ASTM Special Technical Publication No. 228

REPORT ON

ELEVATED-TEMPERATURE PROPERTIES

OF

CHROMIUM STEELS

(12-27 per cent)

Data Compiled by and Issued Under the Auspices of

THE DATA AND PUBLICATIONS PANEL

of

THE ASTM—ASME JOINT COMMITTEE ON

EFFECT OF TEMPERATURE ON THE PROPERTIES OF METALS

Prepared for the Panel by

WARD F. SIMMONS AND HOWARD C. CROSS

Published by the

AMERICAN SOCIETY FOR TESTING MATERIALS

1916 RACE STREET, PHILADELPHIA 3, PENNSYLVANIA

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CONTENTS

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This report is a graphical summary of the elevated-temperature strength data for chromium steels. It includes summary curves for tensile strength; 0.2 per cent offset yield strength; per cent elongation and reduction of area; stresses to produce rupture in 100, 1000, 10,000, and 100,000 hours; and stresses for creep rates of 0.0001 and 0.00001 per cent per hour (one per cent in 10,000 and 100,000 hours). Data for 23 steels ranging from 12 to 27 per cent chromium are given.

This is one of a series of reports on the elevated-temperature strength properties of various metallic materials being prepared under the auspices of the Data and Publications Panel of the ASTM-ASME Joint Committee on Effect of Temperature on the Properties of Metals. Other reports in this series have covered the high-temperature properties of austenitic stainless steels,[1] the chromium-molybdenum steels,[2] selected super-strength alloys,[3] carbon steels,[4] copper-base alloys,[5] wrought medium-carbon alloy steels,[6] the relaxation properties of steels and super-strength alloys,[7] and the high-temperature strength of weldments.[8] Other Data and Publications Panel projects which are expected to result in publications in the near future are the following:

(1) Elevated-temperature properties of aluminum and magnesium alloys.
(2) Physical properties of metals and alloys at low and high temperatures.
(3) Survey of test facilities in the United States for mechanical and physical testing at low and high temperatures.

Data contained in this report came principally from data sheets supplied by the cooperating laboratories. However, to make this report more complete, and therefore more useful, some data have been taken from trade bulletins and the published technical literature. Data sheets were prepared from the data taken from these sources and are included with the data sheets contributed by the cooperating laboratories. The source of the data is given on each data sheet. The cooperating laboratories that supplied data for this report are the following:

Babcock and Wilcox Tube Company
Crucible Steel Company of America
Elliott Company
Firth-Sterling Steel and Carbide Corporation
General Electric Company
Heppenstall Company—Wm. Jessop and Son
National Advisory Committee for Aeronautics, Lewis Flight Propulsion Laboratory

* Prepared by Ward F. Simmons and Howard C. Cross, Battelle Memorial Institute, Columbus, Ohio

[1] Report on the Elevated-Temperature Properties of Stainless Steels (1952). (Issued as separate publication *ASTM STP No. 124).*

[2] Report on the Elevated-Temperature Properties of Chromium-Molybdenum Steels (1953). (Issued as separate publication *ASTM STP No. 151).*

[3] Report on the Elevated-Temperature Properties of Selected Super-Strength Alloys (1954). (Issued as separate publication *ASTM STP No. 160).*

[4] Elevated-Temperature Properties of Carbon Steels (1955). (Issued as separate publication *ASTM STP No. 180).*

[5] Elevated-Temperature Properties of Copper and Copper-Base Alloys (1956). (Issued as separate publication *ASTM STP No. 181).*

[6] Report on Elevated-Temperature Properties of Wrought Medium-Carbon Alloy Steels (1957). (Issued as separate publication *ASTM STP No. 199).*

[7] Relaxation Properties of Steels and Super-Strength Alloys at Elevated Temperatures (1956). (Issued as separate publication *ASTM STP No. 187).*

[8] The Elevated-Temperature Properties of Weld-Deposited Metals and Weldments (1957). (Issued as separate publication *ASTM STP No. 226).*

Titanium Alloy Manufacturing Division of National Lead Company
U. S. Naval Engineering Experiment Station
U. S. Steel Corporation
University of Michigan
University of Minnesota
Wright Air Development Center

The data were organized according to principal alloying elements into the general alloy groups as listed in the table of contents.

The figures have been drawn using various symbols for annealed, normalized, hot rolled, etc., to indicate the approximate processing that each heat of steel has received. The processing as indicated by the symbols cannot be given in detail, and is intended to serve only as a guide in using the data given in the figures. The details of heat treatment, chemical composition, etc., for each steel are given in the data sheets directly following the figures.

In the rupture-strength and creep-strength figures, the individual data points are identified by the corresponding data sheet numbers at the top of each figure. Thus, it is possible to refer to the proper data sheet to check chemical composition, heat treatment, etc., for any data point.

Some of the data sheets from General Electric Company include rupture strength data that have been extrapolated (or interpolated) by the Larson-Miller[9] parameter method as well as by the usual log-log curves. Both values, when available, are included in the data sheets. The values extrapolated by log-log curves are indicated by an asterisk (*) and the values determined by the parameter method by the letter P. In the figures, a flag (⚑) has been attached to the symbol to indicate a point determined by the parameter method.

To facilitate comparing the creep and rupture strengths, the average curves for rupture in 1000 and 100,000 hours, and creep strengths for 0.0001 and 0.00001 per cent per hour have been replotted in Figs. 1 and 2.

Figures 3 to 14 show stress versus rupture-time and creep-rate curves plotted on log-log coordinates. These curves are based on the average curves for the various steels including the extrapolated data for rupture in 10,000 and 100,000 hours.

[9] F. R. Larson and James Miller, "A Time-Temperature Relationship for Rupture and Creep Stresses", *Transactions*, American Society of Mechanical Engineers, Vol. 74, No. 5, July, 1952, pp. 765-775.

Acknowledgment:

The authors wish to thank the contributing organizations and their representatives for taking the time necessary to supply the data sheets on which this report is based. The authors also wish to thank the members of the Data and Publications Panel and the Project Committee for their suggestions and counsel, which were very helpful in preparing the data for publication.

See Figs. 1 to 14 on pp. 3 to 7.

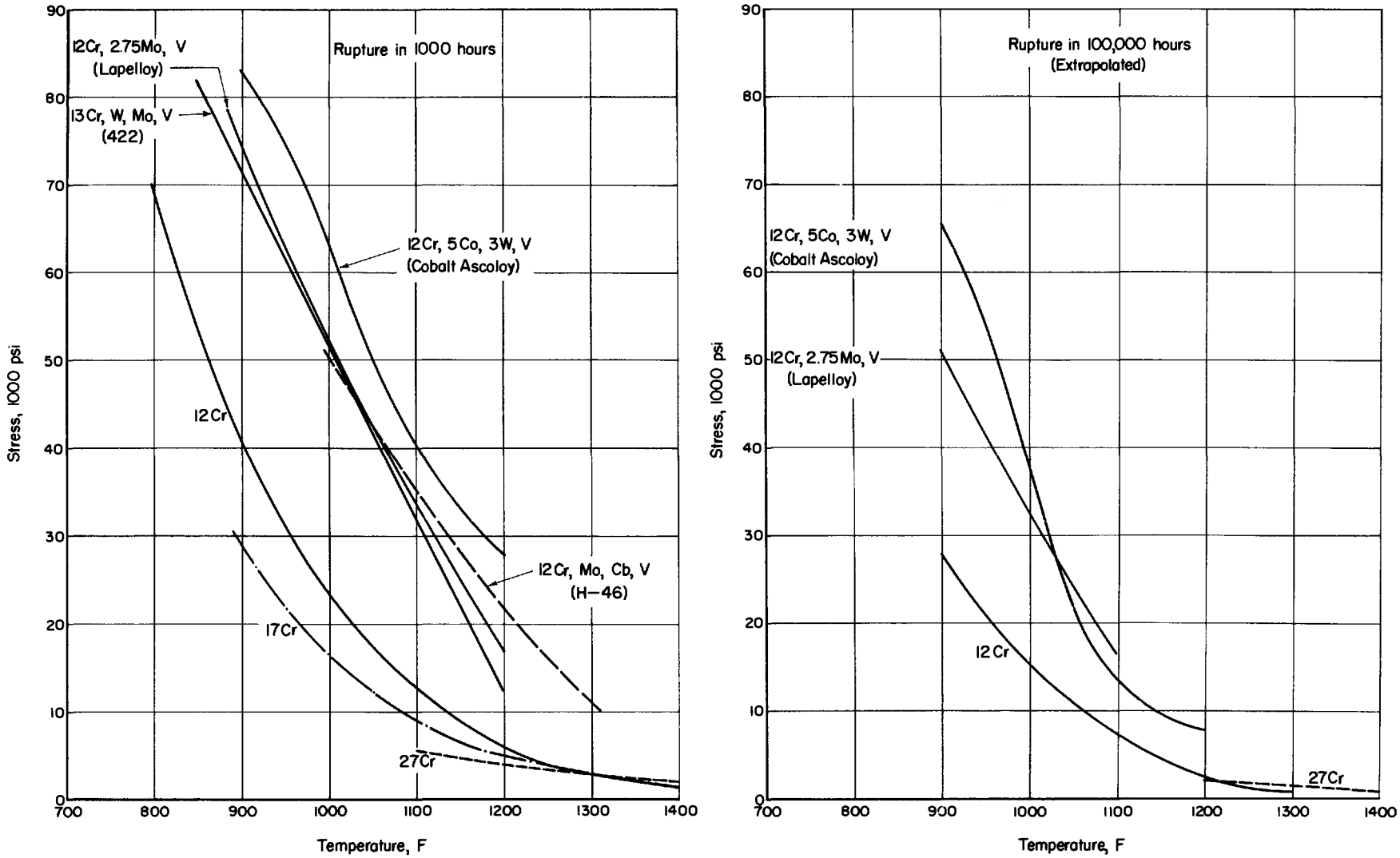
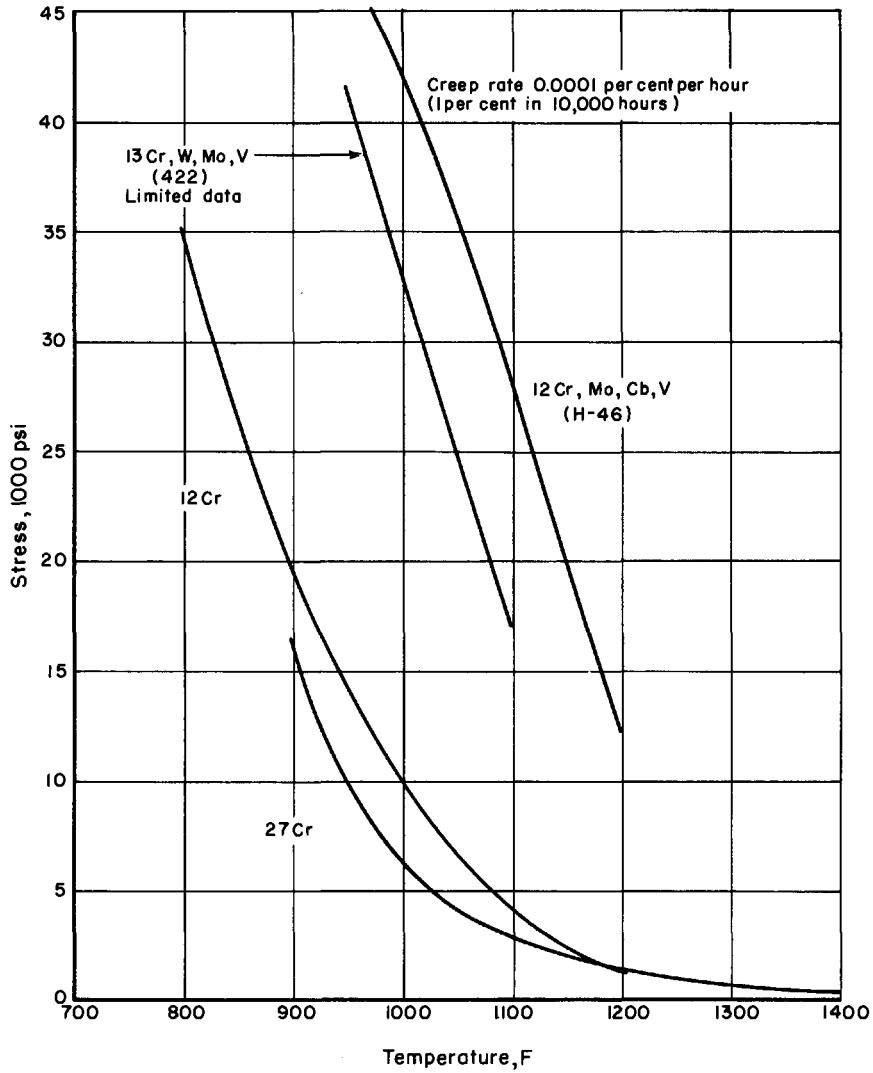


FIGURE I. AVERAGE RUPTURE STRENGTH CURVES



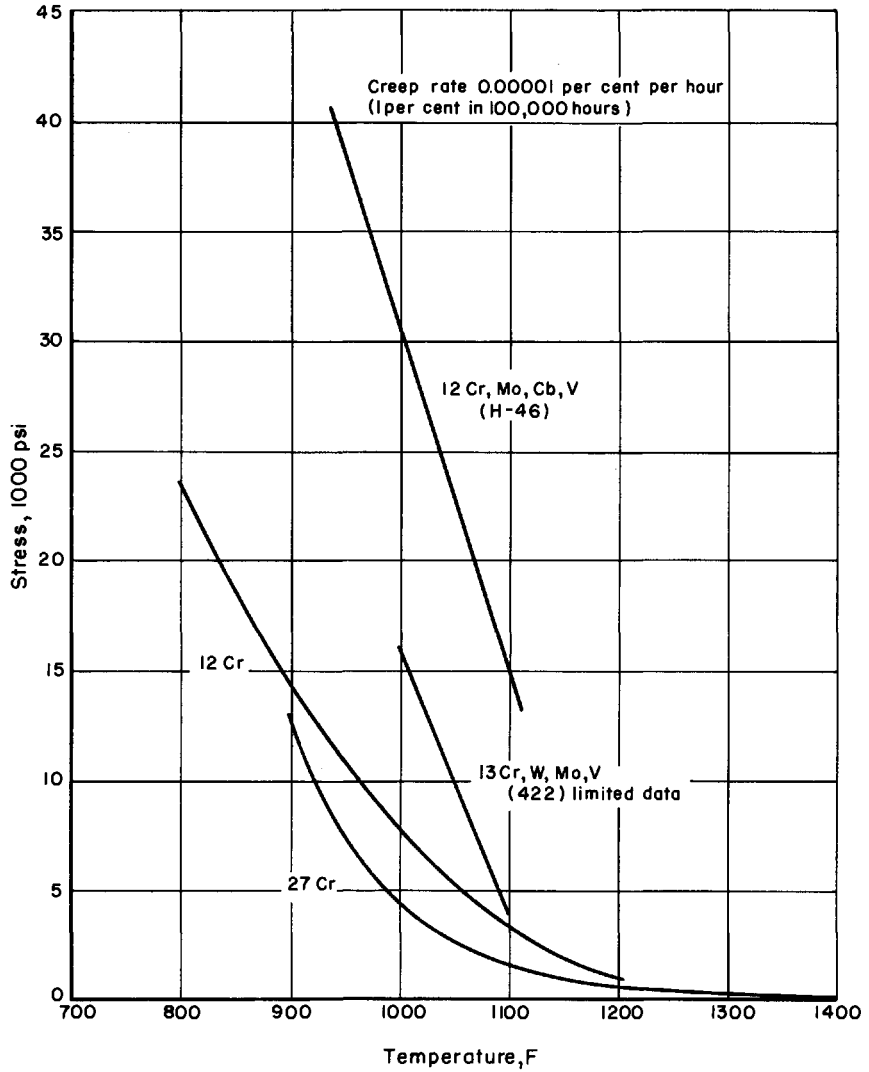


FIGURE 2. AVERAGE RUPTURE STRENGTH CURVES

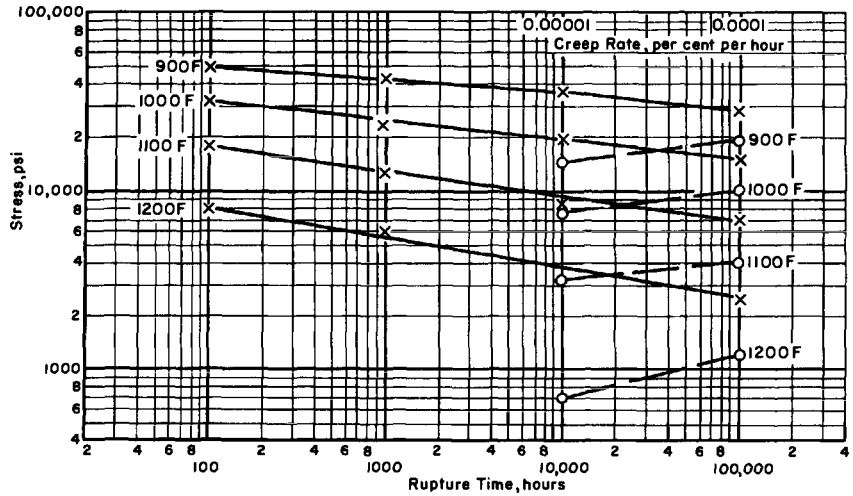


FIGURE 3. STRESS VERSUS RUPTURE-TIME AND CREEP-RATE CURVES FOR 12 Cr STEEL BASED ON AVERAGE DATA

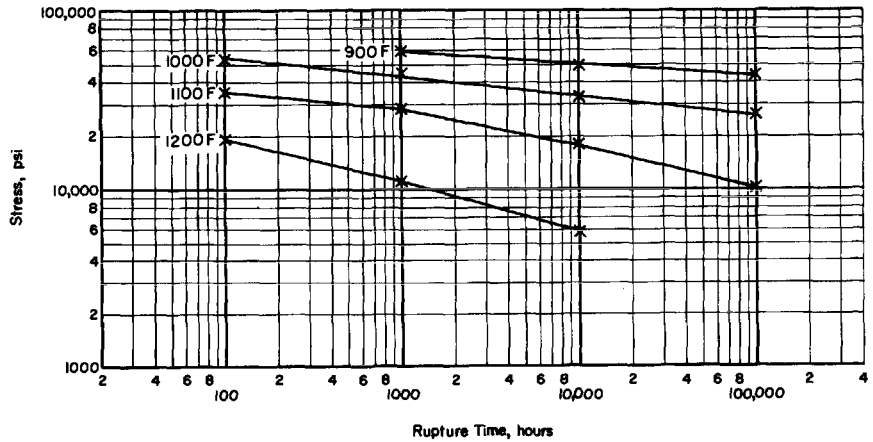


FIGURE 4. STRESS VERSUS RUPTURE-TIME CURVES FOR 13 Cr, 2 Ni, 3 W STEEL BASED ON AVERAGE DATA

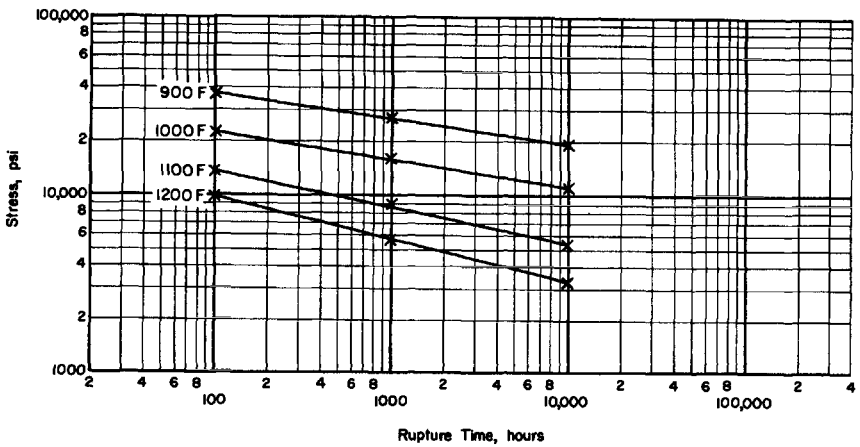


FIGURE 5. STRESS VERSUS RUPTURE-TIME CURVES FOR 12 Cr, 2 Ni STEEL BASED ON AVERAGE DATA FROM TWO HEATS

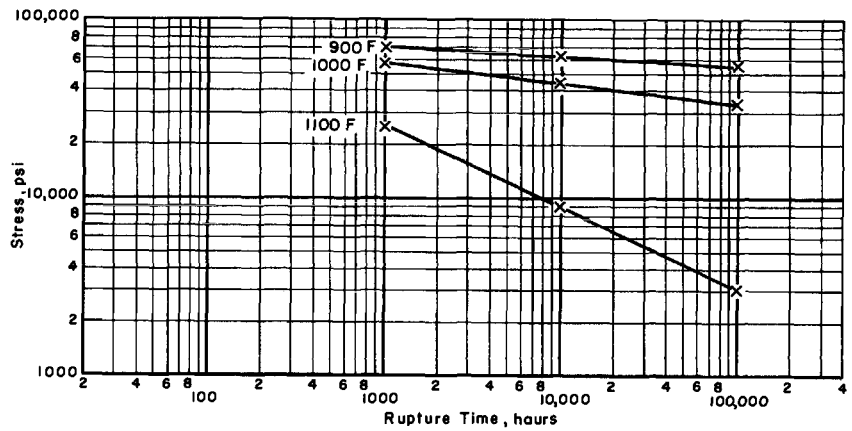


FIGURE 6. STRESS VERSUS RUPTURE-TIME CURVES FOR 12 Cr, Cb STEEL BASED ON AVERAGE DATA

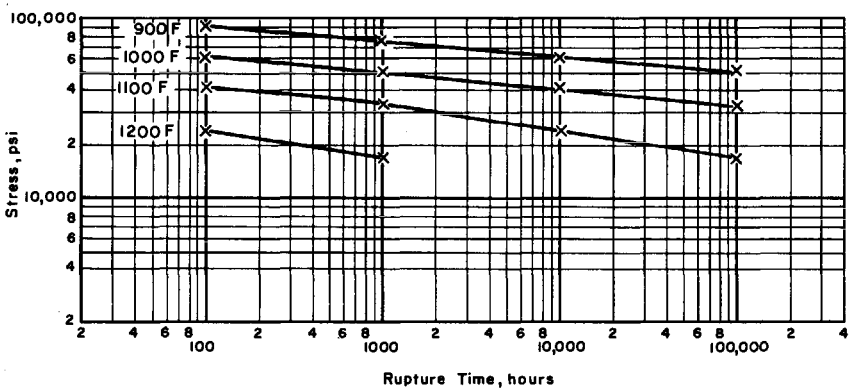


FIGURE 7. STRESS VERSUS RUPTURE-TIME CURVES FOR 12 Cr, 2.75 Mo, V STEEL BASED ON AVERAGE DATA

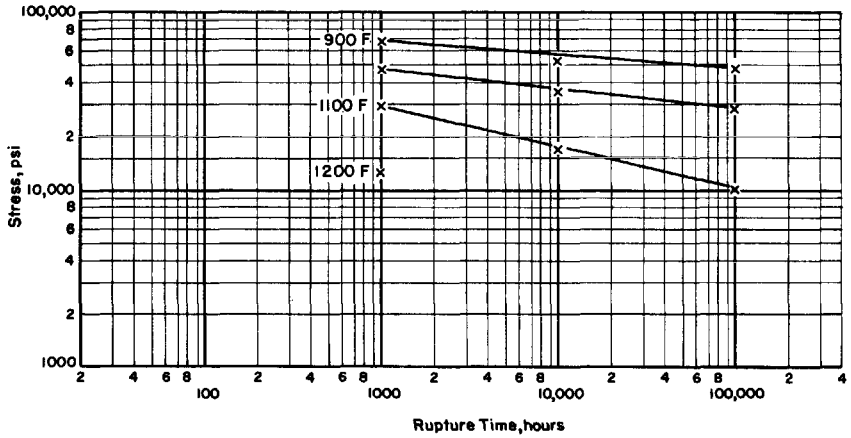


FIGURE 8. STRESS VERSUS RUPTURE—TIME CURVES FOR 12 Cr, 2.5 W, V STEEL BASED ON AVERAGE DATA

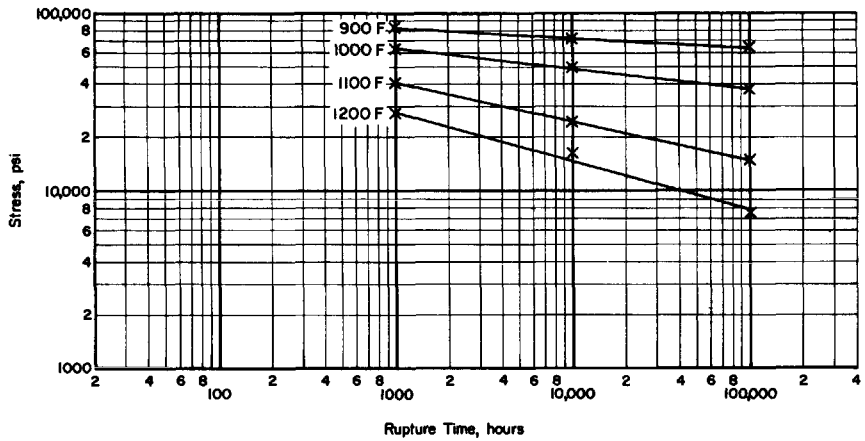


FIGURE 9. STRESS VERSUS RUPTURE—TIME CURVES FOR 12 Cr, 5 Co, 3 W, V STEEL BASED ON AVERAGE DATA

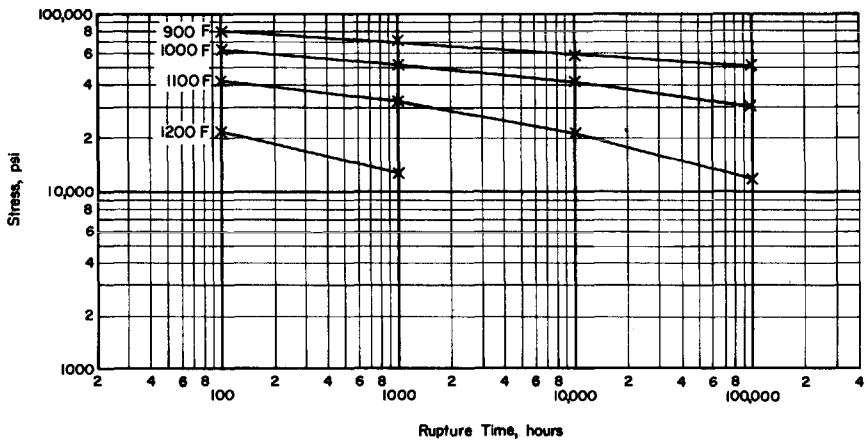


FIGURE 10. STRESS VERSUS RUPTURE—TIME CURVES FOR 13 Cr, W, Mo, V STEEL BASED ON AVERAGE DATA

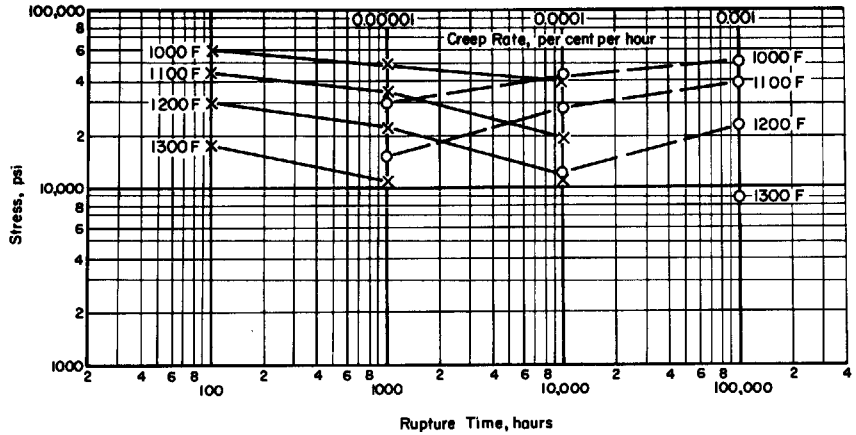


FIGURE 11. STRESS VERSUS RUPTURE-TIME AND CREEP-RATE CURVES FOR 12 Cr, Mo, Cb, V STEEL BASED ON AVERAGE DATA

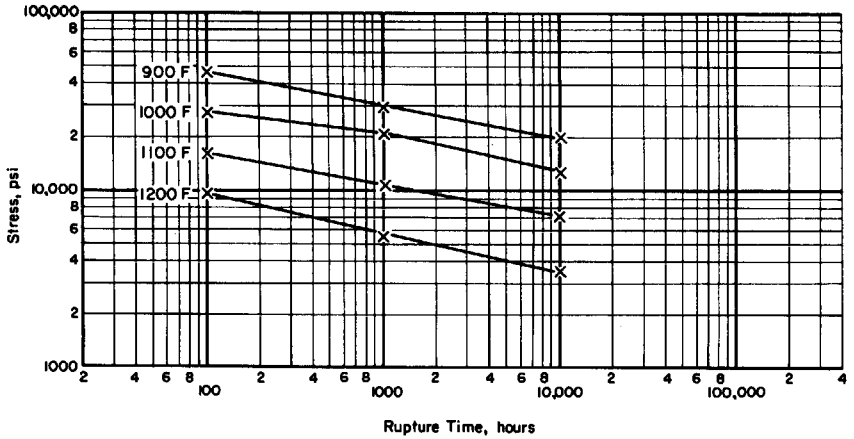


FIGURE 12. STRESS VERSUS RUPTURE-TIME CURVES FOR 16 Cr, 2 Ni STEEL BASED ON DATA FROM TWO HEATS

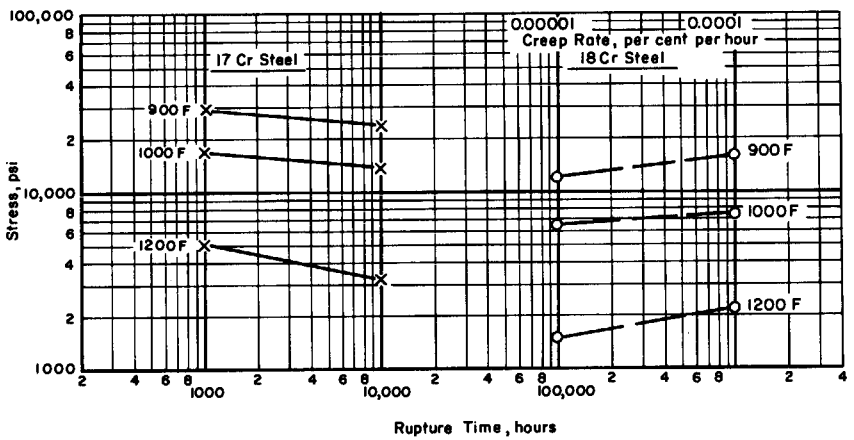


FIGURE 13. STRESS VERSUS RUPTURE-TIME AND CREEP-RATE CURVES FOR 17 Cr AND 18 Cr STEELS BASED ON LIMITED DATA

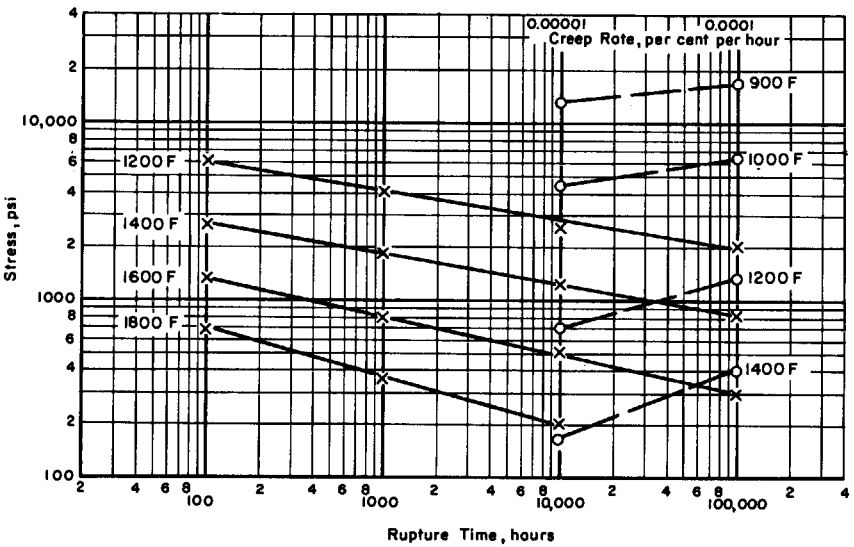


FIGURE 14. STRESS VERSUS RUPTURE-TIME AND CREEP-RATE CURVES FOR 27 Cr STEEL BASED ON LIMITED DATA

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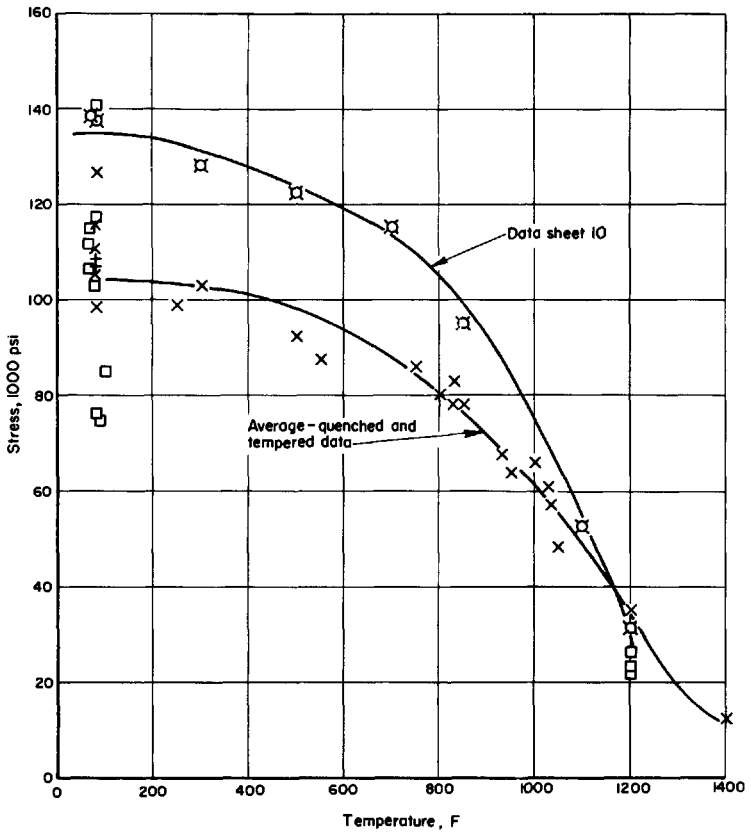
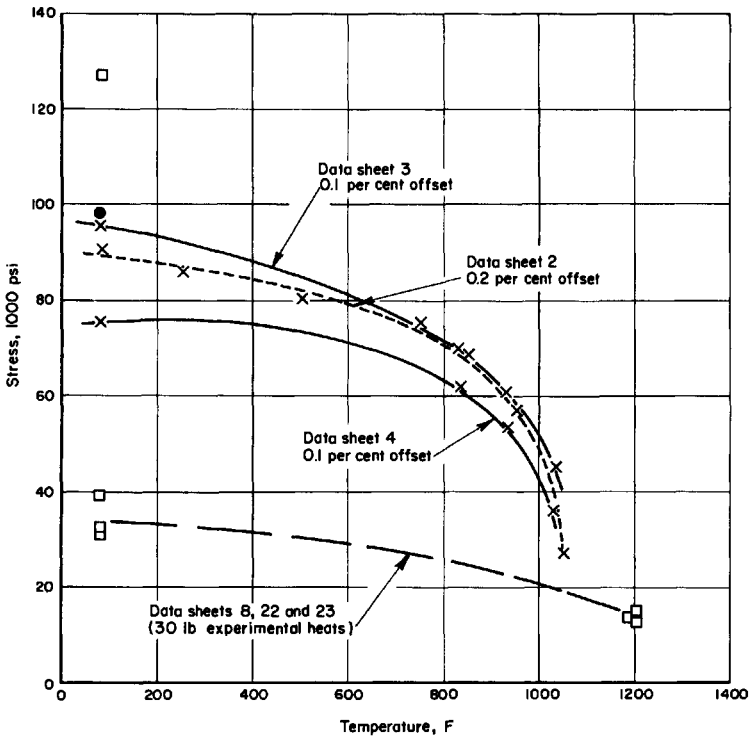
12 Chromium Steels



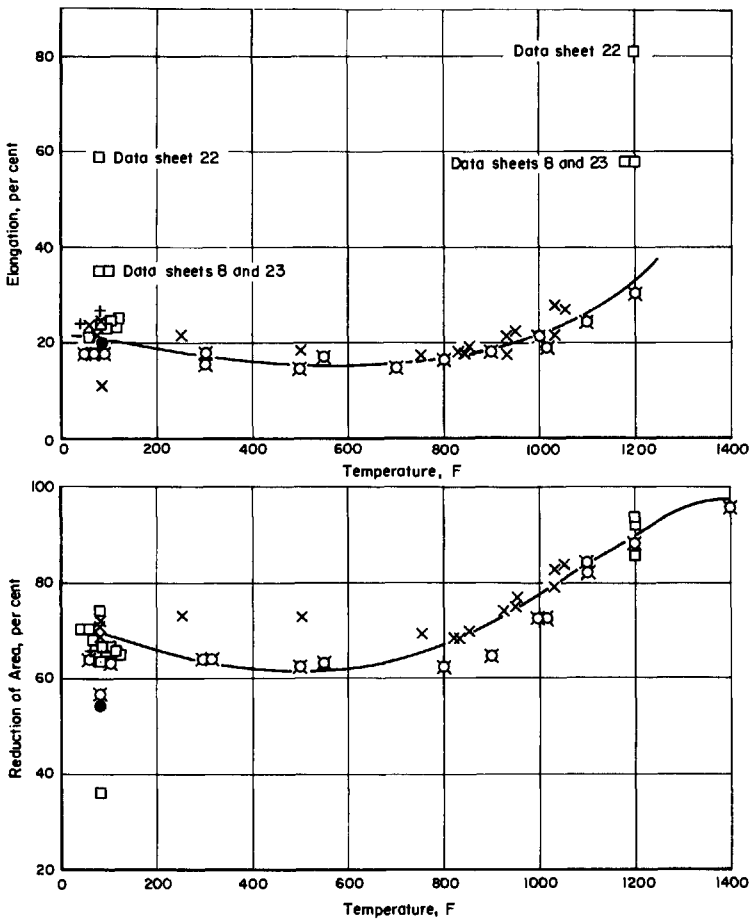
TENSILE STRENGTH

12 Cr STEEL



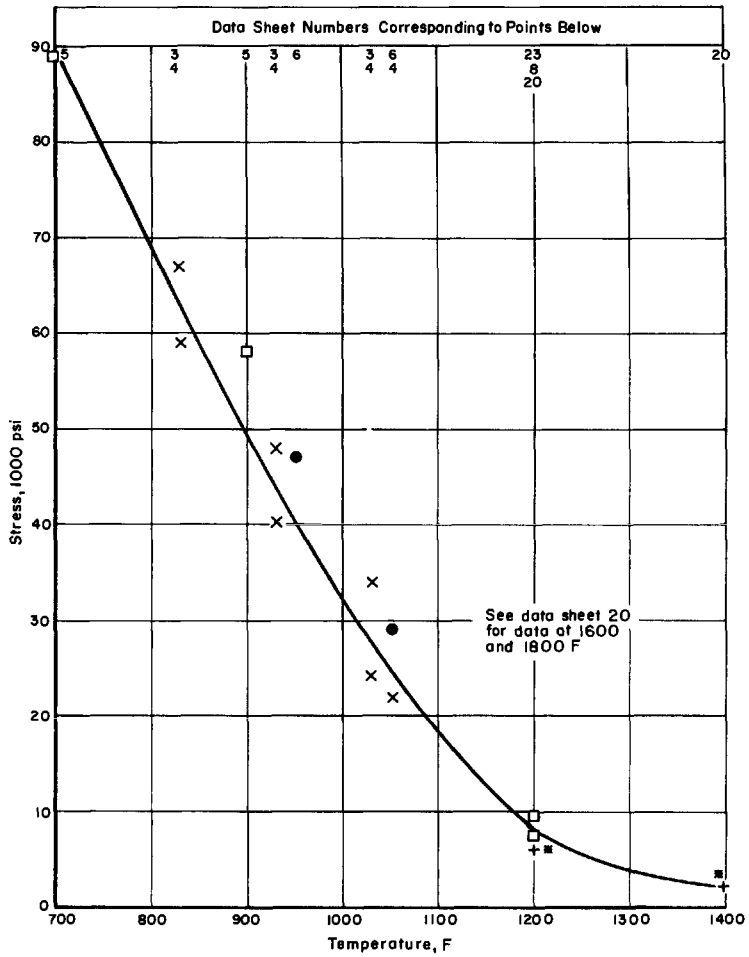
YIELD STRENGTHS

12 Cr STEEL



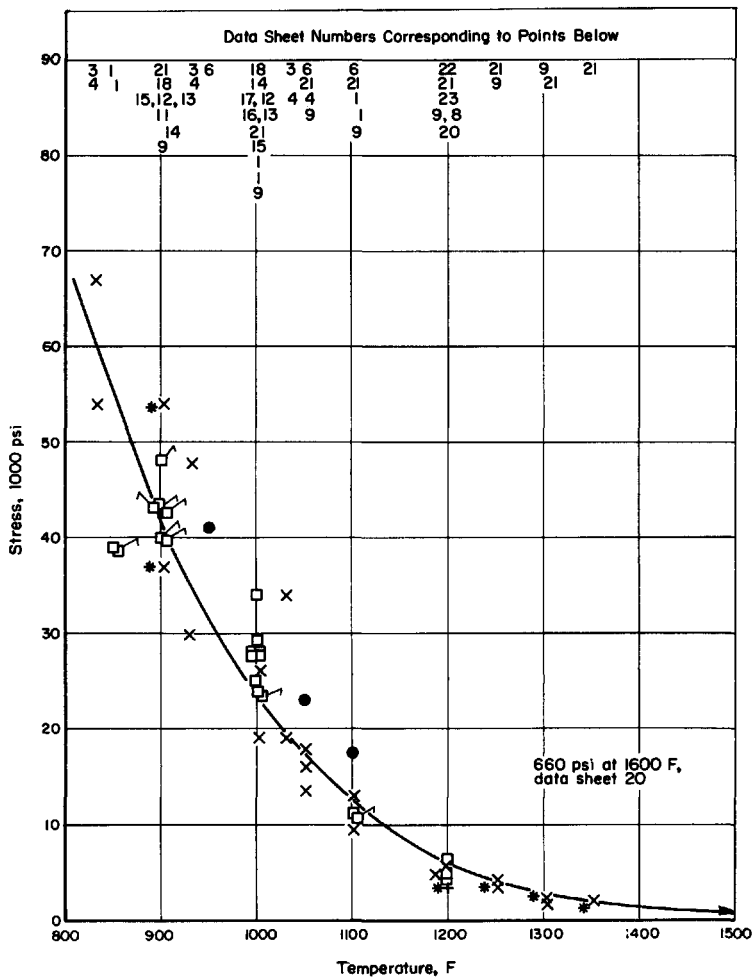
ELONGATION AND REDUCTION OF AREA

12 Cr STEEL



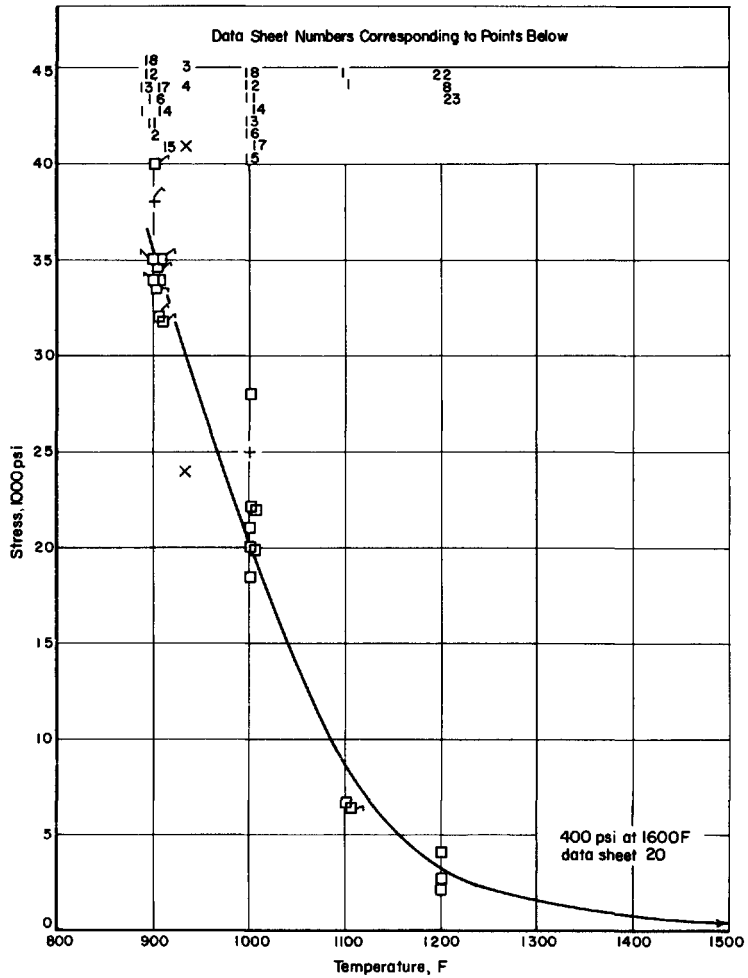
RUPTURE IN 100 HOURS

12 Cr STEEL



RUPTURE IN 1000 HOURS

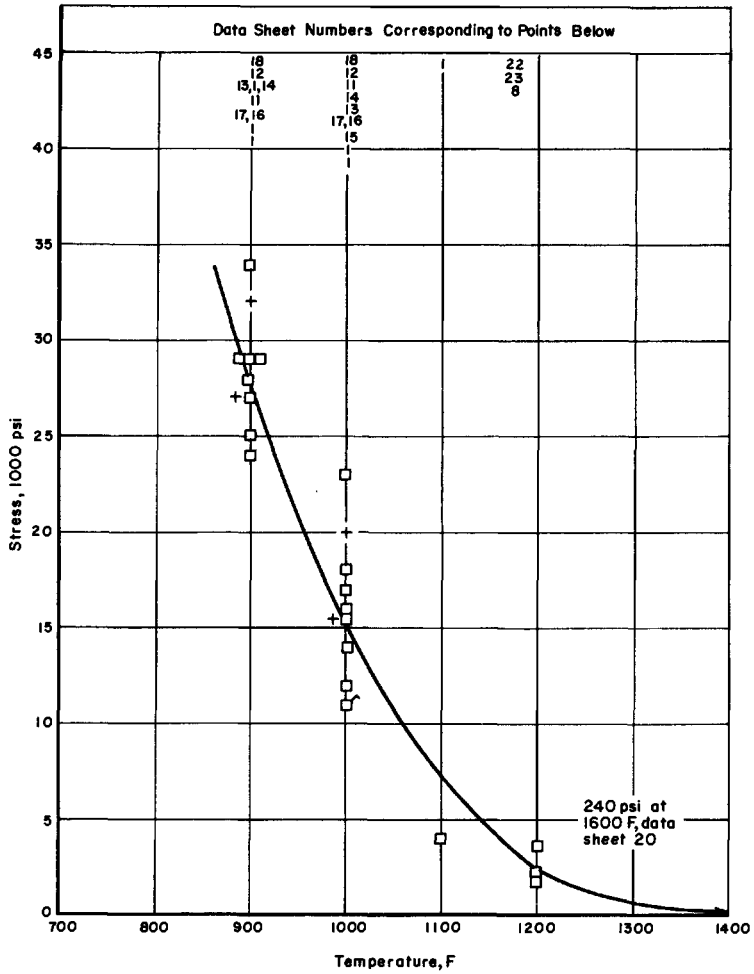
12 Cr STEEL



RUPTURE IN 10,000 HOURS

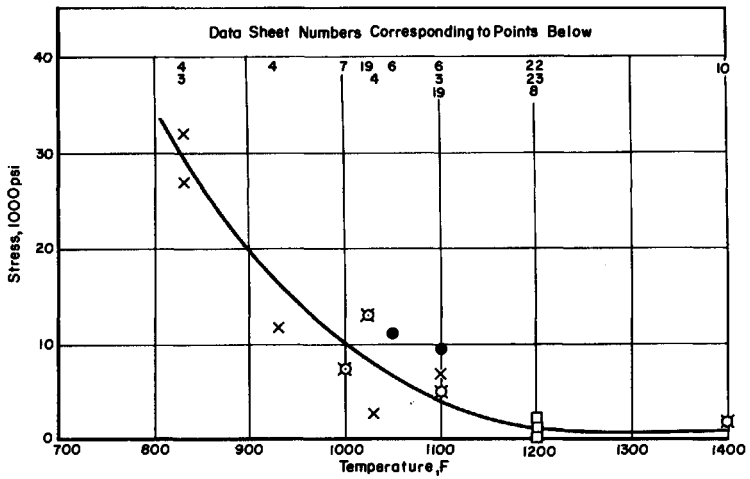
(EXTRAPOLATED)

12 Cr STEEL

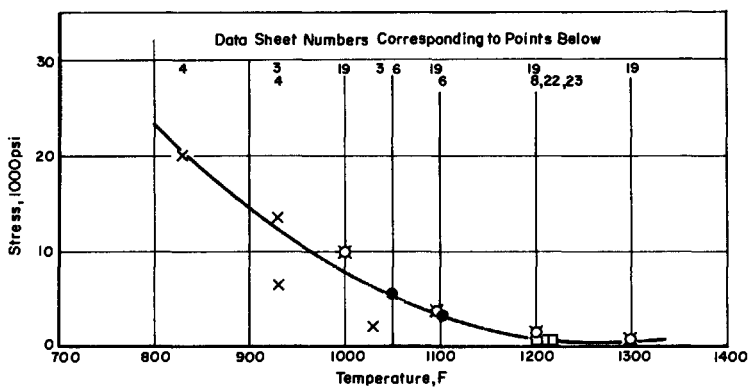


RUPTURE IN 100,000 HOURS
(EXTRAPOLATED)

12 Cr STEEL



CREEP RATE 0.0001 PER CENT PER HOUR
(1 PER CENT IN 10,000 HOURS)



CREEP RATE 0.00001 PER CENT PER HOUR
(1 PER CENT IN 100,000 HOURS)

12 Cr STEEL

(1)

ASTM-ASME JOINT COMMITTEE ON EFFECT OF TEMPERATURE ON PROPERTIES OF METALS

TYPE OF MATERIAL 12 Cr (Type 403)			TYPE OF MELTING FURNACE				SIZE OF HEAT Commercial					
CHEMICAL COMPOSITION, PER CENT	C	Mn	P	S	Si	Cr	Ni	Mo				
	0.11	0.44			0.39	12.04	0.31					
DEOXIDATION												
FORM-CAST OR WROUGHT Wrought 1-5/16" x 1-13/16" Bar												
HEAT TREATMENT Finished at 1450 F, A.C. With Fans, Tempered 1150 F												
MICROSTRUCTURE												
GRAIN SIZE					HARONESS							
SOURCE OF DATA General Electric Company												

SHORT TIME TENSILE PROPERTIES

TEMPERATURE, °F	MODULUS OF ELASTICITY, 1,000,000 P.S.I.	OFFSET YIELD (1) STRENGTH, 1000 P.S.I.	TENSILE STRENGTH, 1000 P.S.I.	ELONGATION IN 2", PER CENT	REDUCTION IN AREA, PER CENT
RT			106.4	24.0	64.2

CREEP AND RUPTURE STRENGTHS

TEMP., °F	STRESS FOR RUPTURE IN TIMES INDICATED, 1000 P.S.I.(2)				STRESS FOR DESIGNATED CREEP RATE, 1000 P.S.I.(2)		
	100 HRS.	1000 HRS.	10,000 HRS.	100,000 HRS.	0.000001 %/HR.	0.00001 %/HR.	0.0001 %/HR.
900		39	34*	29*			
		39P	32P	24P			
1000		24	17	12*			
		24P	17P	11P			
1100		11	6.8	4*			
		11P	6.8P	--			
P indicates strength value obtained by use of Larson-Miller parameter T(25 + log t).							

ORIGINAL CREEP AND RUPTURE DATA

TEMP., °F	STRESS, 1000 P.S.I.	DURATION, HOURS(3)	INTERCEPT, %(4)	MINIMUM CREEP RATE, %/HR.	TRANSITION TIME, HRS.(5)	TOTAL EXT. (CREEP TEST), %	TOTAL ELONG. (RUPTURE TEST), %	REDUCTION IN AREA, %
800	57.0	654 R					17.0	78.0
800	55.0	2707 R					19.0	77.0
850	75.0	1 R					8.0	68.0
850	66.0	2 R					5.0	70.0
850	54.0	28 R					3.0	74.0
900	50.0	68 R					19.0	76.0
900	45.0	101 R					22.0	82.0
900	42.0	189 R					22.0	82.0
900	40.0	765 R					20.0	83.0
900	36.0	4044 R					20.0	84.0
900	35.0	5102 R					16.0	84.0
1000	35.0	42 R					27.0	84.0
1000	26.0	611 R					28.0	87.0
1000	22.0	1748 R					28.0	86.0
1000	18.0	7438 R					28.0	84.0
1100	20.0	46 R					31.0	88.0
1100	15.0	263 R					27.0	86.0
1100	12.0	690 R					58.0	90.0
1100	7.0	8356 R					37.0	91.0

(2)

ASTM-ASME JOINT COMMITTEE ON EFFECT OF TEMPERATURE ON PROPERTIES OF METALS

TYPE OF MATERIAL 12 Cr			TYPE OF MELTING FURNACE Electric Arc				SIZE OF HEAT 13,500 lb					
CHEMICAL COMPOSITION, PER CENT	C	Mn	P	S	Si	Cr	Ni	Mo				
	0.12	0.42	0.01	0.26	0.156	12.45	0.10					
DEOXIDATION												
FORM-CAST OR WROUGHT Wrought Bar 1" Round												
HEAT TREATMENT Quenched 1750 F, Tempered 1150 (2 Hr) A.C.												
MICROSTRUCTURE												
GRAIN SIZE					HARONESS 217-228 BHN							
SOURCE OF DATA Available High Temperature Creep Characteristics of Metals & Alloys, ASME-ASTM, 1938.												

SHORT TIME TENSILE PROPERTIES

TEMPERATURE, °F	MODULUS OF ELASTICITY, 1,000,000 P.S.I.	OFFSET YIELD (1) STRENGTH, 1000 P.S.I.	TENSILE STRENGTH, 1000 P.S.I.	ELONGATION IN 2", PER CENT	REDUCTION IN AREA, PER CENT
80		90.0	105.9 (a)	24.2	71.0
250		85.4	99.0 (b)	21.8	73.1
500		80.6	92.4 (a)	18.7	72.9
750		75.5	86.1 (a)	17.5	69.2
851		69.4	78.4 (a)	19.2	69.9
950		57.3	64.2 (b)	22.3	77.3
1050		36.5	48.4 (b)	27.5	83.8

(a) Average of 3 tests.
(b) Average of 2 tests.

ORIGINAL CREEP AND RUPTURE DATA

TEMP., °F	STRESS, 1000 P.S.I.	DURATION, HOURS(3)	INTERCEPT, %(4)	MINIMUM CREEP RATE, %/HR.	TRANSITION TIME, HRS.(5)	TOTAL EXT. (CREEP TEST), %	TOTAL ELONG. (RUPTURE TEST), %	HARDNESS AFTER TESTING
850	10.0	2205	0.0156	0.0000002		0.0154		
850	15.0	2730	0.0807	0.0000001		0.0812		
850	15.0	2019	0.0389	0.0000032		0.0457		
850	20.0	2020	0.0746	0.000012		0.0988		
850	25.0	1200	0.1318	0.0000227		0.1588		
850	30.0	2227	0.1787	0.0000472		0.2843		
850	30.0	2736	0.208	0.0000430		0.325		
850	30.0	2040	0.318	0.0000470		0.414		
850	35.0	1489	0.605	0.00038		1.171		
850	40.0	1825	1.105	0.000964		2.905		

(3)

ASTM-ASME JOINT COMMITTEE ON EFFECT OF TEMPERATURE ON PROPERTIES OF METALS

TYPE OF MATERIAL 12 Cr (Type 410)			TYPE OF MELTING FURNACE --				SIZE OF HEAT Commercial					
CHEMICAL COMPOSITION, PER CENT	C	Mn	P	S	Si	Cr	Ni	Mo				
	0.14	0.43	0.003	0.017	0.35	12.2	0.20					
DEOXIDATION --												
FORM-CAST OR WROUGHT 7/8" Wrought Bars												
HEAT TREATMENT 1800 F, 1/2 Hr, OQ - 1200 F, 1 Hr, FC												
MICROSTRUCTURE --												
GRAIN SIZE					HARDNESS 222 BHN							
SOURCE OF DATA U. S. N. Engineering Experiment Station												

SHORT TIME TENSILE PROPERTIES

TEMPERATURE, °F	MODULUS OF ELASTICITY, 1,000,000 P.S.I.	OFFSET YIELD (1) STRENGTH, 1000 P.S.I.	TENSILE STRENGTH, 1000 P.S.I.	ELONGATION IN 2", PER CENT	REDUCTION IN AREA, PER CENT
RT		95.8 (6)	115.5	22	69
830		69.5 (6)	82.9	18	69
930		61.0 (6)	70.2	18	75
1030		45.7 (6)	61.0	22	79

CREEP AND RUPTURE STRENGTHS

TEMP., °F	STRESS FOR RUPTURE IN TIMES INDICATED, 1000 P.S.I.(2)				STRESS FOR DESIGNATED CREEP RATE, 1000 P.S.I.(2)		
	100 HRS.	1000 HRS.	10,000 HRS.	100,000 HRS.	0.000001 %/HR.	0.00001 %/HR.	0.0001 %/HR.
830	67	61					
930	48	44	41			13.5	27
1030	34	29				2.2	
1100							7

ORIGINAL CREEP AND RUPTURE DATA

TEMP., °F	STRESS, 1000 P.S.I.	DURATION, HOURS(3)	INTERCEPT, %(4)	MINIMUM CREEP RATE, %/HR.	TRANSITION TIME, HRS.(5)	TOTAL EXT. (CREEP TEST), %	TOTAL ELONG. (RUPTURE TEST), %	HARDNESS AFTER TESTING
830	70.0	33 R					21.0	
830	60.0	1558 R					21.0	
930	50.0	40 R					25.0	
930	45.0	895 R	1.38	0.0041	425		29.0	
930	40.0	10000 +	1.13	0.0012			See Note	
			NOTE: Specimen removed at 8.4% elongation					
1030	40.0	14 R					33.0	
1030	35.0	83 R			40		33.0	
1030	30.0	625 R	0.32	0.011	370		32.0	
930	20.0	2112	0.083	0.000028	--	0.142		
930	13.0	3360	0.044	0.000009	--	0.077		
1030	7.0	2172	0.060	0.000030	--	0.123		
1030	5.0	2040	0.090	0.000020	--	0.130		
1030	2.5	1512	0.013	0.000011	--	0.031		
1100	10.0	2016	0.247	0.00020	--	0.650		

(1) 0.2 PER CENT OFFSET UNLESS OTHERWISE INDICATED.
(2) EXTRAPOLATED VALUES INDICATED BY *
(3) DURATION OF TEST (RUPTURE TEST INDICATED BY R).
(4) THE INTERCEPT IS THE PROJECTION BACK TO ZERO TIME FROM THE PORTION OF THE TEST SHOWING THE MINIMUM OR SECOND-STAGE CREEP RATE.
(5) THE TRANSITION TIME IS THE BEGINNING OF THE THIRD STAGE, OR AN ACCELERATING CREEP RATE.
(6) 0.1% OFFSET YIELD STRENGTH.

(4)

ASTM-ASME JOINT COMMITTEE ON EFFECT OF TEMPERATURE ON PROPERTIES OF METALS

TYPE OF MATERIAL	12 Cr (Type 410)	TYPE OF MELTING FURNACE	--	SIZE OF HEAT	Commercial

CHEMICAL COMPOSITION, PER CENT	C	Mn	P	S	Si	Cr	Ni	Mo
	0.11	0.36	0.010	0.020	0.17	12.78	0.01	

DEOXIDATION --

FORM-CAST OR WROUGHT 1" Wrought Bars

HEAT TREATMENT 1800 F, 1/2 Hr, WQ - 1200 F, 1 Hr, FC

MICROSTRUCTURE --

GRAIN SIZE HARDNESS 210 BHN

SOURCE OF DATA U. S. N. Engineering Experiment Station

SHORT TIME TENSILE PROPERTIES

TEMPERATURE, °F	MODULUS OF ELASTICITY, 1,000,000 P.S.I.	OFFSET YIELD (1) STRENGTH, 1000 P.S.I.	TENSILE STRENGTH, 1000 P.S.I.	ELONGATION IN 2" PER CENT	REDUCTION IN AREA, PER CENT
RT		75.8 (6)	98.5	24	72
830		63.0 (6)	78.5	18	69
930		53.2 (6)	68.0	22	75
1030		36.7 (6)	57.5	28	83

CREEP AND RUPTURE STRENGTHS

TEMP., °F	STRESS FOR RUPTURE IN TIMES INDICATED, 1000 P.S.I. (2)				STRESS FOR DESIGNATED CREEP RATE, 1000 P.S.I. (2)		
	100 HRS.	1000 HRS.	10,000 HRS.	100,000 HRS.	0.000001 %/HR.	0.00001 %/HR.	0.0001 %/HR.
830	59	54				20	32*
930	40	30	24*			6.5*	11.7
1030	24	18					2.8
1050	22	16					

ORIGINAL CREEP AND RUPTURE DATA

TEMP. °F	STRESS, 1000 P.S.I.	DURATION, HOURS(3)	INTERCEPT, %(4)	MINIMUM CREEP RATE, %/HR.	TRANSITION TIME, HRS.(5)	TOTAL EXT. (CREEP TEST), %	TOTAL ELONG. (RUPTURE TEST), %	HARDNESS AFTER TESTING
830	60.0	80 R					27.0	
830	55.0	623 R					24.0	
930	40.0	94 R					30.0	
930	35.0	210 R					44.0	
930	30.0	1187 R					38.0	
930	25.0	3384 +	Specimen removed at 9.7% elongation.					
1030	30.0	45 R					42.0	
1030	25.0	75 R					35.0	
1030	20.0	308 R					55.0	
1030	18.0	862 R					51.0	
1050	30.0	10 R					39.0	
1050	25.0	38 R					52.0	
1050	18.0	377 R					62.0	

(5)

ASTM-ASME JOINT COMMITTEE ON EFFECT OF TEMPERATURE ON PROPERTIES OF METALS

TYPE OF MATERIAL	12 Cr (Type 403)	TYPE OF MELTING FURNACE		SIZE OF HEAT	

CHEMICAL COMPOSITION, PER CENT	C	Mn	P	S	Si	Cr	Ni	Mo	Al	Sn
	0.11	0.51	0.018	0.010	0.34	12.20	0.06	0.05	0.03	0.0089

DEOXIDATION

FORM-CAST OR WROUGHT Wrought

HEAT TREATMENT Normalized at 1675 F, Heated to 1550 F, Cooled at 25° Per Hour to 1225 F, Soaked, Then Cooled to 1100 F in Furnace and Air Cooled From 1100 F.

MICROSTRUCTURE

GRAIN SIZE HARDNESS 24-26 R_C

SOURCE OF DATA University of Minnesota: Mechanics & Materials.

SHORT TIME TENSILE PROPERTIES

TEMPERATURE, °F	MODULUS OF ELASTICITY, 1,000,000 P.S.I.	OFFSET YIELD (1) STRENGTH, 1000 P.S.I.	TENSILE STRENGTH, 1000 P.S.I.	ELONGATION IN 2" PER CENT	REDUCTION IN AREA, PER CENT
RT	29.5	127	141	11	36

CREEP AND RUPTURE STRENGTHS

TEMP., °F	STRESS FOR RUPTURE IN TIMES INDICATED, 1000 P.S.I. (2)				STRESS FOR DESIGNATED CREEP RATE, 1000 P.S.I. (2)		
	100 HRS.	1000 HRS.	10,000 HRS.	100,000 HRS.	0.000001 %/HR.	0.00001 %/HR.	0.0001 %/HR.
700	89	--	--	--			
900	58	--	--	--			

(1) 0.2 PER CENT OFFSET UNLESS OTHERWISE INDICATED.

(2) EXTRAPOLATED VALUES INDICATED BY *

ORIGINAL CREEP AND RUPTURE DATA

TEMP. °F	STRESS, 1000 P.S.I.	DURATION, HOURS(3)	INTERCEPT, %(4)	MINIMUM CREEP RATE, %/HR.	TRANSITION TIME, HRS.(5)	TOTAL EXT. (CREEP TEST), %	TOTAL ELONG. (RUPTURE TEST), %	HARDNESS AFTER TESTING
700	90.0	16.3 R					17.8	
700	85.0	26.5					--	
700	85.0	93.1					--	
700	87.5	121.6					--	
700	90.0	7.4 R					18.1	
700	95.0	-- R					13.9	
700	92.9	9.4 R					16.4	
700	94.0	1.8 R					17.2	
700	96.0	-- R					13.6	
700	40.0	189.0					--	
700	65.0	272.1					--	
700	92.5	4.0 R					17.4	
700	100.0	-- R					14.2	
700	80.0	74.0				0.3	--	
700	80.0	124.5				4.6	--	
700	88.0	428.0					--	
900	65.0	1.3 R					22.2	
900	60.0	5.8 R					22.2	
900	55.0	21.6 R					23.2	
900	75.0	0.04R					18.3	
900	70.0	0.4 R					19.0	
900	50.0	49.1 R					31.2	
900	42.0	296.2 R					24.2	

(6)

ASTM-ASME JOINT COMMITTEE ON EFFECT OF TEMPERATURE ON PROPERTIES OF METALS

TYPE OF MATERIAL	12 Cr (Type 410)	TYPE OF MELTING FURNACE	--	SIZE OF HEAT	--

CHEMICAL COMPOSITION, PER CENT	C	Mn	P	S	Si	Cr	Ni	Mo
Nominal	0.15 Max.					11.5-13.5		

DEOXIDATION --

FORM-CAST OR WROUGHT Precision Cast Test Bars

HEAT TREATMENT 1800 F, 1 Hr, OQ - 1200 F, 1 Hr, A.C.

MICROSTRUCTURE --

GRAIN SIZE HARDNESS 241 BHN

SOURCE OF DATA U. S. N. Engineering Experiment Station

SHORT TIME TENSILE PROPERTIES

TEMPERATURE, °F	MODULUS OF ELASTICITY, 1,000,000 P.S.I.	OFFSET YIELD (1) STRENGTH, 1000 P.S.I.	TENSILE STRENGTH, 1000 P.S.I.	ELONGATION IN 2", PER CENT	REDUCTION IN AREA, PER CENT
RT		97.8	126.5	20	54

CREEP AND RUPTURE STRENGTHS

TEMP., °F	STRESS FOR RUPTURE IN TIMES INDICATED, 1000 P.S.I. (2)				STRESS FOR DESIGNATED CREEP RATE, 1000 P.S.I. (2)		
	100 HRS.	1000 HRS.	10,000 HRS.	100,000 HRS.	0.000001 %/HR.	0.00001 %/HR.	0.0001 %/HR.
950	47	41				--	--
1050	29	23				5.5	11.0
1100	--	17.5				3.5	9.5

ORIGINAL CREEP AND RUPTURE DATA

TEMP. °F	STRESS, 1000 P.S.I.	DURATION, HOURS(3)	INTERCEPT, %(4)	MINIMUM CREEP RATE, %/HR.	TRANSITION TIME, HRS.(5)	TOTAL EXT. (CREEP TEST), %	TOTAL ELONG. (RUPTURE TEST), %	HARDNESS AFTER TESTING
950	45.0	260 R					17.0	
950	40.0	2002 R	0.40	0.00184	550		29.0	
1050	25.0	431 R					13.0	
1050	20.0	3300 R	1.20	0.0018	2000		13.0	
1100	15.0	3892 R	0.62	0.0011	1300		12.0	
1050	7.5	1704	0.185	0.000025	--	0.227		
1050	5.0	2040	0.120	0.0000075	--	0.135		
1100	7.5	2064	0.141	0.000045	--	0.232		
1100	5.0	2607	0.128	0.000019	--	0.213		

(3) DURATION OF TEST (RUPTURE TEST INDICATED BY R).

(4) THE INTERCEPT IS THE PROJECTION BACK TO ZERO TIME FROM THE PORTION OF THE TEST SHOWING THE MINIMUM OR SECOND-STAGE CREEP RATE.

(5) THE TRANSITION TIME IS THE BEGINNING OF THE THIRD STAGE, OR AN ACCELERATING CREEP RATE.

(7)

ASTM-ASME JOINT COMMITTEE ON EFFECT OF TEMPERATURE ON PROPERTIES OF METALS

TYPE OF MATERIAL	12 Cr	TYPE OF MELTING FURNACE				SIZE OF HEAT					
CHEMICAL COMPOSITION, PER CENT	C	Mn	P	S	Si	Cr	Ni	Mo			
	0.12	0.56			0.32	12.23					
DEOXIDATION											
FORM-CAST OR WROUGHT	Wrought 3/4" Bars										
HEAT TREATMENT	Normalized 1800 F, Tempered 1100 F										
MICROSTRUCTURE											
GRAIN SIZE					HARDNESS	225 BHN					
SOURCE OF DATA	Compilation of Available High Temperature Creep Characteristics of Metals & Alloys, ASME-ASTM, 1938.										

SHORT TIME TENSILE PROPERTIES

TEMPERATURE, °F	MODULUS OF ELASTICITY, 1,000,000 P.S.I.	OFFSET YIELD (1) STRENGTH, 1000 P.S.I.	TENSILE STRENGTH, 1000 P.S.I.	ELONGATION IN 2", PER CENT	REDUCTION IN AREA, PER CENT
70			111.2	19.0	56.7
300			103.25	18.0	64.2
550			87.7	17.5	63.3
800			80.5	16.5	62.4
1000			65.7	21.5	73.8
1200			35.3	32.5	88.1
1400			12.4	45.0	95.6

CREEP AND RUPTURE STRENGTHS

TEMP., °F	STRESS FOR RUPTURE IN TIMES INDICATED, 1000 P.S.I.(2)				STRESS FOR DESIGNATED CREEP RATE, 1000 P.S.I.(2)		
	100 HRS.	1000 HRS.	10,000 HRS.	100,000 HRS.	0.000001 %/HR.	0.00001 %/HR.	0.0001 %/HR.
1000							7.85

ORIGINAL CREEP AND RUPTURE DATA

TEMP. °F.	STRESS, 1000 P.S.I.	DURATION, HOURS(3)	INTERCEPT, %(4)	MINIMUM CREEP RATE, %/HR.	TRANSITION TIME, HRS.(5)	TOTAL EXT. (CREEP TEST), %	TOTAL ELONG. (RUPTURE TEST), %	HARDNESS AFTER TESTING
800	10.0	1000	0.034	0.000016		0.050		
800	20.0	750	0.075	0.000026		0.095		
800	30.0	750	0.175	0.000014		0.222		
800	40.0	750	0.248	0.00025		0.438		
1000	3.0	6000	0.0825	--		0.0825		
1000	10.0	1000	0.110	0.000148		0.258		
1200	3.0	750	0.244	0.000021		0.260		
1400	1.0	1000	0.229	0.000034		0.266		

(8)

ASTM-ASME JOINT COMMITTEE ON EFFECT OF TEMPERATURE ON PROPERTIES OF METALS

TYPE OF MATERIAL	12 Cr	TYPE OF MELTING FURNACE	Induction				SIZE OF HEAT	30 lb			
CHEMICAL COMPOSITION, PER CENT	C	Mn	P	S	Si	Cr	Ni	Mo			
	0.10	0.46	0.010	0.018	0.24	12.26					
DEOXIDATION											
FORM-CAST OR WROUGHT	Forged to 1" Rounds										
HEAT TREATMENT	Normalized From 1750 F + Annealed From 1650 F										
MICROSTRUCTURE											
GRAIN SIZE	7/8 ASTM Ferrite Grain Size				HARDNESS	156-159 BHN					
SOURCE OF DATA	University of Michigan										

SHORT TIME TENSILE PROPERTIES

TEMPERATURE, °F	MODULUS OF ELASTICITY, 1,000,000 P.S.I.	OFFSET YIELD (1) STRENGTH, 1000 P.S.I.	TENSILE STRENGTH, 1000 P.S.I.	ELONGATION IN 2", PER CENT	REDUCTION IN AREA, PER CENT
RT		30.9	76.1	35.0	70.1
1200		12.5	23.5	58.0	92.1

CREEP AND RUPTURE STRENGTHS

TEMP., °F	STRESS FOR RUPTURE IN TIMES INDICATED, 1000 P.S.I.(2)				STRESS FOR DESIGNATED CREEP RATE, 1000 P.S.I.(2)		
	100 HRS.	1000 HRS.	10,000 HRS.	100,000 HRS.	0.000001 %/HR.	0.00001 %/HR.	0.0001 %/HR.
1200	7.8	4.8	2.9*	1.75*		0.525*	0.140

ORIGINAL CREEP AND RUPTURE DATA

TEMP. °F.	STRESS, 1000 P.S.I.	DURATION, HOURS(3)	INTERCEPT, %(4)	MINIMUM CREEP RATE, %/HR.	TRANSITION TIME, HRS.(5)	TOTAL EXT. (CREEP TEST), %	TOTAL ELONG. (RUPTURE TEST), %	HARDNESS AFTER TESTING
1200	15.0	0.52 R					78.0	
1200	11.0	6.08 R					90.0	
1200	8.0	76. R					71.0	
1200	6.0	368. R					75.0	
1200	5.0	824. R					75.5	
1200	1.5	1260	0.12	0.000116		0.264		
1200	1.0	1350	0.049	0.000045		0.112		
1200	0.78	1340	0.033	0.000024		0.065		

(9)

ASTM-ASME JOINT COMMITTEE ON EFFECT OF TEMPERATURE ON PROPERTIES OF METALS

TYPE OF MATERIAL	12 Cr	TYPE OF MELTING FURNACE				SIZE OF HEAT					
CHEMICAL COMPOSITION, PER CENT	C	Mn	P	S	Si	Cr	Ni	Mo	Cu		
	0.086	0.43	0.018	0.009	0.39	12.52	0.09		0.03		
DEOXIDATION											
FORM-CAST OR WROUGHT	Wrought										
HEAT TREATMENT	1750 F Quench + 1150 F Temper										
MICROSTRUCTURE	Tempered Martensite and Delta Ferrite										
GRAIN SIZE	6-8				HARDNESS	252 DPH					
SOURCE OF DATA	U.S. Steel Corp. Research Lab.										

CREEP AND RUPTURE STRENGTHS

TEMP., °F	STRESS FOR RUPTURE IN TIMES INDICATED, 1000 P.S.I.(2)				STRESS FOR DESIGNATED CREEP RATE, 1000 P.S.I.(2)		
	100 HRS.	1000 HRS.	10,000 HRS.	100,000 HRS.	0.000001 %/HR.	0.00001 %/HR.	0.0001 %/HR.
900		37.0*					
1000		19.0					
1050		13.7					
1100		9.8					
1200		4.9					
1250		3.5*					
1300		2.5*					

ORIGINAL CREEP AND RUPTURE DATA

TEMP. °F.	STRESS, 1000 P.S.I.	DURATION, HOURS(3)	INTERCEPT, %(4)	MINIMUM CREEP RATE, %/HR.	TRANSITION TIME, HRS.(5)	TOTAL EXT. (CREEP TEST), %	TOTAL ELONG. (RUPTURE TEST), %	HARDNESS AFTER TESTING
1000	50.0	1.5 R	--	3.46				
1000	40.0	7.3 R		1.01			43.0	
1000	30.0	84. R		0.106			52.0	
1000	25.0	200.5 R		0.062			60.0	
1000	15.0	5358. R		0.0019				
1200	15.0	3.66 R	0.77	3.26			64.0	
1200	10.0	47.2 R	0.38	0.256				
1200	7.0	120. R	0.60	0.105				
1200	5.50	680. R	0.85	0.0134			79.0	
1200	4.00	2608. R	0.73	0.00354			89.0	

(10)

ASTM-ASME JOINT COMMITTEE ON EFFECT OF TEMPERATURE ON PROPERTIES OF METALS

TYPE OF MATERIAL	12 Cr	TYPE OF MELTING FURNACE				SIZE OF HEAT					
CHEMICAL COMPOSITION, PER CENT	C	Mn	P	S	Si	Cr	Ni	Mo			
	0.10	0.48			0.24	11.87					
DEOXIDATION											
FORM-CAST OR WROUGHT	Wrought 1" Bars										
HEAT TREATMENT	Annealed 1350, Normalized 1700 F, Tempered 1000 F										
MICROSTRUCTURE											
GRAIN SIZE					HARDNESS	300 BHN					
SOURCE OF DATA	Compilation of Available High Temperature Creep Characteristics of Metals & Alloys, ASME-ASTM, 1938.										

SHORT TIME TENSILE PROPERTIES

TEMPERATURE, °F	MODULUS OF ELASTICITY, 1,000,000 P.S.I.	OFFSET YIELD (1) STRENGTH, 1000 P.S.I.	TENSILE STRENGTH, 1000 P.S.I.	ELONGATION IN 2", PER CENT	REDUCTION IN AREA, PER CENT
70			138.15	19.0	64.2
70			138.70	19.5	64.3
300			128.55	15.5	64.7
500			122.60	15.0	62.3
700			115.60	15.0	56.3
900			95.10	18.0	64.9
1000			75.10	20.0	73.4
1100			52.95	24.5	82.4
1200			36.20	30.5	88.9

CREEP AND RUPTURE STRENGTHS

TEMP., °F	STRESS FOR RUPTURE IN TIMES INDICATED, 1000 P.S.I.(2)				STRESS FOR DESIGNATED CREEP RATE, 1000 P.S.I.(2)		
	100 HRS.	1000 HRS.	10,000 HRS.	100,000 HRS.	0.000001 %/HR.	0.00001 %/HR.	0.0001 %/HR.
1400							2.0

(1) 0.2 PER CENT OFFSET UNLESS OTHERWISE INDICATED.

(2) EXTRAPOLATED VALUES INDICATED BY *

(3) DURATION OF TEST (RUPTURE TEST INDICATED BY R).

(4) THE INTERCEPT IS THE PROJECTION BACK TO ZERO TIME FROM THE PORTION OF THE TEST SHOWING THE MINIMUM OR SECOND-STAGE CREEP RATE.

(5) THE TRANSITION TIME IS THE BEGINNING OF THE THIRD STAGE, OR AN ACCELERATING CREEP RATE.

ORIGINAL CREEP AND RUPTURE DATA

TEMP., °F	STRESS, 1000 P.S.I.	DURATION, HOURS(3)	INTERCEPT, %(4)	MINIMUM CREEP RATE, %/HR.	TRANSITION TIME HRS.(5)	TOTAL EXT. (CREEP TEST), %	TOTAL ELONG. (RUPTURE TEST), %	HARDNESS AFTER TESTING
800	35.0	250	0.140	0.00024		0.20		
1000	15.0	250	0.215	0.00214		0.758		
1200	5.0	500		0.1710		50.0		
1400	0.25	250	0.077	0.000142		0.112		
1400	0.50	500	0.033	0.00043		0.142		
1400	1.00	1000	1.35	0.04000		9.95		

ASTM-ASME JOINT COMMITTEE ON EFFECT OF TEMPERATURE ON PROPERTIES OF METALS

TYPE OF MATERIAL 12 Cr (Type 403)	TYPE OF MELTING FURNACE						SIZE OF HEAT Commercial				
CHEMICAL COMPOSITION, PER CENT	C	Mn	P	S	Si	Cr	Ni	Mo			
	0.10	0.43			0.31	12.67	0.41	0.32			
DEOXIDATION											
FORM-CAST OR WROUGHT	Wrought Bar 1-7/16" x 5-1/16"										
HEAT TREATMENT	Finished Rolled at 1450 F, Tempered 1150 F										
MICROSTRUCTURE											
GRAIN SIZE						HARDNESS					
SOURCE OF DATA	General Electric Company										

SHORT TIME TENSILE PROPERTIES

TEMPERATURE, °F	MODULUS OF ELASTICITY, 1,000,000 P.S.I.	OFFSET (1) YIELD STRENGTH, 1000 P.S.I.	TENSILE STRENGTH, 1000 P.S.I.	ELONGATION IN 2" PER CENT	REDUCTION IN AREA, PER CENT
80			114.9	23.0	67.5
800	25.0				
900	23.1				
1000	19.1				
1100	16.2				

CREEP AND RUPTURE STRENGTHS

TEMP., °F	STRESS FOR RUPTURE IN TIMES INDICATED, 1000 P.S.I.(2)				STRESS FOR DESIGNATED CREEP RATE, 1000 P.S.I.(2)		
	100 HRS.	1000 HRS.	10,000 HRS.	100,000 HRS.	0.000001 %/HR.	0.00001 %/HR.	0.0001 %/HR.
900		40P	34P	28P			
1000		28	22*	18*			

P indicates strength value obtained by use of Larson-Miller parameter T(25 + log t).

ORIGINAL CREEP AND RUPTURE DATA

TEMP., °F	STRESS, 1000 P.S.I.	DURATION, HOURS(3)	INTERCEPT, %(4)	MINIMUM CREEP RATE, %/HR.	TRANSITION TIME, HRS.(5)	TOTAL EXT. (CREEP TEST), %	TOTAL ELONG. (RUPTURE TEST), %	REDUCTION IN AREA, %
1000	40.0	11 R					18.0	85.0
1000	32.0	201 R					19.0	82.0
1000	28.0	577 R					16.0	84.0
1000	26.3	3442 R					17.0	76.0
1000	24.0	4751 R					18.0	72.0

ASTM-ASME JOINT COMMITTEE ON EFFECT OF TEMPERATURE ON PROPERTIES OF METALS

TYPE OF MATERIAL 12 Cr (Type 403)	TYPE OF MELTING FURNACE						SIZE OF HEAT Commercial				
CHEMICAL COMPOSITION, PER CENT	C	Mn	P	S	Si	Cr	Ni	Mo			
	0.13	0.43			0.28	12.44	0.44	0.30			
DEOXIDATION											
FORM-CAST OR WROUGHT	Wrought 3/4" x 1-1/8" Bar										
HEAT TREATMENT	Air Cooled From Rolls										
MICROSTRUCTURE											
GRAIN SIZE						HARDNESS					
SOURCE OF DATA	General Electric Company										

SHORT TIME TENSILE PROPERTIES

TEMPERATURE, °F	MODULUS OF ELASTICITY, 1,000,000 P.S.I.	OFFSET (a) YIELD (1) STRENGTH, 1000 P.S.I.	TENSILE STRENGTH, 1000 P.S.I.	ELONGATION IN 2" PER CENT	REDUCTION IN AREA, PER CENT
80		80.9	107.9	26.5	70.0

(a) 0.02% Offset yield strength.

(1) 0.2 PER CENT OFFSET UNLESS OTHERWISE INDICATED.
(2) EXTRAPOLATED VALUES INDICATED BY *

CREEP AND RUPTURE STRENGTHS

TEMP., °F	STRESS FOR RUPTURE IN TIMES INDICATED, 1000 P.S.I.(2)				STRESS FOR DESIGNATED CREEP RATE, 1000 P.S.I.(2)		
	100 HRS.	1000 HRS.	10,000 HRS.	100,000 HRS.	0.000001 %/HR.	0.00001 %/HR.	0.0001 %/HR.
900		43P	38P	32P			
1000		31	25*	20*			

P indicates strength value obtained by use of Larson-Miller parameter T(25 + log t).

ORIGINAL CREEP AND RUPTURE DATA

TEMP., °F	STRESS, 1000 P.S.I.	DURATION, HOURS(3)	INTERCEPT, %(4)	MINIMUM CREEP RATE, %/HR.	TRANSITION TIME HRS.(5)	TOTAL EXT. (CREEP TEST), %	TOTAL ELONG. (RUPTURE TEST), %	REDUCTION IN AREA, %
1000	42.0	15 R					18.0	85.0
1000	36.0	222 R					18.0	85.0
1000	32.0	815 R					18.0	82.0
1000	30.0	920 R					18.0	87.0
1000	27.0	4409 R					17.0	88.0

ASTM-ASME JOINT COMMITTEE ON EFFECT OF TEMPERATURE ON PROPERTIES OF METALS

TYPE OF MATERIAL 12 Cr (Type 403)	TYPE OF MELTING FURNACE						SIZE OF HEAT Commercial				
CHEMICAL COMPOSITION, PER CENT	C	Mn	P	S	Si	Cr	Ni	Mo			
	0.10	0.35			0.34	12.43	0.29				
DEOXIDATION											
FORM-CAST OR WROUGHT	Wrought 1-1/8" x 4-11/16" Bar										
HEAT TREATMENT	Finish Rolled 1450 F, A.C., 1175 F – 15 Hr, 1100 F – 15 Hr										
MICROSTRUCTURE											
GRAIN SIZE						HARDNESS					
SOURCE OF DATA	General Electric Company										

SHORT TIME TENSILE PROPERTIES

TEMPERATURE, °F	MODULUS OF ELASTICITY, 1,000,000 P.S.I.	OFFSET YIELD (1) STRENGTH, 1000 P.S.I.	TENSILE STRENGTH, 1000 P.S.I.	ELONGATION IN 2" PER CENT	REDUCTION IN AREA, PER CENT
80			111.4	21.5	67.5

CREEP AND RUPTURE STRENGTHS

TEMP., °F	STRESS FOR RUPTURE IN TIMES INDICATED, 1000 P.S.I.(2)				STRESS FOR DESIGNATED CREEP RATE, 1000 P.S.I.(2)		
	100 HRS.	1000 HRS.	10,000 HRS.	100,000 HRS.	0.000001 %/HR.	0.00001 %/HR.	0.0001 %/HR.
900		42P	35P	29P			
1000		28	21*	16*			

P indicates strength value obtained by use of Larson-Miller parameter T(25 + log t).

ORIGINAL CREEP AND RUPTURE DATA

TEMP., °F	STRESS, 1000 P.S.I.	DURATION, HOURS(3)	INTERCEPT, %(4)	MINIMUM CREEP RATE, %/HR.	TRANSITION TIME, HRS.(5)	TOTAL EXT. (CREEP TEST), %	TOTAL ELONG. (RUPTURE TEST), %	REDUCTION IN AREA, %
1000	42.0	12 R					15.0	82.0
1000	32.0	410 R					16.0	86.0
1000	28.0	683 R					17.0	83.0
1000	26.0	1743 R					16.0	81.0
1000	22.0	6762 R					17.0	66.0

ASTM-ASME JOINT COMMITTEE ON EFFECT OF TEMPERATURE ON PROPERTIES OF METALS

TYPE OF MATERIAL 12 Cr (Type 403)	TYPE OF MELTING FURNACE						SIZE OF HEAT Commercial				
CHEMICAL COMPOSITION, PER CENT	C	Mn	P	S	Si	Cr	Ni	Mo			
	0.10	0.43			0.31	12.67	0.41	0.32			
DEOXIDATION											
FORM-CAST OR WROUGHT	Wrought Bar 1-1/4" x 2-11/16"										
HEAT TREATMENT	Finished Rolled at 1450 F, Tempered 1150 F										
MICROSTRUCTURE											
GRAIN SIZE						HARDNESS					
SOURCE OF DATA	General Electric Company										

SHORT TIME TENSILE PROPERTIES

TEMPERATURE, °F	MODULUS OF ELASTICITY, 1,000,000 P.S.I.	OFFSET YIELD (1) STRENGTH, 1000 P.S.I.	TENSILE STRENGTH, 1000 P.S.I.	ELONGATION IN 2" PER CENT	REDUCTION IN AREA, PER CENT
RT			117.4	23.0	67.0

(3) DURATION OF TEST (RUPTURE TEST INDICATED BY R).
(4) THE INTERCEPT IS THE PROJECTION BACK TO ZERO TIME FROM THE PORTION OF THE TEST SHOWING THE MINIMUM OR SECONO-STAGE CREEP RATE.
(5) THE TRANSITION TIME IS THE BEGINNING OF THE THIRD STAGE, OR AN ACCELERATING CREEP RATE.

CREEP AND RUPTURE STRENGTHS

TEMP., °F	STRESS FOR RUPTURE IN TIMES INDICATED, 1000 P.S.I.(2)				STRESS FOR DESIGNATED CREEP RATE, 1000 P.S.I.(2)		
	100 HRS.	1000 HRS.	10,000 HRS.	100,000 HRS.	0.000001 %/HR.	0.00001 %/HR.	0.0001 %/HR.
900		40P	34P	29P			
1000		29	22*	17*			

P indicates strength value obtained by use of Larson-Miller parameter T(25 + log t).

ORIGINAL CREEP AND RUPTURE DATA

TEMP. °F.	STRESS, 1000 P.S.I.	DURATION, HOURS(3)	INTERCEPT, %(4)	MINIMUM CREEP RATE, %/HR.	TRANSITION TIME, HRS.(5)	TOTAL EXT. (CREEP TEST), %	TOTAL ELONG. (RUPTURE TEST), %	REDUCTION IN AREA, %
1000	40.0	14 R					21.0	84.0
1000	32.0	268 R					18.0	82.0
1000	28.0	1174 R					14.0	76.0
1000	26.0	2293 R					16.0	72.0
1000	24.0	4561 R					12.0	60.0

(15)

ASTM-ASME JOINT COMMITTEE ON EFFECT OF TEMPERATURE ON PROPERTIES OF METALS

TYPE OF MATERIAL 12 Cr (Type 403)	TYPE OF MELTING FURNACE						SIZE OF HEAT Commercial				
CHEMICAL COMPOSITION, PER CENT	C	Mn	P	S	Si	Cr	Ni	Mo			
	0.11	0.44			0.39	12.04	0.31				
DEOXIDATION											
FORM-CAST OR WROUGHT Wrought 1-1/4" x 5" Bar											
HEAT TREATMENT Finished Rolled at 1450 F, A.C. With Fans, Tempered 1150 F											
MICROSTRUCTURE											
GRAIN SIZE					HARDNESS						
SOURCE OF DATA General Electric Company											

SHORT TIME TENSILE PROPERTIES

TEMPERATURE, °F	MODULUS OF ELASTICITY, 1,000,000 P.S.I.	OFFSET YIELD (1) STRENGTH, 1000 P.S.I.	TENSILE STRENGTH, 1000 P.S.I.	ELONGATION IN 2", PER CENT	REDUCTION IN AREA, PER CENT
80			103.9	24.0	66.3

CREEP AND RUPTURE STRENGTHS

TEMP., °F	STRESS FOR RUPTURE IN TIMES INDICATED, 1000 P.S.I.(2)				STRESS FOR DESIGNATED CREEP RATE, 1000 P.S.I.(2)		
	100 HRS.	1000 HRS.	10,000 HRS.	100,000 HRS.	0.000001 %/HR.	0.00001 %/HR.	0.0001 %/HR.
900		42P	32P	25P			
1000		25	18.5*	14*			

P indicates strength value obtained by use of Larson-Miller parameter T(25 + log t).

ORIGINAL CREEP AND RUPTURE DATA

TEMP. °F.	STRESS, 1000 P.S.I.	DURATION, HOURS(3)	INTERCEPT, %(4)	MINIMUM CREEP RATE, %/HR.	TRANSITION TIME, HRS.(5)	TOTAL EXT. (CREEP TEST), %	TOTAL ELONG. (RUPTURE TEST), %	REDUCTION IN AREA, %
1000	40.0	18 R					17.0	85.0
1000	34.0	42 R					21.0	84.0
1000	30.0	198 R					23.0	86.0
1000	24.0	1390 R					20.0	86.0
1000	20.0	5946 R					20.0	84.0

(16)

ASTM-ASME JOINT COMMITTEE ON EFFECT OF TEMPERATURE ON PROPERTIES OF METALS

TYPE OF MATERIAL 12 Cr (Type 403)	TYPE OF MELTING FURNACE						SIZE OF HEAT Commercial				
CHEMICAL COMPOSITION, PER CENT	C	Mn	P	S	Si	Cr	Ni	Mo			
	0.09	0.50			0.28	12.35	0.41	0.29			
DEOXIDATION											
FORM-CAST OR WROUGHT Wrought 3/4" x 1-1/8" Bar											
HEAT TREATMENT Finished at 1450 F, A.C. With Fans, Tempered 1150 F											
MICROSTRUCTURE											
GRAIN SIZE					HARDNESS						
SOURCE OF DATA General Electric Company											

SHORT TIME TENSILE PROPERTIES

TEMPERATURE, °F	MODULUS OF ELASTICITY, 1,000,000 P.S.I.	OFFSET YIELD (1) STRENGTH, 1000 P.S.I.	TENSILE STRENGTH, 1000 P.S.I.	ELONGATION IN 2", PER CENT	REDUCTION IN AREA, PER CENT
80			112.4	24.0	67.9

CREEP AND RUPTURE STRENGTHS

TEMP., °F	STRESS FOR RUPTURE IN TIMES INDICATED, 1000 P.S.I.(2)				STRESS FOR DESIGNATED CREEP RATE, 1000 P.S.I.(2)		
	100 HRS.	1000 HRS.	10,000 HRS.	100,000 HRS.	0.000001 %/HR.	0.00001 %/HR.	0.0001 %/HR.
900			35P	27P			
1000		27	20*	15.5*			

P indicates strength value obtained by use of Larson-Miller parameter T(25 + log t).

ORIGINAL CREEP AND RUPTURE DATA

TEMP. °F.	STRESS, 1000 P.S.I.	DURATION, HOURS(3)	INTERCEPT, %(4)	MINIMUM CREEP RATE, %/HR.	TRANSITION TIME, HRS.(5)	TOTAL EXT. (CREEP TEST), %	TOTAL ELONG. (RUPTURE TEST), %	REDUCTION IN AREA, %
1000	36.0	67 R					24.0	86.0
1000	32.0	214 R					30.0	85.0
1000	26.0	1337 R					23.0	85.0
1000	22.0	5324 R					20.0	84.0

(17)

ASTM-ASME JOINT COMMITTEE ON EFFECT OF TEMPERATURE ON PROPERTIES OF METALS

TYPE OF MATERIAL 12 Cr (Type 403)	TYPE OF MELTING FURNACE						SIZE OF HEAT Commercial				
CHEMICAL COMPOSITION, PER CENT	C	Mn	P	S	Si	Cr	Ni	Mo	V		
	0.13	0.40			0.27	12.36	0.18	0.45	0.03		
DEOXIDATION											
FORM-CAST OR WROUGHT Wrought 2-1/16" x 8" Bar											
HEAT TREATMENT Air Cooled From Rolls											
MICROSTRUCTURE											
GRAIN SIZE					HARDNESS						
SOURCE OF DATA General Electric Company											

SHORT TIME TENSILE PROPERTIES

TEMPERATURE, °F	MODULUS OF ELASTICITY, 1,000,000 P.S.I.	OFFSET (a) YIELD (1) STRENGTH, 1000 P.S.I.	TENSILE STRENGTH, 1000 P.S.I.	ELONGATION IN 2", PER CENT	REDUCTION IN AREA, PER CENT
80		79.4	106.2	24.5	67.2
(a) 0.02% Offset yield strength.					

CREEP AND RUPTURE STRENGTHS

TEMP., °F	STRESS FOR RUPTURE IN TIMES INDICATED, 1000 P.S.I.(2)				STRESS FOR DESIGNATED CREEP RATE, 1000 P.S.I.(2)		
	100 HRS.	1000 HRS.	10,000 HRS.	100,000 HRS.	0.000001 %/HR.	0.00001 %/HR.	0.0001 %/HR.
900			35P	27P			
1000		27	20*	15.5*			

P indicates strength value obtained by use of Larson-Miller parameter T(25 + log t).

ORIGINAL CREEP AND RUPTURE DATA

TEMP. °F.	STRESS, 1000 P.S.I.	DURATION, HOURS(3)	INTERCEPT, %(4)	MINIMUM CREEP RATE, %/HR.	TRANSITION TIME, HRS.(5)	TOTAL EXT. (CREEP TEST), %	TOTAL ELONG. (RUPTURE TEST), %	REDUCTION IN AREA, %
1000	36.0	67 R					24.0	86.0
1000	32.0	214 R					30.0	85.0
1000	26.0	1337 R					23.0	85.0
1000	22.0	5324 R					20.0	84.0

(1) 0.2 PER CENT OFFSET UNLESS OTHERWISE INDICATED.
(2) EXTRAPOLATED VALUES INDICATED BY *
(3) DURATION OF TEST (RUPTURE TEST INDICATED BY R).
(4) THE INTERCEPT IS THE PROJECTION BACK TO ZERO TIME FROM THE PORTION OF THE TEST SHOWING THE MINIMUM OR SECOND-STAGE CREEP RATE.
(5) THE TRANSITION TIME IS THE BEGINNING OF THE THIRD STAGE, OR AN ACCELERATING CREEP RATE.

(18)

ASTM-ASME JOINT COMMITTEE ON EFFECT OF TEMPERATURE ON PROPERTIES OF METALS

TYPE OF MATERIAL 12 Cr (Type 403)	TYPE OF MELTING FURNACE						SIZE OF HEAT Commercial				
CHEMICAL COMPOSITION, PER CENT	C	Mn	P	S	Si	Cr	Ni	Mo			
	0.13	0.35			0.32	12.31	0.36	0.19			
DEOXIDATION											
FORM-CAST OR WROUGHT Wrought 1-3/16" x 5-7/16" Bar											
HEAT TREATMENT Finish Rolled 1450 F, A. C. With Fans, 1175 F – 15 Hr, 1100 F – 15 Hr											
MICROSTRUCTURE											
GRAIN SIZE					HARDNESS						
SOURCE OF DATA General Electric Company											

SHORT TIME TENSILE PROPERTIES

TEMPERATURE, °F	MODULUS OF ELASTICITY, 1,000,000 P.S.I.	OFFSET (a) YIELD (1) STRENGTH, 1000 P.S.I.	TENSILE STRENGTH, 1000 P.S.I.	ELONGATION IN 2", PER CENT	REDUCTION IN AREA, PER CENT
80		92.9	114.9	24.5	66.3

(a) 0.02% Offset yield strength.

CREEP AND RUPTURE STRENGTHS

TEMP., °F	STRESS FOR RUPTURE IN TIMES INDICATED, 1000 P.S.I.(2)				STRESS FOR DESIGNATED CREEP RATE, 1000 P.S.I.(2)		
	100 HRS.	1000 HRS.	10,000 HRS.	100,000 HRS.	0.000001 %/HR.	0.00001 %/HR.	0.0001 %/HR.
900		48P	40P	34P			
1000		34	28	23*			

P indicates strength value obtained by use of Larson-Miller parameter T(25 + log t).

ORIGINAL CREEP AND RUPTURE DATA

TEMP. °F.	STRESS, 1000 P.S.I.	DURATION, HOURS(3)	INTERCEPT, %(4)	MINIMUM CREEP RATE, %/HR.	TRANSITION TIME, HRS.(5)	TOTAL EXT. (CREEP TEST), %	TOTAL ELONG. (RUPTURE TEST), %	REDUCTION IN AREA, %
1000	50.0	6 R					14.0	80.0
1000	42.0	57 R					17.0	82.0
1000	32.0	1811 R					16.0	84.0
1000	29.0	6624 R					21.0	87.0

(19)

ASTM-ASME JOINT COMMITTEE ON EFFECT OF TEMPERATURE ON PROPERTIES OF METALS

TYPE OF MATERIAL 12 Cr	TYPE OF MELTING FURNACE						SIZE OF HEAT				
CHEMICAL COMPOSITION, PER CENT	C	Mn	P	S	Si	Cr	Ni	Mo			
	0.11	0.45			0.30	13.22					
DEOXIDATION											
FORM-CAST OR WROUGHT Wrought											
HEAT TREATMENT Normalized and Tempered											
MICROSTRUCTURE											
GRAIN SIZE					HARDNESS						
SOURCE OF DATA "Properties of Carbon & Alloy Seamless Steel Tubing for High Temperature and High Pressure Service," Babcock & Wilcox Tube Company.											

CREEP AND RUPTURE STRENGTHS

TEMP., °F	STRESS FOR RUPTURE IN TIMES INDICATED, 1000 P.S.I.(2)				STRESS FOR DESIGNATED CREEP RATE, 1000 P.S.I.(2)		
	100 HRS.	1000 HRS.	10,000 HRS.	100,000 HRS.	0.000001 %/HR.	0.00001 %/HR.	0.0001 %/HR.
1000						10.0	13.0
1100						4.0	5.2
1200						1.5	2.1
1300						0.9	1.4

(20)

ASTM-ASME JOINT COMMITTEE ON EFFECT OF TEMPERATURE ON PROPERTIES OF METALS

TYPE OF MATERIAL 12 Cr + N_2	TYPE OF MELTING FURNACE							SIZE OF HEAT				
CHEMICAL COMPOSITION, PER CENT	C	Mn	P	S	Si	Cr	Ni	Mo	N_2			
	0.105	0.38	0.020	0.010	0.36	26.12	0.20	0.02	0.125			
DEOXIDATION												
FORM-CAST OR WROUGHT Hot Rolled Bar												
HEAT TREATMENT As Hot Rolled												
MICROSTRUCTURE												
GRAIN SIZE 4-6 ASTM Ferrite Grain Size						HARDNESS 167 BHN						
SOURCE OF DATA University of Michigan												

CREEP AND RUPTURE STRENGTHS

TEMP., °F	STRESS FOR RUPTURE IN TIMES INDICATED, 1000 P.S.I.(2)				STRESS FOR DESIGNATED CREEP RATE, 1000 P.S.I.(2)		
	100 HRS.	1000 HRS.	10,000 HRS.	100,000 HRS.	0.000001 %/HR.	0.00001 %/HR.	0.0001 %/HR.
1200	6.2*	4.3*					
1400	2.3*						
1600	1.10	0.66	0.40*	0.24*			
1800	0.59*						

ORIGINAL CREEP AND RUPTURE DATA

TEMP. °F.	STRESS, 1000 P.S.I.	DURATION, HOURS(3)	INTERCEPT, %(4)	MINIMUM CREEP RATE, %/HR.	TRANSITION TIME, HRS.(5)	TOTAL EXT. (CREEP TEST), %	TOTAL ELONG. (RUPTURE TEST), %	HARDNESS AFTER TESTING
1200	5.0	390.0 R					64.0	
1400	2.25	125.5 R					56.0	
1600	1.00	181.5 R					74.0	
1600	0.75	579.5 R					85.0	
1600	0.65	1143.0 R					85.0	
1800	0.65	65.0					108.5	

(21)

ASTM-ASME JOINT COMMITTEE ON EFFECT OF TEMPERATURE ON PROPERTIES OF METALS

TYPE OF MATERIAL 12Cr-1/2Mo	TYPE OF MELTING FURNACE						SIZE OF HEAT				
CHEMICAL COMPOSITION, PER CENT	C	Mn	P	S	Si	Cr	Ni	Mo			
	0.08	0.37	0.022	0.021	0.22	12.14	0.19	0.49			
DEOXIDATION											
FORM-CAST OR WROUGHT Wrought											
HEAT TREATMENT 1750 F Quench + 1220 F Temper											
MICROSTRUCTURE Tempered Martensite and Delta Ferrite											
GRAIN SIZE 5-8					HARDNESS 231 DPH						
SOURCE OF DATA U.S. Steel Corp. Research Lab.											

CREEP AND RUPTURE STRENGTHS

TEMP., °F	STRESS FOR RUPTURE IN TIMES INDICATED, 1000 P.S.I.(2)				STRESS FOR DESIGNATED CREEP RATE, 1000 P.S.I.(2)		
	100 HRS.	1000 HRS.	10,000 HRS.	100,000 HRS.	0.000001 %/HR.	0.00001 %/HR.	0.0001 %/HR.
900		54.*					
1000		26.					
1050		18.					
1100		13.0					
1200		6.0					
1250		4.2					
1300		2.9					
1350		2.0*					

ORIGINAL CREEP AND RUPTURE DATA

TEMP. °F.	STRESS, 1000 P.S.I.	DURATION, HOURS(3)	INTERCEPT, %(4)	MINIMUM CREEP RATE, %/HR.	TRANSITION TIME, HRS.(5)	TOTAL EXT. (CREEP TEST), %	TOTAL ELONG. (RUPTURE TEST), %	HARDNESS AFTER TESTING
1000	50.0	1.8 R		3.0			55.0	
1000	45.0	6.2 R		1.03			33.0	
1000	40.0	20.2 R		--				
1000	35.0	83.3 R		0.10			41.0	
1000	25.0	1457. R		--				
1100	35.0	1.25 R		5.74				
1100	30.0	5.5 R		1.55				
1100	20.0	100. R		0.056				
1100	15.0	522.5 R		0.023				
1100	12.0	1692. R		0.0072				
1300	15.0	0.33 R		--				
1300	10.0	4.25 R		2.7				
1300	7.2	19.5		0.45				
1300	4.5	158.5 R		0.075				
1300	3.0	711. R		0.014				

(1) 0.2 PER CENT OFFSET UNLESS OTHERWISE INDICATED.

(2) EXTRAPOLATED VALUES INDICATED BY *

(3) DURATION OF TEST (RUPTURE TEST INDICATED BY R).

(4) THE INTERCEPT IS THE PROJECTION BACK TO ZERO TIME FROM THE PORTION OF THE TEST SHOWING THE MINIMUM OR SECOND-STAGE CREEP RATE.

(5) THE TRANSITION TIME IS THE BEGINNING OF THE THIRD STAGE, OR AN ACCELERATING CREEP RATE.

(22)

ASTM-ASME JOINT COMMITTEE ON EFFECT OF TEMPERATURE ON PROPERTIES OF METALS

TYPE OF MATERIAL	12 Cr + 0.5 Mo + 1 Co	TYPE OF MELTING FURNACE	Induction	SIZE OF HEAT	30 lb

CHEMICAL COMPOSITION, PER CENT	C	Mn	P	S	Si	Cr	Ni	Mo	N_2	Co
	0.10	0.51	0.014	0.016	0.24	12.33		0.50	0.091	1.11

DEOXIDATION

FORM-CAST OR WROUGHT Forged to 1" Round Bars

HEAT TREATMENT Normalized 1750 F and Annealed 1650 F

MICROSTRUCTURE

GRAIN SIZE 8 ASTM Ferrite Grain Size HARDNESS 170-171 BHN

SOURCE OF DATA University of Michigan

SHORT TIME TENSILE PROPERTIES

TEMPERATURE, °F	MODULUS OF ELASTICITY, 1,000,000 P.S.I.	OFFSET YIELD (1) STRENGTH, 1000 P.S.I.	TENSILE STRENGTH, 1000 P.S.I.	ELONGATION IN 2", PER CENT	REDUCTION IN AREA, PER CENT
RT		39.0	85.0	81.0	70.3
1200		14.35	26.25	59.0	93.4

CREEP AND RUPTURE STRENGTHS

TEMP., °F	STRESS FOR RUPTURE IN TIMES INDICATED, 1000 P.S.I.(2)				STRESS FOR DESIGNATED CREEP RATE, 1000 P.S.I.(2)		
	100 HRS.	1000 HRS.	10,000 HRS.	100,000 HRS.	0.000001 %/HR.	0.00001 %/HR.	0.0001 %/HR.
1200	9.6	6.2	4.1*	2.7*		0.63*	2.1*

(1) 0.2 PER CENT OFFSET UNLESS OTHERWISE INDICATED.

(2) EXTRAPOLATED VALUES INDICATED BY *

ORIGINAL CREEP AND RUPTURE DATA

TEMP., °F	STRESS, 1000 P.S.I.	DURATION, HOURS(3)	INTERCEPT, %(4)	MINIMUM CREEP RATE, %/HR.	TRANSITION TIME, HRS.(5)	TOTAL EXT. (CREEP TEST), %	TOTAL ELONG. (RUPTURE TEST), %	HARDNESS AFTER TESTING
1200	19.0	0.4 R					62.0	
1200	14.0	6.3 R					65.0	
1200	9.5	106.0 R					63.0	
1200	7.0	547.0 R					65.0	
1200	6.0	1288.5 R					71.0	
1200	1.5	1500	0.120	0.000052		0.197		
1200	1.0	1275	0.072	0.000024		0.103		

(3) DURATION OF TEST (RUPTURE TEST INDICATED BY R).

(4) THE INTERCEPT IS THE PROJECTION BACK TO ZERO TIME FROM THE PORTION OF THE TEST SHOWING THE MINIMUM OR SECOND-STAGE CREEP RATE.

(5) THE TRANSITION TIME IS THE BEGINNING OF THE THIRD STAGE, OR AN ACCELERATING CREEP RATE.

(23)

ASTM-ASME JOINT COMMITTEE ON EFFECT OF TEMPERATURE ON PROPERTIES OF METALS

TYPE OF MATERIAL	12 Cr + 0.50 Mo + N_2	TYPE OF MELTING FURNACE	Induction	SIZE OF HEAT	30 lb

CHEMICAL COMPOSITION, PER CENT	C	Mn	P	S	Si	Cr	Ni	Mo	N_2
	0.11	0.38	0.019	0.021	0.18	12.34		0.42	0.131

DEOXIDATION

FORM-CAST OR WROUGHT Forged to 1" Rounds

HEAT TREATMENT Normalized From 1750 F and Annealed 1650 F

MICROSTRUCTURE

GRAIN SIZE 7/8 ASTM Ferrite Grain Size HARDNESS 140-146 BHN

SOURCE OF DATA University of Michigan

SHORT TIME TENSILE PROPERTIES

TEMPERATURE, °F	MODULUS OF ELASTICITY, 1,000,000 P.S.I.	OFFSET YIELD (1) STRENGTH, 1000 P.S.I.	TENSILE STRENGTH, 1000 P.S.I.	ELONGATION IN 2", PER CENT	REDUCTION IN AREA, PER CENT
RT		32.0	75.5	35.0	74.3
1200		13.0	22.6	58.0	91.3

CREEP AND RUPTURE STRENGTHS

TEMP., °F	STRESS FOR RUPTURE IN TIMES INDICATED, 1000 P.S.I.(2)				STRESS FOR DESIGNATED CREEP RATE, 1000 P.S.I.(2)		
	100 HRS.	1000 HRS.	10,000 HRS.	100,000 HRS.	0.000001 %/HR.	0.00001 %/HR.	0.0001 %/HR.
1200	8.5	5.6	3.5*	2.1*		0.57*	1.85*

(1) 0.2 PER CENT OFFSET UNLESS OTHERWISE INDICATED.

(2) EXTRAPOLATED VALUES INDICATED BY *

ORIGINAL CREEP AND RUPTURE DATA

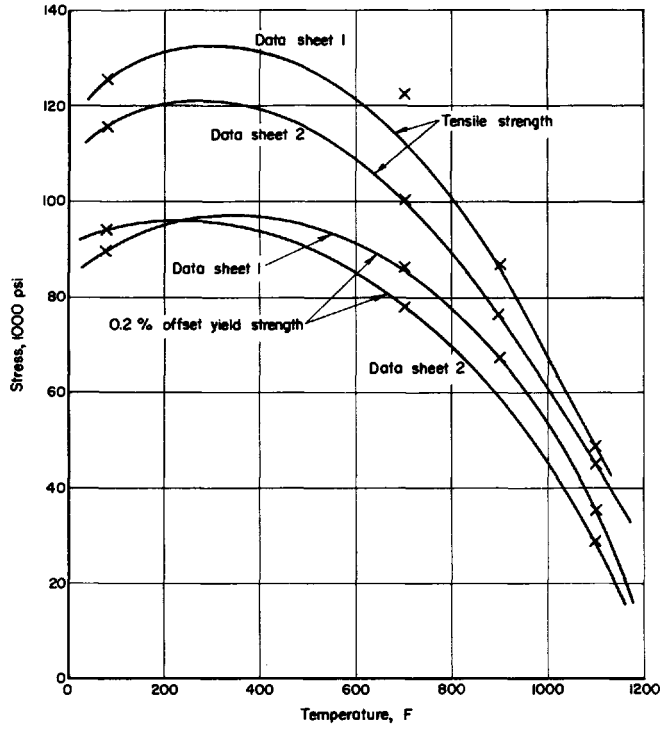
TEMP., °F	STRESS, 1000 P.S.I.	DURATION, HOURS(3)	INTERCEPT, %(4)	MINIMUM CREEP RATE, %/HR.	TRANSITION TIME, HRS.(5)	TOTAL EXT. (CREEP TEST), %	TOTAL ELONG. (RUPTURE TEST), %	HARDNESS AFTER TESTING
1200	15.0	2.5 R					58.0	
1200	8.0	151.0 R					68.0	
1200	6.75	452.0 R					65.0	
1200	5.5	1118.0 R					66.0	
1200	1.5	1290.0	0.049	0.000065		0.131		
1200	1.0	1237.0	0.046	0.000033		0.087		
1200	0.78	1340.0	0.042	0.000018		0.066		

(3) DURATION OF TEST (RUPTURE TEST INDICATED BY R).

(4) THE INTERCEPT IS THE PROJECTION BACK TO ZERO TIME FROM THE PORTION OF THE TEST SHOWING THE MINIMUM OR SECOND-STAGE CREEP RATE.

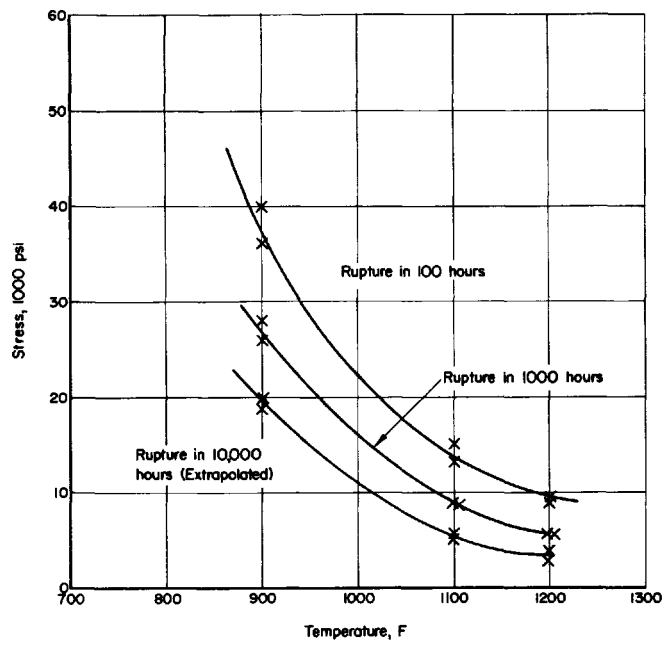
(5) THE TRANSITION TIME IS THE BEGINNING OF THE THIRD STAGE, OR AN ACCELERATING CREEP RATE.

12 Chromium, 2 Nickel Steels



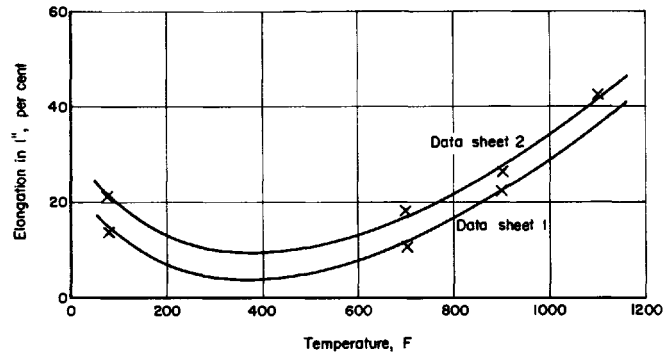
TENSILE AND YIELD STRENGTH DATA

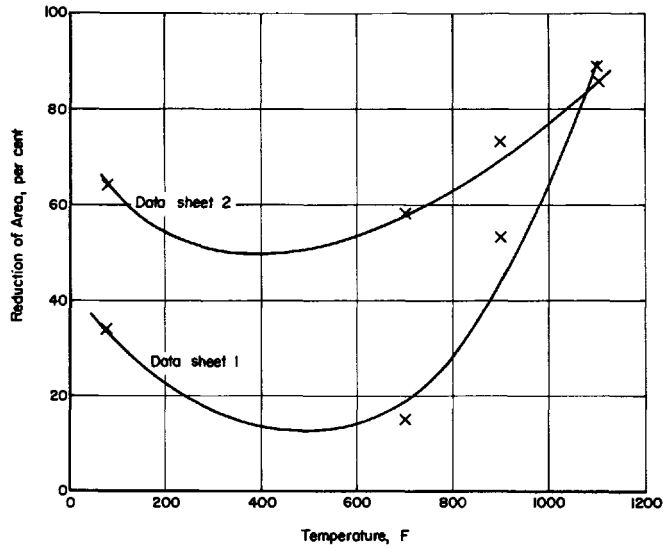
12 Cr, 2 Ni STEEL



RUPTURE STRENGTH DATA

12 Cr, 2 Ni STEEL





ELONGATION AND REDUCTION IN AREA

12 Cr, 2 Ni STEEL

(1)

ASTM-ASME JOINT COMMITTEE ON EFFECT OF TEMPERATURE ON PROPERTIES OF METALS

TYPE OF MATERIAL	12 Cr, 2 Ni (Type 414)	TYPE OF MELTING FURNACE	Induction	SIZE OF HEAT	30 lb

CHEMICAL COMPOSITION, PER CENT	C	Mn	P	S	Si	Cr	Ni	N_2
	0.13	0.58	0.022	0.017	0.52	12.37	1.82	0.124

DEOXIDATION

FORM-CAST OR WROUGHT Wrought. 5/8- and 1-1/2"-Square Forged Bars

HEAT TREATMENT 1800 F, 1/2 Hr, OQ; 1225 F, 4 Hr, OQ

MICROSTRUCTURE Tempered and Untempered Martensite

GRAIN SIZE Austenitic Grain Size, ASTM No. 6 to 7 | HARDNESS 21 R_C

SOURCE OF DATA U.S. Steel Corp. Research and Development Lab.

SHORT TIME TENSILE PROPERTIES

TEMPERATURE, °F	MODULUS OF ELASTICITY, 1,000,000 P.S.I.	OFFSET YIELD (1) STRENGTH, 1000 P.S.I.	TENSILE STRENGTH, 1000 P.S.I.	ELONGATION IN 2", PER CENT	REDUCTION IN AREA, PER CENT
RT (a)		90.4	126.8	14.0	34.7
700 (b)		86.5	122.5	11.0	15.0
900 (b)		67.0	87.0	22.5	53.0
1100 (b)		35.4	49.7	--	89.0

(a) 0.254" Diameter specimens, 1-inch gage length.
(b) 0.254" Diameter specimens, 2-inch gage length.

CREEP AND RUPTURE STRENGTHS

TEMP., °F	STRESS FOR RUPTURE IN TIMES INDICATED, 1000 P.S.I.(2)				STRESS FOR DESIGNATED CREEP RATE, 1000 P.S.I.(2)		
	100 HRS.	1000 HRS.	10,000 HRS.	100,000 HRS.	0.000001 %/HR.	0.00001 %/HR.	0.0001 %/HR.
900	40.0	28.0	20.0*				
1100	15.2	8.8	5.1*				
1200	9.5	5.6	3.2*				

(1) 0.2 PER CENT OFFSET UNLESS OTHERWISE INDICATED.
(2) EXTRAPOLATED VALUES INDICATED BY *

ORIGINAL CREEP AND RUPTURE DATA

TEMP., °F	STRESS, 1000 P.S.I.	DURATION, HOURS(3)	INTERCEPT, %(4)	MINIMUM CREEP RATE, %/HR.	TRANSITION TIME, HRS.(5)	TOTAL EXT. (CREEP TEST), %	TOTAL ELONG. (RUPTURE TEST), %	HARDNESS AFTER TESTING
900	60.0	1.43		5.71	0.75		31.8	Rb 98.3
900	50.0	11.1		0.971	4.6		40.0	Rb 97.7
900	45.0	29.3		0.364	--		39.6	Rb 96.3
900	40.0	103.3		0.127	38.0		43.8	Rb 96.5
900	35.0	212.0		0.047	125.0		25.2	Rb 95.8
900	30.0	712.0		0.021	415.0		58.0	Rb 95.1
1100	30.0	1.5		7.46	0.65		48.0	Rb 95.2
1100	20.0	16.9		0.899	5.8		56.2	Rb 94.6
1100	15.0	108.0		0.170	47.5		66.2	Rb 90.5
1100	10.0	596.0		0.0316	348.0		80.4	Rb 84.8
1100	8.5	1212.8		0.0138	758.0		78.0	Rb 83.8
1200	30.0	0.12		105.6	--		50.2	Rb 94.6
1200	20.0	0.90		16.0	--		61.4	Rb 90.1
1200	10.0	78.0		0.248	29.2		95.2	Rb 88.6
1200	8.5	114.0		0.146	42.0		82.4	Rb 88.5
1200	8.14	266.8		0.0678	94.5		73.6	Rb 87.3
1200	6.5	404.5		0.0473	228.0		89.4	Rb 88.4
1200	5.22	1295.0		0.0137	863.0		82.0	Rb 86.3

(3) DURATION OF TEST (RUPTURE TEST INDICATED BY R).
(4) THE INTERCEPT IS THE PROJECTION BACK TO ZERO TIME FROM THE PORTION OF THE TEST SHOWING THE MINIMUM OR SECOND-STAGE CREEP RATE.
(5) THE TRANSITION TIME IS THE BEGINNING OF THE THIRD STAGE, OR AN ACCELERATING CREEP RATE.

(2)

ASTM-ASME JOINT COMMITTEE ON EFFECT OF TEMPERATURE ON PROPERTIES OF METALS

TYPE OF MATERIAL	12 Cr, 2 Ni (Type 414)	TYPE OF MELTING FURNACE	Induction	SIZE OF HEAT	100 lb

CHEMICAL COMPOSITION, PER CENT	C	Mn	P	S	Si	Cr	Ni	Mo	N_2
	0.13	0.78	0.008	0.017	0.71	12.31	1.88		0.015

DEOXIDATION

FORM-CAST OR WROUGHT Wrought 5/8- and 1-1/2"-Square Forged Bars

HEAT TREATMENT 1800 F, 1/2 Hr, OQ; 1225 F, 4 Hr, OQ

MICROSTRUCTURE Tempered Martensite

GRAIN SIZE Austenitic Grain Size, ASTM No. 6 to 7 | HARDNESS 22 R_C

SOURCE OF DATA U.S. Steel Corp. Research and Development Lab.

SHORT TIME TENSILE PROPERTIES

TEMPERATURE, °F	MODULUS OF ELASTICITY, 1,000,000 P.S.I.	OFFSET YIELD (1) STRENGTH, 1000 P.S.I.	TENSILE STRENGTH, 1000 P.S.I.	ELONGATION IN 2", PER CENT	REDUCTION IN AREA, PER CENT
RT (a)		94.0	116.4	21.5	64.6
700 (b)		78.4	101.3	18.0	58.7
900 (b)		--	77.2	26.3	73.3
1100 (b)		29.6	45.7	42.3	86.6

(a) 0.254" Diameter specimens, 1-inch gage length.
(b) 0.254" Diameter specimens, 2-inch gage length.

CREEP AND RUPTURE STRENGTHS

TEMP., °F	STRESS FOR RUPTURE IN TIMES INDICATED, 1000 P.S.I.(2)				STRESS FOR DESIGNATED CREEP RATE, 1000 P.S.I.(2)		
	100 HRS.	1000 HRS.	10,000 HRS.	100,000 HRS.	0.000001 %/HR.	0.00001 %/HR.	0.0001 %/HR.
900	36.0	26.0	19.2*				
1100	13.3	8.7	5.6*				
1200	9.7	6.3	4.0*				

(1) 0.2 PER CENT OFFSET UNLESS OTHERWISE INDICATED.
(2) EXTRAPOLATED VALUES INDICATED BY *

ORIGINAL CREEP AND RUPTURE DATA

TEMP., °F	STRESS, 1000 P.S.I.	DURATION, HOURS(3)	INTERCEPT, %(4)	MINIMUM CREEP RATE, %/HR.	TRANSITION TIME, HRS.(5)	TOTAL EXT. (CREEP TEST), %	TOTAL ELONG. (RUPTURE TEST), %	HARDNESS AFTER TESTING
900	55.0	2.1		2.92	0.9		33.8	Rb 96.1
900	47.0	9.7		0.870	5.6		36.4	Rb 95.6
900	40.0	42.5		0.232	18.0		39.6	Rb 95.5
900	32.0	223.0		0.0553	131.3		46.0	Rb 93.1
900	27.5	730.5		0.0228	427.0		50.0	Rb 93.5
1100	30.0	0.6		16.0	0.25		46.4	Rb 92.7
1100	20.0	11.2		0.986	4.8		52.6	Rb 91.3
1100	15.0	53.0		0.204	17.6		70.2	Rb 89.2
1100	9.5	610.0		0.0202	313.0		70.2	Rb 86.2
1100	8.0	1520.0		0.0097	847.0		92.0	Rb 85.4
1200	20.0	1.2		11.52	0.6		50.8	Rb 91.8
1200	15.0	8.5		1.52	3.3		52.6	Rb 91.4
1200	10.0	91.5		0.1181	40.4		60.2	Rb 90.8
1200	8.5	213.8		0.0571	96.0		72.2	Rb 88.5
1200	7.5	420.3		0.0218	180.0		78.2	Rb 88.3
1200	6.0	1298.0		0.0081	900.0		78.0	Rb 85.3

(3) DURATION OF TEST (RUPTURE TEST INDICATED BY R).
(4) THE INTERCEPT IS THE PROJECTION BACK TO ZERO TIME FROM THE PORTION OF THE TEST SHOWING THE MINIMUM OR SECOND-STAGE CREEP RATE.
(5) THE TRANSITION TIME IS THE BEGINNING OF THE THIRD STAGE, OR AN ACCELERATING CREEP RATE.

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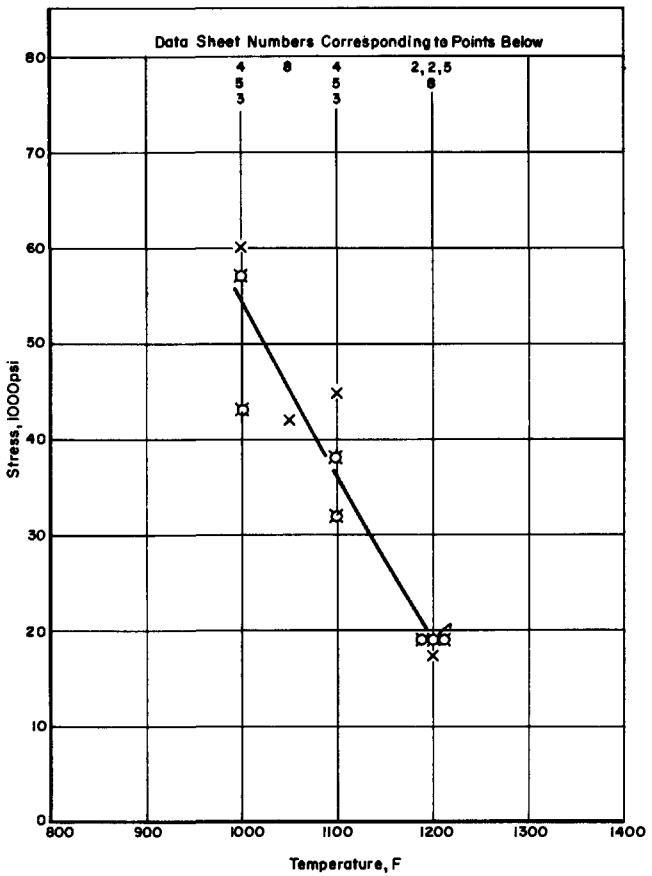
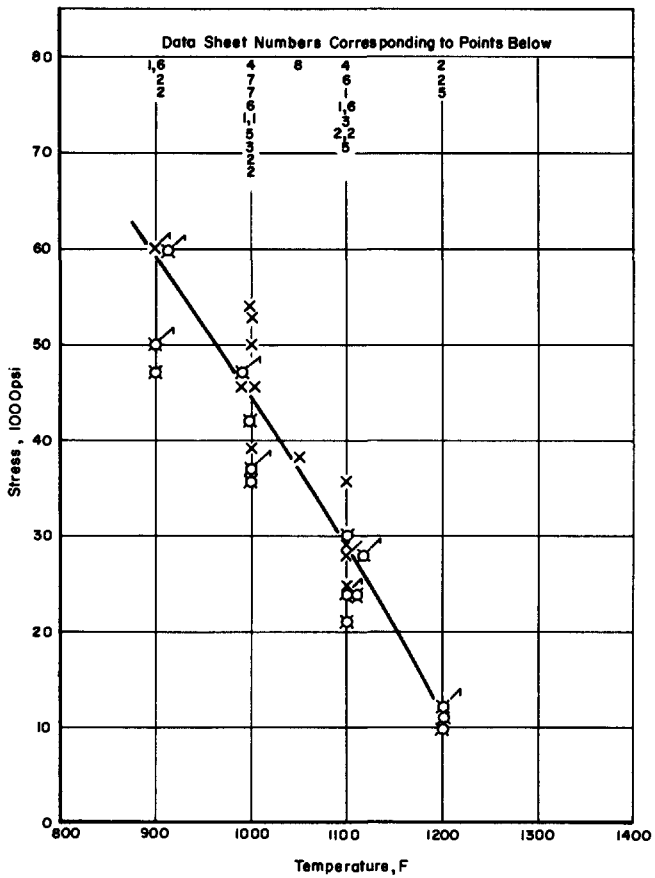
13 Chromium, 2 Nickel, 3 Tungsten Steels (Greek Ascoloy)



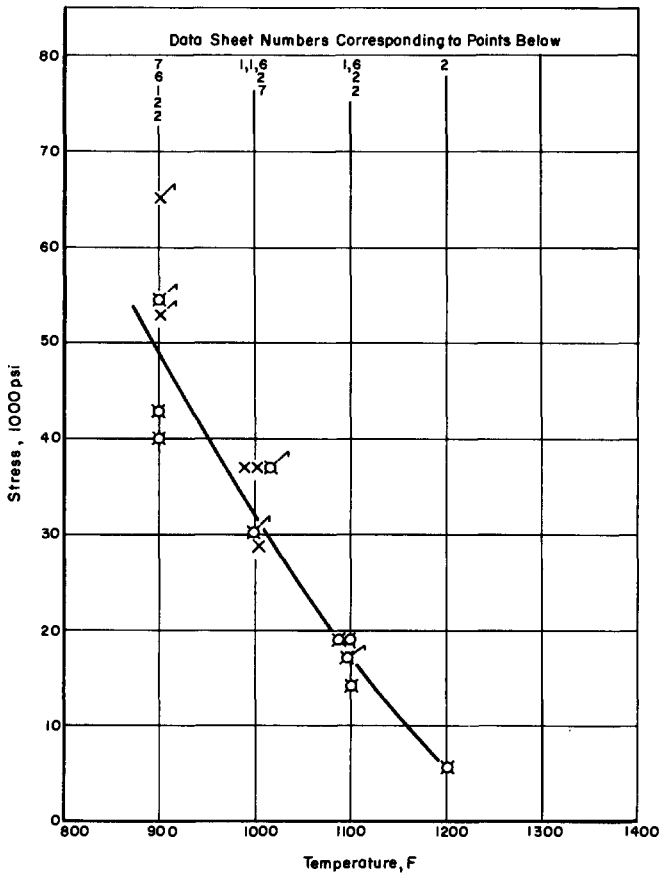
RUPTURE IN 100 HOURS

13 Cr, 2 Ni, 3W STEEL



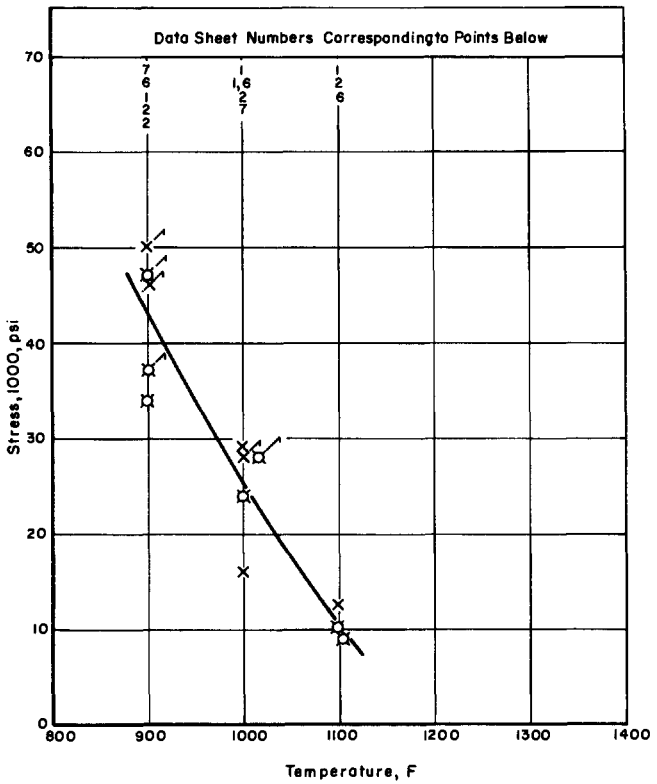
RUPTURE IN 1000 HOURS

13 Cr, 2 Ni, 3W STEEL



RUPTURE IN 10,000 HOURS
(EXTRAPOLATED)

13 Cr, 2 Ni, 3W STEEL



RUPTURE IN 100,000 HOURS
(EXTRAPOLATED)

13Cr, 2Ni, 3W STEEL

(1)

ASTM-ASME JOINT COMMITTEE ON EFFECT OF TEMPERATURE ON PROPERTIES OF METALS

TYPE OF MATERIAL 13 Cr, 2 Ni, 3 W	TYPE OF MELTING FURNACE						SIZE OF HEAT Commercial				
CHEMICAL COMPOSITION, PER CENT	C	Mn	P	S	Si	Cr	Ni	Mo	W		
	0.07	0.29			0.30	12.25	2.05		2.82		
DEOXIDATION											
FORM-CAST OR WROUGHT											
HEAT TREATMENT 2050 F, 1 Hr, OQ; 1200 F, 2 Hr, A.C.											
MICROSTRUCTURE											
GRAIN SIZE							HARDNESS				
SOURCE OF DATA General Electric Company											

CREEP AND RUPTURE STRENGTHS

TEMP., °F	STRESS FOR RUPTURE IN TIMES INDICATED, 1000 P.S.I.(2)				STRESS FOR DESIGNATED CREEP RATE, 1000 P.S.I.(2)		
	100 HRS.	1000 HRS.	10,000 HRS.	100,000 HRS.	0.000001 %/HR.	0.00001 %/HR.	0.0001 %/HR.
900		60P	53P	46P			
1000		46P	37P	28P			
		46	37*	29*			
1100		28P					
		29	19*	12.5*			

P indicates strength value obtained by use of Larson-Miller parameter T(25 + log t).

ORIGINAL CREEP AND RUPTURE DATA

TEMP., °F	STRESS, 1000 P.S.I.	DURATION, HOURS(3)	INTERCEPT, %(4)	MINIMUM CREEP RATE, %/HR.	TRANSITION TIME, HRS.(5)	TOTAL EXT. (CREEP TEST), %	TOTAL ELONG. (RUPTURE TEST), %	REDUCTION IN AREA, %
1000	66.0	1 R					13.4	73.0
1000	60.0	8 R					13.9	76.0
1000	50.0	283 R					13.9	76.5
1000	45.8	1167 R					13.4	76.0
1000	42.8	2278 R					10.6	72.5
1000	38.0	7695 R					10.4	61.0
1100	50.0	1 R					14.6	81.0
1100	44.0	17 R					14.6	81.0
1100	37.0	179 R					10.5	75.5
1100	32.0	552 R					9.8	75.0
1100	26.0	1772 R					14.6	83.0

(2)

ASTM-ASME JOINT COMMITTEE ON EFFECT OF TEMPERATURE ON PROPERTIES OF METALS

TYPE OF MATERIAL 13 Cr, 2 Ni, 3 W	TYPE OF MELTING FURNACE						SIZE OF HEAT				
CHEMICAL COMPOSITION, PER CENT	C	Mn	P	S	Si	Cr	Ni	Mo	W		
	0.12	0.37	0.006	0.008	0.24	11.88	2.08		2.98		
DEOXIDATION											
FORM-CAST OR WROUGHT											
HEAT TREATMENT 1/2 Hr, 1800 F, A.C.; 1-1/2 Hr, 1260 F, A.C.											
MICROSTRUCTURE											
GRAIN SIZE							HARDNESS				
SOURCE OF DATA General Electric Company											

SHORT TIME TENSILE PROPERTIES

TEMPERATURE, °F	MODULUS OF ELASTICITY, 1,000,000 P.S.I.	OFFSET YIELD (1) STRENGTH, 1000 P.S.I.	TENSILE STRENGTH, 1000 P.S.I.	ELONGATION IN 2" PER CENT	REDUCTION IN AREA, PER CENT
80		--	130.0	21	62

CREEP AND RUPTURE STRENGTHS

TEMP., °F	STRESS FOR RUPTURE IN TIMES INDICATED, 1000 P.S.I.(2)				STRESS FOR DESIGNATED CREEP RATE, 1000 P.S.I.(2)		
	100 HRS.	1000 HRS.	10,000 HRS.	100,000 HRS.	0.000001 %/HR.	0.00001 %/HR.	0.0001 %/HR.
900		50P	43P	37P			
900		47	40*	34*			
1000		37P	30P	24P			
1000		36					
1100		24P	18P	10P			
1100		24	14.3*				
1200	19P	12P					
1200	19	11.9	5.9*				

P indicates strength value obtained by use of Larson-Miller parameter T(25 + log t).

(1) 0.2 PER CENT OFFSET UNLESS OTHERWISE INDICATED.

(2) EXTRAPOLATED VALUES INDICATED BY *

ORIGINAL CREEP AND RUPTURE DATA

TEMP., °F	STRESS, 1000 P.S.I.	DURATION, HOURS(3)	INTERCEPT, %(4)	MINIMUM CREEP RATE, %/HR.	TRANSITION TIME, HRS.(5)	TOTAL EXT. (CREEP TEST), %	TOTAL ELONG. (RUPTURE TEST), %	HARDNESS AFTER TESTING
900	70.0	5 R						
900	65.0	11 R						
900	60.0	34 R						
900	55.0	110 R						
900	45.0	2850 R						
1000	45.0	51 R						
1000	35.0	1630 R						
1100	35.5	17 R						
1100	33.0	65 R						
1100	30.0	165 R						
1100	28.0	345 R						
1100	24.0	830 R						
1100	20.0	2250 R						
1200	25.0	28 R						
1200	20.0	63 R						
1200	17.3	295 R						
1200	15.0	450 R						
1200	12.5	710 R						
1200	10.0	1850 R						

(3)

ASTM-ASME JOINT COMMITTEE ON EFFECT OF TEMPERATURE ON PROPERTIES OF METALS

TYPE OF MATERIAL 13 Cr, 2 Ni, 3 W	TYPE OF MELTING FURNACE --						SIZE OF HEAT Commercial				
CHEMICAL COMPOSITION, PER CENT	C	Mn	P	S	Si	Cr	Ni	Mo	W		
	0.12	0.31			0.31	13.18	1.99		2.98		
DEOXIDATION											
FORM-CAST OR WROUGHT 7/8" Wrought Bars											
HEAT TREATMENT 1800 F, 1 Hr, OQ; 1300 F, 1 Hr, A.C.											
MICROSTRUCTURE --											
GRAIN SIZE							HARDNESS 245 BHN				
SOURCE OF DATA U.S.N. Engineering Experiment Station											

SHORT TIME TENSILE PROPERTIES

TEMPERATURE, °F	MODULUS OF ELASTICITY, 1,000,000 P.S.I.	OFFSET YIELD (1) STRENGTH, 1000 P.S.I.	TENSILE STRENGTH, 1000 P.S.I.	ELONGATION IN 2" PER CENT	REDUCTION IN AREA, PER CENT
RT	28.9	92.8	120.6	24	66
1000	18.4	53.0	69.8	21	76
1100	16.9	43.5	57.6	28	84

CREEP AND RUPTURE STRENGTHS

TEMP., °F	STRESS FOR RUPTURE IN TIMES INDICATED, 1000 P.S.I.(2)				STRESS FOR DESIGNATED CREEP RATE, 1000 P.S.I.(2)		
	100 HRS.	1000 HRS.	10,000 HRS.	100,000 HRS.	0.000001 %/HR.	0.00001 %/HR.	0.0001 %/HR.
1000	43	39					
1100	32	25				3.5	8.0

ORIGINAL CREEP AND RUPTURE DATA

TEMP., °F	STRESS, 1000 P.S.I.	DURATION, HOURS(3)	INTERCEPT, %(4)	MINIMUM CREEP RATE, %/HR.	TRANSITION TIME, HRS.(5)	TOTAL EXT. (CREEP TEST), %	TOTAL ELONG. (RUPTURE TEST), %	HARDNESS AFTER TESTING
1000	50.0	10 R					38.0	
1000	45.0	39 R					41.0	
1000	40.0	684 R	1.75	0.0094	370		30.0	
1100	40.0	12 R					30.0	
1100	30.0	310 R					29.0	
1100	27.0	234 R					26.0	
1100	12.0	2016	0.245	0.000287	--	0.821		
1100	7.5	2040	0.126	0.000079	--	0.287		
1100	5.5	1872	0.173	0.000034	--	0.234		

(3) DURATION OF TEST (RUPTURE TEST INDICATED BY R).

(4) THE INTERCEPT IS THE PROJECTION BACK TO ZERO TIME FROM THE PORTION OF THE TEST SHOWING THE MINIMUM OR SECOND-STAGE CREEP RATE.

(5) THE TRANSITION TIME IS THE BEGINNING OF THE THIRD STAGE, OR AN ACCELERATING CREEP RATE.

(4)

ASTM-ASME JOINT COMMITTEE ON EFFECT OF TEMPERATURE ON PROPERTIES OF METALS

TYPE OF MATERIAL	13 Cr, 2 Ni, 3W			TYPE OF MELTING FURNACE	--			SIZE OF HEAT	Commercial			
CHEMICAL COMPOSITION, PER CENT	C	Mn	P	S	Si	Cr	Ni	Mo	W			
	0.15	0.25	0.014	0.004	0.22	13.09	1.95		3.01			
DEOXIDATION												
FORM-CAST OR WROUGHT	3/4" Wrought Bars											
HEAT TREATMENT	1800 F, 1 Hr, OQ; 1200 F, 1 Hr, A. C.											
MICROSTRUCTURE												
GRAIN SIZE							HARDNESS	270 BHN				
SOURCE OF DATA	U.S.N. Engineering Experiment Station											

SHORT TIME TENSILE PROPERTIES

TEMPERATURE, °F	MODULUS OF ELASTICITY, 1,000,000 P.S.I.	OFFSET (1) YIELD STRENGTH, 1000 P.S.I.	TENSILE STRENGTH, 1000 P.S.I.	ELONGATION IN 2", PER CENT	REDUCTION IN AREA, PER CENT
RT		118.6	135.0	22	66
1000		71.4	84.5	22	76
1100		51.5	67.6	26	82

CREEP AND RUPTURE STRENGTHS

TEMP., °F	STRESS FOR RUPTURE IN TIMES INDICATED, 1000 P.S.I.(2)				STRESS FOR DESIGNATED CREEP RATE, 1000 P.S.I.(2)		
	100 HRS.	1000 HRS.	10,000 HRS.	100,000 HRS.	0.000001 %/HR.	0.00001 %/HR.	0.0001 %/HR.
1000	60	54				--	21.0
1100	45	36				4.3	12.0

ORIGINAL CREEP AND RUPTURE DATA

TEMP. °F.	STRESS, 1000 P.S.I.	DURATION, HOURS(3)	INTERCEPT, %(4)	MINIMUM CREEP RATE, %/HR.	TRANSITION TIME, HRS.(5)	TOTAL EXT. (CREEP TEST), %	TOTAL ELONG. (RUPTURE TEST), %	HARDNESS AFTER TESTING
1000	63.0	49 R					32.0	
1000	55.0	638 R	0.85	0.0048	300		27.0	
1100	45.0	113 R					31.0	
1100	35.0	1333 R	0.77	0.0022	750		22.0	
1000	25.0	2016	0.135	0.000198	1650?	0.570		
1100	15.0	2064	0.192	0.000164	1100?	0.620		
1100	11.0	2016	0.144	0.000080	--	0.305		
1100	8.0	2016	0.110	0.000039	--	0.189		

(5)

ASTM-ASME JOINT COMMITTEE ON EFFECT OF TEMPERATURE ON PROPERTIES OF METALS

TYPE OF MATERIAL	13 Cr, 2 Ni, 3 W			TYPE OF MELTING FURNACE	Electric			SIZE OF HEAT	Commercial				
CHEMICAL COMPOSITION, PER CENT	C	Mn	P	S	Si	Cr	Ni	Mo	Al	W	Cu		
	0.12	0.35			0.31	12.88	1.98	0.05	0.04	2.86	0.11		
DEOXIDATION													
FORM-CAST OR WROUGHT	Hot Rolled 1" Bars Annealed												
HEAT TREATMENT	1800 F, 2 Hr, A.C.; 1050 F, 2 Hr, A.C.												
MICROSTRUCTURE													
GRAIN SIZE							HARDNESS	36 R_C					
SOURCE OF DATA	NACA Lewis Laboratory												

SHORT TIME TENSILE PROPERTIES

TEMPERATURE, °F	MODULUS OF ELASTICITY, 1,000,000 P.S.I.	OFFSET YIELD (1) STRENGTH, 1000 P.S.I.	TENSILE STRENGTH, 1000 P.S.I.	ELONGATION IN 2", PER CENT	REDUCTION IN AREA, PER CENT
1000			102.0		70
1100			78.4		76

CREEP AND RUPTURE STRENGTHS

TEMP., °F	STRESS FOR RUPTURE IN TIMES INDICATED, 1000 P.S.I.(2)				STRESS FOR DESIGNATED CREEP RATE, 1000 P.S.I.(2)		
	100 HRS.	1000 HRS.	10,000 HRS.	100,000 HRS.	0.000001 %/HR.	0.00001 %/HR.	0.0001 %/HR.
1000	57	42					
1100	38	21					
1200	19	10					

ORIGINAL CREEP AND RUPTURE DATA

TEMP. °F.	STRESS, 1000 P.S.I.	DURATION, HOURS(3)	INTERCEPT, %(4)	MINIMUM CREEP RATE, %/HR.	TRANSITION TIME, HRS.(5)	TOTAL EXT. (CREEP TEST), %	TOTAL ELONG. (RUPTURE TEST), %	REDUCTION IN AREA, %
1000	40.0	1687 R						21.0
1000	45.0	649 R						36.0
1000	50.0	308 R						44.1
1000	54.0	188 R						53.5
1000	58.0	65.5 R						66.0
1000	68.0	7.4 R						73.0
1000	77.0	2.8 R						65.0
1000	90.0	0.13R						66.0
1100	20.0	834 R						12.0
1100	25.0	662 R						12.0
1100	29.0	421 R						21.0
1100	34.0	178 R						30.0
1100	37.0	100 R						40.0
1100	40.0	36.9 R						59.0
1100	44.0	8.6 R						69.0
1100	50.0	1.3 R						78.0
1200	8.0	1493 R						20.0
1200	10.0	848 R						21.0
1200	15.0	225 R						24.0
1200	20.0	78.1 R						32.0
1200	24.0	31.1 R						50.0
1200	27.0	13.2 R						63.0
1200	30.0	2.2 R						74.0
1200	36.0	0.4 R						78.0

(6)

ASTM-ASME JOINT COMMITTEE ON EFFECT OF TEMPERATURE ON PROPERTIES OF METALS

TYPE OF MATERIAL	13 Cr, 2 Ni, 3 W			TYPE OF MELTING FURNACE				SIZE OF HEAT	Commercial			
CHEMICAL COMPOSITION, PER CENT	C	Mn	P	S	Si	Cr	Ni	Mo	W			
	0.17	0.28			0.28	12.03	1.78		2.93			
DEOXIDATION												
FORM-CAST OR WROUGHT												
HEAT TREATMENT	2012 F, 4 Hr, A.C.; 1202 F, 4 Hr, A.C.; 1112 F, 2 Hr, F.C.											
MICROSTRUCTURE												
GRAIN SIZE							HARDNESS					
SOURCE OF DATA	General Electric Company											

SHORT TIME TENSILE PROPERTIES

TEMPERATURE, °F	MODULUS OF ELASTICITY, 1,000,000 P.S.I.	OFFSET (a) YIELD (1) STRENGTH, 1000 P.S.I.	TENSILE STRENGTH, 1000 P.S.I.	ELONGATION IN 2", PER CENT	REDUCTION IN AREA, PER CENT
80		87.5	143.4	16.4	40
(a) 0.02% Offset yield strength.					

CREEP AND RUPTURE STRENGTHS

TEMP., °F	STRESS FOR RUPTURE IN TIMES INDICATED, 1000 P.S.I.(2)				STRESS FOR DESIGNATED CREEP RATE, 1000 P.S.I.(2)		
	100 HRS.	1000 HRS.	10,000 HRS.	100,000 HRS.	0.000001 %/HR.	0.00001 %/HR.	0.0001 %/HR.
900		60P	54P	47P			
1000		47P	37P	28P			
1100		28P					
		30	19*	12*			

P indicates strength value obtained by use of Larson-Miller parameter T(25 + log t).

ORIGINAL CREEP AND RUPTURE DATA

TEMP. °F.	STRESS, 1000 P.S.I.	DURATION, HOURS(3)	INTERCEPT, %(4)	MINIMUM CREEP RATE, %/HR.	TRANSITION TIME, HRS.(5)	TOTAL EXT. (CREEP TEST), %	TOTAL ELONG. (RUPTURE TEST), %	HARDNESS AFTER TESTING
1000	60.0	8.0 R						
1000	50.0	295.0 R						
1000	40.0	5500 R						
1100	40.0	58 R						
1100	30.0	1000 R						
1100	25.0	2650 R						
1100	20.0	7300 R						

(1) 0.2 PER CENT OFFSET UNLESS OTHERWISE INDICATED.

(2) EXTRAPOLATED VALUES INDICATED BY *

(3) DURATION OF TEST (RUPTURE TEST INDICATED BY R).

(4) THE INTERCEPT IS THE PROJECTION BACK TO ZERO TIME FROM THE PORTION OF THE TEST SHOWING THE MINIMUM OR SECOND-STAGE CREEP RATE.

(5) THE TRANSITION TIME IS THE BEGINNING OF THE THIRD STAGE, OR AN ACCELERATING CREEP RATE.

(7)

ASTM-ASME JOINT COMMITTEE ON EFFECT OF TEMPERATURE ON PROPERTIES OF METALS

TYPE OF MATERIAL 13 Cr, 2 Ni, 3 W					TYPE OF MELTING FURNACE			SIZE OF HEAT Commercial			
CHEMICAL COMPOSITION, PER CENT	C	Mn	P	S	Si	Cr	Ni	Mo	W		
	0.12	0.67			0.37	12.90	2.1		3.1		
DEOXIDATION											
FORM-CAST OR WROUGHT											
HEAT TREATMENT 1800 F, OQ - 1000 F, A.C.; 1000 F, A.C.											
MICROSTRUCTURE											
GRAIN SIZE						HARDNESS					
SOURCE OF DATA General Electric Company											

SHORT TIME TENSILE PROPERTIES

TEMPERATURE, °F	MODULUS OF ELASTICITY, 1,000,000 P.S.I.	OFFSET YIELD (1) STRENGTH, 1000 P.S.I.	TENSILE STRENGTH, 1000 P.S.I.	ELONGATION IN 2", PER CENT	REDUCTION IN AREA, PER CENT

CREEP AND RUPTURE STRENGTHS

TEMP., °F	STRESS FOR RUPTURE IN TIMES INDICATED, 1000 P.S.I.(2)				STRESS FOR DESIGNATED CREEP RATE, 1000 P.S.I.(2)		
	100 HRS.	1000 HRS.	10,000 HRS.	100,000 HRS.	0.000001 %/HR.	0.00001 %/HR.	0.0001 %/HR.
900			65P	50P			
1000		50P					
		53	29*	16*			

P indicates strength value obtained by use of Larson-Miller parameter T(25 + log t).

ORIGINAL CREEP AND RUPTURE DATA

TEMP., °F	STRESS, 1000 P.S.I.	DURATION, HOURS(3)	INTERCEPT, %(4)	MINIMUM CREEP RATE, %/HR.	TRANSITION TIME, HRS.(5)	TOTAL EXT. (CREEP TEST), %	TOTAL ELONG. (RUPTURE TEST), %	HARDNESS AFTER TESTING
1000	65.0	138 R					10.0	
1000	55.0	700 R					8.0	
1000	45.0	1550 R					8.0	
1000	40.0	3450 R					5.0	
1000	35.0	4500 R					4.0	

(8)

ASTM-ASME JOINT COMMITTEE ON EFFECT OF TEMPERATURE ON PROPERTIES OF METALS

TYPE OF MATERIAL 13 Cr, 2 Ni, 3 W					TYPE OF MELTING FURNACE			SIZE OF HEAT			
CHEMICAL COMPOSITION, PER CENT	C	Mn	P	S	Si	Cr	Ni	Mo	W		
	0.15					13.0	2.0		3.0		
DEOXIDATION											
FORM-CAST OR WROUGHT											
HEAT TREATMENT 1750 F, 1/2 Hr, OQ; 1200 F, 4 Hr, A.C.											
MICROSTRUCTURE											
GRAIN SIZE *						HARDNESS 28 R_C					
SOURCE OF DATA Firth-Sterling Steel and Carbide Corp.											

CREEP AND RUPTURE STRENGTHS

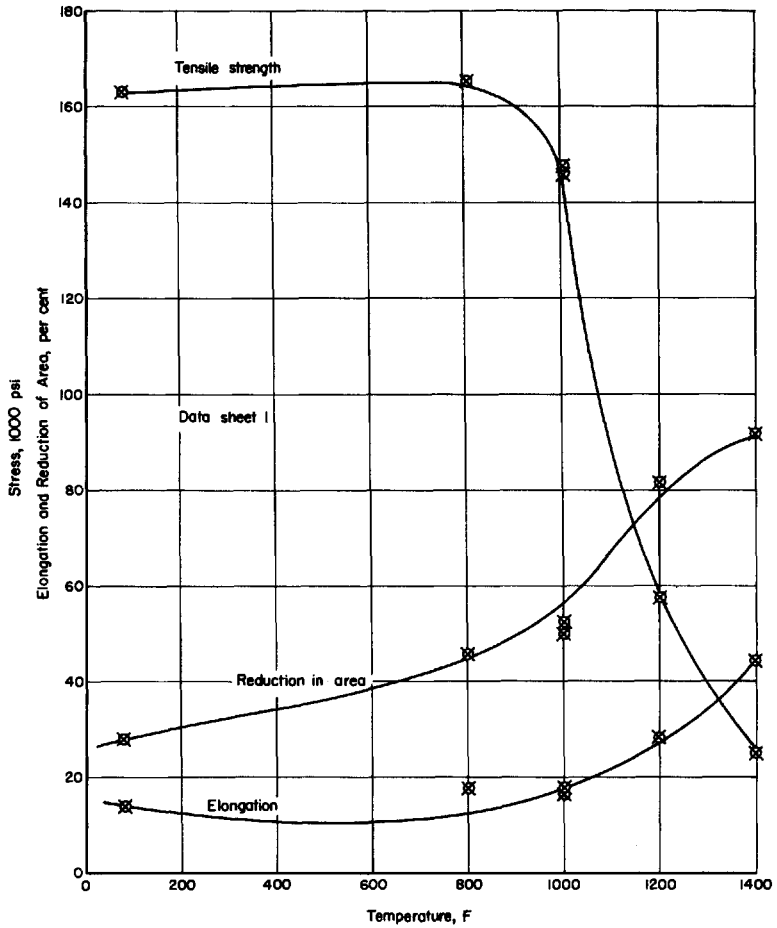
TEMP., °F	STRESS FOR RUPTURE IN TIMES INDICATED, 1000 P.S.I.(2)				STRESS FOR DESIGNATED CREEP RATE, 1000 P.S.I.(2)		
	10 HRS.	100 HRS.	500 HRS.	1000 HRS.	0.000001 %/HR.	0.00001 %/HR.	0.0001 %/HR.
1050	48	42	39	38			
1200	25	17.5	11				
Notched: 60°, 50% reduction of area, 0.005" radius.							
1050	71	60	54				
1200	32	22	13.5				

ORIGINAL CREEP AND RUPTURE DATA

TEMP., °F	STRESS, 1000 P.S.I.	DURATION, HOURS(3)	INTERCEPT, %(4)	MINIMUM CREEP RATE, %/HR.	TRANSITION TIME, HRS.(5)	TOTAL EXT. (CREEP TEST), %	TOTAL ELONG. (RUPTURE TEST), %	REDUCTION IN AREA, %
				Heat S-509				
1050	50.0	2.8 R					27.2	77.7
1050	47.0	12.3 R					22.0	77.5
1050	44.0	66.5 R					35.7	77.4
1050	38.0	760.9 R					32.2	77.0
1200	27.0	5.2 R					34.1	86.4
1200	20.0	55.3 R					27.3	--
1200	18.0	90.7 R					29.5	--
1200	16.0	149.1 R					29.3	84.3
1200	14.0	287.4 R					53.2	87.2
1200	12.0	417.2 R					42.5	81.8
				Heat S-509 Notched				
1050	70.0	13.8						
1050	65.0	49.5						
1050	60.0	146.4						
1050	55.0	220.9						
	55.0	312.9						
1200	32.0	12.4						
1200	30.0	18.3						
1200	24.0	61.2						
1200	20.0	148.4						
1200	15.0	325.9						
				Heat S-771				
1050	57.0	1.3					31.0	78.0
1050	44.0	75.4					27.9	82.1
1050	41.0	136.8					29.0	81.8
1200	27.0	2.7					33.3	85.0
1200	24.0	6.3					23.6	88.0
1200	20.0	55.9					25.0	--
1200	18.0	109.7					36.0	85.5
1200	16.0	161.0					25.6	88.1
1200	14.0	296.9					44.8	91.4
1200	12.0	343.3					38.5	90.2
				Heat S-771 Notched				
1050	70.0	20.3						
1050	65.0	39.2						
1050	60.0	225.5						
1050	55.0	321.5						
1200	34.0	0.05						
1200	30.0	36.7						
1200	24.0	70.7						
1200	20.0	197.0						
1200	15.0	438.5						

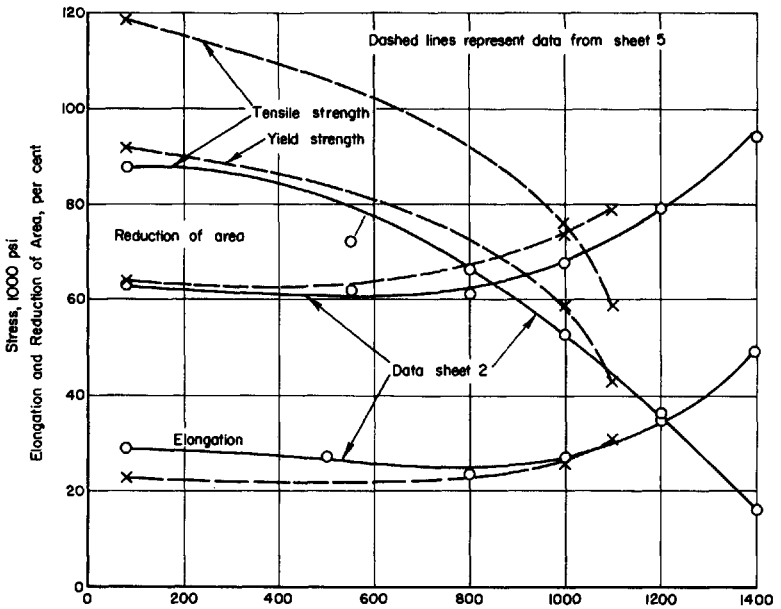
(1) 0.2 PER CENT OFFSET UNLESS OTHERWISE INDICATED.
(2) EXTRAPOLATED VALUES INDICATED BY *
(3) DURATION OF TEST (RUPTURE TEST INDICATED BY R).
(4) THE INTERCEPT IS THE PROJECTION BACK TO ZERO TIME FROM THE PORTION OF THE TEST SHOWING THE MINIMUM OR SECOND-STAGE CREEP RATE.
(5) THE TRANSITION TIME IS THE BEGINNING OF THE THIRD STAGE, OR AN ACCELERATING CREEP RATE.

12 Chromium, 3 Tungsten Steels



SHORT-TIME TENSILE DATA

12 Cr, 3 W STEEL



SHORT-TIME TENSILE DATA

12 Cr, 3 W STEEL

(1)

ASTM-ASME JOINT COMMITTEE ON EFFECT OF TEMPERATURE ON PROPERTIES OF METALS

TYPE OF MATERIAL	12 Cr, 3 W			TYPE OF MELTING FURNACE				SIZE OF HEAT				
CHEMICAL COMPOSITION, PER CENT	C	Mn	P	S	Si	Cr	Ni	Mo	W		
	0.09	0.57			0.37	12.0			3.0		
DEOXIDATION											
FORM-CAST OR WROUGHT	1" Bars, Wrought										
HEAT TREATMENT	Normalized 2000 F										
MICROSTRUCTURE											
GRAIN SIZE					HARDNESS	315 BHN					
SOURCE OF DATA	Compilation of Available High Temperature Creep Characteristics of Metals & Alloys, ASME-ASTM, 1938.										

SHORT TIME TENSILE PROPERTIES

TEMPERATURE, °F	MODULUS OF ELASTICITY, 1,000,000 P.S.I.	OFFSET YIELD (1) STRENGTH, 1000 P.S.I.	TENSILE STRENGTH, 1000 P.S.I.	ELONGATION IN 2", PER CENT	REDUCTION IN AREA, PER CENT
70			163.0	14.0	28.6
800			165.4	17.5	45.5
1000			147.2	18.0	52.2
1000			146.6	17.0	49.8
1200			57.8	28.5	81.5
1400			25.0	44.0	91.1

CREEP AND RUPTURE STRENGTHS

TEMP., °F	STRESS FOR RUPTURE IN TIMES INDICATED, 1000 P.S.I.(2)				STRESS FOR DESIGNATED CREEP RATE, 1000 P.S.I.(2)		
	100 HRS.	1000 HRS.	10,000 HRS.	100,000 HRS.	0.000001 %/HR.	0.00001 %/HR.	0.0001 %/HR.

ORIGINAL CREEP AND RUPTURE DATA

TEMP. °F	STRESS, 1000 P.S.I.	DURATION, HOURS(3)	INTERCEPT, %(4)	MINIMUM CREEP RATE, %/HR.	TRANSITION TIME, HRS.(5)	TOTAL EXT. (CREEP TEST), %	TOTAL ELONG. (RUPTURE TEST), %	HARDNESS AFTER TESTING
800	30.0	250	0.025	0.000017		0.029		
900*	30.0	500	0.107	0.000136		0.171		
1000*	30.0	500	0.400	0.00058		0.685		
1200	3.0	250	0.039	0.000084		0.059		
1200*	10.0	250	0.174	0.000456		0.286		
1300	3.0	250	0.025	0.000121		0.086		

(2)

ASTM-ASME JOINT COMMITTEE ON EFFECT OF TEMPERATURE ON PROPERTIES OF METALS

TYPE OF MATERIAL	12 Cr, 3 W			TYPE OF MELTING FURNACE				SIZE OF HEAT				
CHEMICAL COMPOSITION, PER CENT	C	Mn	P	S	Si	Cr	Ni	Mo	W		
	0.09	0.57			0.37	12.0			3.0		
DEOXIDATION											
FORM-CAST OR WROUGHT	Wrought 1" Bars										
HEAT TREATMENT	Annealed 1550 F										
MICROSTRUCTURE											
GRAIN SIZE					HARDNESS	180 BHN					
SOURCE OF DATA	Compilation of Available High Temperature Creep Characteristics of Metals & Alloys, ASME-ASTM, 1938.										

SHORT TIME TENSILE PROPERTIES

TEMPERATURE, °F	MODULUS OF ELASTICITY, 1,000,000 P.S.I.	OFFSET YIELD (1) STRENGTH, 1000 P.S.I.	TENSILE STRENGTH, 1000 P.S.I.	ELONGATION IN 2", PER CENT	REDUCTION IN AREA, PER CENT
70			87.7	29.5	63.5
550			72.4	27.5	62.1
800			66.4	23.5	61.1
1000			53.8	27.2	67.9
1200			36.9	35.0	79.7
1400			16.5	50.0	94.5

CREEP AND RUPTURE STRENGTHS

TEMP., °F	STRESS FOR RUPTURE IN TIMES INDICATED, 1000 P.S.I.(2)				STRESS FOR DESIGNATED CREEP RATE, 1000 P.S.I.(2)		
	100 HRS.	1000 HRS.	10,000 HRS.	100,000 HRS.	0.000001 %/HR.	0.00001 %/HR.	0.0001 %/HR.

ORIGINAL CREEP AND RUPTURE DATA

TEMP. °F	STRESS, 1000 P.S.I.	DURATION, HOURS(3)	INTERCEPT, %(4)	MINIMUM CREEP RATE, %/HR.	TRANSITION TIME, HRS.(5)	TOTAL EXT. (CREEP TEST), %	TOTAL ELONG. (RUPTURE TEST), %	HARDNESS AFTER TESTING
900	30.0	250	0.100	0.000167		0.141		
1200*	3.0	250	0.007	0.000083		0.028		
1300	3.0	250	0.095	0.000092		0.118		
1400	1.0*	500	0.042	0.000290		0.093		
1400	3.0*	500	0	0.00178		0.890		
1500	1.0	500	0.056	0.000660		0.391		

(3) DURATION OF TEST (RUPTURE TEST INDICATED BY R).

(4) THE INTERCEPT IS THE PROJECTION BACK TO ZERO TIME FROM THE PORTION OF THE TEST SHOWING THE MINIMUM OR SECOND-STAGE CREEP RATE.

(5) THE TRANSITION TIME IS THE BEGINNING OF THE THIRD STAGE, OR AN ACCELERATING CREEP RATE.

(3)

ASTM-ASME JOINT COMMITTEE ON EFFECT OF TEMPERATURE ON PROPERTIES OF METALS

TYPE OF MATERIAL	12 Cr, 3 W			TYPE OF MELTING FURNACE				SIZE OF HEAT				
CHEMICAL COMPOSITION, PER CENT	C	Mn	P	S	Si	Cr	Ni	Mo	W		
	0.08	0.43	0.012	0.016	0.113	11.61	0.114		3.01		
DEOXIDATION											
FORM-CAST OR WROUGHT	Wrought Bar 1 x 4" x 5' Plate										
HEAT TREATMENT	Furnace Cooled 1472 F										
MICROSTRUCTURE											
GRAIN SIZE					HARDNESS						
SOURCE OF DATA	Compilation of Available High Temperature Creep Characteristics of Metals & Alloys, ASME-ASTM, 1938										

SHORT TIME TENSILE PROPERTIES

TEMPERATURE, °F	MODULUS OF ELASTICITY, 1,000,000 P.S.I.	OFFSET YIELD (1) STRENGTH, 1000 P.S.I.	TENSILE STRENGTH, 1000 P.S.I.	ELONGATION IN 2", PER CENT	REDUCTION IN AREA, PER CENT
80			99.2	25.5	66.8

CREEP AND RUPTURE STRENGTHS

TEMP., °F	STRESS FOR RUPTURE IN TIMES INDICATED, 1000 P.S.I.(2)				STRESS FOR DESIGNATED CREEP RATE, 1000 P.S.I.(2)		
	100 HRS.	1000 HRS.	10,000 HRS.	100,000 HRS.	0.000001 %/HR.	0.00001 %/HR.	0.0001 %/HR.

(1) 0.2 PER CENT OFFSET UNLESS OTHERWISE INDICATED.

(2) EXTRAPOLATED VALUES INDICATED BY *

ORIGINAL CREEP AND RUPTURE DATA

TEMP, °F	STRESS, 1000 P.S.I.	DURATION, HOURS(3)	INTERCEPT, %(4)	MINIMUM CREEP RATE, %/HR.	TRANSITION TIME, HRS.(5)	TOTAL EXT. (CREEP TEST), %	TOTAL ELONG. (RUPTURE TEST), %	HARDNESS AFTER TESTING
1022	7.5	9700	0.182	0.000001		0.193		
1022	10.0	9700	0.332	0.000005		0.382		
1022	12.5	9700	0.527	0.000004		0.574		
1022	15.0	700	0.582	0.000235		0.740		

(3) DURATION OF TEST (RUPTURE TEST INDICATED BY R).
(4) THE INTERCEPT IS THE PROJECTION BACK TO ZERO TIME FROM THE PORTION OF THE TEST SHOWING THE MINIMUM OR SECOND-STAGE CREEP RATE.
(5) THE TRANSITION TIME IS THE BEGINNING OF THE THIRD STAGE, OR AN ACCELERATING CREEP RATE.

(4)

ASTM-ASME JOINT COMMITTEE ON EFFECT OF TEMPERATURE ON PROPERTIES OF METALS

TYPE OF MATERIAL	12 Cr, 3 W	TYPE OF MELTING FURNACE					SIZE OF HEAT				
CHEMICAL COMPOSITION, PER CENT	C	Mn	P	S	Si	Cr	Ni	Mo	W		
	0.09	0.32			0.34	13.05			2.76		
DEOXIDATION											
FORM-CAST OR WROUGHT	Wrought										
HEAT TREATMENT	Annealed										
MICROSTRUCTURE											
GRAIN SIZE							HARDNESS				
SOURCE OF DATA	"Properties of Carbon & Alloy Seamless Steel Tubing for High Temperature and High Pressure Service," Babcock & Wilcox Tube Company.										

SHORT TIME TENSILE PROPERTIES

TEMPERATURE, °F	MODULUS OF ELASTICITY, 1,000,000 P.S.I.	OFFSET YIELD (1) STRENGTH, 1000 P.S.I.	TENSILE STRENGTH, 1000 P.S.I.	ELONGATION IN 2", PER CENT	REDUCTION IN AREA, PER CENT

CREEP AND RUPTURE STRENGTHS

TEMP, °F	STRESS FOR RUPTURE IN TIMES INDICATED, 1000 P.S.I.(2)				STRESS FOR DESIGNATED CREEP RATE, 1000 P.S.I.(2)		
	100 HRS.	1000 HRS.	10,000 HRS.	100,000 HRS.	0.000001 %/HR.	0.00001 %/HR	0.0001 %/HR.
1200						3.0	5.2

(1) 0.2 PER CENT OFFSET UNLESS OTHERWISE INDICATED.
(2) EXTRAPOLATED VALUES INDICATED BY *

(5)

ASTM-ASME JOINT COMMITTEE ON EFFECT OF TEMPERATURE ON PROPERTIES OF METALS

TYPE OF MATERIAL	12 Cr, 3 W (Type 418)	TYPE OF MELTING FURNACE					SIZE OF HEAT	Commercial			
CHEMICAL COMPOSITION, PER CENT	C	Mn	P	S	Si	Cr	Ni	Mo	W		
	0.10	0.39	0.010	0.021	0.33	13.23	0.27		3.09		
DEOXIDATION											
FORM-CAST OR WROUGHT	7/8" Wrought Bars										
HEAT TREATMENT	1800 F, 1 Hr, OQ; 1200 F, 1 Hr, A.C.										
MICROSTRUCTURE	--										
GRAIN SIZE							HARDNESS	235 BHN			
SOURCE OF DATA	U.S.N. Engineering Experiment Station										

SHORT TIME TENSILE PROPERTIES

TEMPERATURE, °F	MODULUS OF ELASTICITY, 1,000,000 P.S.I.	OFFSET YIELD (1) STRENGTH, 1000 P.S.I.	TENSILE STRENGTH, 1000 P.S.I.	ELONGATION IN 2", PER CENT	REDUCTION IN AREA, PER CENT
RT		92.0	118.6	23	64
1000		58.8	76.2	26	74
1100		43.0	58.8	31	79

CREEP AND RUPTURE STRENGTHS

TEMP, °F	STRESS FOR RUPTURE IN TIMES INDICATED, 1000 P.S.I.(2)				STRESS FOR DESIGNATED CREEP RATE, 1000 P.S.I.(2)		
	100 HRS.	1000 HRS.	10,000 HRS.	100,000 HRS.	0.000001 %/HR.	0.00001 %/HR.	0.0001 %/HR.
1000	51	47					
1100	33	26					10

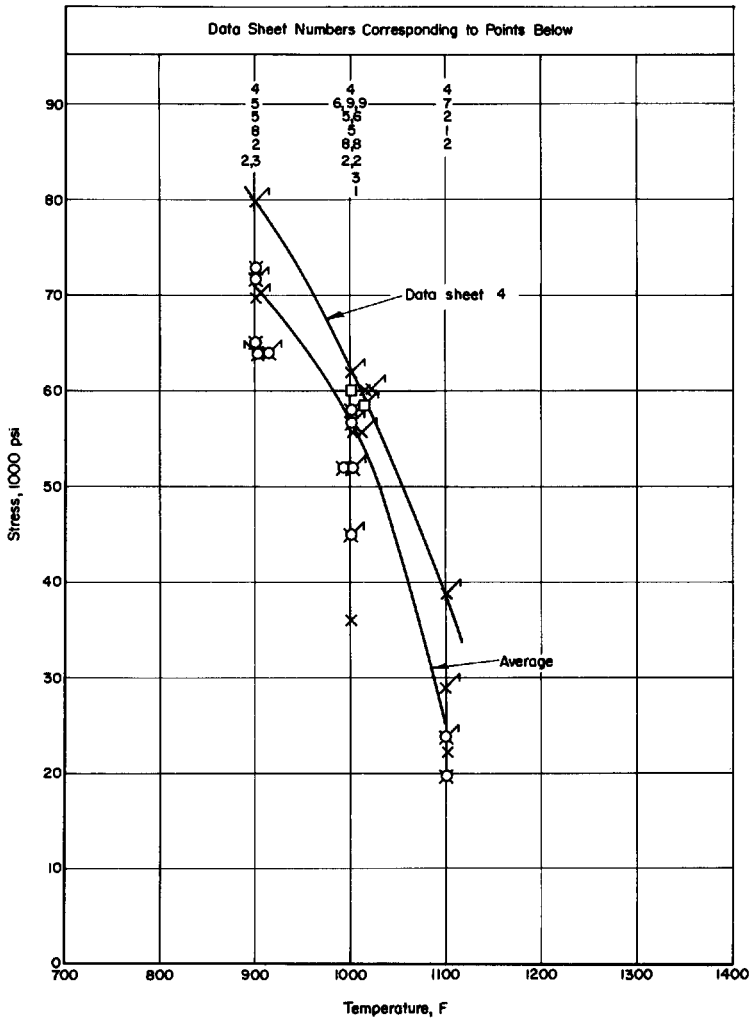
(1) 0.2 PER CENT OFFSET UNLESS OTHERWISE INDICATED.
(2) EXTRAPOLATED VALUES INDICATED BY *

ORIGINAL CREEP AND RUPTURE DATA

TEMP, °F	STRESS, 1000 P.S.I.	DURATION, HOURS(3)	INTERCEPT, %(4)	MINIMUM CREEP RATE, %/HR.	TRANSITION TIME, HRS.(5)	TOTAL EXT. (CREEP TEST), %	TOTAL ELONG. (RUPTURE TEST), %	HARDNESS AFTER TESTING
1000	55.0	19 R					19.0	
1000	48.0	729 R	0.38	0.014	100		29.0	
1100	35.0	62 R					35.0	
1100	33.0	95 R					45.0	
1100	27.0	879 R	2.14	0.0032	410		22.0	
1100	20.0	1800	0.51	0.00065	?	?		
1100	12.0	2016	0.227	0.00016	--	0.543		

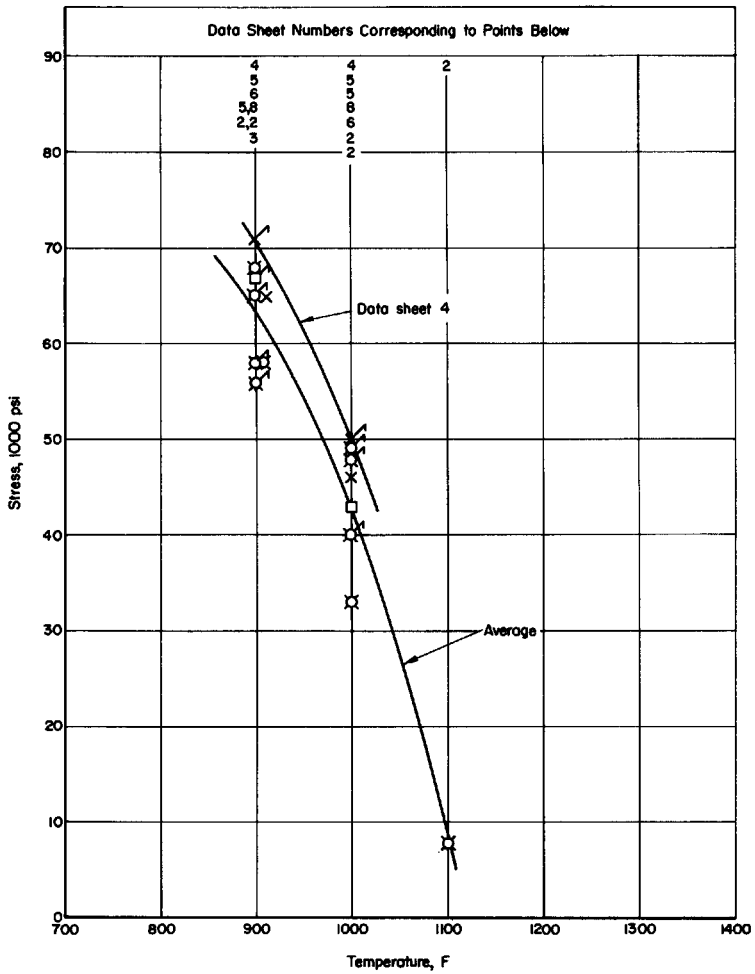
(3) DURATION OF TEST (RUPTURE TEST INDICATED BY R).
(4) THE INTERCEPT IS THE PROJECTION BACK TO ZERO TIME FROM THE PORTION OF THE TEST SHOWING THE MINIMUM OR SECOND-STAGE CREEP RATE.
(5) THE TRANSITION TIME IS THE BEGINNING OF THE THIRD STAGE, OR AN ACCELERATING CREEP RATE.

12 Chromium, Columbium Steels



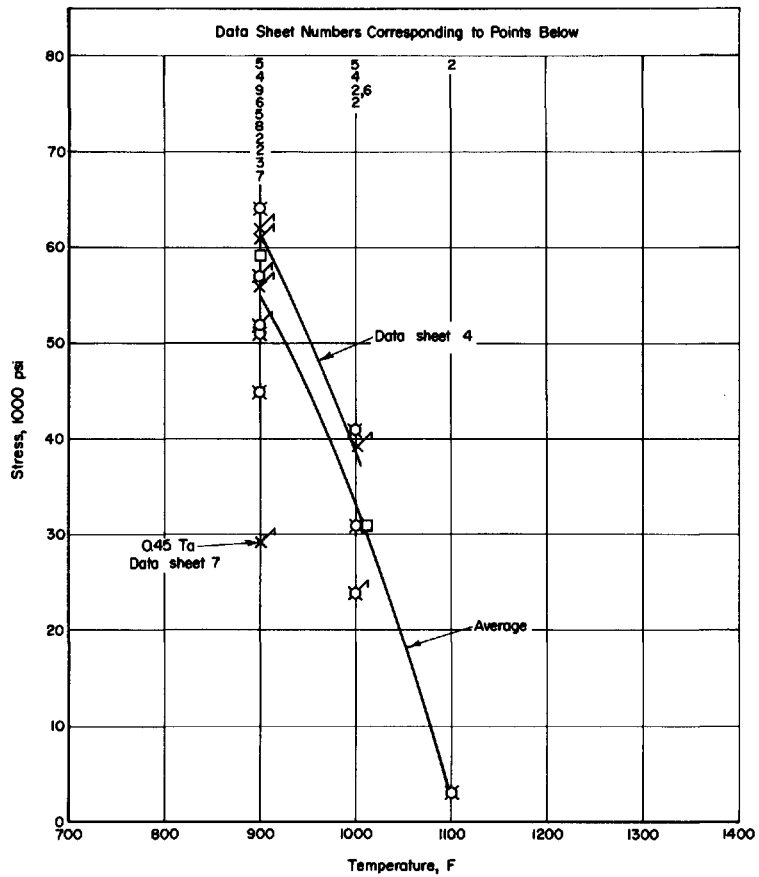
RUPTURE IN 1000 HOURS

12 Cr, Cb STEEL



RUPTURE IN 10,000 HOURS
(EXTRAPOLATED)

12 Cr, Cb STEEL



RUPTURE IN 100,000 HOURS
(EXTRAPOLATED)

12 Cr, Cb STEEL

(1)

ASTM-ASME JOINT COMMITTEE ON EFFECT OF TEMPERATURE ON PROPERTIES OF METALS

TYPE OF MATERIAL	12 Cr, Cb (Type 410 Cb)	TYPE OF MELTING FURNACE	--	SIZE OF HEAT	Commercial

CHEMICAL COMPOSITION, PER CENT	C	Mn	P	S	Si	Cr	Ni	Mo	Cb
	0.07	0.43	0.018	0.018	0.32	13.72	0.16		0.40

DEOXIDATION

FORM-CAST OR WROUGHT 1-1/8" Wrought Bars

HEAT TREATMENT 1800 F, 1 Hr, OQ; 1200 F, 1 Hr, A.C.

MICROSTRUCTURE

GRAIN SIZE HARDNESS 231 BHN

SOURCE OF DATA U.S.N. Engineering Experiment Station

SHORT TIME TENSILE PROPERTIES

TEMPERATURE, °F	MODULUS OF ELASTICITY, 1,000,000 P.S.I.	OFFSET YIELD (1) STRENGTH, 1000 P.S.I.	TENSILE STRENGTH, 1000 P.S.I.	ELONGATION IN 2", PER CENT	REDUCTION IN AREA, PER CENT
RT		84.6	103.0	24	70
1000		52.8	65.2	24	74
1100		41.6	52.0	28	79

CREEP AND RUPTURE STRENGTHS

TEMP., °F	STRESS FOR RUPTURE IN TIMES INDICATED, 1000 P.S.I.(2)				STRESS FOR DESIGNATED CREEP RATE, 1000 P.S.I.(2)		
	100 HRS.	1000 HRS.	10,000 HRS.	100,000 HRS.	0.000001 %/HR.	0.00001 %/HR.	0.0001 %/HR.
1000	41	36				13	20
1100	29	22				3.8	8.5

ORIGINAL CREEP AND RUPTURE DATA

TEMP. °F	STRESS, 1000 P.S.I.	DURATION, HOURS(3)	INTERCEPT, %(4)	MINIMUM CREEP RATE, %/HR.	TRANSITION TIME, HRS.(5)	TOTAL EXT. (CREEP TEST), %	TOTAL ELONG. (RUPTURE TEST), %	HARDNESS AFTER TESTING
1000	50.0	2 R					27.0	
1000	40.0	220 R	0.45	0.0095	100		26.0	
1000	37.0	794 R	0.53	0.0044	250		32.0	
1100	35.0	9 R					24.0	
1100	30.0	79 R					33.0	
1100	26.0	277 R	0.16	0.0046	90		20.0	
1100	23.0	686 R	0.19	0.0032	275		32.0	
1000	20.0	2016	0.236	0.000062	--	0.363		
1000	15.0	2016	0.140	0.000031	--	0.202		
1100	17.0	840	0.287	0.00061	300	1.13		
1100	10.0	2040	0.062	0.00028	470	1.16		
1100	6.5	2040	0.042	0.000043	--	0.129		

(2)

ASTM-ASME JOINT COMMITTEE ON EFFECT OF TEMPERATURE ON PROPERTIES OF METALS

TYPE OF MATERIAL	12 Cr, Cb	TYPE OF MELTING FURNACE	Induction	SIZE OF HEAT	Experimental

CHEMICAL COMPOSITION, PER CENT	C	Mn	P	S	Si	Cr	Ni	Mo	Cb
	0.09	0.42			0.42	13.42	0.77		0.32

DEOXIDATION

FORM-CAST OR WROUGHT

HEAT TREATMENT 2012 F, 2 Hr, A.C.; 1200 F, 2 Hr, F.C.

MICROSTRUCTURE

GRAIN SIZE HARDNESS

SOURCE OF DATA General Electric Company

SHORT TIME TENSILE PROPERTIES

TEMPERATURE, °F	MODULUS OF ELASTICITY, 1,000,000 P.S.I.	OFFSET YIELD (1) STRENGTH, 1000 P.S.I.	TENSILE STRENGTH, 1000 P.S.I.	ELONGATION IN 2", PER CENT	REDUCTION IN AREA, PER CENT
80			137.9	16	49

CREEP AND RUPTURE STRENGTHS

TEMP., °F	STRESS FOR RUPTURE IN TIMES INDICATED, 1000 P.S.I.(2)				STRESS FOR DESIGNATED CREEP RATE, 1000 P.S.I.(2)		
	100 HRS.	1000 HRS.	10,000 HRS.	100,000 HRS.	0.000001 %/HR.	0.00001 %/HR.	0.0001 %/HR.
900		65P	58P	52P			
		64	58*	51*			
1000		52P	40P	24P			
		52	33*	31*			
1100		24P					
		20	8*	3.1*			

P indicates strength value obtained by use of Larson-Miller parameter T(23 + log t).

ORIGINAL CREEP AND RUPTURE DATA

TEMP. °F	STRESS, 1000 P.S.I.	DURATION, HOURS(3)	INTERCEPT, %(4)	MINIMUM CREEP RATE, %/HR.	TRANSITION TIME, HRS.(5)	TOTAL EXT. (CREEP TEST), %	TOTAL ELONG. (RUPTURE TEST), %	REDUCTION IN AREA, %
900	78.0	11 R					7.5	
900	72.0	430 R					7.5	
900	66.0	3000 R					7.5	
900	63.0	1100 R					7.0	
900	60.0	4000 R					5.5	
1000	70.0	1.5R					8.2	
1000	64.0	178					6.0	
1000	58.0	580 R					9.0	
1000	52.0	870 R					6.0	
1000	47.0	1700 R					8.0	
1000	40.0	3700 R					9.0	
1100	46.0	150 R					4.0	
1100	26.0	540 R					9.0	
1100	14.0	2600 R					17.0	
1200	20.0	46 R					12.5	78.0

(3)

ASTM-ASME JOINT COMMITTEE ON EFFECT OF TEMPERATURE ON PROPERTIES OF METALS

TYPE OF MATERIAL	12 Cr, Cb	TYPE OF MELTING FURNACE	Induction	SIZE OF HEAT	Experimental

CHEMICAL COMPOSITION, PER CENT	C	Mn	P	S	Si	Cr	Ni	Mo	Cb
	0.06	0.50			0.40	12.17	0.70		0.30

DEOXIDATION

FORM-CAST OR WROUGHT

HEAT TREATMENT 2012 F, 2 Hr, A.C.; 1200 F, 2 Hr, F.C.

MICROSTRUCTURE

GRAIN SIZE HARDNESS

SOURCE OF DATA General Electric Company

SHORT TIME TENSILE PROPERTIES

TEMPERATURE, °F	MODULUS OF ELASTICITY, 1,000,000 P.S.I.	OFFSET YIELD (1) STRENGTH, 1000 P.S.I.	TENSILE STRENGTH, 1000 P.S.I.	ELONGATION IN 2", PER CENT	REDUCTION IN AREA, PER CENT
80			117.0	21	62

CREEP AND RUPTURE STRENGTHS

TEMP., °F	STRESS FOR RUPTURE IN TIMES INDICATED, 1000 P.S.I.(2)				STRESS FOR DESIGNATED CREEP RATE, 1000 P.S.I.(2)		
	100 HRS.	1000 HRS.	10,000 HRS.	100,000 HRS.	0.000001 %/HR.	0.00001 %/HR.	0.0001 %/HR.
900		64P	56P	45P			
1000		45P					

P indicates strength value obtained by use of Larson-Miller parameter T(23 + log t).

ORIGINAL CREEP AND RUPTURE DATA

TEMP. °F	STRESS, 1000 P.S.I.	DURATION, HOURS(3)	INTERCEPT, %(4)	MINIMUM CREEP RATE, %/HR.	TRANSITION TIME, HRS.(5)	TOTAL EXT. (CREEP TEST), %	TOTAL ELONG. (RUPTURE TEST), %	REDUCTION IN AREA, %
1000	66.0	2.5 R					12.0	57.0
1000	58.0	72 R					6.0	54.0
1000	56.0	247 R					2.0	11.0
1000	52.0	114 R					8.0	71.0
1000	48.0	325 R					6.0	69.0
1100	46.0	22 R					7.0	50.0
1000	42.0	1640 R					9.0	77.0
1000	38.0	2468 R					6.0	73.0

(1) 0.2 PER CENT OFFSET UNLESS OTHERWISE INDICATED.

(2) EXTRAPOLATED VALUES INDICATED BY *

(3) DURATION OF TEST (RUPTURE TEST INDICATED BY R).

(4) THE INTERCEPT IS THE PROJECTION BACK TO ZERO TIME FROM THE PORTION OF THE TEST SHOWING THE MINIMUM OR SECOND-STAGE CREEP RATE.

(5) THE TRANSITION TIME IS THE BEGINNING OF THE THIRD STAGE, OR AN ACCELERATING CREEP RATE.

(4)

ASTM-ASME JOINT COMMITTEE ON EFFECT OF TEMPERATURE ON PROPERTIES OF METALS

TYPE OF MATERIAL	12 Cr, Cb	TYPE OF MELTING FURNACE	Induction	SIZE OF HEAT	Experimental

CHEMICAL COMPOSITION, PER CENT	C	Mn	P	S	Si	Cr	Ni	Mo	Cb
	0.11	0.49	0.011	0.015	0.38	12.09	0.12		0.32

DEOXIDATION

FORM-CAST OR WROUGHT

HEAT TREATMENT 2125 F, 1/2 Hr, OQ; 1200 F, 2 Hr, A.C.; 1200 F, 2 Hr, A.C.

MICROSTRUCTURE

GRAIN SIZE | HARDNESS

SOURCE OF DATA General Electric Company

SHORT TIME TENSILE PROPERTIES

TEMPERATURE, °F	MODULUS OF ELASTICITY, 1,000,000 P.S.I.	OFFSET (a) YIELD (1) STRENGTH, 1000 P.S.I.	TENSILE STRENGTH, 1000 P.S.I.	ELONGATION IN 2", PER CENT	REDUCTION IN AREA, PER CENT
80		103.5	143.5	18	60

(a) 0.02% Offset yield strength.

CREEP AND RUPTURE STRENGTHS

TEMP., °F	STRESS FOR RUPTURE IN TIMES INDICATED, 1000 P.S.I.(2)				STRESS FOR DESIGNATED CREEP RATE, 1000 P.S.I.(2)		
	100 HRS.	1000 HRS.	10,000 HRS.	100,000 HRS.	0.000001 %/HR.	0.00001 %/HR.	0.0001 %/HR.
900		80P	71P	62P			
1000		62P	50P	39P			
1100		39P	--	--			

P indicates strength value obtained by use of Larson-Miller parameter T(25 + log t).

ORIGINAL CREEP AND RUPTURE DATA

TEMP, °F.	STRESS, 1000 P.S.I.	DURATION, HOURS(3)	INTERCEPT, %(4)	MINIMUM CREEP RATE, %/HR.	TRANSITION TIME, HRS.(5)	TOTAL EXT. (CREEP TEST), %	TOTAL ELONG. (RUPTURE TEST), %	REDUCTION IN AREA, %
1000	65.0	414 R					7.0	62.0
1000	60.0	1196 R					6.0	52.0
1000	55.0	2394 R					5.0	45.0
1200	45.0	12.0 R					6.0	21.0
1200	40.5	19.9 R					9.0	25.0
1200	32.25	41.5 R					7.0	14.0

(5)

ASTM-ASME JOINT COMMITTEE ON EFFECT OF TEMPERATURE ON PROPERTIES OF METALS

TYPE OF MATERIAL	12 Cr, Cb	TYPE OF MELTING FURNACE	Induction	SIZE OF HEAT	Experimental

CHEMICAL COMPOSITION, PER CENT	C	Mn	P	S	Si	Cr	Ni	Mo	Cb
	0.09	0.30			0.36	12.72	0.39		0.32

DEOXIDATION

FORM-CAST OR WROUGHT Wrought 1" D

HEAT TREATMENT 2012 F, 2 Hr, A.C.; 1200 F, 2 Hr, F.C.

MICROSTRUCTURE

GRAIN SIZE | HARDNESS

SOURCE OF DATA General Electric Company

SHORT TIME TENSILE PROPERTIES

TEMPERATURE, °F	MODULUS OF ELASTICITY, 1,000,000 P.S.I.	OFFSET (1) YIELD STRENGTH, 1000 P.S.I.	TENSILE STRENGTH, 1000 P.S.I.	ELONGATION IN 2", PER CENT	REDUCTION IN AREA, PER CENT
80			131.9	18	56

CREEP AND RUPTURE STRENGTHS

TEMP, °F	STRESS FOR RUPTURE IN TIMES INDICATED, 1000 P.S.I.(2)				STRESS FOR DESIGNATED CREEP RATE, 1000 P.S.I.(2)		
	100 HRS.	1000 HRS.	10,000 HRS.	100,000 HRS.	0.000001 %/HR.	0.00001 %/HR.	0.0001 %/HR.
900		72P	65P	57P			
		73	68	64*			
1000		57P	48P				
		58	49*	41*			

P indicates strength value obtained by use of Larson-Miller parameter T(25 + log t).

ORIGINAL CREEP AND RUPTURE DATA

TEMP, °F.	STRESS, 1000 P.S.I.	DURATION, HOURS(3)	INTERCEPT, %(4)	MINIMUM CREEP RATE, %/HR.	TRANSITION TIME, HRS.(5)	TOTAL EXT. (CREEP TEST), %	TOTAL ELONG. (RUPTURE TEST), %	HARDNESS AFTER TESTING
900	82.0	17 R					6.0	
900	70.0	2500 R					7.0	
900	67.0	19100 R					1.9	
1000	66.0	33 R					6.0	
1000	58.0	790 R					7.0	
1000	52.0	4000 R					4.0	

(1) 0.2 PER CENT OFFSET UNLESS OTHERWISE INDICATED.

(2) EXTRAPOLATED VALUES INDICATED BY *

(6)

ASTM-ASME JOINT COMMITTEE ON EFFECT OF TEMPERATURE ON PROPERTIES OF METALS

TYPE OF MATERIAL	12 Cr, Cb	TYPE OF MELTING FURNACE		SIZE OF HEAT	Commercial

CHEMICAL COMPOSITION, PER CENT	C	Mn	P	S	Si	Cr	Ni	Mo	Cb
	0.12	0.42	0.012	0.010	0.32	12.10	0.27		0.31

DEOXIDATION

FORM-CAST OR WROUGHT Wheel and Shaft Forg.

HEAT TREATMENT

MICROSTRUCTURE

GRAIN SIZE | HARDNESS

SOURCE OF DATA General Electric Company

SHORT TIME TENSILE PROPERTIES

TEMPERATURE, °F	MODULUS OF ELASTICITY, 1,000,000 P.S.I.	OFFSET (1) YIELD STRENGTH, 1000 P.S.I.	TENSILE STRENGTH, 1000 P.S.I.	ELONGATION IN 2", PER CENT	REDUCTION IN AREA, PER CENT
80		98.0	134.5	20	59

(a) 0.02% Offset yield strength.

CREEP AND RUPTURE STRENGTHS

TEMP., °F	STRESS FOR RUPTURE IN TIMES INDICATED, 1000 P.S.I.(2)				STRESS FOR DESIGNATED CREEP RATE, 1000 P.S.I.(2)		
	100 HRS.	1000 HRS.	10,000 HRS.	100,000 HRS.	0.000001 %/HR.	0.00001 %/HR.	0.0001 %/HR.
900			67P	59P			
1000		58P					
		60	43*	31*			

P indicates strength value obtained by use of Larson-Miller parameter T(25 + log t).

ORIGINAL CREEP AND RUPTURE DATA

TEMP, °F.	STRESS, 1000 P.S.I.	DURATION, HOURS(3)	INTERCEPT, %(4)	MINIMUM CREEP RATE, %/HR.	TRANSITION TIME, HRS.(5)	TOTAL EXT. (CREEP TEST), %	TOTAL ELONG. (RUPTURE TEST), %	HARDNESS AFTER TESTING
1000	66.0	132 R					6.8	67.5
1000	60.0	1134 R					7.4	68.0
1000	56.0	2071 R					6.8	60.0
1000	52.0	2311 R					7.4	59.0
1000	48.0	5282 R					7.0	55.0

(7)

ASTM-ASME JOINT COMMITTEE ON EFFECT OF TEMPERATURE ON PROPERTIES OF METALS

TYPE OF MATERIAL	12 Cr, Ta	TYPE OF MELTING FURNACE	Induction	SIZE OF HEAT	Experimental

CHEMICAL COMPOSITION, PER CENT	C	Mn	P	S	Si	Cr	Ni	Mo	Ta
	0.15	0.52	0.016	0.014	0.20	12.81			0.45

DEOXIDATION

FORM-CAST OR WROUGHT

HEAT TREATMENT 2000 F, 1 Hr, OQ; 1200 F, 2 Hr, A.C.

MICROSTRUCTURE

GRAIN SIZE | HARDNESS

SOURCE OF DATA General Electric Company

SHORT TIME TENSILE PROPERTIES

TEMPERATURE, °F	MODULUS OF ELASTICITY, 1,000,000 P.S.I.	OFFSET (a) YIELD (1) STRENGTH, 1000 P.S.I.	TENSILE STRENGTH, 1000 P.S.I.	ELONGATION IN 2", PER CENT	REDUCTION IN AREA, PER CENT
80		103.0	135.75	17	60

(a) 0.02% Offset yield strength.

CREEP AND RUPTURE STRENGTHS

TEMP., °F	STRESS FOR RUPTURE IN TIMES INDICATED, 1000 P.S.I.(2)				STRESS FOR DESIGNATED CREEP RATE, 1000 P.S.I.(2)		
	100 HRS.	1000 HRS.	10,000 HRS.	100,000 HRS.	0.000001 %/HR.	0.00001 %/HR.	0.0001 %/HR.
1000				29P			
1100		29P					

P indicates strength value obtained by use of Larson-Miller parameter T(25 + log t).

ORIGINAL CREEP AND RUPTURE DATA

TEMP, °F (b)	STRESS, 1000 P.S.I.	DURATION, HOURS(3)	INTERCEPT, %(4)	MINIMUM CREEP RATE, %/HR.	TRANSITION TIME, HRS.(5)	TOTAL EXT. (CREEP TEST), %	TOTAL ELONG. (RUPTURE TEST), %	HARDNESS AFTER TESTING
1200	40.0	9.9 R					21.0	
1200	30.0	24.2 R					13.0	
1200	25.0	24.2 R					20.0	
1200	20.0	58.1 R					30.0	
	(b) Test specimen with 1" gage length and 0.160" diameter.							

(3) DURATION OF TEST (RUPTURE TEST INDICATED BY R).

(4) THE INTERCEPT IS THE PROJECTION BACK TO ZERO TIME FROM THE PORTION OF THE TEST SHOWING THE MINIMUM OR SECOND-STAGE CREEP RATE.

(5) THE TRANSITION TIME IS THE BEGINNING OF THE THIRD STAGE, OR AN ACCELERATING CREEP RATE.

(8)

ASTM-ASME JOINT COMMITTEE ON EFFECT OF TEMPERATURE ON PROPERTIES OF METALS

TYPE OF MATERIAL	12 Cr, Cb	TYPE OF MELTING FURNACE	Induction	SIZE OF HEAT	Experimental

CHEMICAL COMPOSITION, PER CENT	C	Mn	P	S	Si	Cr	Ni	Mo	Cb		
	0.15	0.52				12.56			0.46		

DEOXIDATION	
FORM-CAST OR WROUGHT	Wrought 1" D
HEAT TREATMENT	2050 F, OQ; 1200 F, A.C.; 1200 F, A.C.
MICROSTRUCTURE	
GRAIN SIZE	HARDNESS
SOURCE OF DATA	General Electric Company

SHORT TIME TENSILE PROPERTIES

TEMPERATURE, °F	MODULUS OF ELASTICITY, 1,000,000 P.S.I.	OFFSET (a) YIELD (1) STRENGTH, 1000 P.S.I.	TENSILE STRENGTH, 1000 P.S.I.	ELONGATION IN 2", PER CENT	REDUCTION IN AREA, PER CENT
80		99.0	135.0	18	64

(a) 0.02% Offset yield strength.

CREEP AND RUPTURE STRENGTHS

TEMP., °F	STRESS FOR RUPTURE IN TIMES INDICATED, 1000 P.S.I.(2)				STRESS FOR DESIGNATED CREEP RATE, 1000 P.S.I.(2)		
	100 HRS.	1000 HRS.	10,000 HRS.	100,000 HRS.	0.000001 %/HR.	0.00001 %/HR.	0.0001 %/HR.
900		70P	65P	56P			
1000		56P					
		56	46*				

P indicates strength value obtained by use of Larson-Miller parameter T(25 + log t).

(1) 0.2 PER CENT OFFSET UNLESS OTHERWISE INDICATED.
(2) EXTRAPOLATED VALUES INDICATED BY *

ORIGINAL CREEP AND RUPTURE DATA

TEMP. °F	STRESS, 1000 P.S.I.	DURATION, HOURS(3)	INTERCEPT, %(4)	MINIMUM CREEP RATE, %/HR.	TRANSITION TIME, HRS.(5)	TOTAL EXT. (CREEP TEST), %	TOTAL ELONG. (RUPTURE TEST), %	REDUCTION IN AREA, %
1000	70.0	13.0 R					8.0	69.0
1000	60.0	520.0 R					9.0	69.0
1000	52.0	2566 R					8.0	68.0

(3) DURATION OF TEST (RUPTURE TEST INDICATED BY R).
(4) THE INTERCEPT IS THE PROJECTION BACK TO ZERO TIME FROM THE PORTION OF THE TEST SHOWING THE MINIMUM OR SECOND-STAGE CREEP RATE.
(5) THE TRANSITION TIME IS THE BEGINNING OF THE THIRD STAGE, OR AN ACCELERATING CREEP RATE.

(9)

ASTM-ASME JOINT COMMITTEE ON EFFECT OF TEMPERATURE ON PROPERTIES OF METALS

TYPE OF MATERIAL	12 Cr, Cb	TYPE OF MELTING FURNACE	Induction	SIZE OF HEAT	Experimental

CHEMICAL COMPOSITION, PER CENT	C	Mn	P	S	Si	Cr	Ni	Mo	Cb		
	0.15	0.53				12.28			0.26		

DEOXIDATION	
FORM-CAST OR WROUGHT	Wrought 1" D
HEAT TREATMENT	2000 F, OQ; 1200 F, A.C.
MICROSTRUCTURE	
GRAIN SIZE	HARDNESS
SOURCE OF DATA	General Electric Company

SHORT TIME TENSILE PROPERTIES

TEMPERATURE, °F	MODULUS OF ELASTICITY, 1,000,000 P.S.I.	OFFSET (a) YIELD (1) STRENGTH, 1000 P.S.I.	TENSILE STRENGTH, 1000 P.S.I.	ELONGATION IN 2", PER CENT	REDUCTION IN AREA, PER CENT
80		103.0	138.0	20	64

(a) 0.02% Offset yield strength.

CREEP AND RUPTURE STRENGTHS

TEMP., °F	STRESS FOR RUPTURE IN TIMES INDICATED, 1000 P.S.I.(2)				STRESS FOR DESIGNATED CREEP RATE, 1000 P.S.I.(2)		
	100 HRS.	1000 HRS.	10,000 HRS.	100,000 HRS.	0.000001 %/HR.	0.00001 %/HR.	0.0001 %/HR.
900				61P			
1000		60P					
		60					

P indicates strength value obtained by use of Larson-Miller parameter T(25 + log t).

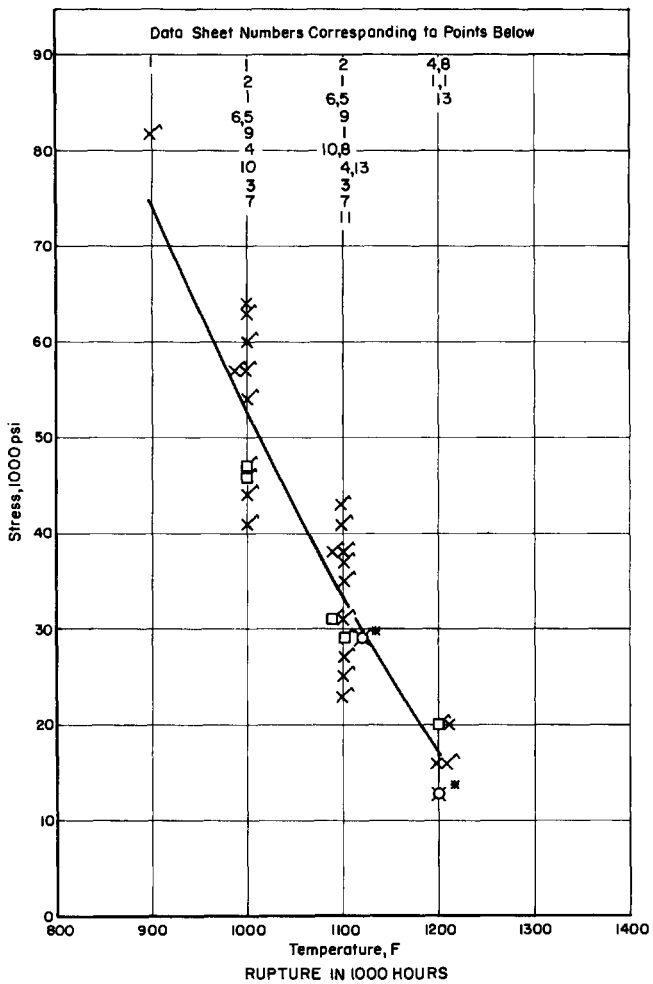
(1) 0.2 PER CENT OFFSET UNLESS OTHERWISE INDICATED.
(2) EXTRAPOLATED VALUES INDICATED BY *

ORIGINAL CREEP AND RUPTURE DATA

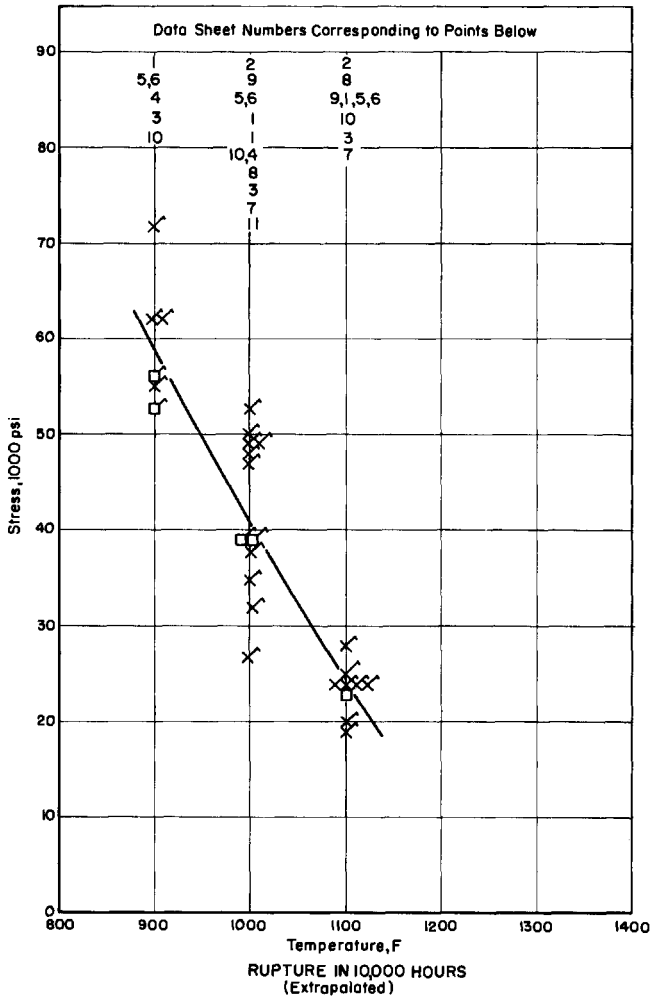
TEMP. °F	STRESS, 1000 P.S.I.	DURATION, HOURS(3)	INTERCEPT, %(4)	MINIMUM CREEP RATE, %/HR.	TRANSITION TIME, HRS.(5)	TOTAL EXT. (CREEP TEST), %	TOTAL ELONG. (RUPTURE TEST), %	REDUCTION IN AREA, %
1000	65.0	414 R					7.0	62.0
1000	60.0	1196 R					6.0	52.0
1000	55.0	2394 R					5.0	45.0

(3) DURATION OF TEST (RUPTURE TEST INDICATED BY R).
(4) THE INTERCEPT IS THE PROJECTION BACK TO ZERO TIME FROM THE PORTION OF THE TEST SHOWING THE MINIMUM OR SECOND-STAGE CREEP RATE.
(5) THE TRANSITION TIME IS THE BEGINNING OF THE THIRD STAGE, OR AN ACCELERATING CREEP RATE.

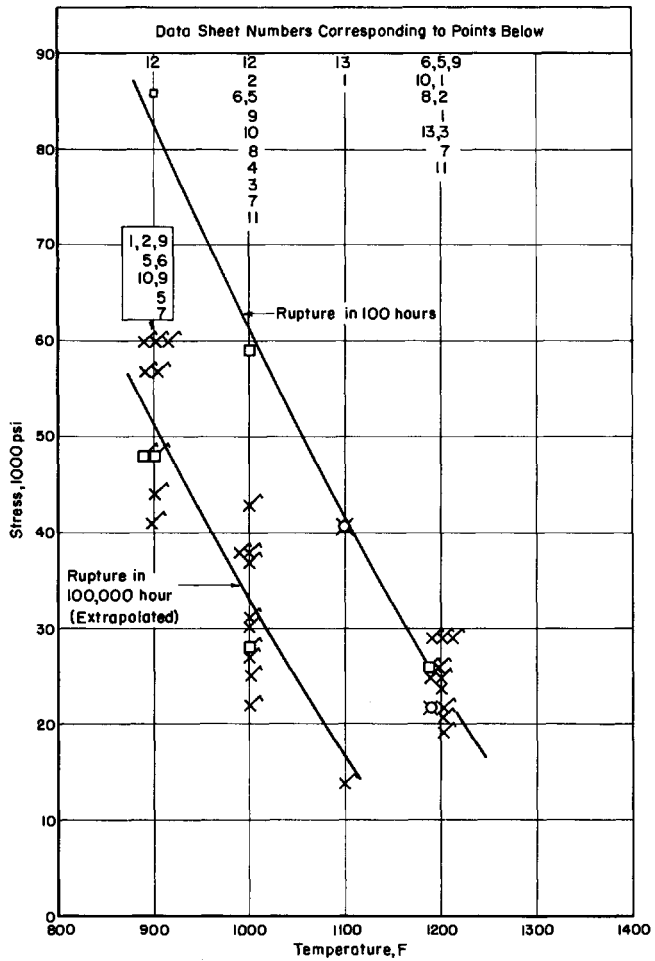
12 Chromium, 2.75 Molybdenum, Vanadium Steels (Lapelloy)



12Cr, 2.75 Mo, V STEEL



12Cr, 2.75 Mo, V STEEL



RUPTURE IN 100 AND 100,000 HOURS

12Cr, 2.75 Mo, V STEEL

(1)

ASTM-ASME JOINT COMMITTEE ON EFFECT OF TEMPERATURE ON PROPERTIES OF METALS

TYPE OF MATERIAL 12 Cr, 2.75 Mo, V			TYPE OF MELTING FURNACE					SIZE OF HEAT Commercial				
CHEMICAL COMPOSITION, PER CENT	C	Mn	P	S	Si	Cr	Ni	Mo	V			
	0.27	1.08	0.024	0.027	0.27	11.75	0.21	2.88	0.25			
DEOXIDATION												
FORM-CAST OR WROUGHT Wrought 3/8" Square												
HEAT TREATMENT 2000 F, 1 Hr, OQ; 1300 F, 2 Hr, A.C.												
MICROSTRUCTURE												
GRAIN SIZE					HARDNESS							
SOURCE OF DATA General Electric Company												

SHORT TIME TENSILE PROPERTIES

TEMPERATURE, °F	MODULUS OF ELASTICITY, 1,000,000 P.S.I.	OFFSET (a) YIELD (1) STRENGTH, 1000 P.S.I.	TENSILE STRENGTH, 1000 P.S.I.	ELONGATION IN 2", PER CENT	REDUCTION IN AREA, PER CENT
80		101.9	149.3	19.0	44.1
(a) 0.02% Offset yield strength.					

CREEP AND RUPTURE STRENGTHS

TEMP., °F	STRESS FOR RUPTURE IN TIMES INDICATED, 1000 P.S.I.(2)				STRESS FOR DESIGNATED CREEP RATE, 1000 P.S.I.(2)		
	100 HRS.	1000 HRS.	10,000 HRS.	100,000 HRS.	0.000001 %/HR.	0.00001 %/HR.	0.0001 %/HR.
900		82P	72P	60P			
1000		60P	47P				
1000		64	48*				
1100		35P	24P	14P			
		41					
1200	26P	16P					
	24	15.7					
P indicates strength value obtained by use of Larson-Miller parameter T(25 + log t).							

ORIGINAL CREEP AND RUPTURE DATA

TEMP, °F	STRESS, 1000 P.S.I.	DURATION, HOURS(3)	INTERCEPT, %(4)	MINIMUM CREEP RATE, %/HR.	TRANSITION TIME, HRS.(5)	TOTAL EXT. (CREEP TEST), %	TOTAL ELONG. (RUPTURE TEST), %	HARDNESS AFTER TESTING
1000	100.0	0.074 R					21.0	
1000	80.0	21.0 R					24.0	
1000	90.0	1.3 R					22.0	
1000	70.0	82.0 R					24.0	
1000	60.0	3121 R					17.0	
1000	50.0	>7800					>3.0	
900	100.0	318 R					10.0	
1100	60.0	10 R					32.0	
1100	100.0	0.0014R					18.0	
1100	90.0	0.017 R					17.0	
1100	80.0	0.15 R					25.0	
1100	70.0	2.7 R					22.0	
1100	50.0	163.6 R					21.0	
1100	40.0	1922 R					14.0	
1100	30.0	3819 R					17.0	
1200	60.0	0.067 R					38.0	
1200	50.0	0.50 R					54.0	
1200	40.0	4.4 R					33.0	
1200	30.0	73.0 R					28.0	
1200	25.0	90.0 R					19.0	
1200	20.0	280.0 R					20.0	
1200	15.0	1203 R					26.0	
1350	50.0	0.001 R					30.0	
1350	40.0	0.016 R					34.0	
1350	30.0	0.14 R					21.0	
1350	20.0	0.8 R					65.0	
1350	15.0	2.7 R					60.0	
1350	10.0	25.2 R					50.0	
All test specimens had 1" gage length and 0.160" diameter.								

(2)

ASTM-ASME JOINT COMMITTEE ON EFFECT OF TEMPERATURE ON PROPERTIES OF METALS

TYPE OF MATERIAL 12 Cr, 2.75 Mo, V			TYPE OF MELTING FURNACE Induction					SIZE OF HEAT Experimental				
CHEMICAL COMPOSITION, PER CENT	C	Mn	P	S	Si	Cr	Ni	Mo	V			
	0.173	1.23	0.008	0.028	0.57	11.11	0.12	2.81	0.26			
DEOXIDATION												
FORM-CAST OR WROUGHT Wrought 1-3/8" Round												
HEAT TREATMENT 2000 F, 1 Hr, OQ; 1100 F, 3 Hr, A.C.												
MICROSTRUCTURE												
GRAIN SIZE					HARDNESS							
SOURCE OF DATA General Electric Company												

SHORT TIME TENSILE PROPERTIES

TEMPERATURE, °F	MODULUS OF ELASTICITY, 1,000,000 P.S.I.	OFFSET (a) YIELD (1) STRENGTH, 1000 P.S.I.	TENSILE STRENGTH, 1000 P.S.I.	ELONGATION IN 2", PER CENT	REDUCTION IN AREA, PER CENT
80		107.5	156.25	16.5	41.0
(a) 0.02% Offset yield strength.					

CREEP AND RUPTURE STRENGTHS

TEMP., °F	STRESS FOR RUPTURE IN TIMES INDICATED, 1000 P.S.I.(2)				STRESS FOR DESIGNATED CREEP RATE, 1000 P.S.I.(2)		
	100 HRS.	1000 HRS.	10,000 HRS.	100,000 HRS.	0.000001 %/HR.	0.00001 %/HR.	0.0001 %/HR.
900				60P			
1000		60P	53P	43P			
1100		43P	28P				
1200	25P						
P indicates strength value obtained by use of Larson-Miller parameter T(25 + log t).							

ORIGINAL CREEP AND RUPTURE DATA

TEMP, °F	STRESS, 1000 P.S.I.	DURATION, HOURS(3)	INTERCEPT, %(4)	MINIMUM CREEP RATE, %/HR.	TRANSITION TIME, HRS.(5)	TOTAL EXT. (CREEP TEST), %	TOTAL ELONG. (RUPTURE TEST), %	HARDNESS AFTER TESTING
1100	60.0	11.7 R					29.0	
1100	50.0	208.7 R					24.0	
1200	40.0	30.3 R					23.0	
1200	30.0	111.9 R					27.0	
1200	20.0	270.0 R					30.0	
All test specimens had 1" gage and 0.160" diameter.								

(3)

ASTM-ASME JOINT COMMITTEE ON EFFECT OF TEMPERATURE ON PROPERTIES OF METALS

TYPE OF MATERIAL 12 Cr, 2.75 Mo, V			TYPE OF MELTING FURNACE					SIZE OF HEAT Commercial				
CHEMICAL COMPOSITION, PER CENT	C	Mn	P	S	Si	Cr	Ni	Mo	V			
	0.31	1.05	0.019	0.014	0.28	11.12	0.20	2.84	0.23			
DEOXIDATION												
FORM-CAST OR WROUGHT Wrought 3-3/4" Round												
HEAT TREATMENT 2000 F, 1 Hr, OQ; 1325 F, 2 Hr, A.C.												
MICROSTRUCTURE												
GRAIN SIZE					HARDNESS							
SOURCE OF DATA General Electric Company												

SHORT TIME TENSILE PROPERTIES

TEMPERATURE, °F	MODULUS OF ELASTICITY, 1,000,000 P.S.I.	OFFSET (a) YIELD (1) STRENGTH, 1000 P.S.I.	TENSILE STRENGTH, 1000 P.S.I.	ELONGATION IN 2", PER CENT	REDUCTION IN AREA, PER CENT
80		76.0	129.25	17.5	34.71
(a) 0.02% Offset yield strength.					

CREEP AND RUPTURE STRENGTHS

TEMP., °F	STRESS FOR RUPTURE IN TIMES INDICATED, 1000 P.S.I.(2)				STRESS FOR DESIGNATED CREEP RATE, 1000 P.S.I.(2)		
	100 HRS.	1000 HRS.	10,000 HRS.	100,000 HRS.	0.000001 %/HR.	0.00001 %/HR.	0.0001 %/HR.
900			55P	44P			
1000		44P	35P	27P			
1100		27P	20P				
1200	22P						
P indicates strength value obtained by use of Larson-Miller parameter T(25 + log t).							

ORIGINAL CREEP AND RUPTURE DATA

TEMP, °F	STRESS, 1000 P.S.I.	DURATION, HOURS(3)	INTERCEPT, %(4)	MINIMUM CREEP RATE, %/HR.	TRANSITION TIME, HRS.(5)	TOTAL EXT. (CREEP TEST), %	TOTAL ELONG. (RUPTURE TEST), %	HARDNESS AFTER TESTING
1100	60.0	1.7 R					32.0	
1100	50.0	6.9 R					44.0	
1200	40.0	0.4 R					40.0	
1200	30.0	9.3 R					33.0	
1200	20.0	337.9 R					26.0	
All test specimens had 1" gage and 0.016" diameter.								

(1) 0.2 PER CENT OFFSET UNLESS OTHERWISE INDICATED.

(2) EXTRAPOLATED VALUES INDICATED BY *

(3) DURATION OF TEST (RUPTURE TEST INDICATED BY R).

(4) THE INTERCEPT IS THE PROJECTION BACK TO ZERO TIME FROM THE PORTION OF THE TEST SHOWING THE MINIMUM OR SECOND-STAGE CREEP RATE.

(5) THE TRANSITION TIME IS THE BEGINNING OF THE THIRD STAGE, OR AN ACCELERATING CREEP RATE.

(4)

ASTM-ASME JOINT COMMITTEE ON EFFECT OF TEMPERATURE ON PROPERTIES OF METALS

TYPE OF MATERIAL 12 Cr, 2.75 Mo, V	TYPE OF MELTING FURNACE						SIZE OF HEAT Commercial				
CHEMICAL COMPOSITION, PER CENT	C	Mn	P	S	Si	Cr	Ni	Mo	V		
	0.27	1.08	0.024	0.027	0.27	11.75	0.21	2.88	0.25		
DEOXIDATION											
FORM-CAST OR WROUGHT Wrought 4" Round											
HEAT TREATMENT 2000 F, 6 Hr, OQ; 1300 F, 6 Hr, A.C.											
MICROSTRUCTURE											
GRAIN SIZE						HARDNESS					
SOURCE OF DATA General Electric Company											

SHORT TIME TENSILE PROPERTIES

TEMPERATURE, °F	MODULUS OF ELASTICITY, 1,000,000 P.S.I.	OFFSET (a) YIELD (1) STRENGTH, 1000 P.S.I.	TENSILE STRENGTH, 1000 P.S.I.	ELONGATION IN 2", PER CENT	REDUCTION IN AREA, PER CENT
80		87.0	136.3	15.0	31.8
(a) 0.02% Offset yield strength.					

CREEP AND RUPTURE STRENGTHS

TEMP., °F	STRESS FOR RUPTURE IN TIMES INDICATED, 1000 P.S.I. (2)				STRESS FOR DESIGNATED CREEP RATE, 1000 P.S.I. (2)		
	100 HRS.	1000 HRS.	10,000 HRS.	100,000 HRS.	0.000001 %/HR.	0.00001 %/HR.	0.0001 %/HR.
900			56P	48P			
1000		47P	39P	28P			
1100		29P					
1200		20P					
P indicates strength value obtained by use of Larson-Miller parameter T(23 + log t).							

ORIGINAL CREEP AND RUPTURE DATA

TEMP. °F	STRESS, 1000 P.S.I.	DURATION, HOURS (3)	INTERCEPT, %(4)	MINIMUM CREEP RATE, %/HR.	TRANSITION TIME, HRS. (5)	TOTAL EXT. (CREEP TEST), %	TOTAL ELONG. (RUPTURE TEST), %	HARDNESS AFTER TESTING
1100	60.0	0.7 R					34.0	
1100	50.0	9.0 R					34.0	
1200	40.0	1.8 R					30.0	
1200	30.0	18.6 R					46.0	
1200	20.0	100.0 R					26.0	
	All test specimens had 1" gage length and 0.160" diameter.							

(5)

ASTM-ASME JOINT COMMITTEE ON EFFECT OF TEMPERATURE ON PROPERTIES OF METALS

TYPE OF MATERIAL 12 Cr, 2.75 Mo, V	TYPE OF MELTING FURNACE						SIZE OF HEAT Commercial				
CHEMICAL COMPOSITION, PER CENT	C	Mn	P	S	Si	Cr	Ni	Mo	V		
	0.30	0.93	--	--	0.31	11.64	0.13	2.60	0.28		
DEOXIDATION											
FORM-CAST OR WROUGHT Wrought 1" Round											
HEAT TREATMENT 2000 F, 1 Hr, OQ; 1325 F, 2 Hr											
MICROSTRUCTURE											
GRAIN SIZE						HARDNESS					
SOURCE OF DATA General Electric Company											

SHORT TIME TENSILE PROPERTIES

TEMPERATURE, °F	MODULUS OF ELASTICITY, 1,000,000 P.S.I.	OFFSET (a) YIELD (1) STRENGTH, 1000 P.S.I.	TENSILE STRENGTH, 1000 P.S.I.	ELONGATION IN 2", PER CENT	REDUCTION IN AREA, PER CENT
80		95.0	143.75	15.0	33.10
(a) 0.02% Offset yield strength.					

CREEP AND RUPTURE STRENGTHS

TEMP., °F	STRESS FOR RUPTURE IN TIMES INDICATED, 1000 P.S.I. (2)				STRESS FOR DESIGNATED CREEP RATE, 1000 P.S.I. (2)		
	100 HRS.	1000 HRS.	10,000 HRS.	100,000 HRS.	0.000001 %/HR.	0.00001 %/HR.	0.0001 %/HR.
900			62P	57P			
1000		57P	49P	38P			
1100		38P	24P				
1200	29P						
P indicates strength value obtained by use of Larson-Miller parameter T(23 + log t).							

(1) 0.2 PER CENT OFFSET UNLESS OTHERWISE INDICATED.

(2) EXTRAPOLATED VALUES INDICATED BY *

ORIGINAL CREEP AND RUPTURE DATA

TEMP. °F	STRESS, 1000 P.S.I.	DURATION, HOURS (3)	INTERCEPT, %(4)	MINIMUM CREEP RATE, %/HR.	TRANSITION TIME, HRS. (5)	TOTAL EXT. (CREEP TEST), %	TOTAL ELONG. (RUPTURE TEST), %	HARDNESS AFTER TESTING
1100	60.0	4.4 R					13.0	
1100	50.0	127.7 R					13.0	
1200	30.0	52.3 R					19.0	
1200	20.0	384.0 R					18.0	
	All test specimens had 1" gage and 0.016" diameter.							

(6)

ASTM-ASME JOINT COMMITTEE ON EFFECT OF TEMPERATURE ON PROPERTIES OF METALS

TYPE OF MATERIAL 12 Cr, 2.75 Mo, V	TYPE OF MELTING FURNACE						SIZE OF HEAT Commercial				
CHEMICAL COMPOSITION, PER CENT	C	Mn	P	S	Si	Cr	Ni	Mo	V		
	0.26	1.04	--	--	0.30	11.10	0.11	2.54	0.24		
DEOXIDATION											
FORM-CAST OR WROUGHT Wrought 1" Round											
HEAT TREATMENT 2000 F, 1 Hr, OQ; 1352 F, 2 Hr, A.C.											
MICROSTRUCTURE											
GRAIN SIZE						HARDNESS					
SOURCE OF DATA General Electric Company											

SHORT TIME TENSILE PROPERTIES

TEMPERATURE, °F	MODULUS OF ELASTICITY, 1,000,000 P.S.I.	OFFSET (a) YIELD (1) STRENGTH, 1000 P.S.I.	TENSILE STRENGTH, 1000 P.S.I.	ELONGATION IN 2", PER CENT	REDUCTION IN AREA, PER CENT
80		94.0	140.25	15.0	36.94
(a) 0.02% Offset yield strength.					

CREEP AND RUPTURE STRENGTHS

TEMP., °F	STRESS FOR RUPTURE IN TIMES INDICATED, 1000 P.S.I. (2)				STRESS FOR DESIGNATED CREEP RATE, 1000 P.S.I. (2)		
	100 HRS.	1000 HRS.	10,000 HRS.	100,000 HRS.	0.000001 %/HR.	0.00001 %/HR.	0.0001 %/HR.
900			62P	57P			
1000		57P	49P	38P			
1100		38P	24P				
1200	29P						
P indicates strength value obtained by use of Larson-Miller parameter T(23 + log t).							

ORIGINAL CREEP AND RUPTURE DATA

TEMP. °F	STRESS, 1000 P.S.I.	DURATION, HOURS (3)	INTERCEPT, %(4)	MINIMUM CREEP RATE, %/HR.	TRANSITION TIME, HRS. (5)	TOTAL EXT. (CREEP TEST), %	TOTAL ELONG. (RUPTURE TEST), %	HARDNESS AFTER TESTING
1100	60.0	3.1 R					34.0	
1100	40.0	434.1 R					26.0	
1200	30.0	24.2 R					36.0	
1200	20.0	207.8 R					45.0	
	All test specimens had 1" gage and 0.016" diameter.							

(7)

ASTM-ASME JOINT COMMITTEE ON EFFECT OF TEMPERATURE ON PROPERTIES OF METALS

TYPE OF MATERIAL 12 Cr, 2.75 Mo, V	TYPE OF MELTING FURNACE						SIZE OF HEAT Commercial				
CHEMICAL COMPOSITION, PER CENT	C	Mn	P	S	Si	Cr	Ni	Mo	V		
	0.26	0.95			0.18	11.06	0.15	2.58	0.28		
DEOXIDATION											
FORM-CAST OR WROUGHT Wrought 1-13/16" x 2-5/16"											
HEAT TREATMENT 2000 F, 1 Hr, OQ; 1100 F, 3 Hr, A.C.											
MICROSTRUCTURE											
GRAIN SIZE						HARDNESS					
SOURCE OF DATA General Electric Company											

SHORT TIME TENSILE PROPERTIES

TEMPERATURE, °F	MODULUS OF ELASTICITY, 1,000,000 P.S.I.	OFFSET (a) YIELD (1) STRENGTH, 1000 P.S.I.	TENSILE STRENGTH, 1000 P.S.I.	ELONGATION IN 2", PER CENT	REDUCTION IN AREA, PER CENT
80		78.75	124.75	19.5	39.7
(a) 0.02% Offset yield strength.					

(3) DURATION OF TEST (RUPTURE TEST INDICATED BY R).

(4) THE INTERCEPT IS THE PROJECTION BACK TO ZERO TIME FROM THE PORTION OF THE TEST SHOWING THE MINIMUM OR SECOND-STAGE CREEP RATE.

(5) THE TRANSITION TIME IS THE BEGINNING OF THE THIRD STAGE, OR AN ACCELERATING CREEP RATE.

CREEP AND RUPTURE STRENGTHS

TEMP., °F	STRESS FOR RUPTURE IN TIMES INDICATED, 1000 P.S.I.(2)				STRESS FOR DESIGNATED CREEP RATE, 1000 P.S.I.(2)		
	100 HRS.	1000 HRS.	10,000 HRS.	100,000 HRS.	0.000001 %/HR.	0.00001 %/HR.	0.0001 %/HR.
900				41P			
1000		41P	32P	25P			
1100		25P	19P				
1200	21P						
P indicates strength value obtained by use of Larson-Miller parameter T(25 + log t).							

ORIGINAL CREEP AND RUPTURE DATA

TEMP., °F	STRESS, 1000 P.S.I.	DURATION, HOURS(3)	INTERCEPT, %(4)	MINIMUM CREEP RATE, %/HR.	TRANSITION TIME, HRS.(5)	TOTAL EXT. (CREEP TEST), %	TOTAL ELONG. (RUPTURE TEST), %	HARDNESS AFTER TESTING
1100	50.0	3.3 R					40.0	
1200	40.0	0.2 R					34.0	
1200	30.0	1.6 R					37.0	
1200	20.0	160.9 R					30.0	
	All test specimens had 1" gage length and 0.160" diameter.							

(8)

ASTM-ASME JOINT COMMITTEE ON EFFECT OF TEMPERATURE ON PROPERTIES OF METALS

TYPE OF MATERIAL 12 Cr, 2.75 Mo, V	TYPE OF MELTING FURNACE				SIZE OF HEAT Commercial					
CHEMICAL COMPOSITION, PER CENT	C	Mn	P	S	Si	Cr	Ni	Mo	V	
	0.32	1.08	0.018	0.015	0.40	11.58	0.18	2.57	0.25	
DEOXIDATION										
FORM-CAST OR WROUGHT Wrought 3-1/2" Round										
HEAT TREATMENT 2000 F, 6 Hr, OQ; 1300 F, 6 Hr, A.C.										
MICROSTRUCTURE										
GRAIN SIZE						HARDNESS				
SOURCE OF DATA General Electric Company										

SHORT TIME TENSILE PROPERTIES

TEMPERATURE, °F	MODULUS OF ELASTICITY, 1,000,000 P.S.I.	OFFSET(a) YIELD (1) STRENGTH, 1000 P.S.I.	TENSILE STRENGTH, 1000 P.S.I.	ELONGATION IN 2" PER CENT	REDUCTION IN AREA, PER CENT
80		87.5	143.5	17.0	45.4
(a) 0.02% Offset yield strength.					

CREEP AND RUPTURE STRENGTHS

TEMP., °F	STRESS FOR RUPTURE IN TIMES INDICATED, 1000 P.S.I.(2)				STRESS FOR DESIGNATED CREEP RATE, 1000 P.S.I.(2)		
	100 HRS.	1000 HRS.	10,000 HRS.	100,000 HRS.	0.000001 %/HR.	0.00001 %/HR.	0.0001 %/HR.
1000			38P	30P			
1100		31P	25P				
1200	25	20					
P indicates strength value obtained by use of Larson-Miller parameter T(25 + log t).							

ORIGINAL CREEP AND RUPTURE DATA

TEMP., °F	STRESS, 1000 P.S.I.	DURATION, HOURS(3)	INTERCEPT, %(4)	MINIMUM CREEP RATE, %/HR.	TRANSITION TIME, HRS.(5)	TOTAL EXT. (CREEP TEST), %	TOTAL ELONG. (RUPTURE TEST), %	HARDNESS AFTER TESTING
1200	30.0	30.0 R					39.0	
1200	25.0	113.7 R					22.0	
1200	20.0	1061.8 R					22.0	
	All test specimens had 1" gage length and 0.160" diameter.							

(9)

ASTM-ASME JOINT COMMITTEE ON EFFECT OF TEMPERATURE ON PROPERTIES OF METALS

TYPE OF MATERIAL 12 Cr, 2.75 Mo, V	TYPE OF MELTING FURNACE Induction						SIZE OF HEAT Experimental				
CHEMICAL COMPOSITION, PER CENT	C	Mn	P	S	Si	Cr	Ni	Mo	V		
	0.247	1.18	0.007	0.026	0.50	11.22	0.13	2.78	0.26		
DEOXIDATION											
FORM-CAST OR WROUGHT Wrought 1-1/8" Round											
HEAT TREATMENT 2000 F, 1 Hr, OQ; 1200 F, 2 Hr, A.C.											
MICROSTRUCTURE											
GRAIN SIZE						HARDNESS					
SOURCE OF DATA General Electric Company											

(1) 0.2 PER CENT OFFSET UNLESS OTHERWISE INDICATED.
(2) EXTRAPOLATED VALUES INDICATED BY *

SHORT TIME TENSILE PROPERTIES

TEMPERATURE, °F	MODULUS OF ELASTICITY, 1,000,000 P.S.I.	OFFSET(a) YIELD (1) STRENGTH, 1000 P.S.I.	TENSILE STRENGTH, 1000 P.S.I.	ELONGATION IN 2" PER CENT	REDUCTION IN AREA, PER CENT
80		107.5	154.5	16.5	41.0
(a) 0.02% Offset yield strength.					

CREEP AND RUPTURE STRENGTHS

TEMP., °F	STRESS FOR RUPTURE IN TIMES INDICATED, 1000 P.S.I.(2)				STRESS FOR DESIGNATED CREEP RATE, 1000 P.S.I.(2)		
	100 HRS.	1000 HRS.	10,000 HRS.	100,000 HRS.	0.000001 %/HR.	0.00001 %/HR.	0.0001 %/HR.
900				60P			
1000		59P	50P	37P			
1100		37P	24P				
1200	29P						
P indicates strength value obtained by use of Larson-Miller parameter T(25 + log t).							

ORIGINAL CREEP AND RUPTURE DATA

TEMP., °F	STRESS, 1000 P.S.I.	DURATION, HOURS(3)	INTERCEPT, %(4)	MINIMUM CREEP RATE, %/HR.	TRANSITION TIME, HRS.(5)	TOTAL EXT. (CREEP TEST), %	TOTAL ELONG. (RUPTURE TEST), %	HARDNESS AFTER TESTING
1100	60.0	11.5 R					19.0	
1100	50.0	293.2 R					11.0	
1200	40.0	14.5 R					21.0	
1200	30.0	56.8 R					20.0	
1200	20.0	300.5 R					21.0	
	All test specimens had 1" gage and 0.016" diameter.							

(10)

ASTM-ASME JOINT COMMITTEE ON EFFECT OF TEMPERATURE ON PROPERTIES OF METALS

TYPE OF MATERIAL 12 Cr, 2.75 Mo, V	TYPE OF MELTING FURNACE						SIZE OF HEAT Commercial				
CHEMICAL COMPOSITION, PER CENT	C	Mn	P	S	Si	Cr	Ni	Mo	V		
	0.27	1.08	0.024	0.027	0.27	11.75	0.21	2.88	0.25		
DEOXIDATION											
FORM-CAST OR WROUGHT Wrought 4" Round											
HEAT TREATMENT											
MICROSTRUCTURE											
GRAIN SIZE						HARDNESS					
SOURCE OF DATA General Electric Company											

SHORT TIME TENSILE PROPERTIES

TEMPERATURE, °F	MODULUS OF ELASTICITY, 1,000,000 P.S.I.	OFFSET YIELD (1) STRENGTH, 1000 P.S.I.	TENSILE STRENGTH, 1000 P.S.I.	ELONGATION IN 2" PER CENT	REDUCTION IN AREA, PER CENT

CREEP AND RUPTURE STRENGTHS

TEMP., °F	STRESS FOR RUPTURE IN TIMES INDICATED, 1000 P.S.I.(2)				STRESS FOR DESIGNATED CREEP RATE, 1000 P.S.I.(2)		
	100 HRS.	1000 HRS.	10,000 HRS.	100,000 HRS.	0.000001 %/HR.	0.00001 %/HR.	0.0001 %/HR.
900			53P	47P			
1000		46P	39P	31P			
1100		31P	23P				
1200	26P						
P indicates strength value obtained by use of Larson-Miller parameter T(25 + log t).							

ORIGINAL CREEP AND RUPTURE DATA

TEMP., °F	STRESS, 1000 P.S.I.	DURATION, HOURS(3)	INTERCEPT, %(4)	MINIMUM CREEP RATE, %/HR.	TRANSITION TIME, HRS.(5)	TOTAL EXT. (CREEP TEST), %	TOTAL ELONG. (RUPTURE TEST), %	HARDNESS AFTER TESTING
1100	50.0	5.6 R					23.0	
1200	30.0	38.3 R					29.0	
1200	20.0	438.3 R					28.0	
	All test specimens had 1" gage length and 0.160" diameter.							

(3) DURATION OF TEST (RUPTURE TEST INDICATED BY R).
(4) THE INTERCEPT IS THE PROJECTION BACK TO ZERO TIME FROM THE PORTION OF THE TEST SHOWING THE MINIMUM OR SECOND-STAGE CREEP RATE.
(5) THE TRANSITION TIME IS THE BEGINNING OF THE THIRD STAGE, OR AN ACCELERATING CREEP RATE.

(11)

ASTM-ASME JOINT COMMITTEE ON EFFECT OF TEMPERATURE ON PROPERTIES OF METALS

TYPE OF MATERIAL	12 Cr, 2.75 Mo, V	TYPE OF MELTING FURNACE					SIZE OF HEAT	Commercial			
CHEMICAL COMPOSITION, PER CENT	C	Mn	P	S	Si	Cr	Ni	Mo	V		
	0.30	0.90	0.020	0.023	0.30	12.16	0.34	2.80	0.28		
DEOXIDATION											
FORM-CAST OR WROUGHT	Wrought 6-1/4" Round										
HEAT TREATMENT	2000 F, 6 Hr, OQ; 1300 F, 6 Hr, A.C.										
MICROSTRUCTURE											
GRAIN SIZE							HARDNESS				
SOURCE OF DATA	General Electric Company										

SHORT TIME TENSILE PROPERTIES

TEMPERATURE, °F	MODULUS OF ELASTICITY, 1,000,000 P.S.I.	OFFSET(a) YIELD (1) STRENGTH, 1000 P.S.I.	TENSILE STRENGTH, 1000 P.S.I.	ELONGATION IN 2", PER CENT	REDUCTION IN AREA, PER CENT
80		71.0	107.0	22.5	46.9
(a) 0.02% Offset yield strength.					

CREEP AND RUPTURE STRENGTHS

TEMP., °F	STRESS FOR RUPTURE IN TIMES INDICATED, 1000 P.S.I.(2)				STRESS FOR DESIGNATED CREEP RATE, 1000 P.S.I.(2)		
	100 HRS.	1000 HRS.	10,000 HRS.	100,000 HRS.	0.000001 %/HR.	0.00001 %/HR.	0.0001 %/HR.
1000			27P	22P			
1100		23P					
1200	29P						
P indicates strength value obtained by use of Larson-Miller parameter T(25 + log t).							

ORIGINAL CREEP AND RUPTURE DATA

TEMP. °F.	STRESS, 1000 P.S.I.	DURATION, HOURS(3)	INTERCEPT, %(4)	MINIMUM CREEP RATE, %/HR.	TRANSITION TIME, HRS.(5)	TOTAL EXT. (CREEP TEST), %	TOTAL ELONG. (RUPTURE TEST), %	HARDNESS AFTER TESTING
1200	30.0	0.9 R					57.0	
1200	25.0	4.4 R					49.0	
1200	20.0	57.2 R					34.0	
	All test specimens had 1" gage and 0.0 6" diameter.							

(12)

ASTM-ASME JOINT COMMITTEE ON EFFECT OF TEMPERATURE ON PROPERTIES OF METALS

TYPE OF MATERIAL	12 Cr, 2.75 Mo, V (Lapelloy)	TYPE OF MELTING FURNACE					SIZE OF HEAT				
CHEMICAL COMPOSITION, PER CENT	C	Mn	P	S	Si	Cr	Ni	Mo	V		
	0.3	1.05	0.019	0.024	0.35	12.12	0.22	2.87	0.28		
DEOXIDATION											
FORM-CAST OR WROUGHT											
HEAT TREATMENT	45 Min at 2000 F in Salt Bath, Quenched in 500 F Salt Bath for 30 Min,										
MICROSTRUCTURE	Reheated to 1320 F for 4 Hr, Then A.C. to Room Temperature.										
GRAIN SIZE							HARDNESS	27-30 R_c			
SOURCE OF DATA	University of Minnesota										

SHORT TIME TENSILE PROPERTIES

TEMPERATURE, °F	MODULUS OF ELASTICITY, 1,000,000 P.S.I.	OFFSET YIELD (1) STRENGTH, 1000 P.S.I.	TENSILE STRENGTH, 1000 P.S.I.	ELONGATION IN 2", PER CENT	REDUCTION IN AREA, PER CENT
RT	--	100	136	20.0	49.5

CREEP AND RUPTURE STRENGTHS

TEMP., °F	STRESS FOR RUPTURE IN TIMES INDICATED, 1000 P.S.I.(2)				STRESS FOR DESIGNATED CREEP RATE, 1000 P.S.I.(2)		
	100 HRS.	1000 HRS.	10,000 HRS.	100,000 HRS.	0.000001 %/HR.	0.00001 %/HR.	0.0001 %/HR.
900	86	--	--	--			
1000	59	--	--	--			

(1) 0.2 PER CENT OFFSET UNLESS OTHERWISE INDICATED.

(2) EXTRAPOLATED VALUES INDICATED BY *

ORIGINAL CREEP AND RUPTURE DATA

TEMP. °F.	STRESS, 1000 P.S.I.	DURATION, HOURS(3)	INTERCEPT, %(4)	MINIMUM CREEP RATE, %/HR.	TRANSITION TIME, HRS.(5)	TOTAL EXT. (CREEP TEST), %	TOTAL ELONG. (RUPTURE TEST), %	HARDNESS AFTER TESTING
900	100.0	0.05 R					15.1	
900	90.0	16.3 R					15.5	
900	85.0	140.0 R					--	
900	95.0	1.8 R					13.8	
900	98.0	0.3 R					16.9	
900	90.0	10.9 R					19.8	
900	95.0	2.8 R					17.4	
900	87.0	51.2 R					14.7	
1000	80.0	0.6 R					17.7	
1000	65.0	19.6 R					17.9	
1000	72.0	4.8 R					21.6	
1000	86.0	0.2 R					19.5	
1000	88.0	0.04 R					17.4	
1000	58.0	160.5 R					27.2	
1000	65.0	18.8 R					17.4	

(13)

ASTM-ASME JOINT COMMITTEE ON EFFECT OF TEMPERATURE ON PROPERTIES OF METALS

TYPE OF MATERIAL	12 Cr, 2.75 Mo, V (Lapelloy)	TYPE OF MELTING FURNACE					SIZE OF HEAT	1 Ton			
CHEMICAL COMPOSITION, PER CENT	C	Mn	P	S	Si	Cr	Ni	Mo	V		
	0.26	1.12	0.015	0.019	0.68	12.17	0.19	2.25	0.30		
DEOXIDATION											
FORM-CAST OR WROUGHT	Rolled Bar Stock										
HEAT TREATMENT	1 Hr at 1750 F, A.C. + 1 Hr 1900 F, A.C. + Temper 4 Hr at 1300 F.										
MICROSTRUCTURE	Tempered Martensite and Delta Ferrite.										
GRAIN SIZE							HARDNESS				
SOURCE OF DATA	University of Michigan										

SHORT TIME TENSILE PROPERTIES

TEMPERATURE, °F	MODULUS OF ELASTICITY, 1,000,000 P.S.I.	OFFSET YIELD (1) STRENGTH, 1000 P.S.I.	TENSILE STRENGTH, 1000 P.S.I.	ELONGATION IN 2", PER CENT	REDUCTION IN AREA, PER CENT

CREEP AND RUPTURE STRENGTHS

TEMP., °F	STRESS FOR RUPTURE IN TIMES INDICATED, 1000 P.S.I.(2)				STRESS FOR DESIGNATED CREEP RATE, 1000 P.S.I.(2)		
	100 HRS.	1000 HRS.	10,000 HRS.	100,000 HRS.	0.000001 %/HR.	0.00001 %/HR.	0.0001 %/HR.
1100	41.5	29.0*					
1200	22.0	13.0*					

ORIGINAL CREEP AND RUPTURE DATA

TEMP. °F.	STRESS, 1000 P.S.I.	DURATION, HOURS(3)	INTERCEPT, %(4)	MINIMUM CREEP RATE, %/HR.	TRANSITION TIME, HRS.(5)	TOTAL EXT. (CREEP TEST), %	TOTAL ELONG. (RUPTURE TEST), %	HARDNESS AFTER TESTING
1100	50.0	11.9 R					27.0	
1100	46.0	31.3 R					26.0	
1100	39.0	350. R					23.5	
1100	36.0	399. R					28.5	
1100	33.0	543. R					21.5	
1200	33.0	15.6 R					32.0	
1200	27.0	41.3 R					29.0	
1200	16.0	423. R					47.5	

(3) DURATION OF TEST (RUPTURE TEST INDICATED BY R).

(4) THE INTERCEPT IS THE PROJECTION BACK TO ZERO TIME FROM THE PORTION OF THE TEST SHOWING THE MINIMUM OR SECOND-STAGE CREEP RATE.

(5) THE TRANSITION TIME IS THE BEGINNING OF THE THIRD STAGE, OR AN ACCELERATING CREEP RATE.

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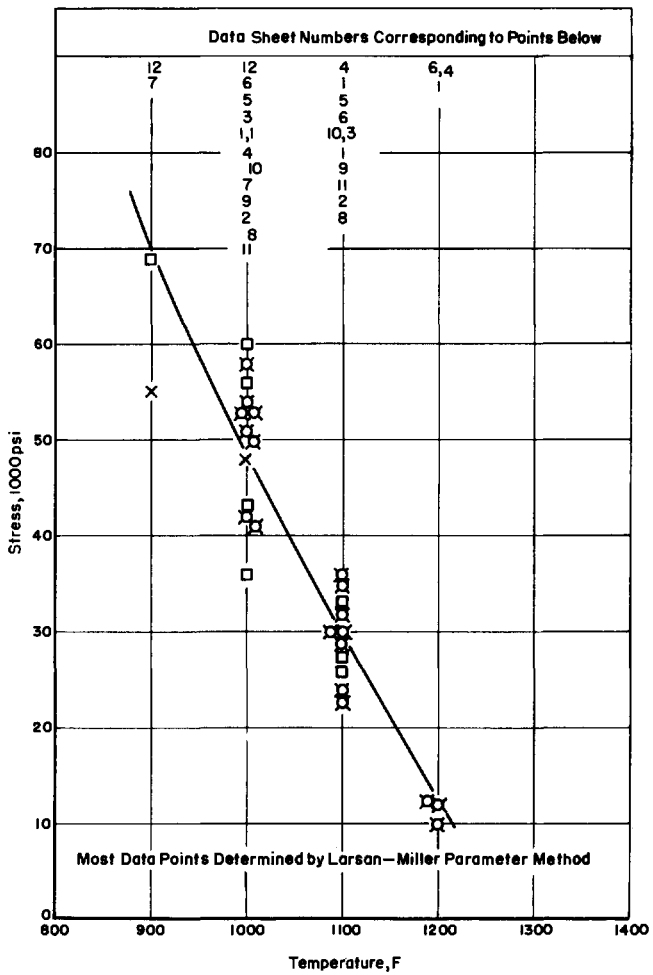
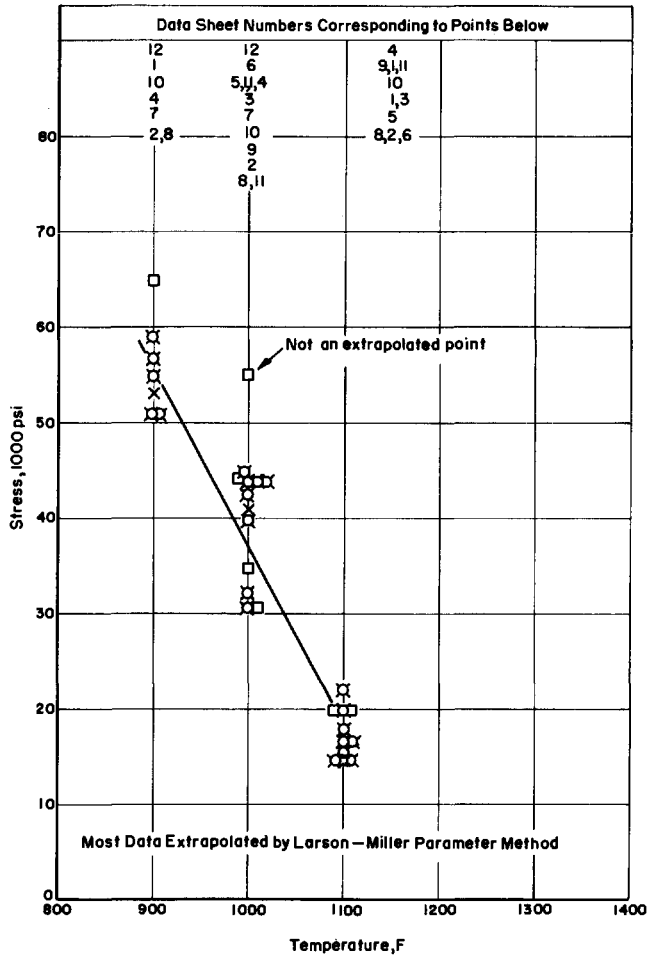
12 Chromium, 2.5 Tungsten, Vanadium Steels



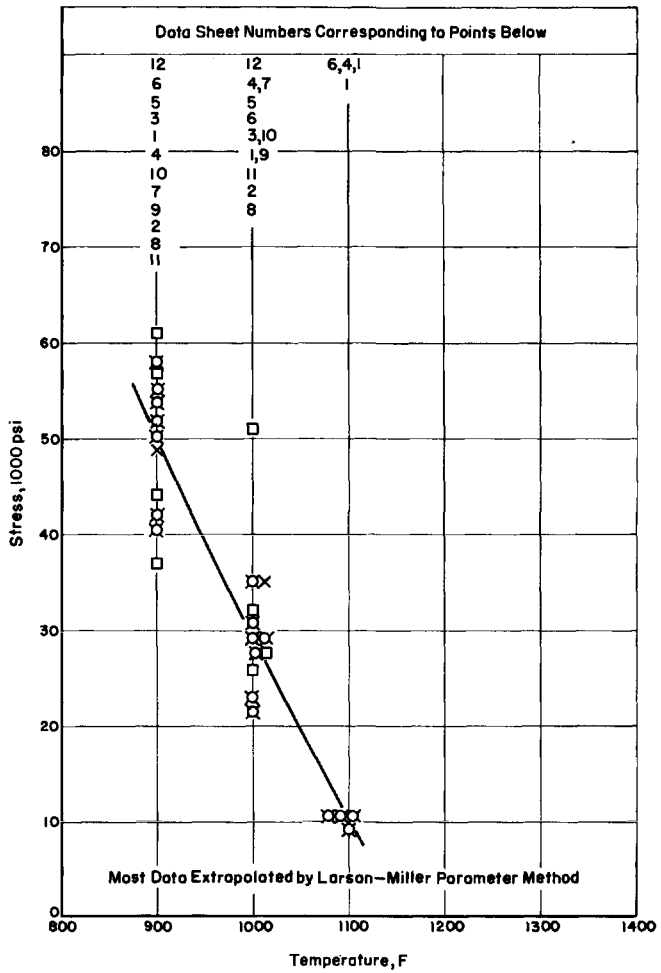
RUPTURE IN 1000 HOURS

12 Cr, 2.5 W, V STEEL



RUPTURE IN 10,000 HOURS
(EXTRAPOLATED)

12 Cr, 2.5 W, V STEEL



RUPTURE IN 100,000 HOURS
(EXTRAPOLATED)

12 Cr, 2.5 W, V STEEL

(1)

ASTM-ASME JOINT COMMITTEE ON EFFECT OF TEMPERATURE ON PROPERTIES OF METALS

TYPE OF MATERIAL 12 Cr, 2.5 W, V											
TYPE OF MELTING FURNACE							SIZE OF HEAT Commercial				
CHEMICAL COMPOSITION, PER CENT	C	Mn	P	S	Si	Cr	Ni	Mo	V	W	
	0.32	1.29	0.020	0.015	0.42	12.5	0.21	0.07	0.26	2.44	
DEOXIDATION											
FORM-CAST OR WROUGHT Wrought 2-9/16" D											
HEAT TREATMENT 1885 F, A.C.; 1200 F, 12 Hr, A.C.											
MICROSTRUCTURE											
GRAIN SIZE							HARDNESS				
SOURCE OF DATA General Electric Company											

SHORT TIME TENSILE PROPERTIES

TEMPERATURE, °F	MODULUS OF ELASTICITY, 1,000,000 P.S.I.	OFFSET(a) YIELD (1) STRENGTH, 1000 P.S.I.	TENSILE STRENGTH, 1000 P.S.I.	ELONGATION IN 2" PER CENT	REDUCTION IN AREA, PER CENT
80		126.2	156.3	14.5	41.0
(a) 0.02% Offset yield strength.					

CREEP AND RUPTURE STRENGTHS

TEMP., °F	STRESS FOR RUPTURE IN TIMES INDICATED, 1000 P.S.I.(2)				STRESS FOR DESIGNATED CREEP RATE, 1000 P.S.I.(2)		
	100 HRS.	1000 HRS.	10,000 HRS.	100,000 HRS.	0.000001 %/HR.	0.00001 %/HR.	0.0001 %/HR.
900			59P	54P			
1000		53P	44P	28P			
1000		53	44*				
1100		29P	17P	9.4P			
1100		35(a)	20*(a)	11*(a)			
1200	19P	10P					
P indicates strength value obtained by use of Larson-Miller parameter T(25 + log t).							
(a) Notched.							

ORIGINAL CREEP AND RUPTURE DATA

TEMP. °F	STRESS, 1000 P.S.I.	DURATION, HOURS(3)	INTERCEPT, %(4)	MINIMUM CREEP RATE, %/HR.	TRANSITION TIME, HRS.(5)	TOTAL EXT. (CREEP TEST), %	TOTAL ELONG. (RUPTURE TEST), %	REDUCTION IN AREA, %
1000	60.0	82 R					14.0	39.3
1000	54.0	1118 R					11.0	41.0
1000	50.0	4195 R					9.0	41.8
1050	58.0	17 R					18.0	39.6
1050	50.0	407 R					11.0	41.7
1050	45.0	762 R					11.0	42.1
1050	32.0	4422 R					7.0	43.3
1100	35.0	427 R					11.0	43.1
1200	35.0	2 R					20.0	42.0
1200	25.0	15 R					18.0	43.5
1200	20.0	88 R					17.0	44.7
1300	10.0	32 R					36.0	46.6
1100	56.0	96 R					Notched(b)	--
1100	46.0	336 R					Notched(b)	--
1100	34.0	1197 R					Notched(b)	--
1100	24.0	4920 R					Notched(b)	--
(b) Notched bar with 0.253" root diameter, 0.357" major diameter, 60 degree notch, and 0.011" notched radius.								

(2)

ASTM-ASME JOINT COMMITTEE ON EFFECT OF TEMPERATURE ON PROPERTIES OF METALS

TYPE OF MATERIAL 12 Cr, 2.5 W, V											
TYPE OF MELTING FURNACE							SIZE OF HEAT Commercial				
CHEMICAL COMPOSITION, PER CENT	C	Mn	P	S	Si	Cr	Ni	Mo	W	V	
	0.28	1.33			0.32	12.68	0.16		2.54	0.23	
DEOXIDATION											
FORM-CAST OR WROUGHT Forged Bucket											
HEAT TREATMENT 1900 F, 4 Hr, A.Q.; 1200 F, 12 Hr, A.C.											
MICROSTRUCTURE											
GRAIN SIZE							HARDNESS				
SOURCE OF DATA General Electric Company											

SHORT TIME TENSILE PROPERTIES

TEMPERATURE, °F	MODULUS OF ELASTICITY, 1,000,000 P.S.I.	OFFSET(a) YIELD (1) STRENGTH, 1000 P.S.I.	TENSILE STRENGTH, 1000 P.S.I.	ELONGATION IN 2" PER CENT	REDUCTION IN AREA, PER CENT
80		100.0	151.2	18.0	47.2
(a) 0.02% Offset yield strength.					

CREEP AND RUPTURE STRENGTHS

TEMP., °F	STRESS FOR RUPTURE IN TIMES INDICATED, 1000 P.S.I.(2)				STRESS FOR DESIGNATED CREEP RATE, 1000 P.S.I.(2)		
	100 HRS.	1000 HRS.	10,000 HRS.	100,000 HRS.	0.000001 %/HR.	0.00001 %/HR.	0.0001 %/HR.
900			51P	42P			
1000		42P	32P	23P			
1100		24P	15P				
1200	17P						
P indicates strength value obtained by use of Larson-Miller parameter T(25 + log t).							

ORIGINAL CREEP AND RUPTURE DATA

TEMP. °F	STRESS, 1000 P.S.I.	DURATION, HOURS(3)	INTERCEPT, %(4)	MINIMUM CREEP RATE, %/HR.	TRANSITION TIME, HRS.(5)	TOTAL EXT. (CREEP TEST), %	TOTAL ELONG. (RUPTURE TEST), %	REDUCTION IN AREA, %
1050	56.0	4 R					9.0	
1050	26.0	10,787 R					9.0	47.0
1100	26.0	701 R					--	
1150	40.0	4 R					16.0	
1200	11.0	298 R					34.0	
1250	20.0	7 R					27.0	
1300	11.8	10 R					37.0	
Test specimens 0.160" diameter, 1-inch gage length.								

(3)

ASTM-ASME JOINT COMMITTEE ON EFFECT OF TEMPERATURE ON PROPERTIES OF METALS

TYPE OF MATERIAL 12 Cr, 2.5 W, V											
TYPE OF MELTING FURNACE							SIZE OF HEAT Commercial				
CHEMICAL COMPOSITION, PER CENT	C	Mn	P	S	Si	Cr	Ni	Mo	W	V	
	0.28	1.43			0.47	12.74	0.12		2.37	0.26	
DEOXIDATION											
FORM-CAST OR WROUGHT Forged Bucket											
HEAT TREATMENT 1900 F, 4 Hr, A.Q.; 1200 F, 12 Hr, A.C.											
MICROSTRUCTURE											
GRAIN SIZE							HARDNESS				
SOURCE OF DATA General Electric Company											

SHORT TIME TENSILE PROPERTIES

TEMPERATURE, °F	MODULUS OF ELASTICITY, 1,000,000 P.S.I.	OFFSET(a) YIELD (1) STRENGTH, 1000 P.S.I.	TENSILE STRENGTH, 1000 P.S.I.	ELONGATION IN 2" PER CENT	REDUCTION IN AREA, PER CENT
80		105.0	149.2	18.0	47.8
(a) 0.02% Offset yield strength.					

CREEP AND RUPTURE STRENGTHS

TEMP., °F	STRESS FOR RUPTURE IN TIMES INDICATED, 1000 P.S.I.(2)				STRESS FOR DESIGNATED CREEP RATE, 1000 P.S.I.(2)		
	100 HRS.	1000 HRS.	10,000 HRS.	100,000 HRS.	0.000001 %/HR.	0.00001 %/HR.	0.0001 %/HR.
900				55P			
1000		54P	43P	29P			
1100		30P	17P				
1200	20P						
P indicates strength value obtained by use of Larson-Miller parameter T(25 + log t).							

ORIGINAL CREEP AND RUPTURE DATA

TEMP. °F	STRESS, 1000 P.S.I.	DURATION, HOURS(3)	INTERCEPT, %(4)	MINIMUM CREEP RATE, %/HR.	TRANSITION TIME, HRS.(5)	TOTAL EXT. (CREEP TEST), %	TOTAL ELONG. (RUPTURE TEST), %	HARDNESS AFTER TESTING
1050	55.0	94 R					12.0	
1100	35.4	473 R					19.0	
1150	40.0	39 R					11.0	
1150	10.0	4517	Discontinued					
1200	11.0	592 R					--	
1250	20.0	16 R					21.0	
1300	11.8	11 R					34.0	
Test specimens 0.160" diameter, 1-inch gage length.								

(1) 0.2 PER CENT OFFSET UNLESS OTHERWISE INDICATED.

(2) EXTRAPOLATED VALUES INDICATED BY *

(3) DURATION OF TEST (RUPTURE TEST INDICATED BY R).

(4) THE INTERCEPT IS THE PROJECTION BACK TO ZERO TIME FROM THE PORTION OF THE TEST SHOWING THE MINIMUM OR SECOND-STAGE CREEP RATE.

(5) THE TRANSITION TIME IS THE BEGINNING OF THE THIRD STAGE, OR AN ACCELERATING CREEP RATE.

(4)

ASTM-ASME JOINT COMMITTEE ON EFFECT OF TEMPERATURE ON PROPERTIES OF METALS

TYPE OF MATERIAL 12 Cr, 2.5 W, V				TYPE OF MELTING FURNACE				SIZE OF HEAT Commercial			
CHEMICAL COMPOSITION, PER CENT	C	Mn	P	S	Si	Cr	Ni	Mo	W	V	
	0.27	1.18			0.33	12.58	0.12		2.35	0.18	
DEOXIDATION											
FORM-CAST OR WROUGHT Forged Bucket											
HEAT TREATMENT 1900 F, 4 Hr, A.Q.; 1200 F, 12 Hr, A.C.											
MICROSTRUCTURE											
GRAIN SIZE							HARDNESS				
SOURCE OF DATA General Electric Company											

SHORT TIME TENSILE PROPERTIES

TEMPERATURE, °F	MODULUS OF ELASTICITY, 1,000,000 P.S.I.	OFFSET(a) YIELD (1) STRENGTH, 1000 P.S.I.	TENSILE STRENGTH, 1000 P.S.I.	ELONGATION IN 2" PER CENT	REDUCTION IN AREA, PER CENT
80		104.0	150.0	17.0	45.2
(a) 0.02% Offset yield strength.					

CREEP AND RUPTURE STRENGTHS

TEMP., °F	STRESS FOR RUPTURE IN TIMES INDICATED, 1000 P.S.I.(2)				STRESS FOR DESIGNATED CREEP RATE, 1000 P.S.I.(2)		
	100 HRS.	1000 HRS.	10,000 HRS.	100,000 HRS.	0.000001 %/HR.	0.00001 %/HR.	0.0001 %/HR.
900			55P	52P			
1000		51P	44P	35P			
1100		36P	22P	11P			
1200	26P	12P					
P indicates strength value obtained by use of Larson-Miller parameter T(25 + log t).							

ORIGINAL CREEP AND RUPTURE DATA

TEMP., °F	STRESS, 1000 P.S.I.	DURATION, HOURS(3)	INTERCEPT, %(4)	MINIMUM CREEP RATE, %/HR.	TRANSITION TIME, HRS.(5)	TOTAL EXT. (CREEP TEST), %	TOTAL ELONG. (RUPTURE TEST), %	HARDNESS AFTER TESTING
1050	56.0	8 R					16.0	
1050	38.0	5151 R					6.0	
1100	37.0	396 R					18.0	
1150	40.0	168 R					13.0	
1200	15.8	461 R					--	
1250	20.0	38 R					19.0	
1300	12.0	32 R					38.0	
Test specimens 0.160" diameter, 1-inch gage length.								

(5)

ASTM-ASME JOINT COMMITTEE ON EFFECT OF TEMPERATURE ON PROPERTIES OF METALS

TYPE OF MATERIAL 12 Cr, 2.5 W, V				TYPE OF MELTING FURNACE				SIZE OF HEAT Commercial			
CHEMICAL COMPOSITION, PER CENT	C	Mn	P	S	Si	Cr	Ni	Mo	V	W	
	0.29	1.00	--	--	0.26	11.68	0.12	--	0.25	2.42	
DEOXIDATION											
FORM-CAST OR WROUGHT Wrought 4-1/16" D											
HEAT TREATMENT 1900 F, A.C.; 1200 F, 16 Hr, A.C.; 1150 F, 20 Hr, A.C.											
MICROSTRUCTURE											
GRAIN SIZE							HARDNESS				
SOURCE OF DATA General Electric Company											

SHORT TIME TENSILE PROPERTIES

TEMPERATURE, °F	MODULUS OF ELASTICITY, 1,000,000 P.S.I.	OFFSET(a) YIELD (1) STRENGTH, 1000 P.S.I.	TENSILE STRENGTH, 1000 P.S.I.	ELONGATION IN 2" PER CENT	REDUCTION IN AREA, PER CENT
80		103.0	153.5	16	41.4
(a) 0.02% Offset yield strength.					

CREEP AND RUPTURE STRENGTHS

TEMP., °F	STRESS FOR RUPTURE IN TIMES INDICATED, 1000 P.S.I.(2)				STRESS FOR DESIGNATED CREEP RATE, 1000 P.S.I.(2)		
	100 HRS.	1000 HRS.	10,000 HRS.	100,000 HRS.	0.000001 %/HR.	0.00001 %/HR.	0.0001 %/HR.
900				57P			
1000		56P	44P	32P			
1100		33P	21P	--			
1200	24P	--	--				
P indicates strength value obtained by use of Larson-Miller parameter T(25 + log t).							

ORIGINAL CREEP AND RUPTURE DATA

TEMP., °F	STRESS, 1000 P.S.I.	DURATION, HOURS(3)	INTERCEPT, %(4)	MINIMUM CREEP RATE, %/HR.	TRANSITION TIME, HRS.(5)	TOTAL EXT. (CREEP TEST), %	TOTAL ELONG. (RUPTURE TEST), %	HARDNESS AFTER TESTING
1000	60.0	393 R					13.0	70.0
1050	55.0	192 R					12.0	73.0
1100	45.0	167 R					12.0	77.0
1200	35.0	7 R					17.0	85.0
1200	30.0	44 R					14.0	85.0
1200	20.0	227 R					16.0	83.0
1350	13.0	4 R					30.0	93.0

(6)

ASTM-ASME JOINT COMMITTEE ON EFFECT OF TEMPERATURE ON PROPERTIES OF METALS

TYPE OF MATERIAL 12 Cr, 2.5 W, V				TYPE OF MELTING FURNACE				SIZE OF HEAT Commercial			
CHEMICAL COMPOSITION, PER CENT	C	Mn	P	S	Si	Cr	Ni	Mo	W	V	
	0.30	1.24				12.34			2.72	0.24	
DEOXIDATION											
FORM-CAST OR WROUGHT Forged Bucket											
HEAT TREATMENT 1900 F, 4 Hr, A.Q.; 1200 F, 12 Hr, A.C.											
MICROSTRUCTURE											
GRAIN SIZE							HARDNESS				
SOURCE OF DATA General Electric Company											

SHORT TIME TENSILE PROPERTIES

TEMPERATURE, °F	MODULUS OF ELASTICITY, 1,000,000 P.S.I.	OFFSET(a) YIELD (1) STRENGTH, 1000 P.S.I.	TENSILE STRENGTH, 1000 P.S.I.	ELONGATION IN 2" PER CENT	REDUCTION IN AREA, PER CENT
80		106.2	159.0	16.0	37.9
(a) 0.02% Offset yield strength.					

CREEP AND RUPTURE STRENGTHS

TEMP., °F	STRESS FOR RUPTURE IN TIMES INDICATED, 1000 P.S.I.(2)				STRESS FOR DESIGNATED CREEP RATE, 1000 P.S.I.(2)		
	100 HRS.	1000 HRS.	10,000 HRS.	100,000 HRS.	0.000001 %/HR.	0.00001 %/HR.	0.0001 %/HR.
900				58P			
1000		58P	44P	31P			
1100		32P	20P	11P			
1200	23P	12.5P					
P indicates strength value obtained by use of Larson-Miller parameter T(25 + log t).							

ORIGINAL CREEP AND RUPTURE DATA

TEMP., °F	STRESS, 1000 P.S.I.	DURATION, HOURS(3)	INTERCEPT, %(4)	MINIMUM CREEP RATE, %/HR.	TRANSITION TIME, HRS.(5)	TOTAL EXT. (CREEP TEST), %	TOTAL ELONG. (RUPTURE TEST), %	HARDNESS AFTER TESTING
1050	55.0	154 R					14.0	
1050	33.0	8293 R					7.0	
1100	37.0	501 R					15.0	
1150	40.0	140 R					11.0	
1200	16.0	233 R					--	
1250	20.0	28 R					21.0	
1300	11.8	30 R					44.0	
Test specimens 0.160" diameter, 1-inch gage length.								

(1) 0.2 PER CENT OFFSET UNLESS OTHERWISE INDICATED.

(2) EXTRAPOLATED VALUES INDICATED BY *

(3) DURATION OF TEST (RUPTURE TEST INDICATED BY R).

(4) THE INTERCEPT IS THE PROJECTION BACK TO ZERO TIME FROM THE PORTION OF THE TEST SHOWING THE MINIMUM OR SECOND-STAGE CREEP RATE.

(5) THE TRANSITION TIME IS THE BEGINNING OF THE THIRD STAGE, OR AN ACCELERATING CREEP RATE.

(7)

ASTM-ASME JOINT COMMITTEE ON EFFECT OF TEMPERATURE ON PROPERTIES OF METALS

TYPE OF MATERIAL	12 Cr, 2.5 W, V	TYPE OF MELTING FURNACE					SIZE OF HEAT	Commercial			
CHEMICAL COMPOSITION, PER CENT	C	Mn	P	S	Si	Cr	Ni	Mo	W	V	
	0.34	0.46				12.47			2.93	0.24	
DEOXIDATION											
FORM-CAST OR WROUGHT	Wrought 1" Diameter Bar										
HEAT TREATMENT	2050 F, O.Q.; 1400 F, A.C.										
MICROSTRUCTURE											
GRAIN SIZE					HARDNESS						
SOURCE OF DATA	General Electric Company										

SHORT TIME TENSILE PROPERTIES

TEMPERATURE, °F	MODULUS OF ELASTICITY, 1,000,000 P.S.I.	OFFSET YIELD (1) STRENGTH, 1000 P.S.I.	TENSILE STRENGTH, 1000 P.S.I.	ELONGATION IN 2", PER CENT	REDUCTION IN AREA, PER CENT
80			133.0	17.0	38.0

CREEP AND RUPTURE STRENGTHS

TEMP., °F	STRESS FOR RUPTURE IN TIMES INDICATED, 1000 P.S.I.(2)				STRESS FOR DESIGNATED CREEP RATE, 1000 P.S.I.(2)		
	100 HRS.	1000 HRS.	10,000 HRS.	100,000 HRS.	0.000001 %/HR.	0.00001 %/HR	0.0001 %/HR.
900		55P	53P	49P			
1000		48	41*	35*			

P indicates strength value obtained by use of Larson-Miller parameter T(25 + log t).

ORIGINAL CREEP AND RUPTURE DATA

TEMP. °F.	STRESS, 1000 P.S.I.	DURATION, HOURS(3)	INTERCEPT, %(4)	MINIMUM CREEP RATE, %/HR.	TRANSITION TIME, HRS.(5)	TOTAL EXT. (CREEP TEST), %	TOTAL ELONG. (RUPTURE TEST), %	REDUCTION IN AREA, %
1000	60.0	17 R					21.0	65.0
1000	56.0	11 R					19.0	72.0
1000	52.0	83 R					15.0	66.0
1000	50.0	594 R					16.0	71.0
1000	40.0	13,000	Discontinued					

(8)

ASTM-ASME JOINT COMMITTEE ON EFFECT OF TEMPERATURE ON PROPERTIES OF METALS

TYPE OF MATERIAL	12 Cr, 2.5 W, V	TYPE OF MELTING FURNACE					SIZE OF HEAT	Commercial			
CHEMICAL COMPOSITION, PER CENT	C	Mn	P	S	Si	Cr	Ni	Mo	W	V	
	0.30	1.26			0.40	12.65	0.16		2.31	0.26	
DEOXIDATION											
FORM-CAST OR WROUGHT	Forged Bucket										
HEAT TREATMENT	1900 F, 4 Hr, A.Q.; 1200 F, 12 Hr, A.C.										
MICROSTRUCTURE											
GRAIN SIZE					HARDNESS						
SOURCE OF DATA	General Electric Company										

SHORT TIME TENSILE PROPERTIES

TEMPERATURE, °F	MODULUS OF ELASTICITY, 1,000,000 P.S.I.	OFFSET(a) YIELD (1) STRENGTH, 1000 P.S.I.	TENSILE STRENGTH, 1000 P.S.I.	ELONGATION IN 2", PER CENT	REDUCTION IN AREA, PER CENT
80		111.2	162.0	14.5	34.1

(a) 0.02% Offset yield strength.

CREEP AND RUPTURE STRENGTHS

TEMP., °F	STRESS FOR RUPTURE IN TIMES INDICATED, 1000 P.S.I.(2)				STRESS FOR DESIGNATED CREEP RATE, 1000 P.S.I.(2)		
	100 HRS.	1000 HRS.	10,000 HRS.	100,000 HRS.	0.000001 %/HR.	0.00001 %/HR	0.0001 %/HR.
900			51P	41P			
1000		41P	*31P	22P			
1100		23P	15P				
1200	17P						

P indicates strength value obtained by use of Larson-Miller parameter T(25 + log t).

(1) 0.2 PER CENT OFFSET UNLESS OTHERWISE INDICATED.
(2) EXTRAPOLATED VALUES INDICATED BY *

ORIGINAL CREEP AND RUPTURE DATA

TEMP. °F.	STRESS, 1000 P.S.I.	DURATION, HOURS(3)	INTERCEPT, %(4)	MINIMUM CREEP RATE, %/HR.	TRANSITION TIME, HRS.(5)	TOTAL EXT. (CREEP TEST), %	TOTAL ELONG. (RUPTURE TEST), %	HARDNESS AFTER TESTING
1050	55.0	7 R					22.0	
1100	26.0	712 R					24.0	
1150	40.0	3.5 R					19.0	
1200	11.0	433 R					29.0	
1250	20.0	7 R					27.0	
1300	12.0	9 R					38.0	
	Test specimens	0.160" diameter, 1-inch gage length.						

(9)

ASTM-ASME JOINT COMMITTEE ON EFFECT OF TEMPERATURE ON PROPERTIES OF METALS

TYPE OF MATERIAL	12 Cr, 2.5 W, V	TYPE OF MELTING FURNACE					SIZE OF HEAT	Commercial			
CHEMICAL COMPOSITION, PER CENT	C	Mn	P	S	Si	Cr	Ni	Mo	V	W	
	0.29	1.00	--	--	0.26	11.68	0.12	--	0.25	2.42	
DEOXIDATION											
FORM-CAST OR WROUGHT	Wrought 4-1/16" D										
HEAT TREATMENT	1900 F, A.C.; 1200 F, 16 Hr, A.C.; 1150 F, 20 Hr, A.C., 1300 F, 5 Hr, A.C.										
MICROSTRUCTURE											
GRAIN SIZE					HARDNESS						
SOURCE OF DATA	General Electric Company										

SHORT TIME TENSILE PROPERTIES

TEMPERATURE, °F	MODULUS OF ELASTICITY, 1,000,000 P.S.I.	OFFSET(a) YIELD (1) STRENGTH, 1000 P.S.I.	TENSILE STRENGTH, 1000 P.S.I.	ELONGATION IN 2", PER CENT	REDUCTION IN AREA, PER CENT
80		93.0	142.0	19.5	49.8

(a) 0.02% Offset yield strength.

CREEP AND RUPTURE STRENGTHS

TEMP., °F	STRESS FOR RUPTURE IN TIMES INDICATED, 1000 P.S.I.(2)				STRESS FOR DESIGNATED CREEP RATE, 1000 P.S.I.(2)		
	100 HRS.	1000 HRS.	10,000 HRS.	100,000 HRS.	0.000001 %/HR.	0.00001 %/HR	0.0001 %/HR.
900				44P			
1000		43P	35P	28P			
1100		28P	20P	--			
1200	23P	--	--				

P indicates strength value obtained by use of Larson-Miller parameter T(25 + log t).

ORIGINAL CREEP AND RUPTURE DATA

TEMP. °F.	STRESS, 1000 P.S.I.	DURATION, HOURS(3)	INTERCEPT, %(4)	MINIMUM CREEP RATE, %/HR.	TRANSITION TIME, HRS.(5)	TOTAL EXT. (CREEP TEST), %	TOTAL ELONG. (RUPTURE TEST), %	REDUCTION IN AREA, %
1100	45.0	9 R					10.0	81.0
1200	35.0	3 R					21.0	85.0
1200	30.0	19 R					18.0	83.0
1200	20.0	192 R					8.0	80.0

(10)

ASTM-ASME JOINT COMMITTEE ON EFFECT OF TEMPERATURE ON PROPERTIES OF METALS

TYPE OF MATERIAL	12 Cr, 2.5 W, V	TYPE OF MELTING FURNACE					SIZE OF HEAT	Commercial			
CHEMICAL COMPOSITION, PER CENT	C	Mn	P	S	Si	Cr	Ni	Mo	W	V	
	0.28	1.33	--	--	0.35	12.86	0.12		2.54	0.23	
DEOXIDATION											
FORM-CAST OR WROUGHT	Forged Bucket										
HEAT TREATMENT	1900 F, 4 Hr, A.Q.; 1200 F, 12 Hr, A.C.										
MICROSTRUCTURE											
GRAIN SIZE					HARDNESS						
SOURCE OF DATA	General Electric Company										

SHORT TIME TENSILE PROPERTIES

TEMPERATURE, °F	MODULUS OF ELASTICITY, 1,000,000 P.S.I.	OFFSET(a) YIELD (1) STRENGTH, 1000 P.S.I.	TENSILE STRENGTH, 1000 P.S.I.	ELONGATION IN 2", PER CENT	REDUCTION IN AREA, PER CENT
80		117.0	158.2	18.5	44.0

(a) 0.02% Offset yield strength.

(3) DURATION OF TEST (RUPTURE TEST INDICATED BY R).
(4) THE INTERCEPT IS THE PROJECTION BACK TO ZERO TIME FROM THE PORTION OF THE TEST SHOWING THE MINIMUM OR SECOND-STAGE CREEP RATE.
(5) THE TRANSITION TIME IS THE BEGINNING OF THE THIRD STAGE, OR AN ACCELERATING CREEP RATE.

CREEP AND RUPTURE STRENGTHS

TEMP., °F	STRESS FOR RUPTURE IN TIMES INDICATED, 1000 P.S.I. (2)				STRESS FOR DESIGNATED CREEP RATE, 1000 P.S.I. (2)		
	100 HRS.	1000 HRS.	10,000 HRS.	100,000 HRS.	0.000001 %/HR.	0.00001 %/HR.	0.0001 %/HR.
900			57P	50P			
1000		50P	40P	29P			
1100		30P	18P				
1200	21P	--	--				

P indicates strength value obtained by use of Larson-Miller parameter T(25 + log t).

ORIGINAL CREEP AND RUPTURE DATA

TEMP. °F.	STRESS 1000 PSI.	DURATION, HOURS(3)	INTERCEPT, %(4)	MINIMUM CREEP RATE, %/HR.	TRANSITION TIME, HRS.(5)	TOTAL EXT. (CREEP TEST), %	TOTAL ELONG. (RUPTURE TEST), %	REDUCTION IN AREA, %
1050	56.0	16 R					14.0	
1100	48.0	24 R					17.0	
1150	35.5	73 R					13.0	
1100	34.9	512 R					19.0	
1100	33.0	709 R					22.0	
1050	33.0	6467 R					11.0	37
1200	28.0	29 R					19.0	
1250	20.0	20 R					20.0	
1300	16.0	5 R					29.0	
1200	14.2	465 R					29.0	
1300	12.0	12 R					42.0	
1150	10.0	4516+					Discontinued	

Test specimens 1" gage length, 0.160" diameter.

(11)

ASTM-ASME JOINT COMMITTEE ON EFFECT OF TEMPERATURE ON PROPERTIES OF METALS

TYPE OF MATERIAL 12 Cr, 2.5 W, V — TYPE OF MELTING FURNACE — SIZE OF HEAT Commercial

CHEMICAL COMPOSITION, PER CENT	C	Mn	P	S	Si	Cr	Ni	Mo	W	V
	0.29	1.00			0.26	11.68	0.12		2.42	0.25

DEOXIDATION

FORM-CAST OR WROUGHT Wrought 4-1/16" D

HEAT TREATMENT 1900 F, A.C.; 1200 F, 16 Hr, A.C.; 1150 F, 20 Hr, A.C.; 1400 F, 5 Hr, A.C.

MICROSTRUCTURE

GRAIN SIZE — HARDNESS

SOURCE OF DATA General Electric Company

SHORT TIME TENSILE PROPERTIES

TEMPERATURE, °F	MODULUS OF ELASTICITY, 1,000,000 P.S.I.	OFFSET(a) YIELD (1) STRENGTH, 1000 P.S.I.	TENSILE STRENGTH, 1000 P.S.I.	ELONGATION IN 2", PER CENT	REDUCTION IN AREA, PER CENT
80		93.0	126.25	23.5	52.5

(a) 0.02% Yield strength.

CREEP AND RUPTURE STRENGTHS

TEMP., °F	STRESS FOR RUPTURE IN TIMES INDICATED, 1000 P.S.I. (2)				STRESS FOR DESIGNATED CREEP RATE, 1000 P.S.I. (2)		
	100 HRS.	1000 HRS.	10,000 HRS.	100,000 HRS.	0.000001 %/HR.	0.00001 %/HR.	0.0001 %/HR.
900				37P			
1000		36P	31P	26P			
1100		26P	20P	--			
1200	22P	--	--	--			

P indicates strength value obtained by use of Larson-Miller parameter T(25 + log t).

ORIGINAL CREEP AND RUPTURE DATA

TEMP. °F.	STRESS 1000 PSI.	DURATION, HOURS(3)	INTERCEPT, %(4)	MINIMUM CREEP RATE, %/HR.	TRANSITION TIME, HRS.(5)	TOTAL EXT. (CREEP TEST), %	TOTAL ELONG. (RUPTURE TEST), %	REDUCTION IN AREA, %
1150	40.0	1 R					21.0	81.0
1200	35.0	1 R					23.0	85.0
1200	20.0	171 R					16.0	84.0

(12)

ASTM-ASME JOINT COMMITTEE ON EFFECT OF TEMPERATURE ON PROPERTIES OF METALS

TYPE OF MATERIAL 12 Cr, 2.5 W, V — TYPE OF MELTING FURNACE Induction — SIZE OF HEAT Experimental

CHEMICAL COMPOSITION, PER CENT	C	Mn	P	S	Si	Cr	Ni	Mo	W	V
	0.20	0.25			0.33	13.14			3.14	0.22

DEOXIDATION

FORM-CAST OR WROUGHT Wrought 1/2"-Diameter Bar

HEAT TREATMENT 2010 F, 4 Hr, A.C.; 1200 F, 2 Hr, A.C.; 1110 F, 2 Hr, A.C.

MICROSTRUCTURE

GRAIN SIZE — HARDNESS

SOURCE OF DATA General Electric Company

SHORT TIME TENSILE PROPERTIES

TEMPERATURE, °F	MODULUS OF ELASTICITY, 1,000,000 P.S.I.	OFFSET YIELD (1) STRENGTH, 1000 P.S.I.	TENSILE STRENGTH, 1000 P.S.I.	ELONGATION IN 2", PER CENT	REDUCTION IN AREA, PER CENT
80			146.5	19.0	43.6

CREEP AND RUPTURE STRENGTHS

TEMP., °F	STRESS FOR RUPTURE IN TIMES INDICATED, 1000 P.S.I. (2)				STRESS FOR DESIGNATED CREEP RATE, 1000 P.S.I. (2)		
	100 HRS.	1000 HRS.	10,000 HRS.	100,000 HRS.	0.000001 %/HR.	0.00001 %/HR.	0.0001 %/HR.
900		69P	65P	61P			
1000		60	55	51*			

P indicates strength value obtained by use by Larson-Miller parameter T(25 + log t).

(1) 0.2 PER CENT OFFSET UNLESS OTHERWISE INDICATED.

(2) EXTRAPOLATED VALUES INDICATED BY *

ORIGINAL CREEP AND RUPTURE DATA

TEMP. °F.	STRESS 1000 PSI.	DURATION, HOURS(3)	INTERCEPT, %(4)	MINIMUM CREEP RATE, %/HR.	TRANSITION TIME, HRS.(5)	TOTAL EXT. (CREEP TEST), %	TOTAL ELONG. (RUPTURE TEST), %	REDUCTION IN AREA, %
1000	69.0	13 R					15.0	65.0
1000	60.0	1817 R					12.0	60.0
1000	55.0	11,913 R					8.0	35.0

(3) DURATION OF TEST (RUPTURE TEST INDICATED BY R).

(4) THE INTERCEPT IS THE PROJECTION BACK TO ZERO TIME FROM THE PORTION OF THE TEST SHOWING THE MINIMUM OR SECOND-STAGE CREEP RATE.

(5) THE TRANSITION TIME IS THE BEGINNING OF THE THIRD STAGE, OR AN ACCELERATING CREEP RATE.

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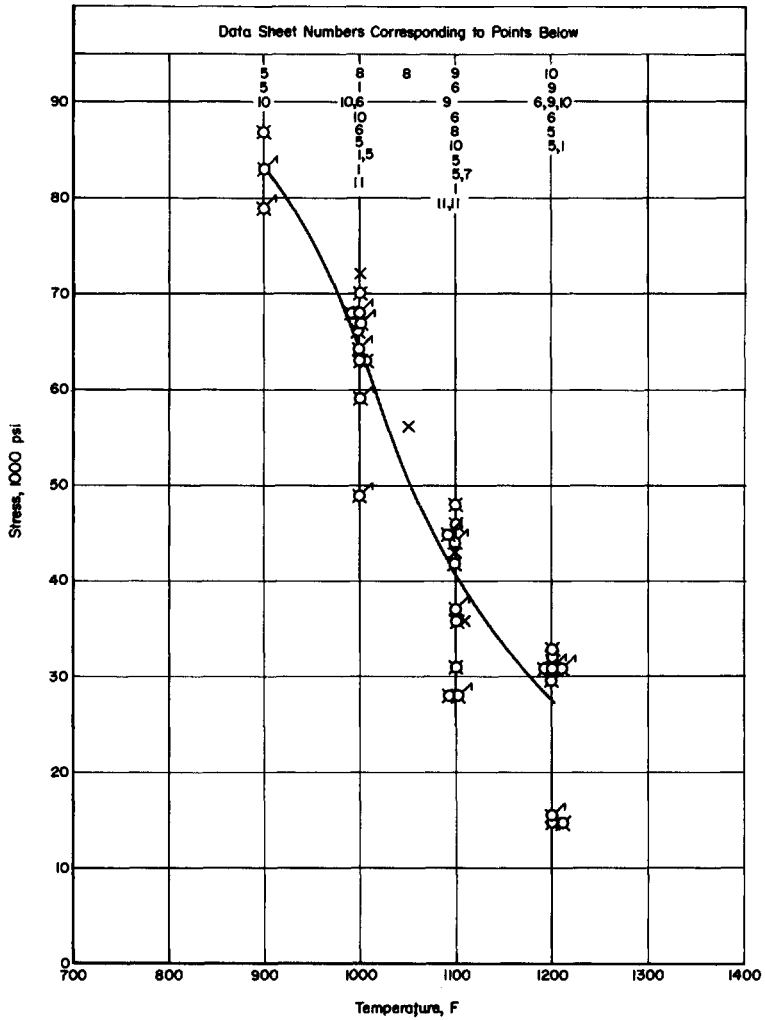
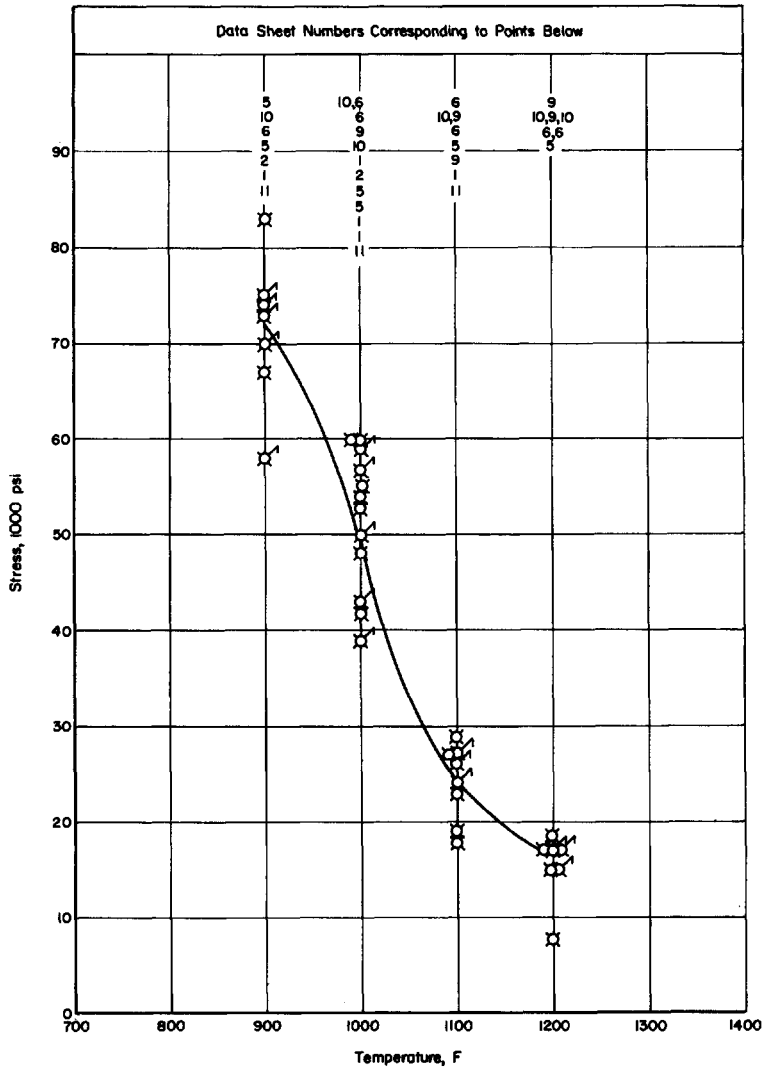
12 Chromium, 5 Cobalt, 3 Tungsten, Vanadium Steels (Cobalt Ascoloy)



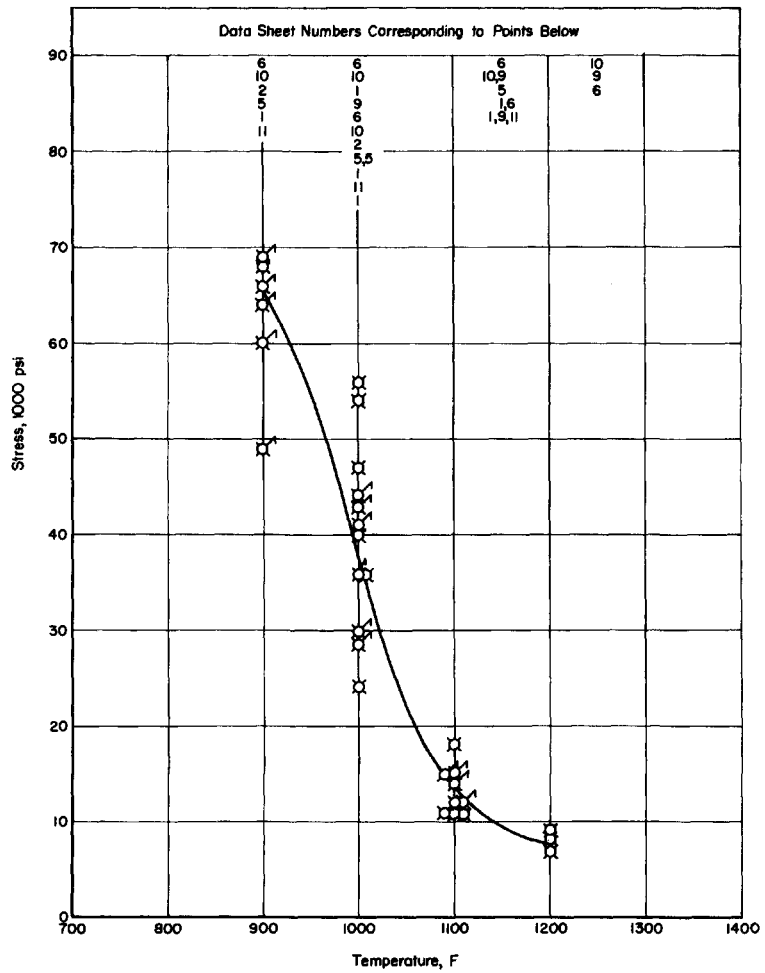
RUPTURE IN 1000 HOURS

12Cr, 5Co, 3W, V STEEL



RUPTURE IN 10,000 HOURS
(EXTRAPOLATED)

12 Cr, 5Co, 3W, V STEEL



RUPTURE IN 100,000 HOURS
(EXTRAPOLATED)

12Cr, 5Co, 3W, V STEEL

(1)

ASTM-ASME JOINT COMMITTEE ON EFFECT OF TEMPERATURE ON PROPERTIES OF METALS

TYPE OF MATERIAL	12 Cr, 5 Co, 3 W, V	TYPE OF MELTING FURNACE					SIZE OF HEAT	Commercial			
CHEMICAL COMPOSITION, PER CENT	C	Mn	P	S	Si	Cr	Ni	Mo	Co	V	W
	0.18	1.15			0.38	11.61	0.24	0.07	5.13	0.27	3.35
DEOXIDATION											
FORM-CAST OR WROUGHT	Wrought 4-1/4" D										
HEAT TREATMENT	1742 F, 5 Hr, A.C.; 1200 F, 8 Hr, A.C.										
MICROSTRUCTURE											
GRAIN SIZE							HARDNESS				
SOURCE OF DATA	General Electric Company										

SHORT TIME TENSILE PROPERTIES

TEMPERATURE, °F	MODULUS OF ELASTICITY, 1,000,000 P.S.I.	OFFSET YIELD (1) STRENGTH, 1000 P.S.I.	TENSILE STRENGTH, 1000 P.S.I.	ELONGATION IN 2", PER CENT	REDUCTION IN AREA, PER CENT
80			163.4	17.5	48.1

CREEP AND RUPTURE STRENGTHS

TEMP., °F	STRESS FOR RUPTURE IN TIMES INDICATED, 1000 P.S.I.(2)				STRESS FOR DESIGNATED CREEP RATE, 1000 P.S.I.(2)		
	100 HRS.	1000 HRS.	10,000 HRS.	100,000 HRS.	0.000001 %/HR.	0.00001 %/HR.	0.0001 %/HR.
900			67P	60P			
1000		59P	43P	30P			
1000		63	54*	47*			
1000		70(a)	42*(a)	24*(a)			
1100		31	19*	12*			
1200	25	15*					

P indicates strength value obtained by use of Larson-Miller parameter T(25 + log t).

(a) Notched.

ORIGINAL CREEP AND RUPTURE DATA

TEMP. °F	STRESS, 1000 P.S.I.	DURATION, HOURS(3)	INTERCEPT, %(4)	MINIMUM CREEP RATE, %/HR.	TRANSITION TIME, HRS.(5)	TOTAL EXT. (CREEP TEST), %	TOTAL ELONG. (RUPTURE TEST), %	REDUCTION IN AREA, %
1000	70.0	29 R					12.0	65.0
1000	66.0	478 R					14.0	66.0
1000	64.0	559 R					12.0	63.0
1000	62.0	1421 R					10.0	60.0
1000	59.0	2704 R					9.0	54.0
1100	52.0	15 R					12.0	76.0
1100	46.0	139 R					11.0	69.0
1100	42.0	171 R					11.0	72.0
1100	38.0	383 R					11.0	72.0
1100	32.0	804 R					5.0	11.0
1100	24.0	3410 R					12.0	54.0
1100	21.0	2591 R					13.0	46.0
1200	35.0	8 R					15.0	84.0
1200	32.0	27 R					14.0	81.0
1200	28.0	68 R					14.0	80.0
1200	24.0	110 R					17.0	79.0
1200	22.0	211 R					17.0	80.0
1000	76.0	474 R					Notched(b)	
1000	74.0	751 R					Notched(b)	--
1000	70.0	1088 R					Notched(b)	--
1000	60.0	2022 R					Notched(b)	--
1000	50.0	4190 R					Notched(b)	2.0

(b) Notched bar with 0.253" root diameter, 0.357" major diameter, 60 degree notch, and 0.011" notch radius.

(2)

ASTM-ASME JOINT COMMITTEE ON EFFECT OF TEMPERATURE ON PROPERTIES OF METALS

TYPE OF MATERIAL	12 Cr, 5 Co, 3 W, V	TYPE OF MELTING FURNACE					SIZE OF HEAT	Commercial			
CHEMICAL COMPOSITION, PER CENT	C	Mn	P	S	Si	Cr	Ni	Mo	Co	V	W
	0.20	1.23			0.56	12.66	0.43	0.12	5.32	0.21	2.68
DEOXIDATION											
FORM-CAST OR WROUGHT	Wrought 1-3/4" x 3-1/8" Bar										
HEAT TREATMENT	1750 F, 1-1/2 Hr, A.C.; 1200 F, 5 Hr, A.C.										
MICROSTRUCTURE											
GRAIN SIZE							HARDNESS				
SOURCE OF DATA	General Electric Company										

CREEP AND RUPTURE STRENGTHS

TEMP., °F	STRESS FOR RUPTURE IN TIMES INDICATED, 1000 P.S.I.(2)				STRESS FOR DESIGNATED CREEP RATE, 1000 P.S.I.(2)		
	100 HRS.	1000 HRS.	10,000 HRS.	100,000 HRS.	0.000001 %/HR.	0.00001 %/HR.	0.0001 %/HR.
			Double Pin Shear				
1000		39	30	24*			
	Test specimen - reduced test section 0.160" diameter, 4" gage length.						
900			70P	66P			
1000		66	53*	40*			
	P indicates strength value obtained by use of Larson-Miller parameter T(25 + log t).						

ORIGINAL CREEP AND RUPTURE DATA

TEMP. °F	STRESS, 1000 P.S.I.	DURATION, HOURS(3)	INTERCEPT, %(4)	MINIMUM CREEP RATE, %/HR.	TRANSITION TIME, HRS.(5)	TOTAL EXT. (CREEP TEST), %	TOTAL ELONG (RUPTURE TEST), %	REDUCTION IN AREA, %
	0.187" diameter pin loaded in double shear with a clevis-type fixture.							
1000	54.0	2.5 R						
1000	45.0	44 R						
1000	40.0	804 R						
1000	38.0	821 R						
1000	35.0	2873 R						
1000	30.0	9361 R						
850	120.0	0.5 R					5.0(d)	45.0
850	100.0	1498 R					7.0(d)	51.0
1000	74.0	32 R					11.0	66.0
1000	70.0	171 R					10.0	60.0
1000	64.0	1787 R					6.0	21.0
1000	61.0	2918 R					5.0	15.0
1000	58.0	4170 R					4.0	10.0

(d) Test specimen reduced section 0.160" diameter, 4" gage length.

(5)

ASTM-ASME JOINT COMMITTEE ON EFFECT OF TEMPERATURE ON PROPERTIES OF METALS

TYPE OF MATERIAL	12 Cr, 5 Co, 3 W, V	TYPE OF MELTING FURNACE					SIZE OF HEAT	Commercial			
CHEMICAL COMPOSITION, PER CENT	C	Mn	P	S	Si	Cr	Ni	Mo	Co	W	V
	0.20	1.23	--	--	0.56	12.66	0.43	--	5.32	2.6	0.21
DEOXIDATION											
FORM-CAST OR WROUGHT	Wrought 1-3/4" x 3-1/8"										
HEAT TREATMENT	2000 F, 1-1/2 Hr, A.C.; 1200 F, 3-1/2 Hr, F.C.										
MICROSTRUCTURE											
GRAIN SIZE							HARDNESS				
SOURCE OF DATA	General Electric Company										

SHORT TIME TENSILE PROPERTIES

TEMPERATURE, °F	MODULUS OF ELASTICITY, 1,000,000 P.S.I.	OFFSET YIELD (1) STRENGTH, 1000 P.S.I.	TENSILE STRENGTH, 1000 P.S.I.	ELONGATION IN 2", PER CENT	REDUCTION IN AREA, PER CENT
80		--	166.9	12.0	22.3

CREEP AND RUPTURE STRENGTHS

TEMP., °F	STRESS FOR RUPTURE IN TIMES INDICATED, 1000 P.S.I.(2)				STRESS FOR DESIGNATED CREEP RATE, 1000 P.S.I.(2)		
	100 HRS.	1000 HRS.	10,000 HRS.	100,000 HRS.	0.000001 %/HR.	0.00001 %/HR.	0.0001 %/HR.
900		83P	73P	64P			
900		87	83*				
1000		64P	50P	36P			
1000		63	48	36*			
1100		37P	24P	14P			
1100		36					
1200	27P	15.5P	--				
1200	27	15	8				

P indicates strength value obtained by use of Larson-Miller parameter T(25 + log t).

(1) 0.2 PER CENT OFFSET UNLESS OTHERWISE INDICATED.

(2) EXTRAPOLATED VALUES INDICATED BY *

(3) DURATION OF TEST (RUPTURE TEST INDICATED BY R).

(4) THE INTERCEPT IS THE PROJECTION BACK TO ZERO TIME FROM THE PORTION OF THE TEST SHOWING THE MINIMUM OR SECOND-STAGE CREEP RATE.

(5) THE TRANSITION TIME IS THE BEGINNING OF THE THIRD STAGE, OR AN ACCELERATING CREEP RATE.

ORIGINAL CREEP AND RUPTURE DATA

TEMP, °F.	STRESS, 1000 P.S.I.	DURATION, HOURS(3)	INTERCEPT, %(4)	MINIMUM CREEP RATE, %/HR.	TRANSITION TIME, HRS.(5)	TOTAL EXT. (CREEP TEST), %	TOTAL ELONG. (RUPTURE TEST), %	REDUCTION IN AREA, %
900	90.0	164 R					8.0	41.0
900	85.0	3982 R					7.0	16.0
1000	70.0	64 R					12.0	48.0
1000	64.0	727 R					7.0	20.0
1000	60.0	1635 R					4.0	14.0
1000	56.0	2840 R					2.0	4.0
1000	50.0	7192 R					3.0	10.0
1100	52.0	105 R					7.0	45.0
1100	48.0	151 R					7.0	45.0
1100	38.0	828 R					5.0	24.0
1100	32.0	2368 R					6.0	18.0
1100	28.0	3383 R					4.0	11.0
1100	25.0	3772 R					6.0	20.0
1200	35.0	30 R					12.0	71.0
1200	28.0	104 R					11.0	64.0
1200	25.0	138 R					11.0	65.0
1200	18.0	585 R					10.0	36.0
1200	12.0	2161 R					10.0	25.0
1200	9.0	6686 R					10.0	18.0

(6)

ASTM-ASME JOINT COMMITTEE ON EFFECT OF TEMPERATURE ON PROPERTIES OF METALS

TYPE OF MATERIAL	12 Cr, 5 Co, 3 W, V	TYPE OF MELTING FURNACE	Induction	SIZE OF HEAT	Experimental

CHEMICAL COMPOSITION, PER CENT	C	Mn	P	S	Si	Cr	Ni	Mo	Co	W	V
	0.24	0.78			0.36	12.19		0.26	5.23	2.98	0.26

DEOXIDATION

FORM-CAST OR WROUGHT Wrought 7/8" x 7/8" Bar

HEAT TREATMENT 2010 F. 3 Hr. Cool at 1800 F/Hr. 1200 F. 3 Hr. F.C.

MICROSTRUCTURE

GRAIN SIZE HARDNESS

SOURCE OF DATA General Electric Company

SHORT TIME TENSILE PROPERTIES

TEMPERATURE, °F	MODULUS OF ELASTICITY, 1,000,000 P.S.I.	OFFSET YIELD (1) STRENGTH, 1000 P.S.I.	TENSILE STRENGTH, 1000 P.S.I.	ELONGATION IN 2", PER CENT	REDUCTION IN AREA, PER CENT
80			165.9	12.0	23.0

CREEP AND RUPTURE STRENGTHS

TEMP., °F	STRESS FOR RUPTURE IN TIMES INDICATED, 1000 P.S.I.(2)				STRESS FOR DESIGNATED CREEP RATE, 1000 P.S.I.(2)		
	100 HRS.	1000 HRS.	10,000 HRS.	100,000 HRS.	0.000001 %/HR.	0.00001 %/HR.	0.0001 %/HR.
900			74P	69P			
1000		68P	59P	43P			
1000		66	60*	56*			
1100		44P	26P	12P			
1100		46	29*	18*			
1200		31P	15P				
1200		30	15	7.1*			

P indicates strength value obtained by use of Larson-Miller parameter T(25 + log t).

ORIGINAL CREEP AND RUPTURE DATA

TEMP, °F.	STRESS, 1000 P.S.I.	DURATION, HOURS(3)	INTERCEPT, %(4)	MINIMUM CREEP RATE, %/HR.	TRANSITION TIME, HRS.(5)	TOTAL EXT. (CREEP TEST), %	TOTAL ELONG. (RUPTURE TEST), %	REDUCTION IN AREA, %
1000	76.0	23 R					9.0	51.0
1000	74.0	1748 R					4.0	12.0
1000	69.0	468 R					9.0	29.0
1000	64.0	3510 R					5.0	14.0
1100	64.0	57 R					9.0	41.0
1100	50.0	424 R					4.0	16.0
1100	40.0	1992 R					4.0	9.0
1100	35.0	3667 R					4.0	4.0
1200	37.3	51 R					7.0	36.0
1200	30.0	92 R					7.0	32.0
1200	20.0	330 R					9.0	32.0
1200	12.0	1822 R					14.0	36.0

(1) 0.2 PER CENT OFFSET UNLESS OTHERWISE INDICATED.

(2) EXTRAPOLATED VALUES INDICATED BY *

(7)

ASTM-ASME JOINT COMMITTEE ON EFFECT OF TEMPERATURE ON PROPERTIES OF METALS

TYPE OF MATERIAL	12 Cr, 5 Co, 3 W, V	TYPE OF MELTING FURNACE	--	SIZE OF HEAT	--

CHEMICAL COMPOSITION, PER CENT	C	Mn	P	S	Si	Cr	Ni	Mo	W	V	Co
	0.18	1.21	0.009	0.004	0.51	11.67	0.12	0.03	2.98	0.21	5.24

DEOXIDATION

FORM-CAST OR WROUGHT 1" Wrought Bar

HEAT TREATMENT 1800 F. 1 Hr. OQ; 1200 F. 1 Hr. A.C.

MICROSTRUCTURE --

GRAIN SIZE HARDNESS 345 BHN

SOURCE OF DATA U.S.N. Engineering Experiment Station

SHORT TIME TENSILE PROPERTIES

TEMPERATURE, °F	MODULUS OF ELASTICITY, 1,000,000 P.S.I.	OFFSET YIELD (1) STRENGTH, 1000 P.S.I.	TENSILE STRENGTH, 1000 P.S.I.	ELONGATION IN 2", PER CENT	REDUCTION IN AREA, PER CENT
RT		145.0	171.4	16	51

CREEP AND RUPTURE STRENGTHS

TEMP., °F	STRESS FOR RUPTURE IN TIMES INDICATED, 1000 P.S.I.(2)				STRESS FOR DESIGNATED CREEP RATE, 1000 P.S.I.(2)		
	100 HRS.	1000 HRS.	10,000 HRS.	100,000 HRS.	0.000001 %/HR.	0.00001 %/HR.	0.0001 %/HR.
1050	66	56				6.5	19
1100	52	36					10

ORIGINAL CREEP AND RUPTURE DATA

TEMP, °F.	STRESS, 1000 P.S.I.	DURATION, HOURS(3)	INTERCEPT, %(4)	MINIMUM CREEP RATE, %/HR.	TRANSITION TIME, HRS.(5)	TOTAL EXT. (CREEP TEST), %	TOTAL ELONG. (RUPTURE TEST), %	HARDNESS AFTER TESTING
1050	70.0	50 R					25.0	
1050	60.0	968 R	0.95	0.002	600		17.0	
1050	55.0	814 R	1.00	0.002	375		17.0	
1050	45.0	2386 R	0.42	0.0009	1650		10.0	
1100	60.0	32 R					21.0	
1100	45.0	420 R	0.73	0.001	160		13.0	
1100	35.0	1086 R	0.46	0.001	350		15.0	
1050	10.0	2088	0.062	0.000023	--	0.107		
1050	7.5	2040	0.047	0.000014	--	0.076		
1100	7.0	2064	0.087	0.000059	--	0.208		
1100	5.0	1272	0.037	0.000039	--	0.087		

(8)

ASTM-ASME JOINT COMMITTEE ON EFFECT OF TEMPERATURE ON PROPERTIES OF METALS

TYPE OF MATERIAL	12 Cr, 5 Co, 3 W, V	TYPE OF MELTING FURNACE	--	SIZE OF HEAT	--

CHEMICAL COMPOSITION, PER CENT	C	Mn	P	S	Si	Cr	Ni	Mo	W	V	Co
	0.18	1.21	0.009	0.004	0.51	11.67	0.12	0.03	2.98	0.21	5.24

DEOXIDATION

FORM-CAST OR WROUGHT 1" Wrought Bars

HEAT TREATMENT 1800 F, 1 Hr, OQ; 1300 F, 1 Hr, A.C.

MICROSTRUCTURE --

GRAIN SIZE HARDNESS 320 BHN

SOURCE OF DATA U.S.N. Engineering Experiment Station

SHORT TIME TENSILE PROPERTIES

TEMPERATURE, °F	MODULUS OF ELASTICITY, 1,000,000 P.S.I.	OFFSET YIELD (1) STRENGTH, 1000 P.S.I.	TENSILE STRENGTH, 1000 P.S.I.	ELONGATION IN 2", PER CENT	REDUCTION IN AREA, PER CENT
RT		133.7	157.8	20	54
1000		80.1	99.1	25	74
1100		63.6	83.0	26	78

CREEP AND RUPTURE STRENGTHS

TEMP., °F	STRESS FOR RUPTURE IN TIMES INDICATED, 1000 P.S.I.(2)				STRESS FOR DESIGNATED CREEP RATE, 1000 P.S.I.(2)		
	100 HRS.	1000 HRS.	10,000 HRS.	100,000 HRS.	0.000001 %/HR.	0.00001 %/HR.	0.0001 %/HR.
1000	78	72					
1100	54	43				6	16

(3) DURATION OF TEST (RUPTURE TEST INDICATED BY R).

(4) THE INTERCEPT IS THE PROJECTION BACK TO ZERO TIME FROM THE PORTION OF THE TEST SHOWING THE MINIMUM OR SECOND-STAGE CREEP RATE.

(5) THE TRANSITION TIME IS THE BEGINNING OF THE THIRD STAGE, OR AN ACCELERATING CREEP RATE.

ORIGINAL CREEP AND RUPTURE DATA

TEMP, °F	STRESS, 1000 P.S.I.	DURATION, HOURS(3)	INTERCEPT, %(4)	MINIMUM CREEP RATE, %/HR.	TRANSITION TIME, HRS.(5)	TOTAL EXT. (CREEP TEST), %	TOTAL ELONG. (RUPTURE TEST), %	HARDNESS AFTER TESTING
1000	75.0	364 R	1.43	0.012	270		22.0	
1000	70.0	1993 R	2.18	0.0012	1200		18.0	
1100	62.0	14 R					24.0	
1100	50.0	404 R	0.83	0.005	290		20.0	
1100	40.0	1623 R	0.39	0.00086	850		18.0	
1100	13.0	2040	0.092	0.000068	--	0.229		
1100	9.0	2064	0.069	0.000022	--	0.113		

(9)

ASTM-ASME JOINT COMMITTEE ON EFFECT OF TEMPERATURE ON PROPERTIES OF METALS

TYPE OF MATERIAL 12 Cr, 5 Co, 3 W, V	TYPE OF MELTING FURNACE Induction						SIZE OF HEAT Experimental				
CHEMICAL COMPOSITION, PER CENT	C	Mn	P	S	Si	Cr	Ni	Mo	Co	V	W
	0.2	1.0			0.4	12			5.0	0.25	3.0
DEOXIDATION											
FORM-CAST OR WROUGHT Wrought 1" x 1" Bar											
HEAT TREATMENT 2010 F, 3 Hr, Cool at 1800 F, 1 Hr; 1200 F, 3 Hr, F.C.											
MICROSTRUCTURE											
GRAIN SIZE							HARDNESS				
SOURCE OF DATA General Electric Company											

SHORT TIME TENSILE PROPERTIES

TEMPERATURE, °F	MODULUS OF ELASTICITY, 1,000,000 P.S.I.	OFFSET YIELD (1) STRENGTH, 1000 P.S.I.	TENSILE STRENGTH, 1000 P.S.I.	ELONGATION IN 2" PER CENT	REDUCTION IN AREA, PER CENT
80			157.4	16.0	37.9

CREEP AND RUPTURE STRENGTHS

TEMP, °F	STRESS FOR RUPTURE IN TIMES INDICATED, 1000 P.S.I.(2)				STRESS FOR DESIGNATED CREEP RATE, 1000 P.S.I.(2)		
	100 HRS.	1000 HRS.	10,000 HRS.	100,000 HRS.	0.000001 %/HR.	0.00001 %/HR.	0.0001 %/HR.
1000			57P	44P			
1100		45P	27P	15P			
1100		48	23	11*			
1200		31P	17P				
1200		32	18	8.7*			

P indicates strength value obtained by use of Larson-Miller parameter T(25 + log t).

ORIGINAL CREEP AND RUPTURE DATA

TEMP, °F	STRESS, 1000 P.S.I.	DURATION, HOURS(3)	INTERCEPT, %(4)	MINIMUM CREEP RATE, %/HR.	TRANSITION TIME, HRS.(5)	TOTAL EXT. (CREEP TEST), %	TOTAL ELONG. (RUPTURE TEST), %	REDUCTION IN AREA, %
1100	60.0	62 R					9.0	54.0
1100	50.0	497 R					4.0	12.0
1100	41.0	1655 R					2.5	7.0
1100	20.0	16,413 R					3.0	8.0
1200	46.0	1.5R					13.0	80.0
1200	30.0	175 R					5.0	48.0
1200	20.0	709 R					10.0	48.0
1200	12.0	2590 R					18.0	25.0
1200	10.0	6406 R					8.0	15.0

(10)

ASTM-ASME JOINT COMMITTEE ON EFFECT OF TEMPERATURE ON PROPERTIES OF METALS

TYPE OF MATERIAL 12 Cr, 5 Co, 3 W, V	TYPE OF MELTING FURNACE						SIZE OF HEAT Commercial				
CHEMICAL COMPOSITION, PER CENT	C	Mn	P	S	Si	Cr	Ni	Mo	Co	V	W
	0.25	1.0			0.38	12.08			5.03	0.28	2.78
DEOXIDATION											
FORM-CAST OR WROUGHT Wrought 3/4" x 3/4" Bar											
HEAT TREATMENT 2010 F, 4 Hr, Cool at 1900 F/Hr; 1200 F, 4 Hr, F.C.											
MICROSTRUCTURE											
GRAIN SIZE							HARDNESS				
SOURCE OF DATA General Electric Company											

SHORT TIME TENSILE PROPERTIES

TEMPERATURE, °F	MODULUS OF ELASTICITY, 1,000,000 P.S.I.	OFFSET YIELD (1) STRENGTH, 1000 P.S.I.	TENSILE STRENGTH, 1000 P.S.I.	ELONGATION IN 2", PER CENT	REDUCTION IN AREA, PER CENT
80			167.4	13.5	24.4

CREEP AND RUPTURE STRENGTHS

TEMP, °F	STRESS FOR RUPTURE IN TIMES INDICATED, 1000 P.S.I.(2)				STRESS FOR DESIGNATED CREEP RATE, 1000 P.S.I.(2)		
	100 HRS.	1000 HRS.	10,000 HRS.	100,000 HRS.	0.000001 %/HR.	0.00001 %/HR.	0.0001 %/HR.
900		79P	75P	68P			
1000		67P	55P	41P			
1000		68	60*	54*			
1100		42P	27P	15P			
1200		31P	17P				
1200		33	17	9*			

P indicates strength value obtained by use of Larson-Miller parameter T(25 + log t).

ORIGINAL CREEP AND RUPTURE DATA

TEMP, °F	STRESS, 1000 P.S.I.	DURATION, HOURS(3)	INTERCEPT, %(4)	MINIMUM CREEP RATE, %/HR.	TRANSITION TIME, HRS.(5)	TOTAL EXT. (CREEP TEST), %	TOTAL ELONG. (RUPTURE TEST), %	REDUCTION IN AREA, %
1000	80.0	4 R					12.0	52.0
1000	75.0	109 R					10.0	36.0
1000	68.0	832 R					5.0	12.0
1000	62.0	5013 R					4.0	9.0
1200	40.0	16 R					10.0	71.0
1200	30.0	158 R					10.0	32.0
1200	20.0	585 R					12.0	18.0
1200	14.0	2010 R					10.0	23.0

(11)

ASTM-ASME JOINT COMMITTEE ON EFFECT OF TEMPERATURE ON PROPERTIES OF METALS

TYPE OF MATERIAL 12 Cr, 5 Co, 3 W, V	TYPE OF MELTING FURNACE						SIZE OF HEAT Commercial				
CHEMICAL COMPOSITION, PER CENT	C	Mn	P	S	Si	Cr	Ni	Mo	Co	V	W
	0.18	0.35			0.24	12.34	0.16	0.12	4.5	0.25	4.69
DEOXIDATION											
FORM-CAST OR WROUGHT Wrought 4" Diameter Bar											
HEAT TREATMENT 1775 F, 6 Hr, A.C.; 1200 F, 12 Hr, A.C.											
MICROSTRUCTURE											
GRAIN SIZE							HARDNESS				
SOURCE OF DATA General Electric Company											

SHORT TIME TENSILE PROPERTIES

TEMPERATURE, °F	MODULUS OF ELASTICITY, 1,000,000 P.S.I.	OFFSET (a) YIELD (1) STRENGTH, 1000 P.S.I.	TENSILE STRENGTH, 1000 P.S.I.	ELONGATION IN 2", PER CENT	REDUCTION IN AREA, PER CENT
80		100.0	147.8	15.7	39.4
(a) 0.02% Offset yield strength.					

CREEP AND RUPTURE STRENGTHS

TEMP, °F	STRESS FOR RUPTURE IN TIMES INDICATED, 1000 P.S.I.(2)				STRESS FOR DESIGNATED CREEP RATE, 1000 P.S.I.(2)		
	100 HRS.	1000 HRS.	10,000 HRS.	100,000 HRS.	0.000001 %/HR.	0.00001 %/HR.	0.0001 %/HR.
900			58P	49P			
1000		49P	39P	28P			
1100		28P					
1100		28	18*	11*			

P indicates strength value obtained by use of Larson-Miller parameter T(25 + log t).

ORIGINAL CREEP AND RUPTURE DATA

TEMP, °F	STRESS, 1000 P.S.I.	DURATION, HOURS(3)	INTERCEPT, %(4)	MINIMUM CREEP RATE, %/HR.	TRANSITION TIME, HRS.(5)	TOTAL EXT. (CREEP TEST), %	TOTAL ELONG. (RUPTURE TEST), %	REDUCTION IN AREA, %
1000	65.0	33 R					10.0	68.0
1000	60.0	79 R					7.0	67.0
1000	58.0	1087 R					12.0	63.0
1100	42.0	68 R					14.0	74.0
1100	35.0	298 R					12.0	72.0
1100	28.0	1042 R					13.0	68.0
1100	22.0	3411 R					9.0	29.0

(1) 0.2 PER CENT OFFSET UNLESS OTHERWISE INDICATED.

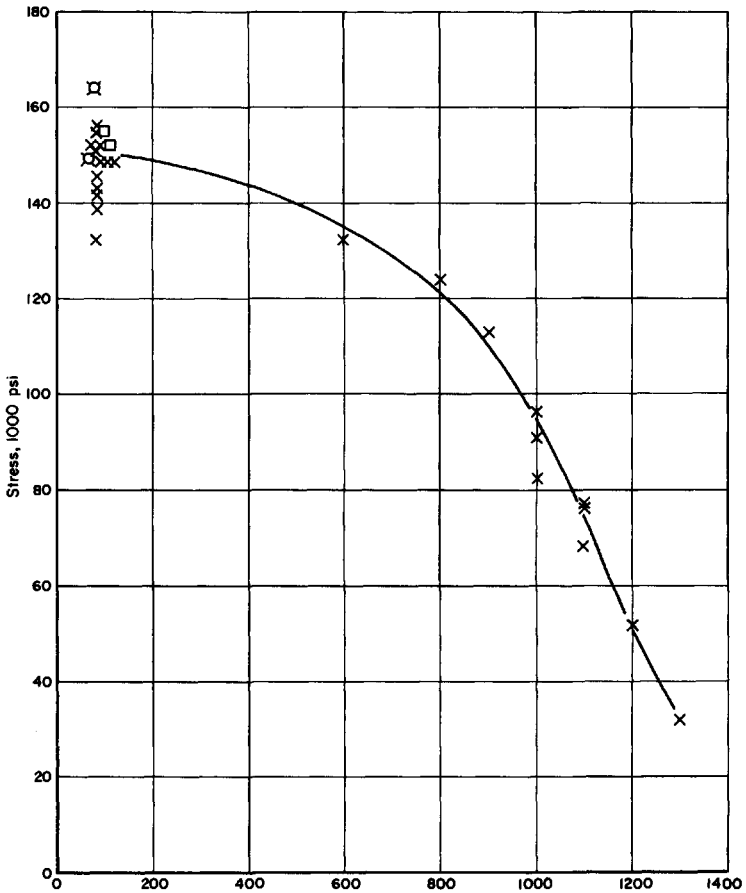
(2) EXTRAPOLATED VALUES INDICATED BY *

(3) DURATION OF TEST (RUPTURE TEST INDICATED BY R).

(4) THE INTERCEPT IS THE PROJECTION BACK TO ZERO TIME FROM THE PORTION OF THE TEST SHOWING THE MINIMUM OR SECOND-STAGE CREEP RATE.

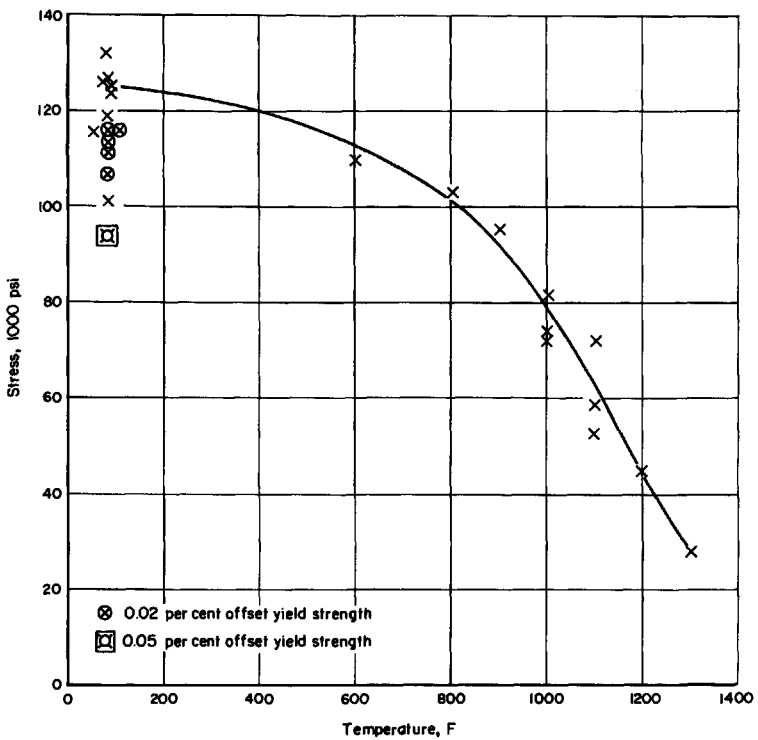
(5) THE TRANSITION TIME IS THE BEGINNING OF THE THIRD STAGE, OR AN ACCELERATING CREEP RATE.

13 Chromium, Tungsten, Molybdenum, Vanadium Steels (422)



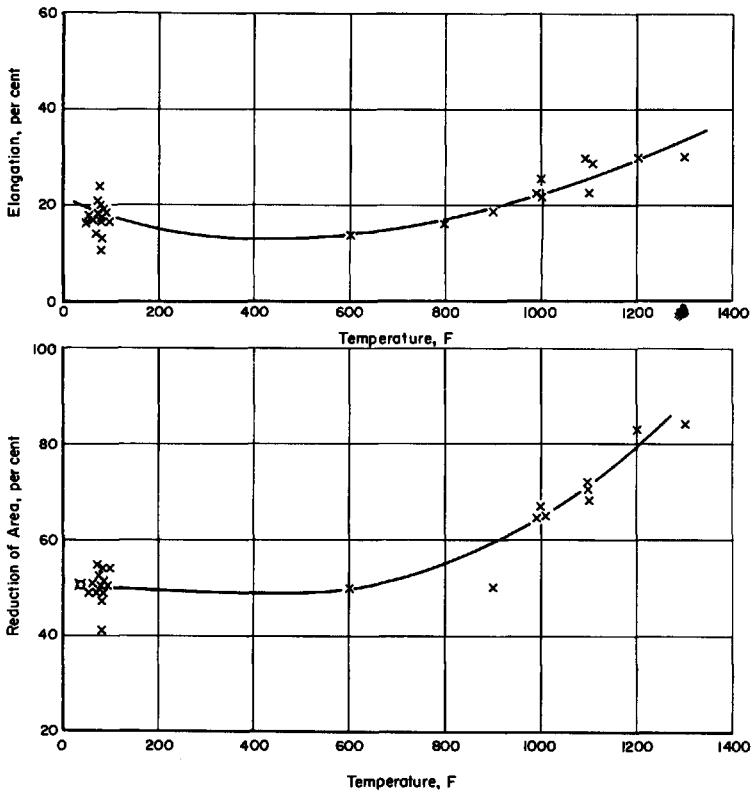
TENSILE STRENGTH

13 Cr, W, Mo, V STEEL



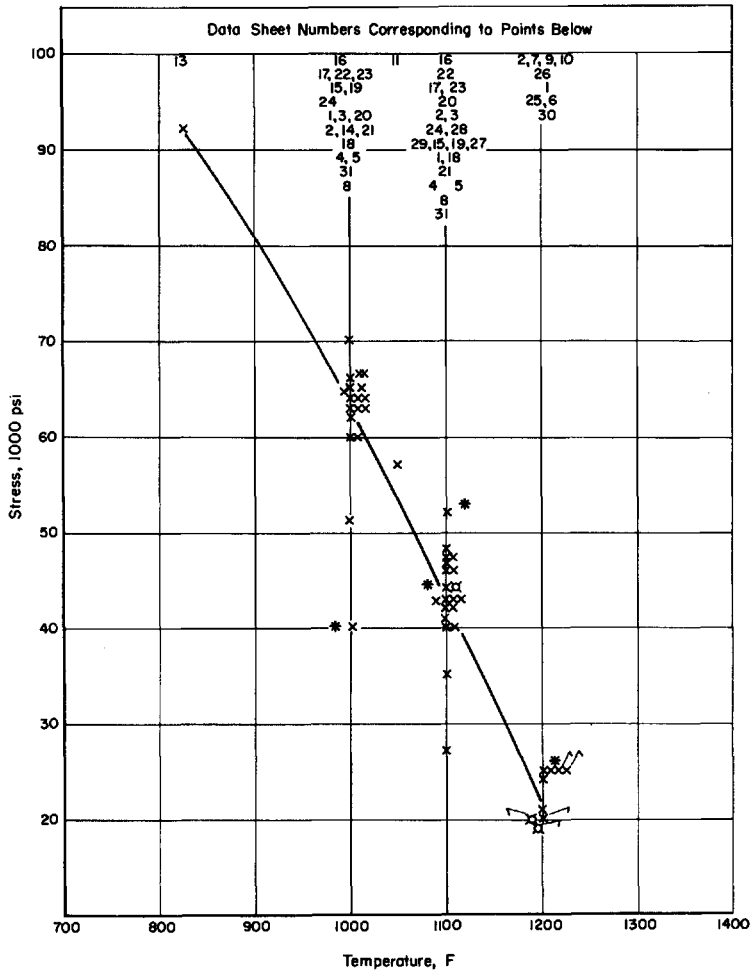
0.2 PER CENT OFFSET YIELD STRENGTH

13 Cr, W, Mo, V STEEL



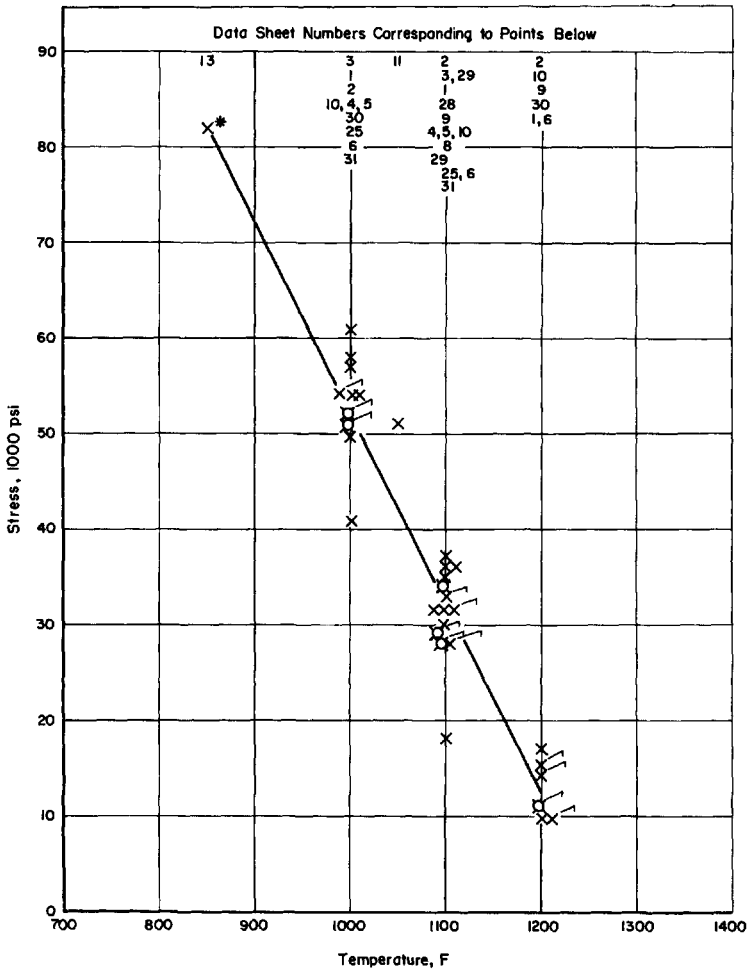
ELONGATION AND REDUCTION OF AREA

13 Cr, W, Mo, V STEEL



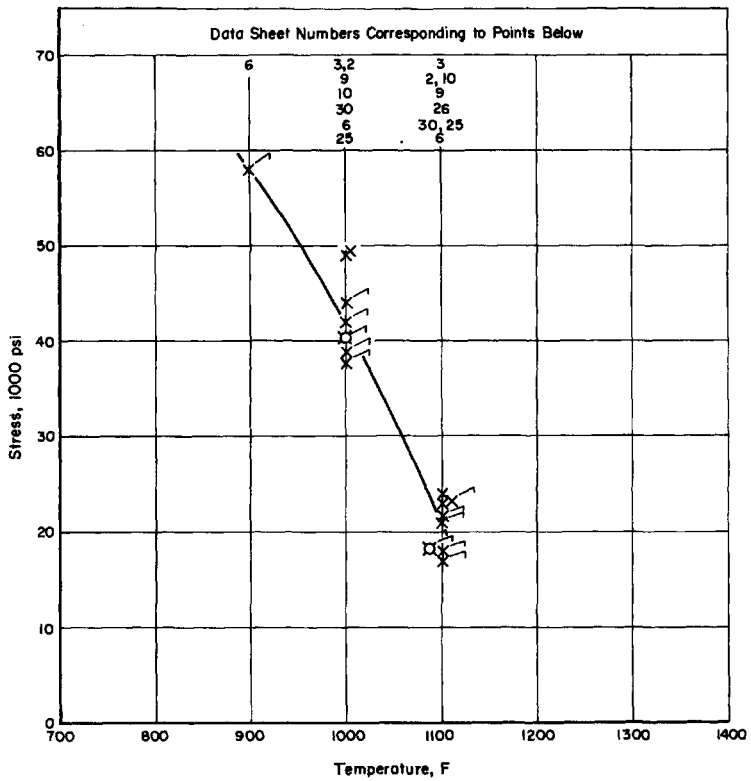
RUPTURE IN 100 HOURS

13 Cr, W, Mo, V STEEL



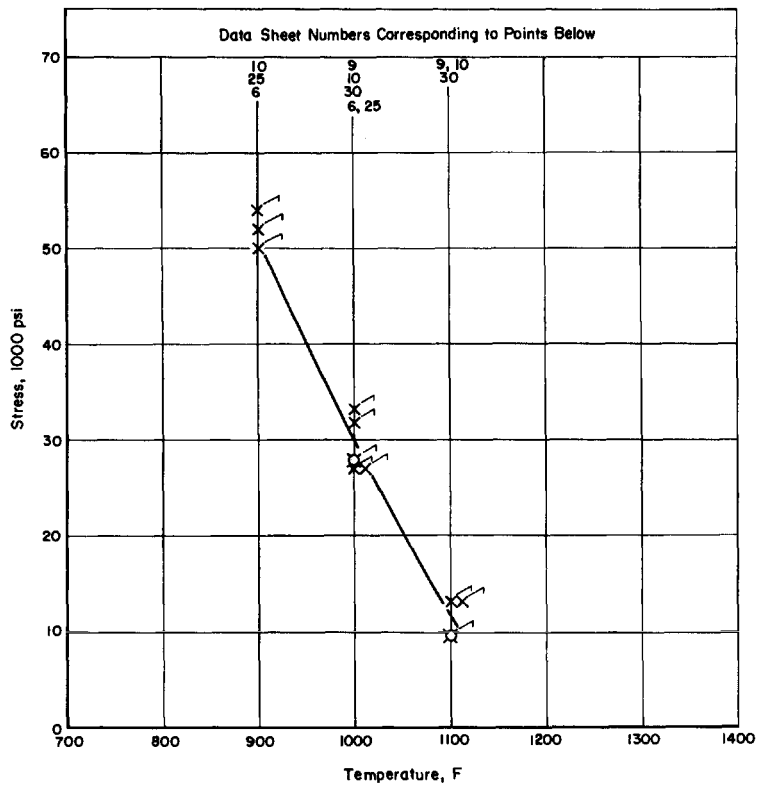
RUPTURE IN 1000 HOURS

13 Cr, W, Mo, V STEEL



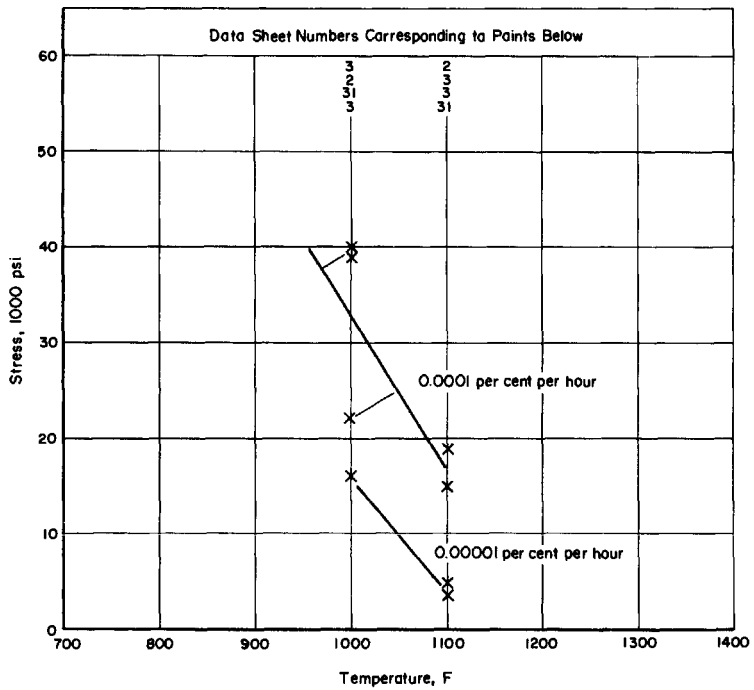
RUPTURE IN 10,000 HOURS
(EXTRAPOLATED)

13 Cr, W, Mo, V STEEL



RUPTURE IN 100,000 HOURS
(EXTRAPOLATED)

13 Cr, W, Mo, V STEEL



CREEP STRENGTHS

13 Cr, W, Mo, V STEEL

(1)

ASTM-ASME JOINT COMMITTEE ON EFFECT OF TEMPERATURE ON PROPERTIES OF METALS

TYPE OF MATERIAL	13 Cr, W, Mo, V (422)	TYPE OF MELTING FURNACE	Electric	SIZE OF HEAT	Commercial

CHEMICAL COMPOSITION, PER CENT	C	Mn	P	S	Si	Cr	Ni	Mo	W	V
	0.23	0.81			0.022	13.19	0.65	1.03	0.84	0.25

DEOXIDATION

FORM-CAST OR WROUGHT 1" Hot Rolled and Annealed

HEAT TREATMENT 1900 F, 1/2 Hr, OQ; 1200 F, 2 Hr, A.C.

MICROSTRUCTURE

GRAIN SIZE | HARDNESS 33 R_C

SOURCE OF DATA NACA Lewis Laboratory

CREEP AND RUPTURE STRENGTHS

TEMP, °F	STRESS FOR RUPTURE IN TIMES INDICATED, 1000 P.S.I.(2)				STRESS FOR DESIGNATED CREEP RATE, 1000 P.S.I.(2)		
	100 HRS.	1000 HRS.	10,000 HRS.	100,000 HRS.	0.000001 %/HR.	0.00001 %/HR.	0.0001 %/HR.
1000	64	58*					
1100	42	35					
1200	21	10					

ORIGINAL CREEP AND RUPTURE DATA

TEMP. °F	STRESS, 1000 P.S.I.	DURATION, HOURS(3)	INTERCEPT, %(4)	MINIMUM CREEP RATE, %/HR.	TRANSITION TIME, HRS.(5)	TOTAL EXT. (CREEP TEST), %	TOTAL ELONG. (RUPTURE TEST), %	REDUCTION IN AREA, %
975	65.0	358 R						62.0
975	65.0	496 R						63.0
1000	60.0	376 R						64.0
1000	65.0	60.4 R						70.0
1000	65.0	72.4 R						66.0
1000	70.0	7.7 R						78.0
1000	85.0	0.16 R						63.0
1025	65.0	16.2 R						66.0
1040	65.0	5.0 R						70.0
1080	40.0	750 R						60.0
1100	35.0	984 R						49.0
1100	40.0	276 R						64.0
1100	40.0	296 R						59.0
1100	50.0	8.0 R						76.0
1100	65.0	0.22 R						69.0
1125	40.0	63.4 R						67.0
1125	40.0	62.1 R						67.0
1150	40.0	24.2 R						69.0
1150	40.0	17.8 R						70.0
1275	22.0	1134 R						53.0
1165	22.0	486 R						62.0
1175	22.0	328 R						65.0
2175	22.0	392 R						62.0
1180	40.0	3.6 R						75.0
1200	8.0	2842 R						70.0
1200	10.0	2712 R						--
1200	15.0	307 R						75.0
1200	22.0	117 R						70.0
1200	22.0	79 R						71.0
1200	30.0	19.2 R						73.0
1200	45.0	0.8 R						78.0
1200	55.0	0.042R						76.0
1200	56.3	0.016R						76.0
1225	10.0	745 R						72.6
1225	22.0	39.1 R						72.0
1225	22.0	33.2 R						74.0
1250	10.0	294 R						76.5
1250	22.0	16.3 R						78.0
1250	22.0	13 R						78.5
1255	40.0	0.32 R						78.2
1275	10.0	95.5 R						86.0
1275	10.0	62.1 R						88.0
1275	40.0	0.12 R						81.0
1295	22.0	3.1 R						85.0
1300	10.0	24.7 R						88.0
1300	10.0	41 R						87.0
1325	22.0	1.8 R						87.0
1340	10.0	11 R						92.0
1340	10.0	14.9 R						91.0
1350	22.0	0.7 R						90.0
1390	10.0	3.2 R						91.0
1400	10.0	2.7 R						94.0
1400	22.0	0.1 R						93.0
1400	22.0	0.084R						92.5
1445	10.0	1.3 R						91.0

(2)

ASTM-ASME JOINT COMMITTEE ON EFFECT OF TEMPERATURE ON PROPERTIES OF METALS

TYPE OF MATERIAL	13 Cr, W, Mo, V (422)	TYPE OF MELTING FURNACE	Induction	SIZE OF HEAT	1 Ton

CHEMICAL COMPOSITION, PER CENT	C	Mn	P	S	Si	Cr	Ni	Mo	W	V
	0.19	0.83			0.28	13.13	0.73	1.03	1.11	0.34

DEOXIDATION

FORM-CAST OR WROUGHT Wrought 1" Round

HEAT TREATMENT 1900 F, 1 Hr, OQ; 1200 F, 2 Hr, A.C. Heat No. 1590-A5

MICROSTRUCTURE Tempered Martensite + 20% Ferrite

GRAIN SIZE | HARDNESS 34.5 R_C

SOURCE OF DATA Crucible Steel Company

SHORT TIME TENSILE PROPERTIES

TEMPERATURE, °F	MODULUS OF ELASTICITY, 1,000,000 P.S.I.	OFFSET YIELD (1) STRENGTH, 1000 P.S.I.	TENSILE STRENGTH, 1000 P.S.I.	ELONGATION IN 2", PER CENT	REDUCTION IN AREA, PER CENT
80		125	149	18.5	52
1000		82	96	25	67
1100		72	76	29.5	69
1200		45	52	30	83
1300		28	32	30	84
80(a)		127	152	19	45
80(b)		121	151	15	43
80(c)		109	138	16	45

Note: Short time tensile properties as given above were on creep specimens which had been exposed as follows:

(a) At 1000 F, 40,000 psi for 2150 Hr.

(b) At 1000 F, 30,000 psi for 7240 Hr.

(c) At 1100 F, 20,000 psi for 3330 Hr.

CREEP AND RUPTURE STRENGTHS

TEMP, °F	STRESS FOR RUPTURE IN TIMES INDICATED, 1000 P.S.I.(2)				STRESS FOR DESIGNATED CREEP RATE, 1000 P.S.I.(2)		
	100 HRS.	1000 HRS.	10,000 HRS.	100,000 HRS.	0.000001 %/HR.	0.0001 %/HR.	LENGTH TEST, HR
1000	63	57	49*			39	7820
1100	46	37	23*			19	3330
1200	25	17*					

ORIGINAL CREEP AND RUPTURE DATA

TEMP. °F	STRESS, 1000 P.S.I.	DURATION, HOURS(3)	INTERCEPT, %(4)	MINIMUM CREEP RATE, %/HR.	TRANSITION TIME, HRS.(5)	TOTAL EXT. (CREEP TEST), %	TOTAL ELONG. (RUPTURE TEST), %	HARDNESS AFTER TESTING
1000	70.0	13 R					18.0	
1000	65.0	63 R					16.0	
1000	60.0	301 R					14.0	
1000	55.0	1720 R		0.0025			11.0*	
1000	50.0	7820 R	0.96	0.0003	4400		12.0*	
1000	40.0	Discontin. 2184	0.47	0.00012	--		0.67	34
1000	30.0	Discontin. 7240	0.32	0.00002	--		0.49	34
1100	60.0	1.3R					23.0	
1100	50.0	31 R					19.0	
1100	45.0	251 R					16.5	
1100	42.0	502 R					21.0	
1100	39.0	725 R					24.0	
1100	30.0	2720 R	0.40	0.0005	1280		11.0*	
1100	20.0	Discontin. 3330	0.40	0.00011	--		0.66	29
1200	30.0	36 R					17.0	
1200	27.0	49 R					14.0	
1200	25.0	133 R					19.0	
1200	20.0	336 R					22.0	

*Creep Specimen - 2.25" gage length. (Others 1.4")

(1) 0.2 PER CENT OFFSET UNLESS OTHERWISE INDICATED.

(2) EXTRAPOLATED VALUES INDICATED BY *

(3) DURATION OF TEST (RUPTURE TEST INDICATED BY R).

(4) THE INTERCEPT IS THE PROJECTION BACK TO ZERO TIME FROM THE PORTION OF THE TEST SHOWING THE MINIMUM OR SECOND-STAGE CREEP RATE.

(5) THE TRANSITION TIME IS THE BEGINNING OF THE THIRD STAGE, OR AN ACCELERATING CREEP RATE.

(3)

ASTM-ASME JOINT COMMITTEE ON EFFECT OF TEMPERATURE ON PROPERTIES OF METALS

TYPE OF MATERIAL	13 Cr, W, Mo, V (422)	TYPE OF MELTING FURNACE	--	SIZE OF HEAT	Commercial

CHEMICAL COMPOSITION, PER CENT	C	Mn	P	S	Si	Cr	Ni	Mo	W	V
	0.19	0.84			0.32	13.85	0.74	0.98	1.13	0.24

DEOXIDATION

FORM-CAST OR WROUGHT 1" Wrought Bar

HEAT TREATMENT 1900 F, 1 Hr, OQ; 1200 F, 1 Hr, OQ

MICROSTRUCTURE

GRAIN SIZE | HARDNESS 290 BHN

SOURCE OF DATA U.S.N. Engineering Experiment Station

SHORT TIME TENSILE PROPERTIES

TEMPERATURE, °F	MODULUS OF ELASTICITY, 1,000,000 P.S.I.	OFFSET YIELD (1) STRENGTH, 1000 P.S.I.	TENSILE STRENGTH, 1000 P.S.I.	ELONGATION IN 2", PER CENT	REDUCTION IN AREA, PER CENT
RT		124.4	149.2	18	52
1000		74.6	91.4	22	65
1100		59.2	77.2	25	71

CREEP AND RUPTURE STRENGTHS

TEMP., °F	STRESS FOR RUPTURE IN TIMES INDICATED, 1000 P.S.I.(2)				STRESS FOR DESIGNATED CREEP RATE, 1000 P.S.I.(2)		
	100 HRS.	1000 HRS.	10,000 HRS.	100,000 HRS.	0.000001 %/HR.	0.00001 %/HR.	0.0001 %/HR.
1000	64	61	49			16	40
1100	46	36	24			5.3	15

ORIGINAL CREEP AND RUPTURE DATA

TEMP. °F.	STRESS, 1000 P.S.I.	DURATION, HOURS(3)	INTERCEPT, %(4)	MINIMUM CREEP RATE, %/HR.	TRANSITION TIME, HRS.(5)	TOTAL EXT. (CREEP TEST), %	TOTAL ELONG. (RUPTURE TEST), %	HARDNESS AFTER TESTING
1000	65.0	74 R					31.0	
1000	62.0	1382 R	1.07	0.0030	975		19.0	
1000	60.0	1285 R	1.03	0.0026	925		19.0	
1000	50.0	8753 R	0.63	0.00043	7000		22.0	
1100	50.0	36 R					28.0	
1100	45.0	146 R					26.0	
1100	39.0	656 R	0.45	0.0030	350		21.0	
1100	35.0	1210 R	0.58	0.0012	500		23.0	
1100	30.0	2802 R	0.22	0.00059	1750		21.0	
1000	34.0	2040	0.183	0.000033	--	0.250		
1000	30.0	2016	0.120	0.000036	--	0.193		
1000	28.0	2016	0.169	0.000030	--	0.229		
1000	20.0	2040	0.052	0.000014	--	0.080		
1000	18.5	2040	0.100	0.000017	--	0.137		
1100	10.0	2016	0.064	0.000054	--	0.172		
1100	6.0	2088	0.030	0.000012	--	0.055		

(4)

ASTM-ASME JOINT COMMITTEE ON EFFECT OF TEMPERATURE ON PROPERTIES OF METALS

TYPE OF MATERIAL	13 Cr, W, Mo, V (422)	TYPE OF MELTING FURNACE		SIZE OF HEAT	

CHEMICAL COMPOSITION, PER CENT	C	Mn	P	S	Si	Cr	Ni	Mo	W	V
	0.23	0.81	0.011	0.022	0.16	13.19	0.65	1.03	0.84	0.25

DEOXIDATION

FORM-CAST OR WROUGHT Disc Forging 12-1/8" diameter x 3-1/8" thick

HEAT TREATMENT 1900 F, OQ; 1200 F, 2 Hr

MICROSTRUCTURE

GRAIN SIZE | HARDNESS

SOURCE OF DATA Elliott Company

SHORT TIME TENSILE PROPERTIES

TEMPERATURE, °F	MODULUS OF ELASTICITY, 1,000,000 P.S.I.	OFFSET YIELD (1) STRENGTH, 1000 P.S.I.	TENSILE STRENGTH, 1000 P.S.I.	ELONGATION IN 2", PER CENT	REDUCTION IN AREA, PER CENT
RT		132	155	17.0	50.2
RT		127	152	14.0	39.6

CREEP AND RUPTURE STRENGTHS

TEMP., °F	STRESS FOR RUPTURE IN TIMES INDICATED, 1000 P.S.I.(2)				STRESS FOR DESIGNATED CREEP RATE, 1000 P.S.I.(2)		
	100 HRS.	1000 HRS.	10,000 HRS.	100,000 HRS.	0.000001 %/HR.	0.00001 %/HR.	0.0001 %/HR.
1000	60	54					
1100	40	32					

(1) 0.2 PER CENT OFFSET UNLESS OTHERWISE INDICATED.

(2) EXTRAPOLATED VALUES INDICATED BY *

ORIGINAL CREEP AND RUPTURE DATA

TEMP. °F.	STRESS, 1000 P.S.I.	DURATION, HOURS(3)	INTERCEPT, %(4)	MINIMUM CREEP RATE, %/HR.	TRANSITION TIME, HRS.(5)	TOTAL EXT. (CREEP TEST), %	TOTAL ELONG. (RUPTURE TEST), %	HARDNESS AFTER TESTING
1000	70.0	2 R					21.0	
1000	65.0	12 R					21.0	
1000	60.0	40 R					16.0	
1000	55.0	615 R					17.0	
1000	54.0	620 R					18.0	
1000	53.0	1894 R					15.0	
1100	50.0	14 R					23.0	
1100	45.0	120 R					21.0	
1100	43.0	88 R					21.0	
1100	42.0	192 R					23.0	
1100	42.0	136 R					21.0	
1100	36.0	318 R					--	
1100	35.0	295 R					18.0	
1100	32.0	405 R					10.0	
1100	30.0	911 R					16.0	
	All test bars cut tangentially from rim of forging. 1" gage length x 0.250" diameter.							

(5)

ASTM-ASME JOINT COMMITTEE ON EFFECT OF TEMPERATURE ON PROPERTIES OF METALS

TYPE OF MATERIAL	13 Cr, W, Mo, V (142OWM)	TYPE OF MELTING FURNACE		SIZE OF HEAT	

CHEMICAL COMPOSITION, PER CENT	C	Mn	P	S	Si	Cr	Ni	Mo	W	V
	0.19	0.83	0.023	0.026	0.22	12.69	0.78	0.98	0.83	0.29

DEOXIDATION

FORM-CAST OR WROUGHT Disc Forging, 12-1/8" diameter x 3-1/8" thick

HEAT TREATMENT

MICROSTRUCTURE

GRAIN SIZE | HARDNESS

SOURCE OF DATA Elliott Company

SHORT TIME TENSILE PROPERTIES

TEMPERATURE, °F	MODULUS OF ELASTICITY, 1,000,000 P.S.I.	OFFSET YIELD (1) STRENGTH, 1000 P.S.I.	TENSILE STRENGTH, 1000 P.S.I.	ELONGATION IN 2", PER CENT	REDUCTION IN AREA, PER CENT
RT		126	152	19.0	49.9
RT		126	155	16.0	49.2

CREEP AND RUPTURE STRENGTHS

TEMP., °F	STRESS FOR RUPTURE IN TIMES INDICATED, 1000 P.S.I.(2)				STRESS FOR DESIGNATED CREEP RATE, 1000 P.S.I.(2)		
	100 HRS.	1000 HRS.	10,000 HRS.	100,000 HRS.	0.000001 %/HR.	0.00001 %/HR.	0.0001 %/HR.
1000	60	54					
1100	40	32					

ORIGINAL CREEP AND RUPTURE DATA

TEMP. °F.	STRESS, 1000 P.S.I.	DURATION, HOURS(3)	INTERCEPT, %(4)	MINIMUM CREEP RATE, %/HR.	TRANSITION TIME, HRS.(5)	TOTAL EXT. (CREEP TEST), %	TOTAL ELONG. (RUPTURE TEST), %	HARDNESS AFTER TESTING
1000	65.0	21 R					19.0	
1000	62.0	72 R					19.0	
1000	59.0	377 R					19.0	
1000	57.0	383 R					18.0	
1000	55.0	843 R					18.0	
1000	52.0	5340 R					6.0	
1100	46.0	29 R					25.0	
1100	44.0	55 R					15.0	
1100	42.0	89 R					16.0	
1100	41.0	257 R					19.0	
1100	39.0	246 R					17.0	
1100	37.0	398 R					16.0	
1100	35.0	649 R					9.0	
1100	31.0	1296 R					9.0	
	All test bars cut tangentially from rim of forging. 1" gage length x 0.250" diameter.							

(3) DURATION OF TEST (RUPTURE TEST INDICATED BY R).

(4) THE INTERCEPT IS THE PROJECTION BACK TO ZERO TIME FROM THE PORTION OF THE TEST SHOWING THE MINIMUM OR SECOND-STAGE CREEP RATE.

(5) THE TRANSITION TIME IS THE BEGINNING OF THE THIRD STAGE, OR AN ACCELERATING CREEP RATE.

(6)

ASTM-ASME JOINT COMMITTEE ON EFFECT OF TEMPERATURE ON PROPERTIES OF METALS

TYPE OF MATERIAL	13 Cr, W, Mo, V	TYPE OF MELTING FURNACE					SIZE OF HEAT	Commercial			
CHEMICAL COMPOSITION, PER CENT	C	Mn	P	S	Si	Cr	Ni	Mo	W	V	
	0.22	0.81	0.011	0.022	0.16	13.19	0.65	1.03	0.84	0.25	
DEOXIDATION											
FORM-CAST OR WROUGHT	Forged Bucket										
HEAT TREATMENT	1900 F, 4 Hr, A.Q.; 1200 F, 12 Hr, A.C.										
MICROSTRUCTURE											
GRAIN SIZE							HARDNESS				
SOURCE OF DATA	General Electric Company										

SHORT TIME TENSILE PROPERTIES

TEMPERATURE, °F	MODULUS OF ELASTICITY, 1,000,000 P.S.I.	OFFSET(a) YIELD (1) STRENGTH, 1000 P.S.I.	TENSILE STRENGTH, 1000 P.S.I.	ELONGATION IN 2", PER CENT	REDUCTION IN AREA, PER CENT
80		114.2	149.2	24.0	51.7

(a) 0.02% Offset yield strength.

CREEP AND RUPTURE STRENGTHS

TEMP, °F	STRESS FOR RUPTURE IN TIMES INDICATED, 1000 P.S.I.(2)				STRESS FOR DESIGNATED CREEP RATE, 1000 P.S.I.(2)		
	100 HRS.	1000 HRS.	10,000 HRS.	100,000 HRS.	0.000001 %/HR.	0.00001 %/HR.	0.0001 %/HR.
900			58P	50P			
1000		50P	39P	27P			
1100		28P	17P				
1200	20P	10P					

P indicates strength value obtained by use of Larson-Miller parameter T(25 + log t).

ORIGINAL CREEP AND RUPTURE DATA

TEMP, °F	STRESS, 1000 P.S.I.	DURATION, HOURS(3)	INTERCEPT, %(4)	MINIMUM CREEP RATE, %/HR.	TRANSITION TIME, HRS.(5)	TOTAL EXT. (CREEP TEST), %	TOTAL ELONG. (RUPTURE TEST), %	HARDNESS AFTER TESTING
1050	56.0	21 R					13.0	
1100	47.3	13 R					16.0	
1100	30.0	591 R					19.0	
1100	32.3	676 R					21.0	
1150	35.0	24 R					19.0	
1150	12.0	4517	Discontinued					
1200	28.0	31 R					17.0	
1200	15.8	241 R					30.0	
1200	13.5	554 R					27.0	
1250	20.0	19 R					20.0	
1300	15.8	7 R					--	
1300	11.8	17 R					39.0	

Test specimens 0.160" diameter, 1" gage length.

(7)

ASTM-ASME JOINT COMMITTEE ON EFFECT OF TEMPERATURE ON PROPERTIES OF METALS

TYPE OF MATERIAL	13 Cr, W, Mo, V (422)	TYPE OF MELTING FURNACE	Induction				SIZE OF HEAT	1 Ton			
CHEMICAL COMPOSITION, PER CENT	C	Mn	P	S	Si	Cr	Ni	Mo	W	V	
	0.21	0.82			0.29	13.12	0.72	1.03	1.08	0.34	
DEOXIDATION											
FORM-CAST OR WROUGHT	Wrought 1" Round										
HEAT TREATMENT	1900 F, OQ + 1300 F, 2 Hr, A.C.					Heat 1591-A5					
MICROSTRUCTURE											
GRAIN SIZE							HARDNESS	31 R_C			
SOURCE OF DATA	Crucible Steel Company										

SHORT TIME TENSILE PROPERTIES

TEMPERATURE, °F	MODULUS OF ELASTICITY, 1,000,000 P.S.I.	OFFSET YIELD (1) STRENGTH, 1000 P.S.I.	TENSILE STRENGTH, 1000 P.S.I.	ELONGATION IN 2", PER CENT	REDUCTION IN AREA, PER CENT
80		116	142	20	54

(1) 0.2 PER CENT OFFSET UNLESS OTHERWISE INDICATED.
(2) EXTRAPOLATED VALUES INDICATED BY *

CREEP AND RUPTURE STRENGTHS

TEMP, °F	STRESS FOR RUPTURE IN TIMES INDICATED, 1000 P.S.I.(2)				STRESS FOR DESIGNATED CREEP RATE, 1000 P.S.I.(2)		
	100 HRS.	1000 HRS.	10,000 HRS.	100,000 HRS.	0.000001 %/HR.	0.00001 %/HR.	0.0001 %/HR.
1000	58						
1100	44						
1200	25*						

ORIGINAL CREEP AND RUPTURE DATA

TEMP, °F	STRESS, 1000 P.S.I.	DURATION, HOURS(3)	INTERCEPT, %(4)	MINIMUM CREEP RATE, %/HR.	TRANSITION TIME, HRS.(5)	TOTAL EXT. (CREEP TEST), %	TOTAL ELONG. (RUPTURE TEST), %	HARDNESS AFTER TESTING
1000	65.0	6.5 R					13.0	
1000	60.0	47 R					15.0	
1000	57.0	147 R					18.0	
1100	45.0	73 R					20.0	
1100	40.0	442 R					15.0	
1200	30.0	17 R					16.0	
1200	27.0	51 R					22.0	

(8)

ASTM-ASME JOINT COMMITTEE ON EFFECT OF TEMPERATURE ON PROPERTIES OF METALS

TYPE OF MATERIAL	13 Cr, W, Mo, V (422)	TYPE OF MELTING FURNACE	Induction				SIZE OF HEAT	1 Ton			
CHEMICAL COMPOSITION, PER CENT	C	Mn	P	S	Si	Cr	Ni	Mo	W	V	
	0.21	0.82			0.29	13.12	0.72	1.03	1.08	0.34	
DEOXIDATION											
FORM-CAST OR WROUGHT	Wrought 1" Round										
HEAT TREATMENT	1900 F, OQ + 1350 F, 2 Hr, A.C.					Heat 1591-A5					
MICROSTRUCTURE											
GRAIN SIZE							HARDNESS	29 R_C			
SOURCE OF DATA	Crucible Steel Company										

SHORT TIME TENSILE PROPERTIES

TEMPERATURE, °F	MODULUS OF ELASTICITY, 1,000,000 P.S.I.	OFFSET YIELD (1) STRENGTH, 1000 P.S.I.	TENSILE STRENGTH, 1000 P.S.I.	ELONGATION IN 2", PER CENT	REDUCTION IN AREA, PER CENT
80		101	132	20	54

CREEP AND RUPTURE STRENGTHS

TEMP, °F	STRESS FOR RUPTURE IN TIMES INDICATED, 1000 P.S.I.(2)				STRESS FOR DESIGNATED CREEP RATE, 1000 P.S.I.(2)		
	100 HRS.	1000 HRS.	10,000 HRS.	100,000 HRS.	0.000001 %/HR.	0.00001 %/HR.	0.0001 %/HR.
1000	40*						
1100	35	30					

ORIGINAL CREEP AND RUPTURE DATA

TEMP, °F	STRESS, 1000 P.S.I.	DURATION, HOURS(3)	INTERCEPT, %(4)	MINIMUM CREEP RATE, %/HR.	TRANSITION TIME, HRS.(5)	TOTAL EXT. (CREEP TEST), %	TOTAL ELONG. (RUPTURE TEST), %	HARDNESS AFTER TESTING
1000	65.0	5.3 R					22.0	
1000	60.0	24 R					21.0	
1000	55.0	51 R					19.0	
1100	45.0	1.8 R					24.0	
1100	40.0	7.5 R					17.0	
1100	32.0	446 R					14.0	
1100	29.0	1314 R	0.81	0.00217	560		14.0	
1200	30	5.7 R					25.0	

(3) DURATION OF TEST (RUPTURE TEST INDICATED BY R).
(4) THE INTERCEPT IS THE PROJECTION BACK TO ZERO TIME FROM THE PORTION OF THE TEST SHOWING THE MINIMUM OR SECOND-STAGE CREEP RATE.
(5) THE TRANSITION TIME IS THE BEGINNING OF THE THIRD STAGE, OR AN ACCELERATING CREEP RATE.

(9)

ASTM-ASME JOINT COMMITTEE ON EFFECT OF TEMPERATURE ON PROPERTIES OF METALS

TYPE OF MATERIAL	13 Cr, W, Mo, V	TYPE OF MELTING FURNACE					SIZE OF HEAT	Commercial			
CHEMICAL COMPOSITION, PER CENT	C	Mn	P	S	Si	Cr	Ni	Mo	W	V	
	0.19	0.77	0.020	0.018	0.20	12.79	0.77	1.03	1.15	0.24	
DEOXIDATION											
FORM-CAST OR WROUGHT	Wrought Bar 2-9/16" Diameter										
HEAT TREATMENT	1900 F, 3 Hr, OQ; 1150 F, 12 Hr										
MICROSTRUCTURE											
GRAIN SIZE							HARDNESS				
SOURCE OF DATA	General Electric Company										

SHORT TIME TENSILE PROPERTIES

TEMPERATURE, °F	MODULUS OF ELASTICITY, 1,000,000 P.S.I.	OFFSET(a) YIELD (1) STRENGTH, 1000 P.S.I.	TENSILE STRENGTH, 1000 P.S.I.	ELONGATION IN 2", PER CENT	REDUCTION IN AREA, PER CENT
80		107.3	143.5	18.5	49.2
(a) 0.02% Offset yield strength.					

CREEP AND RUPTURE STRENGTHS

TEMP., °F	STRESS FOR RUPTURE IN TIMES INDICATED, 1000 P.S.I.(2)				STRESS FOR DESIGNATED CREEP RATE, 1000 P.S.I.(2)		
	100 HRS.	1000 HRS.	10,000 HRS.	100,000 HRS.	0.000001 %/HR.	0.00001 %/HR.	0.0001 %/HR.
1000			44P	33P			
1100		33P	22P	13P			
1200	25P	14.5P					
P indicates strength value obtained by use of Larson-Miller parameter T(25 + log t).							

ORIGINAL CREEP AND RUPTURE DATA

TEMP. °F.	STRESS, 1000 P.S.I.	DURATION, HOURS(3)	INTERCEPT, %(4)	MINIMUM CREEP RATE, %/HR.	TRANSITION TIME, HRS.(5)	TOTAL EXT. (CREEP TEST), %	TOTAL ELONG. (RUPTURE TEST), %	REDUCTION IN AREA, %
1050	50.0	327 R					24.0	75.0
1050	49.0	548 R					23.0	72.0
1100	32.0	1293 R					23.0	72.0
1200	30.0	36 R					27.0	86.0
1200	20.0	300 R					37.0	88.0
1300	15.0	22 R					40.0	83.0
1300	10.0	103 R					52.0	92.0

(10)

ASTM-ASME JOINT COMMITTEE ON EFFECT OF TEMPERATURE ON PROPERTIES OF METALS

TYPE OF MATERIAL	13 Cr, W, Mo, V	TYPE OF MELTING FURNACE					SIZE OF HEAT	Commercial			
CHEMICAL COMPOSITION, PER CENT	C	Mn	P	S	Si	Cr	Ni	Mo	W	V	
	0.22	0.80	0.022	0.015	0.30	13.59	0.61	1.02	1.02	0.25	
DEOXIDATION											
FORM-CAST OR WROUGHT	Wrought Bar 1-5/16" Diameter										
HEAT TREATMENT	1900 F, OQ; 1150 F Temper										
MICROSTRUCTURE											
GRAIN SIZE							HARDNESS				
SOURCE OF DATA	General Electric Company										

SHORT TIME TENSILE PROPERTIES

TEMPERATURE, °F	MODULUS OF ELASTICITY, 1,000,000 P.S.I.	OFFSET(a) YIELD (1) STRENGTH, 1000 P.S.I.	TENSILE STRENGTH, 1000 P.S.I.	ELONGATION IN 2", PER CENT	REDUCTION IN AREA, PER CENT
80		113.0	152.2	19.5	50.6
(a) 0.02% Offset yield strength.					

CREEP AND RUPTURE STRENGTHS

TEMP., °F	STRESS FOR RUPTURE IN TIMES INDICATED, 1000 P.S.I.(2)				STRESS FOR DESIGNATED CREEP RATE, 1000 P.S.I.(2)		
	100 HRS.	1000 HRS.	10,000 HRS.	100,000 HRS.	0.000001 %/HR.	0.00001 %/HR.	0.0001 %/HR.
900				54P			
1000		54P	42P	32P			
1100		32P	23P	13P			
1200	25P	15P					
P indicates strength value obtained by use of Larson-Miller parameter T(25 + log t).							

(1) 0.2 PER CENT OFFSET UNLESS OTHERWISE INDICATED.

(2) EXTRAPOLATED VALUES INDICATED BY *

ORIGINAL CREEP AND RUPTURE DATA

TEMP. °F.	STRESS, 1000 P.S.I.	DURATION, HOURS(3)	INTERCEPT, %(4)	MINIMUM CREEP RATE, %/HR.	TRANSITION TIME, HRS.(5)	TOTAL EXT. (CREEP TEST), %	TOTAL ELONG. (RUPTURE TEST), %	REDUCTION IN AREA, %
1050	60.0	40 R					14.0	70.0
1150	50.0	3 R					16.0	78.0
1150	40.0	29 R					18.0	78.0
1150	30.0	170 R					17.0	82.0
1200	25.0	109 R					22.0	83.0
1200	20.0	359 R					18.0	84.0
1300	15.0	15 R					27.0	91.0
1300	10.0	73 R					41.0	93.0

(11)

ASTM-ASME JOINT COMMITTEE ON EFFECT OF TEMPERATURE ON PROPERTIES OF METALS

TYPE OF MATERIAL	13 Cr, W, Mo, V (422)	TYPE OF MELTING FURNACE	ARC	SIZE OF HEAT	13 Tons						
CHEMICAL COMPOSITION, PER CENT	C	Mn	P	S	Si	Cr	Ni	Mo	W	V	
	0.22	0.80			0.37	13.63	0.61	1.02	1.02	0.28	
DEOXIDATION											
FORM-CAST OR WROUGHT	Wrought 1" Round										
HEAT TREATMENT	1900 F, OQ + 1200 F, 2 Hr					Heat No. W4543					
MICROSTRUCTURE											
GRAIN SIZE							HARDNESS				
SOURCE OF DATA	Crucible Steel Company										

SHORT TIME TENSILE PROPERTIES

TEMPERATURE, °F	MODULUS OF ELASTICITY, 1,000,000 P.S.I.	OFFSET YIELD (1) STRENGTH, 1000 P.S.I.	TENSILE STRENGTH, 1000 P.S.I.	ELONGATION IN 2" PER CENT	REDUCTION IN AREA, PER CENT
600		110	132	14	50
800		103	124	16	52
900		95	113	19	50

CREEP AND RUPTURE STRENGTHS

TEMP., °F	STRESS FOR RUPTURE IN TIMES INDICATED, 1000 P.S.I.(2)				STRESS FOR DESIGNATED CREEP RATE, 1000 P.S.I.(2)		
	100 HRS.	1000 HRS.	10,000 HRS.	100,000 HRS.	0.000001 %/HR.	0.00001 %/HR.	0.0001 %/HR.
1050	57	51					

ORIGINAL CREEP AND RUPTURE DATA

TEMP. °F.	STRESS, 1000 P.S.I.	DURATION, HOURS(3)	INTERCEPT, %(4)	MINIMUM CREEP RATE, %/HR.	TRANSITION TIME, HRS.(5)	TOTAL EXT. (CREEP TEST), %	TOTAL ELONG. (RUPTURE TEST), %	HARDNESS AFTER TESTING
1050	65.0	16 R					24.0	
1050	60.0	53 R					29.0	
1050	55.0	193 R					20.0	
1050	50.0	1173 R					19.0	
1050	45.0	1258 R	0.78	0.00162	840		8.0*	
	*2.25 inch gage length.							

(12)

ASTM-ASME JOINT COMMITTEE ON EFFECT OF TEMPERATURE ON PROPERTIES OF METALS

TYPE OF MATERIAL	13 Cr, W, Mo, V	TYPE OF MELTING FURNACE					SIZE OF HEAT	Commercial			
CHEMICAL COMPOSITION, PER CENT	C	Mn	P	S	Si	Cr	Ni	Mo	V	W	
	0.19	0.77	0.020	0.018	0.20	12.79	0.77	1.03	0.24	1.15	
DEOXIDATION											
FORM-CAST OR WROUGHT	2" x 3" Wrought Bar										
HEAT TREATMENT	1900, OQ; 1150 F, A.C.										
MICROSTRUCTURE											
GRAIN SIZE							HARDNESS				
SOURCE OF DATA	General Electric Company										

SHORT TIME TENSILE PROPERTIES

TEMPERATURE, °F	MODULUS OF ELASTICITY, 1,000,000 P.S.I.	OFFSET(a) YIELD (1) STRENGTH, 1000 P.S.I.	TENSILE STRENGTH, 1000 P.S.I.	ELONGATION IN 2", PER CENT	REDUCTION IN AREA, PER CENT
80		116.0	146.0	17.5	47.5
(a) 0.02% Offset yield strength.					

(3) DURATION OF TEST (RUPTURE TEST INDICATED BY R).

(4) THE INTERCEPT IS THE PROJECTION BACK TO ZERO TIME FROM THE PORTION OF THE TEST SHOWING THE MINIMUM OR SECOND-STAGE CREEP RATE.

(5) THE TRANSITION TIME IS THE BEGINNING OF THE THIRD STAGE, OR AN ACCELERATING CREEP RATE.

ORIGINAL CREEP AND RUPTURE DATA

TEMP, °F	STRESS, 1000 P.S.I.	DURATION, HOURS(3)	INTERCEPT, %(4)	MINIMUM CREEP RATE, %/HR.	TRANSITION TIME, HRS.(5)	TOTAL EXT. (CREEP TEST), %	TOTAL ELONG. (RUPTURE TEST), %	REDUCTION IN AREA, %
1100	45.0	117 R					19.0	76.0
1200	30.0	65 R					81.0	21.0
1200	22.0	246 R					18.0	79.0
1250	15.0	52 R					29.0	88.0

(13)

ASTM-ASME JOINT COMMITTEE ON EFFECT OF TEMPERATURE ON PROPERTIES OF METALS

TYPE OF MATERIAL	13 Cr, W, Mo, V (422)	TYPE OF MELTING FURNACE	ARC	SIZE OF HEAT	15 Tons

CHEMICAL COMPOSITION, PER CENT	C	Mn	P	S	Si	Cr	Ni	Mo	W	V
	0.23	0.87				13.16	0.70	1.01	1.20	0.25

DEOXIDATION

FORM-CAST OR WROUGHT: Wrought 1" ϕ

HEAT TREATMENT: 1900 F, OQ; 1150 F, 2 Hr

MICROSTRUCTURE

GRAIN SIZE | HARDNESS: 33.5 R_c

SOURCE OF DATA: Crucible Steel Company

CREEP AND RUPTURE STRENGTHS

TEMP., °F	STRESS FOR RUPTURE IN TIMES INDICATED, 1000 P.S.I.(2)				STRESS FOR DESIGNATED CREEP RATE, 1000 P.S.I.(2)		
	100 HRS.	1000 HRS.	10,000 HRS.	100,000 HRS.	0.000001 %/HR.	0.00001 %/HR.	0.0001 %/HR.
850	92	82*					

ORIGINAL CREEP AND RUPTURE DATA

TEMP, °F	STRESS, 1000 P.S.I.	DURATION, HOURS(3)	INTERCEPT, %(4)	MINIMUM CREEP RATE, %/HR.	TRANSITION TIME, HRS.(5)	TOTAL EXT. (CREEP TEST), %	TOTAL ELONG. (RUPTURE TEST), %	HARDNESS AFTER TESTING
850	104.0	2 R					15.0	
850	95.0	51 R					15.0	
850	90.0	227 R					17.0	
850	85.0	554 R					20.0	

(14)

ASTM-ASME JOINT COMMITTEE ON EFFECT OF TEMPERATURE ON PROPERTIES OF METALS

TYPE OF MATERIAL	13 Cr, W, Mo, V (422)	TYPE OF MELTING FURNACE	ARC	SIZE OF HEAT	15 Tons

CHEMICAL COMPOSITION, PER CENT	C	Mn	N_2	S	Si	Cr	Ni	Mo	Al	W	V
	0.21	0.84	0.03			13.05	0.68	1.09	0.008	1.01	0.22

DEOXIDATION

FORM-CAST OR WROUGHT: Wrought 1" Square

HEAT TREATMENT: 1800 F, OQ and 1200 F, 2 Hr | Heat No. W6184

MICROSTRUCTURE: Tempered Martensite and 15% Ferrite

GRAIN SIZE | HARDNESS: 31 R_c

SOURCE OF DATA: Crucible Steel Company

CREEP AND RUPTURE STRENGTHS

TEMP., °F	STRESS FOR RUPTURE IN TIMES INDICATED, 1000 P.S.I.(2)				STRESS FOR DESIGNATED CREEP RATE, 1000 P.S.I.(2)		
	100 HRS.	1000 HRS.	10,000 HRS.	100,000 HRS.	0.000001 %/HR.	0.00001 %/HR.	0.0001 %/HR.
1000	63.5						
1100	43						

ORIGINAL CREEP AND RUPTURE DATA

TEMP, °F	STRESS, 1000 P.S.I.	DURATION, HOURS(3)	INTERCEPT, %(4)	MINIMUM CREEP RATE, %/HR.	TRANSITION TIME, HRS.(5)	TOTAL EXT. (CREEP TEST), %	TOTAL ELONG. (RUPTURE TEST), %	HARDNESS AFTER TESTING
1000	69.0	16 R					19.0	
1000	62.0	151 R					20.0	
1100	52.5	5 R					23.0	
1100	40.0	356 R					22.0	

(1) 0.2 PER CENT OFFSET UNLESS OTHERWISE INDICATED.

(2) EXTRAPOLATED VALUES INDICATED BY *

(15)

ASTM-ASME JOINT COMMITTEE ON EFFECT OF TEMPERATURE ON PROPERTIES OF METALS

TYPE OF MATERIAL	13 Cr, W, Mo, V (422)	TYPE OF MELTING FURNACE	ARC	SIZE OF HEAT	15 Tons

CHEMICAL COMPOSITION, PER CENT	C	Mn	N_2	S	Si	Cr	Ni	Mo	W	V
	0.23	0.79	0.04			13.18	0.69	1.05	0.97	0.26

DEOXIDATION

FORM-CAST OR WROUGHT: Wrought 1" Square | Heat No. 40051

HEAT TREATMENT: 1800 F, OQ; 1200 F, 2 Hr

MICROSTRUCTURE: Tempered Martensite and 18% Ferrite

GRAIN SIZE | HARDNESS: 32 R_c

SOURCE OF DATA: Crucible Steel Company

CREEP AND RUPTURE STRENGTHS

TEMP., °F	STRESS FOR RUPTURE IN TIMES INDICATED, 1000 P.S.I.(2)				STRESS FOR DESIGNATED CREEP RATE, 1000 P.S.I.(2)		
	100 HRS.	1000 HRS.	10,000 HRS.	100,000 HRS.	0.000001 %/HR.	0.00001 %/HR.	0.0001 %/HR.
1000	65						
1100	43						

ORIGINAL CREEP AND RUPTURE DATA

TEMP, °F	STRESS, 1000 P.S.I.	DURATION, HOURS(3)	INTERCEPT, %(4)	MINIMUM CREEP RATE, %/HR.	TRANSITION TIME, HRS.(5)	TOTAL EXT. (CREEP TEST), %	TOTAL ELONG. (RUPTURE TEST), %	HARDNESS AFTER TESTING
1000	69.0	12 R					21.0	
1000	62.0	534 R					19.0	
1100	52.5	5 R					22.0	
1100	40.0	252 R					19.0	

(16)

ASTM-ASME JOINT COMMITTEE ON EFFECT OF TEMPERATURE ON PROPERTIES OF METALS

TYPE OF MATERIAL	13 Cr, W, Mo, V (422)	TYPE OF MELTING FURNACE	ARC	SIZE OF HEAT	15 Tons

CHEMICAL COMPOSITION, PER CENT	C	Mn	P	S	Si	Cr	Ni	Mo	W	V	N_2
	0.23	0.79				13.18	0.69	1.05	0.97	0.26	0.04

DEOXIDATION

FORM-CAST OR WROUGHT: Wrought 1" Square

HEAT TREATMENT: 1900 F, OQ; 1200 F, 2 Hr | Heat No. 40051

MICROSTRUCTURE: Tempered Martensite and 10% Ferrite

GRAIN SIZE | HARDNESS: 34.5 R_c

SOURCE OF DATA: Crucible Steel Company

CREEP AND RUPTURE STRENGTHS

TEMP., °F	STRESS FOR RUPTURE IN TIMES INDICATED, 1000 P.S.I.(2)				STRESS FOR DESIGNATED CREEP RATE, 1000 P.S.I.(2)		
	100 HRS.	1000 HRS.	10,000 HRS.	100,000 HRS.	0.000001 %/HR.	0.00001 %/HR.	0.0001 %/HR.
1000	70						
1100	52*						

ORIGINAL CREEP AND RUPTURE DATA

TEMP, °F	STRESS, 1000 P.S.I.	DURATION, HOURS(3)	INTERCEPT, %(4)	MINIMUM CREEP RATE, %/HR.	TRANSITION TIME, HRS.(5)	TOTAL EXT. (CREEP TEST), %	TOTAL ELONG. (RUPTURE TEST), %	HARDNESS AFTER TESTING
1000	73.0	35 R					18.0	
1000	69.0	215 R					18.0	
1100	58.0	5 R					23.0	
1100	52.5	75 R					21.0	

(3) DURATION OF TEST (RUPTURE TEST INDICATED BY R).

(4) THE INTERCEPT IS THE PROJECTION BACK TO ZERO TIME FROM THE PORTION OF THE TEST SHOWING THE MINIMUM OR SECOND-STAGE CREEP RATE.

(5) THE TRANSITION TIME IS THE BEGINNING OF THE THIRD STAGE, OR AN ACCELERATING CREEP RATE.

(17)

ASTM-ASME JOINT COMMITTEE ON EFFECT OF TEMPERATURE ON PROPERTIES OF METALS

TYPE OF MATERIAL	13 Cr, W, Mo, V (422)	TYPE OF MELTING FURNACE	ARC	SIZE OF HEAT	15 Tons

CHEMICAL COMPOSITION, PER CENT	C	Mn	P	S	Si	Cr	Ni	Mo	W	V	N_2
	0.23	0.77				13.18	0.69	1.05	0.97	0.26	0.04

DEOXIDATION	
FORM-CAST OR WROUGHT	Wrought 1" Square
HEAT TREATMENT	1900 F, OQ; 1200 F, 2 Hr — Heat No. 40050
MICROSTRUCTURE	Tempered Martensite and 1% Ferrite
GRAIN SIZE	HARDNESS 34 R_C
SOURCE OF DATA	Crucible Steel Company

CREEP AND RUPTURE STRENGTHS

TEMP., °F	STRESS FOR RUPTURE IN TIMES INDICATED, 1000 P.S.I.(2)				STRESS FOR DESIGNATED CREEP RATE, 1000 P.S.I.(2)		
	100 HRS.	1000 HRS.	10,000 HRS.	100,000 HRS.	0.000001 %/HR.	0.00001 %/HR.	0.0001 %/HR.
1000	66						
1100	47						

ORIGINAL CREEP AND RUPTURE DATA

TEMP. °F.	STRESS 1000 P.S.I.	DURATION, HOURS(3)	INTERCEPT, %(4)	MINIMUM CREEP RATE, %/HR.	TRANSITION TIME, HRS.(5)	TOTAL EXT. (CREEP TEST), %	TOTAL ELONG. (RUPTURE TEST), %	HARDNESS AFTER TESTING
1000	69.0	29 R					24.0	
1000	65.0	213 R					19.0	
1100	52.5	26 R					25.0	
1100	46.0	118 R					21.0	

(18)

ASTM-ASME JOINT COMMITTEE ON EFFECT OF TEMPERATURE ON PROPERTIES OF METALS

TYPE OF MATERIAL	13 Cr, W, Mo, V (422)	TYPE OF MELTING FURNACE	ARC	SIZE OF HEAT	15 Tons

CHEMICAL COMPOSITION, PER CENT	C	Mn	N_2	S	Si	Cr	Ni	Mo	Al	V	W
	0.21	0.82	0.03			13.12	0.70	1.01	0.012	0.30	1.03

DEOXIDATION	
FORM-CAST OR WROUGHT	Wrought 1" Square
HEAT TREATMENT	1800 F, OQ; 1200 F, 2 Hr — Heat No. W6019
MICROSTRUCTURE	Tempered Martensite and 16% Ferrite
GRAIN SIZE	HARDNESS 31 R_C
SOURCE OF DATA	Crucible Steel Company

CREEP AND RUPTURE STRENGTHS

TEMP., °F	STRESS FOR RUPTURE IN TIMES INDICATED, 1000 P.S.I.(2)				STRESS FOR DESIGNATED CREEP RATE, 1000 P.S.I.(2)		
	100 HRS.	1000 HRS.	10,000 HRS.	100,000 HRS.	0.000001 %/HR.	0.00001 %/HR.	0.0001 %/HR.
1000	62						
1100	42						

ORIGINAL CREEP AND RUPTURE DATA

TEMP. °F.	STRESS 1000 P.S.I.	DURATION, HOURS(3)	INTERCEPT, %(4)	MINIMUM CREEP RATE, %/HR.	TRANSITION TIME, HRS.(5)	TOTAL EXT. (CREEP TEST), %	TOTAL ELONG. (RUPTURE TEST), %	HARDNESS AFTER TESTING
1000	69.0	19 R					20.0	
1000	62.0	95 R					24.0	
1100	52.5	3 R					23.0	
1100	40.0	242 R					20.0	

(19)

ASTM-ASME JOINT COMMITTEE ON EFFECT OF TEMPERATURE ON PROPERTIES OF METALS

TYPE OF MATERIAL	13 Cr, W, Mo, V (422)	TYPE OF MELTING FURNACE	ARC	SIZE OF HEAT	15 Tons

CHEMICAL COMPOSITION, PER CENT	C	Mn	N_2	S	Si	Cr	Ni	Mo	Al	W	V
	0.21	0.82	0.03			13.12	0.70	1.01	0.012	1.03	0.30

DEOXIDATION	
FORM-CAST OR WROUGHT	Wrought 1" Square
HEAT TREATMENT	1900 F, OQ; 1200 F, 2 Hr — Heat No. W6019
MICROSTRUCTURE	Tempered Martensite and 7% Ferrite
GRAIN SIZE	HARDNESS 32.5 R_C
SOURCE OF DATA	Crucible Steel Company

CREEP AND RUPTURE STRENGTHS

TEMP., °F	STRESS FOR RUPTURE IN TIMES INDICATED, 1000 P.S.I.(2)				STRESS FOR DESIGNATED CREEP RATE, 1000 P.S.I.(2)		
	100 HRS.	1000 HRS.	10,000 HRS.	100,000 HRS.	0.000001 %/HR.	0.00001 %/HR.	0.0001 %/HR.
1000	65						
1100	43						

ORIGINAL CREEP AND RUPTURE DATA

TEMP. °F.	STRESS 1000 P.S.I.	DURATION, HOURS(3)	INTERCEPT, %(4)	MINIMUM CREEP RATE, %/HR.	TRANSITION TIME, HRS.(5)	TOTAL EXT. (CREEP TEST), %	TOTAL ELONG. (RUPTURE TEST), %	HARDNESS AFTER TESTING
1000	69.0	18 R					26.0	
1000	62.0	473 R					17.0	
1100	52.5	4 R					23.0	
1100	40.0	412 R					23.0	

(20)

ASTM-ASME JOINT COMMITTEE ON EFFECT OF TEMPERATURE ON PROPERTIES OF METALS

TYPE OF MATERIAL	13 Cr, W, Mo, V (422)	TYPE OF MELTING FURNACE	ARC	SIZE OF HEAT	15 Tons

CHEMICAL COMPOSITION, PER CENT	C	Mn	P	S	Si	Cr	Ni	Mo	W	V	N_2
	0.23	0.81				13.16	0.82	1.03	1.09	0.26	0.04

DEOXIDATION	
FORM-CAST OR WROUGHT	Wrought 1" Square
HEAT TREATMENT	1900 F, OQ; 1200 F, 2 Hr — Heat No. 40058
MICROSTRUCTURE	Tempered Martensite and 2% Ferrite
GRAIN SIZE	HARDNESS 33.5 R_C
SOURCE OF DATA	Crucible Steel Company

CREEP AND RUPTURE STRENGTHS

TEMP., °F	STRESS FOR RUPTURE IN TIMES INDICATED, 1000 P.S.I.(2)				STRESS FOR DESIGNATED CREEP RATE, 1000 P.S.I.(2)		
	100 HRS.	1000 HRS.	10,000 HRS.	100,000 HRS.	0.000001 %/HR.	0.00001 %/HR.	0.0001 %/HR.
1000	64						
1100	46.5						

ORIGINAL CREEP AND RUPTURE DATA

TEMP. °F.	STRESS 1000 P.S.I.	DURATION, HOURS(3)	INTERCEPT, %(4)	MINIMUM CREEP RATE, %/HR.	TRANSITION TIME, HRS.(5)	TOTAL EXT. (CREEP TEST), %	TOTAL ELONG. (RUPTURE TEST), %	HARDNESS AFTER TESTING
1000	69.0	11 R					23.0	
1000	62.0	334 R					26.0	
1100	52.5	14 R					21.0	
1100	46.0	121 R					19.0	

(21)

ASTM-ASME JOINT COMMITTEE ON EFFECT OF TEMPERATURE ON PROPERTIES OF METALS

TYPE OF MATERIAL	13 Cr, W, Mo, V (422)	TYPE OF MELTING FURNACE	ARC	SIZE OF HEAT	15 Tons

CHEMICAL COMPOSITION, PER CENT	C	Mn	P	S	Si	Cr	Ni	Mo	W	V	N_2
	0.23	0.81				13.16	0.82	1.03	1.09	0.26	0.04

DEOXIDATION	
FORM-CAST OR WROUGHT	Wrought 1" Square
HEAT TREATMENT	1800 F, OQ; 1200 F, 2 Hr, A.C. — Heat No. 40058
MICROSTRUCTURE	Tempered Martensite and 10% Ferrite
GRAIN SIZE	HARDNESS 32 R_C
SOURCE OF DATA	Crucible Steel Company

CREEP AND RUPTURE STRENGTHS

TEMP., °F	STRESS FOR RUPTURE IN TIMES INDICATED, 1000 P.S.I.(2)				STRESS FOR DESIGNATED CREEP RATE, 1000 P.S.I.(2)		
	100 HRS.	1000 HRS.	10,000 HRS.	100,000 HRS.	0.000001 %/HR.	0.00001 %/HR.	0.0001 %/HR.
1000	63						
1100	41						

ORIGINAL CREEP AND RUPTURE DATA

TEMP. °F.	STRESS 1000 P.S.I.	DURATION, HOURS(3)	INTERCEPT, %(4)	MINIMUM CREEP RATE, %/HR.	TRANSITION TIME, HRS.(5)	TOTAL EXT. (CREEP TEST), %	TOTAL ELONG. (RUPTURE TEST), %	HARDNESS AFTER TESTING
1000	69.0	11 R					18.0	
1000	62.0	178 R					19.0	
1100	52.5	6 R					21.0	
1100	40.0	130 R					20.0	

(1) 0.2 PER CENT OFFSET UNLESS OTHERWISE INDICATED.
(2) EXTRAPOLATED VALUES INDICATED BY *
(3) DURATION OF TEST (RUPTURE TEST INDICATED BY R).
(4) THE INTERCEPT IS THE PROJECTION BACK TO ZERO TIME FROM THE PORTION OF THE TEST SHOWING THE MINIMUM OR SECOND-STAGE CREEP RATE.
(5) THE TRANSITION TIME IS THE BEGINNING OF THE THIRD STAGE, OR AN ACCELERATING CREEP RATE.

(22)

ASTM-ASME JOINT COMMITTEE ON EFFECT OF TEMPERATURE ON PROPERTIES OF METALS

TYPE OF MATERIAL	13 Cr, W, Mo, V (422)	TYPE OF MELTING FURNACE			ARC		SIZE OF HEAT	13 Tons				
CHEMICAL COMPOSITION, PER CENT	C	Mn	P	S	Si	Cr	Ni	Mo	W	V	N_2	
	0.23	0.77				12.76	0.76	0.98	1.11	0.26	0.04	
DEOXIDATION												
FORM-CAST OR WROUGHT	Wrought 1" Square											
HEAT TREATMENT	1900 F, OQ; 1200 F, 2 Hr						Heat No. K6671					
MICROSTRUCTURE	Tempered Martensite											
GRAIN SIZE						HARDNESS	34.5 R_C					
SOURCE OF DATA	Crucible Steel Company											

CREEP AND RUPTURE STRENGTHS

TEMP, °F	STRESS FOR RUPTURE IN TIMES INDICATED, 1000 P.S.I.(2)				STRESS FOR DESIGNATED CREEP RATE, 1000 P.S.I.(2)		
	100 HRS.	1000 HRS.	10,000 HRS.	100,000 HRS.	0.000001 %/HR.	0.00001 %/HR.	0.0001 %/HR.
1000	66.5						
1100	48						

ORIGINAL CREEP AND RUPTURE DATA

TEMP, °F.	STRESS, 1000 P.S.I.	DURATION, HOURS(3)	INTERCEPT, %(4)	MINIMUM CREEP RATE, %/HR.	TRANSITION TIME, HRS.(5)	TOTAL EXT. (CREEP TEST), %	TOTAL ELONG. (RUPTURE TEST), %	HARDNESS AFTER TESTING
1000	69.0	45 R					17.0	
1000	66.0	133 R					19.0	
1100	52.5	17 R					20.0	
1100	46.0	205 R					18.0	

(23)

ASTM-ASME JOINT COMMITTEE ON EFFECT OF TEMPERATURE ON PROPERTIES OF METALS

TYPE OF MATERIAL	13 Cr, W, Mo, V (422)	TYPE OF MELTING FURNACE			ARC		SIZE OF HEAT	13 Tons				
CHEMICAL COMPOSITION, PER CENT	C	Mn	P	S	Si	Cr	Ni	Mo	W	V	N_2	
	0.23	0.77				12.76	0.76	0.98	1.11	0.26	0.04	
DEOXIDATION												
FORM-CAST OR WROUGHT	Wrought 1" Square											
HEAT TREATMENT	1800 F, OQ; 1200 F, 2 Hr						Heat No. K6671					
MICROSTRUCTURE	Tempered Martensite and 4% Ferrite											
GRAIN SIZE						HARDNESS	33.5 R_C					
SOURCE OF DATA	Crucible Steel Company											

CREEP AND RUPTURE STRENGTHS

TEMP, °F	STRESS FOR RUPTURE IN TIMES INDICATED, 1000 P.S.I.(2)				STRESS FOR DESIGNATED CREEP RATE, 1000 P.S.I.(2)		
	100 HRS.	1000 HRS.	10,000 HRS.	100,000 HRS.	0.000001 %/HR.	0.00001 %/HR.	0.0001 %/HR.
1000	65.5						
1100	47						

ORIGINAL CREEP AND RUPTURE DATA

TEMP, °F.	STRESS, 1000 P.S.I.	DURATION, HOURS(3)	INTERCEPT, %(4)	MINIMUM CREEP RATE, %/HR.	TRANSITION TIME, HRS.(5)	TOTAL EXT. (CREEP TEST), %	TOTAL ELONG. (RUPTURE TEST), %	HARDNESS AFTER TESTING
1000	69.0	26 R					17.0	
1000	63.0	253 R					17.0	
1100	52.5	22 R					19.0	
1100	46.0	127 R					20.0	

(24)

ASTM-ASME JOINT COMMITTEE ON EFFECT OF TEMPERATURE ON PROPERTIES OF METALS

TYPE OF MATERIAL	13 Cr, W, Mo, V (422)	TYPE OF MELTING FURNACE			ARC		SIZE OF HEAT	15 Tons				
CHEMICAL COMPOSITION, PER CENT	C	Mn	P	S	Si	Cr	Ni	Mo	W	V	N_2	
	0.23	0.77				13.18	0.69	1.05	0.97	0.26	0.04	
DEOXIDATION												
FORM-CAST OR WROUGHT	Wrought 1" Square											
HEAT TREATMENT	1800 F, OQ; 1200 F, 2 Hr						Heat No. 40050					
MICROSTRUCTURE	Tempered Martensite and 6% Ferrite											
GRAIN SIZE						HARDNESS	33 R_C					
SOURCE OF DATA	Crucible Steel Company											

CREEP AND RUPTURE STRENGTHS

TEMP., °F	STRESS FOR RUPTURE IN TIMES INDICATED, 1000 P.S.I.(2)				STRESS FOR DESIGNATED CREEP RATE, 1000 P.S.I.(2)		
	100 HRS.	1000 HRS.	10,000 HRS.	100,000 HRS.	0.000001 %/HR.	0.00001 %/HR.	0.0001 %/HR.
1000	64.5						
1100	44*						

ORIGINAL CREEP AND RUPTURE DATA

TEMP, °F.	STRESS, 1000 P.S.I.	DURATION, HOURS(3)	INTERCEPT, %(4)	MINIMUM CREEP RATE, %/HR.	TRANSITION TIME, HRS.(5)	TOTAL EXT. (CREEP TEST), %	TOTAL ELONG. (RUPTURE TEST), %	HARDNESS AFTER TESTING
1000	69.0	6 R					21.0	
1000	64.0	144 R					24.0	
1100	52.5	14 R					27.0	
1100	46.0	61 R					20.0	

(25)

ASTM-ASME JOINT COMMITTEE ON EFFECT OF TEMPERATURE ON PROPERTIES OF METALS

TYPE OF MATERIAL	13 Cr, W, Mo, V	TYPE OF MELTING FURNACE					SIZE OF HEAT	Commercial			
CHEMICAL COMPOSITION, PER CENT	C	Mn	P	S	Si	Cr	Ni	Mo	W	V	
	0.23	0.81	0.011	0.022	0.16	13.19	0.65	1.03	0.84	0.25	
DEOXIDATION											
FORM-CAST OR WROUGHT	Wrought Bar 3-1/2" Diameter										
HEAT TREATMENT	1900 F, A.C.; 1100 F, 4 Hr, A.C.; 1200 F, 5 Hr, F.C.										
MICROSTRUCTURE											
GRAIN SIZE						HARDNESS					
SOURCE OF DATA	General Electric Company										

SHORT TIME TENSILE PROPERTIES

TEMPERATURE, °F	MODULUS OF ELASTICITY, 1,000,000 P.S.I.	OFFSET(a) YIELD (1) STRENGTH, 1000 P.S.I.	TENSILE STRENGTH, 1000 P.S.I.	ELONGATION IN 2" PER CENT	REDUCTION IN AREA, PER CENT
80		94.0	149.0	18.5	50.4

(a) 0.02% Offset yield strength.

CREEP AND RUPTURE STRENGTHS

TEMP, °F	STRESS FOR RUPTURE IN TIMES INDICATED, 1000 P.S.I.(2)				STRESS FOR DESIGNATED CREEP RATE, 1000 P.S.I.(2)		
	100 HRS.	1000 HRS.	10,000 HRS.	100,000 HRS.	0.000001 %/HR.	0.00001 %/HR.	0.0001 %/HR.
900				52P			
1000		51P	38P	27P			
1100		28P	18P				
1200	20P						

P indicates strength value obtained by use of Larson-Miller parameter T(25 + log t).

ORIGINAL CREEP AND RUPTURE DATA

TEMP, °F.	STRESS, 1000 P.S.I.	DURATION, HOURS(3)	INTERCEPT, %(4)	MINIMUM CREEP RATE, %/HR.	TRANSITION TIME, HRS.(5)	TOTAL EXT. (CREEP TEST), %	TOTAL ELONG. (RUPTURE TEST), %	REDUCTION IN AREA, %
1100	50.0	19 R					16.0	71.0
1200	25.0	34 R					17.0	85.0
1200	15.0	415 R					19.0	89.0

(26)

ASTM-ASME JOINT COMMITTEE ON EFFECT OF TEMPERATURE ON PROPERTIES OF METALS

TYPE OF MATERIAL	13 Cr, W, Mo, V	TYPE OF MELTING FURNACE					SIZE OF HEAT	Commercial			
CHEMICAL COMPOSITION, PER CENT	C	Mn	P	S	Si	Cr	Ni	Mo	W	V	
	0.20	0.73	0.017	0.011	0.26	12.85	0.77	1.02	1.15	0.26	
DEOXIDATION											
FORM-CAST OR WROUGHT	Wrought Bar 4-9/16" Diameter										
HEAT TREATMENT	1900 F, OQ; 1150 F, 12 Hr, F.C.										
MICROSTRUCTURE											
GRAIN SIZE						HARDNESS					
SOURCE OF DATA	General Electric Company										

SHORT TIME TENSILE PROPERTIES

TEMPERATURE, °F	MODULUS OF ELASTICITY, 1,000,000 P.S.I.	OFFSET(a) YIELD (1) STRENGTH, 1000 P.S.I.	TENSILE STRENGTH, 1000 P.S.I.	ELONGATION IN 2" PER CENT	REDUCTION IN AREA, PER CENT
80		116.8	156.0	17.0	41.4

(a) 0.02% Offset yield strength.

(1) 0.2 PER CENT OFFSET UNLESS OTHERWISE INDICATED.
(2) EXTRAPOLATED VALUES INDICATED BY *
(3) DURATION OF TEST (RUPTURE TEST INDICATED BY R).
(4) THE INTERCEPT IS THE PROJECTION BACK TO ZERO TIME FROM THE PORTION OF THE TEST SHOWING THE MINIMUM OR SECOND-STAGE CREEP RATE.
(5) THE TRANSITION TIME IS THE BEGINNING OF THE THIRD STAGE, OR AN ACCELERATING CREEP RATE.

CREEP AND RUPTURE STRENGTHS

TEMP., °F	STRESS FOR RUPTURE IN TIMES INDICATED, 1000 P.S.I. (2)				STRESS FOR DESIGNATED CREEP RATE, 1000 P.S.I. (2)		
	100 HRS.	1000 HRS.	10,000 HRS.	100,000 HRS.	0.000001 %/HR.	0.00001 %/HR.	0.0001 %/HR.
1100			21P				
1200	24P						

P indicates strength value obtained by use of Larson-Miller parameter T(20 + log t).

ORIGINAL CREEP AND RUPTURE DATA

TEMP. °F	STRESS 1000 P.S.I.	DURATION HOURS (3)	INTERCEPT, % (4)	MINIMUM CREEP RATE, %/HR.	TRANSITION TIME, HRS. (5)	TOTAL EXT. (CREEP TEST), %	TOTAL ELONG. (RUPTURE TEST), %	REDUCTION IN AREA, %
1200	25.0	82 R					24.0	83.0
1250	18.0	46 R					20.0	89.0
1250	13.0	107 R					26.0	91.0

(27)

ASTM-ASME JOINT COMMITTEE ON EFFECT OF TEMPERATURE ON PROPERTIES OF METALS

TYPE OF MATERIAL: 13 Cr, W, Mo, V (422) — TYPE OF MELTING FURNACE: ARC — SIZE OF HEAT: 15 Tons

CHEMICAL COMPOSITION, PER CENT	C	Mn	N_2	S	Si	Cr	Ni	Mo	Al	W	V
	0.21	0.84	0.03			13.05	0.68	1.09	0.008	1.01	0.22

DEOXIDATION

FORM-CAST OR WROUGHT: Wrought 1" Square

HEAT TREATMENT: 1900 F, OQ; 1200 F, 2 Hr — Heat No. W6184

MICROSTRUCTURE: Tempered Martensite and 4% Ferrite

GRAIN SIZE — HARDNESS: 32.5 R_c

SOURCE OF DATA: Crucible Steel Company

CREEP AND RUPTURE STRENGTHS

TEMP., °F	STRESS FOR RUPTURE IN TIMES INDICATED, 1000 P.S.I. (2)				STRESS FOR DESIGNATED CREEP RATE, 1000 P.S.I. (2)		
	100 HRS.	1000 HRS.	10,000 HRS.	100,000 HRS.	0.000001 %/HR.	0.00001 %/HR.	0.0001 %/HR.
1100	43						

ORIGINAL CREEP AND RUPTURE DATA

TEMP. °F	STRESS 1000 P.S.I.	DURATION HOURS (3)	INTERCEPT, % (4)	MINIMUM CREEP RATE, %/HR.	TRANSITION TIME, HRS. (5)	TOTAL EXT. (CREEP TEST), %	TOTAL ELONG. (RUPTURE TEST), %	HARDNESS AFTER TESTING
1000	69.0	20 R					24.0	
1100	52.5	3 R					26.0	
1100	40.0	405 R					19.0	

(28)

ASTM-ASME JOINT COMMITTEE ON EFFECT OF TEMPERATURE ON PROPERTIES OF METALS

TYPE OF MATERIAL: 13 Cr, W, Mo, V (422) — TYPE OF MELTING FURNACE — SIZE OF HEAT: Commercial

CHEMICAL COMPOSITION, PER CENT	C	Mn	P	S	Si	Cr	Ni	Mo	W	V
	0.23	0.81			0.16	13.19	0.65	1.03	0.84	0.25

DEOXIDATION

FORM-CAST OR WROUGHT: 3/4" Round

HEAT TREATMENT: A. C. From 1900 F, Tempered 24 Hr at 1200 F

MICROSTRUCTURE: Martensite

GRAIN SIZE — HARDNESS: 299-306

SOURCE OF DATA: Wright Air Development Center - University of Michigan

CREEP AND RUPTURE STRENGTHS

TEMP., °F	STRESS FOR RUPTURE IN TIMES INDICATED, 1000 P.S.I. (2)				STRESS FOR DESIGNATED CREEP RATE, 1000 P.S.I. (2)		
	100 HRS.	1000 HRS.	10,000 HRS.	100,000 HRS.	0.000001 %/HR.	0.00001 %/HR.	0.0001 %/HR.
1100	44.0	34.0					

(1) 0.2 PER CENT OFFSET UNLESS OTHERWISE INDICATED.
(2) EXTRAPOLATED VALUES INDICATED BY *

ORIGINAL CREEP AND RUPTURE DATA

TEMP. °F	STRESS 1000 P.S.I.	DURATION HOURS (3)	INTERCEPT, % (4)	MINIMUM CREEP RATE, %/HR.	TRANSITION TIME, HRS. (5)	TOTAL EXT. (CREEP TEST), %	TOTAL ELONG. (RUPTURE TEST), %	HARDNESS AFTER TESTING
1100	39.0	366 R	--	0.00628	--	--	20.9	--
1100	35.0	816 R	0.65	0.00224	300	--	19.6	--
1100	30.0	1120	0.40	0.00088	840	1.51	--	--

(29)

ASTM-ASME JOINT COMMITTEE ON EFFECT OF TEMPERATURE ON PROPERTIES OF METALS

TYPE OF MATERIAL: 13 Cr, W, Mo, V (422) — TYPE OF MELTING FURNACE — SIZE OF HEAT: Commercial

CHEMICAL COMPOSITION, PER CENT	C	Mn	P	S	Si	Cr	Ni	Mo	V	W
	0.23	0.81			0.16	13.19	0.65	1.03	0.25	0.84

DEOXIDATION

FORM-CAST OR WROUGHT: 3/4" Round

HEAT TREATMENT: OQ From 1900 F, Tempered 4 Hr at 1200 F

MICROSTRUCTURE: Martensite

GRAIN SIZE — HARDNESS: 307

SOURCE OF DATA: Wright Air Development Center - University of Michigan

SHORT TIME TENSILE PROPERTIES

TEMPERATURE, °F	MODULUS OF ELASTICITY, 1,000,000 P.S.I.	OFFSET YIELD (1) STRENGTH, 1000 P.S.I.	TENSILE STRENGTH, 1000 P.S.I.	ELONGATION IN 2", PER CENT	REDUCTION IN AREA, PER CENT

CREEP AND RUPTURE STRENGTHS

TEMP., °F	STRESS FOR RUPTURE IN TIMES INDICATED, 1000 P.S.I. (2)				STRESS FOR DESIGNATED CREEP RATE, 1000 P.S.I. (2)		
	100 HRS.	1000 HRS.	10,000 HRS.	100,000 HRS.	0.000001 %/HR.	0.00001 %/HR.	0.0001 %/HR.
1100	43.0	36.0					

ORIGINAL CREEP AND RUPTURE DATA

TEMP. °F	STRESS 1000 P.S.I.	DURATION HOURS (3)	INTERCEPT, % (4)	MINIMUM CREEP RATE, %/HR.	TRANSITION TIME, HRS. (5)	TOTAL EXT. (CREEP TEST), %	TOTAL ELONG. (RUPTURE TEST), %	HARDNESS AFTER TESTING
1100	30.0	1003	0.50	0.00049	--	0.99	--	--

(3) DURATION OF TEST (RUPTURE TEST INDICATED BY R).
(4) THE INTERCEPT IS THE PROJECTION BACK TO ZERO TIME FROM THE PORTION OF THE TEST SHOWING THE MINIMUM OR SECOND-STAGE CREEP RATE.
(5) THE TRANSITION TIME IS THE BEGINNING OF THE THIRD STAGE, OR AN ACCELERATING CREEP RATE.

ASTM-ASME JOINT COMMITTEE ON EFFECT OF TEMPERATURE ON PROPERTIES OF METALS

TYPE OF MATERIAL	13 Cr, W, Mo, V	TYPE OF MELTING FURNACE			SIZE OF HEAT	Commercial

CHEMICAL COMPOSITION, PER CENT	C	Mn	P	S	Si	Cr	Ni	Mo	W	V
	0.23	0.81	0.011	0.022	0.16	13.19	0.65	1.03	0.84	0.25

DEOXIDATION	
FORM-CAST OR WROUGHT	Wrought Bar 3-1/2" Diameter
HEAT TREATMENT	1900 F, A.C.; 1100 F, 4 Hr, A.C.
MICROSTRUCTURE	
GRAIN SIZE	HARDNESS
SOURCE OF DATA	General Electric Company

SHORT TIME TENSILE PROPERTIES

TEMPERATURE, °F	MODULUS OF ELASTICITY, 1,000,000 P.S.I.	OFFSET(a) YIELD (1) STRENGTH, 1000 P.S.I.	TENSILE STRENGTH, 1000 P.S.I.	ELONGATION IN 2", PER CENT	REDUCTION IN AREA, PER CENT
80		117.8	164.0	18.5	46.6

(a) 0.02% Offset yield strength.

CREEP AND RUPTURE STRENGTHS

TEMP., °F	STRESS FOR RUPTURE IN TIMES INDICATED, 1000 P.S.I.(2)				STRESS FOR DESIGNATED CREEP RATE, 1000 P.S.I.(2)		
	100 HRS.	1000 HRS.	10,000 HRS.	100,000 HRS.	0.000001 %/HR.	0.00001 %/HR.	0.0001 %/HR.
1000		52P	40P	28P			
1100		29P	18P	9.6P			
1200	20P	11P					

P indicates strength value obtained by use of Larson-Miller parameter T(23 + log t).

(1) 0.2 PER CENT OFFSET UNLESS OTHERWISE INDICATED.
(2) EXTRAPOLATED VALUES INDICATED BY *

ORIGINAL CREEP AND RUPTURE DATA

TEMP. °F.	STRESS, 1000 P.S.I.	DURATION, HOURS(3)	INTERCEPT, %(4)	MINIMUM CREEP RATE, %/HR.	TRANSITION TIME, HRS.(5)	TOTAL EXT. (CREEP TEST), %	TOTAL ELONG. (RUPTURE TEST), %	REDUCTION IN AREA, %
1100	50.0	28 R					14.0	74.0
1100	35.0	595 R					10.0	62.0
1200	35.0	4 R					20.0	85.0
1200	25.0	43 R					16.0	85.0
1200	20.0	133 R					16.0	79.0
1200	15.0	257 R					19.0	85.0
1300	10.0	29 R					30.0	94.0

(3) DURATION OF TEST (RUPTURE TEST INDICATED BY R).
(4) THE INTERCEPT IS THE PROJECTION BACK TO ZERO TIME FROM THE PORTION OF THE TEST SHOWING THE MINIMUM OR SECOND-STAGE CREEP RATE.
(5) THE TRANSITION TIME IS THE BEGINNING OF THE THIRD STAGE, OR AN ACCELERATING CREEP RATE.

ASTM-ASME JOINT COMMITTEE ON EFFECT OF TEMPERATURE ON PROPERTIES OF METALS

TYPE OF MATERIAL	13 Cr, W, Mo, V (420)	TYPE OF MELTING FURNACE	--	SIZE OF HEAT	Commercial

CHEMICAL COMPOSITION, PER CENT	C	Mn	P	S	Si	Cr	Ni	Mo	W	V
	0.22	0.55			0.22	13.44	0.38	0.48	0.23	0.19

DEOXIDATION	
FORM-CAST OR WROUGHT	7/8" Wrought Bars
HEAT TREATMENT	1800 F, 1 Hr, OQ; 1200 F, 1 Hr, A.C.
MICROSTRUCTURE	--
GRAIN SIZE	HARDNESS 282 BHN
SOURCE OF DATA	U.S.N. Engineering Experiment Station

SHORT TIME TENSILE PROPERTIES

TEMPERATURE, °F	MODULUS OF ELASTICITY, 1,000,000 P.S.I.	OFFSET YIELD (1) STRENGTH, 1000 P.S.I.	TENSILE STRENGTH, 1000 P.S.I.	ELONGATION IN 2", PER CENT	REDUCTION IN AREA, PER CENT
RT		118.9	139.0	17	54
1000		72.0	82.0	22	65
1100		52.6	68.4	23	72

CREEP AND RUPTURE STRENGTHS

TEMP., °F	STRESS FOR RUPTURE IN TIMES INDICATED, 1000 P.S.I.(2)				STRESS FOR DESIGNATED CREEP RATE, 1000 P.S.I.(2)		
	100 HRS.	1000 HRS.	10,000 HRS.	100,000 HRS.	0.000001 %/HR.	0.00001 %/HR.	0.0001 %/HR.
1000	51	42				--	22.0
1100	27	18				3.8*	6.4

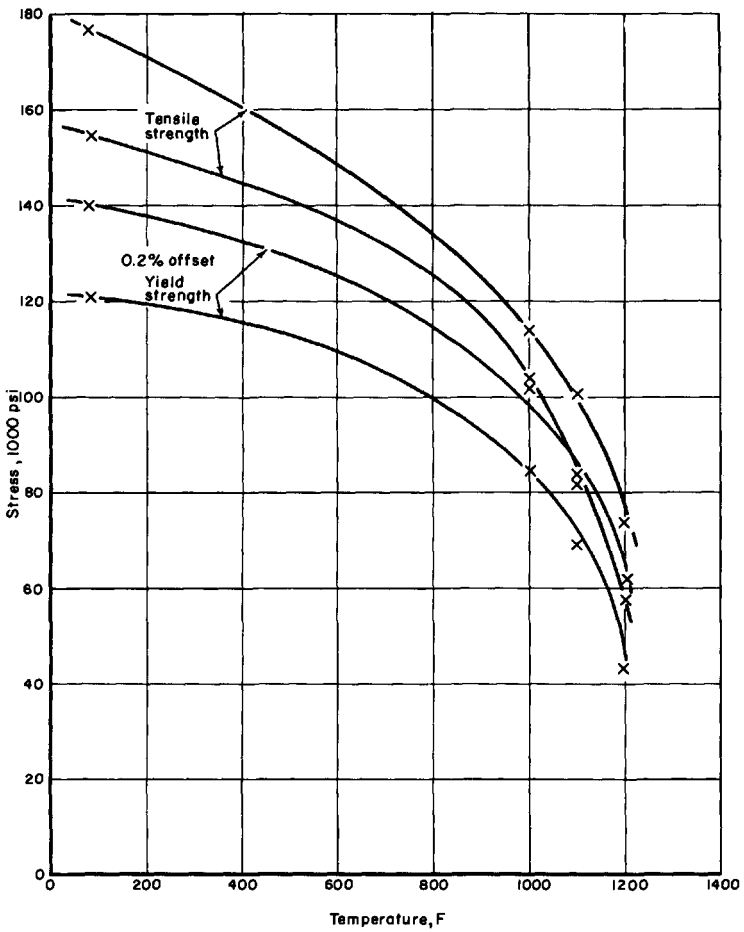
(1) 0.2 PER CENT OFFSET UNLESS OTHERWISE INDICATED.
(2) EXTRAPOLATED VALUES INDICATED BY *

ORIGINAL CREEP AND RUPTURE DATA

TEMP. °F.	STRESS, 1000 P.S.I.	DURATION, HOURS(3)	INTERCEPT, %(4)	MINIMUM CREEP RATE, %/HR.	TRANSITION TIME, HRS.(5)	TOTAL EXT. (CREEP TEST), %	TOTAL ELONG. (RUPTURE TEST), %	HARDNESS AFTER TESTING
1000	55.0	45 R					25.0	
1000	40.0	1904 R	0.60	0.00248	1050		29.0	
1100	35.0	21 R					38.0	
1100	25.0	346 R					48.0	
1100	22.0	243 R					34.0	
1100	22.0	385 R					44.0	
1100	20.0	409 R	0.25	0.0094	100		45.0	
1000	20.0	1896	0.297	0.000058	--	0.408		
1100	10.0	1270	0.174	0.00074	800	1.42		
1100	6.0	2064	0.205	0.000072	--	0.355		

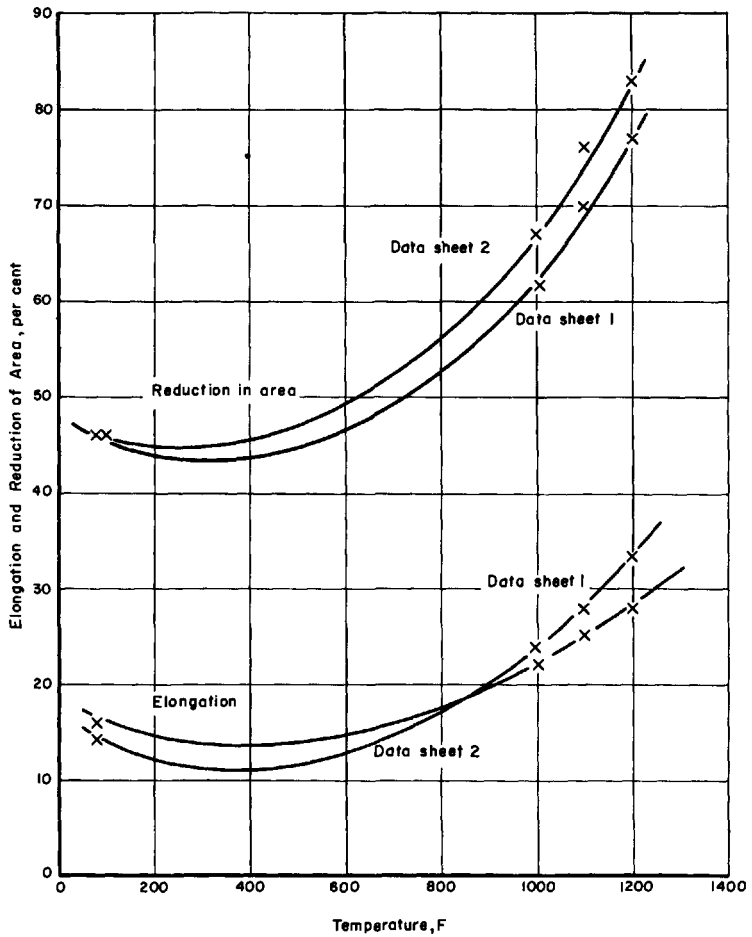
(3) DURATION OF TEST (RUPTURE TEST INDICATED BY R).
(4) THE INTERCEPT IS THE PROJECTION BACK TO ZERO TIME FROM THE PORTION OF THE TEST SHOWING THE MINIMUM OR SECOND-STAGE CREEP RATE.
(5) THE TRANSITION TIME IS THE BEGINNING OF THE THIRD STAGE, OR AN ACCELERATING CREEP RATE.

12 Chromium, 2 Tungsten, 2 Molybdenum, Vanadium Steels (422M)



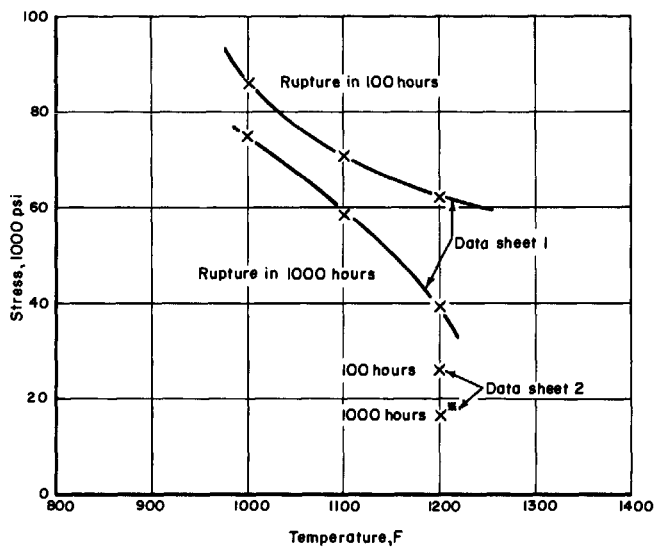
TENSILE AND YIELD STRENGTHS

12Cr, 2W, 2Mo, V STEEL



ELONGATION AND REDUCTION IN AREA

12 Cr, 2W, 2Mo, V STEEL



RUPTURE STRENGTHS

12Cr, 2W, 2Mo, V STEEL

(1)

ASTM-ASME JOINT COMMITTEE ON EFFECT OF TEMPERATURE ON PROPERTIES OF METALS

TYPE OF MATERIAL	12 Cr, 2 W, 2 Mo, V (Modified 422)	TYPE OF MELTING FURNACE	Induction	SIZE OF HEAT	1 Ton

CHEMICAL COMPOSITION, PER CENT	C	Mn	P	S	Si	Cr	Ni	Mo	W	V	N
	0.27	0.84			0.24	11.81	0.19	2.23	1.72	0.49	0.06

DEOXIDATION

FORM-CAST OR WROUGHT Wrought 5/8" Round

HEAT TREATMENT 2000 F, OQ + 1200 F, 2 Hr Heat No. 7747A3

MICROSTRUCTURE Tempered Martensite and 10% Ferrite

GRAIN SIZE HARDNESS 38 R_C

SOURCE OF DATA Crucible Steel Company

SHORT TIME TENSILE PROPERTIES

TEMPERATURE, °F	MODULUS OF ELASTICITY, 1,000,000 P.S.I.	OFFSET YIELD (1) STRENGTH, 1000 P.S.I.	TENSILE STRENGTH, 1000 P.S.I.	ELONGATION IN 2" PER CENT	REDUCTION IN AREA, PER CENT
80		140.0	177.0	16	46
1000		102.0	119.0	22	62
1100		84.0	101.0	25	70
1200		62.0	74.0	28	77

CREEP AND RUPTURE STRENGTHS

TEMP., °F	STRESS FOR RUPTURE IN TIMES INDICATED, 1000 P.S.I. (2)				STRESS FOR DESIGNATED CREEP RATE, 1000 P.S.I. (2)		
	100 HRS.	1000 HRS.	10,000 HRS.	100,000 HRS.	0.000001 %/HR.	0.00001 %/HR.	0.0001 %/HR.
1000	86	75					50*
1100	71	58					
1200	62	39					20.5*

(1) 0.2 PER CENT OFFSET UNLESS OTHERWISE INDICATED.

(2) EXTRAPOLATED VALUES INDICATED BY *

ORIGINAL CREEP AND RUPTURE DATA

TEMP. °F.	STRESS, 1000 P.S.I.	DURATION, HOURS (3)	INTERCEPT, %(4)	MINIMUM CREEP RATE, %/HR.	TRANSITION TIME, HRS. (5)	TOTAL EXT. (CREEP TEST), %	TOTAL ELONG. (RUPTURE TEST), %	HARDNESS AFTER TESTING
1000	90.0	12 R					18.0	
1000	85.0	177 R					18.0	
1000	80.0	338 R					14.0	
1000	75.0	1332 R					19.0	
1000	70.0	2326 R	1.00	0.0013	1375		11.0(a)	
1000	60.0	Discontinued 4848	0.77	0.00035	1360		2.64(a)	
1050	80.0	15 R					24.0	
1050	75.0	34 R					23.0	
1050	70.0	164 R					22.0	
1050	65.0	641 R					17.0	
1050	55.0	1652 R	0.82	0.0014	725		11.0(a)	
1100	70.0	16 R					20.0	
1100	65.0	53 R					23.0	
1100	60.0	157 R					19.0	
1100	60.0	160 R					21.0	
1100	55.0	278 R					22.0	
1100	50.0	378 R	0.66	0.00517	175		9.5(a)	
1100	40.0	974 R	0.35	0.00160	425		7.5(a)	
1100	40.0	1341 R	0.38	0.00152	350		11.0(a)	
1100	30.0	2734 R	0.34	0.00038	840		6.0(a)	Fractured in Shoulder

(a) Creep specimens - 2.4" gage length. (Others 1.4".)

(3) DURATION OF TEST (RUPTURE TEST INDICATED BY R).

(4) THE INTERCEPT IS THE PROJECTION BACK TO ZERO TIME FROM THE PORTION OF THE TEST SHOWING THE MINIMUM OR SECOND-STAGE CREEP RATE.

(5) THE TRANSITION TIME IS THE BEGINNING OF THE THIRD STAGE, OR AN ACCELERATING CREEP RATE.

(2)

ASTM-ASME JOINT COMMITTEE ON EFFECT OF TEMPERATURE ON PROPERTIES OF METALS

TYPE OF MATERIAL	12 Cr, 2 W, 2 Mo, V (Modified 422)	TYPE OF MELTING FURNACE	Induction	SIZE OF HEAT	1 Ton

CHEMICAL COMPOSITION, PER CENT	C	Mn	P	S	Si	Cr	Ni	Mo	W	V	N_2
	0.27	0.84			0.24	11.81	0.19	2.23	1.72	0.49	0.06

DEOXIDATION

FORM-CAST OR WROUGHT Wrought 5/8" Round

HEAT TREATMENT 2000 F, OQ; 1300 F, 2 Hr Heat No. 7747A3

MICROSTRUCTURE Tempered Martensite and 10% Ferrite

GRAIN SIZE HARDNESS 33 R_C

SOURCE OF DATA Crucible Steel Company

SHORT TIME TENSILE PROPERTIES

TEMPERATURE, °F	MODULUS OF ELASTICITY, 1,000,000 P.S.I.	OFFSET YIELD (1) STRENGTH, 1000 P.S.I.	TENSILE STRENGTH, 1000 P.S.I.	ELONGATION IN 2" PER CENT	REDUCTION IN AREA, PER CENT
80		121	155	14.5	46
1000		85	104	23.5	67
1100		69	83	28	76
1200		43	58	33.5	83

CREEP AND RUPTURE STRENGTHS

TEMP., °F	STRESS FOR RUPTURE IN TIMES INDICATED, 1000 P.S.I. (2)				STRESS FOR DESIGNATED CREEP RATE, 1000 P.S.I. (2)		
	100 HRS.	1000 HRS.	10,000 HRS.	100,000 HRS.	0.000001 %/HR.	0.00001 %/HR.	0.0001 %/HR.
1200	26	17*					

(1) 0.2 PER CENT OFFSET UNLESS OTHERWISE INDICATED.

(2) EXTRAPOLATED VALUES INDICATED BY *

ORIGINAL CREEP AND RUPTURE DATA

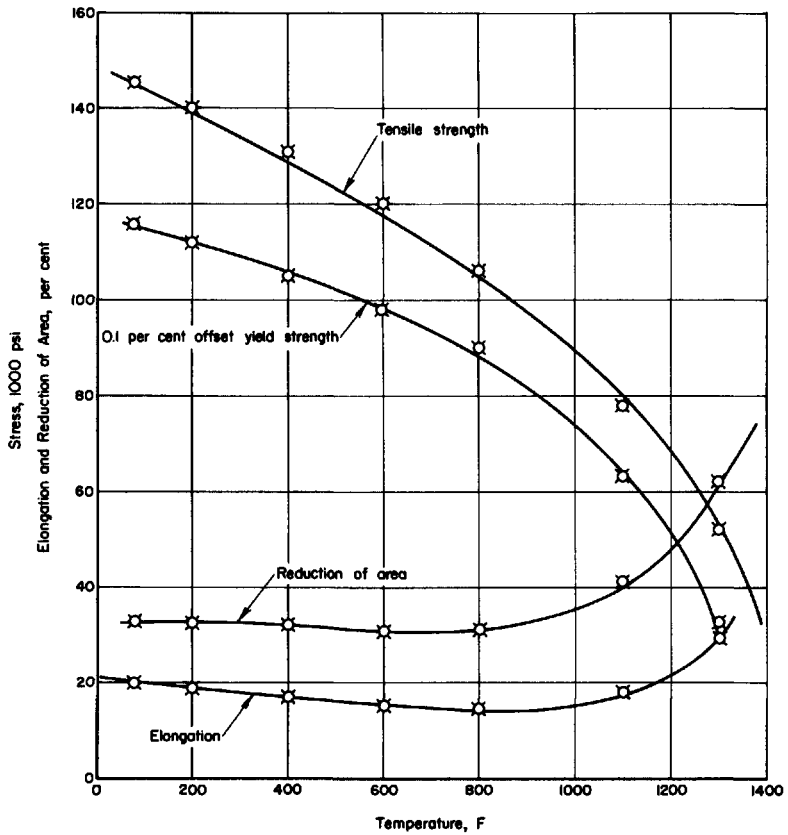
TEMP. °F.	STRESS, 1000 P.S.I.	DURATION, HOURS (3)	INTERCEPT, %(4)	MINIMUM CREEP RATE, %/HR.	TRANSITION TIME, HRS. (5)	TOTAL EXT. (CREEP TEST), %	TOTAL ELONG. (RUPTURE TEST), %	HARDNESS AFTER TESTING
1200	40.0	2.3R					34.5	
1200	30.0	49 R					34.0	
1200	25.0	132 R					33.5	
1200	20.0	456 R					45.5	

(3) DURATION OF TEST (RUPTURE TEST INDICATED BY R).

(4) THE INTERCEPT IS THE PROJECTION BACK TO ZERO TIME FROM THE PORTION OF THE TEST SHOWING THE MINIMUM OR SECOND-STAGE CREEP RATE.

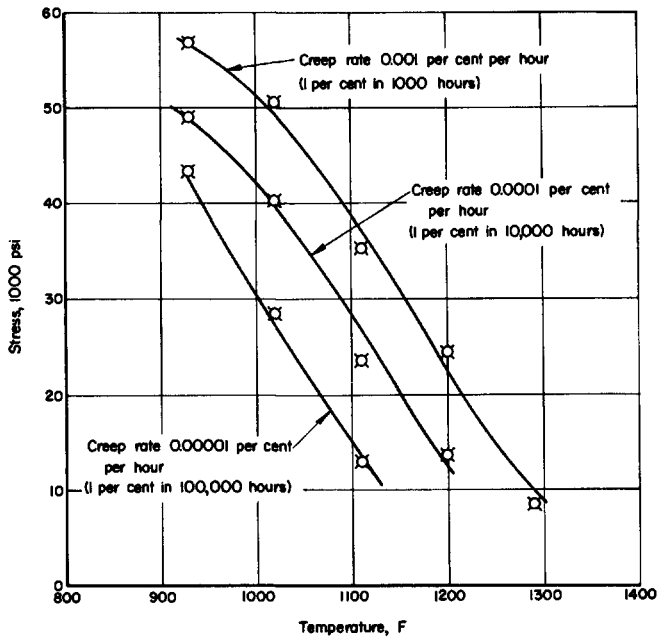
(5) THE TRANSITION TIME IS THE BEGINNING OF THE THIRD STAGE, OR AN ACCELERATING CREEP RATE.

12 Chromium, Molybdenum, Columbium, Vanadium Steels (H-46)



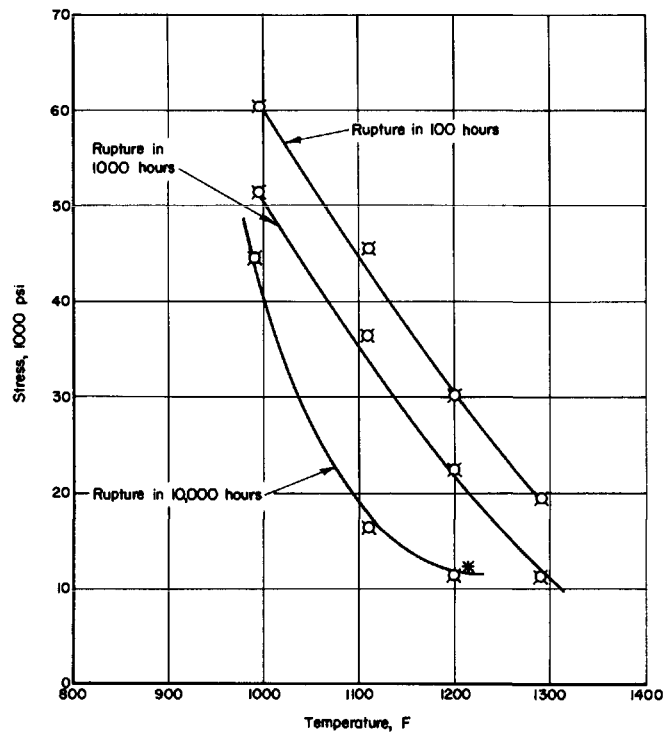
SHORT-TIME TENSILE DATA

12Cr, Mo, Cb, V STEEL



CREEP STRENGTHS

12Cr, Mo, Cb, V STEEL



RUPTURE STRENGTHS

12 Cr, Mo, Cb, V STEEL

(1)

ASTM-ASME JOINT COMMITTEE ON EFFECT OF TEMPERATURE ON PROPERTIES OF METALS

TYPE OF MATERIAL 12 Cr, Mo, Cb, V (H-46)		TYPE OF MELTING FURNACE					SIZE OF HEAT				
CHEMICAL COMPOSITION, PER CENT	C	Mn	P	S	Si	Cr	Ni	Mo	Cb	V	
Nominal	0.15	0.57			0.4	11.5		0.45	0.25	0.30	
DEOXIDATION											
FORM-CAST OR WROUGHT Wrought Bars and Discs											
HEAT TREATMENT 2100 F, A.C., Tempered 1200 F											
MICROSTRUCTURE											
GRAIN SIZE							HARDNESS				
SOURCE OF DATA William Jessop and Sons, Ltd., Data Sheet—Heppenstall Company											

SHORT TIME TENSILE PROPERTIES

TEMPERATURE, °F	MODULUS OF ELASTICITY, 1,000,000 P.S.I.	OFFSET(a) YIELD (1) STRENGTH, 1000 P.S.I.	TENSILE STRENGTH, 1000 P.S.I.	ELONGATION IN 2", PER CENT	REDUCTION IN AREA, PER CENT
80	31.6	116.5	145.5	20.0	33.0
200	31.0	112.2	140.5	19.0	33.0
400	30.0	105.6	131.0	17.6	32.0
600	28.9	98.3	120.5	15.7	31.0
800	27.8	90.0	106.8	15.0	31.2
1100	24.0	63.6	78.3	18.7	40.9
1300	20.9	33.0	52.1	29.6	62.4
1470			16.5	50.0	85.0

(a) 0.1% Offset yield strength.

CREEP AND RUPTURE STRENGTHS(b)

TEMP., °F	STRESS FOR RUPTURE IN TIMES INDICATED, 1000 P.S.I.(2)				STRESS FOR DESIGNATED CREEP RATE, 1000 P.S.I.(2)		
	100 HRS.	1000 HRS.	10,000 HRS.	100,000 HRS.	0.00001 %/HR.	0.0001 %/HR.	0.001 %/HR.
930					43.7	49.2	57.1
1020	60.5	51.5	44.8		28.7	40.4	50.5
1110	45.5	36.5	16.5		13.0	23.6	35.2
1200	30.7	22.4	11.5*			13.9	24.6
1290	19.3	11.4					8.7

(b) These are average data from bars and gas turbine discs.

(1) 0.2 PER CENT OFFSET UNLESS OTHERWISE INDICATED.

(2) EXTRAPOLATED VALUES INDICATED BY *

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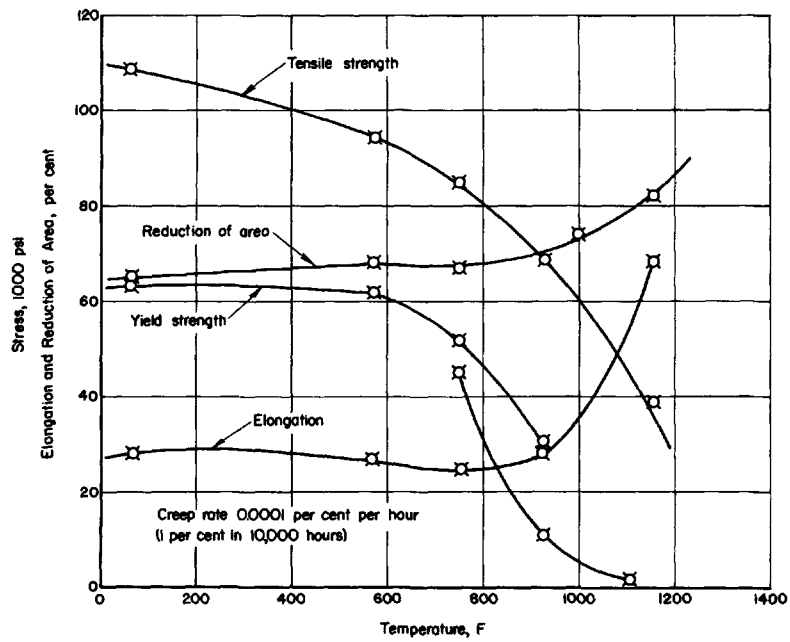
14 Chromium Steels



SHORT-TIME TENSILE AND CREEP DATA

14 Cr STEEL

(1)

ASTM-ASME JOINT COMMITTEE ON EFFECT OF TEMPERATURE ON PROPERTIES OF METALS

TYPE OF MATERIAL 14 Cr	TYPE OF MELTING FURNACE						SIZE OF HEAT				
CHEMICAL COMPOSITION, PER CENT	C	Mn	P	S	Si	Cr	Ni	Mo			
	0.29	0.27	0.013	0.019	0.79	13.71	0.23				
DEOXIDATION											
FORM-CAST OR WROUGHT Wrought Bars 5/8" Diameter											
HEAT TREATMENT Hardened and Tempered											
MICROSTRUCTURE											
GRAIN SIZE							HARDNESS 225 BHN				
SOURCE OF DATA Compilation of Available High Temperature Creep Characteristics of Metals & Alloys, ASME-ASTM, 1938											

SHORT TIME TENSILE PROPERTIES

TEMPERATURE, °F	MODULUS OF ELASTICITY, 1,000,000 P.S.I.	OFFSET YIELD (1) STRENGTH, 1000 P.S.I.	TENSILE STRENGTH, 1000 P.S.I.	ELONGATION IN 2", PER CENT	REDUCTION IN AREA, PER CENT
65		64.1	109.0	28	65.5
572		61.9	94.5	27	68
752		52.0	84.9	25	67
932		25.7	68.8	28	74
1160		--	39.0	68	82

CREEP AND RUPTURE STRENGTHS

TEMP., °F	STRESS FOR RUPTURE IN TIMES INDICATED, 1000 P.S.I.(2)				STRESS FOR DESIGNATED CREEP RATE, 1000 P.S.I.(2)		
	100 HRS.	1000 HRS.	10,000 HRS.	100,000 HRS.	0.000001 %/HR.	0.00001 %/HR.	0.0001 %/HR.
752							45.0
932							11.2
1112							1.85

(1) 0.2 PER CENT OFFSET UNLESS OTHERWISE INDICATED.
(2) EXTRAPOLATED VALUES INDICATED BY *

ORIGINAL CREEP AND RUPTURE DATA

TEMP. °F.	STRESS 1000 P.S.I.	DURATION, HOURS(3)	INTERCEPT, %(4)	MINIMUM CREEP RATE, %/HR.	TRANSITION TIME, HRS.(5)	TOTAL EXT. (CREEP TEST), %	TOTAL ELONG. (RUPTURE TEST), %	HARDNESS AFTER TESTING
752	67.2	180 R		0.0460			23.5	
752	53.75	500	0.70	0.0014		1.40		
752	47.0	500	0.40	0.00019		0.50		
752	42.6	500	0.14	0.00005		0.17		
752	42.6	1000	0.16	0.000022		0.182		
932	26.88	852 R		0.0082			35.0	
932	17.92	500	0.53	0.00034		0.70		
932	15.68	500	0.40	0.00020		0.50		
932	11.2	500	0.14	0.00011		0.20		
932	10.07	500	0.08	0.00008		0.125		
1112	6.72	1080 R		0.0090			51.0	
1112	4.48	500	0.22	0.00266		1.55		
1112	2.24	500	0.12	0.00020		0.225		

(3) DURATION OF TEST (RUPTURE TEST INDICATED BY R).
(4) THE INTERCEPT IS THE PROJECTION BACK TO ZERO TIME FROM THE PORTION OF THE TEST SHOWING THE MINIMUM OR SECOND-STAGE CREEP RATE.
(5) THE TRANSITION TIME IS THE BEGINNING OF THE THIRD STAGE, OR AN ACCELERATING CREEP RATE.

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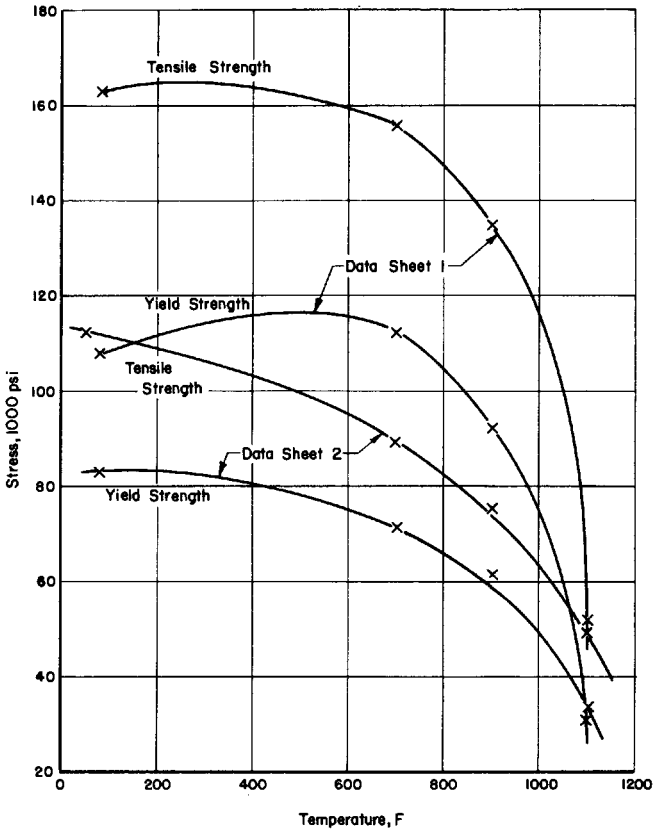
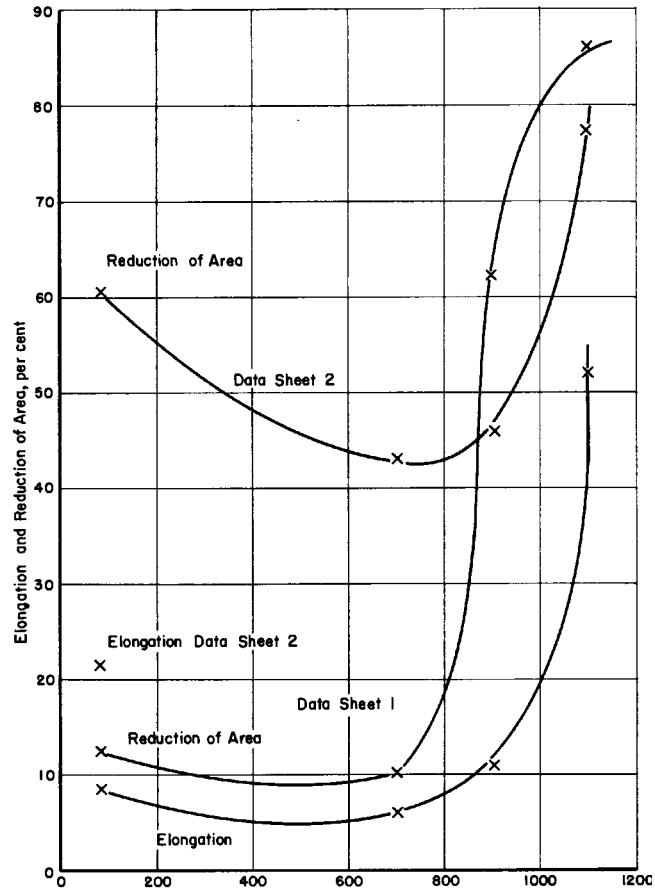
16 Chromium, 2 Nickel Steels



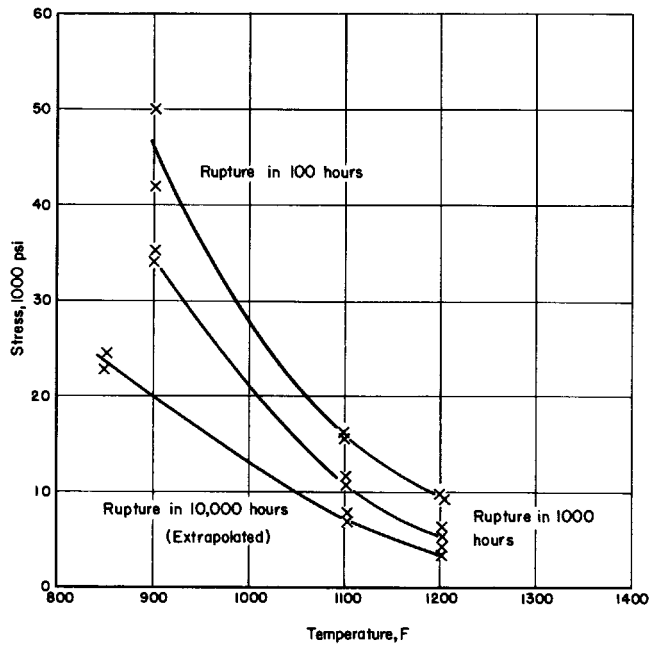
SHORT-TIME TENSILE DATA

16 Cr, 2 Ni Steel



ELONGATION AND REDUCTION OF AREA

16 Cr, 2 Ni Steel



RUPTURE STRENGTHS

16 Cr, 2 Ni Steel

(1)

ASTM-ASME JOINT COMMITTEE ON EFFECT OF TEMPERATURE ON PROPERTIES OF METALS

TYPE OF MATERIAL	16 Cr, 2 Ni (Type 431)			TYPE OF MELTING FURNACE	Induction			SIZE OF HEAT	30 lb			
CHEMICAL COMPOSITION, PER CENT	C	Mn	P	S	Si	Cr	Ni	Mo	N_2			
	0.16	0.58	0.021	0.022	0.53	16.13	1.82		0.063			
DEOXIDATION												
FORM-CAST OR WROUGHT	Wrought 5/8- and 1-1/2"-Square Forged Bars											
HEAT TREATMENT	1800 F, 1/2 Hr, OQ; 1225 F, 4 Hr, OQ											
MICROSTRUCTURE	Tempered and Untempered Martensite											
GRAIN SIZE	Austenitic Grain Size, ASTM No. 8						HARDNESS	36.7 R_C				
SOURCE OF DATA	U. S. Steel Corp., Research and Development Laboratory											

SHORT TIME TENSILE PROPERTIES

TEMPERATURE, °F	MODULUS OF ELASTICITY, 1,000,000 P.S.I.	OFFSET YIELD (1) STRENGTH, 1000 P.S.I.	TENSILE STRENGTH, 1000 P.S.I.	ELONGATION IN 2", PER CENT	REDUCTION IN AREA, PER CENT
RT[a]		107.8	163.1	8.0	12.7
700[b]		112.2	156.4	6.0	10.0
900[b]		92.2	135.0	11.0	62.0
1100[b]		31.0	51.4	52.5	86.0

(a) 0.254" Diameter specimens, 1" gage length.
(b) 0.254" Diameter specimens, 2" gage length.

CREEP AND RUPTURE STRENGTHS

TEMP., °F	STRESS FOR RUPTURE IN TIMES INDICATED, 1000 P.S.I.(2)				STRESS FOR DESIGNATED CREEP RATE, 1000 P.S.I.(2)		
	100 HRS.	1000 HRS.	10,000 HRS.	100,000 HRS.	0.000001 %/HR.	0.00001 %/HR.	0.0001 %/HR.
900	50.2	34.5	24.0*				
1100	16.5	10.8	7.1*				
1200	9.6	6.0	3.7*				

(1) 0.2 PER CENT OFFSET UNLESS OTHERWISE INDICATED.
(2) EXTRAPOLATED VALUES INDICATED BY *

ORIGINAL CREEP AND RUPTURE DATA

TEMP. °F	STRESS, 1000 P.S.I.	DURATION, HOURS(3)	INTERCEPT, %(4)	MINIMUM CREEP RATE, %/HR.	TRANSITION TIME, HRS.(5)	TOTAL EXT. (CREEP TEST), %	TOTAL ELONG. (RUPTURE TEST), %	HARDNESS AFTER TESTING
900	90.0	1.0		4.54	0.5		15.8	R_C 30.5
900	79.4	4.6		1.20	2.2		21.6	R_C 27.9
900	70.0	13.8		0.546	6.0		24.4	R_C 23.9
900	59.4	20.0		0.358	7.1		34.4	R_C 22.2
900	49.4	108.0		0.112	51.0		44.6	R_C 20.8
900	44.4	211.7		0.0541	99.0		44.2	R_C 20.1
900	34.4	1559.0		0.0128	--		53.0	Rb 98.7
1100	30.0	3.1		4.38	1.1		53.8	Rb 99.8
1100	25.0	9.5		1.422	3.6		53.8	Rb 98.8
1100	17.5	76.5		0.205	37.0		57.6	Rb 97.6
1100	15.0	140.7		0.1105	50.0		78.4	Rb 96.4
1100	10.7	1087.0		0.0200	--		84.0	Rb 90.6
1200	25.0	0.55		23.6	0.25		50.4	Rb 98.2
1200	20.0	2.1		7.29	--		62.0	Rb 98.8
1200	15.0	12.6		1.26	4.0		78.2	Rb 95.6
1200	10.0	88.25		0.17	24.6		82.2	Rb 94.5
1200	7.5	298.0		0.0521	63.0		79.2	Rb 92.5
1200	6.8	550.0		0.0280	98.2		66.0	Rb 90.8

(3) DURATION OF TEST (RUPTURE TEST INDICATED BY R).
(4) THE INTERCEPT IS THE PROJECTION BACK TO ZERO TIME FROM THE PORTION OF THE TEST SHOWING THE MINIMUM OR SECOND-STAGE CREEP RATE.
(5) THE TRANSITION TIME IS THE BEGINNING OF THE THIRD STAGE, OR AN ACCELERATING CREEP RATE.

(2)

ASTM-ASME JOINT COMMITTEE ON EFFECT OF TEMPERATURE ON PROPERTIES OF METALS

TYPE OF MATERIAL	16 Cr, 2 Ni (Type 431)			TYPE OF MELTING FURNACE	Electric			SIZE OF HEAT	Commercial			
CHEMICAL COMPOSITION, PER CENT	C	Mn	P	S	Si	Cr	Ni	Mo	N_2			
	0.11	0.37	0.007	0.018	0.17	15.60	1.87		0.010			
DEOXIDATION												
FORM-CAST OR WROUGHT	Wrought 3/4"-Diameter Forged Bars											
HEAT TREATMENT	1800 F, 1/2 Hr, OQ; 1225 F, 4 Hr, OQ											
MICROSTRUCTURE	Tempered Martensite											
GRAIN SIZE	Austenitic Grain Size, ASTM No. 6						HARDNESS	22.0 R_C				
SOURCE OF DATA	U. S. Steel Corp., Research and Development Laboratory											

SHORT TIME TENSILE PROPERTIES

TEMPERATURE, °F	MODULUS OF ELASTICITY, 1,000,000 P.S.I.	OFFSET YIELD (1) STRENGTH, 1000 P.S.I.	TENSILE STRENGTH, 1000 P.S.I.	ELONGATION IN 2", PER CENT	REDUCTION IN AREA, PER CENT
RT[a]		83.2	112.5	21.5	60.4
700[b]		71.5	89.8	--	43.5
900[b]		61.8	75.2	--	46.0
1100[b]		33.2	49.1	--	77.5

(a) 0.254" Diameter specimens, 1" gage length.
(b) 0.505" Diameter specimens, 2" gage length.

CREEP AND RUPTURE STRENGTHS

TEMP., °F	STRESS FOR RUPTURE IN TIMES INDICATED, 1000 P.S.I.(2)				STRESS FOR DESIGNATED CREEP RATE, 1000 P.S.I.(2)		
	100 HRS.	1000 HRS.	10,000 HRS.	100,000 HRS.	0.000001 %/HR.	0.00001 %/HR.	0.0001 %/HR.
900	42.0	34.0	23.0*				
1100	16.2	10.5	6.8*				
1200	9.1	5.7	3.5*				

(1) 0.2 PER CENT OFFSET UNLESS OTHERWISE INDICATED.
(2) EXTRAPOLATED VALUES INDICATED BY *

ORIGINAL CREEP AND RUPTURE DATA

TEMP. °F	STRESS, 1000 P.S.I.	DURATION, HOURS(3)	INTERCEPT, %(4)	MINIMUM CREEP RATE, %/HR.	TRANSITION TIME, HRS.(5)	TOTAL EXT. (CREEP TEST), %	TOTAL ELONG. (RUPTURE TEST), %	HARDNESS AFTER TESTING
900	60.0	1.16		4.80	0.5		29.6	Rb 97.2
900	50.0	11.3		0.595	4.8		31.4	Rb 95.7
900	40.0	176.7		0.0685	31.2		37.6	Rb 95.0
900	35.0	882.0		0.0189	603.0		38.2	Rb 96.3
900	30.0	2042.0		0.00807	1742.0		48.0	Rb 94.9
1100	30.0	1.35		4.3	0.55		53.0	Rb 95.4
1100	20.0	31.25		0.352	15.4		52.6	Rb 91.7
1100	15.0	150.75		0.0747	65.0		56.8	Rb 88.8
1100	10.0	1223.1		0.0162	--		62.0	Rb 84.1
1200	20.0	1.0		12.8	0.4		48.2	Rb 90.8
1200	15.0	6.7		1.79	2.6		63.8	Rb 88.8
1200	10.0	62.8		0.252	10.7		91.6	Rb 85.0
1200	6.85	425.0		0.032	131.0		69.6	Rb 84.9
1200	6.0	735.5		0.0202	154.0		85.0	Rb 82.8

(3) DURATION OF TEST (RUPTURE TEST INDICATED BY R).
(4) THE INTERCEPT IS THE PROJECTION BACK TO ZERO TIME FROM THE PORTION OF THE TEST SHOWING THE MINIMUM OR SECOND-STAGE CREEP RATE.
(5) THE TRANSITION TIME IS THE BEGINNING OF THE THIRD STAGE, OR AN ACCELERATING CREEP RATE.

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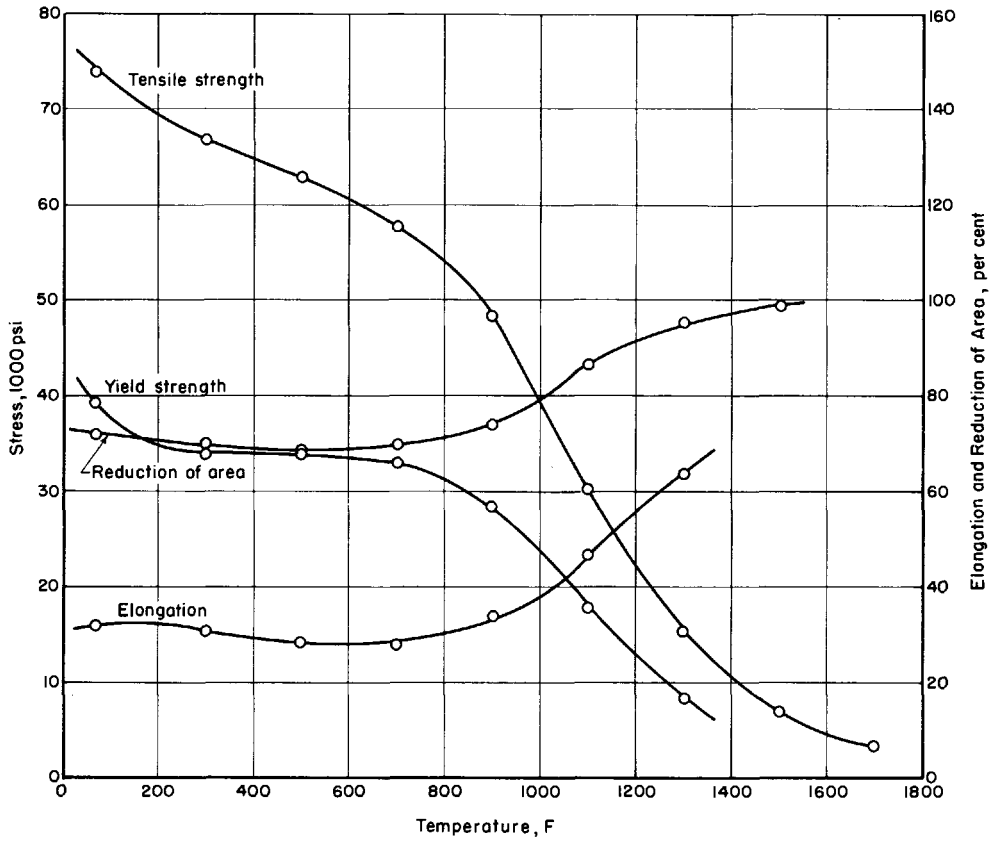
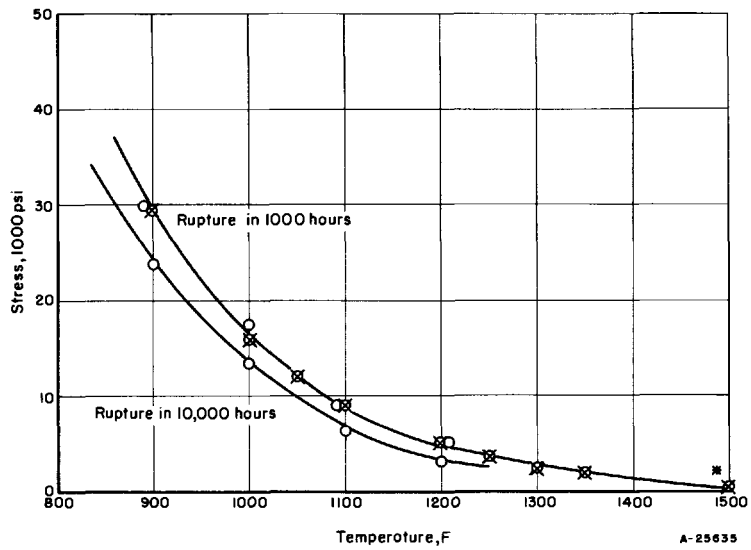
17 Chromium Steels



SHORT-TIME TENSILE DATA

17 Cr STEEL



RUPTURE STRENGTHS

17 Cr STEEL

(1)

ASTM-ASME JOINT COMMITTEE ON EFFECT OF TEMPERATURE ON PROPERTIES OF METALS

TYPE OF MATERIAL 17 Cr (Type 430)	TYPE OF MELTING FURNACE						SIZE OF HEAT				
CHEMICAL COMPOSITION, PER CENT	C	Mn	P	S	Si	Cr	Ni	Mo			
	0.12 Max	1.00 Max	0.03 Max	0.03 Max	0.75 Max	14.0-18.0	0.50 Max				
DEOXIDATION											
FORM-CAST OR WROUGHT											
HEAT TREATMENT Annealed 1400-1500 F											
MICROSTRUCTURE											
GRAIN SIZE					HARDNESS						
SOURCE OF DATA U.S. Steel Publication – "Steels For Elevated Temperature Service"											

SHORT TIME TENSILE PROPERTIES

TEMPERATURE, °F	MODULUS OF ELASTICITY, 1,000,000 P.S.I.	OFFSET YIELD (1) STRENGTH, 1000 P.S.I.	TENSILE STRENGTH, 1000 P.S.I.	ELONGATION IN 2", PER CENT	REDUCTION IN AREA, PER CENT
70		39.5	74.0	32	72
300		34.0	67.0	31	70
500		34.0	63.0	28	69
700		33.0	58.0	28	70
900		28.5	48.5	34	74
1100		18.0	30.5	47	87
1300		8.0	15.5	64	96
1500			7.0	83	99
1700			3.5		

CREEP AND RUPTURE STRENGTHS

TEMP., °F	STRESS FOR RUPTURE IN TIMES INDICATED, 1000 P.S.I.(2)				STRESS FOR DESIGNATED CREEP RATE, 1000 P.S.I.(2)		
	100 HRS.	1000 HRS.	10,000 HRS.	100,000 HRS.	0.000001 %/HR.	0.00001 %/HR.	0.0001 %/HR.
800							
900		30.0	24.0			12.0	15.4
1000		17.5	13.5			6.7	8.6
1100		9.1	6.5			3.4	4.3
1200		5.0	3.4			1.5	2.2
1300						0.9	1.4
1400						0.6	0.9
1500							
1600							

(1) 0.2 PER CENT OFFSET UNLESS OTHERWISE INDICATED.
(2) EXTRAPOLATED VALUES INDICATED BY *

ORIGINAL CREEP AND RUPTURE DATA

TEMP. °F.	STRESS, 1000 P.S.I.	DURATION, HOURS(3)	INTERCEPT, %(4)	MINIMUM CREEP RATE, %/HR.	TRANSITION TIME, HRS.(5)	TOTAL EXT. (CREEP TEST), %	TOTAL ELONG. (RUPTURE TEST), %	HARDNESS AFTER TESTING
900	45.0	2.8 R		4.56			41.0	
900	40.0	29.3 R		0.51			53.0	
900	35.0	92.3 R		0.15			58.0	
900	30.0	944.5 R		0.023			54.0	
1050	25.0	4.4 R		2.92			57.0	
1050	20.0	17.3 R		0.942			60.0	
1050	15.0	400. R		0.035			81.0	
1050	12.0	1283. R		0.011			66.0	
1200	15.0	1.2 R		11.1			65.0	
1200	10.0	23.2 R		0.62			87.0	
1200	6.0	418. R		0.03			90.0	
1200	4.0	2871. R		0.0038			103.0	
1350	8.0	0.66R		--			81.0	
1350	5.0	10.6 R		0.876			92.0	
1350	3.0	150. R		0.062			84.0	
1350	2.0	1620. R		--			88.0	

(3) DURATION OF TEST (RUPTURE TEST INDICATED BY R).
(4) THE INTERCEPT IS THE PROJECTION BACK TO ZERO TIME FROM THE PORTION OF THE TEST SHOWING THE MINIMUM OR SECOND-STAGE CREEP RATE.
(5) THE TRANSITION TIME IS THE BEGINNING OF THE THIRD STAGE, OR AN ACCELERATING CREEP RATE.

(2)

ASTM-ASME JOINT COMMITTEE ON EFFECT OF TEMPERATURE ON PROPERTIES OF METALS

TYPE OF MATERIAL 17 Cr (Type 430)	TYPE OF MELTING FURNACE						SIZE OF HEAT				
CHEMICAL COMPOSITION, PER CENT	C	Mn	P	S	Si	Cr	Ni	Mo	N_2	Al	
	0.09	0.41	0.010	0.014	0.237	16.87	0.15	0.02	0.078	0.004	
DEOXIDATION											
FORM-CAST OR WROUGHT Wrought											
HEAT TREATMENT 1425 F A. C.											
MICROSTRUCTURE Ferrite Matrix With Carbide Precipitate; Partially Spheroidized Pearlite Areas.											
GRAIN SIZE 5-6					HARDNESS 158 DPH						
SOURCE OF DATA U.S. Steel Corp. Research Laboratory											

SHORT TIME TENSILE PROPERTIES

TEMPERATURE, °F	MODULUS OF ELASTICITY, 1,000,000 P.S.I.	OFFSET YIELD (1) STRENGTH, 1000 P.S.I.	TENSILE STRENGTH, 1000 P.S.I.	ELONGATION IN 2", PER CENT	REDUCTION IN AREA, PER CENT

CREEP AND RUPTURE STRENGTHS

TEMP., °F	STRESS FOR RUPTURE IN TIMES INDICATED, 1000 P.S.I.(2)				STRESS FOR DESIGNATED CREEP RATE, 1000 P.S.I.(2)		
	100 HRS.	1000 HRS.	10,000 HRS.	100,000 HRS.	0.000001 %/HR.	0.00001 %/HR.	0.0001 %/HR.
900		29.5					
1000		16.0					
1050		12.0					
1100		9.0					
1200		5.0					
1250		3.8					
1300		2.8					
1350		2.1					
1500		0.88*					

(1) 0.2 PER CENT OFFSET UNLESS OTHERWISE INDICATED.
(2) EXTRAPOLATED VALUES INDICATED BY *

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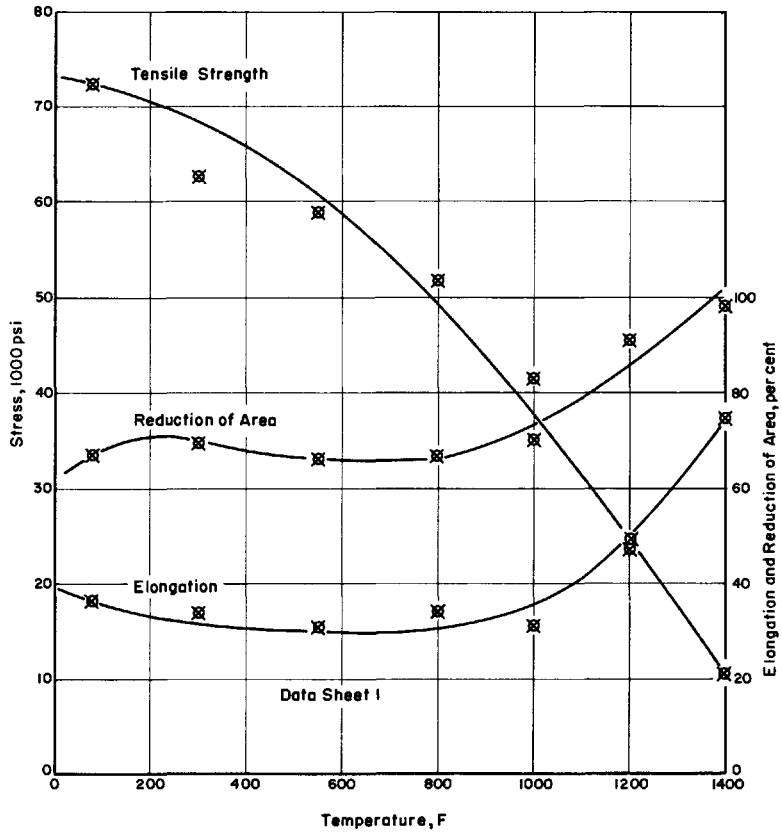
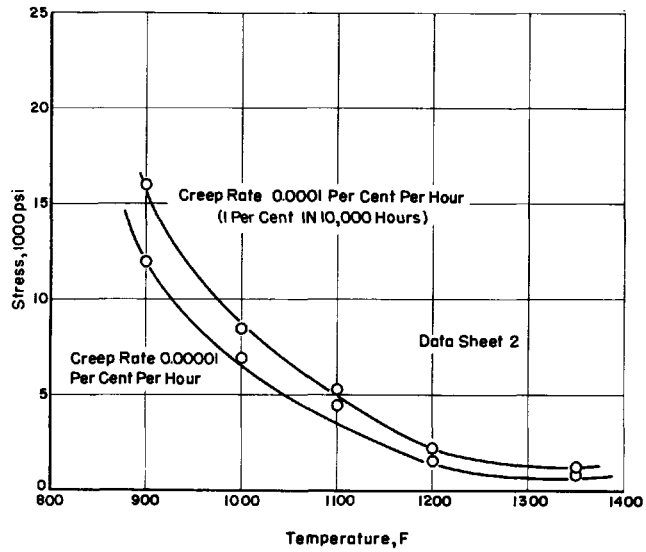
18 Chromium Steels



SHORT-TIME TENSILE DATA

18 Cr STEEL



CREEP STRENGTHS

18 Cr STEEL

(1)

ASTM-ASME JOINT COMMITTEE ON EFFECT OF TEMPERATURE ON PROPERTIES OF METALS

TYPE OF MATERIAL	18 Cr	TYPE OF MELTING FURNACE			SIZE OF HEAT						
CHEMICAL COMPOSITION, PER CENT	C	Mn	P	S	Si	Cr	Ni	Mo			
	0.10	0.44			0.23	18.08					
DEOXIDATION											
FORM-CAST OR WROUGHT	3/4" Bars - Wrought										
HEAT TREATMENT	Normalized 1800 F										
MICROSTRUCTURE											
GRAIN SIZE					HARDNESS	150 BHN					
SOURCE OF DATA	Compilation of Available High Temperature Creep Characteristics of Metals & Alloys, ASME-ASTM, 1938										

SHORT TIME TENSILE PROPERTIES

TEMPERATURE, °F	MODULUS OF ELASTICITY, 1,000,000 P.S.I.	OFFSET YIELD (1) STRENGTH, 1000 P.S.I.	TENSILE STRENGTH, 1000 P.S.I.	ELONGATION IN 2", PER CENT	REDUCTION IN AREA, PER CENT
70			72.4	36.5	67.1
300			62.8	34.0	69.8
550			59.0	31.0	66.9
800			52.0	34.5	68.5
1000			41.7	31.5	70.5
1200			23.9	49.5	91.1
1400			10.7	75.5	98.8

CREEP AND RUPTURE STRENGTHS

TEMP., °F	STRESS FOR RUPTURE IN TIMES INDICATED, 1000 P.S.I. (2)				STRESS FOR DESIGNATED CREEP RATE, 1000 P.S.I. (2)		
	100 HRS.	1000 HRS.	10,000 HRS.	100,000 HRS.	0.000001 %/HR.	0.00001 %/HR.	0.0001 %/HR.

(1) 0.2 PER CENT OFFSET UNLESS OTHERWISE INDICATED.
(2) EXTRAPOLATED VALUES INDICATED BY *

(2)

ASTM-ASME JOINT COMMITTEE ON EFFECT OF TEMPERATURE ON PROPERTIES OF METALS

TYPE OF MATERIAL	18 Cr	TYPE OF MELTING FURNACE			SIZE OF HEAT						
CHEMICAL COMPOSITION, PER CENT	C	Mn	P	S	Si	Cr	Ni	Mo			
	0.10	0.31			0.86	17.30					
DEOXIDATION											
FORM-CAST OR WROUGHT	Wrought										
HEAT TREATMENT	Annealed										
MICROSTRUCTURE											
GRAIN SIZE					HARDNESS						
SOURCE OF DATA	"Properties of Carbon and Alloy Seamless Steel Tubing for High Temperature and High Pressure Service", Babcock & Wilcox Tube Company.										

SHORT TIME TENSILE PROPERTIES

TEMPERATURE, °F	MODULUS OF ELASTICITY, 1,000,000 P.S.I.	OFFSET YIELD (1) STRENGTH, 1000 P.S.I.	TENSILE STRENGTH, 1000 P.S.I.	ELONGATION IN 2", PER CENT	REDUCTION IN AREA, PER CENT

CREEP AND RUPTURE STRENGTHS

TEMP., °F	STRESS FOR RUPTURE IN TIMES INDICATED, 1000 P.S.I. (2)				STRESS FOR DESIGNATED CREEP RATE, 1000 P.S.I. (2)		
	100 HRS.	1000 HRS.	10,000 HRS.	100,000 HRS.	0.000001 %/HR.	0.00001 %/HR.	0.0001 %/HR.
900						12.0	16.0
1000						7.0	8.5
1100						4.5	5.2
1200						1.6	2.1
1350						0.9	1.2

(1) 0.2 PER CENT OFFSET UNLESS OTHERWISE INDICATED.
(2) EXTRAPOLATED VALUES INDICATED BY *

ORIGINAL CREEP AND RUPTURE DATA

TEMP. °F	STRESS 1000 P.S.I.	DURATION, HOURS (3)	INTERCEPT, %(4)	MINIMUM CREEP RATE, %/HR.	TRANSITION TIME, HRS. (5)	TOTAL EXT. (CREEP TEST), %	TOTAL ELONG. (RUPTURE TEST), %	HARDNESS AFTER TESTING
900*	10.0	250	0.032	0.000248		0.094		
950*	10.0	250	0.009	0.000136		0.042		
1000*	3.0	1000	0.028	0.000038		0.066		
1000*	10.0	500	0.013	0.000442		0.234		
1050*	10.0	250	0.210	0.00218		0.760		
1200	3.0	750	0.164	0.000195		0.310		
1300*	1.0	250	0.002	0.000032		0.009		
1400*	1.0	500	0.004	0.000150		0.079		
1500	1.0	500	0.033	0.000638		0.352		

(3) DURATION OF TEST (RUPTURE TEST INDICATED BY R).
(4) THE INTERCEPT IS THE PROJECTION BACK TO ZERO TIME FROM THE PORTION OF THE TEST SHOWING THE MINIMUM OR SECOND-STAGE CREEP RATE.
(5) THE TRANSITION TIME IS THE BEGINNING OF THE THIRD STAGE, OR AN ACCELERATING CREEP RATE.

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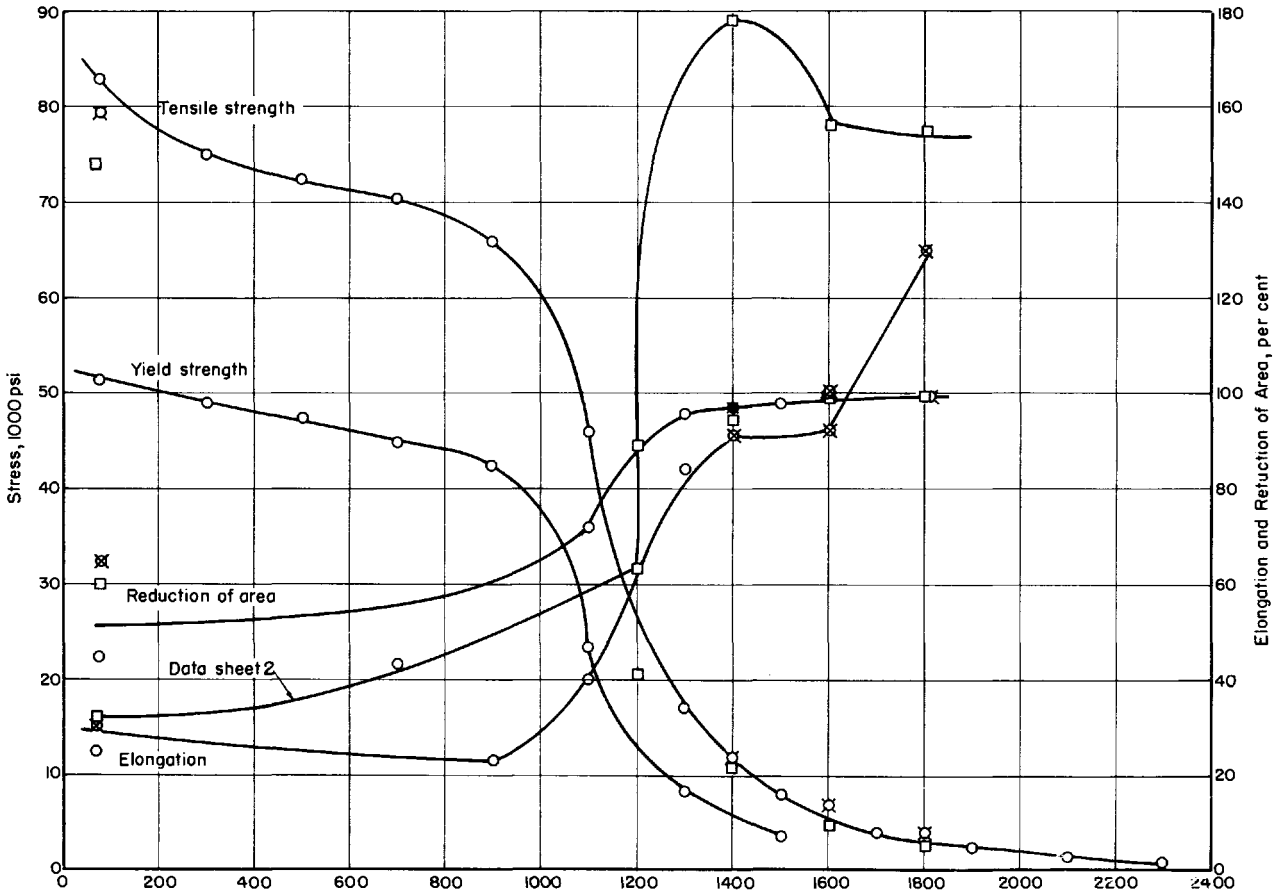
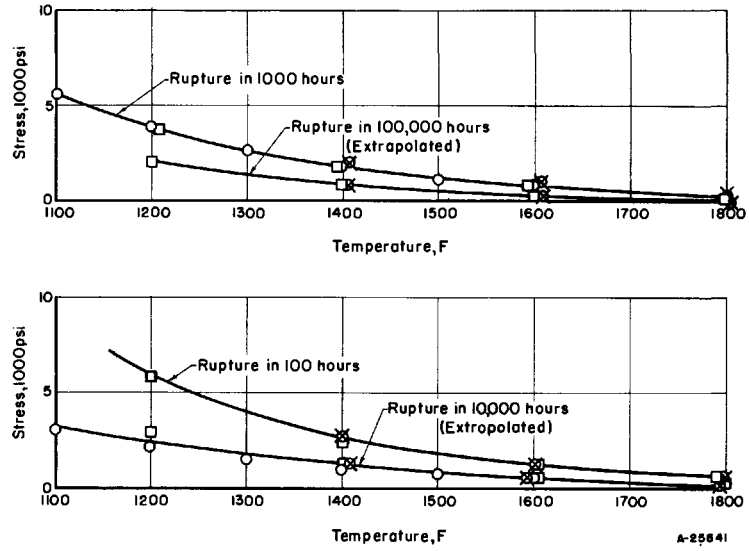
27 Chromium Steels



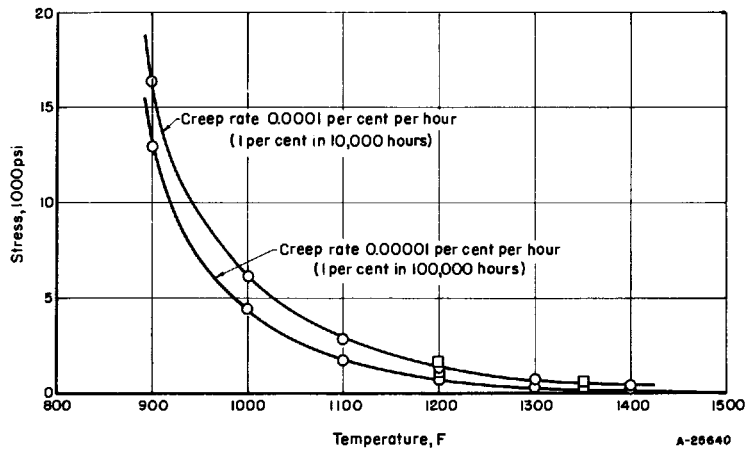
SHORT-TIME TENSILE DATA

27Cr STEEL



RUPTURE STRENGTHS

27Cr STEEL



CREEP STRENGTHS

27Cr STEEL

(1)

ASTM-ASME JOINT COMMITTEE ON EFFECT OF TEMPERATURE ON PROPERTIES OF METALS

TYPE OF MATERIAL 27 Cr			TYPE OF MELTING FURNACE					SIZE OF HEAT				
CHEMICAL COMPOSITION, PER CENT		C	Mn	P	S	Si	Cr	Ni	Mo	N_2		
	Nominal	0.20 Max	1.50 Max	0.03 Max	0.03 Max	0.75 Max	23.0-30.0	0.50 Max		0.10-0.25		
DEOXIDATION												
FORM-CAST OR WROUGHT												
HEAT TREATMENT	Annealed 1450-1600 F and Cool Rapidly											
MICROSTRUCTURE												
GRAIN SIZE							HARDNESS					
SOURCE OF DATA	U.S. Steel Publication – "Steel for Elevated Temperature Service"											

SHORT TIME TENSILE PROPERTIES

TEMPERATURE, °F	MODULUS OF ELASTICITY, 1,000,000 P.S.I.	OFFSET YIELD (1) STRENGTH, 1000 P.S.I.	TENSILE STRENGTH, 1000 P.S.I.	ELONGATION IN 2", PER CENT	REDUCTION IN AREA, PER CENT
70		51.5	83.0	25	45
300		49.0	75.0		
500		47.5	72.5		
700		45.0	70.5		
900		42.5	66.0	23	43
1100		23.5	46.0	40	72
1300		8.5	17.0	84	91
1500		3.5	8.0		98
1700			4.0		
1900			2.5		
2100			1.5		
2300			1.0		

CREEP AND RUPTURE STRENGTHS

TEMP., °F	STRESS FOR RUPTURE IN TIMES INDICATED, 1000 P.S.I. (2)				STRESS FOR DESIGNATED CREEP RATE, 1000 P.S.I. (2)		
	100 HRS.	1000 HRS.	10,000 HRS.	100,000 HRS.	0.000001 %/HR.	0.00001 %/HR.	0.0001 %/HR.
900						13.0	16.4
1000						4.5	6.1
1100		5.6	3.0			1.8	2.8
1200		4.0	2.2			0.8	1.4
1300		2.7	1.6			0.3	0.7
1400		1.8	1.1			0.1	0.3
1500		1.2	0.8				
1600		0.8	0.5				

(2)

ASTM-ASME JOINT COMMITTEE ON EFFECT OF TEMPERATURE ON PROPERTIES OF METALS

TYPE OF MATERIAL 27 Cr			TYPE OF MELTING FURNACE					SIZE OF HEAT				
CHEMICAL COMPOSITION, PER CENT		C	Mn	P	S	Si	Cr	Ni	Mo	N_2		
		0.12	0.45	0.014	0.009	0.47	25.40			0.125		
DEOXIDATION												
FORM-CAST OR WROUGHT	1" Round Bars											
HEAT TREATMENT												
MICROSTRUCTURE												
GRAIN SIZE	3-5 ASTM Ferrite Grain Size						HARDNESS	160-170 BHN				
SOURCE OF DATA	University of Michigan											

SHORT TIME TENSILE PROPERTIES

TEMPERATURE, °F	MODULUS OF ELASTICITY, 1,000,000 P.S.I.	OFFSET YIELD (1) STRENGTH, 1000 P.S.I.	TENSILE STRENGTH, 1000 P.S.I.	ELONGATION IN 2", PER CENT	REDUCTION IN AREA, PER CENT
RT		47.0	74.125	32.0	60.3
1200			20.9	63.0	89.2
1400			10.55	179.0	94.8
1600			4.75	156.0	98.5
1800			2.875	155.0	99.2

CREEP AND RUPTURE STRENGTHS

TEMP., °F	STRESS FOR RUPTURE IN TIMES INDICATED, 1000 P.S.I. (2)				STRESS FOR DESIGNATED CREEP RATE, 1000 P.S.I. (2)		
	100 HRS.	1000 HRS.	10,000 HRS.	100,000 HRS.	0.000001 %/HR.	0.00001 %/HR.	0.0001 %/HR.
1200	5.9	4.1	2.9*	2.0*			
1400	2.4	1.7	1.2*	0.85*			
1600	1.2	0.74	0.46*	0.29*			
1800	0.67	0.39	0.23*	0.14*			

(1) 0.2 PER CENT OFFSET UNLESS OTHERWISE INDICATED.
(2) EXTRAPOLATED VALUES INDICATED BY *

ORIGINAL CREEP AND RUPTURE DATA

TEMP. °F.	STRESS, 1000 P.S.I.	DURATION, HOURS(3)	INTERCEPT, %(4)	MINIMUM CREEP RATE, %/HR.	TRANSITION TIME, HRS.(5)	TOTAL EXT. (CREEP TEST), %	TOTAL ELONG. (RUPTURE TEST), %	HARDNESS AFTER TESTING
1200	12.5	1.3R					54.0	
1200	10.0	3.3R					57.5	
1200	9.0	6.3R					75.0	
1200	6.0	88.0R						
1200	4.8	361.0R					64.5	
1200	4.0	1173.0R					66.0	
1400	6.0	0.4R					130.0	
1400	4.5	1.9R					108.0	
1400	3.5	9.4R					147.0	
1400	2.0	331.0R					67.0	
1400	1.65	1316.0R					55.0	
1600	3.0	0.4R					146.0	
1600	2.5	1.5R					138.0	
1600	2.0	7.0R					173.0	
1600	1.25	95.0R					87.0	
1600	0.9	308.5R					66.0	
1600	0.66	1867.0R					66.0	
1800	1.7	0.8R					161.0	
1800	1.45	1.7R					215.0	
1800	1.2	6.7R					184.0	
1800	0.7	90.5R					84.0	
1800	0.45	381.0R					62.0	
1800	0.34	2026.0R					84.0	

(3) DURATION OF TEST (RUPTURE TEST INDICATED BY R).
(4) THE INTERCEPT IS THE PROJECTION BACK TO ZERO TIME FROM THE PORTION OF THE TEST SHOWING THE MINIMUM OR SECOND-STAGE CREEP RATE.
(5) THE TRANSITION TIME IS THE BEGINNING OF THE THIRD STAGE, OR AN ACCELERATING CREEP RATE.

(3)

ASTM-ASME JOINT COMMITTEE ON EFFECT OF TEMPERATURE ON PROPERTIES OF METALS

TYPE OF MATERIAL 27 Cr	TYPE OF MELTING FURNACE Electric						SIZE OF HEAT				
CHEMICAL COMPOSITION, PER CENT	C	Mn	P	S	Si	Cr	Ni	Mo	N_2		
	0.17	0.56	0.009	0.015	0.31	25.70			0.13		
DEOXIDATION											
FORM-CAST OR WROUGHT Hot-Rolled											
HEAT TREATMENT Normalized From 1750 F											
MICROSTRUCTURE											
GRAIN SIZE 1-3 ASTM Ferrite Grain Size							HARDNESS 170 BHN				
SOURCE OF DATA University of Michigan											

SHORT TIME TENSILE PROPERTIES

TEMPERATURE, °F	MODULUS OF ELASTICITY, 1,000,000 P.S.I.	OFFSET YIELD (1) STRENGTH, 1000 P.S.I.	TENSILE STRENGTH, 1000 P.S.I.	ELONGATION IN 2", PER CENT	REDUCTION IN AREA, PER CENT
RT		50.0	79.5	31.0	65.3
1400			11.75	91.0	97.3
1600			7.1	92.0	99.4
1800			4.075	130.0	99.7

CREEP AND RUPTURE STRENGTHS

TEMP., °F	STRESS FOR RUPTURE IN TIMES INDICATED, 1000 P.S.I. (2)				STRESS FOR DESIGNATED CREEP RATE, 1000 P.S.I. (2)		
	100 HRS.	1000 HRS.	10,000 HRS.	100,000 HRS.	0.000001 %/HR.	0.00001 %/HR.	0.0001 %/HR.
1400	2.75	1.90	1.35*	0.93*			
1600	1.30	0.86	0.58*	0.38*			
1800	0.70	0.40	0.23*	0.13*			

(1) 0.2 PER CENT OFFSET UNLESS OTHERWISE INDICATED.
(2) EXTRAPOLATED VALUES INDICATED BY *

(4)

ASTM-ASME JOINT COMMITTEE ON EFFECT OF TEMPERATURE ON PROPERTIES OF METALS

TYPE OF MATERIAL 27 Cr	TYPE OF MELTING FURNACE						SIZE OF HEAT				
CHEMICAL COMPOSITION, PER CENT	C	Mn	P	S	Si	Cr	Ni	Mo			
	0.20	0.80			0.36	26.94					
DEOXIDATION											
FORM-CAST OR WROUGHT Wrought											
HEAT TREATMENT Annealed											
MICROSTRUCTURE											
GRAIN SIZE							HARDNESS				
SOURCE OF DATA "Properties of Carbon and Alloy Seamless Tubing for High Temperature and High Pressure Service", Babcock & Wilcox Tube Company.											

SHORT TIME TENSILE PROPERTIES

TEMPERATURE, °F	MODULUS OF ELASTICITY, 1,000,000 P.S.I.	OFFSET YIELD (1) STRENGTH, 1000 P.S.I.	TENSILE STRENGTH, 1000 P.S.I.	ELONGATION IN 2", PER CENT	REDUCTION IN AREA, PER CENT

CREEP AND RUPTURE STRENGTHS

TEMP., °F	STRESS FOR RUPTURE IN TIMES INDICATED, 1000 P.S.I. (2)				STRESS FOR DESIGNATED CREEP RATE, 1000 P.S.I. (2)		
	100 HRS.	1000 HRS.	10,000 HRS.	100,000 HRS.	0.000001 %/HR.	0.00001 %/HR.	0.0001 %/HR.
1200						1.0	1.6
1350						0.18	0.4

(1) 0.2 PER CENT OFFSET UNLESS OTHERWISE INDICATED.
(2) EXTRAPOLATED VALUES INDICATED BY *

ORIGINAL CREEP AND RUPTURE DATA

TEMP. °F	STRESS, 1000 P.S.I.	DURATION, HOURS(3)	INTERCEPT, %(4)	MINIMUM CREEP RATE, %/HR.	TRANSITION TIME, HRS.(5)	TOTAL EXT. (CREEP TEST), %	TOTAL ELONG. (RUPTURE TEST), %	HARDNESS AFTER TESTING
1400	7.0	0.2R					51.0	
1400	5.7	1.3R					55.5	
1400	5.0	3.4R					134.0	
1400	3.0	28.5R					14.0	
1400	2.5	193.0R					57.5	
1400	2.0	814.0R					67.0	
1400	0.78	1173	0.08	0.00045		0.60		
1600	4.0	0.2R					117.0	
1600	3.0	1.0R					87.0	
1600	2.2	2.5R					69.0	
1600	1.2	218.0R					61.0	
1600	1.0	274.0R					28.0	
1600	0.875	916.0R					49.0	
1600	0.729	2904.0R					42.0	
1800	2.5	0.1R					64.0	
1800	1.6	2.8R					137.0	
1800	1.3	7.4R					105.0	
1800	0.7	260.0R					60.0	
1800	0.65	119.0R					123.0	
1800	0.5	408.0R					83.0	
1800	0.45	584.0R					61.0	

(3) DURATION OF TEST (RUPTURE TEST INDICATED BY R).
(4) THE INTERCEPT IS THE PROJECTION BACK TO ZERO TIME FROM THE PORTION OF THE TEST SHOWING THE MINIMUM OR SECOND-STAGE CREEP RATE.
(5) THE TRANSITION TIME IS THE BEGINNING OF THE THIRD STAGE, OR AN ACCELERATING CREEP RATE.

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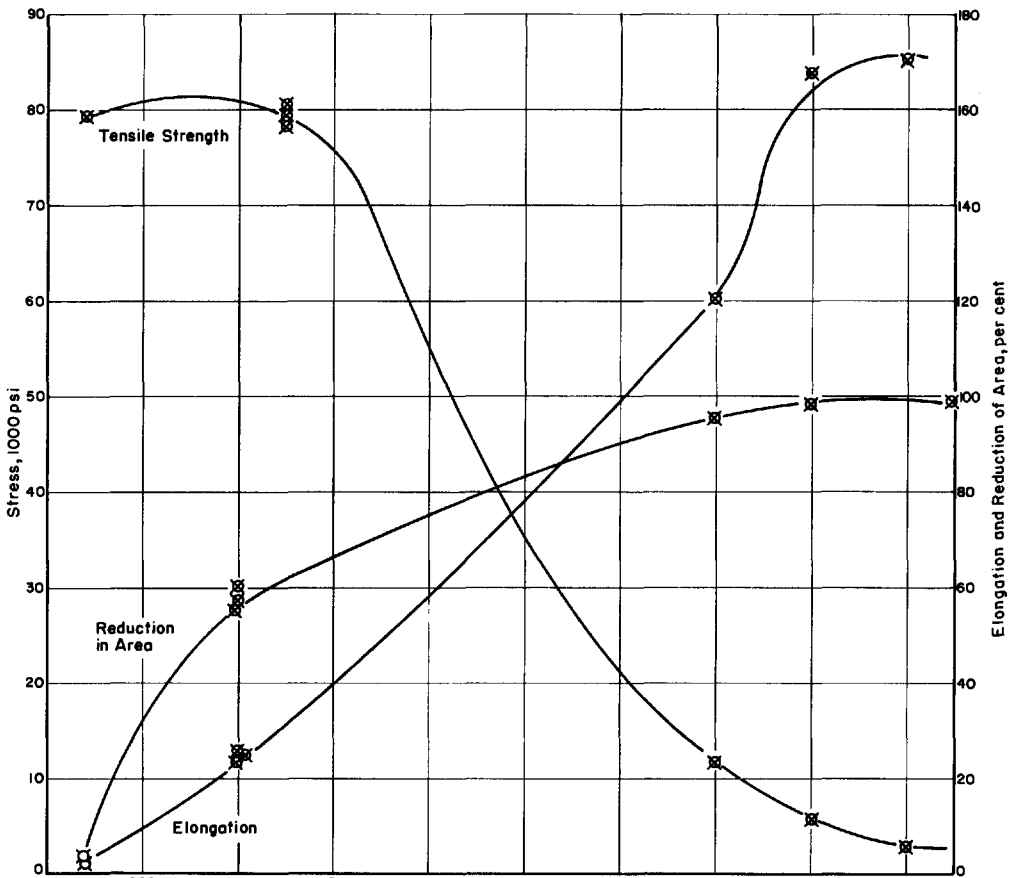
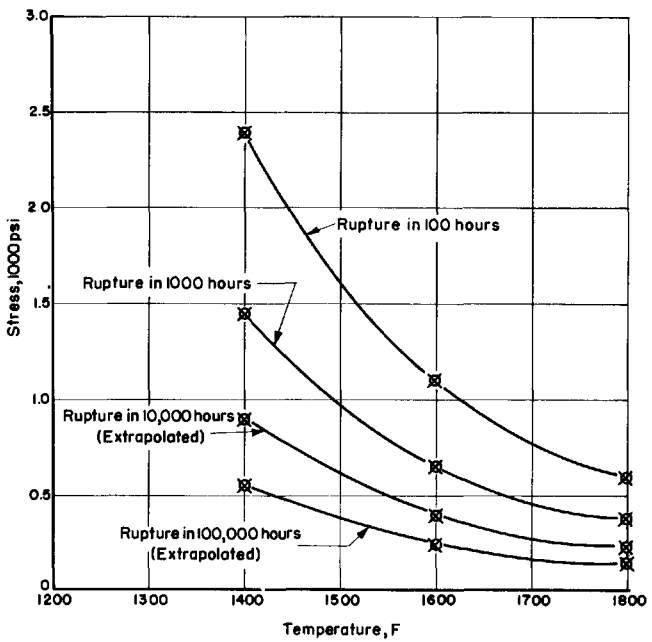
27 Chromium, Molybdenum Steels



SHORT-TIME TENSILE DATA

27 Cr, Mo STEEL



RUPTURE STRENGTHS

27 Cr, Mo STEEL

(1)

ASTM-ASME JOINT COMMITTEE ON EFFECT OF TEMPERATURE ON PROPERTIES OF METALS

TYPE OF MATERIAL 27 Cr + Mo			TYPE OF MELTING FURNACE Electric				SIZE OF HEAT				
CHEMICAL COMPOSITION, PER CENT	C	Mn	P	S	Si	Cr	Ni	Mo	N_2		
	0.12	0.65	0.011	0.013	0.49	28.20		0.63	0.11		
DEOXIDATION											
FORM-CAST OR WROUGHT Hot Rolled											
HEAT TREATMENT Normalized From 1750 F											
MICROSTRUCTURE											
GRAIN SIZE 4-6 ASTM Ferrite Grain Size							HARDNESS 170 BHN				
SOURCE OF DATA University of Michigan											

SHORT TIME TENSILE PROPERTIES

TEMPERATURE, °F	MODULUS OF ELASTICITY, 1,000,000 P.S.I.	OFFSET YIELD (1) STRENGTH, 1000 P.S.I.	TENSILE STRENGTH, 1000 P.S.I.	ELONGATION IN 2" PER CENT	REDUCTION IN AREA PER CENT
RT		55.0	69.5	3.0	3.5
400			70.5	24.0	57.3
400			68.8	25.0	56.2
400			69.6	25.5	60.0
1400			12.0	121.0	95.9
1600			5.9	168.0	98.7
1800			3.1	171.0	99.7

CREEP AND RUPTURE STRENGTHS

TEMP., °F	STRESS FOR RUPTURE IN TIMES INDICATED, 1000 P.S.I.(2)				STRESS FOR DESIGNATED CREEP RATE, 1000 P.S.I.(2)		
	100 HRS.	1000 HRS.	10,000 HRS.	100,000 HRS.	0.000001 %/HR.	0.00001 %/HR.	0.0001 %/HR.
1400	2.40	1.45	0.90*	0.56*			
1600	1.10	0.66	0.40*	0.24*			
1800	0.60	0.38	0.24*	0.15*			

(1) 0.2 PER CENT OFFSET UNLESS OTHERWISE INDICATED.
(2) EXTRAPOLATED VALUES INDICATED BY *

ORIGINAL CREEP AND RUPTURE DATA

TEMP. °F.	STRESS, 1000 P.S.I.	DURATION, HOURS(3)	INTERCEPT, %(4)	MINIMUM CREEP RATE, %/HR.	TRANSITION TIME, HRS.(5)	TOTAL EXT. (CREEP TEST), %	TOTAL ELONG. (RUPTURE TEST), %	HARDNESS AFTER TESTING
1400	7.0	0.6R					147.0	95.9
1400	5.6	1.8R					126.0	96.0
1400	4.5	5.3R					187.0	97.1
1400	2.2	146.0R					130.0	97.8
1400	1.5	884.0R					111.0	93.9
1400	0.78	1114.	0.052	0.0011		1.3		
1600	3.5	0.6R					138.0	99.0
1600	2.8	1.4R					146.0	99.1
1600	2.0	6.8R					185.0	98.7
1600	1.0	125.0R					148.0	98.9
1600	0.8	433.0R					124.0	97.1
1600	0.6	1683.0R					96.0	92.0
1800	1.8	0.5R					177.0	99.7
1800	1.3	2.0R					152.0	99.5
1800	0.925	17.1R					159.0	99.4
1800	0.60	93.0R					80.0	97.7
1800	0.4	726.0R					73.0	83.3

(3) DURATION OF TEST (RUPTURE TEST INDICATED BY R).
(4) THE INTERCEPT IS THE PROJECTION BACK TO ZERO TIME FROM THE PORTION OF THE TEST SHOWING THE MINIMUM OR SECOND-STAGE CREEP RATE.
(5) THE TRANSITION TIME IS THE BEGINNING OF THE THIRD STAGE, OR AN ACCELERATING CREEP RATE.

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Miscellaneous 12 Chromium Steels

12 Chromium, Titanium Steels
12 Chromium, Aluminum Steels
12 Chromium, Molybdenum, Aluminum Steels
12 Chromium, 3 Molybdenum Steels
12 Chromium, 3 Molybdenum, 2 Nickel Steels
12 Chromium, 2 Tungsten Steels

(1)

ASTM-ASME JOINT COMMITTEE ON EFFECT OF TEMPERATURE ON PROPERTIES OF METALS

TYPE OF MATERIAL	12 Cr, Ti	TYPE OF MELTING FURNACE	Induction	SIZE OF HEAT	30 lb

CHEMICAL COMPOSITION, PER CENT	C	Mn	P	S	Si	Cr	Ni	Mo	Ti	B
	0.107	0.37			0.28	12.8			0.90	0.013

DEOXIDATION: 1 Lb Al Per Ton

FORM-CAST OR WROUGHT: Forged, Then Rolled to 5/8" Diameter

HEAT TREATMENT: A.C. From 2100 F, Tempered at 1100 F

MICROSTRUCTURE: Ferrite and TiC

GRAIN SIZE: HARDNESS:

SOURCE OF DATA: Titanium Alloy Mfg. Div. of National Lead Co.

CREEP AND RUPTURE STRENGTHS

TEMP., °F	STRESS FOR RUPTURE IN TIMES INDICATED, 1000 P.S.I.(2)				STRESS FOR DESIGNATED CREEP RATE, 1000 P.S.I.(2)		
	100 HRS.	1000 HRS.	10,000 HRS.	100,000 HRS.	0.000001 %/HR.	0.00001 %/HR.	0.0001 %/HR.
1100	21.0	17.0*					

ORIGINAL CREEP AND RUPTURE DATA

TEMP. °F	STRESS, 1000 P.S.I.	DURATION, HOURS(3)	INTERCEPT, %(4)	MINIMUM CREEP RATE, %/HR.	TRANSITION TIME, HRS.(5)	TOTAL EXT. (CREEP TEST), %	TOTAL ELONG. (RUPTURE TEST), %	HARDNESS AFTER TESTING
1100	20.0	158 R					13.0	
1100	25.0	6 R					21.0	
1100	25.0	8 R					19.0	
1100	30.0	7 R					28.0	
1100	35.0	<1 R					17.0	
1100	40.0	<1 R					28.0	

(2)

ASTM-ASME JOINT COMMITTEE ON EFFECT OF TEMPERATURE ON PROPERTIES OF METALS

TYPE OF MATERIAL	12 Cr, Ti	TYPE OF MELTING FURNACE	Induction	SIZE OF HEAT	30 lb

CHEMICAL COMPOSITION, PER CENT	C	Mn	P	S	Si	Cr	Ni	Mo	Ti	B
	0.119	0.37			0.28	12.8	4.01		0.72	0.016

DEOXIDATION: 1 Lb Al Per Ton

FORM-CAST OR WROUGHT: Forged, Then Rolled to 5/8" Diameter

HEAT TREATMENT: A.C. From 2100 F, Tempered at 1100 F

MICROSTRUCTURE: Ferrite and TiC

GRAIN SIZE: HARDNESS:

SOURCE OF DATA: Titanium Alloy Mfg. Div. of National Lead Co.

CREEP AND RUPTURE STRENGTHS

TEMP., °F	STRESS FOR RUPTURE IN TIMES INDICATED, 1000 P.S.I.(2)				STRESS FOR DESIGNATED CREEP RATE, 1000 P.S.I.(2)		
	100 HRS.	1000 HRS.	10,000 HRS.	100,000 HRS.	0.000001 %/HR.	0.00001 %/HR.	0.0001 %/HR.
1100	20.0	13.0*					

ORIGINAL CREEP AND RUPTURE DATA

TEMP. °F	STRESS, 1000 P.S.I.	DURATION, HOURS(3)	INTERCEPT, %(4)	MINIMUM CREEP RATE, %/HR.	TRANSITION TIME, HRS.(5)	TOTAL EXT. (CREEP TEST), %	TOTAL ELONG. (RUPTURE TEST), %	HARDNESS AFTER TESTING
1100	20.0	104 R					58.0	
1100	25.0	16 R					19.0	
1100	25.0	25 R					35.0	
1100	30.0	22 R					38.0	
1100	30.0	17 R					38.0	
1100	35.0	5 R					27.0	

(1) 0.2 PER CENT OFFSET UNLESS OTHERWISE INDICATED.
(2) EXTRAPOLATED VALUES INDICATED BY *
(3) DURATION OF TEST (RUPTURE TEST INDICATED BY R).
(4) THE INTERCEPT IS THE PROJECTION BACK TO ZERO TIME FROM THE PORTION OF THE TEST SHOWING THE MINIMUM OR SECOND-STAGE CREEP RATE.
(5) THE TRANSITION TIME IS THE BEGINNING OF THE THIRD STAGE, OR AN ACCELERATING CREEP RATE.

(3)

ASTM-ASME JOINT COMMITTEE ON EFFECT OF TEMPERATURE ON PROPERTIES OF METALS

TYPE OF MATERIAL	12 Cr, Al (Type 405)	TYPE OF MELTING FURNACE		SIZE OF HEAT	

CHEMICAL COMPOSITION, PER CENT	C	Mn	P	S	Si	Cr	Ni	Mo	Al
	0.07	0.44	0.026	0.012	0.41	12.09	0.26		0.27

DEOXIDATION:

FORM-CAST OR WROUGHT: 1" Square Bars

HEAT TREATMENT: Pack annealed 3-1/2 Hr at 1550 F, F.C. 106 Hr to 1100 F, Tempered 2 Hr at 1200 F, F.C. to 300 F.

MICROSTRUCTURE:

GRAIN SIZE: HARDNESS: 150 BHN

SOURCE OF DATA: University of Michigan, Timken Roller Bearing Co.

SHORT TIME TENSILE PROPERTIES

TEMPERATURE, °F	MODULUS OF ELASTICITY, 1,000,000 P.S.I.	OFFSET YIELD (1) STRENGTH, 1000 P.S.I.	TENSILE STRENGTH, 1000 P.S.I.	ELONGATION IN 2", PER CENT	REDUCTION IN AREA, PER CENT
RT			74.7	32.5	70.2
RT			75.6	34.5	70.9
800			55.9	26.0	69.1
900			47.3	35.5	74.2
1000			40.5	43.5	75.8
1000		29.4	37.6	34.0	80.7

CREEP AND RUPTURE STRENGTHS

TEMP., °F	STRESS FOR RUPTURE IN TIMES INDICATED, 1000 P.S.I.(2)				STRESS FOR DESIGNATED CREEP RATE, 1000 P.S.I.(2)		
	100 HRS.	1000 HRS.	10,000 HRS.	100,000 HRS.	0.000001 %/HR.	0.00001 %/HR.	0.0001 %/HR.
800					10.0	23.0	40.0*
900						17.5	30.0*
1000	21.5	16.5	13.0*			4.5*	8.4*

ORIGINAL CREEP AND RUPTURE DATA

TEMP. °F	STRESS, 1000 P.S.I.	DURATION, HOURS(3)	INTERCEPT, %(4)	MINIMUM CREEP RATE, %/HR.	TRANSITION TIME, HRS.(5)	TOTAL EXT. (CREEP TEST), %	TOTAL ELONG. (RUPTURE TEST), %	HARDNESS AFTER TESTING
800	35.0	1079	0.410	0.000030		0.460		
800	20.0	1053	0.089	0.000005		0.095		
800	10.0	1027	0.051	0.0000010		0.057		
900	25.0	1006	0.410	0.000027		0.440		
900	17.5	983	0.188	0.000010		0.196		
900	10.0	1054	0.061	0.000003		0.064		
900	6.0	1081	0.030	0.000007		0.040		
1000	30.0	6.6 R					31.0	
1000	22.5	85 R					35.5	
1000	19.0	204 R					38.0	
1000	16.0	1548 R					33.0	
1000	12.0	1050	0.135	0.000390	350	0.743		
1000	10.0	1006	0.100	0.000017	400	0.322		
1000	7.0	1103	0.061	0.000056		0.124		
1000	5.5	1178	0.104	0.000100		0.228		
1000	5.0	1010	0.061	0.000004		0.065		

(4)

ASTM-ASME JOINT COMMITTEE ON EFFECT OF TEMPERATURE ON PROPERTIES OF METALS

TYPE OF MATERIAL	12 Cr, Mo, Al (Type 405 + Mo)	TYPE OF MELTING FURNACE		SIZE OF HEAT	

CHEMICAL COMPOSITION, PER CENT	C	Mn	P	S	Si	Cr	Ni	Mo	Al
	0.06	0.46	0.009	0.009	0.29	11.72	0.24	0.49	0.27

DEOXIDATION:

FORM-CAST OR WROUGHT: 0.890" Thick Rolled Plate

HEAT TREATMENT: Annealed, 1 Hr, 1800F; A.C. 1200 F; Tempered 1 Hr 1200 F, and Tempered 2 Hr 1200 F and F.C. to 300 F

MICROSTRUCTURE:

GRAIN SIZE: HARDNESS: 163 BHN

SOURCE OF DATA: University of Michigan, Timken Roller Bearing Co.

SHORT TIME TENSILE PROPERTIES

TEMPERATURE, °F	MODULUS OF ELASTICITY, 1,000,000 P.S.I.	OFFSET YIELD (1) STRENGTH, 1000 P.S.I.	TENSILE STRENGTH, 1000 P.S.I.	ELONGATION IN 2", PER CENT	REDUCTION IN AREA, PER CENT
RT		43.5	71.9	27.5	57.0
RT			71.8	30.5	58.3
RT			71.3	32.5	61.1
800			50.7	27.0	59.5
900			46.8	29.0	60.5
1000			39.2	41.0	70.0
1000		25.7	37.3	33.5	71.3

CREEP AND RUPTURE STRENGTHS

TEMP., °F	STRESS FOR RUPTURE IN TIMES INDICATED, 1000 P.S.I.(2)				STRESS FOR DESIGNATED CREEP RATE, 1000 P.S.I.(2)		
	100 HRS.	1000 HRS.	10,000 HRS.	100,000 HRS.	0.000001 %/HR.	0.00001 %/HR.	0.0001 %/HR.
800						19.0	28.0
900						12.5	19.5
1000	23.0	17.0*	13.0*			2.6*	7.3

ORIGINAL CREEP AND RUPTURE DATA

TEMP. °F	STRESS, 1000 P.S.I.	DURATION, HOURS(3)	INTERCEPT, %(4)	MINIMUM CREEP RATE, %/HR.	TRANSITION TIME, HRS.(5)	TOTAL EXT. (CREEP TEST), %	TOTAL ELONG. (RUPTURE TEST), %	HARDNESS AFTER TESTING
800	30.0	1053	0.530	0.000150		0.702		
800	22.5	1100	0.159	0.000025		0.185		
800	15.0	1055	0.094	0.000003		0.099		
900	20.0	1175	0.390	0.000120		0.537		
900	16.0	1100	0.130	0.000035		0.167		
900	10.0	1155	0.056	0.000003		0.059		
1000	31.0	1.2 R					38.0	
1000	24.0	67.0 R					42.0	
1000	21.0	233.0 R					39.0	
1000	18.0	649.5 R					41.5	
1000	10.0	1005	0.200	0.000176		0.372		
1000	7.0	1103	0.162	0.000116		0.309		
1000	5.5	1053	0.062	0.000051		0.119		
1000	4.0	1081	0.038	0.000025		0.066		

(5)

ASTM-ASME JOINT COMMITTEE ON EFFECT OF TEMPERATURE ON PROPERTIES OF METALS

TYPE OF MATERIAL	12 Cr, 3 Mo	TYPE OF MELTING FURNACE		SIZE OF HEAT	
CHEMICAL COMPOSITION, PER CENT	C	Mn	P	S	Si	Cr	Ni	Mo
	0.15	0.76	0.023	0.015	1.22	11.84	0.25	3.00
DEOXIDATION								
FORM-CAST OR WROUGHT	Barstock							
HEAT TREATMENT	Normalized at 1900 F, Tempered 6 Hr at 1150 F							
MICROSTRUCTURE	Tempered Martensite Plus Delta Ferrite							
GRAIN SIZE					HARDNESS	321-352 BHN		
SOURCE OF DATA	University of Michigan							

CREEP AND RUPTURE STRENGTHS

TEMP., °F	STRESS FOR RUPTURE IN TIMES INDICATED, 1000 P.S.I.(2)				STRESS FOR DESIGNATED CREEP RATE, 1000 P.S.I.(2)		
	100 HRS.	1000 HRS.	10,000 HRS.	100,000 HRS.	0.000001 %/HR.	0.00001 %/HR.	0.0001 %/HR.
1000	70.0	60.0	52.0*			9.1*	44.5*
1100	44.5	28.0	16.0*			3.2*	10.5

ORIGINAL CREEP AND RUPTURE DATA

TEMP. °F	STRESS, 1000 P.S.I.	DURATION, HOURS(3)	INTERCEPT, %(4)	MINIMUM CREEP RATE, %/HR.	TRANSITION TIME, HRS.(5)	TOTAL EXT. (CREEP TEST), %	TOTAL ELONG. (RUPTURE TEST), %	HARDNESS AFTER TESTING
1000	78.0	28 R					20.5	
1000	72.0	36 R					27.0	
1000	65.0	377 R					23.5	
1000	62.0	658 R					22.0	
1000	57.0	2409 R					16.0	
1000	27.5	1237	0.33	0.000050		0.40		
1000	17.5	1250	0.17	0.000026		0.19		
1100	50.0	35 R					23.0	
1100	40.0	247 R					18.5	
1100	35.0	397 R					15.0	
1100	32.0	505 R					6.5	
1100	28.0	1257 R					16.0	
1100	15.0	1222	0.21	0.000195		0.44		
1100	7.0	1312	0.08	0.000046		0.15		
1200	27.0	40 R					34.0	

(1) 0.2 PER CENT OFFSET UNLESS OTHERWISE INDICATED.
(2) EXTRAPOLATED VALUES INDICATED BY *
(3) DURATION OF TEST (RUPTURE TEST INDICATED BY R).
(4) THE INTERCEPT IS THE PROJECTION BACK TO ZERO TIME FROM THE PORTION OF THE TEST SHOWING THE MINIMUM OR SECOND-STAGE CREEP RATE.
(5) THE TRANSITION TIME IS THE BEGINNING OF THE THIRD STAGE, OR AN ACCELERATING CREEP RATE.

(6)

ASTM-ASME JOINT COMMITTEE ON EFFECT OF TEMPERATURE ON PROPERTIES OF METALS

TYPE OF MATERIAL	12 Cr, 3 Mo, 2 Ni	TYPE OF MELTING FURNACE		SIZE OF HEAT	
CHEMICAL COMPOSITION, PER CENT	C	Mn	P	S	Si	Cr	Ni	Mo
	0.16	1.43	0.018	0.025	1.05	11.85	1.52	2.85
DEOXIDATION								
FORM-CAST OR WROUGHT	Barstock							
HEAT TREATMENT	Normalized From 1850 F and Tempered 2 Hr at 1200 F							
MICROSTRUCTURE	Tempered Martensite Plus Ferrite Stringers							
GRAIN SIZE					HARDNESS	321-331 BHN		
SOURCE OF DATA	University of Michigan							

SHORT TIME TENSILE PROPERTIES

TEMPERATURE, °F	MODULUS OF ELASTICITY, 1,000,000 P.S.I.	OFFSET YIELD (1) STRENGTH, 1000 P.S.I.	TENSILE STRENGTH, 1000 P.S.I.	ELONGATION IN 2", PER CENT	REDUCTION IN AREA, PER CENT

CREEP AND RUPTURE STRENGTHS

TEMP., °F	STRESS FOR RUPTURE IN TIMES INDICATED, 1000 P.S.I.(2)				STRESS FOR DESIGNATED CREEP RATE, 1000 P.S.I.(2)		
	100 HRS.	1000 HRS.	10,000 HRS.	100,000 HRS.	0.000001 %/HR.	0.00001 %/HR.	0.0001 %/HR.
1000	64.0	49.0	37.5*				21.0*
1100	32.0	21.0	13.5*				5.0*

ORIGINAL CREEP AND RUPTURE DATA

TEMP. °F	STRESS, 1000 P.S.I.	DURATION, HOURS(3)	INTERCEPT, %(4)	MINIMUM CREEP RATE, %/HR.	TRANSITION TIME, HRS.(5)	TOTAL EXT. (CREEP TEST), %	TOTAL ELONG. (RUPTURE TEST), %	HARDNESS AFTER TESTING
1000	68.0	58 R					21.5	
1000	60.0	174 R					22.0	
1000	55.0	66 R					28.5	
1000	55.0	72 R					32.0	
1000	50.0	864 R					21.0	
1000	17.5	1407	0.25	0.000052		0.33		
1100	42.0	24 R					30.0	
1100	35.0	40 R					39.0	
1100	27.0	276 R					33.0	
1100	23.0	697 R					31.5	
1100	20.0	1192 R					33.0	
1100	7.0	1407 R	0.26	0.000170		0.50		

(7)

ASTM-ASME JOINT COMMITTEE ON EFFECT OF TEMPERATURE ON PROPERTIES OF METALS

TYPE OF MATERIAL	12 Cr, 2 W	TYPE OF MELTING FURNACE		SIZE OF HEAT	
CHEMICAL COMPOSITION, PER CENT	C	Mn	P	S	Si	Cr	Ni	Mo	W
	0.07	0.42			0.25	11.75			1.83
DEOXIDATION									
FORM-CAST OR WROUGHT	Wrought								
HEAT TREATMENT	Annealed								
MICROSTRUCTURE									
GRAIN SIZE					HARDNESS				
SOURCE OF DATA	"Properties of Carbon and Alloy Seamless Steel Tubing for High Temperature and High Pressure Service", Babcock & Wilcox Tube Company.								

SHORT TIME TENSILE PROPERTIES

TEMPERATURE, °F	MODULUS OF ELASTICITY, 1,000,000 P.S.I.	OFFSET YIELD (1) STRENGTH, 1000 P.S.I.	TENSILE STRENGTH, 1000 P.S.I.	ELONGATION IN 2", PER CENT	REDUCTION IN AREA, PER CENT

CREEP AND RUPTURE STRENGTHS

TEMP., °F	STRESS FOR RUPTURE IN TIMES INDICATED, 1000 P.S.I.(2)				STRESS FOR DESIGNATED CREEP RATE, 1000 P.S.I.(2)		
	100 HRS.	1000 HRS.	10,000 HRS.	100,000 HRS.	0.000001 %/HR.	0.00001 %/HR.	0.0001 %/HR.
800						23.0	33.0
1000						7.2	10.0
1100						4.2	6.0

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