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HIGH STRENGTH STEEL AND METHOD OF TREATMENT THEREOF

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This invention relates generally to high strength nonmagnetic steels and their treatment, and more particularly to steels for generator retaining rings and a method of treating the rings to produce a high yield strength.

This application is a continuation-in-part of our copending application, Serial No. 106,452, filed May 1, 1961, now abandoned.

In the electric power industry, there is need for high-strength, ductile, fine-grained, nonmagnetic steel ring forgings for coil supports in generator rotors. These ring forgings are usually referred to as retaining rings. These rings conventionally range in size from 27 to 63 inches in outside diameter, 19 to 30 inches in length, and 2 to 6 inches in wall thickness. These retaining rings must withstand high operating stresses, and must be nonmagnetic (less than about 1.2 magnetic permeability) to prevent current losses.

As the size and capacity of generators increase, higher strength retaining rings are required. The strength requirements of retaining rings for generators now being designed is about 170,000 p.s.i. yield strength at .2 percent offset and an elongation of approximately 15 percent. This compares with prior art retaining rings which need a strength of only about 125,000 p.s.i. yield strength at 0.2 percent offset and an elongation of approximately 20 percent.

It is therefore a principal object of this invention to provide a nonmagnetic steel and method of treatment thereof to produce a high yield strength.

It is a more particular object of this invention to provide a steel suitable for forming generator retaining rings and a method of treating the rings formed therefrom to provide high yield strength.

Other objects and a fuller understanding of this invention may be had from the following description and claims.

According to this invention, suitable combinations of solution treatment, cold working, and aging are applied to austenitic steels of a given composition to produce retaining rings that exhibit high yield strength and good tensile ductility required of these retaining rings. The broad composition ranges for such a steel are as follows:

Table I

C	0.10 to 0.45
Mn	12.0 to 20.00
Si	0.40 to 1.00
Ni	0 to 8.00
Cr	13.0 to 20.00
Mo	0 to 2.50
V	0 to 1.00
N	0.20 to 0.45
X	0 to .40
Fe and residual impurities	Balance

wherein X is Cb or a mixture of Cb and Ta. Table II below indicates 13 specific compositions of steel which have been used to evaluate retaining-ring steels having the requisite high yield strength and tensile ductility required.

Table II

Steel	A	B	C	D	E	F	G	H	I	J	K	L	M
C	0.16	0.15	0.25	0.41	0.16	0.22	0.24	0.22	0.19	0.19	0.15	0.17	0.15
Mn	15.10	15.00	15.00	14.80	15.00	15.40	14.90	14.10	14.15	14.20	14.24	14.30	14.30
P	0.017	0.017	0.018	0.013	0.022	0.021	0.017	0.017	0.004	0.004	0.003	0.003	0.004
S	0.010	0.009	0.007	0.007	0.008	0.008	0.006	0.006	0.006	0.004	0.004	0.004	0.005
Si	0.46	0.74	0.67	0.47	0.72	0.71	0.62	0.63	0.68	0.71	0.68	0.74	0.71
Ni	0.32	0.33	0.32	0.30	0.32	5.16	5.16	5.16	0.52	0.52	0.51	0.50	0.51
Cr	18.30	17.90	17.80	13.10	17.70	17.80	17.20	17.40	19.30	19.20	17.20	17.10	17.10
Mo						2.08	2.07						
V						0.80	0.85	0.82	0.02	0.02	0.16	0.25	0.39
Al[1]	0.010	0.005	0.006	0.004	0.009	0.004	0.007	0.007	0.009	0 007	0.009	0.008	0.008
N	0.44	0.44	0.39	0.26	0.39	0.34	0.39	0.38	0.36	0.42	0.35	0.33	0.34
Cb					0.39				0.17	0.27	0.18	0.18	0.18
Fe and residual impurities	Bal.	Bal.	Bal.	Bal.	Bal.	Bal.	Bal.	Bal.	Bal.	Bal.	Bal.	Bal.	Bal.

[1] Acid soluble.

NOTE.—Blanks denote residual amounts (less than 0.05%) of these elements.

Conventionally, steel retaining rings for generators are formed by providing an ingot and forging the ingot at about 2200° F. to a blank, punching a hole in the forged blank, mandrel forging to enlarge the hole and water quenching. Rough machining may be performed at this point and the blank ultrasonically inspected if the grain size is small enough to so permit. The forged blank is then solution treated at temperatures between 1900° F. and 2200° F. and water quenched. The blank is then expanded at temperatures below 450° F., and a final machining may be performed. A final ultrasonic inspection may then be performed if the grain size is sufficiently small. One method of expanding the blank is described in application Serial No. 37,719, filed June 21,

1960, entitled "Method and Apparatus for Enlarging Rings."

It has been found that if the rings are aged at temperatures between 500° F. and 1400° F. after they have been expanded, a substantial increase in yield strength is obtained. Also, it has been found to be beneficial for certain of the steels tested to perform the expanding in two steps and age the steel after each step.

Table III below indicates various treatments given to test specimen bars formed from various compositions of steel listed in Table II above and test results of such treatments.

Table III

Steel	Solution Temp., ° F.	Amount of Prestrain, Percent	Aging Temp., ° F.	Yield Strength (0.2% offset), p.s.i.	Tensile Strength, p.s.i.	Elongation in 2 inches, Percent	Reduction of Area, Percent	Charpy V-Notch Test, Energy Absorbed at Room Temp., ft.-lb.
A	1,950	30	600	163,500	173,800	28.0	60.0	
		35		175,000	186,700	26.0	57.0	
		40		186,900	189,000	22.5	55.0	
B	1,950	30	600	168,600	173,500	27.0	59.5	
		35		181,600	186,800	20.5	56.0	
		40		197,100	200,800	14.0	52.5	
C	1,950	30	600	170,400	176,900	26.5	50.5	
		35		184,900	189,200	23.5	48.5	
		40		203,300	207,600	[1] 11.5	43.0	
C	1,900	35	500	200,800	207,700	14.5	39.2	
			600	191,900	196,300	20.5	39.2	13.0
			700	181,400	186,000	22.5	46.6	
C	1,950	35	500	187,200	189,900	21.5	45.3	
			600	184,900	189,200	23.5	48.5	18.5
			700	182,900	188,900	25.0	49.4	
C	2,000	30	600	166,400	174,200	25.0	50.5	
		35		182,200	187,200	23.5	46.5	
		40		191,400	195,200	[1] 17.5	44.5	
D	1,950	30	600	169,300	178,600	27.0	41.0	
		35		177,600	184,900	22.5	35.5	5.0
		40		195,000	199,200	21.0	42.0	
D	2,000	30	600	163,800	175,800	30.5	45.0	
		35		171,200	180,300	24.0	38.0	
		40		186,500	192,100	22.0	38.0	
E	1,950	25	600	169,900	178,500	25.5	51.7	
		25	700	180,800	184,700	24.0	51.0	40.5
		30	600	192,500	196,600	18.0	48.5	
		35	600	210,400	213,000	[1] 7.0	43.0	
F	2,100	20	1,300	163,100	173,300	24.0	45.0	
		30	1,050	185,000	191,500	23.5	46.0	
			1,175	178,900	186,200	23.5	39.5	
			1,300	178,000	189,400	18.5	23.0	
G	2,000	25	[2] 925	176,200	181,000	20.0	41.5	
			[2] 1,050	176,200	183,600	21.0	41.5	
	2,050	25	[2] 925	176,100	182,000	22.0	48.0	
			[2] 1,050	174,100	183,100	23.0	45.5	
G	2,100	25	925	184,000	189,300	22.0	50.1	
			[2] 925	182,500	187,700	20.0	39.2	
			1,050	176,100	185,700	22.5	47.5	
			[2] 1,050	188,300	190,900	21.5	39.5	79.5
			1,175	185,700	194,900	19.0	37.5	
			[2] 1,175	181,300	192,900	18.5	30.5	
G	2,100	30	800	187,800	191,200	15.5	29.8	
			[2] 800	205,100	205,100	17.5	40.9	
			925	192,700	196,300	22.0	46.2	
			[3] 925	188,300	192,300	20.5	42.9	
			[2] 925	196,600	199,700	20.0	41.7	
			1,050	195,100	200,500	20.0	43.6	
			[2] 1,050	193,000	196,000	22.0	39.8	
H	2,100	25	925	166,900	175,400	21.0	43.3	
			[2] 925	172,400	178,700	22.5	45.0	56.0
			1,050	169,200	177,800	22.5	41.0	
			[2] 1,050	171,700	178,400	23.5	33.3	
			1,175	164,800	177,100	24.5	41.5	
			[2] 1,175	168,400	180,200	21.5	32.3	
H	2,100	30	800	194,200	197,300	17.0	41.9	
			[2] 800	199,400	199,400	19.5	41.3	
			[2] 900	181,800	184,100	18.5	33.5	
			925	194,500	200,100	18.5	42.2	
			[2] 925	195,700	197,600	19.5	42.1	
			1,050	189,900	196,400	19.5	40.5	
			[2] 1,050	194,700	197,500	19.5	37.5	
H	2,100	33	[3] 900	213,200	213,200	17.5	40.6	
I	1,950	25	700	170,400	175,700	25.0	53.6	
		[4] 26	700	168,700	171,900	26.0	56.6	
		[4] 32	700	181,700	181,700	21.0	48.8	
J	1,950	25	700	167,700	171,700	24.0	52.7	
		[4] 25	700	166,800	169,500	24.0	50.6	
		[4] 30	700	175,700	175,700	22.0	51.5	
K	1,950	25	700	171,900	179,500	24.0	53.0	
		[4] 25	700	166,400	170,000	26.0	56.9	
		[4] 31	700	173,500	174,000	22.0	53.0	72.5
L	1,950	25	700	165,100	170,400	26.0	50.5	
		[4] 25	700	162,900	167,500	27.0	53.6	
		[4] 30	700	170,700	171,200	25.0	52.1	
M	1,950	[4] 31	700	179,500	179,500	16.0	47.0	

[1] Broke at gage mark.
[2] Aged for 7 hours and air-cooled to room temperature.
[3] Aged for 4 hours and air-cooled to room temperature.
[4] Prestrained at 350° F.

NOTE.—All specimen blanks (1¼ inches square by 5 inches long) were solution-treated for 2 hours at the indicated temperatures, except specimens I through M which were solution-treated for 4 hours at the indicated temperatures, air-cooled to room temperature (to simulate the water quenching of retaining rings with a wall thickness of about 4 inches), machined to 0.600-inch-diameter tensile specimens, prestrained (elongated) the indicated amounts, aged at the indicated temperatures for 2 hours (except where noted), air-cooled to room temperature, then pulled to failure. All fractures were nonmagnetic (below 1.2 Permeability).

Table IV below shows the treatment and results for steels G and H, wherein the specimen bars were strained in two steps and aged after each step.

Table IV

Steel	Solution Temp., ° F.	Amount of Prestrain, Percent	Aging Temp., ° F.[1]	Amount of Prestrain, Percent	Aging Temp., ° F.[2]	Yield Strength (0.2% Offset), p.s.i.	Tensile Strength, p.s.i.	Elongation in 2 inches, Percent	Reduction of Area, Percent
G	2,100	----	----	25	1,050	188,300	190,900	21.5	39.5
		----	1,050	25	1,050	166,100	175,900	29.0	46.4
		10	1,050	15	1,050	177,200	183,600	26.0	47.5
		15	1,050	10	1,050	176,000	182,200	25.0	40.0
		----	----	25	925	182,500	187,700	20.0	39.2
		----	1,050	25	925	177,100	184,000	21.5	45.0
		10	925	15	925	183,000	186,200	23.5	46.0
		10	1,050	15	925	168,800	176,600	22.0	47.0
H	2,100	----	----	25	1,050	171,700	178,400	23.5	33.3
		----	1,050	25	1,050	175,400	184,800	24.0	46.4
		10	1,050	15	1,050	166,400	175,900	29.0	45.2
		15	1,050	10	1,050	163,400	173,300	26.0	40.0
		----	----	----	925	172,400	178,700	22.5	45.0
		----	1,050	25	925	174,400	181,500	22.5	46.0
		10	925	15	925	174,400	180,400	22.5	42.0
		10	1,050	15	925	176,300	180,800	21.5	42.0

[1] Aged for 2 hours and air-cooled to room temperature.
[2] Aged for 7 hours and air-cooled to room temperature.

The above results indicate that the steel should be solution treated at temperatures between 1900° F. and 2200° F., the strain should be between 15 and 40 percent, and the aging should be between 500° F. and 1400° F. More particularly, steels A, B, C, D, E, I, J, K, L and M preferably should be solution treated between 1900° F. and 2050° F., strained between 20 percent and 40 percent and aged between 500° F. and 800° F. Preferably steels of the composition F, G and H should be solution treated between 2000° F. and 2200° F., strained between 20 and 40 percent and aged at temperatures between 800° F. and 1200° F. Preferably rings made of steels A, B, C and D should be expanded at temperatures in the range 200° F. to 450° F. between 34 and 38 percent and aged between 500° F. and 800° F. with the prior solution treatment being at between 1900° F. and 2050° F. Rings formed from steels E, I, J, K, L and M should be expanded at temperatures in the range 70° F. to 450° F. between 24 to 32 percent and aged between 500° F. and 800° F. with the prior solution treatment being at between 1900° F. and 2100° F. Rings formed from steels F, G and H should be solution treated between 2000° F. and 2200° F., and expanded at ambient tempeartures between 24 and 32 percent and aged between 800° F. and 1200° F.

Generally, the optimum temperature for solution treating steels A, B, C, D, E, I, J, K, L and M is about 1950° F., and for steels F, G and H about 2100° F. Increasing the solution temperature in general induces a decrease in yield and tensile strengths and an increase in tensile ductility as would be expected.

The optimum aging temperature is generally lowered for steels F, G and H as the amount of strain (cold work) of each steel increases. For steel C, strained to 35 percent, the yield and tensile strengths decreased and tensile ductility increased as the aging temperature was increased from 500° F. to 700° F. However, for steel E strained to 25 percent, the yield and tensile strength increased and the tensile ductility decreased as the aging temperature increased from 600° F. to 700° F. In steel D the austenitic grain size was moderately coarse, the effects of which will be discussed later. Steels E, G, H and K have the best properties in Charpy V-notch tests. For steels according to this invention, the energy absorbed in a room temperature Charpy V-notch test should exceed 15 ft. pounds.

The austenitic grain sizes of each of these steels solution treated at various temperatures are given in Table V below:

Table V

Steel	Austenite Grain Size, ASTM No., of Steels Solution-Treated for 2 Hours at Indicated Temperature			
	1900° F.	1950° F.	2000° F.	2100° F.
A	----	2 to 3	2 to 3	
B	----	3½ to 4½	3 to 4	
C	3 to 4	3 to 4	2 to 3	
D	----	1½ to 3	1½ to 3	
E	----	6½ to 7½	6½ to 7½	
F	----	----	----	4½ to 5½.
G	----	----	6 to 7	5 to 6.[1]
H	----	----	----	5½ to 6½.[1]
I	----	5 to 6[1]	----	
J	----	5 to 6[1]	----	
K	----	5 to 6[1]	----	
L	----	5 to 6[1]	----	
M	----	5 to 6[1]	----	

[1] Some specimens of these steels exhibited duplex grains, some as large as ASTM No. 1 to 2.

Retaining rings having a large grain size (ASTM No. 2 or larger) are not amenable to ultrasonic testing. However, rings having a fine grain size (ASTM No. 4 or smaller) are amenable to ultrasonic testing. ASTM grain size No. 3 is a borderline case. Steels A through E and I through M solution treated at 1950° F. and steels F through H at 2100° F. are amenable to ultrasonic testing, although steels A and D would be borderline cases. The A coarse grain size also seriously impairs yield strength and impact strength of these steels.

Certain elements exert a specific effect on the properties of these steels. Increasing the silicon content from 0.46 percent (steel A) to 0.74 percent (steel B) promoted a moderate increase in yield and tensile strength and a moderate decrease in tensile ductility. Decreasing the chromium content from about 17.80 percent (steel C) to 13.10 percent (steel D) promoted the retention of only 0.26 percent nitrogen in steel D as compared to 0.39 percent nitrogen in steel C; since nitrogen increases the austenite stability of austenitic steels and contributes toward high yield strength, the carbon content was increased from 0.25 percent (steel C) to 0.41 percent (steel D) to maintain good austenite stability and high yield strength. The addition of 0.39 percent columbium (steel E) promoted a very fine austenite grain size (ASTM No. 6½ to 7½) as compared to that (ASTM No. 3½ to 4½) of steel B, a steel with a composition similar to steel E, except for

the absence of columbium. The addition of columbium also promoted a marked increase in the yield and tensile strength with lesser amounts of cold work and a moderate decrease in tensile ductility. The addition of about 5.16 percent of nickel, 2.08 percent of molybdenum, and 0.82 percent of vanadium (steels F and G) promoted an increase in yield and tensile strength with lesser amounts of cold work; in the absence of these elements (see the data for steel C), greater amounts of cold work would be necessary to achieve the desired high strengths. Reducing the molybdenum content from 2.07 percent (steel G) to residual, i.e., less than 0.05 percent (steel H) promoted a decrease in yield and tensile strength, and greater amounts of cold work were required to achieve the desired high strengths.

It has been found that in some cases larger amounts of columbium, e.g., .39%, may tend to segregate into undesirable, eutectic-like, semi-continuous columbium carbides during solidification of heavy ingots. This segregation is particularly noticeable in the upper half of the ingots. Therefore it has been found that a lower amount of columbium tends to reduce either the tendency of the columbium to segregate or the harmful effects of the segregation or both without substantially impairing the physical properties of the steel. Although the lower columbium content has some slight effect toward coarser grains, cf. steel E with steels I through M, this effect is no serious and the grain size is sufficiently fine to permit ultrasonic inspection. It has further been found that when the columbium content is lowered, as in steels I through M, the addition of vanadium has some beneficial effect. It is believed that the vanadium does not tend to segregate to the extent that columbium segregates and thus will tend to promote uniformly fine grain throughout the ingot structure.

While we have shown and described certain preferred embodiments of the invention, it is apparent that other modifications may arise. Therefore, we do not wish to be limited to the disclosure set forth but only by the scope of the appended claims.

We claim:

1. An austenitic stainless steel, in the strained and aged condition, consisting essentially of:

Carbon	.10 to .30%.
Manganese	14 to 17%.
Silicon	.45 to .85%.
Nickel	.05 to 1.0%.
Chromium	13 to 20%.
Nitrogen	.20 to .45%.
X	An effective amount up to .40% to promote fine austenitic grain size and an increase in yield and tensile strength.
Iron and residual impurities	Bal.

wherein X is selected from a group consisting of columbium and mixtures of columbium and tantalum, said steel being characterized by a yield strength at 0.2% offset of at least 170,000 p.s.i.

2. An austenitic stainless steel, in the strained and aged condition, consisting essentially of:

Carbon	.10 to .30%.
Manganese	14 to 17%.
Silicon	.45 to .85%.
Nickel	.05 to 10%.
Chromium	13 to 20%.
Nitrogen	.20 to .45%.
Vanadium	An effective amount up to .50% to promote an increase in yield and tensile strength.

X	An effective amount up to .25% to promote fine austenitic grain size and an increase in yield and tensile strength.
Iron and residual impurities	Bal.

wherein X is selected from a group consisting of columbium and mixtures of columbium and tantalum, said steel being characterized by a yield strength at 0.2% offset of at least 170,000 p.s.i.

3. In a method of manufacturing generator retaining rings from a steel having a composition as follows:

	Percent
Carbon	.10 to .45
Manganese	12 to 20
Silicon	.40 to 1.00
Nickel	8.0 max.
Chromium	13 to 20
Molybdenum	2.5 max.
Vanadium	1.0 max.
Nitrogen	.20 to .45
Columbium	.40 max.
Iron and residual impurities	Bal.

and wherein the steel is forged to a blank, a hole is punched in the blank and enlarged at forging temperatures, and the blank is water quenched, and thereafter the blank is solution treated between 1900° F. and 2200° F., and thereafter the blank is expanded at least once, and wherein the total expansion is between 15% and 40%, the improvement which comprises aging the blank between 500° F. and 1400° F. after each time it is expanded, whereby to produce a yield strength, at .2% offset of at least 170,000 p.s.i.

4. In a method of manufacturing generator retaining rings from a steel having a composition as follows:

	Percent
Carbon	.20 to .45
Manganese	14 to 17
Silicon	.45 to .85
Nickel	.05 to 1.0
Chromium	16 to 20.00
Molybdenum	0.10 max.
Vanadium	.05 max.
Nitrogen	.20 to .45
Iron and residual impurities	Bal.

and wherein the steel is forged to a blank, a hole is punched in the blank and enlarged at forging temperatures, and the blank is water quenched, and thereafter the blank is solution treated between 1900° F. and 2050° F., and thereafter the blank is expanded and wherein the total expansion is between 34% and 38%, the improvement which comprises aging the blank between 500° F. and 800° F. after it is expanded, whereby to produce a yield strength at .2% offset of at least 170,000 p.s.i.

5. In a method of manufacturing generator retaining rings from a steel having a composition as follows:

Carbon	.10 to .30%.
Manganese	14 to 17%.
Silicon	.45 to .85%.
Nickel	.05 to 1.0%.
Chromium	16 to 20.00%.
Molybdenum	0.10% max.
Vanadium	.05% max.
Nitrogen	.20 to .45%.
X	An effective amount up to .40% to promote fine austenitic grain size and an increase in yield and tensile strength.
Iron and residual impurities	Bal.

wherein X is selected from a group consisting of columbium and mixtures of columbium and tantalum, and

wherein the steel is forged to a blank, a hole is punched in the blank and enlarged at forging temperatures, and the blank is water quenched, and thereafter the blank is solution treated between 1900° F. and 2050° F., and thereafter the blank is expanded and wherein the total expansion is between 24% and 32%, the improvement which comprises aging the blank between 500° F. and 800° F. after it is expanded, whereby to produce a yield strength at .2% offset of at least 170,000 p.s.i.

6. In a method of manufacturing generator retaining rings from a steel having a composition as follows:

Carbon	.10 to .30%.
Manganese	14 to 17%.
Silicon	.45 to .85%.
Nickel	.05 to 1.0%
Chromium	16 to 20.00%.
Molybdenum	0.10% max.
Vanadium	An effective amount up to .50% to promote an increase in yield and tensile strength.
Nitrogen	.20 to .45%.
X	An effective amount up to .25% to promote fine austenitic grain size and an increase in yield and tensile strength.
Iron and residual impurities	Bal.

wherein X is selected from a group consisting of columbium and mixtures of columbium and tantalum, and wherein the steel is forged to a blank, a hole is punched in the blank and enlarged at forging temperatures, and the blank is water quenched, and thereafter the blank is solution treated between 1900° F. and 2050° F., and thereafter the blank is expanded and wherein the total expansion is between 24% and 32%, the improvement which comprises aging the blank between 500° F. and 800° F. after it is expanded, whereby to produce a yield strength at .2% offset of at least 170,000 p.s.i.

7. In a method of manufacturing generator retaining rings from a steel having a composition as follows:

	Percent
Carbon	.15 to .30
Manganese	14 to 17
Silicon	.45 to .85
Nickel	4.5 to 6.0
Chromium	16 to 20.00
Molybdenum	1.5 to 2.5
Vanadium	.70 to .90
Nitrogen	.20 to .45
Iron and residual impurities	Bal.

and wherein the steel is forged to a blank, a hole is punched in the blank and enlarged at forging temperatures, and the blank is water quenched, and thereafter the blank is solution-treated between 2000° F. and 2200° F., and thereafter the blank is expanded and wherein the total expansion is between 24% and 32%, the improvement which comprises aging the blank between 800° F. and 1200° F. after it is expanded, whereby to produce a yield strength at .2% offset of at least 170,000 p.s.i.

8. In a method of manufacturing generator retaining rings from a steel having a composition as follows:

	Percent
Carbon	.15 to .30
Manganese	14 to 17
Silicon	.45 to .85
Nickel	4.5 to 6.0
Chromium	16 to 20.00
Molybdenum	1.5 to 2.5
Vanadium	.70 to .90
Nitrogen	.20 to .45
Iron and residual impurities	Bal.

and wherein the steel is forged to a blank, a hole is punched in the blank and enlarged at forging temperatures, and the blank is water quenched, and thereafter the blank is solution-treated between 2000° F. and 2200° F., the improvement which comprises, expanding the blank twice, the total expansion being between 20% and 40%, and aging the blank between 800° F. and 1200° F. after each time it is expanded, whereby to produce a yield strength at .2% offset of at least 170,000 p.s.i.

9. A generator retaining ring comprising an annular steel body, the steel of said body consisting essentially of:

	Percent
Carbon	.20 to .45
Manganese	14 to 17
Silicon	.45 to .85
Nickel	.05 to 1.0
Chromium	16 to 20.00
Molybdenum	0.10 max.
Vanadium	.05 max.
Nitrogen	.20 to .45
Iron and residual impurities	Bal.

said ring being characterized by a yield strength at 0.2% offset of at least 170,000 p.s.i.

10. A generator retaining ring comprising an annular steel body, the steel of said body consisting essentially of:

	Percent
Carbon	.15 to .30
Manganese	14 to 17
Silicon	.45 to .85
Nickel	4.5 to 6.0
Chromium	16 to 20.00
Molybdenum	1.5 to 2.5
Vanadium	.70 to .90
Nitrogen	.20 to .45
Iron and residual impurities	Bal.

said ring being characterized by a yield strength at 0.2% offset of at least 170,000 p.s.i.

11. A generator retaining ring comprising an annular steel body, the steel of said body consisting essentially of:

Carbon	.10 to .30%.
Manganese	14 to 17%.
Silicon	.45 to .85%.
Nickel	.05 to 1.0%.
Chromium	16 to 20.00%.
Molybdenum	0.10% max.
Vanadium	.05% max.
Nitrogen	.20 to .45%.
X	An effective amount up to .40% to promote fine austenitic grain size and an increase in yield and tensile strength.
Iron and residual impurities	Bal.

wherein X is selected from a group consisting of columbium and mixtures of columbium and tantalum, said ring being characterized by a yield strength at 0.2% offset of at least 170,000 p.s.i.

12. A generator retaining ring comprising an annular steel body, the steel of said body consisting essentially of:

Carbon	.10 to .30%.
Manganese	14 to 17%.
Silicon	.45 to .85%.
Nickel	.05 to 1.0%.
Chromium	16 to 20.00%.
Molybdenum	0.10% max.

Vanadium	An effective amount up to .50% to promote an increase in yield and tensile strength.
Nitrogen	.20 to .45%.
X	An effective amount up to .25% to promote fine austenitic grain size and an increase in yield and tensile strength.
Iron and residual impurities	Bal.

wherein X is selected from a group consisting of columbium and mixtures of columbium and tantalum, said ring being characterized by a yield strength at 0.2% offset of at least 170,000 p.s.i.

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UNITED STATES PATENT OFFICE
CERTIFICATE OF CORRECTION

Patent No. 3,151,979 October 6, 1964

Dennis J. Carney et al.

It is hereby certified that error appears in the above numbered patent requiring correction and that the said Letters Patent should read as corrected below.

Columns 1 and 2, Table II, column "J", line 10 thereof, for "0 007" read -- 0.007 --; column 7, line 69, for "10%" read -- 1.0% --.

Signed and sealed this 26th day of January 1965.

(SEAL)
Attest:

ERNEST W. SWIDER
Attesting Officer

EDWARD J. BRENNER
Commissioner of Patents