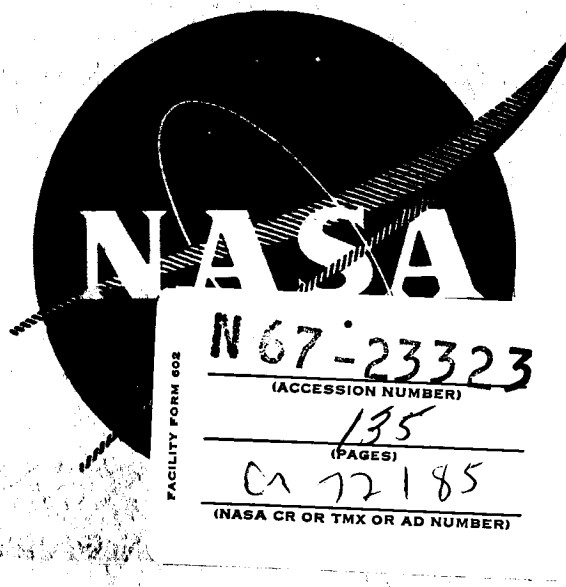


NAS-CR-72185



**GENERATION OF LONG TIME CREEP
DATA ON REFRACTORY ALLOYS
AT ELEVATED TEMPERATURES**

FOURTEENTH QUARTERLY REPORT

Prepared for
**NATIONAL AERONAUTICS AND SPACE ADMINISTRATION
LEWIS RESEARCH CENTER
UNDER CONTRACT NAS 3-2545**

TRW EQUIPMENT LABORATORIES
CLEVELAND, OHIO

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FOURTEENTH QUARTERLY REPORT

For

26 October 1966 to 26 December 1966

GENERATION OF LONG TIME CREEP DATA
OF REFRACTORY ALLOYS AT ELEVATED TEMPERATURES

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National Aeronautics and Space Administration
Contract No. NAS 3-2545

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17 January 1967

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FOREWORD

The work described herein is being performed by TRW Inc. under the sponsorship of the National Aeronautics and Space Administration under Contract NAS 3-2545. The purpose of this study is to obtain design creep data on refractory metal alloys for use in advanced space power systems.

The program is administered for TRW Inc. by E. A. Steigerwald, Program Manager, J. C. Sawyer is the Principal Investigator, and R. R. Ebert contributed to the program. The NASA technical director is Paul E. Moorhead.

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I INTRODUCTION

Space electric power systems depend upon the use of refractory metals in a variety of component areas. A critical property parameter in the design of these systems is the long-time creep strength at very low pressures and elevated temperatures. Since interstitial contamination of refractory metal alloys can occur under conditions of 1×10^{-6} torr, vacuums better than 1×10^{-8} torr must be used to obtain meaningful creep measurements which can be employed in the design of space components. The initial work of this program was to generate 1000 hour creep data on selected refractory alloys which have potential use in advanced space power systems. These alloys are in the form of rolled sheet and forged or rolled plate with the sheet being considered as representative of material for cladding and tubing applications and the plate for turbine components. Following the initial evaluation, primary emphasis has been placed on providing long-time (10,000 hour) creep design data for the tantalum-base alloy T-111 and the molybdenum-base alloys TZC and TZM.

This report presents creep data for T-111, TZC, TZM, tungsten and tungsten alloys.

II MATERIALS AND PROCEDURE

The composition of the various alloys discussed in this report are presented in Table 1 while the material form, the range of test temperatures, and heat treatments are given in Table 2. A detailed review of the available processing histories of the alloys currently under evaluation is presented in Appendix I.

The geometries of the test specimens are shown in Figures 1 and 2. The particular orientation of the specimens with respect to the working direction is given below:

<u>Material Form</u>	<u>Specimen Axis Parallel To</u>
Disc Forging	Radius
Plate	Extruding Direction
Sheet	Rolling Direction

TABLE 1
Chemical Composition of Alloys Being Evaluated in Creep Program (Weight %)(1)

Material	W	Re	Cb	Mo	Ta	Hf	C	Ti	Zr	ppm			
										N2	O2	H2	H2
Tungsten (Vapor Deposited)	Bal.						.0012			<15	12-14	1-3	(2)
Tungsten (Arc-melted)	Bal.						.0058			16	9	4	
Tungsten-25% Rhenium (Arc-Melted)	Bal.	24.9					.0070			7	61	13	
Sylvania A	Bal.					.52	.0300			17	20	3	
TZM (Heat 7502)				Bal.			.010	.51	.091	100	20	7	
(Heat 7463)				Bal.			.016	.48	.080	3	<2	<1	(2)
(Heat KDTZM-1175)				Bal.			.035	.61	.120	43	34	9	
TZC (Heat M-80)				Bal.			.080	1.02	.130	18	41	9	
(Heat M-91)				Bal.			.046	1.17	.270	34	37	10	
(Heat 4345)				Bal.			.127	1.24	.150	-	-	-	
T-111 (Heat 70616)	8.5			Bal.	Bal.	2.30	.0044			20	55	6	
(Heat D-1670)	7.9			Bal.	Bal.	2.17-2.44	<.001			20	72	<5	(2)
(Heat 1102)	Not received												
(Heat 65079)	8.7			Bal.	Bal.	2.30	.003			50	130	4	(2)
(Heat MCN 02A065)							.0041			4	79	1	(2)
Astar 811C	8.0	1.0				0.7	.250						(3)

(1) TRW Analysis
(2) Vendor Analysis
(3) Nominal Composition

TABLE 2
Summary of Material Variables Being Evaluated in Creep Program

Material	Form	Test Temperature	Test Condition
Tungsten	Arc-Melted 0.030" Sheet	3200°F (1760°C) 2800°F (1538°C)	Recrystallized 1 Hour at Test Temperature
Tungsten	Vapor-Deposited 1/8" Diameter Bars	3200°F (1760°C) 2800°F (1538°C)	Recrystallized 1 Hour at Test Temperature
Tungsten-25% Rhenium	Arc-Melted 0.030" Sheet	3200°F (1760°C)	Recrystallized 1 Hour at Test Temperature
Sylvania A	Powder Metallurgy 0.030" Sheet	3200°F (1760°C)	Recrystallized 1 Hour at Test Temperature
TZM (Heat 7463)	5/8" Diameter Bar	2000°F (1093°C)	Stress relieved 2250°F (1232°C), 1/2 hour
(Heat 7502)	"Pancake" Forging	2000°F (1093°C)	(Cond. 1) As-received (Stress-relieved Condition) (Cond. 2) Annealed 1 hour, 2850°F (1566°C)
(Heat KDTZM-1175)	"Pancake" Forging	1600-1856°F (871-1013°C)	As-received (stress relieved 2300°F, 1260°C, 1 hour)
TZC (Heat M-80)	3/4" Plate	1800-2600°F (982-1427°C)	Several test conditions
(Heat M-91)	3/4" Plate		Recrystallized 3092°F (1700°C), 1 hour
(Heat 4345)	3/4" Plate		Stress Relieved 2300-2500°F (1260-1371°C), 1 hour
T-111 (Heat 70616) (Heat D-1670) (Heat 1102) (Heat 65079) (Heat MCN 02A065)	0.030" Sheet	1800-2200°F (982-1204°C)	Recrystallized 2600°F (1426°C) and 3000°F (1649°C), 1 Hour
Astar 811C	0.030" Sheet	2600°F (1427°C)	Recrystallized 3600°F (1982°C), 1/2 Hour.

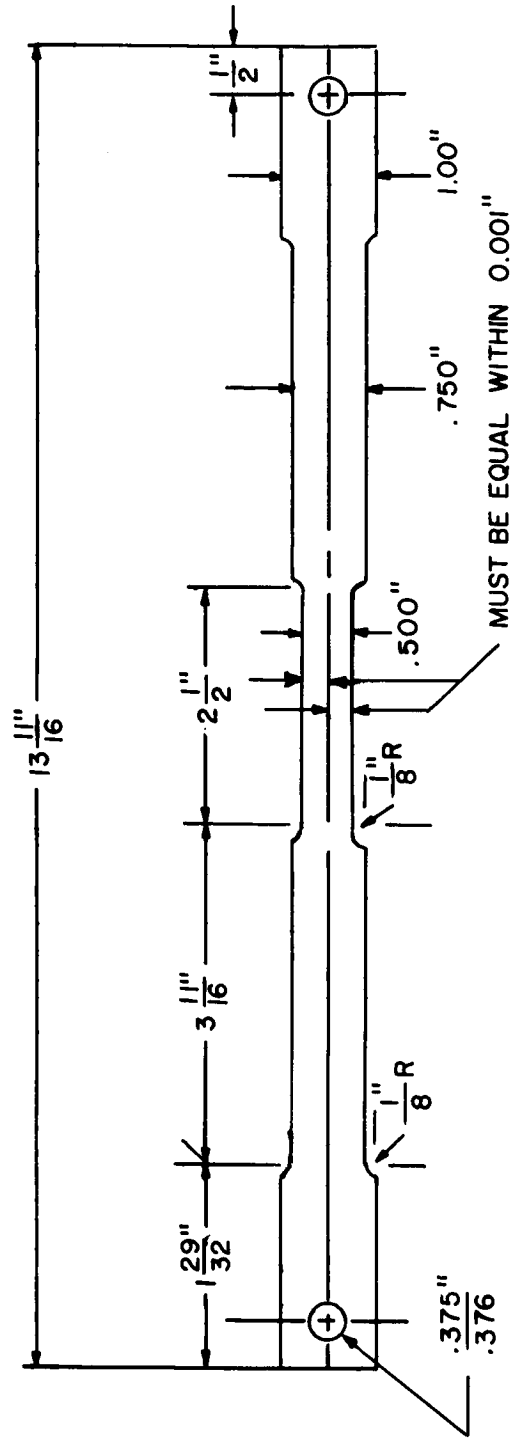
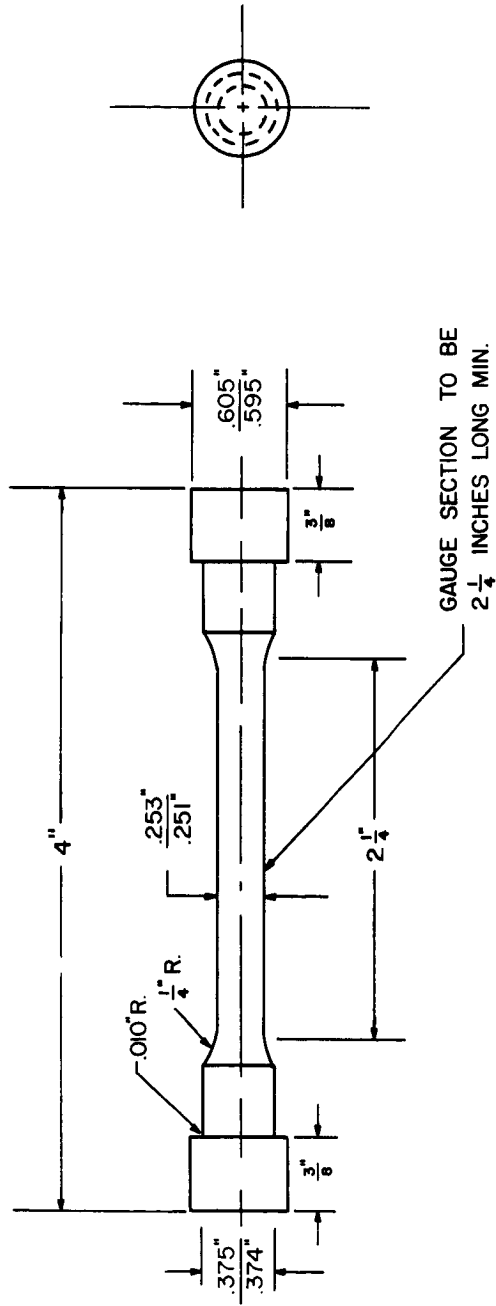


FIGURE 1 CREEP SPECIMEN USED FOR SHEET STOCK



NOTE: ANY TAPER IN GAUGE SECTION MUST BE TOWARDS CENTER

ALL TOLERANCES $\pm .010$ " UNLESS OTHERWISE NOTED

FIGURE 2 CREEP SPECIMEN USED FOR DISC AND PLATE STOCK

The tungsten and tungsten-base alloys were tested as 0.030" thick sheet with the exception of the vapor deposited material which was supplied as 1/8" diameter bar specimens (1)*. As shown in Table 2, all specimens were heat treated for 1 hour at the test temperature prior to the load application. The Sylvania sheet was unusual in that cracking frequently occurred outside of the gauge section (40-100 hours) after a test was initiated. No metallurgical causes could be found to account for this behavior.

The TZM alloy was obtained from two different sources. One lot of material, designated as Heat 7502, was purchased from Climax Molybdenum of Michigan in the form of disc forgings approximately 11 inches in diameter, while a second lot of material (Heat KDTZM-1175) consisted of a section of a disc forging obtained from AiResearch. The latter material was processed by Universal Cyclops to produce improved creep resistance (2) through the development of a fine carbide dispersion. In order to produce this effect it is necessary to work with a carbon level above 0.02%. Climax commercial TZM bar (Heat 7463) has been included in the studies as a means of determining the influence of material form on the creep properties.

To date three different heats of TZC have been tested. Two of these heats (M-80 and M-91) obtained from the General Electric Co., represent a difference in processing treatment. Heat M-80 involved finishing a 2" x 4" sheet bar by rolling at 2925°F (1585°C) using small reductions per pass (approximately 4%). In contrast M-91 employed a finishing temperature of 2372°F (1300°C) and a relatively large degree of deformation per pass. The third lot of TZC (Heat 4345) was prepared by Climax Molybdenum of Michigan by broad forging 3 inch diameter extruded stock at 2400°F (1316°C).

Five heats of T-111 alloy were obtained from three different sources. Two heats were produced by Wah Chang Corporation (Heats 70616 and 65079), two were obtained from Fansteel Corporation (Heats D-1670 and 1102), and one was supplied by NASA Lewis (Heat MCN 02A065). All heats are being evaluated after recrystallization at 3000°F (1649°C) for one hour.

The specimen of Astar 811C, a relatively new tantalum base alloy, developed under contract NAS 3-2542, was obtained from Westinghouse Electric Corp. through NASA Lewis (3). The alloy was supplied as a sheet approximately 0.030" thick in the as-rolled condition.

* Numbers in parentheses refer to references in the Bibliography.

The creep-test procedure involved obtaining a vacuum of 5×10^{-10} torr or better at room temperature, then heating the specimen at a rate so that the pressure never went above 1×10^{-6} torr. Heat treatment was performed on the materials in situ, prior to load application. After heat treatment the specimens were cooled to 600°F or lower and then reheated to the test temperature which was maintained for two hours to insure equilibrium. During testing the vacuum was less than 1×10^{-8} torr and decreased with test time.

Specimen extension is measured over a two-inch gauge length with an optical extensometer that determines the distance between two scribed reference marks to an accuracy of 50 microinches. The program plan involves testing the plate and forged alloys at temperatures between 1600 and 2250°F (871 and 1235°C) until a 1% total extension is obtained. The tungsten material is being tested at 2800 and 3200°F (1566 and 1760°C) for total extensions between 3 and 5%, while the tantalum-base materials are being evaluated at 1800 to 2600°F (982 to 1427°C) to an elongation of approximately 2 to 5%. In most cases the applied stress levels have been selected with the goal of obtaining creep data over total test times between 1000 and 20,000 hours.

III RESULTS AND DISCUSSION

The creep tests in progress, completed or initiated during the fourteenth quarter are graphically presented as percent elongation in the two inch gauge section as a function of the time at the applied stress. Reference marks are placed on the curves to indicate the chamber pressure during the course of the test. The numerical creep data for each test in progress during this quarter are given in Appendix II. Since the tests of tungsten and tungsten-base alloys are now complete, a summary of all data obtained on these alloys is presented.

Tungsten and Tungsten Alloys

The creep data for the tests involving tungsten and tungsten alloys have been plotted in Figures 3, 4, 5, and 6. All curves, except those for Sylvania A (Figure 6) exhibit a creep rate which is either constant or slightly decreasing with time. The Larson-Miller parameter using a constant of 15 was determined at a 1% creep value. The data for the tungsten alloys, tabulated in Table 3 and presented graphically in Figure 7, indicate the following:

1. There is no significant difference between the creep strengths of arc melted or vapor deposited tungsten.
2. The beneficial effects of a 25 w/o rhenium addition to arc melted tungsten is apparent only at the higher stresses.
3. Sylvania A exhibits a creep strength superior to that of tungsten-25 w/o rhenium alloy, however, this advantage is offset by brittleness of the alloy causing some specimens to crack during testing.

The published creep strength of pure tungsten (3, 4) is compared to the current results in Figure 8. The data found in Reference 3 were obtained with a powder metallurgy product and tests were performed in an argon environment. A powder metallurgy product was also used in Reference 4, but the test environment was a 10^{-4} torr vacuum. The creep strength of the arc melted and vapor deposited tungsten is definitely inferior to that of the powder metallurgy product of Reference 3, however, the data from Reference 4 appears to be an extension of that obtained with the arc melted and vapor deposited material. In view of the fact that References 3 and 4 do not provide quantitative data relative to the interstitial content of the material before or after test, the specific causes for the differences observed cannot be determined. However, it is interesting to note that the tests in argon produced higher creep strengths than the tests conducted in vacuum.

Post test photomicrographs of vapor deposited tungsten specimen B-24 are shown in Figure 9. This specimen was tested at 2800°F (1538°C) and 2 Ksi (1.38×10^7 N/m²) for 6812 hours. During that time, 3.71% extension occurred. The unstressed end of the specimen exhibits columnar grains characteristic of the vapor deposited material. The stressed gauge section has a similar structure and in addition exhibits a large amount of grain boundary porosity probably due to vacancy condensation during the test.

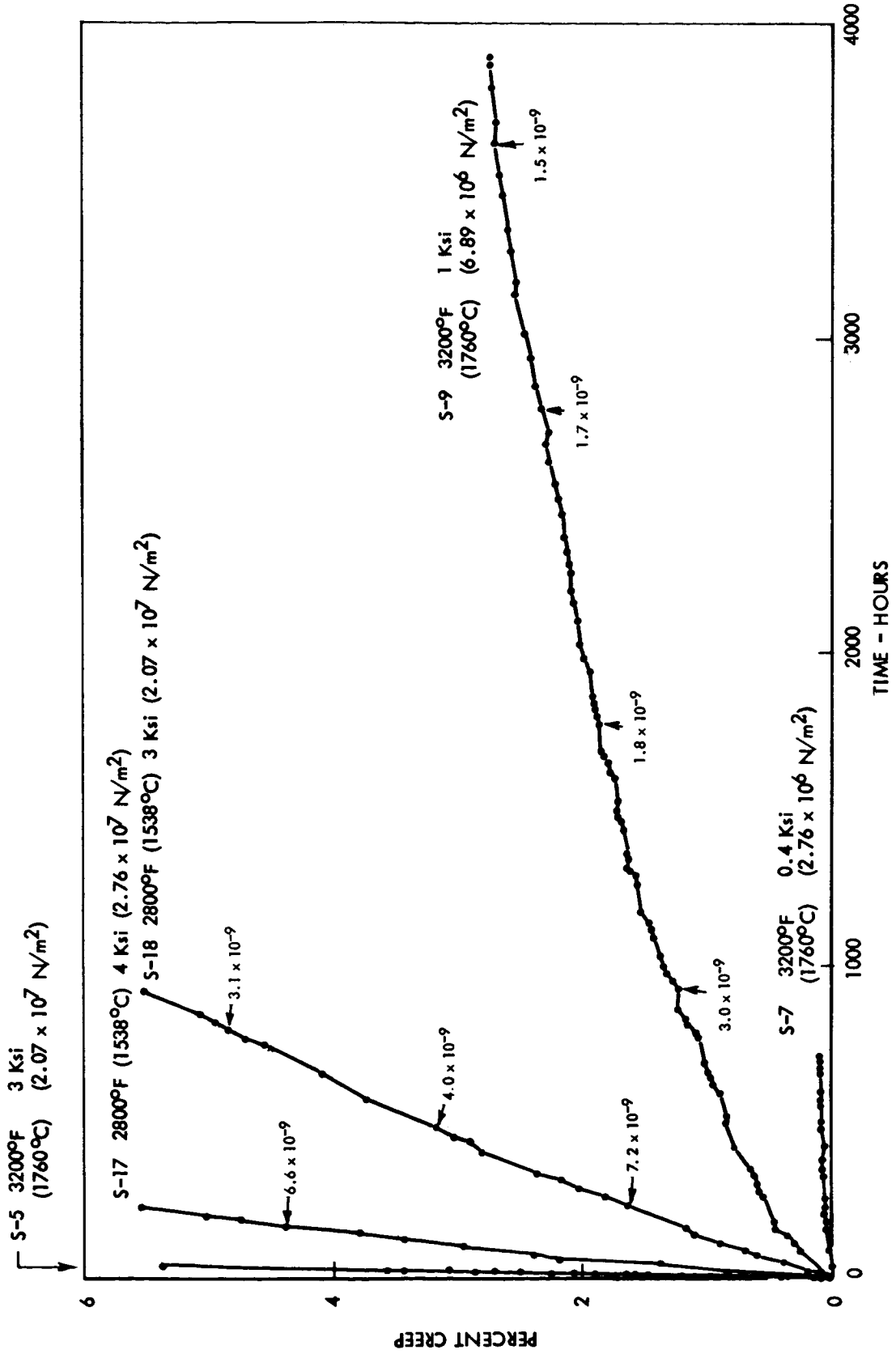


FIGURE 3 CREEP DATA FOR ARC MELTED TUNGSTEN SHEET HEAT NO. KC-1357, RECRYSTALLIZED 1 HOUR AT TEST TEMPERATURE, AND TESTED IN VACUUM ENVIRONMENT <1 X 10⁻⁸ TORR.

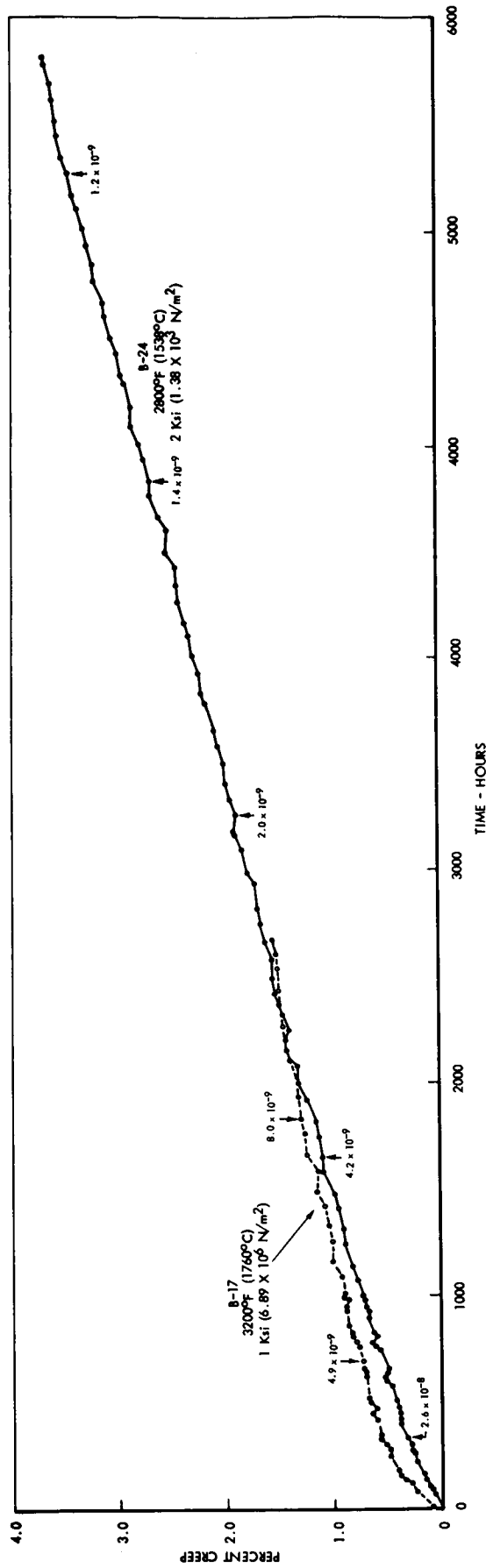


FIGURE 4 CREEP DATA FOR VAPOR-DEPOSITED TUNGSTEN, TESTED IN VACUUM ENVIRONMENT $< 1 \times 10^{-8}$ TORR.

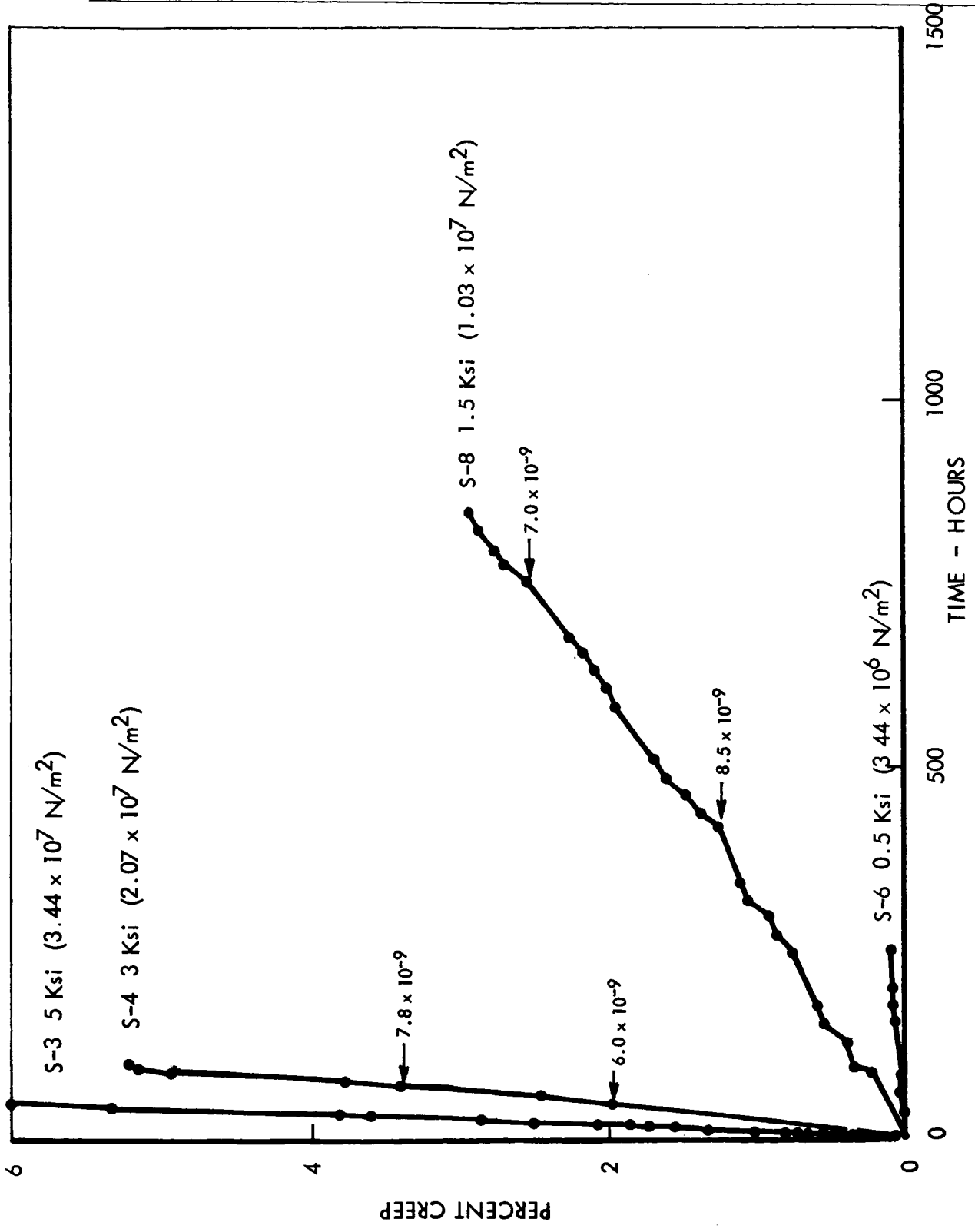


FIGURE 5 CREEP DATA FOR ARC MELTED TUNGSTEN - 25% RHENIUM SHEET, HEAT NO. 3.5-75002, RECRYSTALLIZED 1 HOUR AT 3200°F (1760°C), AND TESTED AT 3200°F (1760°C) IN VACUUM ENVIRONMENT < 1 X 10⁻⁸ TORR.

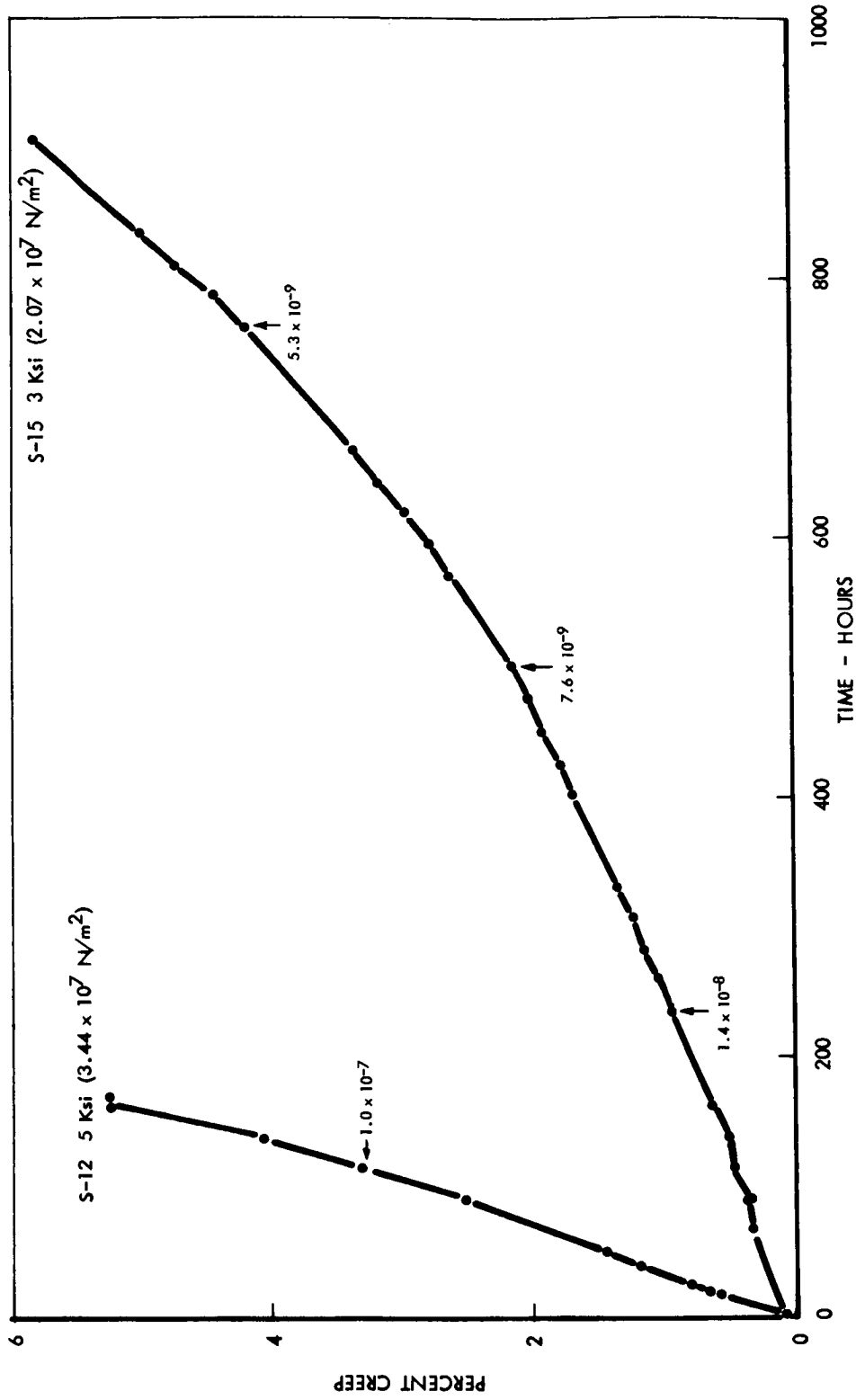
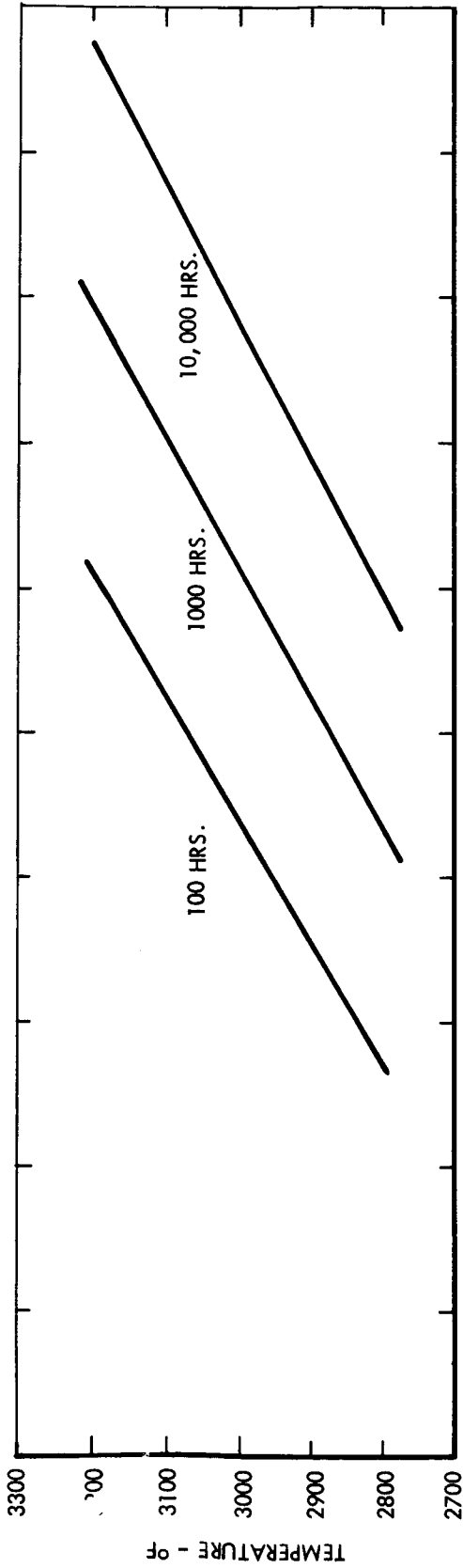


FIGURE 6 CREEP DATA FOR SYLVANIA "A" ALLOY RECRYSTALLIZED 1 HOUR AT 3200°F (1760°C), AND TESTED AT 3200°F (1760°C) IN VACUUM ENVIRONMENT $< 1 \times 10^{-8}$ TORR.



- ARC MELTED TUNGSTEN SHEET HEAT KC 1357
- VAPOR DEPOSITED TUNGSTEN ROD
- △ ARC MELTED TUNGSTEN - 25% RHENIUM SHEET HEAT NO. 35-75002
- SYLVANIA - A SHEET

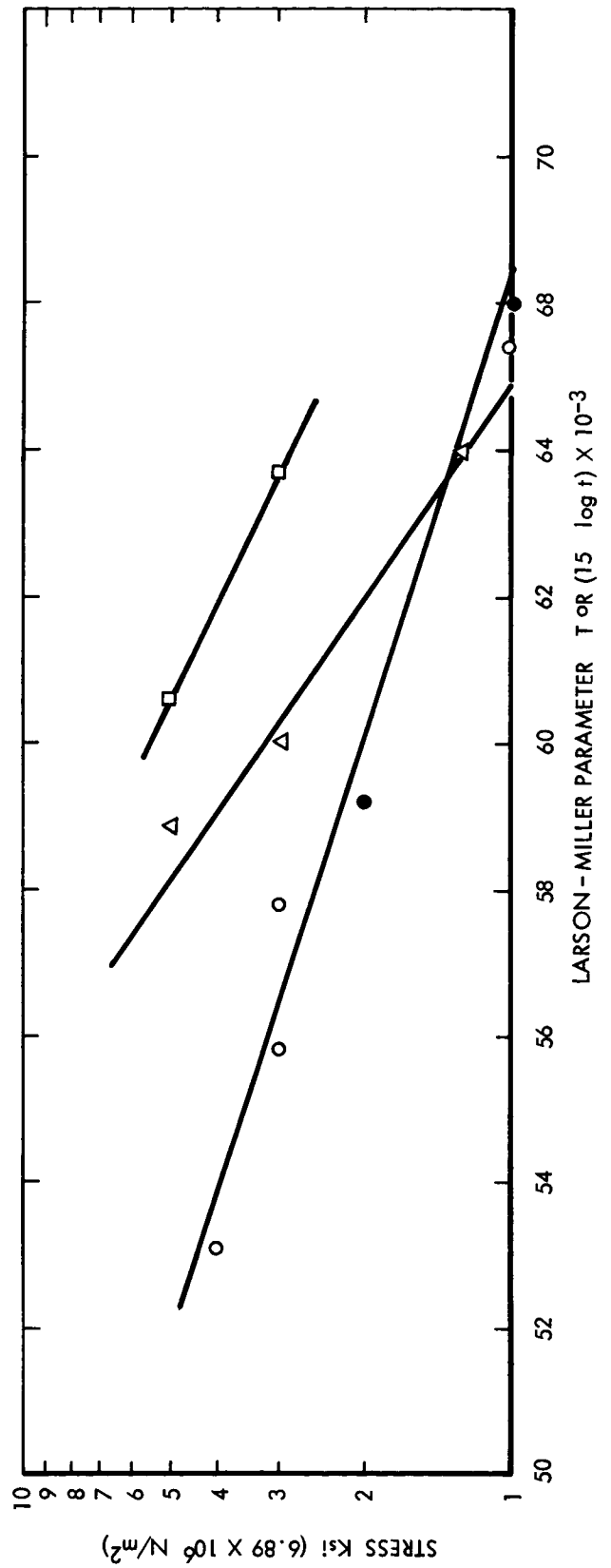


FIGURE 7 LARSON-MILLER PLOT OF DATA FOR 1% CREEP IN TUNGSTEN AND TUNGSTEN BASE ALLOYS, TESTED IN VACUUM ENVIRONMENT <1 X 10⁻⁸ TORR.

TABLE 3

1% Creep Test Data for Tungsten and Tungsten Alloys Annealed One Hour . At

The Test Temperature

<u>Specimen No.</u>	<u>Temperature</u>		<u>Stress</u>		<u>Hours for 1.0% Creep</u>	<u>Larson-Miller T°R(15+logt)x 10⁻³ for 1.0% Creep</u>
	<u>°F</u>	<u>°C</u>	<u>Ksi</u>	<u>N/m²x10⁷</u>		
<u>Arc-Melted Sheet Heat No. KC-1357</u>						
S-5	3200	1760	3.0	2.06	6	57.8
S-9	3200	1760	1.0	0.689	675	65.4
S-17	2800	1538	4.0	2.76	20	53.1
S-18	2800	1538	3.0	2.06	125	55.8
<u>Vapor Deposited Tungsten</u>						
B-17	3200	1760	1.0	0.689	1140	66.0
B-24	2800	1538	2.0	1.38	1500	59.2
<u>Arc-Melted Tungsten-25% Rhenium Sheet Heat No. 35-75002</u>						
S-3	3200	1760	5.0	3.44	12	58.9
S-4	3200	1760	3.0	2.06	25	60.0
S-8	3200	1760	1.5	1.03	315	64.0
<u>Sylvania A Sheet</u>						
S-12	3200	1760	5.0	3.44	35	60.6
S-15	3200	1760	3.0	2.06	250	63.7

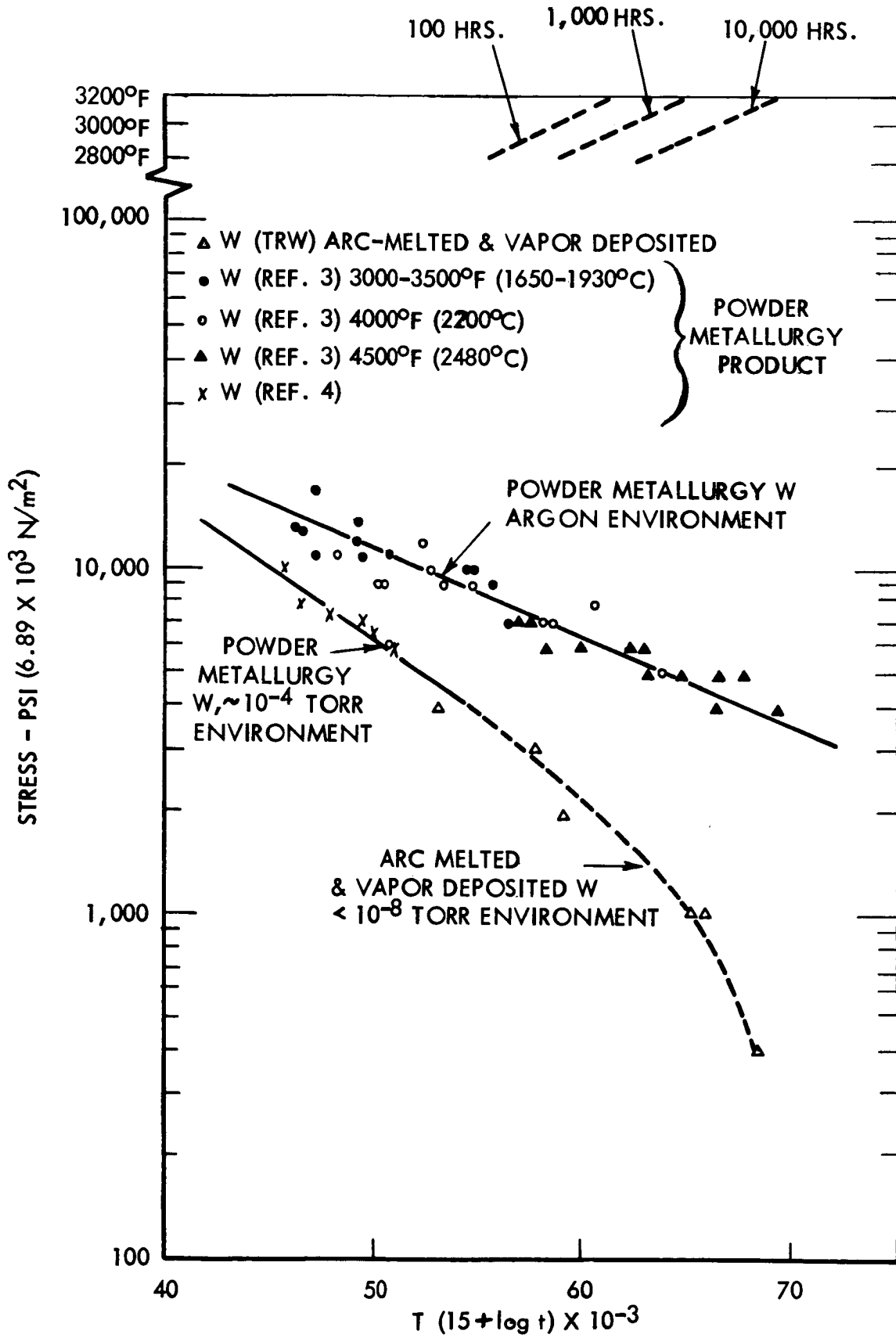
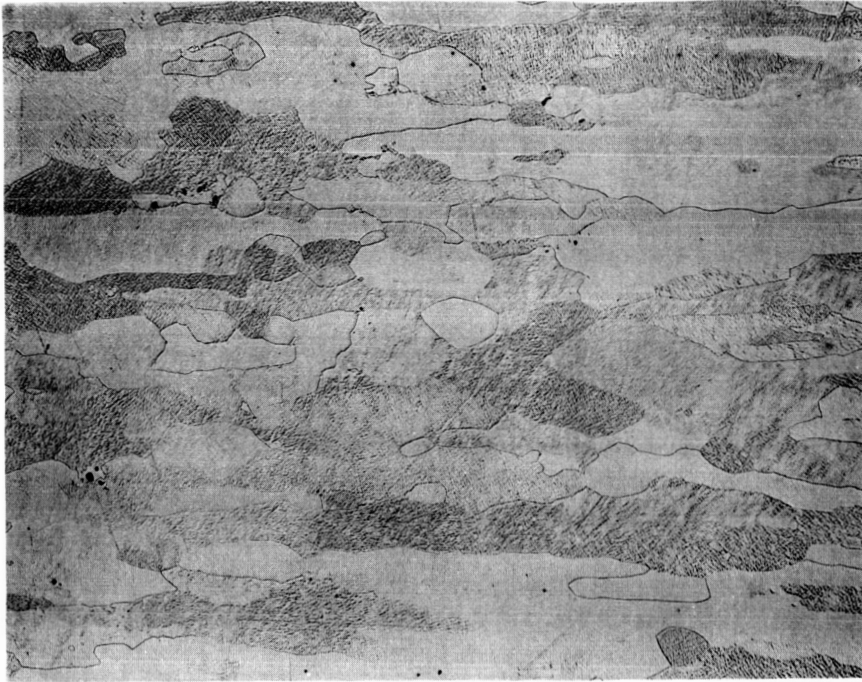
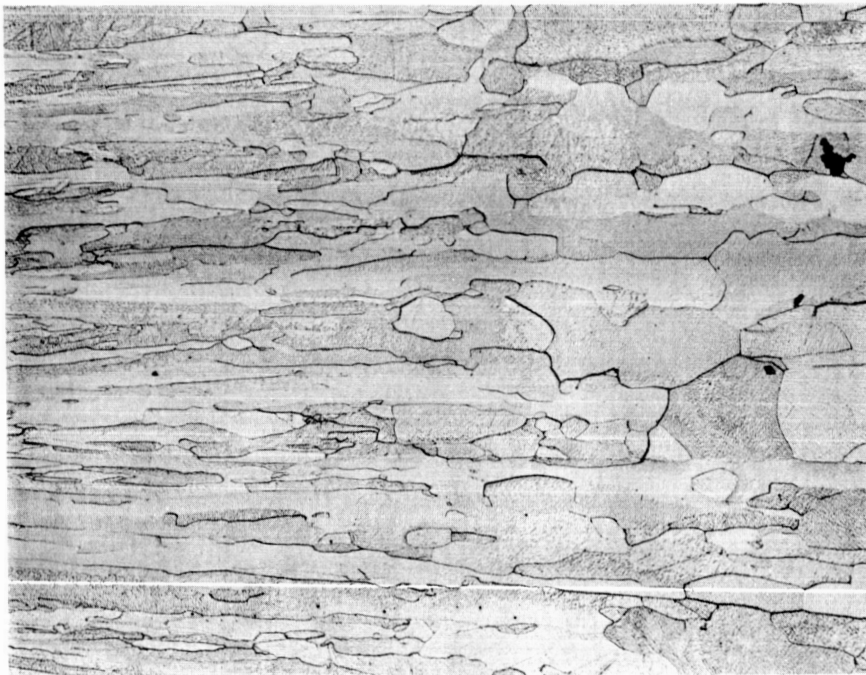


FIGURE 8 LARSON-MILLER PLOT OF TUNGSTEN - 1% CREEP DATA



GAGE SECTION PERPENDICULAR TO SPECIMEN AXIS



HEAD SECTION PERPENDICULAR TO SPECIMEN AXIS

FIGURE 9 VAPOR DEPOSITED W PHOTOMICROGRAPHS AFTER TEST.
MAGNIFICATION: 100 X; ETCHANT: MURAKAMI'S

Molybdenum Base Alloys TZM and TZC

Three heats of TZC alloy, M-80, M-91 and 4345, are being tested using heat treatments which involved either a 3092°F (1700°C) anneal for one hour or a stress relief in the 2300 to 2500°F (1260 to 1371°C) temperature range. The 3092°F (1700°C) anneal caused partial recrystallization of the Heat M-80 material and full recrystallization of the Heat M-91 alloy (see Figure 10). Figure 11 shows the creep data for Heat M-80. All tests of this material are now complete and no further tests are scheduled. Figures 12 and 13 illustrate the creep data for Heat M-91 and 4345. Examination of the data for the new lot of TZC (Heat 4345) shows that it has the tendency to creep in a discontinuous manner similar to the other heats of the same material.

A comparison of the various heats and heat treatments for TZC is given in Figure 14 in terms of the Larson-Miller parameter for 0.5% creep. The values used in determining this curve are given in Table 4 along with other pertinent data relative to the tests.

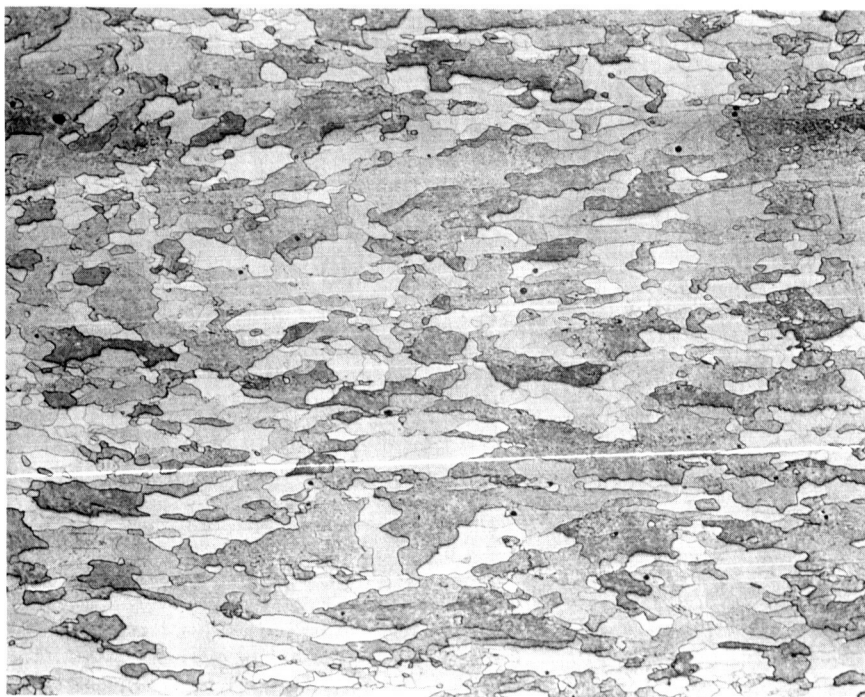
Heat M-80 has the best creep resistance; however, as previously mentioned, it suffers from a lack of ductility at room temperature. While the graph indicates that the stress relieved M-91 is superior to the same heat recrystallized at 3092°F (1700°C) further tests would be required at the higher values of the Larson-Miller parameter to confirm this tentative conclusion. Heat 4345, produced by forging extruded stock appears to have properties at least as good as those of Heat M-91 heat treated in the same manner.

Two tests of molybdenum-base TZM are currently in progress which compare two different heats at the same test conditions of 1800°F (982°C) and 44 Ksi (3.03×10^8 N/m²). Both specimens were cut radially from a disc forging with the major differences being a variation in the carbon content and the method of processing. The creep data plotted in Figure 15 clearly show the superiority of Heat KDTZM-1175 containing the higher carbon content and a greater degree of working during processing. Comparative tests of Heats 7502 and 7463 having essentially the same carbon content, show the superiority of the more severely worked commercial TZM stock, Heat 7463, Figure 16. The creep strengths of TZM and TZC, presented in Figure 17, show that the strength of TZC at high stresses is inferior to TZM (Heat 1175) but at lower stresses where higher temperatures and longer test times are involved the TZC may have some advantage.



100 X

HEAT M-80



100 X

HEAT M-91

FIGURE 10 PHOTOMICROGRAPHS OF TZC PLATE AFTER ANNEALING AT 3092 (1700°C) FOR 1 HOUR. ETCHANT: 15% HF, 15% H₂SO₄, 8% HNO₃, 62% H₂O. 100 X

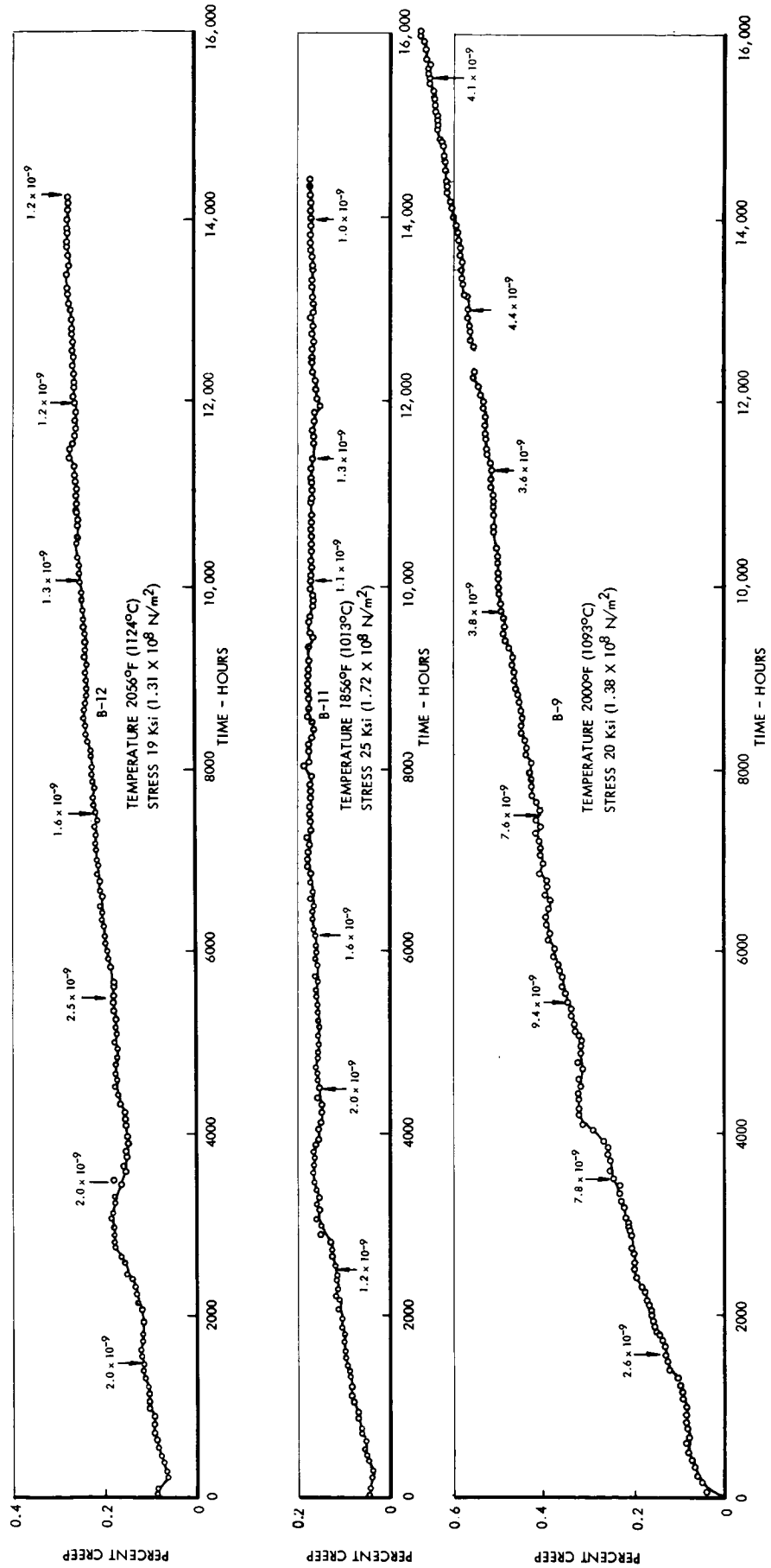


FIGURE 11 CREEP TEST DATA, TZC (HEAT M-80), ANNEALED 3092 F (1700 C), 1 HOUR TESTED IN VACUUM ENVIRONMENT 1×10^{-8} TORR.

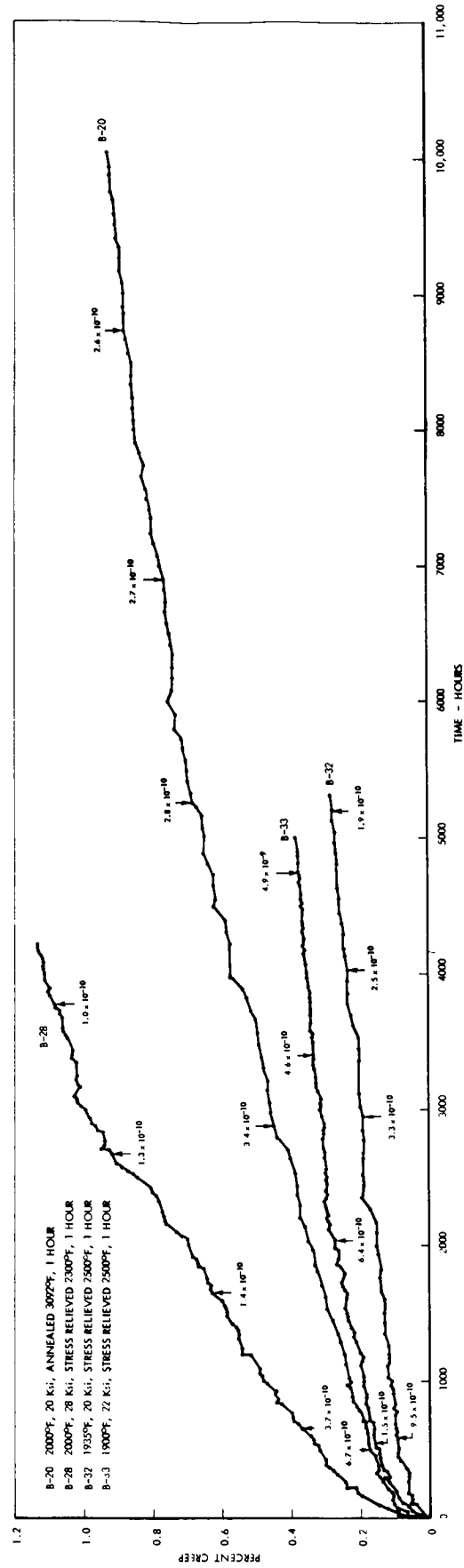


FIGURE 12 CREEP DATA, TZC (HEAT M-91) TESTED IN VACUUM ENVIRONMENT 1×10^{-8} TORR.

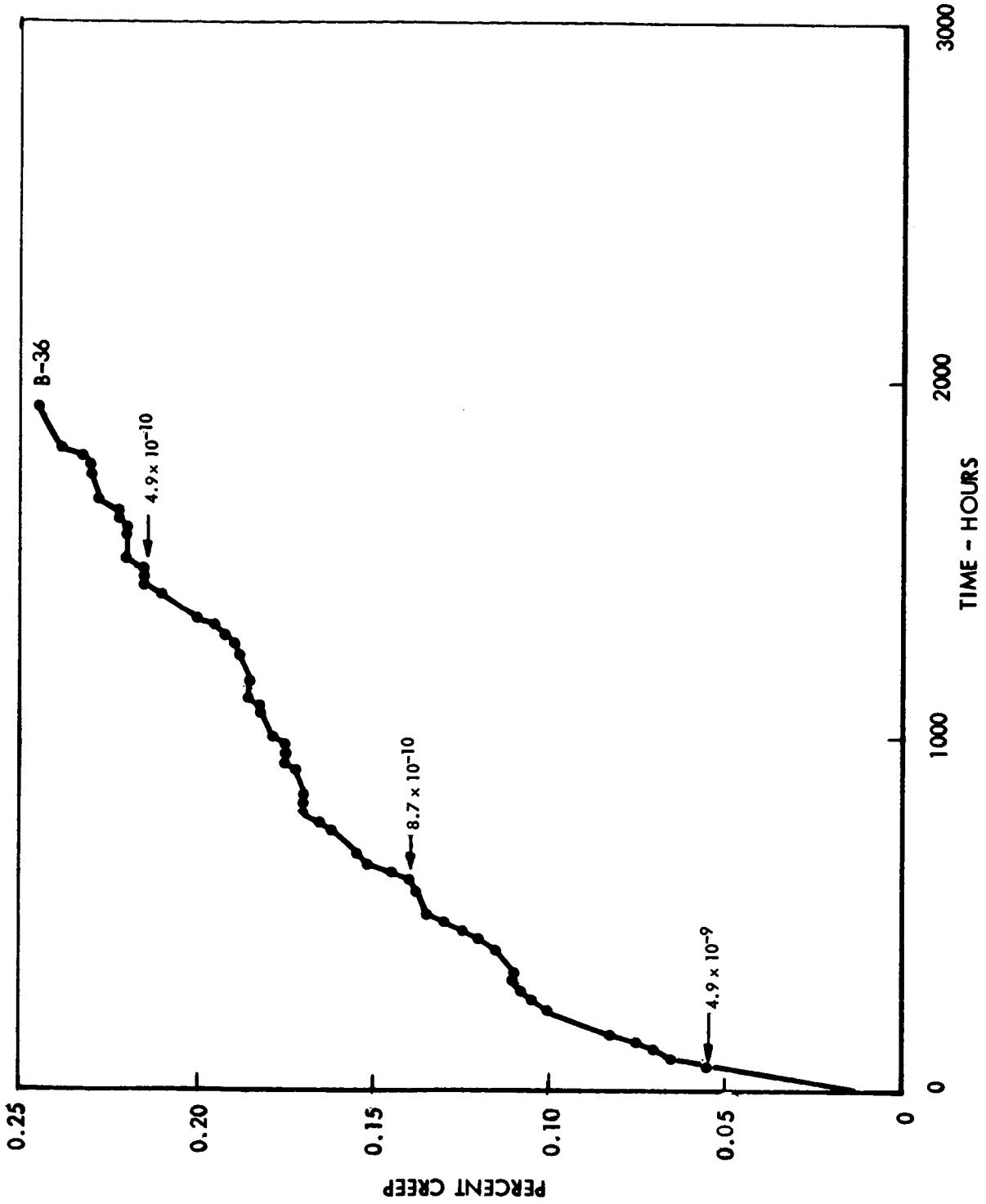


FIGURE 13 CREEP TEST DATA, TZC HEAT 4345, STRESS RELIEVED 2500°F (1371°C), 1 HOUR, TESTED AT 2000°F (1093°C), 22,000 PSI (1.52×10^8 N/m²) IN VACUUM ENVIRONMENT $< 1 \times 10^{-6}$ TORR.

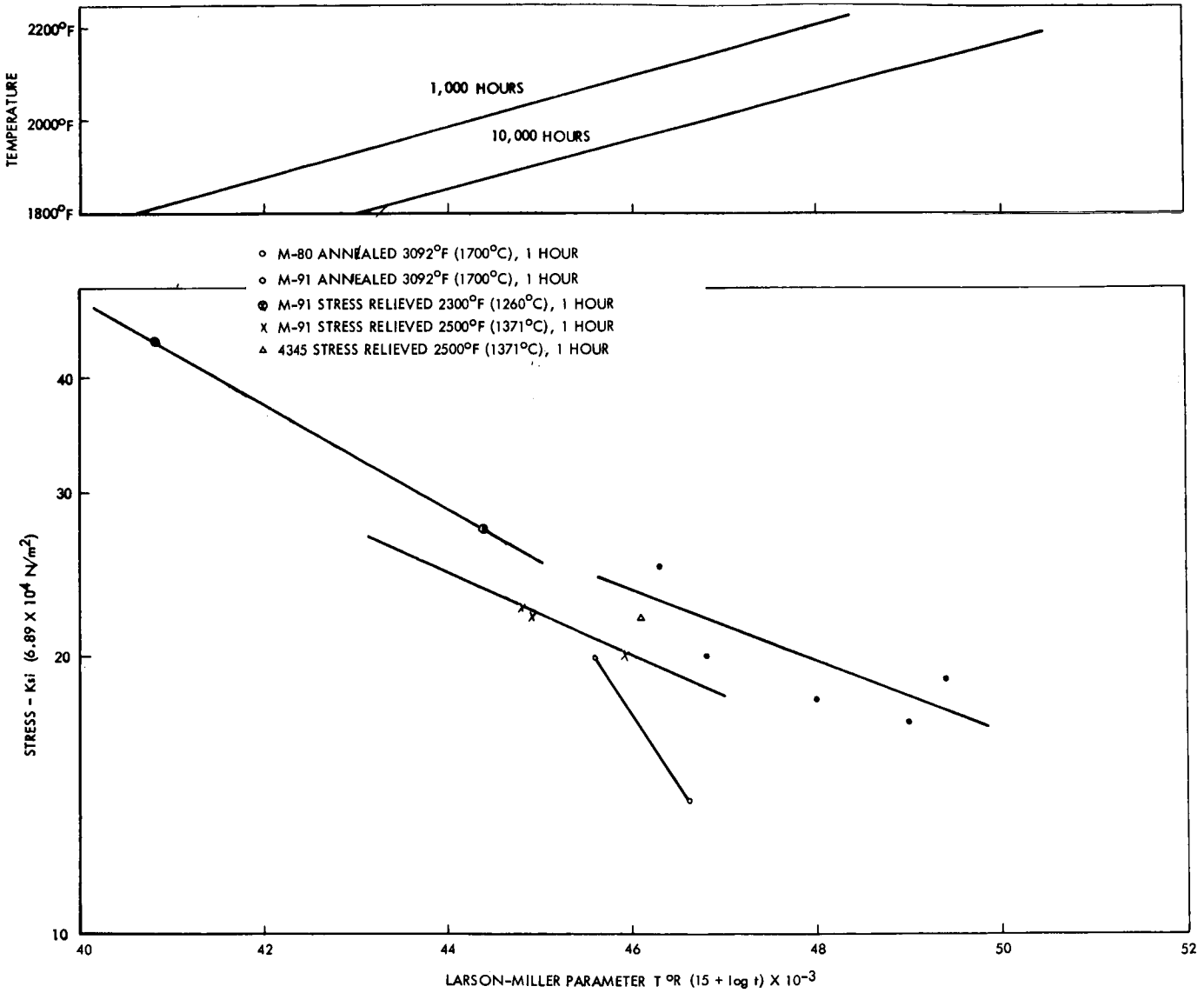


FIGURE 14 LARSON-MILLER PLOT FOR 0.5% CREEP IN MOLYBDENUM BASE TZC ALLOY, TESTED IN VACUUM ENVIRONMENT $< 1 \times 10^{-8}$ TORR.

TABLE 4

0.5% Creep Test Data for TZC Molybdenum-Base Alloy

Specimen No.	Temperature		Stress		Hours for 0.5% Creep	Larson-Miller $T^{\circ}R(15+\log t) \times 10^{-3}$ for 0.5% Creep
	$^{\circ}F$	$^{\circ}C$	Ksi	$N/m^2 \times 10^8$		
<u>Heat M-80, Annealed 3092°F (1700°C), 1 Hour</u>						
B-8A	2200	1204	18	1.24	1,100	48.0
B-10	2200	1204	17	1.17	2,500	49.0
B-9	2000	1093	20	1.38	10,400	46.8
B-12	2056	1124	19	1.31	46,000*	49.4
B-11	1856	1013	25	1.72	100,000*	46.3
<u>Heat M-91, Annealed 3092°F (1700°C)</u>						
B-31	2200	1204	14	0.965	320	46.6
B-20	2000	1093	20	1.38	3,600	45.6
<u>Heat M-91, Stress Relieved 2300°F (1260°C), 1 Hour</u>						
B-28	2000	1093	28	1.93	1,100	44.4
B-19	1800	982	44	3.03	1,075	40.7
<u>Heat M-91, Stress-Relieved 2500°F (1371°C), 1 Hour</u>						
B-30	2200	1204	22	1.52	70	44.9
B-32	1935	1057	20	1.38	14,500*	45.9
B-33	1900	1038	22	1.52	9,500*	44.8
<u>Heat 4345, Stress-Relieved 2500°F (1371°C), 1 Hour</u>						
B-36	2000	1093	22	1.52	6,000*	46.1

* Extrapolated Data

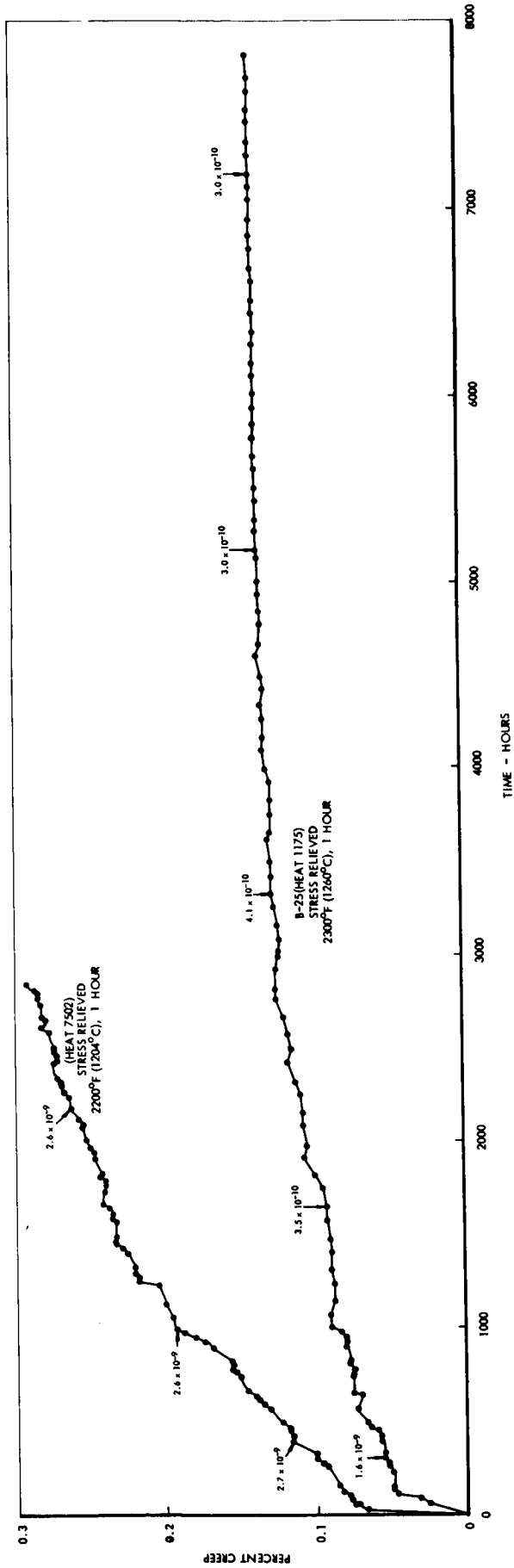


FIGURE 15 CREEP DATA TZM FORGED DISCS - TESTED AT 1800°F (982°C) AND 44 Ksi (3.03×10^8 N/m²) IN VACUUM ENVIRONMENT $< 1 \times 10^{-8}$ TORR.

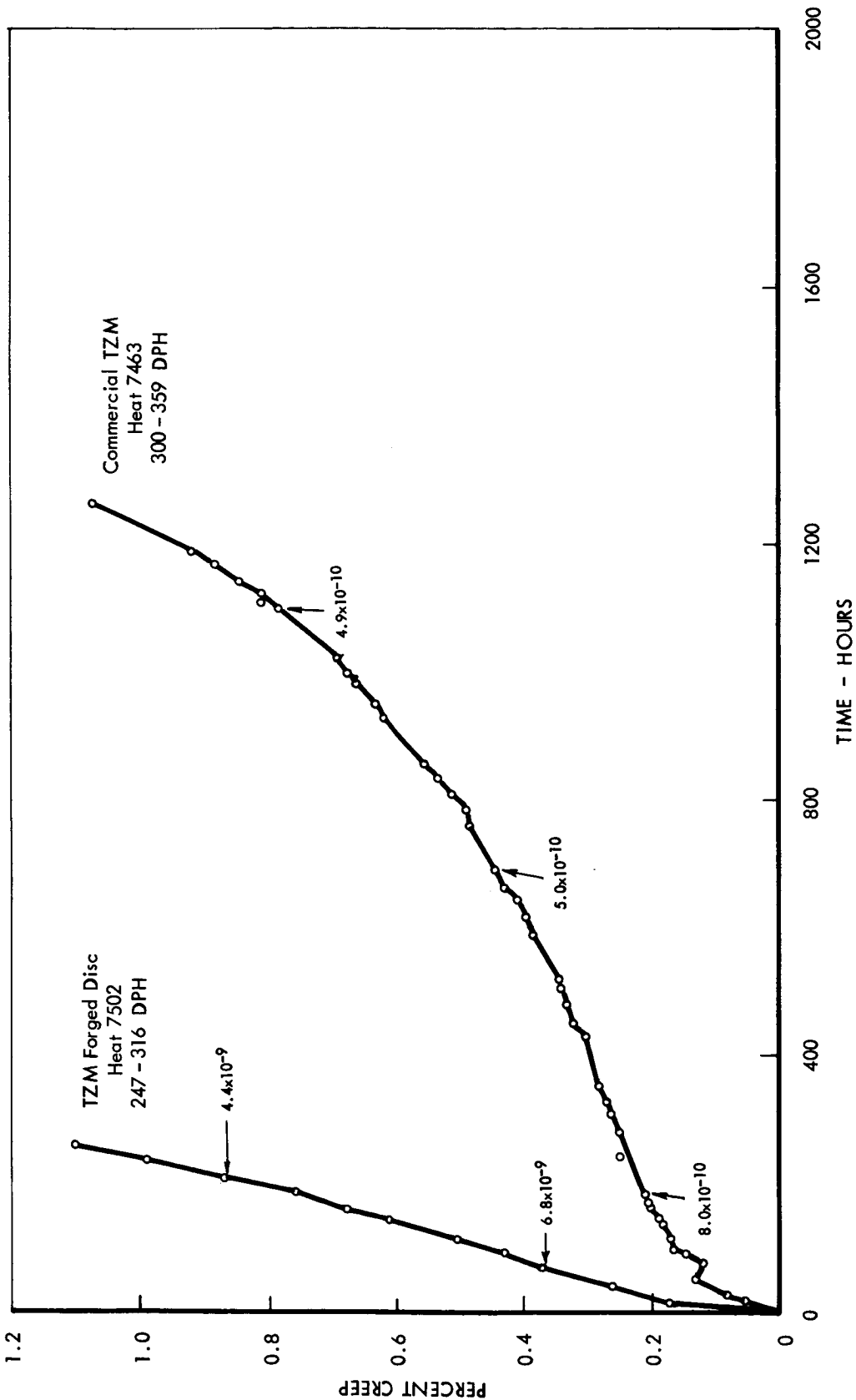


FIGURE 16 CREEP DATA FOR TZM ALLOY IN STRESS RELIEVED CONDITION. TESTED AT 2000°F (1093°C) AND 41 Ksi (2.82×10^8 N/m²) IN VACUUM ENVIRONMENT $< 1 \times 10^{-8}$ TORR.

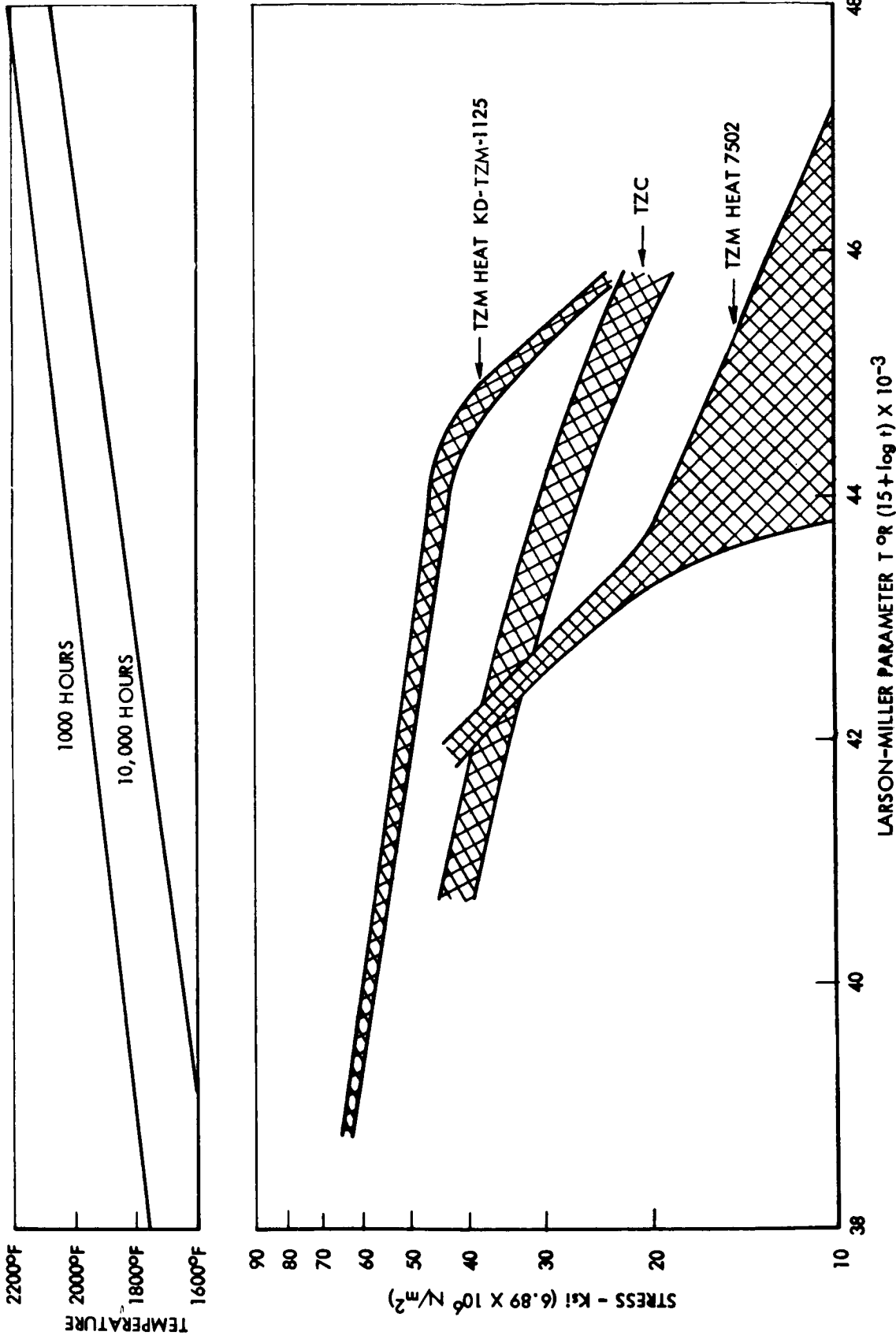


FIGURE 17 LARSON-MILLER COMPARISON OF 0.5% CREEP DATA FOR MOLYBDENUM BASE TZM AND TZC, STRESS RELIEVED 2200-2500°F (1204-1371°C), AND TESTED IN VACUUM ENVIRONMENT $< 1 \times 10^{-8}$ TORR.

Tantalum Base T-111 and 811C

Several heats of T-111 have been evaluated and the creep data for current tests are shown in Figures 18, 19, and 20. A tabulation of the pertinent test data as well as the Larson-Miller 1% creep parameter are given in Table 5 and these values are plotted in Figure 21. The result of this plot shows that there is little significant difference between heats. For this reason, a single curve has been drawn through the various points.

A sample of tantalum base Astar 811C is currently on test at 2600°F (1427°C) and 2 Ksi (1.38×10^7 N/m²). The preliminary treatment given the specimen before test was an anneal at 3600°F (1982°C) for 1/2 hour. A creep of 0.03% has occurred after 860 hours and the best current estimate of the 1% creep life is 25,000 hours. (Larson-Miller parameter = 59.7). This time is comparable to that exhibited by arc-melted tungsten.

IV FUTURE WORK

Primary emphasis will continue on the evaluation of the TZC and T-111 alloys. The creep information accumulated with the T-111 alloy will be examined using the technique of Mendelson, Roberts, and Manson (5).

The new heats of TZC (4345) and T-111 (65079) will be evaluated to determine the mechanical properties of each at both room and elevated temperatures.

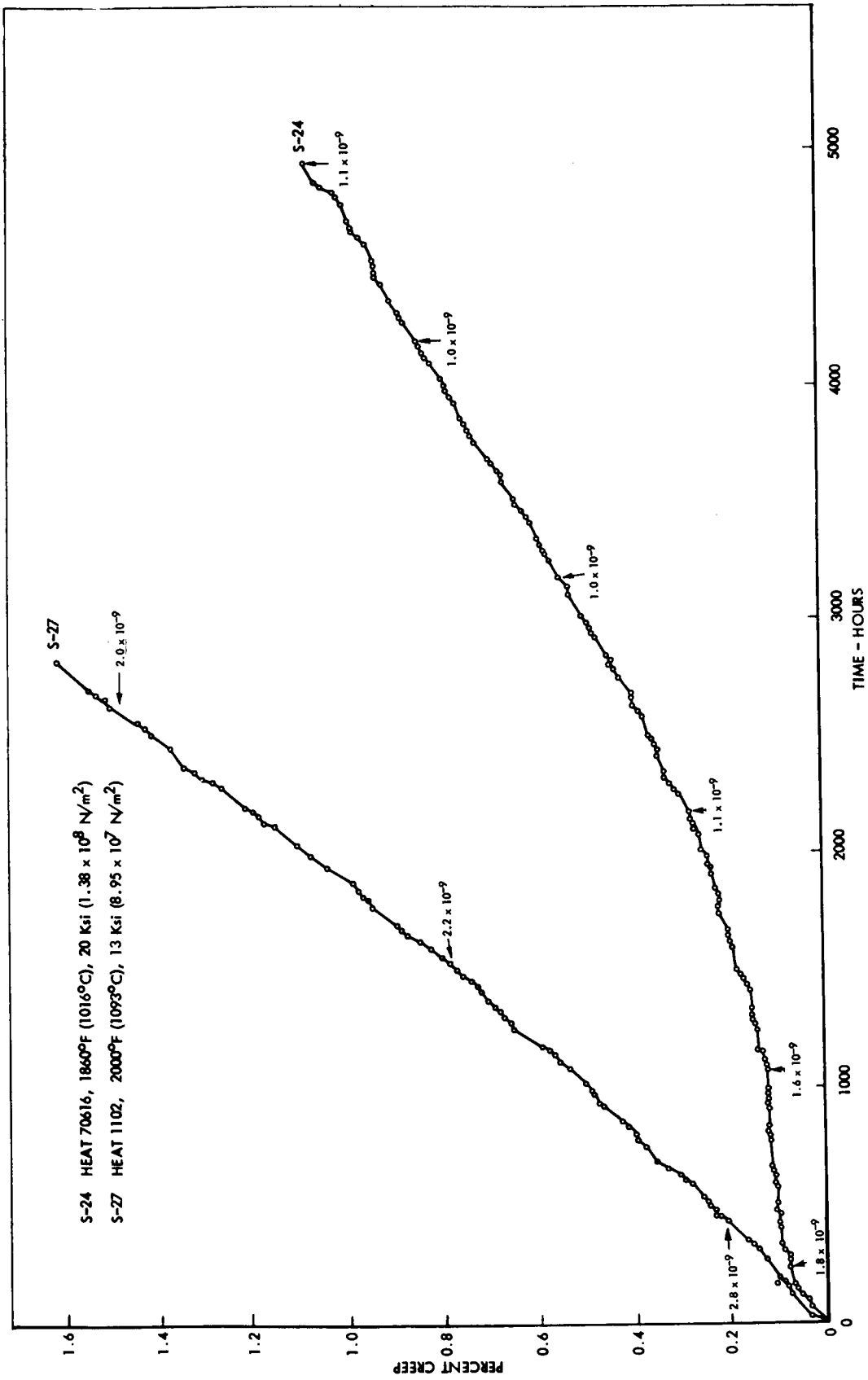


FIGURE 18 CREEP DATA FOR T-111 ALLOY ONE HOUR AT 3000°F (1649°C) IN VACUUM ENVIRONMENT $< 1 \times 10^{-8}$ TORR.

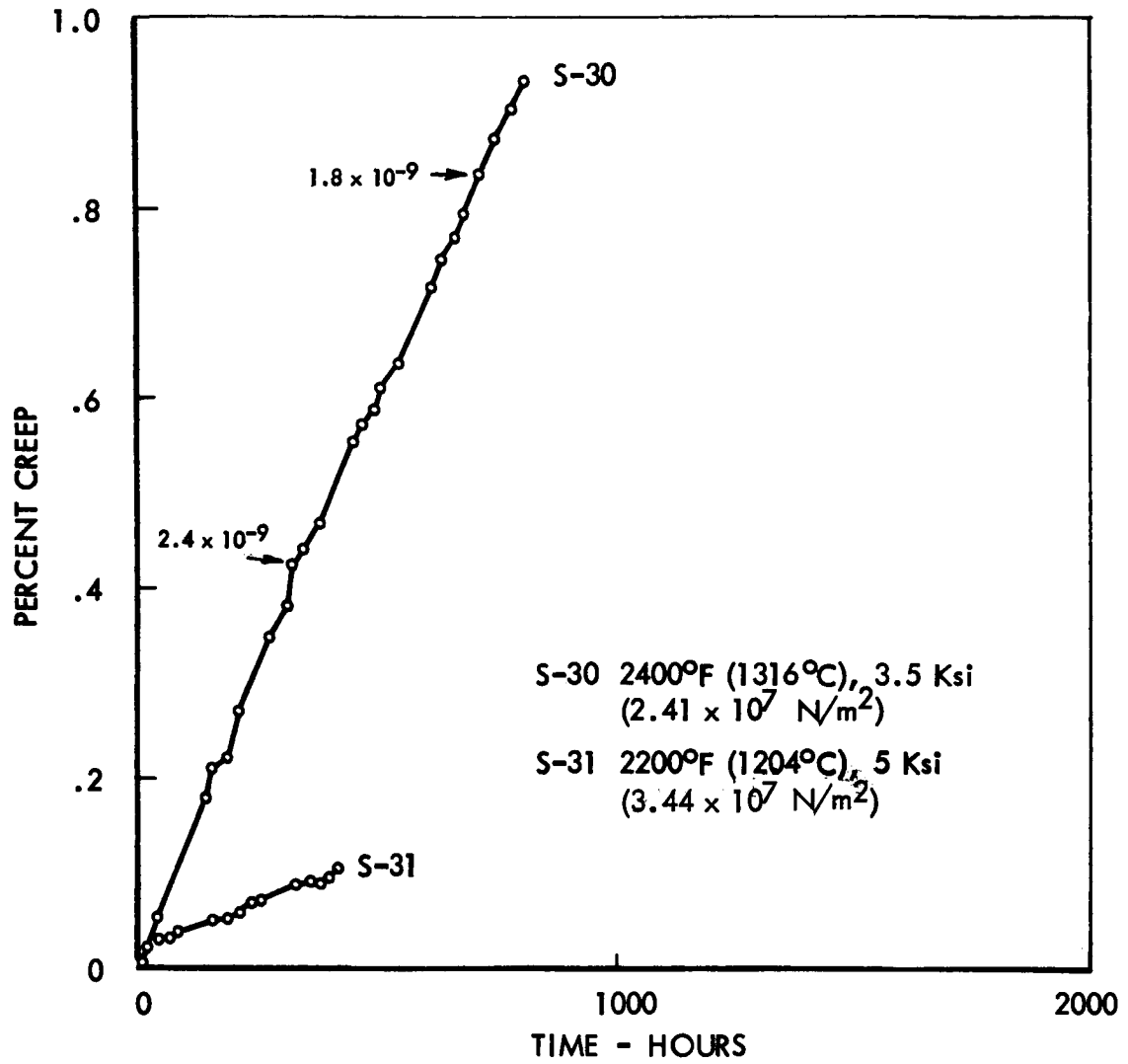


FIGURE 19 CREEP DATA FOR T-111 ALLOY HEAT 65079, RECRYSTALLIZED ONE HOUR, 3000°F (1649°C), TESTED IN VACUUM ENVIRONMENT $<1 \times 10^{-8}$ TORR.

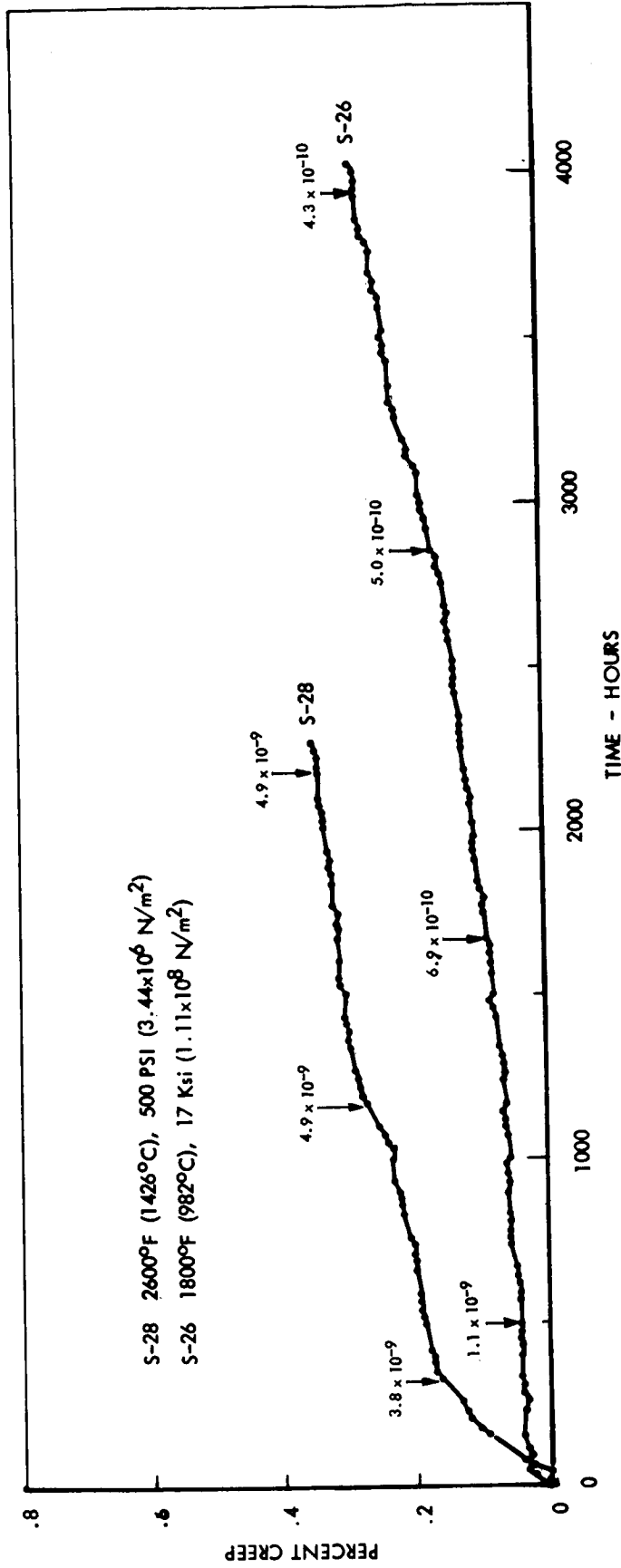


FIGURE 20 CREEP DATA FOR T-111 ALLOY HEAT D-1670, RECRYSTALLIZED 1 HOUR, 3000°F (1649°C), TESTED IN VACUUM ENVIRONMENT $< 1 \times 10^{-8}$ TORR.

TABLE 5

1% Creep Test Data for T-111 Tantalum-Base Alloy

Specimen No.	Test Temperature		Stress		Hours for 1.0% Creep	Larson-Miller $T^{\circ}R(15+\log t) \times 10^{-3}$ for 1.0% Creep
	$^{\circ}F$	$^{\circ}C$	Ksi	$N/m^2 \times 10^8$		
<u>Heat 70616, Recrystallized 3000$^{\circ}F$ (1649$^{\circ}C$), 1 Hour</u>						
S-19	2200	1204	8	0.511	2,000	48.6
S-21	2200	1204	12	0.826	1,140	48.0
S-23	2120	1160	12	0.826	3,150	47.8
S-22	2000	1093	20	1.380	670	43.9
S-24	1860	1016	20	1.380	4,730	43.4
<u>Heat D-1670, Recrystallized 3000$^{\circ}F$ (1649$^{\circ}C$), 1 Hour</u>						
S-25	2000	1093	15	1.030	1,350	44.6
S-26	1800	982	17	1.170	10,000*	43.0
S-25A	2600	1427	1.5	0.103	700*	54.5
S-28	2600	1427	0.5	0.0344	6,500*	57.5
<u>Heat 1102, Recrystallized 3000$^{\circ}F$ (1649$^{\circ}C$), 1 Hour</u>						
S-27	2000	1093	13	0.895	1,880	45.0
S-32	2200	1204	5	0.344	4,000*	49.5
<u>Heat 65079, Recrystallized 3000$^{\circ}F$ (1649$^{\circ}C$), 1 Hour</u>						
S-30	2400	1316	3.5	0.241	900*	51.4
S-31	2200	1204	5	0.344	4,000*	49.5

* Extrapolated Data

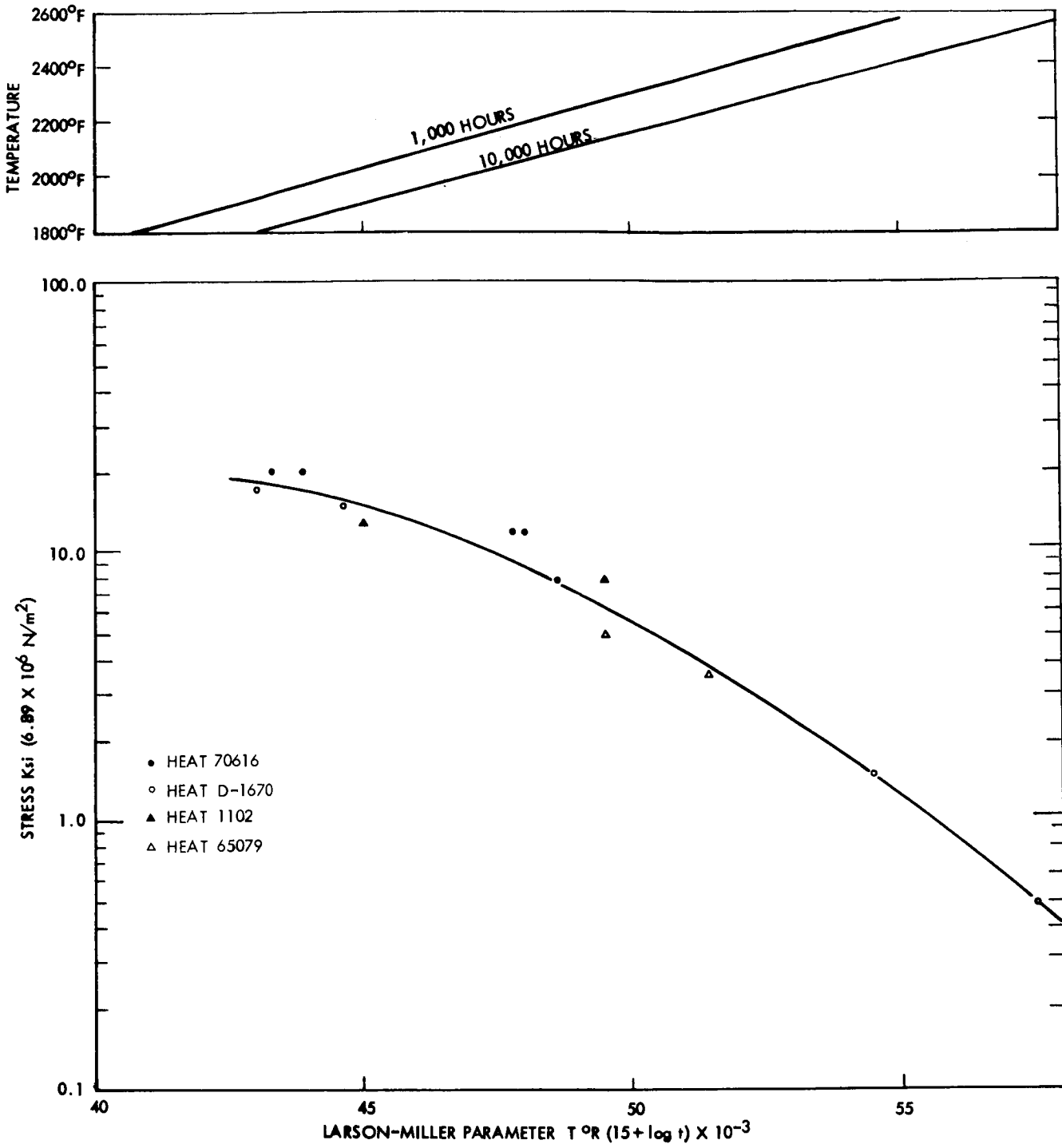


FIGURE 21 LARSON-MILLER PLOT FOR 1% CREEP IN T-111 ALLOY, RECRYSTALLIZED ONE HOUR AT 3000°F (1649°C) AND TESTED IN VACUUM ENVIRONMENT $< 1 \times 10^{-8}$ TORR.

V BIBLIOGRAPHY

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2. Technical Report, AF-APL-TR-61-51, June 25, 1965.
3. Development of Tantalum Base Alloys, NAS 3-2542.
4. F. F. Schmidt and H. R. Ogden, "The Engineering Properties of Tungsten Alloys, DMIC Report 191, September 27, 1963.
5. "Report on the Mechanical and Thermal Properties of Tungsten and TZM Sheet Produced in the Refractory Metal Sheet Rolling Program," Part 0, Bureau of Naval Weapons, Contract No. N600(19)-59530.
6. A. Mendelson, E. Roberts, Jr., and S. S. Manson, "Optimization of Time Temperature Parameters for Creep and Stress Rupture, with Application to Data from German Cooperative Long-Time Creep Program, NASA-TN D2975, August, 1965.

TABLE A-I

PROCESSING HISTORY OF TUNGSTEN SHEET

Vendor:

Universal Cyclops Steel Corporation
Bridgeville, Pennsylvania
Heat KC 1357

Processing History:

- 1) Extruded 4:1 ratio 3100°F & 1705°C) TRW Inc.
- 2) Forged open die 2200°F (1204°C)
- 3) Rolled
 - a) Initial 2300°F (1260°C)
 - b) Intermediate 1800°F (982°C)
 - c) Final 1400°F (760°C)
- 4) Stress Relieved 1700°F (927°C)

Hardness:

487 DPH (48 Rc)

APPENDIX I

Processing History of Test Materials

<u>Table No.</u>	<u>Processing History Of</u>
I	Tungsten - Heat KC 1357
II	Tungsten-25% Rhenium- Heat 3.5-75002
III	Sylvania A
IV	TZM Bar - Heat 7463
V	TZM Disc - Heat 7502
VI	TZM Disc - Heat KD-TZM-1175
VII	TZC - Heat M-80
VIII	TZC - Heat M-91
IX	TZC - Heat 4345
X	T-111 - Heat 70616
XI	T-111 - Heat 65079

TABLE A-II

PROCESSING HISTORY OF TUNGSTEN-25% RHENIUM SHEET

Vendor:

Wah Chang Corporation
Albany Division
Heat 3.5 - 75002

Processing History:

- 1) 0.055" sheet stress relieved one hour
2375°F (1301°C)
- 2) Rolled to 0.035"
- 3) 0.035" sheet stress relieved
 - a) small sheet - 2375°F (1301°C)
 - b) large sheet - 2550°F (1399°C)

Hardness:

452 DPH (45 Rc)

TABLE A-III

PROCESSING HISTORY OF SYLVANIA "A" SHEET

Vendor:

Sylvania Electric Products, Inc.
Chemical and Metallurgical Division
Towanda, Pennsylvania
Sales Order 88-56713

Processing History:

- 1) Rolling slabs were made by isostatically pressing powder
- 2) Slabs rolled at 2732-3452°F (1500-1900°C) to 0.032". Total reduction 90%
- 3) Intermediate annealing - none
- 4) Final stress relief - five minutes at 2732°F (1500°C)
- 5) Sheet trimmed with an abrasive saw and chemically cleaned

Hardness:

579 DPH (54 Rc)

TABLE A-IV

PROCESSING HISTORY OF TZM BAR

Vendor:

Climax Molybdenum Company of Michigan
Coldwater, Michigan
Heat 7463

Processing History:

- 1) Extrude 11-1/2" dia. ingots to 6-7" diameter
- 2) Recrystallize
- 3) Roll to 2" diameter
- 4) Recrystallize
- 5) Roll to 1" diameter
- 6) Swage to 5/8" dia. (75-85% cold work)
- 7) Stress relieve 2250°F (1232°C), 1/2 hour

Hardness:

300-330 DPH (30-34 Rc)

TABLE A-V

PROCESSING HISTORY OF TZM FORGED DISC

Vendor:

Climax Molybdenum Company of Michigan
Coldwater, Michigan
Heat 7502

Processing History:

- 1) Vacuum arc melted ingot 11-1/2" diameter
- 2) Machined to 10-3/4" diameter
- 3) Extruded to 6-1/4" diameter
- 4) Heat treated at 2700°F (1482°C)
- 5) Upset forged at 2200°F (1204°C)
- 6) Stress relieved at 2200°F (1204°C)

Hardness:

266-342 DPH (25-35 Rc)

TABLE A-VI

PROCESSING HISTORY OF TZM FORGED DISC

Vendor:

Received from AiResearch (Universal Cyclops)
Disc. No. 3
Heat KD-TZM-1175

Processing History:

- 1) 11-3/4" dia. ingot, machine to 10-3/4" dia.
- 2) Extrude to 6-1/2" dia. at 2250°D (1232°C)
- 3) Recrystallize at 2800°F (1538°C) for 4 hours
- 4) Forge to 4" dia. billet 3400°F to 2800°F
(1871 to 1538°C)
- 5) Recrystallize at 2950°F (1621°C) for 2 hours
- 6) Forge to flat disc 3/4" thick, 2800°F (1538°C)
starting temperature, 11 blows, finish temper-
ature 2160°F (1182°C)
- 7) Stress relieve at 2300°F (1260°C) for 1 hour

Hardness:

297-335 DPH (29-34 Rc)

TABLE A-VII

PROCESSING HISTORY OF TZC PLATE

Vendor:

General Electric Company
Refractory Metals Plant
Cleveland, Ohio
Heat M-80

Processing History:

- 1) Vacuum arc melted ingot 5.88" diameter
- 2) Machine to 5" diameter
- 3) Extrude 2:30:1 ratio at 3092°F (1700°C) to 4-1/8" x 2.22" plate
- 4) Cross-rolled on small mill (12" diameter) at 2925°F (1585°C) in 4-1/8" direction to 0.740", hydrogen atmosphere, 4% reduction per pass
- 5) Grit blasted and cut to final length with abrasive saw.

Hardness:

296 DPH (29 Rc)

TABLE A-VIII

PROCESSING HISTORY OF TZC PLATE

Vendor:

General Electric Company
Refractory Metals Plant
Cleveland, Ohio
Heat M-91

Processing History:

- 1) Vacuum arc melt ingot 5.88" diameter
- 2) Machine to 5" diameter
- 3) Extrude 2.30:1 at 3092°F (1700°C) to 4-1/8" x 2.22" plate
- 4) Cross-roll on large mill (28" diameter) to produce relatively large degree of deformation per pass and a finishing temperature as low as 2372°F (1300°C)
- 5) Grit blast and cut to final length with abrasive saw

Hardness:

385 DPH (39 Rc)

TABLE A-IX

PROCESSING HISTORY OF TZC PLATE

Vendor:

Climax Molybdenum Company of Michigan
Coldwater, Michigan
Heat 4345

Processing History:

- 1) Machine vacuum arc melted ingot to 5.85" dia.
- 2) Extrude to 3" diameter
- 3) Heat treat in vacuum 3000°F (1649°C)
- 4) Machine to 2.4 - 2.8" diameter
- 5) Upset forged 40% at 2400°F (1316°C)
- 6) Broad forged to 0.825" at 2400°F (1316°C)
- 7) Heat treat in vacuum 2400°F (1316°C), 1 hour
- 8) Machine to 0.70"

Hardness:

319-373 DPH (28-36 Rc)

TABLE A-X

PROCESSING HISTORY OF T-111 SHEET

Vendor:

Wah Chang Corporation
Albany, Oregon
Heat No. 70616-T-111

Processing History:

- 1) Electron beam melt
- 2) Arc cast 5-1/2" ingot
- 3) Forge to 1-1/2" thick sheet bar 2200°F (1204°C)
- 4) Vacuum anneal 2400°F (1316°C)
- 5) Warm roll 800°F (427°C) to 200 mil thick
- 6) Vacuum anneal 2400°F (1316°C)
- 7) Cold roll to final thickness
- 8) Vacuum anneal 2400°F (1316°C)

Hardness:

216-368 DPH (95R_B-37 R_C)

TABLE A-XI

PROCESSING HISTORY OF T-111 SHEET

Vendor:

Wah Chang Corporation
Albany, Oregon
Heat No. 65079

Processing History:

- 1) Forge 6-1/2" diameter arc melted ingot to 1-1/2" sheet bar at 2200°F (1204°C)
- 2) Vacuum anneal 2800°F (1538°C)
- 3) Warm roll 800°F (427°C) to 1/4" thick
- 4) Vacuum anneal 2800°F (1538°C)
- 5) Cold roll to final thickness
- 6) Vacuum anneal (1×10^{-4} Torr) 2800°F (1538°C)
1 Hour

Hardness:

236 DPH (20 Rc)

APPENDIX II

<u>Tungsten and Tungsten Alloys</u>		<u>TZC</u>		<u>T-111</u>	
<u>Table</u>	<u>Specimen No.</u>	<u>Table</u>	<u>Specimen No.</u>	<u>Table</u>	<u>Specimen No.</u>
I	S-5	XIV	B-9	XXIV	S-24
II	S-17	XV	B-11	XXV	S-27
III	S-18	XVI	B-12	XXVI	S-32
IV	S-9	XVII	B-28	XXVII	S-30
V	S-7	XVIII	B-20	XXVIII	S-31
VI	B-17	XIX	B-33	XXIX	S-28
VII	B-24	XX	B-32	XXX	S-26
VIII	S-3	XXI	B-36		
IX	S-4				
X	S-8				
XI	S-6				
XII	S-12				
XIII	S-15				
		<u>TZM</u>		<u>Astar 811C</u>	
		XXII	B-35	XXXI	S-29
		XXIII	B-25		

TABLE I

CREEP TEST DATA, ARC MELTED TUNGSTEN SHEET HEAT KC-1375,
RECRYSTALLIZED 2 HOURS 3200°F (1760°C), TESTED AT 3200°F (1760°C)

3000 psi (2.07 x 10⁷ N/m²)

<u>Time</u> <u>(Hours)</u>	<u>Length Change</u> <u>L (in)</u> <u>(2" G. L.)</u>	<u>Creep</u> <u>(%)</u>	<u>Pressure</u> <u>(Torr)</u>
.25	.00105	.05	8 x 10 ⁻⁷
.50	.00199	.10	8 x 10 ⁻⁷
.75	.00282	.14	8 x 10 ⁻⁷
1.75	.00733	.37	7 x 10 ⁻⁷
2.00	.00820	.41	6 x 10 ⁻⁷
3.00	.01120	.56	5.5 x 10 ⁻⁷
4.25	.01460	.73	2.2 x 10 ⁻⁶
6.00	.01940	.97	1.2 x 10 ⁻⁶
7.25	.02165	1.09	1.2 x 10 ⁻⁶
8.00	.02385	1.20	7 x 10 ⁻⁷
10.00	.02955	1.48	6 x 10 ⁻⁸
11.00	.03150	1.58	5.5 x 10 ⁻⁸
12.10	.03320	1.66	
13.90	.03780	1.89	
16.00	.04160	2.08	9 x 10 ⁻⁸
17.00	.04550	2.26	9.3 x 10 ⁻⁸
18.00	.04975	2.50	8.4 x 10 ⁻⁸
19.00	.05395	2.70	7.9 x 10 ⁻⁸
20.25	.05705	2.85	8.0 x 10 ⁻⁸
21.00	.06165	3.08	7.8 x 10 ⁻⁸
22.25	.06880	3.44	7.6 x 10 ⁻⁸
23.00	.07140	3.57	7.5 x 10 ⁻⁸
32.30	.10778	5.38	6.1 x 10 ⁻⁸

Test Terminated - 5% Creep
Specimen S-5

TABLE II

CREEP TEST DATA, ARC-MELTED TUNGSTEN SHEET, HEAT KC-1375,
RECRYSTALLIZED 2 HOURS, 2800°F (1538°C), TESTED AT 2800°F (1538°C)
4000 psi (2.76 x 10⁷N/m²)

<u>Time</u>	<u>Length Change L (inch) (2" G. L.)</u>	<u>Creep (%)</u>	<u>Pressure (Torr)</u>
1 minute(s)	.00000	.000	1.4 x 10 ⁻⁷
2	-.00030	-.015	1.4 x 10 ⁻⁷
3	.00000	.000	1.4 x 10 ⁻⁷
4	.00005	.002	1.4 x 10 ⁻⁷
5	.00010	.005	1.4 x 10 ⁻⁷
10	-.00005	-.002	1.4 x 10 ⁻⁷
15	.00010	.005	1.4 x 10 ⁻⁷
30	.00005	.002	1.4 x 10 ⁻⁷
45	.00015	.008	1.4 x 10 ⁻⁷
60	.00030	.015	1.4 x 10 ⁻⁷
17.0 hours	.01720	.860	2.2 x 10 ⁻⁸
41.0	.03150	1.375	1.3 x 10 ⁻⁸
65.1	.04385	2.192	1.1 x 10 ⁻⁸
73.3	.04785	2.392	-
98.6	.05900	2.950	8.2 x 10 ⁻⁹
122.5	.06905	3.452	7.2 x 10 ⁻⁹
137.7	.07605	3.802	7.2 x 10 ⁻⁹
163.7	.08790	4.395	6.8 x 10 ⁻⁹
185.4	.09500	4.750	6.6 x 10 ⁻⁹
194.1	.10050	5.025	6.5 x 10 ⁻⁹
218.1	.10905	5.452	5.7 x 10 ⁻⁹

Test Terminated 5% Creep
Specimen S-17

TABLE III

CREEP TEST DATA, ARC-MELTED TUNGSTEN SHEET, HEAT KC-1375,
 RECRYSTALLIZED 2HOURS, 2800°F (1538°C), TESTED AT 2800°F (1538°C)
 3000 psi (2.07×10^7 N/m²)

<u>Time</u>	<u>Length Change ΔL (inch) (2" G.L.)</u>	<u>Creep (%)</u>	<u>Pressure (Torr)</u>
1 Minute(s)	.00010	.005	2.4×10^{-7}
2	.00000	.000	2.4×10^{-7}
3	.00005	.002	2.4×10^{-7}
4	.00000	.000	2.4×10^{-7}
5	.00000	.000	2.4×10^{-7}
6	.00010	.005	2.4×10^{-7}
7	.00015	.008	2.4×10^{-7}
8	.00005	.002	2.4×10^{-7}
9	.00010	.005	2.4×10^{-7}
10	.00010	.005	2.4×10^{-7}
15	.00005	.002	2.4×10^{-7}
30	.00010	.005	2.4×10^{-7}
45	.00015	.008	2.4×10^{-7}
60	.00010	.005	2.4×10^{-7}
3.1 Hours	.00060	.030	2.4×10^{-7}
23.95	.00535	.218	1.0×10^{-8}
46.95	.00830	.415	2.9×10^{-8}
67.4	.01205	.602	2.0×10^{-8}
91.2	.01435	.718	1.7×10^{-8}
114.9	.01835	.918	1.0×10^{-8}
138.8	.02190	1.095	8.7×10^{-9}
162.8	.02355	1.178	8.9×10^{-9}
234.8	.03280	1.640	7.2×10^{-9}
259.0	.03665	1.832	7.4×10^{-9}
282.9	.04075	2.038	7.2×10^{-9}
306.8	.04340	2.170	6.8×10^{-9}
330.8	.04750	2.375	6.4×10^{-9}
403.2	.05605	2.802	3.8×10^{-9}
426.8	.05845	2.922	3.9×10^{-9}
450.8	.06065	3.032	4.1×10^{-9}
479.9	.06370	3.185	4.0×10^{-9}
574.3	.07495	3.748	3.0×10^{-9}
647.0	.08195	4.098	1.7×10^{-9}
738.7	.09155	4.578	1.5×10^{-9}
763.1	.09445	4.722	1.6×10^{-9}
786.9	.09690	4.845	3.1×10^{-9}
811.3	.09880	4.940	1.6×10^{-9}
835.8	.10160	5.080	1.5×10^{-9}
907.5	.11070	5.535	3.0×10^{-9}

Test Terminated 5% Creep
 Specimen S-18

TABLE IV

CREEP TEST DATA, ARC-MELTED TUNGSTEN SHEET HEAT KC-1375
 RECRYSTALLIZED 2 HOURS, 3200°F (1760°C) TESTED AT 3200°F (1760°C)
 1000 psi (6.89×10^6 N/m²)

<u>Time</u>	<u>Length Change</u> <u>ΔL (inch)</u> <u>(2" G. L.)</u>	<u>Creep</u> <u>(%)</u>	<u>Pressure</u> <u>(Torr)</u>
1 minute	.00005	.002	4×10^{-8}
2	.00015	.007	
3	.00015	.007	
4	.00010	.005	
5	.00015	.007	
6	.00020	.010	
7	.00020	.010	
8	.00020	.010	
9	.00020	.010	
10	.00015	.007	
15	.00020	.010	
20	.00010	.005	
25	.00020	.010	
30	.00020	.010	
60	.00020	.010	
90	.00030	.015	
16.6 hours	.00180	.090	2.2×10^{-8}
88.4	.00480	.240	1.0×10^{-8}
112.4	.00615	.308	1.1×10^{-8}
136.3	.00750	.375	9.2×10^{-9}
160.3	.00880	.440	7.8×10^{-9}
184.4	.00960	.480	6.9×10^{-9}
256.3	.01115	.558	5.6×10^{-8}
280.7	.01190	.595	1.6×10^{-9}
340.5	.01215	.608	3.9×10^{-9}
328.4	.01265	.632	6.8×10^{-9}
352.7	.01330	.665	6.5×10^{-9}
424.5	.01575	.788	7.2×10^{-9}
448.9	.01725	.862	6.1×10^{-9}
472.3	.01705	.852	6.3×10^{-9}
496.4	.01725	.862	9.0×10^{-8}
520.4	.01740	.870	4.6×10^{-8}
592.4	.01810	.905	5.0×10^{-8}
619.1	.01930	.965	3.6×10^{-8}

TABLE IV (Continued)

<u>Time</u>	<u>Length Change ΔL (inch) (2" G. L.)</u>	<u>Creep (%)</u>	<u>Pressure (Torr)</u>
640.3 hours	.01960	.980	4.9 x 10 ⁻⁸
664.3	.02010	1.005	4.7 x 10 ⁻⁸
688.2	.02040	1.020	4.0 x 10 ⁻⁹
760.4	.02155	1.077	4.6 x 10 ⁻⁸
784.6	.02190	1.095	1.5 x 10 ⁻⁹
808.7	.02305	1.152	7.2 x 10 ⁻⁹
832.3	.02375	1.188	2.4 x 10 ⁻⁹
856.3	.02455	1.228	2.4 x 10 ⁻⁹
928.5	.02465	1.232	3.0 x 10 ⁻⁹
952.5	.02570	1.285	2.3 x 10 ⁻⁹
977.5	.02660	1.330	8.2 x 10 ⁻⁹
1000.3	.02715	1.358	2.4 x 10 ⁻⁹
1026.3	.02775	1.388	--
1096.6	.02850	1.425	8.3 x 10 ⁻⁹
1121.1	.02875	1.438	8.0 x 10 ⁻⁹
1144.3	.02930	1.465	--
1168.4	.03040	1.520	9.4 x 10 ⁻⁹
1264.3	.03120	1.560	9.2 x 10 ⁻⁹
1288.4	.03145	1.572	2.8 x 10 ⁻⁹
1312.4	.03210	1.655	6.7 x 10 ⁻⁹
1336.9	.03265	1.632	2.4 x 10 ⁻⁹
1360.5	.03300	1.650	--
1431.6	.03345	1.672	4.6 x 10 ⁻¹⁰
1455.4	.03430	1.715	2.4 x 10 ⁻⁹
1479.4	.03445	1.722	3.2 x 10 ⁻⁹
1503.2	.03455	1.728	6.8 x 10 ⁻⁹
1527.5	.03460	1.730	6.6 x 10 ⁻⁹
1599.8	.03525	1.762	5.3 x 10 ⁻⁹
1623.3	.03550	1.775	3.0 x 10 ⁻⁹
1652.7	.03630	1.815	--
1671.4	.03665	1.832	1.8 x 10 ⁻⁹
1691.6	.03690	1.845	2.0 x 10 ⁻⁹
1767.3	.03745	1.872	1.8 x 10 ⁻⁹
1791.8	.03810	1.905	1.7 x 10 ⁻⁹
1815.4	.03825	1.912	1.7 x 10 ⁻⁹
1839.3	.03850	1.925	6.0 x 10 ⁻¹⁰
1863.3	.03865	1.932	3.2 x 10 ⁻⁹
1935.6	.03910	1.955	6.2 x 10 ⁻⁹
1983.5	.04010	2.005	2.5 x 10 ⁻⁹
2031.7	.04040	2.020	7.3 x 10 ⁻⁹
2103.2	.04100	2.050	2.2 x 10 ⁻⁹

TABLE IV (Continued)

<u>Time</u>	<u>Length Change</u> <u>ΔL (inch)</u> <u>(2" G. L.)</u>	<u>Creep</u> <u>(%)</u>	<u>Pressure</u> <u>(Torr)</u>
2157.7	.04135	2.068	7.4×10^{-9}
2199.5	.04180	2.090	--
2248.8	.04205	2.102	--
2295.3	.04260	2.130	2.3×10^{-9}
2320.2	.04275	2.138	2.8×10^{-9}
2367.3	.04325	2.162	2.0×10^{-9}
2439.2	.04370	2.185	2.1×10^{-9}
2487.4	.04420	2.210	2.0×10^{-9}
2535.3	.04465	2.232	6.6×10^{-9}
2607.3	.04555	2.278	1.4×10^{-9}
2660.1	.04620	2.310	7.0×10^{-9}
2703.3	.04570	2.285	5.6×10^{-9}
2775.2	.04710	2.355	1.7×10^{-9}
2847.5	.04770	2.385	1.6×10^{-9}
2943.6	.04850	2.425	2.0×10^{-9}
3015.4	.04940	2.470	5.0×10^{-9}
3135.6	.05090	2.545	5.9×10^{-9}
3184.0	.05110	2.555	5.9×10^{-9}
3279.3	.05145	2.572	2.6×10^{-9}
3351.6	.05215	2.608	6.2×10^{-9}
3447.8	.05320	2.660	3.4×10^{-9}
3519.4	.05355	2.678	1.5×10^{-9}
3618.5	.05405	2.702	2.0×10^{-9}
3692.2	.05420	2.710	1.1×10^{-8}
3793.5	.05475	2.738	2.4×10^{-8}
3856.9	.05510	2.755	4.9×10^{-8}
3886.4	.05520	2.760	1.1×10^{-7}

Test terminated because of high pressure due to leak.

Specimen S-9

TABLE V

CREEP TEST DATA, ARC-MELTED TUNGSTEN SHEET HEAT KC-1375,
 RECRYSTALLIZED 2 HOURS 3200°F (1760°C), TESTED AT 3200°F (1760°C)
 400 psi (2.76×10^6 N/m²)

Time	Length Change ΔL (inch) (2" G. L.)	Creep (%)	Pressure (Torr)
1 minute(s)	-.00010	.0050	2.6×10^{-7}
2	-.00005	.0025	
3	0	0	
4	-.00005	.0025	
5	0	0	
10	-.00035	.0018	
15	-.00020	.0010	
20	.00030	.0015	
25	.00030	.0015	
30	.00025	.0013	
60	.00025	.0013	
19.4 hours	0	0	3.2×10^{-8}
42.3	.00010	.005	1.7×10^{-8}
90.2	.00050	.025	1.4×10^{-8}
163.1	.00100	.050	8.4×10^{-9}
186.3	.00125	.0625	8.8×10^{-9}
210.4	.00145	.0725	1.5×10^{-8}
234.9	.00120	.060	1.8×10^{-8}
258.3	.00100	.055	5.0×10^{-9}
264.5	.00120	.060	1.2×10^{-8}
330.5	.00160	.080	1.2×10^{-8}
354.4	.00180	.090	1.1×10^{-8}
378.8	.00190	.095	6.0×10^{-9}
426.4	.00145	.073	3.8×10^{-9}
485.5	.00190	.095	4.6×10^{-9}
498.8	.00195	.098	9.8×10^{-9}
546.3	.00200	.100	6.9×10^{-9}
569.7	.00210	.105	1.2×10^{-8}
594.4	.00220	.110	8.8×10^{-9}
654.9	.00230	.115	6.8×10^{-9}
666.2	.00235	.118	6.6×10^{-9}
690.8	.00240	.120	8.0×10^{-8}
714.2	.00235	.118	1.4×10^{-6}

Test terminated because of leak in coldwall.
 Specimen S-7

TABLE VI

CREEP TEST DATA, VAPOR DEPOSITED TUNGSTEN, RECRYSTALLIZED 2 HOURS 3200°F (1760°C),
TESTED AT 3200°F (1760°C), 1000 PSI ($6.90 \times 10^6 \text{N/m}^2$)

<u>Time</u>	<u>Length Change ΔL (inch) (2" G. L.)</u>	<u>Creep (%)</u>	<u>Pressure (Torr)</u>
1 minutes	.00010	.005	
2	.00070	.035	
3	.00110	.055	
6	.00120	.060	
14	.00100	.050	
20	.00105	.052	3.8 x 10 ⁻⁷
40	.00110	.055	
60	.00160	.080	
16.3 hours	.00220	.110	1.2 x 10 ⁻⁷
88.4	.00460	.230	7.2 x 10 ⁻⁸
117.4	.00550	.275	6.7 x 10 ⁻⁸
136.6	.00675	.338	1.8 x 10 ⁻⁸
160.3	.00755	.378	3.0 x 10 ⁻⁸
184.1	.00795	.398	8.9 x 10 ⁻⁹
256.0	.00960	.480	1.4 x 10 ⁻⁸
280.0	.00940	.470	7.9 x 10 ⁻⁹
304.1	.01045	.522	6.7 x 10 ⁻⁹
328.4	.01095	.548	8.2 x 10 ⁻⁹
352.2	.01115	.558	1.2 x 10 ⁻⁸
424.3	.01190	.595	5.2 x 10 ⁻⁹
448.1	.01280	.640	4.7 x 10 ⁻⁹
472.1	.01190	.595	6.5 x 10 ⁻⁹
496.0	.01310	.655	6.6 x 10 ⁻⁹
520.2	.01350	.675	6.0 x 10 ⁻⁹
616.2	.01395	.698	5.9 x 10 ⁻⁹
640.7	.01410	.705	5.6 x 10 ⁻⁹
664.2	.01430	.715	7.8 x 10 ⁻⁹
688.2	.01460	.730	4.9 x 10 ⁻⁹
760.3	.01520	.760	4.0 x 10 ⁻⁹
784.1	.01580	.790	5.4 x 10 ⁻⁹
808.1	.01625	.812	5.2 x 10 ⁻⁹
832.3	.01640	.820	5.0 x 10 ⁻⁹
856.4	.01725	.862	--
928.5	.01750	.875	5.2 x 10 ⁻⁹
952.4	.01760	.880	8.4 x 10 ⁻⁹
976.2	.01710	.855	9.8 x 10 ⁻⁹
991.0	.01800	.900	9.8 x 10 ⁻⁹
1014.2	.01800	.900	9.5 x 10 ⁻⁹

TABLE VI (Continued)

<u>Time</u>	<u>Length Change ΔL (inch) (2" G.L.)</u>	<u>Creep (%)</u>	<u>Pressure (Torr)</u>
1088.4	.01845	.922	8.4 x 10 ⁻⁹
1158.3	.02030	1.015	8.0 x 10 ⁻⁹
1254.7	.02030	1.015	9.2 x 10 ⁻⁹
1326.3	.02080	1.040	7.8 x 10 ⁻⁹
1422.7	.02190	1.095	2.6 x 10 ⁻⁸
1494.2	.02330	1.165	1.0 x 10 ⁻⁸
1590.8	.02290	1.145	6.8 x 10 ⁻⁹
1662.2	.02510	1.255	8.0 x 10 ⁻⁹
1758.2	.02540	1.270	9.0 x 10 ⁻⁹
1829.9	.02605	1.302	8.0 x 10 ⁻⁹
1927.7	.02660	1.330	1.4 x 10 ⁻⁸
1998.9	.02700	1.350	1.6 x 10 ⁻⁸
2095.1	.02825	1.412	1.4 x 10 ⁻⁸
2191.3	.02910	1.455	1.4 x 10 ⁻⁸
2263.2	.02950	1.475	1.5 x 10 ⁻⁸
2359.2	.03000	1.500	1.2 x 10 ⁻⁸
2431.8	.03050	1.525	1.2 x 10 ⁻⁸
2527.6	.03065	1.532	1.1 x 10 ⁻⁸
2599.4	.03090	1.545	7.0 x 10 ⁻⁹
2671.0	.03140	1.570	4.6 x 10 ⁻⁹

Test terminated because of inability to see scribe lines.

Specimen B-17

TABLE VII

CREEP TEST DATA, VAPOR DEPOSITED TUNGSTEN, RECRYSTALLIZED 1 HOUR 2800°F (1538°C)

TESTED AT 2800°F (1538°C), 2000 PSI (1.38 x 10⁷N/m²)

<u>Time</u>	<u>Length Change ΔL (inch) (2" G. L.)</u>	<u>Creep (%)</u>	<u>Pressure (Torr)</u>
1 minute(s)	.00020	.010	3.5 x 10 ⁻⁷
2	.00025	.012	3.5 x 10 ⁻⁷
3	.00025	.012	3.5 x 10 ⁻⁷
4	.00025	.012	3.5 x 10 ⁻⁷
5	.00025	.012	3.5 x 10 ⁻⁷
6	.00030	.015	3.5 x 10 ⁻⁷
7	.00040	.020	3.5 x 10 ⁻⁷
8	.00035	.018	3.5 x 10 ⁻⁷
9	.00040	.020	3.5 x 10 ⁻⁷
10	.00035	.018	3.5 x 10 ⁻⁷
15	.00000	.000	3.5 x 10 ⁻⁷
30	-.00005	-.002	3.5 x 10 ⁻⁷
45	.00000	.000	3.5 x 10 ⁻⁷
60	-.00005	-.002	3.5 x 10 ⁻⁷
64.9 hours	.00175	.088	8.0 x 10 ⁻⁸
88.9	.00210	.105	6.4 x 10 ⁻⁸
112.8	.00260	.130	4.6 x 10 ⁻⁸
136.7	.00310	.155	4.1 x 10 ⁻⁸
161.0	.00370	.185	3.8 x 10 ⁻⁸
232.8	.00480	.240	3.4 x 10 ⁻⁸
256.8	.00525	.262	3.1 x 10 ⁻⁸
280.8	.00550	.275	2.9 x 10 ⁻⁸
304.8	.00570	.285	2.7 x 10 ⁻⁸
328.7	.00635	.318	2.6 x 10 ⁻⁸
400.8	.00750	.375	1.6 x 10 ⁻⁸
425.0	.00760	.380	1.3 x 10 ⁻⁸
448.6	.00775	.388	7.8 x 10 ⁻⁹
472.8	.00795	.398	6.3 x 10 ⁻⁹
496.8	.00830	.415	5.6 x 10 ⁻⁹
568.7	.00930	.465	5.0 x 10 ⁻⁹
600.1	.00930	.495	1.1 x 10 ⁻⁹
616.7	.01040	.520	1.2 x 10 ⁻⁸
641.1	.01015	.508	1.1 x 10 ⁻⁸
664.7	.00980	.490	1.0 x 10 ⁻⁸
736.8	.01150	.575	9.9 x 10 ⁻⁹
760.7	.01190	.595	8.6 x 10 ⁻⁹
784.7	.01310	.655	9.7 x 10 ⁻⁹

TABLE VII (Continued)

<u>Time</u>	<u>Length Change ΔL (inch) (2" G.L.)</u>	<u>Creep (%)</u>	<u>Pressure (Torr)</u>
808.5 Hours	.01235	.618	9.4×10^{-9}
832.5	.01270	.635	9.4×10^{-9}
904.5	.01350	.675	9.2×10^{-9}
929.4	.01370	.685	8.6×10^{-9}
952.6	.01410	.705	8.5×10^{-9}
976.8	.01445	.722	7.0×10^{-9}
1001.8	.01460	.730	8.2×10^{-9}
1072.5	.01540	.770	8.0×10^{-9}
1144.8	.01660	.830	7.8×10^{-9}
1240.7	.01775	.888	7.8×10^{-9}
1312.7	.01830	.915	5.6×10^{-9}
1408.5	.01925	.962	5.0×10^{-9}
1480.7	.01960	.980	4.0×10^{-9}
1577.3	.02150	1.075	4.0×10^{-9}
1652.0	.02190	1.095	4.2×10^{-9}
1744.9	.02265	1.132	2.7×10^{-9}
1817.7	.02295	1.148	3.6×10^{-9}
1912.9	.02475	1.238	3.8×10^{-9}
1989.8	.02630	1.315	3.1×10^{-9}
2079.7	.02660	1.330	2.3×10^{-9}
2151.8	.02835	1.418	3.8×10^{-9}
2247.6	.02825	1.412	3.4×10^{-9}
2319.8	.02925	1.462	2.8×10^{-9}
2415.7	.03100	1.550	2.6×10^{-9}
2487.6	.03110	1.555	3.5×10^{-9}
2584.0	.03135	1.568	3.0×10^{-9}
2655.7	.03265	1.632	2.6×10^{-9}
2752.0	.03315	1.658	2.6×10^{-9}
2823.7	.03380	1.690	2.3×10^{-9}
2944.2	.03465	1.732	2.2×10^{-9}
2991.7	.03580	1.790	2.0×10^{-9}
3099.2	.03665	1.832	2.1×10^{-9}
3159.4	.03785	1.892	1.8×10^{-9}
3183.4	.03815	1.908	1.6×10^{-9}
3255.5	.03785	1.892	2.0×10^{-9}
3327.9	.03905	1.952	2.1×10^{-9}
3423.6	.3975	1.988	1.8×10^{-9}
3495.7	.04005	2.002	1.8×10^{-9}

TABLE VII (Continued)

<u>Time</u>	<u>Length Change Δ L (inch) (2" G. L.)</u>	<u>Creep (%)</u>	<u>Pressure (Torr)</u>
3591.9 Hours	.04145	2.072	1.9×10^{-9}
3663.6	.04180	2.090	1.9×10^{-9}
3783.6	.04345	2.172	1.7×10^{-9}
3832.2	.04445	2.222	1.8×10^{-9}
3927.7	.04495	2.248	1.5×10^{-9}
4008.7	.04615	2.308	1.6×10^{-9}
4095.4	.04690	2.345	1.8×10^{-9}
4171.2	.04735	2.368	1.6×10^{-9}
4263.9	.04860	2.430	1.4×10^{-9}
4335.4	.04895	2.448	1.4×10^{-9}
4431.8	.04930	2.465	1.7×10^{-9}
4504.0	.05095	2.548	1.6×10^{-9}
4599.6	.05065	2.532	1.6×10^{-9}
4671.2	.05230	2.615	1.6×10^{-9}
4767.5	.05400	2.700	1.6×10^{-9}
4839.3	.05415	2.706	1.4×10^{-9}
4936.2	.05525	2.762	1.3×10^{-9}
5007.5	.05600	2.800	1.5×10^{-9}
5103.3	.05740	2.870	1.5×10^{-9}
5296.0	.05865	2.932	1.4×10^{-9}
5343.1	.05915	2.958	1.3×10^{-9}
5439.6	.06010	3.005	1.4×10^{-9}
5511.2	.06125	3.062	2.0×10^{-9}
5679.6	.06255	3.128	1.3×10^{-9}
5775.4	.06425	3.212	1.3×10^{-9}
5847.7	.06475	3.238	1.2×10^{-9}
5943.6	.06560	3.280	1.2×10^{-9}
6017.5	.06665	3.332	1.2×10^{-9}
6111.5	.06770	3.385	1.2×10^{-9}
6183.5	.06865	3.432	1.0×10^{-9}
6279.4	.06925	3.462	1.2×10^{-9}

TABLE VII (Continued)

<u>Time</u>	<u>Length Change Δ L (inch) (2" G. L.)</u>	<u>Creep (%)</u>	<u>Pressure (Torr)</u>
6351.5	.07045	3.522	1.2×10^{-9}
6447.4	.07125	3.562	1.1×10^{-9}
6519.7	.07155	3.578	1.2×10^{-9}
6616.4	.07195	3.598	1.2×10^{-9}
6688.7	.07275	3.638	1.3×10^{-9}
6784.4	.07355	3.678	1.1×10^{-9}
6811.5	.07415	3.708	1.1×10^{-9}

Test Terminated - 3%

Specimen B-24

TABLE VIII

CREEP TEST DATA, W-25% Re ALLOY SHEET, RECRYSTALLIZED 3200°F
(1760°C), 48 HOURS, TESTED AT 3200°F (1760°C) 5000 psi (3.45x10⁷N/m²)

<u>Time</u>	<u>Length Change</u> <u>Δ L (inch)</u> <u>(2" G. L.)</u>	<u>Creep</u> <u>(%)</u>	<u>Pressure</u> <u>(Torr)</u>
1 Minute(s)			1.0 x 10 ⁻⁸
2	.00025	.013	
3	.00030	.015	
4	.00030	.015	
6	.00025	.013	
8	.00025	.013	
10	.00025	.013	
12	.00020	.010	
25	.00010	.005	
35	.00025	.013	
40	.00040	.020	
45	.00060	.030	
1.5 Hours	.00130	.065	
2.5	.00325	.162	
4.0	.00490	.245	
4.5	.00705	.352	
5.0	.00725	.362	
5.5	.00735	.368	
6.0	.00845	.422	
6.5	.00960	.480	
7.0	.01085	.542	
7.5	.01190	.595	
8.0	.01315	.658	
8.5	.01450	.725	
9.5	.01575	.788	
11.5	.02010	1.000	
13.5	.02630	1.320	
14.5	.03070	1.540	
16.8	.03430	1.720	7.8 x 10 ⁻⁹
18.1	.03730	1.860	
19.1	.04140	2.070	

TABLE VIII (Continued)

<u>Time</u>	<u>Length Change Δ L (inch) (2" G. L.)</u>	<u>Creep (%)</u>	<u>Pressure (Torr)</u>
20.0 Hours	.04340	2.170	
22.6	.05095	2.550	
25.2	.05725	2.860	8.0 x 10 ⁻⁹
30.0	.07215	3.610	
30.6	.07410	3.700	
40.5	.10670	5.340	6.8 x 10 ⁻⁹
41.4	.10990	5.490	
44.5	.12030	6.030	

Test Terminated - 5% Creep
Specimen S-3

TABLE IX

CREEP TEST DATA, TUNGSTEN-25% Re SHEET, RECRYSTALLIZED
3200°F (1760°C), 45 HOURS, TESTED AT 3200°F (1760°C) 3000 psi
(2.07 x 10⁷N/m²)

<u>Time</u>	<u>Length Change Δ L (inch) (2" G. L.)</u>	<u>Creep (%)</u>	<u>Pressure (Torr)</u>
.5 Hours	0	0	1 x 10 ⁻⁸
1.0	.00015	.0075	
1.5	.00045	.0225	
2.0	.00075	.0375	
2.5	.00075	.0375	
3.0	.00090	.0450	
3.5	.00110	.0550	
44.4	.03945	1.972	6 x 10 ⁻⁹
53.1	.04885	2.442	
68.6	.06780	3.39	7.8 x 10 ⁻⁹
76.2	.07600	3.78	
93.7	.09930	4.96	8.4 x 10 ⁻⁹
95.8	.10335	5.17	
97.2	.10450	5.22	8 x 10 ⁻⁹

Test Terminated - 5% Creep
Specimen S-4

TABLE X

CREEP TEST DATA, TUNGSTEN-25% Re SHEET, RECRYSTALLIZED 3200°F (1760°C), 1 HOUR, TESTED AT 3200°F (1760°C), 1500 psi (1.03 x 10⁷ N/m²)

<u>Time</u>	<u>Length Change Δ L (inch) (2" G. L.)</u>	<u>Creep (%)</u>	<u>Pressure (Torr)</u>
5 Minutes	.00005	0.002	
10	.00010	0.005	
15	.00010	0.005	
20	.00010	0.005	
30	.00010	0.005	
45	.00010	0.005	
60	.00010	0.005	
10.6 Hours	.00005	0.0025	1.4 x 10 ⁻⁷
82.7	.00450	0.2250	2.1 x 10 ⁻⁸
106.6	.00700	0.3500	2.0 x 10 ⁻⁸
130.6	.00735	0.3675	1.6 x 10 ⁻⁸
154.6	.01065	0.5325	1.6 x 10 ⁻⁸
178.8	.01170	0.5850	1.4 x 10 ⁻⁸
250.6	.01535	0.7670	1.0 x 10 ⁻⁸
274.5	.01730	0.8650	9.8 x 10 ⁻⁹
298.6	.01795	0.8970	1.0 x 10 ⁻⁸
322.5	.02135	1.0670	9.6 x 10 ⁻⁹
346.7	.02195	1.0970	9.4 x 10 ⁻⁹
418.5	.02480	1.2400	8.5 x 10 ⁻⁹
422.9	.02700	1.3500	1.5 x 10 ⁻⁸
466.7	.02910	1.4500	8.4 x 10 ⁻⁹
490.7	.03225	1.6120	1.0 x 10 ⁻⁸
515.0	.03345	1.6720	9.6 x 10 ⁻⁹
586.0	.03870	1.9350	1.0 x 10 ⁻⁸
611.1	.04010	2.0050	9.2 x 10 ⁻⁹
634.6	.04140	2.0700	8.9 x 10 ⁻⁹
658.7	.04300	2.1500	1.2 x 10 ⁻⁸
682.7	.04490	2.2450	7.9 x 10 ⁻⁹
754.7	.05065	2.5320	7.0 x 10 ⁻⁹
781.3	.05385	2.6920	7.5 x 10 ⁻⁹
802.6	.05525	2.7600	7.2 x 10 ⁻⁹
826.6	.05700	2.8500	7.2 x 10 ⁻⁹
850.5	.05835	2.9170	8.3 x 10 ⁻⁹

TABLE X (Continued)

<u>Time</u>	<u>Length Change Δ L (inch) (2" G. L.)</u>	<u>Creep (%)</u>	<u>Pressure (Torr)</u>
922.6	.06480	3.2400	8.8 x 10 ⁻⁹
946.9	.06820	3.4100	1.4 x 10 ⁻⁸
970.9	.06940	3.4700	4.4 x 10 ⁻⁹
994.6	.07210	3.6050	4.8 x 10 ⁻⁹
1018.6	.07370	3.6850	5.0 x 10 ⁻⁹
1090.6	.08120	4.0600	5.9 x 10 ⁻⁹
1114.8	.08305	4.1520	9.0 x 10 ⁻⁹
1139.8	.08525	4.2520	5.8 x 10 ⁻⁹
1162.5	.08795	4.3970	6.4 x 10 ⁻⁹
1188.3	.09065	4.5320	-
1258.9	.09770	4.8850	4.2 x 10 ⁻⁹
1283.3	.10085	5.0420	-

Test Terminated - 5% Creep
Specimen S-8

TABLE XI

CREEP TEST DATA, TUNGSTEN-25% Re SHEET, RECRYSTALLIZED 3200°F (1760°C), 1 HOUR, TESTED AT 3200°F (1760°C), 500 psi (3.44 x 10⁶ N/m²)

<u>Time</u>	<u>Length Change Δ L (inch) (2" G. L.)</u>	<u>Creep (%)</u>	<u>Pressure (Torr)</u>
0.1 Hours	0	0	2.4 x 10 ⁻⁷
0.2	0	0	
0.3	0	0	2.1 x 10 ⁻⁷
0.4	0	0	
0.5	0	0	
0.6	0	0	
0.7	0	0	
0.8	0	0	
0.9	0	0	
1.0	0	0	1.9 x 10 ⁻⁷
1.5	0	0	
2.0	0	0	1.5 x 10 ⁻⁷
13.7	-.00005	-.0025	4.5 x 10 ⁻⁸
37.1	0	0	2.4 x 10 ⁻⁸
61.2	.00040	.0200	2.3 x 10 ⁻⁸
85.3	.00050	.0250	2.2 x 10 ⁻⁸
157.5	.00115	.0580	1.3 x 10 ⁻⁸
182.7	.00140	.0700	1.3 x 10 ⁻⁸
205.4	.00150	.0750	1.9 x 10 ⁻⁸
253.3	.00180	.0900	3.6 x 10 ⁻⁷

Test Terminated - Leak in Cold Wall
Specimen S-6

TABLE XII

CREEP TEST DATA, SYLVANIA "A" SHEET, RECRYSTALLIZED 3200°F
(1760°C), 2HOURS, TESTED AT 3200°F (1760°C) 5000 psi (3.45x10⁷N/m²)

<u>Time</u>	<u>Length Change Δ L (inch) (2" G. L.)</u>	<u>Creep (%)</u>	<u>Pressure (Torr)</u>
2 Minutes	.00050	.025	1.7 x 10 ⁻⁷
3	.00070	.035	1.7 x 10 ⁻⁷
4	.00095	.048	1.7 x 10 ⁻⁷
5	.00060	.030	1.7 x 10 ⁻⁷
6	.00075	.038	1.7 x 10 ⁻⁷
7	.00080	.040	1.7 x 10 ⁻⁷
8	.00080	.040	1.7 x 10 ⁻⁷
9	.00075	.038	1.7 x 10 ⁻⁷
10	.00085	.042	1.7 x 10 ⁻⁷
15	.00085	.042	1.7 x 10 ⁻⁷
20	.00095	.048	1.7 x 10 ⁻⁷
25	.00085	.042	1.7 x 10 ⁻⁷
30	.00085	.042	1.7 x 10 ⁻⁷
18.4 Hours	.01170	.585	1.6 x 10 ⁻⁷
21.4	.01330	.665	4.6 x 10 ⁻⁷
26.5	.01595	.798	-
41.5	.02380	1.190	-
42.0	.02895	1.198	1.1 x 10 ⁻⁷
50.4	.02895	1.448	1.0 x 10 ⁻⁷
91.6	.05030	2.515	-
114.2	.06605	3.302	1.0 x 10 ⁻⁷
138.3	.08135	4.068	8.8 x 10 ⁻⁸
162.3	.10495	5.247	8.4 x 10 ⁻⁸
170.3	.10500	5.250	-

Test Terminated - 5% Creep
Specimen S-12

TABLE XIII

CREEP TEST DATA, SYLVANIA "A" ALLOY SHEET, RECRYSTALLIZED 3200°F
(1760°C), 2 HOURS, TESTED AT 3200°F (1760°C), 3000 psi (2.07×10^7 N/m²)

<u>Time</u>	<u>Length Change ΔL (inch) (2" G. L.)</u>	<u>Creep (%)</u>	<u>Pressure (Torr)</u>
2 minutes	.00000	.000	6.4×10^{-7}
4	-.00040	.020	
6	-.00050	.025	
8	-.00060	.030	
10	-.00060	.030	
30	-.00070	.035	
60	-.00070	.035	
1.2 hours	.00130	.065	3.2×10^{-7}
2.3	.00140	.070	---
68.7	.00650	.325	2.0×10^{-8}
91.3	.00730	.365	1.7×10^{-8}
115.0	.00855	.478	1.5×10^{-8}
139.3	.01030	.515	1.6×10^{-8}
163.2	.01275	.638	1.4×10^{-8}
235.2	.01865	.932	1.2×10^{-8}
260.4	.02065	1.032	1.1×10^{-8}
283.5	.02280	1.140	1.0×10^{-9}
307.2	.02450	1.225	9.6×10^{-9}
331.0	.02715	1.358	8.8×10^{-9}
402.9	.03365	1.682	8.4×10^{-9}
426.9	.03540	1.770	7.7×10^{-9}
451.0	.03865	1.932	7.3×10^{-9}
475.1	.04075	2.038	7.9×10^{-9}
499.1	.04315	2.158	7.6×10^{-9}
571.1	.05270	2.635	6.1×10^{-9}
595.0	.05540	2.770	6.0×10^{-9}
619.0	.05960	2.980	5.9×10^{-9}
642.9	.06360	3.180	6.0×10^{-9}
667.1	.06740	3.370	5.8×10^{-9}
763.0	.08400	4.200	5.3×10^{-9}
787.0	.08930	4.465	5.2×10^{-9}
811.1	.09470	4.735	5.7×10^{-9}
835.1	.10000	5.000	5.0×10^{-9}
907.1	.11725	5.862	2.0×10^{-9}

Test Terminated - 5% Creep
Specimen S-15

TABLE XIV

CREEP TEST DATA, TZC PLATE, HEAT M-80, RECRYSTALLIZED AT 3092°F (1700°C) FOR 1 HOUR,
TESTED AT 2000°F (1093°C), 20,000 PSI (1.38 x 10⁸N/m²)

<u>Time</u>	<u>Length Change ΔL (inch) (2" G. L.)</u>	<u>Creep (%)</u>	<u>Pressure (Torr)</u>
1 minutes	.00000	.000	1.2 x 10 ⁻⁹
2	-.00020	-.010	
3	-.00040	-.020	
4	-.00030	-.015	
5	-.00030	-.015	
10	-.00005	-.002	
15	.00005	.002	
20	.00005	.002	
25	.00010	.005	
30	.00010	.005	
60	.00005	.002	
90	-.00005	-.002	
17.2 hours	.00040	.020	2.6 x 10 ⁻⁹
41.3	.00060	.030	2.2 x 10 ⁻⁹
65.2	.00080	.040	2.2 x 10 ⁻⁹
89.2	.00115	.058	2.0 x 10 ⁻⁹
161.3	.00110	.055	1.3 x 10 ⁻⁹
185.7	.00130	.065	1.7 x 10 ⁻⁹
209.1	.00125	.068	1.7 x 10 ⁻⁹
233.2	.00125	.062	1.4 x 10 ⁻⁹
257.3	.00130	.065	1.3 x 10 ⁻⁹
329.2	.00140	.070	2.0 x 10 ⁻⁹
355.9	.00145	.072	3.2 x 10 ⁻⁹
377.0	.00145	.072	3.4 x 10 ⁻⁹
401.1	.00145	.072	2.4 x 10 ⁻⁹
425.0	.00150	.075	1.5 x 10 ⁻⁹
497.2	.00170	.085	1.9 x 10 ⁻⁹
521.4	.00170	.085	3.1 x 10 ⁻⁹
545.4	.00165	.082	4.8 x 10 ⁻⁹
569.2	.00170	.085	4.5 x 10 ⁻⁹
593.1	.00170	.085	4.6 x 10 ⁻⁹
665.2	.00165	.082	5.0 x 10 ⁻⁹
713.3	.00160	.080	4.6 x 10 ⁻⁹
762.8	.00170	.085	--
833.4	.00175	.088	1.5 x 10 ⁻⁸
881.4	.00185	.092	6.1 x 10 ⁻⁹
905.2	.00175	.088	5.8 x 10 ⁻⁹

TABLE XIV (Continued)

<u>Time</u>	<u>Length Change</u> <u>ΔL (inch)</u> <u>(2" G.L.)</u>	<u>Creep</u> <u>(%)</u>	<u>Pressure</u> <u>(Torr)</u>
1001.1 hours	.00185	.092	3.9×10^{-9}
1049.2	.00185	.092	6.4×10^{-9}
1097.3	.00190	.095	--
1168.4	.00195	.098	4.2×10^{-9}
1216.2	.00200	.100	7.5×10^{-9}
1264.3	.00195	.098	7.0×10^{-9}
1336.7	.00210	.105	7.5×10^{-9}
1389.5	.00250	.125	--
1433.4	.00255	.128	7.2×10^{-9}
1504.2	.00260	.130	1.3×10^{-8}
1552.3	.00270	.135	1.2×10^{-8}
1600.2	.00265	.132	2.6×10^{-9}
1672.4	.00270	.135	5.5×10^{-9}
1720.4	.00275	.138	3.8×10^{-9}
1768.5	.00285	.142	4.6×10^{-9}
1840.1	.00305	.152	4.4×10^{-9}
1894.6	.00310	.155	4.4×10^{-9}
1936.3	.00315	.158	3.8×10^{-9}
1985.6	.00310	.155	3.8×10^{-9}
2032.2	.00325	.162	4.0×10^{-9}
2057.0	.00330	.165	4.0×10^{-9}
2104.1	.00335	.168	3.8×10^{-9}
2176.1	.00345	.172	3.5×10^{-9}
2248.4	.00370	.185	4.2×10^{-9}
2272.2	.00360	.180	7.5×10^{-9}
2344.2	.00375	.188	2.4×10^{-9}
2396.9	.00380	.190	4.6×10^{-9}
2440.2	.00390	.195	4.4×10^{-9}
2512.0	.00400	.200	2.7×10^{-9}
2584.4	.00400	.200	2.9×10^{-9}
2680.2	.00400	.200	7.4×10^{-9}
2752.2	.00405	.202	5.4×10^{-9}
2872.4	.00415	.208	3.8×10^{-9}
2920.8	.00420	.210	6.2×10^{-9}
3016.1	.00425	.212	3.8×10^{-9}
3088.4	.00435	.218	2.6×10^{-9}
3184.6	.00440	.220	4.2×10^{-9}
3256.3	.00450	.225	4.4×10^{-9}

TABLE XIV (Continued)

<u>Time</u>	<u>Length Change ΔL (inch) (2" G. L.)</u>	<u>Creep %</u>	<u>Pressure (Torr)</u>
3355.4 hours	.00460	.230	--
3429.1	.00460	.230	--
3530.3	.00490	.245	--
3593.5	.00495	.247	7.8 x 10 ⁻⁹
3689.9	.00500	.250	8.0 x 10 ⁻⁹
3760.5	.00510	.255	8.0 x 10 ⁻⁹
3856.2	.00515	.257	8.2 x 10 ⁻⁹
3928.5	.00525	.262	8.2 x 10 ⁻⁹
4024.1	.00575	.282	8.7 x 10 ⁻⁹
4096.3	.00620	.310	8.2 x 10 ⁻⁹
4192.3	.00640	.320	8.2 x 10 ⁻⁹
4264.1	.00640	.320	8.2 x 10 ⁻⁹
4384.3	.00640	.320	8.4 x 10 ⁻⁹
4432.3	.00640	.320	9.0 x 10 ⁻⁹
4528.3	.00630	.315	8.6 x 10 ⁻⁹
4600.5	.00640	.320	9.4 x 10 ⁻⁹
4696.7	.00625	.312	9.5 x 10 ⁻⁹
4769.2	.00640	.320	8.5 x 10 ⁻⁹
4866.4	.00635	.318	9.2 x 10 ⁻⁹
4936.5	.00630	.315	9.2 x 10 ⁻⁹
5032.5	.00635	.318	9.2 x 10 ⁻⁹
5104.4	.00660	.330	8.4 x 10 ⁻⁹
5200.9	.00660	.330	9.5 x 10 ⁻⁹
5272.3	.00670	.335	8.8 x 10 ⁻⁹
5368.8	.00675	.338	9.4 x 10 ⁻⁹
5440.3	.00685	.342	9.4 x 10 ⁻⁹
5536.2	.00700	.350	1.0 x 10 ⁻⁸
5608.0	.00705	.352	3.4 x 10 ⁻⁹
5705.8	.00715	.358	6.4 x 10 ⁻⁹
5777.0	.00720	.360	4.9 x 10 ⁻⁹
5873.3	.00730	.365	4.9 x 10 ⁻⁹
5945.1	.00745	.372	3.4 x 10 ⁻⁹
6041.2	.00750	.375	2.8 x 10 ⁻⁹
6113.2	.00770	.385	3.4 x 10 ⁻⁹
6209.9	.00770	.385	3.3 x 10 ⁻⁹
6305.5	.00775	.388	3.5 x 10 ⁻⁹
6377.5	.00780	.390	6.3 x 10 ⁻⁹
6449.2	.00775	.388	7.0 x 10 ⁻⁹
6545.7	.00770	.385	8.2 x 10 ⁻⁹
6617.2	.00780	.390	7.4 x 10 ⁻⁹
6713.2	.00780	.390	7.9 x 10 ⁻⁹
6785.3	.00780	.390	7.8 x 10 ⁻⁹
6881.6	.00810	.405	8.0 x 10 ⁻⁹
6953.4	.00790	.395	8.3 x 10 ⁻⁹
7052.7	.00805	.402	8.2 x 10 ⁻⁹
7125.5	.00810	.405	8.1 x 10 ⁻⁹

TABLE XIV (Continued)

<u>Time</u>	<u>Length Change ΔL (inch) (2" G.L.)</u>	<u>Creep (%)</u>	<u>Pressure (Torr)</u>
7217.2 hours	.00810	.410	8.2 x 10 ⁻⁹
7386.0	.00815	.408	7.9 x 10 ⁻⁹
7457.2	.00825	.412	7.5 x 10 ⁻⁹
7553.3	.00830	.415	7.6 x 10 ⁻⁹
7625.7	.00835	.418	7.0 x 10 ⁻⁹
7721.9	.00845	.422	7.0 x 10 ⁻⁹
7793.6	.00845	.422	7.3 x 10 ⁻⁹
7889.4	.00850	.425	6.5 x 10 ⁻⁹
7961.2	.00855	.428	7.1 x 10 ⁻⁹
8057.4	.00855	.428	7.4 x 10 ⁻⁹
8129.4	.00860	.430	7.3 x 10 ⁻⁹
8225.3	.00870	.435	5.2 x 10 ⁻⁹
8297.5	.00875	.438	4.3 x 10 ⁻⁹
8393.2	.00880	.440	1.6 x 10 ⁻⁹
8465.6	.00885	.442	4.8 x 10 ⁻⁹
8561.4	.00890	.445	4.8 x 10 ⁻⁹
8633.1	.00895	.448	4.6 x 10 ⁻⁹
8729.1	.00900	.450	5.3 x 10 ⁻⁹
8801.3	.00905	.452	5.2 x 10 ⁻⁹
8969.3	.00915	.458	6.0 x 10 ⁻⁹
9065.3	.00920	.460	7.5 x 10 ⁻⁹
9137.2	.00925	.462	9.6 x 10 ⁻⁹
9233.1	.00930	.465	1.0 x 10 ⁻⁸
9305.3	.00940	.470	1.0 x 10 ⁻⁸
9401.9	.00965	.482	1.0 x 10 ⁻⁸
9476.5	.00970	.485	1.6 x 10 ⁻⁸
9569.4	.00965	.482	2.7 x 10 ⁻⁹
9642.2	.00965	.482	5.4 x 10 ⁻⁹
9737.6	.00960	.480	3.8 x 10 ⁻⁹
9814.3	.00970	.485	5.0 x 10 ⁻⁹
9904.3	.00980	.490	7.6 x 10 ⁻⁹
9976.3	.00980	.490	4.6 x 10 ⁻¹⁰
10,000.7	.00980	.490	5.2 x 10 ⁻¹⁰
10,072.1	.00985	.492	8.5 x 10 ⁻¹⁰
10,144.3	.00985	.492	1.0 x 10 ⁻⁹
10,240.3	.00990	.495	1.5 x 10 ⁻⁹
10,312.1	.00995	.498	1.9 x 10 ⁻⁹
10,408.5	.01005	.502	2.2 x 10 ⁻⁹

TABLE XIV (Continued)

<u>Time</u>	<u>Length Change ΔL (inch) (2" G.L.)</u>	<u>Creep (%)</u>	<u>Pressure (Torr)</u>
10,576.5	.01010	.505	3.4 x 10 ⁻⁹
10,648.2	.01010	.505	3.2 x 10 ⁻⁹
10,768.7	.01020	.510	2.9 x 10 ⁻⁹
10,816.2	.01020	.510	2.9 x 10 ⁻⁹
10,917.0	.01020	.510	3.3 x 10 ⁻⁹
10,984.1	.01025	.512	3.2 x 10 ⁻⁹
11,008.1	.01025	.512	4.0 x 10 ⁻⁹
11,080.2	.01030	.515	3.6 x 10 ⁻⁹
11,152.5	.01035	.518	3.8 x 10 ⁻⁹
11,248.2	.01030	.515	3.6 x 10 ⁻⁹
11,320.3	.01030	.515	3.9 x 10 ⁻⁹
11,416.5	.01040	.520	4.6 x 10 ⁻⁹
11,488.2	.01040	.520	4.3 x 10 ⁻⁹
11,608.2	.01050	.525	4.2 x 10 ⁻⁹
11,656.9	.01050	.525	4.4 x 10 ⁻⁹
11,752.4	.01055	.528	4.2 x 10 ⁻⁹
11,833.2	.01055	.528	7.1 x 10 ⁻¹⁰
11,920.2	.01060	.530	1.3 x 10 ⁻⁹
11,995.5	.01065	.532	1.5 x 10 ⁻⁹
12,088.7	.01070	.535	2.0 x 10 ⁻⁹
12,160.4	.01080	.540	2.2 x 10 ⁻⁹
12,256.6	.01100	.550	2.0 x 10 ⁻⁹
12,328.8	.01100	.550	2.8 x 10 ⁻⁹
12,424.3	.01110	.555	3.7 x 10 ⁻⁹
12,496.1	.01100	.550	3.2 x 10 ⁻⁹
12,592.3	.01100	.550	3.6 x 10 ⁻⁹
12,664.1	.01120	.560	4.0 x 10 ⁻⁹
12,761.1	.01125	.562	4.0 x 10 ⁻⁹
12,832.3	.01125	.562	4.0 x 10 ⁻⁹
12,928.1	.01130	.565	4.5 x 10 ⁻⁹
13,000.3	.01130	.565	4.4 x 10 ⁻⁹
13,120.9	.01130	.565	4.8 x 10 ⁻⁹
13,167.9	.01140	.570	5.1 x 10 ⁻⁹
13,264.4	.01150	.575	4.4 x 10 ⁻⁹
13,336.0	.01155	.578	4.7 x 10 ⁻⁹
13,432.8	.01160	.580	4.8 x 10 ⁻⁹
13,504.4	.01165	.582	5.0 x 10 ⁻⁹
13,600.2	.01165	.582	1.8 x 10 ⁻⁹

TABLE XIV (Continued)

<u>Time</u>	<u>Length Change Δ L (inch) (2" G. L.)</u>	<u>Creep (%)</u>	<u>Pressure (Torr)</u>
13,672.6 hours	.01165	.582	2.1 x 10 ⁻⁹
13,768.4	.01165	.582	2.5 x 10 ⁻⁹
13,842.3	.01170	.585	3.0 x 10 ⁻⁹
13,936.3	.01180	.590	3.0 x 10 ⁻⁹
14,008.3	.01190	.595	3.3 x 10 ⁻⁹
14,104.2	.01200	.600	3.4 x 10 ⁻⁹
14,176.3	.01205	.602	3.6 x 10 ⁻⁹
14,272.2	.01220	.610	3.9 x 10 ⁻⁹
14,344.6	.01225	.612	3.9 x 10 ⁻⁹
14,441.2	.01225	.612	4.0 x 10 ⁻⁹
14,513.5	.01230	.615	4.4 x 10 ⁻⁹
14,609.2	.01230	.615	4.1 x 10 ⁻⁹
14,681.2	.01235	.618	4.4 x 10 ⁻⁹
14,777.4	.01240	.620	3.8 x 10 ⁻⁹
14,801.3	.01240	.620	3.6 x 10 ⁻⁹
14,825.8	.01245	.622	3.9 x 10 ⁻⁹
14,849.4	.01250	.625	4.0 x 10 ⁻⁹
14,873.2	.01250	.625	3.9 x 10 ⁻⁹
14,945.2	.01260	.630	4.0 x 10 ⁻⁹
14,969.3	.01260	.630	4.1 x 10 ⁻⁹
14,993.4	.01265	.632	4.1 x 10 ⁻⁹
15,041.1	.01265	.632	4.1 x 10 ⁻⁹
15,113.4	.01265	.632	3.6 x 10 ⁻⁹
15,137.3	.01270	.635	3.6 x 10 ⁻⁹
15,161.3	.01270	.635	3.4 x 10 ⁻⁹
15,185.8	.01275	.638	3.6 x 10 ⁻⁹
15,209.7	.01275	.638	3.8 x 10 ⁻⁹
15,281.7	.01275	.638	3.7 x 10 ⁻⁹
15,305.5	.01275	.638	4.0 x 10 ⁻⁹
15,329.4	.01280	.640	3.9 x 10 ⁻⁹
15,353.4	.01285	.642	3.8 x 10 ⁻⁹
15,377.4	.01285	.642	3.5 x 10 ⁻⁹
15,449.6	.01295	.648	3.5 x 10 ⁻⁹
15,473.3	.01295	.648	3.3 x 10 ⁻⁹
15,497.4	.01295	.648	3.4 x 10 ⁻⁹
15,521.3	.01300	.650	4.0 x 10 ⁻⁹
15,545.3	.01300	.650	3.6 x 10 ⁻⁹
15,618.1	.01300	.650	3.8 x 10 ⁻⁹

TABLE XIV (Continued)

<u>Time</u>	<u>Length Change Δ L (inch) (2" G. L.)</u>	<u>Creep (%)</u>	<u>Pressure (Torr)</u>
15,641.4	.01300	.650	3.4 x 10 ⁻⁹
15,665.7	.01305	.652	3.4 x 10 ⁻⁹
15,689.8	.01310	.655	3.1 x 10 ⁻⁹
15,809.7	.01320	.660	3.5 x 10 ⁻⁹
15,833.5	.01325	.662	3.4 x 10 ⁻⁹
15,857.4	.01330	.665	3.4 x 10 ⁻⁹
15,881.7	.01330	.665	3.7 x 10 ⁻⁹
15,977.5	.01335	.668	3.4 x 10 ⁻⁹
16,001.7	.01340	.670	3.4 x 10 ⁻⁹

Test Terminated - Over 10,000 Hours
Specimen B-9

TABLE XV

CREEP TEST DATA, TZC PLATE HEAT M-80, RECRYSTALLIZED 3092°F
(1700°C), 1 HOUR, TESTED AT 1856°F (1013°C), 25,000 psi (1.72 x 10⁸N/m²)

<u>Time</u>	<u>Length Change</u> <u>ΔL (inch)</u> <u>(2" G.L.)</u>	<u>Creep</u> <u>(%)</u>	<u>Pressure</u> <u>(Torr)</u>
1 minute(s)	-.00005	-.002	
2	.00000	.000	
3	-.00005	-.002	
4	.00005	.002	
5	.00005	.002	
6	.00010	.005	
7	.00005	.002	
8	.00000	.000	
9	.00000	.000	
10	.00005	.002	
15	-.00005	-.002	
20	.00015	.008	
25	.00015	.008	
30	.00025	.012	
60	.00065	.032	
19.3 hours	.00085	.042	1.4 x 10 ⁻⁸
42.1	.00095	.048	1.3 x 10 ⁻⁸
68.2	.00095	.048	1.1 x 10 ⁻⁸
138.4	.00090	.045	5.8 x 10 ⁻⁹
162.8	.00085	.042	6.6 x 10 ⁻⁹
186.0	.00085	.042	6.8 x 10 ⁻⁹
210.3	.00080	.040	5.8 x 10 ⁻⁹
306.2	.00075	.038	5.2 x 10 ⁻⁹
330.2	.00090	.045	4.4 x 10 ⁻⁹
354.2	.00085	.042	3.4 x 10 ⁻⁹
381.6	.00095	.048	--
402.4	.00095	.048	3.6 x 10 ⁻⁹
460.7	.00105	.052	2.5 x 10 ⁻⁹
484.5	.00105	.052	2.8 x 10 ⁻⁹
508.5	.00125	.062	3.4 x 10 ⁻⁹
532.4	.00105	.052	3.8 x 10 ⁻⁹
556.8	.00105	.052	3.2 x 10 ⁻⁹
628.9	.00105	.052	3.0 x 10 ⁻⁹
681.7	.00115	.058	--
725.6	.00125	.062	3.1 x 10 ⁻⁹
796.4	.00130	.065	2.0 x 10 ⁻⁹
844.8	.00145	.072	2.2 x 10 ⁻⁹
892.4	.00145	.072	1.6 x 10 ⁻⁹
964.6	.00140	.070	2.8 x 10 ⁻⁹

TABLE XV (Continued)

<u>Time</u>	<u>Length Change</u> <u>ΔL (inch)</u> <u>(2" G. L.)</u>	<u>Creep</u> <u>%</u>	<u>Pressure</u> <u>(Torr)</u>
1012.6 hours	.00155	.078	2.7×10^{-9}
1060.7	.00170	.085	2.6×10^{-9}
1132.3	.00165	.082	2.4×10^{-9}
1186.9	.00165	.082	2.0×10^{-9}
1228.6	.00170	.085	1.8×10^{-9}
1277.8	.00170	.085	2.2×10^{-9}
1324.4	.00165	.082	2.3×10^{-9}
1349.2	.00175	.088	1.4×10^{-9}
1396.3	.00185	.092	1.8×10^{-9}
1468.3	.00185	.092	2.5×10^{-9}
1516.4	.00180	.090	2.6×10^{-9}
1564.4	.00185	.092	3.1×10^{-9}
1636.4	.00195	.098	2.5×10^{-9}
1689.1	.00205	.102	2.2×10^{-9}
1732.4	.00195	.098	2.8×10^{-9}
1804.3	.00200	.100	2.0×10^{-9}
1876.7	.00215	.108	2.0×10^{-9}
1972.6	.00210	.105	2.3×10^{-9}
2044.4	.00225	.112	9.6×10^{-10}
2164.7	.00225	.112	2.5×10^{-9}
2213.1	.00235	.118	1.4×10^{-9}
2308.3	.00230	.115	1.2×10^{-9}
2380.7	.00235	.118	2.5×10^{-9}
2479.4	.00235	.118	1.2×10^{-9}
2548.4	.00235	.118	2.6×10^{-9}
2647.3	.00245	.122	1.8×10^{-9}
2720.0	.00245	.122	1.1×10^{-9}
2822.6	.00260	.130	9.1×10^{-10}
2886.4	.00305	.152	2.2×10^{-9}
2982.1	.00295	.148	1.6×10^{-9}
3052.8	.00320	.160	1.6×10^{-9}
3148.7	.00315	.158	1.6×10^{-9}
3220.7	.00315	.158	1.6×10^{-9}
3316.4	.00310	.155	1.9×10^{-9}
3388.8	.00315	.158	1.8×10^{-9}
3484.6	.00335	.168	1.6×10^{-9}
3556.4	.00330	.165	1.4×10^{-9}
3676.5	.00335	.168	1.5×10^{-9}
3724.5	.00330	.165	1.9×10^{-9}
3820.7	.00330	.165	1.6×10^{-9}
3892.7	.00320	.160	1.7×10^{-9}
3988.9	.00315	.158	2.8×10^{-9}
4061.4	.00315	.158	1.3×10^{-9}
4158.8	.00300	.150	1.8×10^{-9}
4228.7	.00300	.150	6.0×10^{-10}
4325.1	.00300	.150	1.5×10^{-9}
4396.7	.00315	.158	1.8×10^{-9}
4493.1	.00315	.158	2.0×10^{-9}

TABLE XV (Continued)

<u>Time</u>	<u>Length Change ΔL (inch) (2" G. L.)</u>	<u>Creep (%)</u>	<u>Pressure (Torr)</u>
4564.6 hours	.00310	.155	2.0×10^{-9}
4661.2	.00315	.158	1.4×10^{-9}
4732.6	.00320	.160	2.0×10^{-9}
4828.5	.00305	.152	1.7×10^{-9}
4900.3	.00310	.155	1.7×10^{-9}
4998.1	.00305	.152	1.4×10^{-9}
5069.3	.00305	.152	2.4×10^{-9}
5165.5	.00305	.152	1.6×10^{-9}
5237.4	.00310	.155	1.2×10^{-9}
5333.5	.00310	.155	1.1×10^{-9}
5405.5	.00305	.152	1.6×10^{-9}
5502.2	.00305	.152	1.1×10^{-9}
5598.0	.00310	.155	1.4×10^{-9}
5669.8	.00310	.155	1.8×10^{-9}
5741.4	.00320	.160	1.6×10^{-9}
5838.0	.00315	.158	1.6×10^{-9}
5909.4	.00325	.162	1.5×10^{-9}
6005.6	.00315	.158	1.5×10^{-9}
6077.5	.00315	.158	1.6×10^{-9}
6173.9	.00315	.158	1.6×10^{-9}
6245.7	.00320	.160	1.6×10^{-9}
6345.0	.00325	.162	1.0×10^{-9}
6417.7	.00335	.168	1.3×10^{-9}
6509.4	.00335	.168	1.5×10^{-9}
6582.0	.00340	.170	1.0×10^{-9}
6678.2	.00335	.168	1.6×10^{-9}
6749.4	.00340	.170	1.5×10^{-9}
6845.6	.00345	.172	1.6×10^{-9}
6917.9	.00350	.175	2.2×10^{-9}
7014.1	.00355	.178	1.4×10^{-9}
7085.9	.00350	.175	2.1×10^{-9}
7181.9	.00345	.172	2.3×10^{-9}
7253.6	.00355	.178	3.0×10^{-9}
7350.0	.00345	.172	1.4×10^{-9}
7421.6	.00345	.172	1.4×10^{-9}
7517.6	.00345	.172	7.8×10^{-10}
7589.7	.00350	.175	1.8×10^{-9}
7685.4	.00345	.172	1.6×10^{-9}
7757.8	.00340	.170	2.2×10^{-9}
7853.8	.00345	.172	1.8×10^{-9}
7925.4	.00340	.170	1.6×10^{-9}
8021.3	.00340	.170	1.3×10^{-9}
8093.4	.00340	.170	1.6×10^{-9}
8189.3	.00345	.172	1.7×10^{-9}
8261.5	.00345	.172	1.9×10^{-9}
8357.5	.00335	.168	1.1×10^{-9}
8429.5	.00335	.168	1.6×10^{-9}

TABLE XV (Continued)

<u>Time</u>	<u>Length Change ΔL (inch) (2" G.L.)</u>	<u>Creep (%)</u>	<u>Pressure (Torr)</u>
8525.3 hours	.00340	.170	1.7 x 10 ⁻⁹
8597.7	.00350	.175	1.8 x 10 ⁻⁹
8694.0	.00355	.178	1.6 x 10 ⁻⁹
8769.8	.00350	.175	1.7 x 10 ⁻⁹
8861.7	.00355	.178	1.7 x 10 ⁻⁹
8934.4	.00355	.178	1.7 x 10 ⁻⁹
9030.0	.00350	.175	1.7 x 10 ⁻⁹
9106.9	.00350	.175	1.6 x 10 ⁻⁹
9197.3	.00350	.175	2.2 x 10 ⁻⁹
9268.5	.00350	.175	1.5 x 10 ⁻⁹
9364.7	.00345	.172	1.6 x 10 ⁻⁹
9436.8	.00335	.168	1.7 x 10 ⁻⁹
9532.5	.00345	.172	1.7 x 10 ⁻⁹
9604.3	.00345	.172	1.6 x 10 ⁻⁹
9700.8	.00345	.172	1.6 x 10 ⁻⁹
9774.3	.00335	.168	1.7 x 10 ⁻⁹
9868.8	.00330	.165	1.6 x 10 ⁻⁹
9940.4	.00340	.170	1.6 x 10 ⁻⁹
10,060.9	.00345	.172	1.1 x 10 ⁻⁹
10,108.5	.00340	.170	1.0 x 10 ⁻⁹
10,207.3	.00335	.168	1.1 x 10 ⁻⁹
10,276.3	.00335	.168	9.9 x 10 ⁻¹⁰
10,300.4	.00340	.170	9.7 x 10 ⁻¹⁰
10,372.4	.00340	.170	1.3 x 10 ⁻⁹
10,444.8	.00335	.168	1.4 x 10 ⁻⁹
10,540.5	.00345	.172	1.0 x 10 ⁻⁹
10,612.5	.00340	.170	1.0 x 10 ⁻⁹
10,708.9	.00335	.168	1.4 x 10 ⁻⁹
10,780.5	.00335	.168	1.4 x 10 ⁻⁹
10,900.4	.00340	.170	1.0 x 10 ⁻⁹
10,949.4	.00340	.170	1.1 x 10 ⁻⁹
11,044.8	.00340	.170	9.4 x 10 ⁻¹⁰
11,125.6	.00340	.170	1.0 x 10 ⁻⁹
11,212.5	.00340	.170	1.2 x 10 ⁻⁹
11,287.6	.00335	.168	1.4 x 10 ⁻⁹
11,381.1	.00330	.165	1.0 x 10 ⁻⁹
11,453.0	.00300	.150	1.3 x 10 ⁻⁹
11,549.3	.00330	.165	1.0 x 10 ⁻⁹
11,621.4	.00335	.168	1.0 x 10 ⁻⁹
11,716.8	.00340	.170	1.3 x 10 ⁻⁹
11,788.3	.00330	.165	1.3 x 10 ⁻⁹
11,844.5	.00330	.165	1.3 x 10 ⁻⁹
11,956.3	.00310	.155	1.4 x 10 ⁻⁹

TABLE XV (Continued)

<u>Time</u>	<u>Length Change Δ L (inch) (2" G. L.)</u>	<u>Creep (%)</u>	<u>Pressure (Torr)</u>
12,054.0 Hours	.00320	.160	1.4×10^{-9}
12,124.6	.00325	.162	1.3×10^{-9}
12,220.3	.00325	.162	1.1×10^{-9}
12,292.6	.00335	.168	1.0×10^{-9}
12,413.0	.00345	.172	1.0×10^{-9}
12,460.2	.00340	.170	1.1×10^{-9}
12,556.8	.00335	.168	9.5×10^{-10}
12,628.2	.00340	.170	1.1×10^{-9}
12,725.0	.00345	.172	9.4×10^{-10}
12,796.7	.00345	.172	9.2×10^{-10}
12,892.4	.00350	.175	9.5×10^{-10}
12,964.8	.00345	.172	9.4×10^{-10}
13,060.6	.00345	.172	9.0×10^{-10}
13,134.5	.00350	.175	2.0×10^{-9}
13,228.5	.00355	.178	8.8×10^{-10}
13,300.5	.00350	.175	9.6×10^{-10}
13,396.4	.00345	.172	9.6×10^{-10}
13,468.5	.00345	.172	9.2×10^{-10}
13,564.4	.00350	.175	9.0×10^{-10}
13,636.9	.00355	.178	1.0×10^{-9}
13,733.4	.00355	.178	9.0×10^{-10}
13,805.8	.00355	.178	1.0×10^{-9}
13,901.5	.00360	.180	1.0×10^{-9}
13,973.4	.00360	.180	1.0×10^{-9}
14,069.6	.00365	.182	1.1×10^{-9}
14,141.7	.00360	.180	9.0×10^{-10}
14,237.6	.00360	.180	1.0×10^{-9}
14,333.4	.00360	.180	1.0×10^{-9}
14,405.6	.00365	.182	9.4×10^{-10}

Test Terminated - Over 10,000 Hours
Specimen B-11

TABLE XVI

CREEP TEST DATA, TZC PLATE, HEAT M-80, RECRYSTALLIZED AT 3092°F (1700°C), 1 HOUR,
TESTED AT 2056°F (1124°C), 19,000 PSI (1.31 x 10⁸N/m²)

<u>Time</u>	<u>Length Change ΔL (inch) (2" G.L.)</u>	<u>Creep (%)</u>	<u>Pressure (Torr)</u>
1 minutes	.00010	.005	7.0 x 10 ⁻⁸
2	.00020	.010	
3	.00030	.015	
4	.00050	.025	
5	.00055	.028	
6	.00065	.032	
7	.00085	.042	
8	.00095	.048	
9	.00105	.052	
10	.00120	.060	
12	.00130	.065	
13	.00140	.070	
14	.00150	.075	
15	.00160	.080	6.9 x 10 ⁻⁸
20	.00165	.082	
25	.00170	.085	
30	.00170	.085	6.9 x 10 ⁻⁸
40	.00175	.088	
45	.00175	.088	
60	.00180	.090	6.8 x 10 ⁻⁸
90	.00180	.090	6.7 x 10 ⁻⁸
15.7 hours	.00180	.090	3.5 x 10 ⁻⁸
87.1	.00180	.090	1.4 x 10 ⁻⁸
111.2	.00100	.050	9.8 x 10 ⁻⁹
133.4	.00140	.070	7.0 x 10 ⁻⁹
159.0	.00135	.068	3.0 x 10 ⁻⁹
181.6	.00130	.065	--
239.9	.00135	.068	4.2 x 10 ⁻⁹
263.7	.00130	.065	5.1 x 10 ⁻⁹
287.7	.00150	.075	4.5 x 10 ⁻⁹
309.9	.00140	.070	3.8 x 10 ⁻⁹
334.3	.00150	.075	3.2 x 10 ⁻⁹
406.5	.00145	.072	3.5 x 10 ⁻⁹
459.3	.00155	.078	--
503.2	.00150	.075	2.2 x 10 ⁻⁹
573.9	.00175	.088	1.2 x 10 ⁻⁹

TABLE XVI (Continued)

<u>Time</u>	<u>Length Change</u> <u>ΔL (inch)</u> <u>(2" G. L.)</u>	<u>Creep</u> <u>(%)</u>	<u>Pressure</u> <u>(Torr)</u>
622.5 hours	.00175	.088	1.1 x 10 ⁻⁹
669.9	.00180	.090	3.8 x 10 ⁻⁹
742.3	.00185	.092	2.8 x 10 ⁻⁹
790.2	.00190	.095	2.8 x 10 ⁻⁹
838.3	.00185	.092	1.8 x 10 ⁻⁹
909.9	.00195	.098	3.2 x 10 ⁻⁹
964.8	.00205	.102	2.6 x 10 ⁻⁹
1006.2	.00210	.105	2.6 x 10 ⁻⁹
1055.3	.00215	.108	2.7 x 10 ⁻⁹
1102.0	.00220	.110	2.9 x 10 ⁻⁹
1126.8	.00220	.110	1.7 x 10 ⁻⁹
1173.9	.00220	.110	1.0 x 10 ⁻⁹
1245.9	.00215	.108	4.2 x 10 ⁻¹⁰
1294.0	.00225	.112	2.1 x 10 ⁻⁹
1342.0	.00235	.118	2.1 x 10 ⁻¹⁰
1414.1	.00235	.118	1.4 x 10 ⁻⁹
1466.7	.00235	.118	2.5 x 10 ⁻⁹
1509.0	.00225	.112	2.0 x 10 ⁻⁹
1581.8	.00245	.122	7.5 x 10 ⁻¹⁰
1654.2	.00245	.122	1.2 x 10 ⁻⁹
1750.2	.00240	.120	1.3 x 10 ⁻⁹
1822.1	.00235	.118	7.0 x 10 ⁻¹⁰
1942.2	.00235	.118	8.4 x 10 ⁻¹⁰
1990.6	.00240	.120	7.4 x 10 ⁻¹⁰
2086.2	.00250	.125	1.6 x 10 ⁻⁹
2158.2	.00260	.130	1.4 x 10 ⁻⁹
2254.4	.00265	.132	7.2 x 10 ⁻¹⁰
2326.1	.00265	.132	2.0 x 10 ⁻⁹
2424.7	.00280	.140	1.4 x 10 ⁻⁹
2497.4	.00305	.152	1.2 x 10 ⁻⁹
2600.1	.00310	.155	8.0 x 10 ⁻¹⁰
2664.7	.00325	.162	2.4 x 10 ⁻⁹
2759.8	.00345	.172	2.6 x 10 ⁻⁹
2854.3	.00355	.178	1.5 x 10 ⁻⁹
2926.3	.00355	.178	1.5 x 10 ⁻⁹
2998.2	.00355	.178	2.1 x 10 ⁻⁹
3094.0	.00365	.182	2.1 x 10 ⁻⁹
3166.4	.00360	.180	2.2 x 10 ⁻⁹
3262.2	.00355	.178	9.2 x 10 ⁻⁹

TABLE XVI (Continued)

<u>Time</u>	<u>Length Change Δ L (inch) (2" G. L.)</u>	<u>Creep %</u>	<u>Pressure (Torr)</u>
3334.1 hours	.00360	.180	2.2 x 10 ⁻⁹
3454.1	.00340	.170	1.6 x 10 ⁻⁹
3502.1	.00365	.182	2.0 x 10 ⁻⁹
3598.2	.00315	.158	1.1 x 10 ⁻⁹
3670.3	.00315	.158	1.0 x 10 ⁻⁹
3766.6	.00300	.150	9.0 x 10 ⁻¹⁰
3839.0	.00305	.152	2.5 x 10 ⁻⁹
3936.4	.00300	.150	9.1 x 10 ⁻¹⁰
4006.3	.00295	.148	2.0 x 10 ⁻⁹
4102.6	.00305	.152	2.1 x 10 ⁻⁹
4174.3	.00310	.155	1.9 x 10 ⁻⁹
4270.6	.00320	.160	1.0 x 10 ⁻⁹
4342.2	.00330	.165	2.0 x 10 ⁻⁹
4438.7	.00330	.165	2.5 x 10 ⁻⁹
4510.1	.00355	.178	1.4 x 10 ⁻⁹
4606.2	.00340	.170	2.0 x 10 ⁻⁹
4677.8	.00345	.172	1.8 x 10 ⁻⁹
4775.6	.00345	.172	1.8 x 10 ⁻⁹
4846.8	.00335	.168	1.6 x 10 ⁻⁹
4943.1	.00335	.168	1.6 x 10 ⁻⁹
5015.0	.00355	.178	1.7 x 10 ⁻⁹
5111.1	.00340	.170	1.6 x 10 ⁻⁹
5183.2	.00345	.172	1.0 x 10 ⁻⁹
5279.7	.00350	.175	1.6 x 10 ⁻⁹
5375.6	.00355	.178	1.5 x 10 ⁻⁹
5447.3	.00355	.178	2.5 x 10 ⁻⁹
5518.9	.00355	.178	2.5 x 10 ⁻⁹
5615.6	.00355	.178	1.0 x 10 ⁻⁹
5687.0	.00360	.180	2.5 x 10 ⁻⁹
5783.8	.00355	.178	2.4 x 10 ⁻⁹
5855.1	.00365	.182	2.4 x 10 ⁻⁹
5951.5	.00375	.188	2.4 x 10 ⁻⁹
6023.3	.00380	.190	2.5 x 10 ⁻⁹
6122.5	.00395	.198	9.0 x 10 ⁻¹⁰
6195.3	.00390	.195	2.4 x 10 ⁻⁹
6286.9	.00400	.200	2.5 x 10 ⁻⁹

TABLE XVI (Continued)

Time	Length Change ΔL (inch) (2" G.L.)	Creep (%)	Pressure (Torr)
6359.5 hours	.00405	.202	1.0×10^{-9}
6455.8	.00410	.205	1.7×10^{-9}
6527.0	.00415	.208	2.5×10^{-9}
6623.2	.00410	.205	1.6×10^{-9}
6695.6	.00410	.205	2.3×10^{-9}
6791.8	.00420	.210	1.6×10^{-9}
6864.8	.00420	.210	1.6×10^{-9}
6959.5	.00415	.208	1.4×10^{-9}
7031.2	.00420	.210	2.4×10^{-9}
7127.6	.00435	.218	1.0×10^{-9}
7199.2	.00430	.215	2.2×10^{-9}
7295.2	.00430	.215	7.2×10^{-10}
7367.3	.00430	.215	1.1×10^{-9}
7463.2	.00425	.212	1.0×10^{-9}
7535.5	.00430	.215	1.6×10^{-9}
7631.3	.00440	.220	1.6×10^{-9}
7702.9	.00440	.220	1.6×10^{-9}
7798.9	.00440	.220	1.5×10^{-9}
7870.9	.00440	.220	1.7×10^{-9}
7966.8	.00445	.222	1.6×10^{-9}
8039.1	.00440	.220	1.6×10^{-9}
8135.2	.00450	.225	1.4×10^{-9}
8207.0	.00455	.228	1.4×10^{-9}
8302.8	.00465	.232	1.4×10^{-9}
8375.2	.00470	.235	1.4×10^{-9}
8471.6	.00475	.238	1.3×10^{-9}
8546.4	.00480	.240	1.4×10^{-9}
8639.3	.00480	.240	1.4×10^{-9}
8712.3	.00480	.240	1.3×10^{-9}
8807.6	.00470	.235	1.3×10^{-9}
8885.0	.00470	.235	1.4×10^{-9}
8975.7	.00470	.235	1.3×10^{-9}
9046.1	.00475	.238	1.4×10^{-9}
9142.2	.00475	.238	1.3×10^{-9}
9214.3	.00475	.238	1.4×10^{-9}
9310.0	.00475	.238	1.3×10^{-9}
9381.9	.00480	.240	1.4×10^{-9}
9478.8	.00480	.240	1.4×10^{-9}
9551.8	.00485	.242	1.3×10^{-9}
9646.4	.00485	.242	1.3×10^{-9}
9718.0	.00485	.242	1.4×10^{-9}
9838.4	.00490	.245	1.4×10^{-9}
9886.2	.00495	.248	1.4×10^{-9}
9985.1	.00500	.250	1.4×10^{-9}

TABLE XVI (Continued)

<u>Time</u>	<u>Length Change ΔL (inch) (2" G.L.)</u>	<u>Creep (%)</u>	<u>Pressure (Torr)</u>
10,053.9	.00500	.250	1.3 x 10 ⁻⁹
10,077.9	.00500	.250	1.3 x 10 ⁻⁹
10,150.1	.00500	.250	1.4 x 10 ⁻⁹
10,222.5	.00505	.252	1.3 x 10 ⁻⁹
10,318.1	.00510	.255	1.3 x 10 ⁻⁹
10,390.8	.00510	.255	1.3 x 10 ⁻⁹
10,486.6	.00505	.252	1.3 x 10 ⁻⁹
10,558.1	.00510	.255	1.3 x 10 ⁻⁹
10,678.1	.00505	.252	1.2 x 10 ⁻⁹
10,727.0	.00510	.255	1.2 x 10 ⁻⁹
10,822.5	.00515	.258	1.2 x 10 ⁻⁹
10,903.1	.00515	.258	1.2 x 10 ⁻⁹
10,990.1	.00515	.258	1.2 x 10 ⁻⁹
11,064.4	.00515	.258	1.2 x 10 ⁻⁹
11,158.7	.00525	.262	1.2 x 10 ⁻⁹
11,230.8	.00520	.260	1.2 x 10 ⁻⁹
11,327.3	.00525	.262	1.2 x 10 ⁻⁹
11,400.2	.00540	.270	1.2 x 10 ⁻⁹
11,494.4	.00545	.272	1.2 x 10 ⁻⁹
11,565.8	.00535	.266	1.2 x 10 ⁻⁹
11,662.1	.00520	.260	1.2 x 10 ⁻⁹
11,733.8	.00525	.262	1.2 x 10 ⁻⁹
11,832.2	.00525	.262	1.2 x 10 ⁻⁹
11,902.3	.00525	.262	1.2 x 10 ⁻⁹
11,998.9	.00530	.265	1.2 x 10 ⁻⁹
12,070.2	.00530	.265	1.2 x 10 ⁻⁹
12,190.6	.00530	.265	1.3 x 10 ⁻⁹
12,237.8	.00530	.265	1.3 x 10 ⁻⁹
12,334.5	.00530	.265	1.4 x 10 ⁻⁹
12,405.9	.00530	.265	1.2 x 10 ⁻⁹
12,502.6	.00530	.265	1.2 x 10 ⁻⁹
12,574.2	.00535	.268	1.2 x 10 ⁻⁹
12,670.0	.00535	.268	1.2 x 10 ⁻⁹

TABLE XVI (Continued)

<u>Time</u>	<u>Length Change Δ L (inch) (2" G. L.)</u>	<u>Creep (%)</u>	<u>Pressure (Torr)</u>
12,742.3	.00540	.270	1.2 x 10 ⁻⁹
12,838.2	.00545	.272	1.1 x 10 ⁻⁹
12,912.0	.00540	.270	1.1 x 10 ⁻⁹
13,006.1	.00545	.272	1.2 x 10 ⁻⁹
13,078.1	.00550	.275	1.2 x 10 ⁻⁹
13,174.0	.00555	.278	1.1 x 10 ⁻⁹
13,246.1	.00555	.278	1.1 x 10 ⁻⁹
13,342.0	.00555	.278	1.1 x 10 ⁻⁹
13,414.5	.00555	.278	1.2 x 10 ⁻⁹
13,511.0	.00550	.275	1.2 x 10 ⁻⁹
13,583.3	.00555	.278	1.2 x 10 ⁻⁹
13,679.0	.00560	.280	1.2 x 10 ⁻⁹
13,751.0	.00560	.280	1.1 x 10 ⁻⁹
13,847.1	.00560	.280	1.2 x 10 ⁻⁹
13,919.2	.00560	.280	1.2 x 10 ⁻⁹
14,015.2	.00560	.280	1.1 x 10 ⁻⁹
14,111.0	.00560	.280	1.2 x 10 ⁻⁹
14,183.1	.00560	.280	1.3 x 10 ⁻⁹
14,238.6	.00560	.280	1.2 x 10 ⁻⁹

Test Terminated - Over 10,000 Hours
Specimen S-12

TABLE XVII

CREEP TEST DATA, TZC PLATE, HEAT M-91, ANNEALED AT 2300°F (1260°C), FOR
1 HOUR, TESTED AT 2000°F (1093°C), 28,000 PSI (1.93×10^8 N/m²)

<u>Time</u>	<u>Length Change ΔL (inch) (2" G.L.)</u>	<u>Creep (%)</u>	<u>Pressure (Torr)</u>
1 Minute(s)	.00005	.002	9.0×10^{-9}
2	.00005	.002	9.0×10^{-9}
3	.00000	.000	9.0×10^{-9}
4	.00000	.000	9.0×10^{-9}
5	.00005	.002	9.0×10^{-9}
6	.00005	.002	9.0×10^{-9}
7	.00000	.000	9.0×10^{-9}
8	.00005	.002	9.0×10^{-9}
9	.00010	.005	9.0×10^{-9}
10	.00005	.002	9.0×10^{-9}
15	.00005	.002	9.0×10^{-9}
30	.00000	.000	9.0×10^{-9}
45	.00000	.000	9.0×10^{-9}
60	.00000	.000	9.0×10^{-9}
17.3 Hours	.00155	.078	3.4×10^{-9}
25.2	.00170	.085	3.3×10^{-9}
40.8	.00175	.088	1.5×10^{-9}
65.9	.00245	.122	1.1×10^{-9}
88.9	.00290	.145	1.0×10^{-9}
161.5	.00390	.195	6.4×10^{-10}
185.0	.00410	.205	6.4×10^{-10}
209.1	.00425	.212	6.0×10^{-10}
238.5	.00480	.240	5.5×10^{-10}
257.0	.00485	.242	5.2×10^{-10}
329.6	.00530	.265	4.6×10^{-10}
352.2	.00555	.278	4.6×10^{-10}
376.0	.00580	.290	4.6×10^{-10}
400.0	.00590	.295	4.9×10^{-10}
424.4	.00600	.300	4.8×10^{-10}
496.2	.00635	.318	4.2×10^{-10}
520.1	.00645	.322	4.2×10^{-10}
544.6	.00660	.330	4.1×10^{-10}
568.3	.00670	.335	4.2×10^{-10}
591.9	.00685	.342	4.2×10^{-10}

TABLE XVII (Continued)

<u>Time</u>	<u>Length Change ΔL (inch) (2" G.L.)</u>	<u>Creep (%)</u>	<u>Pressure (Torr)</u>
663.9	.00745	.372	3.7 x 10 ⁻¹⁰
687.9	.00765	.382	3.7 x 10 ⁻¹⁰
711.9	.00780	.390	3.8 x 10 ⁻¹⁰
735.8	.00785	.392	3.6 x 10 ⁻¹⁰
760.2	.00800	.400	3.4 x 10 ⁻¹⁰
832.2	.00860	.430	3.6 x 10 ⁻¹⁰
855.9	.00885	.442	3.9 x 10 ⁻¹⁰
879.8	.00890	.445	3.6 x 10 ⁻¹⁰
905.8	.00895	.448	3.6 x 10 ⁻¹⁰
928.6	.00890	.445	4.8 x 10 ⁻¹⁰
990.3	.00940	.470	3.2 x 10 ⁻¹⁰
1014.1	.00955	.478	3.1 x 10 ⁻¹⁰
1037.9	.00970	.485	3.6 x 10 ⁻¹⁰
1061.9	.00980	.490	3.4 x 10 ⁻¹⁰
1085.9	.00975	.488	3.0 x 10 ⁻¹⁰
1182.3	.01030	.515	2.4 x 10 ⁻¹⁰
1206.3	.01075	.538	2.1 x 10 ⁻¹⁰
1230.0	.01075	.538	2.8 x 10 ⁻¹⁰
1254.1	.01070	.535	2.0 x 10 ⁻¹⁰
1328.9	.01100	.550	2.1 x 10 ⁻¹⁰
1350.0	.01100	.550	2.0 x 10 ⁻¹⁰
1373.9	.01110	.555	2.0 x 10 ⁻¹⁰
1397.7	.01115	.558	2.0 x 10 ⁻¹⁰
1421.8	.01135	.568	1.9 x 10 ⁻¹⁰
1493.9	.01165	.582	1.8 x 10 ⁻¹⁰
1517.8	.01170	.585	1.6 x 10 ⁻¹⁰
1542.0	.01175	.588	1.8 x 10 ⁻¹⁰
1566.3	.01190	.595	1.6 x 10 ⁻¹⁰
1589.8	.01200	.600	1.6 x 10 ⁻¹⁰
1662.0	.01250	.625	1.4 x 10 ⁻¹⁰
1685.9	.01260	.630	1.4 x 10 ⁻¹⁰
1710.0	.01265	.632	1.8 x 10 ⁻¹⁰
1734.0	.01280	.640	1.3 x 10 ⁻¹⁰

TABLE XVII (Continued)

<u>Time</u>	<u>Length Change L (inch) (2" G.L.)</u>	<u>Creep (%)</u>	<u>Pressure (Torr)</u>
1759.7	.01285	.642	2.0 x 10 ⁻¹⁰
1830.5	.01310	.655	1.9 x 10 ⁻¹⁰
1854.2	.01330	.665	1.6 x 10 ⁻¹⁰
1877.7	.01340	.670	1.8 x 10 ⁻¹⁰
1902.0	.01345	.672	1.4 x 10 ⁻¹⁰
1925.9	.01355	.678	1.7 x 10 ⁻¹⁰
2021.9	.01390	.695	1.5 x 10 ⁻¹⁰
2046.3	.01405	.702	1.8 x 10 ⁻¹⁰
2070.9	.01430	.715	1.7 x 10 ⁻¹⁰
2093.9	.01460	.730	1.5 x 10 ⁻¹⁰
2166.3	.01520	.760	1.9 x 10 ⁻¹⁰
2190.1	.01530	.765	1.6 x 10 ⁻¹⁰
2216.0	.01540	.770	1.6 x 10 ⁻¹⁰
2247.0	.01545	.772	1.5 x 10 ⁻¹⁰
2262.0	.01550	.775	1.5 x 10 ⁻¹⁰
2334.0	.01565	.782	1.4 x 10 ⁻¹⁰
2357.9	.01570	.785	1.4 x 10 ⁻¹⁰
2381.9	.01580	.790	1.2 x 10 ⁻¹⁰
2409.1	.01600	.800	1.3 x 10 ⁻¹⁰
2430.8	.01610	.805	1.4 x 10 ⁻¹⁰
2502.6	.01690	.845	1.5 x 10 ⁻¹⁰
2526.9	.01715	.858	1.5 x 10 ⁻¹⁰
2550.8	.01745	.872	1.6 x 10 ⁻¹⁰
2574.5	.01780	.890	1.6 x 10 ⁻¹⁰
2598.5	.01805	.902	1.4 x 10 ⁻¹⁰
2670.6	.01835	.918	1.3 x 10 ⁻¹⁰
2694.3	.01850	.925	1.1 x 10 ⁻¹⁰
2718.5	.01895	.948	1.4 x 10 ⁻¹⁰
2743.1	.01880	.940	1.4 x 10 ⁻¹⁰
2767.1	.01880	.940	1.2 x 10 ⁻¹⁰
2838.3	.01890	.945	1.2 x 10 ⁻¹⁰
2862.3	.01910	.955	1.2 x 10 ⁻¹⁰
2885.8	.01930	.965	1.1 x 10 ⁻¹⁰
2909.7	.01940	.970	1.1 x 10 ⁻¹⁰
2933.8	.01960	.980	1.1 x 10 ⁻¹⁰
3006.1	.01990	.995	1.1 x 10 ⁻¹⁰
3029.9	.02015	1.006	1.1 x 10 ⁻¹⁰
3053.7	.02030	1.015	1.1 x 10 ⁻¹⁰
3077.6	.02045	1.022	1.2 x 10 ⁻¹⁰
3101.5	.02045	1.022	1.1 x 10 ⁻¹⁰
3176.2	.02020	1.010	1.2 x 10 ⁻¹⁰
3197.8	.02030	1.015	1.1 x 10 ⁻¹⁰
3222.0	.02035	1.018	1.0 x 10 ⁻¹⁰

TABLE XVII (Continued)

<u>Time</u>	<u>Length Change Δ L (inch) (2" G. L.)</u>	<u>Creep (%)</u>	<u>Pressure (Torr)</u>
3246.1 Hours	.02035	1.018	1.1×10^{-10}
3269.8	.02040	1.020	1.2×10^{-10}
3342.7	.02040	1.020	1.0×10^{-10}
3365.9	.02045	1.022	1.0×10^{-10}
3390.2	.02055	1.028	1.0×10^{-10}
3414.1	.02055	1.028	1.0×10^{-10}
3427.9	.02060	1.030	1.0×10^{-10}
3534.5	.02090	1.045	1.0×10^{-10}
3558.2	.02100	1.050	1.0×10^{-10}
3581.7	.02110	1.055	1.0×10^{-10}
3605.9	.02115	1.058	1.0×10^{-10}
3678.3	.02125	1.062	1.0×10^{-10}
3702.0	.02130	1.065	1.0×10^{-10}
3726.0	.02140	1.070	1.0×10^{-10}
3749.8	.02150	1.075	1.0×10^{-10}
3774.4	.02160	1.080	1.0×10^{-10}
3846.5	.02190	1.095	1.0×10^{-10}
3870.0	.02200	1.100	1.0×10^{-10}
3894.0	.02200	1.100	1.0×10^{-10}
3918.1	.02210	1.105	1.0×10^{-10}
3941.8	.02225	1.112	1.0×10^{-10}
4013.9	.02250	1.115	1.0×10^{-10}
4038.1	.02235	1.118	1.0×10^{-10}
4061.9	.02240	1.120	1.0×10^{-10}
4086.2	.02245	1.122	1.0×10^{-10}
4110.1	.02250	1.125	1.0×10^{-10}
4182.1	.02270	1.135	1.0×10^{-10}
4205.9	.02275	1.138	1.0×10^{-10}
4214.0	.02275	1.138	1.0×10^{-10}

Test Terminated - 1% Creep
Specimen B-28

TABLE XVIII

CREEP TEST DATA, TZC PLATE, HEAT M-91, ANNEALED AT 3092°F (1700°C) FOR 1 HOUR,

TESTED AT 2000°F (1093°C), 20,000 PSI ($1.38 \times 10^8 \text{N/m}^2$)

<u>Time</u>	<u>Length Change ΔL (inch) (2" G.L.)</u>	<u>Creep (%)</u>	<u>Pressure (Torr)</u>
1 Minutes	.00000	.000	8.2×10^{-9}
2	.00005	.002	8.2×10^{-9}
3	.00010	.005	8.2×10^{-9}
4	.00010	.005	8.2×10^{-9}
5	.00015	.008	8.2×10^{-9}
6	.00020	.010	8.2×10^{-9}
7	.00020	.010	8.2×10^{-9}
8	.00020	.010	8.2×10^{-9}
9	.00015	.008	8.2×10^{-9}
10	.00020	.010	8.2×10^{-9}
15	.00025	.012	8.2×10^{-9}
20	.00020	.010	8.2×10^{-9}
25	.00025	.012	8.2×10^{-9}
30	.00025	.012	8.2×10^{-9}
60	.00020	.010	8.2×10^{-9}
1.7 Hours	.00030	.015	8.2×10^{-9}
19.0	.00075	.038	8.4×10^{-9}
43.9	.00100	.050	7.2×10^{-9}
115.2	.00155	.078	4.0×10^{-9}
139.2	.00185	.092	3.2×10^{-9}
163.6	.00210	.105	2.6×10^{-9}
187.1	.00220	.110	2.4×10^{-9}
211.4	.00240	.120	2.1×10^{-9}
283.2	.00270	.135	1.4×10^{-9}
307.3	.00290	.145	1.2×10^{-9}
331.2	.00300	.150	1.1×10^{-9}
355.2	.00295	.148	9.7×10^{-10}
379.3	.00295	.148	9.6×10^{-10}
451.9	.00310	.155	7.9×10^{-10}
499.6	.00350	.175	6.7×10^{-10}
547.7	.00355	.178	6.1×10^{-10}
619.5	.00360	.180	9.2×10^{-10}
643.4	.00365	.182	6.3×10^{-10}
667.4	.00365	.182	8.1×10^{-10}
691.1	.00365	.182	8.2×10^{-10}
715.5	.00375	.188	7.8×10^{-10}

TABLE XVIII (Continued)

<u>Time</u>	<u>Length Change</u> <u>ΔL (inch)</u> <u>(2" G.L.)</u>	<u>Creep</u> <u>(%)</u>	<u>Pressure</u> <u>(Torr)</u>
787.7 Hours	.00410	.205	7.4×10^{-10}
811.6	.00420	.210	7.1×10^{-10}
835.3	.00435	.218	7.2×10^{-10}
859.2	.00440	.220	7.0×10^{-10}
883.2	.00445	.222	7.0×10^{-10}
956.3	.00460	.230	6.6×10^{-10}
980.0	.00470	.235	6.4×10^{-10}
1003.4	.00455	.228	6.4×10^{-10}
1027.2	.00465	.232	6.2×10^{-10}
1123.7	.00485	.242	6.0×10^{-10}
1195.5	.00490	.245	5.7×10^{-10}
1294.7	.00515	.258	6.0×10^{-10}
1367.4	.00525	.262	5.8×10^{-10}
1459.1	.00560	.280	5.6×10^{-10}
1531.7	.00585	.292	5.4×10^{-10}
1627.9	.00600	.300	5.4×10^{-10}
1699.2	.00620	.310	5.4×10^{-10}
1795.3	.00640	.320	5.4×10^{-10}
1867.8	.00655	.328	5.1×10^{-10}
1963.9	.00665	.332	5.1×10^{-10}
2035.6	.00695	.348	4.7×10^{-10}
2131.6	.00720	.360	4.8×10^{-10}
2203.3	.00740	.370	4.9×10^{-10}
2299.8	.00745	.372	4.9×10^{-10}
2371.4	.00755	.378	4.8×10^{-10}
2467.3	.00760	.380	3.6×10^{-10}
2539.5	.00770	.385	2.6×10^{-10}
2635.2	.00800	.400	3.8×10^{-10}
2707.6	.00820	.410	3.4×10^{-10}
2803.4	.00880	.440	3.4×10^{-10}
2875.1	.00900	.450	3.4×10^{-10}
2971.0	.00910	.455	3.1×10^{-10}
3043.1	.00920	.460	3.6×10^{-10}
3139.0	.00935	.468	3.3×10^{-10}
3211.3	.00930	.465	3.4×10^{-10}
3307.3	.00960	.480	3.3×10^{-10}
3379.2	.00965	.482	3.2×10^{-10}

TABLE XVIII (Continued)

<u>Time</u>	<u>Length Change</u> <u>L (inch)</u> <u>(2" G.L.)</u>	<u>Creep</u> <u>(%)</u>	<u>Pressure</u> <u>(Torr)</u>
3475.0 Hours	.00980	.490	3.4 x 10 ⁻¹⁰
3547.4	.00990	.495	3.2 x 10 ⁻¹⁰
3643.8	.00995	.498	3.2 x 10 ⁻¹⁰
3718.6	.01020	.510	3.1 x 10 ⁻¹⁰
3811.5	.01050	.525	3.1 x 10 ⁻¹⁰
3884.2	.01070	.535	3.4 x 10 ⁻¹⁰
3979.7	.01140	.570	3.1 x 10 ⁻¹⁰
4051.3	.01145	.572	2.9 x 10 ⁻¹⁰
4147.1	.01145	.572	2.9 x 10 ⁻¹⁰
4218.3	.01145	.572	3.2 x 10 ⁻¹⁰
4314.4	.01160	.580	3.1 x 10 ⁻¹⁰
4386.5	.01165	.582	3.0 x 10 ⁻¹⁰
4482.2	.01230	.615	2.9 x 10 ⁻¹⁰
4554.1	.01225	.612	3.0 x 10 ⁻¹⁰
4650.5	.01235	.618	3.2 x 10 ⁻¹⁰
4724.0	.01240	.620	3.0 x 10 ⁻¹⁰
4818.5	.01270	.635	3.3 x 10 ⁻¹⁰
4890.2	.01290	.645	3.0 x 10 ⁻¹⁰
5010.6	.01290	.645	3.2 x 10 ⁻¹⁰
5058.3	.01300	.650	4.4 x 10 ⁻¹⁰
5157.1	.01310	.655	3.0 x 10 ⁻¹⁰
5226.0	.01340	.670	2.9 x 10 ⁻¹⁰
5250.1	.01370	.685	2.8 x 10 ⁻¹⁰
5324.2	.01375	.688	2.8 x 10 ⁻¹⁰
5394.5	.01380	.690	2.8 x 10 ⁻¹⁰
5490.3	.01395	.698	2.7 x 10 ⁻¹⁰
5562.2	.01405	.702	2.8 x 10 ⁻¹⁰
5658.7	.01420	.710	2.8 x 10 ⁻¹⁰
5730.2	.01420	.710	2.8 x 10 ⁻¹⁰
5850.2	.01460	.730	2.7 x 10 ⁻¹⁰
5899.1	.01460	.730	2.7 x 10 ⁻¹⁰
5994.6	.01500	.750	2.8 x 10 ⁻¹⁰
6075.3	.01480	.740	2.5 x 10 ⁻¹⁰
6162.3	.01480	.740	2.6 x 10 ⁻¹⁰
6237.3	.01480	.740	2.6 x 10 ⁻¹⁰
6333.6	.01480	.740	2.8 x 10 ⁻¹⁰
6402.7	.01490	.745	2.8 x 10 ⁻¹⁰
6499.1	.01495	.748	2.7 x 10 ⁻¹⁰
6571.2	.01505	.752	2.7 x 10 ⁻¹⁰
6666.5	.01520	.760	2.6 x 10 ⁻¹⁰
6738.0	.01520	.760	2.5 x 10 ⁻¹⁰
6834.3	.01525	.762	2.7 x 10 ⁻¹⁰
6906.0	.01535	.766	2.7 x 10 ⁻¹⁰

TABLE XVIII (Continued)

Time	Length Change ΔL (inch) (2" G. L.)	Creep (%)	Pressure (Torr)
7004.4 Hours	.01550	.775	3.3×10^{-10}
7074.3	.01560	.780	2.6×10^{-10}
7170.1	.01595	.798	2.6×10^{-10}
7242.3	.01600	.800	2.5×10^{-10}
7362.8	.01605	.802	2.6×10^{-10}
7410.0	.01610	.805	2.6×10^{-10}
7506.6	.01620	.810	2.6×10^{-10}
7578.0	.01630	.815	2.5×10^{-10}
7674.8	.01650	.825	2.6×10^{-10}
7746.4	.01640	.820	2.6×10^{-10}
7842.2	.01670	.835	2.5×10^{-10}
7914.5	.01700	.850	2.6×10^{-10}
8010.4	.01710	.855	2.7×10^{-10}
8084.2	.01710	.855	2.6×10^{-10}
8178.2	.01715	.858	2.8×10^{-10}
8250.3	.01715	.858	2.6×10^{-10}
8346.2	.01720	.860	2.6×10^{-10}
8418.3	.01725	.862	2.6×10^{-10}
8514.2	.01735	.868	2.6×10^{-10}
8586.7	.01745	.872	2.7×10^{-10}
8683.2	.01750	.875	2.6×10^{-10}
8755.5	.01760	.880	2.6×10^{-10}
8851.2	.01765	.882	2.6×10^{-10}
8923.1	.01765	.882	2.4×10^{-10}
9019.3	.01770	.885	2.6×10^{-10}
9091.4	.01775	.888	2.8×10^{-10}
9187.3	.01790	.895	2.6×10^{-10}
9283.1	.01785	.892	2.6×10^{-10}
9355.3	.01790	.895	2.6×10^{-10}
9427.7	.01800	.900	1.8×10^{-10}
9523.8	.01810	.905	1.9×10^{-10}
9595.3	.01820	.910	2.2×10^{-10}
9691.6	.01825	.912	2.3×10^{-10}
9763.4	.01835	.918	2.4×10^{-10}
9860.0	.01840	.920	2.6×10^{-10}
9931.7	.01845	.922	2.1×10^{-10}
10,051.8	.01855	.928	2.0×10^{-10}

Test in Progress - Specimen B-20

TABLE XIX

CREEP TEST DATA, TZC PLATE, HEAT NO M-91, ANNEALED AT 2500°F (1371°C) FOR 1 HOUR,
 TESTED AT 1900°F (1038°C), 22,000 PSI (1.52 x 10⁸ N/m²)

Time	Length Change Δ L (inch) (2" G.L.)	Creep (%)	Pressure (Torr)
1 Minute(s)	-.00005	-.002	9.7 x 10 ⁻⁹
2	-.00005	-.002	9.7 x 10 ⁻⁹
3	-.00010	-.005	9.7 x 10 ⁻⁹
4	.00005	.002	9.7 x 10 ⁻⁹
5	.00005	.002	9.7 x 10 ⁻⁹
6	.00005	.002	9.7 x 10 ⁻⁹
7	.00005	.002	9.7 x 10 ⁻⁹
8	.00010	.005	9.7 x 10 ⁻⁹
9	.00010	.005	9.7 x 10 ⁻⁹
10	.00010	.005	9.7 x 10 ⁻⁹
15	.00015	.008	9.7 x 10 ⁻⁹
30	.00020	.010	9.7 x 10 ⁻⁹
45	.00020	.010	9.7 x 10 ⁻⁹
60	.00030	.015	9.7 x 10 ⁻⁹
17.2 Hours	.00065	.032	5.2 x 10 ⁻⁹
41.3	.00115	.058	3.7 x 10 ⁻⁹
44.2	.00120	.060	3.7 x 10 ⁻⁹
70.1	.00180	.090	3.2 x 10 ⁻⁹
98.5	.00195	.098	2.6 x 10 ⁻⁹
116.1	.00200	.100	2.5 x 10 ⁻⁹
137.2	.00200	.100	2.2 x 10 ⁻⁹
161.1	.00205	.102	1.8 x 10 ⁻⁹
184.9	.00210	.105	1.7 x 10 ⁻⁹
209.0	.00205	.102	1.7 x 10 ⁻⁹
281.1	.00240	.120	1.6 x 10 ⁻⁹
305.0	.00245	.122	1.5 x 10 ⁻⁹
329.2	.00250	.125	1.4 x 10 ⁻⁹
353.4	.00270	.135	1.3 x 10 ⁻⁹
377.0	.00275	.138	1.1 x 10 ⁻⁹
449.1	.00285	.142	1.0 x 10 ⁻⁹
473.0	.00295	.148	1.0 x 10 ⁻⁹
497.1	.00300	.150	1.2 x 10 ⁻⁹
521.9	.00310	.155	1.3 x 10 ⁻⁹
546.8	.00310	.155	1.5 x 10 ⁻⁹
617.7	.00315	.158	1.4 x 10 ⁻⁹
641.3	.00320	.160	1.2 x 10 ⁻⁹
664.8	.00325	.162	1.2 x 10 ⁻⁹
689.1	.00335	.168	1.2 x 10 ⁻⁹
713.0	.00340	.170	6.4 x 10 ⁻¹⁰
809.1	.00350	.175	9.6 x 10 ⁻¹⁰
833.4	.00355	.178	9.7 x 10 ⁻¹⁰
858.0	.00360	.180	9.5 x 10 ⁻¹⁰
881.1	.00365	.182	9.2 x 10 ⁻¹⁰
953.4	.00375	.188	8.3 x 10 ⁻¹⁰
977.3	.00380	.190	9.2 x 10 ⁻¹⁰

TABLE XIX (Continued)

Time	Length Change ΔL (inch) (2" G. L.)	Creep (%)	Pressure (Torr)
1003.2	.00380	.190	9.1×10^{-10}
1034.2	.00380	.190	8.8×10^{-10}
1049.2	.00375	.188	8.5×10^{-10}
1121.2	.00390	.195	7.9×10^{-10}
1145.0	.00385	.192	8.2×10^{-10}
1169.1	.00390	.195	7.8×10^{-10}
1195.4	.00390	.195	7.5×10^{-10}
1218.0	.00400	.200	3.5×10^{-10}
1289.8	.00425	.212	6.6×10^{-10}
1314.0	.00430	.215	7.3×10^{-10}
1337.9	.00430	.215	6.9×10^{-10}
1361.8	.00435	.218	4.1×10^{-10}
1385.7	.00445	.222	6.4×10^{-10}
1458.1	.00460	.230	3.2×10^{-10}
1481.5	.00470	.235	3.5×10^{-10}
1505.8	.00470	.235	7.1×10^{-10}
1531.0	.00475	.238	7.0×10^{-10}
1554.2	.00480	.240	6.6×10^{-10}
1625.3	.00470	.235	6.9×10^{-10}
1649.5	.00470	.235	3.1×10^{-10}
1673.1	.00485	.242	6.6×10^{-10}
1696.3	.00490	.245	6.6×10^{-10}
1720.9	.00490	.245	6.4×10^{-10}
1793.2	.00480	.240	6.6×10^{-10}
1817.0	.00495	.246	3.0×10^{-10}
1840.8	.00510	.255	6.4×10^{-10}
1864.9	.00520	.260	6.3×10^{-10}
1888.7	.00520	.260	6.2×10^{-10}
1963.3	.00525	.262	6.5×10^{-10}
1984.9	.00535	.268	2.6×10^{-10}
2009.2	.00535	.268	6.0×10^{-10}
2033.3	.00540	.270	6.4×10^{-10}
2056.9	.00555	.278	6.7×10^{-10}
2129.9	.00570	.285	7.2×10^{-10}
2153.1	.00565	.282	6.8×10^{-10}
2177.4	.00570	.285	7.0×10^{-10}
2201.2	.00580	.290	7.0×10^{-10}
2225.1	.00580	.290	5.8×10^{-10}
2321.7	.00590	.295	6.4×10^{-10}
2345.3	.00585	.292	6.4×10^{-10}
2368.9	.00585	.292	5.7×10^{-10}
2393.0	.00590	.295	6.8×10^{-10}
2465.5	.00585	.292	6.6×10^{-10}
2489.2	.00585	.292	6.8×10^{-10}
2513.2	.00590	.295	6.4×10^{-10}
2536.9	.00590	.295	6.6×10^{-10}
2561.6	.00590	.295	6.4×10^{-10}
2633.7	.00595	.298	6.1×10^{-10}
2657.2	.00595	.298	6.2×10^{-10}

TABLE XIX (Continued)

<u>Time</u>	<u>Length Change Δ L (inch) (2" G. L.)</u>	<u>Creep (%)</u>	<u>Pressure (Torr)</u>
2681. 2 Hours	. 00595	. 298	6. 2 x 10 ⁻¹⁰
2705. 3	. 00600	. 300	6. 4 x 10 ⁻¹⁰
2729. 0	. 00605	. 302	6. 3 x 10 ⁻¹⁰
2801. 0	. 00605	. 302	6. 3 x 10 ⁻¹⁰
2825. 3	. 00605	. 302	6. 2 x 10 ⁻¹⁰
2849. 1	. 00610	. 305	6. 2 x 10 ⁻¹⁰
2873. 4	. 00615	. 308	6. 1 x 10 ⁻¹⁰
2897. 2	. 00615	. 308	6. 1 x 10 ⁻¹⁰
2969. 3	. 00630	. 315	4. 6 x 10 ⁻¹⁰
2993. 1	. 00640	. 320	5. 0 x 10 ⁻¹⁰
3917. 0	. 00635	. 318	5. 0 x 10 ⁻¹⁰
3043. 1	. 00640	. 320	5. 8 x 10 ⁻¹⁰
3065. 3	. 00640	. 320	6. 2 x 10 ⁻¹⁰
3137. 1	. 00650	. 325	5. 0 x 10 ⁻¹⁰
3161. 2	. 00660	. 330	4. 6 x 10 ⁻¹⁰
3185. 1	. 00660	. 330	4. 7 x 10 ⁻¹⁰
3209. 2	. 00660	. 330	6. 0 x 10 ⁻¹⁰
3233. 1	. 00665	. 332	5. 2 x 10 ⁻¹⁰
3305. 0	. 00670	. 335	5. 9 x 10 ⁻¹⁰
3329. 0	. 00675	. 338	5. 9 x 10 ⁻¹⁰
3353. 4	. 00675	. 338	5. 6 x 10 ⁻¹⁰
3377. 2	. 00675	. 338	6. 0 x 10 ⁻¹⁰
3401. 0	. 00675	. 338	4. 6 x 10 ⁻¹⁰
3473. 0	. 00675	. 338	4. 5 x 10 ⁻¹⁰
3500. 0	. 00680	. 340	5. 7 x 10 ⁻¹⁰
3521. 1	. 00685	. 342	5. 8 x 10 ⁻¹⁰
3545. 6	. 00685	. 342	5. 8 x 10 ⁻¹⁰
3569. 2	. 00680	. 340	5. 8 x 10 ⁻¹⁰
3642. 0	. 00695	. 348	5. 5 x 10 ⁻¹⁰
3666. 0	. 00690	. 345	5. 6 x 10 ⁻¹⁰
3690. 2	. 00695	. 348	5. 8 x 10 ⁻¹⁰
3714. 4	. 00695	. 348	5. 4 x 10 ⁻¹⁰
3738. 1	. 00695	. 348	5. 7 x 10 ⁻¹⁰
3810. 1	. 00695	. 348	5. 7 x 10 ⁻¹⁰

TABLE XIX (Continued)

<u>Time</u>	<u>Length Change Δ L (inch) (2" G. L.)</u>	<u>Creep (%)</u>	<u>Pressure (Torr)</u>
3834.2	.00700	.350	5.6×10^{-10}
3858.5	.00705	.352	5.5×10^{-10}
3882.0	.00705	.352	5.6×10^{-10}
3906.0	.00705	.352	5.0×10^{-10}
3978.2	.00710	.355	5.2×10^{-10}
4002.1	.00710	.355	3.6×10^{-10}
4026.7	.00715	.358	4.9×10^{-10}
4050.3	.00720	.360	4.6×10^{-10}
4074.0	.00720	.360	4.5×10^{-10}
4146.2	.00730	.365	5.1×10^{-10}
4170.1	.00725	.362	5.3×10^{-10}
4194.5	.00730	.365	5.5×10^{-10}
4242.0	.00730	.365	5.2×10^{-10}
4314.2	.00735	.368	5.2×10^{-10}
4338.1	.00735	.368	5.0×10^{-10}
4362.1	.00735	.368	5.1×10^{-10}
4386.6	.00735	.368	5.1×10^{-10}
4410.5	.00735	.368	4.8×10^{-10}
4482.7	.00735	.368	5.0×10^{-10}
4506.3	.00740	.370	4.9×10^{-10}
4530.2	.00740	.370	5.0×10^{-10}
4554.2	.00745	.372	4.8×10^{-10}
4578.2	.00745	.372	4.4×10^{-10}
4650.5	.00750	.375	4.9×10^{-10}
4674.1	.00750	.375	4.9×10^{-10}
4698.2	.00750	.375	4.9×10^{-10}
4722.3	.00750	.375	4.9×10^{-10}
4746.2	.00755	.378	4.9×10^{-10}
4818.9	.00755	.378	4.8×10^{-10}
4842.3	.00760	.380	4.9×10^{-10}
4866.6	.00760	.380	4.6×10^{-10}
4890.6	.00765	.382	5.0×10^{-10}
5010.7	.00775	.388	4.7×10^{-10}

Test in Progress
Specimen B-33

TABLE XX

CREEP TEST DATA, TZC PLATE, HEAT M-91, ANNEALED AT 2500°F (1371°C) FOR 1 HOUR
TESTED AT 1935°F (1057°C), 20,000 PSI (1.38 x 10⁸ N/m²)

<u>Time</u>	<u>Length Change ΔL (inch) (2" G.L.)</u>	<u>Creep (%)</u>	<u>Pressure (Torr)</u>
1 Minute(s)	.00000	.000	2.0 x 10 ⁻⁸
2	-.00005	-.002	2.0 x 10 ⁻⁸
3	-.00010	-.005	2.0 x 10 ⁻⁸
4	-.00010	-.005	2.0 x 10 ⁻⁸
5	-.00010	-.005	2.0 x 10 ⁻⁸
6	-.00015	-.008	2.0 x 10 ⁻⁸
7	-.00015	-.008	2.0 x 10 ⁻⁸
8	-.00020	-.010	2.0 x 10 ⁻⁸
9	-.00015	-.008	2.0 x 10 ⁻⁸
10	-.00015	-.008	2.0 x 10 ⁻⁸
15	-.00010	-.005	2.0 x 10 ⁻⁸
30	-.00030	-.015	2.0 x 10 ⁻⁸
45	-.00030	-.015	2.0 x 10 ⁻⁸
60	-.00025	-.012	2.0 x 10 ⁻⁸
16.8 Hours	.00015	.008	1.1 x 10 ⁻⁸
91.2	.00080	.040	2.7 x 10 ⁻⁹
113.1	.00100	.050	2.2 x 10 ⁻⁹
136.1	.00105	.052	2.0 x 10 ⁻⁹
160.9	.00105	.052	1.7 x 10 ⁻⁹
184.9	.00115	.058	1.6 x 10 ⁻⁹
281.3	.00120	.060	5.2 x 10 ⁻¹⁰
305.1	.00120	.060	5.1 x 10 ⁻¹⁰
328.9	.00125	.062	5.1 x 10 ⁻¹⁰
353.0	.00130	.065	5.3 x 10 ⁻¹⁰
428.0	.00170	.085	4.8 x 10 ⁻¹⁰
448.9	.00180	.090	4.6 x 10 ⁻¹⁰
472.8	.00185	.092	1.2 x 10 ⁻⁹
496.7	.00185	.092	4.7 x 10 ⁻¹⁰
520.7	.00185	.092	1.1 x 10 ⁻⁹
592.9	.00190	.095	9.5 x 10 ⁻¹⁰
616.8	.00190	.095	9.8 x 10 ⁻¹⁰
640.9	.00190	.095	9.5 x 10 ⁻¹⁰
665.2	.00195	.098	9.8 x 10 ⁻¹⁰
688.8	.00190	.095	9.8 x 10 ⁻¹⁰
761.0	.00200	.100	9.2 x 10 ⁻¹⁰
784.8	.00195	.098	9.2 x 10 ⁻¹⁰
808.9	.00195	.098	9.8 x 10 ⁻¹⁰
833.0	.00200	.100	1.1 x 10 ⁻⁹

TABLE XX (Continued)

Time (Hours)	Length Change ΔL (inch) (2" G.L.)	Creep (%)	Pressure (Torr)
857.1	.00195	.098	1.4×10^{-9}
929.2	.00210	.105	9.0×10^{-10}
953.1	.00210	.105	7.8×10^{-10}
976.7	.00220	.110	8.3×10^{-10}
1000.9	.00215	.108	8.8×10^{-10}
1024.9	.00230	.115	7.9×10^{-10}
1120.9	.00235	.118	8.1×10^{-10}
1145.0	.00235	.118	7.4×10^{-10}
1169.6	.00230	.115	7.2×10^{-10}
1192.8	.00230	.115	7.1×10^{-10}
1265.2	.00235	.118	8.0×10^{-10}
1346.1	.00250	.125	7.2×10^{-10}
1432.9	.00255	.128	5.6×10^{-10}
1508.1	.00260	.130	5.5×10^{-10}
1604.4	.00250	.125	7.2×10^{-10}
1673.4	.00270	.135	6.3×10^{-10}
1769.5	.00280	.140	4.7×10^{-10}
1841.8	.00280	.140	4.7×10^{-10}
1937.1	.00290	.145	4.6×10^{-10}
2008.7	.00300	.150	4.5×10^{-10}
2105.0	.00300	.150	5.2×10^{-10}
2176.6	.00300	.150	4.2×10^{-10}
2274.3	.00340	.170	4.7×10^{-10}
2345.0	.00385	.192	4.2×10^{-10}
2440.8	.00380	.190	4.0×10^{-10}
2513.0	.00385	.192	4.4×10^{-10}
2633.5	.00380	.190	3.6×10^{-10}
2680.6	.00380	.190	3.8×10^{-10}
2777.3	.00385	.192	4.2×10^{-10}
2848.7	.00385	.192	3.5×10^{-10}
2945.4	.00385	.192	3.3×10^{-10}
3017.1	.00390	.195	3.6×10^{-10}
3112.9	.00395	.198	3.4×10^{-10}
3185.2	.00400	.200	3.2×10^{-10}
3281.1	.00410	.205	3.8×10^{-10}
3354.9	.00410	.205	2.9×10^{-10}
3448.9	.00415	.208	3.0×10^{-10}
3521.0	.00425	.212	3.0×10^{-10}
3616.9	.00445	.222	2.4×10^{-10}
3689.0	.00460	.230	2.5×10^{-10}
3784.9	.00470	.235	2.6×10^{-10}
3857.4	.00475	.238	2.5×10^{-10}
3953.9	.00480	.240	2.6×10^{-10}

TABLE XX (Continued)

<u>Time</u>	<u>Length Change Δ L (inch) (2" G. L.)</u>	<u>Creep (%)</u>	<u>Pressure (Torr)</u>
4026.2	.00480	.240	2.5 x 10 ⁻¹⁰
4121.9	.00490	.245	2.2 x 10 ⁻¹⁰
4193.9	.00500	.250	2.0 x 10 ⁻¹⁰
4290.0	.00505	.252	2.2 x 10 ⁻¹⁰
4362.1	.00510	.255	2.4 x 10 ⁻¹⁰
4458.1	.00515	.258	2.4 x 10 ⁻¹⁰
4553.8	.00520	.260	2.0 x 10 ⁻¹⁰
4626.0	.00530	.265	2.1 x 10 ⁻¹⁰
4698.5	.00530	.265	2.2 x 10 ⁻¹⁰
4794.4	.00535	.268	2.2 x 10 ⁻¹⁰
4866.1	.00540	.270	1.9 x 10 ⁻¹⁰
4962.3	.00545	.272	1.6 x 10 ⁻¹⁰
5034.1	.00550	.275	2.0 x 10 ⁻¹⁰
5130.7	.00560	.280	2.2 x 10 ⁻¹⁰
5202.5	.00560	.280	1.9 x 10 ⁻¹⁰
5322.4	.00570	.285	2.0 x 10 ⁻¹⁰

Test in Progress
Specimen B-32

TABLE XXI

CREEP TEST DATA, TZC PLATE, HEAT NO. 4345, ANNEALED 2500°F (1371°C), 1 HOUR, TESTED AT 2000°F (1093°C), 2200 psi (1.52 x 10⁸N/m²)

<u>Time</u>	<u>Length Change Δ L (inch) (2" G. L.)</u>	<u>Creep (%)</u>	<u>Pressure (Torr)</u>
1 Minute(s)	.00000	.000	2.2 x 10 ⁻⁸
2	.00005	.002	2.2 x 10 ⁻⁸
3	.00000	.000	2.2 x 10 ⁻⁸
4	.00005	.002	2.2 x 10 ⁻⁸
5	.00000	.000	2.2 x 10 ⁻⁸
6	.00005	.002	2.2 x 10 ⁻⁸
7	.00010	.005	2.2 x 10 ⁻⁸
8	.00005	.002	2.2 x 10 ⁻⁸
9	.00005	.002	2.2 x 10 ⁻⁸
10	.00005	.002	2.2 x 10 ⁻⁸
15	.00010	.005	2.2 x 10 ⁻⁸
30	.00015	.008	2.2 x 10 ⁻⁸
45	.00010	.005	2.2 x 10 ⁻⁸
60	.00010	.005	2.2 x 10 ⁻⁸
67.1 Hours	.00110	.055	4.9 x 10 ⁻⁹
91.1	.00130	.065	3.6 x 10 ⁻⁹
115.0	.00140	.070	3.0 x 10 ⁻⁹
139.1	.00150	.075	2.4 x 10 ⁻⁹
163.2	.00165	.082	2.3 x 10 ⁻⁹
235.0	.00200	.100	1.7 x 10 ⁻⁹
259.0	.00210	.105	1.6 x 10 ⁻⁹
283.3	.00215	.108	1.4 x 10 ⁻⁹
307.2	.00220	.110	1.4 x 10 ⁻⁹
331.0	.00220	.110	1.3 x 10 ⁻⁹
403.0	.00230	.115	1.2 x 10 ⁻⁹
430.0	.00240	.120	1.1 x 10 ⁻⁹
451.1	.00250	.125	1.2 x 10 ⁻⁹
475.5	.00260	.130	1.0 x 10 ⁻⁹
499.1	.00270	.135	1.0 x 10 ⁻⁹
572.0	.00275	.138	9.3 x 10 ⁻¹⁰
596.0	.00280	.140	8.7 x 10 ⁻¹⁰
620.1	.00290	.145	8.9 x 10 ⁻¹⁰
644.3	.00305	.152	8.1 x 10 ⁻¹⁰
668.1	.00310	.155	7.9 x 10 ⁻¹⁰

TABLE XXI (Continued)

<u>Time</u>	<u>Length Change Δ L (inch) (2" G. L.)</u>	<u>Creep (%)</u>	<u>Pressure (Torr)</u>
740.0	.00325	.162	7.7 x 10 ⁻¹⁰
764.2	.00330	.165	8.0 x 10 ⁻¹⁰
788.5	.00340	.170	7.0 x 10 ⁻¹⁰
812.0	.00340	.170	7.2 x 10 ⁻¹⁰
835.9	.00340	.170	6.9 x 10 ⁻¹⁰
908.2	.00345	.172	6.6 x 10 ⁻¹⁰
932.1	.00350	.175	7.0 x 10 ⁻¹⁰
956.6	.00350	.175	6.8 x 10 ⁻¹⁰
980.2	.00350	.175	7.0 x 10 ⁻¹⁰
1004.0	.00355	.178	6.6 x 10 ⁻¹⁰
1066.2	.00365	.182	5.7 x 10 ⁻¹⁰
1090.1	.00365	.182	5.9 x 10 ⁻¹⁰
1114.5	.00370	.185	6.4 x 10 ⁻¹⁰
1162.0	.00370	.185	5.6 x 10 ⁻¹⁰
1234.2	.00375	.188	5.6 x 10 ⁻¹⁰
1258.1	.00380	.190	5.0 x 10 ⁻¹⁰
1282.1	.00385	.192	5.5 x 10 ⁻¹⁰
1306.6	.00390	.195	5.1 x 10 ⁻¹⁰
1330.5	.00400	.200	4.9 x 10 ⁻¹⁰
1402.7	.00420	.210	4.6 x 10 ⁻¹⁰
1426.3	.00430	.215	5.0 x 10 ⁻¹⁰
1450.2	.00430	.215	5.4 x 10 ⁻¹⁰
1474.2	.00430	.215	4.9 x 10 ⁻¹⁰
1498.2	.00440	.220	5.3 x 10 ⁻¹⁰
1570.5	.00440	.220	4.6 x 10 ⁻¹⁰
1594.1	.00440	.220	4.9 x 10 ⁻¹⁰
1618.1	.00445	.222	4.8 x 10 ⁻¹⁰
1642.3	.00445	.222	4.6 x 10 ⁻¹⁰
1666.2	.00455	.228	4.8 x 10 ⁻¹⁰
1738.9	.00460	.230	5.0 x 10 ⁻¹⁰
1762.3	.00460	.230	4.6 x 10 ⁻¹⁰
1786.5	.00465	.232	4.7 x 10 ⁻¹⁰
1810.7	.00475	.238	4.8 x 10 ⁻¹⁰
1930.7	.00490	.245	4.1 x 10 ⁻¹⁰

Test In Progress
Specimen B-36

TABLE XXII

CREEP TEST DATA, STRESS RELIEVED TZM FORGED DISC, HEAT NO. 7502, TESTED AT 1800°F (982°C), 44,000 PSI (3.03 x 10⁸ N/m²)

<u>Time</u>	<u>Length Change L (inch) (2" G.L.)</u>	<u>Creep (%)</u>	<u>Pressure (Torr)</u>
1 Minute (s)	.00005	.002	1.2 x 10 ⁻⁸
2	-.00005	-.002	1.2 x 10 ⁻⁸
3	.00000	.000	1.2 x 10 ⁻⁸
4	.00005	.002	1.2 x 10 ⁻⁸
5	.00015	.008	1.2 x 10 ⁻⁸
6	.00015	.008	1.2 x 10 ⁻⁸
7	.00025	.012	1.2 x 10 ⁻⁸
8	.00025	.012	1.2 x 10 ⁻⁸
9	.00020	.010	1.2 x 10 ⁻⁸
10	.00030	.015	1.2 x 10 ⁻⁸
15	.00030	.015	1.2 x 10 ⁻⁸
30	.00030	.015	1.2 x 10 ⁻⁸
45	.00030	.015	1.2 x 10 ⁻⁸
60	.00025	.012	1.2 x 10 ⁻⁸
1.4 Hours	.00030	.015	1.3 x 10 ⁻⁸
25.6	.00135	.068	3.6 x 10 ⁻⁹
53.2	.00145	.072	3.0 x 10 ⁻⁹
64.4	.00150	.075	3.1 x 10 ⁻⁹
87.6	.00155	.078	3.1 x 10 ⁻⁹
111.9	.00155	.078	2.8 x 10 ⁻⁹
135.7	.00165	.082	2.9 x 10 ⁻⁹
159.6	.00170	.085	2.8 x 10 ⁻⁹
256.2	.00185	.092	2.8 x 10 ⁻⁹
279.9	.00190	.095	3.0 x 10 ⁻⁹
303.4	.00200	.100	3.1 x 10 ⁻⁹
327.6	.00200	.100	3.1 x 10 ⁻⁹
400.0	.00230	.115	2.7 x 10 ⁻⁹
423.7	.00230	.115	2.7 x 10 ⁻⁹
447.8	.00235	.118	2.7 x 10 ⁻⁹
471.5	.00235	.118	3.0 x 10 ⁻⁹
496.1	.00245	.122	2.8 x 10 ⁻⁹
568.2	.00265	.132	2.6 x 10 ⁻⁹
591.8	.00270	.135	2.6 x 10 ⁻⁹
615.7	.00275	.138	2.6 x 10 ⁻⁹
639.8	.00280	.140	2.7 x 10 ⁻⁹
663.6	.00290	.145	2.6 x 10 ⁻⁹
735.6	.00300	.150	2.6 x 10 ⁻⁹

TABLE XXII (Continued)

<u>Time</u>	<u>Length Change Δ L (inch) (2" G. L.)</u>	<u>Creep (%)</u>	<u>Pressure (Torr)</u>
759.8 Hours	.00305	.152	2.8×10^{-9}
783.6	.00310	.155	2.8×10^{-9}
807.9	.00310	.155	2.6×10^{-9}
831.8	.00310	.155	2.6×10^{-9}
903.8	.00335	.168	2.6×10^{-9}
927.6	.00345	.172	2.6×10^{-9}
951.6	.00360	.180	2.6×10^{-9}
977.6	.00375	.188	2.6×10^{-9}
999.8	.00385	.192	2.6×10^{-9}
1071.6	.00390	.195	2.7×10^{-9}
1143.7	.00400	.200	2.6×10^{-9}
1239.6	.00410	.205	2.5×10^{-9}
1263.5	.00435	.218	2.4×10^{-9}
1287.9	.00435	.218	2.5×10^{-9}
1311.7	.00440	.220	2.5×10^{-9}
1335.6	.00445	.222	2.5×10^{-9}
1407.6	.00450	.225	2.5×10^{-9}
1434.6	.00455	.228	2.4×10^{-9}
1455.6	.00465	.232	2.4×10^{-9}
1480.1	.00465	.232	2.4×10^{-9}
1503.7	.00465	.232	2.4×10^{-9}
1576.6	.00465	.232	2.4×10^{-9}
1600.6	.00470	.235	2.4×10^{-9}
1624.7	.00470	.235	2.4×10^{-9}
1648.9	.00475	.238	2.6×10^{-9}
1672.6	.00485	.242	2.6×10^{-9}
1744.6	.00480	.240	2.4×10^{-9}
1768.7	.00480	.240	2.4×10^{-9}
1793.0	.00480	.240	2.5×10^{-9}
1816.5	.00485	.242	2.4×10^{-9}
1840.5	.00485	.242	2.4×10^{-9}
1912.7	.00495	.248	2.5×10^{-9}

TABLE XXII (Continued)

<u>Time</u>	<u>Length Change Δ L (inch) (2" G. L.)</u>	<u>Creep (%)</u>	<u>Pressure (Torr)</u>
1936.7	.00495	.248	2.7×10^{-9}
1961.2	.00495	.248	2.5×10^{-9}
1984.7	.00500	.250	2.5×10^{-9}
2008.6	.00505	.252	2.6×10^{-9}
2080.8	.00510	.255	2.6×10^{-9}
2104.6	.00510	.255	2.6×10^{-9}
2129.0	.00515	.258	2.5×10^{-9}
2176.0	.00525	.262	2.5×10^{-9}
2248.7	.00530	.265	2.4×10^{-9}
2272.6	.00535	.268	2.4×10^{-9}
2296.6	.00540	.270	2.5×10^{-9}
2321.2	.00540	.270	2.4×10^{-9}
2345.0	.00545	.272	2.2×10^{-9}
2417.2	.00550	.275	2.4×10^{-9}
2440.8	.00545	.272	2.6×10^{-9}
2464.7	.00545	.272	2.4×10^{-9}
2488.7	.00550	.275	2.5×10^{-9}
2512.7	.00550	.275	2.6×10^{-9}
2585.0	.00555	.278	2.4×10^{-9}
2608.6	.00565	.282	2.4×10^{-9}
2632.8	.00560	.280	2.7×10^{-9}
2656.8	.00560	.280	2.8×10^{-9}
2680.7	.00565	.282	2.8×10^{-9}
2753.4	.00565	.282	2.9×10^{-9}
2776.8	.00570	.285	2.9×10^{-9}
2801.1	.00570	.285	2.6×10^{-9}
2825.1	.00575	.288	3.0×10^{-9}
2945.2	.00585	.292	2.6×10^{-9}

Test in Progress
Specimen B-35

TABLE XXIII

CREEP TEST DATA, STRESS RELIEVED TZM FORGED DISC, HEAT NO. 1175
 TESTED AT 1800°F (982°C), 44,000 psi ($3.03 \times 10^8 \text{N/m}^2$)

<u>Time</u>	<u>Length Change ΔL (inch) (2" G. L.)</u>	<u>Creep (%)</u>	<u>Pressure (Torr)</u>
1 minute(s)	.00000	.000	4.8×10^{-7}
2	.00010	.005	4.8×10^{-7}
3	.00020	.010	4.8×10^{-7}
4	.00025	.012	4.8×10^{-7}
5	.00015	.008	4.8×10^{-7}
6	.00015	.008	4.8×10^{-7}
7	.00010	.005	4.8×10^{-7}
8	.00015	.008	4.8×10^{-7}
9	.00020	.010	4.8×10^{-7}
10	.00020	.010	4.8×10^{-7}
15	.00020	.010	4.8×10^{-7}
30	.00025	.012	4.8×10^{-7}
45	.00025	.012	4.8×10^{-7}
60	.00030	.015	4.8×10^{-7}
65.5 hours	.00055	.028	3.0×10^{-7}
89.1	.00070	.035	2.8×10^{-7}
113.1	.00095	.048	1.1×10^{-8}
137.1	.00100	.050	2.1×10^{-8}
161.1	.00100	.050	1.7×10^{-9}
233.0	.00100	.050	1.0×10^{-9}
257.3	.00105	.052	8.4×10^{-10}
280.9	.00105	.052	1.3×10^{-9}
305.2	.00110	.055	1.6×10^{-9}
329.4	.00110	.055	1.4×10^{-9}
401.0	.00115	.058	1.4×10^{-9}
426.7	.00115	.058	4.0×10^{-10}
449.2	.00120	.060	5.8×10^{-10}
473.4	.00130	.065	7.6×10^{-10}
497.0	.00135	.068	3.8×10^{-10}
569.2	.00145	.072	3.9×10^{-10}
593.1	.00140	.070	5.5×10^{-10}
616.9	.00145	.072	8.4×10^{-10}
640.8	.00140	.070	7.8×10^{-10}
664.8	.00150	.075	5.0×10^{-10}

TABLE XXIII (Continued)

<u>Time</u>	<u>Length Change ΔL (inch) (2" G. L.)</u>	<u>Creep (%)</u>	<u>Pressure (Torr)</u>
736.8	.00150	.075	8.8 x 10 ⁻¹⁰
761.7	.00150	.075	8.6 x 10 ⁻¹⁰
785.0	.00150	.075	5.0 x 10 ⁻¹⁰
808.8	.00155	.078	9.0 x 10 ⁻¹⁰
833.8	.00155	.078	5.0 x 10 ⁻¹⁰
904.7	.00160	.080	8.4 x 10 ⁻¹⁰
928.8	.00160	.080	8.9 x 10 ⁻¹⁰
953.1	.00160	.080	7.0 x 10 ⁻¹⁰
977.0	.00165	.082	6.0 x 10 ⁻¹⁰
1001.0	.00180	.090	9.2 x 10 ⁻¹⁰
1073.0	.00180	.090	9.1 x 10 ⁻¹⁰
1144.9	.00175	.088	8.2 x 10 ⁻¹⁰
1240.7	.00175	.088	7.5 x 10 ⁻¹⁰
1313.2	.00180	.090	9.0 x 10 ⁻¹⁰
1409.5	.00180	.090	5.8 x 10 ⁻¹⁰
1484.2	.00180	.090	4.4 x 10 ⁻¹⁰
1577.2	.00185	.092	4.0 x 10 ⁻¹⁰
1650.2	.00185	.092	3.5 x 10 ⁻¹⁰
1716.9	.00190	.095	4.5 x 10 ⁻¹⁰
1822.5	.00200	.100	4.0 x 10 ⁻¹⁰
1913.6	.00215	.108	4.9 x 10 ⁻¹⁰
1984.0	.00210	.105	3.5 x 10 ⁻¹⁰
2080.1	.00215	.108	3.0 x 10 ⁻¹⁰
2152.2	.00215	.108	4.0 x 10 ⁻¹⁰
2247.9	.00220	.110	3.5 x 10 ⁻¹⁰
2319.8	.00225	.112	2.8 x 10 ⁻¹⁰
2416.7	.00235	.118	3.5 x 10 ⁻¹⁰
2489.7	.00230	.115	2.4 x 10 ⁻¹⁰
2584.3	.00235	.118	2.2 x 10 ⁻¹⁰
2655.9	.00240	.120	2.4 x 10 ⁻¹⁰
2776.3	.00250	.125	3.8 x 10 ⁻¹⁰
2824.0	.00250	.125	4.6 x 10 ⁻¹⁰
2922.9	.00250	.125	4.4 x 10 ⁻¹⁰
2991.8	.00245	.122	4.0 x 10 ⁻¹⁰
3015.8	.00245	.122	4.0 x 10 ⁻¹⁰
3088.0	.00245	.122	3.7 x 10 ⁻¹⁰
3160.4	.00245	.122	4.0 x 10 ⁻¹⁰
3256.0	.00250	.125	4.4 x 10 ⁻¹⁰
3328.7	.00255	.128	4.1 x 10 ⁻¹⁰

TABLE XXIII(Continued)

<u>Time</u>	<u>Length Change Δ L (inch) (2" G. L.)</u>	<u>Creep (%)</u>	<u>Pressure (Torr)</u>
3424.5 Hours	.00255	.128	3.4 x 10 ⁻¹⁰
3496.0	.00255	.128	4.5 x 10 ⁻¹⁰
3615.9	.00260	.130	3.5 x 10 ⁻¹⁰
3664.8	.00255	.128	3.5 x 10 ⁻¹⁰
3760.4	.00255	.128	4.2 x 10 ⁻¹⁰
3831.9	.00255	.128	3.5 x 10 ⁻¹⁰
3928.0	.00255	.128	3.4 x 10 ⁻¹⁰
4002.1	.00260	.130	3.9 x 10 ⁻¹⁰
4096.6	.00260	.130	3.4 x 10 ⁻¹⁰
4168.7	.00255	.128	4.0 x 10 ⁻¹⁰
4265.1	.00265	.132	3.6 x 10 ⁻¹⁰
4338.1	.00270	.135	3.1 x 10 ⁻¹⁰
4432.3	.00260	.130	3.2 x 10 ⁻¹⁰
4503.7	.00270	.135	3.5 x 10 ⁻¹⁰
4600.0	.00290	.145	2.6 x 10 ⁻¹⁰
4671.7	.00270	.135	3.5 x 10 ⁻¹⁰
4770.2	.00270	.135	3.6 x 10 ⁻¹⁰
4840.1	.00275	.138	3.5 x 10 ⁻¹⁰
4936.8	.00275	.138	3.9 x 10 ⁻¹⁰
5008.0	.00280	.140	3.8 x 10 ⁻¹⁰
5128.5	.00285	.142	3.2 x 10 ⁻¹⁰
5175.7	.00290	.145	3.0 x 10 ⁻¹⁰
5275.4	.00290	.145	3.0 x 10 ⁻¹⁰
5343.8	.00290	.145	3.5 x 10 ⁻¹⁰
5440.5	.00290	.145	3.0 x 10 ⁻¹⁰
5512.1	.00295	.148	3.0 x 10 ⁻¹⁰
5607.9	.00295	.148	3.2 x 10 ⁻¹⁰
5680.2	.00300	.150	3.0 x 10 ⁻¹⁰
5776.1	.00300	.150	3.0 x 10 ⁻¹⁰
5849.9	.00300	.150	2.5 x 10 ⁻¹⁰
5943.9	.00300	.150	4.1 x 10 ⁻¹⁰
6016.0	.00300	.150	3.0 x 10 ⁻¹⁰
6111.9	.00300	.150	3.0 x 10 ⁻¹⁰
6184.0	.00300	.150	3.0 x 10 ⁻¹⁰

TABLE XXIII (Continued)

<u>Time</u>	<u>Length Change Δ L (inch) (2" G. L.)</u>	<u>Creep (%)</u>	<u>Pressure (Torr)</u>
6279.9	.00300	.150	3.0×10^{-10}
6352.4	.00300	.150	3.0×10^{-10}
6448.9	.00305	.152	3.0×10^{-10}
6521.2	.00305	.152	3.0×10^{-10}
6616.9	.00305	.152	3.0×10^{-10}
6688.8	.00310	.155	3.5×10^{-10}
6785.0	.00310	.155	3.0×10^{-10}
6857.1	.00315	.158	3.4×10^{-10}
6953.1	.00315	.158	3.0×10^{-10}
7048.9	.00315	.158	3.0×10^{-10}
7121.0	.00315	.158	3.0×10^{-10}
7193.4	.00320	.160	3.0×10^{-10}
7289.5	.00320	.160	3.0×10^{-10}
7361.0	.00320	.160	3.0×10^{-10}
7457.3	.00320	.160	3.0×10^{-10}
7529.1	.00325	.162	3.0×10^{-10}
7625.7	.00325	.162	3.9×10^{-10}
7697.4	.00320	.160	4.0×10^{-10}
7817.5	.00330	.165	3.0×10^{-10}

Test in Progress
Specimen B-25

TABLE XXIV

CREEP TEST DATA, T-111 SHEET, HEAT NO. 70616, ANNEALED 3000°F (1649°C)

FOR 1 HOUR, TESTED AT 1860°F (1016°C), 20,000 PSI (1.38 x 10⁸N/m²)

<u>Time</u>	<u>Length Change ΔL (inch) (2" G.L.)</u>	<u>Creep (%)</u>	<u>Pressure (Torr)</u>
1 Minute(s)	.00010	.005	3.2 x 10 ⁻⁹
2	.00000	.000	3.2 x 10 ⁻⁹
3	.00000	.000	3.2 x 10 ⁻⁹
4	.00010	.005	3.2 x 10 ⁻⁹
5	.00015	.008	3.2 x 10 ⁻⁹
6	.00010	.005	3.2 x 10 ⁻⁹
7	.00020	.010	3.2 x 10 ⁻⁹
8	.00015	.008	3.2 x 10 ⁻⁹
9	.00015	.008	3.2 x 10 ⁻⁹
10	.00020	.010	3.2 x 10 ⁻⁹
15	.00020	.010	3.2 x 10 ⁻⁹
30	.00015	.008	3.2 x 10 ⁻⁹
45	.00015	.008	3.2 x 10 ⁻⁹
60	.00020	.010	3.2 x 10 ⁻⁹
65.2 Hours	.00070	.035	2.6 x 10 ⁻⁹
89.1	.00085	.042	2.2 x 10 ⁻⁹
113.2	.00110	.055	2.1 x 10 ⁻⁹
137.4	.00135	.068	1.9 x 10 ⁻⁹
161.0	.00140	.070	2.0 x 10 ⁻⁹
233.1	.00160	.080	1.8 x 10 ⁻⁹
256.9	.00165	.082	1.8 x 10 ⁻⁹
281.1	.00160	.080	1.8 x 10 ⁻⁹
305.0	.00180	.090	1.8 x 10 ⁻⁹
329.3	.00195	.098	1.7 x 10 ⁻⁹
401.4	.00195	.098	1.8 x 10 ⁻⁹
425.0	.00200	.100	1.6 x 10 ⁻⁹
449.1	.00200	.100	1.6 x 10 ⁻⁹
473.3	.00210	.105	1.7 x 10 ⁻⁹
497.0	.00205	.102	1.9 x 10 ⁻⁹
571.4	.00205	.102	1.7 x 10 ⁻⁹
593.3	.00210	.105	1.7 x 10 ⁻⁹

TABLE XXIV (Continued)

<u>Time</u>	<u>Length Change L (inch) (2" G. L.)</u>	<u>Creep (%)</u>	<u>Pressure (Torr)</u>
617.0	.00210	.105	1.7 x 10 ⁻⁹
641.1	.00215	.108	1.7 x 10 ⁻⁹
665.1	.00220	.110	1.5 x 10 ⁻⁹
761.5	.00230	.115	1.5 x 10 ⁻⁹
785.3	.00230	.115	1.6 x 10 ⁻⁹
809.1	.00235	.118	1.6 x 10 ⁻⁹
833.2	.00235	.118	1.6 x 10 ⁻⁹
908.2	.00235	.118	1.7 x 10 ⁻⁹
929.1	.00240	.120	1.6 x 10 ⁻⁹
953.1	.00240	.120	1.6 x 10 ⁻⁹
976.9	.00245	.122	1.5 x 10 ⁻⁹
1001.0	.00240	.120	1.4 x 10 ⁻⁹
1073.1	.00250	.125	1.6 x 10 ⁻⁹
1097.0	.00250	.125	1.6 x 10 ⁻⁹
1121.1	.00255	.128	1.5 x 10 ⁻⁹
1145.4	.00265	.132	1.6 x 10 ⁻⁹
1169.0	.00275	.138	1.5 x 10 ⁻⁹
1241.2	.00280	.140	1.5 x 10 ⁻⁹
1265.0	.00290	.145	1.5 x 10 ⁻⁹
1289.1	.00300	.150	1.6 x 10 ⁻⁹
1313.2	.00305	.152	1.7 x 10 ⁻⁹
1337.3	.00300	.150	2.0 x 10 ⁻⁹
1409.4	.00310	.155	1.6 x 10 ⁻⁹
1433.4	.00315	.158	1.6 x 10 ⁻⁹
1456.9	.00340	.170	1.6 x 10 ⁻⁹
1481.1	.00350	.175	1.6 x 10 ⁻⁹
1505.0	.00360	.180	1.4 x 10 ⁻⁹
1601.4	.00380	.190	1.7 x 10 ⁻⁹
1625.2	.00390	.195	1.5 x 10 ⁻⁹
1649.8	.00395	.198	1.7 x 10 ⁻⁹
1673.0	.00400	.200	1.6 x 10 ⁻⁹
1745.4	.00435	.218	1.9 x 10 ⁻⁹
1769.2	.00435	.218	1.9 x 10 ⁻⁹
1795.2	.00435	.218	1.8 x 10 ⁻⁹
1826.3	.00440	.220	1.8 x 10 ⁻⁹
1841.2	.00450	.225	1.5 x 10 ⁻⁹
1913.1	.00470	.235	1.0 x 10 ⁻⁹
1937.1	.00470	.235	1.1 x 10 ⁻⁹
1961.1	.00485	.242	1.0 x 10 ⁻⁹
1988.3	.00485	.242	1.0 x 10 ⁻⁹

TABLE XXIV (Continued)

<u>Time</u>	<u>Length Change L (inch) (2" G.L.)</u>	<u>Creep (%)</u>	<u>Pressure (Torr)</u>
2010.0	.00500	.250	1.0 x 10 ⁻⁹
2081.6	.00525	.262	1.4 x 10 ⁻⁹
2105.7	.00535	.268	1.2 x 10 ⁻⁹
2129.3	.00545	.272	1.6 x 10 ⁻⁹
2153.5	.00550	.275	1.4 x 10 ⁻⁹
2177.6	.00560	.280	1.1 x 10 ⁻⁹
2249.7	.00600	.300	1.1 x 10 ⁻⁹
2273.4	.00620	.310	1.1 x 10 ⁻⁹
2297.4	.00640	.320	1.0 x 10 ⁻⁹
2321.9	.00660	.330	1.1 x 10 ⁻⁹
2346.1	.00665	.332	1.0 x 10 ⁻⁹
2417.3	.00690	.345	1.3 x 10 ⁻⁹
2441.5	.00690	.345	1.2 x 10 ⁻⁹
2465.0	.00705	.352	1.2 x 10 ⁻⁹
2488.9	.00715	.356	1.1 x 10 ⁻⁹
2513.0	.00725	.362	1.1 x 10 ⁻⁹
2585.2	.00750	.375	1.3 x 10 ⁻⁹
2609.1	.00765	.382	1.1 x 10 ⁻⁹
2632.8	.00790	.395	1.1 x 10 ⁻⁹
2657.0	.00790	.395	1.1 x 10 ⁻⁹
2680.7	.00790	.395	1.1 x 10 ⁻⁹
2754.4	.00845	.422	1.3 x 10 ⁻⁹
2776.9	.00870	.435	1.1 x 10 ⁻⁹
2801.2	.00880	.440	1.0 x 10 ⁻⁹
2825.2	.00880	.440	1.1 x 10 ⁻⁹
2849.0	.00890	.445	1.1 x 10 ⁻⁹
2921.0	.00940	.470	1.1 x 10 ⁻⁹
2945.2	.00960	.480	1.2 x 10 ⁻⁹
2969.2	.00970	.485	1.1 x 10 ⁻⁹
2993.2	.00985	.492	1.1 x 10 ⁻⁹
3017.1	.01000	.500	1.2 x 10 ⁻⁹
3113.7	.01055	.528	1.0 x 10 ⁻⁹
3137.2	.01060	.530	1.0 x 10 ⁻⁹
3160.9	.01075	.538	1.1 x 10 ⁻⁹
3185.0	.01095	.548	1.0 x 10 ⁻⁹
3257.5	.01140	.570	1.1 x 10 ⁻⁹
3281.1	.01150	.575	1.0 x 10 ⁻⁹
3305.1	.01160	.580	1.0 x 10 ⁻⁹
3328.9	.01175	.588	1.0 x 10 ⁻⁹
3425.6	.01215	.608	1.0 x 10 ⁻⁹
3473.2	.01250	.625	1.1 x 10 ⁻⁹
3497.3	.01280	.640	1.1 x 10 ⁻⁹
3521.0	.01285	.642	1.1 x 10 ⁻⁹
3593.1	.01335	.668	1.1 x 10 ⁻⁹

TABLE XXIV (Continued)

<u>Time</u>	<u>Length Change Δ L (inch) (2" G. L.)</u>	<u>Creep (%)</u>	<u>Pressure (Torr)</u>
3617.3 Hours	.01340	.670	1.0×10^{-9}
3641.1	.01360	.680	1.1×10^{-9}
3665.4	.01380	.690	1.0×10^{-9}
3689.3	.01400	.700	1.1×10^{-9}
3761.3	.01465	.732	1.1×10^{-9}
3785.1	.01475	.738	1.0×10^{-9}
3809.1	.01490	.745	1.1×10^{-9}
3835.2	.01500	.750	1.1×10^{-9}
3857.3	.01515	.758	1.1×10^{-9}
3929.2	.01540	.770	1.1×10^{-9}
3953.2	.01560	.780	1.0×10^{-9}
3977.1	.01575	.788	1.1×10^{-9}
4001.2	.01585	.792	1.1×10^{-9}
4025.3	.01600	.800	1.0×10^{-9}
4097.1	.01645	.822	1.1×10^{-9}
4121.1	.01660	.830	1.0×10^{-9}
4145.4	.01670	.835	1.0×10^{-9}
4169.2	.01690	.845	1.0×10^{-9}
4193.1	.01700	.850	1.0×10^{-9}
4265.1	.01755	.878	1.0×10^{-9}
4292.2	.01765	.882	1.0×10^{-9}
4313.2	.01780	.890	1.0×10^{-9}
4337.5	.01805	.902	1.0×10^{-9}
4361.2	.01810	.905	1.1×10^{-9}
4434.1	.01810	.925	1.0×10^{-9}
4458.1	.01870	.935	1.1×10^{-9}
4482.2	.01875	.938	1.0×10^{-9}
4506.4	.01880	.940	1.1×10^{-9}
4530.2	.01885	.942	1.1×10^{-9}
4602.1	.01910	.955	9.7×10^{-10}
4646.2	.01940	.970	1.1×10^{-9}
4650.6	.01970	.985	1.1×10^{-9}
4674.1	.01980	.990	1.0×10^{-9}
4698.0	.01990	.995	1.1×10^{-9}

TABLE XXIV (Continued)

<u>Time</u>	<u>Length Change Δ L (inch) (2" G. L.)</u>	<u>Creep (%)</u>	<u>Pressure (Torr)</u>
4770.3 Hours	.. 02015	1.008	1.1×10^{-9}
4794.2	. 02040	1.020	1.1×10^{-9}
4818.7	. 02070	1.035	9.8×10^{-10}
4842.3	. 02105	1.052	1.1×10^{-9}
4866.1	. 02130	1.065	1.1×10^{-9}
4938.3	. 02175	1.088	1.1×10^{-9}
4945.5	. 02180	1.090	1.1×10^{-9}

Test Terminated - 1% Creep
Specimen S-24

TABLE XXV

CREEP TEST DATA, T-111, HEAT NO. 1102, ANNEALED 3000°F(1649°C)
1 HOUR, TESTED AT 2000°F (1093°C), 13,000 psi (8.96x10⁷N/m²)

<u>Time</u>	<u>Length Change Δ L (inch) (2" G. L.)</u>	<u>Creep (%)</u>	<u>Pressure (Torr)</u>
1 Minute(s)	.00010	.005	1.1 x 10 ⁻⁸
2	.00000	.000	1.1 x 10 ⁻⁸
3	.00010	.005	1.1 x 10 ⁻⁸
4	.00005	.002	1.1 x 10 ⁻⁸
5	.00015	.008	1.1 x 10 ⁻⁸
6	.00015	.008	1.1 x 10 ⁻⁸
7	.00015	.008	1.1 x 10 ⁻⁸
8	.00020	.010	1.1 x 10 ⁻⁸
9	.00015	.008	1.1 x 10 ⁻⁸
10	.00015	.008	1.1 x 10 ⁻⁸
15	.00020	.010	1.1 x 10 ⁻⁸
30	.00015	.008	1.1 x 10 ⁻⁸
45	.00015	.008	1.1 x 10 ⁻⁸
60	.00020	.010	1.1 x 10 ⁻⁸
1.5 Hours	.00020	.010	1.0 x 10 ⁻⁸
18.1	.00080	.040	8.9 x 10 ⁻⁹
114.4	.00150	.075	4.1 x 10 ⁻⁹
138.2	.00165	.082	4.0 x 10 ⁻⁹
161.9	.00210	.105	3.8 x 10 ⁻⁹
186.0	.00205	.102	3.5 x 10 ⁻⁹
258.4	.00250	.125	3.3 x 10 ⁻⁹
282.1	.00270	.135	3.3 x 10 ⁻⁹
305.1	.00280	.140	3.1 x 10 ⁻⁹
330.0	.00310	.155	3.0 x 10 ⁻⁹
354.6	.00330	.165	2.9 x 10 ⁻⁹
426.7	.00415	.208	2.8 x 10 ⁻⁹
450.2	.00440	.220	2.8 x 10 ⁻⁹
474.2	.00470	.235	2.8 x 10 ⁻⁹
498.3	.00490	.245	2.7 x 10 ⁻⁹
522.1	.00495	.248	2.8 x 10 ⁻⁹
594.1	.00555	.278	2.4 x 10 ⁻⁹
618.3	.00575	.288	2.6 x 10 ⁻⁹
642.1	.00600	.300	2.6 x 10 ⁻⁹
666.5	.00655	.328	2.6 x 10 ⁻⁹
690.3	.00670	.345	2.5 x 10 ⁻⁹
762.3	.00740	.370	2.4 x 10 ⁻⁹

TABLE XXV (Continued)

<u>Time</u>	<u>Length Change Δ L (inch) (2" G. L.)</u>	<u>Creep (%)</u>	<u>Pressure (Torr)</u>
786.1 Hours	.00760	.380	2.4×10^{-9}
810.2	.00785	.392	2.5×10^{-9}
836.2	.00810	.405	2.6×10^{-9}
858.4	.00840	.420	2.4×10^{-9}
930.2	.00915	.458	2.4×10^{-9}
954.2	.00935	.468	2.4×10^{-9}
978.1	.00950	.475	2.3×10^{-9}
1002.3	.00970	.485	2.5×10^{-9}
1026.3	.00990	.495	2.4×10^{-9}
1098.1	.01060	.530	2.5×10^{-9}
1122.1	.01095	.548	2.4×10^{-9}
1146.4	.01120	.560	2.4×10^{-9}
1170.2	.01145	.572	2.3×10^{-9}
1194.1	.01175	.588	2.3×10^{-9}
1266.1	.01285	.642	2.2×10^{-9}
1293.3	.01300	.650	2.3×10^{-9}
1314.2	.01330	.665	2.4×10^{-9}
1338.5	.01350	.675	2.4×10^{-9}
1362.3	.01370	.685	2.4×10^{-9}
1435.1	.01450	.725	2.4×10^{-9}
1459.2	.01480	.740	2.3×10^{-9}
1483.3	.01520	.760	2.3×10^{-9}
1507.4	.01545	.772	2.4×10^{-9}
1531.2	.01565	.782	2.2×10^{-9}
1603.2	.01650	.825	2.2×10^{-9}
1627.3	.01700	.850	2.2×10^{-9}
1651.6	.01745	.872	2.2×10^{-9}
1675.1	.01775	.888	2.2×10^{-9}
1699.1	.01795	.898	2.1×10^{-9}
1771.3	.01900	.950	2.2×10^{-9}
1795.2	.01910	.955	2.3×10^{-9}
1819.7	.01930	.965	2.2×10^{-9}
1843.3	.01950	.975	2.2×10^{-9}
1867.1	.01980	.990	2.2×10^{-9}
1939.3	.02075	1.038	2.1×10^{-9}
1963.2	.02100	1.050	2.2×10^{-9}

TABLE XXV (Continued)

<u>Time</u>	<u>Length Change Δ L (inch) (2" G. L.)</u>	<u>Creep (%)</u>	<u>Pressure (Torr)</u>
1987.4 Hours	.02145	1.072	2.3×10^{-9}
2035.0	.02210	1.105	2.1×10^{-9}
2107.3	.02310	1.155	2.1×10^{-9}
2131.2	.02350	1.175	2.2×10^{-9}
2155.2	.02375	1.188	1.9×10^{-9}
2179.7	.02400	1.200	2.2×10^{-9}
2203.6	.02430	1.215	2.3×10^{-9}
2275.6	.02525	1.262	2.1×10^{-9}
2299.4	.02575	1.288	2.1×10^{-9}
2323.3	.02610	1.305	2.0×10^{-9}
2347.3	.02650	1.325	2.0×10^{-9}
2371.3	.02690	1.345	2.0×10^{-9}
2443.5	.02750	1.375	5.8×10^{-10}
2467.2	.02800	1.400	2.0×10^{-9}
2491.3	.02840	1.420	2.0×10^{-9}
2515.3	.02870	1.435	6.1×10^{-10}
2539.2	.02900	1.450	2.0×10^{-9}
2612.0	.03010	1.505	2.0×10^{-9}
2635.3	.03040	1.530	2.0×10^{-9}
2659.6	.03080	1.540	1.9×10^{-9}
2683.7	.03110	1.555	2.0×10^{-9}
2803.6	.03240	1.620	2.0×10^{-9}

Test in Progress
Specimen S-27

TABLE XXVI

CREEP TEST DATA, T-111 SHEET, HEAT NO. 1102, ANNEALED 3000°F (1649°C), 1 HOUR, TESTED AT 2200°F (1204°C), 8000 psi (5.51x10⁷N/m²)

<u>Time</u>	<u>Length Change Δ L (inch) (2" G. L.)</u>	<u>Creep (%)</u>	<u>Pressure (Torr)</u>
1 Minute(s)	-.00005	-.002	5.8 x 10 ⁻⁸
2	.00000	.000	5.8 x 10 ⁻⁸
3	+.00005	+.002	5.8 x 10 ⁻⁸
4	.00010	.005	5.8 x 10 ⁻⁸
5	.00005	.002	5.8 x 10 ⁻⁸
6	.00005	.002	5.8 x 10 ⁻⁸
7	.00005	.002	5.8 x 10 ⁻⁸
8	.00010	.005	5.8 x 10 ⁻⁸
9	.00005	.002	5.8 x 10 ⁻⁸
10	.00010	.005	5.8 x 10 ⁻⁸
15	.00005	.002	5.8 x 10 ⁻⁸
30	.00005	.002	5.8 x 10 ⁻⁸
45	.00010	.005	5.8 x 10 ⁻⁸
60	.00010	.005	5.8 x 10 ⁻⁸
19.1 Hours	.00030	.015	2.3 x 10 ⁻⁸
91.0	.00100	.050	8.1 x 10 ⁻⁹
115.2	.00115	.058	4.6 x 10 ⁻⁹
139.5	.00130	.065	3.9 x 10 ⁻⁹
163.5	.00145	.072	3.3 x 10 ⁻⁹
283.6	.00160	.080	2.7 x 10 ⁻⁹

Test in Progress
Specimen S-32

TABLE XXVII

CREEP TEST DATA, T-111 SHEET HEAT NO. 65079, ANNEALED 3000°F (1649°C), 1 HOUR, TESTED AT 2400°F (1316°C), 3500 psi (2.41x10⁸N/m²)

<u>Time</u>	<u>Length Change Δ L (inch) (2" G. L.)</u>	<u>Creep (%)</u>	<u>Pressure (Torr)</u>
1 Minute(s)	.00000	.000	2.0 x 10 ⁻⁸
2	.00010	.005	2.0 x 10 ⁻⁸
3	.00010	.005	2.0 x 10 ⁻⁸
4	.00015	.008	2.0 x 10 ⁻⁸
5	.00010	.005	2.0 x 10 ⁻⁸
6	.00010	.005	2.0 x 10 ⁻⁸
7	.00015	.008	2.0 x 10 ⁻⁸
8	.00015	.008	2.0 x 10 ⁻⁸
9	.00020	.010	2.0 x 10 ⁻⁸
10	.00020	.010	2.0 x 10 ⁻⁸
15	.00020	.010	2.0 x 10 ⁻⁸
30	.00015	.008	2.0 x 10 ⁻⁸
45	.00020	.010	2.0 x 10 ⁻⁸
60	.00015	.008	2.0 x 10 ⁻⁸
41.4 Hours	.00110	.055	6.5 x 10 ⁻⁹
113.7	.00425	.212	3.8 x 10 ⁻⁹
137.6	.00360	.180	3.4 x 10 ⁻⁹
161.6	.00415	.208	3.2 x 10 ⁻⁹
186.1	.00480	.240	3.0 x 10 ⁻⁹
210.0	.00540	.270	3.3 x 10 ⁻⁹
282.0	.00700	.350	2.6 x 10 ⁻⁹
305.8	.00765	.382	2.7 x 10 ⁻⁹
329.7	.00850	.426	2.4 x 10 ⁻⁹
353.7	.00885	.442	2.2 x 10 ⁻⁹
377.7	.00945	.472	2.3 x 10 ⁻⁹
449.9	.01110	.555	2.1 x 10 ⁻⁹
473.6	.01150	.590	2.0 x 10 ⁻⁹
497.7	.01180	.590	2.0 x 10 ⁻⁹
521.8	.01225	.612	2.1 x 10 ⁻⁹
545.6	.01275	.638	2.1 x 10 ⁻⁹
618.4	.01435	.718	2.1 x 10 ⁻⁹
641.8	.01495	.748	2.0 x 10 ⁻⁹

TABLE XXVII (Continued)

<u>Time</u>	<u>Length Change Δ L (inch) (2" G. L.)</u>	<u>Creep (%)</u>	<u>Pressure (Torr)</u>
666.0	.01540	.770	2.0×10^{-9}
690.1	.01590	.795	1.8×10^{-9}
716.8	.01675	.838	1.8×10^{-9}
745.8	.01745	.872	1.8×10^{-9}
789.9	.01810	.905	1.8×10^{-9}
810.0	.01870	.935	1.8×10^{-9}

Test in Progress
Specimen S-30

TABLE XXVIII

CREEP TEST DATA, T-111 SHEET, HEAT NO. 65079, ANNEALED 3000°F (1649°C) 1 HOUR, TESTED AT 2200°F (1204°C), 5000 psi (3.44×10^7 N/m²)

<u>Time</u>	<u>Length Change Δ L (inch) (2" G. L.)</u>	<u>Creep (%)</u>	<u>Pressure (Torr)</u>
1 Minute(s)	.00020	.010	3.0×10^{-8}
2	.00020	.010	3.0×10^{-8}
3	.00015	.008	3.0×10^{-8}
4	.00015	.008	3.0×10^{-8}
5	.00020	.010	3.0×10^{-8}
6	.00020	.010	3.0×10^{-8}
7	.00020	.010	3.0×10^{-8}
8	.00025	.012	3.0×10^{-8}
9	.00025	.012	3.0×10^{-8}
10	.00025	.012	3.0×10^{-8}
15	.00025	.012	3.0×10^{-8}
30	.00020	.010	3.0×10^{-8}
45	.00025	.012	3.0×10^{-8}
60	.00020	.010	3.0×10^{-8}
19.1 Hours	.00045	.022	5.4×10^{-8}
43.0	.00055	.028	2.2×10^{-8}
67.0	.00065	.032	4.4×10^{-8}
91.0	.00075	.038	2.7×10^{-8}
163.3	.00105	.052	7.7×10^{-9}
186.9	.00105	.052	8.3×10^{-9}
211.0	.00120	.060	7.3×10^{-9}
235.1	.00135	.068	7.2×10^{-9}
259.0	.00145	.072	7.0×10^{-9}
331.7	.00175	.088	6.0×10^{-9}
355.1	.00180	.090	5.8×10^{-9}
379.3	.00185	.092	5.9×10^{-9}
403.4	.00190	.095	3.4×10^{-9}
523.5	.00210	.105	4.2×10^{-9}

Test in Progress
Specimen S-31

TABLE XXIX

CREEP TEST DATA, T-111 SHEET HEAT NO. D-1670, ANNEALED 3000°F (1649°C) 1 HOUR, TESTED AT 2600°F (1426°C), 500 psi (3.44 x 10⁶ N/m²)

<u>Time</u>	<u>Length Change Δ L (inch) (2" G. L.)</u>	<u>Creep (%)</u>	<u>Pressure (Torr)</u>
1 Minute(s)	.00005	.002	2.6 x 10 ⁻⁸
2	.00005	.002	2.6 x 10 ⁻⁸
3	.00000	.000	2.6 x 10 ⁻⁸
4	.00005	.002	2.6 x 10 ⁻⁸
5	.00000	.000	2.6 x 10 ⁻⁸
6	.00005	.002	2.6 x 10 ⁻⁸
7	.00005	.002	2.6 x 10 ⁻⁸
8	.00005	.002	2.6 x 10 ⁻⁸
9	.00010	.005	2.6 x 10 ⁻⁸
10	.00005	.002	2.6 x 10 ⁻⁸
15	-.00005	-.002	2.6 x 10 ⁻⁸
30	-.00010	-.005	2.6 x 10 ⁻⁸
45	-.00010	-.005	2.6 x 10 ⁻⁸
60	-.00010	-.005	2.6 x 10 ⁻⁸
16.4 Hours	-.00010	-.005	1.6 x 10 ⁻⁸
40.4	.00005	.002	8.0 x 10 ⁻⁹
64.4	.00050	.025	8.4 x 10 ⁻⁹
83.3	.00075	.038	7.9 x 10 ⁻⁹
160.3	.00180	.090	5.5 x 10 ⁻⁹
184.5	.00205	.102	5.5 x 10 ⁻⁹
208.3	.00235	.118	5.3 x 10 ⁻⁹
232.7	.00245	.122	5.0 x 10 ⁻⁹
256.5	.00260	.130	4.2 x 10 ⁻⁹
328.5	.00325	.162	3.8 x 10 ⁻⁹
352.3	.00335	.168	3.6 x 10 ⁻⁹
376.4	.00345	.172	4.6 x 10 ⁻⁹
402.4	.00345	.172	6.0 x 10 ⁻⁹
424.5	.00350	.175	3.6 x 10 ⁻⁹
496.4	.00370	.185	3.3 x 10 ⁻⁹
520.4	.00375	.188	3.4 x 10 ⁻⁹
544.3	.00385	.192	3.9 x 10 ⁻⁹
568.4	.00385	.192	3.5 x 10 ⁻⁹
592.5	.00385	.192	3.7 x 10 ⁻⁹
664.3	.00395	.198	4.2 x 10 ⁻⁹

TABLE XXIX (Continued)

<u>Time</u>	<u>Length Change Δ L (inch) (2" G. L.)</u>	<u>Creep (%)</u>	<u>Pressure (Torr)</u>
688. 3 Hours	. 00395	. 198	4. 0 x 10 ⁻⁹
712. 6	. 00400	. 200	3. 2 x 10 ⁻⁹
736. 4	. 00405	. 202	3. 8 x 10 ⁻⁹
760. 3	. 00410	. 205	3. 1 x 10 ⁻⁹
832. 3	. 00430	. 215	3. 0 x 10 ⁻⁹
859. 4	. 00435	. 218	4. 0 x 10 ⁻⁹
880. 4	. 00435	. 218	5. 4 x 10 ⁻⁹
904. 7	. 00445	. 222	5. 4 x 10 ⁻⁹
928. 5	. 00460	. 230	5. 2 x 10 ⁻⁹
1001. 3	. 00465	. 232	5. 0 x 10 ⁻⁹
1025. 4	. 00465	. 232	4. 9 x 10 ⁻⁹
1049. 5	. 00475	. 238	5. 2 x 10 ⁻⁹
1073. 6	. 00490	. 245	5. 6 x 10 ⁻⁹
1097. 4	. 00505	. 252	5. 3 x 10 ⁻⁹
1169. 4	. 00535	. 268	4. 9 x 10 ⁻⁹
1193. 4	. 00550	. 275	4. 9 x 10 ⁻⁹
1217. 8	. 00555	. 278	4. 8 x 10 ⁻⁹
1241. 3	. 00565	. 282	4. 0 x 10 ⁻⁹
1265. 3	. 00570	. 285	4. 9 x 10 ⁻⁹
1337. 5	. 00585	. 292	5. 0 x 10 ⁻⁹
1361. 4	. 00590	. 295	2. 8 x 10 ⁻⁹
1385. 9	. 00590	. 295	4. 5 x 10 ⁻⁹
1409. 5	. 00595	. 298	2. 9 x 10 ⁻⁹
1433. 3	. 00600	. 300	4. 5 x 10 ⁻⁹
1505. 5	. 00605	. 302	4. 9 x 10 ⁻⁹
1529. 4	. 00615	. 308	5. 0 x 10 ⁻⁹
1553. 5	. 00620	. 310	4. 6 x 10 ⁻⁹
1601. 2	. 00615	. 308	4. 7 x 10 ⁻⁹
1673. 5	. 00625	. 312	4. 6 x 10 ⁻⁹
1697. 4	. 00625	. 312	4. 4 x 10 ⁻⁹
1721. 4	. 00625	. 312	4. 1 x 10 ⁻⁹
1745. 9	. 00625	. 312	4. 6 x 10 ⁻⁹
1769. 8	. 00635	. 318	4. 5 x 10 ⁻⁹
1841. 8	. 00635	. 318	2. 9 x 10 ⁻⁹

TABLE XXIX (Continued)

<u>Time</u>	<u>Length Change Δ L (inch) (2" G. L.)</u>	<u>Creep (%)</u>	<u>Pressure (Torr)</u>
1865.6 Hours	.00640	.320	4.3 x 10 ⁻⁹
1889.5	.00645	.322	4.1 x 10 ⁻⁹
1913.5	.00645	.322	4.1 x 10 ⁻⁹
1937.5	.00650	.325	2.4 x 10 ⁻⁹
2009.7	.00660	.330	4.4 x 10 ⁻⁹
2033.4	.00665	.332	4.1 x 10 ⁻⁹
2057.5	.00665	.332	4.0 x 10 ⁻⁹
2081.4	.00675	.338	4.2 x 10 ⁻⁹
2105.4	.00675	.338	4.1 x 10 ⁻⁹
2178.2	.00680	.340	4.9 x 10 ⁻⁹
2201.6	.00685	.342	2.8 x 10 ⁻⁹
2225.8	.00685	.342	3.0 x 10 ⁻⁹
2249.9	.00690	.345	3.8 x 10 ⁻⁹
2369.8	.00695	.348	3.6 x 10 ⁻⁹

Test in Progress
Specimen S-28

TABLE XXX

CREEP TEST DATA, T-111 SHEET, HEAT NO. 111-D-1670, ANNEALED AT 3000°F (1649°C)
 FOR 1 HOUR, TESTED AT 1800°F (982°C), 17,000 PSI (1.11×10^8 N/m²)

Time	Length Change ΔL (inch) (2" G.L.)	Creep (%)	Pressure (Torr)
1 Minute (s)	.00010	.005	5.2×10^{-8}
2	.00015	.008	5.2×10^{-8}
3	.00015	.008	5.2×10^{-8}
4	.00015	.008	5.2×10^{-8}
5	.00015	.008	5.2×10^{-8}
6	.00015	.008	5.2×10^{-8}
7	.00015	.008	5.2×10^{-8}
8	.00015	.008	5.2×10^{-8}
9	.00020	.010	5.2×10^{-8}
10	.00015	.008	5.2×10^{-8}
15	.00015	.008	5.2×10^{-8}
30	.00015	.008	5.2×10^{-8}
45	.00020	.010	5.2×10^{-8}
60	.00020	.010	5.2×10^{-8}
27.1 Hours	.00050	.025	1.5×10^{-8}
49.6	.00065	.032	1.2×10^{-8}
65.0	.00055	.028	6.4×10^{-9}
88.7	.00055	.028	4.6×10^{-9}
114.7	.00060	.030	3.0×10^{-9}
145.8	.00070	.035	2.4×10^{-9}
160.7	.00070	.035	2.0×10^{-9}
232.7	.00070	.035	1.7×10^{-9}
256.6	.00065	.032	1.6×10^{-9}
280.6	.00075	.038	1.4×10^{-9}
307.8	.00075	.038	1.4×10^{-9}
329.5	.00080	.040	1.3×10^{-9}
404.1	.00075	.038	1.5×10^{-9}
425.4	.00080	.040	1.4×10^{-9}
448.8	.00085	.042	1.4×10^{-9}
473.1	.00085	.042	1.3×10^{-9}
497.2	.00085	.042	1.1×10^{-9}
569.3	.00080	.040	9.4×10^{-10}
592.9	.00080	.040	9.2×10^{-10}
617.1	.00085	.042	8.8×10^{-10}
641.6	.00090	.045	8.8×10^{-10}
665.7	.00095	.048	8.6×10^{-10}
736.9	.00110	.055	8.2×10^{-10}
761.0	.00110	.055	8.2×10^{-10}
784.5	.00110	.055	7.9×10^{-10}
808.5	.00110	.055	7.8×10^{-10}
832.5	.00110	.055	7.7×10^{-10}
904.7	.00110	.055	7.7×10^{-10}
928.5	.00110	.055	7.5×10^{-10}
952.4	.00110	.055	7.5×10^{-10}
976.4	.00110	.055	7.2×10^{-10}

TABLE XXX (Continued)

<u>Time</u>	<u>Length Change Δ L (inch) (2" G. L.)</u>	<u>Creep (%)</u>	<u>Pressure (Torr)</u>
1000. 2 Hours	. 00110	. 055	7. 0 x 10 ⁻¹⁰
1074. 0	. 00110	. 055	7. 3 x 10 ⁻¹⁰
1096. 5	. 00120	. 060	6. 8 x 10 ⁻¹⁰
1120. 7	. 00120	. 060	6. 8 x 10 ⁻¹⁰
1144. 7	. 00120	. 060	6. 9 x 10 ⁻¹⁰
1168. 5	. 00115	. 058	6. 9 x 10 ⁻¹⁰
1240. 5	. 00120	. 060	6. 6 x 10 ⁻¹⁰
1264. 7	. 00115	. 058	6. 5 x 10 ⁻¹⁰
1288. 7	. 00125	. 062	6. 5 x 10 ⁻¹⁰
1312. 7	. 00125	. 062	6. 4 x 10 ⁻¹⁰
1336. 6	. 00130	. 065	6. 2 x 10 ⁻¹⁰
1433. 2	. 00145	. 072	5. 9 x 10 ⁻¹⁰
1456. 7	. 00155	. 078	6. 1 x 10 ⁻¹⁰
1480. 4	. 00155	. 078	6. 1 x 10 ⁻¹⁰
1504. 5	. 00155	. 078	6. 0 x 10 ⁻¹⁰
1577. 0	. 00160	. 080	6. 0 x 10 ⁻¹⁰
1600. 6	. 00165	. 082	7. 1 x 10 ⁻¹⁰
1624. 6	. 00165	. 082	7. 2 x 10 ⁻¹⁰
1648. 4	. 00165	. 082	7. 0 x 10 ⁻¹⁰
1673. 1	. 00170	. 085	6. 9 x 10 ⁻¹⁰
1745. 2	. 00175	. 088	5. 4 x 10 ⁻¹⁰
1768. 7	. 00180	. 090	5. 4 x 10 ⁻¹⁰
1792. 7	. 00175	. 088	5. 4 x 10 ⁻¹⁰
1816. 8	. 00190	. 095	5. 4 x 10 ⁻¹⁰
1840. 5	. 00195	. 098	5. 4 x 10 ⁻¹⁰
1912. 6	. 00200	. 100	5. 4 x 10 ⁻¹⁰
1936. 8	. 00205	. 102	5. 3 x 10 ⁻¹⁰
1960. 6	. 00210	. 105	5. 6 x 10 ⁻¹⁰
1985. 0	. 00205	. 102	5. 2 x 10 ⁻¹⁰
2008. 8	. 00210	. 105	5. 3 x 10 ⁻¹⁰
2080. 8	. 00210	. 105	5. 3 x 10 ⁻¹⁰
2104. 5	. 00210	. 105	5. 0 x 10 ⁻¹⁰
2128. 6	. 00220	. 110	5. 0 x 10 ⁻¹⁰
2154. 6	. 00225	. 112	5. 4 x 10 ⁻¹⁰
2176. 9	. 00230	. 115	5. 0 x 10 ⁻¹⁰

TABLE XXX (Continued)

<u>Time</u>	<u>Length Change</u> <u>Δ L (inch)</u> <u>(2" G. L.)</u>	<u>Creep</u> <u>(%)</u>	<u>Pressure</u> <u>(Torr)</u>
2248.6 Hours	.00235	.118	7.0×10^{-10}
2272.7	.00230	.115	5.1×10^{-10}
2296.6	.00240	.120	5.2×10^{-10}
2320.7	.00245	.122	5.0×10^{-10}
2344.8	.00245	.122	5.1×10^{-10}
2416.6	.00255	.128	4.9×10^{-10}
2440.6	.00260	.130	4.9×10^{-10}
2464.9	.00260	.130	4.8×10^{-10}
2488.7	.00265	.132	5.0×10^{-10}
2512.6	.00265	.132	5.0×10^{-10}
2584.6	.00270	.135	5.0×10^{-10}
2611.7	.00275	.138	5.2×10^{-10}
2632.7	.00275	.138	5.1×10^{-10}
2657.1	.00280	.140	4.9×10^{-10}
2680.7	.00285	.142	5.0×10^{-10}
2753.6	.00290	.145	4.8×10^{-10}
2777.6	.00300	.150	4.9×10^{-10}
2801.7	.00305	.152	4.8×10^{-10}
2825.9	.00310	.155	4.9×10^{-10}
2849.7	.00320	.160	5.0×10^{-10}
2921.6	.00335	.168	4.7×10^{-10}
2945.7	.00340	.170	4.6×10^{-10}
2970.1	.00350	.175	4.6×10^{-10}
2993.6	.00350	.175	4.7×10^{-10}
3017.5	.00360	.180	4.7×10^{-10}
3089.7	.00365	.182	4.8×10^{-10}
3114.1	.00370	.185	4.8×10^{-10}
3138.2	.00390	.195	4.7×10^{-10}
3161.8	.00390	.195	4.8×10^{-10}
3185.6	.00400	.200	4.7×10^{-10}
3257.8	.00430	.215	4.7×10^{-10}
3281.6	.00435	.218	4.7×10^{-10}
3305.8	.00445	.222	4.7×10^{-10}
3353.6	.00445	.222	4.6×10^{-10}
3425.7	.00450	.225	4.4×10^{-10}
3449.6	.00455	.228	4.2×10^{-10}

TABLE XXX (Continued)

<u>Time</u>	<u>Length Change Δ L (inch) (2" G. L.)</u>	<u>Creep (%)</u>	<u>Pressure (Torr)</u>
3473.7 Hours	.00460	.230	4.2×10^{-10}
3498.2	.00470	.235	4.3×10^{-10}
3522.1	.00465	.232	4.5×10^{-10}
3594.1	.00475	.238	4.4×10^{-10}
3617.8	.00475	.238	4.4×10^{-10}
3641.7	.00490	.245	4.4×10^{-10}
3665.8	.00490	.245	4.2×10^{-10}
3689.7	.00500	.250	4.1×10^{-10}
3762.0	.00505	.252	4.1×10^{-10}
3785.7	.00515	.257	4.3×10^{-10}
3809.7	.00530	.265	4.2×10^{-10}
3833.9	.00530	.265	4.3×10^{-10}
3857.7	.00540	.270	4.3×10^{-10}
3930.4	.00540	.270	4.3×10^{-10}
3953.9	.00545	.272	4.0×10^{-10}
3978.1	.00545	.272	4.2×10^{-10}
4002.2	.00550	.275	4.2×10^{-10}
4122.1	.00565	.282	4.1×10^{-10}

Test in Progress
Specimen S-26

TABLE XXXI

CREEP TEST DATA, ASTAR 811C SHEET, ANNEALED 3600°F (1982°C)
1/2 HOUR, TESTED AT 2600°F (1427°C), 2000 psi ($1.38 \times 10^7 \text{N/m}^2$)

<u>Time</u>	<u>Length Change Δ L (inch) (2" G. L.)</u>	<u>Creep (%)</u>	<u>Pressure (Torr)</u>
1 Minute(s)	.00005	.002	1.1×10^{-8}
2	.00010	.005	1.1×10^{-8}
3	.00015	.008	1.1×10^{-8}
4	.00010	.005	1.1×10^{-8}
5	.00010	.005	1.1×10^{-8}
6	.00010	.005	1.1×10^{-8}
7	.00010	.005	1.1×10^{-8}
8	.00010	.005	1.1×10^{-8}
9	.00010	.005	1.1×10^{-8}
10	.00010	.005	1.1×10^{-8}
15	.00010	.005	1.1×10^{-8}
30	.00015	.008	1.1×10^{-8}
45	.00015	.008	1.1×10^{-8}
60	.00015	.008	1.1×10^{-8}
2.9 Hours	.00015	.008	1.1×10^{-8}
18.9	.00015	.008	9.1×10^{-9}
43.0	.00020	.010	8.0×10^{-9}
90.7	.00030	.015	4.6×10^{-9}
163.7	.00030	.015	3.3×10^{-9}
186.9	.00030	.015	3.1×10^{-9}
210.9	.00035	.018	3.0×10^{-9}
235.4	.00035	.018	2.6×10^{-9}
259.3	.00035	.018	2.6×10^{-9}
331.3	.00035	.018	2.0×10^{-9}
355.0	.00035	.018	2.0×10^{-9}
379.0	.00035	.018	2.0×10^{-9}
403.0	.00040	.020	1.8×10^{-9}
427.0	.00040	.020	2.5×10^{-9}
499.2	.00040	.020	1.6×10^{-9}
522.9	.00040	.020	1.7×10^{-9}
546.9	.00040	.020	1.5×10^{-9}
570.9	.00040	.020	1.6×10^{-9}
594.9	.00045	.022	1.7×10^{-9}

TABLE XXXI (Continued)

<u>Time</u>	<u>Length Change Δ L (inch) (2" G. L.)</u>	<u>Creep (%)</u>	<u>Pressure (Torr)</u>
667.6 Hours	.00045	.022	1.8×10^{-9}
691.0	.00050	.025	1.6×10^{-9}
715.3	.00050	.025	1.7×10^{-9}
739.4	.00050	.025	1.5×10^{-9}
859.3	.00060	.030	1.4×10^{-9}
Test in Progress			
<u>Specimen S-29</u>			

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