

Supplemental Report on the Elevated-Temperature Properties Of Chromium-Molybdenum Steels

Issued under the auspices of
The Data and Publications Panel of
The ASTM-ASME Joint Committee on
the Effect of Temperature on the
Properties of Metals

Prepared for the Panel by
John A. VanEck and Ward F. Simmons

ASTM DATA SERIES PUBLICATION NO. DS 6S1



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AMERICAN SOCIETY FOR TESTING AND MATERIALS
1916 Race Street, Philadelphia, Pa. 19103

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8Cr-1Mo	none	65
9Cr-1Mo	22	65-66

Supplemental Report on the Elevated-Temperature Properties Of Chromium-Molybdenum Steels

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 BY
JOHN A. VANECHO AND WARD F. SIMMONS

This compilation is a graphical summary of the elevated-temperature mechanical-property data for commercially produced chromium-molybdenum steels. The data were collected through the efforts of the Data and Publications Panel of the ASTM-ASME Joint Committee on Effect of Temperature on the Properties of Metals.

This supplement contains 38 data graphs and about 126 data sheets representing data from 27 Cr-Mo steels. This compilation is a supplement to *ASTM DS 6*, it does not replace it.

This report is intended as a supplement to *ASTM DS 6* (formerly *STP 151*), which was published in 1953. The original report on chromium-molybdenum steels is a comprehensive report containing data sheets on 52 steels and data summary graphs for 23 steels. Data contained in *DS 6* include short-time tensile properties, creep and stress-rupture data, and Larson-Miller parameter curves.

The Data and Publications Panel has supported a continuous effort to collect high-temperature properties data for metals. These data were, until recently, available in the form of keysort punched cards. The punched-card program was discontinued in June, 1965, but all chromium-molybdenum steel data collected for this program are included in this publication. A special collection of additional chromium-molybdenum steel data was also made by the Panel for this supplement. Data were obtained from the following sources:

Babcock and Wilcox Co.
Crucible Steel Company of America

Edward Valves, Inc.
Elliott Co.
Jones and Laughlin Steel Corp.
Lukens Steel Co.
North American Aviation, Inc.
A. O. Smith Corp.
The Timken Roller Bearing Co.
U. S. Naval Research Laboratory
U. S. Navy Marine Engineering Laboratory
U. S. Steel Corporation Applied Research Laboratory
Vanadium Alloys Steel Corp.

The steels have been grouped by approximate chemical composition as was done in *DS 6*. The data graphs include short-time tensile and yield strengths; elongation and reduction of area; creep data for creep rates of 0.001, 0.0001, and 0.00001 per cent per hour; and rupture data for times of 100, 1000, 10,000, and 100,000 hours. Most of the 10,000-hour rupture data and all of the 100,000-hour data were extrapolated.

To show the approximate processing each material has received, the figures were drawn using various symbols

to indicate annealed, normalized, cast, etc. These processing or condition classifications are very broad and are intended to serve only as a guide in using the figures. The detailed processing, heat treatment, and composition data for each steel are given in the data sheets. Each figure includes the numbers of the appropriate data sheets for easy reference. Since the classification "annealed," for example, includes different annealing temperatures, it is recommended that the data sheets be referred to when using the graphs. Whenever possible, the average data curves from *DS 6* have been included in the figures to facilitate comparison of the data.

Acknowledgments

The authors wish to thank the contributing organizations and their representatives for taking the necessary time and trouble to supply the data upon which this publication is based. We also wish to thank the Data and Publications Panel and the Project Committee for their helpful suggestions and counsel in collecting and preparing the data for publication.

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W. E. Leyda
W. F. Simmons

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Key for all figures

O Annealed
● Normalized and tempered
X Quenched and tempered
◇ Forged (air cooled and tempered)
△ Cold drawn and tempered
+ As rolled
□ Cast

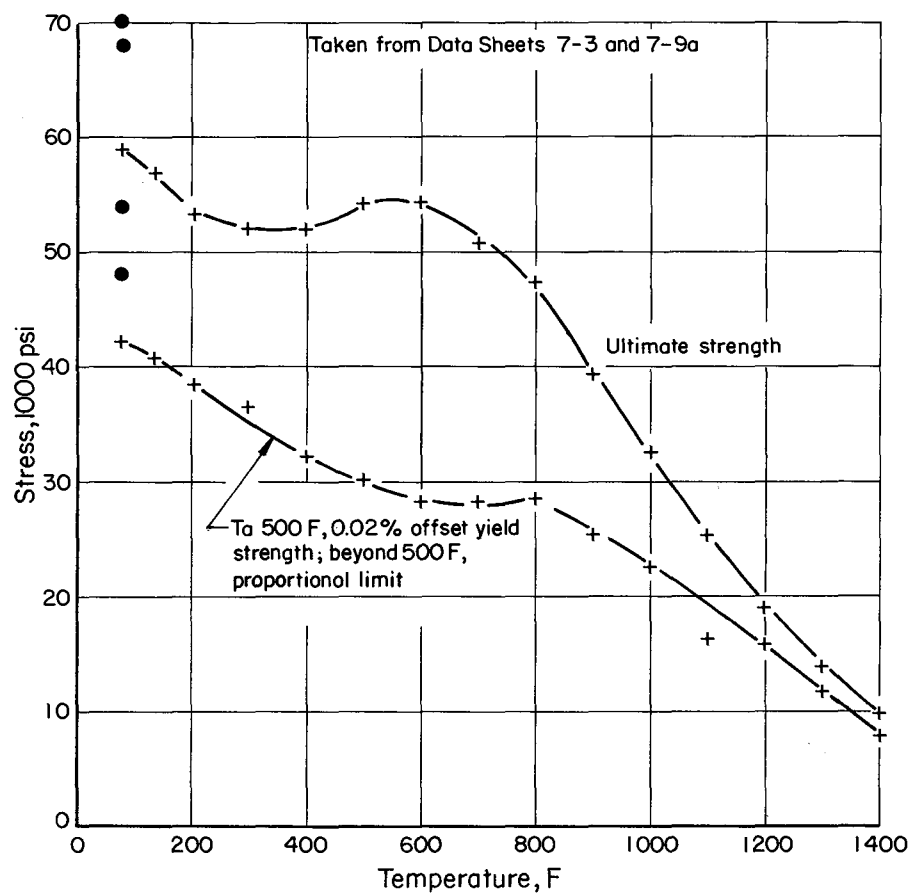


FIGURE 1. ULTIMATE AND YIELD STRENGTH FOR C-V STEEL

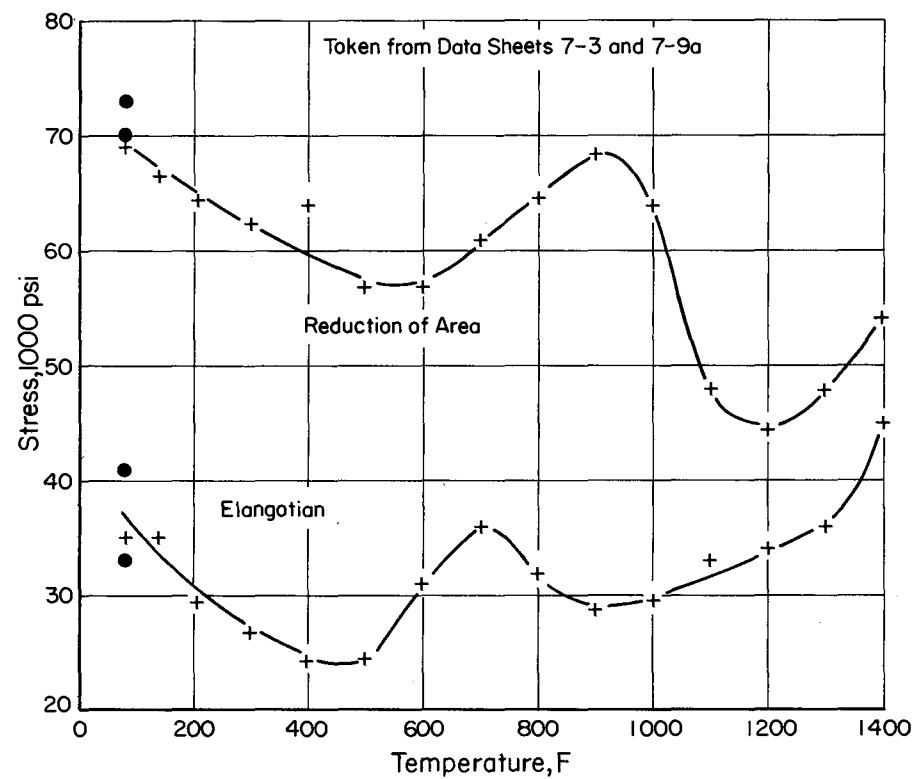


FIGURE 2. ELONGATION AND REDUCTION OF AREA FOR C-V STEEL

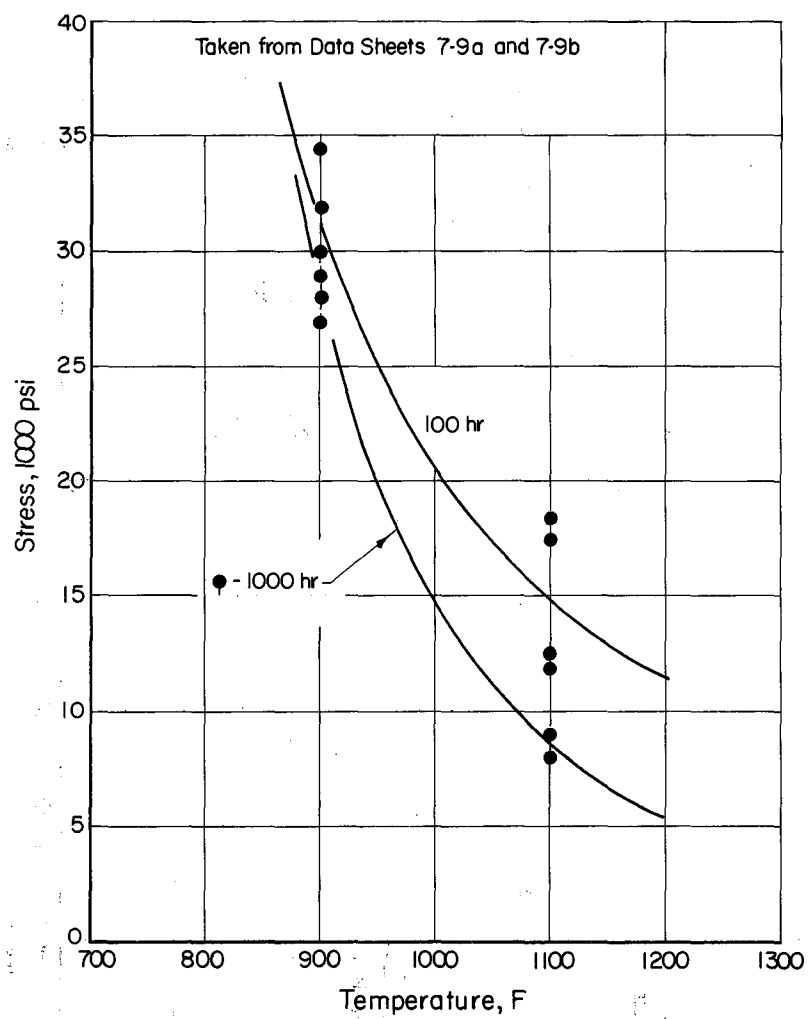


FIGURE 3 STRESS TO RUPTURE IN 100 AND 1000 HOURS FOR C-V STEEL

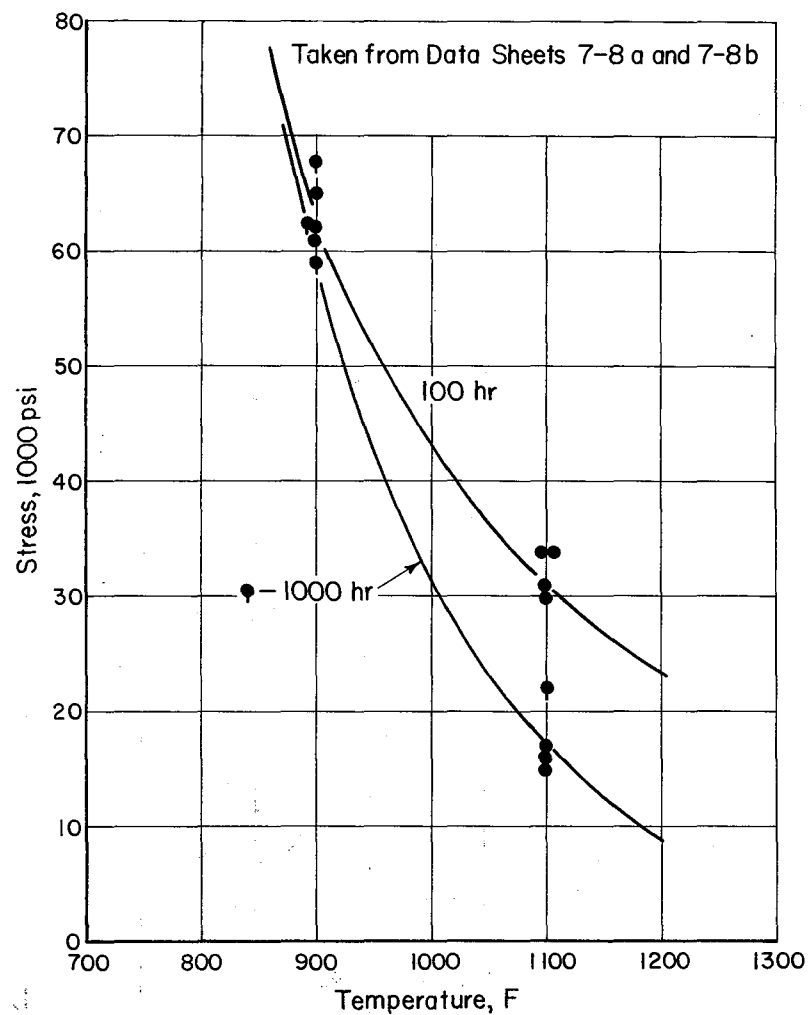


FIGURE 4. STRESS TO RUPTURE IN 100 AND 1000 HOURS FOR $\frac{1}{4}\text{Mo}-\text{V}$ STEEL

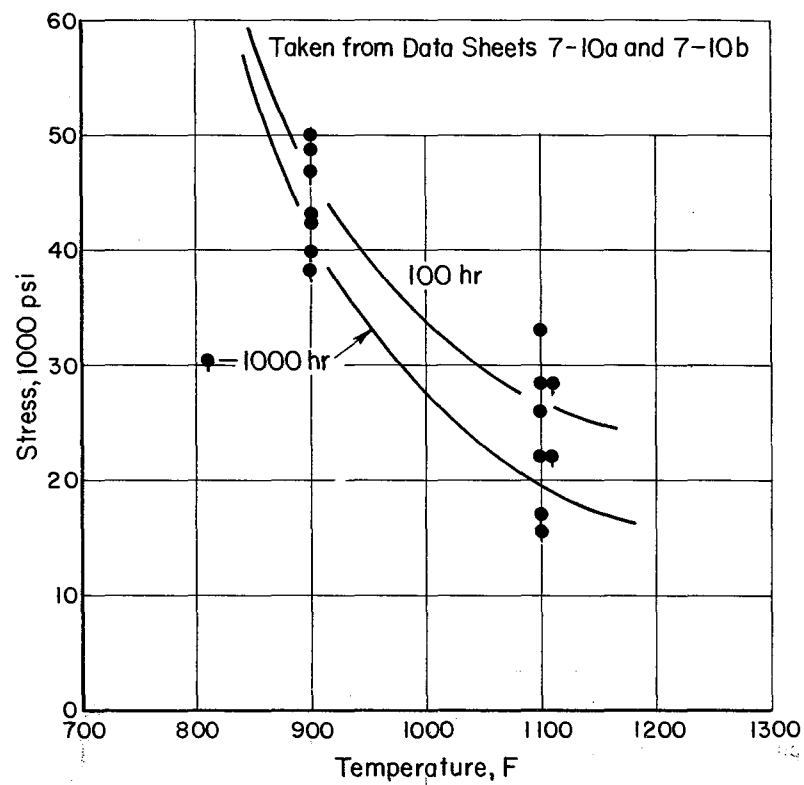


FIGURE 5. STRESS TO RUPTURE IN 100 AND 1000 HOURS FOR $\frac{1}{4}\text{Mo}-\frac{1}{2}\text{V}$ STEEL

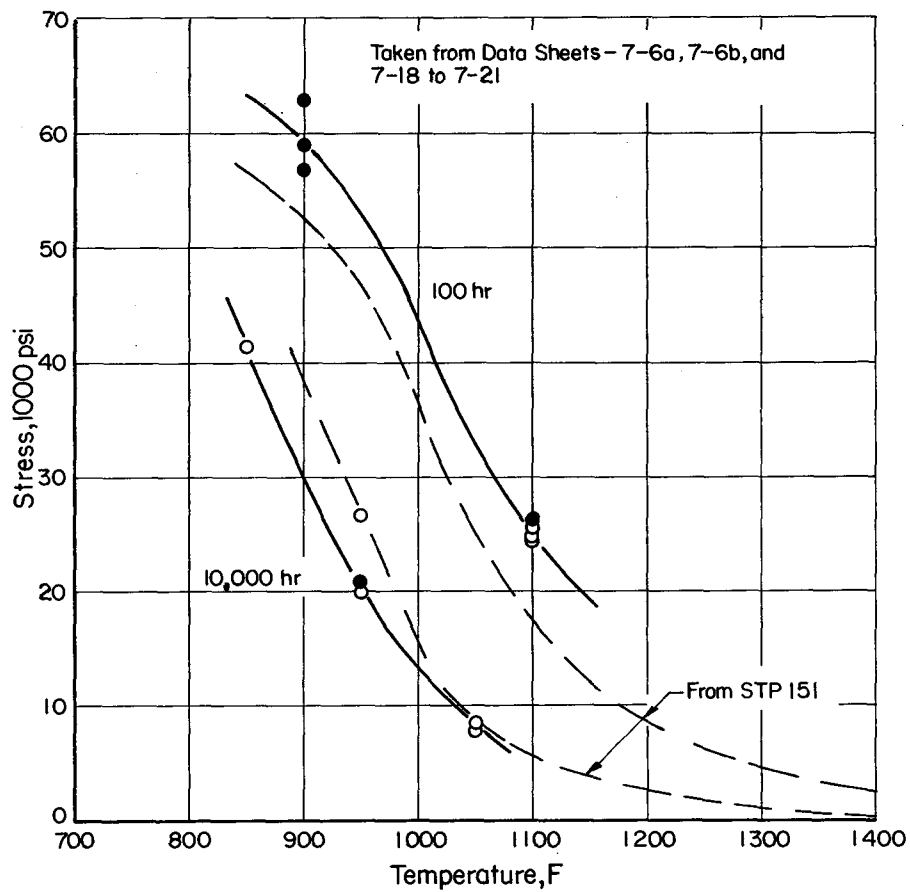


FIGURE 6. STRESS TO RUPTURE IN 100 AND 10,000 HOURS FOR C- $\frac{1}{2}$ Mo STEEL

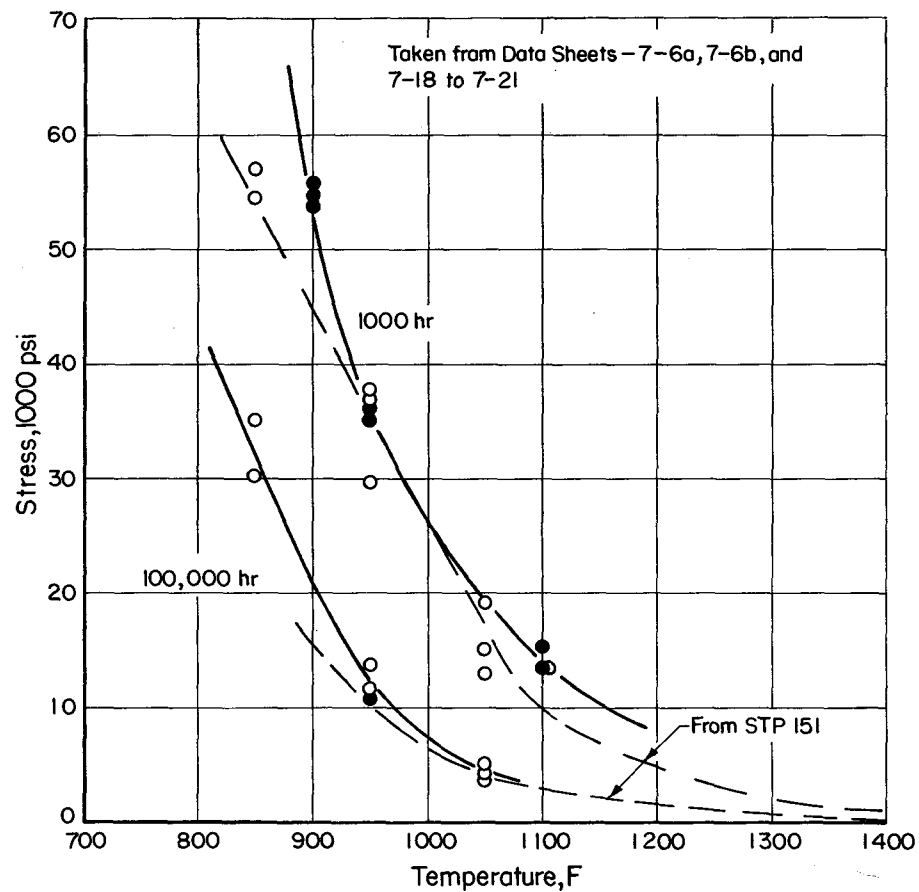


FIGURE 7. STRESS TO RUPTURE IN 1000 AND 100,000 HOURS FOR C- $\frac{1}{2}$ Mo STEEL

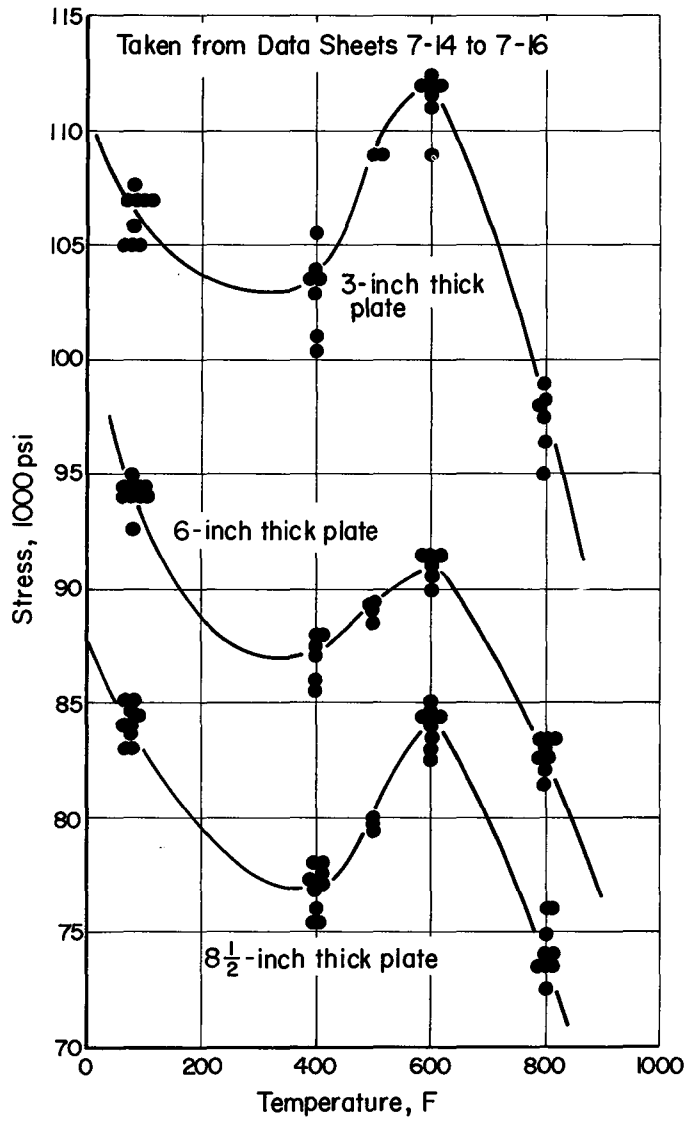


FIGURE 8. ULTIMATE STRENGTH FOR Mn-Mo STEEL

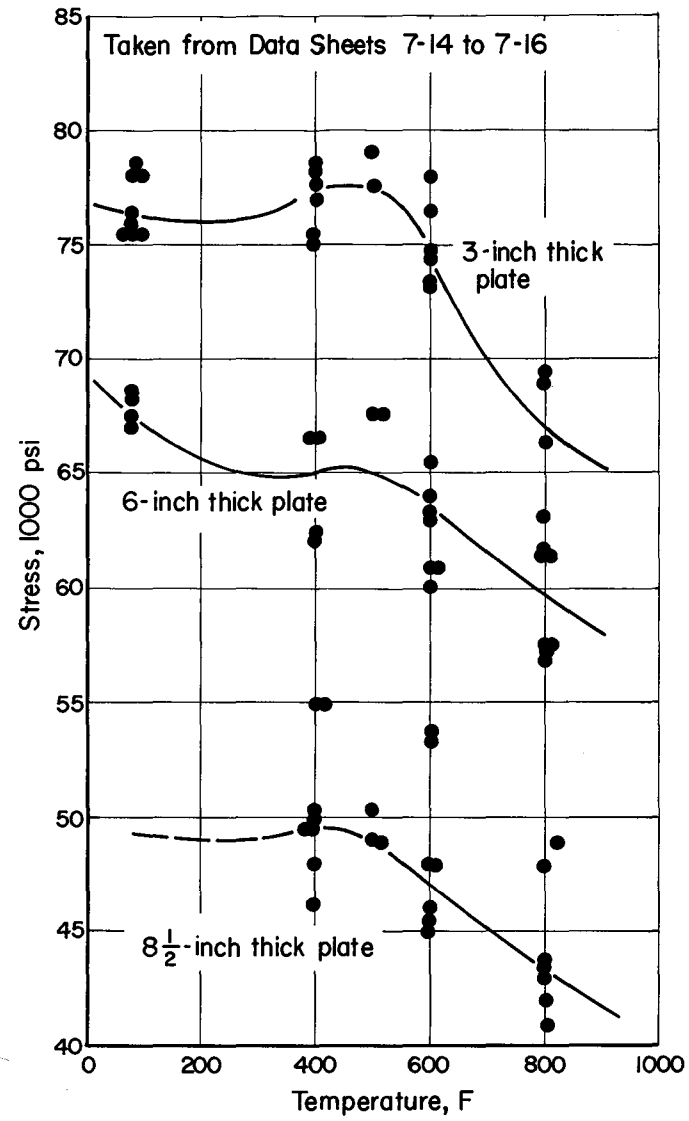


FIGURE 9. YIELD STRENGTH FOR Mn-Mo STEEL

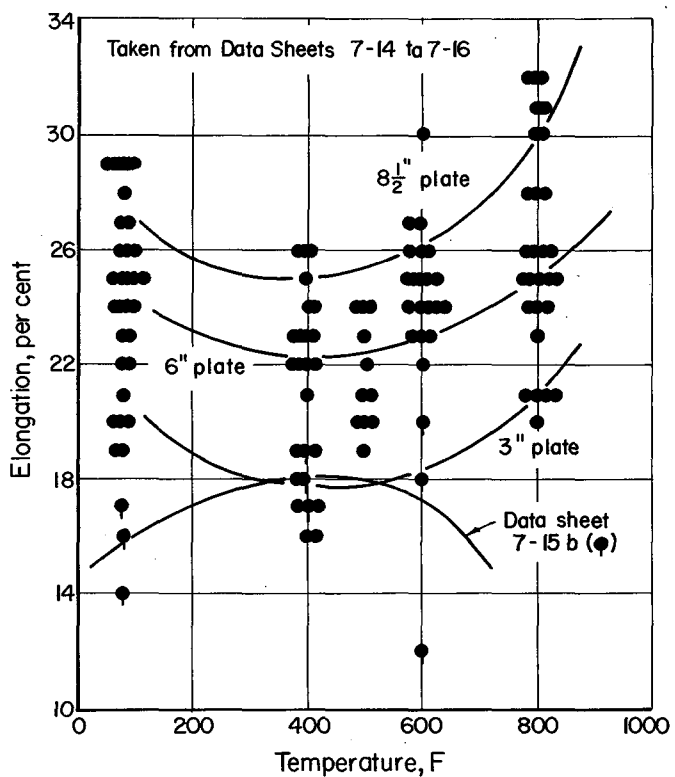


FIGURE 10. ELONGATION FOR Mn-Mo STEEL

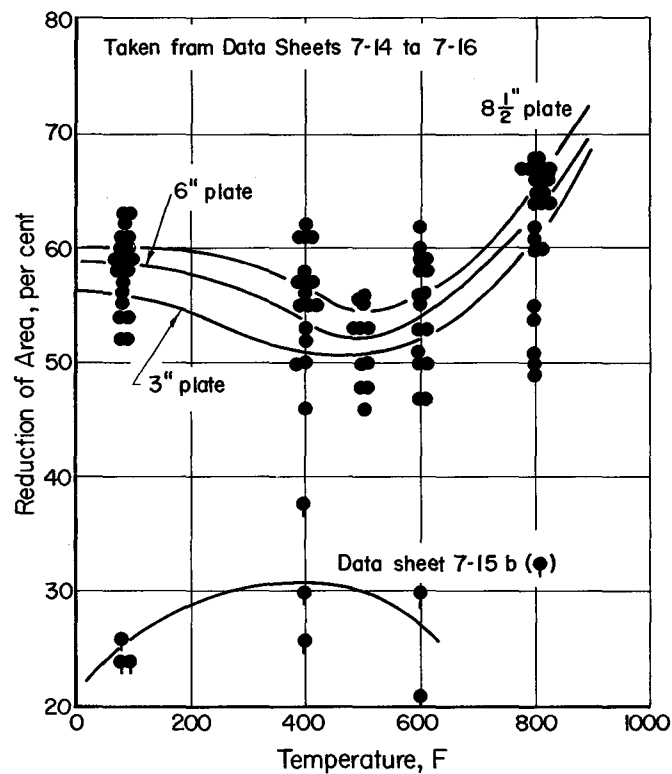


FIGURE 11. REDUCTION OF AREA FOR Mn-Mo STEEL

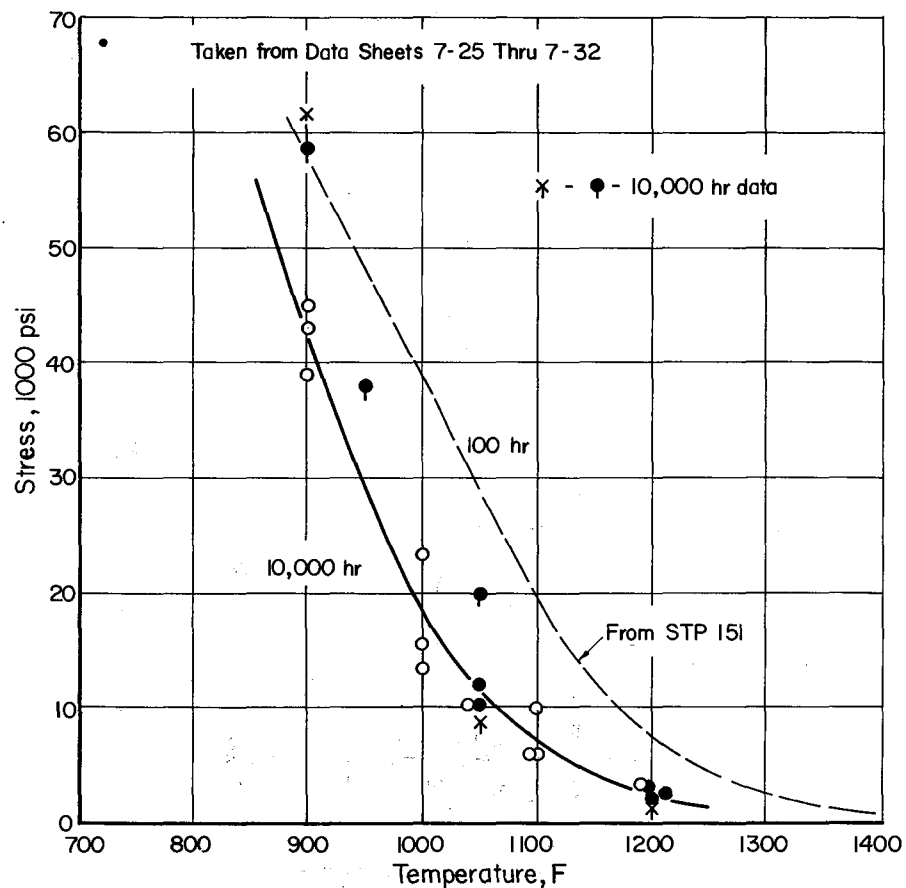


FIGURE 12. STRESS TO RUPTURE IN 100 AND 10,000 HOURS FOR $\frac{1}{2}\text{Cr}-\frac{1}{2}\text{Mo}$ STEEL

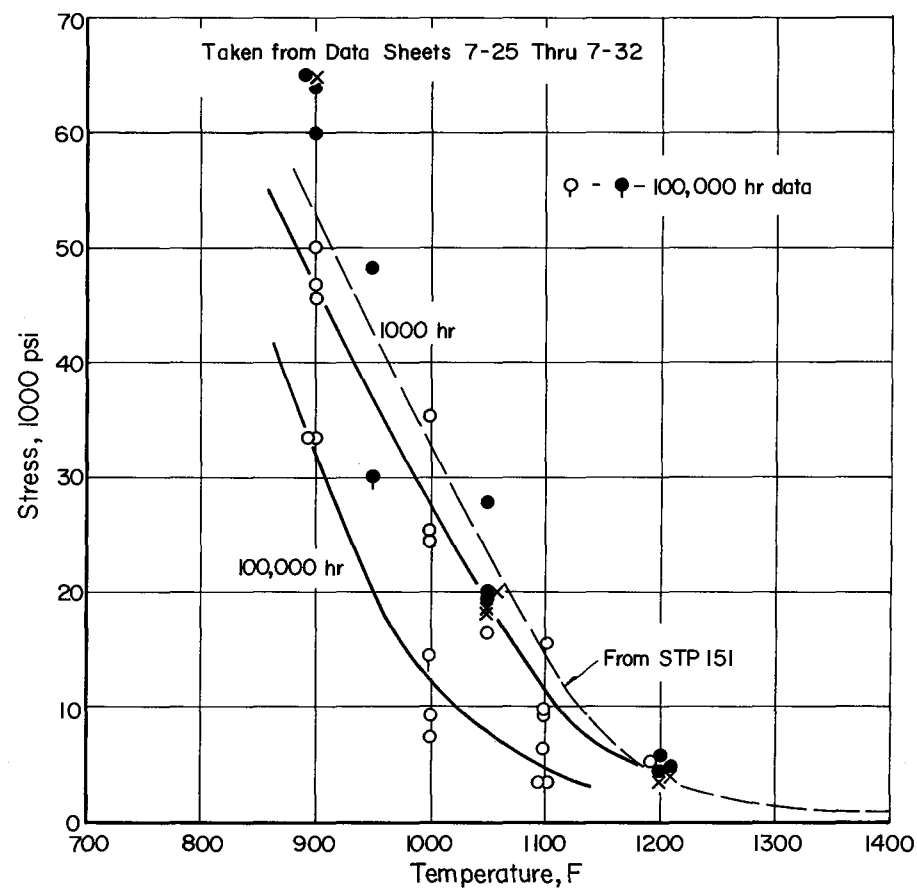


FIGURE 13. STRESS TO RUPTURE IN 1000 AND 100,000 HOURS FOR $\frac{1}{2}\text{Cr}-\frac{1}{2}\text{Mo}$ STEEL

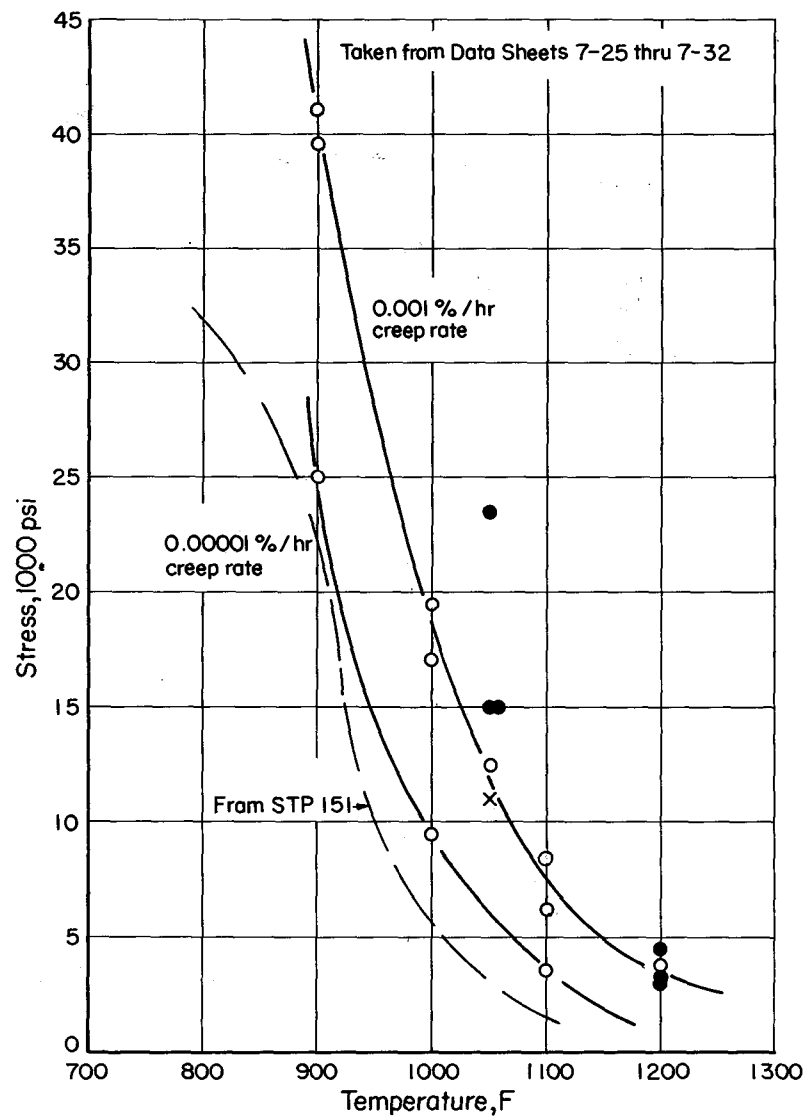


FIGURE 14. STRESSES FOR CREEP RATES OF 0.001 AND 0.00001 % PER HOUR FOR $\frac{1}{2}$ Cr - $\frac{1}{2}$ Mo STEEL

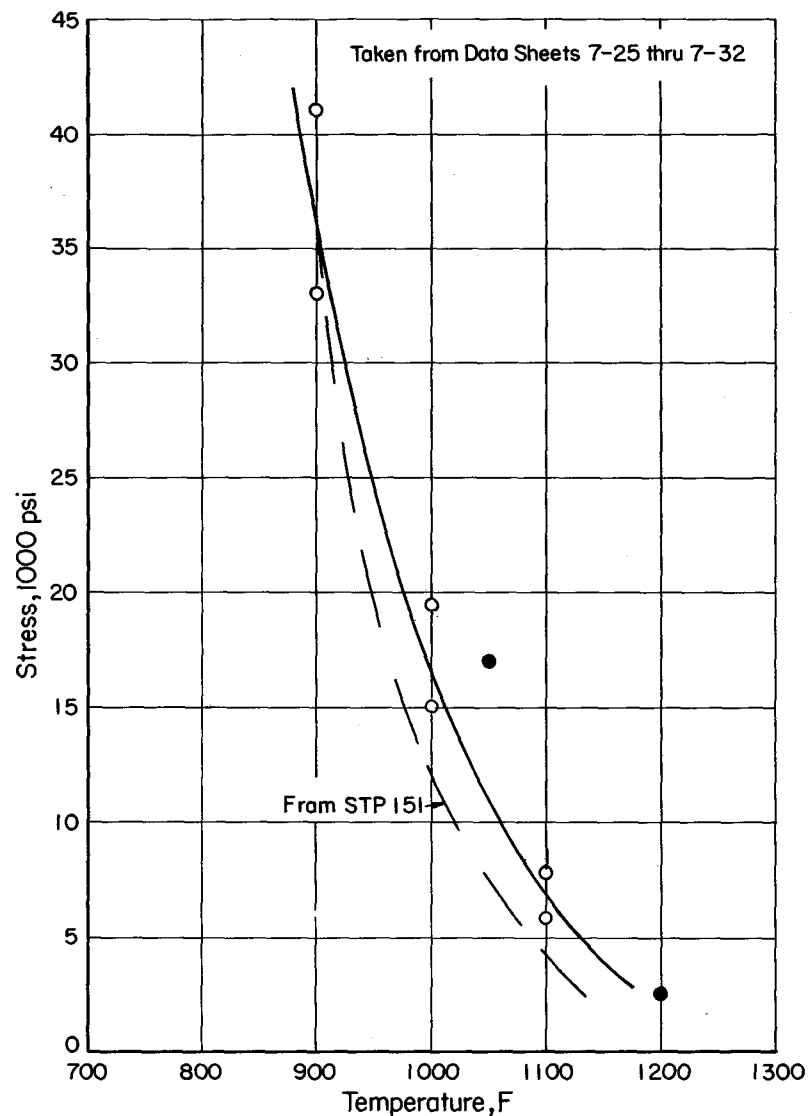


FIGURE 15. STRESSES FOR CREEP RATE OF 0.0001% PER HOUR FOR $\frac{1}{2}$ Cr - $\frac{1}{2}$ Mo STEEL

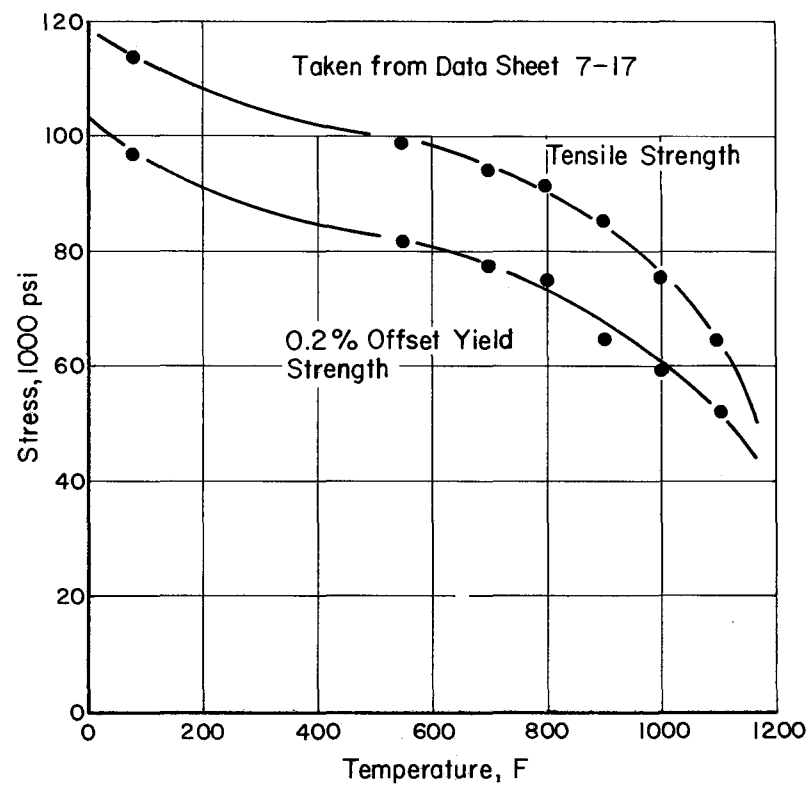


FIGURE 16. TENSILE AND YIELD STRENGTH FOR 1Cr-1Mo+V STEEL

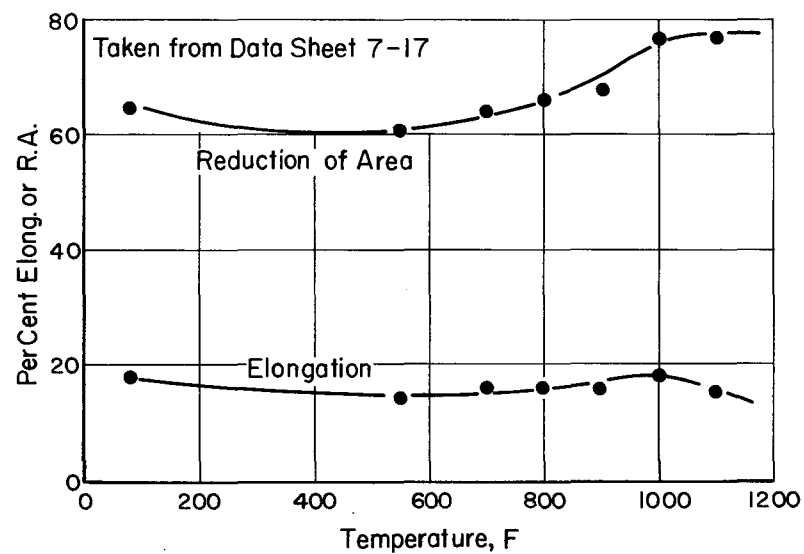


FIGURE 17. ELONGATION AND REDUCTION OF AREA FOR 1Cr-1Mo+V STEEL

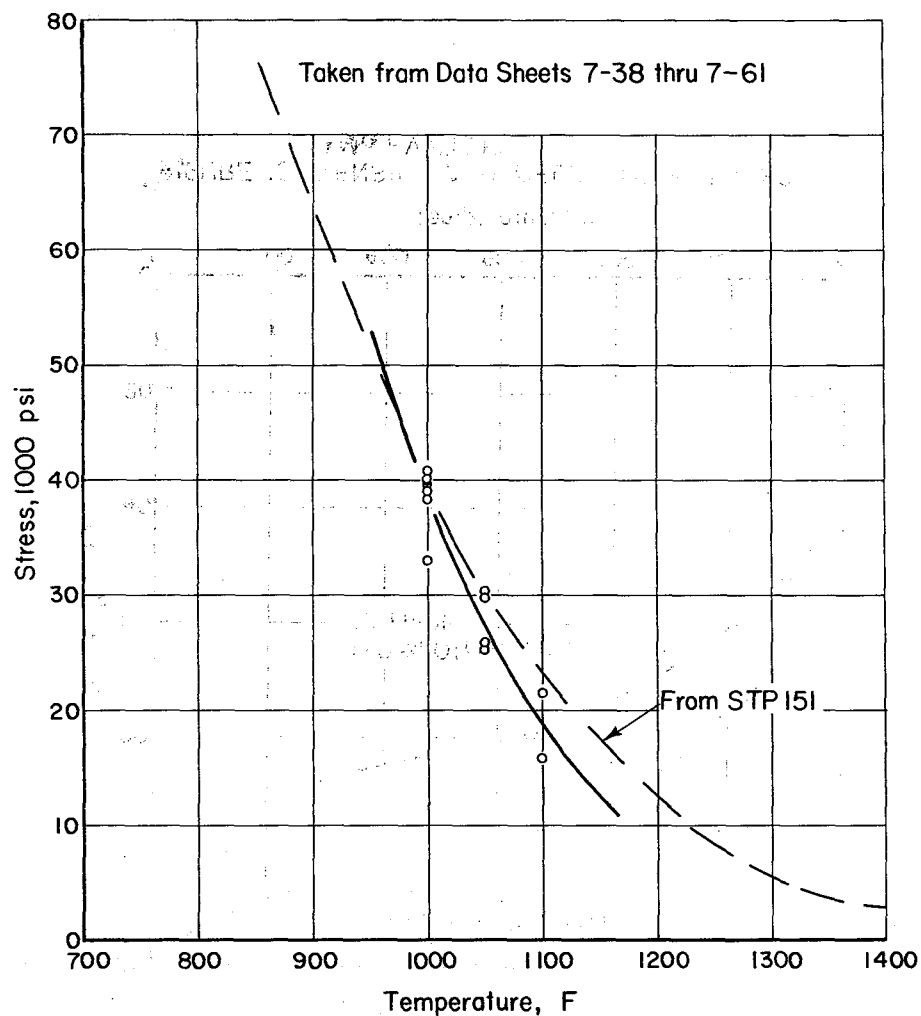


FIGURE 18. STRESS TO RUPTURE IN 100 HOURS FOR $1\frac{1}{4}$ Cr- $\frac{1}{2}$ Mo STEEL

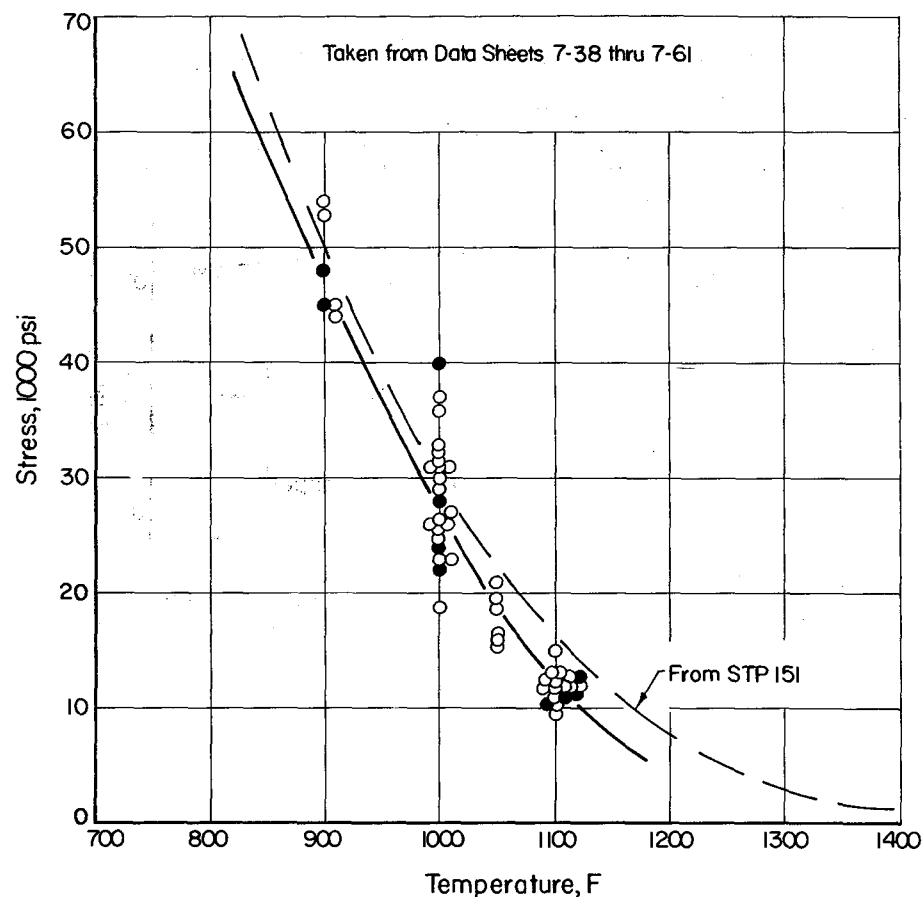


FIGURE 19. STRESS TO RUPTURE IN 1000 HOURS FOR $1\frac{1}{4}$ Cr- $\frac{1}{2}$ Mo STEEL

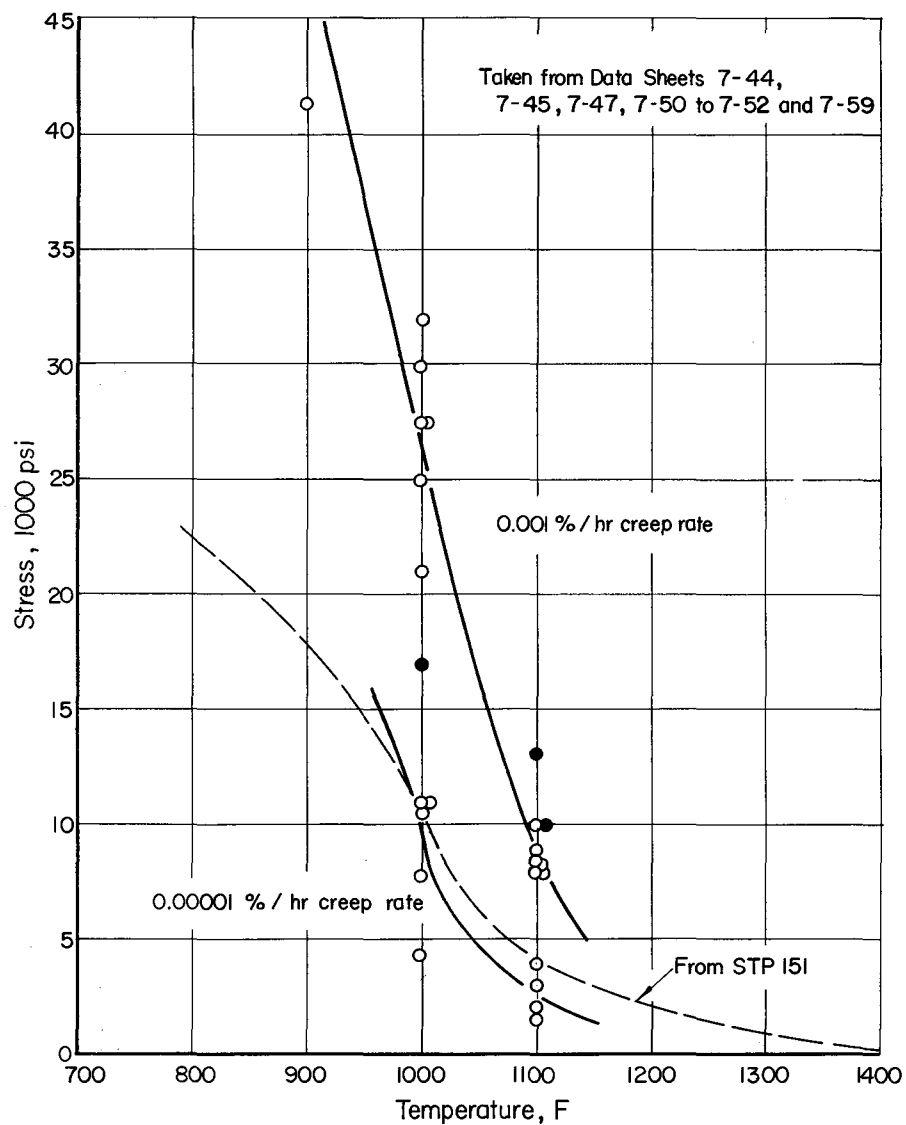


FIGURE 22. STRESSES FOR CREEP RATES OF 0.001 AND 0.00001 % PER HOUR FOR 1 1/4 Cr - 1/2 Mo STEEL

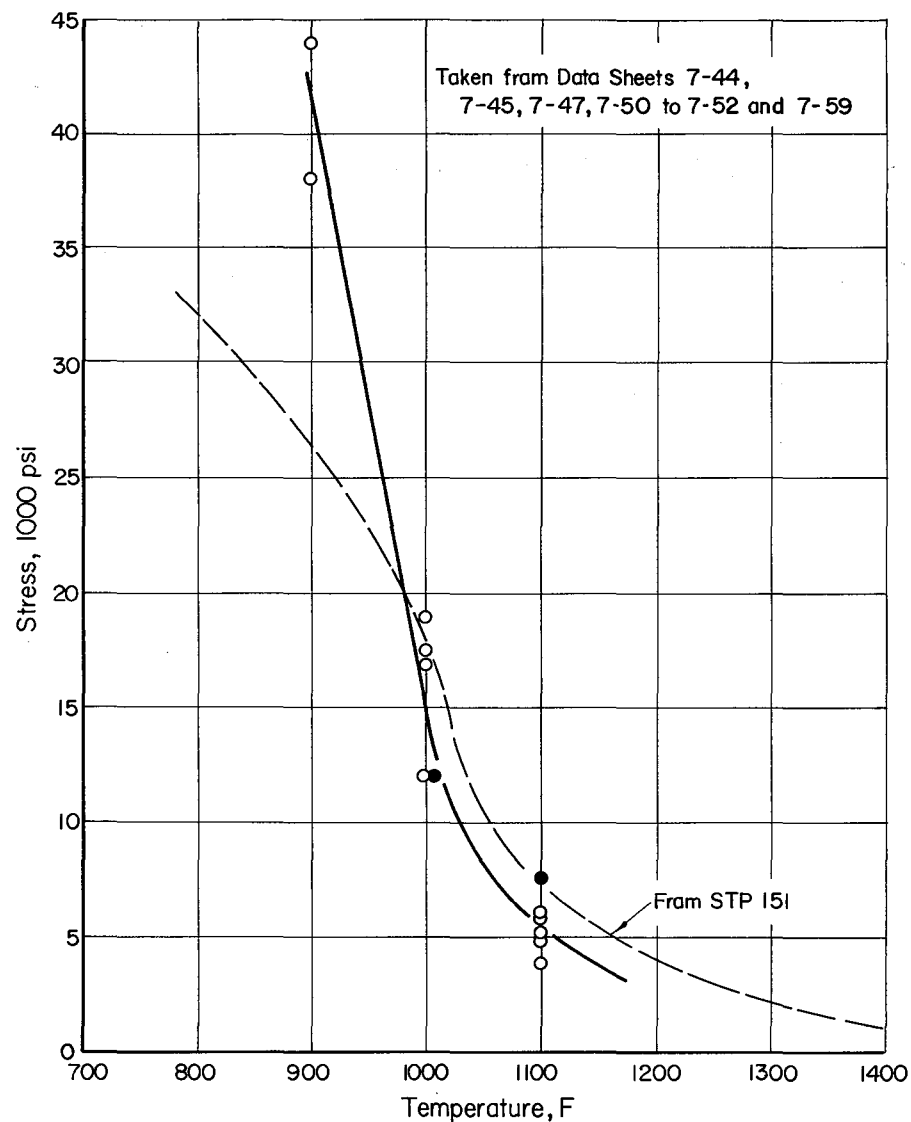


FIGURE 23. STRESSES FOR CREEP RATE OF 0.0001 % PER HOUR FOR 1 1/4 Cr - 1/2 Mo STEEL

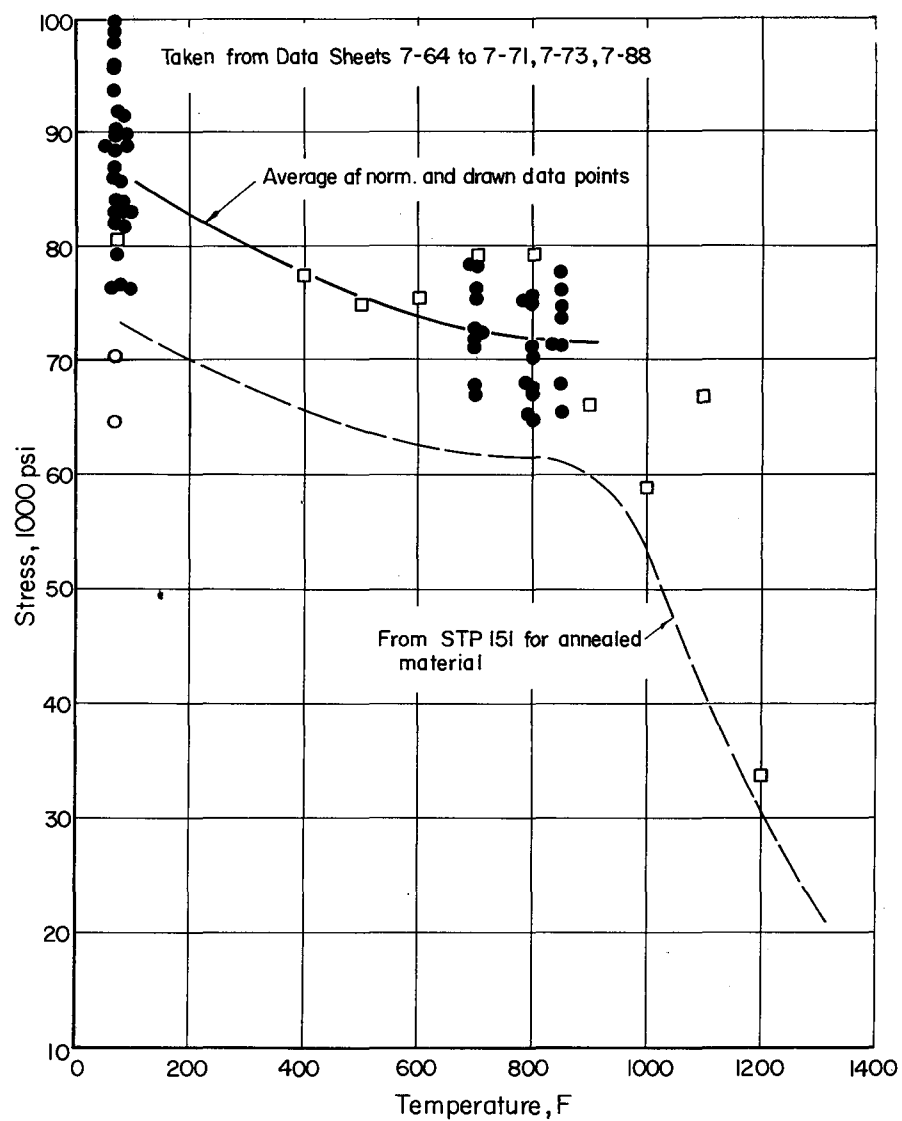


FIGURE 24. TENSILE DATA FOR 2 1/4 Cr-1 Mo STEEL

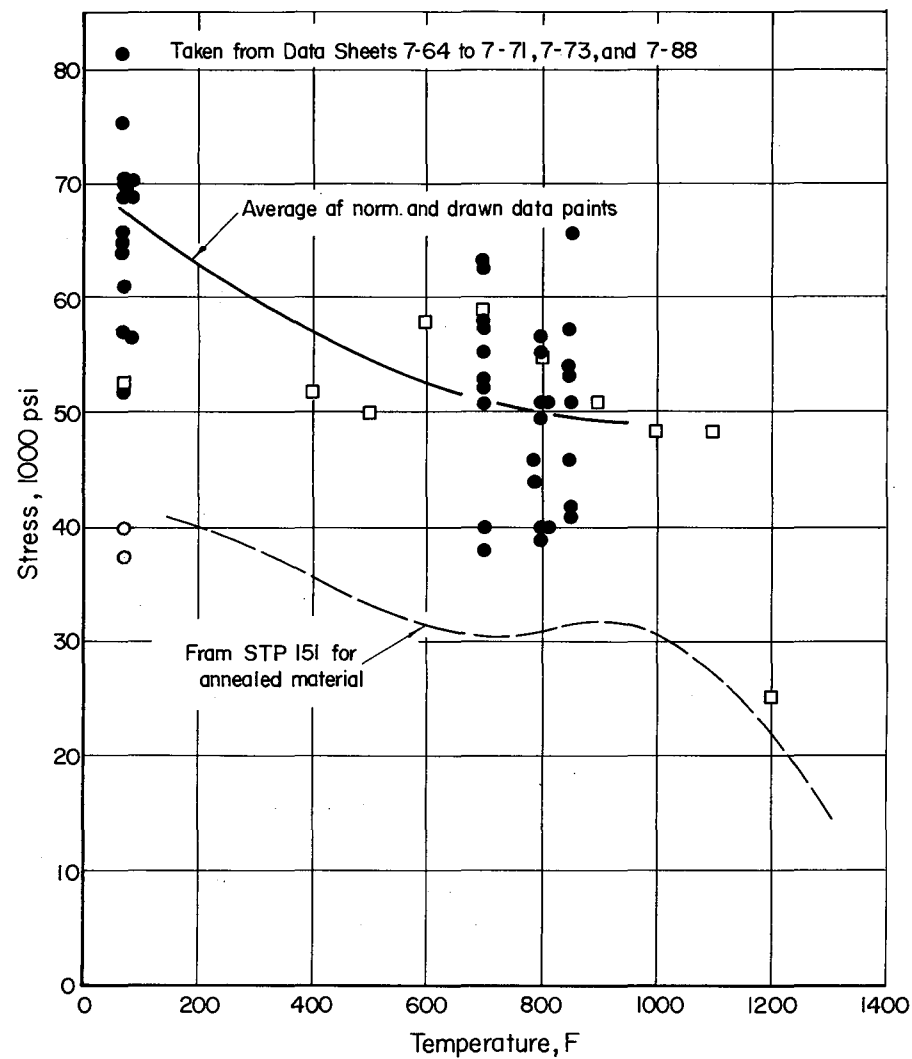
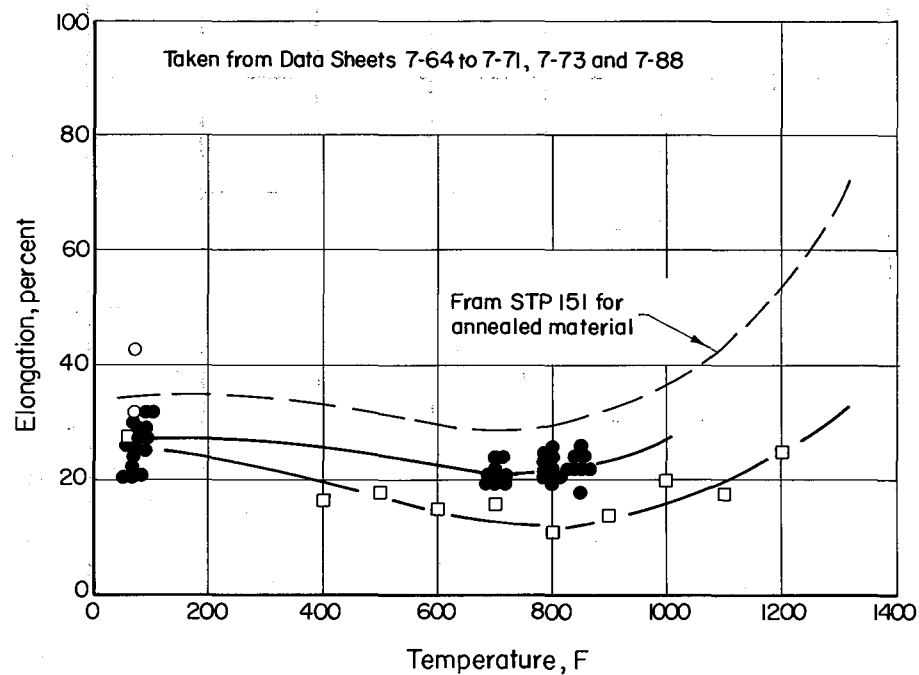
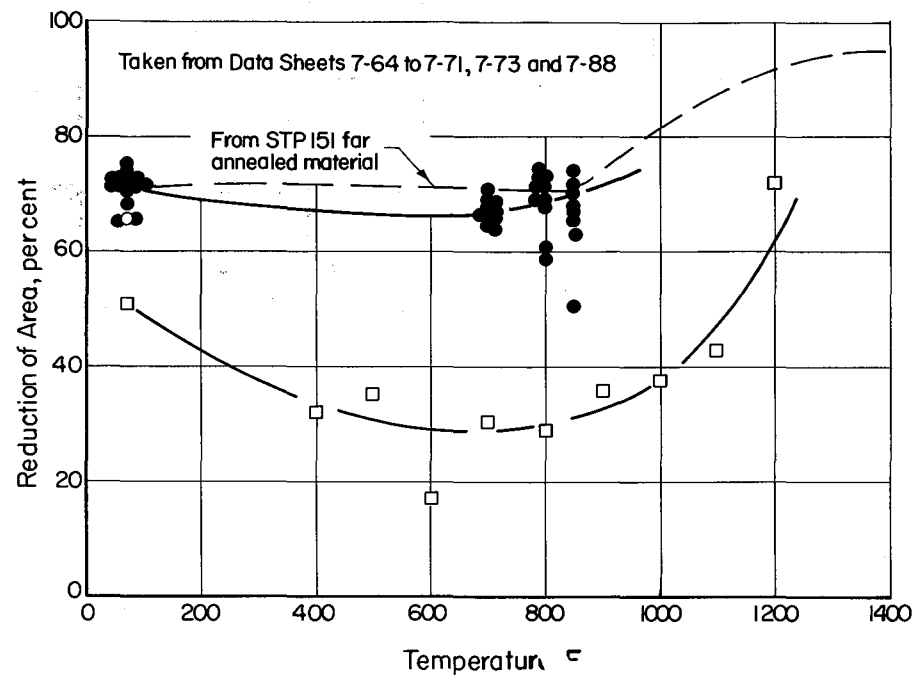


FIGURE 25. YIELD STRENGTH (0.2% OFFSET) DATA FOR 2 1/4 Cr-1 Mo STEEL

FIGURE 26. ELONGATION DATA FOR $2\frac{1}{4}$ Cr-1Mo STEELFIGURE 27. REDUCTION OF AREA DATA FOR $2\frac{1}{4}$ Cr-1Mo STEEL

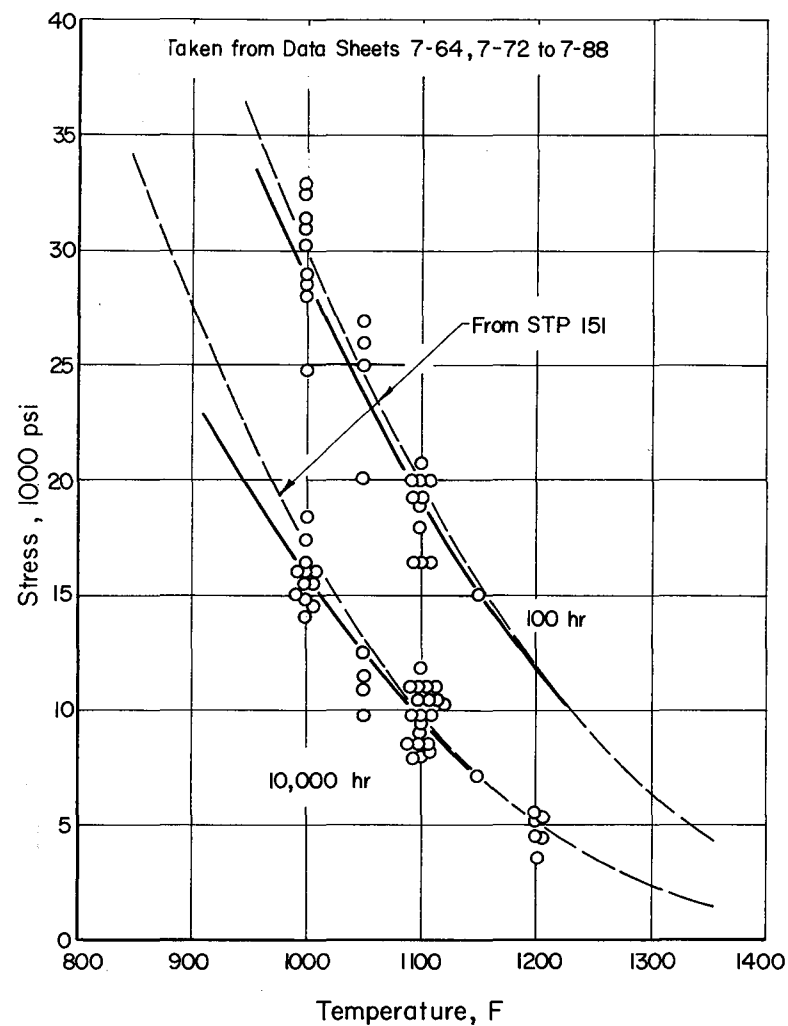


FIGURE 28. STRESS TO RUPTURE IN 100 AND 10,000 HOURS FOR 2 1/4 Cr-1Mo STEEL

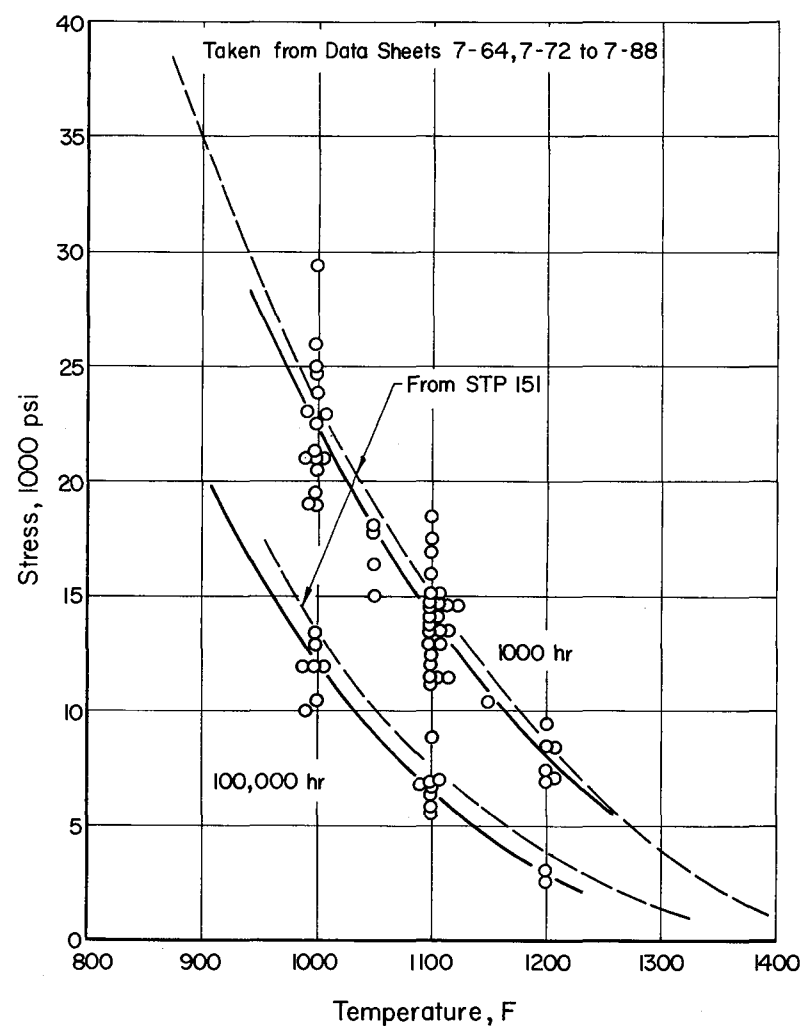


FIGURE 29. STRESS TO RUPTURE IN 1000 AND 100,000 HOURS FOR 2 1/4 Cr-1Mo STEEL

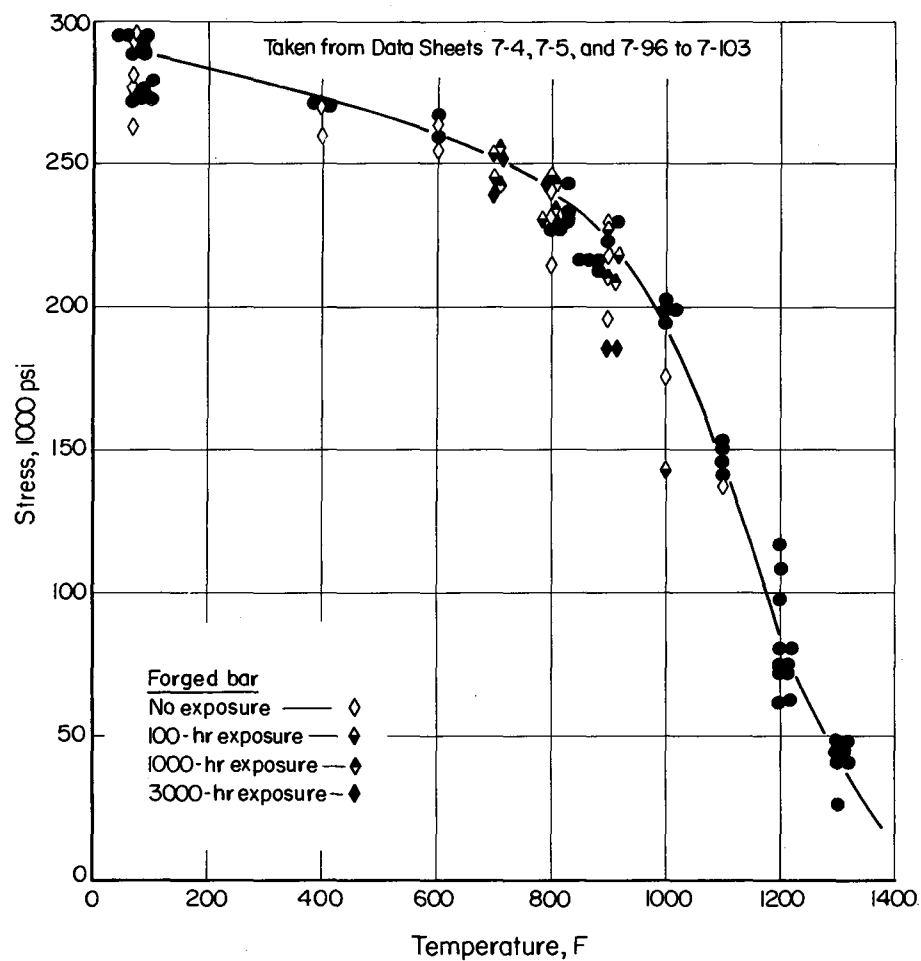


FIGURE 30. TENSILE STRENGTH OF 5Cr- $\frac{1}{4}$ Mo- $\frac{1}{2}$ V STEEL (H-11)

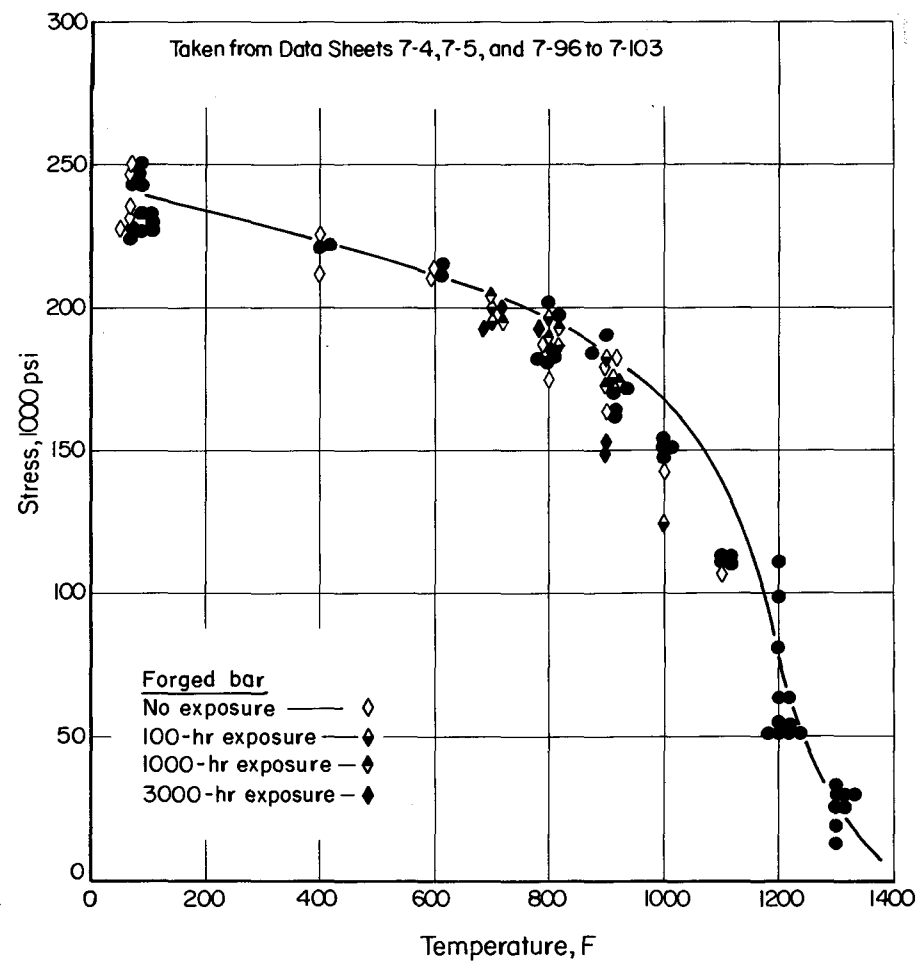


FIGURE 31. YIELD STRENGTH (0.2% OFFSET) OF 5Cr- $\frac{1}{4}$ Mo- $\frac{1}{2}$ V STEEL (H-11)

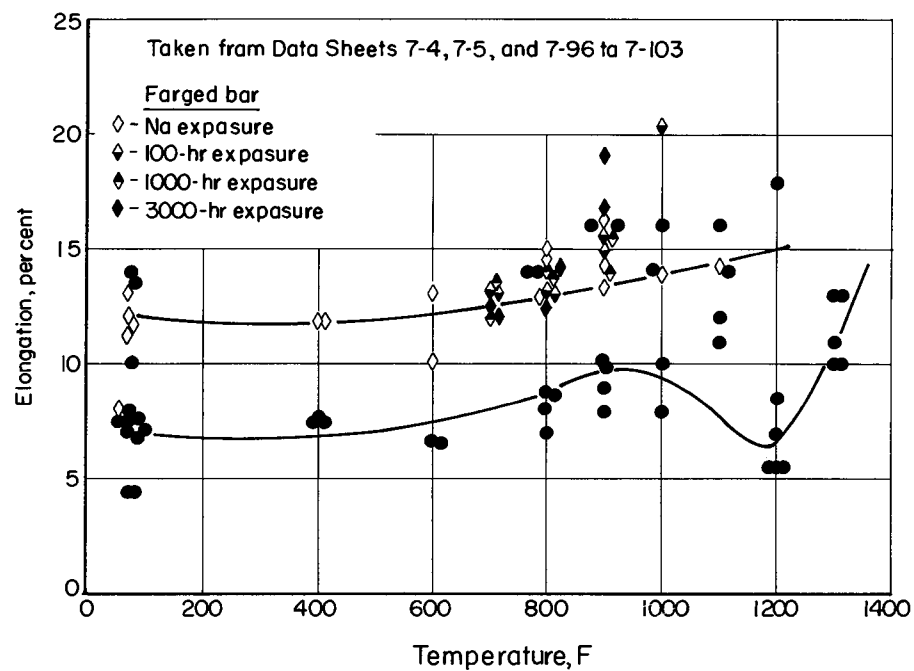


FIGURE 32. ELONGATION OF 5Cr-1 1/4 Mo-1/2 V STEEL (H-II)

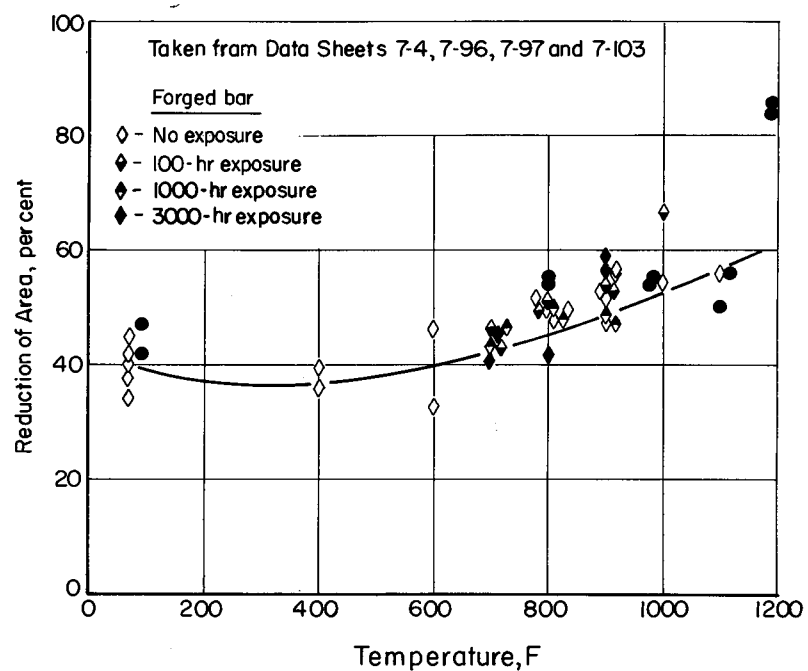


FIGURE 33. REDUCTION OF AREA OF 5Cr-1 1/4 Mo-1/2 V STEEL (H-II)

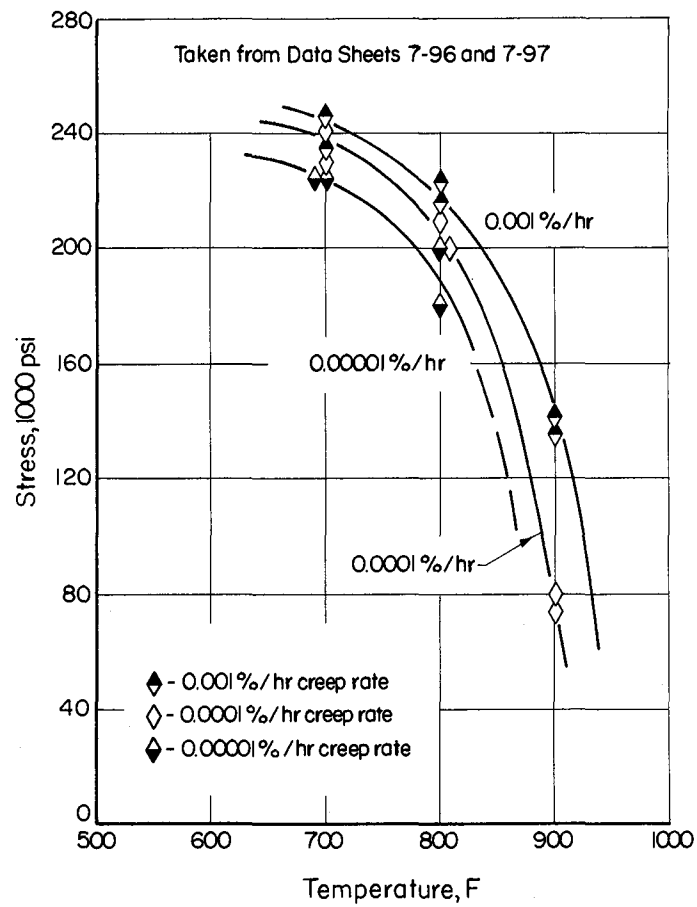


FIGURE 34. CREEP RATES FOR 5Cr, 1¼ Mo-½ V STEEL (H-II)

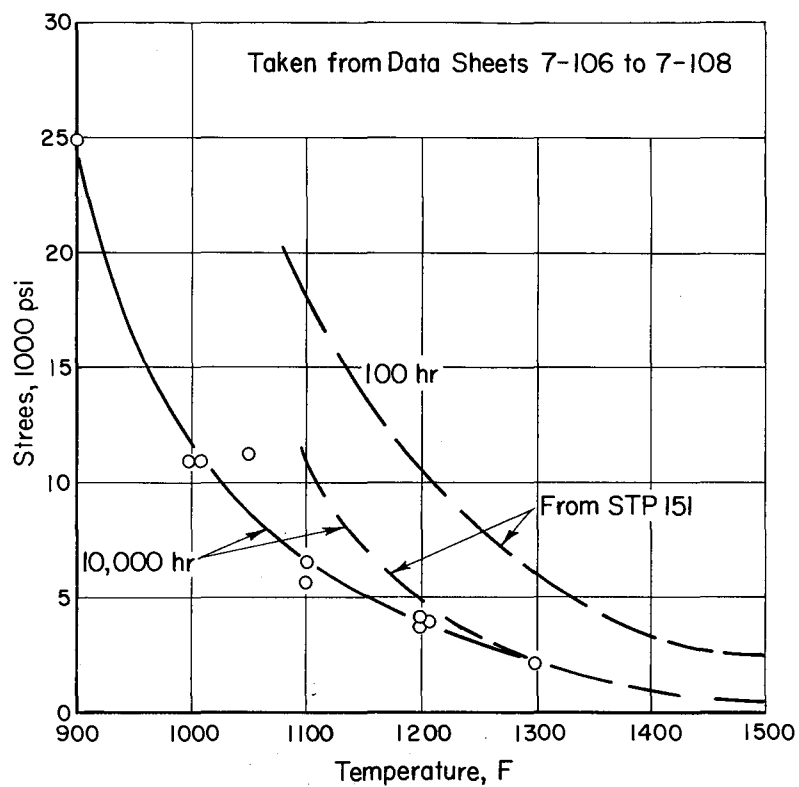


FIGURE 35. STRESS TO RUPTURE IN 100 AND 10,000 HOURS FOR 7Cr - $\frac{1}{2}$ Mo STEEL

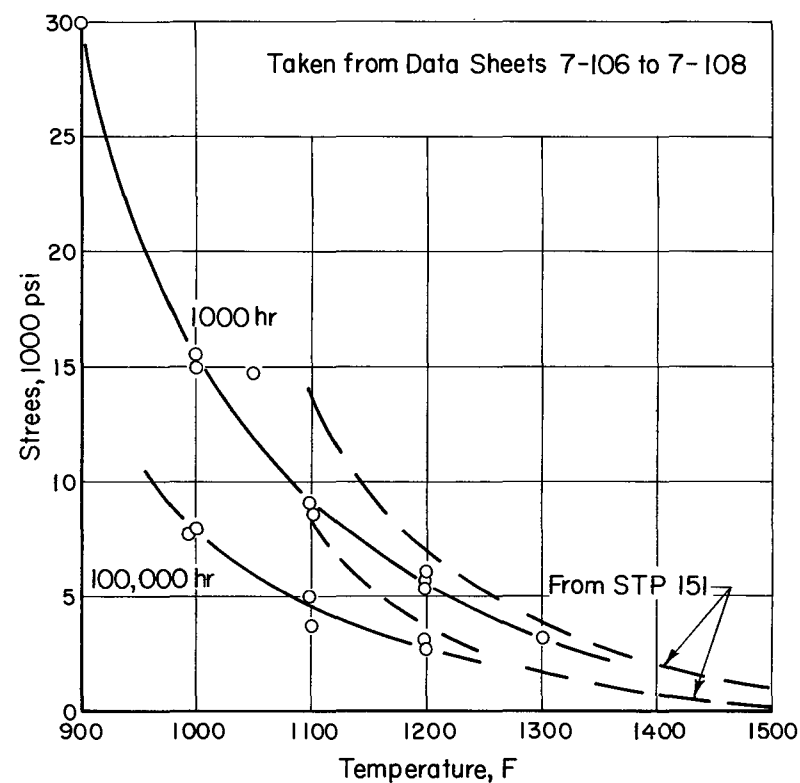


FIGURE 36. STRESS TO RUPTURE IN 1000 AND 100,000 HOURS FOR 7Cr - $\frac{1}{2}$ Mo STEEL

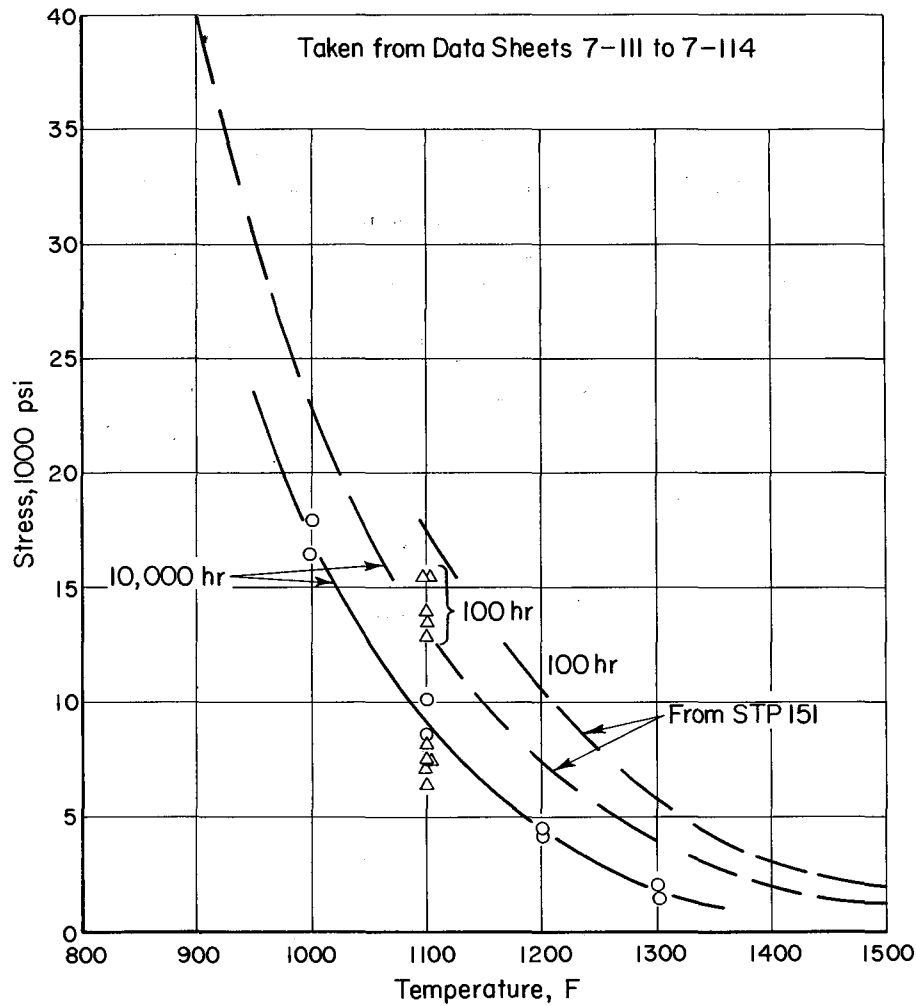


FIGURE 37. STRESS TO RUPTURE IN 100 AND 10,000 HOURS FOR 9 Cr - 1 Mo STEEL

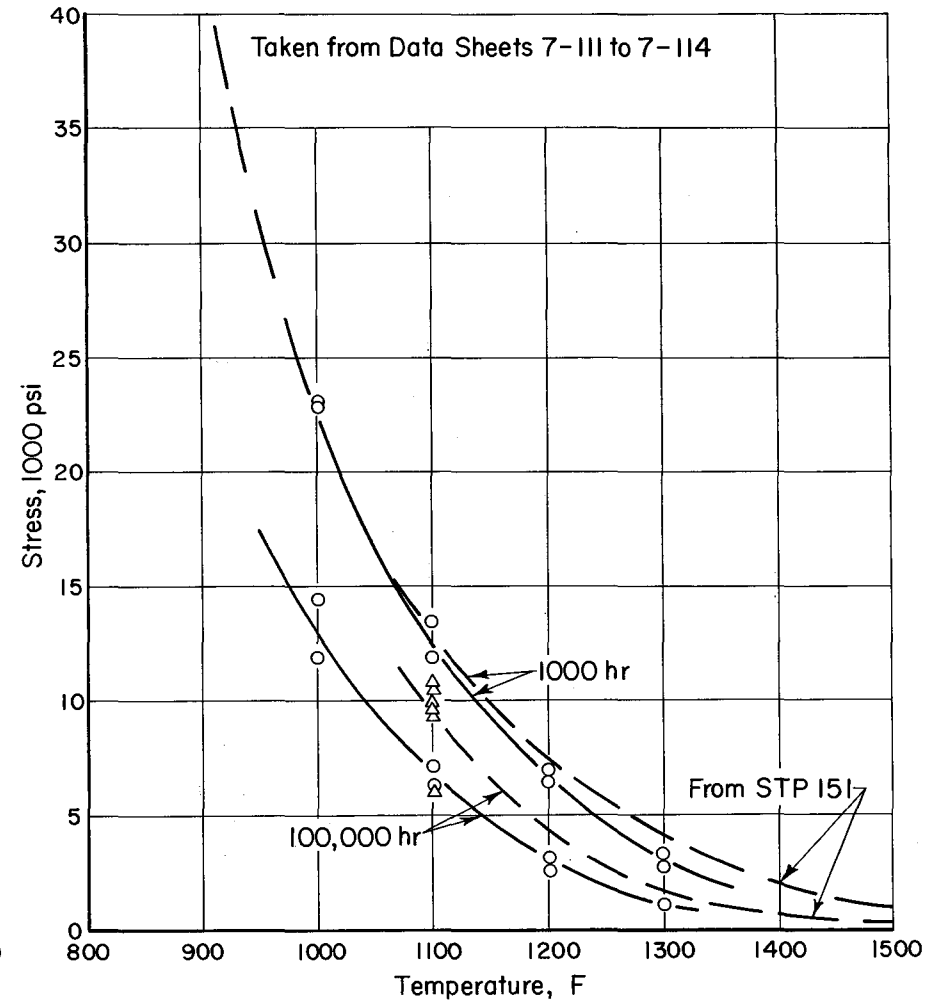


FIGURE 38. STRESS TO RUPTURE IN 1000 AND 100,000 HOURS FOR 9 Cr - 1 Mo STEEL

Data Sheets

ASTM-ASME JOINT COMMITTEE ON EFFECT OF TEMPERATURE ON PROPERTIES OF METALS 7-3

MATERIAL Alloy Steel
ALLOY Jaltan No. 1
PRODUCER Jones and Laughlin Steel Corporation
SPECIFICATIONS V-4410

TYPE OF HEATING Open Hearth
SIZE OF HEAT 250 tons

CHEMICAL COMPOSITION, PER CENT

C	Mn	P	S	Si	Cr	Ni	Co	Mo	W	Cu	Ti	Al	V	B
0.10	0.71	0.008	0.020	0.05								0.036	0.034	
0.15														

DEoxidation Aluminum killed - vanadium addition
FORM & SIZE: BAR SHEET, CASTINGS, ETC. 0.120" thick sheet
HISTORY OF MATERIAL Hot rolled

HEAT TREATMENT As rolled

MICROSTRUCTURE

GRAIN SIZE

HARDNESS

SOURCE OF DATA J & L Research Report No. 598-54

TEMPERATURE F	ELASTIC MODULUS (10 ⁶ PSI)	TENSILE STRENGTH KSI	YIELD STRENGTH, KSI			ELONGATION IN 2" PER CENT	REDUCTION IN AREA PER CENT	Miscellaneous Data						
			0.02%	0.1%	0.2%			Temp. F	Tensile Strength ksi	Approximate Proportional Limit	Elongation in 2" %	Reduc in A %		
82		59.2	42.2			35.0	69.0							
140		57.0	40.9			35.0	66.5	1200	19.1	15.9	34.0	44.5		
205		53.8	38.5			29.5	64.5	1300	13.9	11.8	36.0	48.0		
300		52.1	36.6	Approximate		27.0	62.5	1400	9.7	8.0	45.0	54.0		
400		52.0	32.2	Proportional		24.5	64.0							
500		54.1	30.2	Limit		24.5	57.0							
600		54.4				31.0	57.0							
700		51.0				36.0	61.0							
800		47.3				32.0	64.5							
900		39.3				29.0	68.5							
1000		32.5				29.5	59.0							
1100		25.4				33.0	48.0							

(continued at right)

ORIGINAL CREEP AND RUPTURE DATA
(RUPTURE TIME INDICATED BY R IN TEST DURATION COLUMN)

TEMPERATURE F	STRESS KSI	TIME HOURS FOR TOTAL OR PLASTIC STRAIN (DELETE ONE)				MINIMUM CREEP RATE %/HR	INTERCEPT %	TRANSITION TO THIRD STAGE CREEP		TEST DURATION HOURS R	FINAL EXTENSION OR ELONGATION %
		0.1%	0.2%	0.5%	1.0%			HOURS	%		
Normalized 1800 F, tempered 1250 F											
900	40					--				0.15	47
900	35					8.30				2.2	42
1100	25					--				0.1	23
1100	20					13.30				1.5	49
1100	15					0.40				31.0	35
1100	10					0.048				280.8	26
Normalized 1800 F											
900	70					--				<0.01	45
900	40					1.7				10.8	45
900	35					0.21				83.6	38
1100	32					--				<0.01	46
1100	25					43.0				0.8	47
1100	20					3.6				4.6	46
1100	15					0.42				34.9	43
1100	10					0.021				484.0	24

ASTM-ASME JOINT COMMITTEE ON EFFECT OF TEMPERATURE ON PROPERTIES OF METALS 7-9b

MATERIAL Alloy Steel
ALLOY 0.2V Steel
PRODUCER U. S. Naval Research Laboratory
SPECIFICATIONS

TYPE OF HEATING Induction
SIZE OF HEAT 100 lb

CHEMICAL COMPOSITION, PER CENT

C	Mn	P	S	Si	Cr	Ni	Co	Mo	W	Cu	Ti	Al	V	B
0.20	0.53			0.25									0.20	

DEoxidation Al 1 lb/ton
FORM & SIZE: BAR SHEET, CASTINGS, ETC. Bar
HISTORY OF MATERIAL Forged at 2150 F

HEAT TREATMENT 1. Normalized 1950 F, tempered 1250 for 6 hr. 2. Normalized 2000 F, tempered 1250 F for 6 hr

MICROSTRUCTURE Normalized 1950 F, tempered 1250 F - ASTM 6

GRAIN SIZE

HARDNESS

SOURCE OF DATA U. S. Naval Research Laboratory

TEMPERATURE F	ELASTIC MODULUS (10 ⁶ PSI)	TENSILE STRENGTH KSI	YIELD STRENGTH, KSI			ELONGATION IN 2" PER CENT	REDUCTION IN AREA PER CENT	Miscellaneous Data						
			0.02%	0.1%	0.2%			Temp. F	Tensile Strength ksi	Approximate Proportional Limit	Elongation in 2" %	Reduc in A %		
80		70				48	33	70						

ORIGINAL CREEP AND RUPTURE DATA
(RUPTURE TIME INDICATED BY R IN TEST DURATION COLUMN)

TEMPERATURE F	STRESS KSI	TIME HOURS FOR TOTAL OR PLASTIC STRAIN (DELETE ONE)				MINIMUM CREEP RATE %/HR	INTERCEPT %	TRANSITION TO THIRD STAGE CREEP		TEST DURATION HOURS R	FINAL EXTENSION OR ELONGATION %
		0.1%	0.2%	0.5%	1.0%			HOURS	%		
Normalized 1950 F, tempered 1250 F											
900	45					--				0.03	42
900	35					2.9				5.5	42
900	32					0.5				30.9	35
1100	32					--				0.02	46
1100	25					--				0.3	51
1100	20					0.57				19.2	35
Normalized 2000 F, tempered 1250 F											
900	35					--				31.7	44
900	35					0.77				19.0	41
900	30					0.038				343.2	38
1100	32					--				0.03	37
1100	25					4.6				2.3	31
1100	20					0.45				22.4	39

CREEP AND RUPTURE STRENGTHS

TEMPERATURE F	STRESS, KSI FOR RUPTURE IN TIMES INDICATED					STRESS, KSI FOR DESIGNATED CREEP RATE			
	10 HRS	100 HRS	1,000 HRS	10,000 HRS	100,000 HRS	0.0001 %/HR	0.0005 %/HR	0.001 %/HR	0.01 %/HR
Normalized 1950 F, tempered 1250 F									
900	27	--							
1100	18.5	--							
Normalized 2000 F, tempered 1250 F									
900	32	28							
1100	17.5	--							

ASTM-ASME JOINT COMMITTEE ON EFFECT OF TEMPERATURE ON PROPERTIES OF METALS 7-9a

MATERIAL Alloy Steel
ALLOY 0.2V Steel
PRODUCER U. S. Naval Research Laboratory
SPECIFICATIONS

TYPE OF HEATING Induction
SIZE OF HEAT 100 lb

CHEMICAL COMPOSITION, PER CENT

C	Mn	P	S	Si	Cr	Ni	Co	Mo	W	Cu	Ti	Al	V	B
0.20	0.53			0.25									0.20	

DEoxidation Al 1 lb/ton
FORM & SIZE: BAR SHEET, CASTINGS, ETC. Bar
HISTORY OF MATERIAL Forged at 2150 F

HEAT TREATMENT 1. Normalized 1800 F, tempered 1250 F for 6 hr. 2. Normalized 1800 F

MICROSTRUCTURE Normalized 1800 F, tempered 1250 F - ASTM 8

GRAIN SIZE

HARDNESS

SOURCE OF DATA U. S. Naval Research Laboratory

TEMPERATURE F	ELASTIC MODULUS (10 ⁶ PSI)	TENSILE STRENGTH KSI	YIELD STRENGTH, KSI			ELONGATION IN 2" PER CENT	REDUCTION IN AREA PER CENT	Miscellaneous Data						
			0.02%	0.1%	0.2%			Temp. F	Tensile Strength ksi	Approximate Proportional Limit	Elongation in 2" %	Reduc in A %		
80		68				54	41	73						

CREEP AND RUPTURE STRENGTHS

TEMPERATURE F	STRESS, KSI FOR RUPTURE IN TIMES INDICATED					STRESS, KSI FOR DESIGNATED CREEP RATE			
	10 HRS	100 HRS	1,000 HRS	10,000 HRS	100,000 HRS	0.0001 %/HR	0.0005 %/HR	0.001 %/HR	0.01 %/HR
Normalized 1800 F, tempered 1250 F									
900	29	--							
1100	12	8							
Normalized 1800 F									
900	34.5	30							
1100	12.5	9							

ASTM-ASME JOINT COMMITTEE ON EFFECT OF TEMPERATURE ON PROPERTIES OF METALS
7-8a

MATERIAL Alloy Steel
ALLOY Mo-V Steel
PRODUCER U. S. Naval Research Laboratory

TYPE OF HEATING Induction
SIZE OF HEAT 100 lb

CHEMICAL COMPOSITION, PER CENT

C	Mn	P	S	Si	Ca	Ni	Co	Mo	W	Cu	Ti	Al	V	B
0.17	0.46			0.19				0.30					0.18	
Cu	Fe													

DEOXYGENATION All lb/ton
FORM & SIZE: BAR SHEET, CASTINGS, ETC. Bar
HISTORY OF MATERIAL Forged at 2150 F

HEAT TREATMENT 1. Normalized 1800 F, tempered 1250 F for 6 hr; 2. Normalized 1800 F

MICROSTRUCTURE Normalized 1800 F, tempered 1250 F - ASTM 7

GRAIN SIZE
HARDNESS

SOURCE OF DATA U. S. Naval Research Laboratory

SHORT TIME TENSILE PROPERTIES

TEMPERATURE F	ELASTIC MODULUS (10 ⁶ PSI)	TENSILE STRENGTH KSI	YIELD STRENGTH KSI	ELONGATION IN 2" PER CENT	REDUCTION IN AREA PER CENT	MISCELLANEOUS DATA
Normalized 1800 F, tempered 1250 F						
80	110		94	23	62	

ORIGINAL CREEP AND RUPTURE DATA
(RUPTURE TIME INDICATED BY R IN TEST DURATION COLUMN)

TEMPERATURE F	STRESS KSI	TIME, HOURS, FOR TOTAL OR PLASTIC STRAIN (DELETE ONE)				MINIMUM CREEP RATE %/HR	INTERCEPT %	TRANSITION TO THIRD STAGE CREEP		TEST DURATION HOURS	FINAL ELONGATION OR ELONGATION %
		0.1%	0.2%	0.5%	1.0%			HOURS	%		
Normalized 1950 F, tempered 1250 F											
900	65					6.9				0.8	19
900	60					0.02				259.9	21
1100	40					0.47				8.5	9
1100	32					0.024				68.1	5
1100	25					0.0025				269.8	3
1100	20					0.0014				591.1	2
900	70					--				0.08	19
900	65					0.96				8.5	24
1100	40					0.031				47.0	4
1100	32					0.0056				145.1	3

CREEP AND RUPTURE STRENGTHS

TEMPERATURE F	STRESS, KSI FOR RUPTURE IN TIMES INDICATED					STRESS, KSI FOR DESIGNATED CREEP RATE			
	10 HRS	100 HRS	1,000 HRS	10,000 HRS	100,000 HRS	0.0001%/HR	0.0005%/HR	0.001%/HR	0.01%/HR
Normalized 1950 F, tempered 1250 F									
900	61	59							
1100	30.5	17							16
Normalized 2000 F, tempered 1250 F									
900	62	--							
1100	34	22							25.5

ASTM-ASME JOINT COMMITTEE ON EFFECT OF TEMPERATURE ON PROPERTIES OF METALS
7-10a

MATERIAL Alloy Steel
ALLOY Mo-V Steel
PRODUCER U. S. Naval Research Laboratory

TYPE OF HEATING Induction
SIZE OF HEAT 100 lb

CHEMICAL COMPOSITION, PER CENT

C	Mn	P	S	Si	Ca	Ni	Co	Mo	W	Cu	Ti	Al	V	B
0.23	0.60			0.34				0.29					0.48	
Cu	Fe													

DEOXYGENATION All lb/ton
FORM & SIZE: BAR SHEET, CASTINGS, ETC. Bar
HISTORY OF MATERIAL Forged at 2150 F

HEAT TREATMENT 1. Normalized 1800 F, tempered 1250 F for 6 hr; 2. Normalized 1800 F

MICROSTRUCTURE Normalized 1800 F, tempered 1250 F - ASTM 8

GRAIN SIZE
HARDNESS

SOURCE OF DATA U. S. Naval Research Laboratory

SHORT TIME TENSILE PROPERTIES

TEMPERATURE F	ELASTIC MODULUS (10 ⁶ PSI)	TENSILE STRENGTH KSI	YIELD STRENGTH KSI	ELONGATION IN 2" PER CENT	REDUCTION IN AREA PER CENT	MISCELLANEOUS DATA
Normalized 1800 F, tempered 1250 F						
80	84		67	30	73	

CREEP AND RUPTURE STRENGTHS

TEMPERATURE F	STRESS, KSI FOR RUPTURE IN TIMES INDICATED					STRESS, KSI FOR DESIGNATED CREEP RATE			
	10 HRS	100 HRS	1,000 HRS	10,000 HRS	100,000 HRS	0.0001%/HR	0.0005%/HR	0.001%/HR	0.01%/HR
Normalized 1800 F, tempered 1250 F									
900	42.5	38.5							
1100	22	17							14
Normalized 1800 F									
900	43	40							40
1100	26	15.5							12.5

ASTM-ASME JOINT COMMITTEE ON EFFECT OF TEMPERATURE ON PROPERTIES OF METALS
7-8b

MATERIAL Alloy Steel
ALLOY Mo-V Steel
PRODUCER U. S. Naval Research Laboratory

TYPE OF HEATING Induction
SIZE OF HEAT 100 lb

CHEMICAL COMPOSITION, PER CENT

C	Mn	P	S	Si	Ca	Ni	Co	Mo	W	Cu	Ti	Al	V	B
0.17	0.46			0.19				0.30					0.18	
Cu	Fe													

DEOXYGENATION All lb/ton
FORM & SIZE: BAR SHEET, CASTINGS, ETC. Bar
HISTORY OF MATERIAL Forged at 2150 F

HEAT TREATMENT 1. Normalized 1950 F, tempered 1250 F for 6 hr; 2. Normalized 2000 F, tempered 1250 F for 6 hr

MICROSTRUCTURE Normalized 1950 F, tempered 1250 F - ASTM 6

GRAIN SIZE
HARDNESS

SOURCE OF DATA U. S. Naval Research Laboratory

SHORT TIME TENSILE PROPERTIES

TEMPERATURE F	ELASTIC MODULUS (10 ⁶ PSI)	TENSILE STRENGTH KSI	YIELD STRENGTH KSI	ELONGATION IN 2" PER CENT	REDUCTION IN AREA PER CENT	MISCELLANEOUS DATA
Normalized 1950 F, tempered 1250 F						
80	101		77.5	23	60	

ORIGINAL CREEP AND RUPTURE DATA (RUPTURE TIME INDICATED BY R IN TEST DURATION COLUMN)											
TEMPERATURE F	STRESS KSI	TIME HOURS, FOR TOTAL OR PLASTIC STRAIN (DELETE ONE)				MINIMUM CREEP RATE %/HR	INTERCEPT %	TRANSITION TO THIRD STAGE CREEP		TEST DURATION HOURS	FINAL EXTENSION ELONGATION %
		0.1%	0.2%	0.5%	1.0%			HOURS	%		
Normalized 1800 F, tempered 1250 F											
900	50					4.1				2.6 R	30
900	50					4.9				2.2 R	30
900	45					0.87				16.5 R	36
900	40					0.036				436.6 R	38
1100	32					18.2				1.0 R	36
1100	32					15.6				0.9 R	38
1100	25					0.5				21.3 R	27
1100	25					1.02				17.3 R	46
1100	20					0.025				316.1 R	24
1100	18					0.0087				720.0 R	21
1100	15					0.0026				1920.5 R	24
Normalized 1800 F											
900	60					--				0.1 R	31
900	40					0.00065				1200+	3
1100	32					0.23				30.4 R	30
1100	25					0.056				130.3 R	28
1100	20					0.0163				376.8 R	37
1100	15					0.0032				1133.0 R	21

TEMPERATURE F	STRESS, KSI FOR RUPTURE IN TIMES INDICATED					STRESS, KSI FOR DESIGNATED CREEP RATE			
	10 HRS	100 HRS	1,000 HRS	10,000 HRS	100,000 HRS	0.00001%/HR	0.00005%/HR	0.001%/HR	0.005%/HR
Normalized 1950 F, tempered 1250 F									
900	50	47							--
1100	28.5	22							20.5
Normalized 2000 F, tempered 1250 F									
900	49	--							--
1100	33	28.5							27.5

ASTM-ASME JOINT COMMITTEE ON EFFECT OF TEMPERATURE ON PROPERTIES OF METALS															7-6a	
MATERIAL Alloy Steel DATA AND PUBLICATIONS PANEL DATA SHEET																
ALLOY 0.5Mo Steel TYPE OF HEATING Induction SIZE OF HEAT 100 lb																
PRODUCER U. S. Naval Research Laboratory																
SPECIFICATIONS:																
CHEMICAL COMPOSITION, PER CENT																
C	Mn	P	S	Si	Cr	Ni	Co	Mo	W	Cu	Ti	Al	V	B		
0.22	0.42			0.19				0.54								
Cu	Fe															
DEGRADATION All lb/ton																
FORM & SIZE, BAR, SHEET, CASTINGS, ETC. Bar																
HISTORY OF MATERIAL Forged at 2150 F																
HEAT TREATMENT 1. Normalized 1800 F, tempered 1250 F for 6 hr; 2. Normalized 1800 F																
MICROSTRUCTURE																
GRAIN SIZE Normalized 1800 F, tempered 1250 F - ASTM 5																
HARDNESS																
SOURCE OF DATA U. S. Naval Research Laboratory																
SHORT TIME TENSILE PROPERTIES																
TEMPERATURE	ELASTIC MODULUS (10 ⁶ PSI)	TENSILE STRENGTH (KSI)	YIELD STRENGTH, KSI			ELONGATION IN 2" PER CENT			REDUCTION IN AREA PER CENT			MISCELLANEOUS DATA				
			0.02%	0.1%	0.2%											
Normalized 1800 F, tempered 1250 F																
80		69				46		38		63						

ASTM-ASME JOINT COMMITTEE ON EFFECT OF TEMPERATURE ON PROPERTIES OF METALS															7-10b	
MATERIAL Alloy Steel DATA AND PUBLICATIONS PANEL DATA SHEET																
ALLOY Mo-V Steel TYPE OF HEATING Induction SIZE OF HEAT 100 lb																
PRODUCER U. S. Naval Research Laboratory																
SPECIFICATIONS:																
CHEMICAL COMPOSITION, PER CENT																
C	Mn	P	S	Si	Cr	Ni	Co	Mo	W	Cu	Ti	Al	V	B		
0.23	0.60			0.34				0.29					0.48			
Cu	Fe															
DEGRADATION All lb/ton																
FORM & SIZE, BAR, SHEET, CASTINGS, ETC. Bar																
HISTORY OF MATERIAL Forged at 2150 F																
HEAT TREATMENT 1. Normalized 1950 F, tempered 1250 F for 6 hr; 2. Normalized 2000 F, tempered 1250 F for 6 hr																
MICROSTRUCTURE																
GRAIN SIZE Normalized 1950 F, tempered 1250 F - ASTM 6																
HARDNESS																
SOURCE OF DATA U. S. Naval Research Laboratory																
SHORT TIME TENSILE PROPERTIES																
TEMPERATURE	ELASTIC MODULUS (10 ⁶ PSI)	TENSILE STRENGTH (KSI)	YIELD STRENGTH, KSI			ELONGATION IN 2" PER CENT			REDUCTION IN AREA PER CENT			MISCELLANEOUS DATA				
			0.02%	0.1%	0.2%											
Normalized 1950 F, tempered 1250 F																
80		104				73		25		64						

ORIGINAL CREEP AND RUPTURE DATA (RUPTURE TIME INDICATED BY R IN TEST DURATION COLUMN)											
TEMPERATURE F	STRESS KSI	TIME, HOURS FOR TOTAL OR PLASTIC STRAIN (DELETE ONE)				MINIMUM CREEP RATE %/HR	INTERCEPT %	TRANSITION TO THIRD STAGE CREEP		TEST DURATION HOURS R	FINAL EXTENSION OR ELONGATION %
		0.1%	0.2%	0.5%	1.0%			HOURS	%		
Normalized 1800 F, tempered 1250 F											
900	60					--				<0.01	30
900	58					0.036				210	29
900	55					0.0022				1234	19
900	50					0.0010				2302	8
1100	32					0.75				17.3	29
1100	25					0.04				86.7	12
1100	20					0.0086				243.4	10
1100	15					0.0023				677.7	13
Normalized 1800 F											
1100	32					0.19				26.6	14
1100	25					0.015				141.5	9

CREEP AND RUPTURE STRENGTHS									
TEMPERATURE F	STRESS, KSI FOR RUPTURE IN TIMES INDICATED					STRESS, KSI FOR DESIGNATED CREEP RATE			
	10 HRS	100 HRS	1,000 HRS	10,000 HRS	100,000 HRS	0.00001%/HR	0.00005%/HR	0.001%/HR	0.005%/HR
Normalized 1800 F, tempered 1250 F									
900	59	55							54
1100	24.5	13.5							12.5
Normalized 1800 F									
900	--	--							--
1100	26	--							--

ORIGINAL CREEP AND RUPTURE DATA (RUPTURE TIME INDICATED BY R IN TEST DURATION COLUMN)											
TEMPERATURE F	STRESS KSI	TIME, HOURS, FOR TOTAL OR PLASTIC STRAIN (DELETE ONE)				MINIMUM CREEP RATE %/HR	INTERCEPT %	TRANSITION TO THIRD STAGE CREEP		TEST DURATION HOURS R	FINAL EXTENSION OR ELONGATION %
		0.1%	0.2%	0.5%	1.0%			HOURS	%		
Normalized 1950 F, tempered 1250 F											
900	55					3.5				2.1	25
900	50					0.08				107.3	27
1100	40					5.30				1.3	24
1100	32					0.18				28.1	23
1100	25					0.0065				517.0	7
1100	20					0.00096				1784.5	5
Normalized 2000 F, tempered 1250 F											
900	55					0.94				7.9	27
900	55					0.24				31.0	26
900	50					0.12				64.2	23
1100	40					2.4				2.4	25
1100	40					0.51				9.2	21
1100	32					0.023				115.6	10
1100	32					0.011				217.4	9
										</	

ASTM-ASME JOINT COMMITTEE ON EFFECT OF TEMPERATURE ON PROPERTIES OF METALS
7-6b

MATERIAL Alloy Steel
ALLOY 0.5Mo Steel
TYPE OF MELTING Induction
SIZE OF HEAT 100 lb

PRODUCER U. S. Naval Research Laboratory

CHEMICAL COMPOSITION, PER CENT

C	Mn	P	S	Si	Ca	Ni	Co	Mo	W	Cu	Ti	Al	V	B
0.22	0.42			0.19				0.54						
Cu	Fe													

DEOXIDATION Al 1 lb/ton

FORM & SIZE - BAR, SHEET, CASTINGS, ETC. Bar

HISTORY OF MATERIAL Forged at 2150 F

HEAT TREATMENT 1. Normalized 1950 F, tempered 1250 F for 6 hr; 2. Normalized 2000 F, tempered 1250 F for 6 hr

MICROSTRUCTURE

GRAIN SIZE Normalized 1950 F, tempered 1250 F - ASTM 5

HARDNESS

SOURCE OF DATA U. S. Naval Research Laboratory

SHORT TIME TENSILE PROPERTIES

TEMPERATURE F	ELASTIC MODULUS 10 ⁶ PSI	TENSILE STRENGTH KSI	YIELD STRENGTH KSI			ELONGATION IN 2" PER CENT	REDUCTION IN AREA PER CENT
			0.02%	0.1%	0.2%		
Normalized 1950 F, tempered 1250 F							
80		69.5				47	33

MISCELLANEOUS DATA

ORIGINAL CREEP AND RUPTURE DATA
(RUPTURE TIME INDICATED BY R IN TEST DURATION COLUMN)

TEMPERATURE F	STRESS KSI	TIME, HOURS, FOR TOTAL OR PLASTIC STRAIN (DELETE ONE)				MINIMUM CREEP RATE %/HR	INTERCEPT %	TRANSITION TO THIRD STAGE CREEP		TEST DURATION HOURS	FINAL EXTENSION OR ELONGATION %
		0.1%	0.2%	0.5%	1.0%			HOURS	%		
Normalized 1950 F, tempered 1250 F											
900	60					--				0.02 R	27
900	57					0.013				372.5 R	26
900	55					0.0023				926.5 R	16
900	50					0.00033				2040+	4
1100	40					--				0.3 R	32
1100	32					0.76				16.0 R	25
1100	32					1.3				10.7 R	30
1100	25					0.034				114.4 R	11
1100	20					0.0066				327.7 R	7
Normalized 2000 F, tempered 1250 F											
900	60					--				<0.01 R	30
900	57					0.0065				502.5 R	23
900	55					0.0032				855.6 R	18
1100	40					--				0.6 R	29
1100	32					0.82				12.7 R	28
1100	32					0.44				21.9 R	21
1100	25					0.03				112.0 R	11

CREEP AND RUPTURE STRENGTHS

TEMPERATURE F	STRESS, KSI FOR RUPTURE IN TIMES INDICATED					STRESS, KSI FOR DESIGNATED CREEP RATE			
	10 HRS	100 HRS	1,000 HRS	10,000 HRS	100,000 HRS	0.00001 %/HR	0.00001 %/HR	0.0001 %/HR	0.001 %/HR
Normalized 1950 F, tempered 1250 F									
900	57	55.5							54
1100	25.5	15.5							15.5
Normalized 2000 F, tempered 1250 F									
900	63	54							52
1100	25	18.5							

ASTM-ASME JOINT COMMITTEE ON EFFECT OF TEMPERATURE ON PROPERTIES OF METALS
7-18

MATERIAL Alloy Steel
ALLOY C-1/2 Mo
TYPE OF MELTING Electric Furnace
SIZE OF HEAT Commercial

PRODUCER Babcock & Wilcox

CHEMICAL COMPOSITION, PER CENT

C	Mn	P	S	Si	Ca	Ni	Co	Mo	W	Cu	Ti	Al	V	B
0.15	0.56	0.013	0.021	0.34	0.11	0.06		0.48						
Cu	Fe													

DEOXIDATION

FORM & SIZE - BAR, SHEET, CASTINGS, ETC. Wrought, 3/4-in.-diam. bar

HISTORY OF MATERIAL

HEAT TREATMENT Normalized and tempered

MICROSTRUCTURE

GRAIN SIZE

HARDNESS

SOURCE OF DATA Babcock & Wilcox

(RUPTURE TIME INDICATED BY R IN TEST DURATION COLUMN)

TEMPERATURE F	STRESS KSI	TIME, HOURS, FOR TOTAL OR PLASTIC STRAIN (DELETE ONE)				MINIMUM CREEP RATE %/HR	INTERCEPT %	TRANSITION TO THIRD STAGE CREEP		TEST DURATION HOURS	FINAL EXTENSION OR ELONGATION %
		0.1%	0.2%	0.5%	1.0%			HOURS	%		
950	36									1055	16
950	34									1630	12
950	31									2513	12
950	27									3950	7
950	22									3120	10.5

CREEP AND RUPTURE STRENGTHS

TEMPERATURE F	STRESS, KSI FOR RUPTURE IN TIMES INDICATED				STRESS, KSI FOR DESIGNATED CREEP RATE			
	10 HRS	100 HRS	1,000 HRS	10,000 HRS	0.00001 %/HR	0.00001 %/HR	0.0001 %/HR	0.001 %/HR
950			36.5	21	11*			
*Extrapolated.								

ASTM-ASME JOINT COMMITTEE ON EFFECT OF TEMPERATURE ON PROPERTIES OF METALS
7-19

MATERIAL Alloy Steel
ALLOY C-1/2 Mo
TYPE OF MELTING Electric Furnace
SIZE OF HEAT Commercial

PRODUCER Babcock & Wilcox

CHEMICAL COMPOSITION, PER CENT

C	Mn	P	S	Si	Ca	Ni	Co	Mo	W	Cu	Ti	Al	V	B
0.14	0.55			0.30				0.50						
Cu	Fe													

DEOXIDATION

FORM & SIZE - BAR, SHEET, CASTINGS, ETC. Wrought tube, 2-1/2" O.D. x 0.30" wall

HISTORY OF MATERIAL

HEAT TREATMENT Annealed

MICROSTRUCTURE

GRAIN SIZE

HARDNESS

SOURCE OF DATA Babcock & Wilcox

ORIGINAL CREEP AND RUPTURE DATA
(RUPTURE TIME INDICATED BY R IN TEST DURATION COLUMN)

TEMPERATURE F	STRESS KSI	TIME, HOURS, FOR TOTAL OR PLASTIC STRAIN (DELETE ONE)				MINIMUM CREEP RATE %/HR	INTERCEPT %	TRANSITION TO THIRD STAGE CREEP		TEST DURATION HOURS	FINAL EXTENSION OR ELONGATION %
		0.1%	0.2%	0.5%	1.0%			HOURS	%		
950	33									2382	5
950	30									4568	8
1050	17									1426	13.5
1050	15									2526	14
1050	12.5									3369	16
1050	10									6407	4

CREEP AND RUPTURE STRENGTHS

TEMPERATURE F	STRESS, KSI FOR RUPTURE IN TIMES INDICATED				STRESS, KSI FOR DESIGNATED CREEP RATE			
	10 HRS	100 HRS	1,000 HRS	10,000 HRS	0.00001 %/HR	0.00001 %/HR	0.0001 %/HR	0.001 %/HR
950			37.6	26.8				
1050			19.1	8.6	3.9*			
*Extrapolated.								

ASTM-ASME JOINT COMMITTEE ON EFFECT OF TEMPERATURE ON PROPERTIES OF METALS
7-20

MATERIAL Alloy Steel
ALLOY C-1/2 Mo
TYPE OF MELTING Open Hearth
SIZE OF HEAT 100 T

PRODUCER Republic Steel

CHEMICAL COMPOSITION, PER CENT

C	Mn	P	S	Si	Ca	Ni	Co	Mo	W	Cu	Ti	Al	V	B
0.18	0.53	0.016	0.024	0.18				0.51						
Cu	Fe													

DEOXIDATION

FORM & SIZE - BAR, SHEET, CASTINGS, ETC. 1.65 lb/ton Al added to ladle + 1000 lb of 50% FeSi

HISTORY OF MATERIAL Wrought 3/4-in.-diam. bar

HEAT TREATMENT Annealed

MICROSTRUCTURE

GRAIN SIZE 6

HARDNESS R_p - 71.5

SOURCE OF DATA Babcock & Wilcox

ORIGINAL CREEP AND RUPTURE DATA (RUPTURE TIME INDICATED BY R IN TEST DURATION COLUMN)											
TEMPERATURE F	STRESS KSI	TIME, HOURS, FOR TOTAL OR PLASTIC STRAIN (DELETE ONE)				MINIMUM CREEP RATE %/HR	INTERCEPT %	TRANSITION TO THIRD STAGE CREEP		TEST DURATION HOURS R	FINAL EXTENSION OR ELONGATION %
		0.1%	0.2%	0.5%	1.0%			HOURS	%		
850	50									1,879	23
850	45									6,041	18
850	42									8,991	14
850	37.5									20,171	10.5
950	36									375	12.5
950	30									944	8
950	22									5,311	5.5
950	19.5									12,274	8
1050	15									487	21.5
1050	12.5									1,208	19.5
1050	9.5									5,197	17
1050	8.4									6,102	17.5
1050	8									10,075	17
CREEP AND RUPTURE STRENGTHS											
TEMPERATURE F	STRESS, KSI FOR RUPTURE IN TIMES INDICATED					STRESS, KSI FOR DESIGNATED CREEP RATE					
	10 HRS	100 HRS	1,000 HRS	10,000 HRS	100,000 HRS	0.00001%/HR	0.0001%/HR	0.001%/HR	0.01%/HR	0.05%/HR	
850			54.4	41.3	30.3*						
950			29.6	20	13.7*						
1050			12.9	8	5.0*						
*Extrapolated.											

ASTM-ASME JOINT COMMITTEE ON EFFECT OF TEMPERATURE ON PROPERTIES OF METALS												7-7a			
DATA AND PUBLICATIONS PANEL DATA SHEET															
MATERIAL Alloy Steel															
ALLOY 0.5Mo-V Steel												SIZE OF HEAT 100 lb			
PRODUCER U. S. Naval Research Laboratory															
CHEMICAL COMPOSITION, PER CENT															
C	Mn	P	S	Si	Cr	Ni	Co	Mo	W	Cu	Ti	Al	V	B	
0.20	0.61			0.22				0.50					0.21		
Cu	Fe														
DEFORMATION Al 1 lb/ton															
FORM & SIZE BAR, SHEET, CASTINGS, ETC. Bar															
FORGED AT 2150 F															
HEAT TREATMENT 1. Normalized 1800 F, tempered 1250 F for 6 hr; 2. Normalized 1800 F															
MICROSTRUCTURE															
GRAIN SIZE Normalized 1800 F, tempered 1250 F - ASTM 6															
HARDNESS															
SOURCE OF DATA U. S. Naval Research Laboratory															
SHORT TIME TENSILE PROPERTIES														MISCELLANEOUS DATA	
TEMPERATURE F	ELASTIC MODULUS 10 ⁶ PSI	TENSILE STRENGTH KSI	YIELD STRENGTH, KSI			ELONGATION IN 2 PER CENT	REDUCTION IN AREA PER CENT								
			0.02%	0.1%	0.2%										
Normalized 1800 F, tempered 1250 F															
80		115.5			101	21	65								

ASTM-ASME JOINT COMMITTEE ON EFFECT OF TEMPERATURE ON PROPERTIES OF METALS																
DATA AND PUBLICATIONS PANEL DATA SHEET					SHEET OF		7-21									
MATERIAL		Alloy Steel					TYPE OF HEATING		Electric Furnace		SHEET OF HEAT					
ALLOY		C-1/2 Mo							53 T							
PRODUCER		Babcock & Wilcox														
SPECIFICATIONS:																
		CHEMICAL COMPOSITION, PER CENT														
		C	Mn	P	S	Si	Ca	Ni	Co	Mo	W	Cu	Ti	Al	V	B
		0.16	0.70	0.024	0.018	0.24	0.16	0.13		0.51						
		Cu	Fe													
		0.14														
DEOXYDIZATION		140 lb of FeSi, 140 lb of CaSi														
FORM & SIZE - BAR, SHEET, CASTINGS, ETC.		Wrought 3/4-in. -diam. bar														
IDENTITY OF MATERIAL																
HEAT TREATMENT		Annealed														
MICROSTRUCTURE																
GRAIN SIZE																
HARDNESS		Rp - 74.5														
SOURCE OF DATA		Babcock & Wilcox														

ORIGINAL CREEP AND RUPTURE DATA (RUPTURE TIME INDICATED BY R IN TEST DURATION COLUMN)												
TEMPERATURE F	STRESS KSI	TIME, HOURS, FOR TOTAL OR PLASTIC STRAIN (DELETE ONE)				MINIMUM CREEP RATE %/HR	INTERCEPT %	TRANSITION TO THIRD STAGE CREEP		TEST DURATION HOURS	FINAL EXTENSION OR ELONGATION %	
		0.1%	0.2%	0.5%	1.0%			HOURS	%			
Normalized 1800 F, tempered 1250 F												
900	75					0.145				16.2 R	17	
900	72					0.0095				195.0 R	9	
900	70					0.0025				584.3 R	6	
1100	32					0.0079				80.1 R	NH	
1100	32					--				70.0 R	NH	
1100	25					0.0027				259.4 R	2	
1100	25					0.0024				278.7 R	3	
1100	20					0.00053				864.0 R	2	
Normalized 1800 F												
900	80					0.0014				725.7 R	5	
900	70					0.0001				1727+	--	
1100	32					0.0065				47.2 R	NH	
1100	32					0.0064				44.6 R	NH	
1100	32					0.0032				133.2 R	1.5	
1100	25					0.0032				182.1 R	1.6	
1100	20					0.0016				316.3 R	1	
1100	20					0.0016				338.6 R	2	
CREEP AND RUPTURE STRENGTHS												
TEMPERATURE F	STRESS, KSI FOR RUPTURE IN TIMES INDICATED					STRESS, KSI FOR DESIGNATED CREEP RATE						
	10 HRS	100 HRS	1,000 HRS	10,000 HRS	100,000 HRS	0.00001%/HR	0.0001%/HR	0.001%/HR	0.01%/HR			
Normalized 1800 F, tempered 1250 F												
900		73	69							69		
1100		30	19							22		
Normalized 1800 F												
900	--		77							78		
1100		28	13							17		

ORIGINAL CREEP AND RUPTURE DATA (RUPTURE TIME INDICATED BY R IN TEST DURATION COLUMN)											
TEMPERATURE F	STRESS KSI	TIME, HOURS, FOR TOTAL OR PLASTIC STRAIN (DELETE ONE)				MINIMUM CREEP RATE %/HR	INTERCEPT %	TRANSITION TO THIRD STAGE CREEP		TEST DURATION HOURS R	FINAL EXTENSION OR ELONGATION %
		0.1%	0.2%	0.5%	1.0%			HOURS	%		
850	50									3,575	13
850	48									5,217	11
850	45									9,791	10
950	40									370	9.5
950	36									1,565	7
950	30									3,153	3.5
950	22.5									8,751	4.5
1050	18									536	5
1050	15									955	6
1050	12.5									1,688	7.5
1050	9.5									5,924	9
1050	7									13,845	7.3
CREEP AND RUPTURE STRENGTHS											
TEMPERATURE F	STRESS, KSI FOR RUPTURE IN TIMES INDICATED					STRESS, KSI FOR DESIGNATED CREEP RATE					
	10 HRS	100 HRS	1,000 HRS	10,000 HRS	100,000 HRS	0.00001%/HR	0.0001%/HR	0.001%/HR	0.01%/HR		
850			57	45	35*						
950			37	21.8	11.5*						
1050			15	7.8	4*						
*Extrapolated.											

ASTM-ASME JOINT COMMITTEE ON EFFECT OF TEMPERATURE ON PROPERTIES OF METALS																		7-16a	
DATA AND PUBLICATIONS PANEL DATA SHEET																			
MATERIAL Alloy Steel		TYPE OF HEATING Open Hearth										SIZE OF HEAT Commercial							
ALLOY Mn-Mo																			
PRODUCER SPECIFICATIONS:		CHEMICAL COMPOSITION, PER CENT																	
A-302, Grade B		C	Mn	P	S	Si	Ca	Ni	Co	Mo	W	Cu	Ti	Al	V	B			
		0.25	1.36	0.018	0.036	0.23				0.49									
DEOXIDATION		Rolled 3"-thick plate, 84" wide																	
FORM & SIZE - BAR, SHEET, CASTINGS, ETC.																			
HISTORY OF MATERIAL																			
HEAT TREATMENT		Normalized and tempered																	
MICROSTRUCTURE																			
GRAIN SIZE		217 to 229 BHN																	
HARDNESS																			
SOURCE OF DATA		U. S. Naval Engineering Experiment Station																	
SHORT TIME TENSILE PROPERTIES																		MISCELLANEOUS DATA	
TEMPERATURE F	ELASTIC MODULUS 10 ⁶ PSI	TENSILE STRENGTH KSI	YIELD STRENGTH KSI			ELONGATION IN 2" PER CENT			REDUCTION IN AREA PER CENT			Fracture Stress (1) KSI							
			0.2%	0.1%	0.2%														
80		107.0	One-Fourth Thickness - Transverse																
80		105.8	--																
400		105.5	69.0			78.0			16			45			187				
600		112.0	--			23			50			171							
800		97.5	59.5			68.0			21			55			148				
Center - Longitudinal																			
80		107.0	68.0			75.5			20			45			151				
80		107.0	68.5			76.0			20			51			170				
400		105.5	68.5			77.5			18			48			167				
600		111.0	64.0			73.0			24			51			164				
800		99.0	61.0			69.0			21			60			155				
(1) Breaking load divided by reduced cross-sectional area.																			
(Continued on back)																			

ASTM-ASME JOINT COMMITTEE ON EFFECT OF TEMPERATURE ON PROPERTIES OF METALS																		7-11a	
DATA AND PUBLICATIONS PANEL DATA SHEET																			
MATERIAL Alloy Steel		TYPE OF HEATING Induction										SIZE OF HEAT 100 lb							
ALLOY Cr-Mo-V Steel																			
PRODUCER SPECIFICATIONS:		CHEMICAL COMPOSITION, PER CENT																	
U. S. Naval Research Laboratory		C	Mn	P	S	Si	Ca	Ni	Co	Mo	W	Cu	Ti	Al	V	B			
		0.20	0.55			0.22	0.59			0.27						0.72			
DEOXIDATION		Al 1 lb/ton																	
FORM & SIZE - BAR, SHEET, CASTINGS, ETC.		Bar																	
HISTORY OF MATERIAL		Forged at 2150 F																	
HEAT TREATMENT		1. Normalized 1800 F, tempered 1250 F for 6 hr; 2. Normalized 1800 F																	
MICROSTRUCTURE		Normalized 1800 F, tempered 1250 F - ASTM 7-8																	
GRAIN SIZE																			
HARDNESS																			
SOURCE OF DATA		U. S. Naval Research Laboratory																	
SHORT TIME TENSILE PROPERTIES																		MISCELLANEOUS DATA	
TEMPERATURE F	ELASTIC MODULUS 10 ⁶ PSI	TENSILE STRENGTH KSI	YIELD STRENGTH KSI			ELONGATION IN 2" PER CENT			REDUCTION IN AREA PER CENT			Fracture Stress (1) KSI							
			0.2%	0.1%	0.2%														
80		72	39			37			83										
(1) Breaking load divided by reduced cross-sectional area.																			

ASTM-ASME JOINT COMMITTEE ON EFFECT OF TEMPERATURE ON PROPERTIES OF METALS																		7-16b	
DATA AND PUBLICATIONS PANEL DATA SHEET																			
MATERIAL Alloy Steel		TYPE OF HEATING Open Hearth										SIZE OF HEAT Commercial							
ALLOY Mn-Mo																			
PRODUCER SPECIFICATIONS:		CHEMICAL COMPOSITION, PER CENT																	
A-302, Grade B		C	Mn	P	S	Si	Ca	Ni	Co	Mo	W	Cu	Ti	Al	V	B			
		0.25	1.36	0.018	0.036	0.23				0.49									
DEOXIDATION		Rolled 3"-thick plate, 84" wide																	
FORM & SIZE - BAR, SHEET, CASTINGS, ETC.																			
HISTORY OF MATERIAL																			
HEAT TREATMENT		Normalized and tempered																	
MICROSTRUCTURE																			
GRAIN SIZE		217 to 229 BHN																	
HARDNESS																			
SOURCE OF DATA		U. S. Naval Engineering Experiment Station																	
SHORT TIME TENSILE PROPERTIES																		MISCELLANEOUS DATA	
TEMPERATURE F	ELASTIC MODULUS 10 ⁶ PSI	TENSILE STRENGTH KSI	YIELD STRENGTH KSI			ELONGATION IN 2" PER CENT			REDUCTION IN AREA PER CENT			Fracture Stress (1) KSI							
			0.2%	0.1%	0.2%														
80		105.0	71.5			78.0			21			52			172				
400		101.0	69.0			77.0			17			46			163				
600		112.5	66.5			74.5			24			51			176				
800		95.0	62.2			69.5			21			60			155				
One-Fourth Thickness - Longitudinal																			
80		107.0	72.0			78.5			22			58			179				
80		107.0	71.0			78.0			22			58			185				
400		104.0	70.5			78.2			19			56			172				
400		103.5	70.0			78.5			17			50			173				
500		109.0	71.5			79.0			19			50			179				
500		109.0	69.0			77.5			20			50			180				
600		111.5	69.5			76.5			26			59			189				
600		112.0	70.5			78.0			27			60			190				
800		98.3	--			--			21			65			161				
(1) Breaking load divided by reduced cross-sectional area.																			
(Continued on Card 7-16b)																			

ASTM-ASME JOINT COMMITTEE ON EFFECT OF TEMPERATURE ON PROPERTIES OF METALS																		7-11a	
DATA AND PUBLICATIONS PANEL DATA SHEET																			
MATERIAL Alloy Steel		TYPE OF HEATING Induction										SIZE OF HEAT 100 lb							
ALLOY Cr-Mo-V Steel																			
PRODUCER SPECIFICATIONS:		CHEMICAL COMPOSITION, PER CENT																	
U. S. Naval Research Laboratory		C	Mn	P	S	Si	Ca	Ni	Co	Mo	W	Cu	Ti	Al	V	B			
		0.20	0.55			0.22	0.59			0.27						0.72			
DEOXIDATION		Al 1 lb/ton																	
FORM & SIZE - BAR, SHEET, CASTINGS, ETC.		Bar																	
HISTORY OF MATERIAL		Forged at 2150 F																	
HEAT TREATMENT		1. Normalized 1800 F, tempered 1250 F for 6 hr; 2. Normalized 1800 F																	
MICROSTRUCTURE		Normalized 1800 F, tempered 1250 F - ASTM 7-8																	
GRAIN SIZE																			
HARDNESS																			
SOURCE OF DATA		U. S. Naval Research Laboratory																	
SHORT TIME TENSILE PROPERTIES																		MISCELLANEOUS DATA	
TEMPERATURE F	ELASTIC MODULUS 10 ⁶ PSI	TENSILE STRENGTH KSI	YIELD STRENGTH KSI			ELONGATION IN 2" PER CENT			REDUCTION IN AREA PER CENT			Fracture Stress (1) KSI							
			0.2%	0.1%	0.2%														
80		72	39			37			83										
(1) Breaking load divided by reduced cross-sectional area.																			

1/2 Cr-1/2 Mo

ASTM-ASME JOINT COMMITTEE ON EFFECT OF TEMPERATURE ON PROPERTIES OF METALS																	
DATA AND PUBLICATIONS PANEL DATA SHEET																	
7-26																	
MATERIAL		Alloy Steel															
ALLOY		1/2 Cr - 1/2 Mo															
TYPE OF MELTING		Electric Furnace															
SIZE OF HEAT		Commercial															
PRODUCER		Babcock & Wilcox															
SPECIFICATIONS																	
CHEMICAL COMPOSITION, PER CENT																	
C	Mn	P	S	Si	Cr	Ni	Co	Mo	W	Cu	Ti	Al	V	B			
0.14	0.45	0.016	0.028	0.26	0.54	0.16		0.49									
Cu	Fe																
0.10																	
DEOXYDATION																	
FORM & SIZE - BAR, SHEET, CASTINGS, ETC.																	
Wrought, 3/4-in. -diam. bar																	
HEAT TREATMENT																	
(a) Per ASTM Spec. A-213; (b) Normalized and tempered																	
MICROSTRUCTURE																	
(b) ASTM 7-8																	
GRAIN SIZE																	
(a) BHN - 133; (b) VHN - 149																	
HARDNESS																	
Babcock & Wilcox																	
SOURCE OF DATA																	

ORIGINAL CREEP AND RUPTURE DATA (RUPTURE TIME INDICATED BY R IN TEST DURATION COLUMN)											
TEMPERATURE °F	STRESS KSI	TIME, HOURS, FOR TOTAL OR PLASTIC STRAIN (DELETE ONE)				MINIMUM CREEP RATE %/HR	INTERCEPT %	TRANSITION TO THIRD STAGE CREEP		TEST DURATION HOURS R	FINAL EXTENSION OR ELONGATION %
		0.1%	0.2%	0.5%	1.0%			HOURS	%		
(a) 900	50					0.035				256	31.5
900	47					0.0105				636	32.5
900	44					0.0071				1,819	36.5
900	40					0.00155				7,367	32.5
1000	27					0.026				794	59
1000	25					0.019				1,016	45
1000	22					0.0087				2,211	30
1000	20					0.002				5,210	48
1000	17					0.0015				6,388	44
1100	15									144	88
1100	12					0.016				501	90
1100	10									1,975	46
1100	8					0.00066				2,507	57.5
1100	6.5									6,730	33.5
(b) 950	50									735	13.5
950	45									1,841	9
950	42.5									3,767	8
950	38									10,239	6.5
CREEP AND RUPTURE STRENGTHS											
TEMPERATURE	STRESS, KSI FOR RUPTURE IN TIMES INDICATED					STRESS, KSI FOR DESIGNATED CREEP RATE					
	10 HRS	100 HRS	1,000 HRS	10,000 HRS	100,000 HRS	0.00001%/HR	0.0001%/HR	0.001%/HR	0.01%/HR	0.1%/HR	
900(a)			45.7	39.1	33.4*				33	39	
1000(a)			25.5	15.7	9.3*				15	19	
1100(a)			9.9	6.0	3.6*				6.2	8.3	
950(b)			48.5	38.1	30*						
*Extrapolated.											

ASTM-ASME JOINT COMMITTEE ON EFFECT OF TEMPERATURE ON PROPERTIES OF METALS																	
DATA AND PUBLICATIONS PANEL DATA SHEET																	
7-27																	
MATERIAL		Alloy Steel															
ALLOY		1/2 Cr - 1/2 Mo															
TYPE OF MELTING		Electric Furnace															
SIZE OF HEAT		Commercial															
PRODUCER		Babcock & Wilcox															
SPECIFICATIONS																	
CHEMICAL COMPOSITION, PER CENT																	
C	Mn	P	S	Si	Cr	Ni	Co	Mo	W	Cu	Ti	Al	V	B			
0.13	0.41	0.012	0.015	0.15	0.60	0.07		0.54									
Cu	Fe																
0.03																	
DEOXYDATION																	
FORM & SIZE - BAR, SHEET, CASTINGS, ETC.																	
Wrought tube, 6-5/8-in. O.D. x 0.864-in. wall																	
HEAT TREATMENT																	
Per ASTM Spec. A-213																	
MICROSTRUCTURE																	
GRAIN SIZE																	
HARDNESS																	
SOURCE OF DATA																	
Babcock & Wilcox																	

ORIGINAL CREEP AND RUPTURE DATA (RUPTURE TIME INDICATED BY R IN TEST DURATION COLUMN)											
TEMPERATURE °F	STRESS KSI	TIME, HOURS, FOR TOTAL OR PLASTIC STRAIN (DELETE ONE)				MINIMUM CREEP RATE, %/HR	INTERCEPT %	TRANSITION TO THIRD STAGE CREEP		TEST DURATION HOURS	FINAL EXTENSION OR ELONGATION %
		0.1%	0.2%	0.5%	1.0%			HOURS	%		
900	60									2,251 R	14
900	55									2,881 R	10
900	51					0.0004				3,830 R	8.5
900	45					0.000206				10,128 R	6
900	40					0.000088				23,642 R	4
900	38					0.000035				11,578	
900	25					0.00001				15,890	
1000	40					0.006				543 R	10
1000	30					0.00072				4,030 R	9
1000	28									4,614 R	10
1000-	26.5									5,673 R	11.5
1000	25									7,372 R	14.5
1000	23					0.00021				11,001 R	14
1000	22					0.000092				2,519	
1000	15					0.0000263				9,189	
1000	12					0.0000194				13,151	
1100	20									355 R	31
1100	13					0.0015				2,440 R	21.5
1100	12									3,772 R	36
1100	10					0.000263				10,637 R	18
1100	6					0.00004				9,843	

CREEP AND RUPTURE STRENGTHS									
TEMPERATURE	10 HRS	100 HRS	1,000 HRS	10,000 HRS	100,000 HRS	0.00001%/HR	0.0001%/HR	0.001%/HR	0.01%/HR
900				45	33.5*		25		41
1000			35.5	23.5	14.5*		9.5		19.5
1100			15.5	10	6.5*		3.5		7.9
*Extrapolated.									

ASTM-ASME JOINT COMMITTEE ON EFFECT OF TEMPERATURE ON PROPERTIES OF METALS																	
DATA AND PUBLICATIONS PANEL DATA SHEET																	
7-28																	
MATERIAL		Alloy Steel															
ALLOY		1/2 Cr - 1/2 Mo															
TYPE OF MELTING		Electric Furnace															
SIZE OF HEAT		U. S. Steel															
SPECIFICATIONS																	
CHEMICAL COMPOSITION, PER CENT																	
C	Mn	P	S	Si	Cr	Ni	Co	Mo	W	Cu	Ti	Al	V	B			
0.13	0.51	0.010	0.015	0.22	0.48	0.04		0.58									
Cu	Fe																
0.03																	
DEOXYDATION																	
Silicon deoxidation																	
FORM & SIZE - BAR, SHEET, CASTINGS, ETC.																	
1-in. -square bars																	
HEAT TREATMENT																	
1650 F normalize																	
MICROSTRUCTURE																	
ASTM 1 to 3 (McQuaid-Ehn)																	
GRAIN SIZE																	
HARDNESS																	
SOURCE OF DATA																	
U. S. Steel Applied Research Laboratory																	
SHORT TIME TENSILE PROPERTIES																	
TEMPERATURE °F	ELASTIC MODULUS (10 ⁶ PSI)	TENSILE STRENGTH KSI	YIELD STRENGTH KSI	ELONGATION IN 1" PER CENT	REDUCTION IN AREA PER CENT	MISCELLANEOUS DATA											
80		71.3	73.1	0.02%	0.1%	0.2%											
							35	68									
							33	67									

ORIGINAL CREEP AND RUPTURE DATA (RUPTURE TIME INDICATED BY R IN TEST DURATION COLUMN)											
TEMPERATURE °F	STRESS KSI	TIME, HOURS, FOR TOTAL OR PLASTIC STRAIN (DELETE ONE)				MINIMUM CREEP RATE %/HR	INTERCEPT %	TRANSITION TO THIRD STAGE CREEP		TEST DURATION HOURS R	FINAL EXTENSION OR ELONGATION %
		0.1%	0.2%	0.5%	1.0%			HOURS	%		
900	75					2.56				3.4	36
900	72									54.7	37
900	70									58.6	36
900	69.3					0.101				88.3	33
900	64					0.0027				1102.6	20
1050	50.8					0.64				7.3	38
1050	48.0									10.4	30
1050	45.0					0.142				39.7	20
1050	40.0					0.032				84.0	14
1050	35.0					0.0147				200.6	13
1050	30.0					0.0046				620.4	14
1200	22.9									1.1	80
1200	20.0									7.0	70
1200	17.0					2.5				13.8	64
1200	12.0					0.095				62.7	50
1200	6.4					0.0053				741.9	50

[illegible]

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

7-17

MATERIAL Alloy Steel

DATA AND PUBLICATIONS PANEL DATA SHEET

ALLOY Cr-Mo-V

TYPE OF
HEATING

SIZE OF
HEAT

Commercial

PRODUCER
SPECIFICATIONS:

CHEMICAL COMPOSITION, PER CENT

C	Mn	P	S	Si	Ca	Ni	Co	Mo	W	Cu	Ti	Al	V	B
0.11	0.40	0.015	0.018	0.23	1.00			0.85						0.26
Cu	Fe													

DEOXIDATION

FROM A SIZE - BAR, SHEET, CASTINGS, ETC.
HISTORY OF MATERIAL:

6" I. P. S., 80 Schedule, 0.432" wall thickness, seamless pipe

HEAT TREATMENT

Normalized 2 hr, 1875 F-1950 F; temper 12 hr, 1300 F-1350 F

MICROSTRUCTURE

GRAIN SIZE

REMARKS

SOURCE OF DATA

U. S. Naval Engineering Experiment Station

SHORT TIME TENSILE PROPERTIES

MISCELLANEOUS DATA

TEMPERATURE F	ELASTIC MODULUS 10 ⁶ PSI	TENSILE STRENGTH KSI	YIELD STRENGTH, KSI		ELONGATION IN 2" PER CENT	REDUCTION IN AREA PER CENT	MISCELLANEOUS DATA							
			0.02%	0.1%										
80		113.1			18	65								
550		98.4			14	61								
700		94.0			16	64								
800		91.2			16	66								
900		85.0			16	68								
1000		75.0			18	77								
1100		64.4			15	77								

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

7-35

MATERIAL Alloy Steel	DATA AND PUBLICATIONS PANEL DATA SHEET		
ALL-02 1 Cr - 1/2 Mo	TYPE OF HEATING Electric Furnace	FUEL OF HEAT	
PRODUCER U. S. Steel			

		CHEMICAL COMPOSITION, PER CENT														
		C	Mn	P	S	Si	Cr	Ni	Co	Mo	W	Ca	Ti	Al	V	B
(a)	0.11	0.44	0.005	0.019	0.15	0.97	0.09	0.52						0.005		
(b)	0.12	0.45	0.013	0.015	0.74	1.13	0.031	0.50					0.002	0.010		
		Cu	Fe	N												
(a)	0.03			0.012												
(b)	0.04			0.011												

RECRYSTALLIZATION	Silicon plus 0.5 pound of aluminum per ton
FORM & SIZE - BAR, SHEET, CASTINGS, ETC.	1-in. -square bars
HISTORY OF MATERIAL	

HEAT TREATMENT	(a) Hot rolled and stress relieved; (b) 1650 F normalized and tempered at 1300 F		
MICROSTRUCTURE			
GRAIN SIZE	(a) ASTM 2 to 4 (McQuaid-Ehn); (b) ASTM 1 to 3 (McQuaid-Ehn)		
HARDNESS			
SOURCE OF DATA	U. S. Steel Applied Research Laboratory		

TEMPERATURE F		SHORT TIME TENSILE PROPERTIES													MISCELLANEOUS DATA	
		ELASTIC MODULUS 10 ³ PSI	TENSILE STRENGTH KSI	YIELD STRENGTH KSI			ELONGATION IN 2" PER CENT	REDUCTION IN AREA PER CENT								
				0.02K	0.1K	0.2K										
80 (a)			63.3				35	71.7								
80 (a)			64.7				37	70.3								
80 (b)			75.5				37	73.9								
80 (b)			75.1				35	74.3								

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

MATERIAL

Alloy Steel

1 Cr - 1/2 Mo

Babcock & Wilcox

TYPE OF MELTING

Electric Furnace

SIZE OF HEAT

7-36

DEoxidation

FORM & SIZE, BAR, SHEET, CASTINGS, ETC.

HISTORY OF MATERIAL

Wrought, 3/4-in. diam. bar

HEAT TREATMENT

MICROSTRUCTURE

GRAIN SIZE

HARDNESS

Per ASTM A-213

VHN 142

Babcock & Wilcox

ASTM-ASME JOINT COMMITTEE ON EFFECT OF TEMPERATURE ON PROPERTIES OF METALS
DATA AND PUBLICATIONS PANEL DATA SHEET 7-39

MATERIAL Alloy Steel
ALLOY 1-1/4 Cr - 1/2 Mo
TYPE OF MELTING Electric Furnace
PRODUCER Timken Roller Bearing Company
SPECIFICATIONS:

CHEMICAL COMPOSITION, PER CENT

C	Mn	P	S	Si	Cr	Ni	Co	Mo	W	Cu	Ti	Al	V	B
0.08	0.39	0.013	0.020	0.66	1.18	0.24		0.57						
Cu	Fe													

DEFORMATION Aluminum
FORM & SIZE: BAR, SHEET, CASTINGS, ETC. 2.000" O.D. x 0.375" wall seamless tubing
HISTORY OF MATERIAL

Pierced, hot rolled, cold drawn, annealed from 1625 F

HEAT TREATMENT Annealed from 1625 F

MICROSTRUCTURE

GRAIN SIZE

HARDNESS

SOURCE OF DATA Timken Roller Bearing Company

ORIGINAL CREEP AND RUPTURE DATA
(RUPTURE TIME INDICATED BY R IN TEST DURATION COLUMN)

TEMPERATURE F	STRESS KSI	TIME, HOURS, FOR TOTAL OR PLASTIC STRAIN (DELETE ONE)				MINIMUM CREEP RATE %/HR	INTERCEPT %	TRANSITION TO THIRD STAGE CREEP		TEST DURATION HOURS R	FINAL EXTENSION OR ELONGATION %
		0.1%	0.2%	0.5%	1.0%			HOURS	%		
1000	40.0									107	43
1000	35.0									639	32
1000	30.0									1492	24
1050	35.0									33	42
1050	30.0									122	44
1050	26.0									408	44
1050	23.0									599	61
1050	18.0									1389	61

CREEP AND RUPTURE STRENGTHS

TEMPERATURE F	STRESS, KSI FOR RUPTURE IN TIMES INDICATED					STRESS, KSI FOR DESIGNATED CREEP RATE			
	10 HRS	100 HRS	1,000 HRS	10,000 HRS	100,000 HRS	0.0005%/HR	0.0001%/HR	0.0001%/HR	0.01%/HR
1000	40	32.5	21.5*						
1050	30.3	19.7	10*						

*Extrapolated.

ASTM-ASME JOINT COMMITTEE ON EFFECT OF TEMPERATURE ON PROPERTIES OF METALS
DATA AND PUBLICATIONS PANEL DATA SHEET 7-41

MATERIAL Alloy Steel
ALLOY 1-1/4 Cr - 1/2 Mo
TYPE OF MELTING Electric Furnace
PRODUCER Timken Roller Bearing Company
SPECIFICATIONS:

CHEMICAL COMPOSITION, PER CENT

C	Mn	P	S	Si	Cr	Ni	Co	Mo	W	Cu	Ti	Al	V	B
0.10	0.47	0.010	0.020	0.66	1.28	0.20		0.56						
Cu	Fe													
0.12														

DEFORMATION Aluminum
FORM & SIZE: BAR, SHEET, CASTINGS, ETC. 8.648" O.D. x 1.250" wall seamless tubing
HISTORY OF MATERIAL

Pierced, hot rolled, annealed from 1625 F

HEAT TREATMENT Annealed from 1625 F

MICROSTRUCTURE

GRAIN SIZE

HARDNESS

SOURCE OF DATA Timken Roller Bearing Company

ORIGINAL CREEP AND RUPTURE DATA
(RUPTURE TIME INDICATED BY R IN TEST DURATION COLUMN)

TEMPERATURE F	STRESS KSI	TIME, HOURS, FOR TOTAL OR PLASTIC STRAIN (DELETE ONE)				MINIMUM CREEP RATE %/HR	INTERCEPT %	TRANSITION TO THIRD STAGE CREEP		TEST DURATION HOURS R	FINAL EXTENSION OR ELONGATION %
		0.1%	0.2%	0.5%	1.0%			HOURS	%		
1000	40.0									73	46
1000	35.0									371	46
1000	30.0									790	60
1000	25.0									2601	44

CREEP AND RUPTURE STRENGTHS

TEMPERATURE F	STRESS, KSI FOR RUPTURE IN TIMES INDICATED					STRESS, KSI FOR DESIGNATED CREEP RATE			
	10 HRS	100 HRS	1,000 HRS	10,000 HRS	100,000 HRS	0.0005%/HR	0.0001%/HR	0.0001%/HR	0.01%/HR
1000	38.5	29	19.8*						

*Extrapolated.

ORIGINAL CREEP AND RUPTURE DATA
(RUPTURE TIME INDICATED BY R IN TEST DURATION COLUMN)

TEMPERATURE F	STRESS KSI	TIME, HOURS, FOR TOTAL OR PLASTIC STRAIN (DELETE ONE)				MINIMUM CREEP RATE %/HR	INTERCEPT %	TRANSITION TO THIRD STAGE CREEP		TEST DURATION HOURS R	FINAL EXTENSION OR ELONGATION %
		0.1%	0.2%	0.5%	1.0%			HOURS	%		
1000	40.0									135	31
1000	32.0									1226	23
1000	26.0									2820	22
1000	20.0									5470	17
1000	20.0									5336	11
1050	25.0									355	23
1050	21.0									773	33
1050	13.0									3584	59
1100	20.0									132	47
1100	16.0									304	65
1100	12.5									824	77
1100	10.0									1543	48

CREEP AND RUPTURE STRENGTHS

TEMPERATURE F	STRESS, KSI FOR RUPTURE IN TIMES INDICATED					STRESS, KSI FOR DESIGNATED CREEP RATE			
	10 HRS	100 HRS	1,000 HRS	10,000 HRS	100,000 HRS	0.0005%/HR	0.0001%/HR	0.0001%/HR	0.01%/HR
1000	40.2	33	18*	9.2*					
1050	30	19	9.1*	4.5*					
1100	21.7	11.8	5*						

*Extrapolated.

ASTM-ASME JOINT COMMITTEE ON EFFECT OF TEMPERATURE ON PROPERTIES OF METALS
DATA AND PUBLICATIONS PANEL DATA SHEET 7-40

MATERIAL Alloy Steel
ALLOY 1-1/4 Cr - 1/2 Mo
TYPE OF MELTING Electric Furnace
PRODUCER Timken Roller Bearing Company
SPECIFICATIONS:

CHEMICAL COMPOSITION, PER CENT

C	Mn	P	S	Si	Cr	Ni	Co	Mo	W	Cu	Ti	Al	V	B
0.12	0.40	0.013	0.018	0.63	1.22	0.15		0.58						
Cu	Fe													
0.12														

DEFORMATION Aluminum
FORM & SIZE: BAR, SHEET, CASTINGS, ETC. 2.000" O.D. x 0.428" wall seamless tubing
HISTORY OF MATERIAL

Pierced, hot rolled, Rotorolled, annealed from 1475 F

HEAT TREATMENT Annealed from 1475 F

MICROSTRUCTURE

GRAIN SIZE

HARDNESS

SOURCE OF DATA Timken Roller Bearing Company

[illegible]

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

Alloy Steel

DATA AND PUBLICATIONS PANEL DATA SHEET

7-47

MATERIAL

ALLOY

TYPE OF HEATING

SIZE OF HEAT

-1/4 Cr - 1/2 Mo

Electric Furnace

Commercial

PRODUCER

SPECIFICATIONS

Babcock & Wilcox

CHEMICAL COMPOSITION, PER CENT

	C	Mn	P	S	Si	Cr	Ni	Co	Mo	W	Cu	Ti	Al	V	B
(a)	0.10	0.47	0.012	0.020	0.78	1.22	0.07		0.52						
(b)	0.11	0.48	0.014	0.022	0.81	1.25	0.07		0.50						
	Cu	Fe													
(a)	0.03														

DEOXIDATION

FORM & SIZE - BAR, SHEET, CASTINGS, ETC.

HISTORY OF MATERIAL

Wrought tubing

HEAT TREATMENT

(a) Subcritical anneal; (b) ASTM Spec. A-213

MICROSTRUCTURE

GRAIN SIZE

HARDNESS

SOURCE OF DATA

Babcock & Wilcox

ORIGINAL CREEP AND RUPTURE DATA (RUPTURE TIME INDICATED BY R IN TEST DURATION COLUMN)											
TEMPERATURE F	STRESS KSI	TIME, HOURS, FOR TOTAL OR PLASTIC STRAIN (DELETE ONE)				MINIMUM CREEP RATE %/HR	INTERCEPT %	TRANSITION TO THIRD STAGE CREEP		TEST DURATION HOURS R	FINAL EXTENSION OR ELONGATION %
		0.1%	0.2%	0.5%	1.0%			HOURS	%		
(a) 1000	30									208	44
1000	26									552	51
1000	24									1,062	48.5
1000	18.5									3,825	59
1000	15									14,541	48.5
1100	18.3									80	71.5
1100	13.6									574	54
1100	10									4,264	43
1100	9									7,752	39.5
(b) 1000	38					0.0028				1,057	15
1000	35					0.0029				1,108	15
1000	30					0.00074				2,440	12.5
1000	25					0.00033				3,144	20
1000	19					0.0001				6,925	38
1100	16					0.023				498	35.5
1100	12					0.007				1,375	42.9
1100	10					0.0017				3,544	29.5
1100	8					0.00048				11,433	34

ASTM-ASME JOINT COMMITTEE ON EFFECT OF TEMPERATURE ON PROPERTIES OF METALS																	
DATA AND PUBLICATIONS PANEL DATA SHEET																	
MATERIAL	Alloy Steel																
ALLOY	2-1/4 Cr - 1 Mo																
TYPE OF HEATING	Induction																
SIZE OF HEAT	7-64																
PRODUCER	Electric Steel Foundry Company																
SPECIFICATIONS:	CHEMICAL COMPOSITION, PER CENT																
	C	Mn	P	S	Si	Ca	Ni	Co	Mo	W	Cr	Ti	Al	V	B		
	0.08	0.46	--	--	0.49	2.33	--	--	0.95								
	Co	Fe															
		Bal.															
DEFORMATION																	
FORM & SIZE, BAR, SHEET, CASTINGS, ETC.																	
HISTORY OF MATERIAL																	
Welded with AWS E 9016 electrode																	
HEAT TREATMENT	Stock - 1800 F, 3 hr, 1600 F, 1 hr, W.Q.; 1200 F, 8 hr; weld also SR 4 hr at 1200 F																
MICROSTRUCTURE																	
GRAIN SIZE																	
HARDNESS	See below.																
SOURCE OF DATA	A. O. Smith Company - Metallurgical Research Laboratory																
	SHORT TIME TENSILE PROPERTIES																
TEMPERATURE F	ELASTIC MODULUS (10 ⁶ PSI)	TENSILE STRENGTH KSI	YIELD STRENGTH KSI		ELONGATION IN T PER CENT		REDUCTION IN AREA PER CENT		MISCELLANEOUS DATA								
			0.02%	0.1%	0.2%												
Room	--	70.5	--	--	40.0	32.0	65.9			Stock only							
Room	29.97	71.9	--	--	40.0	18.0	62.9			Stock plus weld - failed in stock							
1000	--	44.5	--	--	19.0	67.7			Stock plus weld - failed in stock								
	Vickers Hardness (10 kg)																
		Max.	Min.	Aver.													
SR	Stock	167	154	159.8													
SR	HAZ	224	158	192.1													
SR	Weld	249	240	244.6													
SR plus	Stock	160	154	154													
10,000 hr at	HAZ	228	165	192.7													
1000 F	Weld	235	215	222.8													

ASTM-ASME JOINT COMMITTEE ON EFFECT OF TEMPERATURE ON PROPERTIES OF METALS																	
DATA AND PUBLICATIONS PANEL DATA SHEET																	
MATERIAL	Alloy Steel																
ALLOY	2-1/4 Cr - 1 Mo																
TYPE OF HEATING	Basic Electric Arc																
SIZE OF HEAT	100 T																
PRODUCER	Lukens Steel Company																
SPECIFICATIONS:	CHEMICAL COMPOSITION, PER CENT																
	C	Mn	P	S	Si	Ca	Ni	Co	Mo	W	Cr	Ti	Al	V	B		
(a)	0.12	0.43	0.008	0.016	0.30	2.40			0.96								
(b)	0.12	0.50	0.009	0.021	0.31	2.30			0.91								
	Co	Fe															
(a)	0.19	Bal.															
(b)	0.18	Bal.															
DEFORMATION	Fine grain																
FORM & SIZE, BAR, SHEET, CASTINGS, ETC.	Plate, 0.226 x 86 x 7-1/4																
HISTORY OF MATERIAL	Test plate size, 13 x 13 x 7-1/4																
Norm.	1650/1700 1 hr/in. + A.C.; Temp. 1250/1275 1 hr/in. + A.C.																
S.R.	2 cycles 1250/1275 1 hr/in. + F.C. to 600 + A.C.; S.R. 3 cycles 1050 1 hr/in. + F.C. to 600 + A.C.																
S.R.	1 cycle 1250/1275 1 hr/in. + F.C. to 600 + A.C.																
HEAT TREATMENT																	
MICROSTRUCTURE	Ferrite and Bainite																
GRAIN SIZE	No. 7 to No. 8																
HARDNESS																	
SOURCE OF DATA	Lukens Steel Company																
	SHORT TIME TENSILE PROPERTIES																
TEMPERATURE F	ELASTIC MODULUS (10 ⁶ PSI)	TENSILE STRENGTH KSI	YIELD STRENGTH KSI		ELONGATION IN T PER CENT		REDUCTION IN AREA PER CENT		MISCELLANEOUS DATA								
			0.02%	0.1%	0.2%												
(a) 70 T*	100.0																
70 B*	92.1				70.3	22	72.8										
850 T	73.7				53.4	22	66.7										
850 B	78.1				41.0	24	62.7										
(b) 70 T	88.6																
70 B	95				65	24	70.5										
850 T	74				53.8	24	71.5										
850 B	65.5				45.7	22	70.5										
	*T = top; B = bottom.																

ORIGINAL CREEP AND RUPTURE DATA (RUPTURE TIME INDICATED BY R IN TEST DURATION COLUMN)											
TEMPERATURE F	STRESS KSI	TIME, HOURS FOR TOTAL OF PLASTIC STRAIN (DELETE ONE)				MINIMUM CREEP RATE %/HR	INTERCEPT %	TRANSITION TO THIRD STAGE CREEP		TEST DURATION HOURS R	FINAL EXTENSION OR ELONGATION %
		0.1%	0.2%	0.4%	1.0%			HOURS	%		
1000	32.0(1)	(not aged)								2.3	21.5
1000	25.0(2)	(not aged)								160.5	22.0
1000	20.0(3)	(1000 hr at 1000 F)								620.2	19.0
1000	18.5(4)	(5000 hr at 1000 F)								1503.0	24.5
1000	17.0(5)	(5000 hr at 1000 F)								3431.7	19.0
1000	13.0(6)	(10,000 hr at 1000 F)								9576.0	21.0
1000	22.5(7)	(10,000 hr at 1000 F)								97.5	22.0
Note: All failures were in the parent stock.											
CREEP AND RUPTURE STRENGTHS											
TEMPERATURE F	STRESS, KSI FOR RUPTURE IN TIMES INDICATED				STRESS, KSI FOR DESIGNATED CREEP RATE				10* HRS	0.0001%/HR	0.001%/HR
	10 HRS	100 HRS	1,000 HRS	10,000 HRS	0.0001%/HR	0.0002%/HR	0.001%/HR	0.002%/HR			
1000					10*						
*Extrapolated.											

ASTM-ASME JOINT COMMITTEE ON EFFECT OF TEMPERATURE ON PROPERTIES OF METALS																	
DATA AND PUBLICATIONS PANEL DATA SHEET																	
MATERIAL	Alloy Steel																
ALLOY	2-1/4 Cr - 1 Mo																
TYPE OF HEATING	Basic Electric Arc																
SIZE OF HEAT	100 T																
PRODUCER	Lukens Steel Company																
SPECIFICATIONS:	CHEMICAL COMPOSITION, PER CENT																
	C	Mn	P	S	Si	Ca	Ni	Co	Mo	W	Cr	Ti	Al	V	B		
(a)	0.13	0.44	0.008	0.025	0.29	2.14			0.95								
(b)	0.13	0.49	0.007	0.019	0.35	2.20			0.98								
	Co	Fe															
(a)	0.20	Bal.															
(b)	0.21	Bal.															
DEFORMATION	Fine grain																
FORM & SIZE, BAR, SHEET, CASTINGS, ETC.	Plate, 226 x 86 x 7-1/4																
HISTORY OF MATERIAL	Test plate size, 13 x 13 x 7-1/4																
Norm.	1650/1700 1 hr/in. + A.C.; Temp. 1250/1275 1 hr/in. + A.C.																
S.R.	2 cycles 1250/1275 1 hr/in. + F.C. to 600 + A.C.; S.R. 3 cycles 1050 1 hr/in. + F.C. to 600 + A.C.																
S.R.	1 cycle 1250/1275 1 hr/in. + F.C. to 600 + A.C.																
HEAT TREATMENT																	
MICROSTRUCTURE	Ferrite and Bainite																
GRAIN SIZE	No. 7 to No. 8																
HARDNESS																	
SOURCE OF DATA	Lukens Steel Company																
	SHORT TIME TENSILE PROPERTIES																
TEMPERATURE F	ELASTIC MODULUS (10 ⁶ PSI)	TENSILE STRENGTH KSI	YIELD STRENGTH KSI		ELONGATION IN T PER CENT		REDUCTION IN AREA PER CENT		MISCELLANEOUS DATA								
			0.02%	0.1%	0.2%												
(a) 70 T*	87.1																
70 B*	98.5				70.2	21	66.1										
850 T	68.0				41.7	18	50.5										
850 B	71.4				50.9	26	74.4										
(b) 70 T	99.5																
70 B	95.8				85.6	21	68										
850 T	76.4				65.8	22	66.8										
850 B	71.5				57.4	22	68										
	*T = top; B = bottom.																

ORIGINAL CREEP AND RUPTURE DATA (RUPTURE TIME INDICATED BY R IN TEST DURATION COLUMN)											
TEMPERATURE F	STRESS KSI	TIME, HOURS, FOR TOTAL OR PLASTIC STRAIN (DELETE ONE)				MINIMUM CREEP RATE %/HR	INTERCEPT %	TRANSITION TO THIRD STAGE CREEP		TEST DURATION HOURS R	FINAL EXTENSION OR ELONGATION %
		0.1%	0.2%	0.5%	1.0%			HOURS	%		
(a) 1000	35									27	81
1000	28									191	85
1000	24									1027	63
1100	20									78	64
1100	15									750	56
1100	13									1914	41
(b) 1000	35									69	60
1000	28									268	50
1000	24									1404	58

ASTM-ASME JOINT COMMITTEE ON EFFECT OF TEMPERATURE ON PROPERTIES OF METALS
DATA AND PUBLICATIONS PANEL DATA SHEET 7-78

MATERIAL Alloy Steel
ALLOY 2-1/4 Cr - 1 Mo
TYPE OF HEATING Electric Furnace
PRODUCER Timken Roller Bearing Company
SPECIFICATIONS

CHEMICAL COMPOSITION, PER CENT

C	Mn	P	S	Si	Ca	Ni	Cu	Mo	W	Ti	Al	V	B
(a) 0.10	0.31	0.012	0.018	0.35	2.31	0.17		0.98					
(b) 0.10	0.42	0.009	0.016	0.35	2.25	0.13		0.98					
(a) 0.11													
(b) 0.13													

DEGRADATION Aluminum
FORM & SIZE, BAR, SHEET, CASTINGS, ETC. Seamless tubing, 2.262" O.D. x 0.590" wall
HISTORY OF MATERIAL
Pierced, hot rolled, cold drawn, annealed from 1650 F

HEAT TREATMENT Annealed from 1650 F

MICROSTRUCTURE
GRAIN SIZE
HARDNESS
SOURCE OF DATA Timken Roller Bearing Company

ORIGINAL CREEP AND RUPTURE DATA (RUPTURE TIME INDICATED BY R IN TEST DURATION COLUMN)											
TEMPERATURE F	STRESS KSI	TIME, HOURS, FOR TOTAL OR PLASTIC STRAIN (DELETE ONE)				MINIMUM CREEP RATE %/HR	INTERCEPT %	TRANSITION TO THIRD STAGE CREEP		TEST DURATION HOURS R	FINAL EXTENSION OR ELONGATION %
		0.1%	0.2%	0.5%	1.0%			HOURS	%		
(a) 1000	22.0									598	53
1000	19.0									1204	58
1100	13.5									350	79
1100	11.0									1245	50
(b) 1000	22									706	57
1000	19.5									1935	48
1100	15									714	57
1100	12.5									2774	35

CREEP AND RUPTURE STRENGTHS											
TEMPERATURE F	STRESS, KSI FOR RUPTURE IN TIMES INDICATED	STRESS, KSI FOR DESIGNATED CREEP RATE				10,000 HRS	10,000 HRS	10,000 HRS	10,000 HRS	10,000 HRS	10,000 HRS
		10 HRS	100 HRS	1,000 HRS	10,000 HRS						
(a) 1000		31.5	29.5								
1100		16.4	11.2								
(b) 1000		29	21								
1100		19.3	14								

ASTM-ASME JOINT COMMITTEE ON EFFECT OF TEMPERATURE ON PROPERTIES OF METALS
DATA AND PUBLICATIONS PANEL DATA SHEET 7-79

MATERIAL Alloy Steel
ALLOY 2-1/4 Cr - 1 Mo
TYPE OF HEATING Electric Furnace
PRODUCER Timken Roller Bearing Company
SPECIFICATIONS

CHEMICAL COMPOSITION, PER CENT

C	Mn	P	S	Si	Ca	Ni	Cu	Mo	W	Ti	Al	V	B
(a) 0.10	0.41	0.011	0.020	0.26	2.18	0.15		0.97					
(b) 0.10	0.41	0.008	0.013	0.34	2.28	0.18		0.98					
(c) 0.09	0.43	0.009	0.016	0.35	2.35	0.17		1.03					
(a) 0.14													
(b) 0.12													
(c) 0.12													

DEGRADATION Aluminum
FORM & SIZE, BAR, SHEET, CASTINGS, ETC. Seamless tubing: (a) 2.812" O.D. x 0.656" wall; (b) and (c) 5-3/4" O.D. x 0.855 wall
HISTORY OF MATERIAL
Pierced, hot rolled, annealed from 1650 F

HEAT TREATMENT Annealed from 1650 F

MICROSTRUCTURE
GRAIN SIZE
HARDNESS
SOURCE OF DATA Timken Roller Bearing Company

ORIGINAL CREEP AND RUPTURE DATA (RUPTURE TIME INDICATED BY R IN TEST DURATION COLUMN)											
TEMPERATURE F	STRESS KSI	TIME, HOURS, FOR TOTAL OR PLASTIC STRAIN (DELETE ONE)				MINIMUM CREEP RATE %/HR	INTERCEPT %	TRANSITION TO THIRD STAGE CREEP		TEST DURATION HOURS R	FINAL EXTENSION OR ELONGATION %
		0.1%	0.2%	0.5%	1.0%			HOURS	%		
(a) 1000	35									16	51
1000	28									97	56
1000	24									375	59
1000	20									1183	74
1100	19									78	77
1100	16									306	79
1100	13									1846	44
(b) 1100	19									165	45
1100	16									621	44
1100	13									2835	41
(c) 1100	19									193	54
1100	16									814	51
1100	13									5127	39

CREEP AND RUPTURE STRENGTHS											
TEMPERATURE F	STRESS, KSI FOR RUPTURE IN TIMES INDICATED	STRESS, KSI FOR DESIGNATED CREEP RATE				10,000 HRS	10,000 HRS	10,000 HRS	10,000 HRS	10,000 HRS	10,000 HRS
		10 HRS	100 HRS	1,000 HRS	10,000 HRS						
(a) 1000		28	21	16*							
1100		18	13.8	10.5*							
(b) 1100		20	15	11*							
(c) 1100		20	15.3	12*							

ASTM-ASME JOINT COMMITTEE ON EFFECT OF TEMPERATURE ON PROPERTIES OF METALS
DATA AND PUBLICATIONS PANEL DATA SHEET 7-80

MATERIAL Alloy Steel
ALLOY 2-1/4 Cr - 1.0 Mo
TYPE OF HEATING Commercial
PRODUCER Titusville Forge
SPECIFICATIONS

CHEMICAL COMPOSITION, PER CENT

C	Mn	P	S	Si	Ca	Ni	Cu	Mo	W	Ti	Al	V	B
0.11	0.45	0.005	0.007	0.28	2.48			0.91					
Cu	Fe												

DEGRADATION
FORM & SIZE, BAR, SHEET, CASTINGS, ETC. Pipe, 10-1/2" O.D. with 1-3/4" wall
HISTORY OF MATERIAL

HEAT TREATMENT Annealed per ASTM Spec. A-335

MICROSTRUCTURE
GRAIN SIZE
HARDNESS
SOURCE OF DATA Babcock & Wilcox

ORIGINAL CREEP AND RUPTURE DATA (RUPTURE TIME INDICATED BY R IN TEST DURATION COLUMN)											
TEMPERATURE F	STRESS KSI	TIME, HOURS, FOR TOTAL OR PLASTIC STRAIN (DELETE ONE)				MINIMUM CREEP RATE %/HR	INTERCEPT %	TRANSITION TO THIRD STAGE CREEP		TEST DURATION HOURS R	FINAL EXTENSION OR ELONGATION %
		0.1%	0.2%	0.5%	1.0%			HOURS	%		
1000	25									650	60.5
1000	22.5									1175	53
1000	20									3098	43.5
1000	17.5									9721	31
1100	15									544	37.5
1100	13.5									3385	22.5
1100	12									5858	43
1200	9									1270	11.5
1200	7									3126	43
1200	5.5									4889	30.5

CREEP AND RUPTURE STRENGTHS											
TEMPERATURE F	STRESS, KSI FOR RUPTURE IN TIMES INDICATED	STRESS, KSI FOR DESIGNATED CREEP RATE				10,000 HRS	10,000 HRS	10,000 HRS	10,000 HRS	10,000 HRS	10,000 HRS
		10 HRS	100 HRS	1,000 HRS	10,000 HRS						
1000			23.1	17.5	13*						
1100			17	11							
1200			9.5	5.3							

ASTM-ASME JOINT COMMITTEE ON EFFECT OF TEMPERATURE ON PROPERTIES OF METALS
DATA AND PUBLICATIONS PANEL DATA SHEET 7-81

MATERIAL: Alloy Steel
ALLOY: 2-1/4 Cr - 1.0 Mo
PRODUCER: Titusville Forge
SPECIFICATIONS: Commercial

CHEMICAL COMPOSITION, PER CENT

C	Mn	P	S	Si	Cr	Ni	Co	Mo	W	Cu	Ti	Al	V	B
0.09	0.38	0.005	0.005	0.38	2.25			0.92						

OXIDIZATION: Pipe, 10-1/2" O.D. with 1-3/4" wall

FORM & SIZE - BAR, SHEET, CASTINGS, ETC.
HISTORY OF MATERIAL

HEAT TREATMENT: Annealed per ASTM Spec. A-335

MICROSTRUCTURE

GRAIN SIZE

HARDNESS

DATE OF DATA: Babcock & Wilcox

ORIGINAL CREEP AND RUPTURE DATA
(RUPTURE TIME INDICATED BY R IN TEST DURATION COLUMN)

TEMPERATURE °C	STRESS KSI	TIME, HOURS, FOR TOTAL OR PLASTIC STRAIN (DELETE ONE)				MINIMUM CREEP RATE %/HR	INTERCEPT %	TRANSITION TO THIRD STAGE CREEP		TEST DURATION HOURS R	FINAL EXTENSION OR ELONGATION %
		0.1%	0.2%	0.5%	1.0%			HOURS	%		
1000	25									467	43.5
1000	20									1042	49.5
1000	18									3201	41.5
1000	16									7597	43
1100	15									343	64.5
1100	12									1987	50.5
1200	10									464	35.5
1200	7.5									1846	34
1200	6.5									2,783	34

CREEP AND RUPTURE STRENGTHS

TEMPERATURE °F	STRESS, KSI FOR RUPTURE IN TIMES INDICATED					STRESS, KSI FOR DESIGNATED CREEP RATE				
	10 HRS	100 HRS	1,000 HRS	10,000 HRS	100,000 HRS	0.0001%/HR	0.0002%/HR	0.0005%/HR	0.001%/HR	
1000			20.5	15.5	12*					
1100			13	9.8						
1200			8.5	5.5						

*Extrapolated.

ASTM-ASME JOINT COMMITTEE ON EFFECT OF TEMPERATURE ON PROPERTIES OF METALS
DATA AND PUBLICATIONS PANEL DATA SHEET 7-82

MATERIAL: Alloy Steel
ALLOY: 2-1/4 Cr - 1.0 Mo
PRODUCER: Titusville Forge
SPECIFICATIONS: Commercial

CHEMICAL COMPOSITION, PER CENT

C	Mn	P	S	Si	Cr	Ni	Co	Mo	W	Cu	Ti	Al	V	B
0.09	0.54	0.005	0.008	0.46	2.40			0.90						

OXIDIZATION: Pipe, 10-1/2" O.D. with 1-3/4" wall

FORM & SIZE - BAR, SHEET, CASTINGS, ETC.
HISTORY OF MATERIAL

HEAT TREATMENT: Annealed per ASTM Spec. A-335

MICROSTRUCTURE

GRAIN SIZE

DATE OF DATA: Babcock & Wilcox

CREEP AND RUPTURE STRENGTHS									
TEMPERATURE °F	STRESS, KSI FOR RUPTURE IN TIMES INDICATED					STRESS, KSI FOR DESIGNATED CREEP RATE			
	10 HRS	100 HRS	1,000 HRS	10,000 HRS	100,000 HRS	0.0001%/HR	0.0002%/HR	0.0005%/HR	0.001%/HR
1000			19	15	12*				
1050		27	16.5	9.8					
1100			11.5	8.6	6.3*				
1150		15	10.4	7.2					
1200			6.9	4.6	3.15*				
				</					

ORIGINAL CREEP AND RUPTURE DATA
(RUPTURE TIME INDICATED BY R IN TEST DURATION COLUMN)

TEMPERATURE °F	STRESS KSI	TIME, HOURS, FOR TOTAL OR PLASTIC STRAIN (DELETE ONE)				MINIMUM CREEP RATE %/HR	INTERCEPT %	TRANSITION TO THIRD STAGE CREEP		TEST DURATION HOURS	FINAL EXTENSION OR ELONGATION %
		0.1%	0.2%	0.5%	1.0%			HOURS	%		
1000	25									80	60.5
1000	20									584	79.5
1000	16.5									2,437	57.5
1000	14									22,242	29.5
1050	21									330	79.5
1050	16									1,529	39.8
1100	15									152	76
1100	12									924	41.5
1100	9									7,086	35.5
1150	12									399	67.5
1150	10									1,181	43
1200	10									116	59
1200	7.5									891	38
1200	5									5,766	17.5

ASTM-ASME JOINT COMMITTEE ON EFFECT OF TEMPERATURE ON PROPERTIES OF METALS
DATA AND PUBLICATIONS PANEL DATA SHEET 7-83

MATERIAL: Alloy Sheet
ALLOY: 2-1/4 Cr - 1.0 Mo
PRODUCER: Titusville Forge
SPECIFICATIONS: Commercial

CHEMICAL COMPOSITION, PER CENT

C	Mn	P	S	Si	Cr	Ni	Co	Mo	W	Cu	Ti	Al	V	B
0.14	0.36	0.005	0.005	0.15	2.07			0.94						

OXIDIZATION: Pipe, 10-1/2" O.D. with 1-3/4" wall

FORM & SIZE - BAR, SHEET, CASTINGS, ETC.
HISTORY OF MATERIAL

HEAT TREATMENT: Annealed per ASTM Spec. A-335

MICROSTRUCTURE

GRAIN SIZE

HARDNESS

DATE OF DATA: Babcock & Wilcox

ORIGINAL CREEP AND RUPTURE DATA
(RUPTURE TIME INDICATED BY R IN TEST DURATION COLUMN)

TEMPERATURE °F	STRESS KSI	TIME, HOURS, FOR TOTAL OR PLASTIC STRAIN (DELETE ONE)				MINIMUM CREEP RATE %/HR	INTERCEPT %	TRANSITION TO THIRD STAGE CREEP		TEST DURATION HOURS R	FINAL EXTENSION OR ELONGATION %
		0.1%	0.2%	0.5%	1.0%			HOURS	%		
1000	25									811	54.5
1000	23.5									1,971	40.5
1000	22									3,058	46
1000	19									8,007	37.5
1000	17									19,153	31.5
1100	15									617	61.5
1100	12									5,014	27
1200	10									387	38
1200	7.5									1,708	27.5
1200	6									3,203	27
								</			

ASTM-ASME JOINT COMMITTEE ON EFFECT OF TEMPERATURE ON PROPERTIES OF METALS																	
DATA AND PUBLICATIONS PANEL DATA SHEET																	
7-87																	
MATERIAL		Alloy Steel															
ALLOY		2-1/4 Cr - 1.0 Mo															
TYPE OF HEATING		Electric Furnace															
SIZE OF HEAT		Commercial															
PRODUCER		Babcock & Wilcox															
SPECIFICATIONS:		CHEMICAL COMPOSITION, PER CENT															
		C	Mn	P	S	Si	Cr	Ni	Co	Mo	W	Cu	Ti	Al	V	B	
		0.11	0.51	0.010	0.015	0.36	2.16	0.11		0.95							
		Cu	Fe														
DEOXIDATION																	
FORM & SIZE - BAR, SHEET, CASTINGS, ETC.		Wrought tube															
HISTORY OF MATERIAL																	
HEAT TREATMENT		Subcritical anneal															
MICROSTRUCTURE																	
GRAIN SIZE																	
HARDNESS		BHN 146															
SOURCE OF DATA		Babcock & Wilcox															

ORIGINAL CREEP AND RUPTURE DATA											
(RUPTURE TIME INDICATED BY R IN TEST DURATION COLUMN)											
TEMPERATURE F	STRESS KSI	TIME, HOURS, FOR TOTAL OR PLASTIC STRAIN (DELETE ONE)				MINIMUM CREEP RATE %/HR	INTERCEPT %	TRANSITION TO THIRD STAGE CREEP		TEST DURATION HOURS R	FINAL EXTENSION OR ELONGATION %
		0.1%	0.2%	0.5%	1.0%			HOURS	%		
1000	22.5									420	53.5
1000	20									1,045	54
1000	16.5									4,013	54.5
1000	15									6,847	37.5
1100	15									183	39.8
1100	12									959	42
1100	9									4,477	34
1100	7.8									13,703	22.5
1200	10									161	42.5
1200	9									270	43.5
1200	7.5									814	41
1200	5									3,418	25
1200	3.7									9,913	16

CREEP AND RUPTURE STRENGTHS									
TEMPERATURE F	STRESS, KSI FOR RUPTURE IN TIMES INDICATED					STRESS, KSI FOR DESIGNATED CREEP RATE			
	10 HRS	100 HRS	1,000 HRS	10,000 HRS	100,000 HRS	0.0001%/HR	0.0005%/HR	0.001%/HR	0.01%/HR
1000			23	14.5					
1100			11.5	8.3	5.8*				
1200			7.1	3.7					

*Extrapolated.

ASTM-ASME JOINT COMMITTEE ON EFFECT OF TEMPERATURE ON PROPERTIES OF METALS																	
DATA AND PUBLICATIONS PANEL DATA SHEET																	
7-88																	
MATERIAL		Alloy Steel															
ALLOY		2-1/4 Cr - 1.0 Mo															
TYPE OF HEATING		Electric Furnace															
SIZE OF HEAT		Commercial															
PRODUCER		Babcock & Wilcox															
SPECIFICATIONS:		CHEMICAL COMPOSITION, PER CENT															
		C	Mn	P	S	Si	Cr	Ni	Co	Mo	W	Cu	Ti	Al	V	B	
		(a) 0.09	0.42	0.012	0.015	0.32	2.03	0.21		0.97							
		(b) 0.11	0.46	0.012	0.017	0.35	2.20	0.13		1.02							
		(a) 0.11															
		(b) 0.08															
DEOXIDATION																	
FORM & SIZE - BAR, SHEET, CASTINGS, ETC.		Wrought tube															
HISTORY OF MATERIAL																	
HEAT TREATMENT		Annealed per ASTM Spec. A-213															
MICROSTRUCTURE																	
GRAIN SIZE		(a), (b) R _p 77															
HARDNESS																	
SOURCE OF DATA		Babcock & Wilcox															
SHORT TIME TENSILE PROPERTIES																	
TEMPERATURE F	ELASTIC MODULUS (10 ⁶ PSI)	TENSILE STRENGTH KSI	YIELD STRENGTH, KSI			ELONGATION IN 2" PER CENT	REDUCTION IN AREA PER CENT	MISCELLANEOUS DATA									
			0.02%	0.1%	0.2%												
(b) Room		64.7			37.6	43											

ORIGINAL CREEP AND RUPTURE DATA									
(RUPTURE TIME INDICATED BY R IN TEST DURATION COLUMN)									
TEMPERATURE F	STRESS KSI	TIME, HOURS, FOR TOTAL OR PLASTIC STRAIN (DELETE ONE)			MINIMUM CREEP RATE %/HR	INTERCEPT %	TRANSITION TO THIRD STAGE CREEP	TEST DURATION HOURS	FINAL EXTENSION OR ELONGATION %
		0.1%	0.2%	0.5%					
(a) 1000	28				0.0031			791	26
1000	23				0.0012			1,857	28
1000	20				0.0005			2,431	52
1000	18				0.00034			4,127	33
1000	16							8,258	31.5
1100	15				0.034			498	38.5
1100	12				0.0028			3,164	40
1100	10.5				0.0012			3,970	53.5
1100	9.2				0.00063			8,229	24
(b) 1000	25				0.040			687	57
1000	20				0.0095			1,798	63.5
1000	18				0.0057			3,680	47.5
1000	16				0.00055			10,854	34
1100	15				0.040			371	52
1100	12				0.00095			2,574	43.5
1100	10				0.00023			8,132	42.5

CREEP AND RUPTURE STRENGTHS

TEMPERATURE F	STRESS, KSI FOR RUPTURE IN TIMES INDICATED					STRESS, KSI FOR DESIGNATED CREEP RATE			
	10 HRS	100 HRS	1,000 HRS	10,000 HRS	100,000 HRS	0.0001%/HR	0.0005%/HR	0.001%/HR	0.01%/HR
(a) 1000			26	15.5	10*			14.5	22.5
1100			13.5	8.7	5.6*			8	10.2
(b) 1000			22.5	16	12*			14	16.5
1100			13.5	9.8	7.3*			9.7	11.5

*Extrapolated.

ASTM-ASME JOINT COMMITTEE ON EFFECT OF TEMPERATURE ON PROPERTIES OF METALS																	
DATA AND PUBLICATIONS PANEL DATA SHEET																	
7-89																	
MATERIAL		Alloy Steel															
ALLOY		3 Cr - 1/2 Mo - 1-1/4 Si															
TYPE OF HEATING		Electric Furnace															
SIZE OF HEAT																	
PRODUCER		U. S. Steel															
SPECIFICATIONS:		CHEMICAL COMPOSITION, PER CENT															
		C	Mn	P	S	Si	Cr	Ni	Co	Mo	W	Cu	Ti	Al	V	B	
		0.11	0.41	0.022	0.012	1.06	2.81	0.25		0.52				0.020			
		Cu	Fe			N											
		0.12		0.014													
DEOXIDATION		Silicon plus 1 pound of aluminum per ton															
FORM & SIZE - BAR, SHEET, CASTINGS, ETC.		1-in. - square bars															
HISTORY OF MATERIAL																	
HEAT TREATMENT		Annealed at 1550 F															
MICROSTRUCTURE																	
GRAIN SIZE																	
HARDNESS																	
SOURCE OF DATA		U. S. Steel Applied Research Laboratory															
SHORT TIME TENSILE PROPERTIES																	
TEMPERATURE F	ELASTIC MODULUS (10 ⁶ PSI)	TENSILE STRENGTH KSI	YIELD STRENGTH, KSI			ELONGATION IN 2" PER CENT	REDUCTION IN AREA PER CENT	MISCELLANEOUS DATA									
			0.02%	0.1%	0.2%												
80		78.9			39	79											
80		78.9			39	79											

CREEP AND RUPTURE STRENGTHS

TEMPERATURE F	STRESS, KSI FOR RUPTURE IN TIMES INDICATED					STRESS, KSI FOR DESIGNATED CREEP RATE			
	10 HRS	100 HRS	1,000 HRS	10,000 HRS	100,000 HRS	0.0001%/HR	0.0005%/HR	0.001%/HR	0.01%/HR
900			31.5	26.1*					
1050			12.9	9.0*					
1200			5.6	3.7*					

*Extrapolated data.

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

MATERIAL

3 Cr - 1 Mo

ALLOT

PRODUCER

SPECIFICATIONS:

TYPE OF HEATING

Electric Furnace

SIZE OF HEAT

7-90

CHEMICAL COMPOSITION, PER CENT

C	Mn	P	S	Si	Cr	Ni	Co	Mo	W	Cu	Ti	Al	V	B
0.11	0.44	0.024	0.017	0.29	2.93	0.33		0.89						
Cu	Fe													
0.16														

DEOXIDATION:

FORM & SIZE, BAR, SHEET, CASTINGS, ETC.

WROUGHT OF MATERIAL:

Wrought bar, 3/4" diam.

HEAT TREATMENT

ANNEALING

MICROSTRUCTURE

GRAIN SIZE

HARDNESS

SOURCE OF DATA

Annealed per ASTM Spec. A-213

Babcock & Wilcox

ORIGINAL CREEP AND RUPTURE DATA (RUPTURE TIME INDICATED BY R IN TEST DURATION COLUMN)											
TEMPERATURE °F	STRESS KSI	TIME, HOURS, FOR TOTAL OR PLASTIC STRAIN (ONLY ONE)				MINIMUM CREEP RATE %/HR	INTERCEPT %	TRANSITION TO THIRD STAGE CREEP		TEST DURATION HOURS	FINAL EXTENSION OR ELONGATION %
		0.1%	0.2%	0.5%	1.0%			HOURS	%		
1000	25									433	55
1000	19.8					0.0057				2,565	61
1000	17.5									3,314	58
1000	15.5									4,842	38.5
1000	12.5									15,825	50.5
1100	17.9									29	84
1100	15									68	76
1100	10					0.024				1,001	102.5
1100	8					0.0029				5,259	65.5
1100	8					0.0059				4,081	37.5
1100	7					0.00062				16,853	43.5
1200	10									107	56.5
1200	7.5									473	88
1200	6									1,694	53
1200	5									3,602	55.5
1200	4.4									6,544	39

CREEP AND RUPTURE STRENGTHS										
TEMPERATURE °F	STRESS, KSI FOR RUPTURE IN TIMES INDICATED					STRESS, KSI FOR DESIGNATIO CREEP RATE				
	10 HRS	100 HRS	1,000 HRS	10,000 HRS	100,000 HRS	0.00001%/HR	0.0001%/HR	0.001%/HR	0.01%/HR	
1000			22.5	13.5	9.6*					
1100			10.1	7.5	5.5*			5.7	7.3	
1200			6.5	4.0	2.4*					
*Extrapolated.										

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

7-13

MATERIAL

ALLOY

PRODUCER

SPECIFICATIONS:

Alloy Steel

5%Cr-1/2%Mo

Base Plate; Electric Steel Foundry Company

TYPE OF HEATING

Induction

WELD OR HEAT

Weld Rod: A. O. Smith Corporation

CHEMICAL COMPOSITION, PER CENT

C	Mn	P	S	Si	Ca	Ni	Co	Mo	W	Cu	Ti	Al	V	B
0.10	0.68			0.40	5.20			0.62						
0.12	0.75	0.03	0.03	0.40	5.00	0.50		0.55						
Cu	Fe													

Carbon in castings
0.10 max for weldability

DEFORMATION

FORM & SIZE - BAR SHEET, CASTINGS, ETC.

HISTORY OF MATERIAL

MEAT TREATMENT

MICROSTRUCTURE

GRAIN SIZE

HARDNESS

SOURCE OF DATA

Joint welded 0.505" dia.

SHORT TERM TENSILE PROPERTIES

Stress relieved

MISCELLANEOUS DATA

TEMPERATURE F	ELASTIC MODULUS IN PSI	TENSILE STRENGTH KSI	YIELD STRENGTH, KSI			ELONGATION IN 2" PER CENT	REDUCTION IN AREA PER CENT	MISCELLANEOUS DATA								
			0.02%	0.1%	0.2%											
Room	30.15	88.8			67.8	19.0	57.3	Stock failure								
1000		51.4				17.0	68.9	Stock failure								

TEMPERATURE F		STRESS, KSI FOR RUPTURE IN TIMES INDICATED					STRESS, KSI FOR DESIGNATED CREEP RATE			
		10 HRS	100 HRS	1,000 HRS	10,000 HRS	100,000 HRS	0.0005%/HR	0.001%/HR	0.005%/HR	0.01%/HR
1000		31.0	25.0	18.0	13.0	9.5				
All specimens failed in the stock.										

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

MATERIAL

Alloy Steel

5 Cr - 1/2 Mo

Babcock & Wilcox

PRODUCT SPECIFICATIONS:

TYPE OF HEATING

Electric Furnace

SIZE OF HEAT

Commercial

7-91

CHEMICAL COMPOSITION, PER CENT

C	Mn	P	S	Si	Cr	Ni	Co	Mo	W	Cu	Ti	Al	V	B
0.11	0.48	0.017	0.013	0.40	4.88	0.15		0.55						
Cu	Fe													
0.05														

OXIDATION

FORM & SUFF. BAR, SHEET, CASTINGS, ETC.

Wrought tubing, 4" O.D. x 1/2" wall

HISTORY OF MATERIAL

HEAT TREATMENT

Annealed per ASTM Spec. A-213

MICROSTRUCTURE

GRAIN SIZE

HARDNESS

SOURCE OF DATA

Babcock & Wilcox

ORIGINAL CREEP AND RUPTURE DATA (RUPTURE TIME INDICATED BY R IN TEST DURATION COLUMN)											
TEMPERATURE °F	STRESS KSI	TIME, HOURS FOR TOTAL OR PLASTIC STRAIN				MINIMUM CREEP RATE %/HR	INTERCEPT %	TRANSITION TO THIRD STAGE CREEP		TEST DURATION HOURS R	FINAL EXTENSION OR ELONGATION %
		0.1%	0.2%	0.5%	1.0%			HOURS	%		
1000	20					0.10				248	51.5
1000	18									378	75
1000	15					0.011				2,224	75.1
1000	14					0.0066				3,786	77.5
1000	13					0.0052				4,078	71
1000	11					0.0014				13,805	70
1100	12									298	80.5
1100	9									1,885	61
1100	7.5					0.0017				5,451	52
1100	6.7					0.0009				11,555	63
1200	7.0					0.046				315	54.5
1200	6.5					0.015				622	39.5
1200	5.5					0.007				2,378	40
1200	5.0					0.005				3,200	43
1200	4.6					0.003				5,598	45
1200	4.2					0.0012				9,920	43.5

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

7-94

MATERIAL Alloy Steel
ALLOY 5 Cr - 1/2 Mo - 1-1/2 S
TYPE OF MELTING Electric Furnace
SIZE OF HEAT Commercial
PRODUCER Babcock & Wilcox

CHEMICAL COMPOSITION, PER CENT

C	Mn	P	S	Si	Cr	Ni	Co	Mo	W	Cu	Ti	Al	V	B
0.11	0.51	0.013	0.013	1.46	4.84	0.26		0.51						
0.11														

DEFORMATION Wrought tube

HEAT TREATMENT Annealed per ASTM Spec. A-213

GRAIN SIZE R_n 85

SOURCE OF DATA Babcock & Wilcox

SHORT TIME TENSILE PROPERTIES *								MISCELLANEOUS DATA	
TEMPERATURE F	ELASTIC MODULUS 10 ⁶ PSI	TENSILE STRENGTH KSI	YIELD STRENGTH, KSI			ELONGATION IN 2 IN PER CENT	REDUCTION IN AREA PER CENT	Charpy V-Notch Impact Data	
			0.02%	0.1%	0.2%			Temp.	Impact Value
75	--	276	--	--	230	14	47	F	(ft-lb)
75	--	274	--	--	228	13	42	300	17, 20
800	--	230	--	--	181	14	55	212	18, 20
800	--	232	--	--	183	14	54	180	18, 19
900	--	216	--	--	172	16	56	140	14, 15, 18
900	--	213	--	--	162	16	55	73	13, 14
1000	--	198	--	--	147	14	55	0	10, 10
1000	--	202	--	--	151	16	54	-50	9, 9
1100	--	151	--	--	111	16	56	-100	8, 8
1100	--	152	--	--	112	14	50	-150	5, 6
1200	--	74	--	--	51	40	86		
1200	--	73	--	--	51	32	84		
*0.252-inch-diameter, 1-inch-gage-length specimens.									

ORIGINAL CREEP AND RUPTURE DATA

TEMPERATURE F	STRESS KSI	TIME, HOURS FOR TOTAL OR PLASTIC STRAIN (RUPTURE TIME INDICATED BY R IN TEST DURATION COLUMN)				MINIMUM CREEP RATE %/HR	INTERCEPT %	TRANSITION TO THIRD STAGE CREEP	TEST DURATION HOURS	FINAL EXTENSION OR ELONGATION %
		0.1%	0.2%	0.5%	1.0%					
Temp.	Hardness	Hot	RT	Hardness						
800	54	R _c 47	54							
900	54	R _c 45	54							
1000	54	R _c 43	54							
1100	54	R _c 35	46							
1200	54	R _a 54	42							

*Specimens held at temperature for 1/2 hr before testing.

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

7-5

MATERIAL Alloy Steel
ALLOY Crucible 218
TYPE OF MELTING Electric Furnace
SIZE OF HEAT 15-1/2 tons
PRODUCER Crucible Steel Company of America

CHEMICAL COMPOSITION, PER CENT

C	Mn	P	S	Si	Cr	Ni	Co	Mo	W	Cu	Ti	Al	V	B
0.37	0.39	0.017	0.019	1.02	5.02	0.18		1.35					0.35	
	Fe													

DEFORMATION Aluminum and calcium-silicon

FORM & SIZE: 0.155-inch-thick sheet

HISTORY OF MATERIAL Teamed into 9-inch by 15-inch ingots; forged to 4-inch by 13-inch slabs and given subcritical anneal; rolled to sheet bar and then sheet.

HEAT TREATMENT 1850 F, 1/2 hr, air cool; 1035 F for 2 + 2 hr

MICROSTRUCTURE Tempered martensite

GRAIN SIZE Rockwell "C" 54

HARDNESS Crucible Steel Company of America

SOURCE OF DATA

SOURCE OF DATA		Crucible Steel Company					MISCELLANEOUS DATA	
		SHORT TIME TENSILE PROPERTIES						
TEMPERATURE F	ELASTIC MODULUS 10 ⁶ PSI	TENSILE STRENGTH KSI	YIELD STRENGTH, KSI			ELONGATION IN 2" PER CENT	REDUCTION IN AREA PER CENT	
			0.02%	0.1%	0.2%			
75		279			226	7		
75		272			233	10		
800		228			--	8		
800		229			182	7		
900		217			164	8		
900		217			170	9		
1000		195			151	10		
1000		198			154	8		
1100		145			111	10		
1100		141			110	12		
1200		74			55	30		
1200		72			53	18		

ORIGINAL CREEP AND RUPTURE DATA

TEMPERATURE F	STRESS KSI	TIME, HOURS FOR TOTAL OR PLASTIC STRAIN (RUPTURE TIME INDICATED BY R IN TEST DURATION COLUMN)				MINIMUM CREEP RATE %/HR	INTERCEPT %	TRANSITION TO THIRD STAGE CREEP	TEST DURATION HOURS	FINAL EXTENSION OR ELONGATION %
		0.1%	0.2%	0.5%	1.0%					
1000	18					0.035			576	54.5
1000	15					0.0099			2,013	--
1000	12					0.0016			10,806	88
1100	10					0.018			573	67.5
1100	8					0.0058			2,726	51
1100	6.6					0.00092			10,499	42
1200	7					0.11			112	86.5
1200	5.5					0.025			800	55.5
1200	4.6					0.0046			2,785	44.5
1200	4					0.0025			5,776	46
1200	3.5					0.0010			9,674	33.5
1300	3.5					0.073			349	79
1300	3					0.028			796	44.5
1300	2.2					0.012			2,666	84
1300	1.65					0.0064			7,491	123.5

*Extrapolated.

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

7-4

MATERIAL Alloy Steel
ALLOY Crucible 218
TYPE OF MELTING Electric Furnace
SIZE OF HEAT 15-1/2 tons
PRODUCER Crucible Steel Company of America

CHEMICAL COMPOSITION, PER CENT

C	Mn	P	S	Si	Cr	Ni	Co	Mo	W	Cu	Ti	Al	V	B
0.36	0.37	0.018	0.014	1.07	5.04	0.26		1.39					0.31	
	Fe													

DEFORMATION Aluminum and calcium-silicon

FORM & SIZE: Wrought 1"-diameter round bar

HISTORY OF MATERIAL Teamed into 10-inch ingots; ingots cogged to 3-inch-square billets; billets given subcritical anneal and then rolled to 1-inch-diameter round bars; bars given full anneal

HEAT TREATMENT 1850 F, 1 hr, air cool; 1035 F for 2 + 2 hr

MICROSTRUCTURE Tempered martensite

GRAIN SIZE Rockwell "C" 54

SOURCE OF DATA Crucible Steel Company of America

ORIGINAL CREEP AND RUPTURE DATA (RUPTURE TIME INDICATED BY R IN TEST DURATION COLUMN)											
TEMPERATURE F	STRESS KSI	TIME HOURS FOR TOTAL OR PLASTIC STRAIN (DELETE ONE)				MINIMUM CREEP RATE %/HR	INTERCEPT %	TRANSITION TO THIRD STAGE CREEP		TEST DURATION HOURS	FINAL EXTENSION OR ELONGATION %
		0.1%	0.2%	0.5%	1.0%			HOURS	%		
Creep Data for Isochronous Curves											
Temp.	Stress	Total Strain (%) in									
F:		1 Hr	10 Hr	100 Hr							
800	150	0.75	0.77	0.88							
800	140	0.66	0.72	0.77							
800	120	0.57	0.64	0.69							
800	100	0.42	0.46	0.51							
800	85	0.33	0.35	0.38							
1000	60	0.31	0.50	--							
1000	50	0.27	0.38	0.79							
1000	40	0.23	0.29	0.64							
1000	20	0.11	0.15	0.21							

ASTM-ASME JOINT COMMITTEE ON EFFECT OF TEMPERATURE ON PROPERTIES OF METALS DATA AND PUBLICATIONS PANEL DATA SHEET											7-96			
MATERIAL	Alloy Steel													
ALLOY	5 Cr - 1-1/4 Mo - 1/2 V										TYPE OF HEAT			
Vanadium-Alloy Steel Company										Electric Furnace (air melt)		Heat 30828		
PRODUCER SPECIFICATIONS											CHEMICAL COMPOSITION, PER CENT			
C	Mn	P	S	Si	Cr	Ni	Co	Mo	W	Fe	Ti	Al	V	B
0.40	0.29	0.016	0.021	0.98	5.11			1.30					0.55	
Cu	Fe													
DECEMBER 1950														
FORM & SIZE, BAR, SHEET, CASTINGS, ETC.														
Forged 2-in. bars														
HEAT TREATMENT														
1850 F soak for 30 min, A.C., tempered 2 hr each at 1000 + 1000 + 1000 + 1020 F; SR at 925 F, 2 hr														
MICROSTRUCTURE														
Tempered martensite														
GRAIN SIZE														
7-8														
HARDNESS														
SOURCE OF DATA														
North American Aviation (Report No. NA59H-739)														
SHORT TIME TENSILE PROPERTIES														
TEMPERATURE F	ELASTIC MODULUS (10 ⁶ PSI)	TENSILE STRENGTH KSI	HARDNESS R _C XXXX	YIELD STRENGTH KSI	0.1%	0.2%	ELONGATION IN 2" PER CENT	REDUCTION IN AREA PER CENT	EXPOSURE TEMP.	YIELD STRENGTH KSI	ULTIMATE STRAIN, KSI	REDUCTION IN AREA, %	ELONGA- TION, %	
Room	296.0	55.9		247.8	11.3		41.8							
72	294.5	55.7		251.0	12.1		41.1		700	200.1	254.3	46.7	13.3	
400	271.3	55.7		226.1	11.9		36.0		800	197.2	244.9	51.5	13.3	
600	265.7	55.7		215.4	13.1		46.6		900	183.3	227.9	54.3	15.7	
800	242.8	55.8		196.0	14.5		49.8		1000	124.4	142.8	66.9	20.4	
900	229.4	55.9		180.8	14.4		48.6							
EXPONED 100 Hr														
									700	205.1	255.6	43.7	12.2	
									800	190.7	243.5	50.1	14.3	
									900	173.4	211.6	48.7	15.5	
EXPONED 1000 Hr														
									700	199.7	253.1	45.5	12.6	
									800	187.4	243.0	41.8	12.6	
									900	153.1	185.7	59.5	19.1	

ORIGINAL CREEP AND RUPTURE DATA (RUPTURE TIME INDICATED BY R IN TEST DURATION COLUMN)											
TEMPERATURE F	STRESS KSI	TIME HOURS FOR TOTAL OR PLASTIC STRAIN (Creep) (DELETE ONE)				MINIMUM CREEP RATE %/HR	INITIAL CREEP RATE %/HR	TRANSITION TO THIRD STAGE CREEP		TEST DURATION HOURS	FINAL EXTENSION OR ELONGATION %
		0.1%	0.2%	0.5%	1.0%			HOURS	%		
700	250		0.1	0.3	14	0.02	2.395				17
700	245		0.3	3.5	292	0.0005	2.110				292
700	243		0.9	10	830	0.00017	1.952				840
700	240		0.5	21	4,400*	0.000057	1.760				2849
700	230		2.8	1270	18,000*	0.000030	1.428				2092
800	230		0.5	1.8	47	0.0038	1.810				69
800	225		0.2	5.0	225	0.0012	1.520				212
800	220		0.5	28	770	0.00047	1.448				793
800	215		1.0	88	2,000	0.00021	1.288				2021
900	180		0.5	27	145*	0.004	0.875				133
900	160		22	163	--	0.825	180				796
900	140		42	395	850*	0.0009	0.562				1350
900	110		200	960	2,300*	0.00037	0.452				
*Extrapolated values.											

CREEP AND RUPTURE STRENGTHS										
TEMPERATURE F	STRESS, KSI FOR RUPTURE IN TIMES INDICATED					STRESS, KSI FOR DESIGNATED CREEP RATE				
	10 HRS	100 HRS	1,000 HRS	10,000 HRS	100,000 HRS	0.0001%/HR	0.0005%/HR	0.001%/HR	0.005%/HR	0.01%/HR
700						225	242	246		
800						200	210	224		
900							75	142		

ASTM-ASME JOINT COMMITTEE ON EFFECT OF TEMPERATURE ON PROPERTIES OF METALS													
DATA AND PUBLICATIONS PANEL DATA SHEET													
MATERIAL	Alloy Steel												
ALLOY	5 Cr - 1-1/4 Mo - 1/2 V												
TYPE OF HEATING	Electric Furnace (air melt)												
PRODUCER	Vanadium-Alloy Steel Co.												
SPECIFICATIONS	Heat 31153												
CHEMICAL COMPOSITION, PER CENT													
C	Mn	P	S	Si	Cr	Ni	Co	Mo	V	Al	B		
0.38	0.29	0.016	0.012	0.84	4.75			1.34				0.48	
Cu	Fe												
DECEMBER 1950													
FORM & SIZE - BAR, SHEET, CASTINGS, ETC.													
Forged 2-in. bars													
HEAT TREATMENT													
1850 F soak 30 min, A.C., tempered 2 hr each at 1000 + 1000 + 1000 + 1020 F; SR at 925 F for 2 hr													
MICROSTRUCTURE													
Tempered martensite													
GRAIN SIZE													
7-8													
HARDNESS													
SOURCE OF DATA													
North American Aviation (Report No. NA59H-739)													
SHORT TIME TENSILE PROPERTIES													
TEMPERATURE	ELASTIC MODULUS (10 ⁶ PSI)	TENSILE STRENGTH KSI	HARDNESS R _C XXXX	YIELD STRENGTH KSI	0.1%	0.2%	ELONGATION IN 2" PER CENT	REDUCTION IN AREA PER CENT	EXPOSURE TEMP. F	YIELD STRENGTH KSI	ULTIMATE STRENGTH KSI	REDUCTION IN AREA, %	ELONGATION, %
Room		281.5	54.4			232.4	11.8	38					
72		279.8	54.3			234.5	13.1	44.9	700	196.8	245.4	43.7	13.1
400		260.0	53.7			211.5	12.1	39.5	800	187.3	231.7	49.6	13.1
600		255.8	54.3			211.0	10.2	32.6	900	176.0	217.4	53.3	15.0
800		232.8	54.3			187.7	15.0	48.4					
900		218.4	54.5			183.0	16.4	52.6					
									700	194.4	243.6	46.8	13.6
									800	192.2	232.4	48.2	13.8
									900	175.0	208.5	47.3	14.1
									700	192.5	240.0	41.7	12.1
									800	192.9	232.3	49.1	14.3
									900	150.3	185.8	55.4	16.8

ORIGINAL CREEP AND RUPTURE DATA (RUPTURE TIME INDICATED BY R IN TEST DURATION COLUMN)											
TEMPERATURE F	STRESS KSI	TIME HOURS FOR TOTAL OR PLASTIC STRAIN (Creep) (DELETE ONE)				MINIMUM CREEP RATE %/HR	Initial Strain %/HR	TRANSITION TO THIRD STAGE CREEP		TEST DURATION HOURS	FINAL EXTENSION OR ELONGATION %
		0.1%	0.2%	0.5%	1.0%			HOURS	%		
700	240		0.1	0.4	16	0.012	2.290				18
700	237		0.5	1.2	69	0.0015	2.248				75
700	235		0.4	17	862	0.00018	1.962				862
700	230		0.2	26	6500*	0.00045	1.595				2718
800	225		0.1	0.4	8	0.02	2.070				18
800	215		0.6	28	677	0.00050	1.465				695
800	210		1.2	28	1230	0.00024	1.348				1396
800	200		1.2	330	4300*	0.00012	1.135				1700
900	180		1.0	27	--	--	1.018				67
900	170		2.4	85	250	0.0023	0.904				251
900	160		10	148	373	0.0019	0.820				384
900	140		47	350	820	0.00087	0.680				863
900	110		185	955	2200*	0.00040	0.470				1145

ASTM-ASME JOINT COMMITTEE ON EFFECT OF TEMPERATURE ON PROPERTIES OF METALS
DATA AND PUBLICATIONS PANEL DATA SHEET

MATERIAL Alloy Steel
ALLOY 7 Cr - 1/2 Mo
TYPE OF MELTING Electric Furnace
SIZE OF HEAT 7-106
PRODUCER U. S. Steel

CHEMICAL COMPOSITION, PER CENT

C	Mn	P	S	Si	Ca	Ni	Co	Mo	W	Cu	Ti	Al	V	B
0.13	0.50	0.007	0.003	0.88	7.34	0.11		0.52						
Cu	Fe	N												
0.09		0.018												

DEOXIDATION Silicon plus 1.4 pounds of aluminum per ton
FORM & SIZE - BAR SHEET, CASTINGS, ETC. Bars, 1 in. square
HISTORY OF MATERIAL

HEAT TREATMENT Annealed at 1550 F
MICROSTRUCTURE
GRAIN SIZE
HARDNESS
SOURCE OF DATA U. S. Steel Applied Research Laboratory

SHORT TIME TENSILE PROPERTIES

TEMPERATURE F	ELASTIC MODULUS 10 ⁶ PSI	TENSILE STRENGTH KSI	YIELD STRENGTH KSI	ELONGATION IN 1" PER CENT	REDUCTION IN AREA PER CENT
80		83.3		36	77.8
80		83.7		36	77.0

MISCELLANEOUS DATA

ASTM-ASME JOINT COMMITTEE ON EFFECT OF TEMPERATURE ON PROPERTIES OF METALS
DATA AND PUBLICATIONS PANEL DATA SHEET

MATERIAL Alloy Steel
ALLOY 7 Cr - 1/2 Mo
TYPE OF MELTING Electric Furnace
SIZE OF HEAT 7-107
PRODUCER Babcock & Wilcox

CHEMICAL COMPOSITION, PER CENT

C	Mn	P	S	Si	Ca	Ni	Co	Mo	W	Cu	Ti	Al	V	B
0.12	0.45	0.018	0.024	0.80	6.70	0.20		0.47						
Cu	Fe													
0.14														

DEOXIDATION
FORM & SIZE - BAR SHEET, CASTINGS, ETC. Wrought 3/4-in.-diam. bar
HISTORY OF MATERIAL

HEAT TREATMENT Annealed per ASTM Spec. A-213
MICROSTRUCTURE
GRAIN SIZE
HARDNESS VHN 151
SOURCE OF DATA Babcock & Wilcox

ORIGINAL CREEP AND RUPTURE DATA
(RUPTURE TIME INDICATED BY R IN TEST DURATION COLUMN)

TEMPERATURE F	STRESS KSI	TIME, HOURS, FOR TOTAL OR PLASTIC STRAIN (DELETE ONE)				MINIMUM CREEP RATE %/HR	INTERCEPT %	TRANSITION TO THIRD STAGE CREEP		TEST DURATION HOURS	FINAL EXTENSION OR ELONGATION %
		0.1%	0.2%	0.5%	1.0%			HOURS	%		
1000	25									23	58.5
1000	22									89	72
1000	18									330	75
1000	14									2,000	77
1000	10									19,842	61
1100	12									74	77.5
1100	9									832	82
1100	7									3,495	72.5
1100	5.7									7,874	52
1100	5.4									14,548	59
1200	7									212	62.5
1200	6									327	73
1200	5									1,246	59
1200	4									9,166	46
1200	2.5									9,575	--

CREEP AND RUPTURE STRENGTHS

TEMPERATURE F	STRESS, KSI FOR RUPTURE IN TIMES INDICATED					STRESS, KSI FOR DESIGNATED CREEP RATE			
	10 HRS	100 HRS	1,000 HRS	10,000 HRS	100,000 HRS	0.0001%/HR	0.0005%/HR	0.001%/HR	0.01%/HR
1000			15.4	11	7.9*				
1100			8.7	5.8	3.8*				
1200			5.4	3.9	3*				

*Extrapolated.

ASTM-ASME JOINT COMMITTEE ON EFFECT OF TEMPERATURE ON PROPERTIES OF METALS
DATA AND PUBLICATIONS PANEL DATA SHEET

MATERIAL Alloy Steel
ALLOY 7 Cr - 1/2 Mo
TYPE OF MELTING Electric Furnace
SIZE OF HEAT Commercial
PRODUCER Babcock & Wilcox

CHEMICAL COMPOSITION, PER CENT

C	Mn	P	S	Si	Ca	Ni	Co	Mo	W	Cu	Ti	Al	V	B
0.11	0.49	0.014	0.013	0.72	7.17	0.19		0.50						
Cu	Fe													
0.03														

DEOXIDATION
FORM & SIZE - BAR SHEET, CASTINGS, ETC. Wrought tube
HISTORY OF MATERIAL

HEAT TREATMENT Annealed per ASTM Spec. A-213
MICROSTRUCTURE
GRAIN SIZE
HARDNESS
SOURCE OF DATA Babcock & Wilcox

ORIGINAL CREEP AND RUPTURE DATA
(RUPTURE TIME INDICATED BY R IN TEST DURATION COLUMN)

TEMPERATURE F	STRESS KSI	TIME, HOURS, FOR TOTAL OR PLASTIC STRAIN (DELETE ONE)				MINIMUM CREEP RATE %/HR	INTERCEPT %	TRANSITION TO THIRD STAGE CREEP		TEST DURATION HOURS	FINAL EXTENSION OR ELONGATION %
		0.1%	0.2%	0.5%	1.0%			HOURS	%		
900	50.0									0.7	40
900	45.0									6.3	42
900	42.0									16.1	55
900	38.0									67.5	38
900	32.0									550.4	54
900	30.0									836.0	61
1050	35.0									0.3	50
1050	28.0									5.1	55
1050	22.0									32.1	73
1050	17.5									253.1	75
1050	14.0									1650.0	81
1200	20.0									0.4	70
1200	15.0									4.2	64
1200	11.0									22.8	62
1200	8.4									160.4	65
1200	6.4									709.6	81

CREEP AND RUPTURE STRENGTHS

TEMPERATURE F	STRESS, KSI FOR RUPTURE IN TIMES INDICATED					STRESS, KSI FOR DESIGNATED CREEP RATE			
	10 HRS	100 HRS	1,000 HRS	10,000 HRS	100,000 HRS	0.0001%/HR	0.0005%/HR	0.001%/HR	0.01%/HR
900			29.9	25.0*					
1050			14.8	11.2*					
1200			6.0	4.2*					

*Extrapolated data.

TEMPERATURE F	STRESS, KSI FOR RUPTURE IN TIMES INDICATED					STRESS, KSI FOR DESIGNATED CREEP RATE			
	10 HRS	100 HRS	1,000 HRS	10,000 HRS	100,000 HRS	0.00005 %/HR	0.0001 %/HR	0.001 %/HR	0.01 %/HR
(a) 1100	14	10	7.5*						
(b) 1100	15.5	11.4	8.2	6*					
(c) 1100	13	9.7	7.2*						
	*Extrapolated.								

ASTM-ASME JOINT COMMITTEE ON EFFECT OF TEMPERATURE ON PROPERTIES OF METALS
DATA AND PUBLICATIONS PANEL DATA SHEET 7-112

MATERIAL Alloy Steel
ALLOY 9 Cr - 1.0 Mo
TYPE OF HEATING Electric Furnace
SIZE OF HEAT
PRODUCER Timken Roller Bearing Company
SPECIFICATIONS:

CHEMICAL COMPOSITION, PER CENT

	C	Mn	P	S	Si	Ca	Ni	Co	Mo	W	Cr	Ti	Al	V	B
(a)	0.10	0.50	0.014	0.014	0.51	8.49	0.17		1.00						
(b)	0.11	0.46	0.011	0.016	0.83	8.25	0.21		0.95						
	Cu	Fe													

OXIDATION Aluminum
FORM & SIZE: BAR, SHEET, CASTINGS, ETC. Seamless tubing, 2.125" O.D. x 0.230" wall
HISTORY OF MATERIAL
Pierced, hot rolled, cold drawn, tempered 1475 F
HEAT TREATMENT Tempered 1475 F
MICROSTRUCTURE
GRAIN SIZE
HARDNESS
SOURCE OF DATA Timken Roller Bearing Company

TEMPERATURE F	STRESS KSI	TIME, HOURS FOR TOTAL OR PLASTIC STRAIN (DELETE ONE)				MINIMUM CREEP RATE %/HR	INTERCEPT %	TRANSITION TO THIRD STAGE CREEP		TEST DURATION HOURS	FINAL EXTENSION OR ELONGATION %
		0.1%	0.2%	0.5%	1.0%			HOURS	%		
(a) 1100	15.0									71	82
1100	11.0									988	70.5
1100	9.0									2918	72
(b) 1100	16									33	71
1100	12									258	83.5
1100	9									1300	74

TEMPERATURE F	STRESS, KSI FOR RUPTURE IN TIMES INDICATED					STRESS, KSI FOR DESIGNATED CREEP RATE			
	10 HRS	100 HRS	1,000 HRS	10,000 HRS	100,000 HRS	0.00005 %/HR	0.0001 %/HR	0.001 %/HR	0.01 %/HR
(a) 1100	15.5	10.8	7.4*						
(b) 1100	13.5	9.4	6.5*						
	*Extrapolated.								

ASTM-ASME JOINT COMMITTEE ON EFFECT OF TEMPERATURE ON PROPERTIES OF METALS
DATA AND PUBLICATIONS PANEL DATA SHEET 7-113

MATERIAL Alloy Steel
ALLOY 9 Cr - 1.0 Mo
TYPE OF HEATING Electric Furnace
SIZE OF HEAT Commercial
PRODUCER Babcock & Wilcox
SPECIFICATIONS:

CHEMICAL COMPOSITION, PER CENT

	C	Mn	P	S	Si	Ca	Ni	Co	Mo	W	Cr	Ti	Al	V	B
	0.14	0.49	0.013	0.016	0.40	8.41	0.31		1.00						
	Cu	Fe													

OXIDATION
FORM & SIZE: BAR, SHEET, CASTINGS, ETC. Wrought 3/4-in. -diam. bar
HISTORY OF MATERIAL
HEAT TREATMENT Annealed per ASTM Spec. A-213
MICROSTRUCTURE
GRAIN SIZE
HARDNESS
SOURCE OF DATA Babcock & Wilcox

TEMPERATURE F	STRESS, KSI FOR RUPTURE IN TIMES INDICATED					STRESS, KSI FOR DESIGNATED CREEP RATE			
	10 HRS	100 HRS	1,000 HRS	10,000 HRS	100,000 HRS	0.00005 %/HR	0.0001 %/HR	0.001 %/HR	0.01 %/HR
1000			22.9	16.5	12*				
1100			12	8.6	6.2*				
1200			6.6	4.6	3.2*				
1300			2.8						
	*Extrapolated.								

TEMPERATURE F	STRESS KSI	TIME, HOURS FOR TOTAL OR PLASTIC STRAIN (DELETE ONE)				MINIMUM CREEP RATE %/HR	INTERCEPT %	TRANSITION TO THIRD STAGE CREEP		TEST DURATION HOURS	FINAL EXTENSION OR ELONGATION %
		0.1%	0.2%	0.5%	1.0%			HOURS	%		
1000	25									530	43
1000	22									1,558	46
1000	19									3,616	57.5
1000	17									7,101	60
1000	15.5									16,091	56.5
1100	15									186	72
1100	12									960	82
1100	9.5									5,875	72.5
1100	8									16,017	50.5
1200	9									119	67.5
1200	7									567	41
1200	6									2,410	42.5
1200	5									4,337	44.5
1200	4.4									12,302	43.5
1300	5									116	104
1300	4									284	106
1300	3									856	103
1300	2									3,250	103.8

ASTM-ASME JOINT COMMITTEE ON EFFECT OF TEMPERATURE ON PROPERTIES OF METALS
DATA AND PUBLICATIONS PANEL DATA SHEET 7-114

MATERIAL Alloy Steel
ALLOY 9 Cr - 1.0 Mo
TYPE OF HEATING Electric Furnace
SIZE OF HEAT Commercial
PRODUCER Babcock & Wilcox
SPECIFICATIONS:

CHEMICAL COMPOSITION, PER CENT

	C	Mn	P	S	Si	Ca	Ni	Co	Mo	W	Cr	Ti	Al	V	B
	0.11	0.50	0.015	0.010	0.44	8.44	0.19		0.98						
	Cu	Fe													
	0.04														

OXIDATION
FORM & SIZE: BAR, SHEET, CASTINGS, ETC. Wrought tube, 4-1/2" O.D. with 0.500" wall
HISTORY OF MATERIAL
HEAT TREATMENT Annealed per ASTM Spec. A-213
MICROSTRUCTURE
GRAIN SIZE
HARDNESS R_h 84
SOURCE OF DATA Babcock & Wilcox

TEMPERATURE F	STRESS KSI	TIME, HOURS FOR TOTAL OR PLASTIC STRAIN (DELETE ONE)				MINIMUM CREEP RATE %/HR	INTERCEPT %	TRANSITION TO THIRD STAGE CREEP		TEST DURATION HOURS	FINAL EXTENSION OR ELONGATION %
		0.1%	0.2%	0.5%	1.0%			HOURS	%		
1000	25					0.034				457	43
1000	22.5					0.015				917	50.5
1000	20					0.0034				3,215	34
1000	17					0.0008				19,453	31
1100	15					0.055				352	49
1100	13.5					0.017				928	39
1100	12					0.0044				3,136	45
1100	10.5					0.0012				8,347	35
1100	9.5					0.00034				15,311	53
1100	7					0.00003				16,262	
1100	5					0.00001				16,474	
1200	9					--				124	84
1200	9					0.074				255	77
1200	8					0.046				255	37
1200	7					0.018				809	42.3
1200	6					0.012				1,696	53
1200	5.6					0.004				2,705	27
1200	5					0.00059				8,232	23
1200	4					0.00022				14,883	
1200	3					0.000041				8,660	
										Discontinued	
										Discontinued	

TEMPERATURE F	STRESS, KSI FOR RUPTURE IN TIMES INDICATED					STRESS, KSI FOR DESIGNATED CREEP RATE			
	10 HRS	100 HRS	1,000 HRS	10,000 HRS	100,000 HRS	0.00005 %/HR	0.0001 %/HR	0.001 %/HR	0.01 %/HR
1000			23	18	14.5*			13.5	17.2
1100			13.5	10.2	7.2*			5*	8.2
1200			7	4.3	2.7*			2.3*	3.5
1300			3.4	2.1	1.2*				
	*Extrapolated.								

