FOREWORD

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The testing was done by the Metcut Research Associates Inc. under Contract No. AF 33(600)-36430 during the period from February 1958 to March 1960 under the direction of Mr. Louis J. Fritz, project engineer.

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ABSTRACT

Creep property data for 17-7 PH and A-286 stainless steel alloys at elevated temperatures were obtained. Test specimens were cut from the sheet material parallel to the rolling direction. Test temperatures were:

17-7 PH at room temperature, 600°, 800°, and 900°F

A-286 at room temperature, 1200°, 1350°, and 1500°F

The data includes ultimate tensile strength, tensile yield strength,elongation, creep deformation, and creep rupture properties at each temperature.

This technical documentary report has been reviewed and is approved.

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INTRODUCTION

Creep deformation has become increasingly important since higher temperatures are required in today's advanced systems. Creep deformation of less than one percent may become a principal design consideration for materials that remain at elevated temperatures for long periods of time.

This report presents data obtained by Metcut Research Associates under contract. The materials selected were 17-7 PH and A-286 stainless steel alloys. These materials were selected to include creep data on ferrous alloys from 600° to 1600°F and are obviously not competitive with each other within this temperature range.

Emphasis was placed on the measurement of increments of creep deformation of one percent or less for periods up to 1,000 hours. Time deformation data is presented as semi-logarithmic plots so that extraction of data from the curves, particularly for the shorter periods, can be readily accomplished. Tabular data are also included so that other methods of plotting may be employed when desired.

MATERIALS PROCUREMENT AND HEAT TREATMENT

The 17-7 PH stainless steel was obtained from the Armco Steel Corporation with a 2D finish. The sheet steel was .063-inch thick. The specimen blanks were heat treated at Armco Steel Corporation as follows:

1. Treat at 1750°F ± 15° for 10 minutes at temperature, air cool to room temperature, and hold for 15 to 30 minutes.

2. Cool to -100°F within the next 30 minutes, hold at -100°F for 8 hours, then raise to room temperature.

3. Nine hours later, heat to 950°F ± 10° for 1 hour, then air cool.

The A-286 material was obtained in the mill annealed condition in sheet form .064-inch thick. The specimen blanks were heat treated at Wall Colmonay Corporation as follows:

1. Degrease in a vapor degreaser.

2. Solution treat at 1650°F for 1 hour in argon, then cool in forced air (hung in the furnace).

3. Age at 1325°F for 16 hours in air (any specimen "out of flat" along the 20-inch length by more than .050-inch, is clamped flat during step 3).

Table 1 gives the nominal chemical composition of 17-7 PH and A-286.

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SPECIMEN PREPARATION

The specimen blanks were cut so that their longitudinal direction was parallel to the rolling direction. After the blanks were heat treated and rough machined they were finish machined, using a "stress free" grinding technique, to the dimensions shown in figures 1 and 2.

The "stress free" grinding was done under the following conditions:

Wheel Speed: 2,500 ft/minute

Depth Increment: 0.001″ per pass down to 0.010″ stock

The last 0.010″ . . . at 0.0005″ increments.

Grinding Wheel: Norton 32A46G12VBEP

Note: This was a soft, friable wheel

Cutting Fluid: Stuart Thredcut 99, (undiluted.)

These conditions have produced a surface suffering a minimum of induced grinding stress and surface injury.

TESTING EQUIPMENT AND PROCEDURES

The test procedures for both materials were essentially the same. Only the test temperatures were different. The tensile and creep specimen drawings are shown in figures 1 and 2.

The tensile tests were run at a controlled strain rate of 0.005 in/in/min through the 0.2 percent yield point then at a head rate of 0.05 in/min to failure. The strain rate was indicated by a strain pacer and the head rate was indicated by a dial indicator. The tensile values are given in tables 2 and 3.

Stress levels for the stress rupture tests were chosen near the 0.2 percent yield points to obtain rupture lives of 1 to 10 hours. Stress rupture and creep data are given in tables 3, 4, 5, 10, 11, and 12. The creep tests were conducted at stress levels chosen to give deformations of approximately 0.05, 0.1, 0.3, 0.5, and 1.0 percent in 10, 100, 300, and 1,000 hours at each of the test temperatures.

The creep frames were the underslung type, were not counter-balanced, and did not include automatic leveling provisions. The sensitivity of each creep frame was checked using a tensile loop dynamometer. The load error due to the arm being "off level" was found to be within 0.5 percent through a range of ± 10 degrees and the reproducibility of the loads was found to be ± 0.1 percent or less.

The test temperatures were measured and controlled with chromel - P/alumel thermocouples.

Rod and tube, and platinum strip extensometers were used to measure creep rates. The rod and tube type extensometer was used in conjunction with a 20X microscope to measure creep rates of 0.5 percent or more in 1,000 hours. The rod and the tube had

notched reference points, and readings were taken by adjusting the microscope's crosshairs to just block off the light between the image of the crosshair and the image of the horizontal surface of the notch. Readings taken with this system were accurate to within 0.0002 of an inch. The intersliding platinum strip extensometer and 50X microscope were used to measure creep rates of 0.5 percent or less in 1,000 hours. The accuracy of the platinum strip readings was determined to be within 0.00005 of an inch.

Three thermocouples and an extensometer were placed on each specimen. The specimen was soaked approximately one-half hour at the desired temperature, the load was applied, deformation on loading was measured, and the time recorded. The creep deformation readings were started immediately after the load was applied to the specimen.

DISCUSSION OF RESULTS

The tensile properties of 17-7 PH are given in table 2. The room temperature ultimate tensile strength values averaged 212,000 psi, the tensile yield strength values (0.2 percent offset) averaged 184,000 psi, and the percentage elongation in 2 inches averaged 13 percent. The following average properties were obtained at 600°, 800°, and 900°F, respectively: ultimate tensile strength, 177,000, 153,000, and 128,000 psi; tensile yield strength, (0.2 percent offset), 143,000, 123,000, and 109,000 psi; percentage elongation in 2 inches, 9, 14.0, and 18 percent.

The results of the creep rupture and creep tests on 17-7 PH at elevated temperature are presented in tables 3 through 8 and figures 3 through 8. The 100-hour, 0.5 percent deformation stress was 153,000 psi at 600°F and 37,000 psi at 900°F.

The tensile properties of A-286 are given in table 9. The room temperature ultimate tensile strength values averaged 164,000 psi, the tensile yield strength (0.2 percent offset) averaged 113,000 psi, and the percentage elongation in 2 inches averaged 20 percent. The following average properties were obtained at 1200°, 1350°, and 1500°F respectively: ultimate tensile strength, 113,000, 79,000, and 38,000 psi; tensile yield strength (0.2 percent offset), 95,000, 70,000, and 34,000 psi; percentage elongation in 2 inches 16, 26, and 73 percent.

The results of the creep rupture and creep tests on A-286 are given in tables 10 and 12 and figures 9 through 14. The 100-hour, 0.5 percent deformation stress was 47,000 psi at 1200°F and 3,400 psi at 1500 °F.

CONCLUSIONS

The tensile properties of 17-7 PH are in general agreement with values from other sources (refs. 1 and 2). However, no explanation is offered for the apparent decrease in elongation of 17-7 PH at 600°F which was observed during this investigation.

The tensile properties of A-286 agree satisfactorily with the values from other sources (refs. 1 and 2). A decrease in percentage elongation of this material occurred at 1200°F. This decrease may be due to a Ni_3Ti precipitation which takes place between 1200°F and 1500°F.

As the temperature increased from 600° to 800°F, the scatter in the creep data for 17-7 PH appeared to show a general increase. The same observation was made of the creep data for A-286 as the temperature increased from 1200° to 1500°F.

LIST OF REFERENCES

1. Sachs, G. and Pray III, R. Ford, Air Weapons Materials Application Handbook Metals and Alloys, Air Research and Development Command, TR 59-66, (December 1959)

2. Strength of Metal Aircraft Elements, Armed Forces Supply Support Center, MIL-HDBK-5, (March 1959)

3. Horne, E. L. and Harden, III, 2/Lt. W. D. Elevated Temperature Creep Properties of B-120VCA Sheet Material, WADD TR 60-525, (November 1960)

4. Fritz, L. J., Low Stress Creep Testing of A-286, Metcut Research Associates Inc., Report No. 363-1585

5. Fritz, L. J., Low Stress Creep Testing of 17-7 PH Stainless, Metcut Research Associates Inc., Report No. 363-1536, (April 1960)

TABLE I

CHEMICAL COMPOSITION (NOMINAL) (REF. 1)

WEIGHT PERCENT

MATERIAL	LIMITS	Fe	Cr	Ni	Mn	Ti	Si	C	Mo	P	S	Al	V	B
A-286	Lower	Balance	10.00	24.00	1.00	1.90	0.40	—	1.00	—	—	—	0.10	0.0010
	Upper		13.50	27.00	2.00	2.30	1.00	0.08	1.50	0.040	0.030	0.35	0.50	0.01
17-7 PH	Lower	Balance	16.00	6.50	—		—	—		—	—	0.75		
	Upper		18.00	7.75	1.00		1.00	0.09		0.040	0.030	1.50		

TABLE 2

TENSILE STRENGTH OF 17-7 PH STAINLESS STEEL AT TEST TEMPERATURE

TEST TEMPERATURE °F	SPECIMEN	ULTIMATE TEN. STRENGTH psi	0.2% OFFSET YIELD STRENGTH psi	ELONG ATION IN 2" %
R T	C-10	212,000	176,000	13
R T	C-11	209,000	182,000	14
R T	C-12	212,000	182,000	13
R T	C-13	212,000	189,000	12
R T	C-14	213,000	192,000	12
	Average	212,000	184,000	13
600	C-15	179,000	147,000	9
600	C- 1	177,000	143,000	9
600	C- 2	175,000	140,000	8
	Average	177,000	143,000	9
800	C-3	153,000	125,000	15
800	C-4	153,000	123,000	12
800	C-5	154,000	122,000	15
	Average	153,000	123,000	14
900	C-7	129,000	106,000	16
900	C-8	129,000	106,000	18
900	C-9	126,000	114,000	19
	Average	128,000	109,000	18

TABLE 3

17-7 PH STAINLESS STEEL RUPTURE AND CREEP DEFORMATION DATA AT 600°F

SPECIMEN	STRESS psi	RUPTURE TIME HOURS	ELONGATION IN 2 INCHES %	DEFORMATION ON LOADING %	TIME TO REACH INDICATED DEFORMATION HOURS				
					0.05 %	0.10 %	0.30 %	0.50 %	1.00 %
C161	110,000	—	0.05	0.47	1200	—	—	—	—
C 23	117,000	—	0.10	0.52	230	1260	—	—	—
C66	125,000	—	0.11	0.57	50	340	—	—	—
C27	130,000	—	0.18	0.60	2.9	78	—	—	—
C89	135,000	—	0.18	0.64	3.2	36	—	—	—
C18	140,000	—	0.26	0.69	2.0	15	—	—	—
C45	145,000	—	0.42	0.74	0.4	2.7	170	—	—
C50	147,000	—	0.51	0.76	0.2	1.5	76	732	—
C26	150,000	—	0.65	0.80	—	0.4	50	410	—
C91	152,000	—	0.59	0.85	0.1	0.7	22	130	—
C21	153,000	—	1.06	0.90	—	0.2	9.0	50	805
C62	155,000	—	1.05	0.93	0.1	0.4	4.5	30	450
C67	157,000	—	1.03	0.93	0.1	0.4	4.0	36	590
C43	158,000	—	1.07	1.10	—	0.2	2.0	90	102
C28	160,000	—	1.57	0.93	0.1	0.4	2.3	17	182
C106	160,500	—	1.07	0.91	—	—	0.5	5.0	95
C83	161,000	—	2.55	1.19	—	—	1.2	3.2	23
C85	162,000	—	1.91	1.28	—	—	0.4	1.2	7.0
C41	165,000	—	3.00	1.39	—	—	0.4	1.5	8.0
C37	175,000	1.3	—	3.88	—	—	—	—	0.1

TABLE 4

17-7 PH STAINLESS STEEL RUPTURE AND CREEP DEFORMATION DATA AT 800 °F

SPECIMEN	STRESS psi	RUPTURE TIME HOURS	ELONGATION IN 2 INCHES ON RUPTURE %	DEFORMATION ON LOADING %	TIME TO REACH INDICATED DEFORMATION HOURS				
					0.05%	0.10%	0.30%	0.50%	1.00%
C159	13,000	—	0.05	0.05	1060	—	—	—	—
C100	20,000	—	0.07	0.08	735	—	—	—	—
C162	27,000	—	0.11	0.11	250	820	—	—	—
C55	40,000	—	0.15	0.16	80	404	—	—	—
C42	50,000	—	0.23	0. 20	38	278	—	—	—
C48	51, 300	—	0.34	0. 21	20	136	880	—	—
C104	55,000	—	0.30	0. 22	31	120	1050	—	—
C102	60,000	—	0.36	0. 24	3.5	55	590	—	—
C86	66,000	—	0.54	0.28	4.6	33	355	1090	—
C71	76,000	—	0.86	0.33	2.5	12	153	453	—
C31	82,000	—	1.11	0.37	1.5	6.0	153	350	900
C56	85,000	—	1.08	0.38	0.8	4.2	110	265	650
C51	87,000	—	1.01	0.39	1.5	4.2	73	222	511
C 52	95,000	—	1.28	0.44	0.3	1.0	30	101	238
C25	100,000	—	1.71	0.47	0.2	0.4	14	50	193
C 93	102,000	—	1.16	0.49	0.4	0.7	8.6	24	93
C47	103,000	—	1.29	0.50	—	0.2	5.0	16	80
C84	105,000	—	1.58	0.52	—	—	3.5	15	69
C40	110,000	261.1	21.0	0.55	—	0.1	1.5	11	50
C59	115,000	—	8.45	0.58	—	0.1	0.5	2.2	14
C24	120,000	66. 9	13.5	0.65	—	0.1	0.6	1.8	7.5
C 29	140,000	2.2	13.5	0.77	—	—	—	0.2	0.3

TABLE 5

17-7PH STAINLESS STEEL RUPTURE AND CREEP DEFORMATION DATA AT 900°F

SPECIMEN	STRESS psi	RUPTURE TIME HOURS	ELONGATION IN 2 INCHES %	DEFORMATION ON LOADING %	TIME TO REACH INDICATED DEFORMATION HOURS				
					0.05%	0.10%	0.30%	0.50%	1.00%
C183	7,000	—	0.05	0.03	1005	—	—	—	—
C68	10,000	—		0.04	110		—	—	—
C75	15,000	—	0.22	0.06	54	213	—	—	—
C16	20,000	—	0.30	0.09	20	77	1500	—	—
C57	23,000	—	0.41	0.10	8.0	45	472	—	—
C64	25,000	—	0.50	0.11	2.7	8.0	255	1214	—
C82	28,000	—	0.64	0.12	2.0	15	183	630	—
C79	30,000	—	0.66	0.13	2.2	7.0	95	400	—
C49	32,000	—	0.94	0.14	1.3	4.7	73	257	—
C81	34,000	—	1.03	0.14	1.0	3.8	45	182	1025
C74	35,000	—	1.02	0.15	0.7	4.0	58	188	822
C88	38,000	—	1.21	0.16	1.0	3.8	51	135	442
C72	43,000	—	1.04	0.18	0.8	2.1	16	52	241
C107	44,000	—	1.24	0.19	0.3	0.5	11	39	153
C78	48,000	—	1.14	0.21	0.3	0.8	12	32	109
C94	50,000	—	1.51	0.22	0.5	1.4	9.2	25	85
C90	55,000	—	1.86	0.24	0.3	0.7	4.5	10	41
C38	60,000	373.5	—	0.26	0.3	0.8	2.6	5.6	21
C65	65,000	—	4.50	0.28	0.2	0.3	1.5	3.8	11
C36	67,000	—	17.2	0.30	—	0.1	1.0	2.5	7.8
C63	70,000	100.3	33.0	0.32	0.1	0.2	1.1	2.4	7.3
C34	80,000	34.3	36.5	0.38	0.1	0.2	0.5	0.9	2.2
C32	100000	2.0	19.0	0.63	—	—	0.1	0.1	0.3
C35	120,000	0.1	15.5	1.61	—	—	—	—	—

TABLE 6

17-7 PH STAINLESS STEEL DEFORMATION – TIME DATA AT 600°F

TIME HOURS	DEFORMATION IN 2 INCHES %	TIME HOURS	DEFORMATION IN 2 INCHES %	TIME HOURS	DEFORMATION IN 2 INCHES %	TIME HOURS	DEFORMATION IN 2 INCHES %
STRESS = 110,000 psi		90	0.065	270	0.185	450	0.37
100	0.02	210	0.08	400	0.20	625	0.38
190	0.035	340	1.00	500	0.20	810	0.38
310	0.04	410	1.01	STRESS = 140,000 psi		1010	0.395
700	0.045	460	1.015	2	0.05	1100	0.390
995	0.045	STRESS = 130,000 psi		15	0.10	STRESS = 147,000 psi	
1200	0.05	2.9	0.05	80	0.145	0.2	0.05
STRESS = 117,000 psi		15	0.06	200	0.175	1.5	0.10
50	0.04	50	0.08	350	0.20	20	0.215
150	0.045	78	0.10	500	0.205	50	0.265
230	0.05	110	0.115	600	0.215	76	0.30
300	0.055	180	0.125	700	0.225	90	0.31
380	0.06	280	0.135	800	0.225	160	0.36
470	0.065	450	0.145	900	0.235	250	0.395
570	0.07	590	0.15	1000	0.240	390	0.43
720	0.07	765	0.165	STRESS = 145.000 psi		515	0.455
860	0.075	900	0.175	0.4	0.05	650	0.480
940	0.08	1000	0.18	2.7	0.10	732	0.50
1085	0.085	STRESS = 135,000 psi		15	0.18	810	0.51
1260	1.00	3.2	0.05	40	0.22	STRESS = 150,000 psi	
STRESS = 125,000 psi		15	0.08	105	0.265	0.4	0.10
10	0.015	36	0.10	170	0.30	15	0.23
50	0.05	160	0.15	300	0.345	50	0.30

TABLE 6 (CONT')

TIME HOURS	DEFORMATION IN 2 INCHES %	TIME HOURS	DEFORMATION IN 2 INCHES %	TIME HOURS	DEFORMATION IN 2 INCHES
STRESS = 150,000 psi		20	0.46	55	0.54
80	0.35	50	0.50	105	0.64
190	0.42	155	0.70	175	0.74
260	0.445	280	0.80	255	0.80
400	0.495	380	0.90	395	0.90
410	0.5	805	1.00	590	1.00
515	0.54	STRESS = 155,000psi		STRESS= 160,000psi	
645	0.57	0.1	0.05	0.1	0.05
810	0.58	0.4	0.10	0.4	0.10
1000	0.58	4.5	0.30	2,3	0.30
STRESS = 152,000psi		20	0.46	17	0.50
0.1	0.05	30	0.50	50	0.685
0.7	0.10	50	0.555	110	0.86
22	0.3	100	0.675	182	1.0
50	0.38	150	0.755	STRESS = 161,000psi	
100	0.46	250	0.860	1.2	0.3
130	0.50	300	0.900	3.2	0.5
180	0.54	450	1.00	23	1.0
310	0.575	STRESS = 157,000 psi		STRESS = 162,000psi	
400	0.59	0.1	0.05	0.4	0.30
STRESS = 153,000psi		0.4	0.10	1.2	0.50
0.2	0.10	4.0	0.30	7.0	1.00
5	0.15	15	0.425		
9	0.30	36	0.50		

TABLE 7

17-7 PH STAINLESS STEEL DEFORMATION — TIME DATA AT 800 °F

TIME HOURS	DEFORMATION IN 2 INCHES %	TIME HOURS	DEFORMATION IN 2 INCHES %	TIME HOURS	DEFORMATION IN 2 INCHES %	TIME HOURS	DEFORMATION IN 2 INCHES %
STRESS = 13,000 psi		820	0.010	636	0.175	STRESS = 66,000 psi	
200	0.02	1000	0.11	785	0.195	4.6	0.05
400	0.025	1080	0.115	960	0.205	10	0.07
600	0.03	STRESS = 40,000 psi		STRESS = 55,000 psi		33	0.10
750	0.035	30	0.02	5	0.02	70	0.135
900	0.04	60	0.035	31	0.05	150	0.20
1060	0.05	80	0.05	120	0.10	260	0.25
STRESS = 20,000 psi		100	0.055	370	0.20	355	0.30
265	0.035	160	0.065	540	0.24	390	0.315
350	0.03	290	0.085	750	0.27	530	0.36
470	0.04	404	0.10	870	0.28	670	0.4
610	0.045	550	0.115	1050	0.30	800	0.435
735	0.05	710	0.13	STRESS = 60,000 psi		965	0.470
895	0.055	960	0.145	3.5	0.05	1090	0.50
1025	0.065	1080	0.150	55	0.10	STRESS = 76,000 psi	
STRESS = 27,000 psi		STRESS = 50,000 psi		110	0.15	2.5	0.05
100	0.04	38	0.05	160	0.017	12	0.10
200	0.045	50	0.06	270	0.21	40	0.18
250	0.05	100	0.07	430	0.27	105	0.26
330	0.06	200	0.09	550	0.29	153	0.30
420	0.07	278	0.10	590	0.30	200	0.335
500	0.08	300	0.11	700	0.315	310	0.41
630	0.09	440	0.13			453	0.50

TABLE 7 (CONT.)

TIME HOURS	DEFORMATION IN 2 INCHES %	TIME HOURS	DEFORMATION IN 2 INCHES %	TIME HOURS	DEFORMATION IN 2 INCHES %	TIME HOURS	DEFORMATION IN 2 INCHES %
655	0.625	265	0.50	200	0.855	1.5	0.3
780	0.695	360	0.62	238	1.00	11	0.5
STRESS = 82,000 psi		450	0.74	STRESS = 100,000 psi		25	0.64
1.5	0.05	550	0.87	0.2	0.05	40	0.80
6	0.10	650	1.00	0.4	0.10	50	1.00
20	0.16	STRESS = 87,000 psi		14	0.30	STRESS = 120,000 psi	
55	0.20	1.5	0.05	30	0.38	0.1	0.1
100	0.245	4.2	0.10	50	0.50	0.6	0.3
153	0.30	25	0.20	85	0.64	1.8	0.5
205	0.355	73	0.30	150	0.85	5	0.75
320	0.475	135	0.375	193	1.00	7.5	1.0
350	0.50	210	0.48	STRESS = 102,000 psi			
425	0.58	222	0.50	0.4	0.05		
550	0.70	310	0.62	0.7	0.10		
680	0.83	390	0.77	8.6	0.30		
900	1.00	511	1.00	10	0.33		
STRESS = 85,000 psi		STRESS = 95,000 psi		15	0.44		
0.8	0.05	0.3	0.05	24	0.5		
4.2	0.10	1.0	0.10	35	0.59		
35	0.20	10	0.2	55	0.7		
95	0.28	30	0.3	70	0.815		
110	0.30	60	0.385	93	1.00		
170	0.38	101	0.50	STRESS = 110,000 psi			
250	0.48	160	0.71	0.1	0.1		

TABLE 8

17-7 PH STAINLESS STEEL DEFORMATION – TIME DATA AT 900°F

TIME HOURS	DEFORMATION IN 2 INCHES %	TIME HOURS	DEFORMATION IN 2 INCHES %	TIME HOURS	DEFORMATION IN 2 INCHES %	TIME HOURS	DEFORMATION IN 2 INCHES %
STRESS = 7,000 psi		560	0.15	570	0.32	490	0.46
30	0.02	665	0.165	710	0.34	630	0.50
200	0.025	840	0.180	840	0.355	700	0.515
400	0.03	980	0.200	1000	0.380	850	0.570
600	0.04	STRESS = 20,000 psi		STRESS = 25,000 psi		1000	0.60
800	0.045	20	0.05	2.7	0.05	STRESS = 30,000 psi	
1005	0.05	77	0.10	8	0.10	2.2	0.05
STRESS = 10,000 psi		115	0.12	35	0.14	7.0	0.10
25	0.02	210	0.15	80	0.18	10	0.11
95	0.045	340	0.18	150	0.23	60	0.235
110	0.05	505	0.21	258	0.3	95	0.30
160	0.06	700	0.24	350	0.34	120	0.315
310	0.07	920	0.255	520	0.37	205	0.395
500	0.08	1070	0.265	755	0.435	355	0.48
640	0.085	1500	0.30	975	0.465	400	0.50
850	0.08	STRESS = 23.000 psi		STRESS = 28,000 psi		510	0.545
STRESS = 15,000 psi		8	0.05	2	0.05	700	0.615
25	0.035	45	0.10	15	0.10	795	0.65
54	0.05	150	0.185	60	0.17	STRESS = 32,000 psi	
140	0.08	260	0.24	115	0.24	1.3	0.05
213	0.10	360	0.27	183	0.3	4.7	0.10
300	0.115	450	0.28	255	0.345	50.	0.255
440	0.14	472	0.30	355	0.395	73	0.30

TABLE 8 (CONT'D)

TIME HOURS	DEFORMATION IN 2 INCHES %	TIME HOURS	DEFORMATION IN 2 INCHES %	TIME HOURS	DEFORMATION IN 2 INCHES %	TIME HOURS	DEFORMATION IN 2 INCHES %
STRESS = 32,000 psi		58	0.30	52	0.50	15	0.32
135	0.375	110	0.38	85	0.595	25	0.50
220	0.455	188	0.50	160	0.8	50	0.715
257	0.50	220	0.54	241	1.00	65	0.845
340	0.58	320	0.66	STRESS = 44,000 psi		85	1.00
445	0.665	420	0.77	0.3	0.05	STRESS = 55,000psi	
550	0.72	515	0.805	0.5	0.10	0.3	0.05
660	0.76	STRESS = 38,000 psi		11	0.30	0.7	0.10
775	0.81	1	0.05	25	0.40	4.5	0.30
STRESS = 34,000 psi		3.8	0.10	50	0.55	10	0.50
1	0.05	15	0.20	85	0.71	25	0.595
3.8	0.10	51	0.30	115	0.845	41	1.00
45	0.30	95	0.40	153	1.00	STRESS = 60,000psi	
105	0.395	135	0.50	STRESS = 48,000psi		0.3	0.05
182	0.50	205	0.635	0.3	0.05	0.8	0.10
295	0.595	295	0.8	0.8	0.10	2.6	0.30
445	0.695	442	1.00	12	0.30	5.6	0.5
600	0.80	STRESS = 43,000 psi		32	0.50	10	0.7
1025	1.00	0.8	0.05	109	1.00	15	0.845
STRESS = 35,000 psi		2.1	0.10	STRESS = 50,000 psi		21	1.00
0.7	0.05	5	0.18	0.5	0.05		
4	0.10	16	0.30	1.4	0.10		
20	0.18	45	0.425	9.2	0.30		

TABLE 8 (CONT'D)

TIME HOURS	DEFORMATION IN 2 INCHES %	TIME HOURS	DEFORMATION IN 2 INCHES %	TIME HOURS	DEFORMATION IN 2 INCHES %	TIME HOURS	DEFORMATION IN 2 INCHES %
STRESS = 65,000 psi		STRESS = 70,000 psi		STRESS = 80,000 psi			
0.2	0.05	0.1	0.05	0.1	0.05		
0.3	0.10	0.2	0.10	0.2	0.10		
1.5	0.30	1.1	0.30	0.5	0.30		
3.8	0.50	2.4	0.50	0.9	0.50		
11	1.0	7.3	1.00	2.2	1.00		

TABLE 9

TENSILE STRENGTH OF A – 286 STAINLESS STEEL AT TEST TEMPERATURE

TEST TEMPERATURE °F	SPECIMEN	ULTIMATE TENSILE STRENGTH psi	0.2% OFFSET YIELD STRENGTH psi	ELONGATION IN 2 INCHES %
RT	F1	165,000	115,000	20
RT	F2	163,000	113,000	20
RT	F3	165,000	112,000	20
RT	F4	164,000	111,000	19
RT	F5	165,000	113,000	20
	AVERAGE	164,000	113,000	20
1200	F17	114,000	92,600	16
1200	F12	110,000	93,600	17
1200	F16	114,000	97,700	15
	AVERAGE	113,000	95, 00	16
1350	F6	79,500	70,000	23
1350	F11	79,000	71,700	29
1350	F14	79,600	69,100	26
	AVERAGE	79,000	69,800	26
1500	F15	39,900	36,100	80
1500	F18	36,500	32,100	73
1500	F19	37,300	33,800	67
	AVERAGE	38,000	34,000	73

TABLE 10

A-286 STAINLESS STEEL RUPTURE AND CREEP DEFORMATION DATA AT 1200°F

SPECIMEN	STRESS psi	RUPTURE TIME HOURS	ELONGATION IN 2 INCHES %	DEFORMATION ON LOADING %	TIME TO REACH INDICATED DEFORMATION - HOURS				
					0.05%	0.10%	0.30%	0.50%	1.00%
F57	4,000	–	0.05	0.02	1200	–	–	–	–
F135	5,000	–	0.05	0.03	790	–	–	–	–
F128	15,000	–	0.11	0.07	290	900	–	–	–
F101	20,000	–	0.29	0.10	75	470	EXT. 1400	–	–
F 50	25,000	–	0.57	0.12	60	205	725	1122	–
F109	30,000	–	1.03	0.15	45	167	473	651	1017
F35	35,000	–	0.25	0.18	12	62	–	–	–
F98	40,000	–	0.25	0.20	8	28	–	–	–
F119	40,000	–	1.03	0.20	8	23	128	195	298
F81	45,000	380.8	10.5	0.22	3	9	52	92	143
F107	55,000	51.3	11.3	0.28	0.5	1.0	7.5	10.5	15.0
F126	60,000	44.9	12.0	0.30	0.2	1.1	5.3	8.6	14.0
F105	60,000	41.5	13.9	0.30	0.3	1.5	5.3	8.2	12.3
F130	65,000	23.3	11.5	0.33	0.2	0.6	2.6	4.2	6.0
F125	70,000	9.3	9.0	0.36	–	0.2	1.2	2.0	3.3

TABLE II

A-286 STAINLESS STEEL RUPTURE AND CREEP DEFORMATION DATA AT 1350 °F

SPECIMEN	STRESS psi	RUPTURE TIME HOURS	ELONGATION IN 2 INCHES %	DEFORMATION ON LOADING %	TIME TO REACH INDICATED DEFORMATION – HOURS				
					0.05%	0.10%	0.30%	0.50%	1.00%
F106	1,200	–	0.05	0.007	1150	–	–	–	–
F99	2,000	–	0.10	0.01	375	1130	–	–	–
F26	3,500	–	0.18	0.02	145	410	–	–	–
F40	5,000	–	0.31	0.03	57	230	1320	–	–
F27	7,000	–	0.60	0.05	29	77	410	875	–
F73	8,000	–	0.71	0.05	22	63	383	780	–
F51	9,000	–	0.90	0.06	18	68	327	645	EXT. 1440
F85	10,000	–	0.32	0.07	4	27	196	–	–
F34	10,000	–	1.13	0.07	4	26	179	348	868
F116	15,000	–	1.78	0.10	2.5	8.7	68	122	254
F48	17,500	–	1.84	0.11	1.0	6.0	48	69	133
F122	20,000	–	2.14	0.13	1.0	4.0	22	35	64
F46	23,000	–	2.07	0.15	0.9	2.5	16	26.0	45.2
F45	25,000	–	1.23	0.16	1.0	1.5	8.5	13.5	24.5
F76	30,000	–	11.3	0.19	0.5	1.1	4.2	7.0	12.5
F132	35,000	46.7	64.5	0.22	–	0.3	1.5	1.9	4.3
F131	40,000	15.3	46.5	0.26	–	0.1	1.0	1.3	2.0
F124	45,000	5.0	39.0	0.29	–	–	0.1	0.2	0.5

TABLE 12

A-286 STAINLESS STEEL RUPTURE AND CREEP DEFORMATION DATA AT 1500 °F

SPECIMEN	STRESS psi	RUPTURE TIME HOURS	ELONGATION IN 2 INCHES %	DEFORMATION ON LOADING %	TIME TO REACH INDICATED DEFORMATION – HOURS				
					0.05%	0.10 %	0.30%	0.50%	1.00%
F 47	400	–	0.03	0.002	–	–	–	–	–
F 111	750	–	0.10	0.005	300	1010	–	–	–
F 83	1,000	–	0.16	0.007	180	450	–	–	–
F 36	1,200	–	0.33	0.008	38	100	805	–	–
F 92	1,500	–	0.51	0.010	32	90	500	1525	–
F 74	2,000	–	0.79	0.014	28	62	300	662	–
F 41	2,100	–	1.25	0.016	11	27	146	311	792
F 104	3,000	–	1.39	0.02	5	12	64	128	327
F 86	4,500	–	1.78	0.03	3.5	7.0	24.5	46	104
F 59	6,000	–	3.72	0.04	1.8	3.6	14.6	25	46.8
F 32	8,000	–	3.29	0.06	1.0	2.2	7.6	12.8	25.5
F 44	8,000	–	2.70	0.06	0.5	1.6	6.6	11.1	21.2
F 58	10,000	–	2.63	0.07	0.3	0.8	2.9	4.5	8.7
F 25	12,000	66.6	77.5	0.08	0.2	0.4	2.0	2.8	4.9
F 43	15,500	9.5	93.0	0.11	–	–	0.1	0.15	0.2

TABLE 13

A-286 STAINLESS STEEL DEFORMATION - TIME DATA AT 1200 °F

TIME HOURS	DEFORMATION IN 2 INCHES %	TIME HOURS	DEFORMATION IN 2 INCHES %	TIME HOURS	DEFORMATION IN 2 INCHES %	TIME HOURS	DEFORMATION IN 2 INCHES %
STRESS = 4,000psi		900	0.10	570	0.235	45	0.08
120	0.005	915	0.105	685	0.285	62	0.10
195	0.01	STRESS = 20,000psi		725	0.30	105	0.14
295	0.015	60	0.04	860	0.355	160	0.19
440	0.02	75	0.05	1000	0.435	215	0.245
670	0.035	195	0.07	1122	0.50	STRESS = 40,000psi	
945	0.045	320	0.08	STRESS = 30,000psi		8	0.05
STRESS = 5000psi		415	0.095	45	0.05	23	0.10
80	0.02	470	0.10	167	0.10	30	0.11
200	0.025	540	0.115	473	0.30	70	0.185
320	0.03	680	0.145	651	0.50	100	0.255
540	0.035	820	0.175	1017	1.00	128	0.30
610	0.04	950	0.205	STRESS = 33,000psi		160	0.37
700	0.045	STRESS = 25,000psi		45	0.045	195	0.50
790	0.05	25	0.025	90	0.065	210	0.535
STRESS = 15,000psi		45	0.055	170	0.105	245	0.70
60	0.025	60	0.05	245	0.145	275	0.785
125	0.03	85	0.065	365	0.215	298	1.0
180	0.035	150	0.085	465	0.285	STRESS = 45,000psi	
290	0.05	205	0.1	585	0.41	3	0.05
315	0.05	220	0.11	725	0.575	9	0.10
495	0.07	315	0.13	STRESS = 35,000psi		20.	0.11
760	0.095	415	0.175	12	0.05	35	0.25

TABLE 13 (CONT'D)

A-286 STAINLESS STEEL DEFORMATION – TIME DATA AT 1200°F

TIME HOURS	DEFORMATION IN 2 INCHES %	TIME HOURS	DEFORMATION IN 2 INCHES %	TIME HOURS	DEFORMATION IN 2 INCHES %	TIME HOURS	DEFORMATION IN 2 INCHES %
STRESS = 45,000psi		143	1.00	STRESS = 60,000psi		2.6	0.30
52	0.30	STRESS = 55,000psi		0.2	0.05	4.2	0.50
65	0.33	0.5	0.05	1.1	0.10	6.0	1.00
80	0.42	1	0.10	5.3	0.30	STRESS = 70,000psi	
92	0.50	7.5	0.30	8.6	0.50	0.2	0.10
105	0.75	10.5	0.50	14	1.00	1.2	0.30
115	0.695	15.0	1.00	STRESS = 65,000psi		2.0	0.50
130	0.875			0.2	0.05	3.3	1.0
				0.6	0.10		

TABLE 14

A - 286 STAINLESS STEEL DEFORMATION - TIME DATA AT 1350 °F

TIME HOURS	DEFORMATION IN 2 INCHES %	TIME HOURS	DEFORMATION IN 2 INCHES %	TIME HOURS	DEFORMATION IN 2 INCHES %	TIME HOURS	DEFORMATION IN 2 INCHES %
STRESS = 1,200 psi		145	0.05	1320	0.30	320	0.265
310	0.005	210	0.065	STRESS = 7,000 psi		383	0.30
525	0.015	360	0.095	29	0.05	405	0.315
590	0.02	410	0.10	45	0.06	530	0.38
810	0.035	540	0.12	77	0.10	630	0.43
1010	0.04	640	0.13	150	0.15	750	0.47
1150	0.05	755	0.135	210	0.195	780	0.5
STRESS = 2,000 psi		880	0.14	285	0.24	865	0.55
35	0.01	970	0.15	385	0.285	985	0.60
120	0.03	STRESS = 5,000 psi		410	0.30	STRESS = 9,000 psi	
165	0.04	20	0.025	510	0.35	18	0.05
285	0.045	57	0.05	640	0.40	68	0.10
375	0.05	100	0.07	720	0.43	120	0.15
450	0.06	150	0.08	820	0.47	220	0.24
550	0.065	230	0.10	875	0.5	327	0.30
700	0.07	370	0.14	910	0.51	350	0.32
785	0.075	470	0.165	1010	0.60	370	0.39
890	0.08	605	0.195	STRESS = 8,000 psi		605	0.47
1025	0.085	690	0.205	22	0.05	645	0.50
1130	0.10	850	0.225	40	0.07	750	0.56
STRESS = 3,500 psi		900	0.235	63	0.10	884	0.66
50	0.02	950	0.245	105	0.13	1440	1.00
110	0.04	1100	0.265	230	0.22		

TABLE 14 (CONT'D)

TIME HOURS	DEFORMATION IN 2 INCHES %	TIME HOURS	DEFORMATION IN 2 INCHES %	TIME HOURS	DEFORMATION IN 2 INCHES %	TIME HOURS	DEFORMATION IN 2 INCHES %
STRESS = 10,000 psi		40	0.15	75	0.51	45.2	1.0
4	0.05	55	0.235	100	0.695	STRESS = 25,000 psi	
20	0.065	68	0.30	133	1.00	1	0.05
26	0.10	85	0.345	STRESS = 20,000 psi		1.5	0.10
40	0.105	100	0.420	1	0.05	10	0.25
85	0.17	122	0.50	4	0.10	8.5	0.3
145	0.265	150	0.605	15	0.145	13.5	0.5
179	0.30	200	0.79	22	0.30	20	0.6
235	0.375	254	1.0	35	0.50	24.5	1.0
348	0.50	STRESS = 17,500 psi		45	0.60	STRESS = 30,000 psi	
445	0.59	1	0.05	60	0.81	0.5	0.05
555	0.705	6	0.10	64	1.0	1.1	0.1
660	0.80	25	0.145	STRESS = 23,000		4.2	0.3
868	1.0	40	0.215	0.9	0.05	7.0	0.5
STRESS = 15,000 psi		48	0.30	2.5	0.10	12.5	1.0
2.5	0.05	60	0.33	16	0.30		
8.7	0.10	64	0.50	26	0.5		

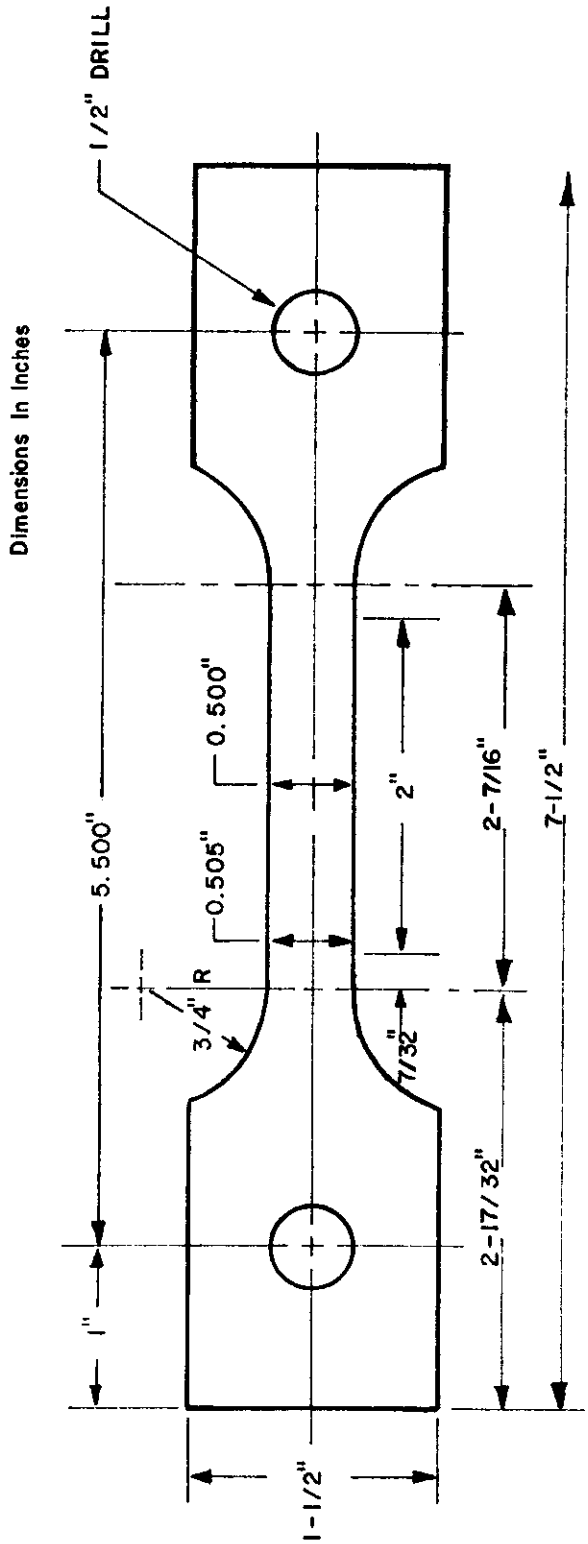
TABLE 15

A-286 STAINLESS STEEL DEFORMATION – TIME DATA AT 1500°F

TIME HOURS	DEFORMATION IN 2 INCHES %	TIME HOURS	DEFORMATION IN 2 INCHES %	TIME HOURS	DEFORMATION IN 2 INCHES %	TIME HOURS	DEFORMATION IN 2 INCHES %
STRESS = 750 psi		STRESS = 1,200 psi		800	0.36	95	0.23
145	0.03	38	0.05	945	0.39	146	0.30
185	0.035	75	0.09	1090	0.42	160	0.32
300	0.05	100	0.10	1525	0.5	265	0.445
440	0.07	150	0.125	STRESS = 2,000 psi		311	0.50
500	0.075	220	0.155	20	0.04	320	0.515
610	0.085	330	0.19	28	0.05	435	0.54
715	0.085	475	0.235	62	0.10	545	0.75
820	0.095	560	0.26	150	0.195	640	0.85
930	0.095	715	0.285	205	0.245	792	1.0
1010	1.0	805	0.30	300	0.30	STRESS = 3,000 psi	
STRESS = 1,000 psi		910	0.32	340	0.34	5	0.05
60	0.025	1015	0.335	505	0.42	10	0.08
115	0.035	STRESS = 1,500 psi		600	0.47	12	0.10
180	0.05	32	0.05	662	0.50	30	0.18
230	0.065	50	0.065	720	0.53	64	0.30
345	0.085	90	0.10	810	0.565	100	0.42
450	0.10	150	0.14	920	0.630	128	0.50
560	0.12	220	0.185	1060	0.680	165	0.61
745	0.125	280	0.235	STRESS = 2,100 psi		200	0.695
845	0.135	390	0.270	11	0.05	260	0.85
995	0.150	500	0.30	27	0.10	327	1.00
1030	0.155	650	0.335	65	0.185		

TABLE 15 (CONT'D)

TIME HOURS	DEFORMATION IN 2 INCHES %	TIME HOURS	DEFORMATION IN 2 INCHES %	TIME HOURS	DEFORMATION IN 2 INCHES %	TIME HOURS	DEFORMATION IN 2 INCHES %
STRESS = 4,500 psi		3.6	0.10	5	0.24	4.5	0.50
3.5	0.05	5	0.14	6.6	0.3	8.7	1.00
7	0.10	14.6	0.30	10	0.35	STRESS = 12,000 psi	
15	0.215	25	0.50	11.1	0.5	0.2	0.05
24.5	0.3	30	0.61	15	0.715	0.4	0.10
46	0.5	35	0.75	21.2	1.0	2.0	0.30
70	0.725	46.8	1.0	STRESS = 10,000 psi		2.8	0.50
104	1.0	STRESS = 8,000 psi		0.3	0.05	4.9	1.00
STRESS = 6,000 psi		0.5	0.05	0.8	0.10		
1.8	0.05	1.6	0.10	2.9	0.30		



NOTE: Thickness from 0.020 to 0.125 as determined by material requirments.

Figure 1. Sheet Specimen for Tensile Testing

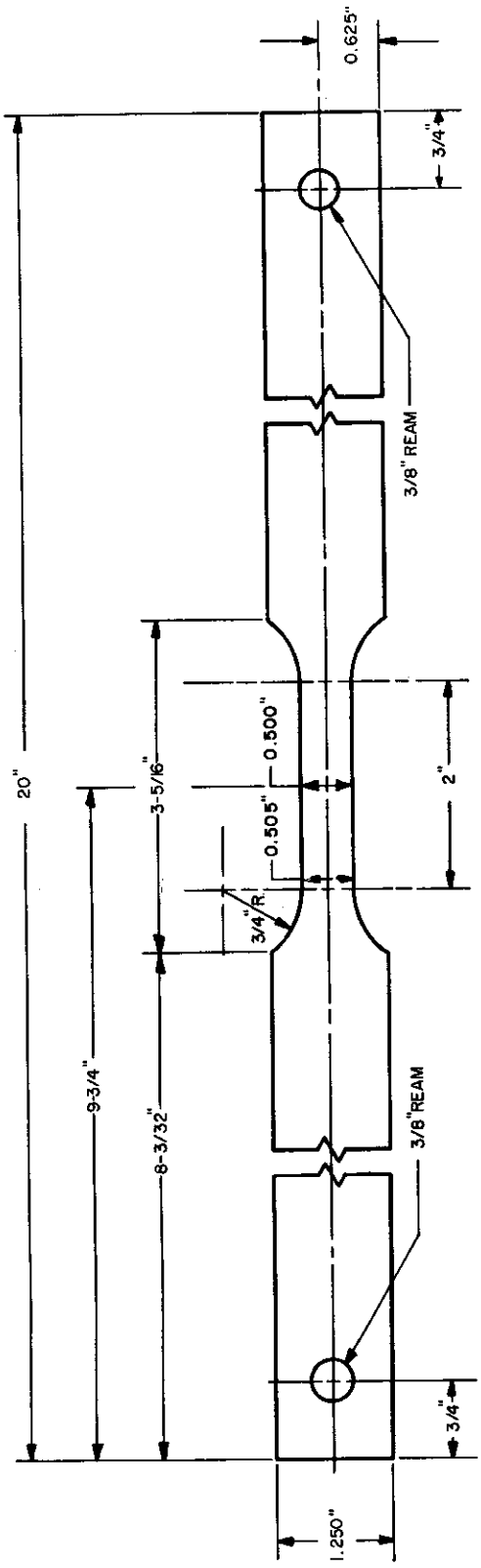


Figure 2. Sheet Specimen for Creep-Rupture Testing

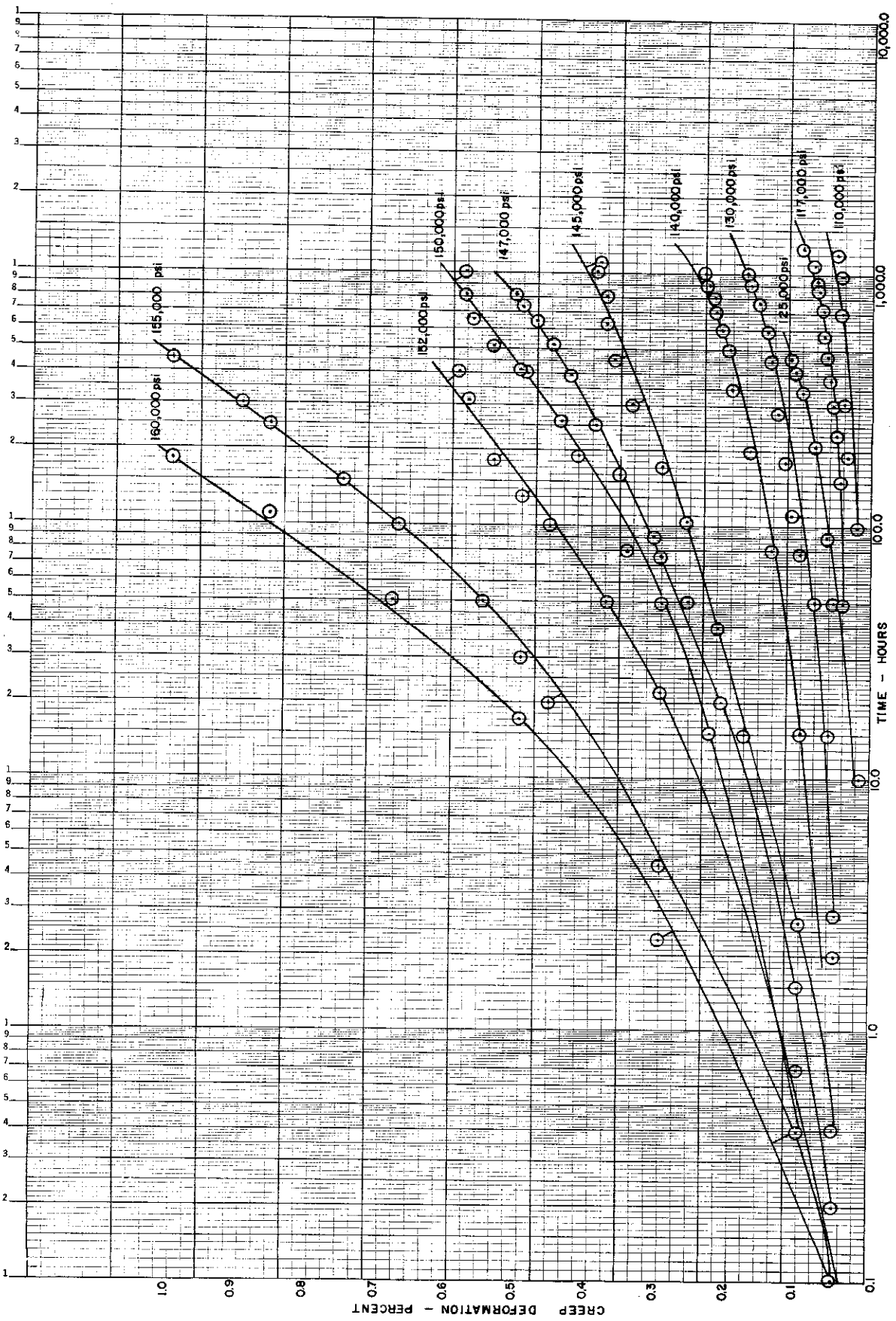


Figure 3. Creep Deformation vs time for 17-7 PH at 600°F

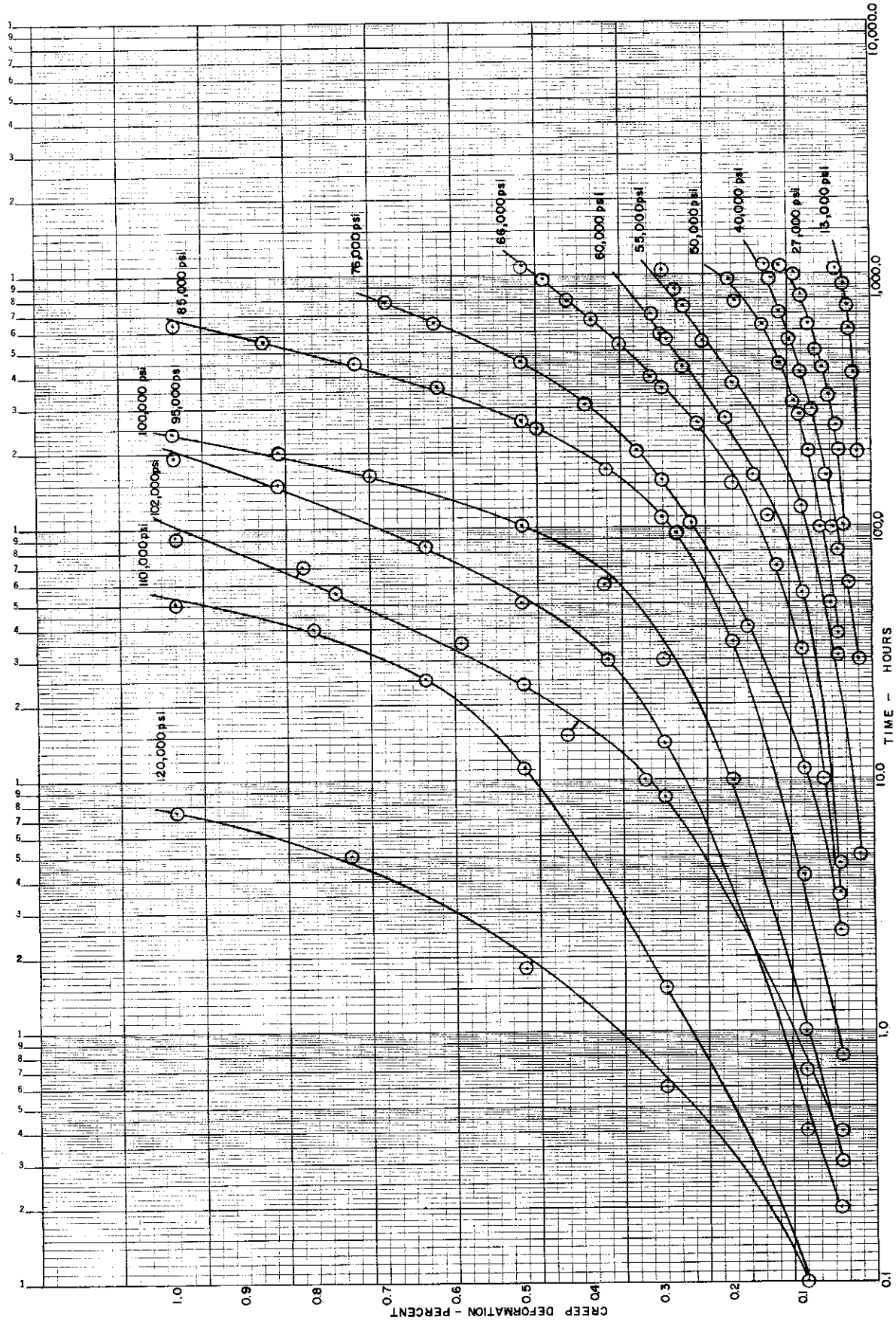


Figure 4. Creep Deformation vs time for 17-7 PH at 800°F

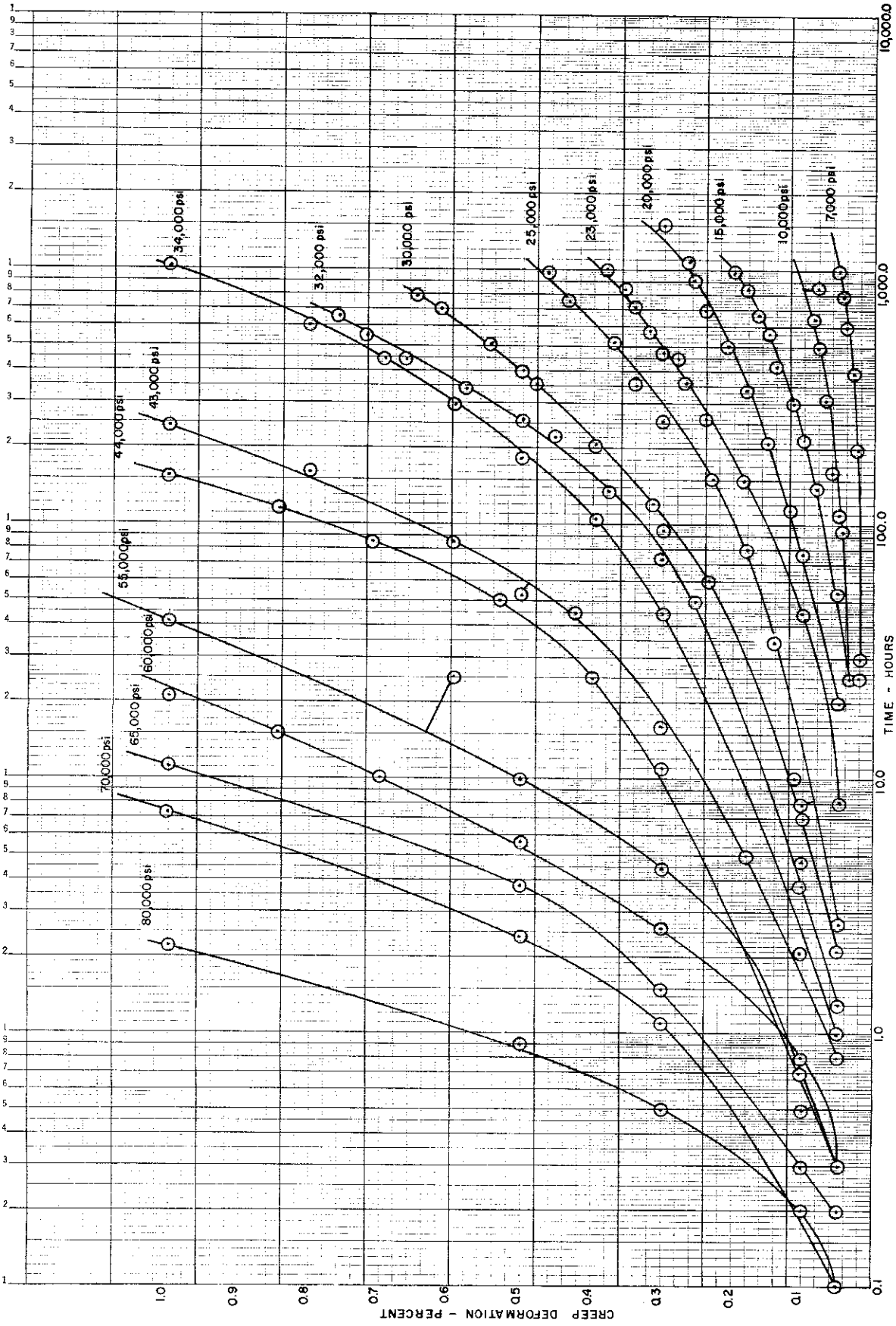


Figure 5. Creep Deformation vs time for 17-7 PH at 900°F

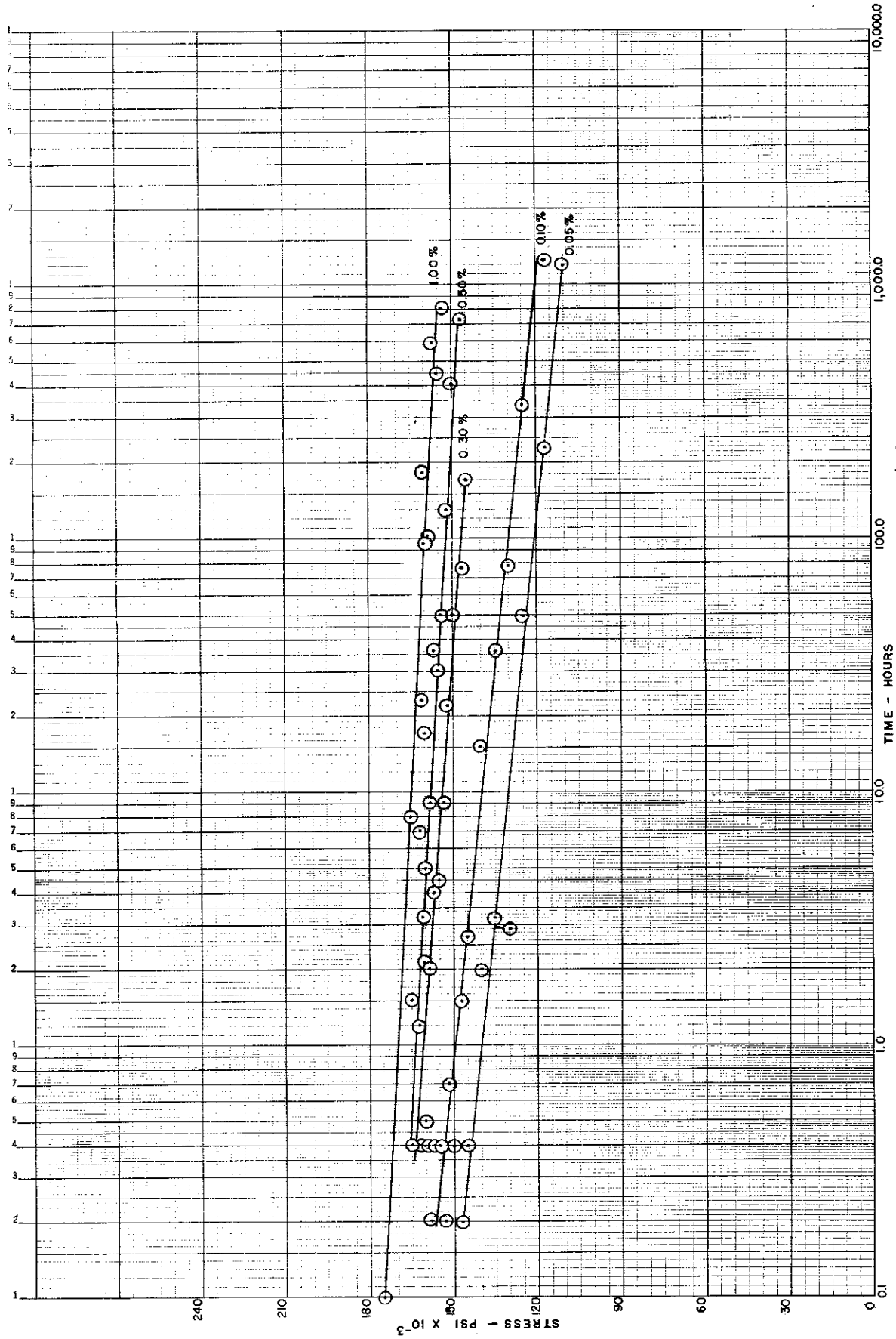


Figure 6. Design Curves for 17-7 PH at 600°F

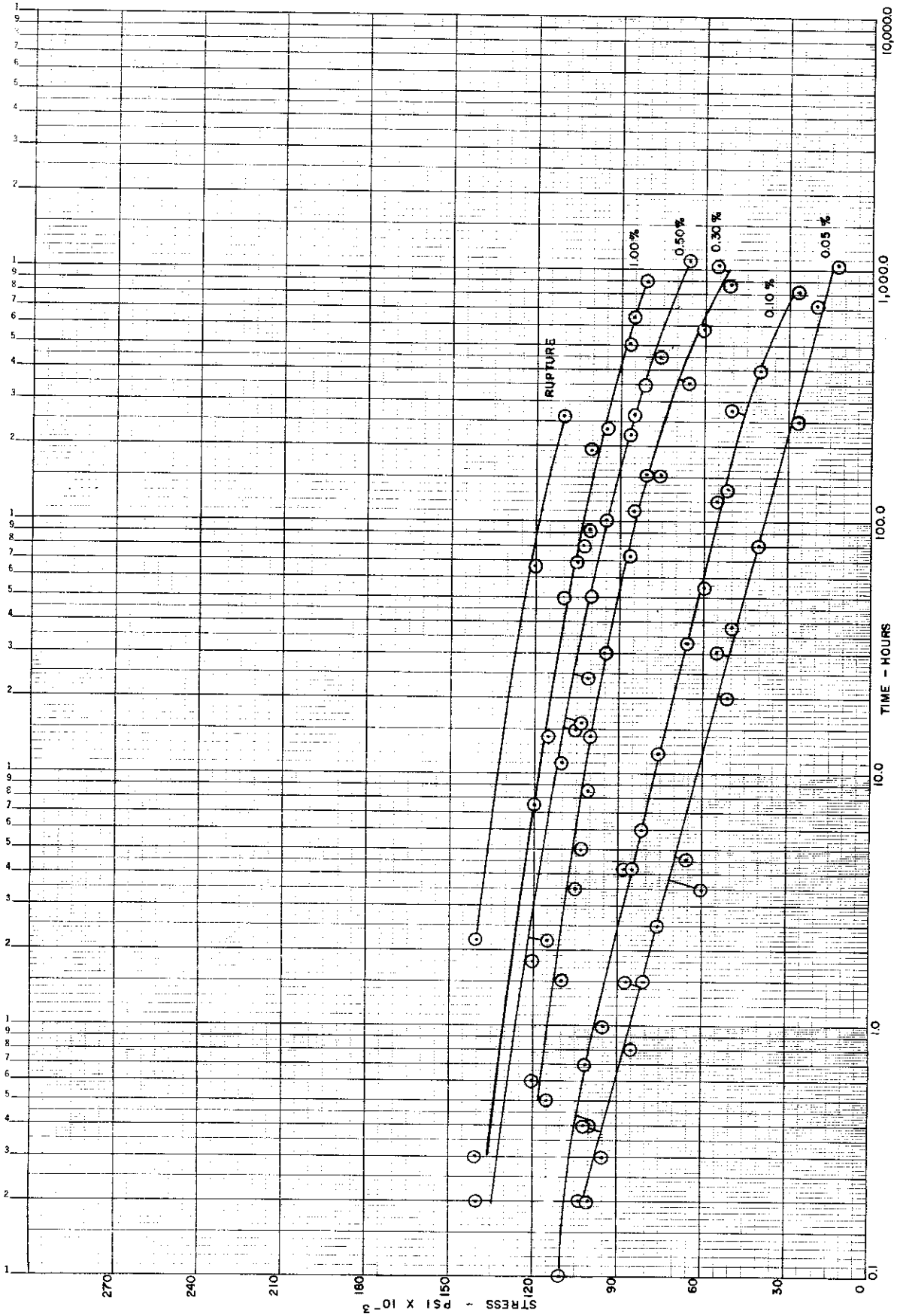


Figure 7. Design Curves for 17-7 PH at 800°F

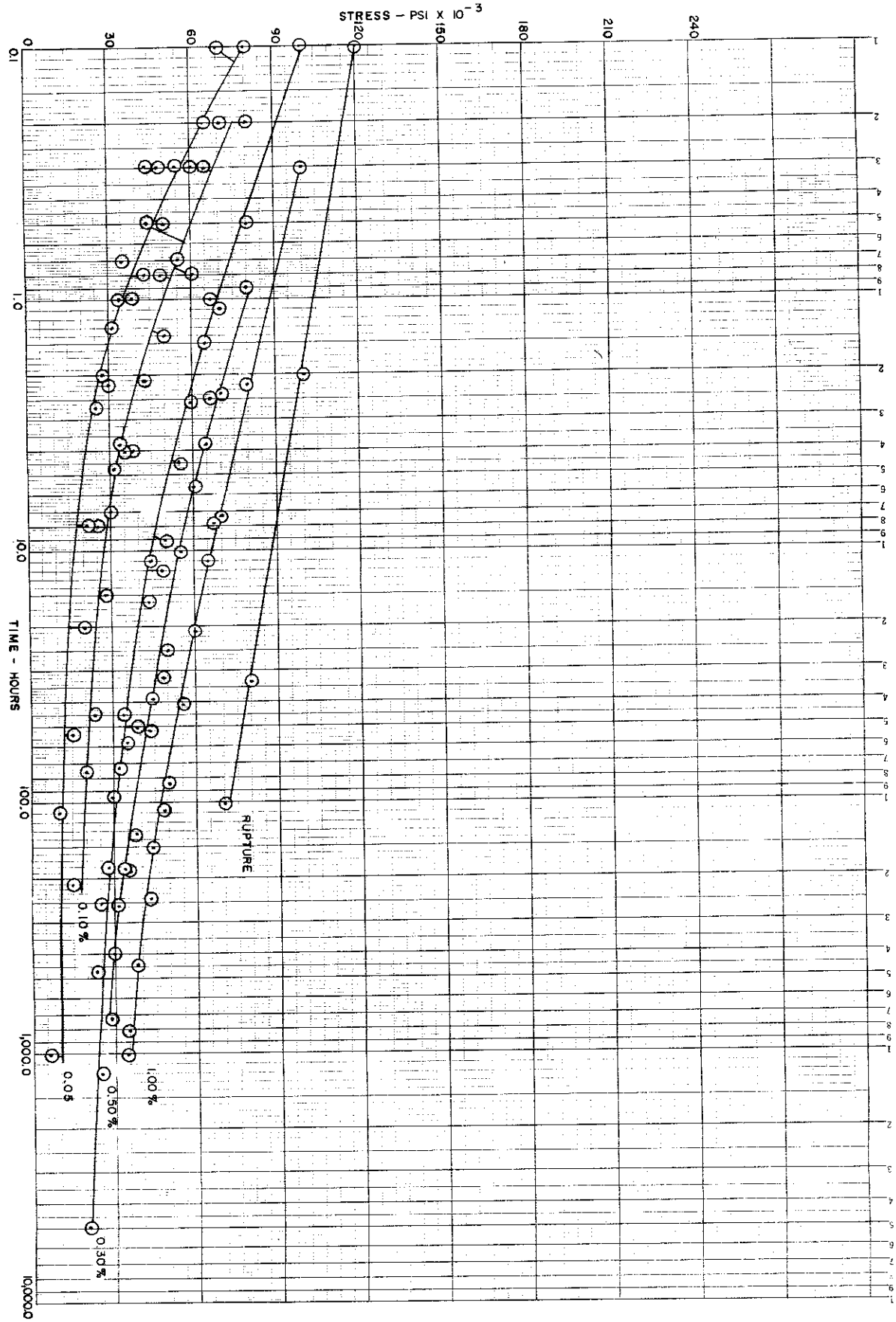


Figure 8. Design Curves for 17-7 PH at 900°F

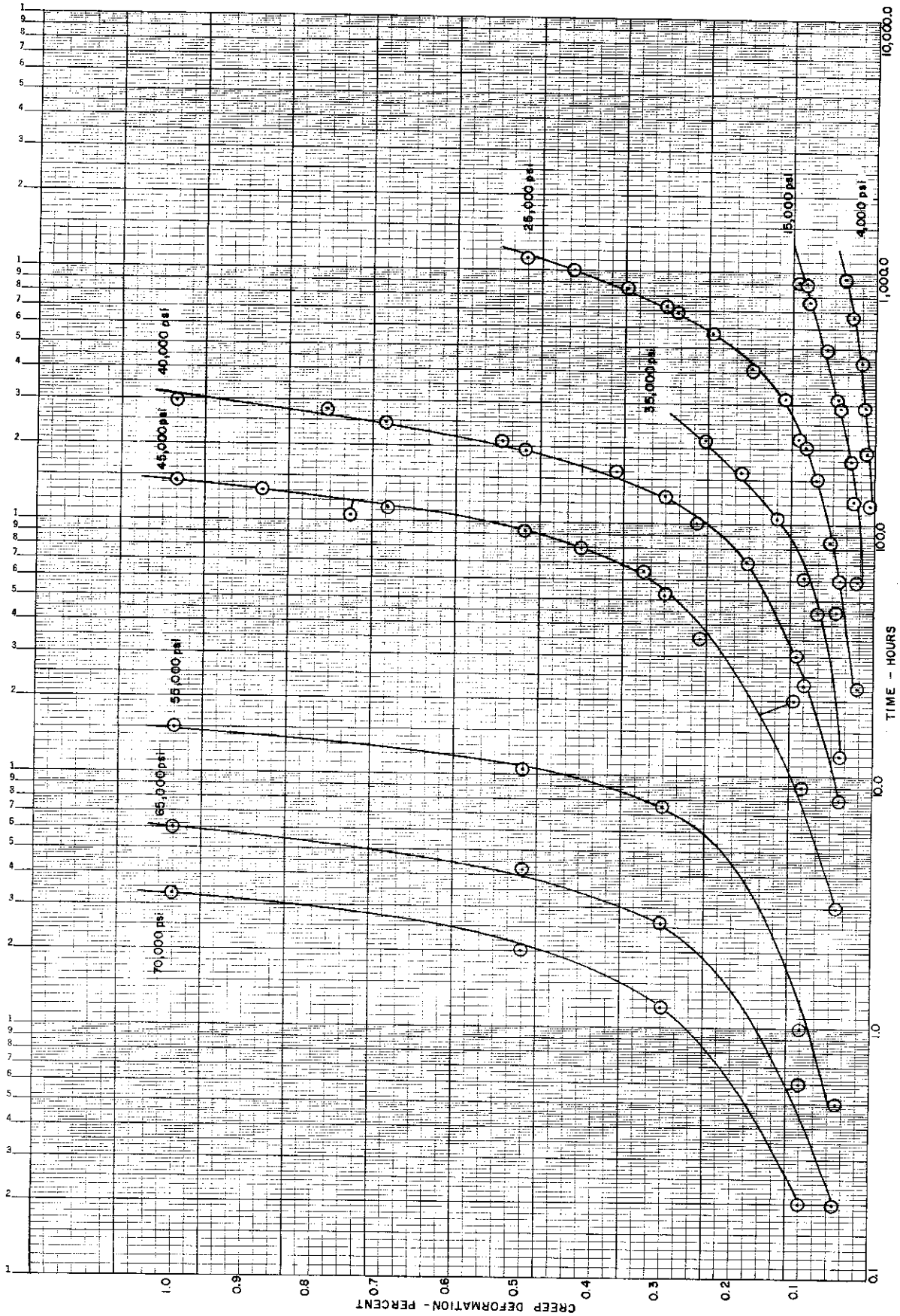


Figure 9. Creep Deformation vs time for A-286 at 1200°F

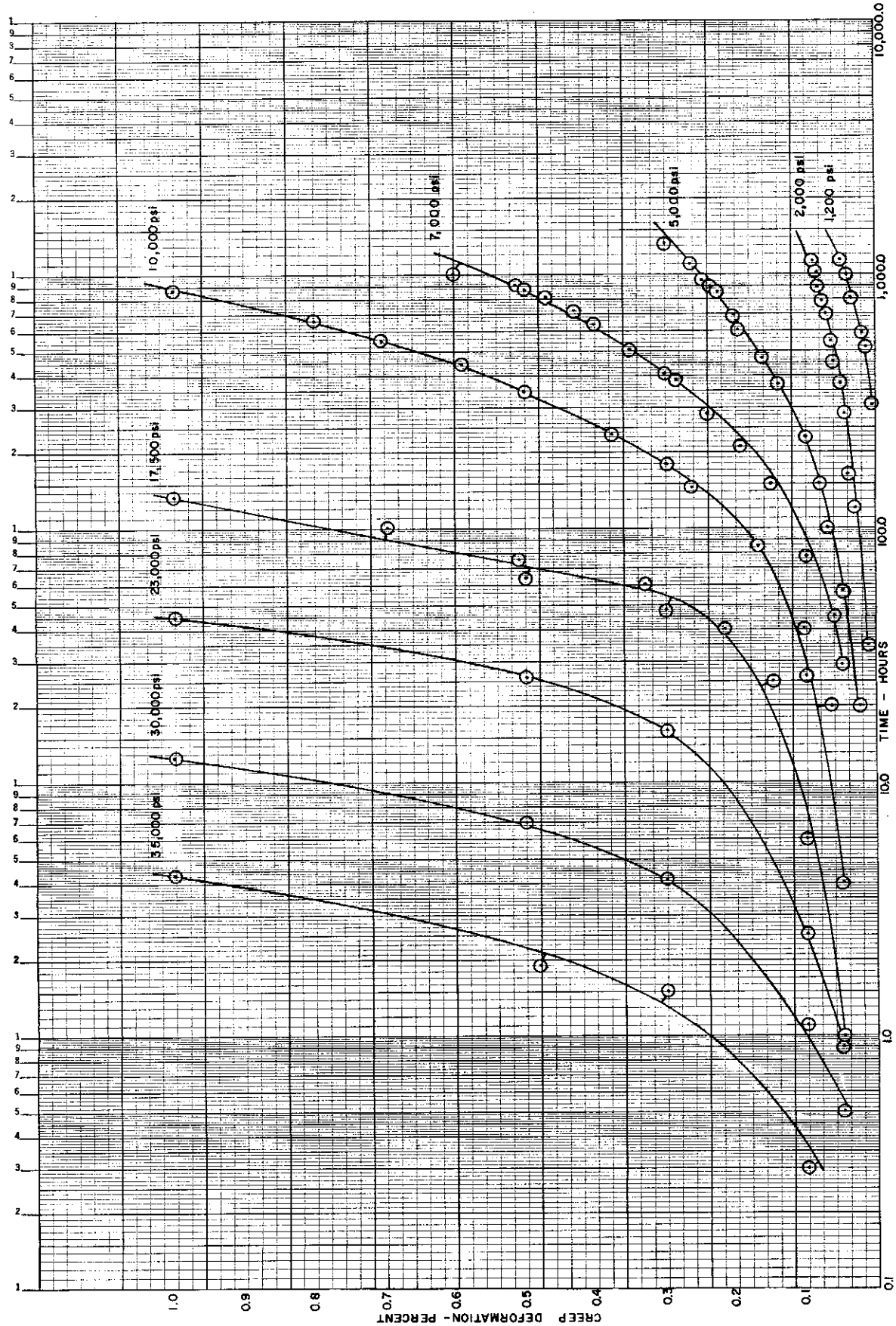


Figure 10. Creep Deformation vs time for A-286 at 1350°F

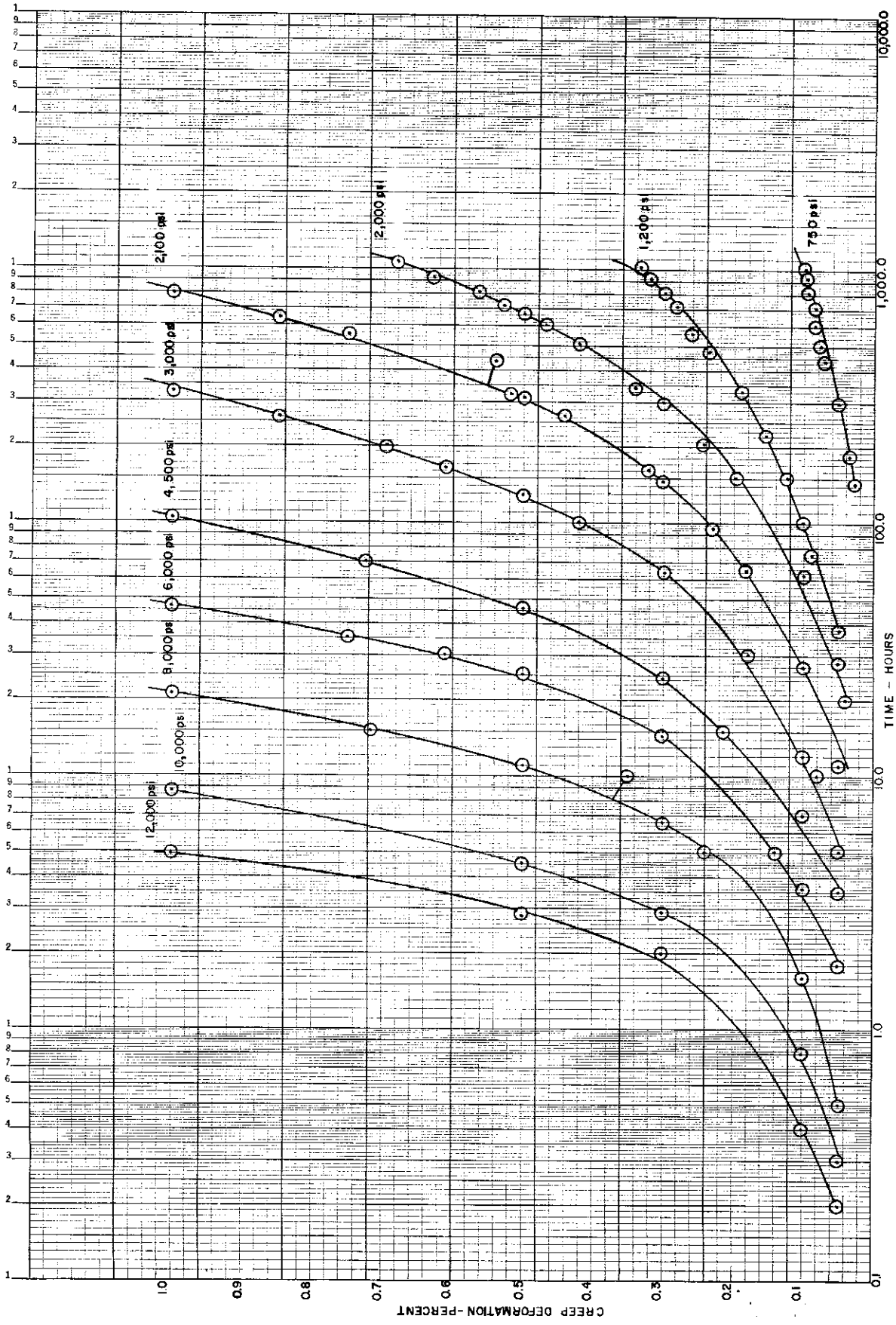


Figure 11. Creep Deformation vs time for A-286 at 1500°F

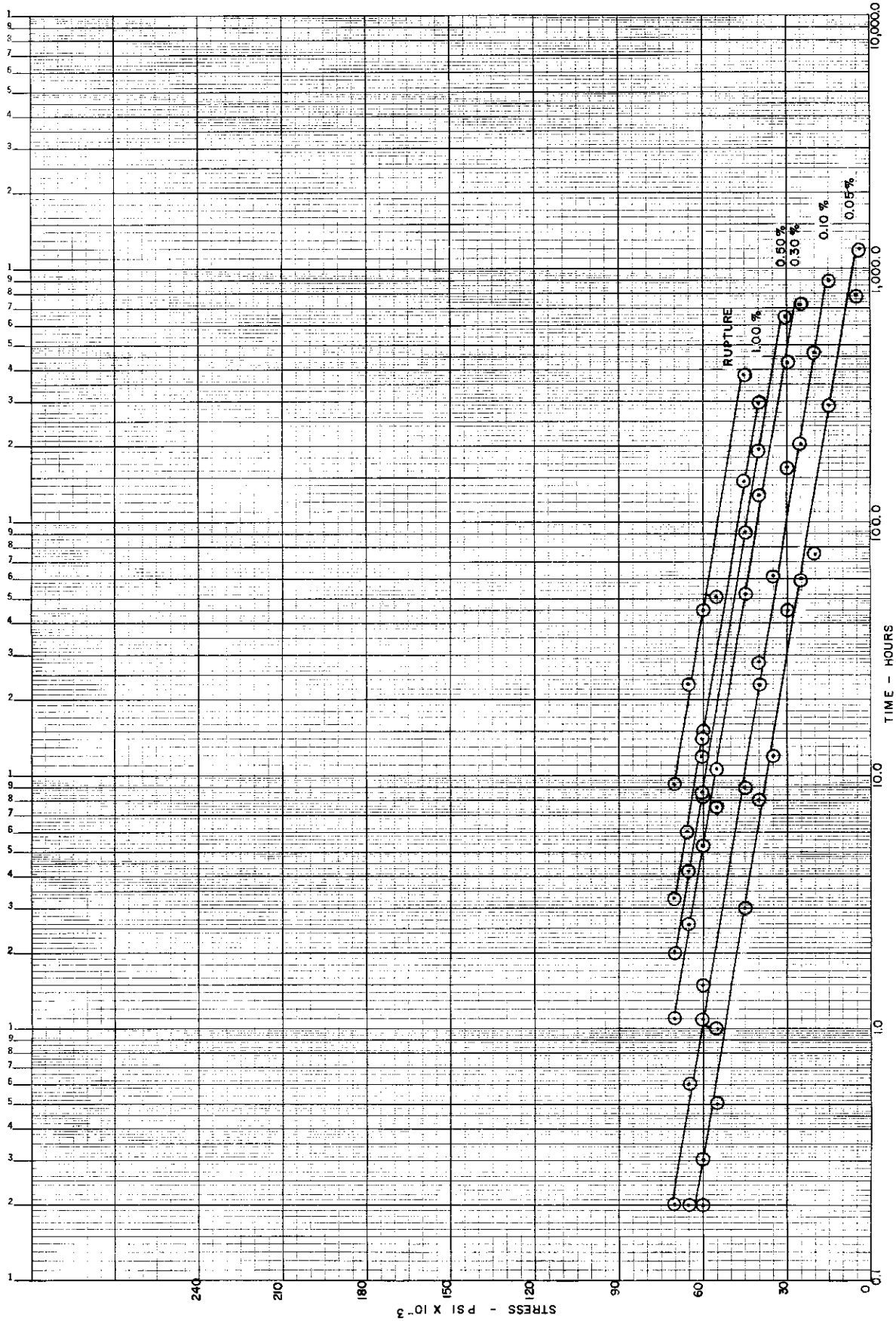


Figure 12. Design Curves for A-286 at 1200°F

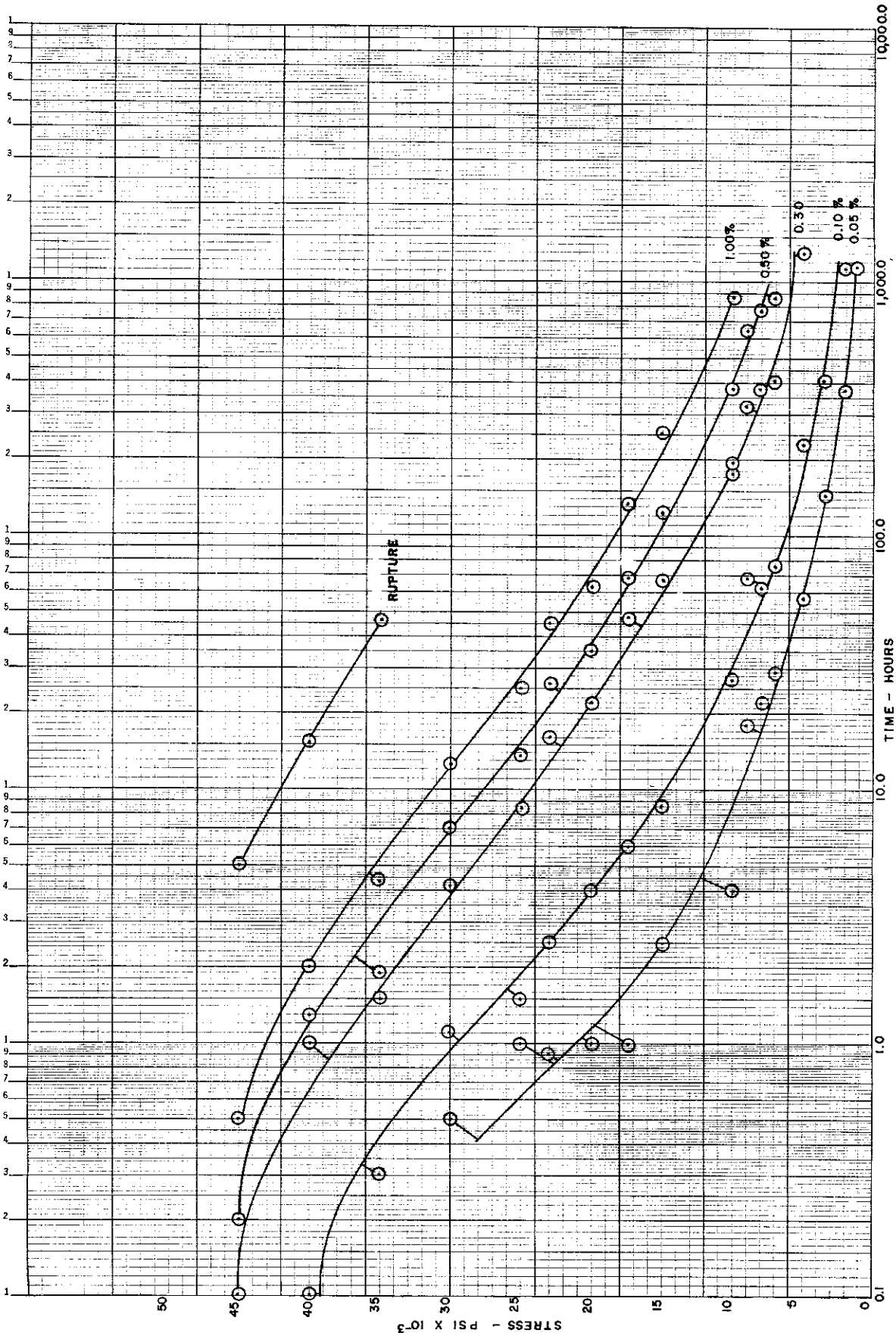


Figure 13. Design Curves for A-286 at 1350°F

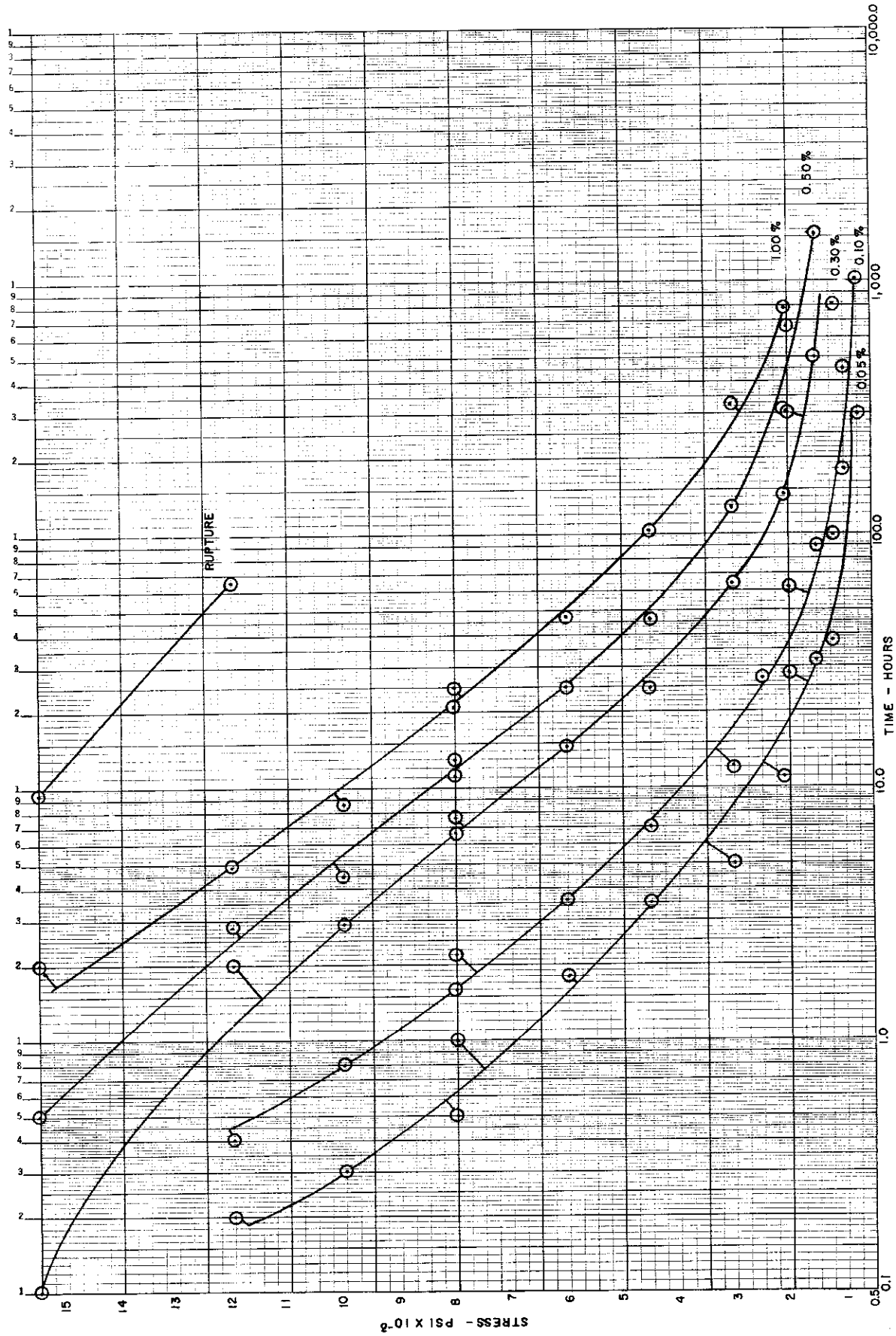


Figure 14. Design Curves for A-286 at 1500°F