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Tables of Data on Chemical Compositions, Physical and Mechanical Properties of Wrought Corrosion-Resisting and Heat-Resisting Chromium and Chromium-Nickel Steels

Prepared by Russell Franks and Francis L. LaQue

for

Committee A-10 on Iron-Chromium, Iron-Chromium-Nickel, and Related Alloys

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TABLES OF CHEMICAL COMPOSITIONS, PHYSICAL AND MECHANICAL PROPERTIES OF WROUGHT CORROSION-RESISTING AND HEAT-RESISTING CHROMIUM AND CHROMIUM-NICKEL STEELS

The data herein presented on the compositions and properties of the corrosion-resisting and heat-resisting chromium and chromium-nickel steels have been assembled by Subcommittee I on Classification of Data,[1] of Committee A-10 on Iron-Chromium, Iron-Chromium-Nickel, and Related Alloys, of the American Society for Testing Materials.

The data in this publication represent a revision of corresponding data given in the "Symposium on Corrosion-Resistant, Heat-Resistant, and Electrical-Resistance Alloys," held in 1924,[2] and the "Tables of Chemical Compositions, Physical and Mechanical Properties, and Corrosion-Resistant Properties of Corrosion-Resistant and Heat-Resistant Alloys," published by the A.S.T.M. in 1930.[3]

In these earlier publications data were presented on a broad range of materials which included both ferrous and non-ferrous alloys, as well as the stainless steels. Because of the tremendous increase in the commercial importance of the stainless steels during recent years, it was decided that their properties should be tabulated in a separate publication.

The present classification provides data on those stainless steels that have received the widest commercial usage. The data have been divided into two parts; Part I covers the wrought hardenable and nonhardenable ferritic straight chromium steels. The ferritic steels hardenable by heat treatment are indicated in the tables as martensitic and those not hardenable as simply ferritic. Part II covers the wrought austenitic chromium-nickel steels.

The stainless steels are identified, where possible, in accordance with appropriate A.S.T.M. designations and grades. For convenient comparison, the type numbers established by the American Iron and Steel Institute are included for these compositions. In addition certain additional compositions for which there are no corresponding A.S.T.M. specifications have also been identified with A.I.S.I. type numbers.

The A.S.T.M. standards prepared by Committee A-10 which cover the wrought chromium and chromium-nickel stainless steels, identified in the tables by the A.S.T.M. designations, are as follows:

Standard Specifications for Corrosion-Resisting Chromium Steel Plate, Sheet, and Strip (A.S.T.M. Designation: A 176 – 42)[4]

Standard Specifications for Corrosion-Resisting Chromium-Nickel Steel Plate, Sheet, and Strip (A.S.T.M. Designation: A 167 – 42)[4]

Standard Specifications for Corrosion-Resisting Chromium and Chromium-Nickel Steel Plate,

[1] Data were collected and tabulated for Subcommittee I, of Committee A-10, by Russell Franks of the Union Carbide and Carbon Research Laboratories, and Francis L. LaQue of The Development and Research Division of The International Nickel Company, Inc.

[2] *Proceedings*, Am. Soc. Testing Mats., Vol. 24, Part II, p. 189 (1924).

[3] *Proceedings*, Am. Soc. Testing Mats., Vol. 30, Part I, Plates V to XV (1930); also issued as separate publication.

[4] 1942 Book of A.S.T.M. Standards, Part I.

Sheet, and Strip for Fusion-Welded Unfired Pressure Vessels (A.S.T.M. Designation: A 240 – 42)[4]

Standard Specifications for High-Strength Corrosion-Resisting Chromium-Nickel Steel Sheet and Strip (A.S.T.M. Designation: A 177 – 39)[4]

Emergency Alternate Provisions in three of the above standards have been issued by the A.S.T.M. for the duration of the War Emergency. References are made in footnotes in Tables I and XI to these Emergency Provisions.

The following table is included to facilitate reference to A.S.T.M. specifications issued by Committee A-1 on Steel that cover steels similar in composition to those for which specifications have been prepared by Committee A-10 and which are referred to in detail in this tabulation of data:

Committee A-1 Specifications		Committee A-10 Specifications for Steels of Similar Composition		A.I.S.I. Type Numbers
A.S.T.M. Designations (Note)	Symbols		Grades	
A 158	P 5a			502
	P 5b			502
	P 8a	A 167	3	304
		A 240	S	
	P 8b	A 167	5, 6	321, 347
		A 240	T, C	
A 182	F 5			502
	F 6	A 176	2	410
	F 8	A 167	3	304
		A 240	S	
A 193	B 5			502
	B 6	A 176	2	410
	B 8	A 167	3	304
		A 240	S	
A 194	3			502
A 199	8			502
A 200	8			502
A 213	T 5			502
	T 8	A 167	3	304
		A 240	S	
	T 18	A 167	5	321
		A 240	T	
	T 19	A 167	6	347
		A 240	C	
	T 20	A 167	11	316
		A 240	M	
A249	T 8	A 167	3	304
		A 240	S	
	T 18	A 167	5	321
		A 240	T	
	T 19	A 167	6	347
		A 240	C	
	T 20	A 167	11	316
		A 240	M	

NOTE.—The designations in this table refer to the following specifications of the American Society for Testing Materials:

Tentative Specifications for Seamless Alloy-Steel Pipe for Service at Temperatures from 750 to 1100 F. (A.S.T.M. Designation: A 158 – 42 T),[5]

Standard Specifications for Forged or Rolled Alloy-Steel Pipe Flanges, Forged Fittings, and Valves and Parts for Service at Temperatures from 750 to 1100 F. (A.S.T.M. Designation: A 182 – 40),[5]

Tentative Specifications for Alloy-Steel Bolting Materials for High-Temperature Service from 750 to 1100 F., Metal Temperatures (A.S.T.M. Designation: A 193 – 40 T),[5]

Standard Specifications for Carbon and Alloy-Steel Nuts for Bolts for High-Pressure and High-Temperature Service to 1100 F. (A.S.T.M. Designation: A 194 – 40),[5]

Standard Specifications for Seamless Cold-Drawn Intermediate Alloy-Steel Heat-Exchanger and Condenser Tubes (A.S.T.M. Designation: A 199 – 40),[5]

Standard Specifications for Seamless Intermediate Alloy-Steel Still Tubes for Refinery Service (A.S.T.M. Designation: A 200 – 40),[5]

Standard Specifications for Seamless Alloy-Steel Boiler and Superheater Tubes (A.S.T.M. Designation: A 213 – 42),[5] and

Standard Specifications for Atomic-Hydrogen-Arc-Welded and Electric-Resistance-Welded Alloy-Steel Boiler and Superheater Tubes (A.S.T.M. Designation: A 249 – 42).[5]

The data for the different steels have been condensed to the simplest form to provide a ready reference for both the maker and user of the steels. As previously indicated, inspection has been made of a large amount of data, and those included herein represent the present authoritative information on the steels covered. Single figures rather than ranges have been used to describe the several properties of these steels. These figures are representative values and not minimum or average values except for the data on cold-rolled sheet and strip of grades 1 and 2 of A.S.T.M. Specifications A 167 – 42 for which minimum figures are given. The values in these tables should not be considered as specification figures as these may be found in the appropriate A.S.T.M. standards for this class of material as referred to in the tables.

Data on the high chromium and chromium-nickel valve and die steels have not been included since these steels are not used for general constructional purposes requiring heat and corrosion resistance. Data are not given for the chromium-silicon valve steels

[5] 1942 Book of A.S.T.M. Standards, Part I.

nor the predominantly austenitic chromium-nickel valve steels that contain 12 to 14 per cent chromium, 12 to 14 per cent nickel, several per cent tungsten and approximately 0.40 per cent carbon. Data are not given for the die steels that contain 12 to 14 per cent chromium and from 1.50 to 2.50 per cent carbon with small percentages of other elements, such as molybdenum, tungsten, and vanadium.

Part I—Wrought Chromium Steels:

Data on the wrought chromium ferritic steels appear in Part I, and cover the following basic compositions:

4 to 6 per cent chromium
8 to 10 per cent chromium
10 to 14 per cent chromium
14 to 18 per cent chromium
23 to 30 per cent chromium

The detailed chemical compositions of these steels appear in Table I. Information as to their physical properties, and on the forging and heat-treating practices to be used in fabricating these chromium steels is given in Table II.

The mechanical properties of the steels in various wrought forms, such as bars, plates, wire, strip, sheet, seamless tubes, forgings, etc., are shown in Tables III to X. The creep characteristics and short-time tensile properties at elevated temperatures are presented graphically by the curves in Figs. 1 to 11.

The basic ferritic chromium steels for which data are furnished are those which may be modified by control of certain constituents, added for specific purposes as follows:

The carbon contents of the steels which contain up to 18 per cent chromium are increased when it is desired to harden the steels by heat treatment.

Molybdenum is added to the 4 to 6 per cent and 8 to 10 per cent chromium steels to enhance strength at elevated temperatures and retain toughness after sojourn at such temperatures. This element is also added in conjunction with sulfur to improve machinability of the 12 to 14 per cent and the 14 to 18 per cent chromium steels.

Combinations involving one or more of the elements phosphorus, sulfur, and selenium are used to improve machinability of the 12 to 14 per cent and the 14 to 18 per cent chromium steels.

Nitrogen is added to the 23 to 30 per cent chromium steels to achieve grain refinement and improvement in workability and toughness.

The chemical compositions of the free-machining types of straight chromium steels are listed in Table I and data on the physical and mechanical properties of some of them are also provided. These free-machining steels are identified in Tables I, II, VI, and VII as A.I.S.I. types 416, 420F, and 430F, and contain, respectively, 12 to 14 per cent chromium with a maximum of 0.15 per cent carbon, 12 to 14 per cent chromium with a minimum of 0.15 per cent carbon, and 14 to 18 per cent chromium with a maximum of 0.12 per cent carbon and small percentages of sulfur, selenium, and molybdenum. These types are similar in composition to the steels representing A.I.S.I. types 410, 420, and 430, with the exception that they contain the small percentages of sulfur, selenium, and molybdenum. It may be assumed that, with the exception of toughness, these free-machining chromium steels have properties quite similar to those of the corresponding chromium steels without the elements added to enhance machinability.

Part II—Wrought Chromium-Nickel Steels:

The austenitic wrought chromium-nickel steels for which data are given in

Part II are those which contain basically the following:

17 per cent chromium, 7 per cent nickel
18 per cent chromium, 8 per cent nickel
24 per cent chromium, 12 per cent nickel
25 per cent chromium, 20 per cent nickel

The detailed chemical compositions of these steels appear in Table XI. Information as to their physical properties, and on the forging and heat-treating practices to be used in fabricating these chromium-nickel steels is given in Table XII.

The mechanical properties of the steels in various wrought forms, such as bars, plates, wire, strip, sheet, seamless tubes, etc., are shown in Tables XIII to XXI. The creep characteristics and short-time tensile properties at elevated temperatures are presented graphically by the curves in Figs. 12 to 26.

The basic chromium-nickel steels for which data are furnished are those which are modified for specific purposes as follows:

Carbon is used to increase strength, especially in the 17 per cent chromium, 7 per cent nickel steel. In this steel, as well as in the other compositions, the effect of too high a carbon content is to reduce resistance to general corrosion, and particularly to intergranular corrosion.

Molybdenum in the 18 per chromium, 8 per cent nickel steels improves resistance to general corrosion, especially by reducing chemicals and halogens; it also improves strength at elevated temperatures, and with sulfur improves machinability.

Columbium is added to the 18 per cent chromium, 8 per cent nickel steels to prevent intergranular corrosion in both weld metal and parent metal.

Titanium also is used in the 18 per cent chromium, 8 per cent nickel steels to prevent intergranular corrosion, but is less effective in weld metal due to the difficulty of preventing loss of titanium in the weld deposit.

Selenium is used to improve machinability and reduce galling of the 18 per cent chromium, 8 per cent nickel steels.

Manganese improves the hot workability of all the chromium-nickel steels, while silicon enhances resistance to scaling at elevated temperatures.

Acknowledgment:

While the classification of these data has been made under the jurisdiction of Subcommittee I, of A.S.T.M. Committee A-10, it would have been impossible to accomplish the task without the aid of the various groups that cooperated with this subcommittee. These groups included the principal manufacturers and users of stainless steels from whom the data were obtained. This assistance is gratefully acknowledged.

PART I

DATA FOR THE WROUGHT CORROSION-RESISTING AND HEAT-RESISTING CHROMIUM STEELS

TABLE I.—CHEMICAL COMPOSITIONS OF WROUGHT CORROSION-RESISTING CHROMIUM STEELS.

A.S.T.M. Designation	A.S.T.M. Grade	A.I.S.I. Type Number	Carbon, per cent	Manganese, max., per cent	Phosphorus, max., per cent	Sulfur, per cent	Silicon, max., per cent	Chromium, per cent	Nickel, max., per cent	Molybdenum, per cent
		502	0.15 max.[a]	0.50	0.030	0.030 max.	0.50	4.00 to 6.00	....	0.45 to 0.65[a]
8 to 10 per cent chromium			0.15 max.	1.50	0.030	0.030 max.	0.50	8.00 to 10.00	....	0.75 to 1.50
A 176 - 42	1	[b]								
A 176 - 42	2	410	0.15 max.	0.60	0.030	0.030 max.	0.75	10.00 to 14.00	0.60	....
		420	0.15 min.	0.60	0.030	0.030 max.	0.60	12.00 to 14.00	....	....
		420F	0.15 min.	0.60	0.030	0.070 min.[c]	0.60	12.00 to 14.00	....	0.60 max.
		416	0.15 max.	0.60	0.030	0.070 min.[c]	0.75	12.00 to 14.00	....	0.60 max.
		440	0.12 min.	1.00	0.030	0.030 max.	0.60	14.00 to 18.00	....	....
A 176 - 42	4	430	0.12 max.	1.00	0.030	0.030 max.	1.00	14.00 to 18.00	0.60	....
A 240 - 42	A									
		430F	0.12 max.	1.00	0.030	0.070 min.[c]	1.00	14.00 to 18.00	....	0.60 max.
A 176 - 42	5	[d]								
A 176 - 42	6	446[e]	0.35 max.	1.00	0.030	0.030 max.	1.00	23.00 to 30.00	0.60	....
A 240 - 42	B									

[a] A.I.S.I. type 502 has a carbon content of 0.10 max., per cent; molybdenum optional.
[b] A.I.S.I. type 403 is similar to A.S.T.M. grade 1.
[c] Or selenium 0.07 min., per cent.
[d] A.I.S.I. type 442 is similar to A.S.T.M. grade 5.
[e] A nitrogen content of 0.10 min., per cent, insures grain refinement.

TABLE II.—PHYSICAL PROPERTIES AND WORKING CHARACTERISTICS OF WROUGHT CORROSION-RESISTING CHROMIUM STEELS IN THE ANNEALED CONDITION.

A.S.T.M. Designation	....	8 to 10 per cent Chromium	A 176 - 42	....	....	A 176 A 240	A 176 A 240
A.S.T.M. Grade	....		2	....	....	4 A	6 B
A.I.S.I. Type No.	502		410	420	440	430 430	446 446
Modulus of elasticity in tension, psi	29 000 000	....	29 000 000	29 000 000	29 000 000	29 000 000	29 000 000
Modulus of elasticity in torsion, psi	....	....	....	11 700 000	....	....	....
Density, lb. per cu. in.	0.28	....	0.28	0.28	0.28	0.28	0.27
Density, g. per cu. cm.	7.8	....	7.7	7.7	7.7	7.7	7.6
Specific electrical resistance at room temperature, microhms per cm. per sq. cm.	40	....	57	55	60	60	67
Magnetic permeability	ferromagnetic	ferromagnetic	ferromagnetic	ferromagnetic	ferromagnetic	ferromagnetic	ferromagnetic
Specific heat, Btu. per lb. per deg. Fahr. (32 to 212 F.)	0.11	....	0.11	0.11	0.11	0.11	0.12
Thermal conductivity, Btu. per hr. per sq. ft. per ft. per deg. Fahr. 212 F.	21.2	....	14.4	14.4	14.0	15.1	12.1
392 F.	20.8	....	15.0	....	....	15.2	12.7
572 F.	20.4	....	15.5	....	....	15.2	13.3
752 F.	19.8	....	16.1	....	....	15.2	13.8
932 F.	19.5	....	....	....	....	15.2	14.1
Mean coefficient of thermal expansion per deg. Fahr. 32 to 212 F.	0.0000062	0.0000062	0.0000061	0.0000057	0.0000056	0.0000058	0.0000059
32 to 600 F.	0.0000068	0.0000067	....	....	....	0.0000061	....
32 to 1000 F.	0.0000072	0.0000068	0.0000072	....	....	0.0000063	0.0000063
32 to 1200 F.	0.0000073	0.0000072	....	0.0000068	....	....	....
32 to 1832 F.	....	....	0.0000076	0.0000076	....	0.0000073	0.0000076
Maximum temperature without excessive scaling, deg. Fahr.	1150	1200	1250	1200	1400	1550	2000
Melting point range, deg. Fahr.	2700 to 2800	....	2700 to 2790	....	....	2700 to 2750	2700 to 2750
Forging practice: Initial temperature, deg. Fahr.	2100 to 2200	2000 to 2150	2000 to 2150	2000 to 2150	1900 to 2050	1900 to 2050	1900 to 2000
Forging practice: Final temperature, deg. Fahr.	1500 to 1600	1850 to 1900	1400 to 1500	1700 to 1750	1750 to 1800	1300 to 1500	1300 to 1450
Forging practice: Method of cooling	slow cool	slow cool	slow cool	slow cool	slow cool	air cool	air cool
Annealing temperatures, deg. Fahr. Low anneal	cool from 1325-1375	cool from 1325-1375	air cool from 1200-1350	....	....	....	....
Annealing temperatures, deg. Fahr. Full anneal	slow cool from 1525-1600	slow cool from 1575-1675	slow cool from 1500-1600	slow cool from 1550-1650	slow cool from 1550-1650	air cool or rapid cool from 1400-1450	rapid cool from 1450-1550
Hardening temperature, deg. Fahr.	rapid cool from 1600-1700	rapid cool from 1675	rapid cool from 1750-1800	rapid cool from 1850-1900	rapid cool from 1850-1950	nonhardening	nonhardening
Maximum cold reduction of wire before anneal, per cent	75	....	75	....	....	75	75
Riveting and hot forming temperatures, deg. Fahr.	below 1450	1250 to 1400	below 1450	....	....	below 1450	below 1650

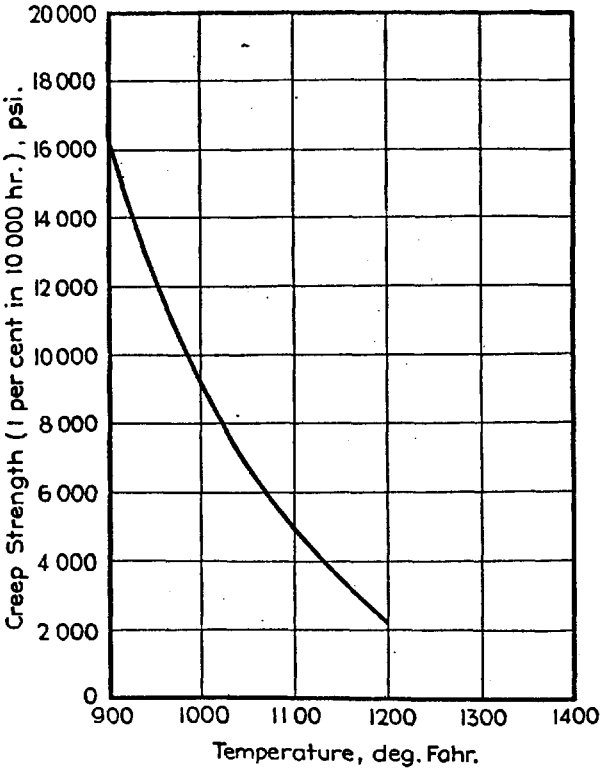

FIG. 1.—Creep Strength at Various Temperatures of 4 to 6 per cent Chromium Steel (A.I.S.I. Type No. 502).

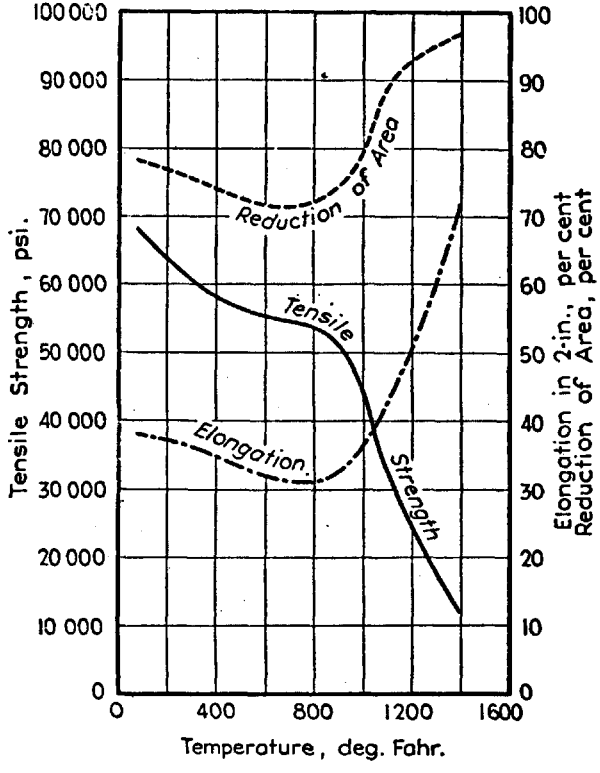

FIG. 2.—Short-Time High-Temperature Tensile Properties of 4 to 6 per cent Chromium Steel (A.I.S.I. Type No. 502).

TABLE III.—MECHANICAL PROPERTIES OF 4 TO 6 PER CENT CHROMIUM STEEL.

CHEMICAL COMPOSITION, PER CENT

Carbon	0.15 max.	Silicon	0.50 max.	A.S.T.M. Designation	.....
Manganese	0.50 max.	Chromium	4 to 6	A.S.T.M. Grade	.....
Phosphorus	0.03 max.	Molybdenum	0.45 to 0.65	A.I.S.I. Type No.	502
Sulfur	0.03 max.			Structure	Martensitic

MECHANICAL PROPERTIES

Form and Treatment	Tensile Strength, psi.	Yield Strength (offset = 0.2 per cent), psi.	Yield Point,[a] psi.	Proportional Limit, psi.	Elongation in 2 in., per cent	Reduction of Area, per cent	Impact Resistance, ft-lb.		Hardness Number		Endurance Limit (Fatigue), psi.	Cold Bend, deg.	Ductility	
							Charpy	Izod	Brinell (3000-kg. load, 10-mm. ball)	Rockwell			Erichsen Value mm.	Olsen Value,[c] in.
Sheet:														
Annealed	65 000	...	35 000	...	28	...	...	...	...	B70	...	180	...	0.250 to 0.450
Strip:														
Cold-rolled	...	...	...	...	...	...	...	...	...	...	...	...	...	...
Annealed	75 000	...	35 000	...	28	...	...	...	...	B75	...	180	...	...
Wire:														
Cold-drawn, 50 per cent	100 000	92 500	...	...	8	...	...	...	...	B97	...	180	...	...
Annealed	73 000	30 000	...	...	28	...	...	...	...	B72	...	180	...	...
Plate:														
Annealed	70 000	...	40 000	...	28	...	...	85	155	...	...	180	...	...
Tubing:														
Annealed	70 000	...	39 000	...	35	...	45	...	145	...	...	...	...	...
Bars:														
Cold-drawn	...	...	...	...	...	...	...	...	...	...	...	...	...	...
Annealed	70 000	...	37 000	26 000	35	70	45	85	143	...	...	180	...	...
Hardened and Tempered[b]	176 000	...	144 000	...	18	60	...	30	350	...	...	...	...	...
Forgings:														
Annealed	...	...	...	...	...	...	...	...	...	...	...	...	...	...

[a] *Yield point* as determined with dividers must not be confused with a defined *yield strength*, such as, at 0.2 per cent offset.
[b] Oil quenched from a temperature between 1600 and 1700 F.; tempered at 700 F.
[c] Depending on thickness with maximum value in thinner thicknesses.

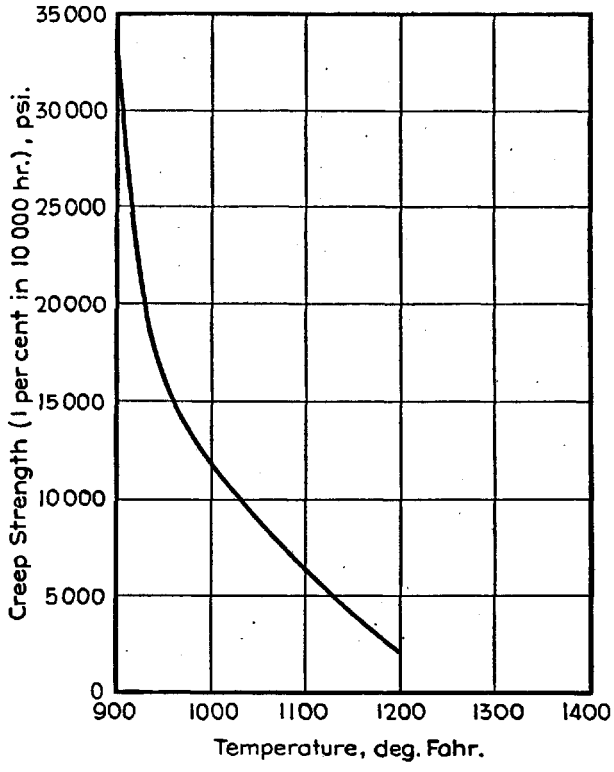

FIG. 3.—Creep Strength at Various Temperatures of 8 to 10 per cent Chromium Steel.

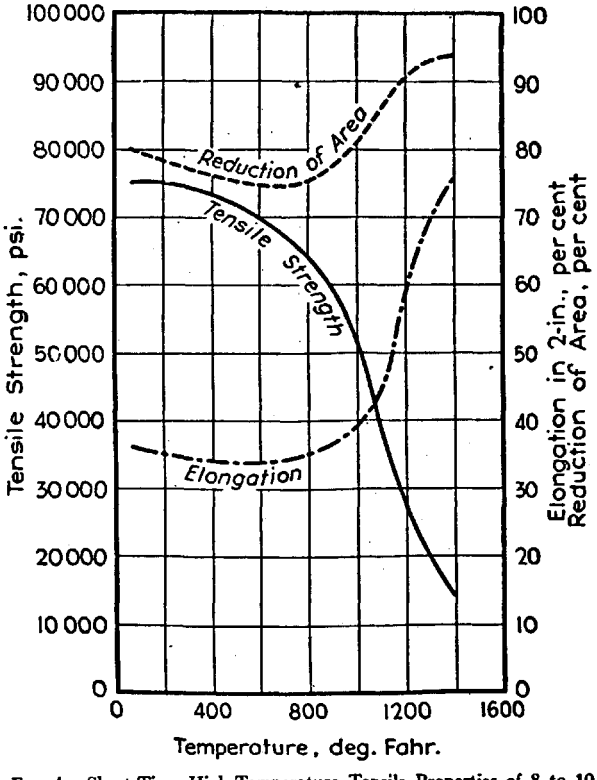

FIG. 4.—Short-Time High-Temperature Tensile Properties of 8 to 10 per cent Chromium Steel.

TABLE IV.—MECHANICAL PROPERTIES OF 8 TO 10 PER CENT CHROMIUM STEEL.

Chemical Composition, per cent			
Carbon	0.15 max.	Silicon	0.50 max.
Manganese	1.50 max.	Chromium	8 to 10
Phosphorus	0.03 max.	Molybdenum	0.75 to 1.50
Sulfur	0.03 max.		

A.S.T.M. Designation	
A.S.T.M. Grade	
A.I.S.I. Type No.	
Structure	Martensitic

Mechanical Properties

Form and Treatment	Tensile Strength, psi.	Yield Strength (offset = 0.2 per cent), psi.	Yield Point,[a] psi.	Proportional Limit, psi.	Elongation in 2 in., per cent	Reduction of Area, per cent	Impact Resistance ft-lb.		Hardness Number		Endurance Limit (Fatigue), psi.	Cold Bend, deg.
							Charpy	Izod	Brinell (3000-kg load, 10-mm. ball)	Rockwell		
Sheet:												
Annealed	85 000	...	53 000	...	27	...	...	...	...	...	...	180
Strip:												
Cold-rolled	...	...	...	...	...	...	...	...	...	...	...	...
Annealed	...	...	...	...	...	...	...	...	...	...	...	...
Wire:												
Cold-drawn	...	...	...	...	...	...	...	...	...	...	...	...
Annealed	...	...	...	...	...	...	...	...	...	...	...	...
Plate:												
Annealed	...	...	...	...	...	...	...	...	...	...	...	...
Tubing:												
Annealed	70 000	...	43 000	...	35	70	45	...	145	...	...	180
Bars:												
Cold-Drawn	...	...	...	...	...	...	...	...	...	...	...	...
Annealed	70 000	...	45 000	...	30	70	45	90	145	...	...	180
Hardened and Tempered	...	...	...	...	...	...	...	...	...	...	...	...
Forgings:												
Annealed	...	...	...	...	...	...	...	...	...	...	...	...

[a] *Yield point* as determined with dividers must not be confused with a defined *yield strength*, such as, at 0.2 per cent offset.

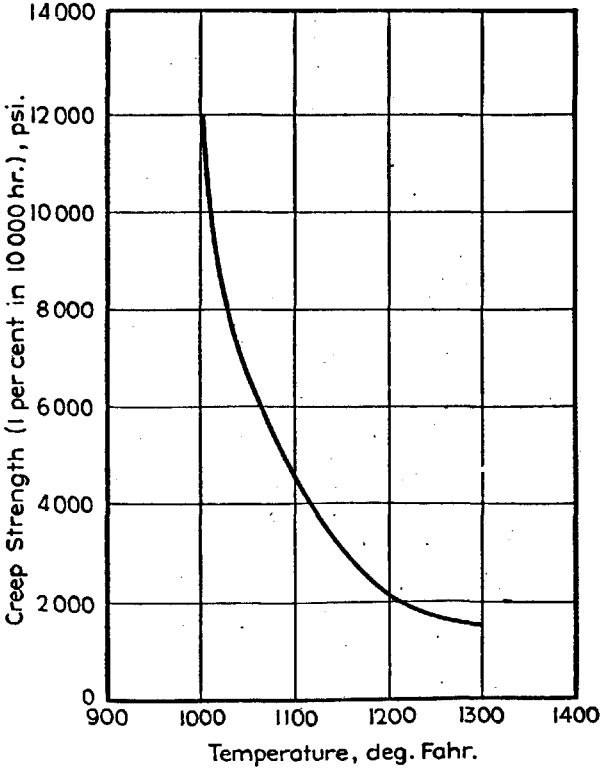

FIG. 5.—Creep Strength at Various Temperatures of Low-Carbon, 10 to 14 per cent Chromium Steel (A.S.T.M. Designation: A 176 - 42, Grade 2; A.I.S.I. Type No. 410).

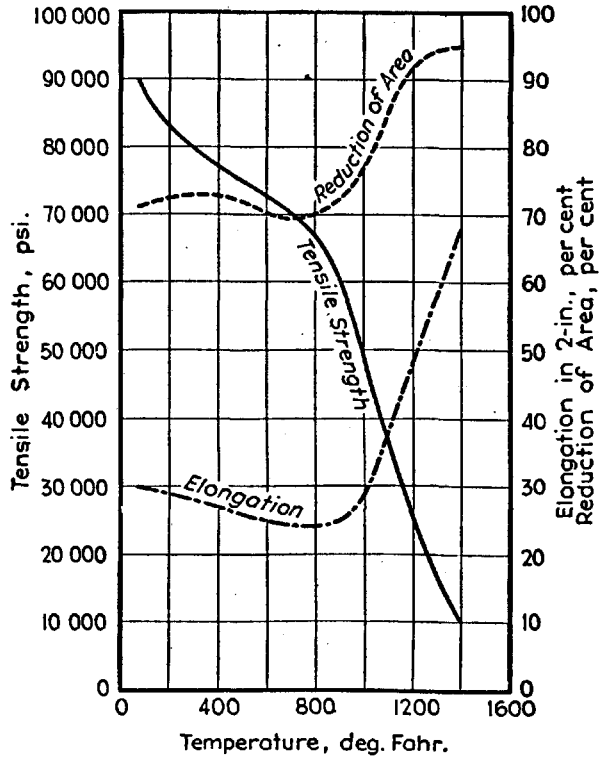

FIG. 6.—Short-Time High-Temperature Tensile Properties of Low-Carbon, 10 to 14 per cent Chromium Steel (A.S.T.M. Designation: A 176 - 42, Grade 2; A.I.S.I. Type No. 410).

TABLE V.—MECHANICAL PROPERTIES OF LOW-CARBON, 10 TO 14 PER CENT CHROMIUM STEEL.

Chemical Composition, per cent			
Carbon	0.15 max.	Silicon	0.75 max.
Manganese	0.60 max.	Chromium	10 to 14
Phosphorus	0.03 max.	Nickel	0.60 max.
Sulfur	0.03 max.		

A.S.T.M. Designation	A 176 - 42
A.S.T.M. Grade	2
A.I.S.I. Type No.	410
Structure	Martensitic

Mechanical Properties

Form and Treatment	Tensile Strength, psi.	Yield Strength (offset = 0.2 per cent), psi.	Yield Point,[a] psi.	Proportional Limit, psi.	Elongation in 2 in., per cent	Reduction of Area, per cent	Impact Resistance, ft-lb.		Hardness Number		Endurance Limit (Fatigue), psi.	Cold Bend, deg.	Ductility	
							Charpy	Izod	Brinell (3000-kg. load, 10-mm. ball)	Rockwell			Erichsen Value, mm.	Olsen Value, in.
Sheet:														
Annealed	70 000	...	40 000	...	26	...	...	...	...	B75	...	180	7 to 8	0.3 to 0.4
Strip:														
Cold-rolled, 40 per cent	125 000	...	110 000	...	3	...	...	...	...	C23	...	...	...	...
Annealed	75 000	...	40 000	...	28	...	...	...	...	B80	...	...	8	...
Wire:														
Cold-drawn, 20 per cent	88 000	75 000	...	35 000	12	...	...	...	...	B90	...	...	...	...
Cold-drawn, 40 per cent	102 000	95 000	...	55 000	10	...	...	...	...	B95	...	...	...	...
Cold-drawn, 60 per cent	110 000	105 000	...	75 000	6	...	...	...	...	B100	...	...	...	...
Annealed	72 000	37 000	...	24 000	25	...	...	...	...	B75	...	180	...	...
Plate:														
Annealed	75 000	...	42 000	...	30	60	...	...	135	...	...	180	...	...
Tubing:														
Annealed	72 000	...	40 000	...	30	...	...	...	150	B80	...	...	...	...
Bars:														
Cold-drawn, 20 per cent	90 000	70 000	...	56 000	20	50	...	...	185	...	...	...	...	...
Annealed	73 000	40 000	52 000	34 000	30	68	...	90	155	...	40 000	180	...	...
Hardened and Tempered[b] 800 F	187 000	134 000	166 000	100 000	15	55	...	30	385	...	90 000	...	...	...
Hardened and Tempered[b] 1300 F	95 000	65 000	75 000	53 000	23	55	...	85	195	...	55 000	...	...	...
Forgings:														
Annealed	85 000	...	55 000	...	25	60	...	85	155	...	...	...	...	...

[a] *Yield point* as determined with dividers must not be confused with a defined *yield strength*, such as, at 0.2 per cent offset.
[b] Oil quenched from a temperature between 1750 and 1800 F.; tempered at 800, and 1300 F.

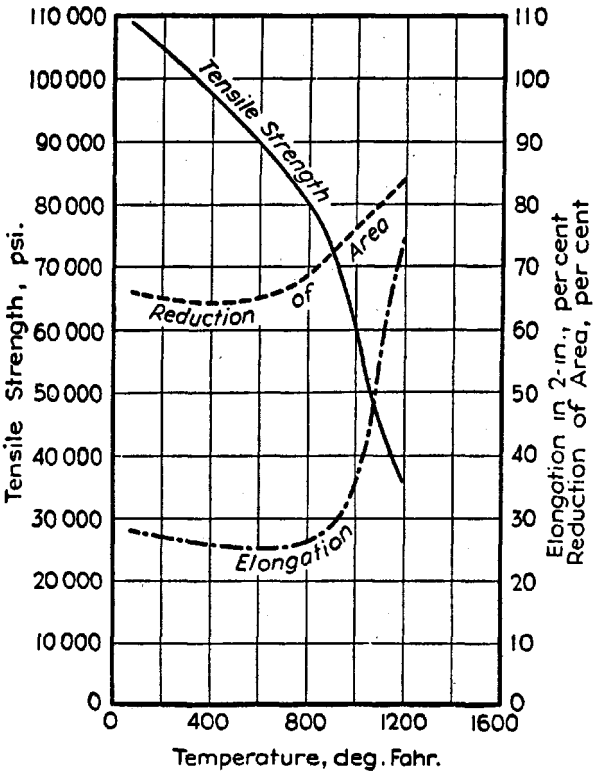

FIG. 7.—Short-Time High-Temperature Tensile Properties of High-Carbon, 12 to 14 per cent Chromium Steel (A.I.S.I. Type No. 420).

TABLE VI.—MECHANICAL PROPERTIES OF HIGH-CARBON, 12 TO 14 PER CENT CHROMIUM STEEL.

Chemical Composition, per cent			
Carbon	0.15 min.[c]	Sulfur	0.03 max.
Manganese	0.60 max.	Silicon	0.60 max.
Phosphorus	0.03 max.	Chromium	12 to 14

A.S.T.M. Designation	.....
A.S.T.M. Grade	.....
A.I.S.I. Type No.	420
Structure	Martensitic

Mechanical Properties

Form and Treatment	Tensile Strength, psi.	Yield Strength (offset = 0.2 per cent), psi.	Yield Point,[a] psi.	Proportional Limit, psi.	Elongation in 2 in., per cent	Reduction of Area, per cent	Impact Resistance ft-lb.		Hardness Number		Endurance Limit (Fatigue), psi.	Cold Bend, deg.
							Charpy	Izod	Brinell (3000-kg. load, 10-mm. ball)	Rockwell		
Sheet:												
Annealed	...	...	...	...	...	...	...	...	...	...	...	...
Strip:												
Cold-rolled	...	...	...	...	...	...	...	...	...	...	...	...
Annealed	...	...	...	...	...	...	...	...	...	...	...	...
Wire:												
Cold-drawn, 30 per cent	135 000	120 000	...	77 000	7	50	...	...	...	C25	...	...
Annealed	95 000	47 000	...	31 000	23	65	...	...	...	B93	...	180
Plate:												
Annealed	...	...	...	...	...	...	...	...	...	...	...	...
Tubing:												
Annealed	...	...	...	...	...	...	...	...	...	...	...	...
Bars:												
Cold-drawn	...	...	...	...	...	...	...	...	...	...	...	...
Annealed	90 000	...	57 000	38 000	28	65	...	30	190	B92	80 000	180
Hardened and tempered[b] 500 F.	240 000	191 000	220 000	161 000	5	7	...	...	490	C51	...	...
Hardened and tempered[b] 1400 F.	100 000	70 000	80 000	56 000	27	65	...	70	200	...	...	...
Forgings:												
Annealed	...	...	...	...	...	...	...	...	...	...	...	...

[a] *Yield point* as determined with dividers must not be confused with a defined *yield strength*, such as, at 0.2 per cent offset.
[b] Oil quenched from a temperature of 1850 F.; tempered at 500 and 1400 F.
[c] Data obtained on steels which contained 0.30 to 0.40 per cent carbon.

TABLE VII.—MECHANICAL PROPERTIES OF 12 TO 14 PER CENT CHROMIUM STEEL (FREE MACHINING).

Chemical Composition, per cent				A.S.T.M. Designation	...
Carbon	0.15 max.	Silicon	0.75 max.	A.S.T.M. Grade	...
Manganese	0.60 max.	Chromium	12 to 14	A.I.S.I. Type No.	416
Phosphorus	0.03 max.	Molybdenum	0.60 max.	Structure	Martensitic
Sulfur or Selenium	0.07 min.				

Mechanical Properties

Form and Treatment	Tensile Strength, psi.	Yield Strength (offset = 0.2 per cent), psi.	Yield Point,[a] psi.	Proportional Limit, psi.	Elongation in 2 in., per cent	Reduction of Area, per cent	Impact Resistance ft-lb.		Hardness Number		Endurance Limit (Fatigue), psi.	Cold Bend, deg.
							Charpy	Izod	Brinell (3000-kg. load, 10-mm. ball)	Rockwell		
Sheet:												
Annealed	...	...	...	...	...	...	...	...	...	...	...	...
Strip:												
Cold-rolled	...	...	...	...	...	...	...	...	...	...	...	...
Annealed	...	...	...	...	...	...	...	...	...	...	...	...
Wire:												
Cold-drawn	...	...	...	...	...	...	...	...	...	...	...	...
Annealed	75 000	...	...	40 000	25	...	...	...	...	B82	...	180
Plate:												
Annealed	...	...	...	...	...	...	...	...	...	...	...	...
Tubing:												
Annealed	...	...	...	...	...	...	...	...	...	...	...	...
Bars:												
Cold-drawn	104 000	...	...	55 000	15	45	...	...	217	...	57 000	...
Annealed	80 000	...	45 000	36 000	25	60	...	35	180	...	43 000	180
Hardened and tempered[b] 700 F.	160 000	...	145 000	...	12	40	...	...	300	...	...	...
Hardened and tempered[b] 1400 F.	86 000	...	48 000	42 000	25	60	...	35	180	...	...	...
Forgings:												
Annealed	89 000	...	50 000	...	23	55	...	30	193	...	...	...

[a] *Yield point* as determined with dividers must not be confused with a defined *yield strength*, such as, at 0.2 per cent offset.
[b] Oil quenched from a temperature of 1800 F.; tempered at 700, and 1400 F.

TABLE VIII.—MECHANICAL PROPERTIES OF HIGH-CARBON, 14 TO 18 PER CENT CHROMIUM STEEL.

Chemical Composition, per cent			
Carbon	0.12 min.[a]	Sulfur	0.03 max.
Manganese	1.00 max.	Silicon	0.60 max.
Phosphorus	0.03 max.	Chromium	14 to 18

A.S.T.M. Designation	.....
A.S.T.M. Grade	.....
A.I.S.I. Type No.	440
Structure	Martensitic

Mechanical Properties

Form and Treatment	Tensile Strength, psi.	Yield Strength (offset = 0.2 per cent), psi.	Yield Point,[a] psi.	Proportional Limit, psi.	Elongation in 2 in., per cent	Reduction of Area, per cent	Impact Resistance ft-lb.		Hardness Number		Endurance Limit (Fatigue), psi.	Cold Bend, deg.
							Charpy	Izod	Brinell (3000-kg. load, 10-mm. ball)	Rockwell		
Sheet:												
Annealed	...	...	...	...	...	...	...	...	...	...	...	...
Strip:												
Cold-rolled	...	...	...	...	...	...	...	...	...	...	...	...
Annealed	...	...	...	...	...	...	...	...	...	...	...	...
Wire:												
Cold-drawn	...	...	...	...	...	...	...	...	...	...	...	...
Annealed	105 000	...	65 000	35 000	18	...	...	...	...	B95	...	...
Plate:												
Annealed	...	...	...	...	...	...	...	...	...	...	...	...
Tubing:												
Annealed	...	...	...	...	...	...	...	...	...	...	...	...
Bars:												
Cold-drawn	...	...	...	...	...	...	...	...	...	...	...	...
Annealed	106 000	...	65 000	32 000	20	50	...	30	217	...	50 000	...
Hardened and tempered[b] 600 F.	259 000	...	228 000	...	2	7	...	9	530	...	110 000	...
Hardened and tempered[b] 1300 F.	125 000	...	92 000	...	20	40	...	14	260	...	70 000	...
Forgings:												
Annealed	110 000	...	65 000	...	20	40	...	7	223	...	...	...

[a] *Yield point* as determined with dividers must not be confused with a defined *yield strength*, such as, at 0.2 per cent offset.
[b] Oil quenched from a temperature of 1850 F.; tempered at 600 and 1300 F.
[c] Data obtained on steels which contained 0.60 to 0.80 per cent carbon.

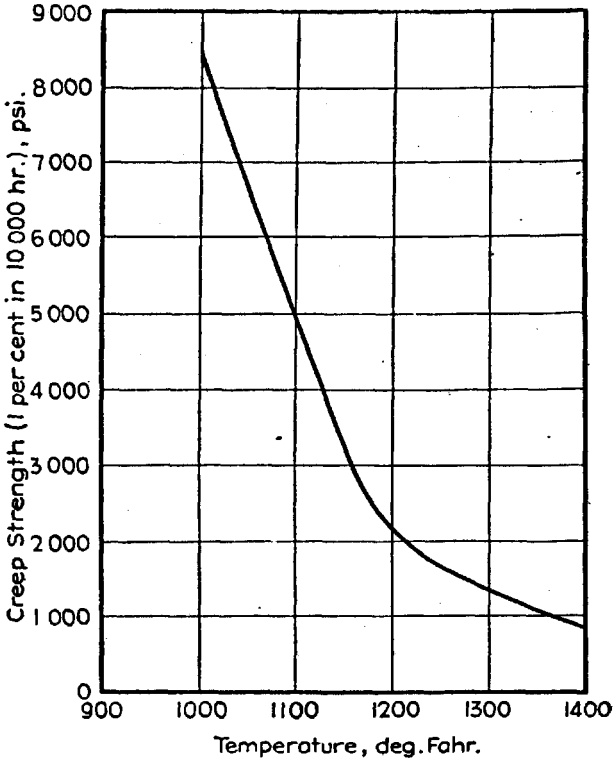

FIG. 8.—Creep Strength at Various Temperatures of Low-Carbon, 14 to 18 per cent Chromium Steel (A.S.T.M. Designations: A 176 – 42, Grade 4, and A 240 – 42, Grade A; A.I.S.I. Type No. 430).

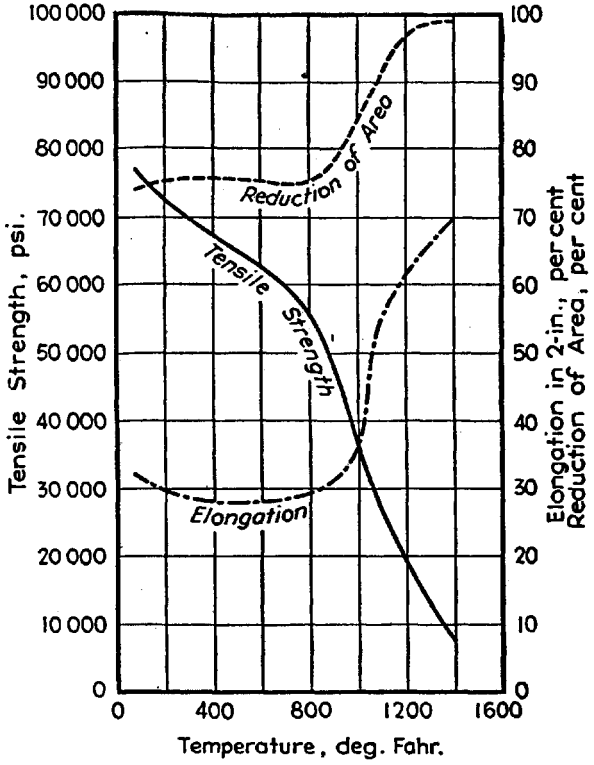

FIG. 9.—Short-Time High-Temperature Tensile Properties of Low-Carbon, 14 to 18 per cent Chromium Steel (A.S.T.M. Designations: A 176 – 42, Grade 4, and A 240 – 42, Grade A; A.I.S.I. Type No. 430).

TABLE IX.—MECHANICAL PROPERTIES OF LOW-CARBON, 14 TO 18 PER CENT CHROMIUM STEEL.

Chemical Composition, per cent			
Carbon	0.12 max.	Silicon	1.00 max.
Manganese	1.00 max.	Chromium	14 to 18
Phosphorus	0.03 max.	Nickel	0.60 max.
Sulfur	0.03 max.		

A.S.T.M. Designation	A 176 - 42	A 240 - 42
A.S.T.M. Grade	4	A
A.I.S.I. Type No.	430	430
Structure	Ferritic	Ferritic

Mechanical Properties

Form and Treatment	Tensile Strength, psi.	Yield Strength (offset = 0.2 per cent), psi.	Yield Point,[a] psi.	Proportional Limit, psi.	Elongation in 2 in., per cent	Reduction of Area, per cent	Impact Resistance, ft-lb.		Hardness Number		Endurance Limit (Fatigue), psi.	Cold Bend, deg.	Ductility	
							Charpy	Izod	Brinell (3000-kg. load, 10-mm. ball)	Rockwell			Erichsen Value, mm.	Olsen Value, in.
Sheet:														
Annealed	80 000	...	50 000	...	25	...	...	...	...	B80	...	180	7 to 9	0.275 to 0.375
Strip:														
Cold-rolled	100 000	...	88 000	...	8	...	...	...	...	B98	...	...	...	...
Annealed	80 000	...	50 000	...	25	...	...	...	...	B80	...	180	7 to 9	0.3 to 0.4
Wire:														
Cold-drawn, 20 per cent	90 000	...	80 000	35 000	13	...	...	...	...	B93	...	...	...	...
Cold-drawn, 40 per cent	100 000	...	95 000	55 000	10	...	...	...	...	B98	...	...	...	...
Cold-drawn, 60 per cent	110 000	...	105 000	75 000	8	...	...	...	...	C23	...	...	...	...
Annealed	80 000	...	50 000	20 000	25	...	...	...	...	B82	...	180	...	...
Plate														
Annealed	80 000	...	50 000	...	25	50	...	...	170	B80	...	180	...	...
Tubing:														
Annealed	80 000	...	50 000	...	25	50	...	...	...	B80	...	...	...	...
Bars:														
Cold-drawn, 20 per cent	92 000	...	85 000	45 000	15	45	...	...	190	...	46 000	...	...	...
Annealed	80 000	...	50 000	33 000	25	50	...	...	170	...	40 000	...	...	...
Hardened and Tempered	...	...	...	...	...	...	...	...	...	...	...	...	...	...
Forgings:														
Annealed	80 000	...	50 000	...	25	50	...	...	170	...	...	...	...	...

[a] *Yield point* as determined with dividers must not be confused with a defined *yield strength*, such as, at 0.2 per cent offset.

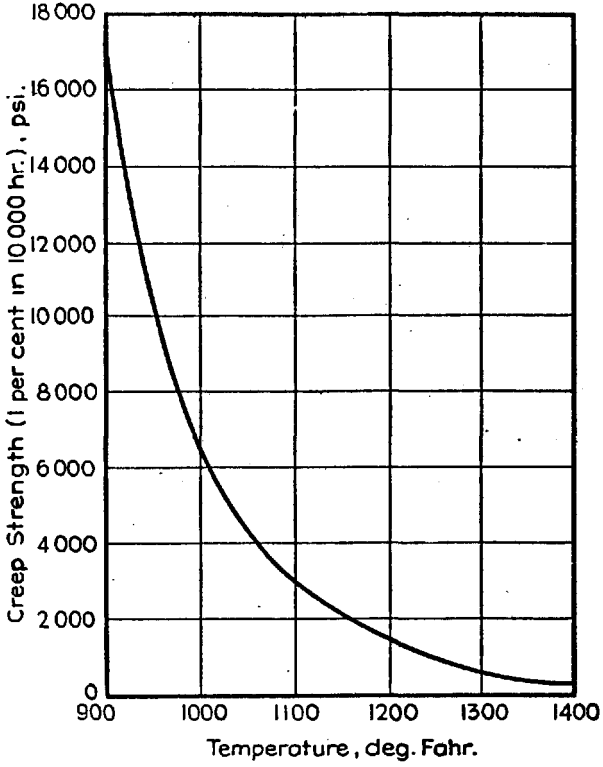

FIG. 10.—Creep Strength at Various Temperatures of 23 to 30 per cent Chromium Steel (A.S.T.M. Designations: A 176 – 42, Grade 6, and A 240 – 42, Grade B; A.I.S.I. Type No. 446).

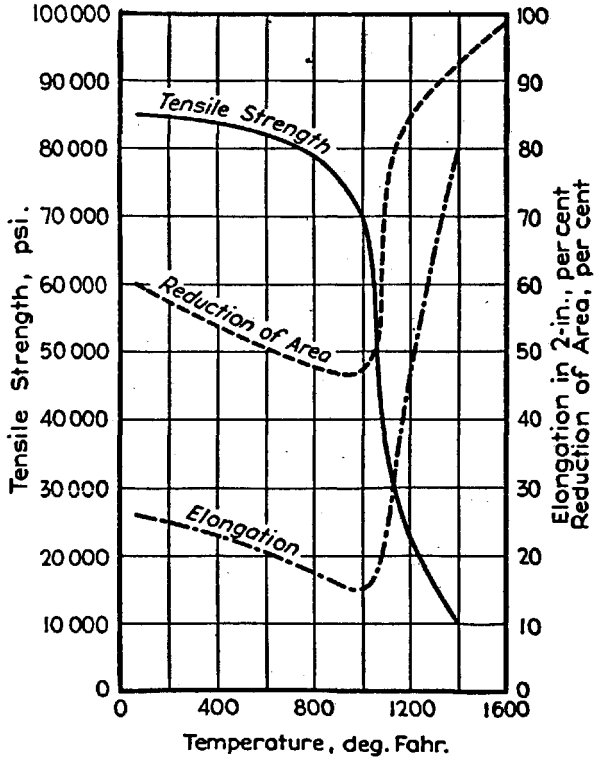

FIG. 11.—Short-Time High-Temperature Tensile Properties of 23 to 30 per cent Chromium Steel (A.S.T.M. Designations: A 176 – 42, Grade 6, and A 240 – 42, Grade B; A.I.S.I. Type No. 446).

TABLE X.—MECHANICAL PROPERTIES OF 23 TO 30 PER CENT CHROMIUM STEEL.

CHEMICAL COMPOSITION, PER CENT			
Carbon	0.35 max.	Silicon	1.00 max.
Manganese	1.00 max.	Chromium	23 to 30
Phosphorus	0.03 max.	Nickel	0.60 max.
Sulphur	0.03 max.		

A.S.T.M. Designation	A 176 - 42	A 240 - 42
A.S.T.M. Grade	6	B
A.I.S.I. Type No.	446	446
Structure	Ferritic	Ferritic

MECHANICAL PROPERTIES

Form and Treatment	Tensile Strength, psi.	Yield Strength (offset = 0.2 per cent), psi.	Yield Point,[a] psi.	Proportional Limit, psi.	Elongation in 2 in., per cent	Reduction of Area, per cent	Impact Resistance, ft-lb.		Hardness Number		Endurance Limit (Fatigue), psi.	Cold Bend, deg.	Ductility	
							Charpy	Izod	Brinell (3000-kg. load, 10-mm. ball)	Rockwell			Erichsen Value, mm.	Olsen Value, in.
Sheet:														
Annealed	85 000	...	55 000	...	25	...	...	...	...	B83	...	180	7 to 8	0.275 to 0.375
Strip:														
Cold-rolled	...	...	...	...	...	...	...	...	...	...	...	...	...	...
Annealed	87 000	...	55 000	...	25	...	...	...	...	B84	...	180	7 to 8	0.3 to 0.4
Wire:														
Cold-drawn, 65 per cent	135 000	...	115 000	...	...	...	...	...	...	...	...	...	...	...
Annealed	90 000	...	50 000	...	25	...	...	...	...	B84	...	...	...	...
Plate:														
Annealed	85 000	...	55 000	...	25	...	...	2	...	B83	...	180	...	...
Tubing:														
Annealed	83 000	...	55 000	...	25	50	...	...	175	B85	...	...	...	...
Bars:														
Cold-drawn	...	...	...	...	...	...	...	...	...	...	...	...	...	...
Annealed	85 000	...	55 000	37 000	25	45	...	2	...	B84	48 000	180	...	...
Hardened and Tempered	...	...	...	...	...	...	...	...	...	...	...	...	...	...
Forgings:														
Annealed	...	...	...	...	...	...	...	...	...	...	...	...	...	...

[a] *Yield point* as determined with dividers must not be confused with a defined *yield strength*, such as, at 0.2 per cent offset.
[b] Nitrogen usually 0.10 *min.* per cent, to insure grain refinement and workability.

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PART II

DATA FOR THE WROUGHT CORROSION-RESISTING AND HEAT-RESISTING CHROMIUM-NICKEL STEELS

TABLE XI.—CHEMICAL COMPOSITIONS OF WROUGHT CORROSION-RESISTING CHROMIUM-NICKEL STEELS.

A.S.T.M. Designation	A.S.T.M. Grade	A.I.S.I. Type Number	Carbon, per cent	Manganese, max., per cent	Phosphorus,[a] max., per cent	Sulfur,[a] per cent	Silicon, max., per cent	Chromium, per cent	Nickel, per cent	Molybdenum, per cent
A 167 - 42	1	301	0.08 to 0.20	2.00	0.035[a]	0.030 max.[a]	0.75	16.00 to 18.00	6.00 to 8.00	....
A 177 - 39										
A 167 - 42	2	302	0.08 to 0.20	2.00	0.035[a]	0.030 max.[a]	0.75	17.00 to 19.00	8.00 to 10.00	....
		303	0.20 max.	2.00	0.035[a,b]	0.070 min.[a,c]	....	17.00 to 19.00	8.00 to 10.00	0.60 max.
A 167 - 42	3	304	0.08 max.	2.00	0.035[a]	0.030 max.[a]	0.75	18.00 to 20.00	8.00 to 10.00	....
A 240 - 42	S	d	0.07 max.[e]	2.50	0.035[a]	0.030 max.[a]	0.75	18.00 min.	8.00 min.	....
A 167 - 42	4	f								
	5[g]		0.10 max.	1.50[h]	0.035[a]	0.030 max.[a]	0.75	18.00 min.[h]	8.00 min.[h]	....
A 240 - 42	T[i]	j	0.07 max.[k]	2.50	0.035	0.030 max.[a]	0.75	17.00 min.	9.00 min.	....
A 167 - 42	6[l]	347	0.10 max.	1.50[m]	0.035[a]	0.030 max.[a]	0.75	18.00 min.[m]	8.00 min.[m]	....
A 240 - 42	C[n]	o	0.07 max.[p]	2.50	0.035[a]	0.030 max.[a]	0.75	17.00 min.	9.50 min.	....
	7	q								
	8	309	0.20 max.	2.00	0.035[a]	0.030 max.[a]	3.50	22.00 to 24.00	12.00 to 15.00	....
A 167 - 42	9	r								
	10	310	0.25 max.	2.00	0.035[a]	0.030 max.[a]	2.00	24.00 to 26.00	19.00 to 22.00	....
	11	316	0.08 max.[s]	2.00	0.035[a]	0.030 max.[a]	0.75	16.00 min.[t]	10.00 min.[t]	2.00 to 3.00
A 240 - 42	M	t	0.07 max.[u]	2.50	0.035[a]	0.030 max.[a]	0.75	17.00 min.	10.00 min.	2.00 min.
A 167 - 42	12	v								

[a] Emergency Alternate Provisions EA - A 167 and EA - A 240 provide for a phosphorus and a sulfur content of 0.040 max., per cent, respectively, in A.S.T.M. Specifications A 167 - 42 and A 240 - 42.

[b] This steel may contain up to 0.17 per cent phosphorus with 0.10 max., per cent sulfur, or 0.07 min., per cent selenium.

[c] Or selenium 0.07 min., per cent.

[d] A.I.S.I. type 304 is similar to A.S.T.M. grade S.

[e] Emergency Alternate Provisions EA - A 240 provide for a carbon content of 0.08 max., per cent, which requirement is the same as in A.I.S.I. type 304.

[f] A.I.S.I. type 308 is similar to A.S.T.M. grade 4.

[g] Grade 5 has a minimum titanium content of four times the carbon content.

[h] Emergency Alternate Provisions EA - A 167 provide for a manganese content of 2.00 max., per cent, chromium from 17.00 to 19.00 per cent, and nickel from 8.00 to 12.00 per cent, which requirements are the same as in A.I.S.I. type 321.

[i] Grade T has a titanium content of not less than five times the carbon content and not more than 0.60 per cent; Emergency Alternate Provisions EA - A 240 provide for changing the titanium content to be "not less than four times the carbon content and not more than 0.60 per cent," which requirement as to the titanium: carbon ratio is the same as in A.I.S.I. type 321.

[j] A.I.S.I. type 321 is similar to A.S.T.M. grade T.

[k] Emergency Alternate Provisions EA - A 240 provide for a carbon content of 0.10 max., per cent, which requirement is the same as in A.I.S.I. type 321.

[l] Grade 6 has a minimum columbium content of ten times the carbon content; Emergency Alternate Provisions EA - A 167 provide for changing the columbium content to be "eight times the carbon content," which requirement is the same as in A.I.S.I. type 347.

[m] Emergency Alternate Provisions EA - A 167 provide for a manganese content of 2.00 max., per cent, chromium from 17.00 to 19.00 per cent, and nickel from 8.00 to 12.00 per cent, which requirements are the same as in A.I.S.I. type 347.

[n] Grade C has a columbium content of not less than ten times the carbon content and not more than 1 per cent; Emergency Alternate Provisions EA - A 240 provide for changing the columbium content to be "not less than eight times the carbon content and not more than 1 per cent," which requirement as to the columbium: carbon ratio is the same as in A.I.S.I. type 347.

[o] A.I.S.I. type 347 is similar to A.S.T.M. grade C.

[p] Emergency Alternate Provisions EA - A 240 provide for a carbon content of 0.10 max., per cent, which requirement is the same as in A.I.S.I. type 347.

[q] A.I.S.I. type 302B is similar to A.S.T.M. grade 7.

[r] A.I.S.I. type 309S is similar to A.S.T.M. grade 9.

[s] Emergency Alternate Provisions EA - A 167 provide for a carbon content of 0.10 max., per cent, chromium from 16.00 to 18.00 per cent, and nickel from 10.00 to 14.00 per cent, which requirements are the same as in A.I.S.I. type 316.

[t] A.I.S.I. type 316 is similar to A.S.T.M. grade M.

[u] Emergency Alternate Provisions EA - A 240 provide for a carbon content of 0.08 max., per cent.

[v] A.I.S.I. type 317 is similar to A.S.T.M. grade 12.

TABLE XII.—PHYSICAL PROPERTIES AND WORKING CHARACTERISTICS OF WROUGHT CORROSION-RESISTING CHROMIUM-NICKEL STEELS IN THE ANNEALED CONDITION.

A.S.T.M. Designation	A 167 - 42 A 177 - 39	A 167 - 42	....	A 167 A 240	A 167 - 42	A 167 - 42	A 167 A 240	A 167 A 240	A 167 A 240
A.S.T.M. Grade	1	2	....	3 S	8	10	11 M	5 T	6 C
A.I.S.I. Type No.	301	302	303	304 304	309	310	316 316	321 321	347 347
Modulus of elasticity in tension, psi	28 000 000[a]	28 000 000	28 000 000	28 000 000	29 000 000	30 000 000	28 000 000	28 000 000	28 000 000
Modulus of elasticity in torsion, psi	12 500 000[b]	12 500 000[b]	....	12 500 000	....	....	....	....	....
Density, lb. per cu. in.	0.29	0.29	0.29	0.29	0.29	0.29	0.29	0.29	0.29
Density, g. per cu. cm.	7.9	7.9	7.9	7.9	7.9	7.9	8.0	7.9	8.0
Specific electrical resistance at room temperature, microhms per cm. per sq. cm.	72	72	72	72	78	80	76	72	73
Magnetic permeability, Annealed	....	1.003	1.003	1.02	1.003	1.003	1.003	1.02	1.02
Magnetic permeability, 10 per cent cold-worked	....	1.10	....	1.10	....	....	....	....	....
Magnetic permeability, Severely cold-worked	....	10.0	....	7.0	....	....	10.0	....	....
Specific heat, Btu. per lb. per deg. Fahr. (32 to 212 F.)	0.12	0.12	0.12	0.12	0.12	0.12	0.12	0.12	0.12
Thermal conductivity, Btu. per hr. per sq. ft. per ft. per deg. Fahr., 212 F	....	9.4	9.4	9.4	....	7.5	9.0	9.3	9.3
Thermal conductivity, 392 F	....	10.2	....	10.3	....	8.2	....	10.2	10.2
Thermal conductivity, 572 F	....	10.9	....	11.0	....	8.8	....	11.1	11.1
Thermal conductivity, 752 F	....	11.6	....	11.8	....	9.5	....	11.9	11.9
Thermal conductivity, 932 F	....	12.4	12.4	12.5	....	10.0	12.1	12.8	12.8
Mean coefficient of thermal expansion per deg. Fahr., 32 to 212 F	0.0000094	0.0000096	....	0.0000096	0.0000083	0.0000080	0.0000089	0.0000093	0.0000093
Mean coefficient of thermal expansion per deg. Fahr., 32 to 572 F	....	0.0000099	....	0.0000099	....	....	....	....	....
Mean coefficient of thermal expansion per deg. Fahr., 32 to 932 F	0.0000101	0.0000102	....	0.0000102	0.0000096	0.0000092	0.0000097	0.0000103	0.0000103
Mean coefficient of thermal expansion per deg. Fahr., 32 to 1112 F	....	0.0000104	....	0.0000104	....	....	....	....	....
Mean coefficient of thermal expansion per deg. Fahr., 32 to 1832 F	....	0.0000112	....	0.0000112	0.0000115	0.0000106	....	....	....
Maximum temperature without excessive scaling, deg. Fahr.	....	1650	1600	1650	2000	2000	1650	1650	1650
Melting point range, deg. Fahr.	2550 to 2590	2550 to 2590	2550 to 2590	2550 to 2650	2550 to 2650	2550 to 2650	2500 to 2550	2550 to 2600	2550 to 2600
Forging practice, Initial temperature, deg. Fahr.	2150 to 2250	2000 to 2200	2100 to 2200	2000 to 2200	2000 to 2150	2000 to 2150	2100 to 2200	2100 to 2200	2100 to 2200
Forging practice, Final temperature, deg. Fahr.	1700 to 1750	1700 to 1750	1700 to 1750	1650 to 1700	1800 to 1850	1800 to 1850	1700 to 1750	1650 to 1700	1700 to 1750
Annealing temperatures, deg. Fahr., Low anneal	....	....	....	....	....	....	....	1550 to 1650	1550 to 1650
Annealing temperatures, deg. Fahr., Full anneal	1950 to 2050	1950 to 2050	1950 to 2050	1950 to 2050	2000 to 2100	2000 to 2100	1950 to 2050	1950 to 2050	1950 to 2050
Hardening temperature	[c]	[c]	[c]	[c]	[c]	[c]	[c]	[c]	[c]
Maximum cold reduction of wire before anneal, per cent	80	80	50	80	80	80	80	80	80
Riveting and hot forming temperatures, deg. Fahr.	....	1900 to 2100	....	1900 to 2100	1900 to 2100	1900 to 2100	1900 to 2100	1900 to 2100	1900 to 2100

[a] Type 301 is used in the cold-worked condition for light-weight high-strength structures. As cold-worked the modulus in tension is lowered. By stress-relief heat treatment this value may be raised to 27,500,000 psi.

[b] As cold-worked, this value decreases.

[c] Nonhardening for all grades and types.

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TABLE XIII.—MECHANICAL PROPERTIES OF 17 PER CENT CHROMIUM, 7 PER CENT NICKEL STEEL.

CHEMICAL COMPOSITION, PER CENT

Carbon	0.08 to 0.20	Silicon	0.75 max.
Manganese	2.00 max.	Chromium	16 to 18
Phosphorus	0.035 max.	Nickel	6 to 8
Sulfur	0.03 max.		

A.S.T.M. Designation	{A 167 - 42 {A 177 - 39
A.S.T.M. Grade	1
A.I.S.I. Type No.	301
Structure	Austenitic

MECHANICAL PROPERTIES

Form and Treatment	Tensile Strength, psi.	Yield Strength (offset = 0.2 per cent), psi.	Yield Point, psi.	Proportional Limit,[a] psi.	Elongation in 2 in., per cent	Reduction of Area, per cent	Impact Resistance, ft-lb. Charpy	Impact Resistance, ft-lb. Izod	Hardness Number Brinell (3000-kg. load, 10-mm. ball)	Hardness Number Rockwell	Endurance Limit (Fatigue), psi.	Cold Bend, deg.	Ductility Erichsen Value, mm.	Ductility Olsen Value, in.
Sheet:														
Cold-rolled, ¼ Hard	125 000 min.	75 000 min.	...	...	25 min.	...	...	...	...	C25	...	...	...	...
Cold-rolled, ½ Hard	150 000 min.	110 000 min.	...	35 000 min.	15 to 18[b]	...	...	...	...	C32	...	...	...	...
Cold-rolled, ¾ Hard	175 000 min.	135 000 min.	...	45 000 min.	10 to 12[b]	...	...	...	...	C37	...	...	...	...
Cold-rolled, Hard	185 000 min.	140 000 min.	...	55 000 min.	8 to 9[b]	...	...	...	...	C41	80 000	...	...	...
Annealed	75 000 min.	30 000 min.	...	14 000 min.	40 min.	...	...	...	...	B80	35 000	...	10 to 14	...
Strip:														
Cold-rolled, ¼ Hard	150 000 min.	110 000 min.	...	35 000 min.	15 to 18[b]	...	...	...	...	C32	...	...	...	...
Cold-rolled, ½ Hard	175 000 min.	135 000 min.	...	45 000 min.	10 to 12[b]	...	...	...	...	C37	...	...	...	...
Cold-rolled, Hard	185 000 min.	140 000 min.	...	55 000 min.	8 to 9[b]	...	...	...	...	C41	80 000	...	...	...
Annealed	75 000 min.	30 000 min.	...	14 000 min.	40 min.	...	...	...	...	B80	35 000	...	10 to 14	...
Wire:														
Cold-drawn, 20 per cent.	170 000	120 000	...	60 000	20	...	...	...	...	C33	...	...	...	...
Cold-drawn, 40 per cent.	220 000	180 000	...	100 000	8	...	...	...	...	C42	...	...	...	...
Cold-drawn, 60 per cent.	270 000	240 000	...	145 000	5	...	...	...	...	C47	...	...	...	...
Annealed	120 000	35 000	...	20 000	44	...	...	...	...	B85	...	180	...	...
Plate:														
Annealed	100 000	...	45 000	...	50	70	...	...	163	...	39 000	...	...	...
Tubing:														
Cold-drawn	...	...	...	...	...	...	...	...	...	...	...	...	...	...
Annealed	...	...	...	...	...	...	...	...	...	...	...	...	...	...
Bars:														
Cold-drawn, 30 per cent.	183 000	159 000	...	...	16	49	...	...	...	C36	78 000	180	...	...
Annealed	100 000	32 000	45 000	...	55	66	...	...	...	B80	39 000	...	...	...

[a] Proportional limit values at offset of 0.01 per cent.
[b] Elongation values vary with thickness being higher with greater thickness.

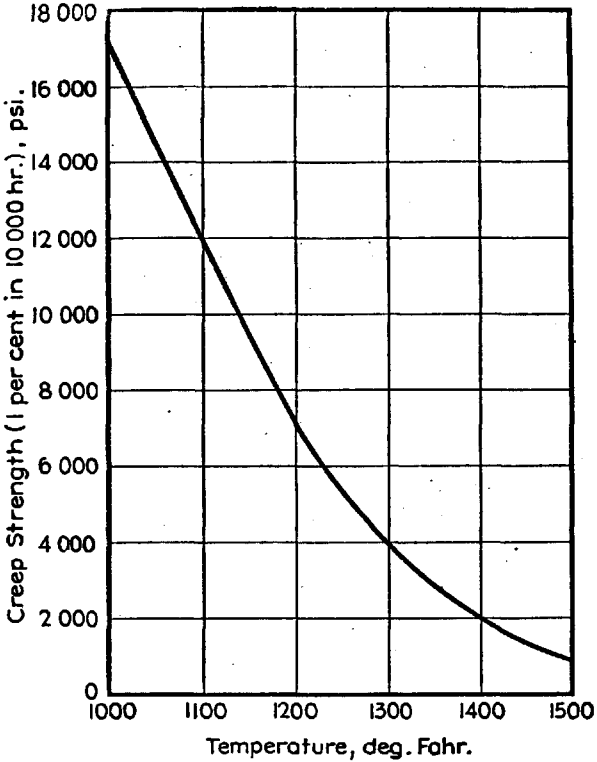

FIG. 12.—Creep Strength at Various Temperatures of 18 per cent Chromium, 8 per cent Nickel Steel (A.S.T.M. Designation: A 167 – 42, Grade 2; A.I.S.I. Type No. 302).

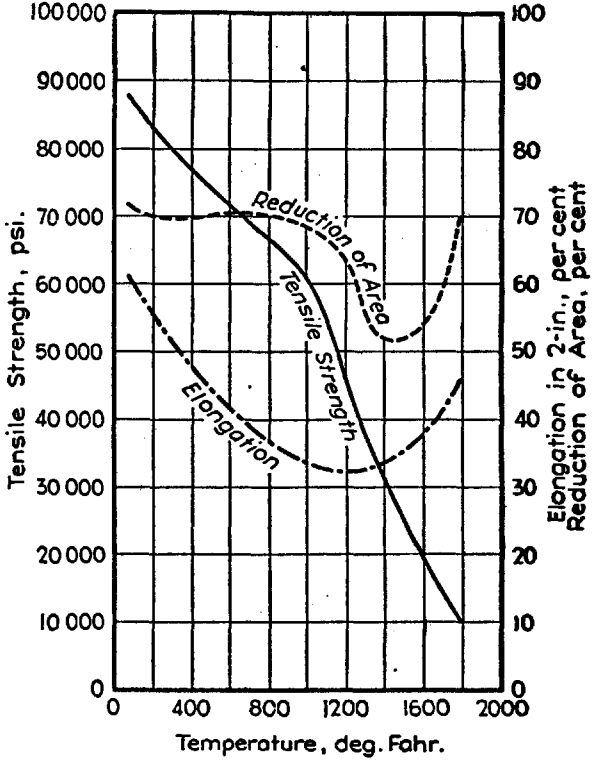

FIG. 13.—Short-Time High-Temperature Tensile Properties of 18 per cent Chromium, 8 per cent Nickel Steel (A.S.T.M. Designation: A 167 – 42, Grade 2; A.I.S.I. Type No. 302).

TABLE XIV.—MECHANICAL PROPERTIES OF 18 PER CENT CHROMIUM, 8 PER CENT NICKEL STEEL.

Chemical Composition, per cent			
Carbon	0.08 to 0.20	Silicon	0.75 max.
Manganese	2.00 max.	Chromium	17 to 19
Phosphorus	0.035 max.	Nickel	8 to 10
Sulfur	0.03 max.		

A.S.T.M. Designation	A 167 - 42
A.S.T.M. Grade	2
A.I.S.I. Type No.	302
Structure	Austenitic

Mechanical Properties

Form and Treatment	Tensile Strength, psi	Yield Strength (offset = 0.2 per cent), psi.	Yield Point,[a] psi.	Proportional Limit,[b] psi.	Elongation in 2 in., per cent	Reduction of Area, per cent	Impact Resistance, ft-lb.		Hardness Number		Endurance Limit (Fatigue), psi.	Cold Bend, deg.	Ductility	
							Charpy	Izod	Brinell (3000-kg. load, 10-mm. ball)	Rockwell			Erichsen Value, mm.	Olsen Value, in.
Sheet:														
Cold-rolled, quarter hard	125 000 min.	75 000 min.	...	35 000 min.	20 min.	...	...	...	...	C25	...	...	...	...
Annealed	75 000 min.	30 000 min.	...	14 000 min.	40 min.	...	...	...	...	B80	...	180	10 to 14	0.4 to 0.5
Strip:														
Cold-rolled, quarter hard	125 000 min.	75 000 min.	...	35 000 min.	20 min.	...	...	...	...	C25	...	...	...	...
Annealed	75 000 min.	30 000 min.	...	14 000 min.	40 min.	...	...	...	...	B80	...	180	10 to 14	0.4 to 0.5
Wire:														
Cold-drawn 20 per cent	140 000	105 000	...	40 000	25	...	...	...	...	C32	...	...	...	...
Cold-drawn 40 per cent	195 000	165 000	...	60 000	10	...	...	...	...	C40	...	...	...	...
Cold-drawn 60 per cent	250 000	225 000	...	100 000	5	...	...	...	...	C45	...	...	...	...
Annealed	105 000	30 000	...	20 000	55	...	...	...	...	B80	...	180	...	...
Plate:														
Annealed	85 000	...	41 000	...	50	73	...	...	150	...	...	180	...	...
Tubing:														
Cold-drawn	...	...	...	...	...	...	...	...	...	...	...	...	...	...
Annealed	...	...	...	...	...	...	...	...	...	...	...	...	...	...
Bars:														
Cold-drawn, 25 per cent	155 000	...	135 000	...	20	58	...	50	320	...	83 000	180	...	...
Annealed	85 000	30 000	40 000	...	60	65	80	90	160	B80	34 000	180	...	...

[a] *Yield point* as determined with dividers must not be confused with a defined *yield strength*, such as, at 0.2 per cent offset.
[b] Proportional limit values at offset of 0.01 per cent.

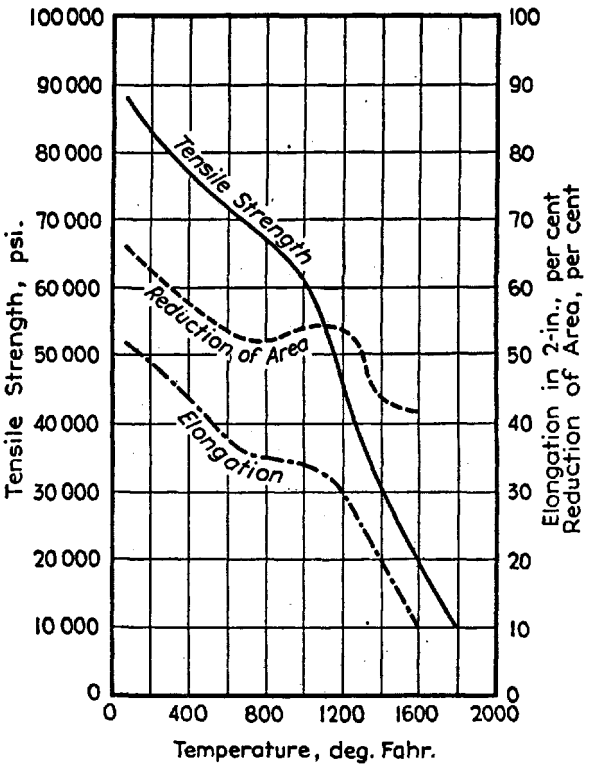

FIG. 14.—Short-Time High-Temperature Tensile Properties of 18 per cent Chromium, 8 per cent Nickel Steel (Free Machining) (A.I.S.I. Type No. 303).

TABLE XV.—MECHANICAL PROPERTIES OF 18 PER CENT CHROMIUM, 8 PER CENT NICKEL STEEL (FREE MACHINING).

Chemical Composition, per cent				A.S.T.M. Designation	
Carbon	0.20 max.	Chromium	17 to 19	A.S.T.M. Grade	
Manganese	2.00 max.	Nickel	8 to 10	A.I.S.I. Type No.	303
Phosphorus	0.035 max.[a]	Molybdenum	0.60 max.	Structure	Austenitic
Sulfur or Selenium	0.07 min.				

Mechanical Properties

Form and Treatment	Tensile Strength, psi.	Yield Strength (offset = 0.2 per cent), psi.	Yield Point, psi.	Proportional Limit, psi.	Elongation in 2 in., per cent	Reduction of Area, per cent	Impact Resistance, ft-lb.		Hardness Number		Endurance Limit (Fatigue), psi.	Cold Bend, deg.	Ductility	
							Charpy	Izod	Brinell (3000-kg. load, 10-mm. ball)	Rockwell			Erichsen Value, mm.	Olsen Value, in.
Sheet:														
Cold-rolled	...	...	...	...	...	...	...	...	...	...	...	...	...	...
Annealed	...	...	...	...	...	...	...	...	...	...	...	...	...	...
Strip:														
Cold-rolled	...	...	...	...	...	...	...	...	...	...	...	...	...	...
Annealed	...	...	...	...	...	...	...	...	...	...	...	...	...	...
Wire:														
Cold-drawn {20 per cent	135 000	110 000	...	40 000	22	...	...	...	...	C30	...	...	...	...
Cold-drawn {40 per cent	180 000	170 000	...	75 000	10	...	...	...	...	C38	...	...	...	...
Annealed	105 000	35 000	...	20 000	52	...	...	...	...	B86	...	180	...	...
Plate:														
Annealed	...	...	...	...	...	...	...	...	...	...	...	...	...	...
Tubing:														
Cold-drawn	...	...	...	...	...	...	...	...	...	...	...	...	...	...
Annealed	...	...	...	...	...	...	...	...	...	...	...	...	...	...
Bars:														
Cold-drawn	115 000	...	80 000	...	35	50	...	80	220	...	48 000	180	...	...
Annealed	85 000	...	35 000	...	55	60	...	80	160	...	35 000	180	...	...

[a] This steel may contain up to 0.17 per cent phosphorus with 0.10 max. per cent sulfur or 0.07 min. per cent selenium.

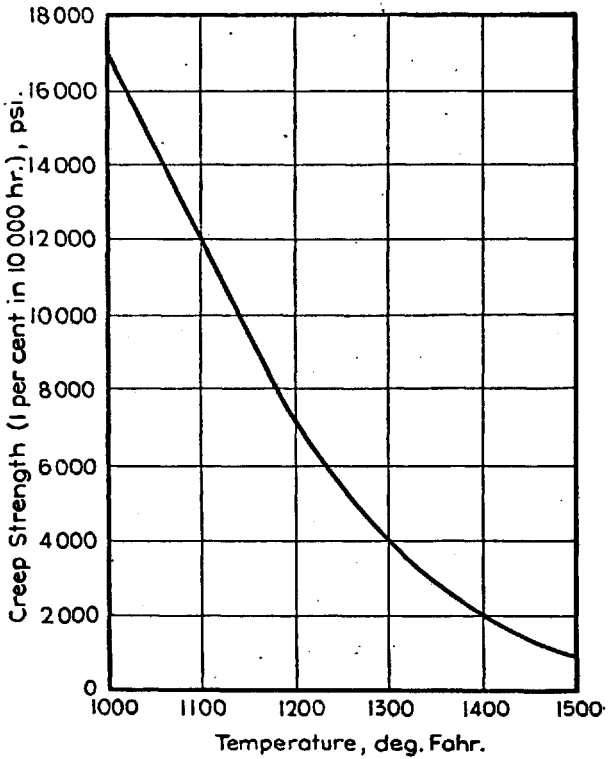

FIG. 15.—Creep Strength at Various Temperatures of Low-Carbon, 18 per cent Chromium, 8 per cent Nickel Steel (A.S.T.M. Designations: A 167 – 42, Grade 3, and A 240 – 42, Grade S; A.I.S.I. Type No. 304).

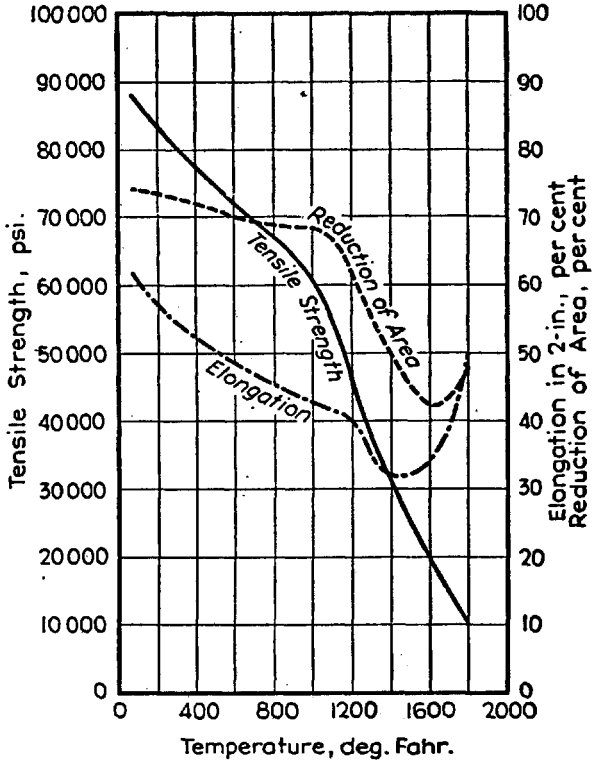

FIG. 16.—Short-Time High-Temperature Tensile Properties of Low-Carbon, 18 per cent Chromium, 8 per cent Nickel Steel (A.S.T.M. Designations: A 167 – 42, Grade 3, and A 240 – 42, Grade S; A.I.S.I. Type No. 304).

TABLE XVI.—MECHANICAL PROPERTIES OF LOW-CARBON, 18 PER CENT CHROMIUM, 8 PER CENT NICKEL STEEL.

Chemical Composition, per cent			
Carbon	0.08 max.	Silicon	0.75 max.
Manganese	2.00 max.	Chromium	18 to 20
Phosphorus	0.035 max.	Nickel	8 to 10
Sulfur	0.03 max.		

A.S.T.M. Designation	A 167 - 42	A 240 - 42
A.S.T.M. Grade	3	S
A.I.S.I. Type No.	304	304 is similar to grade S
Structure	Austenitic	Austenitic

Mechanical Properties

Form and Treatment	Tensile Strength, psi.	Yield Strength (offset = 0.2 per cent), psi.	Yield Point,[a] psi.	Proportional Limit, psi.	Elongation in 2 in., per cent	Reduction of Area, per cent	Impact Resistance, ft-lb.		Hardness Number		Endurance Limit (Fatigue), psi.	Cold Bend, deg.	Ductility	
							Charpy	Izod	Brinell (3000-kg. load, 10-mm. ball)	Rockwell			Erichsen Value, mm.	Olsen Value, in.
Sheet:														
Cold-rolled	...	...	...	...	...	...	...	...	...	...	...	...	...	...
Annealed	85 000[b]	...	35 000	...	60	...	...	...	...	B80	35 000	180	10 to 14	0.4 to 0.5
Strip:														
Cold-rolled	...	...	...	...	...	...	...	...	...	...	...	...	...	...
Annealed	90 000[b]	...	40 000	...	50	...	...	...	...	B80	...	180	10 to 14	0.4 to 0.5
Wire:														
Cold-drawn (20 per cent	140 000	105 000	...	40 000	25	...	...	...	...	C32	...	...	...	...
Cold-drawn (40 per cent	195 000	165 000	...	60 000	10	...	...	...	...	C40	...	...	...	...
Cold-drawn (60 per cent	250 000	225 000	...	100 000	5	...	...	...	...	C45	...	...	...	...
Annealed	105 000	30 000	...	20 000	55	...	...	...	...	B80	...	180	...	...
Plate:														
Annealed	85 000	...	35 000	...	60	65	...	100	150	B80	35 000	180	...	...
Tubing:														
Cold-drawn (Half hard	150 000	...	110 000	...	10	...	...	...	280	C30	...	...	...	...
Cold-drawn (Full hard	185 000	...	140 000	...	5	...	...	...	325	C35	...	...	...	...
Annealed	85 000	...	35 000	...	60	65	80	100	150	B80	35 000	180	...	...
Bars:														
Cold-drawn, 25 per cent	150 000	...	120 000	...	20	...	...	48	320	...	...	180	...	...
Annealed	85 000	30 000	40 000	...	60	70	...	90	160	B80	34 000	180	...	...

[a] *Yield point* as determined with dividers must not be confused with defined *yield strength*, such as, at 0.2 per cent offset.
[b] This is a representative and not a minimum value. Therefore, it must not be compared with the minimum values shown for grades 1 and 2 of A.S.T.M. Standard A 167 - 42 (see Tables XIII and XIV).

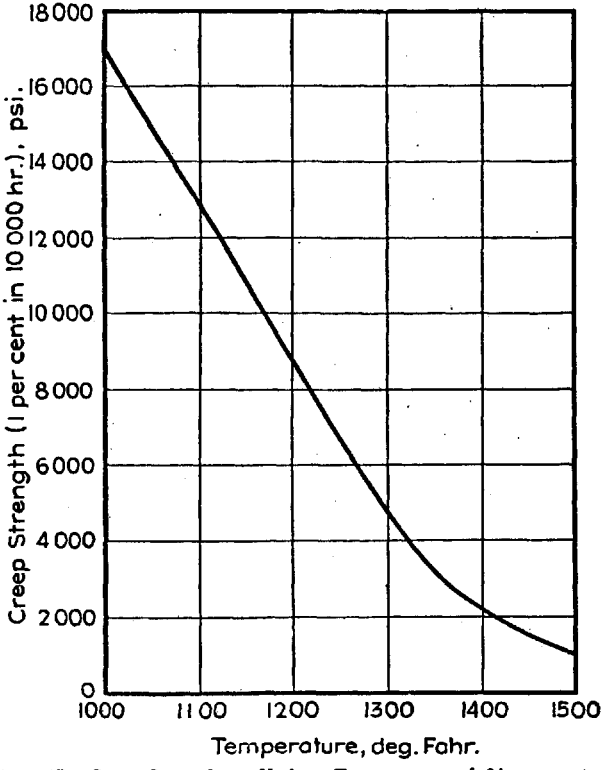

FIG. 17.—Creep Strength at Various Temperatures of 24 per cent Chromium, 12 per cent Nickel Steel (A.S.T.M. Designation: A 167 – 42, Grade 8; A.I.S.I. Type No. 309).

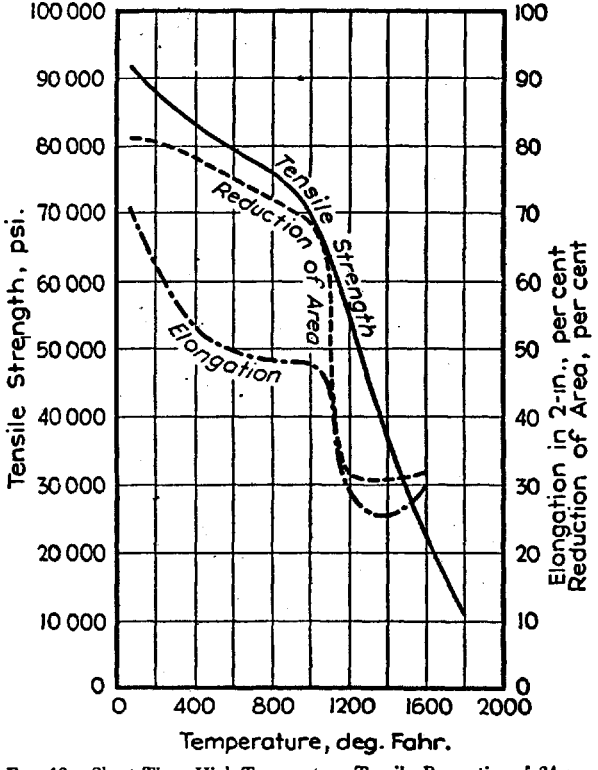

FIG. 18.—Short-Time High-Temperature Tensile Properties of 24 per cent Chromium, 12 per cent Nickel Steel (A.S.T.M. Designation: A 167 – 42, Grade 8; A.I.S.I. Type No. 309).

TABLE XVII.—MECHANICAL PROPERTIES OF 24 PER CENT CHROMIUM, 12 PER CENT NICKEL STEEL.

Chemical Composition, per cent			
Carbon	0.20 max.	Silicon	3.50 max.
Manganese	2.00 max.	Chromium	22 to 24
Phosphorus	0.035 max.	Nickel	12 to 15
Sulfur	0.03 max.		

A.S.T.M. Designation	A 167 - 42
A.S.T.M. Grade	8
A.I.S.I. Type No.	309
Structure	Austenitic

Mechanical Properties

Form and Treatment	Tensile Strength, psi.	Yield Strength (offset = 0.2 per cent), psi.	Yield Point,[a] psi.	Proportional Limit, psi.	Elongation in 2 in., per cent	Reduction of Area, per cent	Impact Resistance, ft-lb.		Hardness Number		Endurance Limit (Fatigue), psi.	Cold Bend, deg.	Ductility	
							Charpy	Izod	Brinell (3000-kg. load, 10-mm. ball)	Rockwell			Erichsen Value, mm.	Olsen Value, in.
Sheet:														
Cold-rolled	...	...	...	...	...	...	...	...	...	...	...	...	...	...
Annealed	90 000[b]	...	45 000	...	47	...	...	...	...	B85	...	180	...	...
Strip:														
Cold-rolled (30 per cent)	116 000[b]	...	...	...	15	...	...	...	...	...	...	...	...	...
Cold-rolled (60 per cent)	166 000[b]	...	...	...	3	...	...	...	...	...	...	...	...	...
Annealed	90 000[b]	...	50 000	...	47	...	...	...	...	B85	...	180	7 to 8	...
Wire:														
Cold-drawn (20 per cent)	130 000	...	115 000	50 000	12	...	...	...	...	C25	...	...	...	...
Cold-drawn (40 per cent)	160 000	...	150 000	75 000	8	...	...	...	...	C33	...	...	...	...
Cold-drawn (60 per cent)	190 000	...	175 000	100 000	5	...	...	...	...	C37	...	...	...	...
Annealed	100 000	30 000	50 000	25 000	42	...	...	...	...	B86	...	180	...	...
Plate:														
Annealed	100 000	...	50 000	...	55	60	...	...	...	...	...	...	...	...
Tubing:														
Cold-drawn	...	...	...	...	...	...	...	...	...	...	...	...	...	...
Annealed	...	...	...	...	...	...	...	...	...	...	...	...	...	...
Bars:														
Cold-drawn	...	...	...	...	...	...	...	...	...	...	...	...	...	...
Annealed	100 000	...	50 000	...	54	60	...	100	170	...	...	180	...	...

[a] *Yield point* as determined with dividers must not be confused with a defined *yield strength*, such as, at 0.2 per cent offset.

[b] This is a representative and not a minimum value. Therefore, it must not be compared with the minimum values shown for grades 1 and 2 of A.S.T.M. Standard A 167 - 42 see Tables XIII and XIV).

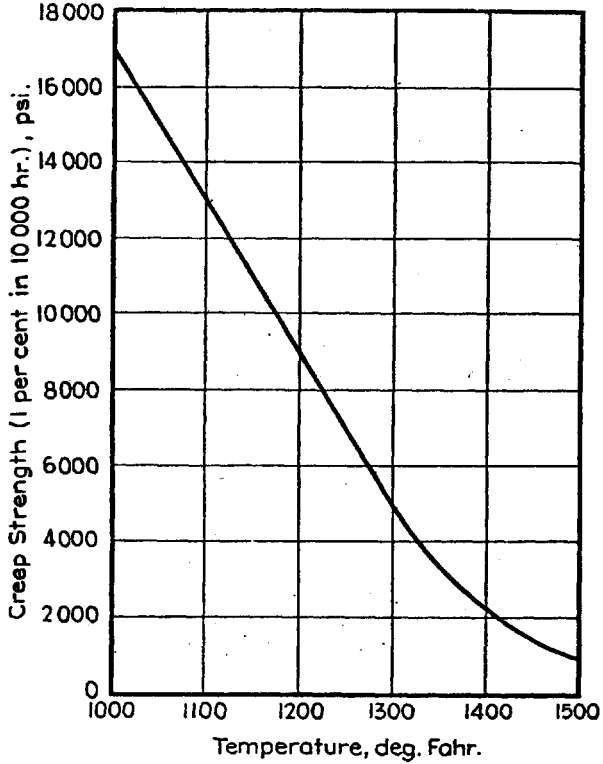

FIG. 19.—Creep Strength at Various Temperatures of 25 per cent Chromium, 20 per cent Nickel Steel (A.S.T.M. Designation: A 167 – 42, Grade 10; A.I.S.I. Type No. 310).

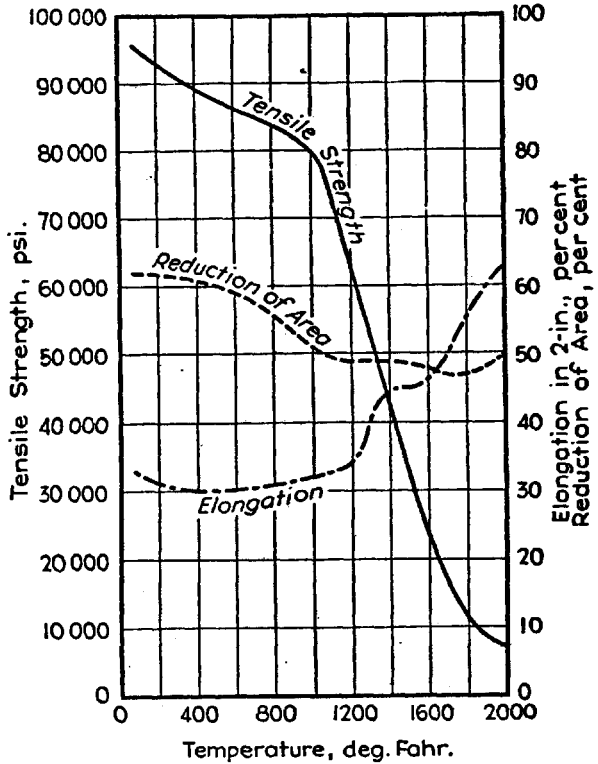

FIG. 20.—Short-Time High-Temperature Tensile Properties of 25 per cent Chromium, 20 per cent Nickel Steel (A.S.T.M. Designation: A 167 – 42, Grade 10; A.I.S.I. Type No. 310).

TABLE XVIII.—MECHANICAL PROPERTIES OF 25 PER CENT CHROMIUM, 20 PER CENT NICKEL STEEL.

Chemical Composition, per cent			
Carbon	0.25 max.	Silicon	2.00 max.
Manganese	2.00 max.	Chromium	24 to 26
Phosphorus	0.035 max.	Nickel	19 to 22
Sulfur	0.03 max.		

A.S.T.M. Designation	A 167 - 42
A.S.T.M. Grade	10
A.I.S.I. Type No.	310
Structure	Austenitic

Mechanical Properties

Form and Treatment	Tensile Strength, psi.	Yield Strength (offset = 0.2 per cent), psi.	Yield Point,[a] psi.	Proportional Limit, psi.	Elongation in 2 in., per cent	Reduction of Area, per cent	Impact Resistance, ft-lb.		Hardness Number		Endurance Limit (Fatigue), psi.	Cold Bend, deg.	Ductility	
							Charpy	Izod	Brinell (3000-kg. load, 10-mm. ball)	Rockwell			Erichsen Value, mm.	Olsen Value, in.
Sheet:														
Cold-rolled	...	...	...	...	...	...	...	...	...	...	...	...	...	...
Annealed	95 000[b]	...	50 000	...	40	...	...	...	...	B85	...	180	...	...
Strip:														
Cold-rolled	...	...	...	...	...	...	...	...	...	...	...	...	...	...
Annealed	...	...	...	...	...	...	...	...	...	...	...	...	...	...
Wire:														
Cold-drawn	...	...	...	...	...	...	...	...	...	...	...	...	...	...
Annealed	100 000	...	50 000	...	40	...	...	...	B85	...	...	180	...	...
Plate:														
Annealed	100 000	...	50 000	...	40	55	...	...	...	B85	...	180	...	...
Tubing:														
Cold-drawn	...	...	...	...	...	...	...	...	...	...	...	...	...	...
Annealed	100 000	...	50 000	...	40	55	...	60	...	B85	...	...	...	...
Bars:														
Cold-drawn	...	...	...	...	...	...	...	...	...	...	...	...	...	...
Annealed	100 000	...	50 000	...	40	55	...	60	170	B85	...	180	...	...

[a] *Yield point* as determined with dividers must not be confused with a defined *yield strength*, such as, at 0.2 per cent offset.
[b] This is a representative and not a minimum value. Therefore, it must not be compared with the minimum values shown for grades 1 and 2 of A.S.T.M. Standard A 167 - 42 (see Tables XIII and XIV).

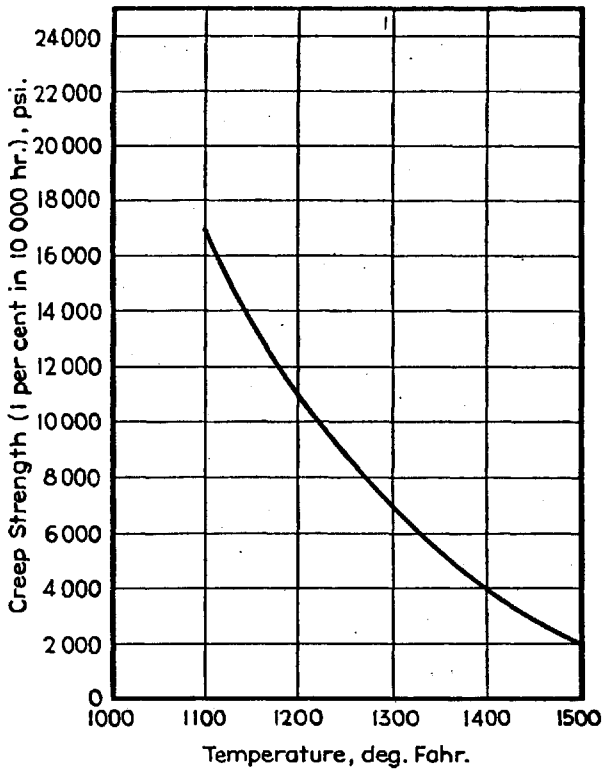

FIG. 21.—Creep Strength at Various Temperatures of 18 per cent Chromium, 12 per cent Nickel, 2 to 3 per cent Molybdenum Steel (A.S.T.M. Designations: A 167 – 42, Grade 11, and A 240 – 42, Grade M; A.I.S.I. Type No. 316).

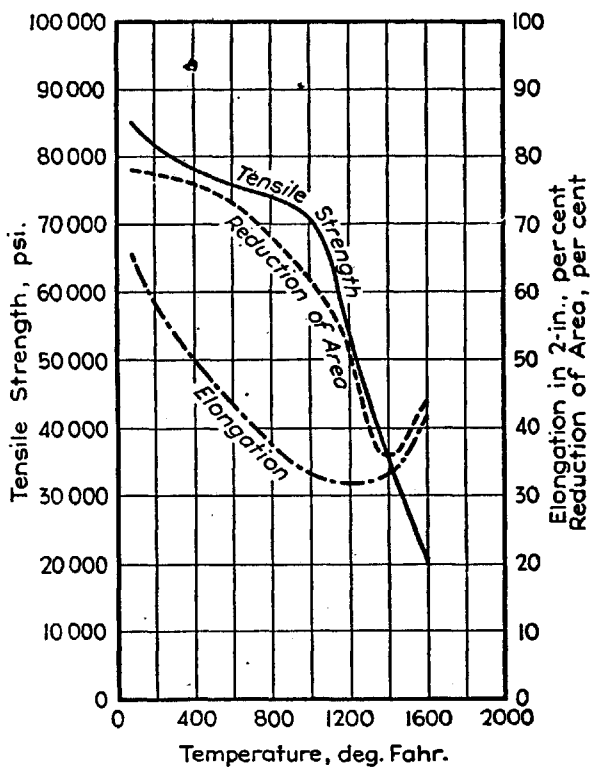

FIG. 22.—Short-Time High-Temperature Tensile Properties of 18 per cent Chromium, 12 per cent Nickel, 2 to 3 per cent Molybdenum Steel (A.S.T.M. Designations: A 167 – 42, Grade 11, and A 240 – 42, Grade M; A.I.S.I. Type No. 316).

TABLE XIX.—MECHANICAL PROPERTIES OF 18 PER CENT CHROMIUM, 12 PER CENT NICKEL, 2 TO 3 PER CENT MOLYBDENUM STEEL.

Chemical Composition, per cent			
Carbon	0.08 max.	Silicon	0.75 max.
Manganese	2.00 max.	Chromium	16 min.
Phosphorus	0.035 max.	Nickel	10 min.
Sulfur	0.03 max.	Molybdenum	2 to 3

A.S.T.M. Designation	A 167 - 42	A 240 - 42
A.S.T.M. Grade	11	M
A.I.S.I. Type No.	316	316 is similar to grade M
Structure	Austenitic	Austenitic

Mechanical Properties

Form and Treatment	Tensile Strength, psi.	Yield Strength (offset = 0.2 per cent), psi.	Yield Point,[a] psi.	Proportional Limit, psi.	Elongation in 2 in., per cent	Reduction of Area, per cent	Impact Resistance, ft-lb.		Hardness Number		Endurance Limit (Fatigue), psi.	Cold Bend, deg.	Ductility	
							Charpy	Izod	Brinell (3000-kg. load, 10-mm. ball)	Rockwell			Erichsen Value, mm.	Olsen Value, in.
Sheet:														
Cold-rolled	...	...	...	...	...	...	...	...	...	...	...	...	...	...
Annealed	88 000[b]	...	40 000	...	52	...	...	...	...	B85	39 000	180	10 to 14	0.4 to 0.475
Strip:														
Cold-rolled, 30 per cent	145 000[b]	122 000	...	...	12	...	...	...	...	...	...	...	...	...
Cold-rolled, 40 per cent	159 000[b]	137 000	...	...	7	...	...	...	...	...	...	...	...	...
Annealed	90 000[b]	35 000	...	...	40	...	...	...	...	B85	...	180	10 to 14	0.4 to 0.5
Wire:														
Cold-drawn, 20 per cent	130 000	100 000	...	45 000	21	...	...	...	...	C25	...	...	...	...
Cold-drawn, 40 per cent	170 000	140 000	...	75 000	12	...	...	...	...	C33	...	...	...	...
Cold-drawn, 60 per cent	205 000	180 000	...	105 000	6	...	...	...	...	C38	...	...	...	...
Annealed	90 000	30 000	...	20 000	55	...	...	...	...	B85	...	180	...	...
Plate:														
Annealed	88 000	...	40 000	...	55	65	...	95	170	B85	39 000	180	...	...
Tubing:[c]														
Cold-drawn	...	...	...	...	...	...	...	...	...	...	...	...	...	...
Annealed	85 000	...	40 000	...	55	...	...	...	...	B85	...	...	...	...
Bars:														
Cold-drawn, 30 per cent	141 000	116 000	...	...	13	60	...	...	...	C29	...	...	...	...
Annealed	85 000	30 000	40 000	...	55	65	78	100	170	...	38 000	180	...	...

[a] *Yield point* as determined with dividers must not be confused with a defined *yield strength*, such as, at 0.2 per cent offset.

[b] This is a representative and not a minimum value. Therefore, it must not be compared with the minimum values shown for grades 1 and 2 of A.S.T.M. Standard A 167 - 42 (see Tables XIII and XIV).

[c] Some seamless tubing is made from a steel containing about 16 per cent chromium, 13 per cent nickel, and 3 per cent molybdenum.

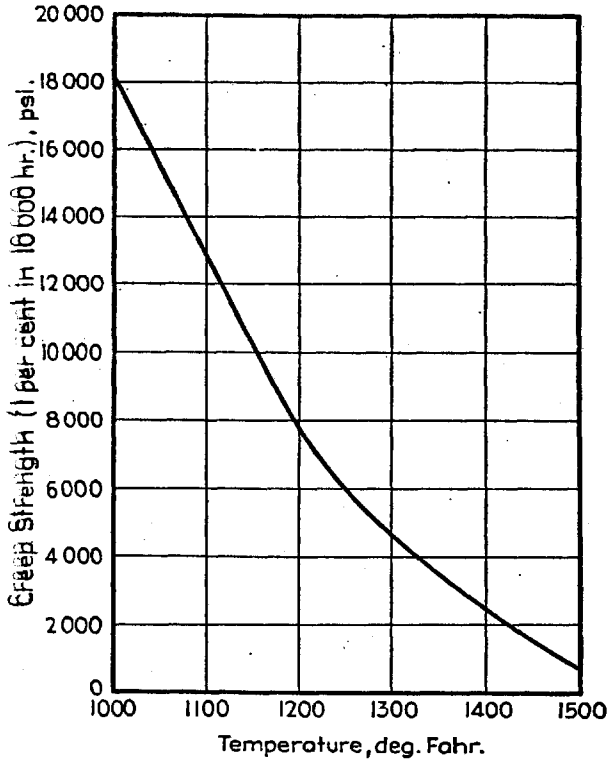

FIG. 23.—Creep Strength at Various Temperatures of 18 per cent Chromium, 8 per cent Nickel, Titanium Stabilized Steel (A.S.T.M. Designations: A 167 – 42, Grade 5, and A 240 – 42, Grade T; A.I.S.I. Type No. 321).

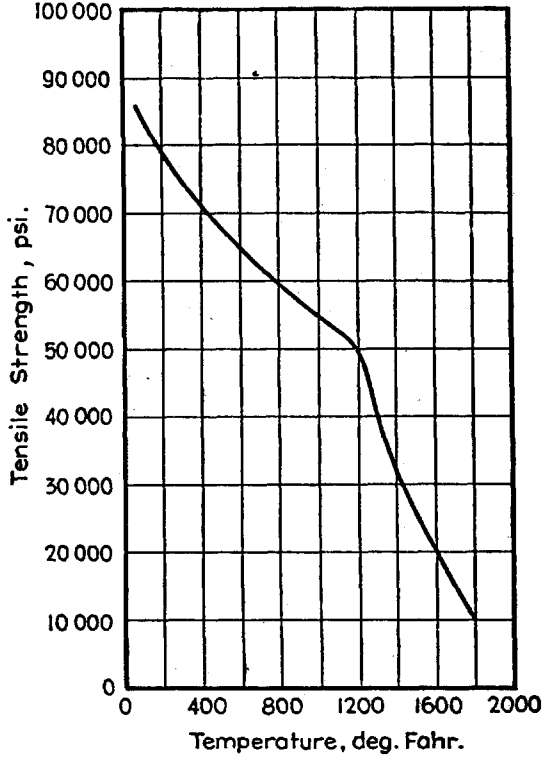

FIG. 24.—Short-Time High-Temperature Tensile Properties of 18 per cent Chromium, 8 per cent Nickel, Titanium Stabilized Steel (A.S.T.M. Designations: A 167 – 42, Grade 5, and A 240 – 42, Grade T; A.I.S.I. Type No. 321).

TABLE XX.—MECHANICAL PROPERTIES OF 18 PER CENT CHROMIUM, 8 PER CENT NICKEL, TITANIUM STABILIZED STEEL.

Chemical Composition, per cent			
Carbon	0.10 max.	Silicon	0.75 max.
Manganese	2.00 max.	Chromium	18.00 min.
Phosphorus	0.035 max.	Nickel	8 min.
Sulfur	0.03 max.	Titanium	4 × C min.

A.S.T.M. Designation	A 167 - 42	A 240 - 42
A.S.T.M. Grade	5	T
A.I.S.I. Type No.	321	321 is similar to grade T
Structure	Austenitic	Austenitic

Mechanical Properties

Form and Treatment	Tensile Strength, psi.	Yield Strength (offset = 0.2 per cent), psi.	Yield Point,[a] psi.	Proportional Limit, psi.	Elongation in 2 in., per cent	Reduction of Area, per cent	Impact Resistance, ft-lb.		Hardness Number		Endurance Limit (Fatigue), psi.	Cold Bend, deg.	Ductility	
							Charpy	Izod	Brinell (3000-kg. load, 10-mm. ball)	Rockwell			Erichsen Value, mm.	Olsen Value, in.
Sheet:														
Cold-rolled	...	...	...	...	...	...	...	...	...	...	...	...	...	...
Annealed	85 000[b]	...	35 000	...	54	...	...	...	...	B80	...	180	12	0.400 to 0.475
Strip:														
Cold-rolled, 35 per cent	147 000[b]	136 000	...	...	7	...	...	...	...	...	...	...	...	...
Annealed	88 000[b]	...	39 000	...	56	...	...	...	...	B80	...	180	12	...
Wire:														
Cold-drawn 20 per cent	100 000	90 000	...	40 000	23	...	...	...	...	C20	...	...	...	...
Cold-drawn 40 per cent	145 000	130 000	...	70 000	10	...	...	...	...	C32	...	...	...	...
Cold-drawn 60 per cent	190 000	175 000	...	95 000	4	...	...	...	...	C37	...	...	...	...
Annealed	90 000	30 000	...	20 000	55	...	...	...	...	B85	...	180	...	...
Plate:														
Annealed	89 000	...	38 000	...	55	60	...	100	170	...	...	180	...	...
Tubing:														
Cold-drawn	...	...	...	...	...	...	...	...	...	...	...	...	...	...
Annealed	...	...	...	...	...	...	...	...	...	...	...	...	...	...
Bars:														
Cold-drawn	...	...	...	...	...	...	...	...	...	...	...	...	...	...
Annealed	90 000	...	40 000	...	55	60	...	100	170	B85	...	180	...	...

[a] *Yield point* as determined with dividers must not be confused with a defined *yield strength*, such as, at 0.2 per cent offset.

[b] This is a representative and not a minimum value. Therefore, it must not be compared with the minimum values shown for grades 1 and 2 of A.S.T.M. Standard A 167 - 42 (see Tables XIII and XIV).

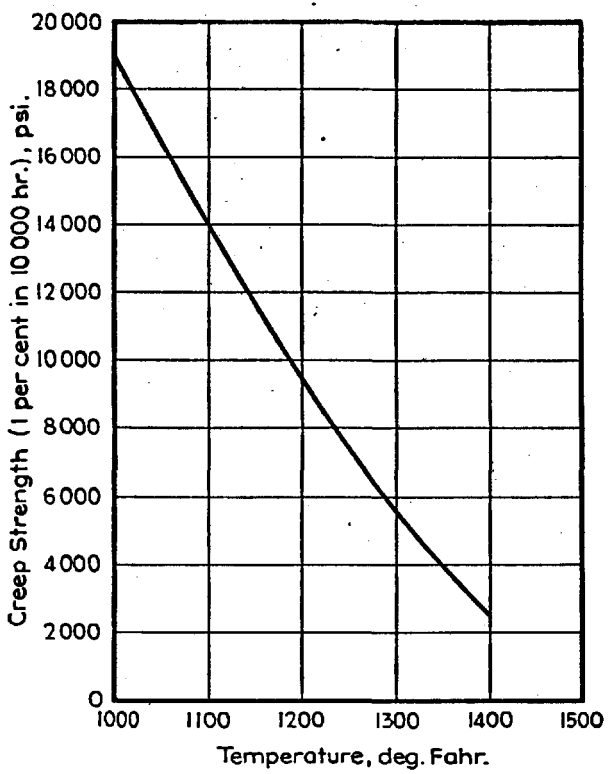

FIG. 25.—Creep Strength at Various Temperatures of 18 per cent Chromium, 8 per cent Nickel, Columbium Stabilized Steel (A.S.T.M. Designations. A 167 – 42, Grade 6, and A 240 – 42, Grade C; A.I.S.I. Type No. 347).

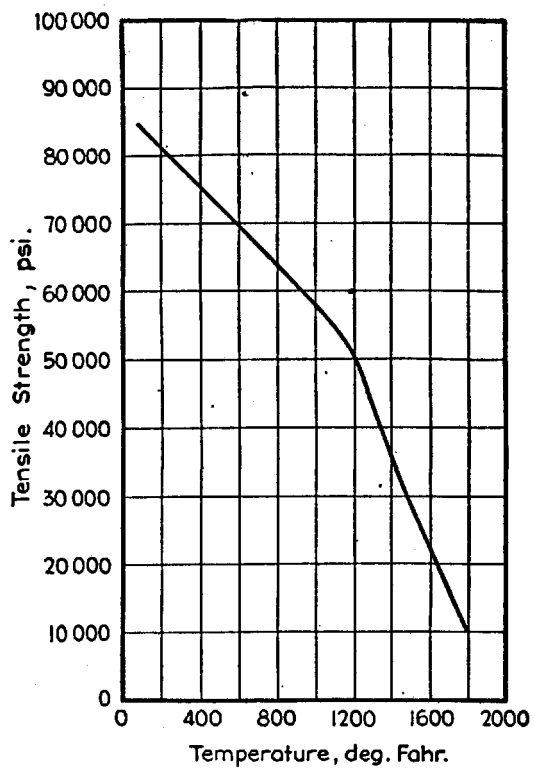

FIG. 26.—Short-Time High-Temperature Tensile Properties of 18 per cent Chromium, 8 per cent Nickel, Columbium Stabilized Steel (A.S.T.M. Designations: A 167 – 42, Grade 6, and A 240 – 42, Grade C; A.I.S.I. Type No. 347).

TABLE XXI.—MECHANICAL PROPERTIES OF 18 PER CENT CHROMIUM, 8 PER CENT NICKEL, COLUMBIUM STABILIZED STEEL.

Chemical Composition, per cent			
Carbon	0.10 max.	Silicon	0.75 max.
Manganese	2.00 max.	Chromium	18.00 min.
Phosphorus	0.035 max.	Nickel	8 min.
Sulfur	0.03 max.	Columbium	10 × C min.

A.S.T.M. Designation	A 167 - 42	A 240 - 42
A.S.T.M. Grade	6	C
A.I.S.I. Type No.	347	347 is similar to grade C
Structure	Austenitic	Austenitic

Mechanical Properties

Form and Treatment	Tensile Strength, psi.	Yield Strength (offset = 0.2 per cent), psi.	Yield Point,[a] psi.	Proportional Limit, psi.	Elongation in 2 in., per cent	Reduction of Area, per cent	Impact Resistance, ft-lb.		Hardness Number		Endurance Limit (Fatigue), psi.	Cold Bend, deg.	Ductility	
							Charpy	Izod	Brinell (3000-kg. load, 10-mm. ball)	Rockwell			Erichsen Value, mm.	Olsen Value, in.
Sheet:														
Cold-rolled	...	...	...	...	...	...	...	...	...	...	...	...	...	...
Annealed	90 000[b]	...	40 000	...	50	...	...	...	...	B85	...	180	12	0.400 to 0.475
Strip:														
Cold-rolled, 20 per cent	132 000[b]	102 000	...	...	23	...	...	...	...	...	...	...	...	...
Cold-rolled, 30 per cent	152 000[b]	125 000	...	...	10	...	...	...	...	...	...	...	...	...
Annealed	90 000[b]	...	38 000	...	50	...	...	...	...	B85	...	180	12	...
Wire:														
Cold-drawn, 20 per cent	100 000	90 000	...	40 000	23	...	...	...	...	C20	...	...	...	...
Cold-drawn, 40 per cent	145 000	130 000	...	70 000	10	...	...	...	...	C32	...	...	...	...
Cold-drawn, 60 per cent	190 000	175 000	...	95 000	4	...	...	...	...	C37	...	...	...	...
Annealed	90 000	30 000	...	20 000	55	...	...	...	...	B85	...	180	...	...
Plate:														
Annealed	90 000	...	37 000	...	50	60	...	100	170	...	...	180	...	...
Tubing:														
Cold-drawn	...	...	...	...	...	...	...	...	...	...	...	...	...	...
Annealed	90 000	...	40 000	...	50	60	...	100	170	...	...	...	...	...
Bars:														
Cold-drawn	...	...	...	...	...	...	...	...	...	...	...	...	...	...
Annealed	90 000	...	40 000	...	50	60	...	100	170	...	...	180	...	...

[a] *Yield point* as determined with dividers must not be confused with a defined *yield strength*, such as, at 0.2 per cent offset.

[b] This is a representative and not a minimum value. Therefore, it must not be compared with the minimum values shown for grades 1 and 2 of A.S.T.M. Standard A 167 - 42 (see Tables XIII and XIV).