

Dec. 2, 1958

E. J. DULIS ET AL
SUBSTANTIALLY NICKEL-FREE AUSTENITIC AND
CORROSION RESISTING Cr-Mn-N STEELS

2,862,812

Filed May 16, 1958

3 Sheets-Sheet 1

Fig. 1.

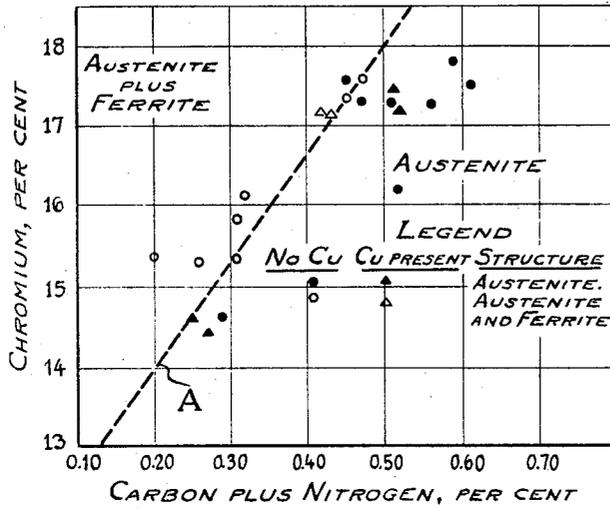
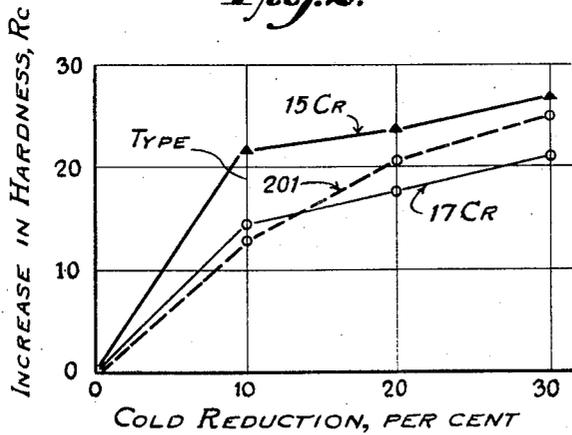


Fig. 2.



INVENTORS.
EDWARD J. DULIS
PETER PAYSON.
BY

Ward, Neal, Haselton Orme & McElhammon
ATTORNEYS.

Dec. 2, 1958

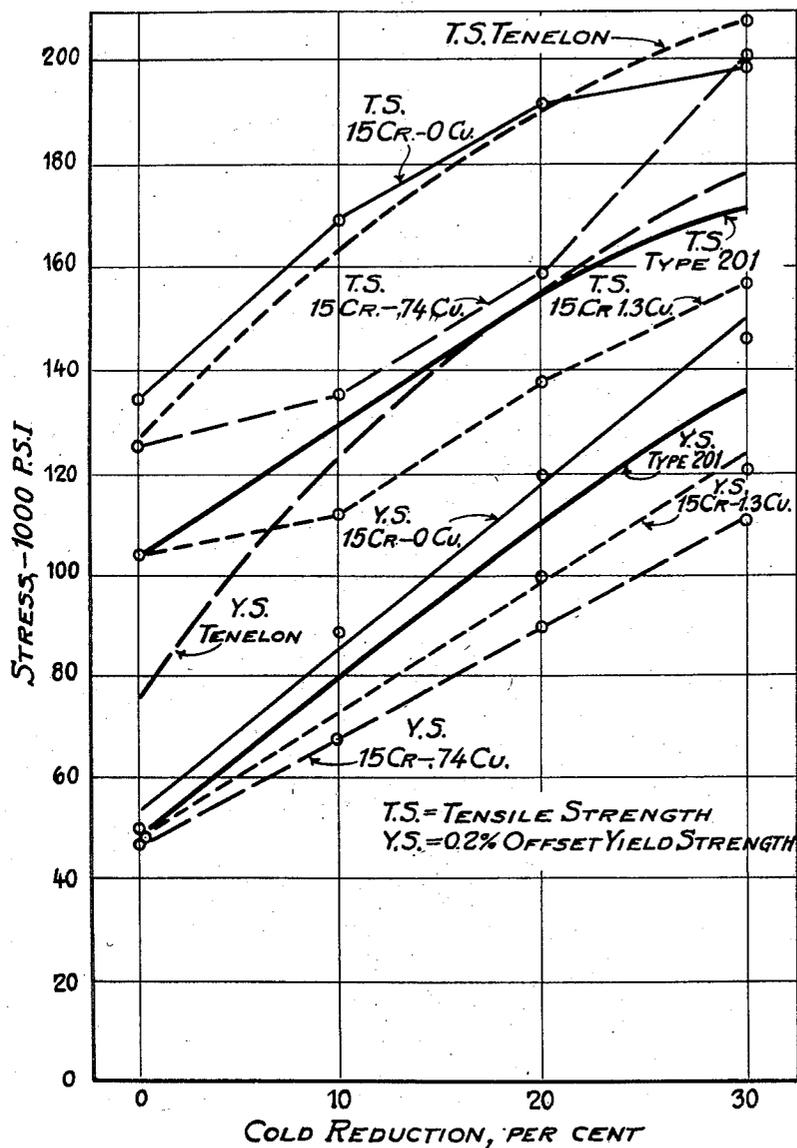
E. J. DULIS ET AL
SUBSTANTIALLY NICKEL-FREE AUSTENITIC AND
CORROSION RESISTING Cr-Mn-N STEELS

2,862,812

Filed May 16, 1958

3 Sheets-Sheet 2

Fig. 3.



INVENTORS.
EDWARD J. DULIS.
PETER FAYSON.

BY

Ward, Keel, Haselton, Dime & McElhannon
ATTORNEYS.

Dec. 2, 1958

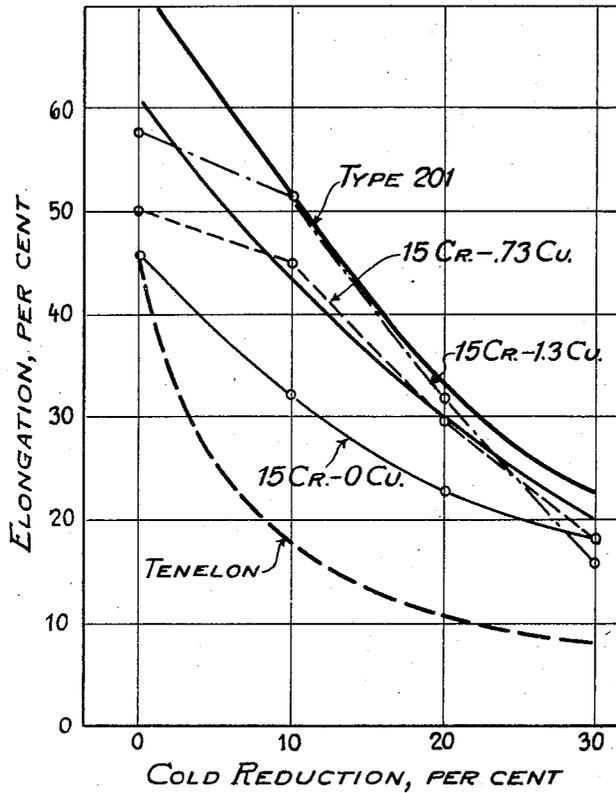
E. J. DULIS ET AL
SUBSTANTIALLY NICKEL-FREE AUSTENITIC AND
CORROSION RESISTING Cr-Mn-N STEELS

2,862,812

Filed May 16, 1958

3 Sheets-Sheet 3

Fig. 4.



INVENTORS.
EDWARD J. DULIS.
PETER PAYSON.
BY

Woodward, Harselton, Orme & McChannon
ATTORNEYS.

1

2,862,812

**SUBSTANTIALLY NICKEL-FREE AUSTENITIC
AND CORROSION RESISTING Cr-Mn-N
STEELS**

Edward J. Dulis and Peter Payson, Pittsburgh, Pa., as-
signors to Crucible Steel Company of America, Pitts-
burgh, Pa., a corporation of New Jersey

Application May 16, 1958, Serial No. 735,900

5 Claims. (Cl. 75-125)

This invention pertains to corrosion resistant, austenitic stainless steels, and more particularly to a substantially nickel-free steel of this type, which contains as essential constituents in addition to iron, only carbon, manganese, chromium and nitrogen, and preferably also copper, with- in critically restricted ranges of each and in balanced proportions such as to impart an wholly austenitic structure together with excellent hot and cold forming properties as well as excellent strength and ductility and good cor- rosion resistance.

This application is a continuation-in-part of our co- pending application Serial No. 651,042, filed April 5, 1957.

The past, present, and anticipated future shortage of nickel has necessitated steel-industry-wide efforts to de- velop austenitic stainless steels in which the nickel of the well-known 18Cr-8Ni (AISI 300 series) steels is re- placed by other austenite forming and stabilizing elements, such as carbon, nitrogen, manganese, and copper. At present, two new grades of such steels, in which nickel is partially replaced by manganese and nitrogen have suc- cessfully passed the development stage and are now ac- cepted as the AISI Type 201 and 202 steels, having typical analyses of about 6.5Mn-4.5Ni-17Cr-0.25N max.- 0.15C max. and 9Mn-5Ni-18Cr-0.25N max.-0.15C max., respectively. There has also been developed the 16-16-1 type of steel, i. e., 16Cr-16Mn-1Ni which is competitive with the higher nickel-bearing grades afore- said for certain applications. However, all such steels require substantial amounts of nickel and hence are ob- jectionable on this ground for reasons above noted.

Recently, owing to the success of the Cr-Ni-Mn steels, research directed to the development of complete- ly nickel-free Cr-Mn-N austenitic, corrosion resisting steels has been intensified. In the development of a new steel of this type, the following goals are sought: The steel should retain a fully austenitic structure after solu- tion annealing at about 2000° F. and rapid cooling to room temperature. Also, the retention of a fully aus- tenitic structure at normal hot working temperatures up to about 2300° F. is necessary because substantial amounts of delta ferrite will seriously impair the hot-

2

workability of the steel by causing cracking and tearing during the initial conversion into bars, rods, and strip. Also such a steel should have suitable mechanical prop- erties (strength, ductility, and work-hardening character- istics) for successful fabrication and commercial utility, and also adequate corrosion resistance for the intended type of application. In addition, the steel should have good drawability, weldability, and elevated-temperature mechanical properties.

Now we have developed a steel which meets these re- quirements, which requires no nickel as an essential con- stituent. The steel of our invention is characterized in being wholly or 100% austenitic at all temperatures from the melting temperature down to room or atmospheric temperature. Our steel being thus free from high tem- perature ferrite at all temperatures up to 2300° F., i. e., normal hot rolling temperatures, can be easily reduced from the ingot stage to hot bands without tearing or rupture.

Our steel can be annealed at about 2050° F. and as an- nealed has a yield strength of about 50,000 p. s. i. and a tensile strength of about 145,000 p. s. i. (a ratio of about 1:3), and an elongation of about 45%. When cold reduced 30%, the steel has a yield strength of about 140,000 p. s. i., a tensile strength of about 195,000 p. s. i. (a ratio of about 1:1.4) and an elongation of about 15%. The steel accordingly has excellent cold forming prop- erties by reason of its low yield strength combined with high ductility, as annealed, and by reason of its high ductility after a 30% reduction. Likewise, as both an- nealed and cold reduced, it has adequate strength and ductility for use as a structural material in service.

Although the corrosion resistance of our steel to boiling nitric acid is not as high as in the relatively high nickel- bearing grades, such as Types 201, 202 and 301, it is su- perior to that of the 16-16-1 nickel-bearing steel.

The steel of the invention is, however, primarily intend- ed as a stainless type of steel for structural applications, subject primarily to atmospheric exposure, such as for exterior and interior paneling and trim on railway cars, automotive truck bodies, building structures and the like. Our tests have shown that for such applications, our new steel has adequate corrosion resistance. In addition, it has the requisite hot and cold formability, and the requi- site strength and ductility both as annealed and as cold reduced, for such applications.

The broad range of analysis of our steel is:

	Composition, percent
Manganese -----	11-under 14
Chromium -----	14-18
Copper -----	0-2
Silicon -----	0-3
Nitrogen -----	0.15-0.4
Carbon -----	0-0.15
Nitrogen plus carbon, minimum -	0.075(Cr-12.5)+0.1
Balance -----	Iron

Within the broad range aforesaid our invention is directed to two preferred compositions, one containing typically about 15% chromium and the other typically about 17% chromium.

The broad and preferred ranges for the typically 15Cr steel are:

	Composition, Percent	
	Broad	Preferred
Manganese.....	11-under 14....	11.5-13.5.
Chromium.....	14-16.5.....	14.5-15.5.
Copper.....	0-2.....	over 0.5-1.5.
Silicon.....	0-3.....	0.15-1.5.
Carbon.....	0-0.15.....	0-under 0.10.
Nitrogen.....	0.15-0.4.....	0.25-0.35.
(C+N) min.....	0.075 (Cr-12.5) +0.1.	same.
Balance.....	Iron.....	Iron.

The broad and preferred ranges for our typically 17Cr steel are:

	Composition, Percent	
	Broad	Preferred
Manganese.....	11-under 14....	11.5-13.5.
Chromium.....	16.5-18.....	16.5-17.5.
Copper.....	0-2.....	over 0.5-1.5.
Silicon.....	0-3.....	0.15-1.5.
Carbon.....	0-0.2.....	0.05-0.15.
Nitrogen.....	0.25-0.4.....	0.3-0.4.
(C+N) min.....	0.075 (Cr-12.5) +0.1.	same.
Balance.....	Iron.....	Iron.

By balance iron in our steel is meant iron except for impurities within commercial tolerances, i. e., P and S about 0.04 max. each, and nickel about 0.5 max.

Copper is a preferred addition to our steel in the amounts stated, as it improves resistance of the steel to work hardening and also improves the corrosion resistance.

As stated, the ranges and proportioning of the alloying constituents in our steel are critical for providing the desirable combination of properties aforesaid. For assuring an wholly austenitic structure in our steel, we have found that the minimum carbon plus nitrogen content should be related to the chromium content as follows:

(1) Percent (C+N) min.=

$$0.075(\text{percent Cr}-12.5)+0.10$$

Although manganese over our broad range of about 10 to under 14% helps to stabilize the austenite in the steel, beyond this range it tends to form ferrite. Likewise chromium above about 17% tends to introduce a ferritic structure.

Even with chromium and manganese thus limited, however, the steel will not have an wholly austenitic structure in the absence of appropriate additions of the potent austenite stabilizers carbon and nitrogen. As shown by the above formula, derived from test results hereinafter presented, the minimum carbon plus nitrogen, for assuring an wholly austenitic structure, increases with the chromium content. Thus for our typically 15Cr

steel, the minimum carbon plus nitrogen is about 0.27%, and for our typically 17Cr steel the minimum carbon plus nitrogen is about 0.45%. On the high side there are definite upper limits for each of carbon and nitrogen that can be tolerated.

High carbon produces chromium carbide precipitation in weld zones of welded structures made of the steel, thus depleting the chromium and lowering the corrosion resistance of the steel thereat. And since the steel of the invention is primarily intended for applications aforesaid involving welded structures, the carbon must be kept sufficiently low to assure good corrosion resistance throughout the entire structure including the weld zones. To this end, the carbon should not exceed about 0.15% and preferably should be held under 0.1%.

Nitrogen is limited on the high side by the extent of its solubility in the steel. Nitrogen present beyond the limit of solubility will evolve in gaseous form from the steel and thereby produce porous and unsound ingots. And while increasing amounts of the chromium and manganese in the steel, increase the solubility of nitrogen therein, and thus in this respect, function to increase austenite formation, there are definite upper limits beyond which an wholly austenitic structure cannot be achieved in this direction, owing to the aforesaid counteracting tendency for manganese above about 15% to produce ferrite, and the same tendency of chromium above about 17% to do so.

Our above formula for minimum carbon plus nitrogen shows, for example, that in a chromium-manganese steel containing about 18% chromium and 0.1% carbon, about 0.4% nitrogen is required to impart a completely austenitic structure at normal hot working temperatures. We have found, however, that in order to keep 0.4% nitrogen in solution, about 15% or more of manganese is required. But this amount of manganese in turn tends to promote the formation of delta ferrite at the hot-working temperatures. The alternative of increasing the carbon thereby to permit of reducing the nitrogen and manganese contents, does not solve this problem, since it reduces the corrosion resistance of the steel at weld zones as above explained.

We accordingly set the upper limit for nitrogen at 0.4% and preferably at 0.35%, in our steel in conjunction with the aforesaid upper broad and preferred limits for carbon, manganese and chromium and the minimum carbon plus nitrogen to assure the combination of good corrosion resistance and a completely austenitic structure at hot working temperatures and upon cooling to room temperature.

It will thus be seen that the ranges and relative proportions for each of the essential alloying constituents, namely, carbon, manganese, chromium and nitrogen, are quite critical in our steel, and insofar as we are aware, previously untaught in the art as to significance or as to the novel results achieved thereby.

In the accompanying drawings to be discussed more in detail, post:

Fig. 1 is a phase diagram showing the relation between the minimum of carbon plus nitrogen versus chromium content of the steels of the invention for maintaining an wholly austenitic structure;

Fig. 2 illustrates graphically the variation in Rockwell "C" hardness versus percent of cold reduction of representative steels of the invention as compared to the Type 201 commercial grade;

Fig. 3 illustrates graphically the variation in tensile and yield strength with percent of cold reduction of representative steels of the invention as compared to commercial steels; while Fig. 4 is a graphical showing of the corresponding variation in percent tensile elongation versus percent cold reduction for these same steels.

As the experimental basis for our findings above stated, a series of 15-pound heats of varying C—Cr—Mn—N analyses were induction melted and cast into ingots. The ingots were heated to about 2000° F., soaked one-half hour, and hammered into slabs 3½" wide and ¾" thick. The slabs were surface ground, heated to 1900–1950° F., and rolled into strips 3" wide and ¼" thick. The compositions of these steels as determined by chemical analysis are given in the following Table I.

presence of carbides or nitrides and delta ferrite phases in the microstructure. In the as-cast and hot rolled conditions, as well as after a solution anneal at 2000° and 2100° F., all steels, with the exception of Steel 6971 (15.4Cr—0.08C—0.12N), were fully austenitic (non-magnetic). After a solution anneal at 2300° F., however some steels developed delta ferrite. The results as hot rolled and as solution annealed at 2300° F. are compiled in Table II.

TABLE II
Hardness, grain size, and austenite stability data

Bar	Composition, percent ¹					As-Hot-Rolled Hardness, Rc	2,300° F. for 15 min., Water Quench		
	C	N	C+N	Cr	Cu		Hardness, Rc	Magne-Gage Reading	Ferrite, percent
6973	0.07	0.22	0.29	14.63		36	17	0	0
6972	0.07	0.22	0.29	14.63		36	16	0	0
6971	0.08	0.12	0.20	15.38		31	17	80	15
6974	0.07	0.19	0.26	15.31		34	17	15	4
6975	0.07	0.24	0.31	15.35		36	16	3	1
6976	0.07	0.24	0.31	15.84		37	19	12	3
6977	0.06	0.26	0.32	16.15		36	18	15	4
6961	0.10	0.35	0.45	17.36		38	19	3	1
6963	0.14	0.33	0.47	17.30		38	17	0	0
6962	0.14	0.33	0.47	17.57		40	19	0	<1
6964	0.19	0.37	0.56	17.29		41	20	0	0
6965	0.19	0.32	0.51	17.31		39	18	0	0
6966	0.17	0.28	0.45	17.58		38	16	0	0
6968	0.22	0.30	0.52	16.19		39	20	0	0
6969	0.24	0.27	0.51	17.28		39	17	0	0
6967	0.24	0.35	0.59	17.82		41	20	0	0
6970	0.31	0.30	0.61	17.51		40	17	0	0
6982	0.07	0.18	0.24	14.62	0.74	34	11	0	0
6983	0.07	0.20	0.27	14.43	1.33	32	11	0	0
6979	0.14	0.28	0.42	17.17	0.67	37	15	3	1
6978	0.14	0.29	0.43	17.15	1.30	37	14	0	<1
6980	0.23	0.28	0.51	17.45	0.75	38	16	0	0
6981	0.24	0.28	0.52	17.20	1.33	39	16	0	0

¹ All steels contained 11.5–12.5% manganese, balance iron.

² With exception of Steel 6971, all steels were nonmagnetic.

TABLE I
Chemical compositions of steels—wt. percent

Bar	C	Mn	Si	Ni	Cr	Cu	N	C+N
6973	0.068	11.72	0.44	0.11	14.63	0.03	0.22	0.288
6972	0.074	11.83	0.43	0.10	14.63	0.03	0.22	0.294
6971	0.078	11.41	0.45	0.09	15.38	0.03	0.125	0.203
6974	0.071	11.72	0.44	0.11	15.31	0.03	0.19	0.261
6975	0.071	11.83	0.45	0.13	15.35	0.04	0.24	0.311
6976	0.066	11.39	0.39	0.14	15.84	0.04	0.24	0.306
6977	0.062	12.05	0.51	0.12	16.15	0.03	0.26	0.322
6961	0.103	12.30	0.40	0.19	17.36	0.03	0.35	0.453
6963	0.137	12.07	0.45	0.12	17.30	0.03	0.33	0.467
6962	0.144	12.36	0.44	0.13	17.57	0.03	0.33	0.474
6964	0.187	12.21	0.45	0.12	17.29	0.03	0.37	0.557
6965	0.188	12.29	0.44	0.12	17.31	0.03	0.32	0.508
6966	0.171	12.18	0.44	0.12	17.58	0.03	0.28	0.451
6968	0.22	11.25	0.40	0.12	16.19	0.03	0.30	0.52
6969	0.24	11.61	0.36	0.12	17.28	0.03	0.27	0.51
6967	0.24	12.49	0.46	0.13	17.82	0.03	0.35	0.59
6970	0.31	12.16	0.46	0.12	17.51	0.03	0.30	0.61
6982	0.070	11.58	0.40	0.11	14.62	0.74	0.18	0.25
6983	0.067	12.10	0.44	0.14	14.43	1.33	0.20	0.267
6979	0.136	11.77	0.45	0.15	17.17	0.67	0.28	0.416
6978	0.135	11.55	0.44	0.16	17.15	1.30	0.29	0.425
6980	0.23	11.83	0.45	0.16	17.45	0.75	0.28	0.51
6981	0.24	11.55	0.41	0.15	17.20	1.33	0.28	0.52

Specimens (1 x 1 x ¾ in.) of all steels listed in Table I were heated at 2000, 2100 and 2300° F. for 15 minutes and water quenched. To produce suitable surfaces for the determination of hardness and magnetic response, the scaled surfaces of the specimens were removed by wet grinding and finishing on #320 grit belts. Rockwell "C" hardness determinations were made, and the magnetic response of the specimens was measured by use of a Magne-Gage. The Magne-Gage readings were converted into percent ferrite values on the basis of a correlation chart (T. V. Simpkinson and M. J. Lavigne, Metal Progress, February 1949, p. 164). Subsequently, the specimens were prepared metallographically, and microscopic examinations were made to establish the

The phase relations after the 2300° F. solution anneal are also shown graphically in Figure 1 of the accompanying drawings, in which the percent of carbon-plus-nitrogen content of each steel is plotted as abscissae against the percent of chromium content plotted as ordinates. The diagonal graph A represents the transus between the single phase, all-austenite region and the mixed phase, austenite plus ferrite region. Graph A thus depicts the minimum carbon-plus-nitrogen that is required to render the steel completely austenitic for any given chromium content of the steels according to the invention containing about 11 to under 14% manganese. This graph corresponds to the aforesaid Equation 1. The graph shows: (a) that at the 15% chromium level a minimum of about 0.27% carbon plus nitrogen is required and (b) that at the 17% chromium level a minimum of about 0.42% carbon-plus-nitrogen is required to make these 11–under 14% manganese steels fully austenitic at 2300° F. Microscopic examination revealed that no residual carbides or nitrides were present in the microstructure of these steels after the 2100° F. and 2300° F. solution annealing treatments.

As pointed out above, the preferred steels of the present invention are those in which the carbon does not exceed about 0.15% for reasons above explained. Accordingly, the steels in Table I having carbon of not over 0.15% were selected for further investigation as follows:

Samples (12 x 1 x ¾ in.) of these selected steels were solution-treated at 2100° F. for 15 minutes and water quenched. The scaled surfaces of the heat-treated samples were removed by sand blasting, and the samples of each steel were cold rolled to 10, 20 and 30% reductions in thickness. Standard ASTM tensile test specimens (2" in gage length and 0.5" in width) were prepared from samples in the annealed condition and after 10, 20 and 30% cold reductions. The results of the

room temperature tensile tests are shown in Table III below.

The data show that an increase in the carbon plus nitrogen content decreases the tendency of the steel to

TABLE III
Room-temperature tensile properties

Steel No.	C	N	C+N	Cr	Cu	Cold Reduction, Percent	0.2% Offset Yield Strength, 1,000 p. s. i.	Tensile Strength, 1,000 p. s. i.	Elong., Percent	Red. Area, Percent
6972	0.07	0.22	0.29	14.6		0	50	134	46	42
						10	89	169	22	20
						20	119	191	23	22
						30	146	199	19	21
6961	0.10	0.35	0.45	17.4		0	58	115	55	58
						10	113	144	34	60
						20	119	161	31	50
						30				
6962	0.14	0.33	0.47	17.6		0	63	116	56	61
						10	97	143	31	54
						20	108	170	20	46
						30	141	191	12	37
6982	0.07	0.18	0.25	14.6	0.74	0	47	125	50	41
						10	68	135	45	39
						20	90	159	30	31
						30	111	201	18	35
6983	0.07	0.20	0.27	14.4	1.33	0	48	104	58	58
						10		112	51	58
						20	100	138	32	45
						30	121	157	16	45
6979	0.14	0.28	0.42	17.2	0.67	0	56	110	59	58
						10	85	123	46	55
						20	114	153	22	52
						30	141	173	14	44
6978	0.14	0.29	0.43	17.2	1.30	0	55	109	58	59
						10	86	122	46	56
						20	122	160	23	49
						30	131	171	15	42

The yield strengths of the typically 15% chromium steels of the above table, in the annealed condition ranged from 47,000 to 50,000 p. s. i., the tensile strengths from 104,000 to 134,000 p. s. i., and the elongations from 46 to 58%. The yield strengths of the typically 17% chromium steels in the annealed condition ranged from 55,000 to 63,000 p. s. i., the tensile strengths from 109,000 to 116,000 p. s. i., and the elongations from 50 to 59%. The results show that an increase in the carbon plus nitrogen content tends to increase the yield and tensile strengths slightly, whereas additions of copper cause a decrease in the yield and tensile strengths.

To obtain a simple criterion for evaluating the work-hardening characteristics of these steels, hardness of the samples after the different cold reductions was determined. To obtain a measure for the austenite stability upon cold working, Magne-Gage readings were taken on the cold reduced specimens. Again the Magne-Gage readings were converted into percent ferrite (ferromagnetic phase) values as mentioned above. These hardness and transformation data are shown in Table IV below.

transform to martensite during cold deformation. Also demonstrated is the austenite-stabilizing effect of copper; that is, due to cold-working during the cold-rolling operation, the copper-bearing steels were less prone to work harden as well as to transform to martensite than the steels that did not contain copper. For example, after 10% cold reduction Steel 6972 (no Cu) had 12% ferrite (martensite) in the microstructure; Steel 6982 (0.74Cu) had less than 1%; and Steel 6983 (1.33Cu) had none.

The average hardness increase of the 15% Cr and the 17% Cr steels upon cold rolling, together with a curve for Type 201 steel, are shown in Figure 2. On the basis of this graph, the work-hardening characteristics of the 17% Cr steel closely resemble the characteristics of Type 201 steel, whereas the 15% Cr steel shows a higher rate of work-hardening up to 10% reduction than the 17% Cr steel.

The tensile properties and work-hardening characteristics of our steels are summarized and compared with the respective properties of known types of steels in the following Table V and in Figs. 3 and 4 of the drawings.

TABLE IV
Work-hardening and transformation characteristics

Steel No.	Composition, Percent ¹					2,100° F., W. Q.			10% Cold-Reduced		
	C	N	C+N	Cr	Cu	Rc	Magne Gage	Percent Ferrite	Rc	Magne Gage	Percent Ferrite
6972	0.07	0.22	0.29	14.63		17	0	0	40	55	12
6961	0.10	0.35	0.45	17.36		23	0	0	35	0	0
6962	0.14	0.33	0.47	17.57		20	0	0	35	0	0
6982	0.07	0.18	0.25	14.62	0.74	15	0	0	22	2	1
6983	0.07	0.20	0.27	14.43	1.33	12	0	0	20	0	0
6979	0.14	0.28	0.42	17.17	0.67	17	0	0	28	0	0
6978	0.14	0.29	0.43	17.15	1.30	17	0	0	26	0	0
						20% Cold-Reduced			30% Cold-Reduced		
6972	0.07	0.22	0.29	14.63		42	80	15	44	110	19
6961	0.10	0.35	0.45	17.36		38	5	1			
6962	0.14	0.33	0.47	17.57		40	0	0	42	5	2
6982	0.07	0.18	0.25	14.62	0.74	38	30	7	43	110	19
6983	0.07	0.20	0.27	14.43	1.33	34	15	4	37	15	4
6979	0.14	0.28	0.42	17.17	0.67	38	0	0	40	0	0
6978	0.14	0.29	0.43	17.15	1.30	35	0	0	38	0	0

¹ All steels contained 11.5-12.5% manganese, balance iron.

In Table V the values for steels according to the invention are presented as the range of results given in the above Table IV, whereas the values for the comparison materials were obtained from the following sources: For U. S. Steel's Cr—Mn—N steel "Tenelon," from D. J. Carney, Steel, November 7, 1955, p. 138; for AISI Types 201 and 202, from R. A. Lula and W. G. Renshaw, Metal Progress, February 1956, p. 73, and E. V. Bennett, National Research Council, Materials Advisory Board Report No. MAB-45-SM, June 10, 1935 (reprinted January 23, 1956); and for AISI Type 301, from the above cited Metal Progress article.

TABLE V
Comparison of tensile properties

Steel	Condition	Yield Strength, 1,000 p. s. i.	Tensile Strength, 1,000 p. s. i.	Percent Elongation	Percent Reduction of Area
This invention 15 Cr.....	Annealed.....	47-50	104-134	46-58	35-58
	30% Cold Reduced.....	111-146	157-201	16-19	21-45
This invention 17 Cr.....	Annealed.....	55- 63	109-116	50-59	54-61
	30% Cold Reduced.....	131-141	171-191	12-15	37-44
U. S. Steel's Cr—Mn—N(Tenelon).....	Annealed.....	78	127	45	-----
	30% Cold Reduced.....	192	202	8	-----
AISI Type 201.....	Annealed.....	50- 55	105-115	55-75	-----
	30% Cold Reduced.....	138	172	22	-----
AISI Type 202.....	Annealed.....	40- 55	100-105	55-70	-----
	30% Cold Reduced.....	132	155	17	-----
AISI Type 301.....	Annealed.....	40	100	63	-----
	30% Cold Reduced.....	140	170	20	-----

An examination of values given in Table V and in Figs. 3 and 4 of the drawings shows that the yield and tensile strengths of our steels are slightly higher and the elongations slightly lower than those of the standard Type 301, 201 and 202 steels; however, the differences are not significant. Also, it is worthy of note that our 17% Cr steels, in general, exhibit more favorable tensile properties than the U. S. Steel experimental nickel-free, Cr—Mn—N steel. This steel evidently corresponds to that of the U. S. Steel Corporation's recently issued Patent 2,778,731, D. J. Carney, from Table II of which it is seen that the steel contains substantial amounts of delta ferrite as solution annealed at temperatures ranging from 1900 to 2300° F., this by reason of the high chromium content (17.5-20%) in conjunction with high manganese (15-20%) and low carbon plus nitrogen, as shown by the compositions given in Table I of the patent.

Reverting to Figs. 3 and 4 of the drawings, it will be seen, as previously discussed, that the effect of adding copper to the steel of the invention, is to decrease the martensite transformation and work-hardening tendencies during cold working. This behavior is manifested by a significant lowering of the yield strength and the tensile strength and accompanying increase in tensile elongation for the copper-bearing steels as compared to the same steel without copper.

To test the corrosion behavior of the steels of this invention in a relatively mild corrosive medium, such as is encountered in actual weathering conditions, specimens of the steels, one with copper and one without (Heats 6972 and 6983) were subjected to a water-vapor-column corrosion test in the solution-annealed (2100° F. for 15 min., water quench) condition. The test was conducted for 10 cycles, each cycle consisting of an 8-hour exposure to water vapor at 100° F. and of a 16-hour drying period. For comparison, specimens of the AISI Type 302 steel and of plain carbon steel were included in these tests. Visual examination of the surfaces of the specimens after the test exposure revealed that the steels of the invention tested showed some localized staining. The Type 302 specimen was apparently not affected, and the plain carbon steel was fully covered with heavy rust.

What is claimed is:

1. An alloy steel consisting essentially of about: 11 to under 14% manganese, 14 to 18% chromium, up to 2%

copper, up to 3% silicon, 0.15 to 0.4% nitrogen, up to 0.15% carbon, the minimum carbon plus nitrogen content being related to the chromium content in accordance with the following equation, percent (C+N) min.=0.075 (percent Cr—12.5)+0.1, balance substantially iron, said alloy being characterized by an wholly austenitic structure as quenched from 2300° F. and by good corrosion resistance to atmospheric exposure.

2. An alloy steel consisting essentially of about: 11 to under 14% manganese, 16.5 to 18% chromium, up to 2% copper, up to 3% silicon, up to 0.2% carbon, 0.25 to 0.4% nitrogen, the minimum carbon plus nitrogen

content being related to the chromium content in accordance with the following equation, percent (C+N) min.=0.075 (percent Cr—12.5)+0.1, balance substantially iron, said alloy being characterized by an wholly austenitic structure as quenched from 2300° F. and by good corrosion resistance to atmospheric exposure.

3. An alloy steel consisting essentially of about: 11.5 to 13.5% manganese, 16.5 to 17.5% chromium, from more than 0.5 to 1.5% copper, from 0.15 to 1.5% silicon, from 0.05 to 0.15% carbon, from 0.25 to 0.4% nitrogen, the minimum carbon plus nitrogen content being related to the chromium content in accordance with the following equation, percent (C+N) min.=0.075 (percent Cr—12.5)+0.1, balance substantially iron, said alloy being characterized by an wholly austenitic structure as quenched from 2300° F. and by good corrosion resistance to atmospheric exposure.

4. An alloy steel consisting essentially of about: 11 to under 14% manganese, 14 to 16.5% chromium, up to 2% copper, up to 3% silicon, up to 0.15% carbon, from 0.15 to 0.4% nitrogen, the minimum carbon plus nitrogen content being related to the chromium content in accordance with the following equation, percent (C+N) min.=0.75 (percent Cr—12.5)+0.1, balance substantially iron, said alloy being characterized by an wholly austenitic structure as quenched from 2300° F. and by good corrosion resistance to atmospheric exposure.

5. An alloy steel consisting essentially of about: 11.5 to 13.5% manganese, 14.5 to 15.5% chromium, from more than 0.5 to 1.5% copper, from 0.15 to 1.5% silicon, carbon under 0.1%, from 0.25 to 0.35% nitrogen, the minimum carbon plus nitrogen content being related to the chromium content in accordance with the following equation, percent (C+N) min.=0.075 (percent Cr—12.5)+0.1, balance substantially iron, said alloy being characterized by an wholly austenitic structure as quenched from 2300° F. and by good corrosion resistance to atmospheric exposure.

References Cited in the file of this patent

UNITED STATES PATENTS

2,198,598	Becket et al.	Apr. 30, 1940
2,698,785	Jennings	Jan. 4, 1955
2,789,048	De Long et al.	Apr. 16, 1957

FOREIGN PATENTS

152,291	Austria	Jan. 25, 1938
---------	---------------	---------------

UNITED STATES PATENT OFFICE
CERTIFICATE OF CORRECTION

Patent No. 2,862,812

December 2, 1958

Edward J. Dulis et al.

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

Column 10, line 53, for "min.=0.75" read -- min.=0.075 --.

Signed and sealed this 7th day of April 1959.

(SEAL)

Attest:

KARL H. AXLINE
Attesting Officer

ROBERT C. WATSON
Commissioner of Patents