

SEVENTH PROGRESS REPORT  
TO  
MATERIALS LABORATORY, WRIGHT AIR DEVELOPMENT CENTER  
DEPARTMENT OF THE AIR FORCE  
ON  
FOUR LOW-ALLOY STEELS FOR ROTOR DISKS OF GAS TURBINES  
IN JET ENGINES

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SUMMARY

This report is the Seventh Progress Report on an investigation being carried out for the Materials Laboratory, Wright Air Development Center, Department of the Air Force, under Air Force Contract Number: AF 33 (038)-13496 (Expenditure Order Number: 605-227 SR-7)

The purpose of this investigation is to determine the effect of heat treatment upon the high temperature properties of four low-alloy steels, 4340, "17-22A"S, H-40, and C-422, in the form of forged J-33 jet engine disks, and to establish design data for each steel, heat treated to give the best practical properties. A concurrent investigation of the high temperature properties of the products of isothermal transformation of these four steels was carried out utilizing bar stock in order to define the relationship between structure and properties. Correlations involving relative properties of disks and bar stock and the results of the microstructural study were developed.

All creep-rupture testing of the normalized 4340 disk at 1000°F has been completed.

All three H-40 disks were retempered for 4 hours at 1250°F in order to reduce their hardness to 280 to 320 Brinell. A survey of the rupture properties at the rim of these retempered disk materials was carried out at 1100°F. The oil-quenched and tempered H-40 disk (No. 3) was selected for determination of design data at 1000°, 1100°, and 1200°F. This testing

is now in progress. Also, the tensile properties of this retempered disk material have been determined at room temperature, 1000°, 1100°, and 1200°F.

The results of the microstructural study, utilizing bar stock, indicate that the best high temperature strengths were exhibited by coarse bainitic structures for the 4340, "17-22A"S, and H-40 steels. In the case of a mixed structure of martensite and coarse bainite, increasing amounts of martensite resulted in poorer high temperature properties. Also, the presence of appreciable amounts of clear acicular ferrite (associated with the formation of coarse bainite) resulted in lower elevated temperature properties.

The results obtained in the disk investigation were in good agreement with those obtained in the bar stock study for the 4340 and "17-22A"S steels. The variation between the properties of the H-40 disk material and bar stock material could be attributed to differences in microstructure and grain size.

Because of the transformation characteristics of C-422 steel, only the normalized and oil-quenched structures were investigated in the bar stock. Both heat treatments yielded similar structures and similar high temperature properties. The results obtained in the disk study were in good agreement with those obtained in the bar stock study.

A more complete, detailed analysis of the correlative microstructural study of the bar stock and disk material will be presented in the final report on this investigation.

## INTRODUCTION

This report covers the progress made between 1 July 1952 and 30 September 1952 on an investigation of the high temperature properties of four low-alloy steels, 4340, "17-22A"S, H-40, and C-422, in the form of forged J-33 jet engine disks.

The objectives of this investigation are to determine the effect of heat treatment upon the high temperature properties of each of these four steels and to obtain design data at 1000°, 1100°, and 1200°F for the heat treated disk of each steel showing the best practical properties.

A concurrent investigation of the high temperature properties of the products of isothermal transformation for each of the four steels was carried out utilizing bar stock.

Correlations of the results of the disk study and the bar stock study were made in order to help explain the properties of the disks after various heat treatments.

## RESULTS

The results obtained to date are presented separately for each steel under (1) disk investigation, and (2) investigation of the properties of the products of isothermal transformation. The latter section includes brief summaries of the results of the microstructural study of the disk material and bar stock material.

## Disk Investigation

### 4340 STEEL

The last creep-rupture test at 1000°F and 24,000 psi on a surface plane tangential specimen at the rim of the normalized disk was completed with the following results:

Rupture Time (Hrs.)	Elongation in 2 in. (%)	Reduction of Area (%)	Time to Reach 1-Percent Total Deformation (Hrs.)	Time at Transition to Third Stage Creep (Hrs.)	Minimum Creep Rate (%/Hour)
635	3.5	2.4	470	320	0.0015

The results of the testing of disks 1, 3, and 4 were presented in the Sixth Progress Report.

### "17-22A" S AND C-422 STEELS

Creep-rupture testing of these two steels was completed in the 1 April to 30 June period and the results were presented in the Sixth Progress Report.

### H-40 STEEL

The survey at 1100°F of the rupture properties of the three disks retempered 4 hours at 1250°F has been completed, and the results are shown in Table I and figures 1 and 2. Disks No. 1 (normalized + tempered) and No. 3 (oil quenched + tempered) had similar high temperature strengths, but the oil-quenched and tempered disk exhibited better rupture-test ductility. Therefore, disk No. 3 was selected for further testing at 1000°, 1100°, and 1200°F. This testing is now in progress, and the results obtained to date are shown in Table I and figures 1 and 2.

The high temperature strengths of the H-40 bar stock, as-received disk materials, and retempered disk materials at 1100°F are shown in Table II.

The tensile properties of retempered (4 hours at 1250°F) disk No. 3 have been determined at room temperature, 1000°, 1100°, and 1200°F and are shown in Table III and figure 3.

Investigation of the Properties of the Products  
of Isothermal Transformation,

4340 STEEL

The results of the bar stock study show that the best high temperature properties can be obtained at 1000° and 1100°F with a coarse, upper bainite type of structure. Using the stress to cause 1-percent total deformation in 1000 hours at 1000°F as a basis of comparison, the strengths of the various structures were as follows:

<u>Heat Treatment and Structure</u>	<u>Strength (psi)</u>
1. Austenitize 1750°F + 28 hrs. at 850°F. 70% upper bainite + 30% martensite.	17,300
2. Austenitize 1750°F + 1-1/2 hrs. at 650°F. 100% lower bainite.	Approximately 13,300
3. Normalize 1750°F. 35% martensite + 65% upper and lower bainite.	13,300
4. Austenitize 1750°F + 10 hrs. at 1240°F. 35% ferrite + 65% medium pearlite.	Approximately 14,000
5. Oil quench 1750°F. 100% martensite.	11,500
6. Austenitize 1750°F + 111 hrs. at 1050°F 10% ferrite + 90% very fine carbide aggregate.	Less than 11,500

These structures were tempered to a Brinell hardness of 280 to 320 wherever necessary before testing.

The actual number of structures developed by isothermal treatment were very limited and consequently only outline the influence of micro-structure upon high temperature properties. Considering the limited data available, the results obtained in the bar stock study were in good agreement

with those obtained in the disk study. The 1000 hour 1-percent total deformation strengths at 1000°F for the three disks were as follows:

Disk No.	Heat Treatment	Strength (psi)
1	(a) Normalize 1750°F + temper 2 hrs. at 1200°F. (b) Normalize 1750°F. (15% martensite + 82% bainite + 3% ferrite)	20,500
3	(a) Oil quench 1750°F + temper 8 hrs. at 1200°F. (b) Oil quench 1550°F + temper at 1050°F. (85% tempered ground mass of martensite and bainites + 15% ferrite)	10,000
4	Interrupted-quench 1750°F + temper 2 hrs. at 1200°F. (Tempered ground mass of bainite. Very little evidence of tempered martensite. No free ferrite.)	21,000

The superiority of the normalized disk over the normalized and tempered bar stock was attributed to two factors, namely:

- (1) The disk test specimens were approximately 20 points Brinell harder than the bar stock test specimens.
- (2) The disk showed less martensite and lower bainite than the bar stock.

The superiority of the disk material over the isothermally transformed upper bainite bar stock was attributed to the fact that the disk showed less martensite than the bar stock.

The 1000-hour 1-percent total deformation strengths of the oil-quenched and tempered disk specimens and bar stock specimens were similar at 1000°F even though the structures involved were not similar. Although the structure of the oil-quenched and tempered disk showed appreciable amounts of what appeared to be a coarse bainite, it also showed about 15-percent of what appeared to be a supersaturated ferrite. The low strengths and high ductilities in the rupture test may be due to this ferritic structure.

The interrupted-quenched and tempered disk was superior to the isothermally transformed upper bainitic bar stock. The disk exhibited a structure which appeared to be entirely bainitic. The superiority of the disk material is attributed to the fact that very little martensite, if any, was present.

The upper pearlitic structure developed in the bar stock by holding 10 hours at 1240°F showed a good 1000-hour 1-percent total deformation strength at 1000°F. It is thought that at the stresses involved, the stability of the structure was the chief factor contributing to the strength exhibited, but that at higher stresses using different criteria for comparison (creep strength or rupture strength), the upper pearlitic structure would not show up as good because of its inherent weak strength. This fact was observed in the case of "17-22A" S upper pearlitic bar stock material.

The lower pearlitic structure developed in the bar stock by holding 111 hours at 1050°F showed very poor high temperature properties. Examinations of the microstructure of this material before and after testing showed that the material spheroidized rapidly during testing at 1000°F.

A more complete analysis of the structure-property correlation between the disk and bar stock materials, including photomicrographs, will be presented in the final report.

#### "17-22A" S STEEL

The results of the bar stock study indicate that a coarse bainitic structure produces the highest 1000-hour 1-percent total deformation strength at 1100°F. Using the 1000-hour 1-percent total deformation strengths at 1100°F as a basis for comparison, the isothermal structures studied had the following strengths:



<u>Heat Treatment and Structure</u>	<u>Strength (psi)</u>
1. Normalize 1750°F. 15% martensite + 85% coarse bainite.	19,000
2. Austenitize 1750°F + 1-1/2 hrs. at 1300°F. 55% ferrite + 45% medium pearlite.	16,000
3. Austenitize 1750°F + 5 min. at 700°F. 95% lower bainite + 5% ferrite.	15,500
4. Oil quench 1750°F. 98% martensite + 2% ferrite.	15,000
5. Austenitize 1750°F + 2 hrs. at 900°F. 40% martensite + 60% upper bainite and acicular ferrite.	14,000
6. Austenitize 1750°F + 10 hrs. at 1150°F. 60% ferrite + 40% fine pearlite.	Less than 14,000

These structures were tempered to a Brinell hardness of 280 to 320 before testing wherever necessary.

Considering the behavior of the normalized bar stock, it appears that the poor strength of the upper bainitic bar stock developed by holding for 2 hours at 900°F, results from the large amounts of martensite and clear acicular ferrite present.

Although the upper pearlitic structure, developed by holding for 1-1/2 hours at 1300°F, had a fairly high 1000-hour 1-percent total deformation strength (16,000 psi) at 1100°F, subsequent testing at 19,000 psi and 1100°F showed this structure to have a poorer creep strength and rupture strength than all of the other structures tested except the fine pearlite + ferrite structure.

The tempered lower pearlitic structure, developed by holding for 10 hours at 1150°F, had very poor properties at 1100°F. Testing at 1100°F produced rapid spheroidization of this structure.

The 1000-hour 1-percent total deformation strengths of the three disks at 1100°F were as follows:

Disk No.	Heat Treatment	Strength (psi)
1	Normalize 1750°F + temper 2 hrs. at 1200°F. (Ferrite + medium pearlite + tempered constituent).	14,000
2	Oil Quench 1750°F + temper 8 hrs. at 1200°F. (Tempered ground mass of martensite and upper and lower bainites).	19,000
4	Interrupted-quench 1750°F + temper 2 hrs. at 1200°F + temper 2 hrs. at 1200°F. (Tempered ground mass of mostly upper bainite and probably some martensite and lower bainite).	20,500

The normalized and tempered disk showed poorer properties than the normalized and tempered bar stock material. Examination of the disk showed that it did not harden upon heat treatment. The structure of the disk consisted of free ferrite, medium pearlite, and a tempered constituent. The high temperature properties of the disk were similar to those of the upper pearlitic bar stock, which had been developed by holding for 1-1/2 hours at 1300°F.

The oil-quenched and tempered disk had a higher 1000-hour 1-percent total deformation strength than the oil-quenched and tempered bar stock. The tempered disk showed large amounts of what appeared to be upper or coarse bainite, whereas the oil-quenched and tempered bar stock was 98 percent martensite.

The interrupted-quenched and tempered disk had the highest 1000-hour 1-percent total deformation strength at 1100°F. It exhibited a structure similar to that of the oil-quenched and tempered disk, except that it appeared to have somewhat higher percentages of coarse bainite present.

H-40 STEEL

The results of the bar stock study show that the highest 1000-hour 1-percent total deformation strength at 1100°F can be obtained with a coarse bainitic structure. The structures studied had the following 1000-hour 1-percent total deformation strengths at 1100°F:

<u>Heat Treatment and Structure</u>	<u>Strength (psi)</u>
1. Normalize 1950°F. 70% bainite + 30% martensite.	27,750
2. Oil quench 1950°F. 98% martensite + 2% ferrite.	23,250
3. Austenitize 1950°F + 10 hrs. at 750°F. 60% martensite + 40% acicular ferrite and bainite.	21,500

These structures were tempered to a Brinell hardness of 280 to 320 before testing.

The H-40 steel behaved similar to the 4340 and "17-22A" S steels. The best properties were obtained with a coarse bainitic structure with as little martensite and clear acicular ferrite present as possible.

The 1000-hour rupture strengths and 1-percent total deformation strengths at 1100°F of the three disks before and after tempering 4 hours at 1250°F were as follows:

<u>Disk No.</u>	<u>Heat Treatment</u>	<u>BHN</u>	<u>Rupture Strength (psi)</u>	<u>1-Percent Strength (psi)</u>
As-Received:				
1	Normalize 1950°F + temper 2 hrs. at 1200°F + temper 3 hrs. at 1200°F. (Tempered ground mass of martensite + bainite and acicular ferrite. Grain size was 1/5).	About 340	35,000	29,750
3	Oil quench 1950°F + temper 8 hrs. at 1200°F + temper 3 hrs. at 1200°F. (Tempered ground mass of martensite + bainite and acicular ferrite. Grain size was 1/4).	About 345	37,000	35,000

Disk No.	Heat Treatment	BHN	Rupture Strength (psi)	1-Percent Strength (psi)
4	Interrupted-quench 1950°F + temper 2 hrs. at 1200°F + temper 3 hrs. at 1200°F. (Tempered ground mass of martensite + bainite and acicular ferrite. Grain size was 1/4).	About 350	34,000	33,000
<u>After Re-tempering 4 hours at 1250°F:</u>				
1	- - - -	287/303	32,250	32,250
3	- - - -	295/315	32,000	30,000
4	- - - -	287/311	32,250	29,000

The structures, hardnesses, and high temperature strengths of the three as-received disks were somewhat similar. The structures of the disk specimens and bar stock specimens were not comparable, and it was not possible to get a complete correlation of their respective properties. The superiority of the as-received disks as compared to the bar stock materials could be partially explained on the basis of two factors, namely:

- (1) The disk specimens were 25 to 40 points Brinell harder than the bar stock specimens.
- (2) The as-received disks exhibited a coarser grain size than the bar stock specimens.

Retempering the disks for 4 hours at 1250°F produced the following effects:

- (1) Reduced the hardness of all three disks to 280 to 320 Brinell.
- (2) Reduced the 1000-hour rupture strengths at 1100°F for all three disks.
- (3) Reduced the 1000-hour 1-percent total deformation strengths at 1100°F of disks Nos. 3 and 4, but increased this strength of disk No. 1.

- (4) Improved the rupture test ductility of all three disks. The elongation values obtained in rupture testing at 1100°F before and after tempering at 1250°F were as follows:

<u>Disk No.</u>	<u>Elongation in 2-inches</u>	
	<u>Before Tempering</u>	<u>After Tempering</u>
1	1.3% - 8.3%	2.3% - 10.5%
3	1.0% - 3.1%	4.5% - 17.0%
4	1.3% - 5.6%	2.5% - 10.5%

### C-422 STEEL

Because of the transformation characteristics of this steel, only the normalized and the oil-quenched structures were tested in the bar stock study. The structures developed were very similar, and the 1000-hour 1-percent total deformation strengths at 1100°F were as follows:

<u>Heat Treatment and Structure</u>	<u>Strength (psi)</u>
1. Normalize 1900°F. 98% martensite + 2% white etching spheroids.	28,750
2. Oil quench 1900°F. 98% martensite + 2% white etching spheroids.	30,000

Both structures were tempered to a Brinell hardness of 280 to 320 before testing.

The 1000-hour 1-percent total deformation strengths at 1100°F of the two C-422 disks were as follows:

<u>Disk No.</u>	<u>Heat Treatment</u>	<u>Strength (psi)</u>
1	(a) Normalize 1900°F + temper 2 hrs. at 1200°F. (b) Full anneal 6 hrs. at 1600°F Normalize 1900°F + temper 2 + 2 hrs. at 1200°F.	29,000
4	(a) Oil quench 1900°F + temper 8 hrs. at 1200°F. (b) Full anneal 6 hrs. at 1600°F. Oil quench 1900°F + temper 2 + 2 hrs. at 1200°F.	30,000

The structures of these two disks differed somewhat. The structure of the normalized and tempered disk exhibited a heavy carbide network in a martensite matrix, whereas the oil quenched and tempered disk exhibited a more uniform martensite structure.

The results obtained in the disk investigation were in very good agreement with those obtained in the bar stock study.

### FUTURE WORK

The creep-rupture testing of H-40 disk No. 3 at 1000°, 1100°, and 1200°F will be continued in order to accumulate the additional required design data.

When the testing of the H-40 disk is completed, a final report covering this investigation will be issued. This report will include a more complete analysis, including photomicrographs, of the structure-property correlation between the disk and the bar stock materials.

TABLE I

## Creep-Rupture Test Data for the Retempered H-40 Disks at 1000°, 1100°, and 1200°F

Spec. No.	Specimen Location (a)	Test Temp. (°F)	Stress (psi)	Rupture Time (hrs.)	Elongation in 2 in. (%)	Reduction of Area (%)	Time to Reach Specified Total Deformations (hrs.)				Time at Start of Third Stage Creep (hrs.)	Minimum Creep Rate (%/hour)
							0.1%	0.2%	0.5%	1.0%		
Disk No. 1. Heat Treatment: N. 1950°F + T. 2 hrs. at 1200°F + T. 3 hrs. at 1200°F + T. 4 hrs. at 1250°F. BHN=287/303												
9W	SRR	1100	60,000	2.7	10.5	37.4	(d)	(d)	0.04	0.5	-	-
9X	CRR	1100	50,000 <sup>(b)</sup>	43	3.0	7.8	(d)	(d)	0.3	10.7	25	0.026
9Y	CRR	1100	45,000	81	2.7	6.2	(d)	(d)	5	53	68	0.0096
9Z	SRR	1100	34,000 <sup>(c)</sup>	735	2.3	4.3	(d)	1	219	652	520	0.001
Disk No. 3. Heat Treatment: O.Q. 1950°F + T. 8 hrs. at 1200°F + T. 3 hrs. at 1200°F + T. 4 hrs. at 1250°F. BHN=293/335												
8W	SRR	1000	65,000	(e)	-	-	-	-	-	-	-	-
9W	SRR	1100	60,000	10	17.0	50.0	(d)	(d)	0.1	1.4	-	0.285
9Y	CRR	1100	50,000	80	8.0	22.0	(d)	(d)	1.5	23	30	0.020
9X	CRR	1100	42,000 <sup>(b)</sup>	175	5.0	8.8	(d)	(d)	13	84	100	0.0066
5A <sup>(f)</sup>	SRR	1100	40,000	313	2.0	7.0	(d)	(d)	94	304 <sup>(g)</sup>	282	0.0016
9A <sup>(f)</sup>	SRC	1100	39,350	(e)	-	-	(d)	(d)	19	-	-	-
9Z	SRR	1100	36,000	514	4.5	10.0	(d)	2	71	280	280	0.0024
14Z	STR	1100	33,000	(e)	-	-	(d)	2	-	-	-	-
10Y	CRR	1100	28,000	(h)	-	-	(d)	16	-	-	-	-
10Z	SRR	1100	20,000	(h)	-	-	1	256	-	-	-	-
7W	SRR	1200	35,000	36	5.5	8.1	(d)	(d)	5.5	18	-	0.039
7X	CRR	1200	30,000	(e)	-	-	(d)	0.1	12	-	-	-
Disk No. 4. Heat Treatment: I.Q. 1950°F + T. 2 hrs. at 1200°F + T. 3 hrs. at 1200°F + T. 4 hrs. at 1250°F. BHN=287/311.												
9W	SRR	1100	60,000	2.9	10.5	40.2	(d)	(d)	0.03	0.8	0.7	0.38
9X	CRR	1100	50,000	70	4.5	8.2	(d)	(d)	1.5	26	55	0.020
9Y	CRR	1100	45,000	144	2.5	7.4	(d)	(d)	13	94	44	0.0084
9Z	SRR	1100	39,000	273	6.5	12.6	(d)	(d)	14	100	100	0.0056

- (a) SRR - Surface plane radial specimen at rim of disk  
 CRR - Central plane radial specimen at rim of disk  
 SRC - Surface plane radial specimen at center of disk  
 STR - Surface plane tangential specimen at rim of disk

- (b) Broke in gage mark  
 (c) Broke in fillet  
 (d) Specimen reached this deformation on loading  
 (e) Rupture test in progress  
 (f) 0.250-inch specimen  
 (g) Extrapolated value  
 (h) Creep test in progress

TABLE II

High Temperature Strengths of H-40 Bar Stock, As-Received Disk Materials, and Retempered Disk Materials At 1100°F

Material	Heat Treatment	BHN	Rupture Strengths (psi)				Stress to Cause 1-Percent Total Deformation at Indicated Times (psi)			
			1 hr.	10 hr.	100 hr.	1000 hr.	1 hr.	10 hr.	100 hr.	500 hr. 1000 hr.
<u>As-Received Disks.</u>										
Disk No. 1	N. 1950°F + T. 2 hrs. at 1200°F + T. 3 hrs. at 1200°F.	About 340	-	65,000	48,000	35,500	-	72,000	46,000	34,000 29,750
Disk No. 3	O. Q. 1950°F + T. 8 hrs. at 1200°F + T. 3 hrs. at 1200°F.	About 345	-	73,000	51,500	37,000	-	70,000	49,250	37,500 35,000
Disk No. 4	I. Q. 1950°F + T 2 hrs. at 1200°F + T. 3 hrs. at 1200°F.	About 350	-	73,500	50,000	34,000	-	72,000	49,000	37,000 33,000
<u>Retempered Disk Materials.</u>										
Disk No. 1	N. 1950°F + T. 2 hrs. at 1200°F + T. 3 hrs. at 1200°F + T. 4 hrs. at 1250°F.	287/303	64,500	55,000	44,000	32,250	57,000	49,500	41,500	35,000 32,250
Disk No. 3	O. Q. 1950°F + T. 8 hrs. at 1200°F + T. 3 hrs. at 1200°F + T. 4 hrs. at 1250°F.	295/315	73,000	60,000	48,500	32,000	62,000	53,000	41,000	33,000 30,000
Disk No. 4	I. Q. 1950°F + T. 2 hrs. at 1200°F + T. 3 hrs. at 1200°F + T. 4 hrs. at 1250°F.	287/311	63,500	56,000	47,500	32,250	59,500	52,000	42,500	33,000* 29,000*

Continued on next page



Table II (continued)

Material	Heat Treatment	BHN	Rupture Strengths (psi)				Stress to Cause 1-Percent Total Deformation at Indicated Times (psi)			
			1 hr.	10 hr.	100 hr.	1000 hr.	1 hr.	10 hr.	100 hr.	1000 hr.
Bar Stock	N. 1950°F + T. 18 hrs. at 1200°F.	312/320	-	-	-	30,000	-	-	-	27,750
Bar Stock	O.Q. 1950°F + T. 12 hrs. at 1200°F.	322	-	-	-	29,000*	-	-	-	23,250
Bar Stock	Aust. 1950°F + 10 hrs. at 750°F + T. 1 hr. at 1300°F.	308/313	-	-	-	31,000*	-	-	-	21,500

\* Extrapolated value.

TABLE III

Short Time Tensile Properties of Retempered H-40 Disk No. 3

Heat Treatment: O.Q. 1950°F + T. 8 Hrs. at 1200°F + T. 3 Hrs. at 1200°F + T. 4 Hrs. at 1250°F, BHN=295/333

Specimen Number	Specimen Location (a)	Test Temp. (°F)	Tensile Strength (psi)	Offset Yield Strengths (psi)		Proportional Limit (psi)	Elongation in 2 in. (%)	Reduction of Area (%)
				0.02%	0.1%	0.2%		
3W	SRR	Room	146,500	113,500	126,500	130,000	15.5	50.5
3X	CRR	Room	145,250	113,000	125,500	129,000	16.5	51.5
1Z	SRR	Room	155,000	120,000	133,500	139,000	13.5	44.0
1Y	CRR	1000	99,750	68,500	87,000	94,000	15.0	50.5
14W	STR	1000	96,750	70,000	86,500	92,250	19.0	61.0
3Y	CRR	1100	80,250	54,500	68,500	74,500	21.0	61.0
14X	CTR	1100	80,000	54,000	68,500	74,500	16.5	48.8
3Z	SRR.	1200	65,500	39,000	50,500	55,500	15.0	53.5
14Y	CTR	1200	63,750	39,750	52,000	58,000	16.0	47.8

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(a) SRR - Surface plane radial specimen at rim of disk  
 CRR - Central plane radial specimen at rim of disk  
 STR - Surface plane tangential specimen at rim of disk  
 CTR - Central plane tangential specimen at rim of disk

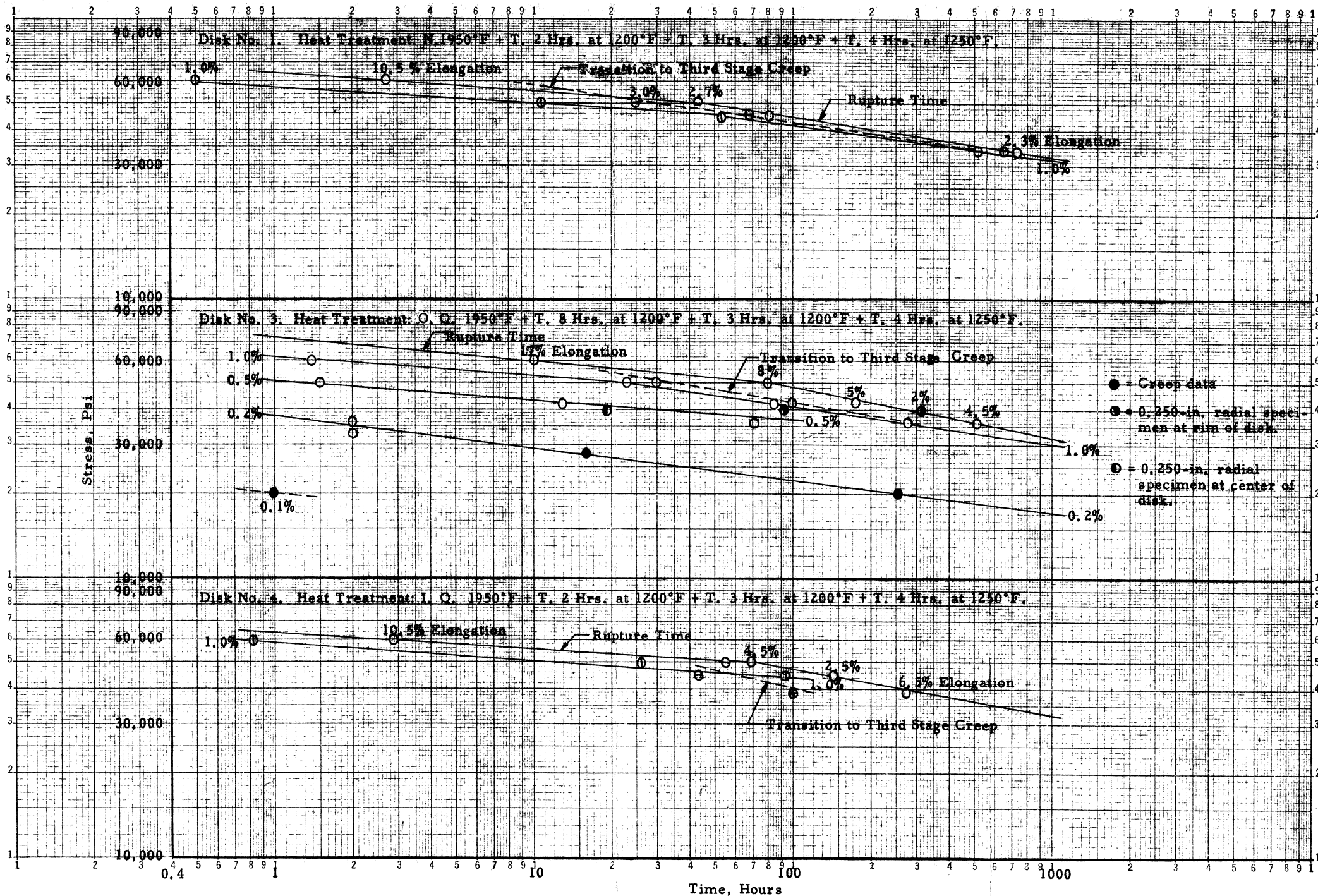


Figure 1. Curves of Stress Against Time for Indicated Total Deformations for Retempered H-40 Disks Nos. 1, 3, and 4 at 1100°F.

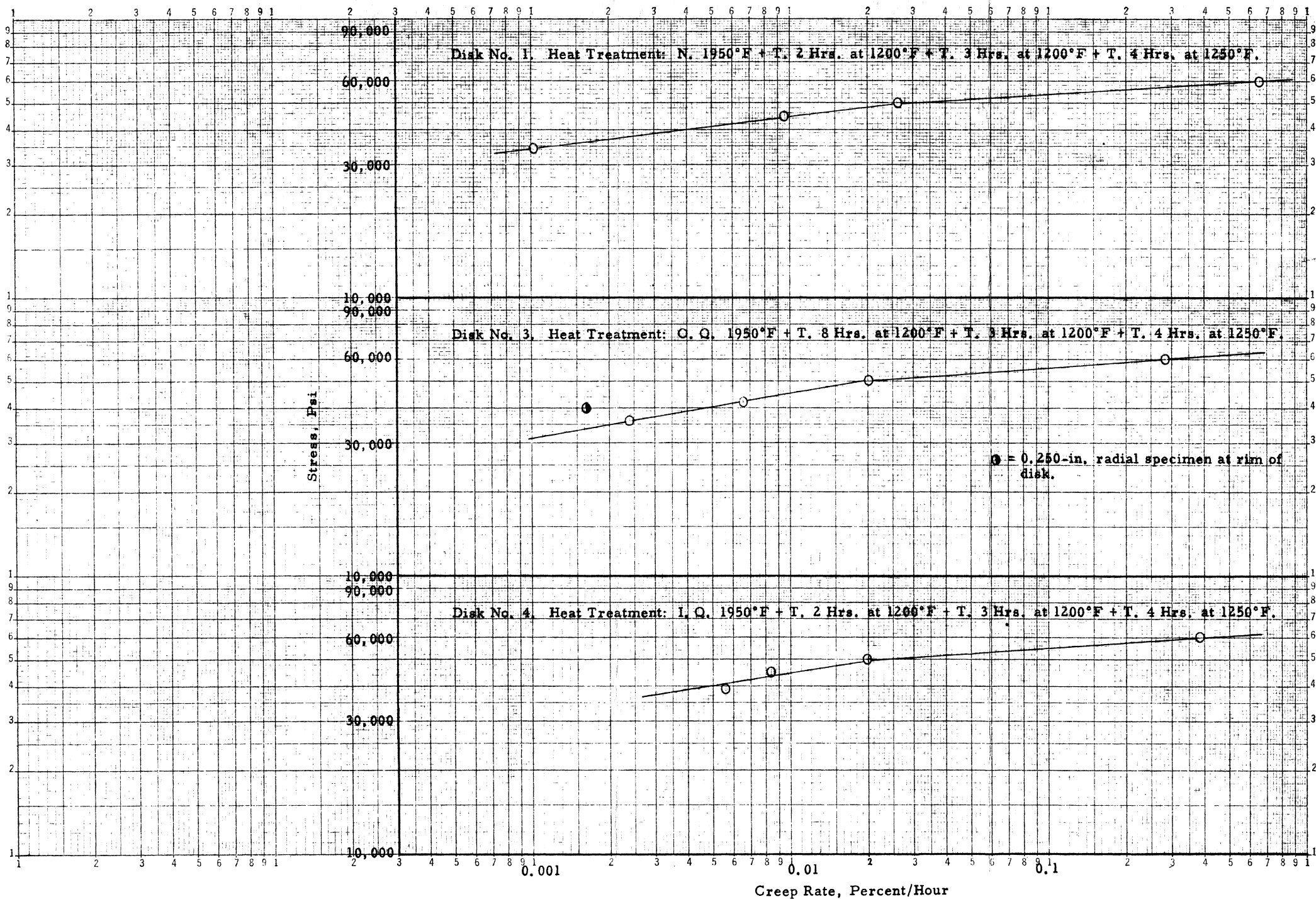


Figure 2. Stress-Creep Rate Curves for Retempered H-40 Disks Nos. 1, 3, and 4 at 1100°F.



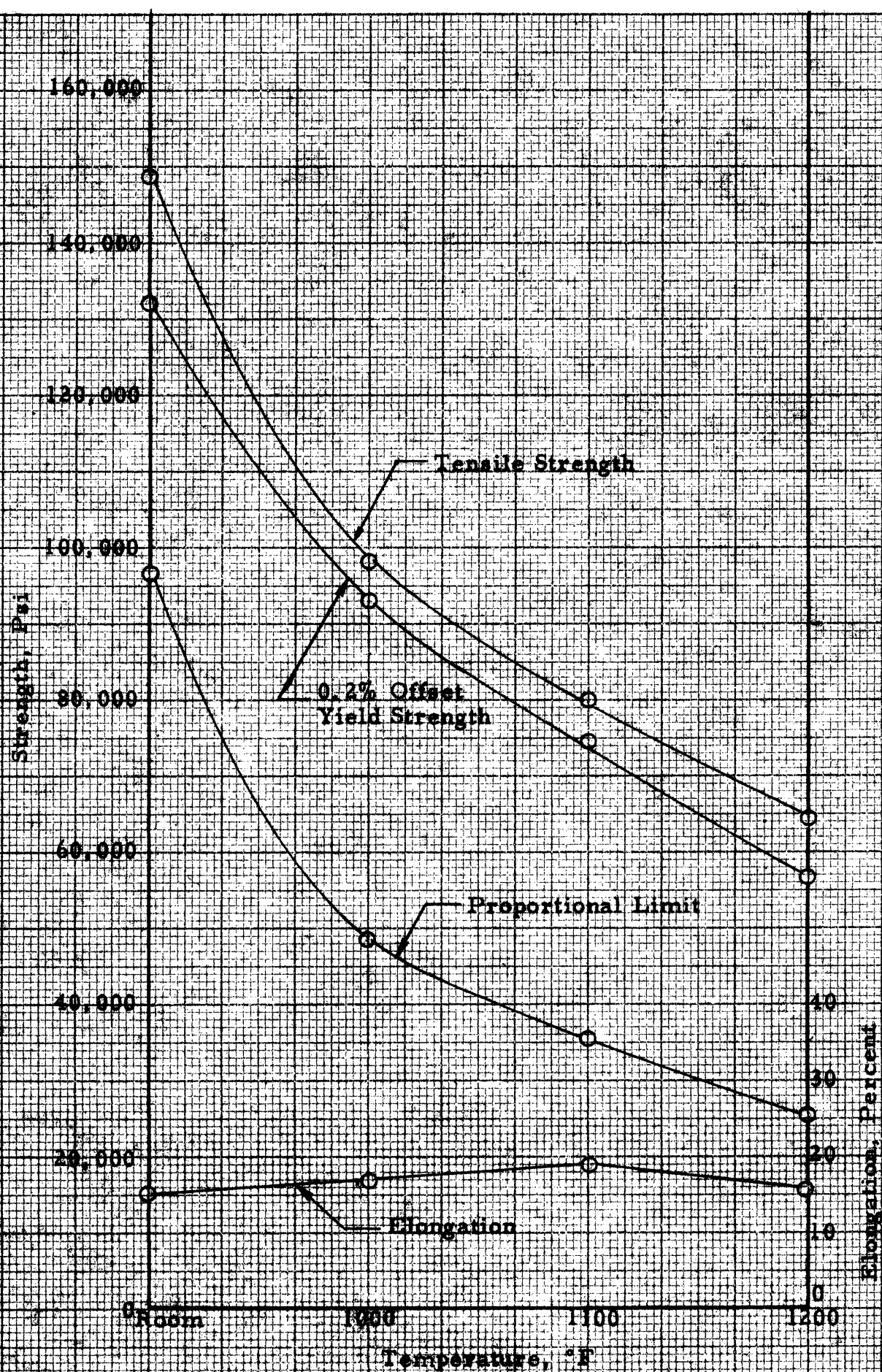


Figure 3. Summary of the Short Time Tensile Properties of Retempered B-40 Disk No. 3. Heat Treatment: O, Q, 1950°F\*1.5 Hrs. at 1200°F\*1.5 Hrs. at 1200°F + T, 4 Hrs. at 1250°F.



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