

AD 606108

ML TDR 64-79

**ELEVATED TEMPERATURE TENSILE AND CREEP PROPERTIES OF
M-252 (BAR), INCONEL 700 (BAR), AND INCONEL 713 (CAST)
NICKEL BASE ALLOYS**

SIDNEY O. DAVIS

COPY	2	OF	3	pages
HARD COPY	\$.3.00			
MICROFICHE	\$.75			

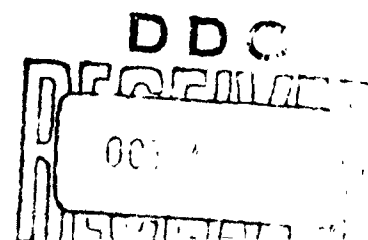
78p

TECHNICAL DOCUMENTARY REPORT No. ML TDR 64-79

JULY 1964

AIR FORCE MATERIALS LABORATORY
RESEARCH AND TECHNOLOGY DIVISION
AIR FORCE SYSTEMS COMMAND
WRIGHT-PATTERSON AIR FORCE BASE, OHIO

Project No 7381 Task No 738103



ML TDR 64-79

FOREWORD

This report was prepared by the Materials Engineering Branch, Materials Applications Division, Air Force Materials Laboratory, Research and Technology Division and was initiated under Project No. 7381, "Materials Applications," Task No. 738103, "Data Collection and Correlation," Mr. Sidney O. Davis, project engineer.

Testing was done by the Joliet Metallurgical Laboratories, Inc. under Contract No. AF 33(600)-36462.

Data reduction and curve plotting were performed by the Monsanto Research Corporation under Contract No. AF 33(616)-8483.

TABLE OF CONTENTS

	PAGE
INTRODUCTION	1
MATERIALS TESTED AND APPLICATIONS	2
TEST PROCEDURES	2
CONCLUSIONS	3
APPENDIX-RESULTS OF TEST MATERIALS	5

ABSTRACT

Room and elevated temperature tensile and elevated temperature creep properties to 1000 hours were determined at three representative application temperatures for M-252 (bar), Inconel 700 (bar), and Inconel 713 (cast). Tabulated tensile and creep data, deformation versus time curves, and stress versus time curves for 0.1, 0.3, 0.5, and 1% creep are presented.

This technical documentary report has been reviewed and is approved.



W. P. CONRARDY, Chief
Materials Engineering Branch
Materials Applications Division

TABLES

TABLE	PAGE
1. Chemical Compositions	6
2. Tensile Test Data - M-252 (Bar)	6
3. Tensile Test Data - Inconel 700 (Bar)	7
4. Tensile Test Data - Inconel 713C (Cast)	7
5. M-252 (Bar) Elongation-Time Data at 1350°F	11
6. M-252 (Bar) Creep Deformation and Rupture Data at 1350°F	13
7. M-252 (Bar) Elongation-Time Data at 1500°F	15
8. M-252 (Bar) Creep Deformation and Rupture Data at 1500°F	17
9. M-252 (Bar) Elongation-Time Data at 1600°F	19
10. M-252 (Bar) Creep Deformation and Rupture Data at 1600°F	21
11. Inconel 700 (Bar) Elongation-Time Data at 1500°F	23
12. Inconel 700 (Bar) Creep Deformation and Rupture Data at 1500°F	25
13. Inconel 700 (Bar) Elongation-Time Data at 1600°F	27
14. Inconel 700 (Bar) Creep Deformation and Rupture Data at 1600°F	29
15. Inconel 700 (Bar) Elongation-Time Data at 1700°F	31
16. Inconel 700 (Bar) Creep Deformation and Rupture Data at 1700°F	33
17. Inconel 713C Elongation-Time Data at 1500°F	35
18. Inconel 713C Creep Deformation and Rupture Data at 1500°F	37
19. Inconel 713C Elongation-Time Data at 1600°F	39
20. Inconel 713C Creep Deformation and Rupture Data at 1600°F	41
21. Inconel 713C Elongation-Time Data at 1700°F	43
22. Inconel 713C Creep Deformation and Rupture Data at 1700°F	45

ILLUSTRATIONS

FIGURE		PAGE
1.	Test Specimen Configurations	8
2.	Creep Deformation Versus Log Time of M-252 (Bar) at 1350°F	10
3.	Creep Rupture Properties of M-252 (Bar) at 1350°F	12
4.	Creep Deformation Versus Log Time of M-252 (Bar) at 1500°F	14
5.	Creep Rupture Properties of M-252 (Bar) at 1500°F	16
6.	Creep Deformation Versus Log Time of M-252 (Bar) at 1600°F	18
7.	Creep Rupture Properties of M-252 (Bar) at 1600°F	20
8.	Creep Deformation Versus Log Time of Inconel 700 (Bar) at 1500°F	22
9.	Creep Rupture Properties of Inconel 700 (Bar) at 1500°F	24
10.	Creep Deformation Versus Log Time of Inconel 700 (Bar) at 1600°F	26
11.	Creep Rupture Properties of Inconel 700 (Bar) at 1600°F	28
12.	Creep Deformation Versus Log Time of Inconel 700 (Bar) at 1700°F	30
13.	Creep Rupture Properties of Inconel 700 (Bar) at 1700°F	32
14.	Creep Deformation Versus Log Time of Inconel 713C (Cast) at 1500°F	34
15.	Creep Rupture Properties of Inconel 713C at 1500°F	36
16.	Creep Deformation Versus Log Time of Inconel 713C at 1600°F	38
17.	Creep Rupture Properties of Inconel 713C at 1600°F	40
18.	Creep Deformation Versus Log Time of Inconel 713C at 1700°F	42
19.	Creep Rupture Properties of Inconel 713C at 1700°F	44

INTRODUCTION

CREEP

At normal ambient temperatures, a structure designed on yield strength deforms to some extent immediately upon load application and then no further deformation occurs with time. At elevated temperatures this same structure will continue to deform with time under a constant load. This continued deformation under load is called creep. Creep eventually can result in creep-rupture when the ultimate strength of the material is reached.

DESIGNING FOR CREEP

The creep rate (the slope of the percent deformation per gage length versus log-time curve) depends on the applied stresses, temperature, the composition of the material of interest, and metallurgical considerations. Creep tests establish finite values for the creep rates. This is fortunate from a design point of view for without such data structures might be highly overdesigned. With creep data in hand, the designer can select design stresses which recognize the occurrence of creep, at the same time limiting it to tolerable values within the contemplated life-span of the system.

Fracture due to creep raises another limitation. Here, the designer must consider time when selecting design stresses. The "time until fracture" variable for a given material may be determined by creep-rupture tests. Creep and creep-rupture tests are identical except that in the latter case stresses are higher and the test is carried to failure. The test specimens are held constantly at the temperature of interest, under static load, and elongation is measured periodically. Customary testing time is 1000 hours, although it can range from several hours to over ten years.

The measured creep strength is commonly expressed as (a) the stress producing a creep rate of 0.0001% per hour, or (b) the stress for a creep rate of 0.0001% per hour at the given temperature. Rupture values are usually reported as the stress for fracture in 100, 1000, 10,000, or 100,000 hours at the specific temperature utilized.

Designers of elevated temperature structures, therefore, must base design stresses on longtime creep and rupture strength, and take into account the limiting temperature determined by the scaling or oxidation resistance of the material.

CREEP DATA PRESENTED

This report presents creep data for three elevated temperature nickel base alloys at simulated application temperatures. No attempt was made to interpret these test results on the basis of microstructure and chemistry nor have any conclusions regarding the relative merit of these alloys been made. The intended scope of this report is data compilation in a form which is best suited for potential users of these alloys. The data presented is not to be construed as being representative of all heats of the material, but rather specifically applies to the lots tested.

MATERIALS TESTED AND APPLICATIONS^a

1. M-252 (Bar) - This material was purchased from Universal Cyclops as 5/8-inch-diameter rolled bar. Heat treatment procedure was as follows:

1950°F - 4 hours - air cool

1400°F - 15 hours - air cool

M-252 is a vacuum melted nominal 54 Ni - 19 Cr - 10 Co - 10 Mo - 2.5 Ti material used for torque rings and gas turbine buckets.

2. Inconel 700 (Bar) - Purchased from the Huntington Alloys Division of the International Nickel Co. as 5/8-inch-diameter hot rolled bar from heat number 5982U. Heat treatment procedure was as follows:

2160°F - 2 hours - air cool

1600°F - 4 hours - air cool

Inconel 700 (Bar) is used as rotor turbine blades up to 1650°F. It is a nominal 46 Ni - 28.5 Co - 15 Cr - 3.75 Mo - 3.0 Al - 2.35 Ti alloy.

3. Inconel 713C - Supplied by the Huntington Alloys Division of the International Nickel Co. as investment cast rounds with threaded ends. The material came from heat number X-4027 and was tested in the as-cast condition. 713C is noted for its high rupture strength at 1700°F, good castability, and exceptional resistance to thermal fatigue. A present application is turbine blades in advanced engines. It is a nominal Ni (+Co) Bal - 13 Cr - 6 Al - 4.5 Mo - 2.0 Cb - .6 Ti - .13 C alloy.

TEST PROCEDURES

Tensile and creep specimens for M-252 and Inconel 700 were machined to a nominal 0.3-inch diameter and 2-inch gage length. The cast Inconel 713C specimens were tested as-received with a 1-inch gage length. Specimen drawings are shown in Figure 1.

A Tinius Olsen tensile machine was used for all tensile tests. Standard loading rates were used with strain measured with an extensometer at all test temperatures. The resultant tensile data are presented in Tables 2, 3, and 4. The results compare favorably with typical test results in the literature.

Tatnall lever-type creep test frames were used for creep testing. Load accuracy checked by a Tatnall representative indicated a $\pm 0.5\%$ of nominal load accuracy for the test stands used.

^aSee Table 1 for chemical compositions of M-252, Inconel 700 (Bar) and Inconel 713C.

ML TDR 64-79

The test furnaces were provided with quartz viewing ports to permit optical measurement of creep deformation. Deformation was monitored using platinum strips and a Gaertner Model M115A optical microscope. This microscope uses an 8-inch relay lens with a 50X objective giving sensitivity of 20 microinches over a total measuring range of 0.080 inches.

Creep data are presented both as deformation versus time for constant stress and stress versus time for a constant deformation. These creep tests were performed at stress levels calculated to produce deformation of 0.3, 0.5, and 1.0% in 1000 hours. Also included on the constant deformation plots is a 0.1% curve which was determined from the elongation-time data. Whenever possible stress rupture data are also included.

For 1000-hour tests at 1600°F and 1700°F difficulties were encountered with the platinum strips, etched reference lines becoming indistinguishable from the strip upon which the lines were etched. This was due to the platinum strips' etched lines deteriorating as a function of time. When this occurred it is noted in the tabular data. However, in those cases when the test was continued with replacement strips, the creep curve before and after the interruption was found to be continuous.

The creep curves derived from testing are presented in Figures 2 through 19. Corresponding tabulated data are presented in Tables 5 through 22.

CONCLUSIONS

The specific mode of presentation of the creep data reported here allows potential users of M-252, Inconel 700, and Inconel 713C to evaluate them more completely than is usually found in literature from other sources. Tensile comparisons with vendors' literature indicate a good correlation with typical tensile results.

ML TDR 64-79

APPENDIX

RESULTS OF TEST MATERIALS

TABLE 1

CHEMICAL COMPOSITIONS			
ELEMENT	M-252	INCONEL 700	INCONEL 713C
Cr	18.64	14.87	11.90
Si	0.60	0.22	0.49
Fe	0.84	0.40	0.86
Mn	1.15	0.21	0.13
Mo	9.86	3.27	5.00
Ni	BAL	BAL	BAL
C	0.14	0.14	0.11
Al	0.89	3.27	5.60
Ti	2.58	2.10	0.52
Cb	9.77	-	2.10
S	0.006	0.007	-
P	0.016	-	-
Co	-	29.35	-
Cu	-	0.03	-

TABLE 2

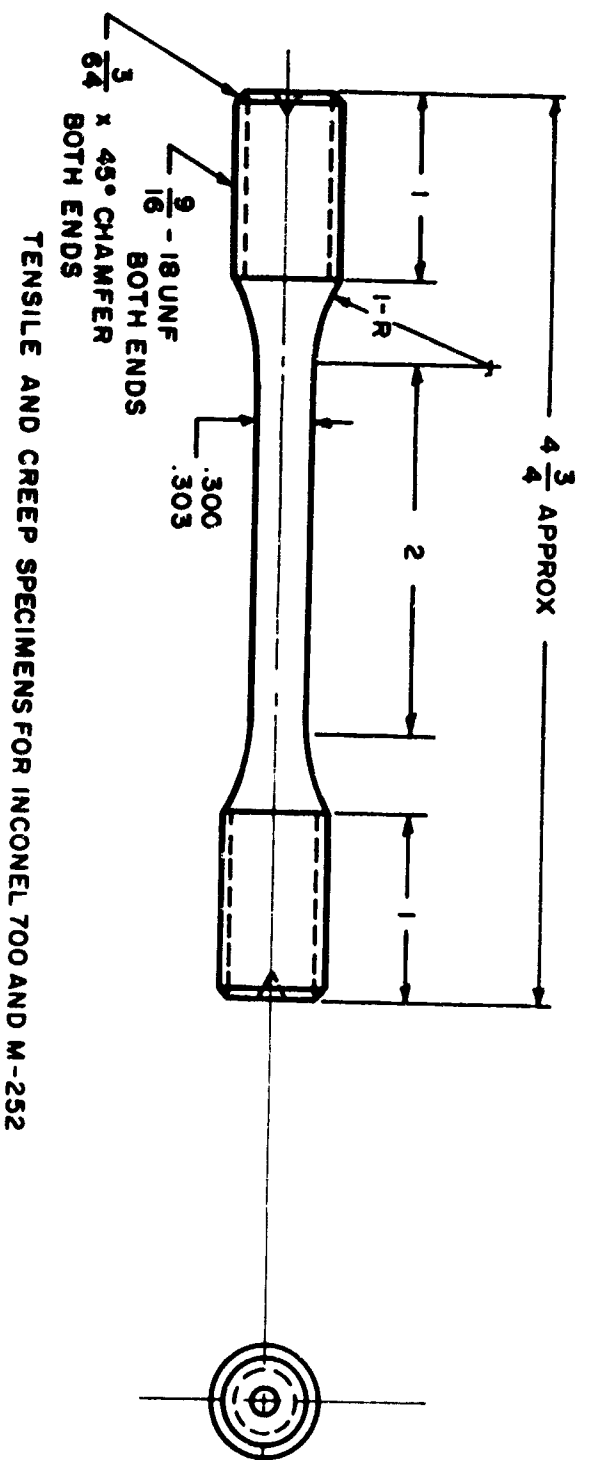
TENSILE TEST DATA - M-252 (BAR)				
TEST TEMPERATURE (°F)	ULTIMATE TENSILE STRENGTH (PSI)	0.2% OFFSET YIELD STRENGTH (PSI)	ELONGATION (% IN 2 INCHES)	REDUCTION IN AREA (%)
75	179,000	121,500	23.0	26.5
75	176,500	119,000	23.5	26.0
75	181,000	124,000	22.0	27.0
1350	144,000	118,500	8.0	10.5
1350	139,500	114,500	9.5	12.0
1350	142,500	105,000	16.0	17.0
1500	100,000	90,500	24.0	35.5
1500	98,500	92,000	14.0	21.5
1500	102,500	92,000	21.0	31.5
1600	71,000	59,500	30.0	47.5
1600	68,000	63,500	31.0	52.5
1600	72,000	65,000	38.5	55.5

TABLE 3

TENSILE TEST DATA — INCONEL 700 (BARI)				
TEST TEMPERATURE (°F)	ULTIMATE TENSILE STRENGTH (PSI)	0.2% OFFSET YIELD STRENGTH (PSI)	ELONGATION (% IN 2 INCHES)	REDUCTION IN AREA (%)
75	169,500	112,000	29.0	32.5
75	170,000	112,000	27.5	30.0
75	169,500	109,500	28.0	30.0
1500	101,000	90,500	4.0	7.0
1500	103,000	92,000	4.5	8.5
1500	105,000	93,000	5.0	7.0
1600	75,500	65,500	6.0	8.0
1600	77,000	72,500	6.5	9.0
1600	78,500	74,000	4.5	4.5
1700	54,000	50,000	12.0	13.0
1700	53,000	49,000	10.5	13.5
1700	54,000	50,500	15.0	17.5

TABLE 4

TENSILE TEST DATA — INCONEL 713C (CAST)				
TEST TEMPERATURE (°F)	ULTIMATE TENSILE STRENGTH (PSI)	0.2% OFFSET YIELD STRENGTH (PSI)	ELONGATION (% IN 1 INCH)	REDUCTION IN AREA (%)
75	123,000	105,500	6.5	10.5
75	117,000	105,000	7.0	12.0
75	116,000	102,000	6.5	12.0
1500	119,000	88,000	5.0	11.0
1500	117,000	88,500	6.0	11.5
1500	120,500	94,000	3.5	3.5
1600	105,500	81,000	5.0	8.0
1600	104,000	80,500	3.5	6.5
1600	104,500	77,000	6.0	10.0
1700	82,500	56,500	10.0	13.0
1700	82,000	60,000	10.0	12.5
1700	83,500	59,500	10.0	10.5



8

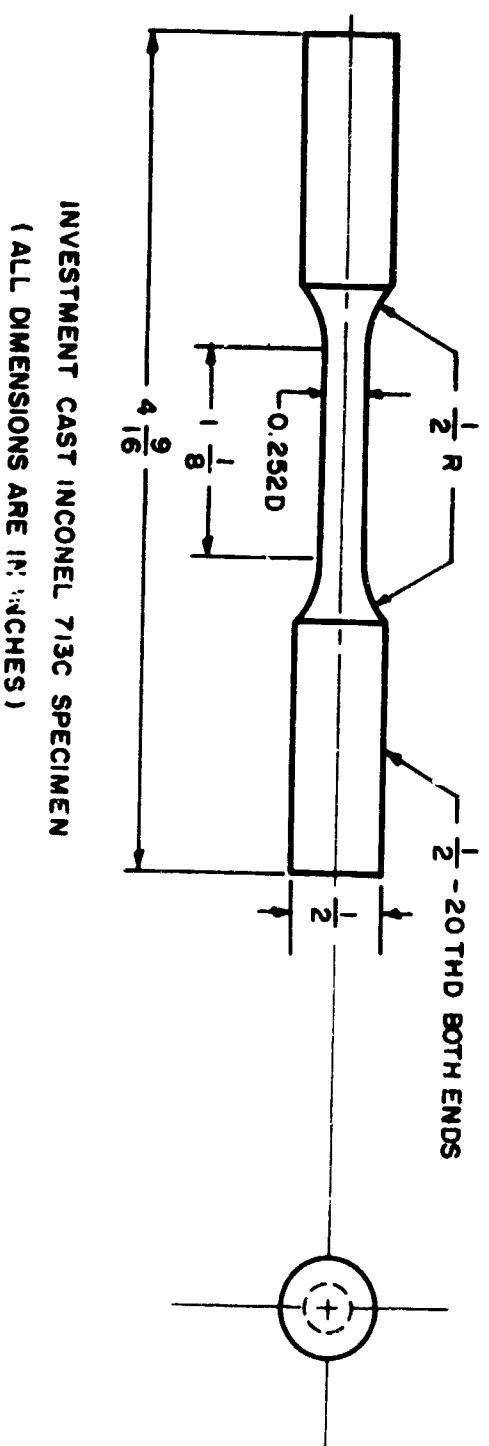


Figure 1. Test Specimen Configurations

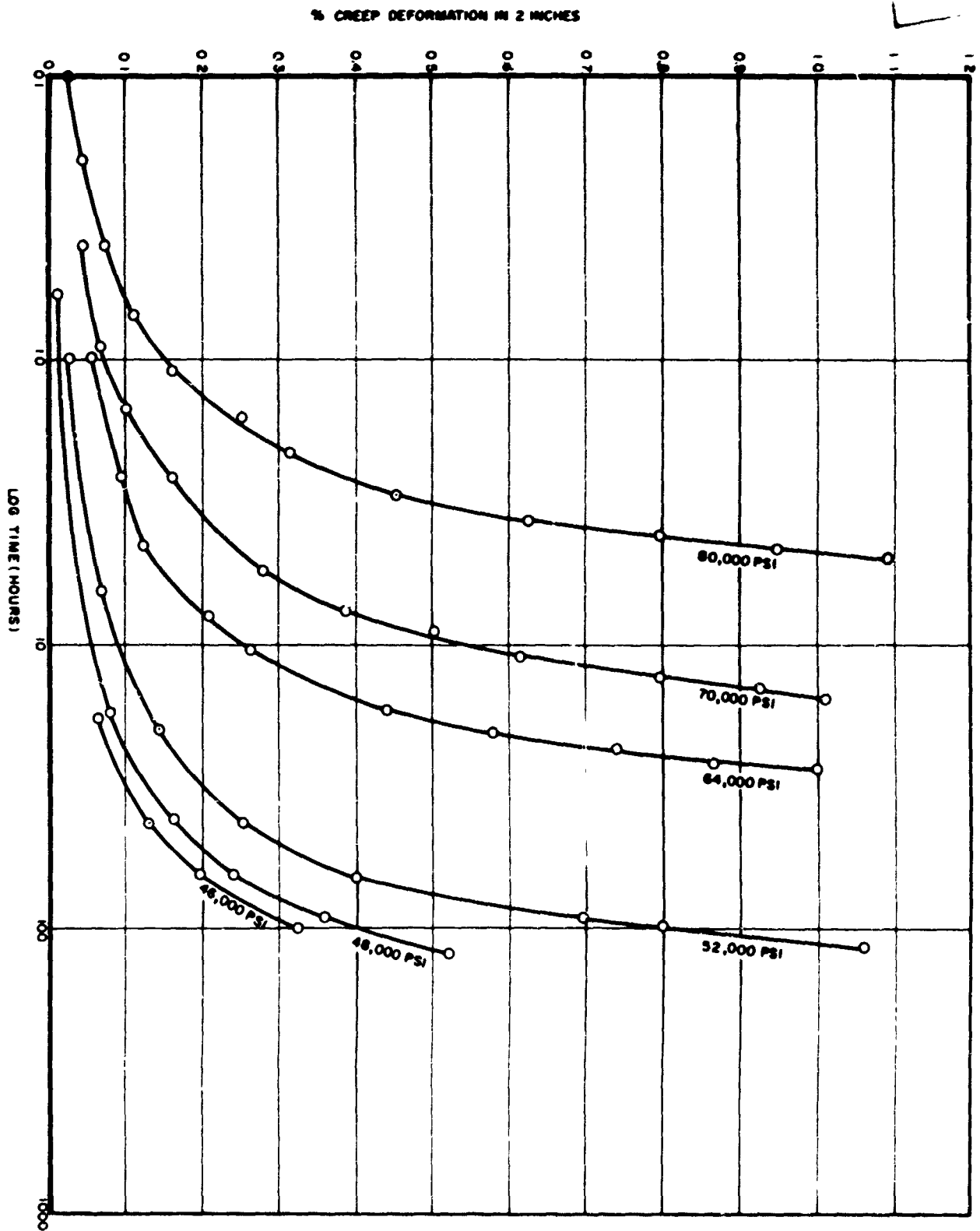


Figure 2. Creep Deformation Versus Log Time of M-252 (Bar) at 1350°F

10

or

1/2
FR. S

TABLE 5

M-252 (BAR) ELONGATION-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)
80,000-9.1 ^a		7.3	0.382	11.3	0.293	113.1	0.463
0.1	0.023	7.7	0.387	11.5	0.300	118.6	0.504
0.2	0.045	8.1	0.406	12.9	0.318	120.5	0.521
0.3	0.066	8.5	0.451	14.1	0.342	46,000-99.2	
0.4	0.076	8.7	0.473	16.9	0.441	1.9	0.022
0.5	0.090	8.9	0.458	17.7	0.470	18.5	0.066
0.7	0.110	8.95	0.502	18.0	0.490	25.9	0.078
0.9	0.145	9.0	0.506	18.1	0.495	42.7	0.129
1.1	0.161	9.5	0.527	18.2	0.500	44.0	0.137
1.6	0.253	10.0	0.569	19.1	0.522	48.0	0.161
1.8	0.266	10.5	0.598	20.6	0.579	65.1	0.198
2.1	0.316	11.0	0.616	22.2	0.719	73.2	0.229
2.6	0.386	11.5	0.684	23.3	0.741	91.1	0.282
3.0	0.473	12.0	0.715	24.1	0.793	96.6	0.293
3.1	0.510	12.5	0.751	24.7	0.824	98.1	0.311
3.6	0.628	13.0	0.797	25.8	0.864	99.2	0.324
4.1	0.796	13.5	0.841	26.8	0.956	52,000-114.8	
4.4	0.875	14.0	0.869	27.2	0.991	1.0	0.023
4.6	0.951	14.5	0.927	27.3	0.999	6.6	0.069
4.7	0.953	15.0	0.965	52,000-114.8		20.1	0.142
4.9	1.044	15.2	0.990	1.0	0.023	25.3	0.188
5.0	1.092	15.4	1.004	6.6	0.069	41.8	0.251
70,000-41.5		15.5	1.011	20.1	0.142	49.7	0.295
0.15	0.043	64,000-90.9		25.3	0.188	66.5	0.399
0.4	0.045	0.5	0.049	41.8	0.251	73.4	0.461
0.9	0.067	1.0	0.057	49.7	0.295	90.4	0.698
1.2	0.102	1.5	0.079	66.5	0.399	96.9	0.801
1.5	0.103	2.1	0.091	73.4	0.461	111.6	1.021
2.1	0.138	2.6	0.095	90.4	0.698	114.8	1.061
2.6	0.164	3.1	0.106	96.9	0.801	48,000-120.6	
3.2	0.176	3.6	0.112	111.6	1.021	0.6	0.010
3.4	0.179	4.5	0.123	114.8	1.061	0.8	0.012
3.8	0.189	5.4	0.137	48,000-120.6		17.6	0.081
4.3	0.214	6.6	0.157	0.6	0.010	24.9	0.103
4.5	0.221	7.9	0.208	0.8	0.012	41.5	0.163
5.1	0.246	8.9	0.231	17.6	0.081	48.2	0.188
5.5	0.279	9.1	0.221	24.9	0.103	65.1	0.241
5.6	0.293	9.5	0.243	41.5	0.163	71.7	0.279
5.7	0.301	9.9	0.243	48.2	0.188	89.7	0.357
5.8	0.308	10.2	0.244	65.1	0.241	96.5	0.387
6.4	0.327	10.5	0.263	71.7	0.279		
6.9	0.361	10.7	0.273	89.7	0.357		
		11.1	0.285	96.5	0.387		

a. STRESS LEVEL RUPTURE TIME (HOURS)

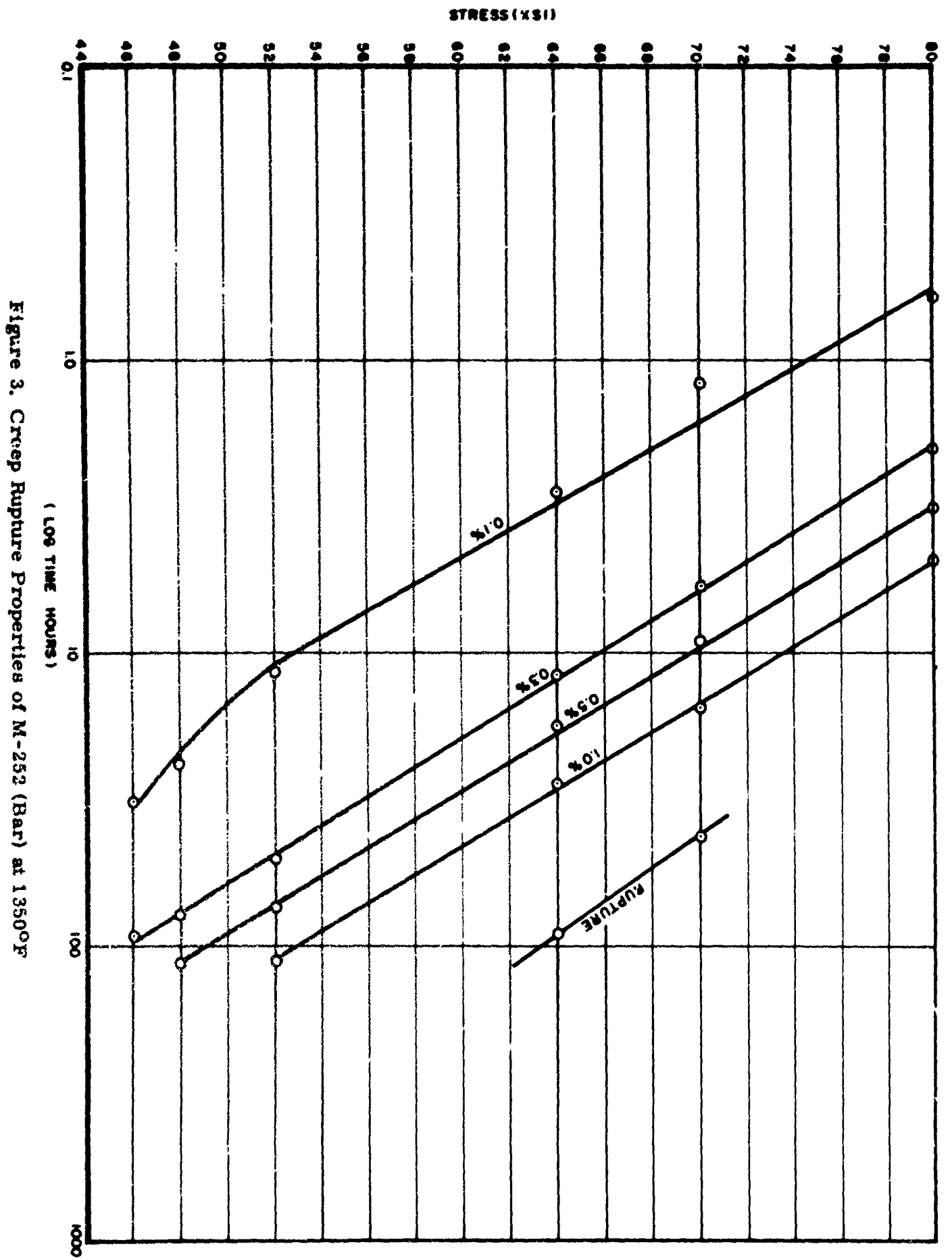


Figure 3. Creep Rupture Properties of M-252 (Bar) at 1350°F

TABLE 6

M-252 (BAR) CREEP DEFORMATION AND RUPTURE DATA AT 1350 °F							
STRESS (PSI)	TIME (HOURS)	ELONGATION (% IN 2 INCHES)	REDUCTION IN AREA (%)	LOADING (DEFORMATION %)	TIME TO REACH INDICATED DEFORMATION-HOURS		
					0.3%	0.5%	1.0%
80,000	9.1 ^a	3.0	—	0.35	2.0	3.1	4.8
76,000	b	—	—	0.34	—	—	—
70,000	41.5	16.0	12.5	0.32	5.7	9.2	15.4
64,000	90.9	23.0	24.0	0.26	11.5	18.2	27.3
52,000	114.8 ^b	—	—	0.21	50.0	75.0	110.5
48,000	120.6 ^b	—	—	0.18	76.0	118.0	—
46,000	99.2 ^b	—	—	0.17	97.5	—	—
a. NO FAILURE. TEST BAR PULLED OUT OF ADAPTER IN TIME INDICATED.							
b. TEST TERMINATED AT TIME INDICATED. NO FAILURE.							

11/2
FIMMIES

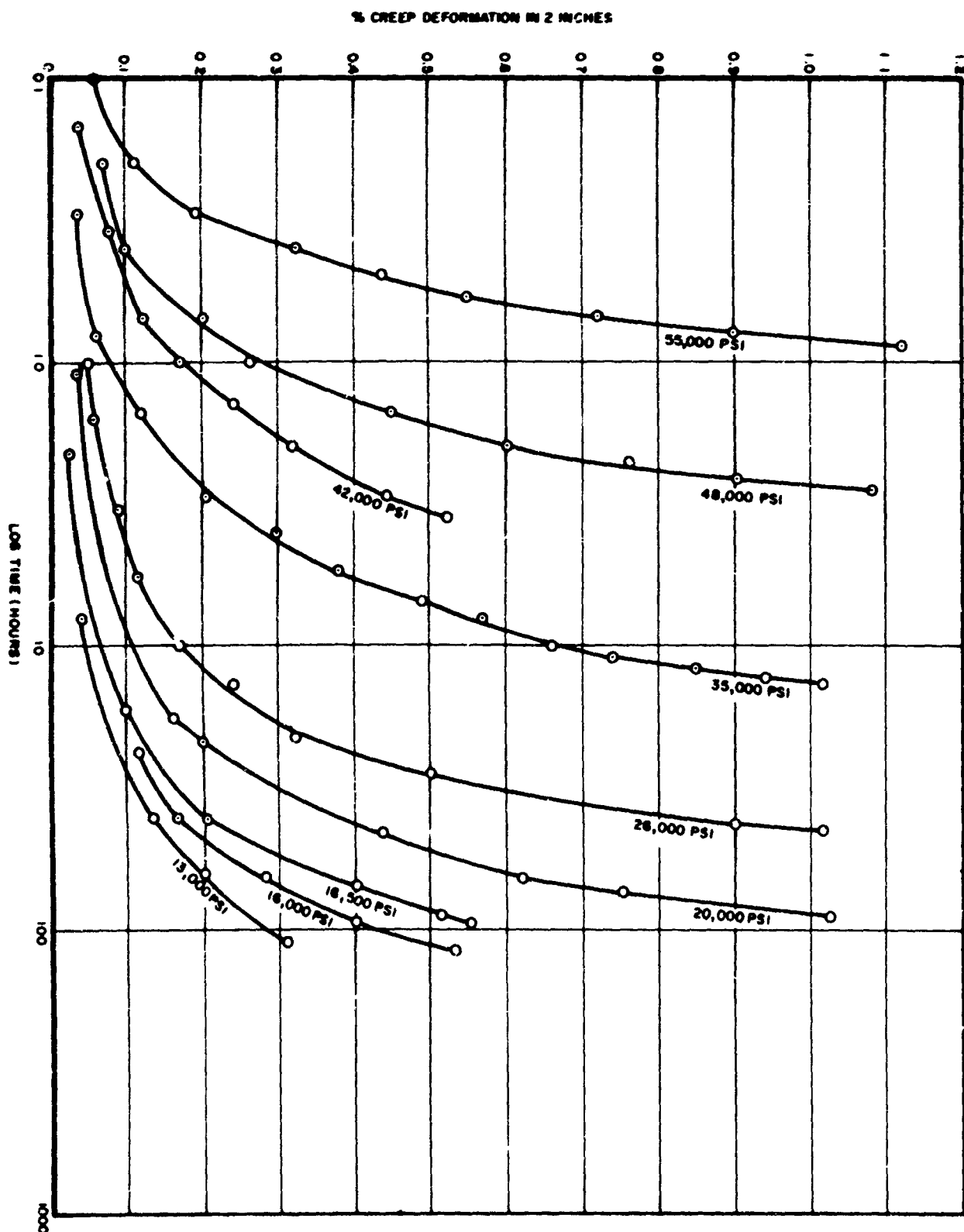


Figure 4. Creep Deformation Versus Log Time of M-252 (Bar) at 1500°F

14

TABLE 7

M-252 (BAR) ELONGATION-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)
55,000-4.0 ^a		1.8	0.291	13.0	0.938	17.9	0.161
0.1	0.062	1.9	0.302	13.5	0.976	22.3	0.203
0.2	0.113	2.0	0.321	13.6	0.985	38.2	0.339
0.3	0.193	2.2	0.336	13.8	1.003	46.5	0.436
0.4	0.325	2.5	0.380	13.9	1.018	66.6	0.619
0.5	0.437	2.8	0.414	26,000-167.1		73.7	0.752
0.55	0.497	3.0	0.445	0.4	0.037	90.0	1.025
0.6	0.551	3.2	0.459	1.0	0.051	16,500-96.1	
0.7	0.742	3.4	0.491	1.6	0.058	2.1	0.023
0.8	0.898	3.5	0.503	2.1	0.071	16.8	0.100
0.9	1.119	3.6	0.522	2.7	0.083	19.1	0.113
1.0	1.369	35,000-30.8		3.3	0.088	23.8	0.143
48,000-11.0		0.3	0.038	4.1	0.092	41.4	0.206
0.2	0.071	0.5	0.051	5.1	0.100	47.4	0.255
0.4	0.099	0.8	0.059	5.7	0.116	63.7	0.379
0.7	0.203	1.0	0.082	6.3	0.118	69.8	0.401
1.0	0.264	1.5	0.117	7.6	0.136	88.9	0.513
1.15	0.317	2.0	0.156	8.8	0.155	96.0	0.552
1.45	0.415	2.5	0.169	9.9	0.173	16,000-119.6	
1.6	0.447	3.0	0.206	10.2	0.200	2.2	0.028
1.7	0.510	3.5	0.262	11.2	0.210	16.6	0.106
2.0	0.599	3.7	0.277	11.6	0.219	24.1	0.114
2.3	0.763	3.9	0.287	12.6	0.227	40.4	0.165
2.4	0.791	4.0	0.298	13.7	0.240	42.6	0.207
2.5	0.828	4.1	0.309	16.7	0.291	47.8	0.211
2.6	0.903	4.5	0.323	17.3	0.300	65.1	0.281
2.7	0.951	5.0	0.352	18.8	0.303	71.1	0.323
2.8	1.012	5.5	0.379	20.1	0.323	87.5	0.388
2.9	1.057	6.0	0.416	23.1	0.399	93.1	0.399
42,000-17.1		6.5	0.443	24.4	0.409	112.3	0.478
0.15	0.037	6.8	0.479	25.1	0.426	119.6	0.531
0.25	0.068	7.0	0.492	26.0	0.458	13,000-110.2	
0.35	0.080	7.1	0.492	26.9	0.468	1.8	0.019
0.5	0.093	7.2	0.503	27.5	0.481	16.4	0.089
0.7	0.122	7.3	0.511	28.0	0.485	23.4	0.105
0.85	0.148	7.5	0.519	28.3	0.490	40.7	0.137
1.0	0.169	8.0	0.568	28.5	0.498	47.9	0.148
1.2	0.196	9.0	0.605	42.7	0.899	63.9	0.202
1.3	0.219	10.0	0.661	45.2	0.994	70.3	0.226
1.4	0.240	11.0	0.742	45.3	1.002	37.1	0.247
1.5	0.256	11.5	0.799	45.6	1.014	95.8	0.259
1.6	0.267	12.0	0.848	20,000-90.1		108.8	0.296
1.7	0.281	12.5	0.891	1.1	0.018	110.2	0.310

a. STRESS LEVEL - RUPTURE TIME (HOURS)

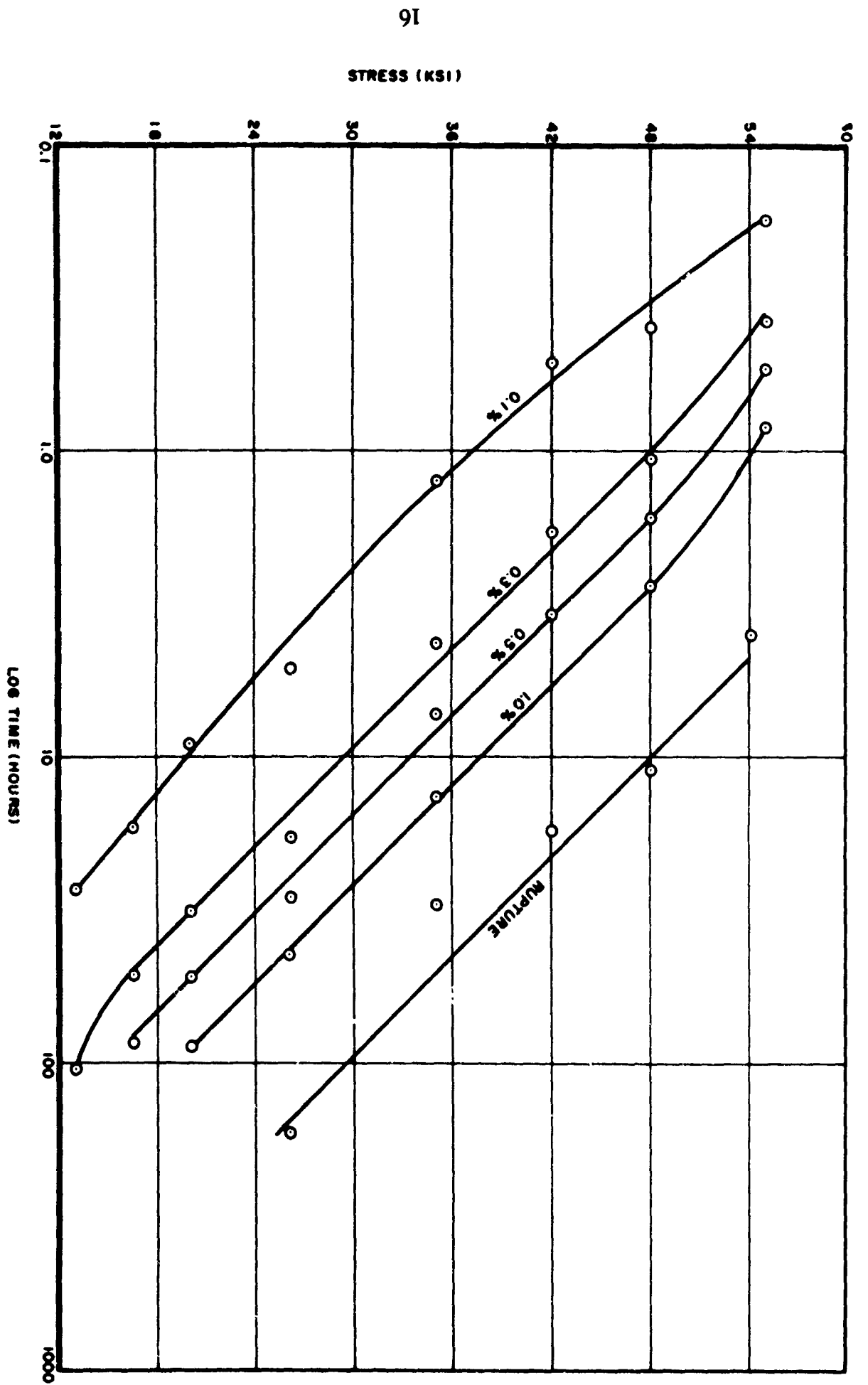


Figure 5. Creep Rupture Properties of M-252 (Bar) at 1500°F

TABLE 8

M-252 (BAR) CREEP DEFORMATION AND RUPTURE DATA AT 1500 °F							
STRESS (PSI)	TIME (HOURS)	ELONGATION (% IN 2 INCHES)	REDUCTION IN AREA (%)	LOADING (DEFORMATION %)	TIME TO REACH INDICATED DEFORMATION - HOURS		
					0.3 %	0.5 %	1.0 %
55,000	4.0	21.0	30.0	0.26	0.4	0.55	0.9
48,000	11.0	23.0	33.0	0.24	1.0	1.7	2.8
42,000	17.1	32.0	35.0	0.23	1.9	3.5	-
35,000	30.8	41.0	46.0	0.20	4.0	7.2	13.8
26,000	167.1	24.0	31.5	0.13	17.3	28.5	45.3
20,000	90.1 ^a	-	-	0.11	35.0	56.0	90.0
16,500	96.1 ^a	-	-	0.09	53.0	88.0	-
16,000	119.6 ^a	-	-	0.09	68.0	115.0	-
13,000	110.2 ^a	-	-	0.08	109.0	-	-
a. TEST TERMINATED AT TIME INDICATED. NO FAILURE							

TABLE 8

M-252 (BAR) CREEP DEFORMATION AND RUPTURE DATA AT 1500 °F							
STRESS (PSI)	TIME (HOURS)	ELONGATION (% IN 2 INCHES)	REDUCTION IN AREA (%)	LOADING (DEFORMATION %)	TIME TO REACH INDICATED DEFORMATION - HOURS		
					0.3 %	0.5 %	1.0 %
55,000	4.0	21.0	30.0	0.26	0.4	0.55	0.9
48,000	11.0	23.0	33.0	0.24	1.0	1.7	2.8
42,000	17.1	32.0	35.0	0.23	1.9	3.5	-
35,000	30.8	41.0	46.0	0.20	4.0	7.2	13.8
26,000	167.1	24.0	31.5	0.13	17.3	28.5	45.3
20,000	90.1 ^a	-	-	0.11	35.0	56.0	90.0
16,500	96.1 ^a	-	-	0.09	53.0	88.0	-
16,000	119.6 ^a	-	-	0.09	68.0	115.0	-
13,000	110.2 ^a	-	-	0.08	109.0	-	-
a. TEST TERMINATED AT TIME INDICATED. NO FAILURE							

11/2
MES

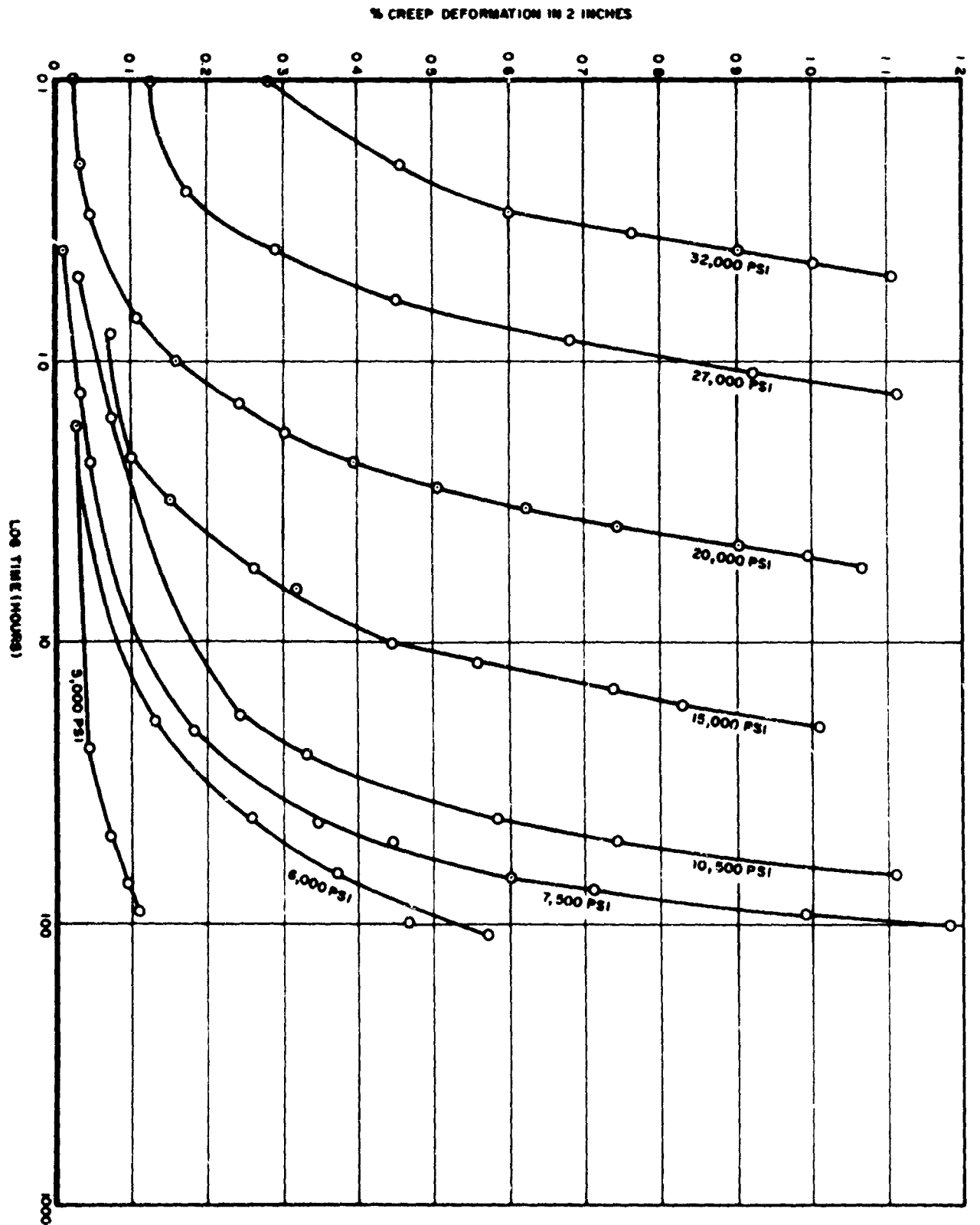


Figure 6. Creep Deformation Versus Log Time of M-252 (Bar) at 1600°F

TABLE 9

M-252 (BARI) ELONGATION-TIME DATA AT 1600°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)
32,000 - 3.7 ^a		1.6	0.276	7.9	0.371	27.3	0.235
0.1	0.278	1.8	0.301	9.2	0.402	43.6	0.346
0.2	0.454	2.3	0.392	9.7	0.430	51.1	0.438
0.25	0.490	2.7	0.491	10.0	0.446	68.1	0.599
0.3	0.598	2.8	0.504	10.4	0.465	75.0	0.711
0.35	0.762	3.3	0.619	10.6	0.481	91.8	0.989
0.4	0.902	3.5	0.674	10.8	0.504	98.7	1.181
0.45	1.000	3.85	0.741	11.8	0.557	6,000 - 107.6	
0.5	1.104	4.1	0.795	14.7	0.735	1.7	0.027
27,000 - 8.6		4.5	0.898	15.3	0.763	18.9	0.128
0.1	0.123	4.7	0.928	15.9	0.782	25.9	0.144
0.25	0.172	4.9	0.990	16.6	0.825	42.4	0.255
0.3	0.216	5.0	1.011	18.2	0.965	49.9	0.289
0.4	0.290	5.2	1.062	18.7	1.001	66.1	0.372
0.45	0.319	15,000 - 99.3		18.9	1.007	68.4	0.369
0.6	0.447	0.8	0.069	10,500 - 73.5		73.8	0.403
0.7	0.510	1.2	0.058	0.5	0.031	91.0	0.466
0.85	0.679	2.2	0.097	1.6	0.074	107.6	0.571
1.1	0.919	3.1	0.148	18.1	0.240	5,000 - 90.2	
1.2	0.959	3.7	0.196	25.2	0.330	1.6	0.030
1.3	1.110	4.0	0.215	42.4	0.583	18.3	0.038
20,000 - 40.7		4.3	0.228	50.2	0.741	23.7	0.041
0.1	0.024	4.9	0.241	66.0	1.110	41.6	0.063
0.2	0.031	5.4	0.258	73.4	1.318	48.8	0.069
0.3	0.046	5.6	0.265	7,500 - 98.8		65.8	0.078
0.5	0.078	5.8	0.266	0.4	0.010	73.1	0.094
0.7	0.103	6.0	0.280	1.3	0.033	89.9	0.110
1.0	0.158	6.2	0.291	2.3	0.045		
1.2	0.200	6.4	0.304	20.5	0.181		
1.4	0.238	6.5	0.315	25.8	0.232		

^a STRESS LEVEL - RUPTURE TIME (HOURS)

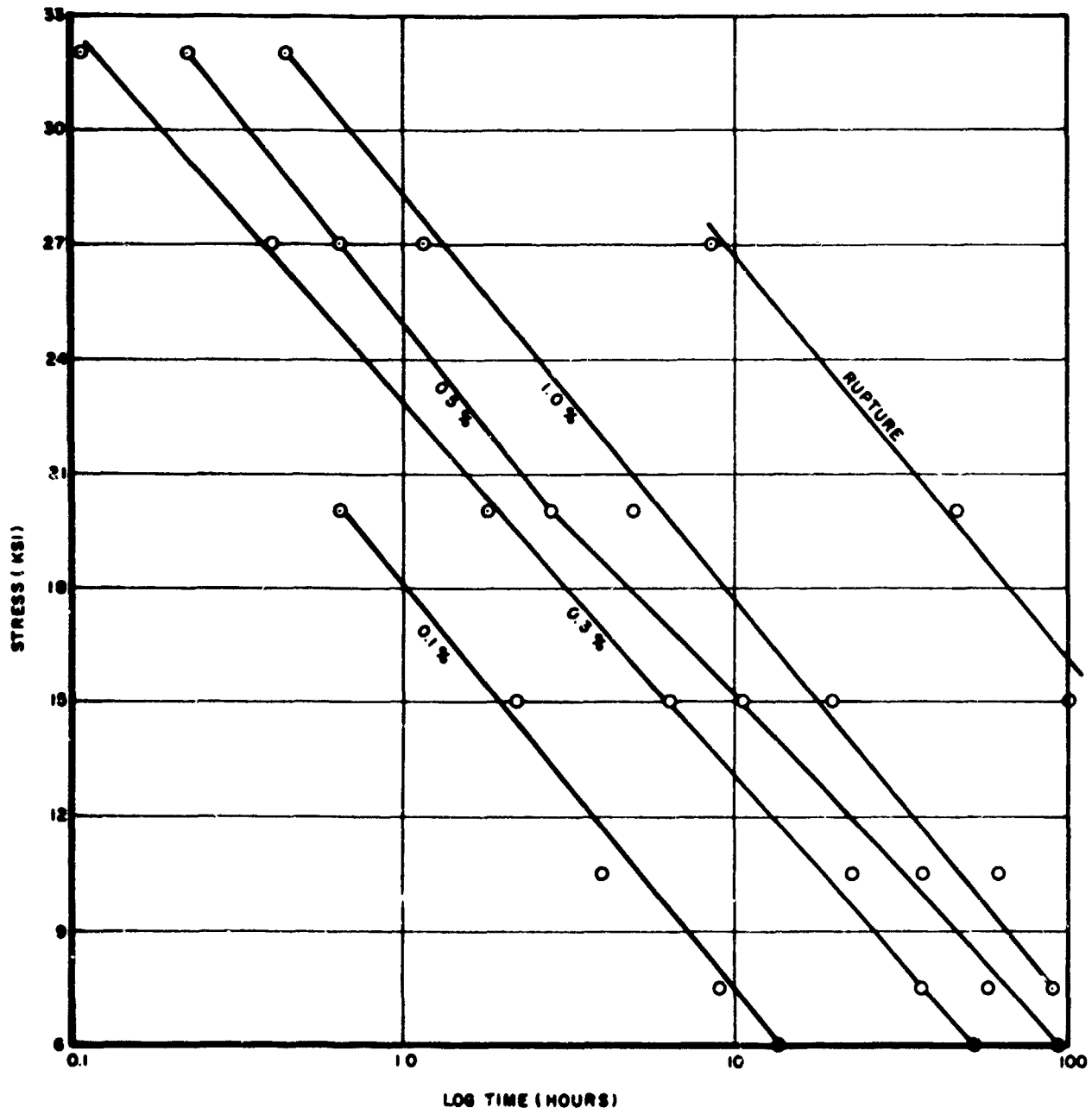


Figure 7. Creep Rupture Properties of M-252 (Bar) at 1600°F

TABLE 10

M-252 (BAR) CREEP DEFORMATION AND RUPTURE DATA AT 1600°F							
STRESS (PSI)	TIME (HOURS)	ELONGATION (% IN 2 INCHES)	REDUCTION IN AREA(%)	LOADING (DEFORMATION %)	TIME TO REACH INDICATED DEFORMATION-HOURS		
					0.3%	0.5%	1.0%
32,000	3.7 ^b	51.0	—	0.25	0.15	0.25	0.45
27,000	8.6	42.0	48.0	0.18	0.4	0.7	1.2
20,000	40.7	46.0	50.0	0.14	1.8	2.8	5.0
15,000	99.3	42.5	45.5	0.10	6.4	10.8	18.7
10,500	73.5 ^a	—	—	0.07	22.5	36.5	61.0
7,500	98.8 ^a	—	—	0.05	36.0	60.0	92.5
6,000	107.6 ^a	—	—	—	55.0	94.5	—
5,000	90.2 ^a	—	—	0.04	c	—	—
a. TEST TERMINATED AT TIME INDICATED. NO FAILURE							
b. NO FAILURE. EXCESSIVE ELONGATION OF TEST BAR SHUT OFF TEST STAND							
c. TEST TERMINATED. OBTAINED ONLY 0.11% DEFORMATION IN 89.9 HOURS							

1/2
FRAMES

27

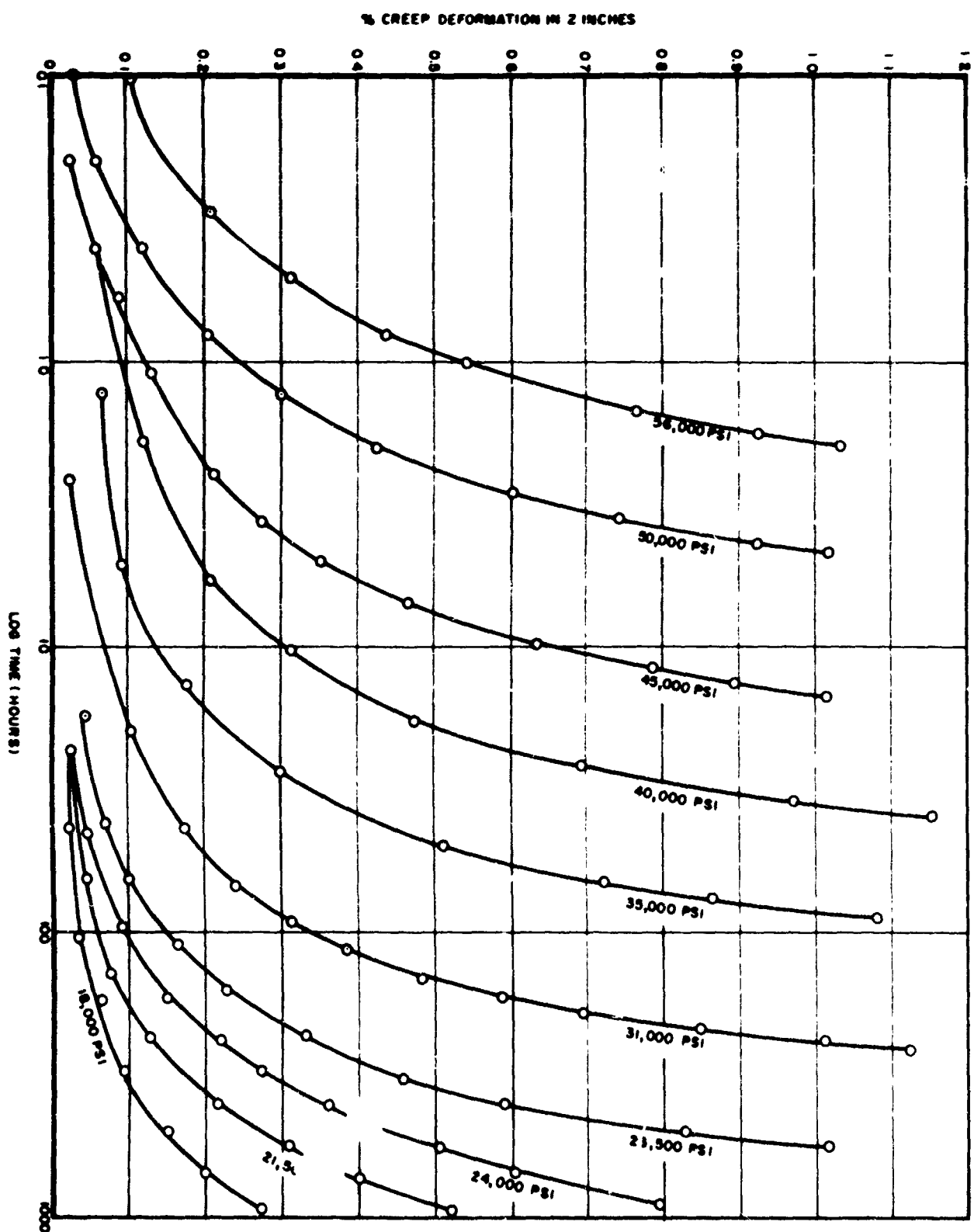


Figure 8. Creep Deformation Versus Log Time of Inconel 700 (Bar) at 1500°F

27

TABLE II

INCONEL 700 (BAR) ELONGATION - 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)
56,000-3.1 ^a		7.6	0.494	187.6	0.657	647.4	0.555
0.1	0.105	7.7	0.499	195.1	0.693	700.3	0.606
0.3	0.207	8.2	0.531	211.9	0.794	742.7	0.641
0.4	0.247	8.6	0.546	218.8	0.844	816.1	0.698
0.5	0.311	9.2	0.584	235.7	0.942	865.2	0.752
0.6	0.356	10.0	0.632	243.2	1.010	910.8	0.791
0.8	0.435	10.8	0.673	260.0	1.121	984.2	0.869
0.9	0.477	11.7	0.728	26,500-1282.1		1031.8	0.913
1.0	0.539	12.5	0.785	17.5	0.027	1079.1	0.971
1.15	0.593	13.3	0.849	24.8	0.041	1128.8	1.029
1.35	0.701	13.8	0.889	41.8	0.065	1150.9	1.039
1.5	0.766	14.4	0.943	49.0	0.075	21,500-1026.5	
1.75	0.900	14.7	0.968	65.8	0.098	18.3	0.024
1.8	0.923	15.0	0.989	73.2	0.109	66.1	0.041
2.0	1.031	15.1	0.998	90.0	0.131	139.2	0.072
50,000-10.1		15.2	1.011	113.9	0.160	168.6	0.092
0.1	0.031	40,000-77.0		138.1	0.193	235.0	0.124
0.2	0.057	0.4	0.058	163.8	0.225	282.9	0.155
0.3	0.086	0.9	0.089	169.8	0.240	331.1	0.181
0.4	0.116	1.2	0.103	186.7	0.264	402.3	0.216
0.5	0.134	1.9	0.120	210.5	0.292	473.6	0.259
0.6	0.167	2.7	0.145	217.5	0.305	570.2	0.311
0.8	0.202	5.9	0.206	234.7	0.328	617.8	0.333
1.0	0.237	10.4	0.311	240.9	0.332	667.4	0.365
1.2	0.272	14.7	0.389	258.4	0.354	738.8	0.402
1.3	0.296	18.8	0.473	282.0	0.383	786.1	0.421
1.4	0.315	21.1	0.526	289.7	0.398	858.1	0.460
1.55	0.335	26.6	0.688	331.2	0.457	906.3	0.493
1.7	0.360	35.1	0.971	336.8	0.468	954.1	0.518
2.0	0.424	36.6	1.033	354.5	0.491	1026.4	0.561
2.1	0.453	39.8	1.150	361.8	0.507	18,000-1113.4	
2.5	0.517	35,000-220.3		380.5	0.541	18.7	0.018
2.9	0.599	1.3	0.062	403.2	0.589	43.8	0.020
3.3	0.687	5.2	0.090	426.8	0.643	67.4	0.028
3.6	0.739	13.8	0.174	451.3	0.707	105.2	0.031
3.9	0.793	21.2	0.233	499.7	0.825	128.4	0.038
4.15	0.860	27.8	0.297	505.4	0.847	177.1	0.059
4.3	0.896	36.1	0.381	522.6	0.884	207.1	0.059
4.4	0.920	43.0	0.438	546.6	0.951	274.2	0.083
4.5	0.947	50.2	0.511	553.9	0.971	320.4	0.092
4.6	0.988	66.8	0.720	570.4	1.016	370.0	0.106
4.7	1.013	73.6	0.812	24,000-1151.1		442.4	0.128
45,000-22.9		90.4	1.077	23.2	0.022	513.2	0.148
0.2	0.043	31,000-565.9		46.5	0.046	610.0	0.165
0.4	0.072	2.6	0.019	71.1	0.056	657.0	0.183
0.6	0.088	19.7	0.102	94.7	0.087	706.5	0.197
1.1	0.131	27.1	0.122	144.6	0.116	778.1	0.209
1.4	0.151	43.8	0.168	169.9	0.151	825.1	0.223
2.5	0.209	51.1	0.200	192.7	0.168	896.3	0.248
3.2	0.250	67.7	0.239	218.2	0.187	946.6	0.262
3.6	0.272	75.1	0.259	243.1	0.218	994.7	0.269
4.0	0.289	91.8	0.308	262.9	0.232	1064.7	0.290
4.1	0.299	98.2	0.326	311.2	0.269	1113.2	0.303
5.0	0.348	116.1	0.383	335.4	0.289		
5.6	0.381	121.7	0.402	360.3	0.314		
6.0	0.407	138.3	0.453	407.8	0.359		
6.5	0.428	146.6	0.480	456.2	0.400		
7.1	0.466	164.3	0.539	506.3	0.437		
7.5	0.490	170.6	0.582	576.5	0.504		

a. STRESS LEVEL RUPTURE TIME (HOURS)

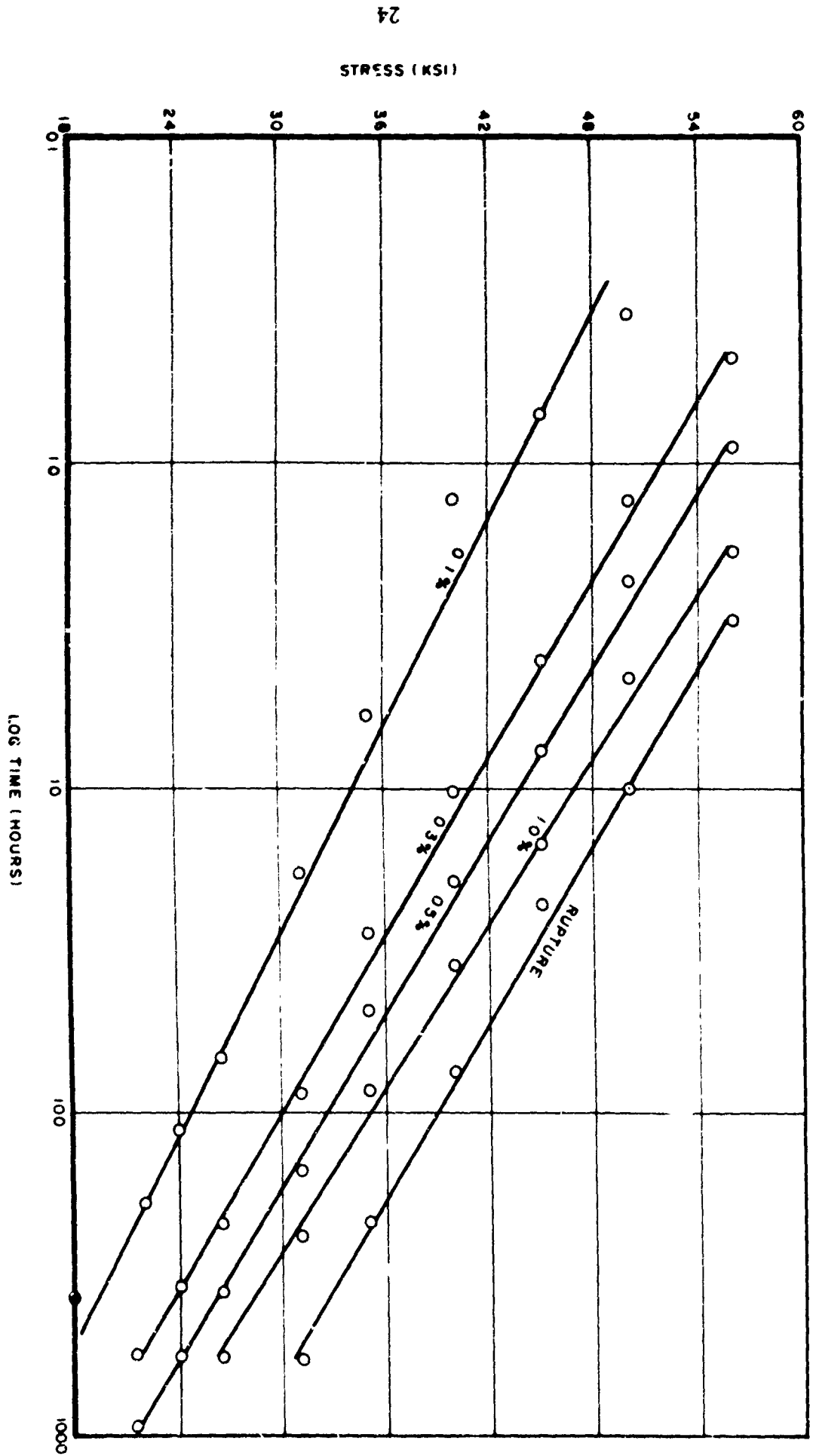


Figure 9. Creep Rupture Properties of Inconel 700 (Bar) at 1500°F

TABLE 12

INCONEL 700 (BAR) CREEP DEFORMATION AND RUPTURE DATA AT 1500 °F							
STRESS (PSI)	TIME (HOURS)	ELONGATION (% IN 2 INCHES)	REDUCTION IN AREA (%)	LOADING (DEFORMATION %)	TIME TO EACH INDICATED DEFORMATION - HOURS		
					0.3 %	0.5 %	1.0 %
56,000	a						
56,000	3.1	5.0 ^b	5.5	0.28	0.5	0.95	1.95
50,000	10.1	7.0	9.0	0.25	1.4	2.4	4.7
45,000	22.9	4.5 ^b	4.5	0.21	4.1	7.7	15.1
40,000	77.0	10.5	8.5	0.18	10.0	20.0	35.8
35,000	220.3	12.0	14.5	0.17	28.0	49.0	86.0
31,000	565.9	11.0	14.0	0.16	88.0	153.0	242.0
26,500	1282.1	10.0	11.5	0.14	214.0	360.0	565.0
24,000	1151.1 ^c	—	—	0.12	345.0	575.0	1110.0
21,500	1026.5 ^c	—	—	0.10	550.0	920.0	—
18,000	1113.4 ^c	—	—	0.09	1100.0	—	—
a. TEST DISCONTINUED DUE TO MALFUNCTION OF TEST STAND DURING LOADING OPERATION. b. FAILURE OCCURRED IN GAGE MARK c. TEST TERMINATED IN TIME INDICATED. NO FAILURE.							

112
FORM 15

16

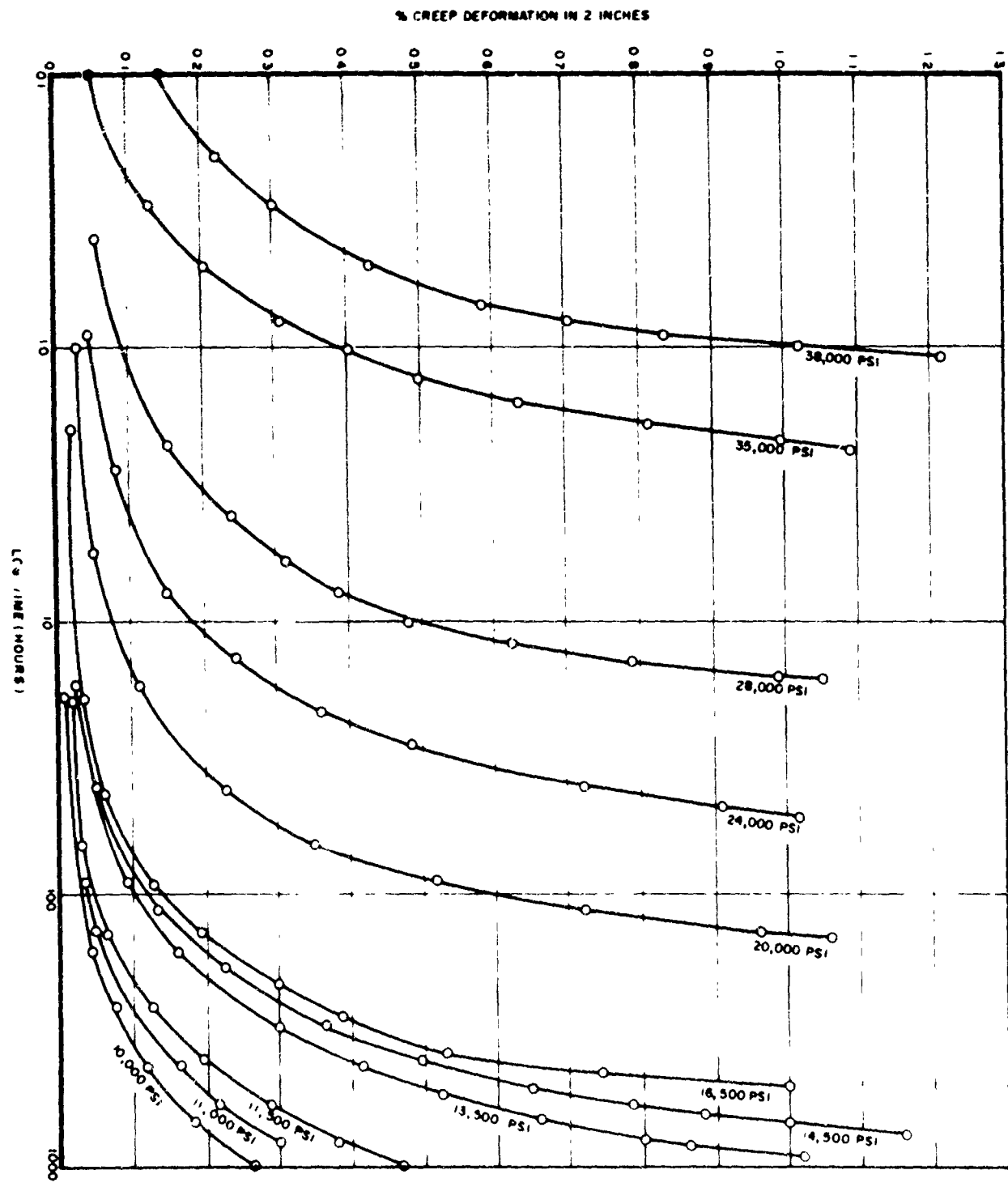


Figure 10. Creep Deformation Versus Log Time of Inconel 700 (Bar) at 1600°F

210

TABLE 13

INCONEL 700(BAR) ELONGATION- TIME DATA AT 1600 °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)
38,000 - 3.2 ^a		24,000 - 133.6		380.5		210.8	
0.1	0.146	0.9	0.044	428.9	0.655	259.2	0.128
0.2	0.223	2.8	0.081	434.5	0.679	307.5	0.154
0.3	0.301	4.6	0.109	451.4	0.744	355.0	0.173
0.4	0.370	7.9	0.150	458.3	0.773	404.6	0.195
0.5	0.429	10.1	0.193	475.2	0.864	476.0	0.225
0.6	0.512	13.8	0.246	482.8	0.878	523.3	0.247
0.7	0.588	16.7	0.284	499.2	0.968	595.2	0.287
0.8	0.702	17.9	0.310	506.5	0.997	643.5	0.309
0.9	0.835	21.6	0.361	507.0	1.000	691.4	0.337
1.0	1.021	24.3	0.411	14,500 - 809.7		763.5	0.370
1.1	1.226	28.2	0.476	16.8	0.025	811.3	0.383
35,000 - 9.6		35.4	0.617	41.1	0.053	907.2	0.439
0.1	0.050	40.6	0.724	65.6	0.079	981.3	0.468
0.3	0.127	48.1	0.912	114.2	0.134	1006.2	0.487
0.5	0.203	51.2	1.018	138.4	0.165	1029.3	0.503
0.7	0.274	20,000 - 344.8		186.6	0.228	11,000 - 813.4	
0.8	0.317	1.0	0.027	235.5	0.275	16.9	0.020
1.0	0.402	5.6	0.051	284.2	0.341	89.5	0.037
1.1	0.434	17.3	0.111	305.8	0.365	136.9	0.049
1.3	0.497	24.2	0.141	353.2	0.432	186.4	0.071
1.6	0.632	41.4	0.228	402.7	0.497	258.0	0.104
1.8	0.749	49.0	0.264	474.2	0.582	305.1	0.115
1.9	0.813	65.5	0.351	521.4	0.648	330.3	0.128
2.0	0.870	72.3	0.388	593.0	0.787	376.8	0.144
2.1	0.929	89.4	0.517	642.7	0.884	426.4	0.166
2.2	0.996	96.8	0.579	690.8	0.999	474.6	0.189
2.3	1.042	113.4	0.719	761.2	1.160	545.0	0.206
2.4	1.091	119.9	0.767	809.4	1.298	593.2	0.218
28,000 - 43.3		137.8	0.962	13,500 - 925.9		689.7	0.259
0.4	0.056	145.2	1.058	17.3	0.022	738.5	0.282
0.7	0.083	161.1	1.319	42.0	0.049	788.2	0.296
1.0	0.101	16,500 - 1027.9		89.4	0.095	807.3	0.305
1.7	0.139	2.0	0.021	138.1	0.137	10,000 - 1087.1	
2.3	0.153	19.3	0.036	162.6	0.160	19.0	0.009
2.9	0.186	42.3	0.062	212.0	0.209	41.2	0.009
3.5	0.205	48.9	0.071	257.5	0.256	89.2	0.029
4.1	0.238	92.9	0.128	305.9	0.303	162.5	0.042
4.7	0.251	98.7	0.135	331.7	0.326	191.7	0.048
5.2	0.282	115.4	0.164	380.9	0.368	258.2	0.071
5.5	0.289	122.4	0.168	425.6	0.417	306.1	0.077
6.0	0.312	139.1	0.195	497.5	0.487	353.5	0.087
6.9	0.353	146.3	0.208	546.5	0.524	426.8	0.116
7.9	0.383	163.4	0.229	597.8	0.577	499.1	0.135 ^b
8.7	0.416	169.8	0.244	621.8	0.600 ^b	538.7	0.140
9.7	0.468	187.2	0.265	670.1	0.659	595.5	0.163
10.0	0.485	194.4	0.274	742.2	0.741	641.0	0.177
10.5	0.518	212.2	0.301	789.9	0.802	690.4	0.182
11.6	0.586	218.5	0.307	813.5	0.846	762.0	0.208
12.2	0.625	260.6	0.365	835.7	0.865	809.3	0.219
13.0	0.703	265.4	0.368	910.0	0.991	881.4	0.240
14.1	0.789	283.4	0.389	925.7	1.020	929.5	0.249
15.0	0.874	290.8	0.408	11,500 - 1029.5		977.2	0.266
15.6	0.949	307.6	0.428	19.7	0.021	1039.5	0.283
16.0	0.991	313.5	0.439	67.5	0.033		
16.2	1.012	331.8	0.462	91.2	0.049		
16.4	1.029	356.5	0.491	139.5	0.065		

^a STRESS LEVEL - RUPTURE TIME (HOURS)^b NEW PLATINUM STRIPS

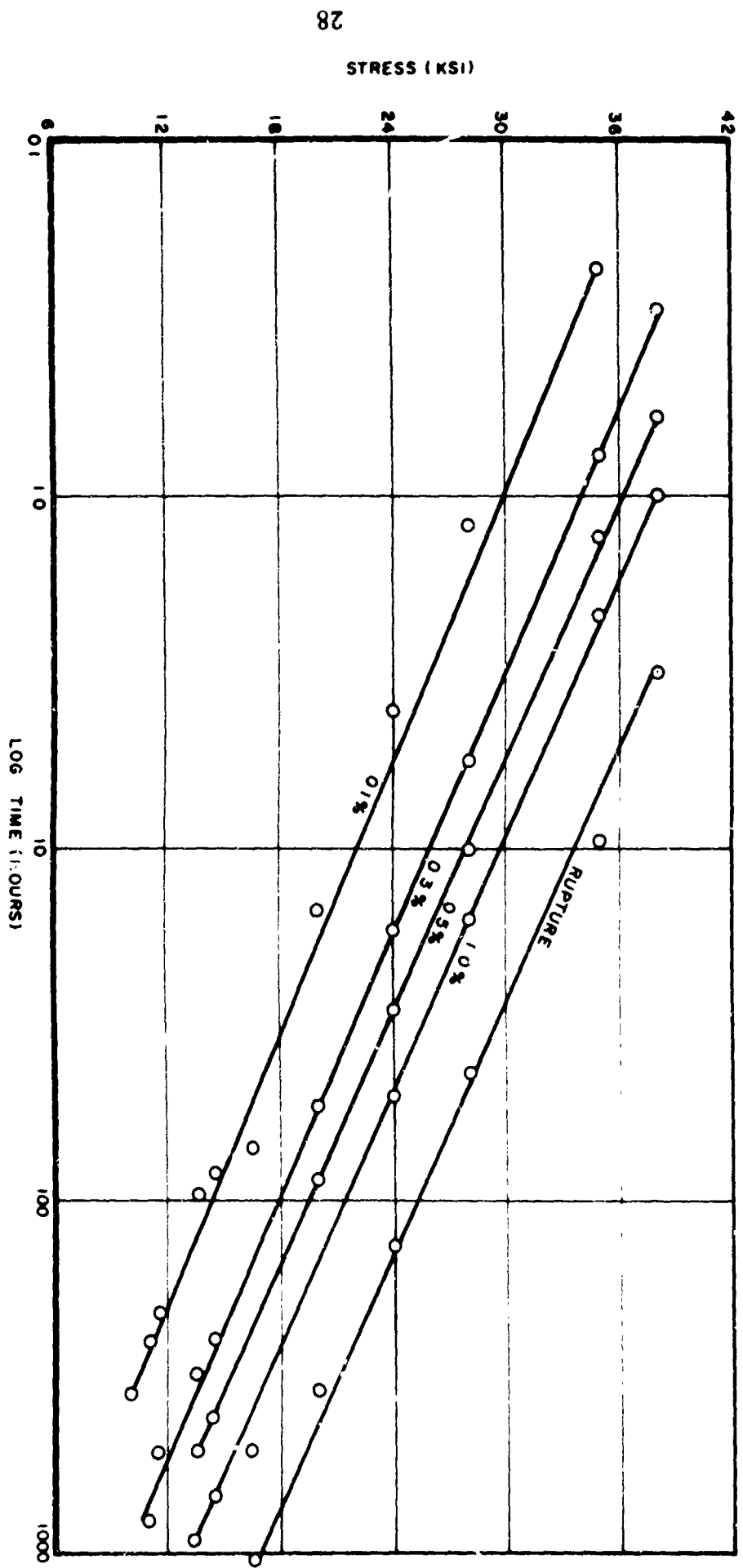


Figure 11. Creep Rupture Properties of Inconel 700 (Bar) at 1600°F

TABLE 14

INCONEL 700 (DAR) CREEP DEFORMATION AND RUPTURE DATA AT 1600 °F							
STRESS (PSI)	TIME (HOURS)	ELONGATION (% IN 2 INCHES)	REDUCTION IN AREA (%)	LOADING (DEFORMATION %)	TIME TO REACH INDICATED DEFORMATION - HOURS		
					0.3 %	0.5 %	1.0 %
38,000	3.2	10.5	10.0	0.22	0.3	0.6	1.0
35,000	9.6	16.0	16.0	0.18	0.75	1.3	2.2
28,000	43.3	13.5	14.0	0.14	5.8	10.3	16.1
24,000	133.6	16.5	18.5	0.13	17.3	29.5	50.5
20,000	344.8	12.0	16.0	0.10	56.0	88.0	141.0
16,500	1027.9	12.0	11.5	0.08	212.0	360.0	507.0
14,500	809.7 ^a	-	-	0.065	250.0	405.0	691.0
13,500	925.9 ^a	-	-	0.06	300.0	515.0	920.0
11,500	1029.5 ^a	-	-	0.04	625.0	1030.0	-
11,000	813.4 ^a	-	-	0.03	795.0	-	-
10,000	1087.1 ^a	-	-	0.03	1100.0 ^b	-	-
a. TEST TERMINATED IN TIME INDICATED. NO FAILURE.							
b. EXTRAPOLATED VALUE.							

1/12
FD-113

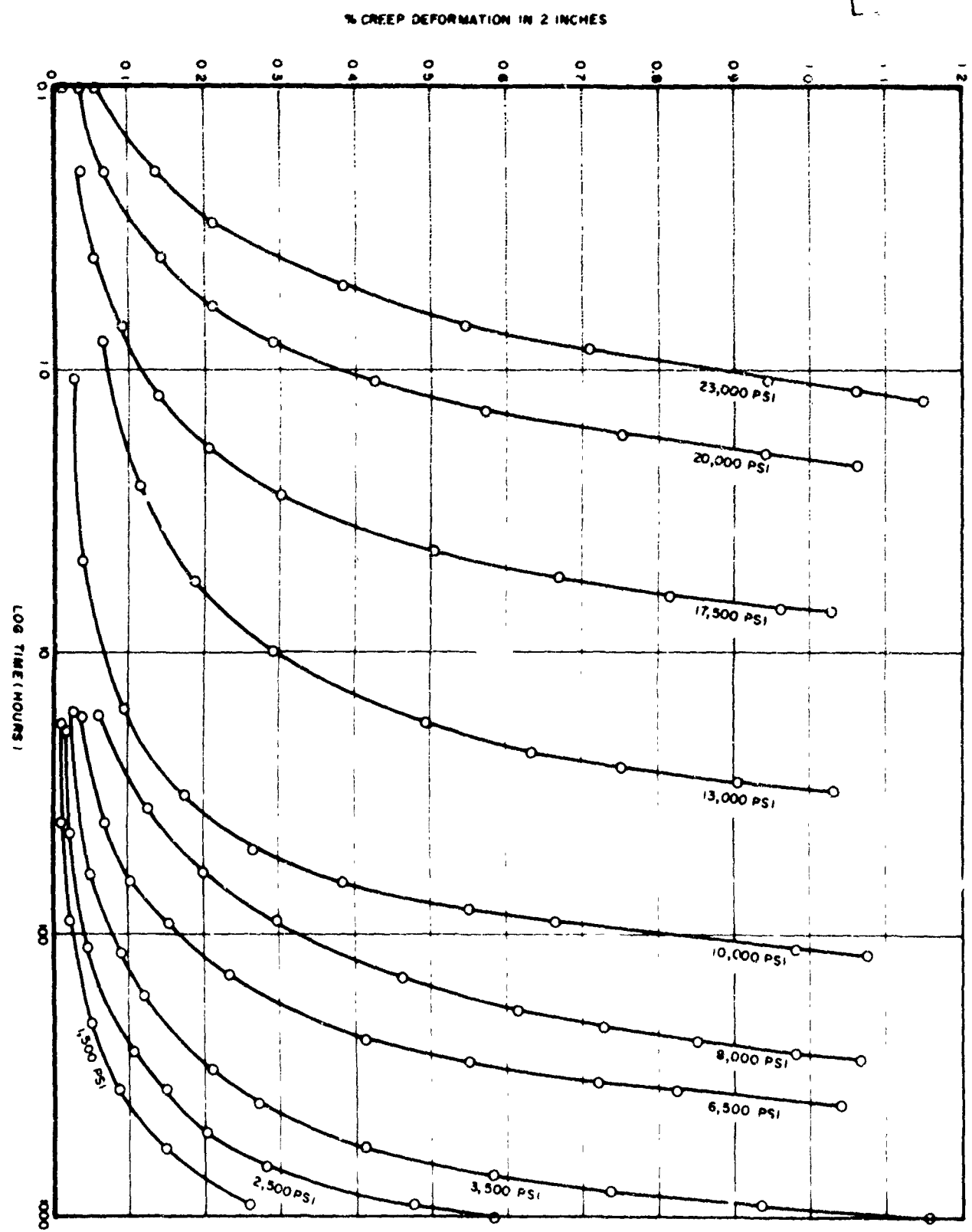


Figure 12. Creep Deformation Versus Log Time of Inconel 700 (Bar) at 1700°F

TABLE 15

INCONEL 700 (BAR) ELONGATION-TIME DATA AT 1700 °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)
23,000-49 ^a		2.4	0.254	65.2	0.382	353.0	0.242
0.1	0.056	2.65	0.283	81.4	0.549	400.0	0.269
0.2	0.134	2.75	0.292	90.2	0.664	449.2	0.311
0.3	0.208	2.8	0.298	113.0	0.981	473.5	0.328
0.4	0.291	3.3	0.353	116.6	1.032	568.4	0.413 ^b
0.5	0.383	3.8	0.415	119.6	1.07	642.6	0.483
0.6	0.460	4.4	0.506	8,000-583.2		713.4	0.579
0.7	0.545	4.6	0.527	16.7	0.060	808.4	0.736
0.85	0.707	5.0	0.588	19.2	0.073	908.7	0.935
1.0	0.841	5.5	0.671	35.7	0.125	978.8	1.097
1.1	0.944	5.9	0.747	41.7	0.147	1000.4	1.155
1.2	1.043	6.4	0.836	59.9	0.198	2,500-1003.7	
1.3	1.147	6.8	0.926	65.1	0.213	19.4	0.015
20,000-9.2		7.0	0.962	82.3	0.263	43.7	0.022
0.1	0.036	7.1	0.982	89.1	0.292	113.9	0.043
0.2	0.065	7.2	1.003	106.2	0.338	163.6	0.071
0.4	0.142	7.3	1.028	117.4	0.364	259.6	0.104
0.6	0.209	13,000-100.5		142.8	0.460	358.6	0.149
0.8	0.289	0.8	0.063	163.3	0.517	427.7	0.171
0.85	0.307	1.2	0.080	188.0	0.613	499.6	0.199 ^b
0.9	0.343	2.6	0.115	213.3	0.726	571.4	0.223
1.0	0.374	4.1	0.147	239.2	0.849	595.5	0.244
1.1	0.424	5.7	0.191	264.9	0.980	668.6	0.280
1.2	0.473	7.7	0.233	281.6	1.065	763.9	0.343
1.3	0.518	10.0	0.293	6,500-963.8		838.0	0.420
1.4	0.569	10.6	0.305	16.9	0.035	908.5	0.475
1.7	0.752	18.1	0.492	40.6	0.067	1003.6	0.582
1.85	0.827	18.7	0.507	65.2	0.101	1,500-1102.3	
1.9	0.873	19.7	0.534	90.6	0.153	18.1	0.010
2.0	0.939	22.9	0.636	139.1	0.234	41.1	0.010
2.1	0.996	25.8	0.749	188.6	0.313	91.8	0.23
2.15	1.032	29.2	0.906	237.4	0.416	139.7	0.037
2.2	1.066	30.7	0.961	285.5	0.551	209.6	0.049
17,500-24.6		31.5	1.013	334.8	0.719	258.2	0.062
0.1	0.019	35.4	1.209	359.2	0.826	354.8	0.085
0.2	0.034	10,000-288.2		383.1	0.925	451.9	0.107
0.4	0.054	1.1	0.025	408.6	1.039	594.8	0.151 ^b
0.7	0.089	4.9	0.039	3,500-1001.7		689.6	0.166
1.0	0.122	16.1	0.094	16.3	0.022	763.1	0.193
1.25	0.136	23.4	0.126	65.2	0.049	857.5	0.231
1.6	0.180	31.7	0.173	115.7	0.089	930.7	0.255
1.9	0.205	41.8	0.217	163.7	0.121		
2.0	0.215	50.2	0.264	233.7	0.156		
2.15	0.229	57.9	0.317	304.8	0.210		

^a STRESS LEVEL - RUPTURE TIME (HOURS)^b NEW PLATINUM STRIPS.

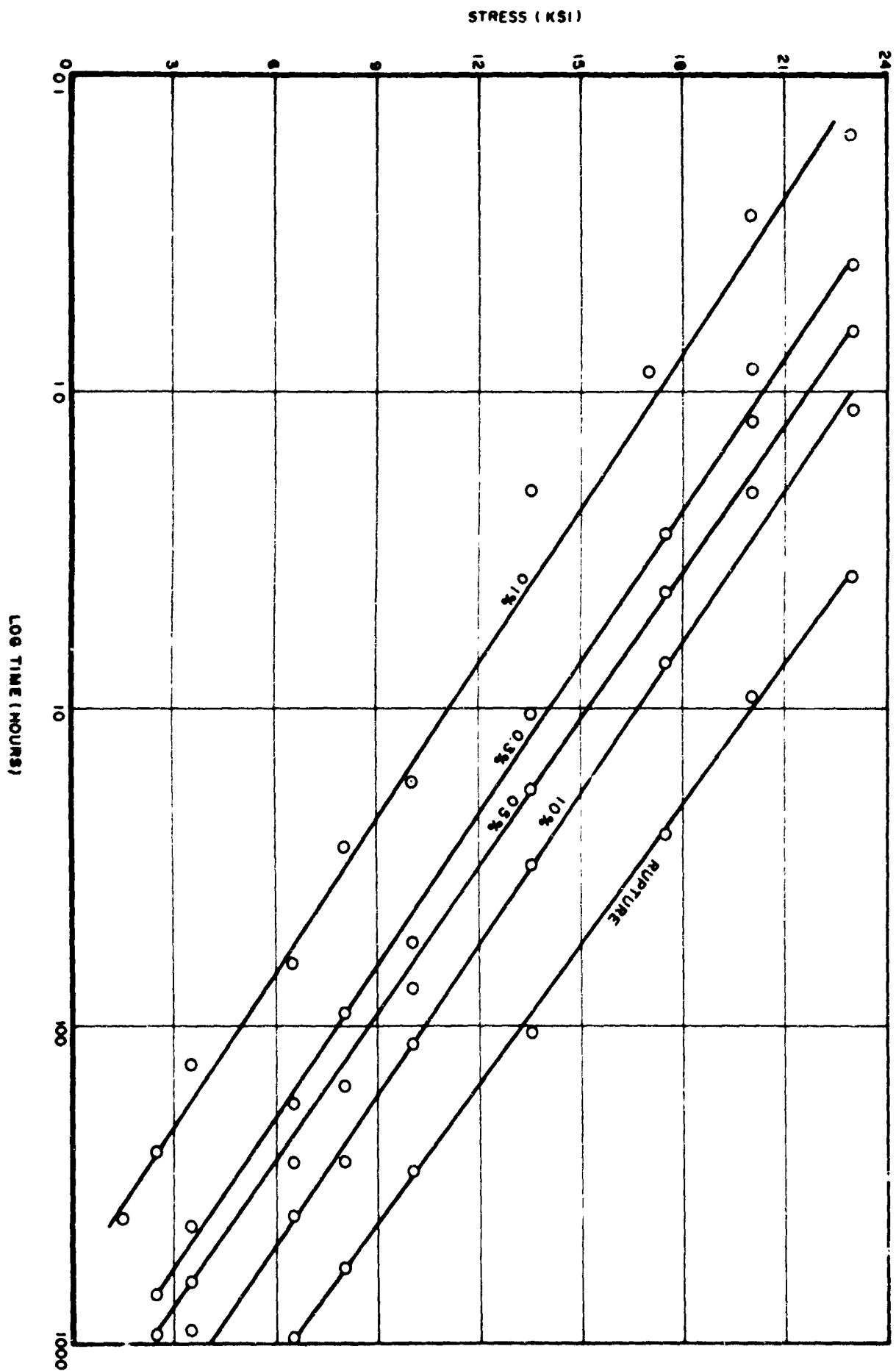


Figure 13. Creep Rupture Properties of Inconel 700 (Bar) at 1700°F

TABLE 16

INCONEL 700 (BAR) CREEP DEFORMATION AND RUPTURE DATA AT 1700°F							
STRESS (PSI)	TIME (HOURS)	ELONGATION (% IN 2 INCHES)	REDUCTION IN AREA (%)	LOADING (DEFORMATION %)	TIME TO REACH INDICATED DEFORMATION-HOURS		
					0.3 %	0.5 %	1.0 %
23,000	4.9	20.5	22.0	0.12	0.4	0.65	1.15
20,000	9.2	20.0	18.0	0.11	0.85	1.25	2.1
17,500	24.6	18.5	16.5	0.10	2.8	4.4	7.2
13,000	100.5	18.0	17.5	0.07	10.4	18.5	31.3
10,000	288.2	11.0	11.5	0.06	55.5	77.0	114.0
8,000	583.2	10.0	12.0	0.05	93.0	158.0	269.0
6,500	963.8	8.0 ^a	8.5	0.05	180.0	270.0	400.0
3,500	1001.7 ^b	—	—	0.03	430.0	655.0	940.0
2,500	1003.7 ^b	—	—	0.02	700.0	930.0	—
1,500	1102.3 ^b	—	—	—	1020.0 ^c	—	—
a. FAILURE OCCURRED IN GAGE MARK. b. TEST TERMINATED IN TIME INDICATED. NO FAILURE. c. EXTRAPOLATED VALUE.							

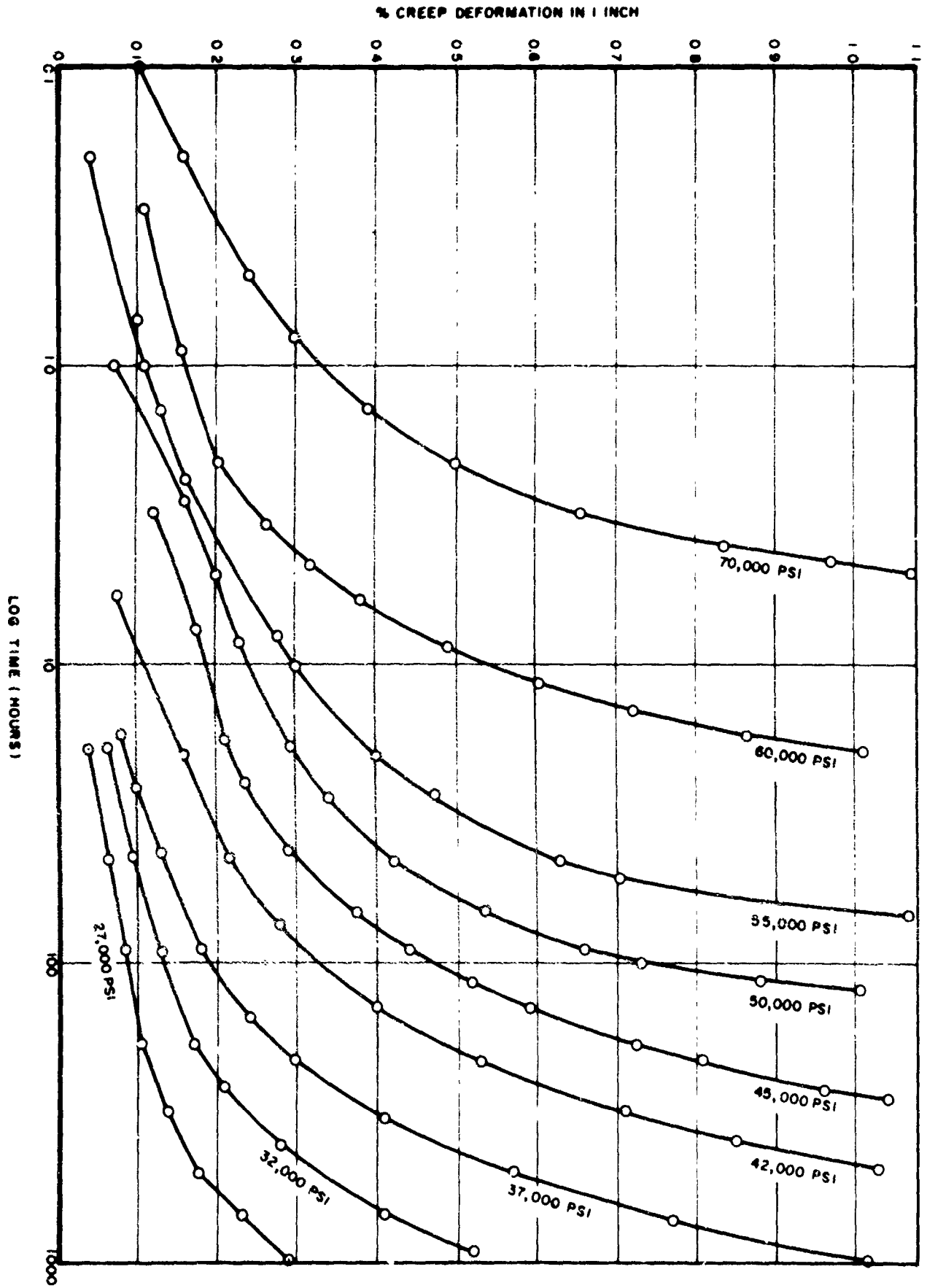


Figure 14. Creep Deformation Versus Log Time of Inconel 713C (Cast) at 1500°F

TABLE 17

INCONEL 713C ELONGATION - TIME DATA AT 1500° F							
TIME (HOURS)	DEFORMATION (% IN 1 INCH)	TIME (HOURS)	DEFORMATION (% IN 1 INCH)	TIME (HOURS)	DEFORMATION (% IN 1 INCH)	TIME (HOURS)	DEFORMATION (% IN 1 INCH)
70,000-9.5 ^a		55,000-101.8		186.1 0.725		668.5 0.735	
0.1	0.104	0.2	0.040	210.0	0.809	717.0	0.771
0.2	0.158	0.4	0.098	234.0	0.884	761.7	0.818
0.3	0.196	0.7	0.100	259.2	0.963	834.1	0.894
0.5	0.241	1.0	0.109	283.0	1.043	883.2	0.944
0.6	0.260	1.4	0.131	42,000-903.0		934.4	0.987
0.7	0.280	1.9	0.155	5.9	0.076	958.7	1.016
0.8	0.294	2.4	0.162	20.1	0.159	32,000-979.0	
0.9	0.305	3.0	0.194	28.8	0.182	19.1	0.066
1.0	0.325	3.7	0.222	44.3	0.215	43.8	0.096
1.2	0.361	4.4	0.242	50.8	0.226	68.3	0.115
1.4	0.388	4.9	0.245	67.3	0.256	91.0	0.128
1.8	0.448	8.0	0.278	75.0	0.278	115.5	0.140
2.1	0.498	10.1	0.299	91.7	0.306	139.1	0.146
2.2	0.510	10.3	0.303	99.0	0.314	187.7	0.173
2.9	0.630	20.6	0.400	116.0	0.358	235.0	0.192
3.1	0.656	24.7	0.437	122.2	0.362	259.6	0.209
3.3	0.700	28.1	0.476	139.7	0.399	308.7	0.221
3.7	0.773	45.3	0.633	146.8	0.412	334.0	0.244
4.0	0.835	52.6	0.705	164.3	0.439	378.6	0.260
4.5	0.970	69.2	1.070	170.2	0.446	403.1	0.279
4.6	0.988	50,000-197.7		189.3	0.492	452.0	0.301
4.7	1.022	1.0	0.072	213.3	0.530	501.2	0.324
4.9	1.073	2.9	0.158	236.0	0.570	570.9	0.351
60,000-50.6		5.1	0.199	259.4	0.618	643.4	0.388
0.1	0.066	8.5	0.232	283.1	0.658	690.0	0.414
0.3	0.110	18.7	0.289	309.4	0.713	788.5	0.463
0.9	0.156	20.6	0.304	332.8	0.754	813.3	0.475
1.1	0.164	27.9	0.338	358.5	0.803	862.0	0.492
2.1	0.203	41.7	0.400	381.4	0.848	906.8	0.519
2.7	0.229	46.0	0.422	405.6	0.891	27,000-1028.8	
3.4	0.262	48.7	0.449	430.1	0.952	19.1	0.038
4.2	0.288	66.0	0.536	452.3	0.982	45.1	0.065
4.7	0.320	74.9	0.567	477.0	1.029	90.9	0.083
5.7	0.362	90.1	0.661	37,000-958.7		139.0	0.095
6.2	0.362	98.8	0.732	17.4	0.082	186.6	0.104
7.0	0.410	114.2	0.880	26.1	0.101	234.9	0.120
7.9	0.448	123.3	1.007	41.9	0.128	309.1	0.159
8.7	0.489	45,000-492.7		65.6	0.154	333.8	0.140
9.7	0.523	3.1	0.121	89.8	0.181	402.7	0.158
10.3	0.555	7.7	0.176	115.1	0.200	475.1	0.171
10.9	0.576	18.0	0.211	150.6	0.242	502.2	0.177
11.3	0.598	25.4	0.238	186.2	0.272	570.7	0.197
11.6	0.605	42.4	0.292	209.7	0.297	643.3	0.211
12.5	0.648	48.2	0.316	257.9	0.340	691.0	0.228
13.3	0.685	67.1	0.376	329.7	0.408	739.0	0.235
14.1	0.721	76.1	0.389	401.7	0.477	790.2	0.253
15.7	0.792	91.2	0.440	426.0	0.499	863.3	0.262
17.2	0.864	115.1	0.517	498.1	0.571	905.8	0.279
19.1	0.977	139.9	0.593	547.3	0.616	978.9	0.290
19.5	1.010	163.6	0.667	595.5	0.660	1028.8	0.301

a. STRESS LEVEL - RUPTURE TIME (HOURS)

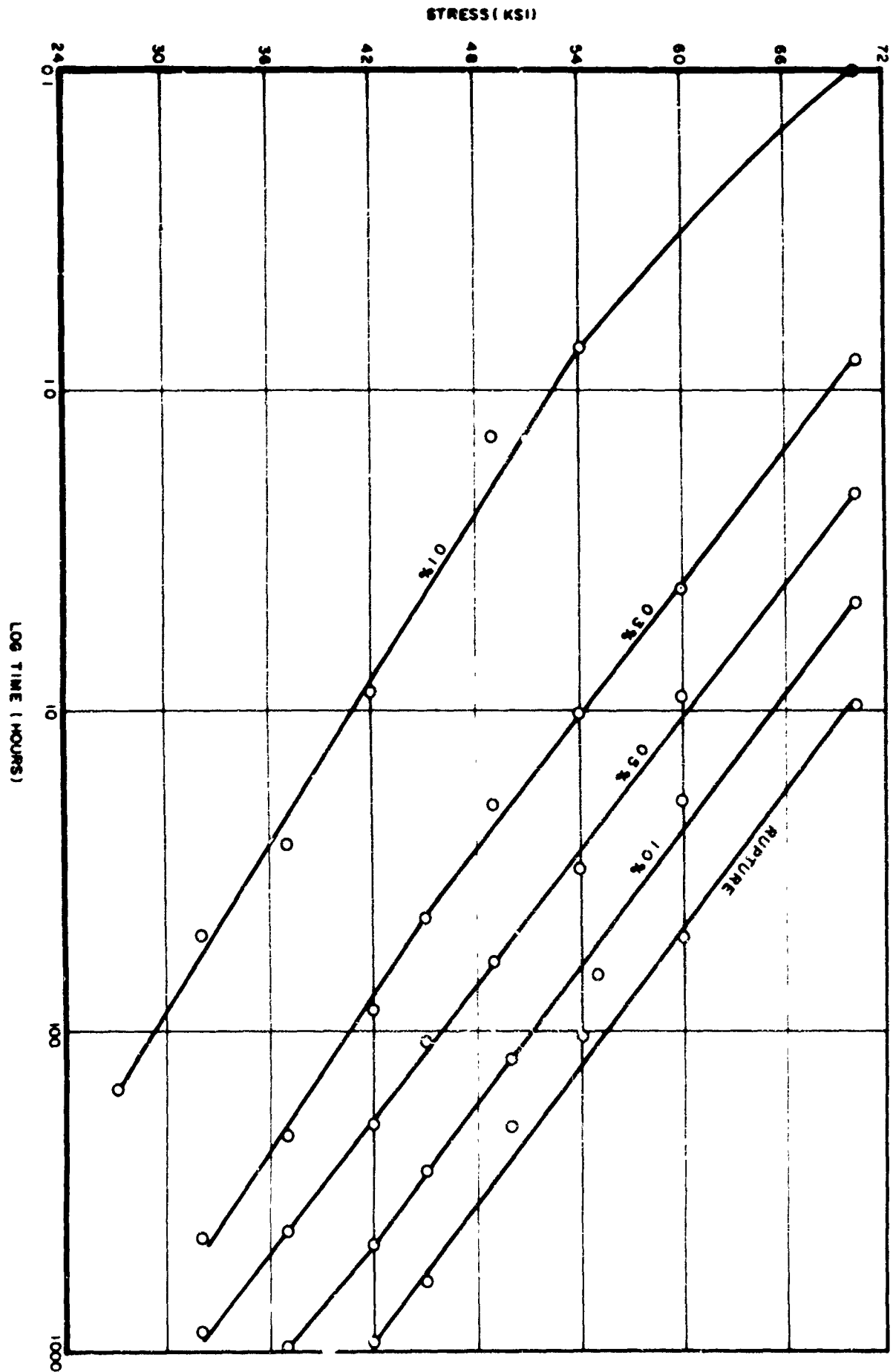


Figure 15. Creep Rupture Properties of Inconel 713C at 1500°F

TABLE 18

INCONEL 713C CREEP DEFORMATION AND RUPTURE DATA AT 1500 °F							
STRESS (PSI)	TIME (HOURS)	ELONGATION (% IN/INCH)	REDUCTION IN AREA (%)	LOADING (DEFORMATION %)	TIME TO REACH INDICATED DEFORMATION - HOURS		
					0.3 %	0.5 %	1.0 %
70,000	9.5	4.5	3.5	0.44	0.9	2.1	4.6
60,000	50.6	4.0	5.0	0.38	4.4	9.1	19.4
55,000	101.8	2.0	2.0	0.35	10.2	31.0	67.0
50,000	197.7	3.5	4.0	0.31	20.5	60.0	123.0
45,000	a	—	—	0.28	—	—	—
45,000	492.7	3.0	4.0	0.27	45.0	110.0	275.0
42,000	903.0	3.0	3.5	0.25	90.0	195.0	460.0
37,000	958.7 ^b	—	—	0.23	210.0	425.0	945.0
32,000	979.0 ^b	—	—	0.20	450.0	880.0	—
27,000	1028.8 ^b	—	—	0.18	1030.0	—	—
a TEST TERMINATED IMMEDIATELY AFTER LOADING DUE TO MALFUNCTIONING OF TEMPERATURE CONTROLLER.							
b TEST TERMINATED IN TIME INDICATED. NO FAILURE							

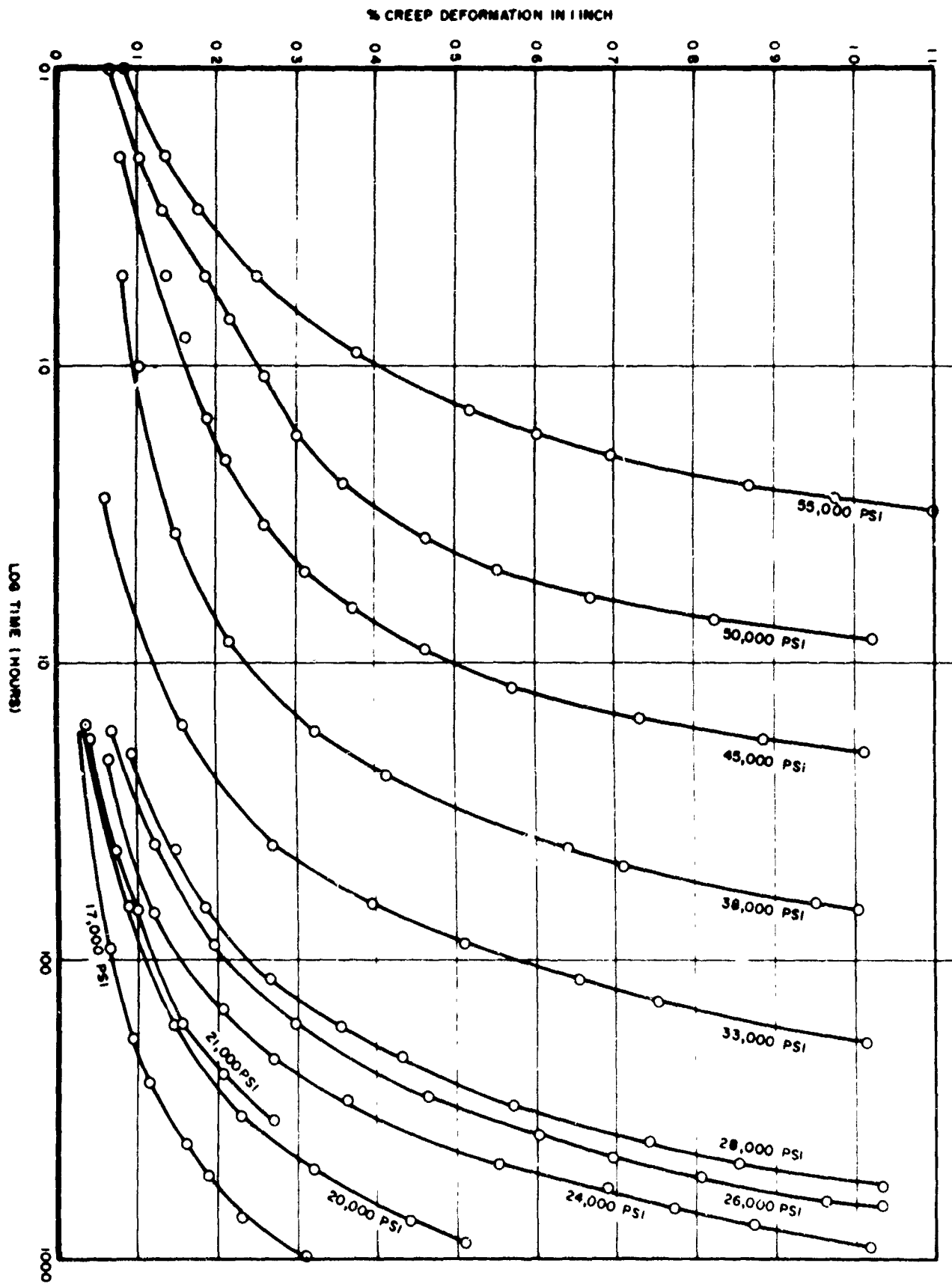


Figure 16. Creep Deformation Versus Log Time of Inconel 713C at 1600°F

TABLE 19

INCONEL 713C ELONGATION - TIME DATA AT 1600 °F

TIME (HOURS)	DEFORMATION (% IN 1 INCH)	TIME (HOURS)	DEFORMATION (% IN 1 INCH)	TIME (HOURS)	DEFORMATION (% IN 1 INCH)	TIME (HOURS)	DEFORMATION (% IN 1 INCH)
55,000-720		57	0.344	187.5	1.008	883.5	0.988
0.1	0.086	6.5	0.371	188.0	1.012	906.3	1.015
0.2	0.136	7.2	0.391	28,000-928.2		21,000-342.8	
0.3	0.176	7.8	0.420	20	0.096	18.3	0.041
0.4	0.215	8.3	0.441	27.6	0.118	42.7	0.073
0.5	0.250	9.0	0.462	42.5	0.152	67.6	0.099
0.7	0.309	9.8	0.489	49.2	0.160	116.2	0.134
0.9	0.374	10.0	0.501	67.2	0.186	165.4	0.154
1.2	0.458	11.0	0.538	91.6	0.233	239.5	0.206
1.4	0.516	12.0	0.575	115.7	0.264	288.9	0.245
1.7	0.606	13.1	0.611	140.2	0.313	313.0	0.259
2.0	0.694	14.7	0.690	167.0	0.357	342.8	0.271
2.3	0.774	15.4	0.732	186.4	0.383	20,000-864.4	
2.55	0.868	16.7	0.804	210.8	0.429	16.1	0.033
2.8	0.974	18.0	0.886	236.4	0.473	40.7	0.070
3.1	1.094	19.0	0.943	261.5	0.509	66.9	0.091
50,000-18.6		20.1	1.010	307.2	0.530	116.5	0.119
0.1	0.067	38,000-123.0		355.1	0.658	165.1	0.144
0.2	0.102	0.5	0.081	402.0	0.744	238.1	0.175
0.3	0.130	1.0	0.102	451.8	0.816	331.2	0.231
0.5	0.184	1.9	0.118	475.5	0.852	403.7	0.258
0.7	0.216	3.7	0.151	524.6	0.938	505.5	0.317
1.1	0.248	5.2	0.173	549.0	0.984	573.5	0.353
1.3	0.265	8.5	0.217	572.2	1.031	620.5	0.374
1.5	0.286	12.8	0.267	26,000-673.3		740.9	0.440
1.7	0.302	17.0	0.325	17.2	0.071	790.0	0.463
1.9	0.315	19.1	0.344	40.9	0.126	813.1	0.468
2.2	0.344	23.8	0.416	89.1	0.197	834.9	0.485
2.5	0.358	41.5	0.640	112.8	0.224	859.5	0.497
2.8	0.393	47.7	0.709	161.5	0.297	867.2	0.502
3.1	0.416	63.8	0.952	208.9	0.372	884.4	0.511
3.8	0.466	65.1	0.972	281.2	0.466	17,000-977.1	
4.3	0.507	66.0	0.988	329.9	0.523	16.7	0.028
4.9	0.553	66.5	0.995	378.2	0.604	90.4	0.064
5.5	0.614	67.0	1.003	451.2	0.698	185.0	0.093
6.0	0.670	33,000-318.4		523.8	0.805	258.2	0.114
6.5	0.737	2.8	0.060	571.0	0.862	353.5	0.136
7.1	0.826	4.5	0.079	616.9	0.936	425.0	0.160
7.8	0.948	16.2	0.158	640.3	0.959	525.3	0.189
8.0	0.979	20.1	0.171	665.8	1.011	595.9	0.205 ^b
8.2	1.019	25.6	0.197	24,000-906.3		618.5	0.209
45,000-39.4		40.9	0.276	21.1	0.056	643.0	0.214
0.2	0.079	48.9	0.322	69.5	0.119	715.2	0.232
0.5	0.134	64.5	0.395	143.8	0.205	787.8	0.258
0.8	0.160	73.1	0.440	217.2	0.269	809.3	0.262
1.1	0.175	88.5	0.512	290.4	0.361	856.7	0.278
1.5	0.187	97.0	0.553	385.1	0.459	929.0	0.291
2.1	0.212	114.7	0.653	479.8	0.551	977.1	0.311
2.8	0.236	122.6	0.686	575.0	0.669 ^b		
3.5	0.261	138.1	0.752	668.8	0.770		
4.2	0.289	147.2	0.811	764.7	0.869		
4.7	0.307	162.1	0.874	861.1	0.962		
4.9	0.311	170.5	0.926				

a STRESS LEVEL - RUPTURE TIME (HOURS)

b NEW PLATINUM STRIPS

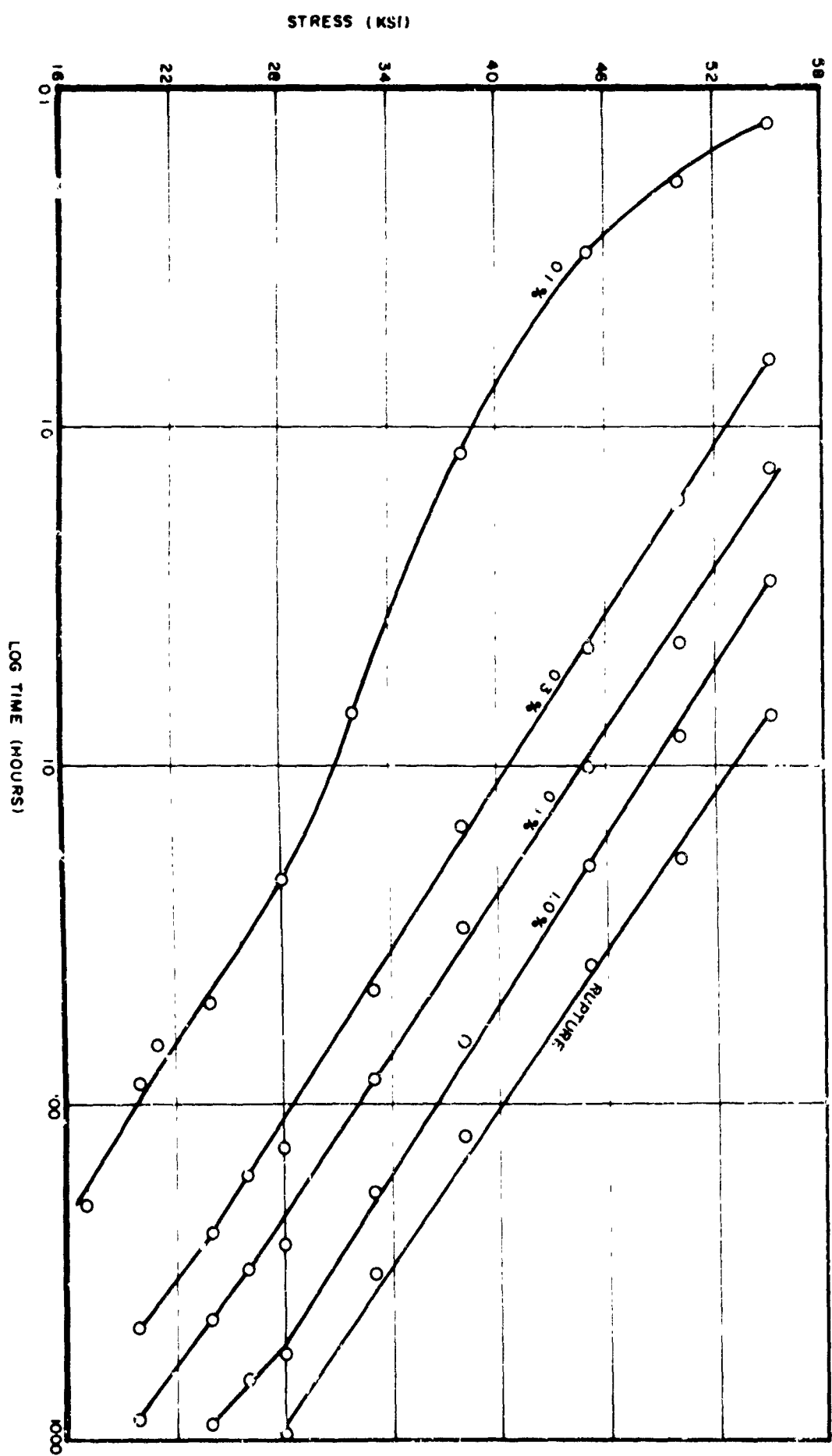


Figure 17. Creep Rupture Properties of Inconel 713C at 1600°F

TABLE 20

INCONEL 713C CREEP DEFORMATION AND RUPTURE DATA AT 1600° F							
STRESS (PSI)	TIME (HOURS)	ELONGATION (% IN 1 INCH)	REDUCTION IN AREA (%)	LOADING (DEFORMATION %)	TIME TO REACH INDICATED DEFORMATION - HOURS		
					0.3 %	0.5 %	1.0 %
55,000	7.2	5.0	3.5	0.43	0.65	1.35	2.9
50,000	18.6	2.0	3.5	0.40	1.7	4.2	8.1
45,000	39.4	3.0	3.0	0.35	4.6	10.0	20.0
38,000	123.0	3.0	3.5	0.29	15.0	31.0	67.0
33,000	318.4	4.0	5.5	0.26	45.0	86.0	186.0
28,000	928.2	3.0	4.0	0.23	135.0	255.0	560.0
26,000	673.3 ^a	—	—	0.20	165.0	310.0	660.0
24,000	906.3 ^a	—	—	0.19	240.0	430.0	890.0
21,000	342.8 ^b	—	—	0.17	380.0 ^c	—	—
20,000	884.4 ^a	—	—	0.17	480.0	870.0	—
17,000	977.1 ^a	—	—	0.13	950.0	—	—
a. TEST TERMINATED IN TIME INDICATED NO FAILURE. b. TEST TERMINATED IN TIME INDICATED DUE TO POOR TEMPERATURE CONTROL. c. EXTRAPOLATED VALUE.							

Figure 18. Creep Deformation Versus Log Time of Inconel 713C at 1700°F

LOG TIME (HOURS)

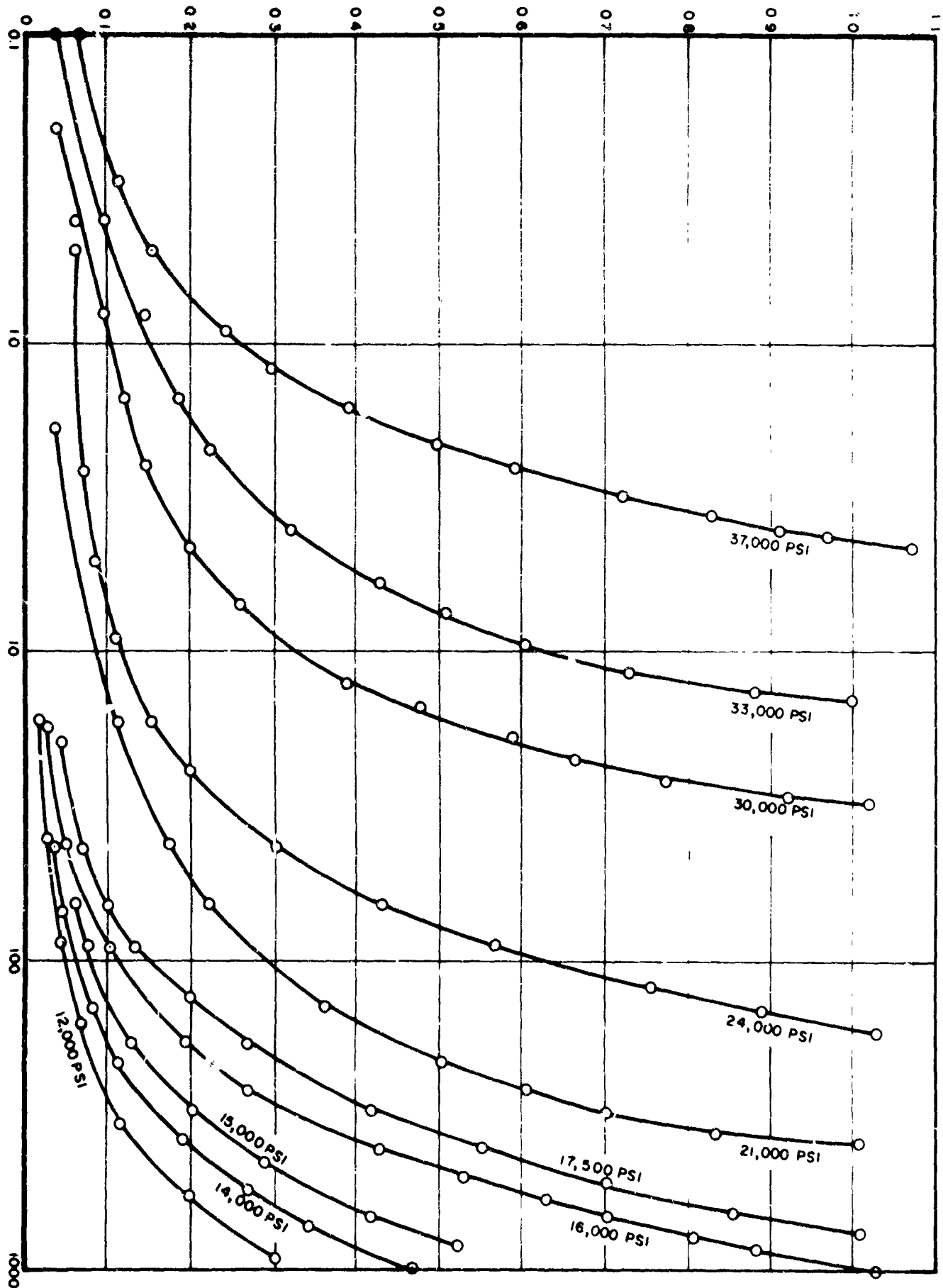


TABLE 21

INCONEL 713C ELONGATION - TIME DATA AT 1700° F							
TIME (HOURS)	DEFORMATION (% IN 1 INCH)	TIME (HOURS)	DEFORMATION (% IN 1 INCH)	TIME (HOURS)	DEFORMATION (% IN 1 INCH)	TIME (HOURS)	DEFORMATION (% IN 1 INCH)
37,000-7.8 ^a		0.2	0.038	89.9	0.267	16.9	0.030
0.1	0.064	0.4	0.056	98.1	0.289	40.5	0.043
0.3	0.109	0.8	0.092	113.5	0.320	65.1	0.061
0.5	0.148	1.0	0.102	138.4	0.361	89.9	0.075
0.7	0.194	1.5	0.120	161.0	0.410	137.6	0.100
0.9	0.240	1.9	0.128	185.3	0.462	186.2	0.131
1.0	0.262	2.5	0.145	209.4	0.506	235.5	0.163
1.2	0.294	3.4	0.164	215.9	0.524	307.4	0.205
1.3	0.329	4.5	0.200	234.9	0.557	379.0	0.247
1.6	0.389	5.3	0.219	256.9	0.604	450.8	0.292
1.9	0.456	6.1	0.243	306.4	0.700	521.9	0.336
2.1	0.497	7.0	0.261	331.0	0.751	594.2	0.734
2.3	0.548	8.0	0.290	353.5	0.834	666.7	0.420
2.5	0.590	9.2	0.327	376.8	0.958	735.6	0.464
2.8	0.654	11.5	0.389	384.1	1.008	808.1	0.509
3.1	0.722	12.5	0.407	17,500-917.4		831.9	0.523
3.4	0.780	14.1	0.460	19.7	0.042	14,000-1055.3	
3.6	0.830	15.0	0.482	43.5	0.070	17.1	0.027
4.0	0.912	16.0	0.505	66.8	0.100	41.7	0.034
4.2	0.968	18.9	0.590	91.1	0.133	47.0	0.036
4.4	1.031	22.1	0.664	139.8	0.199	70.3	0.045
4.5	1.067	26.1	0.773	166.5	0.224	141.8	0.081
33,000-19.1		29.0	0.921	188.1	0.269	215.4	0.114
0.1	0.034	30.0	0.991	235.5	0.317	309.9	0.157
0.4	0.096	30.5	1.020	306.4	0.420	383.0	0.193
0.8	0.144	24,000-180.1		337.1	0.462	478.5	0.233
1.2	0.165	0.5	0.049	377.8	0.508	549.8	0.272
1.5	0.182	2.6	0.071	401.4	0.549	650.2	0.314 ^b
1.8	0.197	5.1	0.086	475.1	0.634	720.7	0.345 ^b
2.2	0.223	9.6	0.113	522.9	0.702	814.0	0.398
3.1	0.263	13.8	0.140	598.2	0.793	887.9	0.431
3.6	0.295	17.0	0.156	647.5	0.856	936.2	0.456
3.7	0.302	24.2	0.202	697.1	0.926	984.7	0.470
4.0	0.319	38.7	0.281	722.5	0.966	1006.5	0.479
4.6	0.346	43.0	0.306	747.0	1.011	1031.7	0.494
5.1	0.382	45.9	0.330	16,000-985.5		1055.3	0.511
6.0	0.430	65.8	0.432	17.5	0.028	12,000-917.2	
6.7	0.470	73.7	0.483	42.1	0.051	16.6	0.021
6.9	0.473	89.0	0.568	90.7	0.102	41.0	0.029
7.2	0.494	96.5	0.616	185.1	0.196	89.2	0.043
7.5	0.510	113.6	0.710	210.5	0.226	162.8	0.068
8.1	0.544	120.3	0.756	260.8	0.276	245.1	0.090
8.6	0.573	137.1	0.845	308.6	0.331	340.9	0.118
9.2	0.603	144.6	0.891	405.2	0.428	413.7	0.143
10.0	0.642	161.3	0.985	499.2	0.532	486.5	0.170
10.7	0.688	168.5	1.028	596.0	0.632 ^b	580.8	0.202 ^b
11.5	0.730	21,000-391.9		670.7	0.704 ^b	677.0	0.225 ^b
12.5	0.798	1.9	0.034	767.3	0.811	772.4	0.254
13.4	0.882	17.0	0.116	839.1	0.883	869.1	0.288
14.0	0.965	24.1	0.134	913.7	0.955	892.8	0.297
14.2	0.999	41.6	0.175	985.5	1.032	917.2	0.306
30,000-38.5		65.3	0.222	15,000-831.9			

a. STRESS LEVEL — RUPTURE TIME (HOURS).

b. NEW PLATINUM STRIPS.

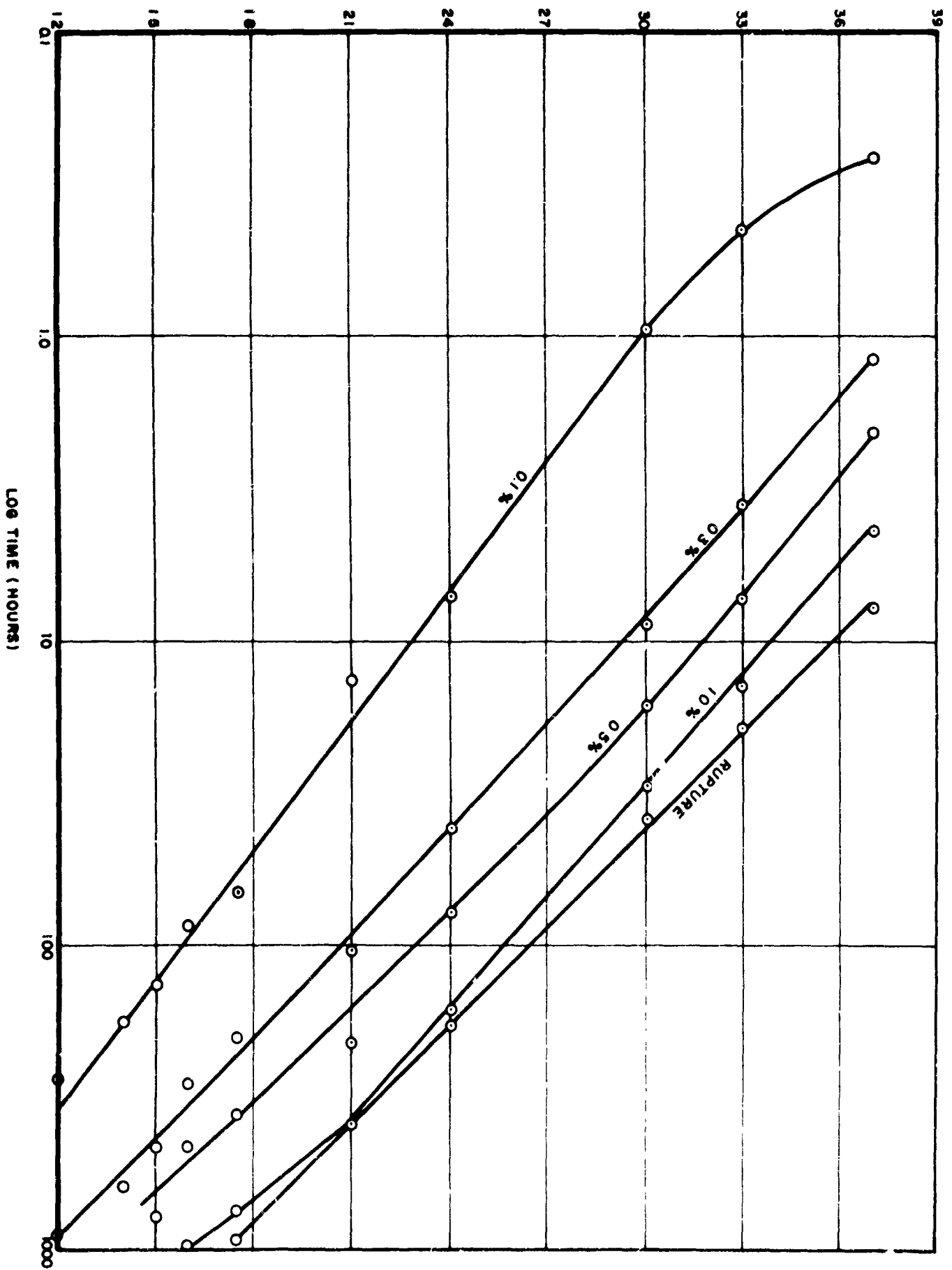


Figure 19. Creep Rupture Properties of Inconel 713C at 1700°F

TABLE 22

INCONEL 713C CREEP DEFORMATION AND RUPTURE DATA AT 1700 °F							
STRESS (PSI)	TIME (HOURS)	ELONGATION (% IN 1 INCH)	REDUCTION IN AREA (%)	LOADING (DEFORMATION %)	TIME TO REACH INDICATED DEFORMATION - HOURS		
					0.3%	0.5%	1.0%
37,000	7.8	4.0	6.0	0.36	1.2	2.1	4.3
33,000	19.1	4.0	4.0	0.33	3.7	7.3	14.2
30,000	38.5	3.0	3.0	0.29	8.4	15.8	30.2
24,000	180.1	2.5	3.0	0.23	42.0	77.0	165.0
21,000	391.9	3.0	3.0	0.21	105.0	205.0	380.0
17,500	917.4	2.5	2.5	0.18	215.0	370.0	740.0
16,000	985.5 ^a	—	—	0.15	280.0	470.0	950.0
15,000	831.9 ^a	—	—	0.15	460.0	790.0	—
14,000	1055.3 ^a	—	—	0.13	620.0	1040.0	—
12,000	917.2 ^a	—	—	0.11	905.0	—	—
^a . TEST TERMINATED IN TIME INDICATED. NO FAILURE							