen, and remainder substantially all iron. The double-treatment steel essentially consists of about .01% to .15% carbon, 7% to 15% chromium, 3.5% to 10% nickel, 4% to 12% molybdenum, up to .150% nitrogen, and remainder substantially all iron.

In the steel of my invention the percentage of molybdenum employed and its relation to the chromium and nickel contents thereof are both critical. For if the steel is either too low in chromium or too high in molybdenum, practical difficulties are encountered. I find that with a chromium content near the lower part of the given range molybdenum may be somewhat higher than would otherwise be permissible; while if the chromium content approaches the upper limit of permissible range, then the molybdenum content must be correspondingly diminished.

The steel of my invention displays requisite softness and ductility following a preliminary solution-treatment, that is, an anneal, as by heating for about one-half hour at temperatures of about 1600° F. to 2000° F. And in this condition the steel can be worked with comparative ease to close dimensional tolerances and required intricacy of configuration. The products readily lend themselves to hardening by a simple ageing treatment conducted at comparately low temperatures and enduring for relatively short periods of time, all as more particularly described hereinafter. And the hardened products thereby acquire enhanced qualities of hardness and strength. These qualities are retained during prolonged operation at both room temperatures and elevated temperatures.

A preferred chromium-nickel-molybdenum alloy steel according to my invention which is hardenable by single-treatment analyzes about 9% to 12% chromium, about 5% to 8% molybdenum, with the sum of the chromium and molybdenum contents about 15% to 19%, about 5% to 8% nickel, the nickel content being inversely proportioned with respect to the sum of the chromium and molybdenum contents, carbon .05% to 0.12%, nitrogen .005% to .150%, manganese .01% to 2.0%, phosphorus up to about 0.05% maximum, sulphur up to about 0.05% maximum, silicon about .10% to 2.0%, remainder substantially all iron. This steel is stainless.

A preferred stainless steel which is hardenable by double-treatment analyzes about 7% to 15% chromium, about 3.5% to 10% nickel, about 4% to 12.0% molybdenum, .02% to .15% carbon, .005% to .150% nitrogen, and remainder substantially all iron.

In order to bring the single-treatment steel of my invention into a soft condition which is suitable for fabricating operations, I subject the metal to a solution-treatment, that is, an anneal, at temperatures ranging from about 1600° to 2000° F. I find that these relatively high annealing temperatures effectively serve to place the metal in an austenitic and molybdenum-soluble condition. I further find that the steel when cooled as by quenching in air, oil or water, is transformed to a martensitic condition, with molybdenum in solution. Although the length of time at annealing treatment is not too critical I find that at an annealing temperature of 2000° F. a treatment enduring for approximately one-half an hour is entirely satisfactory. Lower temperatures, of course, would require longer times. The annealing treatment is conducted in any heat-treating furnace suitable for the purpose.

In its annealed and quenched condition, my single-treatment steel displays a structure which is basically martensitic, a soft martensite. This is clearly discernible under the microscope. Moreover, it is usually free of delta-ferrite. It is ductile and possesses good qualities of directionality, together with hardness of about Rockwell C28–38.

The double-treatment steel of my invention preferably is solution-treated at a temperature of 1800° to 2100° F. and cooled to room temperature. With this treatment the steel is in an austenitic condition. The hardness is less than Rockwell B100.

The steel, following solution-anneal, is readily formed and fabricated as by punching, bending, stretching, shrinking, or the like, or by drilling, cutting, threading, and so forth; particularly is this true of the double-treatment steel where treated at the higher solution-anneal temperatures. The steel is successfully and readily brazed and soldered. Or it can be welded in accordance with known welding operations.

Upon conclusion of the fabrication operations I harden the single-treatment steel, preferably by an ageing treatment conducted at relatively low temperature but for a short period of time. More particularly, I subject the steel products to an ageing temperature of approximately 850° to 1400° F. for a period of approximately one hour. Following the ageing treatment, I cool the steel, as in air or water. This single-step, low-temperature ageing treatment, of relatively short duration, apparently brings about a precipitation of a molybdenum-rich phase. It may be supposed that it is this precipitated phase, rich in molybdenum and distributed uniformly throughout the steel to which may be attributed the improved mechanical properties of hardness and strength. Unlike many known precipitation-hardened alloys, the steel of my invention retains these properties even following prolonged operation at high temperatures. This I attribute to the stability of the molybdenum-rich phase present in the hardened condition of the steel.

The double-treatment steel, following fabrication, preferably is subjected to transformation by reheating at a temperature of about 1200° to 1700° F. and cooling to

a temperature of 90° to −320° F. The times of heating and of cooling are not particularly critical although the heating usually is for a period of an hour or more and the cold treatment is for a period up to 24 hours or longer. The structure is martensitic. Where desired, the steel may be transformed by cold-working instead of by the reheating and cold-treatment noted.

Following transformation, I harden the steel by again reheating, this at a temperature of 800° to 1200° F. for periods up to 12 hours. The hardened steel is possessed of excellent mechanical properties.

As more specifically illustrative of the practice of my invention, one preferred single-treatment composition analyzes approximately 12% chromium, 6% nickel, 6% molybdenum, and remainder substantially all iron. A further preferred composition analyzes approximately 10% chromium, 7% nickel, 6% molybdenum, and remainder substantially all iron. Another analyzes about 9% chromium, 8% nickel, 6% molybdenum, and remainder substantially all iron. Others analyze about 10% chromium, 7% nickel, 7% molybdenum, and remainder substantially all iron; about 12% chromium, 5% nickel, 6% molybdenum, and remainder substantially all iron; and about 12% chromium, 5% nickel, 7% molybdenum, and remainder substantially all iron. Also about 11% chromium, 5% nickel, 6% molybdenum, and remainder substantially all iron; and about 11% chromium, 5% nickel, 7% molybdenum, and remainder substantially all iron. The alloy steels of my invention with less than about 8% chromium are not considered to be stainless steels because I find that, where the chromium content is less than about 8%, there is loss of passivity. For the several preferred single treatment steels it will be seen that the sum of the chromium and molybdenum contents ranges from about 15% to about 19%, with the nickel contents correspondingly ranging from about 8% down to about 5%, giving ratios for the chromium plus molybdenum contents of about 1.9 to 3.8. Actually, as more fully appears hereinafter (Table I), this ratio may range from about 1.7 to 4.5.

The analyses of a number of chromium-nickel-molybdenum single-treatment stainless steels according to my invention are given in Table I below:

TABLE I

Specific Examples of Single-Treatment Cr–Ni–Mo *Stainless Steels*

Heat No.	C	MN*	P*	S*	Si*	Cr	Ni	Mo	Cb	Cr+Mo	Cr+Mo / Ni
R2419	.076	.46	.017	.010	.38	11.96	5.92	5.85		17.81	3.01
R2420	.071					10.90	7.00	5.85		16.75	2.39
R2421	.070					9.91	6.98	5.93		15.84	2.27
R2422	.070					9.04	8.01	5.78		14.82	1.85
R2423	.069					9.80	7.00	6.73		16.53	2.36
R2425	.098					9.07	7.93	7.95		17.02	2.15
R2426	.066					8.14	9.01	7.88		16.02	1.78
R2427	.091					7.86	9.07	9.01		16.87	1.86
R2552	.024	.44	.019	.008	.42	13.82	4.17	5.86	.11	19.68	4.72
R2554	.024					13.57	5.28	5.71	.10	19.28	3.65
R2555	.026					12.83	4.19	6.01	.12	18.84	4.48
R2557	.023					12.50	5.18	6.01	.11	18.51	3.57
R2558	.023					11.94	5.15	6.08	.10	18.02	3.50
R2560	.022					11.58	5.23	6.88	.09	18.46	3.53
R2561	.021					10.53	5.16	6.03	.09	16.56	3.21
R2562	.021					10.46	5.15	6.91	.09	17.37	3.37

*Mn, P, S and Si checked on R2419 and R2552. Additions of these elements were the same for every other heat in this group.

It is noted that the sum of the chromium and molybdenum contents for the specific examples given above ranges from a low of 14.82 (heat No. R2422) to a high of 19.68 (heat No. R2552) and that the ratio of Cr+Mo to Ni for these various examples ranges from a minimum of 1.78 (heat No. R2426) to a maximum of 4.72 (heat No. R2552).

Specimens from the several steels identified in Table I were first annealed at 2000° F. for ½ hr. and oil quenched. Following this they were heated at 1050° F. for 1 hour and air-cooled. The room temperature mechanical properties of the samples in the annealed condition are given in Table II(*a*) below, the mechanical properties of the samples in the hardened condition being given in Table II(*b*):

TABLE II(*a*)

Room Temperature Mechanical Properties of the Steels of Table I in the Annealed Condition [1]

Heat No.	U.T.S., p.s.i.	0.2% Y.S., p.s.i.	Percent El. in 2"	Percent Red. Area	Rockwell "C" Hard.
R2419	160,000	105,000	12	48	35
R2420	162,000	110,000	12	48	36
R2421	170,000	115,000	11	44	38
R2422	161,000	104,000	13	52	36
R2423	164,000	112,000	12	46	37
R2425	148,000	97,000	13	54	32
R2426	142,000	91,000	13	56	30
R2427	128,000	78,000	16	58	28
R2552	131,900	66,400	20	58	27
R2554	144,700	63,600	19	57	27
R2555	135,800	76,100	20	49	28
R2557	148,700	81,900	18	54	28
R2558	151,900	90,000	17	56	30
R2560	146,200	84,600	18	53	28
R2561	157,200	114,500	16	60	31
R2562	150,000	100,000	17	50	30

[1] 2000° F. for ½ hr. and oil quenched.

TABLE II(*b*)

Room Temperature Mechanical Properties of the Steels of Table I in the Hardened Condition [1]

Heat No.	U.T.S., p.s.i.	0.2% Y.S., p.s.i.	Percent El. in 2"	Percent Red. Area	Rockwell "C" Hard.
R2419	230,000	165,000	12	43	43
R2420	230,000	159,000	13	47	46
R2421	245,000	181,000	13	46	48
R2422	234,000	171,000	14	46	47
R2423	255,000	181,000	10	38	49
R2425	227,000	136,000	11	36	47
R2426	203,000	113,000	15	44	46
R2427	150,000	110,000	17	52	46
R2552	147,800	97,300	21	59	32
R2554	160,000	110,900	18	52	34
R2555	159,100	118,300	21	59	37
R2557	181,800	147,200	18	56	35
R2558	191,900	161,900	17	56	40
R2560	209,000	164,800	13	38	43
R2561	213,400	185,900	16	53	43
R2562	217,100	181,800	15	43	45

[1] 2000° F. for ½ hour and oil quenched, +1050° F. for 1 hour and air cooled.

Now as to the double-treatment steels of my invention, a preferred steel analyzes approximately 11% chromium, 6% nickel, 8% molybdenum, and remainder substantially all iron. Another analyzes about 12% chromium, 6% nickel, 7% molybdenum, and remainder substantially all iron. A further steel analyzes about 13% chromium, 6% nickel, 6% molybdenum, and remainder substantially all iron. In these steels the carbon content amounts to about .08%, the manganese about .60%, the phosphorus about .010%, the sulphur about .010%, the silicon .40%, and the nitrogen .025%. For these preferred steels, the sum of the chromium and molybdenum

contents is about 19%, the nickel about 6%, and the ratio of the sum of the chromium and molybdenum contents to the nickel content is about 3.2.

The analyses of several double-treatment stainless steels according to my invention are set forth in the Table III below:

TABLE III

Specific Examples of Double-Treatment Cr–Ni–Mo *Stainless Steels*

Heat No.	C	Mn	P	S	Si	Cr	Ni	Mo	N	Cb	Cr+Mo	Cr+Mo / Ni
R2640	.095	1.25	.024	.017	.30	12.08	6.00	5.98	.094	.13	18.06	3.01
R2641	.095	1.25	.026	.017	.33	12.82	6.01	6.12	.089	.12	18.94	3.15
R2643	.093	1.40	.023	.016	.28	10.72	6.98	6.13	.083	.10	16.85	2.41
R2644	.094	1.20	.024	.017	.26	11.46	7.02	6.08	.090	.09	17.54	2.50
R2645	.089	1.25	.016	.017	.37	12.89	6.98	5.88	.081	.13	18.77	2.69
R2646	.096	.95	.017	.021	.31	10.93	6.03	7.06	.069	.11	17.99	2.98
R2647	.093	.94	.013	.020	.28	11.70	6.06	7.02	.058	.11	17.72	2.92
R2648	.11	1.19	.020	.020	.30	10.55	7.11	7.03	.077	.11	17.58	2.47
R2649	.099	1.19	.020	.020	.33	11.89	7.09	7.02	.084	.11	18.82	2.65

Here it is seen that the sum of the chromium and nickel contents for the specific examples given ranges from 16.85 (heat No. R2643) to 18.94 (heat No. R2641), and that the ratio of the Cr+Mo to the Ni, for these examples, ranges from a minimum of 2.41 (heat No. R2643) to a maximum of 3.15 (heat No. R2641).

In the annealed condition (2000° F. for 30 minutes and air-cooled) the hardness of the examples given in Table III does not exceed Rockwell B97.

The mechanical properties of the steels of Table III after hardening by double-treatment, specifically heating at 1400° F. for 1½ hours and air-cooling to 75° F. to effect transformation, then reheating at 1050° F. for 2 hours and air-cooling, are given in Table IV (*a*) below:

TABLE IV(*a*)

[Anneal 2000° F. ½ hr.—water quench; plus 1,400° F. 90 mins.—cool to 75° F.; plus reheat 1,050° F. 2 hours—air cool]

Heat No.	Ult. Ten. str., p.s.i.	0.2% Y.S., p.s.i.	Percent Elong. in 2"	Percent Red. Area	Rockwell Hardness
R2640	195,000	170,000	12	44	C42
R2641	202,000	165,000	13	46	C43
R2643	204,000	167,000	12	42	C43
R2644	208,000	185,000	10	38	C44
R2645	220,000	181,000	11	40	C44
R2646	209,000	178,000	12	40	C45
R2647	214,000	189,000	11	38	C46
R2648	212,000	182,000	14	38	C46
R2649	217,000	187,000	12	36	C47

Similar mechanical properties are had when the steel is heated at 1700° F. for 20 minutes, cooled to room temperature, and then refrigerated at −100° F. for 8 hours ot effect transformation, then reheated to 1050° F. for 2 hours and air-cooled to harden. These properties are given in Table IV(*b*) below:

TABLE IV(*b*)

[Annealed 2,000° F. 30 mins.—water quench; plus 1,700° F. 20 mins.—cool to room temperature and refrigerate at −100° F. 8 hrs.—raise to room temperature; plus reheat to 1,050° F. 2 hrs.—air cool]

Heat No.	Ult. Ten. str., p.s.i.	0.2% Y.S., p.s.i.	Percent Elong. in 2"	Percent Red. Area	Rockwell Hardness
R2640	192,000	176,000	14	41	C43
R2641	205,000	185,000	14	44	C44
R2643	206,000	179,000	11	39	C44
R2644	210,000	181,000	11	41	C44
R2645	212,000	187,000	9	36	C45
R2646	203,000	183,000	11	37	C45
R2647	218,000	186,000	12	39	C46
R2648	210,000	179,000	12	38	C47
R2649	215,000	183,000	9	34	C47

By comparing the analyses of Table III with those of Table I it will be seen that many may be viewed as both single-treatment and double-treatment steels. And the choice of heat-treatment, whether single or double, is made depending upon the severity of the forming and fabricating operations or the ultimate use to which the steel is to be put. Thus for applications where substantial deformation is required during fabrication, and maximum ductility in the annealed or solution-treated condition is desired, the steel is solution-treated at the higher temperature to assure a fully austenitic structure, and hardening had by transformation treatment followed by ageing. On the other hand, where the amount of deformation is insubstantial and maximum ductility in the solution-treated condition is not required, then a solution-treatment at a lower temperature is adequate and hardening is achieved by simple ageing treatment of the solution-treated steel without necessity for the separate transformation step; actually, the solution-treatment at the lower temperature range and cooling effects partial transformation, at least sufficient to assure hardening by the subsequent ageing step.

The steels of my invention not only are suited to duty at room temperature but, in addition, they are well adapted to service at elevated temperatures.

Accordingly, it will be seen that I provide in my invention a steel and method of heat-treating the same, in which the many objects and advantages hereinbefore set forth are successfully achieved. My steel displays markedly superior mechanical properties, particularly strength and hardness, and is well suited to duty at room temperatures, as well as at high temperatures. In my steel there is had a good resistance to corrosion, even when subjected to reducing acids. And, it is to be noted, the improvement in corrosion resistance is without sacrifice of the precipitation-hardenable qualities of the steel. Upon age-hardening, the steel achieves considerable resistance to wear, abrasion and galling.

The steels of my invention lend themselves admirably to the production of wrought products as well as castings. The metal in the solution-treated or annealed condition can be machined, welded and formed with comparative ease.

Inasmuch as many embodiments may be made of my invention as described herein and inasmuch as many changes in the present embodiments will suggest themselves to those skilled in the art, it will be understood that I desire the foregoing disclosure to be considered as simply illustrative, and not as a limitation.

I claim as my invention:

1. Precipitation-hardenable chromium-nickel-molybdenum alloy steel essentially consisting of about 5% to 14% chromium, 4% to 12% nickel, 4% to 12% molybdenum, with the ratio between the sum of the chromium and molybdenum contents and the nickel content ranging from about 1.7 to 4.7 and the remainder essentially iron.

2. Precipitation-hardenable chromium-nickel-molybdenum alloy steel essentially consisting of about 7% to 15% chromium, 3.5% to 10% nickel, 4% to 12% molybdenum, with the ratio between the sum of the chromium and molybdenum contents and the nickel content ranging from about 2.4 to 3.2 and the remainder essentially iron.

3. Precipitation-hardenable stainless steel essentially

consisting of approximately: 9% to 12% chromium, 5% to 8% nickel, 5% to 8% molybdenum, with the sum of the chromium and molybdenum contents about 15% to about 19%, and the remainder essentially iron.

4. Precipitation-hardenable stainless steel essentially consisting of approximately: 9% to 12% chromium, 5% to 8% molybdenum with the sum of the chromium and molybdenum contents about 15% to about 19%, 5% to 8% nickel with the nickel content being inversely proportioned to the sum of the chromium and molybdenum contents, and the remainder essentially iron.

5. Precipitation-hardenable stainless steel essentially consisting of approximately: 9% chromium, 8% nickel, 6% molybdenum, and remainder essentially iron.

6. Precipitation-hardenable stainless steel essentially consisting of approximately: 10% chromium, 7% nickel, 7% molybdenum, and remainder essentially iron.

7. Precipitation-hardenable stainless steel essentially consisting of approximately: 11% chromium, 5% nickel, 6% molybdenum, and remainder essentially iron.

8. Precipitation-hardenable stainless steel essentially consisting of approximately: 11% chromium, 5% nickel, 7% molybdenum, and remainder essentially iron.

9. Precipitation-hardenable stainless steel essentially consisting of approximately: 11% chromium, 7% nickel, 6% molybdenum, and remainder essentially iron.

10. Precipitation-hardenable stainless steel essentially consisting of approximately: 12% chromium, 5% nickel, 6% molybdenum, and remainder essentially iron.

11. Precipitation-hardenable stainless steel essentially consisting of approximately: 12% chromium, 5% nickel, 7% molybdenum, and remainder essentially iron.

12. Precipitation-hardenable stainless steel essentially consisting of approximately: 12% chromium, 6% nickel, 6% molybdenum, and remainder essentially iron.

13. Precipitation-hardenable stainless steel essentially consisting of about 11% chromium, 6% nickel, 8% molybdenum, and remainder essentially iron.

14. Precipitation-hardenable stainless steel essentially consisting of about 12% chromium, 6% nickel, 7% molybdenum, and remainder essentially iron.

15. Precipitation-hardenable stainless steel essentially consisting of about 13% chromium, 6% nickel, 6% molybdenum, and remainder essentially iron.

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2,875,042	Kegerise et al.	Feb. 24, 1959
2,958,618	Allen	Nov. 1, 1960