

Sept. 26, 1944.

R. FRANKS

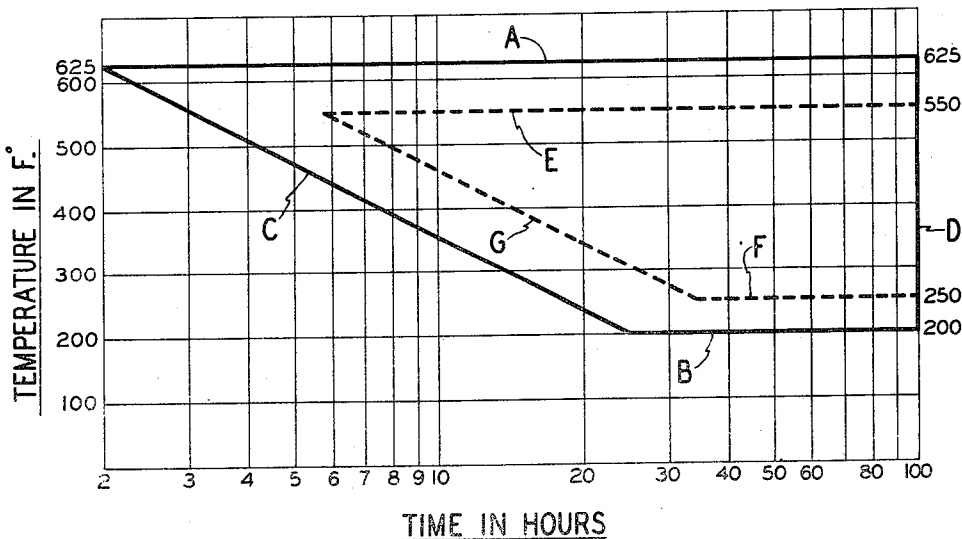
2,358,799

METHOD OF PRODUCING COLD ROLLED STEEL STRUCTURAL MEMBERS

Filed June 17, 1941

2 Sheets-Sheet 1

Fig. 1.



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2 Sheets-Sheet 2

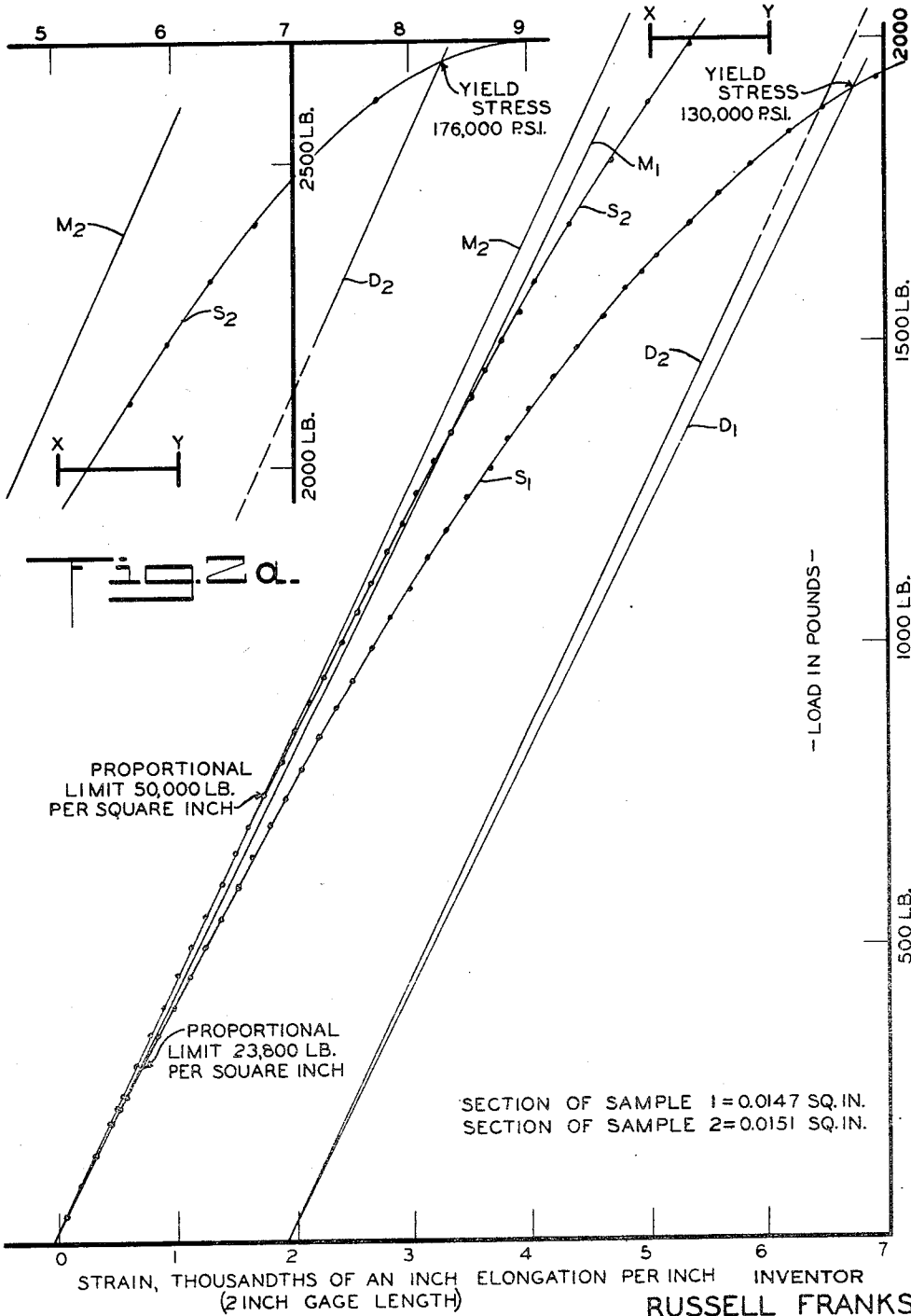


Fig. 2a.

Fig. 2.

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UNITED STATES PATENT OFFICE

2,358,799

METHOD OF PRODUCING COLD ROLLED
STEEL STRUCTURAL MEMBERS

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of West Virginia

Application June 17, 1941, Serial No. 398,400

6 Claims. (Cl. 148—12)

This application is in part a continuation of my application Serial Number 297,229, filed September 30, 1939, which in turn is in part a continuation of my application Serial Number 247,210, filed December 22, 1938.

The present invention relates to cold rolled and otherwise cold worked austenitic type chromium steels. The large demand for improved steels for building strong, light structures, notably in the field of transportation, has been met in part by cold rolled corrosion-resistant steels containing chromium within the limits of 12% and 30% together with enough austenite-promoting elements to make the steels at least predominantly austenitic. Steels of this type may be cold rolled to a tensile strength of more than 160,000 pounds per square inch by a reduction in thickness of, say, 10% to 60% of the original thickness. The cold rolling does not seriously affect the resistance of the material to atmospheric corrosion and weathering, and it is therefore safe to use thin, light-weight sections of the strengthened material in structures exposed to the weather.

A shortcoming of these steels, which has hindered the exploitation of their exceptionally high tensile strength, lies in their relatively poor elastic properties revealed, for instance, by the low value of proportional limit obtained by conventional testing methods. Indeed, it has been suggested that the cold-rolled material does not have a true proportional limit and that it begins to elongate permanently as soon as a small load is applied. It is likewise difficult to determine the modulus of elasticity of the material from experimentally determined stress-strain values. Designers customarily assume a modulus of elasticity of about 25 million pounds per square inch, construct a line representing this modulus on an experimentally determined stress-strain diagram, construct a second line parallel to this assumed modulus line and spaced therefrom by a distance equivalent to a strain of 0.2% in two inches or 0.002 inch per inch of gage length, and take as the "yield stress" the point of intersection of the second line with the stress-strain curve. The "yield strength" calculated from the yield stress obtained in this manner is considerably below the measured strength at the stress that will cause the steel to rupture, and may be, for instance, as low as 100,000 pounds per square inch. The yield stress value is of course outside the elastic limit, but is high enough to permit of fairly accurate determination.

Another shortcoming of the cold rolled aus-

tenitic type steels is that their strengths, measured by conventional methods, are different in tension than in compression, and different when measured along the direction of rolling than when measured transverse thereto. In a typical instance, the following yield strengths (0.2% set), maximum tensile strengths, and buckling strengths in compression, in pounds per square inch, were measured on samples of the same cold rolled austenitic type chromium nickel steel, respectively in the direction of rolling (L) and transverse thereto (T):

	In tension	In compression
Yield strength, L.....	117,000	95,000
Yield strength, T.....	103,000	137,000
Tensile strength (buckling strength) L.....	178,000	138,000
Tensile strength (buckling strength) T.....	175,000	168,000

Thus, although the tensile strength as ordinarily measured was 178,000 pounds per square inch, designers could take but little advantage of this property because lower stresses caused permanent large deformation in tension and compression.

Although the superior resistance of the austenitic type chromium steels to corrosion gives them an advantage over the strong light metal alloys, for instance the "Duralumin," "Hiduminium," and "Birmabright" groups of aluminum alloys, their greater specific gravity is a handicap which can be overcome only by the development of relatively very great strength while maintaining satisfactory toughness, ductility, and fatigue resistance. Heretofore, it has not been possible to produce steels which notably surpassed the light metal alloys on a strength to weight ratio basis and were otherwise wholly satisfactory. For several years there has been a large demand for improved high strength corrosion resistant steels for aircraft and other structures, for instance for aircraft used in over-water service and therefore exposed to corrosive waters.

It is an object of this invention to improve the elastic properties (as evidenced for instance by such properties as the yield point, yield strength, and modulus of elasticity) of cold rolled and otherwise cold worked (e. g., cold drawn, cold twisted or bent, cold pressed) austenitic type corrosion resistant chromium steel without very materially altering its toughness, ductility, ultimate tensile strength, ultimate compressive strength, hardness, or resistance to corrosion.

Further objects of the invention are to impart

to cold worked steel of the type described a definitely determinable and high proportional limit and to raise its "yield strength" as determined in the manner described above; to provide such a steel having a definitely determinable high modulus of elasticity substantially the same as that of a fully annealed steel of the same composition; and to increase the fatigue endurance of such a steel. Other objects of this invention are to provide a method for raising the proportional limits to above 30,000 pounds per square inch and the yield strengths to above 120,000 pounds per square inch, and preferably above 150,000 pounds per square inch, both in the direction of rolling and in a direction transverse thereto, and both in compression and in tension; to provide a method for making more nearly similar the tensile and compressive elastic properties; and to provide a method for making the elastic properties more nearly uniform in all directions throughout the steel section.

Further objects of the invention are a method of producing a cold rolled austenitic type chromium steel structural member, characterized by a proportional limit at least 45,000 pounds per square inch and a yield strength (to 0.2% set) upward of 160,000 pounds per square inch, in tension and in compression, in the direction of rolling and transverse thereto; by a calculated modulus of elasticity substantially the same as that of fully annealed steel of the same composition; by an improved resistance to fatigue; by high toughness, ductility and resistance to corrosion; by a metallographic structure substantially free from microscopically visible precipitated carbides or similar compounds; and by a bright cold-rolled surface.

The objects of the invention are attained by a method which comprises subjecting cold rolled (or otherwise cold worked) austenitic type corrosion resistant chromium steels to a heat treatment for controlled periods of time at temperatures within the range of 200° F. to 625° F., preferably within the range of 250° F. to 550° F.

The invention will be more particularly described with reference to the accompanying drawings, in which:

Fig. 1 is a diagram on semilogarithmic coordinates, indicating the ranges of time and temperature to be used in the practice of the invention;

Fig. 2 is a diagram on rectangular cartesian coordinates, of the observed stress-strain curves (S_1 and S_2) of an austenitic type of steel, respectively before and after subjection to the treatment of the invention. Also shown in this figures are the lines (M_1 and M_2) from which moduli of elasticity may be determined and the line (D_1 and D_2) from which yield stresses may be determined, and

Fig. 2a is a continuation of the upper portion of Fig. 2. The line X—Y in Fig. 2a corresponds with the line X—Y in Fig. 2.

It is essential to the successful application of the method of the invention that the time of treatment be properly related to the temperature of treatment. For any given temperature within the range of 200° to 625° F. there is a minimum time of treatment and a maximum time of treatment, the optimum time being between the minimum and maximum and depending on such factors as the composition of the steel, the amount of cold work that has been done on the steel, the tensile and elastic properties desired, and economic factors. A treatment for a time shorter than the minimum is ineffective to produce a use-

ful improvement in elastic properties. A treatment for a time longer, or at a temperature higher, than the maximum often produces undesirable effects, including one or more of such effects as a decrease in strength, for instance by an annealing (softening) action; the formation of a surface scale or a dark surface discoloration; a decrease in resistance to surface corrosion; a susceptibility to intergranular corrosion; a loss of toughness; an increase in hardness, as by precipitation of carbides or other compounds; or a coarsening of the grain structure. When the time of treatment is properly related to the temperature, none of these undesirable effects occurs and, indeed, there is not even a metallographic change observable under the microscope at magnifications of 2000 diameters.

The correct relationship of time and temperature is indicated graphically in Fig. 1. Suitable times and temperatures are those included between lines A, B, C, and D, and preferred times and temperatures are included between lines E, F, G, and D. Time temperature combinations above the line A are such as will produce undesirable effects while those below the lines B and C will not bring about the desired improvements.

The lines C and G of Fig. 1 may be represented by the formula: $(H)10^{aT}=K$, wherein H is the time in hours, T is the temperature in Fahrenheit degrees, and a is 0.002588. The value of K is 83 in the case of line C, and 150 in the case of line G.

Although periods of time somewhat longer than 100 hours, say up to 200 hours, may be used at the lower temperatures without serious effects, such long heating times are not commercially attractive.

The use of temperatures between 475° and 625° F. may in some instances produce a slight surface discoloration, not ordinarily displeasing in general appearance. Any discoloration may be removed very quickly with acid or an acid pickling solution without damaging the cold rolled surface finish. If desired, an inert or "bright annealing" atmosphere may be used to avoid or minimize discoloration of the steel, thereby affording somewhat greater latitude to the times that may be used at these higher temperatures.

The method of the invention may be applied to advantage to a wide variety of cold worked austenitic type corrosion resistant steels containing about 12% to 25% chromium. Such steels may contain 4% to 16% of nickel or manganese or mixtures of nickel and manganese; up to 0.3%, or somewhat more, carbon; with other elements, such as silicon, nitrogen, copper, columbium, tungsten, and molybdenum, customarily or occasionally added to austenitic type chromium steels. Preferably, the chromium content is between 15% and 19%, and the total amount of nickel and manganese does not exceed 10% and is at least 5%. If the steel contains a small amount of molybdenum or tungsten, the total nickel and manganese percentage is preferably at least 8% to improve the hot working properties; if the amount of such elements is large, the total nickel and manganese percentage is preferably at least 10%. Columbium may be present, provided that it is no more than 8 times the carbon content, i. e., provided substantially all of it is combined with the carbon to form a compound insoluble in the steel. It is preferred that the amount of silicon be less than 3%, and in most cases less than 1%. A suitable amount of nitrogen is 0.01% to 0.3%, although the amount of this element

may on occasion be as much as 0.4%. A suitable amount of copper is 0.25% to 2.5%; and of molybdenum or tungsten or both, 1% to 5%.

Experimentally determined effects of the application of the method of the invention to several typical steels of the kind described appear in Tables A to D. In these tables are given the chemical analyses of the respective steels, the remainder in each case being iron and the usual impurities in insignificant amounts; the observed proportional limit in tension, in thousands of pounds per square inch; yield stress in tension, in thousands of pounds per square inch, calculated as indicated above; the observed maximum stress in tension, in thousands of pounds per square inch; and the observed percentage elongation in a two inch gage length. These tensile tests were made on a standard tensile testing machine using a Berry gage and strip samples, of the respective thicknesses indicated in the tables, tested in the direction of rolling. The samples were prepared from hot wrought blanks by cold rolling to final thicknesses. The reduction in thickness by cold rolling is expressed as a percentage of the thickness of the blank before cold rolling.

TABLE A

ANALYSES OF STEELS IN TABLES B TO D

Steel No.	Analysis (remainder Fe and incidental impurities)						
	Per cent Cr	Per cent Ni	Per cent Mn	Per cent Si	Per cent C	Per cent N	Per cent Cb
1.....	17.43	7.75	0.54	0.35	0.11	0.06	None
2.....	18.20	2.21	7.40	0.36	0.08	0.05	None
3.....	18.05	9.55	0.56	0.45	0.11	Low	0.46
4.....	17.29	7.62	0.42	0.32	0.12	0.12	None
5.....	16.97	7.54	0.50	0.25	0.07	0.04	None
6.....	18.07	2.20	9.09	0.46	0.11	0.12	None
7.....	18.07	4.70	4.83	0.39	0.10	0.12	None
8.....	18.05	8.32	0.44	0.31	0.09	0.04	None
9.....	18.95	7.69	Low	Low	0.07	Low	None

TABLE B

TYPICAL EFFECTS OF HEATING AT 200° C. (392° F.) AND AIR COOLING. ALL SAMPLES 0.03 INCH THICK, 30% REDUCTION BY COLD-ROLLING

I. Sixteen hours heating at 200° C. (392° F.)

	Steel number			
	1	2	3	4
Proportional limit as rolled.....	14.4	22	23	30
Proportional limit after heating.....	62	47	60	59
Yield stress as rolled.....	123	126	132	130
Yield stress after heating.....	152	153	166	148
Maximum stress as rolled.....	199	185	176	164
Maximum stress after heating.....	183	182	188	169
Per cent elongation in 2 inch. as rolled.....	18.5	17	8	20.5
Per cent elongation in 2 inch. after heating.....	20	18.5	5	18

II. Sixty-four hours heating at 200° C. (392° F.)

	Steel number		
	5	6	7
Proportional limit as rolled.....	24	24	24
Proportional limit after heating.....	67	39	53
Yield stress as rolled.....	130	119	119
Yield stress after heating.....	174	159	156
Maximum stress as rolled.....	178	190	185
Maximum stress after heating.....	180	190	183
Per cent elongation in 2 inch. as rolled.....	11	17.5	18.5
Per cent elongation in 2 inch. after heating.....	8	18	22.5

TABLE C

TYPICAL EFFECTS OF HEATING 24 HOURS AT 200° C. (392° F.) AND AIR COOLING ON STEEL COLD-ROLLED BY VARIOUS PERCENTAGES OF REDUCTION

STEEL NO. 1, SAMPLES 0.03 INCH THICK

	Percentage reduction by cold-rolling		
	20	30	40
Proportional limit as rolled.....	14.3	14.4	22
Proportional limit after heating.....	42	49	56
Yield stress as rolled.....	94	123	161
Yield stress after heating.....	117	166	193
Maximum stress as rolled.....	178	199	206
Maximum stress after heating.....	169	190	210
Per cent elongation in 2 inches as rolled.....	30	18.5	13
Per cent elongation in 2 inches after heating.....	30	18	8
Rockwell "C" hardness as rolled.....	35	41	45
Rockwell "C" hardness after heating.....	37	43	47

STEEL NO. 1, SAMPLES 0.06 INCH THICK

	Percentage reduction by cold-rolling		
	20	24	28
Proportional limit as rolled.....	36	48	56
Proportional limit after heating.....	103	128	170
Yield stress as rolled.....	118	159	197
Yield stress after heating.....	169	190	203
Maximum stress as rolled.....	162	183	213
Maximum stress after heating.....	31	25	12
Per cent elongation in 2 inches as rolled.....	30	25	8
Per cent elongation in 2 inches after heating.....	36	41	45
Rockwell "C" hardness as rolled.....	38	43	47
Rockwell "C" hardness after heating.....			

TABLE D

TYPICAL EFFECTS OF VARIOUS TIMES OF HEATING AT 200° C. (392° F.) AND AIR COOLING

Steel No. 1, sample 0.03 in. thick, 30% reduction by cold-rolling

	Time of heating, hrs.					
	0	8	16	24	64	72
Proportional limit.....	14.4	56	62	49	53	56
Yield stress.....	123	166	152	166	150	163
Tensile strength.....	199	193	183	190	181	190
Per cent elongation in 2 inches.....	18.5	16	20	18	20	18.5

50 Steel No. 8, sample 0.02 in. thick, 30% reduction by cold-rolling

	Time of heating, hrs.		
	0	1	168
Proportional limit.....	20	25	30
Yield stress.....	125	128	143
Tensile strength.....	162	157	156
Per cent elongation in 2 inches.....	23	25	25

Tables E and F comprise data obtained on two representative steels, before and after applying the heat treatment of the invention, in not only the tensile tests referred to in connection with Tables B to D but also compression tests on cold formed cylindrical tube samples having an inside diameter of 1.5 inch; a wall thickness of 0.035 inch, and a length of 2 inches, the ends being supported in Wood's metal to avoid bending stresses. Samples were tested respectively in the direction that the steel was rolled (Long.) and in the direction transverse thereto (Trans.). The tensile yield strengths were determined as de-

scribed herein above. Yields in compression were measured with Huggenberger gages, those in tension with Berry gages.

TABLE E

Tests of steel containing 18.45% Cr, 8.79% Ni, 0.5% Mn, 0.55% Si, 0.10% C, 0.04% N, remainder Fe; strip section reduced 35% by cold rolling. Tensile samples 0.03 inch thick

	As cold rolled	After 72 hr. at 392° F.
Proportional limit in tension, Long.....	45,000	55,000
Proportional limit in tension, Trans.....	48,000	53,000
Proportional limit in compression, Long.....	17,100	47,600
Proportional limit in compression, Trans.....	42,700	72,000
Yield strength in tension, Long.....	132,000	154,000
Yield strength in tension, Trans.....	130,000	148,000
Yield strength in compression, Long.....	94,100	120,000
Yield strength in compression, Trans.....	150,200	171,000
Maximum stress in tension, Long.....	155,300	173,400
Maximum stress in tension, Trans.....	166,200	178,700
Buckling stress in compression, Long.....	151,800	168,000
Buckling stress in compression, Trans.....	183,110	193,000

TABLE F

Tests of steel containing 17.15% Cr, 7.17% Ni, 1.32% Mn, 0.34% Si, 0.11% C, 0.05% N, remainder Fe; strip section reduced 35% by cold rolling. Tensile samples 0.035 inch thick

	As cold rolled	After 72 hr. at 392° F.
Proportional limit in tension, Long.....	45,000	58,000
Proportional limit in tension, Trans.....	46,000	61,000
Proportional limit in compression, Long.....	39,700	62,000
Proportional limit in compression, Trans.....	47,000	65,000
Yield strength in tension, Long.....	162,000	181,000
Yield strength in tension, Trans.....	140,000	172,000
Yield strength in compression, Long.....	146,000	163,000
Yield strength in compression, Trans.....	185,000	201,000
Maximum stress in tension, Long.....	196,000	198,000
Maximum stress in tension, Trans.....	201,000	202,000
Buckling stress in compression, Long.....	184,500	201,200
Buckling stress in compression, Trans.....	214,300	218,500

Inspection of Tables A to F reveals that the improvement in properties wrought by the heat treatment of this invention is greater, the higher the percentage reduction of section; that the improvement is greater in those steels which are less stably austenitic than an 18% chromium, 8% nickel steel; and that the highest tensile and compressive strengths are to be obtained by a cold reduction of more than 30% of a steel less stably austenitic than "18-8," followed by the heat treatment of the invention.

Further research has shown that to achieve, with satisfactory ductility, in tension and compression, both in the direction of rolling and transverse thereto, a proportional limit at least 45,000 and up to 75,000 pounds per square inch, and a yield strength (0.2% set) upwards of 160,000 and up to 225,000 pounds per square inch, in a chromium-nickel steel containing between 15% and 19% chromium, it is necessary to keep the sum of the chromium and nickel percentages between 21% and 26%, the manganese content below 3%, the silicon content below 0.75%, and the carbon content between 0.01% and 0.2%, the nitrogen content between 0.01% and 0.2%, and to cold roll or otherwise cold work the steel to an extent corresponding to a reduction of section between 30% and 60%.

Although this invention does not depend on any theory, it seems probable that the high strength imparted to autenitic type chromium

steels is a result chiefly of three phenomena: cold working of austenite, cold working of ferrite if any is present, and the alteration of some austenite to a hard pseudo-martensite. If the steel composition is such that the austenite is relatively stable, most of the increased strength imparted by cold work is due to internal straining of austenite (and ferrite if such is present), but if the austenite is unstable a hard pseudo-martensite is produced by cold work, and the increase in strength imparted by the martensitic constituent is greater than is attainable by the moderately great cold straining of austenite or ferrite imparted by rolling mills of conventional capacities.

Figs. 2 and 2a illustrate graphically some of the effects produced by the method of the invention. In preparing these figures, steel number 5 was cold-rolled to strip 0.03 inch thick by a 30% reduction in thickness. One sample of this strip, 0.0147 square inch in cross-sectional area, was then pulled, without heat treatment, in a standard hydraulic tensile testing machine, using a Berry gage and a 2 inch gage length. The unit elongations at observed increments of stress were then plotted, giving the dots appearing on stress-strain line S₁. A straight line (M₁) was then drawn through as many dots on S₁ as possible. The slope of the modulus line M₁ indicates the "calculated" modulus of elasticity of the sample, in this case 27.2 million pounds per square inch. The point at which the stress-strain curve S₁ deviates from the modulus line M₁ indicates the proportional limit, 23,800 pounds per square inch. A deviation line D₁ is drawn parallel to the modulus line M₁, spaced therefrom by a distance representing a strain of two thousandths of one inch per inch; the intersection of this line D₁ with the stress-strain line S₁ indicates the yield stress, 130,000 pounds per square inch.

Still referring to Figs. 2 and 2a, a second sample of the same strip was heated at 392° F. for 72 hours and air-cooled. The treated sample, of 0.0151 square inch cross-sectional area, was then tested in the same manner as that described in the preceding paragraph. The stress-strain line S₂ was thereby obtained, and from this the modulus line M₂ and the deviation line D₂. The modulus line M₂ indicates a proportional limit of 50,000 pounds per square inch and a modulus of elasticity of 28 million pounds per square inch, substantially the modulus of fully annealed material of the same chemical composition. The intersection of the deviation line D₂ with the stress-strain line S₂ indicates a yield stress of 176,000 pounds per square inch.

There is some evidence, obtained by X-ray diffraction methods, to indicate that the heat treating method of this invention acts to release internal stresses within the crystalline structure of the steel without, apparently, producing the results of the known stress-relieving anneal. The absence of a visible precipitate, and the enhanced uniformity of properties throughout a sample of steel, would also indicate that the mechanism of the heat treating method of the invention is through a relief or redistribution of internal stress rather than through the formation of a precipitate. But the invention is not limited to any theory.

The method of the invention also improves the fatigue endurance of the steels of the class described. The data set forth in Table G are self-explanatory and indicate such improvement.

TABLE G

Results of tests of cold drawn bars of steel No. 9, 0.75 inch by 0.5 inch cross-section, in Krause fatigue testing machine. Rotating beam speed 7000 R. P. M. Cantilever loading

Condition of metal	Stress	Millions of cycles	Effect on sample
	Lb./sq. in.		
As cold drawn.....	85,000	11.42	No failure.
Do.....	88,000	0.199	Failed.
Do.....	88,000	0.987	Do.
Held 3 days at 392° F.....	88,000	10.494	No failure.
Do.....	92,000	10	Do.

It has further been found that the proportional limit of steels treated according to the invention is lowered if the steel is subsequently cold-worked, and that the good elastic properties may be restored by again applying the heat-treatment described herein. Inasmuch as many articles are fabricated by steps which involve cold-working of the metal (bending, spinning, etc.), there are instances in which the method of the invention may advantageously be applied to a partially or completely fabricated structure. For this purpose, heating chambers, suitable for handling intricate or large articles and apparatus, may easily be constructed for operation at the low temperatures of this invention.

The application of the method of the invention to cold-rolled corrosion-resistant austenitic chromium steel provides a new material having improved properties which will permit designers to use higher unit stresses in the design of structures, and to use such higher unit stresses with full confidence in the dependability of the steel.

I am aware that it was proposed in British Patent 333,237 to enhance the corrosion resistance of polished austenitic chromium-nickel steels by heating such steels within the temperature range of 100° to 400° C. for a time unspecified. The heat treatment of cold worked steels in accordance with my invention has no detectable effect on the corrosion resistance of the steels. For instance the results of immersing samples of steel No. 1 (Table A) in boiling 65% nitric acid for three successive 48 hour periods, were as appearing in Table H.

TABLE H

Condition of sample	Penetration, inch per month		
	1st period	2nd period	3rd period
As cold rolled.....	0.0018	0.0018	0.0017
After heating 24 hours at 392° F.....	0.0018	0.0018	0.0018
After heating 72 hours at 392° F.....	0.0019	0.0018	0.0017

Prior workers have also observed a slight increase in yield stress by a heat treatment of cold worked austenitic chromium nickel steels at temperatures between 300° and 450° C. (Monypenny, "Stainless Iron and Steel," 2nd ed. page 188) and between 800° and 1100° F. (P. D. Ffield Patents 2,080,367 and 2,080,368). There has heretofore been no knowledge that, in the absence of precipitable compounds, the elastic properties of austenitic type chromium steels may be valuably enhanced as disclosed herein.

I claim:

1. Method of producing a steel structural member having throughout in both tension and compression a proportional limit above 45,000 pounds per square inch and a yield strength (at 0.2% permanent set) above 160,000 pounds per square inch, which comprises cold rolling an austenitic type chromium steel member until it has lost between 30% and 60% of its original thickness, such steel member having the composition: 15% to 19% chromium and 5% to 8% nickel, the sum of the chromium and nickel being between 21% and 26%, 0.01% to 0.2% each of carbon and nitrogen, 0.3% to 3% manganese, 0.08% to 0.8% silicon, remainder iron; and heating such cold rolled member at a temperature between 250° and 550° F. for a time not over 100 hours but at least long enough to satisfy the formula

$$(H) 10^{0.002588T} = 150$$

2. wherein H is the time in hours and T is the temperature on the Fahrenheit scale.

2. Method of producing a steel structural member having throughout in both tension and compression a proportional limit above 45,000 pounds per square inch and a yield strength (at 0.2% permanent set) between 150,000 and 225,000 pounds per square inch, which comprises cold rolling an austenitic type chromium steel member until it has lost between 25% and 60% of its original thickness, such steel member having the composition: 15% to 19% chromium and 5% to 8% nickel, the sum of the chromium and nickel being between 21% and 26%, 0.01% to 0.2% each of carbon and nitrogen, 0.3% to 3% manganese, 0.8% to 0.8% silicon, remainder iron; and heating such cold rolled member at a temperature between 250° and 550° F. for a time not over 100 hours but at least long enough to satisfy the formula $(H) 10^{0.002588T} = 150$ wherein H is the time in hours and T is the temperature on the Fahrenheit scale.

3. A method of producing a steel structural member having throughout in both tension and compression a proportional limit at least 30,000 pounds per square inch and a yield strength (at 0.2% permanent set) at least 120,000 pounds per square inch, which comprises cold rolling an austenitic type chromium steel member until it has lost between 10% and 65% of its original thickness, such member having the composition: 12% to 25% chromium, at least one element selected from the group consisting of nickel and manganese in an aggregate percentage between 4% and 16%, 0.01% to 0.3% carbon, 0.01% to 0.3% nitrogen, remainder principally iron; and heating such cold rolled member at a temperature between 200° and 625° F. for a time at least long enough to satisfy the formula $(H) 10^{0.002588T} = 83$ wherein H is the time in hours and T is the temperature on the Fahrenheit scale.

4. Method of imparting improved resistance to tensile and compressive stresses and to fatigue, to a structure fabricated from a plurality of cold rolled and otherwise cold worked structural members composed of austenitic type chromium steel which comprises heating such fabricated article at a temperature between 200° F. and 550° F. for a time not over 200 hours but at least long enough to satisfy the formula $(H) 10^{0.002588T} = 83$ wherein H is the time in hours and T is the temperature on the Fahrenheit scale.

5. Method of improving the elastic properties of cold worked austenitic type steel of the kind containing in the neighborhood of 18% chromium

and 8% nickel which comprises heating such steel at a temperature in the neighborhood of 400° F. for at least 8 hours but not so long as significantly to impair the surface or to alter its corrosion resistance or to harden the steel or to produce visually apparent precipitation of compounds.

6. Method of imparting improved resistance to tensile and compressive stresses and to fatigue.

to a cold rolled structural member composed of austenitic type chromium steel which comprises heating such cold rolled member at a temperature between 250° F. and 550° F. for a time not over 100 hours but at least long enough to satisfy the formula $(H)10^{0.002588T}=150$ wherein H is the time in hours and T is the temperature on the Fahrenheit scale.

RUSSELL FRANKS.

CERTIFICATE OF CORRECTION.

Patent No. 2,358,799.

September 26, 1944.

RUSSELL FRANKS.

It is hereby certified that error appears in the printed specification of the above numbered patent requiring correction as follows: Page 5, second column, line 36, claim 2, for "0.8% to 0.8%" read --0.08% to 0.8%--; and that the said Letters Patent should be read with this correction therein that the same may conform to the record of the case in the Patent Office.

Signed and sealed this 28th day of November, A. D. 1944.

(Seal)

Leslie Frazer
Acting Commissioner of Patents.