REPORT

ON

THE PROPERTIES OF HASTELLOY X SHEET

AT 1200° TO 1800°F

by

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Wright Aeronautical Division
Wood-Ridge, New Jersey

PROPERTIES OF HASTELLOY X SHEET AT 1200° TO 1800°F

Summary and Conclusions

An investigation of the rupture and total deformation strengths of a 0.063-inch thick sheet of Hastelloy X alloy was carried out. The temperatures covered were 1200°, 1350°, 1500°, 1650°, and 1800°F. The data obtained defined the rupture strengths from 5 to 300 hours and the stresses for total deformations of 0.2, 0.5, 1.0, and 2.0 percent from 1 to 100 hours.

The specimens were taken such as to show variation in properties throughout the sheet. The main evaluation was based on specimens taken transverse to the direction of rolling with check tests on longitudinal specimens.

The main objective was to check the properties of a production sheet against those considered characteristic of the alloy. The investigation was sponsored by the Wright Aeronautical Division, Curtiss-Wright Corporation.

The properties of the sheet investigated were in agreement with values presented for the alloy by the manufacturer, Haynes Stellite Company. The strength values were slightly higher at 1650° and 1800°F although well within the normal range to be expected in practice. The data shows good strength and ductility for a stable material in the range of 1200° to 1800°F.

The particular sheet examined displayed unusually uniform properties for sheet material. Little difference between transverse or longitudinal specimens or between specimens from different locations in the sheet was observed.

The uniformity of properties and agreement with expected properties was much better than is normally the case. It must be realized that normal production material would not be so uniform in properties. The data obtained from Haynes Stellite Company and included in the report shows a more realistic scatter in properties.

It should also be realized that the properties reported are a function of the treatment given the sheet material as well as the chemical composition. Variations from reported properties would be expected for other treatments than that used for the particular sheet examined. In particular, variations would be expected as the result of forming and other fabrication operations subsequently applied to the sheet.

TEST MATERIALS

Test specimens, 22-inches long x 1-inch wide with a 0.500-inch wide x 2.25-inch long gage section, were machined by Wright Aeronautical Division of Curtiss-Wright Corporation from a single sheet of Hastelloy X, Heat X-1037. The original sheet was 8-feet long x 36-inches wide x 0.063-inch thick. The manufacturer, Haynes Stellite Corporation, reported the following chemical analysis:

Cr	W	Fe	C	Si	Co	Ni	Mn	Mo	P	S
21.62	0.24	18.45	0.08	0.47	0.89	Bal.	0.63	8.55	0.006	0.016

The following tensile properties at 75°F were also reported:

Ultimate Tensile Strength	114,000 psi
0.2% Yield Strength	56,000 psi
Elongation/4D	46.0%

The sheet was sheared into three pieces. An end piece was 3 feet, 9 inches long, a center piece 3-feet long, and an end piece 18-inches long. Transverse specimens 1 through 12 were taken from the first piece starting with the original edge. Specimens 13 through 24 were taken from the middle piece, starting at a point 3 feet, 9 inches from the original edge. Specimens 25 through 36 were taken from the third piece starting 6 feet, 9 inches from the original edge.

Subsequently, nine additional transverse specimens were taken from the same sheet, specimens 38 through 41 from the first section, 42 through 45 from the second, and 46 from the third section. In addition, ten specimens were taken in the longitudinal direction from the 3 foot, 9 inch section.

PROCEDURE

The objective of the program was to establish the rupture strength of Hastelloy X sheet material, at 1200°, 1350°, 1500°, 1650°, and 1800°F for the time periods from 5 to 300 hours and the 0.2 percent, 0.5 percent, 1.0 percent, and 2.0 percent deformation strengths for time periods from 1 to 100 hours.

The stress-rupture tests were conducted in single units of the dead weight-beam loaded type, except when low stresses required the use of a direct load.

The following procedure was used to bring the specimens to temperature:

1. Specimens were set up in the units and the heat turned at 4:00 p.m., to bring the temperature within 50°F of the desired temperature by 5:00 p.m.

2. The specimens were allowed to stand overnight, the temperature raised to the test temperature between 8:00 and 9:00 a.m. the next day.

3. Final adjustments to test temperature and for temperature distribution along the length of the specimens were made so that the stress could be applied by 1:00 p.m.

Stresses to produce rupture in the desired time periods were selected by first securing test results in intermediate time periods and then adjusting the stresses to give fracture times near those desired. The resulting stress-rupture time curves for the temperatures of interest allowed the selection of rupture strengths for the desired time periods of 5, 20, 80, and 300 hours with little extrapolation.

Time-elongation creep curves were secured on all tests. The data were obtained by means of extensometers. Collars were fixed on the upper and lower shoulders of the specimens by means of pins inserted through holes drilled in the specimen shoulder. Extension rods were attached to the collars and extended out of the furnace. Rollers carrying a mirror were inserted between each pair of extension rods. As the specimen elongated, the mirrors were rotated and the rotation measured by a scale reflected in the mirrors to a telescope.

The readings on both sides of the specimens were taken and averaged. The sensitivity of the extensometer system was 0.000003 in. per in. in the 2-in. gage length.

Inasmuch as the extensometers were attached to the shoulders of the specimen, the observed deformation included elongation in the fillets and a portion of the shoulders as well as the reduced section. A system of correcting the deformation through a calculated "effective gage length" was used.

TEST RESULTS

The test results, obtained at temperatures of 1200°, 1350°, 1500°, 1650°, and 1800°F, are in Table I and include rupture time, elongation at fracture, deformation on loading and times for total deformation of 0.2, 0.5, 1.0, and 2.0 percent. Time for a total deformation of 0.1 percent has been included, where available because this data was also of interest.

The stress-rupture time data have been plotted as log stress-log rupture time curves at each testing temperature in Figure 1. The main curves are based on the transverse specimens with the results obtained from longitudinal specimens included. The stresses for rupture in the specified times as defined by Figure 1 age given in Table II. In general, the stresses used in testing gave actual test times which were not greatly different from the specified rupture strengths to be established.

The times for total deformations of 0.1, 0.2, 0.5, 1.0 and 2 percent were obtained from the creep curves for each test. The total deformations include the elastic and plastic deformation from loading the specimens. The tabulated values in Table I indicate which of the individual total-deformation values could be obtained from each test. The actual creep curves have not been included in the report. It will be noted in Table I, however, that high stress tests exceeded some of the smaller deformations of interest on loading whereas lower stress tests did not reach the larger total deformations during the tests.

The available total-deformation values were plotted as stress-log time for indicated deformation curves in Figures 2 through 6. Data from both transverse and longitudinal specimens have been included. Stress for the total deformations and time periods specified were read from these curves and are given in Table II.

The stress-rupture time and stress-time for specified total deformation data are compared with Haynes Stellite Company data point in Figures 7 through 12. These data have been plotted as log stress-log total deformation time curves in order to facilitate comparison between the two sets of data. This has been done as a matter of convenience to reduce the scatter in data if a similar plot, as in Figures 2 through 6, had been used.

The rupture strengths and total-deformation strengths are summarized as a function of temperature by Figures 13 through 17.

Discussion of Results

The test data show remarkably little scatter for specimens cut from a large sheet. There was also remarkably little difference between transverse and longitudinal specimens. The particular sheet tested, therefore, was uniform in its high-temperature properties to a degree not usually observed.

The log stress-log rupture time curves showed no changes in slope with increasing rupture time except at 1200°F. There was also very little increase in slope with increasing temperature. Elongations at fracture were also nearly independent of temperature. Such behavior is generally considered evidence of a stable material over the temperature ranges and times considered. Elongations did decrease with increasing time to fracture with values between 10 and 15 percent for rupture in about 300 hours. These are not excessively low values and the decreases are normal for increasing fracture time by creep in stable material.

Low values of elongations were associated with fracture through gage marks. This was not due to embrittlement by the gage marks. It simply reflected the smaller amount of the total elongation measured within the span of the gage marks.

The semi-log curves of stress versus the log of the time for total deformation did show changes in slope. The curves became steeper at 1200°F and flatter at higher temperatures. The reduction in slope was not evident if the data were plotted to log-log coordinates. The decrease in slope at 1200°F appeared related to yielding on loading the specimen. Such yielding tended to reduce the stress sensitivity for a given deformation as might be expected. The decreases in slope for the semi-log total-deformation curves with increasing time are more difficult to explain. These curves normally show a increase in slope. It apparently reflects some sort of strengthening reaction which occurred. More detailed study would be required to explain this behavior.

It will be noted that the variation in stress for a given amount of deformation decreased with increasing temperature. This reflects the decreasing creep resistance with increasing temperature.

Relation of Measured Strengths to Expected Properties for the Material

The properties of the sheet tested agreed remarkably well with those presented for the alloy by the manufacturer, Haynes Stellite Company. Comparative values are given in Table III. Slightly higher values were obtained in this investigation for 1650° and 1800°F. The actual test points were obtained from the Haynes Stellite Company and are included in Figures 7 through 12. Their actual test points tend to show considerably more scatter than were obtained in this investigation. This is probably a more realistic evaluation of the overall characteristics of the material than the remarkably uniform results obtained from the sheet tested. Furthermore, all data from this investigation are within the range of data obtained by Hanes Stellite Company so that there is no real disagreement.

Parameter Correlation of Data

The tests involved in this evaluation were both time consuming and expensive. Accordingly, the Miller-Larsen method of correlating the data was applied to the data with the results shown in Figures 18 through 22. The use of this correlation for total-deformation data has not been extensive and the reliability is, therefore, questionable.

The correlations do show fairly good curves. It will be noted, however, that the values for each temperature of testing start on the high stress side of the scatter band and drift to the low stress side with increasing time, except for the smallest deformation. Thus if a few short-time tests had been used to establish parameter correlations, the longer time predicted values would have been high. It appears, however, that individual sheets could be checked with a few short-time tests over the range and due allowance made for the high values predicted by such tests for the longer time rupture and total-deformation values.

Warning: Experience with such correlations demonstrate that such curves as are given in this report cannot serve as master curves. Each lot of material tends to have a unique set of curves. One or two tests on another material cannot be reliably related to the curves included in this report. Several tests over a range of temperatures are necessary for any one lot of material.

Limitation of Results

There are two main limitations to the data:

1. All experience with evaluation of the high-temperature properties of heat-resistant alloys indicates considerable variation in properties of production material. The fact that the sheet tested for this investigation had nearly identical properties with those claimed for the alloy should not be accepted as proof that all sheets have these exact properties, at least not without further

proof. Furthermore, the source of the test sheet being the same as that for the comparative data probably contributed to the agreement in properties. Other manufacturing procedures might result in considerable variation in properties.

2. It is possible that the properties of Hastelloy X sheet could be considerably altered by fabrication operations. Care should, therefore, be exercised in applying the test results covered by this report to material which has gone through fabrication operations. The properties of all heat-resistant alloys are more or less a function of the prior treatment as well as the chemical composition. Variations in properties may result when the prior history of the test material is altered.

TABLE I

STRESS-RUPTURE AND STRESS-TOTAL DEFORMATION DATA OBTAINED FOR SHEET SPECIMENS OF HASTELLOY X (HEAT X1037) AT 1200°, 1350°, 1500°, 1650°, AND 1800°F

Spec No.	Stress (psi)	Rupture Time (hours)	Elongation (% in 2 in.)	Deformation on loading (%)	Time for Specified Total Deformation 0.1%	0.2%	0.5%	1.0%	2.0%
				1200°F					
11	70,000	2.1	32.5	--	a	a	a	a	a
6	65,000	5.2	35.0	--	a	a	a	a	a
13	53,000	29.2	26.5	--	a	a	a	a	a
47(2)	45,000	78.3	14.0(1)	1.86	a	a	a	a	0.9
1	43,500	107.8	23.0(1)	1.17	a	a	a	a	8.4
39	40,000	189.5	17.5	0.861	a	a	a	3.4	25.9
52(2)	37,000	263.2	18.0(1)	0.486	a	a	2.0	17.2	38.3
25	37,000	252.9	15.0	0.585	a	a	a	18.8	45.7
32	34,000	146.0(c)	--	0.233	a	a	22.5	50.5	90.5
18	31,500	401.0(c)	--	0.191	a	1.0	34.0	72.0	141.0
30	28,000	378.5(c)	--	0.142	a	21.0	69.5	151.5	324.0
42	24,000	285.7(c)	--	0.120	a	25.0	96.0	267.0	b
				1350°F					
12	40,000	6.8	36.0	0.39	a	a	0.07	0.34	0.75
26	32,500	22.1	28.0(1)	0.183	a	0.3	0.77	1.7	3.45
48(2)	27,000	55.5	24.0	0.147	a	0.6	2.2	4.4	8.7
2	27,000	66.1	22.5	0.13	a	0.5	2.4	5.4	11.2
14	22,500	210.1	29.5	0.105	a	1.4	5.6	12.2	25.8
53(2)	20,000	381.5	15.0	0.103	a	2.0	11.8	33.5	90.5
31	20,000	141.5(c)	--	0.102	a	3.0	13.0	31.5	79.0
19	17,500	376.6(c)	--	0.093	0.5	4.0	22.0	78.0	240.0
7	14,000	889.4(c)	--	0.068	1.0	14.0	140.0	(1160.0)	b

TABLE I (continued)

Spec No.	Stress (psi)	Rupture Time (hours)	Elongation (% in 2 in.)	Deformation on loading (%)	Time for Specified Total Deformation 0.1%	0.2%	0.5%	1.0%	2.0%
				1500°F					
23	24,000	6.6	39.5	0.179	a	0.05	0.1	0.32	0.73
27	18,000	25.6	28.5(1)	0.105	a	0.23	1.1	2.63	4.87
49(2)	15,000	62.1	17.5(1)	0.095	0.02	0.9	3.6	8.4	15.4
3	14,500	83.2	22.0	0.086	0.18	1.3	6.0	12.0	22.8
54(2)	12,000	253.4	17.0(1)	0.059	0.5	3.0	18.0	44.0	78.0
15	11,500	404.1	12.0	0.070	0.5	4.0	33.5	96.0	167.5
44	10,500	260.7(c)	--	0.058	0.7	6.7	71.0	(220.0)	(574.0)
8	9,600	1149.9(c)	--	0.057	2.0	22.0	234.0	636.0	983.0
20	7,800	260.0(c)	--	0.047	4.0	29.0	(440.0)	b	b
				1650°F					
9	13,000	7.5	30.0	0.095	--	0.05	0.24	0.54	1.1
28	10,500	23.3	17.0	0.073	--	0.4	1.6	3.2	6.3
4	8,700	43.7	17.5	0.061	--	1.4	5.4	9.6	16.1
50(2)	8,300	71.6	14.5(1)	0.0595	--	0.4	1.0	6.2	17.4
40	8,000	93.8	14.0	0.0514	--	1.5	8.9	17.3	29.1
16	7,000	231.2	19.0	0.035	3.0	16.5	42.7	66.3	95.8
55(2)	6,500	356.6	12.0	0.0471	3.0	18.0	56.0	98.0	158.0
21	6,200	394.3	12.5	0.048	4.0	21.8	61.5	108.0	159.0
33	5,500	500.4(c)	--	0.037	11.0	52.0	151.5	241.0	334.0
				1800°F					
22	8,000	6.7	22.5	0.073	--	0.058	0.2	0.43	0.85
35	7,000	9.6	17.5	0.067	--	0.22	0.94	1.7	2.9
41	6,000	19.5	19.5	0.063	--	0.32	1.0	2.1	4.14
29	5,000	47.7	16.5	0.047	--	1.9	5.55	9.5	13.5
51(2)	4,000	110.9	11.0(1)	0.078	--	3.0	15.5	35.0	57.0
5	3,650	122.2	6.0(1)	0.038	8.0	17.0	38.0	60.7	86.5
34	3,000	324.1	10.0	0.027	7.0	20.0	69.0	117.5	170.0
56(2)	2,800	438.2	7.5	0.0374	11.0	53.0	102.0	168.0	245.0
46	2,500	330.9(c)	--	0.021	56.5	109.0	209.0	303.0	(500.0)

(1) Broken in gage mark.
(2) Longitudinal specimens.
(a) Deformation reached on loading.
(b) Excessive extrapolation required.
(c) Discontinued at indicated time.
(-) Extrapolated values.

TABLE II

RUPTURE AND TOTAL DEFORMATION STRENGTHS OF HASTELLOY X (HEAT X-1037) SHEET MATERIAL AT 1200°, 1350°, 1500°, 1650°, and 1800°F

Temperature	Stress for Rupture or Indicated Total Deformation in Specified Time Periods						
	1 hr	5 hrs	10 hrs	25 hrs	50 hrs	100 hrs	300 hrs
				Rupture Strength (psi)			
1200		65,000	60,000	54,000	48,500	44,000	37,000
1350		42,000	37,500	32,000	28,500	25,500	21,000
1500		24,750	21,500	18,500	16,500	14,500	12,000
1650		13,000	11,500	9,900	8,800	7,800	6,500
1800		8,200	7,000	5,700	4,750	4,000	3,200
				2.0% Total Deformation Strength (psi)			
1200	45,000	43,900	43,200	40,000	36,600	33,200	
1350	38,500	30,700	27,300	23,000	21,300	19,500	
1500	22,500	18,300	16,500	14,250	13,400	12,500	
1650	13,200	10,600	9,600	8,350	7,500	6,700	
1800	8,300	6,100	5,200	4,500	4,000	3,500	
				1.0% Total Deformation Strength (psi)			
1200	42,000	39,200	38,000	36,500	33,600	29,800	
1350	34,700	27,000	23,700	21,700	18,800	17,000	
1500	20,500	16,600	15,000	13,600	12,600	11,750	
1650	12,000	9,700	8,700	7,500	6,900	6,200	
1800	7,300	5,600	4,800	4,200	3,700	3,200	
				0.5% Total Deformation Strength (psi)			
1200	38,000	36,000	35,000	33,500	29,200	25,000	
1350	30,750	24,000	21,000	18,000	16,500	14,800	
1500	18,500	14,800	13,300	11,800	11,200	10,250	
1650	11,000	9,000	8,000	7,000	6,500	5,800	
1800	6,300	4,900	4,300	3,750	3,300	2,800	

TABLE II (continued)

Temperature	Stress for Rupture or Indicated Total Deformation in Specified Time Periods						
	1 hr	5 hrs	10 hrs	25 hrs	50 hrs	100 hrs	300 hrs
			0.2% Total Deformation Strength (psi)				
1200	31,500	29,500	28,800	26,500	21,700	17,000	
1350	24,200	17,200	15,000	12,300	10,000	8,000	
1500	15,000	11,500	10,200	9,000	8,000	7,200	
1650	9,200	7,250	6,800	6,100	5,600	5,100	
1800	5,300	4,100	3,600	3,000	2,800	2,500	
			0.1% Total Deformation Strength (psi)				
1200							
1350	14,000	8,200	(6,100)				
1500	10,400	7,500	(6,100)				
1650	(8,200)	6,100	5,600	(5,000)			
1800	(4,600)	3,600	3,200	2,700	2,500	(2,200)	

(   ) Extrapolated Value

TABLE III

RUPTURE AND TOTAL DEFORMATION STRENGTHS OBTAINED AT 1200°, 1350°, 1500° 1650°, AND 1800°F ON HASTELLOY X SHEET MATERIAL, HEAT X1037, COMPARED WITH DATA PUBLISHED BY HAYNES STELLITE COMPANY

Test Temp (°F)	Rupture or Total Deformation Strengths for Indicated Time Periods					
	10 hours		50 hours		100 hours	
	X1037	Haynes	X1037	Haynes	X1037	Haynes
			Rupture Strength			
1200	60,000	58,000			44,000	42,000
1350	37,500	36,000			22,500	26,000
1500	21,500	21,000			14,500	14,000
1650	11,500	12,000			7,800	8,300
1800	7,000	7,000			4,000	3,400
			2% Total Deformation Strength			
1200	43,200	50,000	36,600	40,000	33,200	35,000
1350	27,300	28,000	21,300	23,000	19,500	21,000
1500	16,500	17,500	13,400	14,000	12,500	13,000
1650	9,600	9,000	7,500	6,500	6,700	5,800
1800	5,200	4,600	4,000	3,700	3,500	2,700
			1% Total Deformation Strength			
1200	38,000	45,000	33,600	35,000	29,800	30,000
1350	23,700	26,000	18,800	20,000	17,000	18,500
1500	15,000	15,000	12,600	12,000	11,750	11,000
1650	8,700	8,000	6,900	5,700	6,200	5,000
1800	4,800	4,200	3,700	2,800	3,200	2,400
			0.5% Total Deformation Strength			
1200	35,000	37,000	29,200	28,000	25,000	25,000
1350	21,000	22,000	16,500	15,000	14,800	13,000
1500	13,300	12,500	11,200	10,000	10,250	9,000
1650	8,000	7,000	6,500	5,000	5,800	4,400
1800	4,300	3,600	3,300	2,400	------	------
			0.2% Total Deformation Strength			
1200	28,800	29,000	21,700	20,000	17,000	17,000
1350	15,000	16,000	10,000	10,000	8,000	8,500
1500	10,200	10,000	8,000	7,000	7,200	6,000
1650	6,800	5,100	5,600	3,600	5,100	3,200
1800	3,600	2,700	2,800	1,800	------	------

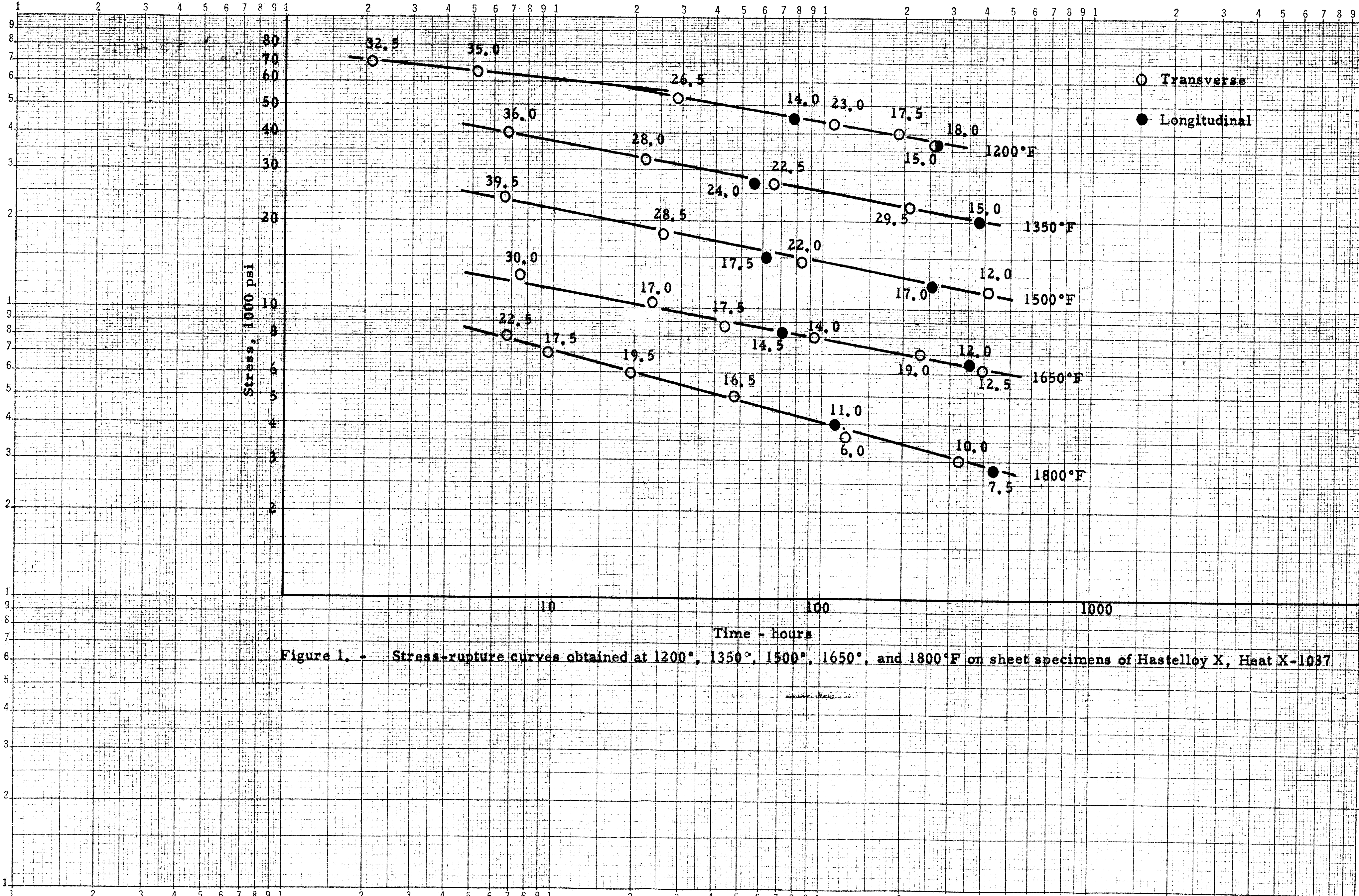

Figure 1. - Stress-rupture curves obtained at 1200°, 1350°, 1500°, 1650°, and 1800°F on sheet specimens of Hastelloy X, Heat X-1037

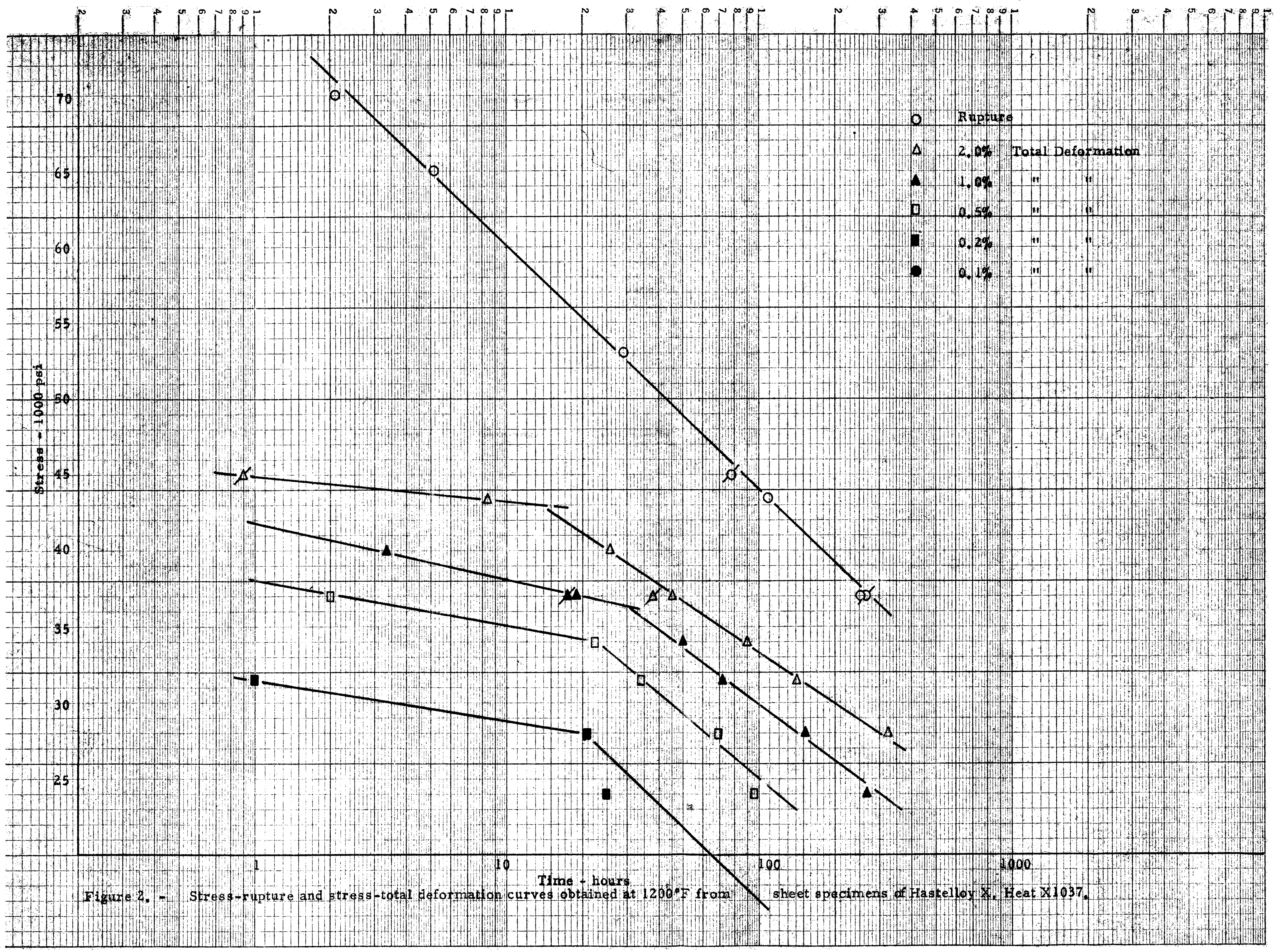

Figure 2. - Stress-rupture and stress-total deformation curves obtained at 1200°F from sheet specimens of Hastelloy X, Heat X1037.

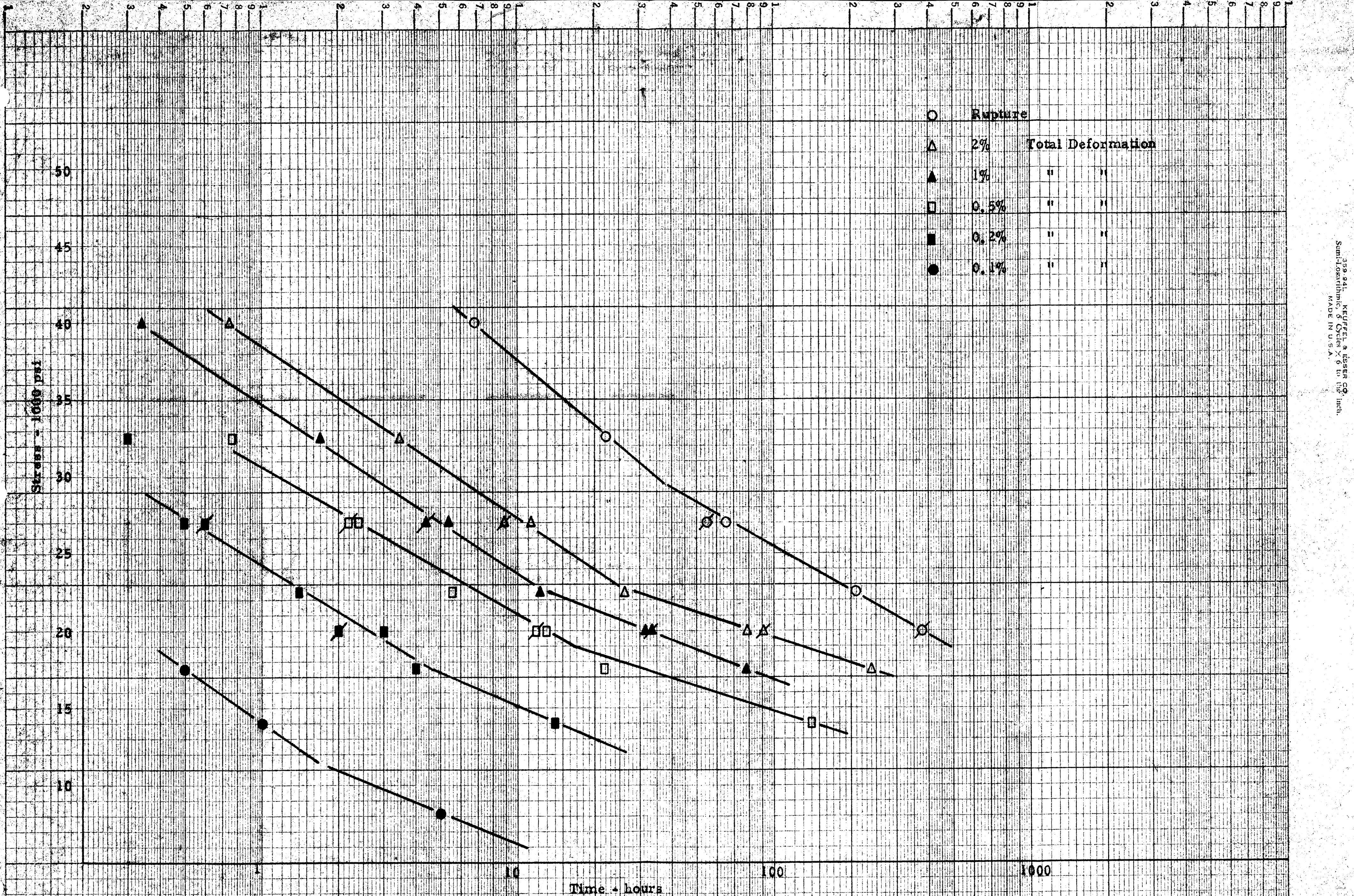

Figure 3. - Stress-rupture and stress-total deformation time curves obtained at 1350°F for sheet specimens of Hastelloy X, Heat X1037.

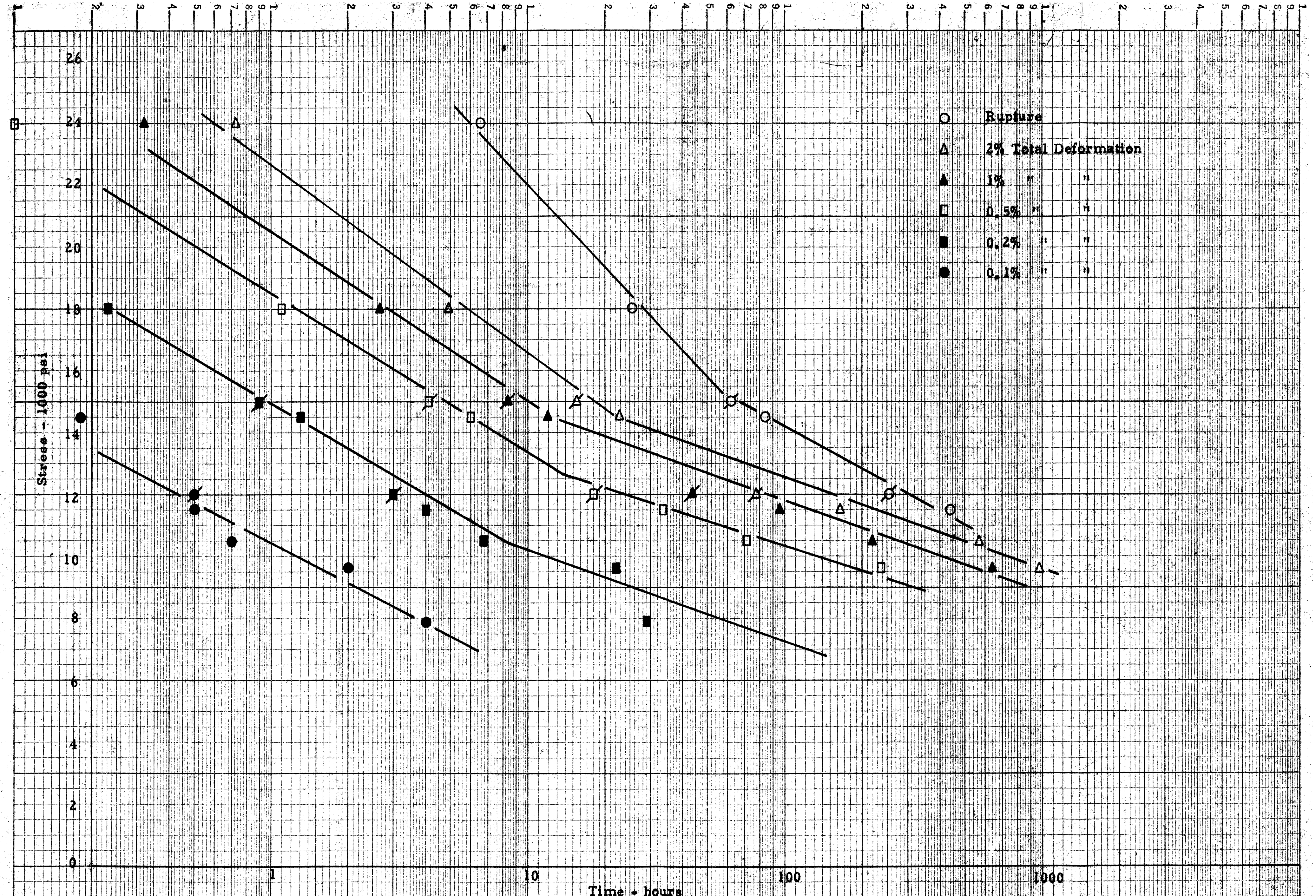

Figure 4. - Stress-rupture and stress-total deformation time curves obtained at 1500°F for sheet specimens of Hastelloy X, Heat X1037.

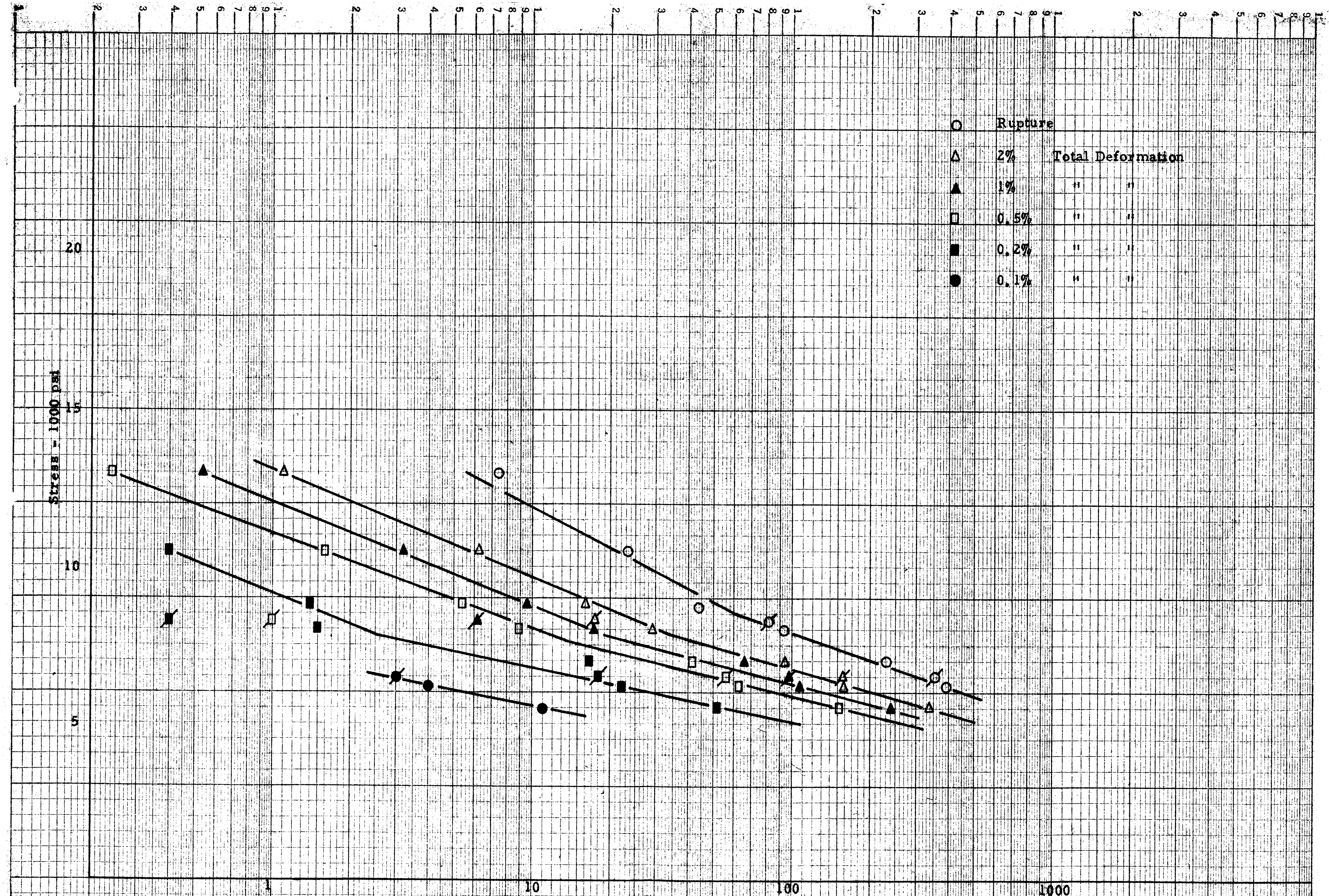

Figure 5. - Stress-rupture and stress-total deformation time curves obtained at 1650°F for sheet specimens of Hastelloy X, Heat X1037.

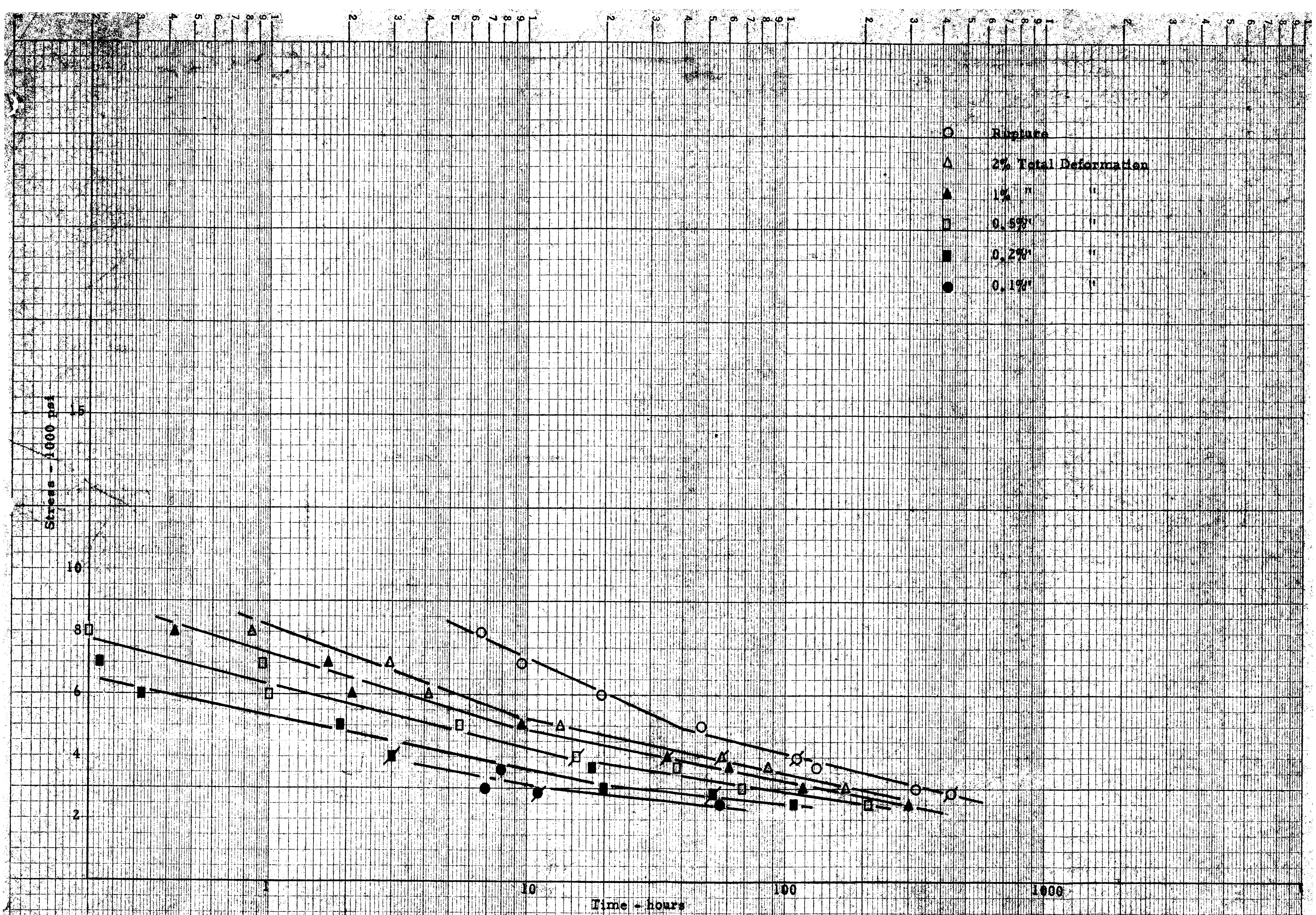

Figure 6. - Stress-rupture and stress-total deformation time curves obtained at 1800°F for sheet specimens of Hastelloy X, Heat X1017.

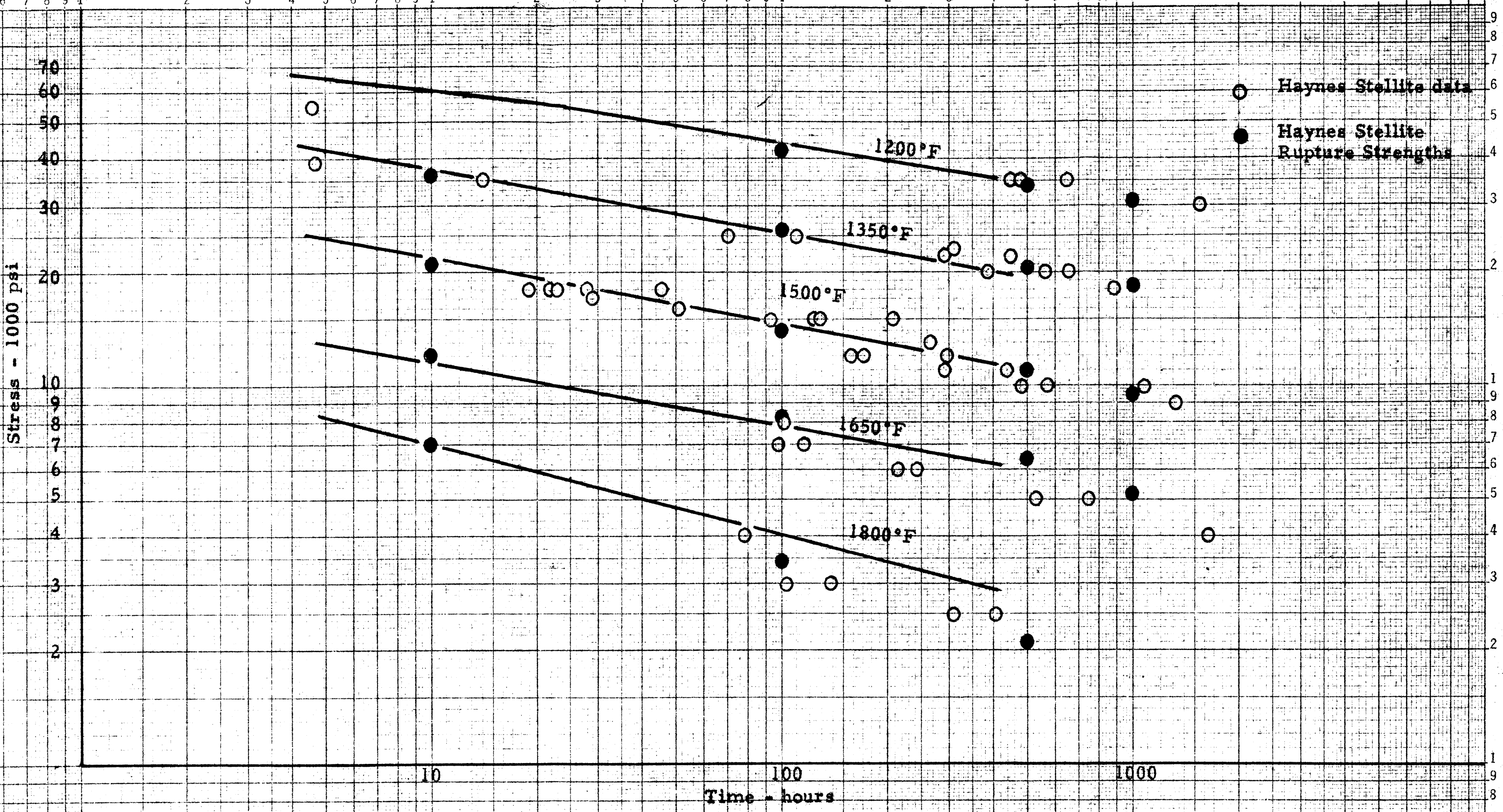

Figure 7. - Stress-rupture time curves at 1200°, 1350°, 1500°, 1650°, and 1800°F for Hastelloy X, Heat X1037, with data points and rupture strengths from Haynes Stellite Company.

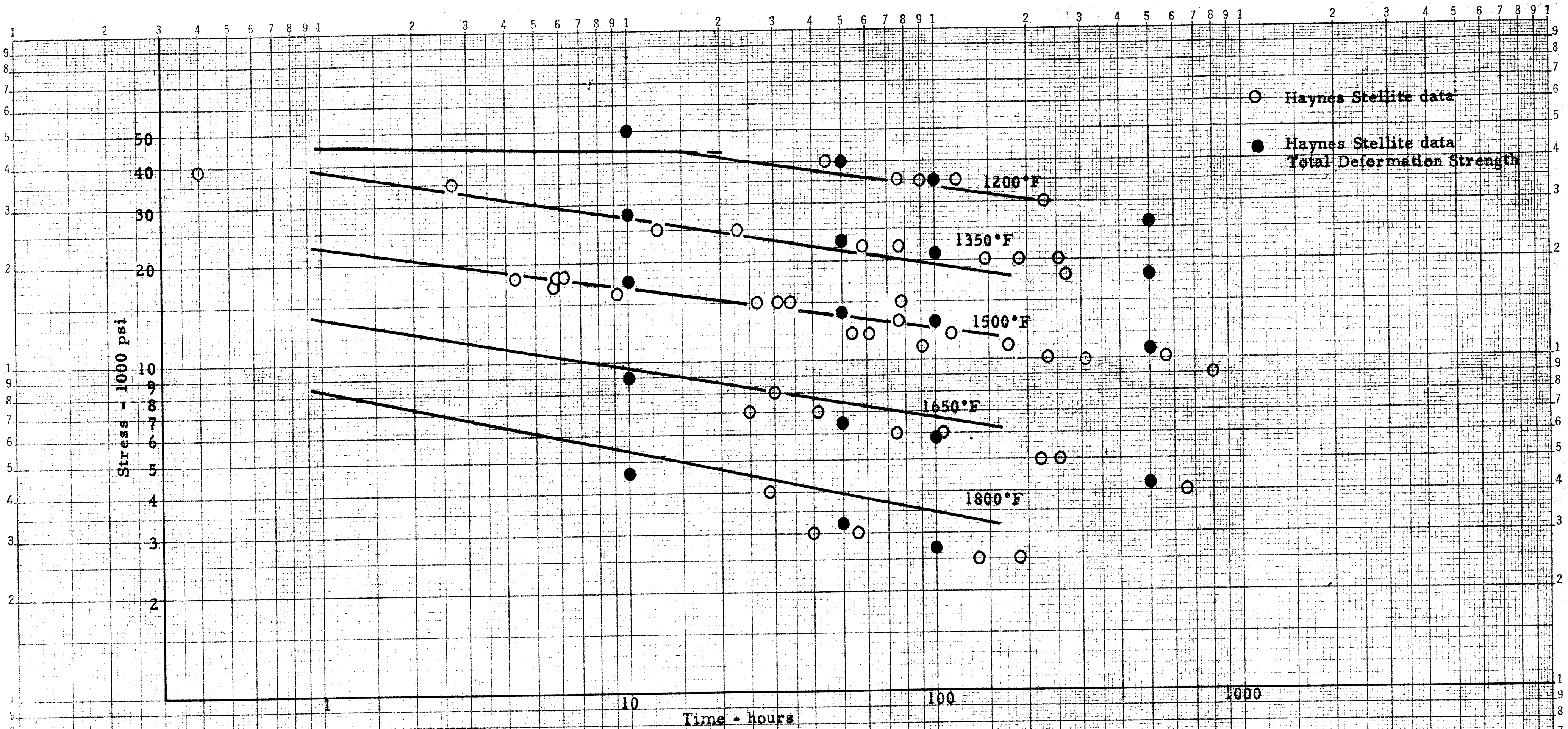

Figure 8. - Stress - 2% total deformation time curves at 1200°, 1350°, 1500°, 1650°, and 1800°F for Hastelloy X, Heat X-1037, with data points and total deformation strengths from Haynes Stellite Company.

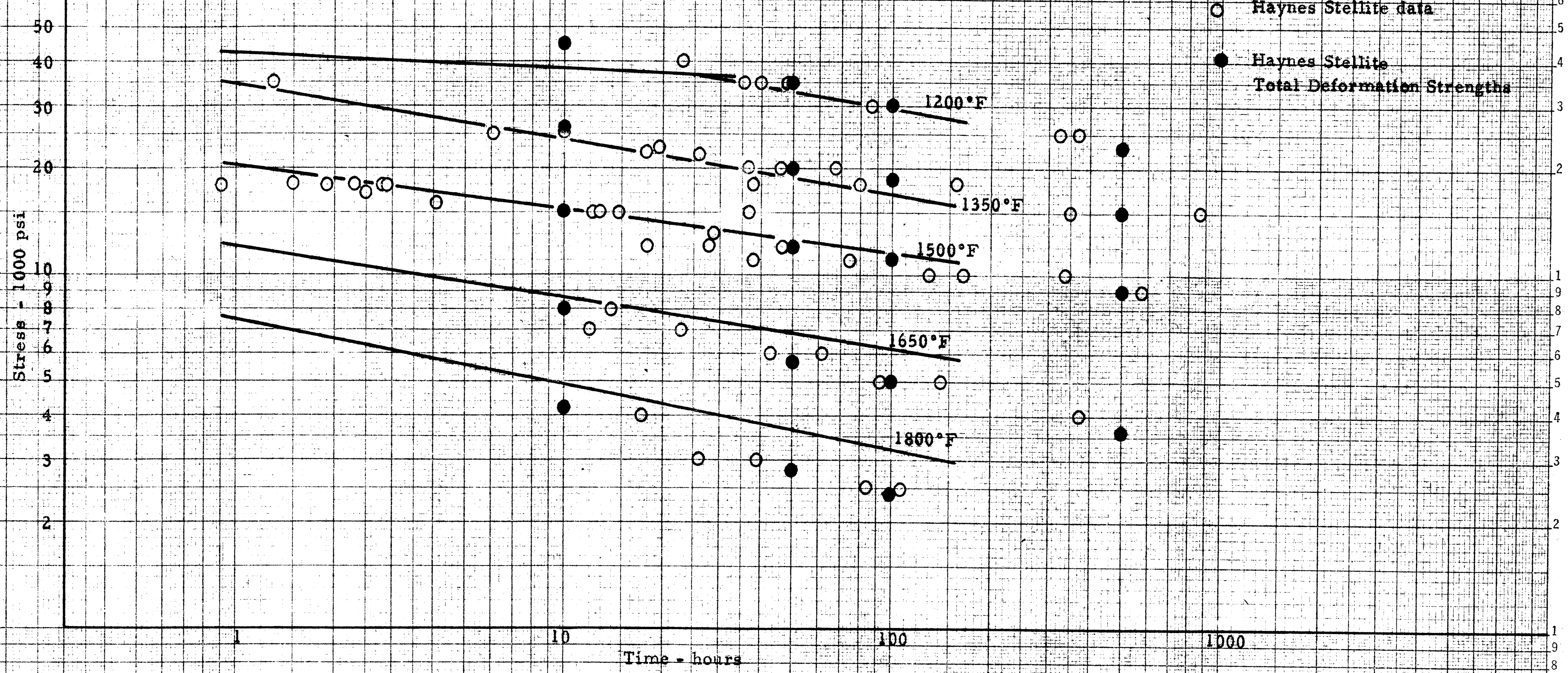

Figure 9.4 Stress - 1% total deformation time curves at 1200°, 1350°, 1500°, 1650°, and 1800°F for Hastelloy X, Heat X-1037, with data points and total deformation strengths from Haynes Stellite Company.

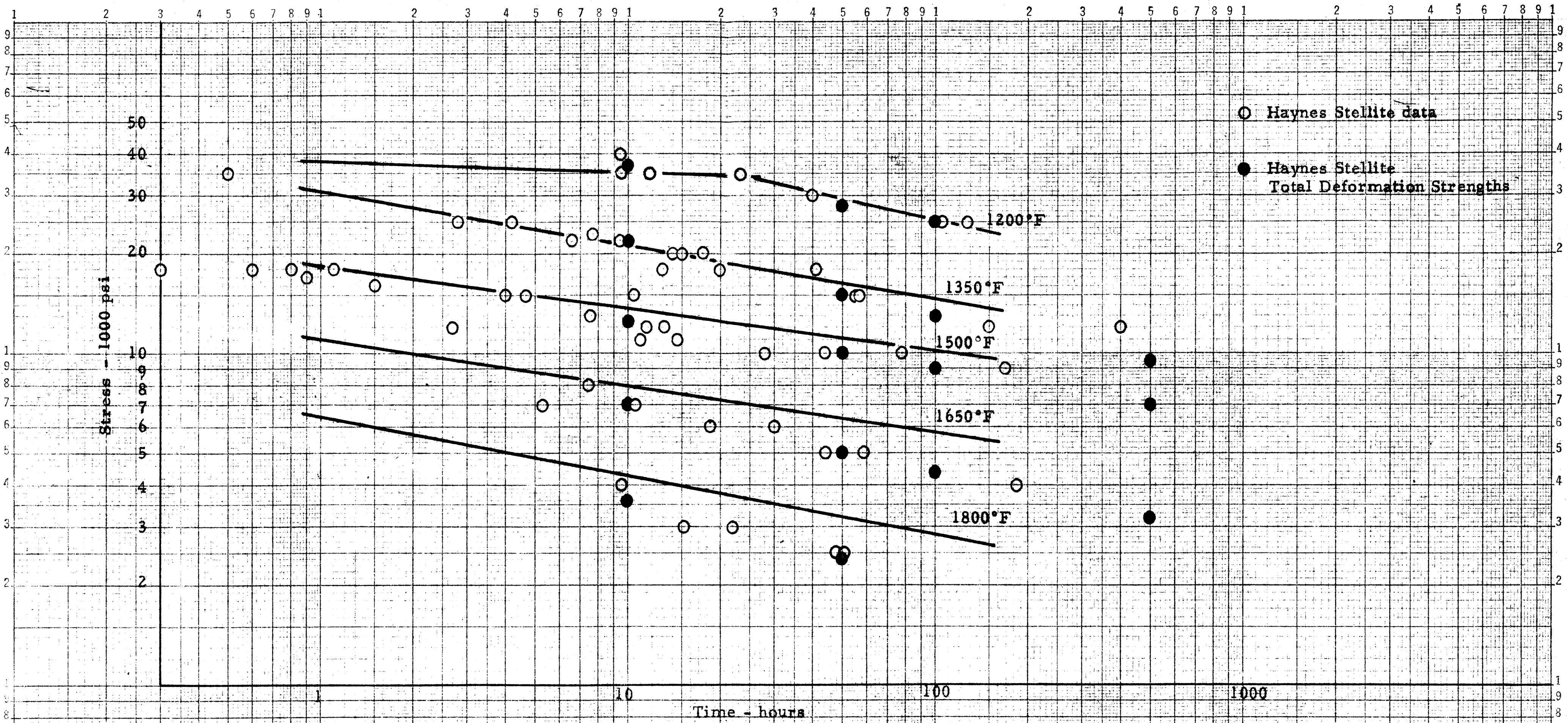

Figure 10. - Stress - 0.5% total deformation time curves at 1200°, 1350°, 1500°, 1650°, and 1800°F for Hastelloy X, Heat X-1037, with data points and total deformation strengths from Haynes Stellite Company.

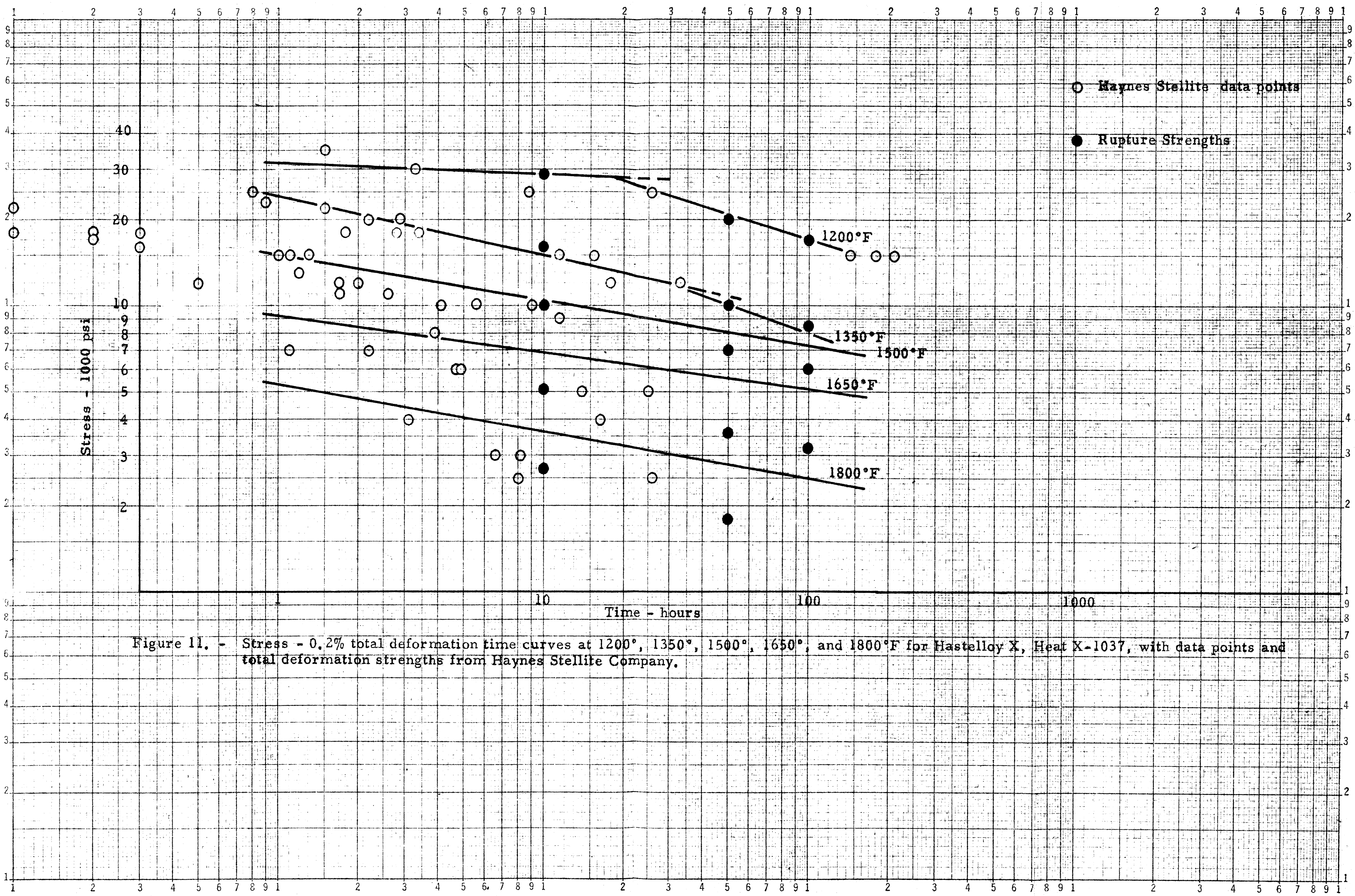

Figure 11. - Stress - 0.2% total deformation time curves at 1200°, 1350°, 1500°, 1650°, and 1800°F for Hastelloy X, Heat X-1037, with data points and total deformation strengths from Haynes Stellite Company.

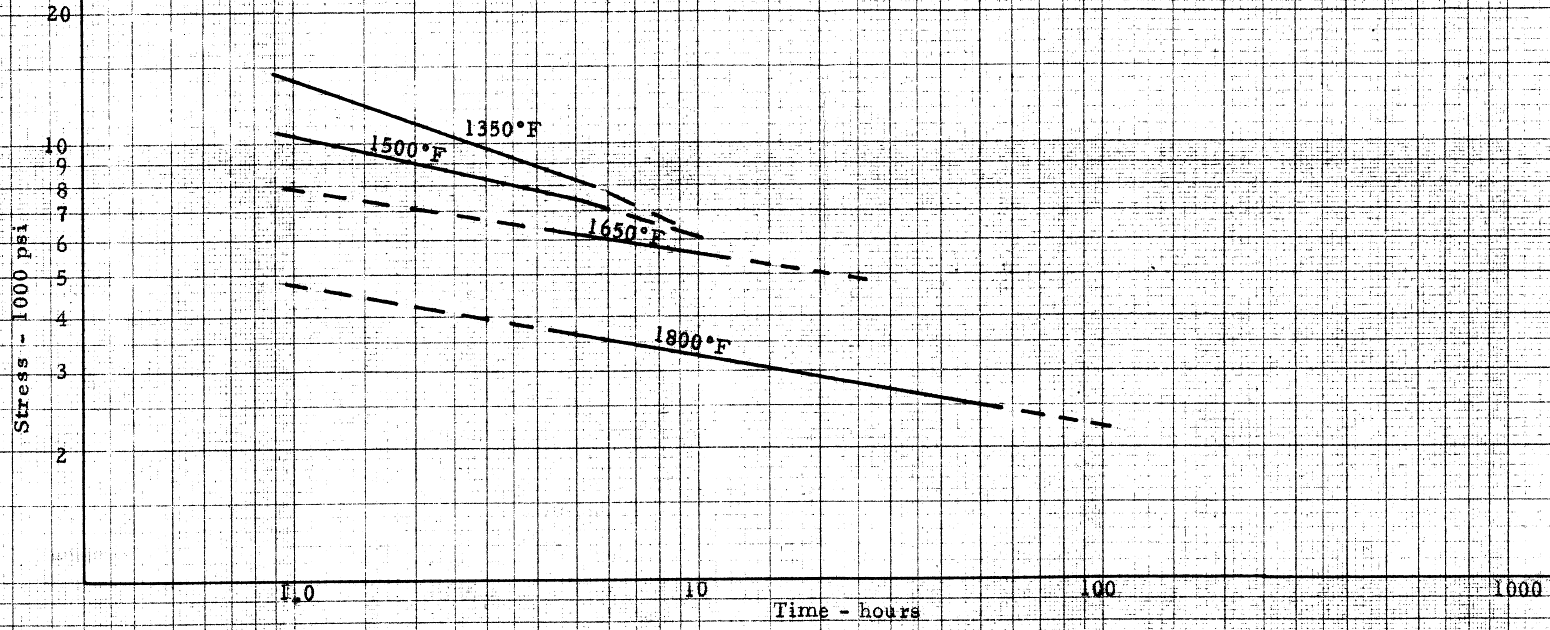

Figure 12. - Stress - 0.1% total deformation in time curves at 1350°, 1500°, 1650°, and 1800°F for Hastelloy X, Heat X-1037.

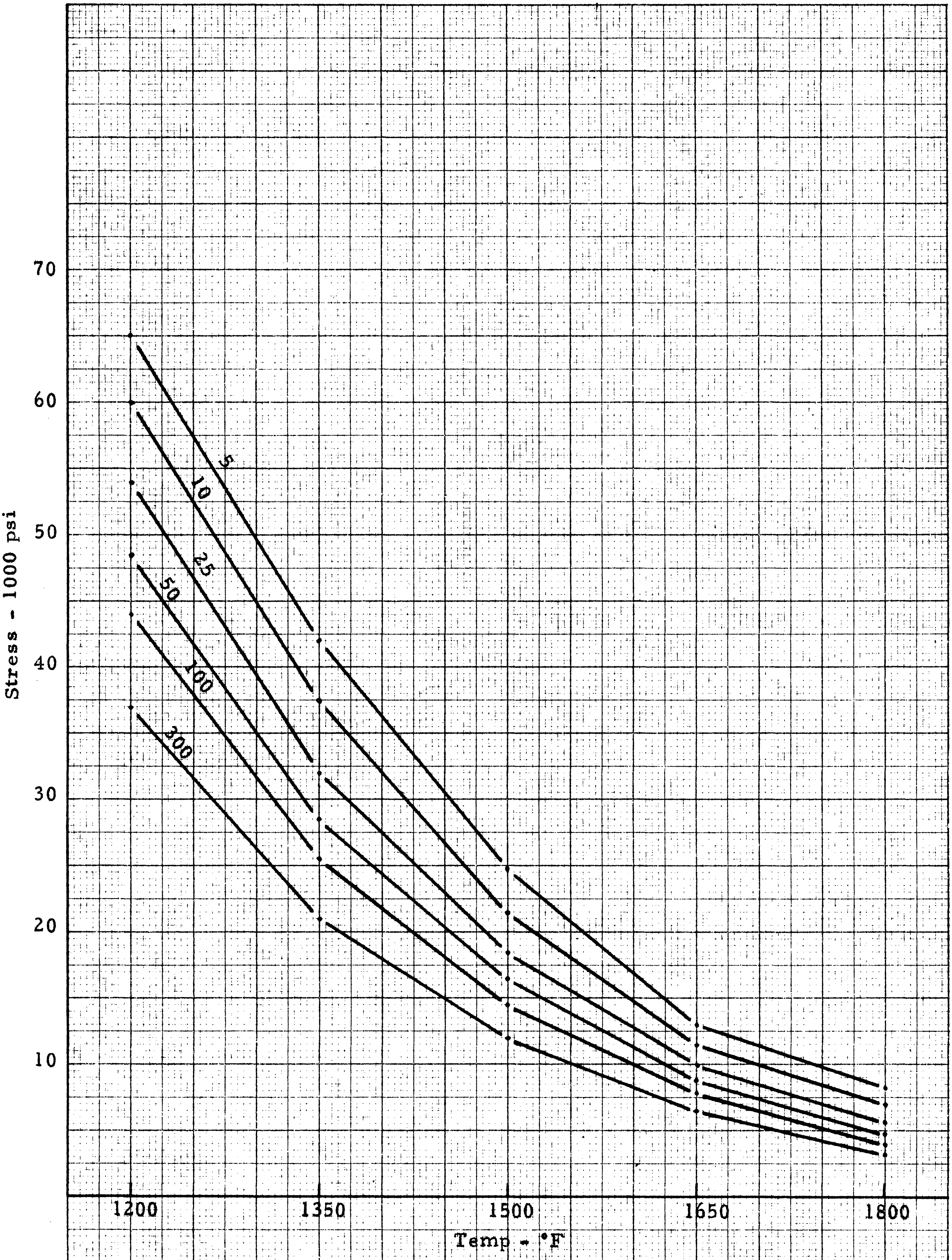

Figure 13. - Summary of rupture strengths for Hastelloy X sheet material (Heat X-1037) at 1200°, 1350°, 1500°, 1650°, and 1800°F for time periods of 5, 10, 25, 50, 100, and 300 hours.

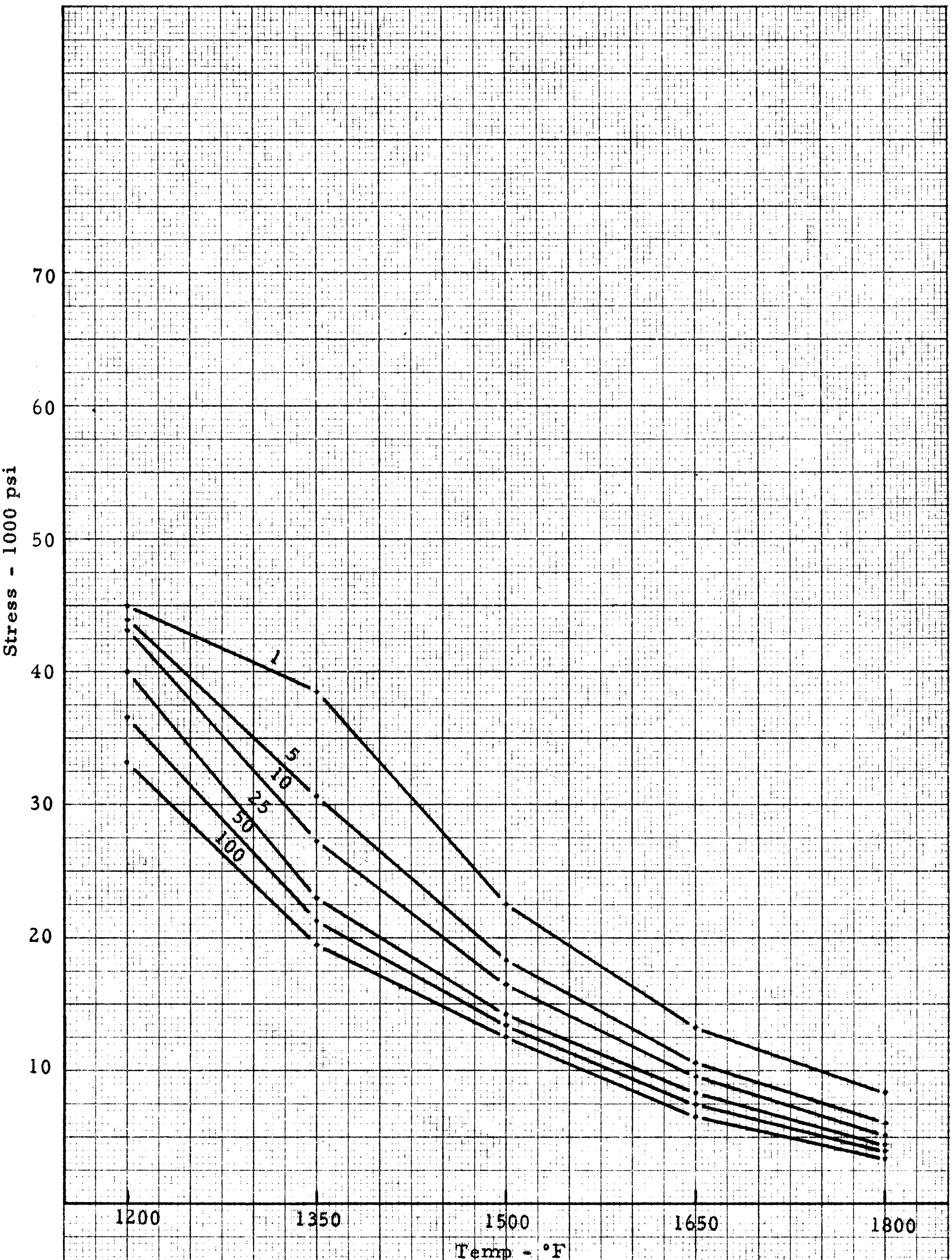

Figure 14. - Summary of 2.0 percent total deformation strengths for Hastelloy X sheet material (Heat X-1037) at 1200°, 1350°, 1500°, 1650°, and 1800°F for time periods of 1, 5, 10, 25, 50, and 100 hours.

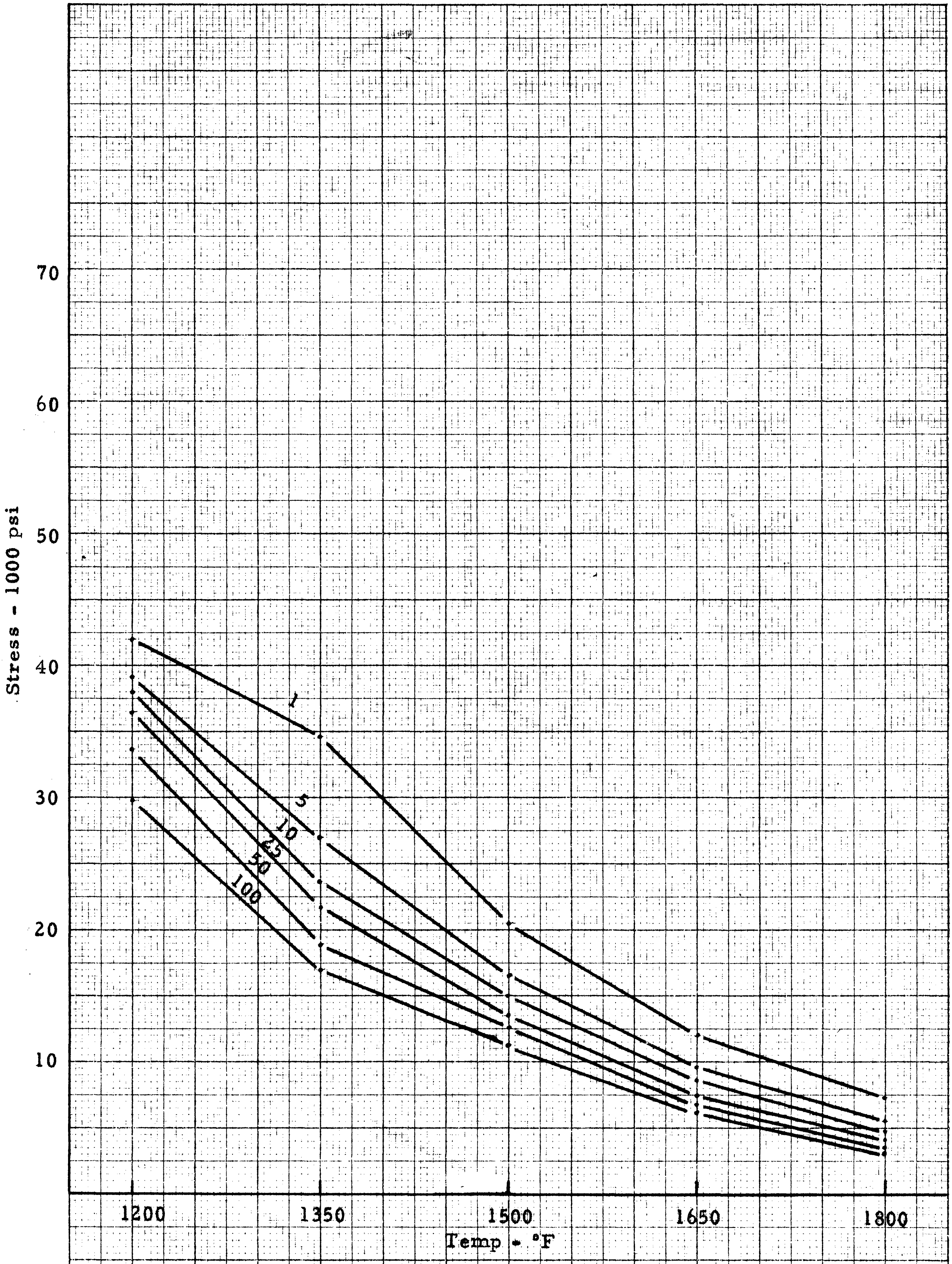

Figure 15. - Summary of 1.0 percent total deformation strengths for Hastelloy X sheet material (Heat X-1037) at 1200°, 1350°, 1500°, 1650°, and 1800°F for time periods of 1, 5, 10, 25, 50, and 100 hours.

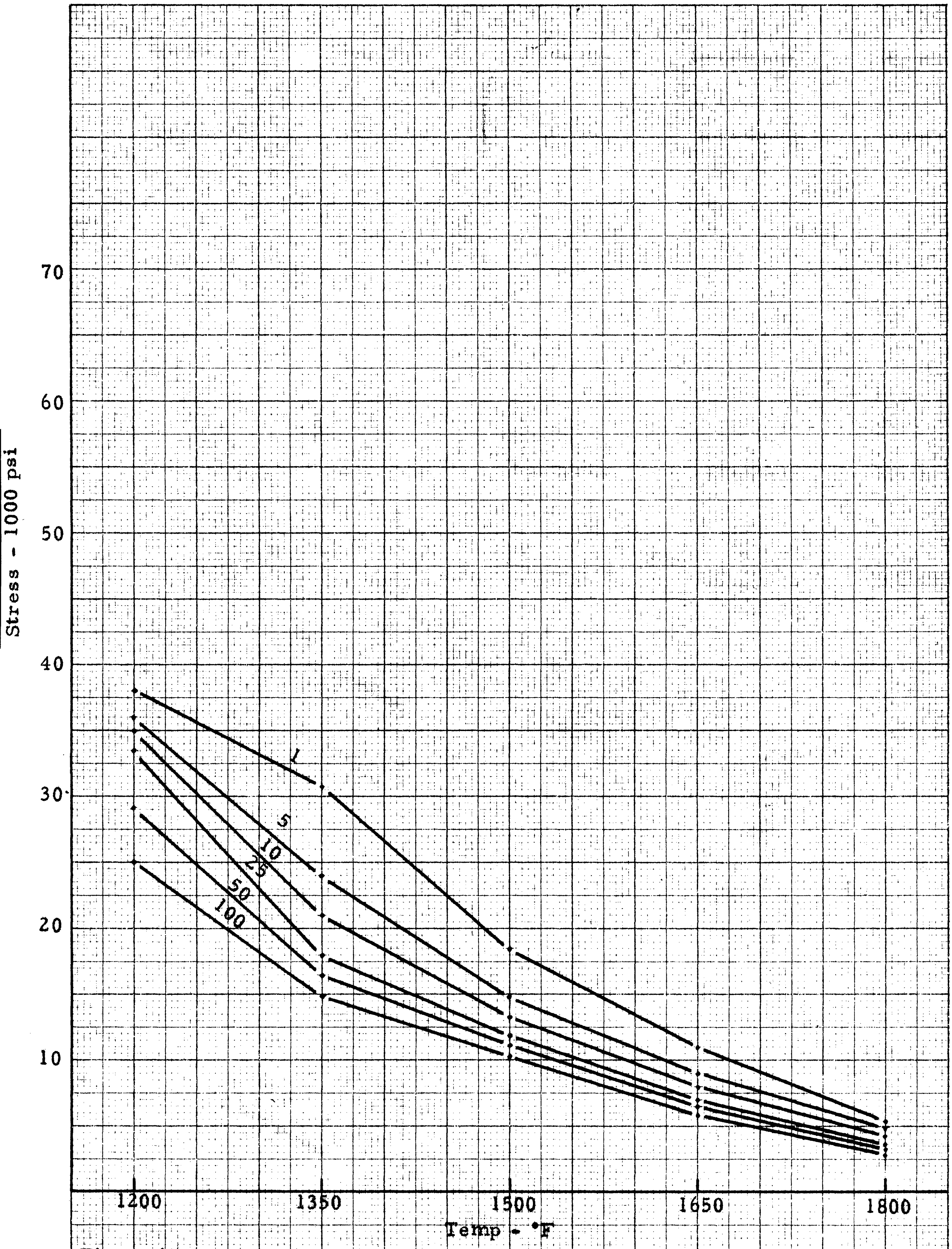

Figure 16. - Summary of 0.5 percent total deformation strengths for Hastelloy X sheet material (Heat X-1037) at 1200°, 1350°, 1500°, 1650°, and 1800°F for time periods of 1, 5, 10, 25, 50, and 100 hours.

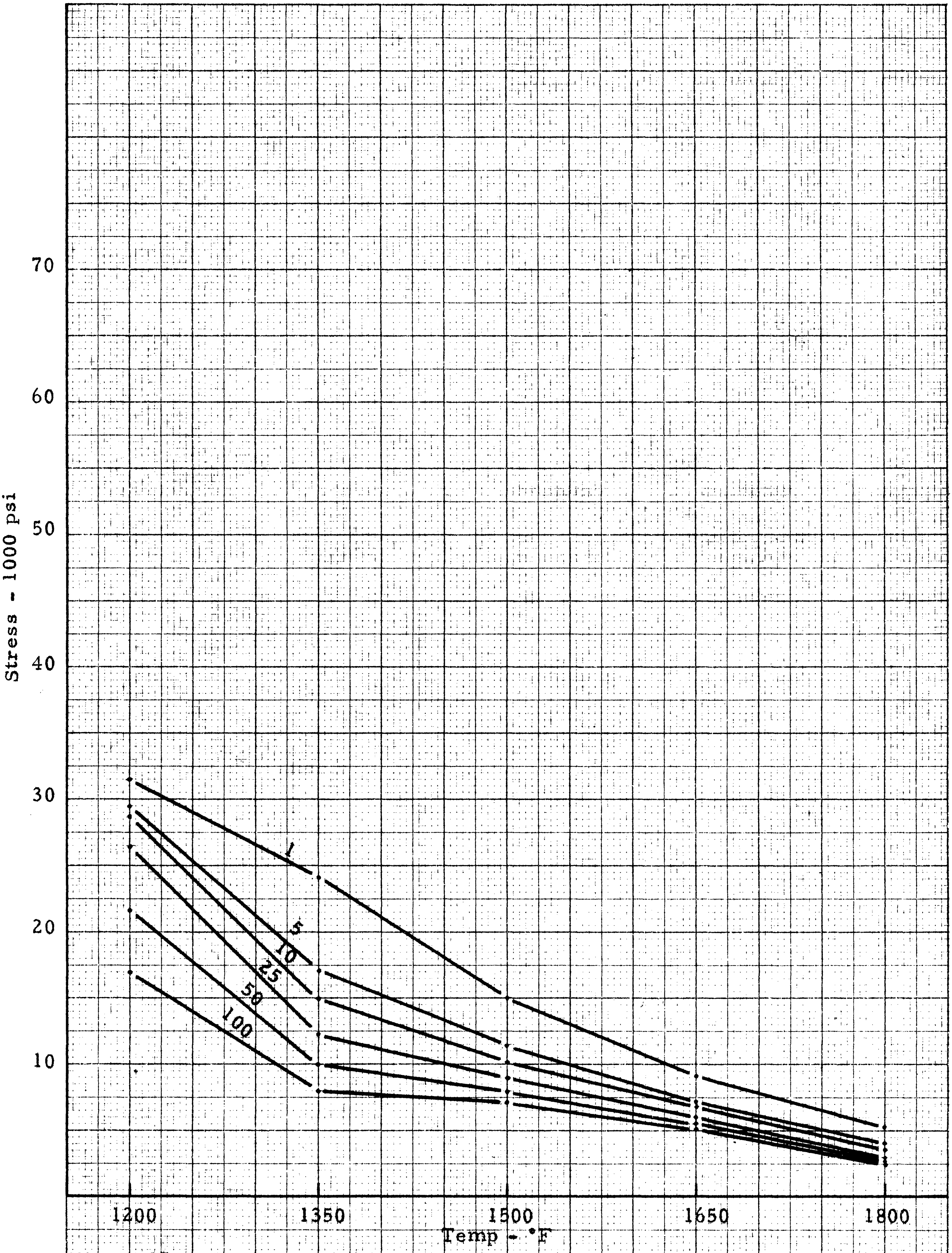

Figure 17. - Summary of 0.2 percent total deformation strengths of Hastelloy X sheet material (Heat X-1037) at 1200°, 1350°, 1500°, 1650°, and 1800°F for time periods of 1, 5, 10, 25, 50, and 100 hours.

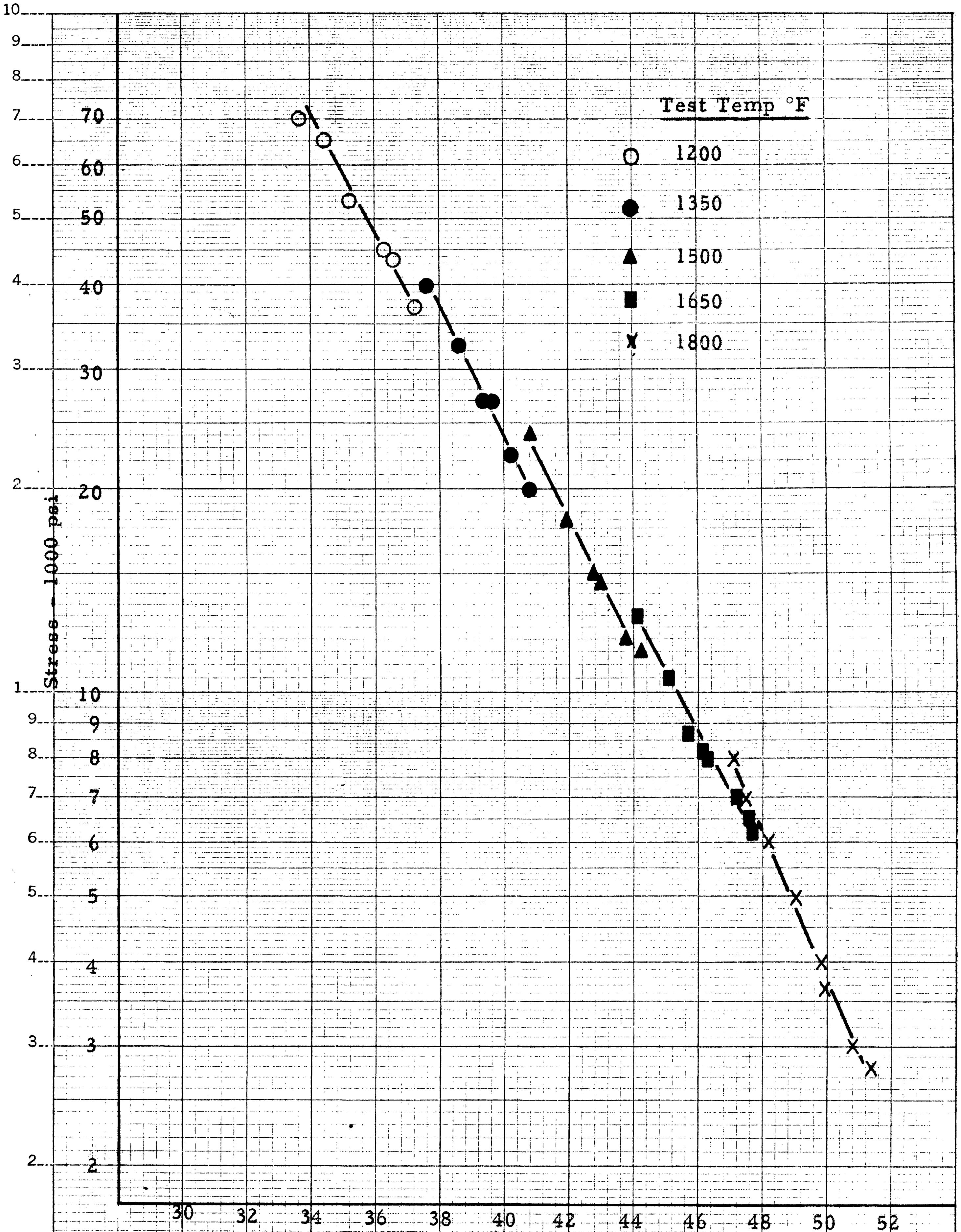

Figure 18. - Stress-time temperature parameter, $P = T(20 + \log t)$, curve for individual stress-rupture tests of Hastelloy X sheet material (Heat X-1037) at 1200°, 1350°, 1500°, 1650°, and 1800°F.

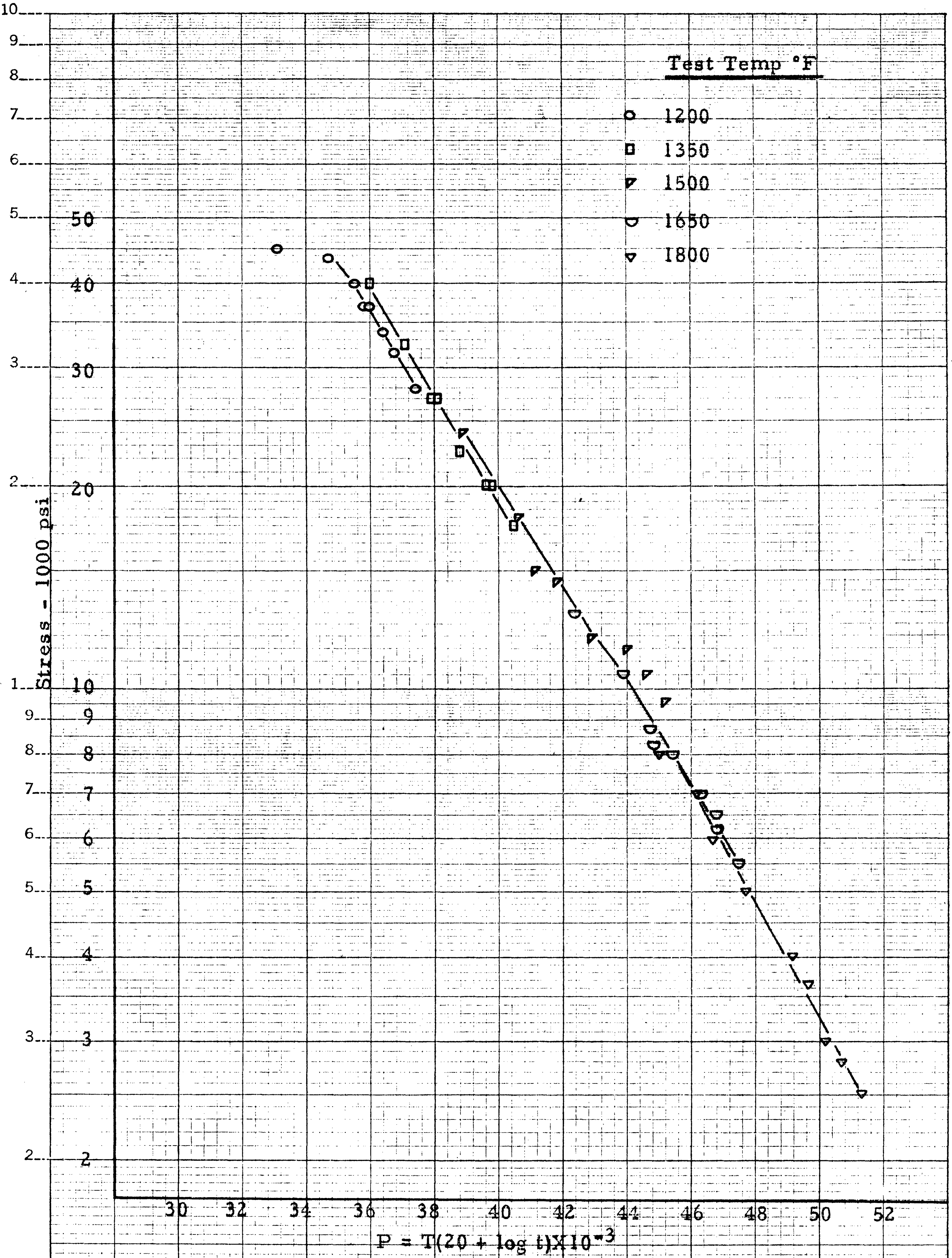

Figure 19. - Stress-time temperature parameter, $P = T(20 + \log t)$, curve for individual 2.0 percent total deformation times of Hastelloy X sheet material (Heat X-1037) at 1200°, 1350°, 1500°, 1650°, and 1800°F.

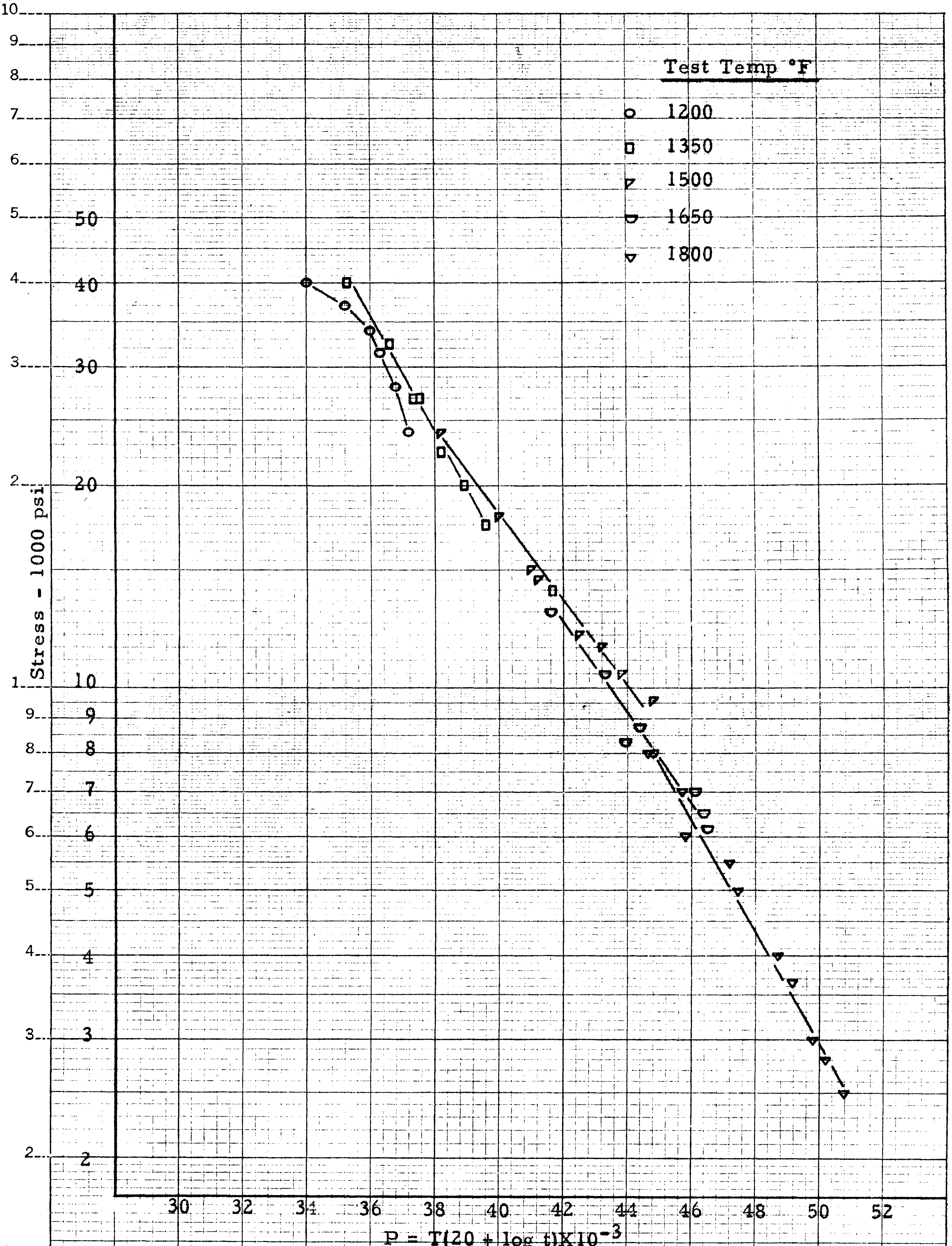

Figure 20. - Stress-time temperature parameter, P = T(20 + log t), curve for individual 1.0 percent total deformation times of Hastelloy X sheet material (Heat X-1037) at 1200°, 1350°, 1500°, 1650°, and 1800°F.

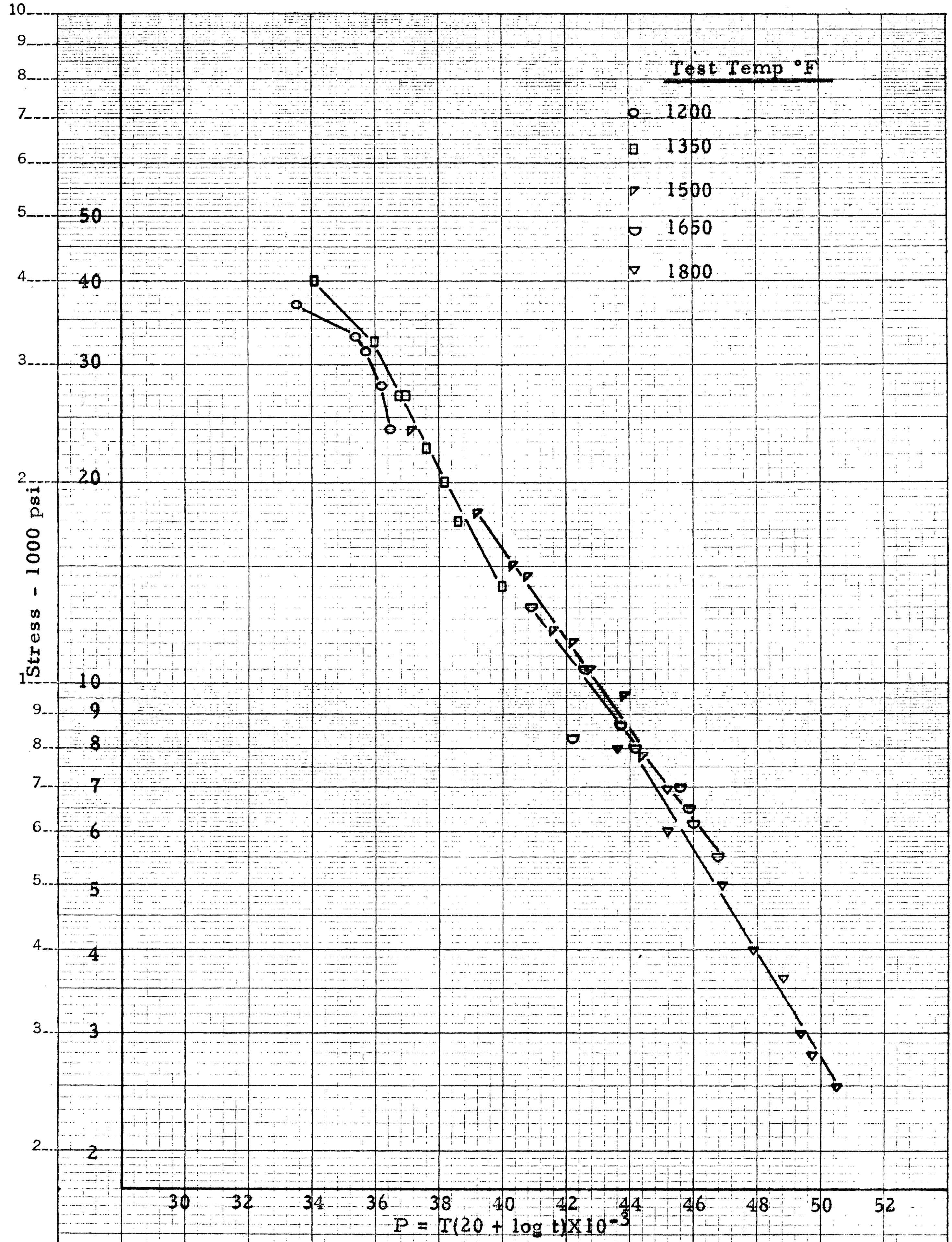

Figure 21. - Stress-time temperature parameter, $P = T(20 + \log t)$, curve for individual 0.5 percent total deformation times of Hastelloy X sheet material, Heat X-1037, at 1200°, 1350°, 1500°, 1650°, and 1800°F.

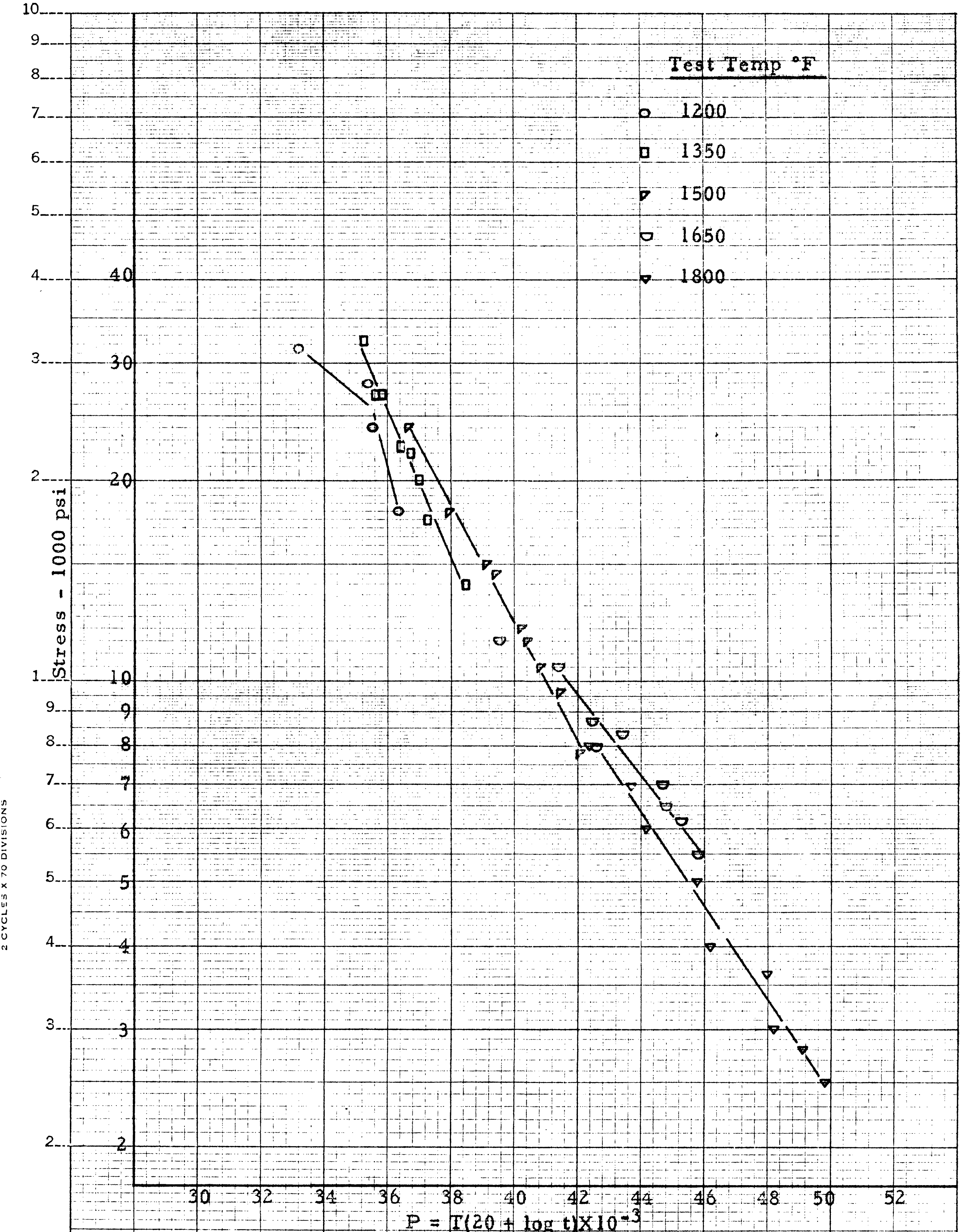

Figure 22. - Stress-time temperature parameter, P = T(20 + log t), curve for individual 0.2 percent total deformation times of Hastelloy X sheet material, Heat X-1037, at 1200°, 1350°, 1500°, 1650°, and 1800°F.