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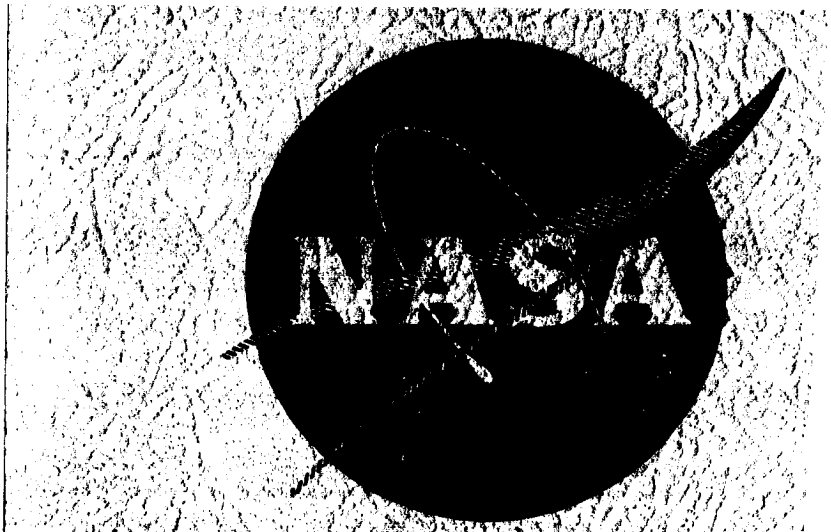

GENERATION OF LONG TIME CREEP DATA ON REFRACTORY ALLOYS AT ELEVATED TEMPERATURES

NINE MONTH SUMMARY REPORT

Prepared for

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION
LEWIS RESEARCH CENTER
UNDER CONTRACT NAS 3-9439

TRW EQUIPMENT LABORATORIES
CLEVELAND, OHIO

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NAS-CR-72391

NINE MONTH SUMMARY REPORT

For

17 March 1967 to 14 December 1967

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

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Prepared for:

National Aeronautics and Space Administration
Contract No. NAS 3-9439

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14 December 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 3-9439. 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, K. D. Sheffler is the Principal Investigator, and R. R. Ebert contributed to the program. The NASA technical director is Paul E. Moorhead.

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ABSTRACT

Molybdenum-base TZC and TZM alloys and tantalum-base T-111 and Astar 811C are being creep tested in a vacuum environment of $<1 \times 10^{-8}$ torr. Test temperatures range from 1600 to 2600°F (871-1427°C) and stresses from 0.5 to 65 Ksi (3.44×10^6 to 4.48×10^8 N/m2). Test parameters have been selected to provide 0.5-1.0% creep in 5000 to 15,000 hours.

Test results with molybdenum-base TZC and TZM show the effects of variations in composition and thermal-mechanical processing history on 1/2% creep life. Analysis of these data using the Larson-Miller parameter indicates that at higher stress levels and lower temperatures a specially processed lot of TZM having a somewhat higher than normal carbon content is superior to TZC in the stress relieved condition, whereas at higher temperatures and lower stresses, the behavior of the two materials is comparable.

A Larson-Miller plot for 1% creep of commercial purity tantalum tubing has been constructed based upon extrapolation of five short term creep tests performed sequentially upon two specimens. The Larson-Miller analysis shows a very sharp change in the creep resistance of the pure tantalum between 1183°F (639°C) and 1350°F (731°C).

The 1% creep data for tantalum-base T-111 alloy show good agreement among results from five of six heats tested, with the sixth heat exhibiting significantly poorer creep resistance.

Tests designed to evaluate the creep behavior of T-111 subjected to continuously increasing loads exhibit progressively increasing creep rates. The experimental techniques involved in these tests and various methods for prediction of continuous load life from static creep test data are discussed.

Results of a single test in progresss on Astar 811C show this alloy to have significantly better creep resistance than T-111.

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INTRODUCTION

Current design concepts for space electric power systems specify refractory metals and alloys in a variety of areas. Among these is the proposed use of molybdenum-base alloys as turbine components and tantalum-base alloys for tubing and capsule fabrication.

One of the most important properties of these materials in such applications is the long time creep strength at elevated temperature. Since the systems under consideration will operate either in the ultra-high vacuum of outer space or in environments such as metal vapor or liquid metals where the partial pressure of reactive gasses is extremely low, it is necessary to determine the creep properties of the proposed materials of construction in an ultra-high vacuum environment in order to generate representative design data.

Various refractory alloys are therefore being creep tested in a vacuum environment of $<1 \times 10^{-8}$ torr for times up to 15,000 hours on a continuation of an NASA program, (NAS-3-2545). Materials of current interest are the molybdenum-base alloys TZM and TZC, commercially pure tantalum, and the tantalum-base alloys T-111 and Astar 811C.

Application of radioactive isotope capsules as a prime energy source for space electric power systems provides another unique design problem, where an enclosed capsule may be subjected to continuously increasing helium gas pressure. Experimental techniques have therefore been developed to vacuum creep test refractory alloys with continuously increasing loads, and various methods to predict creep behavior under these test conditions from static creep test data are being evaluated.

II MATERIALS AND PROCEDURE

The composition of the various alloys discussed in this report are presented in Table 1 and a detailed review of the available processing histories is presented in Appendix I. Raw creep data from each of the tests are presented in Appendix II.

The general creep test program involves evaluation of the molybdenum-base alloys TZC and TZM at temperatures between 1600 and 2250°F (871 and 1235°C) at stresses chosen to provide 1/2% to 1% total creep in 5000 to 15,000 hours. The tantalum-base alloys are being evaluated at 1750 to 2600°F (954 to 1427°C while the commercially pure tantalum is being tested in the 1100 to 1350°F (593 to 732°C) range. In most cases, stresses for the tantalum base tests are also chosen to provide 1% total creep in 5000 to 15,000 hours.

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 11 inch diameter disc forgings. A second lot of TZM, designated Heat No. 7463, was also obtained from Climax, but in the form of rolled and swaged bar. The third lot of this material (Heat KDTZM-1175 Disc No. 3) was a section of a forging obtained from AiResearch. The latter material was specially processed by Universal Cyclops to produce improved creep resistance (1)* through the development of a fine carbide dispersion. A carbon level above 0.02% is necessary in order to produce this effect.

Three different heats of TZC have been tested. Heats M-80 and M-91 were processed by the General Electric Co. M-80 was rolled with very small reductions on each pass and a high finishing temperature, while M-91 was processed by taking a relatively large reduction per pass and finishing at a lower temperature. TZC Heat 4345 was prepared by Climax Molybdenum of Michigan by broad forging 3-inch diameter extruded stock at 2400°F (1316°C).

Six heats of T-111 alloy were obtained from two different sources. Four heats were produced by Wah Chang Corporation (Heats 70616, 65079, 65080, and MCN02A065), and two were obtained from Fansteel Corporation (Heats D-1670 and D-1102). All heats are being evaluated after recrystallization at 3000°F (1649°C) for one hour.

A sample of Astar 811C, a relatively new tantalum-base alloy developed under Contract NAS 3-2542, was obtained from the Westinghouse Electric Corporation through NASA Lewis. This alloy was rolled to 0.030" thick sheet, delivered in the as-worked condition, and tested after a 1/2 hour anneal at 3600°F (1982°C).

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* Numbers in parentheses refer to references listed in the bibliography.

Table 1

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

Material	W	Re	Mo	Ta	Hf	C	Ti	Zr	ppm N_2	ppm O_2	ppm H_2
TZM (Heat 7463)			Bal.			.016	.48	.08	1	2	1(2)
(Heat 7502)			Bal.			.010	.51	.091	100	20	7
(Heat KDTZM-1175)			Bal.			.035	.61	.120	43	34	9
TZC (Heat M-80)			Bal.			.127(4)	1.02	.17	18	41	10
(Heat M-91)			Bal.			.113(4)	1.17	.270	34	37	10
(Heat 4345)			Bal.			.075	1.19	.16	9	19	2
T-111 (Heat 70616)	8.5			Bal.	2.30	.0044			20	55	6
(Heat 65079)	8.7			Bal.	2.30	.003			50	130	4(2)
(Heat 65080)	8.9			Bal.	2.03	.0031			40	105	4(4)
(Heat MCN02A065)	8.6			Bal.	1.95	.004			20	100	3(2)
(Heat D-1102)	7.9			Bal.	2.28	.003			34	20	3(2)
(Heat D-1670)	7.9			Bal.	2.17-2.44	<.001			20	72	<5(2)
Astar 811C	8.0	1.0		Bal.	0.7	.250			-	-	-(3)
Commercially Pure Ta				Bal.		.0051			2.4	7	3(1)

(1) TRW Analysis
(2) Vendor Analysis
(3) Nominal Composition
(4) Average of Several Analyses

Two specimens of commercially pure tantalum tubing were obtained from the Fansteel Metallurgical Corporation through NASA Lewis. These samples were annealed one hour at 1832°F (1000°C) prior to delivery and are being evaluated in this condition.

The static creep test procedure involved obtaining a chamber vacuum of 5×10^{-10} torr or better at room temperature, then heating the specimen at such a rate that the pressure never rose above 1×10^{-6} torr. After test heat treatments were performed in situ prior to load application. After heat treatment the specimens were cooled to 600°F (316°C) or lower and then reheated to the test temperature which was maintained for two hours prior to loading in order to insure complete thermal equilibrium in the test specimen. During testing, the pressure was always less than 1×10^{-8} torr and decreased with test time. Specimen extension was determined over a two-inch gage length by using an optical extensometer to measure the distance between two scribed reference marks with an accuracy of 50 microinches. Temperature was initially recorded by a thermocouple attached to the specimen. An optical pyrometer having a precision of ±1°F was calibrated against the thermocouple and subsequently used as the prime temperature reference.

The continuous loading test procedure required replacement of the static loading weight pan with an aluminum container which collected lead shot from a feeder driven by a continuous-duty DC motor. The loading rate was regulated by controlling the speed of the feeder drive motor. A typical record of load as a function of time is shown in Figure 1.

The geometries of the sheet and bar specimens are shown in Figures 2 and 3. The orientation of the specimens with respect to the working direction is given below:

Material Form	Specimen Axis Parallel To
Disc forging	Radius
Plate	Extruding direction
Sheet	Rolling direction (except where indicated)

A special specimen and grip were developed for testing the tantalum tubing. A specimen machined according to this design is shown in Figure 4. The axes of the loading pins are perpendicular to the flats that are centered in the tube to insure equal loading of each gage section. The grips were hollow heavy-walled cylinders which slide over the ends of the tubing to receive the loading pins. Five sequential tests have been performed in the temperature range between 1100 and 1350°F (593 and 732°C) on two of these specimens cut from one of the as-received tubes. A fifteen-minute anneal at 1832°F (1000°C) was applied between each test sequence.

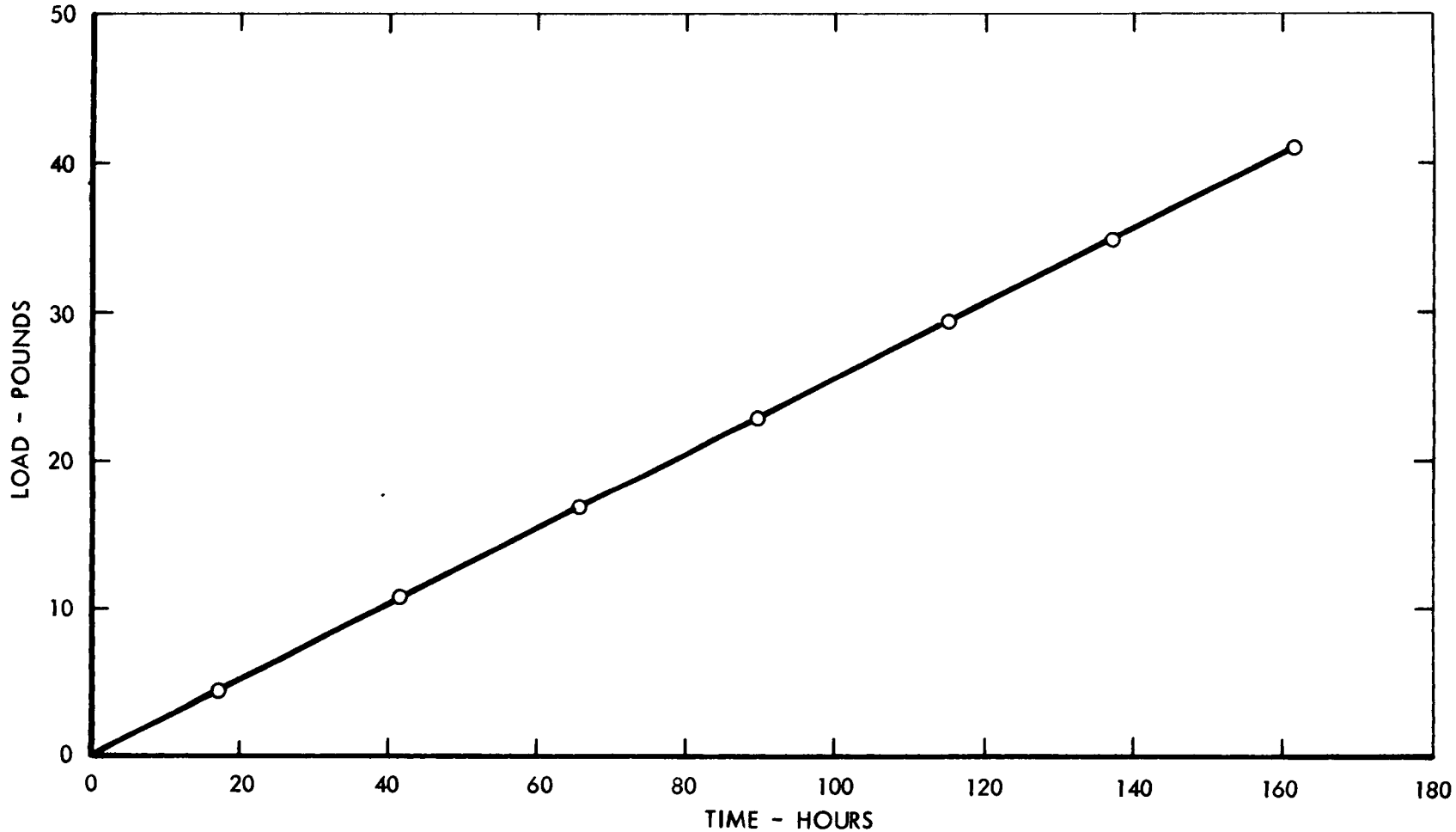


Figure 1. Load on specimen S-51 as a function of test time.

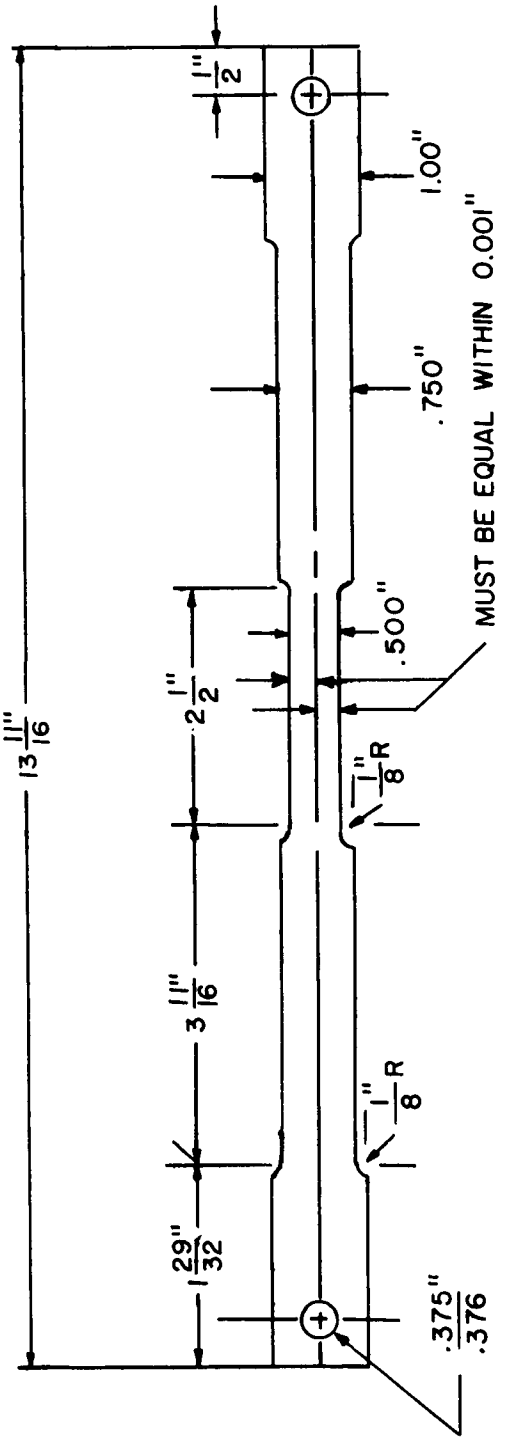
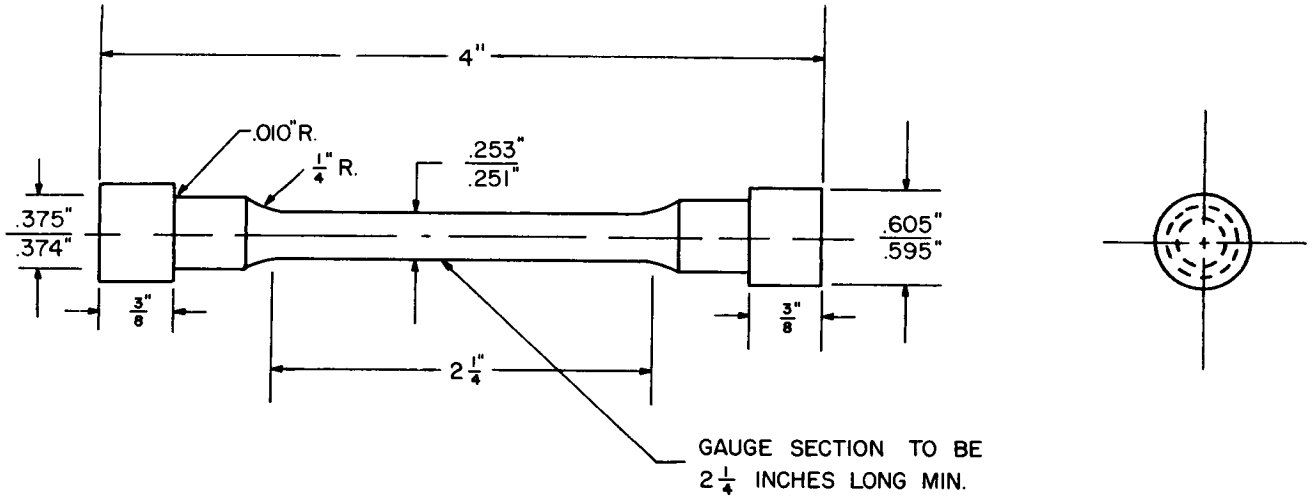


Figure 2. Creep specimen used for sheet stock.



NOTE: ANY TAPER IN GAUGE SECTION MUST BE TOWARDS CENTER

ALL TOLERANCES ± .010" UNLESS OTHERWISE NOTED

Figure 3. Creep specimen used for plate stock.

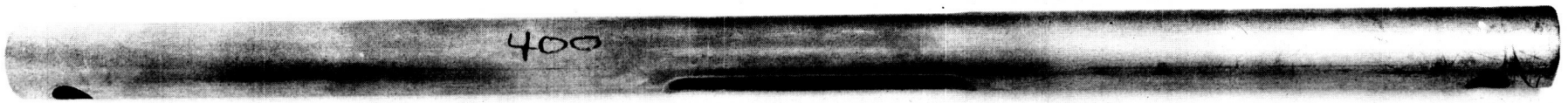


Figure 4. Creep specimen used for commercially pure tantalum tubing.

In addition to the long time creep tests in progress on T-111, a series of short time tests were performed sequentially upon two specimens of this alloy to evaluate the ability of such tests to predict long time data. A preliminary test was conducted at 2000°F (1093°C) in order to establish base-line data. This was followed by a second test consisting of four individual sequences at 2172, 2391, 2000, and 1800°F (1189, 1299, 1093, and 980°C), conducted in that order. The specimen was given the customary pre-test anneal at 3000°F for one hour, and was provided with a 15 minute anneal at the same temperature between each test sequence. The stress was adjusted for each sequence to provide a nominal 1000 hour 1% creep life.

III RESULTS AND DISCUSSION

Molybdenum-Base Alloys

Creep curves for the tests on TZC Heat M-91 (Figure 5) show that the specimens stress relieved at 2500°F (1371°C) achieved steady state creep rates after about 2000 hours, while the specimen recrystallized at 3092°F (1700°C) exhibited a steadily decreasing strain rate throughout the test. This behavior indicates a time and/or strain dependent strengthening process occurring simultaneously with creep. The strengthening may represent either classical work hardening or some form of precipitation hardening mechanism. Post creep tension tests show an increase of strength consistent with this observed hardening during creep (2).

Tests were conducted on two samples from TZC Heat 4345, one stress relieved at 2400°F (1316°C), and the other at 2500°F (1371°C) to evaluate the influence of the different stress relief temperatures on creep behavior. Results of these tests (Figure 6) indicate that the lower stress relief temperature produced slightly improved creep properties.

A summary of the creep tests conducted on TZC, including previously obtained results (3), is presented in Table 2 along with Larson-Miller parameters based on the time for 1/2% creep. Correlation of the Larson-Miller parameters with stress (Figure 7) indicates that in the annealed condition (one hour at 3092°F (1700°C)) TZC Heat M-80 is superior to Heat M-91. Figure 8 shows that M-91 has been fully recrystallized by the annealing treatment, whereas M-80 retains strong remnants of the cold worked structure. Mechanical properties presented in Table 3 indicate that the M-80 material has significantly higher hardness, higher yield strength and lower ductility than M-91.

TABLE 3

TZC
Room Temperature Mechanical Properties

Heat No.	Strength, Ksi			% Reduction of Area	DPH Hardness
	Ultimate	0.2% Yield	% Elongation		
M-80	68.6	68.5	.05	0	268
M-91	85	49	7	7	240

The higher creep strength of the M-80 material may be associated with the more complex substructure implied by the higher yield strength.

Table 2 - Summary of TZC Ultra-High Vacuum Creep Test Results

Specimen No.	Condition	Test Temperature °F	Test Temperature °C	Stress ksi	Stress N/m^2	Time to 0.5% Creep Hours	Larson-Miller Parameter for 0.5% Creep $T^{\circ}R\ (15 + \log t) \times 10^3$
						Heat No. M-80	
B-8A	1 hour 3092°F (1700°C)	2200	1204	18	1.24×10^8	1,100	48.3
B-10	1 hour 3092°F (1700°C)	2200	1204	17	1.17×10^8	2,500	48.9
B-9	1 hour 3092°F (1700°C)	2000	1093	20	1.38×10^8	10,408	46.8
B-11	1 hour 3092°F (1700°C)	1856	1013	25	1.72×10^8	75,000* (14,405)	46.0
B-12	1 hour 3092°F (1700°C)	2056	1125	19	1.31×10^8	35,000* (14,239)	49.2
						Heat No. M-91	
B-20	1 hour 3092°F (1700°C)	2000	1093	20	1.38×10^8	3,650	45.7
B-31	1 hour 3092°F (1700°C)	2200	1204	14	9.65×10^7	329	46.6
B-19	1 hour 2300°F (1260°C)	1800	982	44	3.03×10^8	1,075	41.1
B-28	1 hour 2300°F (1260°C)	2000	1093	28	1.93×10^8	1,100	44.4
B-30	1 hour 2500°F (1371°C)	2200	1204	22	1.52×10^8	70	44.8
B-32	1 hour 2500°F (1371°C)	1935	1057	20	1.38×10^8	14,400*	45.9
B-33	1 hour 2500°F (1371°C)	1900	1038	22	1.52×10^8	7,720	44.6
						Heat No. 4345	
B-36	1 hour 2500°F (1371°C)	2000	1093	22	1.52×10^8	5,940	46.2
B-37	1 hour 2400°F (1316°C)	2000	1093	22	1.52×10^8	8,000	46.3

* Extrapolated - Numbers in parentheses indicate actual test time

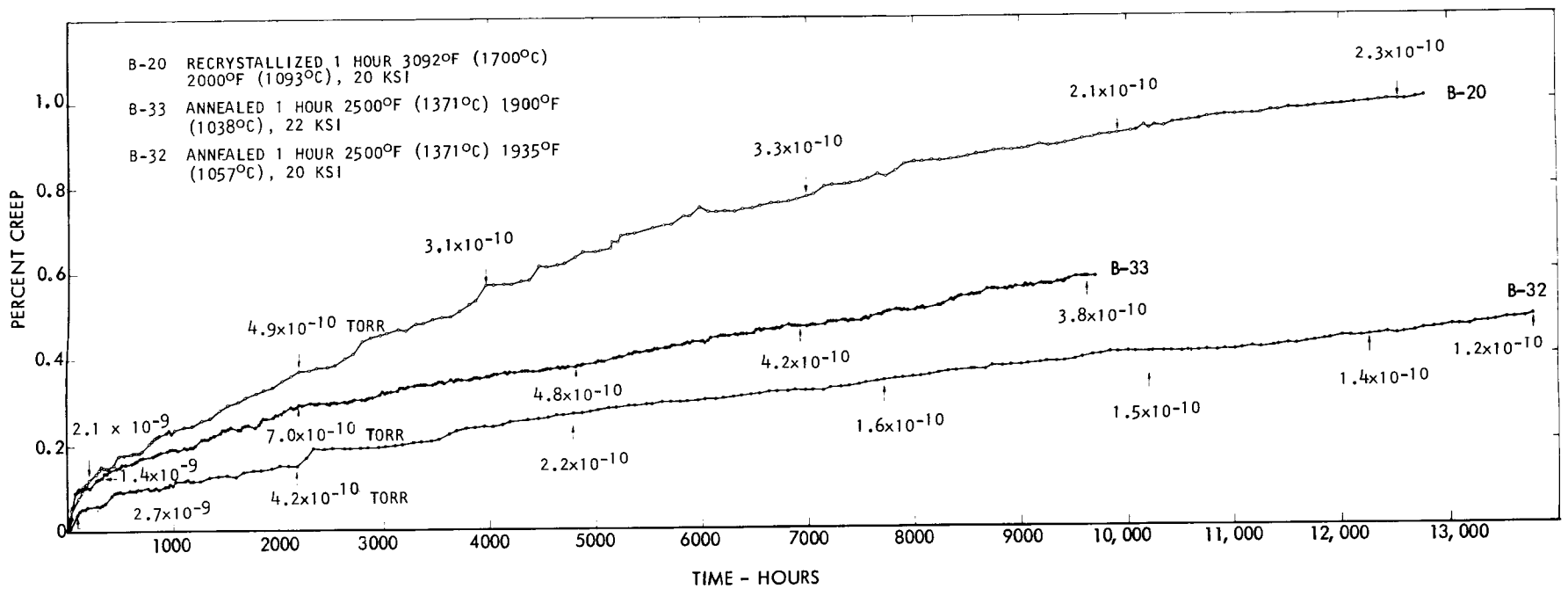


Figure 5. Creep test data, TZC Heat No. M-91 tested in a vacuum environment of $<1 \times 10^{-8}$ torr. Arrows on the curves indicate chamber pressure at various intervals during the test.

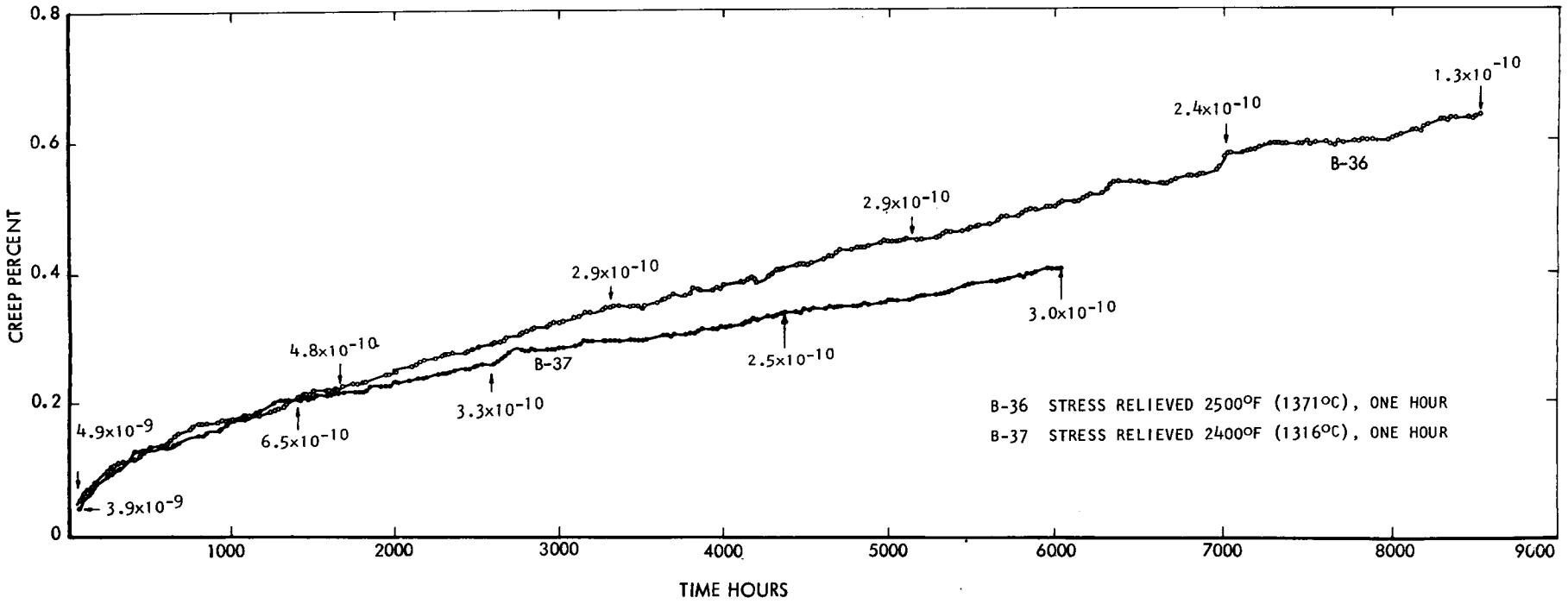


Figure 6. Creep test data, TZC Heat No. 4345 tested at 2000°F (1093°C) and 22 ksi (1.52×10^8 N/m^2) in a vacuum environment of $<1 \times 10^{-8}$ torr. Arrows on the curves indicate chamber pressure at various intervals during the test.

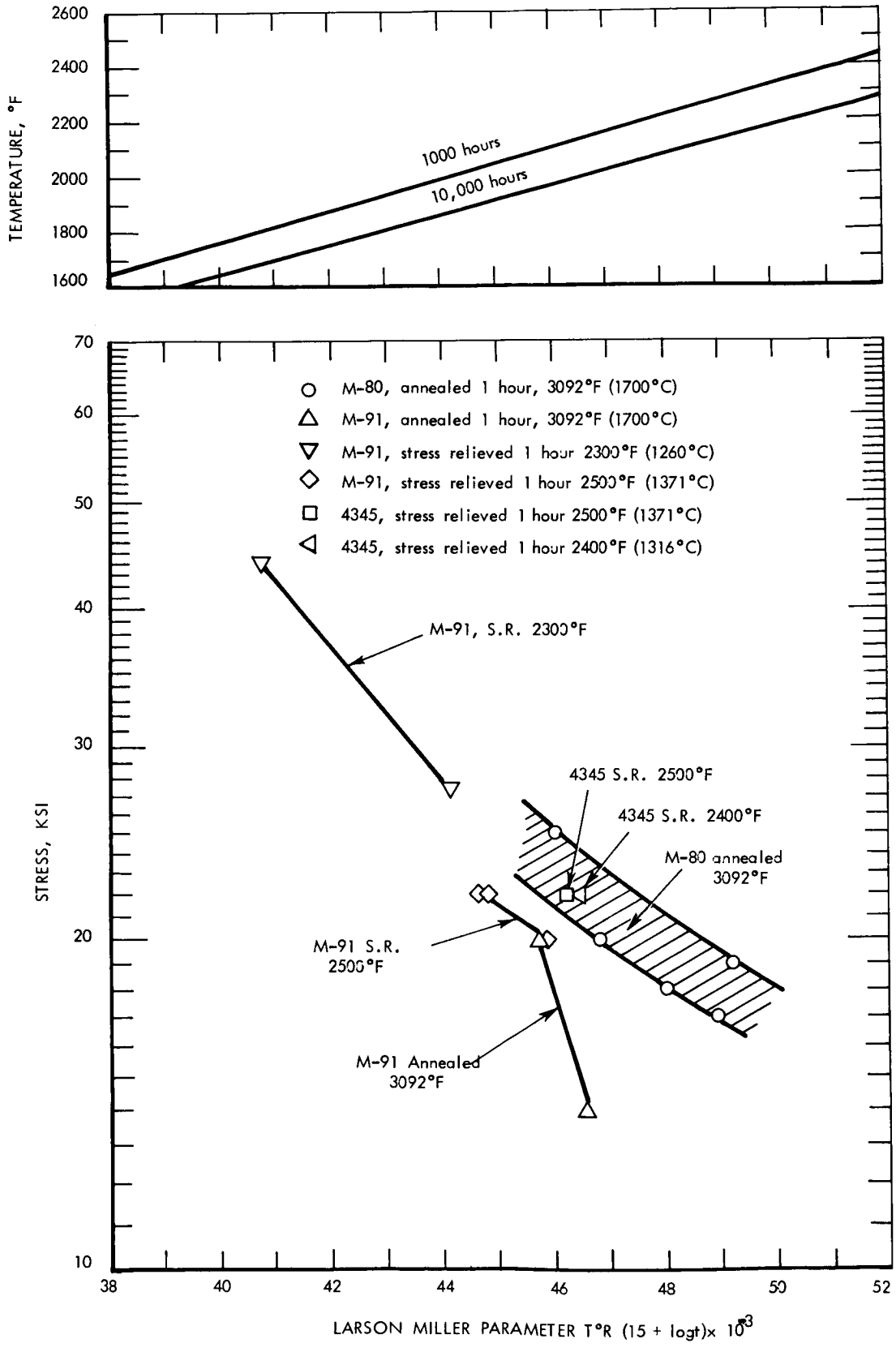
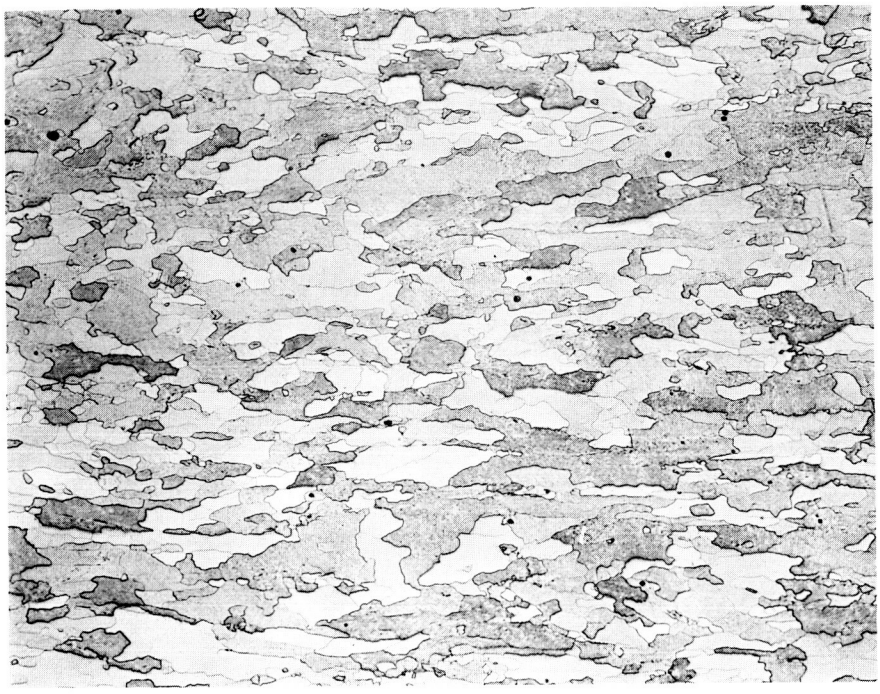
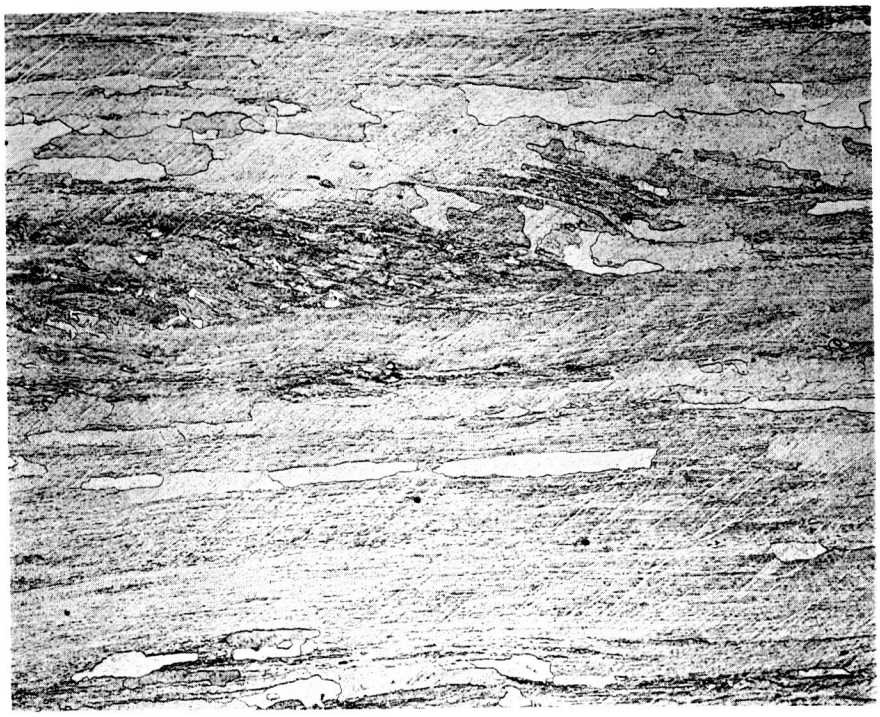


Figure 7. Parametric representation of TZC 0.5% creep test results.



Heat M-91



Heat M-80

Figure 8. Microstructures of TZC plates after annealing at 3092°F (1700°C) one hour. 100X.

The Larson-Miller plot of the TZC data also shows that at identical stress levels stress relief at 2500°F and annealing at 3092°F provide essentailly the same creep resistance in Heat M-91. However, results at several stress levels should be available in order to verify such a comparison.

Creep curves for the tests in progress or completed on TZM during the current reporting period are presented in Figure 9 while a summary of the available creep data is presented in Table 4 and Figure 10. The Larson-Miller plot shows the superiority of Heat KDTZM 1175, which has received the special processing noted earlier in the report.

Comparison of the TZC and TZM results (Figures 7 and 10) indicates that at higher stress levels and lower temperatures, stress relieved TZM is superior to TZC, while at the lower stress levels the behavior of the two materials is comparable. The room temperature strength properties of TZM Heat 1175 (Table 5) are also higher than the annealed TZC alloys and this factor is believed to contribute to the improved creep strength at the lower test temperatures.

TABLE 5

Tensile Properties of TZM Heat KDTZM 1175 Stress Relieved One Hour at 2300°F (1260°C)

Temperature	Ultimate Strength Ksi	0.2% Offset Yield Strength, Ksi	% Elongation	% Reduction of Area
Room Temperature	122	110.9	17.4	29.1
2000°F (1095°C)	78.6	74.1	19.1	50.8

Tantalum and Tantalum-Base Alloys

Commercially Pure Tantalum Tubing

Creep curves for each of the five test sequences performed upon two specimens of commercially pure tantalum tubing obtained from the Fansteel Metallurgical Corporation through NASA Lewis are presented in Figure 11. Results of these sequential tests, summarized in Table 6, show significant variability of the results which cannot be explained at the present time. The creep properties observed are below those previously reported for pure Ta (4), and probably reflect the higher purity of the present samples.

Table 4 - Summary of TZM Ultra-High Vacuum Creep Test Results

Specimen No.	Condition	Test Temperature °F	Test Temperature °C	Stress ksi	Stress N/m^2	Time to 0.5% Creep Hours	Larson-Miller Parameter for 0.5% Creep $T^{\circ}R\ (15 + \log t) \times 10^3$
						Heat No. 7502	
B-1	Stress relieve 2200°F (1204°C)	2130	1165	12.55	8.65×10^7	605	46.1
B-3	Stress relieve 2200°F (1204°C)	2000	1095	10	6.89×10^7	14,200* (10,048)	47.1
B-29	Stress relieve 2200°F (1204°C)	2000	1095	41	2.82×10^8	100	41.8
B-35	Stress relieve 2200°F (1204°C)	1800	982	44	3.03×10^8	7,000	42.6
B-4	Stress relieve 2200°F Plus 1 hour 2850°F (1566°C)	2000	1095	10	6.89×10^7	25,000* (10,012)	47.7
						Heat KDTZM-1175	
B-16	1 hour 2300°F (1260°C)	1855	1013	23.4	1.61×10^8	62,500* (4,376)	45.8
B-18	1 hour 2300°F (1260°C)	1600	871	55	3.79×10^8	60,000* (2,159)	40.7
B-21	1 hour 2300°F (1260°C)	1600	871	65	4.48×10^8	9,600* (1,630)	39.1
B-25	1 hour 2300°F (1260°C)	1800	982	44	3.03×10^8	50,000* (10,152)	44.5
B-38	1 hour 2300°F (1260°C)	2000	1093	22	1.51×10^8	8,500*	46.5
						Heat No. 7463	
B-34	1/2 hour 2250°F (1232°C)	2000	1093	41	2.82×10^8	790	44.0

* Extrapolated - Numbers in parenthesis indicate actual test time

Table 6

Summary of Sequential Creep Test Results on Pure Tantalum Tubing, Specimen Annealed 1 Hour at 1832°F (1000°C) Prior to Test Initiation, and 15 Minutes at 1832°F (1000°C) Between Each Sequence

Test No.	Temperature °F	Temperature °C	Stress Ksi	Stress $N/m^2 \times 10^{-7}$	Extrapolated 1% Creep Life Hours	Actual Testing Hours	Total Extension %	1% Creep Larson-Miller Parameter $T_{\circ R}(15+\log t)$	1% Creep Larson-Miller Parameter $T_{\circ R}(25+\log t)$
B-39A	1100	596	13.6	9.37	31	31.8	1.02	25.8	41.3
B-39B	1100	596	11.6	7.99	603	264.3	0.542	27.8	43.4
B-39C	1183	639	10.1	6.95	462.5	282.4	0.635	29.0	45.4
B-40A	1350	731	7	4.82	9	9	1.00	28.9	47.0
B-40B	1350	731	4.9	3.37	6600	1220	0.275	34.0	52.2

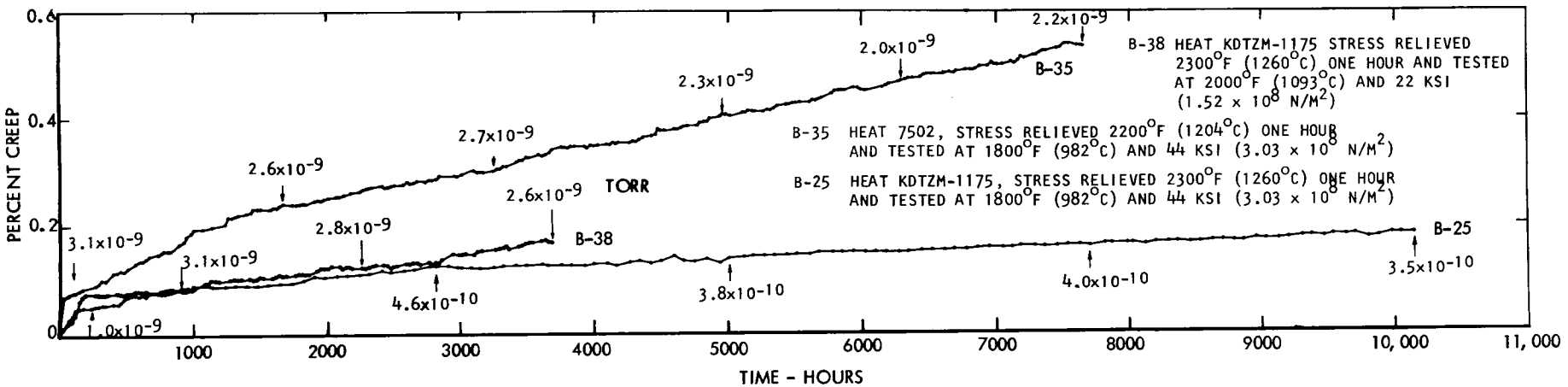


Figure 9. Creep test data, TZM, tested in a vacuum environment of $<1 \times 10^{-8}$ torr. Arrows on the curves indicate chamber pressure at various intervals during the test.

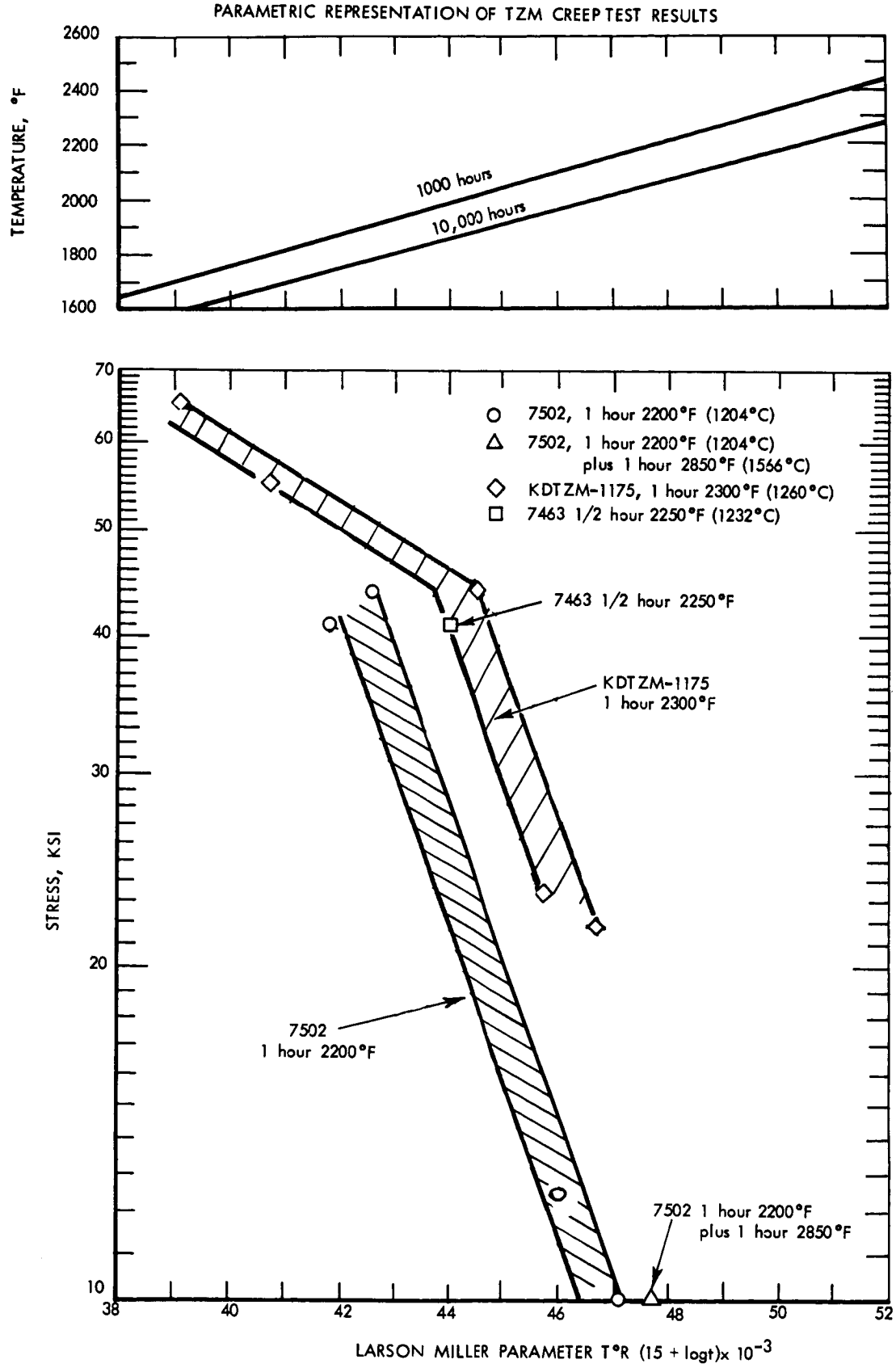


Figure 10. Parametric representation of TZM 0.5% creep test results.

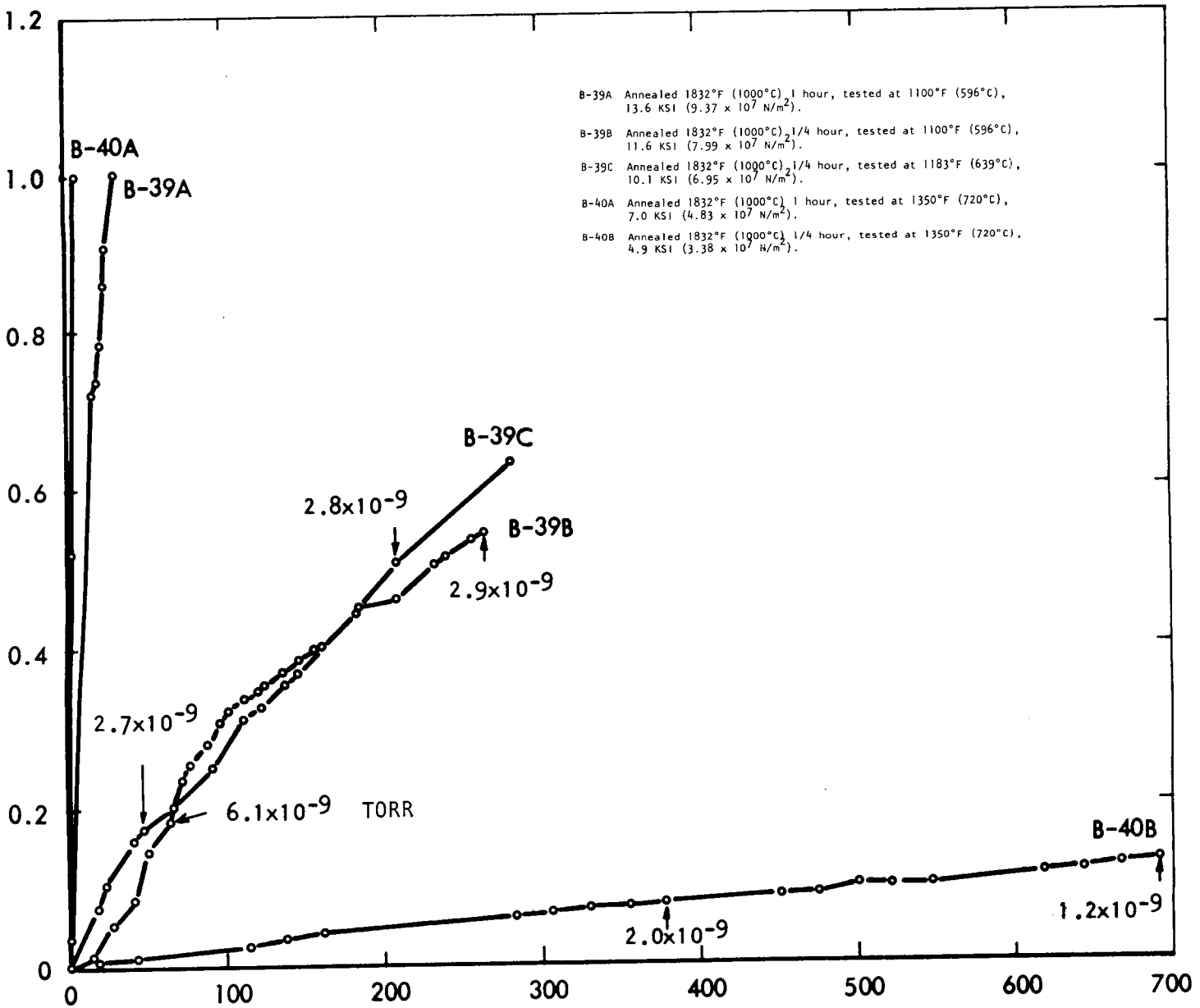


Figure 11. Creep test data, Pure Ta, tested in sequential test program in a vacuum environment of $<1 \times 10^{-8}$ torr. Arrows on the curves indicate chamber pressure at various intervals during the test.

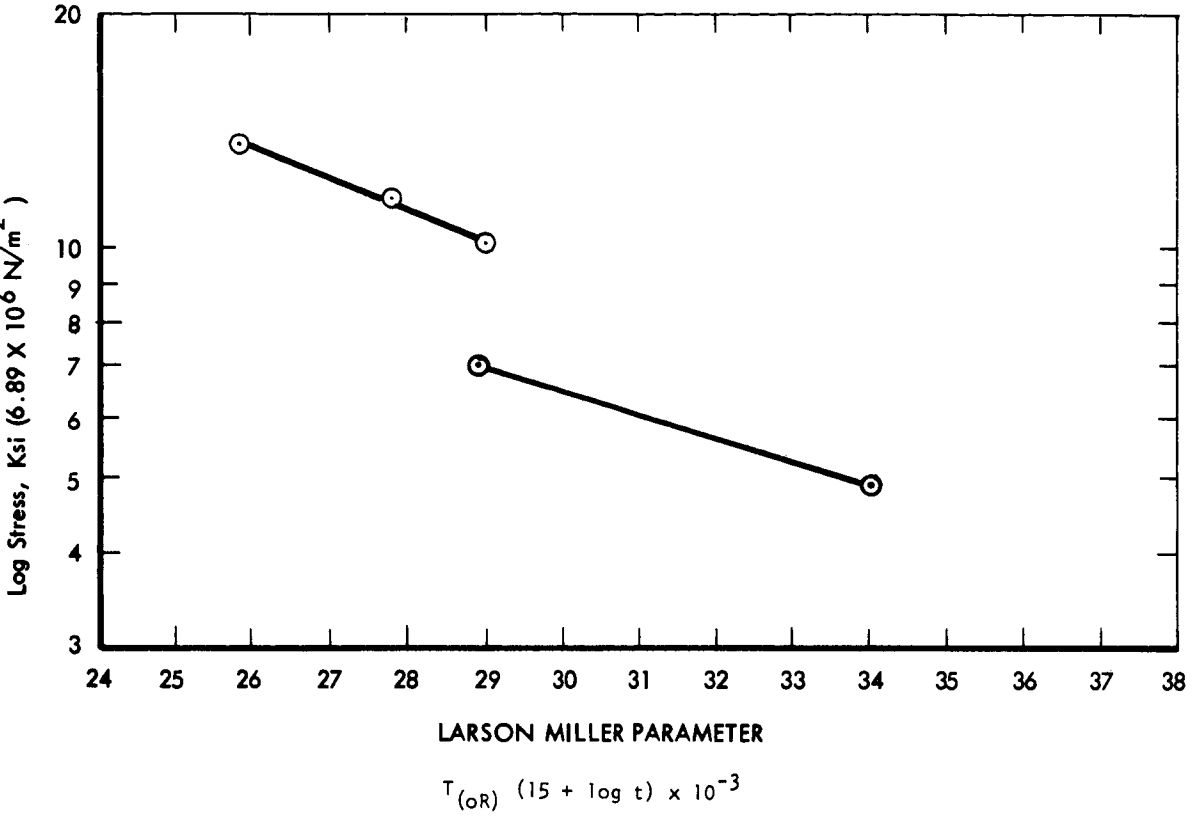


Figure 12. Parametric representation of 1% creep life data for sequential tests on tantalum tubing.

Tantalum Base T-111 Alloy

Creep curves for tests completed or in progress on tantalum base T-111 alloy during the current reporting period are presented in Figures 13 through 25. The behavior of T-111 is significantly different than pure tantalum in that the curves generally show little or no first stage creep and the rate often increases with test time. Such behavior, when observed previously in other metals and alloys (5, 6, 7, 8) has generally been attributed to some form of mechanism which provides thermal and/or strain activated recovery at a faster rate than the strain hardening from creep deformation.

Figure18 shows the significant influence of temperature and stress on the tendency for strain softening in T-111. Test S-28 at 2600°F and 0.5 Ksi provides a classical creep curve with a first stage characterized by a steadily decreasing strain rate followed by a second stage during which the strain rate stays very nearly constant over a long period of time. By comparison, Test S-26 which is being conducted at 1800°F and 17 Ksi, shows a steadily increasing strain rate for almost the entire 10,000 hours of testing. The T-111 creep curves from tests at temperatures between 1800 and 2600°F exhibit behaviors intermediate between these two extremes.

The results of two tests made under identical conditions to evaluate the relative creep resistance of T-111 parallel and perpendicular to the rolling direction are shown in Figure 21. Although the material appears slightly stronger in creep perpendicular to the rolling direction the difference is small enough so that it could represent a statistical variation of test results.

A summary of all of the T-111 creep data generated under static load on the present and previous creep contract is presented in Table 7, and a Larson-Miller plot of these data is shown in Figure 26. Five of the six heats had comparable creep properties while Heat No. 65080 had a significantly lower creep resistance. No differences appear to exist among the chemical compositions and tensile properties of the heats which might account for the wide variation in creep strength. More detailed comparison based on electron microscope and microprobe studies and discussed later in the report. The ASTAR 811C data points shown will be discussed subsequently.

T-111 Sequential Tests

Results of the sequential test program designed to establish a tentative Larson-Miller plot from successive short time tests on a single sample are presented in Table 8 and are included with the complete T-111 results in Figure 26. All of the sequential test data fell within the scatter band of long time tests. However, examination of the creep curves for sequences S-44C and S-44D (Figure 13) shows that the behavior of these two tests was somewhat irregular and it was necessary to run the test for a period of approximately 500 hours before a reliable extrapolation could be made. This result emphasizes the necessity to initiate sequential tests at the lowest temperature in the range of interest and to always progress upward in temperature.

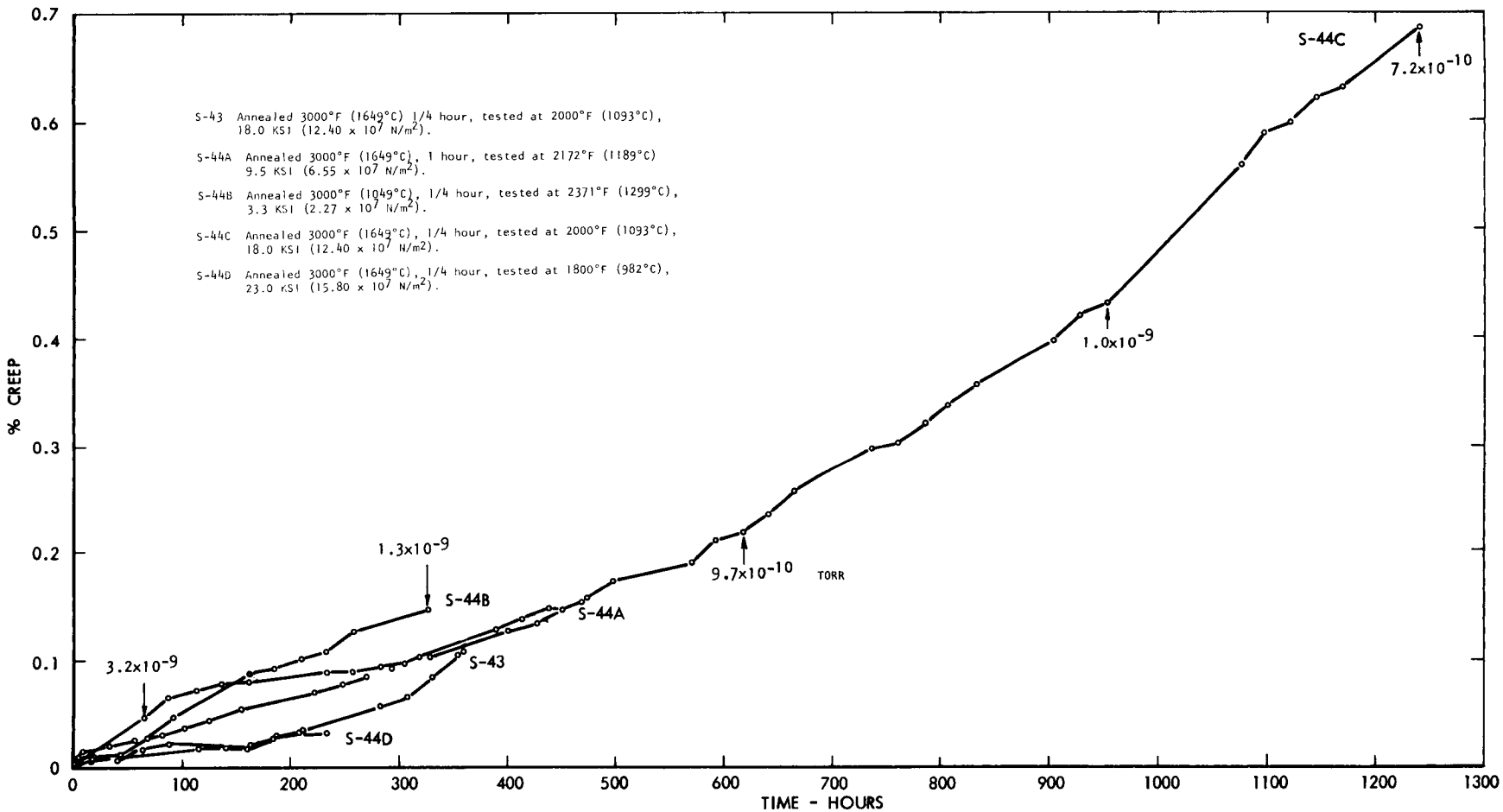


Figure 13. Creep test data, T-111 Heat No. 65079 tested in sequential test program in a vacuum environment of $<1 \times 10^{-8}$ torr. Arrows on the curves indicate chamber pressure at various intervals during the test.

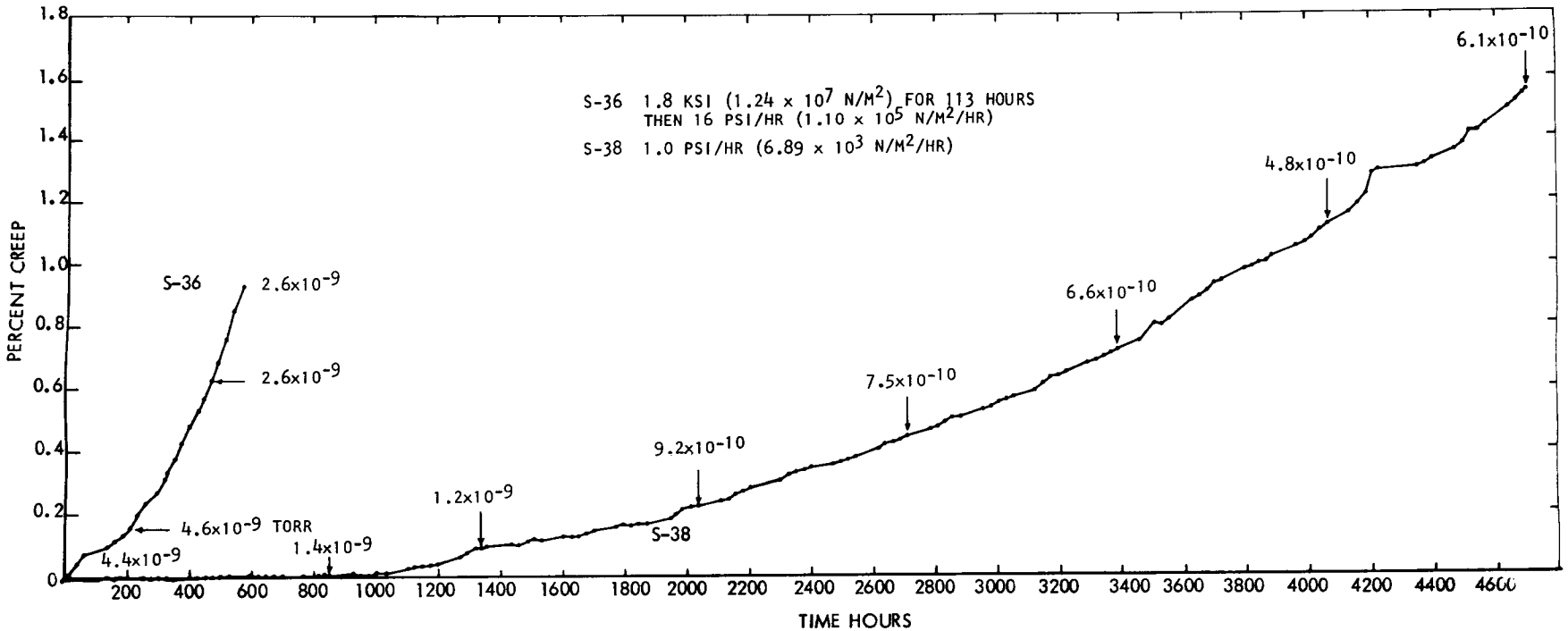


Figure 14. Creep test data, T-111 Heat No. 65080 annealed 1 hour at 3000°F (1649°C), tested in progressive stress program in a vacuum environment of $<1 \times 10^{-8}$ torr. Arrows on the curves indicate chamber pressure at various intervals during the test.

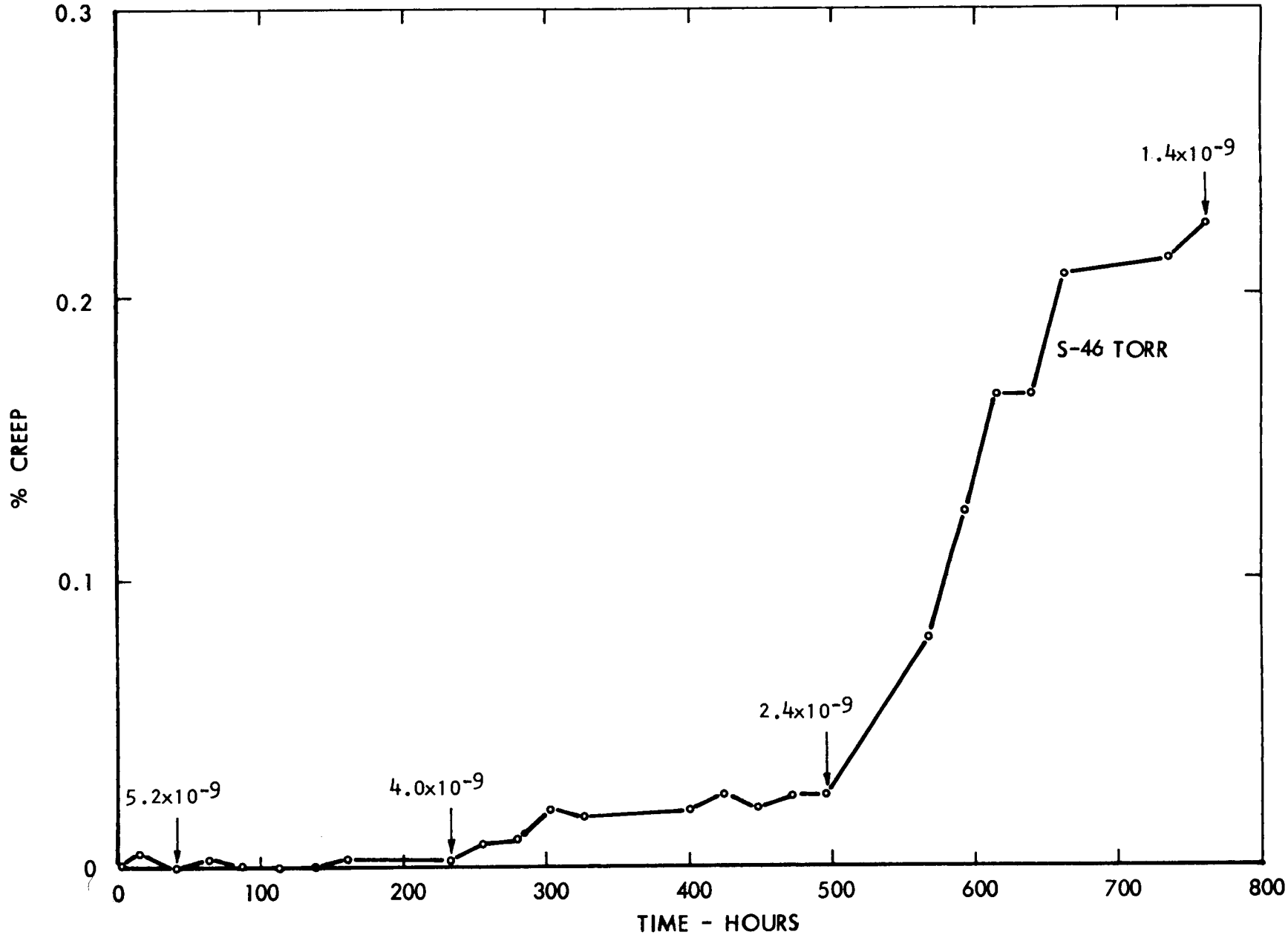


Figure 15. Creep test data, T-111 Heat No. 65079 annealed 1 hour at 3000°F (1649°C), tested at 2200°F (1204°C) and 0.016 KSI per hour, Test No. S-46 in progress stress program, tested in a vacuum environment of $<1 \times 10^{-8}$ torr. Arrows on the curves indicate chamber pressure at various intervals during the test.

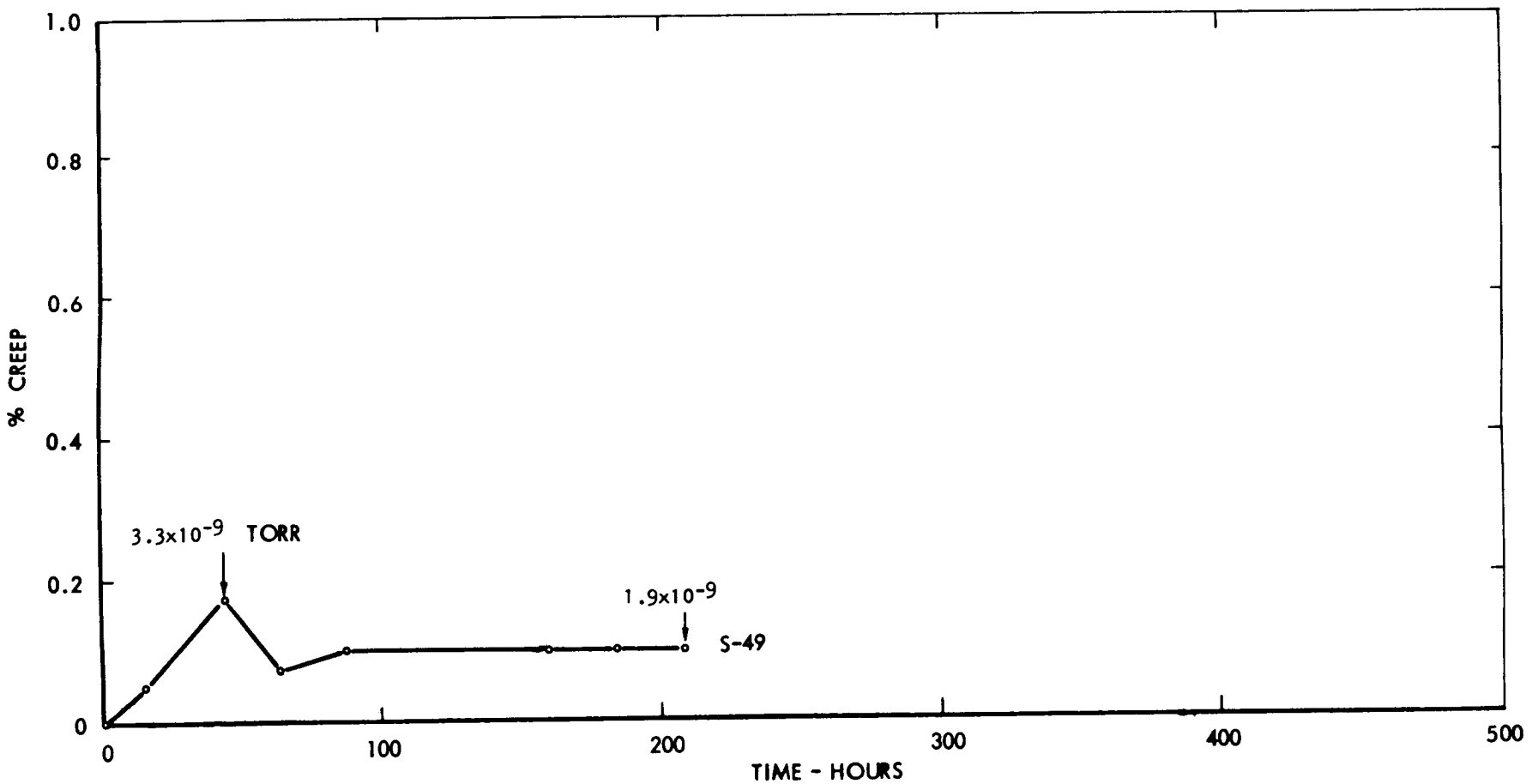


Figure 16. Creep test data, T-111 Heat No. 65079 annealed 1 hour at 3000°F (1649°C), tested at 1800°F (982°C) and 0.020 KSI per hour, Test No. S-49 in progressive stress program, tested in a vacuum environment of $<1 \times 10^{-8}$ torr. Arrows on the curves indicate chamber pressure at various intervals during the test.

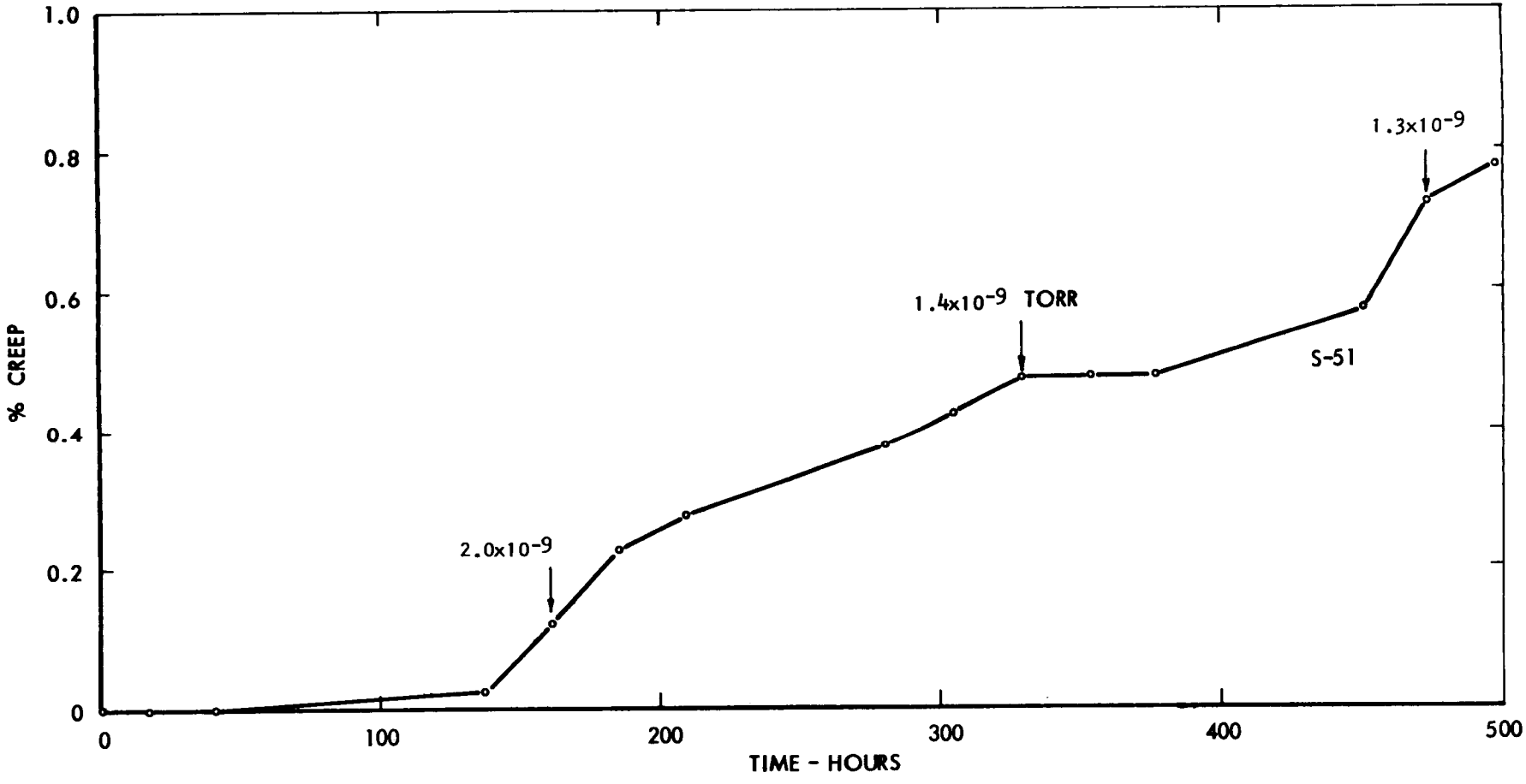


Figure 17. Creep test data, T-111 Heat No. D-1183 annealed 1 hour at 3000°F (1649°C), tested at 2200°F (1204°C) and 0.016 KSI per hour, Test No. S-51 in progressive stress program, tested in a vacuum environment of $<1 \times 10^{-8}$ torr. Arrows on the curves indicate chamber pressure at various intervals during the test.

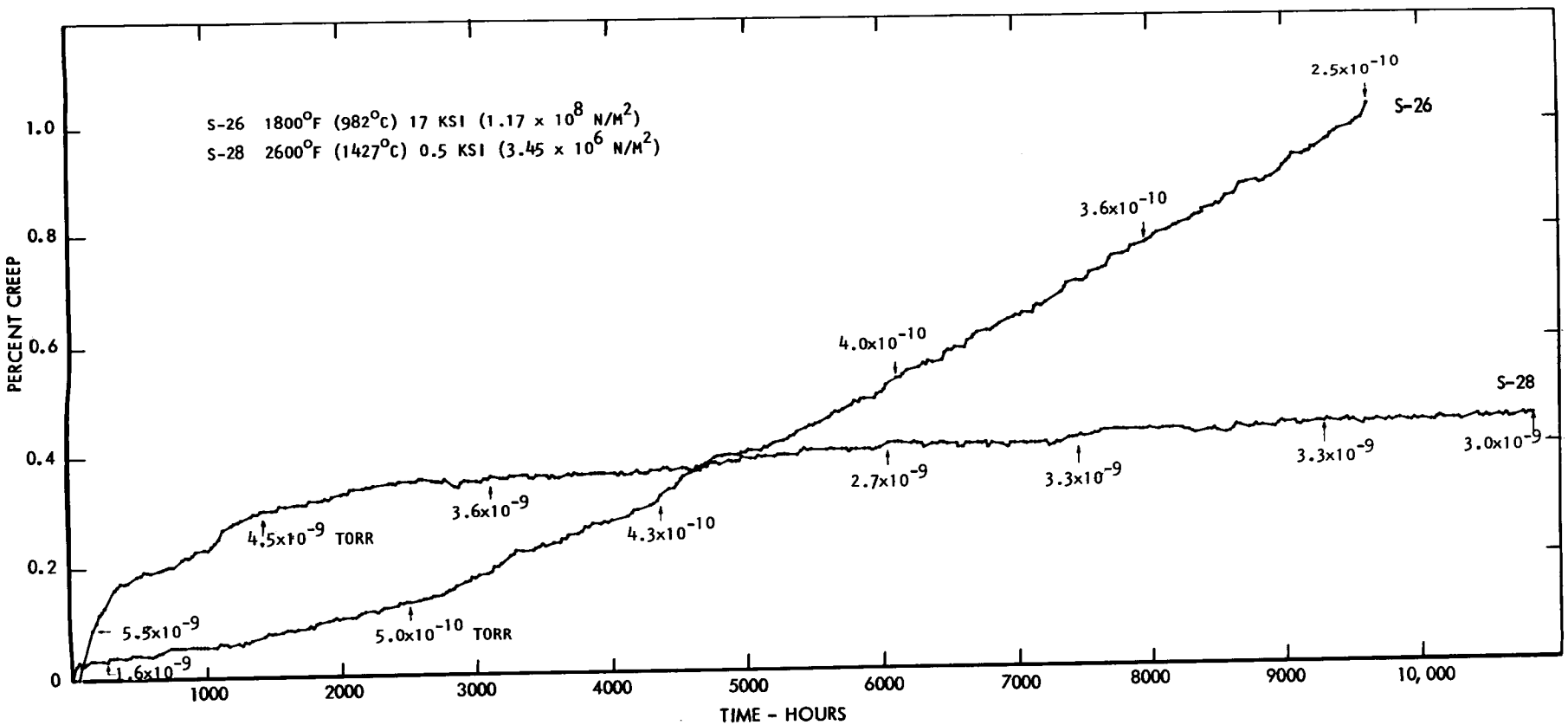


Figure 18. Creep test data, T-111 Heat No. D-1670 annealed 1 hour at 3000°F (1649°C) tested in a vacuum environment of <1 x 10-8 torr. Arrows on the curves indicate chamber pressure at various intervals during the test.

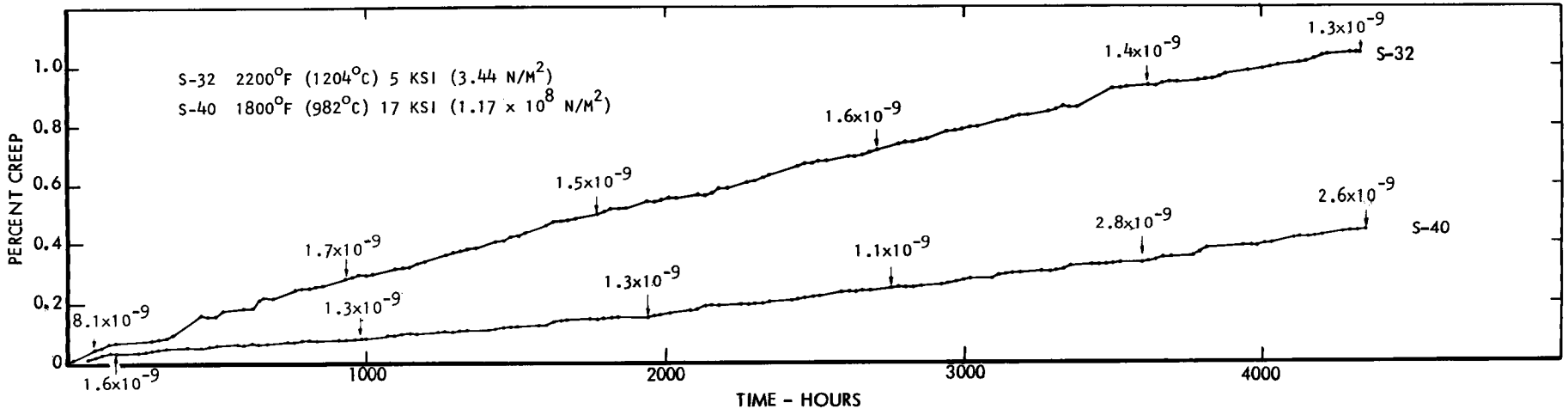


Figure 19. Creep test data, T-111 Heat No. D-1102 annealed 1 hour at 3000°F (1649°C) tested in a vacuum environment of <1 x 10^{-8} torr. Arrows on the curves indicate chamber pressure at various intervals during the test.

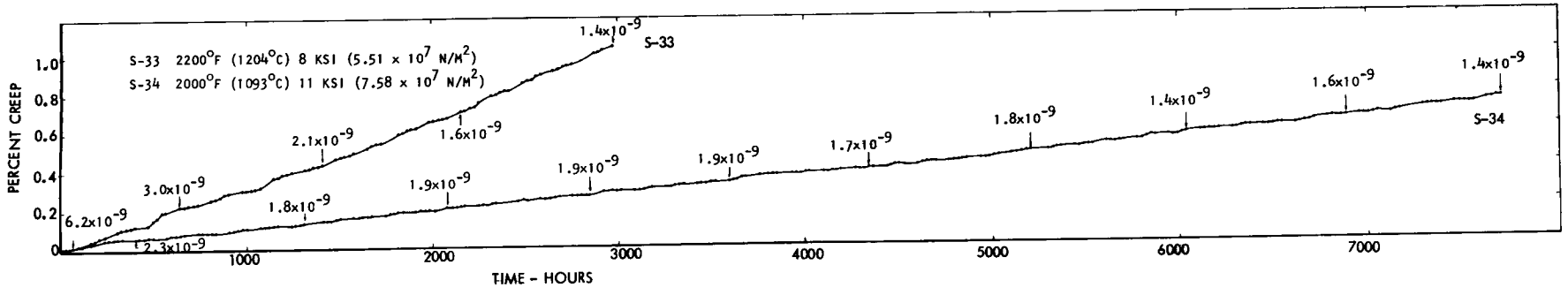


Figure 20. Creep test data, T-111 Heat No. MCN02A065 annealed 1 hour at 3000°F (1649°C), tested in a vacuum environment of $<1 \times 10^{-8}$ torr. Arrows on the curves indicate chamber pressure at various intervals during the test.

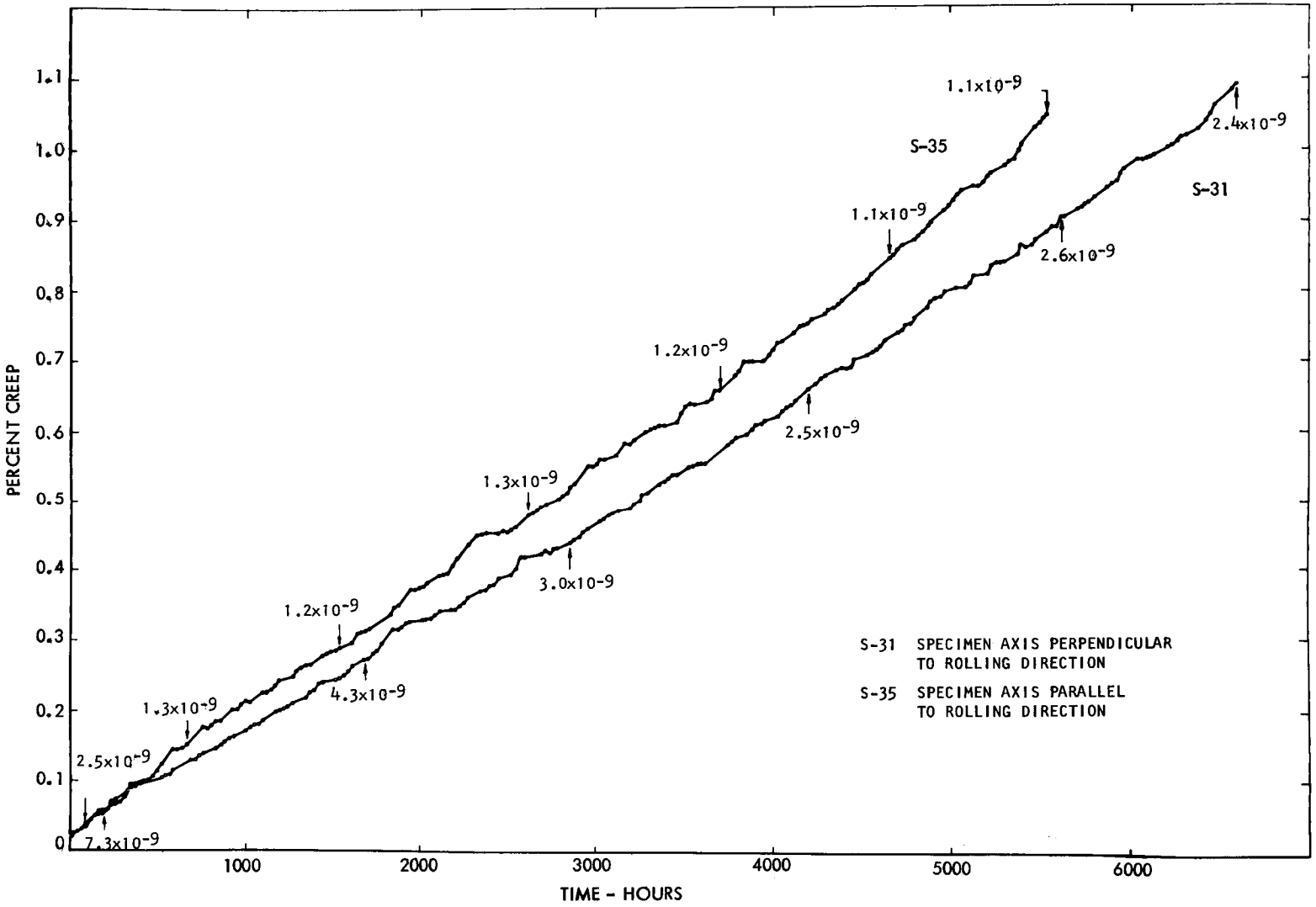


Figure 21. Creep test data, T-111 Heat No. 65079 annealed 1 hour at 3000°F (1649°C), tested at 200°F (1204°C) and 50 KSI (3.44 x 10^7 N/m^2) in a vacuum environment of <1 x 10^{-8} torr. Arrows on the curves indicate chamber pressure at various intervals during the test.

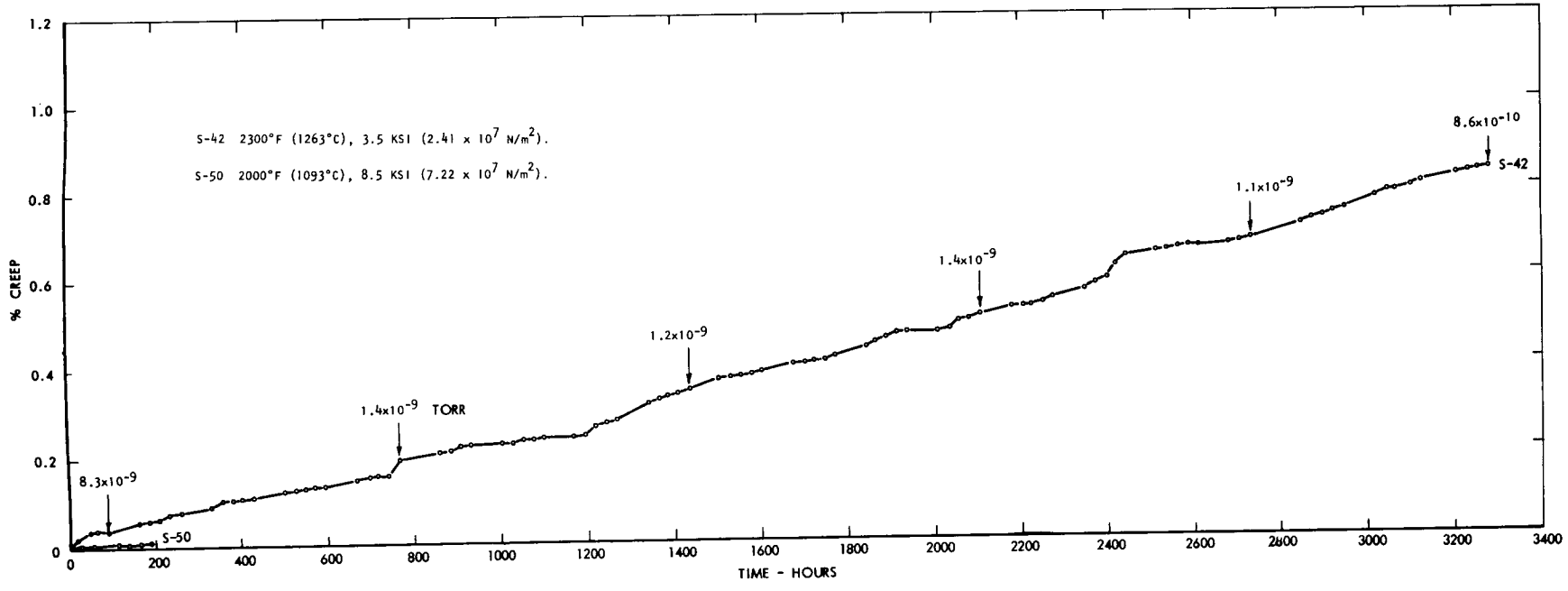


Figure 22. Creep test data, T-111 Heat No. 65079 annealed 1 hour at 3000°F (1649°C), tested at 2300PF (1263°C) and 3.5 KSI (2.4×10^7 N/m^2), Test No. S-42, tested in a vacuum environment of $<1 \times 10^{-8}$ torr. Arrows on the curves indicate chamber pressure at various intervals during the test.

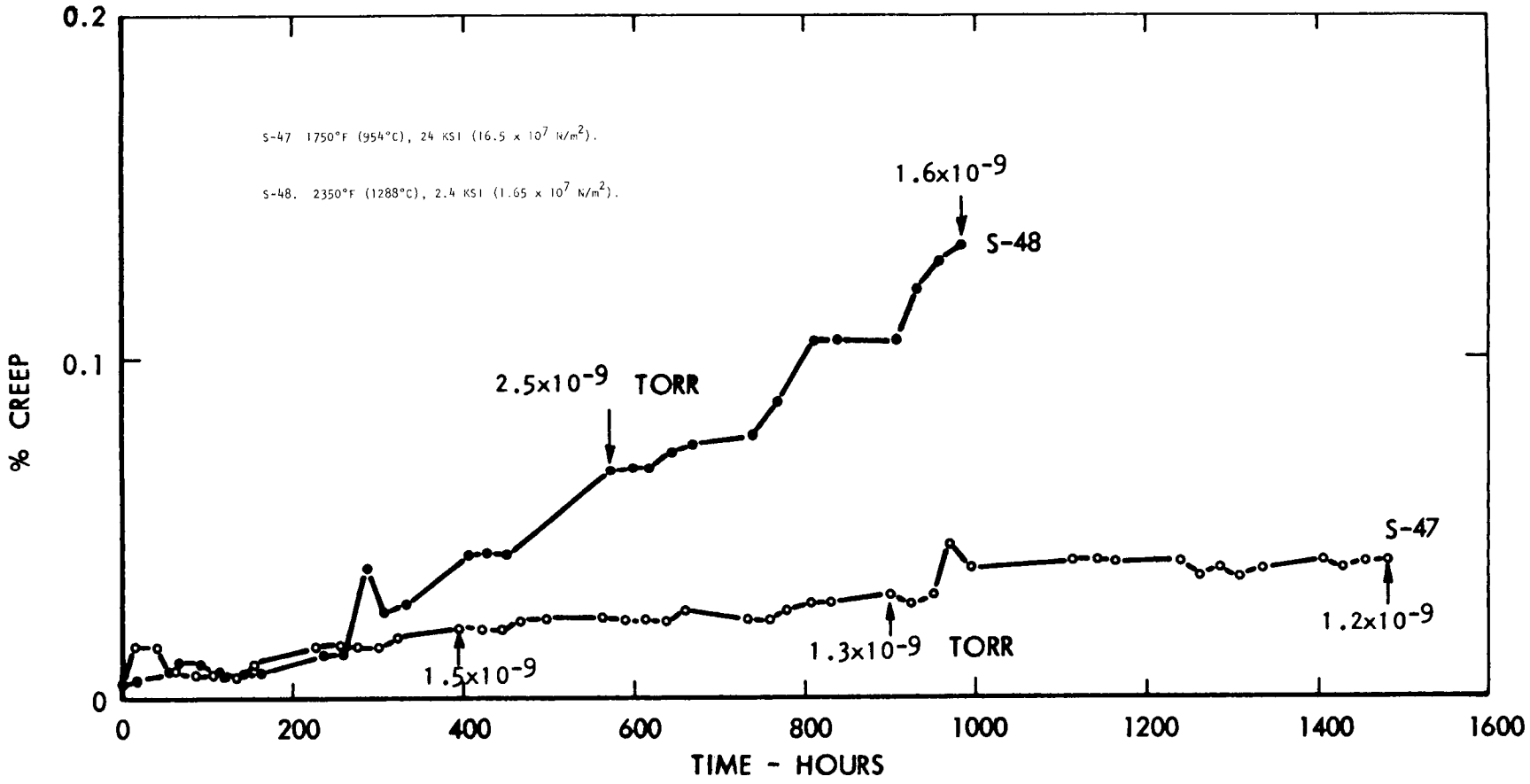


Figure 23. Creep test data, T-111 Heat No. 65079 annealed 1 hour at 3000°F (1649°C), tested in a vacuum environment of $<1 \times 10^{-8}$ torr. Arrows on the curves indicate chamber pressure at various intervals during the test.

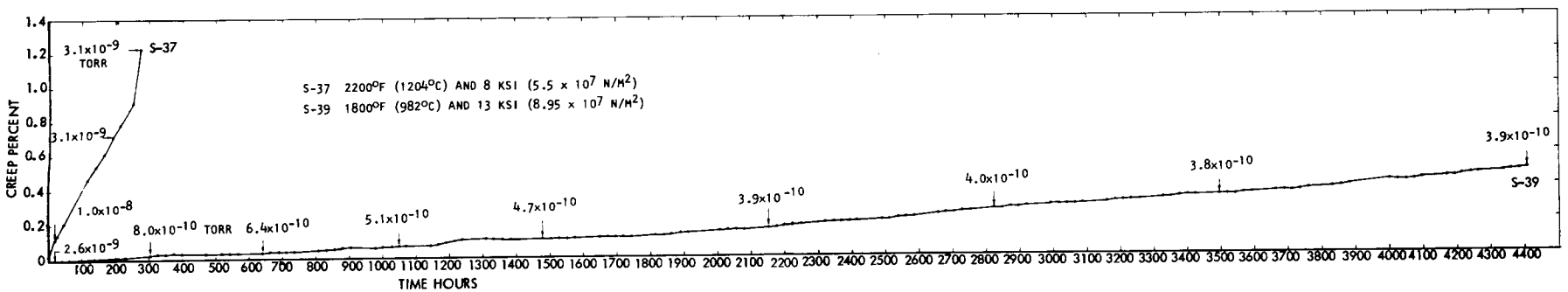


Figure 24. Creep test data, T-111 Heat No. 65080 annealed 1 hour at 3000°F (1649°C) tested in a vacuum environment of $<1 \times 10^{-8}$ torr. Arrows on the curves indicate chamber pressure at various intervals during the test.

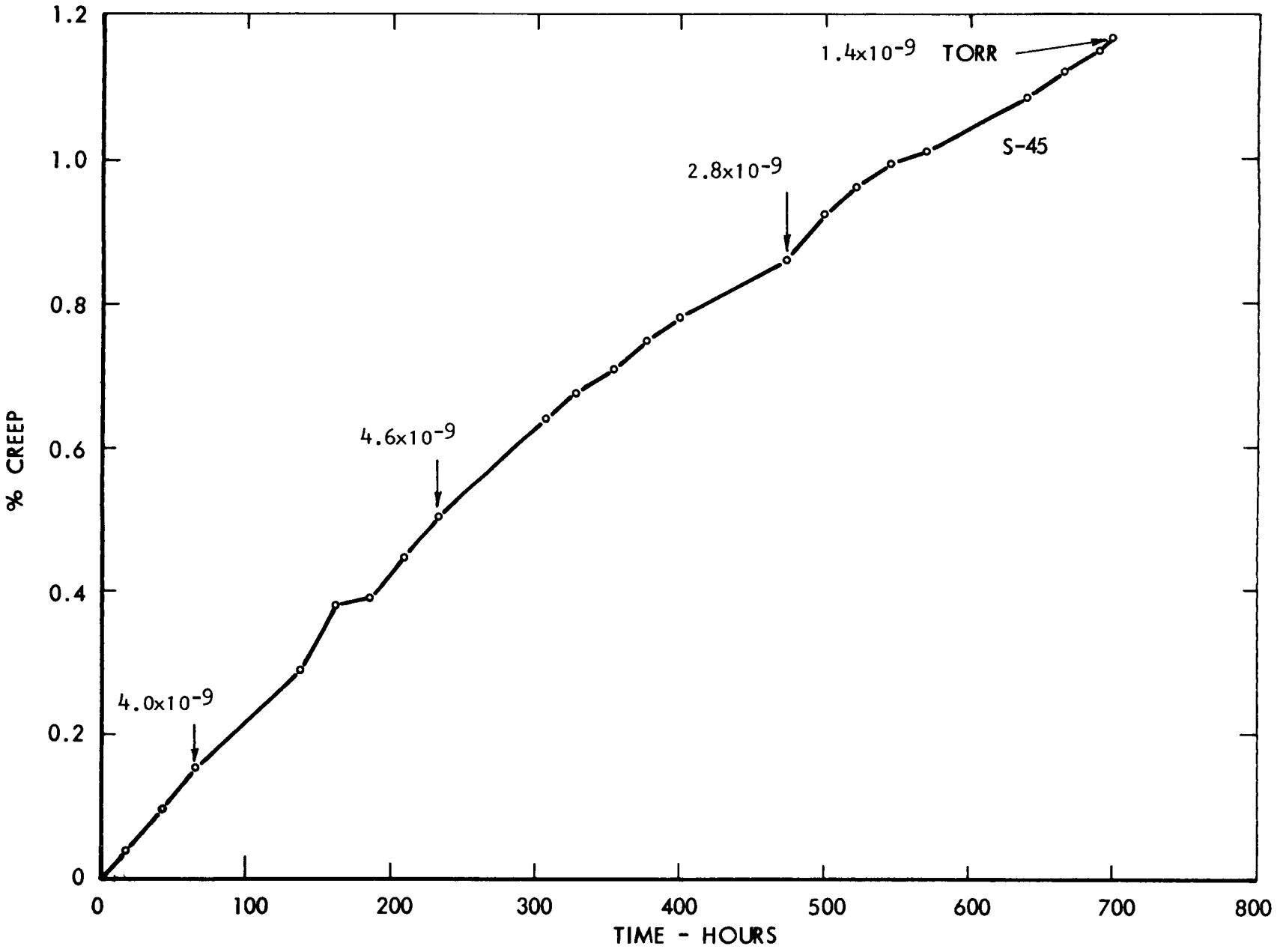


Figure 25. Creep test data, T-111 Heat No. 65080A annealed 1 hour at 3000°F (1649°C), tested at 2200°F (1204°C) and 3 KSI (2.07×10^7 N/m^2), Test No. S-45, tested in a vacuum environment of $<1 \times 10^{-8}$ torr. Arrows on the curves indicate chamber pressure at various intervals during the test.

Table 7

1% Creep Test Data and Larson-Miller Parameter for T-111 Tantalum-Base Alloy Recrystallized 1 Hour 3000°F (1649°C)

Specimen No.	Temperature °F	Temperature °C	Stress ksi	Stress $N/m^2 \times 10^8$	Hours for 1.0% Creep	Larson-Miller Parameter $T°R\ (15 + \log t\ 1\%) \times 10^{-3}$
Heat 70616						
S-19	2200	1204	8	0.551	2,000	48.7
S-21	2200	1204	12	0.826	1,140	48.0
S-23	2120	1160	12	0.826	3,150	47.7
S-22	2000	1093	20	1.380	670	43.8
S-24	1860	1016	20	1.380	4,730	43.3
Heat D-1670						
S-25	2000	1093	15	1.030	1,340	44.6
S-26	1800	982	17	1.170	9,540	42.9
S-25A	2600	1427	1.5	0.103	1,100* (482)	55.2
S-28	2600	1427	0.5	0.0344	55,100* (10,985)	60.0
Heat 1102						
S-27	2000	1093	13	0.895	1,880	45.0
S-32	2200	1204	5	0.344	4,050	49.5
S-40	1800	982	17	1.170	9,015* (4511)	42.8
Heat 65079						
S-30**	2400	1316	3.5	0.241	860	51.3
S-31**	2200	1204	5	0.344	6,160	50.0
S-35	2200	1204	5	0.344	5,400	49.9
S-42	2300	1263	3.5	0.241	3,900* (3448)	51.3
Heat 65079A						
S-47	1750	954	24	1.650	38,000* (1645)	43.3
S-48	2350	1288	2.4	.165	7,270* (1148)	53.0
S-50	2000	1093	8.5	.722	Insufficient to Extrapolate	
Heat MCN02A065						
S-33	2200	1204	8	0.551	2,850	49.1
S-34	2000	1093	11	0.758	10,750* (7867)	46.9
Heat 65080						
S-37	2200	1204	8	0.551	260	46.3
S-39	1800	982	13	0.895	8,345* (4578)	42.7
Heat 65080A						
S-45	2200	1204	3	0.207	554	47.1

* Extrapolated Data - numbers in parenthesis indicate actual test time.

g Direction.

** Specimen Axis perpendicular to rolling direction.

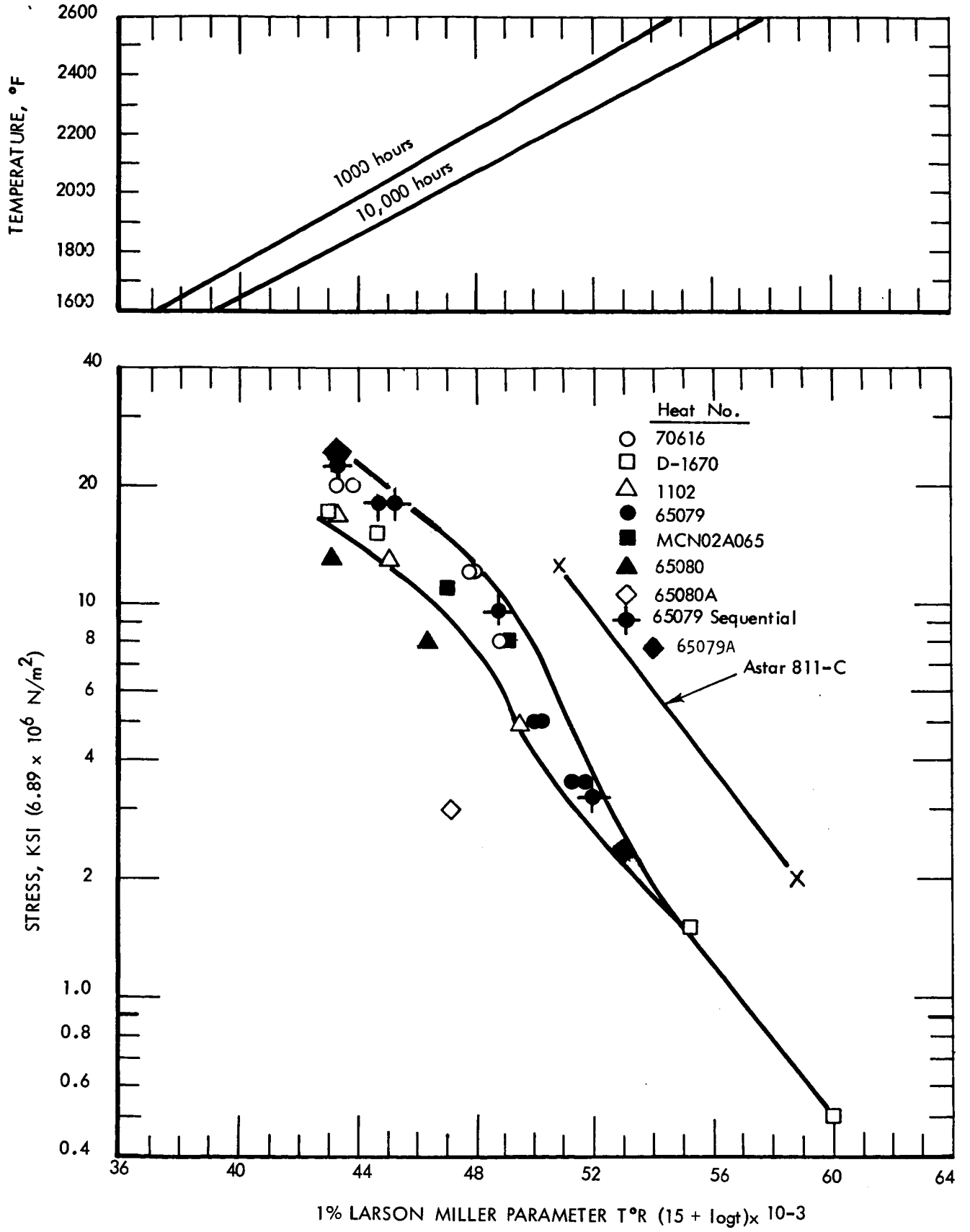


Figure 26. Larson-Miller plot of 1% creep test results on T-111 recrystallized 1 hour at 3000°F (1649°C), plus two data points for ASTAR 811C. High stress ASTAR 811C test recrystallized 1 hour at 3000°F (1649°C), low stress test recrystallized 1/2 hour at 3600°F (2038°C).

Table 8 - Summary of Sequential Creep Test Data on T-111 Alloy Annealed 1 Hour at 3000°F (1649°C) Prior to Test, and 15 Minutes at 3000°F (1649°C) Between Each Sequence

Test No.	Temperature °F	Temperature °C	Stress Ksi	Stress N/m^2	Extrapolated 1% Creep Life Hours	Actual Testing Hours	Total Extension %	1% Creep Larson-Miller Parameter $T_{°R}(15+\log t)\times10^{-3}$
S-43	2000	1093	18	1.24×10^{8}	1500	361	0.108	44.7
S-44A	2172	1189	9.5	6.55×10^{7}	3250	467	0.152	48.7
S-44B	2371	1299	3.3	2.27×10^{7}	2030	335	0.168	51.9
S-44C	2000	1093	18	1.24×10^{8}	1670	1146	0.095	44.8
S-44D	1800	980	23	8.54×10^{7}	14,650	904	0.090	43.3

Continuous Loading Tests

Creep curves from the continuous loading tests (Figures 14 through 17) show strain rates which progressively increase with time. The creep life data from these tests (see Table 9) have been analyzed using a method similar to that employed by McCoy (9) and Nichols and Winkler (10). The technique is similar to Minor's law of accumulating fatigue damage, which assumes that the percentage of a specimen's useful life "used up" under any given set of test conditions is directly proportional to the period of time which the specimen spends there divided by the life which could be achieved in a static test at those conditions. When the sum of these "life fractions" reaches unity the usefulness of the material is considered exhausted. Stated mathematically this concept takes the form:

$$\sum_{t=0}^{L} \frac{\Delta t_i}{\lambda_i} = 1 \qquad (1)$$

where t is time, λ_i is the specimen life at the i^{th} set of conditions, t_i is the period of time spent under these conditions, and L is the "dynamic" test life of the specimen. The underlying assumption which permits such a statement is that the life λ_i at the i^{th} set of conditions is not influenced by previous testing of the same specimen under other conditions. As applied to creep testing the meaning of this assumption is that the creep life at any temperature and stress is not influenced by previous creep strain imposed at other temperatures and stresses.

To further modify this analysis to creep testing it is necessary to have some form of equation which analytically relates creep life (λ) to temperature and stress. The Larson-Miller correlation presented earlier for T-111 alloy provides an empirical relationship between these variables from which such a function can be generated. To a first approximation the Larson-Miller parameters plotted in Figure 26 show a linear relationship to log stress; i.e.,

$$\log \sigma = A' \{T(C' + \log t)\} + B' \qquad (2)$$

where A' is the slope of the straight line, B' is the intercept on the stress axis, T is absolute temperature (°R), C' is the Larson-Miller constant, and t is the 1% creep life. Taking t to be equivalent to λ in Equation (1), converting to natural logs, and rearranging Equation (2) to solve for life,

$$\ln \lambda = \frac{\ln\sigma - B}{AT} - C$$

Table 9

Summary of Continuous Loading Tests on T-111
Annealed 1 Hour at 3000°F

Test No.	Heat No.	Temperature (°F)	Loading Rate psi/hour	1% Creep Life
S-36	65080	2200	16	600
S-38	65080	2200	1	3830
S-46	65079	2200	16	1000*
S-49	65079	1800	20	-
S-51	D-1183	2200	16	-

* EXTRAPOLATED

or $$\lambda = \sigma^{1/AT}\, e^{-(B/AT+C)} \tag{3}$$

In the case at hand, stress increases linearly with time; i.e.,

$$\sigma = \dot{\sigma} t \tag{4}$$

and $$\lambda = (\dot{\sigma} t)^{1/AT}\, e^{-(B/AT+C)} \tag{5}$$

Incorporating this relationship into Equation 1,

$$\sum_{t=0}^{L} \frac{\Delta t}{(\dot{\sigma} t)^{1/AT}\, e^{-(B/AT+C)}} = 1 \tag{6}$$

Since stress is a continuous function of time the limit of Equation 6 as Δt approaches zero is equal to:

$$\int_0^L \frac{dt}{(\dot{\sigma} t)^{1/AT}\, e^{-(B/AT+C)}} = 1 \tag{7}$$

Rearranging this expression to take all constants outside the integral,

$$\frac{e^{(B/AT+C)}}{\dot{\sigma}^{1/AT}} \int_0^L (t)^{-\frac{1}{AT}}\, dt = 1 \tag{8}$$

assuming that $1/AT \neq 1$, analytical integration of this expression is straight forward, and results in the relationship:

$$\frac{e^{(B/AT+C)}}{\dot{\sigma}^{1/AT}} \left. \frac{t^{(1-\frac{1}{AT})}}{1-\frac{1}{AT}} \right|_0^L = 1 \tag{9}$$

or $$\left(\frac{AT}{AT-1}\right) e^{(B/AT+C)}\, L^{\frac{(AT-1)}{AT}} = \dot{\sigma}^{\frac{1}{AT}} \tag{10}$$

Taking the log of this equation,

$$\ln\left(\frac{AT}{AT-1}\right) + B/AT+C + \left(\frac{AT-1}{AT}\right)\ln L = \frac{\ln\dot{\sigma}}{AT} \qquad (11)$$

which can be solved for either L or $\dot{\sigma}$, as indicated below:

$$\ln\dot{\sigma} = (AT-1)\ln L + AT\ \ln\left\{\frac{AT}{AT-1}\right\} + B+AT(C) \qquad (12)$$

or

$$\ln L = \left\{\frac{\ln\dot{\sigma}}{AT} - \ln\frac{AT}{AT-1} - B/AT-C\right\}\frac{AT}{AT-1} \qquad (13)$$

By manually fitting a straight line to the data in Figure 26 and adjusting for the use of natural logs in the theoretical development, the values A, B, and C can be determined as:

$$A = -1.04 \times 10^{-4}$$

$$B = 13.67$$

$$C = 34.54$$

The validity of this technique for predicting creep life under continuously increasing load from static creep data can be evaluated by using data obtained on T-111, Heat 65080. In this case the value for the slope A was determined from the general Larson-Miller curve for T-111 in Figure 26 while the constant B was obtained by fitting the Larson-Miller curve through the data for Heat 65080. On this basis $A = 1.04 \times 10^{-4}$ and B = 12.91. Predictions made using these constants, presented below, show reasonably good agreement with the experimentally determined results:

Comparison of Predicted and Observed Creep for T-111 Under Continuous Load Conditions

Test No.	1% Creep Life, Hours	
	Experimental	Predicted
S-36	600	485
S-38	3830	4261

Several interesting implications arise from an analysis of the relationship defined by Equation (11). The most important of these involves the existence of a critical stress rate $\dot{\sigma}_{max}$ above which specimen life is limited by the rate of approach to the yield stress rather than by the rate of creep deformation. The yield stress for T-111 in the temperature range of interest (1800 to 2400°F)

(982 to 1316°C) is approximately 32 Ksi. Assuming that specimen extension will become dominated by short term plastic deformation rather than by creep as σ approaches 3/4 of the yield stress (as evidenced by the tendency for the Larson-Miller plot to deviate from linearity at roughly this stress), $\dot{\sigma}_{max}$ can be established through Equation (4) in combination with Equation (12):

$$\ln\dot{\sigma}_{max} = (AT-1)\ \ln\left(\frac{24}{\dot{\sigma}_{max}}\right) + AT\ \ln\frac{AT}{AT-1} + B + AT\ (C)$$

or rearranging to solve for $\dot{\sigma}_{max}$,

$$\ln\dot{\sigma}_{max} = \frac{AT-1}{AT}\ \ln 24 + \ln\frac{AT}{AT-1} + B/AT + C \qquad (14)$$

Solution of Equation (14) at several temperatures in the range of interest provides the following results:

Temperature °F	Temperature °C	Maximum Stress Rate Ksi/Hour	Predicted Time to 1% Strain, Hours
1800	982	0.0002	120,000
2000	1093	0.008	3,000
2200	1204	0.166	144
2400	1316	2.78	8

The times listed above are the minimum test times at each temperature for specimens to be strained to 1% in pure creep. Shorter tests could be run at higher strain rates but the strain incurred would be predominantly short term plastic deformation and would be concentrated during the latter stages of the test when applied stress approaches the yield point. In this case the 1% creep life would be limited essentially by the time required to approach the yield stress at the applied stress rate.

Specimen S-49 which is currently in progress at 1800°F (982°C) and 0.020 Ksi/hour stress rate provides a critical evaluation of possibility of a $\dot{\sigma}_{max}$ value. Direct application of Equation (13) leads to a predicted 1% creep life of 2900 hours; however the stress at this time would be 58 Ksi, which is well over the yield stress and is approaching the ultimate strength at this temperature. At the applied stress rate the stress will reach 24 Ksi in 1200 hours and the yield in 1700 hours. This specimen should reach 1% strain at some time intermediate between these two limits and will presumably sustain the bulk of the deformation in the last few hundred hours of test. The results of this test will allow a appraisal of the above predictions.

Post Test Analysis

The effect of creep exposure on the structure, properties, and composition of T-111 is shown in Table 10 and Figures 27 through 31. Little change was apparent in the microstructure as a result of the 1% creep extension. Only minor variations occurred in composition except for oxygen, which showed a significant and consistent decrease as a result of creep testing. Mechanical test data show a consistent decrease in strength and hardness and in most cases an increase in elongation, all of which are consistent with the previously discussed strain and/or thermally activated softening which results from the imposed creep deformation. The post-creep tension tests from specimens S-31 and S-46 were conducted with tensile specimens having a reduced width/thickness ratio which may account for the decrease in ductility. On this basis of previous work which indicates that the hardness of tantalum is strongly dependent upon oxygen concentration (11), the change of material properties during the creep tests may be associated with the change of oxygen concentration.

Analysis of Heat No. 65080

Chemical analyses, tensile tests, microstructural and microprobe examinations were used to detect possible differences between T-111 Heat 65080 and more representative samples of the T-111 alloys. No significant variations were observed in chemical composition (see Table 11) and tensile properties (2).

A variation in the grain growth characteristics of 65080 which may bear upon the poor creep behavior has been observed. When heat treated for one hour at temperatures up to 3000°F (1640°C), the microstructure of 65080 and other heats of T-111 appear essentailly identical. Above this temperature, however, 65080 has much less tendency for grain growth than Heat No. 70616, for example (see Figure 32). Examination of the microstructure of 65080 at higher magnification in the optical microscope suggested the presence of a precipitate which may be acting to pin the grain boundaries. Electron micrographs were obtained from a two-stage carbon replica of the specimen heat treated one hour at 3500°F (1929°C). The results shown in Figure 33 reveal three distinct features. A light colored, blocky, triangular shaped feature was observed within the center grain in the 5000x print, together with a coarse grain boundary precipitate. The blocky appearance of and the triangular shaped structure and the lack of a clearly defined boundary seen in the 11,500x print suggest that they may be either relatively flat coherent precipitate or etch pits. The third precipitate, shown as small clusters among the triangular structures in Figure 33, has an appearance similar to that previously identified in other tantalum alloys as a tantalum base di-metal carbide.

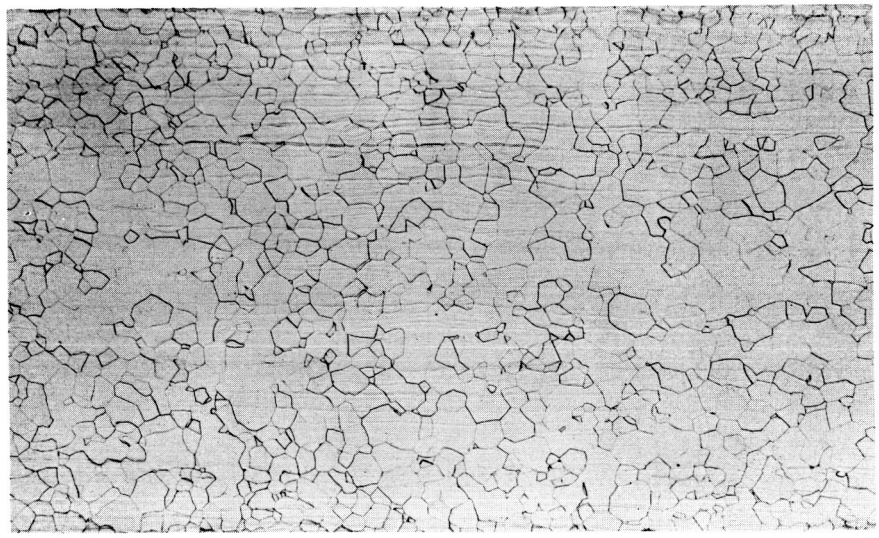
Table 10 Effect of creep exposure on room temperatures mechanical properties and composition of T-111 annealed one hour at 3000°F (1649°C prior to creep testing.

CREEP TEST CONDITION									COMPOSITION				
									Percent		PPM		
Test No.	Heat No.	Stress KSI / $N/m^2 \times 10^{-8}$	Temperature °F / °C	Test Duration Hours	Before / After Creep Testing	Ultimate Tensile Strength KSI	Percent Elongation	Diamond Pyramid Hardness	Hf	C	N_2	O_2	H_2
S-26	D-1670	17 / 1.17	1800 / 982	1624	Before				2.17	.001	20	72	5
					After	***	***	***	2.09	.0032	30	10	5
S-31*	65079	5 / 0.344	2200 / 1204	6602	Before	94.0	35.0						
					After	85.3	8.2+	***	***	***	***	***	***
S-33	MCN-02A 065	8 / 0.551	2200 / 1204	2976	Before	93.1	31.0	247	1.95	.004	20	100	3
					After	85.7	39.0	228	2.07	.004	30	20	31
S-32	D-1102	5 / 0.344	2200 / 1204	4322	Before				2.28	.003	34	20	3
					After	***	***	***	2.17	.003	30	10	24
S-35	65079	5 / 0.344	2200 / 1204	5522	Before	---	---	275	2.30	.003	50	130	4
					After	---	---	257	2.14	.0046	30	10	5
S-36**	65080	.016 KSI/hr.	2200 / 1204	624	Before	95.9	31.8	255	2.03	.0031	40	105	4
					After	91.2	39.0	229	2.19	.002	30	10	30
S-37	65080	8 / 0.551	2200 / 1204	274	Before	95.9	31.8	255	2.03	.0031	40	105	4
					After	90.5	40.0	226	2.30	.003	40	10	22
S-43	65079	18 / 1.24	2000 / 1093	361	Before	---	---	---	2.30	.003	50	130	4
					After	---	---	---	1.33	.003	40	10	31
S-45	65080A	3 / 0.207	2200 / 1204	697	Before	---	---	---	1.95	.004	40	105	4
					After	---	---	---	2.38	.0048	30	10	6
S-46**	65079	.016 KSI/hr.	2200 / 1204	761	Before	94.0	35.0						
					After	91.7	15.4+	***	***	***	***	***	***

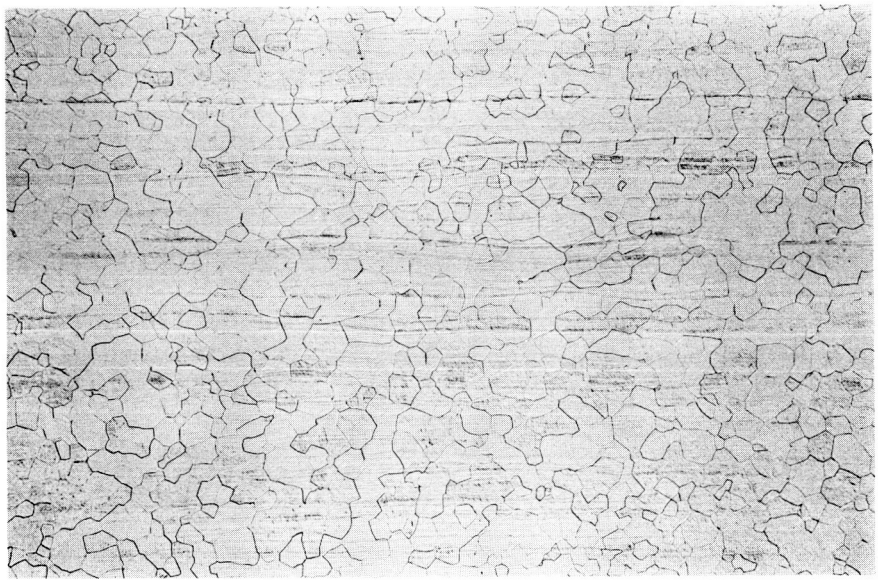
\+ Reduced Gauge Width
* Perpendicular to rolling direction
** Continuous loading test
*** Measurements in Progress

Table 11. Comparison of Chemical Analysis Between T-111 Heats No. 65080 and 65079

Element	Heat No. 65080	Heat No. 65079
W	7.79	8.77
Hf	2.03	2.09
C	0.0019	.0021
O_2	0.001	.001
N_2	0.003	.004
H_2	0.0004	.0005
	SPECTROGRAPHIC SURVEY	
Mn	≤.005	<.005
Si	<.005	<.005
Cr	<.0025	<.0025
Ni	<.005	<.005
Mo	<.010	<.010
Al	<.010	<.005
Cu	<.0025	<.0025
Sn	<.010	<.010
Fe	<.005	<.005
V	<.005	<.005
Mg	<.0025	<.0025
Ti	<.010	<.010
Co	<.0025	<.0025
Pb	<.005	<.005
Nb	<.010	<.010
Y	None Detected	None Detected

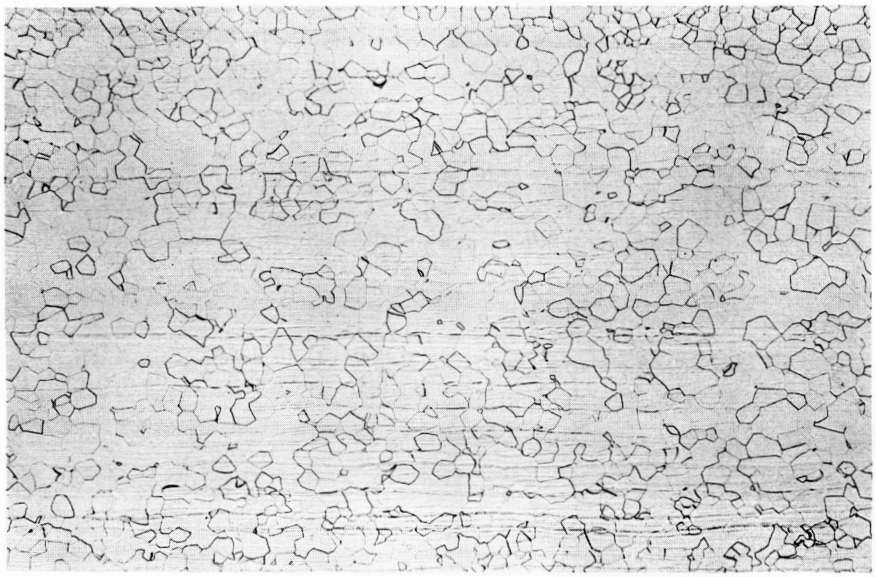


BEFORE CREEP TESTING

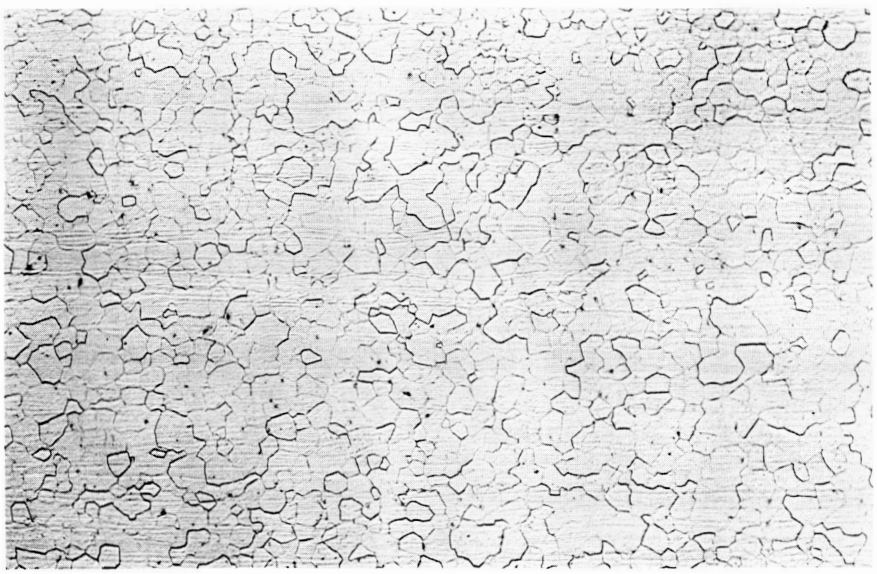


AFTER CREEP TESTING 100X

Figure 27. Microstructure of T-111 specimen S-33 before and after creep testing 2976 hours at 2200°F (1204°C) and 8 Ksi (5.51×10^7 N/m^2).

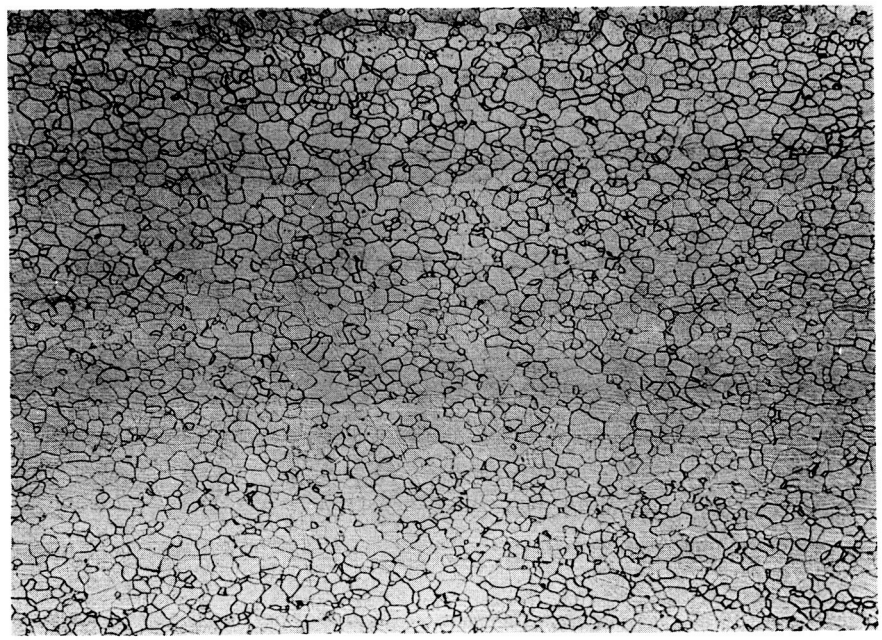


BEFORE CREEP TESTING

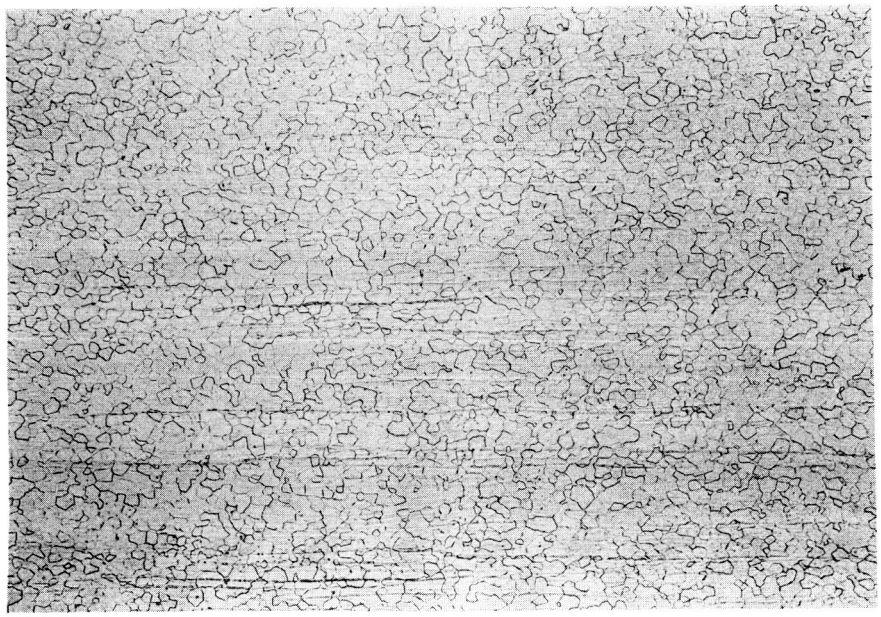


AFTER CREEP TESTING 100X

Figure 28. Microstructure of T-111 specimen S-35 before and after creep testing 5522 hours at 2200°F (1204°C) and 5 Ksi (3.44×10^7 N/m^2).

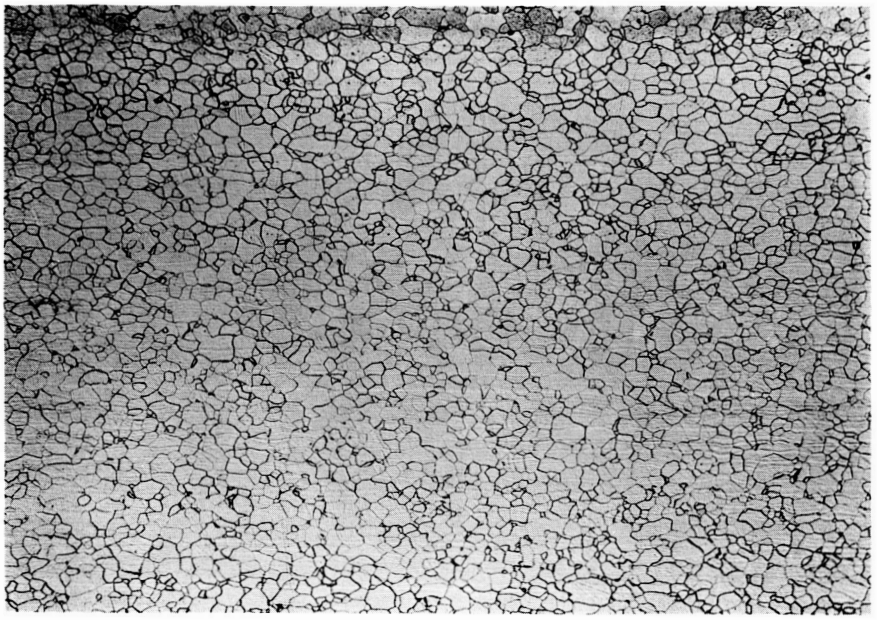


BEFORE CREEP TESTING

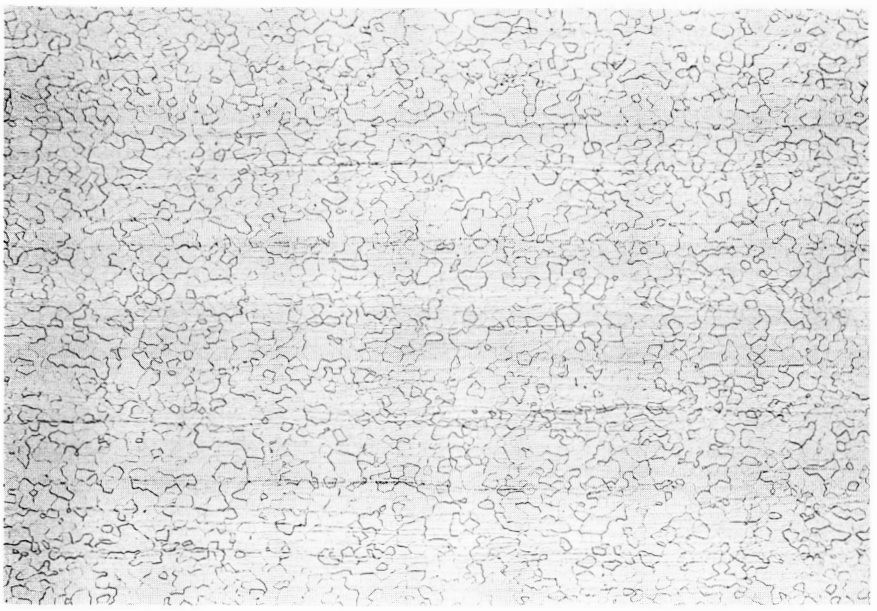


AFTER CREEP TESTING 100X

Figure 29. Microstructure of T-111 specimen S-36 before and after creep testing 624 hours at 2200°F (1204°C) and .016 Ksi/hour continuous loading rate.

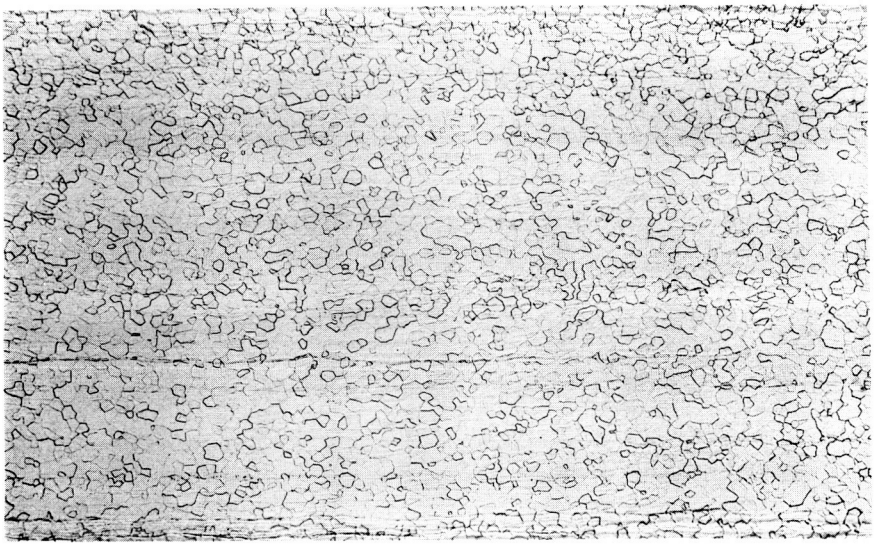


BEFORE CREEP TESTING

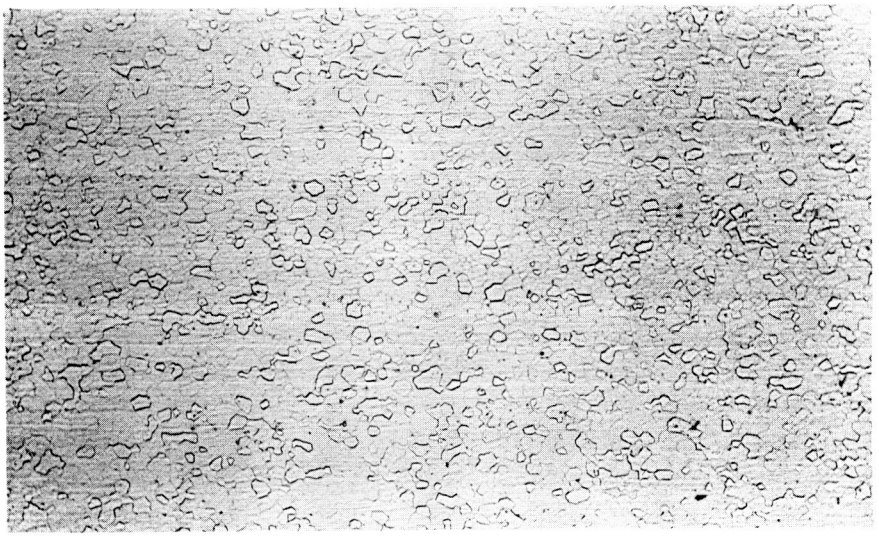


AFTER CREEP TESTING 100X

Figure 30. Microstructure of T-111 specimen S-37 before and after creep testing 274 hours at 2200°F (1204°C) and 8 Ksi (5.51×10^7 N/m^2).

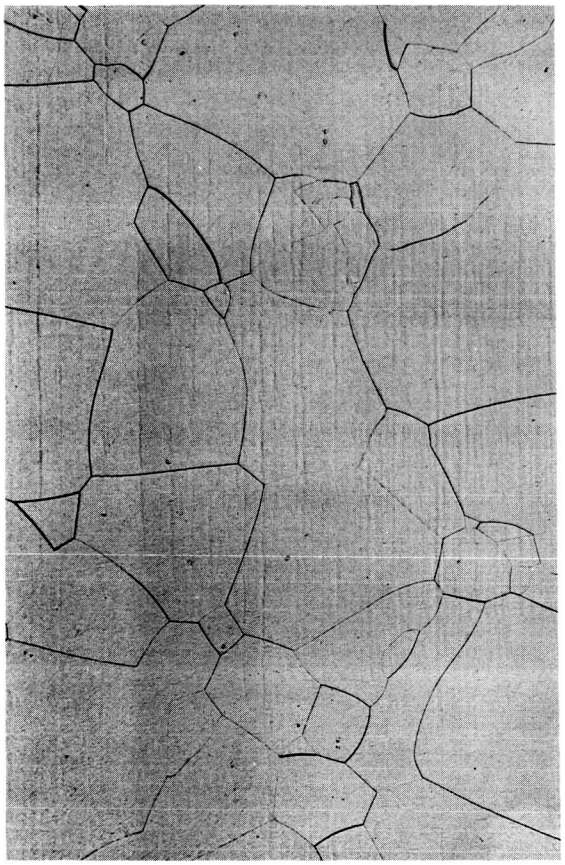


BEFORE CREEP TESTING

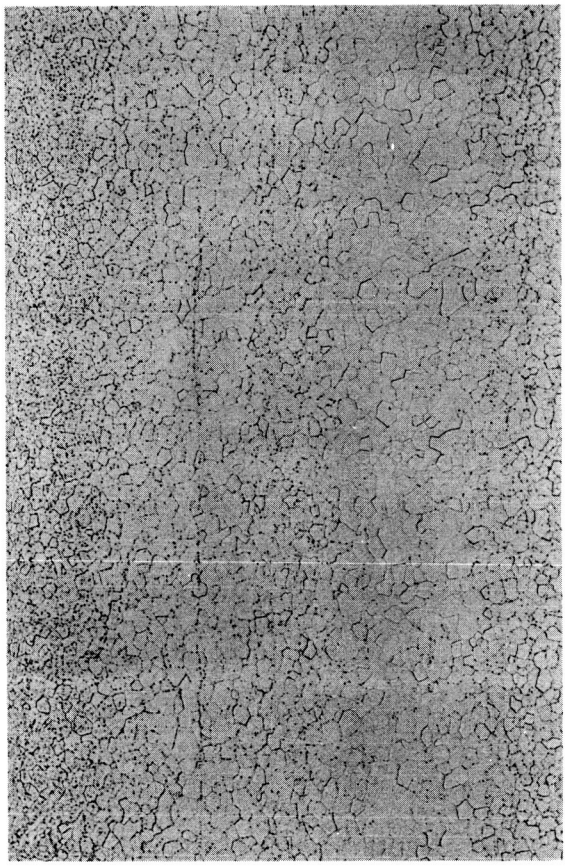


AFTER CREEP TESTING 100X

Figure 31. Microstructure of T-111 specimen S-45 before and after creep testing 697 hours at 2200°F (1204°C) and 3 Ksi (2.07 N/m^2).

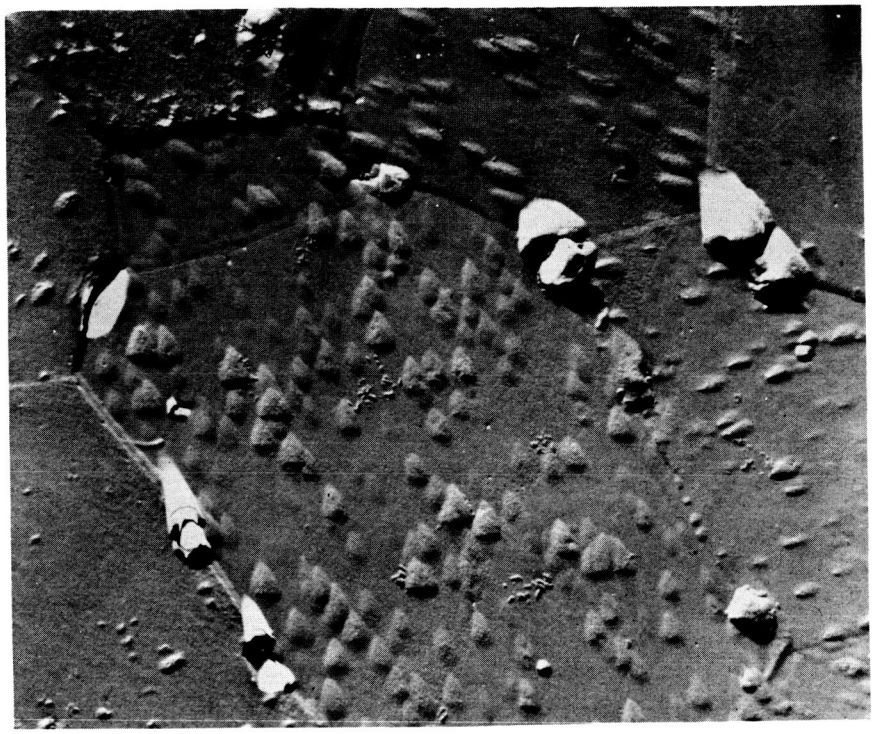


Heat No. 70616
Grain Size
ASTM No. 2.5
Diameter 0.151 mm

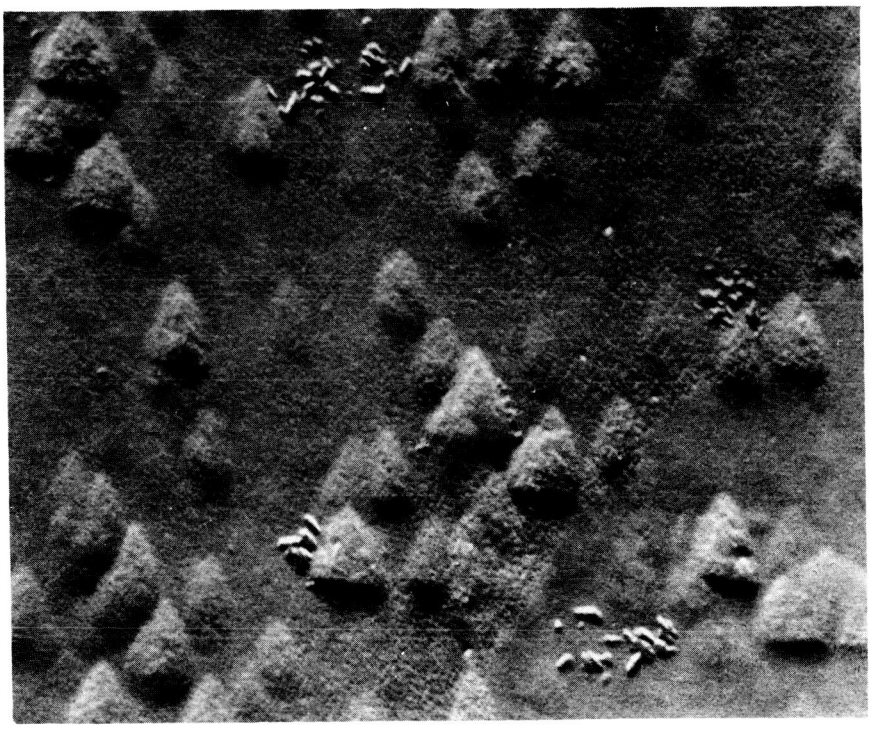


Heat No. 65080
Grain Size
ASTM No. 9
Diameter 0.015 mm

Figure 32. Comparison of samples from T-111 Heats No. 70616 and 65080 annealed 1 hour at 3500°F. 100X



5000X



11,500X

Figure 33. Electron micrographs of T-111 Heat No. 65080 recrystallized 1 hour at 3500°F(1929°C).

The presence of the coarse grain boundary precipitate provides an explanation for the lack of grain growth in the sample heat treated at 3500°F (1929°C). However the present data are not sufficient to definitely establish the nature of the precipitates observed in this sample.

In an attempt to detect a difference in the Heat 65080 material, electron microprobe analyses were conducted on all of the heats in the as received condition. No elements other than Ta, W, and Hf could be detected in a comprehensive scan of emitted wavelengths between 13.5 A and 0.86 A, which covers either the K or L series radiation of the elements between Na and Pb in the periodic table. This range includes yttrium, which has been suggested as a potential impurity that might restrict grain growth in T-111. However, the significant advantage of the probe lies not in its sensitivity to trace impurities but in its ability to resolve local variations of material composition. Measurement of the average alloy content of each heat indicated that 65080 was within the range of the other heats, thereby confirming previous chemical analyses. However, successive scans of the Ta, W, and Hf levels across the thickness of each sheet showed greater random variations of Hf content in 65080 (see Figure 34). Higher hafnium is known to decrease the creep resistance of this type of tantalum alloy (12), but the influence of this apparent segregation upon creep behavior is not known and additional specimens will be examined in the electron microscope in an effort to answer this question.

Although no conclusive reason has been established for the poor creep behavior of Heat 65080, microprobe analysis has revealed the presence of Hf rich precipitates in the Ta-W-Hf solid solution matrix in all of the T-111 heats. In order to better define the nature of these Hf rich areas, photographs of oscilloscope traces representing beam current absorption and Hf X-ray emission were made in areas containing the suspected Hf precipitates. An example of each type of photograph is shown in Figure 35. The absorbed current image shows the presence of non-conducting areas in the sample; although the Hf X-ray image is not very sensitive at this magnification it does show a strong Hf indication. Higher magnification views in the same region (Figure 36) definitely confirm the Hf rich nature of the non-conducting areas. Correllary scans in search of other elements suggest that the precipitate is probably an oxide rather than a carbide of nitride.

Astar 811C

One specimen of the tantalum-base alloy Astar 811C is currently being tested at 2600°F (1427°C) and 2 Ksi (1.38×10^7 N/m^2) after annealing 1/2 hour at 3600°F (1982°C) (Figure 37). This specimen has elongated to .418% in 9978 hours. Extrapolation of the creep curve predicts a 1% creep life of 16,650 hours, indicating that the alloy is significantly stronger than T-111. A 1% creep life of 750 hours at 12.5 Ksi (8.62×10^7 N/m^2) and 2400°F (1316°C) has been reported for the same material annealed 1 hour at 3000°F (1649°C) by Buckman and Goodspeed (12). The 1% creep life Larson-Miller parameter for these two tests, when plotted simultaneously with the T-111 data (Figure 26) further emphasizes the advantage of Astar 811C over T-111.

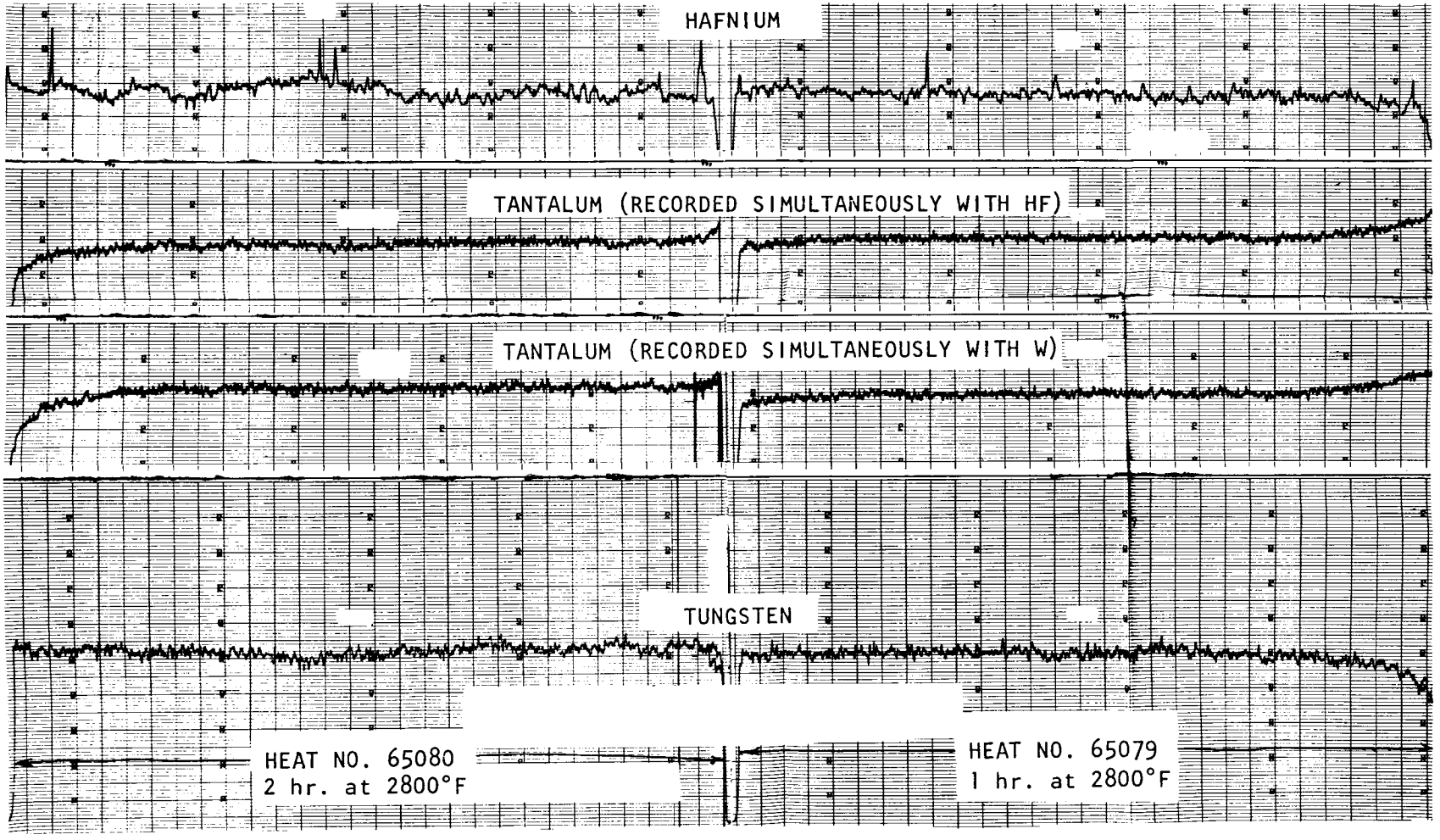
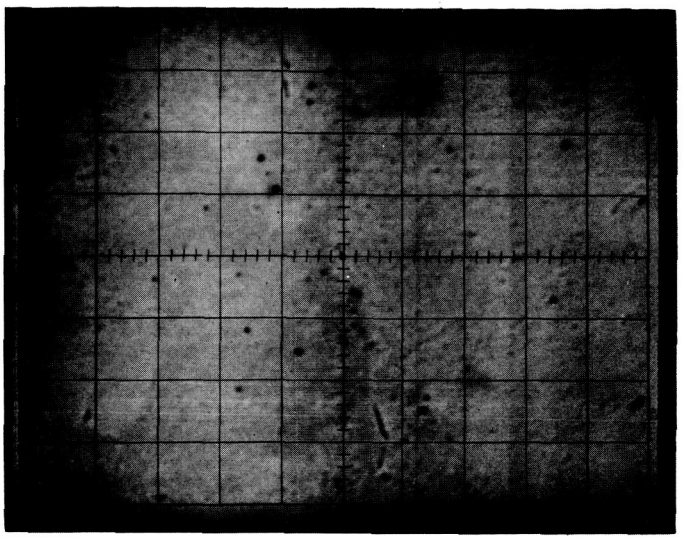
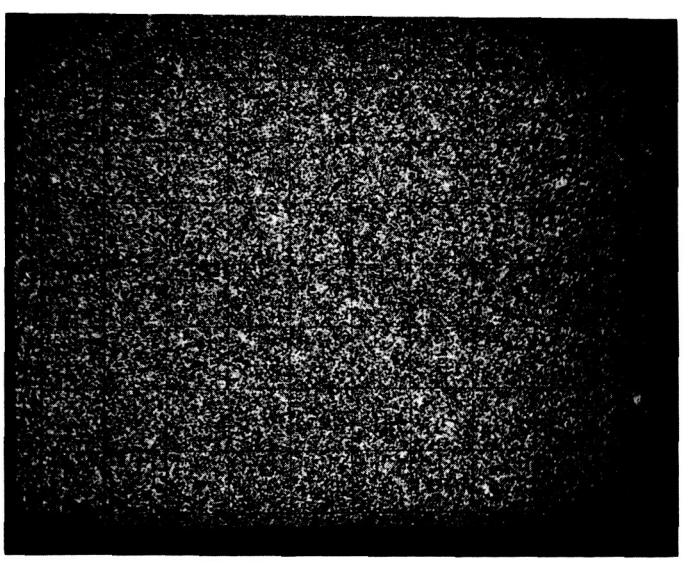


Figure 34. Comparison of Ta, Hf, and W X-ray emission intensities across the thickness of 65079 and 65080 sheet samples. The two Ta scans were recorded simultaneously with the W and Hf scans respectively.

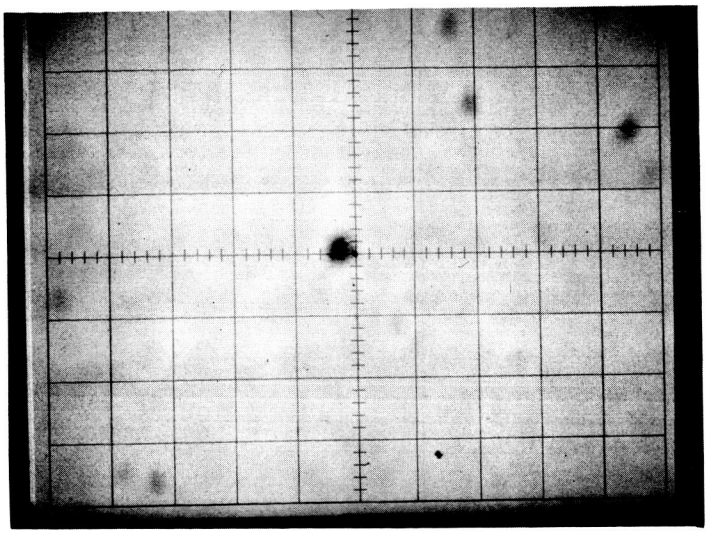


ABSORBED CURRENT IMAGE

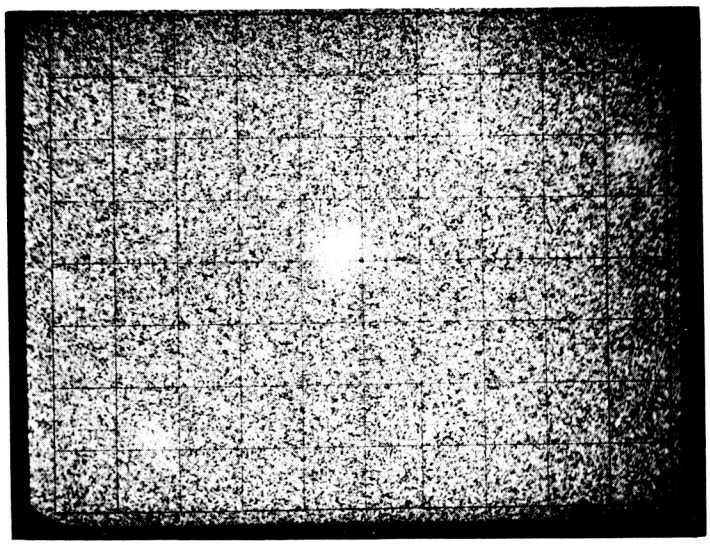


Hf X-RAY IMAGE

Figure 35. Absorbed current and Hf X-ray images of T-111 Heat No. 65079A, taken in identical areas on the electron probe microanalyzer. 800X



ABSORBED CURRENT IMAGE



Hf X-RAY IMAGE

Figure 36. Absorbed current and Hf X-ray images of T-111 Heat No. 65079A, taken in identical areas on the electron probe microanalyzer. 2600X

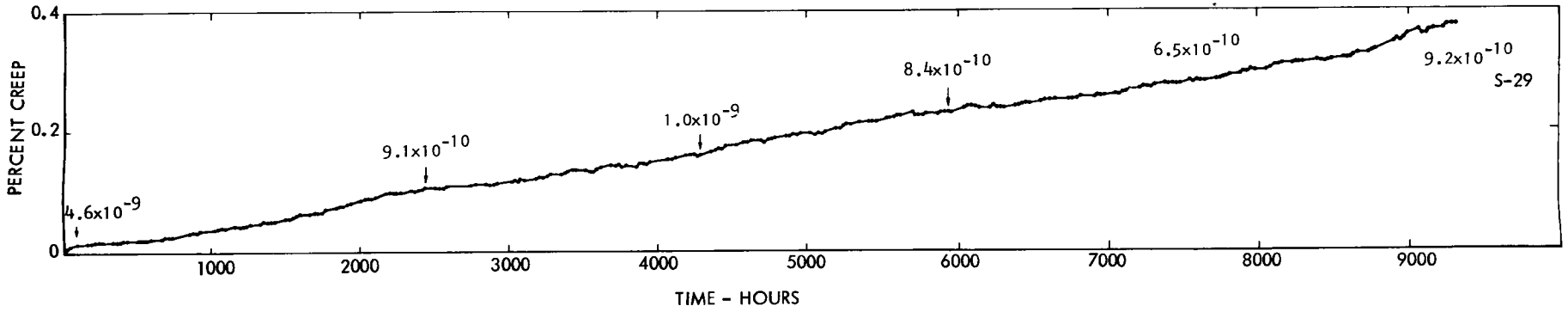


Figure 37. Creep test data, ASTAR-811C Heat No. NAS V-20-WS annealed 1/2 hour at 3600°F (1982°C), tested at 2600°F (1427°C) and 2 KSI (1.38×10^7 N/m^2), Test No. S-29, tested in a vacuum environment of $<1 \times 10^{-8}$ torr. Arrows on the curves indicate chamber pressure at various intervals during the test.

IV SUMMARY

Larson-Miller analysis of creep test results on molybdenum-base TZC and TZM alloys indicated that at higher stress levels and low temperatures a specially processed lot of TZM having a somewhat higher than normal carbon content is superior to TZC in the stress relieved condition, whereas at higher temperatures and lower stresses, the behavior of the two materials tended to converge.

The creep behavior of commercially pure tantalum tubing has been found to be very sensitive to temperature in the 1183 to 1350°F (639 to 731°C) range.

Creep test results for tantalum base T-111 alloy showed excellent reproducibility among five of six heats from two different suppliers, while a sixth heat showed significantly poorer creep resistance.

Experimental techniques have been developed to creep test specimens with continuously increasing stress levels, and methods have been employed to predict the creep behavior of continuously loaded specimens from static creep test data. Limited comparison of predicted 1% creep lives with experimental results provided good agreement.

A single test on a relatively new tantalum alloy, Astar 811C, has shown this material to have significantly better creep resistance than T-111.

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Appendix I

PROCESSING HISTORY OF MATERIALS

TABLE I

PROCESSING HISTORY OF TZC PLATE

Vendor:

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

Processing History:

1. Vacuum arc melt 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-roll 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 blast and cut to final length with abrasive saw.

Hardness:

308 DPH (29 Rc)

TABLE II

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:

335 DPH (34 Rc)

TABLE III

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" diameter
2. Extrude to 3" diameter
3. Heat treat in vacuum 3000°F (1649°C)
4. Machine to 2.4-2.8" diameter
5. Upset forge 40% at 2400°F (1316°C)
6. Broad forge 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 IV

PROCESSING HISTORY OF TZM FORGED DISC

Vendor:

Climax Molybdenum Company of Michigan
Coldwater, Michigan
Heat 7502

Processing History:

1. Vacuum arc melt ingot 11-1/2" diameter
2. Machine to 10-3/4" diameter
3. Extrude to 6-1/4" diameter
4. Heat treat at 2700°F (1482°C)
5. Upset forge at 2200°F (1204°C)
6. Stress relieve at 2200°F (1204°C)

Hardness:

266-342 DPH (25-35 Rc)

TABLE V

PROCESSING HISTORY OF TZM FORGED DISC

Vendor:

AiResearch (Universal Cyclops)
Disc No. 3
Heat KDTZM-1175

Processing History:

1. 11-3/4" diameter ingot, machine to 10-3/4" diameter
2. Extrude to 6-1/2" diameter at 2250°F (1232°C)
3. Recrystallize at 2800°F (1538°C) for 4 hours
4. Forge to 4" diameter 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 temperature 2160°F (1182°C)
7. Stress relieve at 2300°F (1260°C) for 1 hour

Hardness:

297-335 DPH (29-34 Rc)

TABLE VI

PROCESSING HISTORY OF TZM BAR

Vendor:

Climax Molybdenum Company of Michigan
Coldwater, Michigan
Heat 7463

Processing History:

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

Hardness:

300-330 DPH (30-40 Rc)

TABLE VII

PROCESSING HISTORY OF T-111 SHEET

Vendor:

Wah Chang Corporation
Albany, Oregon
Heat No. 70616

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 (1216°C)
7. Cold roll to final thickness
8. Vacuum anneal 2400°F (1316°C)

Hardness:

216-368 DPH ($95R_B$ - 37 Rc)

TABLE VIII

PROCESSING HISTORY OF T-111 SHEET

Vendor:

Wah Chang Corporation
Albany, Oregon
Heat 65076 (MCN02A065)

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 3000°F (1649°C)
3. Warm roll 800°F (427°C) to 1/4" thick
4. Vacuum anneal 3000°F (1649°C)
5. Cold roll to final thickness
6. Vacuum anneal (1×10^{-4} torr) 3000°F (1649°C), 1 hour

Hardness:

262 DPH (25 Rc)

TABLE IX

PROCESSING HISTORY OF T-111 SHEET

Vendor:

Wah Chang Corporation
Albany, Oregon
Heat 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 (1358°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 x 10^{-4} torr) 2800°F (1538°C), 1 hour

Hardness:

236 DPH (20 Rc)

TABLE X

PROCESSING HISTORY OF T-111 SHEET

Vendor:

Wah Chang Corporation
Albany, Oregon
Heat 65080

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 .260 or 0.060" thick
4. Vacuum anneal 2800°F (1538°C), 2 hours
5. Cold roll to final thickness
6. Vacuum anneal (1×10^{-4} torr) 2800°F (1538°C), 2 hours

Hardness:

248 DPH (22 Rc)

TABLE XI

PROCESSING HISTORY OF T-111 SHEET

Vendor:

Wah Chang Corporation
Albany, Oregon
Heat 65080A

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 (1204°C)
3. Warm roll 800°F (427°C) to .260" thick
4. Vacuum anneal 3000°F (1649°C) 1 hour
5. Cold roll to final thickness
6. Material received in the as-worked condition

Hardness:

355 DPH (35 Rc)

TABLE XII

PROCESSING HISTORY OF T-111 SHEET

Vendor:

Fansteel Metallurgical Corporation
North Chicago, Illinois
Heat D-1102

Processing History:

1. Extrude 3.25:1 at 2200°F (1204°C) from 8.44" diameter arc melted ingot
2. Rod roll and flat roll to finish gage from 4.25" diameter billet
3. Deliver in as-worked condition

TABLE XIII

PROCESSING HISTORY OF T-111 SHEET

Vendor:

Fansteel Metallurgical Corporation
North Chicago, Illinois
Heat D-1670

Processing History:

1. Extrude 3.25:1 at 2300°F (1260°C) from 8.44" diameter arc melted ingot
2. Rod roll and flat roll to finish gage from 4.5" diameter billet
3. Deliver in as-worked condition

Hardness:

333 DPH (34 Rc)

APPENDIX II

Summary of Ultra-High Vacuum Creep Test Results Generated on the Refractory Alloy Creep Program

TABLE II-1

Summary of Arc-Melted W Ultra-High Vacuum Creep Test Results

TEST NO.	HEAT NO.	HEAT TREATMENT TIME HOURS	HEAT TREATMENT TEMPERATURE °F	HEAT TREATMENT TEMPERATURE °C	STRESS KSI	STRESS $N/M^2 \times 10^{-7}$	TEST TEMPERATURE °F	TEST TEMPERATURE °C	1% CREEP LIFE HOURS	TEST TIME AT TERMINATION HOURS	1% CREEP LARSON-MILLER PARAMETER $T_{\circ R}(15 + \log t) \times 10^{-3}$
S-5	KC-1357	24	3200	1760	3.0	2.07	3200	1760	6	32	57.8
S-7	KC-1357	2	3200	1760	0.4	0.28	3200	1760	***	714	***
S-9	KC-1357	2	3200	1760	1.0	0.69	3200	1760	675	3886	65.4
S-17	KC-1357	2	2800	1538	4.0	2.80	2800	1538	20	218	53.1
S-18	KC-1357	2	2800	1538	3.0	2.07	2800	1538	125	908	55.8

*** Insufficient creep to extrapolate

TABLE II-2

Summary of Vapor-Deposited W Ultra-High Vacuum Creep Test Results

TEST NO.	HEAT NO.	HEAT TREATMENT TIME HOURS	HEAT TREATMENT TEMPERATURE °F	HEAT TREATMENT TEMPERATURE °C	STRESS KSI	STRESS $N/M^2 \times 10^{-7}$	TEST TEMPERATURE °F	TEST TEMPERATURE °C	1% CREEP LIFE HOURS	TEST TIME AT TERMINATION HOURS	1% CREEP LARSON-MILLER PARAMETER $T_{o_R}(15 + \log t) \times 10^{-3}$
B-17	-	1	3200	1760	1.0	0.69	3200	1760	1140	2671	66.0
B-24	-	1	2800	1538	2.0	1.38	2800	1538	1500	6812	59.2

TABLE II-3

Summary of W-25%Re Ultra-High Vacuum Creep Test Results

TEST NO.	HEAT NO.	HEAT TREATMENT TIME HOURS	HEAT TREATMENT TEMPERATURE °F	HEAT TREATMENT TEMPERATURE °C	STRESS KSI	STRESS $N/M^2 \times 10^{-7}$	TEST TEMPERATURE °F	TEST TEMPERATURE °C	1% CREEP LIFE HOURS	TEST TIME AT TERMINATION HOURS	1% CREEP LARSON-MILLER PARAMETER $T_{°R}(15 + \log t) \times 10^{-3}$
S-3	3.5-75002	48	3200	1760	5.0	3.44	3200	1760	12	45	58.9
S-4	3.5-75002	45	3200	1760	3.0	2.07	3200	1760	25	97	60.0
S-6	3.5-75002	1	3200	1760	0.5	0.34	3200	1760	***	253	***
S-8	3.5-75002	1	3200	1760	1.5	1.03	3200	1760	315	1306	64.0

*** Insufficient creep to extrapolate

TABLE II-4

Summary of Sylvania A Ultra-High Vacuum Creep Test Results

TEST NO.	HEAT NO.	HEAT TREATMENT TIME HOURS	HEAT TREATMENT TEMPERATURE °F	HEAT TREATMENT TEMPERATURE °C	STRESS KSI	STRESS $N/M^2 \times 10^{-7}$	TEST TEMPERATURE °F	TEST TEMPERATURE °C	1% CREEP LIFE HOURS	TEST TIME AT TERMINATION HOURS	1% CREEP LARSON-MILLER PARAMETER $T_{\circ R}(15 + \log t) \times 10^{-3}$
S-12	-	2	3200	1760	5.0	3.44	3200	1760	35	170	60.6
S-15	-	2	3200	1760	3.0	2.07	3200	1760	250	907	63.7

TABLE II-5

Summary of AS-30 Ultra-High Vacuum Creep Test Results

TEST NO.	HEAT NO.	HEAT TREATMENT TIME HOURS	HEAT TREATMENT TEMPERATURE °F	HEAT TREATMENT TEMPERATURE °C	STRESS KSI	STRESS $N/M^2 \times 10^{-7}$	TEST TEMPERATURE °F	TEST TEMPERATURE °C	1/2% CREEP LIFE HOURS	TEST TIME AT TERMINATION HOURS	1/2%CREEP LARSON-MILLER PARAMETER $T_{°R}(15 + \log t) \times 10^{-3}$
B-2	C5	As-Rolled			12.0	8.27	2000	1093	390	806	43.3
B-6	C5	As-Rolled			11.0	7.58	2000	1093	450	1192	43.5
B-7	C5	As-Rolled			8.0	5.51	2200	1204	115	230	45.4

TABLE 11-6

Summary of Cb-132M Ultra-High Vacuum Creep Test Results

TEST NO.	HEAT NO.	HEAT TREATMENT TIME HOURS	HEAT TREATMENT TEMPERATURE °F	HEAT TREATMENT TEMPERATURE °C	STRESS KSI	STRESS $N/M^2 \times 10^{-7}$	TEST TEMPERATURE °F	TEST TEMPERATURE °C	1/2% CREEP LIFE HOURS	TEST TIME AT TERMINATION HOURS	1/2% CREEP LARSON-MILLER PARAMETER $T_{\circ R}(15 + \log t) \times 10^{-3}$
B-13	KC-1454	1	3092	1700	20.0	13.80	2056	1125	275	568	43.8
B-14	KC-1454	1	3092	1700	16.3	8.23	2056	1125	340	691	44.0
B-15	KC-1454	1	3092	1700	7.4	5.10	2256	1236	250	596	47.2

TABLE II-7

Summary of TZM Ultra-High Vacuum Creep Test Results

TEST NO.	HEAT NO.	HEAT TREATMENT TIME HOURS	HEAT TREATMENT TEMPERATURE °F	HEAT TREATMENT TEMPERATURE °C	STRESS KSI	STRESS $N/M^2 \times 10^{-7}$	TEST TEMPERATURE °F	TEST TEMPERATURE °C	1/2% CREEP LIFE HOURS	TEST TIME AT TERMINATION HOURS	1/2% CREEP LARSON-MILLER PARAMETER $T_{\circ R}(15 + \log t) \times 10^{-3}$
B-1	7502	1	2200	1204	12.6	8.65	2130	1165	605	646	46.1
B-3	7502	1	2200	1204	10.0	6.89	2000	1095	14,200*	10,048	47.1
B-29	7502	1	2200	1204	41.0	28.20	2000	1095	100	664	41.8
B-35	7502	1	2200	1204	44.0	30.30	1800	982	7000	7659	42.6
B-4	7502 Plus	1 1	2200 2850	1204 1566	10.0	6.89	2000	1095	25,000*	10,012	47.7
B-16	KDTZM-1175	1	2300	1260	23.4	16.10	1855	1013	62,500*	4376	45.8
B-18	KDTZM-1175	1	2300	1260	55.0	37.90	1600	871	60,000*	2159	40.7
B-21	KDTZM-1175	1	2300	1260	65.0	44.80	1600	871	9600*	1630	39.1
B-25	KDTZM-1175	1	2300	1260	44.0	30.30	1800	982	50,000*	10,152	44.5
B-38	KDTZM-1175	1	2300	1260	22.0	15.10	2000	1093	8500*	**	46.5
B-34	7463	1/2	2250	1232	41.0	28.20	2000	1093	790	1440	44.0

* Extrapolated data

** Test in progress

TABLE II-8

Summary of Cb Modified TZM Ultra-High Vacuum Creep Test Results

TEST NO.	HEAT NO.	HEAT TREATMENT TIME HOURS	HEAT TREATMENT TEMPERATURE °F	HEAT TREATMENT TEMPERATURE °C	STRESS KSI	STRESS $N/M^2 \times 10^{-7}$	TEST TEMPERATURE °F	TEST TEMPERATURE °C	1/2% CREEP LIFE HOURS	TEST TIME AT TERMINATION HOURS	1/2% CREEP LARSON-MILLER PARAMETER $T_{\circ R}(15 + \log t) \times 10^{-3}$
B-23A	4305-4	1	2500	1371	20.0	13.80	2000	1093	20,000*	686	47.5
B-23B	4305-4	-	-	-	28.0	19.30	2000	1093	10,000*	307	46.7
B-23C	4305-4	-	-	-	40.0	27.60	2000	1093	630*	185	43.8
B-23D	4305-4	-	-	-	46.0	31.70	1800	982	4000*	403	42.0
B-23E	4305-4	-	-	-	34.0	23.40	2100	1149	1000*	329	46.1
B-27	4305-4	1	2500	1371	41.0	28.20	2000	1093	1090	1584	44.5

* Extrapolated

TABLE II-9

Summary of TZC Ultra-High Vacuum Creep Test Results

TEST NO.	HEAT NO.	HEAT TREATMENT TIME HOURS	HEAT TREATMENT TEMPERATURE °F	HEAT TREATMENT TEMPERATURE °C	STRESS KSI	STRESS $N/M^2 \times 10^{-7}$	TEST TEMPERATURE °F	TEST TEMPERATURE °C	1/2% CREEP LIFE HOURS	TEST TIME AT TERMINATION HOURS	1/2% CREEP LARSON-MILLER PARAMETER $T_{\circ R}(15 + \log t) \times 10^{-3}$
B-8A	M-80	1	3092	1700	18.0	12.40	2200	1204	1100	2128	48.3
B-10	M-80	1	3092	1700	17.0	11.70	2200	1204	2500	2749	48.9
B-9	M-80	1	3092	1700	20.0	13.80	2000	1093	10,408	16,002	46.8
B-11	M-80	1	3092	1700	25.0	17.20	1856	1013	75,000*	14,406	46.0
B-12	M-80	1	3092	1700	19.0	13.10	2056	1125	75,000*	14,239	49.2
B-20	M-91	1	3092	1700	20.0	13.80	2000	1093	3650	12,795	45.7
B-31	M-91	1	3092	1700	14.0	9.65	2200	1204	329	912	46.6
B-19	M-91	1	2300	1260	44.0	30.30	1800	982	1075	4604	41.1
B-28	M-91	1	2300	1260	28.0	19.30	2000	1093	1100	4214	44.4
B-30	M-91	1	2500	1371	22.0	15.20	2200	1204	70	259	44.8
B-32	M-91	1	2500	1371	20.0	13.80	1935	1057	14,400	**	45.9
B-33	M-91	1	2500	1371	22.0	15.20	1900	1038	7720	9697	44.6
B-36	4345	1	2500	1371	22.0	15.20	2000	1093	5940	8563	46.2
B-37	4345	1	2400	1316	22.0	15.20	2000	1093	8000*	**	46.3

* Extrapolated

** Test in progress

TABLE II-10

Summary of T-222 Ultra-High Vacuum Creep Test Results

TEST NO.	HEAT NO.	HEAT TREATMENT TIME HOURS	HEAT TREATMENT TEMPERATURE °F	HEAT TREATMENT TEMPERATURE °C	STRESS KSI	STRESS $N/M^2 \times 10^{-7}$	TEST TEMPERATURE °F	TEST TEMPERATURE °C	1% CREEP LIFE HOURS	TEST TIME AT TERMINATION HOURS	1% CREEP LARSON-MILLER PARAMETER $T_{\circ R}(15 + \log t) \times 10^{-3}$
S-13	AL-TA-43	1	3000	1649	12.0	8.27	2200	1204	560	1890	47.2
S-14	AL-TA-43	1	3000	1649	19.2	13.20	2056	1124	890	1314	45.1
S-20	AL-TA-43	1	2800	1538	12.0	18.27	2200	1204	405	1389	46.9

TABLE II-11

Summary of ASTAR 811C Ultra-High Vacuum Creep Test Results

TEST NO.	HEAT NO.	HEAT TREATMENT TIME HOURS	HEAT TREATMENT TEMPERATURE °F	HEAT TREATMENT TEMPERATURE °C	STRESS KSI	STRESS $N/M^2 \times 10^{-7}$	TEST TEMPERATURE °F	TEST TEMPERATURE °C	1 % CREEP LIFE HOURS	TEST TIME AT TERMINATION HOURS	1 % CREEP LARSON-MILLER PARAMETER $T_{\circ R}(15 + \log t) \times 10^{-3}$
S-29	NASV-20-WS	1/2	3600	1982	2.0	1.38	2600	1427	24,000*	**	59.3

* Extrapolated
** Test in progress

TABLE 11-12

Summary of T-111 Ultra-High Vacuum Creep Test Results

TEST NO.	HEAT NO.	HEAT TREATMENT TIME HOURS	HEAT TREATMENT TEMPERATURE °F	HEAT TREATMENT TEMPERATURE °C	STRESS KSI	STRESS $N/M^2 \times 10^{-7}$	TEST TEMPERATURE °F	TEST TEMPERATURE °C	1% CREEP LIFE HOURS	TEST TIME AT TERMINATION HOURS	1% CREEP LARSON-MILLER PARAMETER $T_{\circ R}(15 + \log t) \times 10^{-3}$
S-16	70616	1	2600	1427	8.0	5.51	2200	1204	725	1675	47.5
S-19	70616	1	3000	1649	8.0	5.51	2200	1204	2000	4870	48.7
S-21	70616	1	3000	1649	12.0	8.26	2200	1204	1140	3840	48.0
S-23	70616	1	3000	1649	12.0	8.26	2120	1160	3150	3698	47.7
S-22	70616	1	3000	1649	20.0	13.80	2000	1093	670	1099	43.8
S-24	70616	1	3000	1649	20.0	13.80	1860	1016	4730	4946	43.3
S-25	D-1670	1	3000	1649	15.0	10.30	2000	1093	1340	1584	44.6
S-26	D-1670	1	3000	1649	17.0	11.70	1800	982	9540	9624	42.9
S-25A	D-1670	1	3000	1649	1.5	1.03	2600	1427	1100*	482	55.2
S-28	D-1670	1	3000	1649	0.5	0.34	2600	1427	55,000*	**	60.0
S-27	D-1102	1	3000	1649	13.0	8.95	2000	1093	1880	3459	45.0
S-32	D-1102	1	3000	1649	5.0	3.44	2200	1204	4050	4322	49.5
S-40	D-1102	1	2000	1649	17.0	11.70	1800	982	9015*	**	42.8
S-33	MCN02A065	1	3000	1649	8.0	5.51	2200	1204	2850	2976	49.1
S-34	MCN02N065	1	3000	1649	11.0	7.58	2000	1093	10,750*	**	46.9

TABLE II-12 (Continued)

Summary of T-111 Ultra-High Vacuum Creep Test Results

TEST NO.	HEAT NO.	HEAT TREATMENT TIME HOURS	HEAT TREATMENT TEMPERATURE °F	HEAT TREATMENT TEMPERATURE °C	STRESS KSI	STRESS $N/M^2 \times 10^{-7}$	TEST TEMPERATURE °F	TEST TEMPERATURE °C	1 % CREEP LIFE HOURS	TEST TIME AT TERMINATION HOURS	1 % CREEP LARSON-MILLER PARAMETER $T_{o_R}(15 + \log t) \times 10^{-3}$
S-37	65080	1	3000	1649	8.0	5.51	2200	1204	260	274	46.3
S-39	65080	1	3000	1649	13.0	8.95	1800	982	8345*	**	42.7
S-45	65080A	1	3000	1649	3.0	2.07	2200	1204	554	697	47.1
S-30	65079	1	3000	1649	3.5	2.41	2400	1316	860	2137	51.3
S-31	65079	1	3000	1649	5.0	3.44	2200	1204	6160	6594	50.0
S-35	65079	1	3000	1649	5.0	3.44	2200	1204	5400	5522	49.9
S-42	65079	1	3000	1649	3.5	2.41	2300	1263	3900*	**	51.3
S-47	65079	1	3000	1649	24.0	16.50	1750	954	38,000*	**	43.3
S-48	65079	1	3000	1649	2.4	1.65	2350	1288	7270*	**	53.0
S-50	65079	1	3000	1649	8.5	7.22	2000	1093	24,000*	**	47.7
S-43	65079	1/4	3000	1649	18.0	12.40	2000	1093	1500 *	361	44.7
S-44A	65079	1	3000	1649	9.5	6.55	2172	1189	3250*	467	48.7
S-44B	65079	1/4	3000	1649	3.3	2.27	2371	1299	2030*	335	51.9
S-44C	65079	1/4	3000	1649	18.0	12.40	2000	1093	1670*	1146	44.8
S-44D	65079	1/4	3000	1649	23.0	15.80	1800	982	14,650*	**	43.3

* Extrapolated
** Test in progress

TABLE II-13

Summary of T-111 Progressive Stress Ultra-High Vacuum Creep Test Results

TEST NO.	HEAT NO.	HEAT TREATMENT TIME HOURS	HEAT TREATMENT TEMPERATURE °F	HEAT TREATMENT TEMPERATURE °C	STRESS RATE PSI/HR	TEST TEMPERATURE °F	TEST TEMPERATURE °C	1% CREEP LIFE HOURS	TEST TIME AT TERMINATION HOURS
S-36	65080	1	3000	1649	16	2200	1204	600	624
S-38	65080	1	3000	1649	1	2200	1204	3830	4686
S-46	65079	1	3000	1649	16	2200	1204	1000*	761
S-49	65079	1	3000	1649	20	1800	982	***	**
S-51	D-1183	1	3000	1649	16	2200	1204	***	**

* Test in progress
** Insufficient data to extrapolate

TABLE II-14

Summary of Pure Ta Ultra-High Vacuum Creep Test Results

TEST NO.	HEAT NO.	HEAT TREATMENT TIME HOURS	HEAT TREATMENT TEMPERATURE °F	HEAT TREATMENT TEMPERATURE °C	STRESS KSI	STRESS $N/M^2 \times 10^{-7}$	TEST TEMPERATURE °F	TEST TEMPERATURE °C	1% CREEP LIFE HOURS	TEST TIME AT TERMINATION HOURS	1% CREEP LARSON-MILLER PARAMETER $T_{\circ R}(15 + \log t) \times 10^{-3}$
B-39A	-	1	1832	1000	13.6	9.37	1100	596	31	32	25.8
B-39B	-	1/4	1832	1000	11.6	7.99	1100	596	603*	264	27.8
B-39C	-	1/4	1832	1000	10.1	6.95	1183	639	463*	282	29.0
B-40A	-	1	1832	1000	7.0	4.83	1350	720	9	9	28.9
B-40B	-	1/4	1832	1000	4.9	3.38	1350	720	6600*	1220	34.0

* Extrapolated
** Test in progress

APPENDIX III

PREVIOUSLY PUBLISHED REPORTS

ON THE REFRACTORY ALLOY CREEP PROGRAM

J. C. Sawyer and E. B. Evans, "Generation of Valid Long Time Creep Data on Refractory Alloys at Elevated Temperature," First Quarterly Report, Contract NAS-3-2545, October 20, 1963.

J. C. Sawyer and E. B. Evans, "Generation of Valid Long Time Creep Data on Refractory Alloys at Elevated Temperatures," Second Quarterly Report, Contract NAS-3-2545, January 15, 1964.

J. C. Sawyer and E. B. Evans, "Generation of Long Time Creep Data on Refractory Alloys at Elevated Temperatures," Third Quarterly Report, Contract NAS-3-2545, CR-54048, April 20, 1964.

J. C. Sawyer and C. H. Philleo, "Generation of Long Time Creep Data on Refractory Alloys at Elevated Temperatures," Fourth Quarterly Report, Contract NAS-3-2545, CR54123, July 1, 1964.

J. C. Sawyer and C. H. Philleo, "Generation of Long Time Creep Data on Refractory Alloys at Elevated Temperatures," Fifth Quarterly Report, Contract NAS-3-2545, CR 54228, November 9, 1964.

J. C. Sawyer and C. H. Philleo, "Generation of Long Time Creep Data on Refractory Alloys at Elevated Temperatures," Sixth Quarterly Report, Contract NAS-3-2545, CR54287, January 15, 1965.

J. C. Sawyer and C. H. Philleo, "Generation of Long Time Creep Data on Refractory Alloys at Elevated Temperatures," Seventh Quarterly Report, Contract NAS-3-2545,CR54394, April 28, 1965.

J. C. Sawyer and E. A. Steigerwald, "Generation of Long Time Creep Data on Refractory Alloys at Elevated Temperatures," Eighth Quarterly Report, Contract NAS-3-2545, NAS-CR54457, July 7, 1965.

J. C. Sawyer and E. A. Steigerwald, "Generation of Long Time Creep Data on Refractory Alloys at Elevated Temperatures," Ninth Quarterly Report, Contract NAS-3-2545, NAS-CR54773, October 8, 1965.

J. C. Sawyer and E. A. Steigerwald, "Generation of Long Time Creep Data on Refractory Alloys at Elevated Temperatures," Tenth Quarterly Report, Contract NAS-3-2545, NAS-CR54895, January 8, 1966.

J. C. Sawyer and E. A. Steigerwald, "Generation of Long Time Creep Data on Refractory Alloys at Elevated Temperatures," Eleventh Quarterly Report, Contract NAS-3-2545, NAS-CR54973, April 15, 1966.

J. C. Sawyer and E. A. Steigerwald, "Generation of Long Time Creep Data on Refractory Alloys at Elevated Temperatures," Twelfth Quarterly Report, Contract NAS-3-2545, NAS-CR72044, July 15, 1966.

J. C. Sawyer and E. A. Steigerwald, "Generation of Long Time Creep Data on Refractory Alloys at Elevated Temperatures," Thirteenth Quarterly Report, Contract NAS-3-2545, October 14, 1966.

J. C. Sawyer and E. A. Steigerwald, "Generation of Long Time Creep Data on Refractory Alloys at Elevated Temperatures," Fourteenth Quarterly Report, Contract NAS-3-2545, NAS-CR72185, January 17, 1967.

J. C. Sawyer and E. A. Steigerwald, "Generation of Long Time Creep Data on Refractory Alloys at Elevated Temperatures," Final Report, Contract NAS-3-2545, June 6, 1967.

J. C. Sawyer and E. A. Steigerwald, "Generation of Long Time Creep Data on Refractory Alloys at Elevated Temperatures," Supplement to Final Report, "Numerical Creep Data", June 26, 1963 to March 17, 1967, Contract NAS-3-2545, August 15, 1967.

J. C. Sawyer and K. D. Sheffler, "Generation of Long Time Creep Data on Refractory Alloys at Elevated Temperatures," Mid-Contract Report, Contract NAS-3-9439, NAS-CR72319, August 1967.

APPENDIX IV

Numerical Creep Data

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APPENDIX IV (continued)

Tantalum Base Alloys

Material	Heat No.	Stress Ksi	Stress $N/m^2 \times 10^{-8}$	Temperature ^oF	Temperature ^oC	Test No.	Table No.
T-111	65079	3.3	0.227	2371	1299	S-44B	32
T-111	65079	18.0	1.240	2000	1093	S-44C	33
T-111	65079	23.0	1.580	1800	982	S-44D	34
T-111	65080	0.016 Ksi/Hr.	*	2200	1204	S-36	35
T-111	65080	0.001 Ksi/Hr.	*	2200	1204	S-38	36
T-111	65079	0.016 Ksi/Hr.	*	2200	1204	S-46	37

* Continuous Loading Tests

TABLE I

Creep Test Data, TZC Plate Heat M-91, Recrystallized 3092°F (1700°C) 1 Hour, Tested at 2000°F (1093°C), and 20,000 PSI ($1.38 \times 10^8 N/m^2$)

Time	Length Change Δ L (inch) (2" G. L.)	Creep (%)	Pressure (Torr)
1 Minute	.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}

TABLE .1 (Continued)

Time	Length Change Δ L (inch) (2" G. L.)	Creep (%)	Pressure (Torr)
715.5 Hours	.00375	.188	7.8×10^{-10}
787.7	.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}
1,003.4	.00455	.228	6.4×10^{-10}
1,027.2	.00465	.232	6.2×10^{-10}
1,123.7	.00485	.242	6.0×10^{-10}
1,195.5	.00490	.245	5.7×10^{-10}
1,294.7	.00515	.258	6.0×10^{-10}
1,367.4	.00525	.262	5.8×10^{-10}
1,459.1	.00560	.280	5.6×10^{-10}
1,531.7	.00585	.292	5.4×10^{-10}
1,627.9	.00600	.300	5.4×10^{-10}
1,699.2	.00620	.310	5.4×10^{-10}
1,795.3	.00640	.320	5.4×10^{-10}
1,867.8	.00655	.328	5.1×10^{-10}
1,963.9	.00665	.332	5.1×10^{-10}
2,035.6	.00695	.348	4.7×10^{-10}
2,131.6	.00720	.360	4.8×10^{-10}
2,203.3	.00740	.370	4.9×10^{-10}
2,299.8	.00745	.372	4.9×10^{-10}
2,371.4	.00755	.378	4.8×10^{-10}
2,467.3	.00760	.380	3.6×10^{-10}
2,539.5	.00770	.385	2.6×10^{-10}
2,635.2	.00800	.400	3.8×10^{-10}
2,707.6	.00820	.410	3.4×10^{-10}
2,803.4	.00880	.440	3.4×10^{-10}
2,875.1	.00900	.450	3.4×10^{-10}
2,971.0	.00910	.455	3.1×10^{-10}
3,043.1	.00920	.460	3.6×10^{-10}
3,139.0	.00935	.468	3.3×10^{-10}
3,211.3	.00930	.465	3.4×10^{-10}

TABLE 1 (Continued)

Time	Length Change Δ L (inch) (2" G. L.)	Creep (%)	Pressure (Torr)
3,307.3 Hours	.00960	.480	3.3×10^{-10}
3,379.2	.00965	.482	3.2×10^{-10}
3,547.4	.00990	.495	3.2×10^{-10}
3,643.8	.00995	.498	3.2×10^{-10}
3,718.6	.01020	.510	3.1×10^{-10}
3,811.5	.01050	.525	3.1×10^{-10}
3,884.2	.01070	.535	3.4×10^{-10}
3,979.7	.01440	.570	3.1×30^{-10}
4,051.3	.01145	.572	2.9×10^{-10}
4,147.1	.01145	.572	2.9×10^{-10}
4,218.3	.01145	.572	3.2×10^{-10}
4,314.4	.01160	.580	3.1×10^{-10}
4,386.5	.01165	.582	3.0×10^{-10}
4,482.2	.01230	.615	2.9×10^{-10}
4,554.1	.01225	.611	3.0×10^{-10}
4,650.5	.01235	.618	3.2×10^{-10}
4,724.0	.01240	.620	3.0×10^{-10}
4,818.5	.01270	.635	3.3×10^{-10}
4,890.2	.01290	.645	3.0×10^{-10}
5,010.6	.01290	.645	3.2×10^{-10}
5,058.3	.01300	.650	4.4×10^{-10}
5,157.1	.01310	.655	3.0×10^{-10}
5,226.0	.01340	.670	2.9×10^{-10}
5,250.1	.01370	.685	2.8×10^{-10}
5,324.2	.01375	.688	2.8×10^{-10}
5,394.5	.01380	.690	2.8×10^{-10}
5,490.3	.01395	.698	2.7×10^{-10}
5,562.2	.01405	.702	2.8×10^{-10}
5,658.7	.01420	.710	2.8×10^{-10}
5,730.2	.01420	.710	2.8×10^{-10}
5,850.2	.01460	.730	2.7×10^{-10}
5,899.1	.01460	.730	2.7×10^{-10}
5,994.6	.01500	.750	2.8×10^{-10}
6,075.3	.01480	.740	2.5×10^{-10}
6,162.3	.01480	.740	2.6×10^{-10}

TABLE 1 (Continued)

Time	Length Change Δ L (inch) (2" G. L.)	Creep (%)	Pressure (Torr)
6,237.3 Hours	.01480	.740	2.6×10^{-10}
6,333.6	.01480	.740	2.8×10^{-10}
6,402.7	.01490	.745	2.8×10^{-10}
6,499.1	.01495	.748	2.7×10^{-10}
6,571.2	.01505	.752	2.7×10^{-10}
6,666.5	.01520	.760	2.6×10^{-10}
6,738.0	.01520	.760	2.5×10^{-10}
6,834.3	.01525	.762	2.7×10^{-10}
6,906.0	.01535	.766	2.7×10^{-10}
7,004.4	.01550	.775	3.3×10^{-10}
7,074.3	.01560	.780	2.6×10^{-10}
7,170.1	.01595	.798	2.6×10^{-10}
7,242.3	.01600	.800	2.5×10^{-10}
7,362.8	.01605	.807	2.6×10^{-10}
7,410.0	.01610	.805	2.6×10^{-10}
7,506.6	.01620	.810	2.6×10^{-10}
7,578.0	.01630	.815	2.5×10^{-10}
7,674.8	.01650	.825	2.6×10^{-10}
7,746.4	.01640	.820	2.6×10^{-10}
7,842.2	.01670	.835	2.5×10^{-10}
7,914.5	.01700	.850	2.6×10^{-10}
8,010.4	.01710	.855	2.7×10^{-10}
8,084.2	.01710	.855	2.6×10^{-10}
8,178.2	.01715	.858	2.8×10^{-10}
8,250.3	.01715	.858	2.6×10^{-10}
8,346.2	.01720	.860	2.6×10^{-10}
8,418.3	.01725	.862	2.6×10^{-10}
8,514.2	.01735	.868	2.6×10^{-10}
8,586.7	.01745	.872	2.7×10^{-10}
8,683.2	.01750	.875	2.6×10^{-10}
8,755.5	.01760	.880	2.6×10^{-10}
8,851.2	.01765	.882	2.6×10^{-10}
8,923.1	.01765	.882	2.4×10^{-10}
9,019.3	.01770	.885	2.6×10^{-10}
9,091.4	.01775	.888	2.8×10^{-10}

TABLE .1 (Continued)

Time	Length Change Δ L (inch) (2" G. L.)	Creep (%)	Pressure (Torr)
9,187.3	.01790	.895	2.6×10^{-10}
9,283.1	.01785	.892	2.6×10^{-10}
9,355.3	.01790	.895	2.6×10^{-10}
9,427.7	.01800	.900	1.8×10^{-10}
9,523.8	.01810	.905	1.9×10^{-10}
9,595.3	.01820	.910	2.2×10^{-10}
9,691.6	.01825	.912	2.3×10^{-10}
9,763.4	.01835	.918	2.4×10^{-10}
9,860.0	.01840	.920	2.6×10^{-10}
9,931.7	.01845	.922	2.1×10^{-10}
10,051.8	.01855	.928	2.0×10^{-10}
10,099.4	.01860	.930	2.0×10^{-10}
10,219.5	.01870	.935	2.3×10^{-10}
10,267.7	.01880	.940	2.1×10^{-10}
10,364.6	.01880	.940	1.8×10^{-10}
10,435.3	.01895	.948	2.4×10^{-10}
10,532.7	.01900	.950	2.4×10^{-10}
10,603.7	.01905	.952	2.4×10^{-10}
10,699.5	.01910	.955	2.2×10^{-10}
10,771.9	.01920	.960	2.3×10^{-10}
10,867.7	.01925	.962	2.0×10^{-10}
10,940.0	.01930	.965	2.0×10^{-10}
11,037.5	.01930	.965	2.0×10^{-10}
11,108.0	.01935	.968	2.4×10^{-10}
11,203.4	.01935	.968	2.0×10^{-10}
11,275.5	.01940	.970	2.1×10^{-10}
11,371.9	.01950	.975	2.0×10^{-10}
11,444.1	.01950	.975	2.4×10^{-10}
11,539.9	.01960	.980	2.1×10^{-10}
11,611.3	.01960	.980	2.3×10^{-10}
11,707.3	.01965	.982	2.5×10^{-10}
11,779.1	.01970	.985	2.1×10^{-10}
11,875.1	.01970	.985	2.0×10^{-10}
11,947.2	.01975	.988	2.4×10^{-10}

TABLE I (Continued)

Time	Length Change Δ L (inch) (2" G. L.)	Creep (%)	Pressure (Torr)
12,043.2	.01980	.990	2.4×10^{-10}
12,115.5	.01985	.992	2.1×10^{-10}
12,211.8	.01990	.995	2.2×10^{-10}
12,283.3	.01990	.995	2.1×10^{-10}
12,451.1	.02000	1.000	2.1×10^{-10}
12,548.8	.02000	1.000	2.3×10^{-10}
12,619.5	.02000	1.000	2.6×10^{-10}
12,715.4	.02010	1.005	2.4×10^{-10}
12,787.4	.02015	1.008	2.2×10^{-10}
12,794.5	.02015	1.008	$2.x \times 10$

Test terminated - Sufficient data obtained
Specimen B-20

TABLE 2

Creep Test Data, TZC Plate Heat M-91, Stress Relieved at 2500°F (1371°C) 1 Hour, Tested at 1935°F (1057°C), and 20,000 PSI ($1.38 \times 10^8 N/m^2$)

Time	Length Change Δ L (inch) (2" G. L.)	Creep (%)	Pressure (Torr)
1 Minute	.00000	.000	2.0×10^{-8}
2	-.00005	-.002	2.0×10^{-8}
3	-.00010	-.005	2.0×10^{-8}
4	-.00010	-.005	2.0×10^{-8}
5	-.00010	-.005	2.0×10^{-8}
6	-.00015	-.008	2.0×10^{-8}
7	-.00015	-.008	2.0×10^{-8}
8	-.00020	-.010	2.0×10^{-8}
9	-.00015	-.008	2.0×10^{-8}
10	-.00015	-.008	2.0×10^{-8}
15	-.00010	-.005	2.0×10^{-8}
45	-.00030	-.015	2.0×10^{-8}
60	-.00025	-.012	2.0×10^{-8}
16.8 Hours	.00015	.008	1.1×10^{-9}
91.2	.00080	.040	2.7×10^{-9}
113.1	.00100	.050	2.2×10^{-9}
136.1	.00105	.052	2.0×10^{-9}
160.9	.00105	.052	1.7×10^{-9}
184.9	.00115	.058	1.6×10^{-10}
281.3	.00120	.060	5.2×10^{-10}
305.1	.00120	.060	5.1×10^{-10}
328.9	.00125	.067	5.1×10^{-10}
353.0	.00130	.065	5.3×10^{-10}
428.0	.00170	.085	4.8×10^{-10}
448.9	.00180	.090	4.6×10^{-9}
472.8	.00185	.092	1.2×10^{-10}
496.7	.00185	.092	4.7×10^{-10}
520.7	.00185	.092	1.1×10^{-10}
592.9	.00190	.095	9.5×10^{-10}
616.8	.00190	.095	9.8×10^{-10}
640.9	.00190	.095	9.5×10^{-10}
665.2	.00195	.098	9.8×10^{-10}
688.8	.00190	.095	9.8×10^{-10}
761.0	.00200	.100	9.2×10^{-10}
784.8	.00195	.098	9.2×10^{-10}
808.9	.00195	.098	9.8×10^{-10}
833.0	.00200	.100	1.1×10^{-9}

TABLE 2 (Continued)

Time	Length Change Δ L (inch) (2" G. L.)	Creep (%)	Pressure (Torr)
857.1 Hours	.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}
1,000.9	.00215	.108	8.8×10^{-10}
1,024.9	.00230	.115	7.9×10^{-10}
1,120.9	.00235	.118	8.1×10^{-10}
1,145.0	.00235	.118	7.4×10^{-10}
1,169.6	.00230	.115	7.2×10^{-10}
1,192.8	.00230	.115	7.1×10^{-10}
1,265.2	.00235	.118	8.0×10^{-10}
1,346.1	.00250	.125	7.2×10^{-10}
1,432.9	.00255	.128	5.6×10^{-10}
1,508.1	.00260	.130	5.5×10^{-10}
1,604.4	.00250	.125	7.2×10^{-10}
1,673.4	.00270	.135	6.3×10^{-10}
1,769.5	.00280	.140	4.7×10^{-10}
1,841.8	.00280	.140	4.7×10^{-10}
1,937.1	.00290	.145	4.6×10^{-10}
2,008.7	.00300	.150	4.5×10^{-10}
2,105.0	.00300	.150	5.2×10^{-10}
2,176.6	.00300	.150	4.2×10^{-10}
2,274.3	.00340	.170	4.7×10^{-10}
2,345.0	.00385	.192	4.2×10^{-10}
2,440.8	.00380	.190	4.0×10^{-10}
2,513.0	.00385	.192	4.4×10^{-10}
2,633.5	.00380	.190	3.6×10^{-10}
2,680.6	.00380	.190	3.8×10^{-10}
2,777.3	.00385	.192	4.2×10^{-10}
2,848.7	.00385	.192	3.5×10^{-10}
2,945.4	.00385	.192	3.3×10^{-10}
3,017.1	.00390	.195	3.6×10^{-10}
3,112.9	.00395	.198	3.4×10^{-10}
3,185.2	.00400	.200	3.2×10^{-10}
3,281.1	.00410	.205	3.8×10^{-10}
3,354.9	.00410	.205	2.9×10^{-10}
3,448.9	.00415	.208	3.0×10^{-10}
3,521.0	.00425	.212	3.0×10

TABLE 2 (Continued)

Time	Length Change Δ L (inch) (2" G. L.)	Creep (%)	Pressure (Torr)
3,616.9	.00445	.222	2.4×10^{-10}
3,689.0	.00460	.230	2.5×10^{-10}
3,784.9	.00470	.235	2.6×10^{-10}
3,857.4	.00475	.238	2.5×10^{-10}
3,953.9	.00480	.240	2.6×10^{-10}
4,026.2	.00480	.240	2.5×10^{-10}
4,121.9	.00490	.245	2.2×10^{-10}
4,193.9	.00500	.250	2.0×10^{-10}
4,290.0	.00505	.252	2.2×10^{-10}
4,362.1	.00510	.255	2.4×10^{-10}
4,458.1	.00515	.258	2.4×10^{-10}
4,553.8	.00520	.260	2.0×10^{-10}
4,626.0	.00530	.265	2.1×10^{-10}
4,698.5	.00530	.265	2.2×10^{-10}
4,794.4	.00535	.268	2.2×10^{-10}
4,866.1	.00540	.270	1.9×10^{-10}
4,962.3	.00545	.272	1.6×10^{-10}
5,034.1	.00550	.275	2.0×10^{-10}
5,130.7	.00560	.280	2.2×10^{-10}
5,202.5	.00560	.280	1.9×10^{-10}
5,322.4	.00570	.285	2.0×10^{-10}
5,370.0	.00570	.285	1.9×10^{-10}
5,490.2	.00575	.288	1.9×10^{-10}
5,538.4	.00575	.288	2.1×10^{-10}
5,634.7	.00585	.292	2.0×10^{-10}
5,706.1	.00585	.292	1.9×10^{-10}
5,802.8	.00585	.292	1.9×10^{-10}
5,874.4	.00590	.295	2.2×10^{-10}
5,970.3	.00595	.298	1.8×10^{-10}
6,042.6	.00600	.300	1.8×10^{-10}
6,138.5	.00600	.300	1.9×10^{-10}
6,210.1	.00605	.302	1.8×10^{-10}
6,308.2	.00610	.305	1.8×10^{-10}
6,378.7	.00615	.308	1.7×10^{-10}
6,474.2	.00620	.310	1.4×10^{-10}
6,546.2	.00625	.312	1.7×10^{-10}

TABLE 2 (Continued)

Time	Length Change Δ L (inch) (2" G. L.)	Creep (%)	Pressure (Torr)
6,642.6 Hours	.00635	.318	1.7×10^{-10}
6,714.9	.00635	.318	1.6×10^{-10}
6,810.6	.00635	.318	1.8×10^{-10}
6,882.0	.00640	.320	1.6×10^{-10}
6,978.0	.00640	.320	1.6×10^{-10}
7,049.8	.00640	.320	1.9×10^{-10}
7,145.9	.00640	.320	1.6×10^{-10}
7,217.9	.00650	.325	1.7×10^{-10}
7,313.9	.00655	.328	1.8×10^{-10}
7,386.2	.00660	.330	1.6×10^{-10}
7,482.6	.00665	.332	1.5×10^{-10}
7,554.1	.00675	.338	1.6×10^{-10}
7,650.4	.00680	.340	1.7×10^{-10}
7,721.8	.00685	.342	1.6×10^{-10}
7,819.5	.00690	.345	1.6×10^{-10}
7,890.3	.00659	.348	1.6×10^{-10}
7,986.1	.00700	.350	1.6×10^{-10}
8,058.2	.00705	.352	1.6×10^{-10}
8,154.1	.00710	.355	1.7×10^{-10}
8,226.1	.00720	.360	1.8×10^{-10}
8,393.4	.00725	.362	1.6×10^{-10}
8,538.5	.00735	.368	1.5×10^{-10}
8,563.1	.00735	.368	1.6×10^{-10}
8,657.5	.00740	.370	1.9×10^{-10}
8,728.9	.00750	.375	1.5×10^{-10}
8,825.0	.00750	.375	1.6×10^{-10}
8,897.6	.00755	.378	1.6×10^{-10}
8,995.4	.00755	.378	1.6×10^{-10}
9,064.9	.00760	.380	1.5×10^{-10}
9,168.9	.00765	.382	1.4×10^{-10}
9,235.1	.00770	.385	1.4×10^{-10}
9,328.8	.00770	.385	1.4×10^{-10}
9,401.9	.00775	.388	1.6×10^{-10}
9,497.4	.00780	.390	1.6×10^{-10}
9,569.2	.00790	.395	1.4×10^{-10}

TABLE 2 (Continued)

Time	Length Change Δ L (inch) (2" G. L.)	Creep (%)	Pressure (Torr)
9,666.4 Hours	.00800	.400	1.5×10^{-10}
9,736.7	.00805	.402	1.4×10^{-10}
9,832.8	.00815	.408	1.4×10^{-10}
9,904.8	.00815	.408	1.5×10^{-10}
10,001.3	.00815	.408	1.4×10^{-10}
10,193.0	.00815	.408	1.5×10^{-10}
10,240.9	.00815	.408	1.6×10^{-10}
10,338.7	.00815	.408	1.7×10^{-10}
10,408.7	.00815	.408	1.6×10^{-10}
10,506.8	.00815	.408	1.6×10^{-10}
10,577.0	.00820	.410	1.5×10^{-10}
10,673.2	.00820	.410	1.5×10^{-10}
10,745.0	.00820	.410	1.4×10^{-10}
10,841.1	.00820	.410	1.5×10^{-10}
10,913.0	.00825	.412	1.4×10^{-10}
11,009.4	.00825	.412	1.4×10^{-10}
11,080.8	.00830	.415	1.4×10^{-10}
11,177.0	.00835	.418	1.4×10^{-10}
11,249.3	.00835	.418	1.4×10^{-10}
11,369.8	.00840	.420	1.4×10^{-10}
11,416.7	.00845	.422	1.4×10^{-10}
11,513.4	.00850	.425	1.6×10^{-10}
11,585.0	.00850	.425	1.4×10^{-10}
11,681.2	.00860	.430	1.4×10^{-10}
11,752.9	.00865	.432	1.4×10^{-10}
11,851.0	.00870	.435	1.5×10^{-10}
11,920.8	.00875	.438	1.4×10^{-10}
12,017.1	.00885	.442	1.2×10^{-10}
12,088.9	.00885	.442	1.3×10^{-10}
12,184.9	.00885	.442	1.1×10^{-10}
12,257.0	.00890	.445	1.4×10^{-10}
12,353.8	.00895	.448	1.2×10^{-10}
12,425.9	.00900	.450	1.3×10^{-10}
12,521.4	.00895	.448	1.5×10^{-10}
12,593.4	.00900	.450	1.2×10^{-10}

TABLE 2 (Continued)

Time	Length Change Δ L (inch) (2" G. L.)	Creep (%)	Pressure (Torr)
12,690.3 Hours	.00910	.455	1.2×10^{-10}
12,762.5	.00920	.460	1.2×10^{-10}
12,858.6	.00925	.462	1.2×10^{-10}
12,929.8	.00925	.462	1.4×10^{-10}
13,026.3	.00935	.468	1.2×10^{-10}
13,098.0	.00935	.468	1.1×10^{-10}
13,194.2	.00935	.468	1.3×10^{-10}
13,242.3	.00945	.472	1.1×10^{-10}
13,362.0	.00950	.475	1.1×10^{-10}
13,434.6	.00955	.478	1.2×10^{-10}
13,098.0	.00935	.468	1.1×10^{-10}
13,194.2	.00935	.468	1.3×10^{-10}
13,242.3	.00945	.472	1.1×10^{-10}
13,362.0	.00950	.475	1.1×10^{-10}
13,434.6	.00955	.478	1.2×10^{-10}
13,530.0	.00965	.482	1.3×10^{-10}
13,602.5	.00965	.482	1.1×10^{-10}
13,698.0	.00970	.485	1.3×10^{-10}
13,769.9	.00980	.490	1.2×10^{-10}
13,865.9	.00990	.495	1.2×10^{-10}
13,938.0	.00990	.495	1.2×10^{-10}
14,106.4	.00995	.498	1.3×10^{-10}

Test in progress
Specimen B-32

TABLE 3

Creep Test Data, TZC Plate Heat M-91, Stress Relieved 2500°F (1371°C) 1 Hour, Tested at 1900°F (1038°C), and 22,000 PSI ($1.52 \times 10^8 N/m^2$)

Time	Length Change Δ L (inch) (2" G. L.)	Creep (%)	Pressure (Torr)
1 Minute	-.00005	-.002	9.7×10^{-9}
2	-.00005	-.002	9.7×10^{-9}
3	-.00010	-.005	9.7×10^{-9}
4	.00005	.002	9.7×10^{-9}
5	.00005	.002	9.7×10^{-9}
6	.00005	.002	9.7×10^{-9}
7	.00005	.002	9.7×10^{-9}
8	.00010	.005	9.7×10^{-9}
9	.00010	.005	9.7×10^{-9}
10	.00010	.005	9.7×10^{-9}
15	.00015	.008	9.7×10^{-9}
30	.00020	.010	9.7×10^{-9}
45	.00020	.010	9.7×10^{-9}
60	.00030	.015	9.7×10^{-9}
17.2 Hours	.00065	.032	5.2×10^{-9}
41.3	.00115	.058	3.7×10^{-9}
44.2	.00120	.060	3.7×10^{-9}
70.1	.00180	.090	3.2×10^{-9}
98.5	.00195	.098	2.6×10^{-9}
116.1	.00200	.100	2.5×10^{-9}
137.2	.00200	.100	2.2×10^{-9}
161.1	.00205	.102	1.8×10^{-9}
184.9	.00210	.105	1.7×10^{-9}
209.0	.00205	.102	1.7×10^{-9}
305.0	.00245	.122	1.5×10^{-9}
329.2	.00250	.125	1.4×10^{-9}
353.4	.00270	.135	1.3×10^{-9}
377.0	.00275	.138	1.1×10^{-9}
449.1	.00285	.142	1.0×10^{-9}
473.0	.00295	.148	1.0×10^{-9}
497.1	.00300	.150	1.2×10^{-9}
521.9	.00310	.155	1.3×10^{-9}
546.8	.00310	.155	1.5×10^{-9}
617.7	.00315	.158	1.4×10^{-9}
641.3	.00320	.160	1.2×10^{-9}
664.8	.00325	.162	1.2×10^{-9}

TABLE 3 (Continued)

Time	Length Change Δ L (inch) (2" G. L.)	Creep (%)	Pressure (Torr)
689.1 Hours	.00335	.168	1.2×10^{-9}
713.0	.00340	.170	6.4×10^{-10}
809.1	.00350	.175	9.6×10^{-10}
833.4	.00355	.178	9.7×10^{-10}
858.0	.00360	.180	9.5×10^{-10}
881.1	.00365	.182	9.2×10^{-10}
953.4	.00375	.188	8.3×10^{-10}
977.3	.00380	.190	9.2×10^{-10}
1,003.2	.00380	.190	9.1×10^{-10}
1,034.2	.00380	.190	8.8×10^{-10}
1,049.2	.00375	.188	8.5×10^{-10}
1,121.2	.00390	.195	7.9×10^{-10}
1,145.0	.00385	.192	8.2×10^{-10}
1,169.1	.00390	.195	7.8×10^{-10}
1,195.4	.00390	.195	7.5×10^{-10}
1,218.0	.00400	.200	3.5×10^{-10}
1,289.8	.00425	.212	6.6×10^{-10}
1,314.0	.00430	.215	7.3×10^{-10}
1,337.9	.00430	.215	6.9×10^{-10}
1,361.8	.00435	.218	4.1×10^{-10}
1,385.7	.00445	.222	6.4×10^{-10}
1,458.1	.00460	.230	3.2×10^{-10}
1,481.5	.00470	.235	3.5×10^{-10}
1,505.8	.00470	.235	7.1×10^{-10}
1,531.0	.00475	.238	7.0×10^{-10}
1,554.2	.00480	.240	6.6×10^{-10}
1,625.3	.00470	.235	6.9×10^{-10}
1,649.5	.00470	.235	3.1×10^{-10}
1,673.1	.00485	.242	6.6×10^{-10}
1,696.3	.00490	.245	6.6×10^{-10}
1,720.9	.00490	.245	6.4×10^{-10}
1,793.2	.00480	.240	6.6×10^{-10}
1,817.0	.00495	.246	3.0×10^{-10}
1,840.8	.00510	.255	6.4×10^{-10}
1,864.9	.00520	.260	6.3×10^{-10}
1,888.7	.00520	.260	6.2×10^{-10}

TABLE 3 (Continued)

Time	Length Change Δ L (inch) (2" G. L.)	Creep (%)	Pressure (Torr)
1,963.3 Hours	.00525	.262	6.5×10^{-10}
1,984.9	.00535	.268	2.6×10^{-10}
2,009.2	.00535	.268	6.0×10^{-10}
2,033.3	.00540	.270	6.4×10^{-10}
2,056.9	.00555	.278	6.7×10^{-10}
2,129.9	.00570	.285	7.2×10^{-10}
2,153.1	.00565	.282	6.8×10^{-10}
2,177.4	.00570	.285	7.0×10^{-10}
2,201.2	.00580	.290	7.0×10^{-10}
2,225.1	.00580	.290	5.8×10^{-10}
2,321.7	.00590	.295	6.4×10^{-10}
2,345.3	.00585	.292	6.4×10^{-10}
2,368.9	.00585	.292	5.7×10^{-10}
2,393.0	.00590	.295	6.8×10^{-10}
2,465.5	.00585	.292	6.6×10^{-10}
2,489.2	.00585	.292	6.8×10^{-10}
2,513.2	.00590	.295	6.4×10^{-10}
2,536.9	.00590	.295	6.6×10^{-10}
2,561.6	.00590	.295	6.4×10^{-10}
2,633.7	.00595	.298	6.1×10^{-10}
2,657.2	.00595	.298	6.2×10^{-10}
2,681.2	.00595	.298	6.2×10^{-10}
2,705.3	.00600	.300	6.4×10^{-10}
2,729.0	.00605	.302	6.3×10^{-10}
2,801.0	.00605	.302	6.3×10^{-10}
2,825.3	.00605	.302	6.2×10^{-10}
2,849.1	.00610	.305	6.2×10^{-10}
2,873.4	.00615	.308	6.1×10^{-10}
2,897.2	.00615	.308	6.1×10^{-10}
2,969.3	.00630	.315	4.6×10^{-10}
2,993.1	.00640	.320	5.0×10^{-10}
3,917.0	.00635	.318	5.0×10^{-10}
3,043.1	.00640	.320	5.8×10^{-10}
3,065.3	.00640	.320	6.2×10^{-10}
3,137.1	.00650	.325	5.0×10^{-10}

TABLE 3 (Continued)

Time	Length Change Δ L (inch) (2" G. L.)	Creep (%)	Pressure (Torr)
3,161.2 Hours	.00660	.330	4.6×10^{-10}
3,185.1	.00660	.330	4.7×10^{-10}
3,209.2	.00660	.330	6.0×10^{-10}
3,233.1	.00665	.332	5.2×10^{-10}
3,305.0	.00670	.335	5.9×10^{-10}
3,329.0	.00675	.338	5.9×10^{-10}
3,353.4	.00675	.338	5.6×10^{-10}
3,377.2	.00675	.338	6.0×10^{-10}
3,401.0	.00675	.338	4.6×10^{-10}
3,473.0	.00675	.338	4.5×10^{-10}
3,500.0	.00680	.340	5.7×10^{-10}
3,521.1	.00685	.342	5.8×10^{-10}
3,545.6	.00685	.342	5.8×10^{-10}
3,569.2	.00680	.340	5.8×10^{-10}
3,642.0	.00695	.348	5.5×10^{-10}
3,666.0	.00690	.345	5.6×10^{-10}
3,690.2	.00695	.348	5.8×10^{-10}
3,714.4	.00695	.348	5.4×10^{-10}
3,738.1	.00695	.348	5.7×10^{-10}
3,810.1	.00695	.348	5.7×10^{-10}
3,834.2	.00700	.350	5.6×10^{-10}
3,858.5	.00705	.352	5.5×10^{-10}
3,882.0	.00705	.352	5.6×10^{-10}
3,906.0	.00705	.352	5.0×10^{-10}
3,978.2	.00710	.355	5.2×10^{-10}
4,002.1	.00710	.355	3.6×10^{-10}
4,026.7	.00715	.358	4.9×10^{-10}
4,050.3	.00720	.360	4.6×10^{-10}
4,074.0	.00720	.360	4.5×10^{-10}
4,146.2	.00730	.365	5.1×10^{-10}
4,170.1	.00725	.362	5.3×10^{-10}
4,194.5	.00730	.365	5.5×10^{-10}
4,242.0	.00730	.365	5.2×10^{-10}
4,314.2	.00735	.368	5.2×10^{-10}
4,338.1	.00735	.368	5.0×10^{-10}
4,362.1	.00735	.368	5.1×10^{-10}

TABLE 3 (Continued)

Time	Length Change Δ L (inch) (2" G. L.)	Creep (%)	Pressure (Torr)
4,386.6 Hours	.00735	.368	5.1×10^{-10}
4,410.5	.00735	.368	4.8×10^{-10}
4,482.7	.00735	.368	5.0×10^{-10}
4,506.3	.00740	.370	4.9×10^{-10}
4,530.2	.00740	.370	5.0×10^{-10}
4,554.2	.00745	.372	4.8×10^{-10}
4,578.2	.00745	.372	4.4×10^{-10}
4,650.5	.00750	.375	4.9×10^{-10}
4,674.1	.00750	.375	4.9×10^{-10}
4,698.2	.00750	.375	4.9×10^{-10}
4,722.3	.00750	.375	4.9×10^{-10}
4,746.2	.00755	.378	4.9×10^{-10}
4,818.9	.00755	.378	4.8×10^{-10}
4,842.3	.00760	.380	4.9×10^{-10}
4,866.6	.00760	.380	4.6×10^{-10}
4,890.6	.00765	.382	5.0×10^{-10}
5,010.7	.00775	.388	4.7×10^{-10}
5,034.4	.00780	.390	4.7×10^{-10}
5,058.3	.00780	.390	4.6×10^{-10}
5,082.7	.00780	.390	4.6×10^{-10}
5,178.4	.00795	.398	4.6×10^{-10}
5,203.2	.00795	.398	4.5×10^{-10}
5,226.6	.00800	.400	4.3×10^{-10}
5,250.4	.00800	.400	4.6×10^{-10}
5,324.5	.00810	.405	3.8×10^{-10}
5,348.4	.00815	.408	4.1×10^{-10}
5.370.7	.00820	.410	4.4×10^{-10}
5,394.2	.00820	.410	4.4×10^{-10}
5,418.5	.00820	.410	4.6×10^{-10}
5,491.6	.00825	.412	4.1×10^{-10}
5,514.2	.00825	.412	4.3×10^{-10}
5,538.6	.00830	.415	4.0×10^{-10}
5,562.6	.00835	.418	4.6×10^{-10}
5,586.4	.00835	.418	4.0×10^{-10}
5,658.4	.00840	.420	4.5×10^{-10}
5,682.3	.00840	.420	4.3×10^{-10}
5,706.6	.00845	.422	4.6×10^{-10}
5,730.8	.00850	.425	4.1×10^{-10}

TABLE 3 (Continued)

Time	Length Change Δ L (inch) (2" G. L.)	Creep (%)	Pressure (Torr)
5,754.7	.00850	.425	4.2×10^{-10}
5,826.6	.00855	.428	4.1×10^{-10}
5,850.2	.00860	.430	3.7×10^{-10}
5,874.3	.00865	.432	4.3×10^{-10}
5,898.8	.00865	.432	3.8×10^{-10}
5,922.6	.00870	.435	4.5×10^{-10}
5,996.3	.00870	.435	4.0×10^{-10}
6,018.5	.00870	.435	3.7×10^{-10}
6,042.4	.00865	.432	3.9×10^{-10}
6,066.8	.00875	.438	4.4×10^{-10}
6,093.1	.00885	.442	4.4×10^{-10}
6,162.3	.00890	.445	4.1×10^{-10}
6,186.6	.00895	.448	3.7×10^{-10}
6,210.0	.00895	.448	4.0×10^{-10}
6,234.4	.00895	.448	3.6×10^{-10}
6,258.4	.00895	.448	4.3×10^{-10}
6,330.8	.00900	.450	3.6×10^{-10}
6,354.4	.00900	.450	4.3×10^{-10}
6,379.0	.00905	.452	3.6×10^{-10}
6,403.0	.00905	.452	4.0×10^{-10}
6,426.7	.00905	.452	3.9×10^{-10}
6,498.8	.00910	.455	4.0×10^{-10}
6,522.9	.00920	.460	3.8×10^{-10}
6,546.5	.00925	.462	4.1×10^{-10}
6,570.3	.00920	.460	3.8×10^{-10}
6,594.3	.00925	.462	4.1×10^{-10}
6,666.2	.00925	.462	3.8×10^{-10}
6,690.4	.00925	.462	4.0×10^{-10}
6,714.0	.00930	.465	4.0×10^{-10}
6,737.9	.00930	.465	4.2×10^{-10}
6,761.9	.00935	.468	3.2×10^{-10}
6,834.0	.00945	.472	4.0×10^{-10}
6,858.1	.00940	.470	4.0×10^{-10}
6,882.6	.00940	.470	4.2×10^{-10}
6,906.0	.00940	.470	4.1×10^{-10}
6,930.2	.00940	.470	4.2×10

TABLE 3 (Continued)

Time	Length Change Δ L (inch) (2" G. L.)	Creep (%)	Pressure (Torr)
7,002.0 Hours	.00940	.470	3.8×10^{-10}
7,026.3	.00940	.470	4.0×10^{-10}
7,050.3	.00945	.472	4.2×10^{-10}
7,074.3	.00945	.472	4.0×10^{-10}
7,170.7	.00950	.475	4.1×10^{-10}
7,194.5	.00960	.480	4.1×10^{-10}
7,218.2	.00960	.480	4.1×10^{-10}
7,242.1	.00960	.480	3.7×10^{-10}
7,266.6	.00960	.480	4.0×10^{-10}
7,338.5	.00965	.482	4.0×10^{-10}
7,362.2	.00965	.482	4.0×10^{-10}
7,386.2	.00960	.480	3.9×10^{-10}
7,410.0	.00965	.482	3.9×10^{-10}
7,434.0	.00965	.482	3.9×10^{-10}
7,507.7	.00965	.482	3.8×10^{-10}
7,530.1	.00970	.485	3.8×10^{-10}
7,554.2	.00975	.488	3.9×10^{-10}
7,578.4	.00970	.485	3.6×10^{-10}
7,674.4	.00990	.495	3.8×10^{-10}
7,698.1	.00990	.495	3.9×10^{-10}
7,722.0	.01000	.500	3.9×10^{-10}
7,746.3	.01005	.502	4.0×10^{-10}
7,770.1	.01010	.505	4.1×10^{-10}
7,842.2	.01015	.508	4.1×10^{-10}
7,866.6	.01015	.508	3.8×10^{-10}
7,890.2	.01010	.505	3.4×10^{-10}
7,914.3	.01010	.505	3.5×10^{-10}
7,938.3	.01010	.505	3.5×10^{-10}
8,009.5	.01015	.508	3.8×10^{-10}
8,033.4	.01020	.510	3.8×10^{-10}
8,058.1	.01020	.510	3.7×10^{-10}
8,081.6	.01025	.512	3.8×10^{-10}
8,105.1	.01020	.510	3.6×10^{-10}
8,226.7	.01035	.518	3.7×10^{-10}
8,251.3	.01035	.518	3.6×10^{-10}
8,273.0	.01040	.520	3.6×10^{-10}
8,345.6	.01060	.530	3.4×10^{-10}

TABLE 3 (Continued)

Time	Length Change Δ L (inch) (2" G. L.)	Creep (%)	Pressure (Torr)
8,369.4 Hours	.01060	.530	3.5×10^{-10}
8,393.5	.01065	.532	3.6×10^{-10}
8,417.1	.01075	.538	3.6×10^{-10}
8,443.4	.01080	.540	3.6×10^{-10}
8,513.1	.01080	.540	3.6×10^{-10}
8,561.0	.01085	.542	3.7×10^{-10}
8,585.9	.01085	.542	3.6×10^{-10}
8,609.8	.01090	.545	3.5×10^{-10}
8,683.5	.01100	.550	3.5×10^{-10}
8,730.0	.01100	.550	3.5×10^{-10}
8,753.4	.01100	.550	3.4×10^{-10}
8,777.4	.01100	.550	3.4×10^{-10}
8,849.1	.01100	.550	3.5×10^{-10}
8,897.7	.01105	.552	3.5×10^{-10}
8,873.2	.01100	.550	3.5×10^{-10}
8,923.4	.01105	.552	3.6×10^{-10}
8,945.2	.01110	.555	3.7×10^{-10}
9,016.9	.01120	.560	3.6×10^{-10}
9,041.6	.01130	.565	3.5×10^{-10}
9,065.5	.01125	.562	3.7×10^{-10}
9,090.1	.01130	.565	3.8×10^{-10}
9,113.2	.01125	.562	3.8×10^{-10}
9,185.6	.01135	.568	4.0×10^{-10}
9,209.1	.01135	.568	4.0×10^{-10}
9,233.0	.01135	.568	4.1×10^{-10}
9,257.3	.01135	.568	4.0×10^{-10}
9,280.9	.01135	.568	4.0×10^{-10}
9,354.5	.01145	.572	4.0×10^{-10}
9,377.4	.01145	.572	4.0×10^{-10}
9,400.9	.01145	.572	4.1×10^{-10}
9,424.9	.01150	.575	4.1×10^{-10}
9,448.9	.01160	.580	4.0×10^{-10}
9,520.9	.01170	.585	4.0×10^{-10}
9,568.9	.01170	.585	4.0×10^{-10}
9,593.0	.01170	.585	4.0×10^{-10}
9,617.1	.01170	.585	3.8×10^{-10}
9,689.4	.01170	.585	4.2×10^{-10}
9,697.3	.01170	.585	4.1×10^{-10}

Test terminated - sufficient data obtained
Specimen B-33

TABLE 4

Creep Test Data, TZC Plate Heat 4345, Stress Relieved 2500°F (1371°C) 1 Hour, Tested at 2000°F (1093°C), and 2200 PSI ($1.52 \times 10^8 N/m^2$)

Time	Length Change Δ L (inch) (2" G. L.)	Creep (%)	Pressure (Torr)
1 Minute	.00000	.000	2.2×10^{-8}
2	.00005	.002	2.2×10^{-8}
3	.00000	.000	2.2×10^{-8}
4	.00005	.002	2.2×10^{-8}
5	.00000	.000	2.2×10^{-8}
6	.00005	.002	2.2×10^{-8}
7	.00010	.005	2.2×10^{-8}
8	.00005	.002	2.2×10^{-8}
9	.00005	.002	2.2×10^{-8}
10	.00005	.002	2.2×10^{-8}
15	.00010	.005	2.2×10^{-8}
30	.00015	.008	2.2×10^{-8}
45	.00010	.005	2.2×10^{-8}
60	.00010	.005	2.2×10^{-8}
67.1 Hours	.00110	.055	4.9×10^{-9}
91.1	.00130	.065	3.6×10^{-9}
115.0	.00140	.070	3.0×10^{-9}
139.1	.00150	.075	2.4×10^{-9}
163.2	.00165	.082	2.3×10^{-9}
235.0	.00200	.100	1.7×10^{-9}
259.0	.00210	.105	1.6×10^{-9}
283.3	.00215	.108	1.4×10^{-9}
307.2	.00220	.110	1.4×10^{-9}
331.0	.00220	.110	1.3×10^{-9}
403.0	.00230	.115	1.2×10^{-9}
430.0	.00240	.120	1.1×10^{-9}
475.5	.00260	.130	1.0×10^{-9}
499.1	.00270	.135	1.0×10^{-9}
572.0	.00275	.138	9.3×10^{-10}
596.0	.00280	.140	8.7×10^{-10}
620.1	.00290	.145	8.9×10^{-10}
644.3	.00305	.152	8.1×10^{-10}
668.1	.00310	.155	7.9×10^{-10}
740.0	.00325	.162	7.7×10^{-10}
764.2	.00330	.165	8.0×10^{-10}
788.5	.00340	.170	7.0×10^{-10}

TABLE 4 (Continued)

Time	Length Change Δ L (inch) (2" G. L.)	Creep (%)	Pressure (Torr)
812.0 Hours	.00340	.170	7.2×10^{-10}
835.9	.00340	.170	6.9×10^{-10}
908.2	.00345	.172	6.6×10^{-10}
932.1	.00350	.175	7.0×10^{-10}
956.6	.00350	.175	6.8×10^{-10}
980.2	.00350	.175	7.0×10^{-10}
1,004.0	.00355	.178	6.6×10^{-10}
1,066.2	.00365	.182	5.7×10^{-10}
1,090.1	.00365	.182	5.9×10^{-10}
1,114.5	.00370	.185	6.4×10^{-10}
1,162.0	.00370	.185	5.6×10^{-10}
1,234.2	.00375	.188	5.6×10^{-10}
1,258.1	.00380	.190	5.0×10^{-10}
1,282.1	.00385	.192	5.5×10^{-10}
1,306.6	.00390	.195	5.1×10^{-10}
1,330.5	.00400	.200	4.9×10^{-10}
1,402.7	.00420	.210	4.6×10^{-10}
1,426.3	.00430	.215	5.0×10^{-10}
1,450.2	.00430	.215	5.4×10^{-10}
1,474.2	.00430	.215	4.9×10^{-10}
1,498.2	.00440	.220	5.3×10^{-10}
1,570.5	.00440	.220	4.6×10^{-10}
1,594.1	.00440	.220	4.9×10^{-10}
1,618.1	.00445	.222	4.8×10^{-10}
1,642.3	.00445	.222	4.6×10^{-10}
1,666.2	.00455	.228	4.8×10^{-10}
1,738.9	.00460	.230	5.0×10^{-10}
1,762.3	.00460	.230	4.6×10^{-10}
1,786.5	.00465	.232	4.7×10^{-10}
1,810.7	.00475	.238	4.8×10^{-10}
1,930.7	.00490	.245	4.1×10^{-10}
1,954.4	.00490	.245	4.2×10^{-10}
1,978.3	.00500	.250	4.3×10^{-10}
2,002.6	.00500	.250	4.3×10^{-10}
2,098.3	.00515	.258	4.2×10^{-10}
2,123.2	.00520	.260	4.2×10^{-10}

TABLE 4 (Continued)

Time	Length Change Δ L (inch) (2" G. L.)	Creep (%)	Pressure (Torr)
2,146.6 Hours	.00530	.265	3.8×10^{-10}
2,170.4	.00535	.268	4.2×10^{-10}
2,243.5	.00540	.270	3.5×10^{-10}
2,268.4	.00550	.275	3.5×10^{-10}
2,290.5	.00555	.278	3.6×10^{-10}
2,314.2	.00555	.278	4.0×10^{-10}
2,338.4	.00560	.280	4.1×10^{-10}
2,411.6	.00560	.280	3.4×10^{-10}
2,434.2	.00565	.282	3.6×10^{-10}
2,458.4	.00570	.285	3.4×10^{-10}
2,482.6	.00575	.288	3.7×10^{-10}
2,506.4	.00580	.290	3.2×10^{-10}
2,578.4	.00585	.292	3.8×10^{-10}
2,602.3	.00590	.295	3.5×10^{-10}
2,626.5	.00595	.298	3.7×10^{-10}
2,650.7	.00595	.298	3.4×10^{-10}
2,674.7	.00605	.302	3.4×10^{-10}
2,746.6	.00615	.308	3.4×10^{-10}
2,770.1	.00620	.310	3.2×10^{-10}
2,794.3	.00625	.312	4.9×10^{-10}
2,818.8	.00630	.315	3.0×10^{-10}
2,842.5	.00635	.318	3.6×10^{-10}
2,916.3	.00640	.320	3.4×10^{-10}
2,938.5	.00645	.322	1.4×10^{-10}
2,962.4	.00650	.325	3.1×10^{-10}
2,986.8	.00650	.325	3.4×10^{-10}
3,013.1	.00655	.328	2.8×10^{-10}
3,082.3	.00665	.332	1.7×10^{-10}
3,106.6	.00670	.335	2.8×10^{-10}
3,130.0	.00680	.340	3.1×10^{-10}
3,154.3	.00680	.340	1.5×10^{-10}
3,178.3	.00680	.340	1.8×10^{-10}
3,250.7	.00690	.345	2.6×10^{-10}
3,274.4	.00695	.348	3.2×10^{-10}
3,299.0	.00695	.348	2.6×10^{-10}

TABLE 4 (Continued)

Time	Length Change Δ L (inch) (2" G. L.)	Creep (%)	Pressure (Torr)
3,323.0 Hours	.00700	.350	2.9×10^{-10}
3,346.7	.00700	.350	2.9×10^{-10}
3,418.7	.00700	.350	3.0×10^{-10}
3,442.8	.00700	.350	1.8×10^{-10}
3,466.4	.00700	.350	1.8×10^{-10}
3,490.2	.00695	.348	1.6×10^{-10}
3,514.2	.00700	.350	3.0×10^{-10}
3,586.1	.00710	.355	1.8×10^{-10}
3,610.4	.00720	.360	1.7×10^{-10}
3,634.0	.00725	.362	1.7×10^{-10}
3,657.9	.00730	.365	1.6×10^{-10}
3,681.9	.00740	.370	3.0×10^{-10}
3,754.0	.00735	.368	1.6×10^{-10}
3,778.1	.00740	.370	1.6×10^{-10}
3,802.6	.00755	.378	1.7×10^{-10}
3,826.0	.00755	.378	1.6×10^{-10}
3,850.2	.00750	.375	1.5×10^{-10}
3,922.0	.00750	.375	1.6×10^{-10}
3,802.6	.00755	.378	1.7×10^{-10}
3,826.0	.00755	.378	1.6×10^{-10}
3,850.2	.00750	.375	1.5×10^{-10}
3,922.0	.00750	.375	1.6×10^{-10}
3,946.3	.00760	.380	1.5×10^{-10}
3,970.3	.00755	.378	1.6×10^{-10}
3,994.3	.00765	.382	1.4×10^{-10}
4,090.7	.00775	.388	2.0×10^{-10}
4,114.5	.00775	.388	1.6×10^{-10}
4,138.2	.00780	.390	1.7×10^{-10}
4,162.1	.00790	.395	1.3×10^{-10}
4,186.6	.00785	.392	1.5×10^{-10}
4,258.5	.00795	.398	1.5×10^{-10}
4,282.2	.00800	.400	1.5×10^{-10}
4,306.2	.00810	.405	1.6×10^{-10}
4,330.0	.00810	.405	1.4×10^{-10}
4,354.0	.00815	.408	1.4×10^{-10}

TABLE 4 (Continued)

Time	Length Change Δ L (inch) (2" G. L.)	Creep (%)	Pressure (Torr)
4,427.7 Hours	.00825	.412	1.4×10^{-10}
4,450.1	.00825	.412	2.6×10^{-10}
4,474.2	.00825	.412	1.6×10^{-10}
4,498.4	.00825	.412	1.4×10^{-10}
4,522.4	.00830	.415	1.5×10^{-10}
4,594.4	.00840	.420	1.5×10^{-10}
4,618.1	.00850	.425	2.8×10^{-10}
4,642.0	.00850	.425	2.8×10^{-10}
4,666.3	.00860	.430	1.7×10^{-10}
4,690.1	.00870	.435	1.7×10^{-10}
4,762.2	.00870	.435	2.9×10^{-10}
4,786.5	.00875	.438	1.4×10^{-10}
4,810.2	.00875	.438	1.3×10^{-10}
4,834.3	.00875	.438	1.4×10^{-10}
4,929.5	.00890	.445	1.4×10^{-10}
4,953.4	.00900	.450	1.6×10^{-10}
4,978.1	.00895	.448	2.9×10^{-10}
5,001.5	.00895	.448	1.8×10^{-10}
5,025.1	.00895	.448	1.6×10^{-10}
5,146.7	.00900	.450	2.9×10^{-10}
5,171.2	.00900	.450	2.7×10^{-10}
5,193.0	.00905	.452	2.8×10^{-10}
5,265.6	.00910	.455	2.8×10^{-10}
5,289.4	.00910	.455	1.4×10^{-10}
5,313.5	.00920	.460	1.6×10^{-10}
5,337.1	.00925	.462	1.6×10^{-10}
5,363.3	.00925	.462	1.5×10^{-10}
5,433.1	.00925	.462	2.8×10^{-10}
5,457.1	.00930	.465	2.4×10^{-10}
5,481.0	.00935	.468	2.8×10^{-10}
5,505.9	.00940	.470	2.8×10^{-10}
5,529.8	.00945	.472	1.6×10^{-10}
5,603.5	.00950	.475	1.3×10^{-10}
5,650.0	.00960	.480	1.4×10^{-10}
5,673.4	.00970	.485	2.8×10^{-10}

TABLE 4 (Continued)

Time	Length Change Δ L (inch) (2" G. L.)	Creep (%)	Pressure (Torr)
5,697.4 Hours	.00970	.485	2.6×10^{-10}
5,769.0	.00970	.485	1.3×10^{-10}
5,793.2	.00980	.490	2.3×10^{-10}
5,817.7	.00990	.495	1.4×10^{-10}
5,843.4	.00990	.495	1.6×10^{-10}
5,865.1	.00990	.495	1.7×10^{-10}
5,936.9	.01000	.500	1.5×10^{-10}
5,961.5	.01000	.500	2.5×10^{-10}
5,985.5	.01000	.500	2.8×10^{-10}
6,010.1	.01010	.505	1.8×10^{-10}
6,033.1	.01015	.508	2.8×10^{-10}
6,105.6	.01015	.508	1.3×10^{-10}
6,129.1	.01015	.508	1.3×10^{-10}
6,152.9	.01020	.510	2.8×10^{-10}
6,177.3	.01030	.515	1.3×10^{-10}
6,200.9	.01035	.518	2.6×10^{-10}
6,274.5	.01040	.520	2.6×10^{-10}
6,297.3	.01050	.525	1.5×10^{-10}
6,320.9	.01070	.535	1.4×10^{-10}
6,344.9	.01075	.538	1.4×10^{-10}
6,368.9	.01075	.538	2.5×10^{-10}
6,440.9	.01075	.538	1.3×10^{-10}
6,488.9	.01075	.538	1.3×10^{-10}
6,513.0	.01070	.535	1.4×10^{-10}
6,537.1	.01070	.535	1.3×10^{-10}
6,609.4	.01070	.535	2.6×10^{-10}
6,633.0	.01070	.535	2.4×10^{-10}
6,657.7	.01070	.535	1.4×10^{-10}
6,681.8	.01075	.538	2.4×10^{-10}
6,706.0	.01080	.540	2.2×10^{-10}
6,777.7	.01095	.548	1.7×10^{-10}
6,801.1	.01095	.548	1.3×10^{-10}
6,825.3	.01090	.545	1.3×10^{-10}
6,849.0	.01100	.550	1.3×10^{-10}
6,873.2	.01100	.550	1.4×10^{-10}
6,946.8	.01110	.555	2.6×10^{-10}

TABLE 4 (Continued)

Time	Length Change Δ L (inch) (2" G. L.)	Creep (%)	Pressure (Torr)
6,969.4 Hours	.01120	.560	1.4×10^{-10}
6,998.4	.01150	.575	2.4×10^{-10}
7,016.7	.01160	.580	2.6×10^{-10}
7,041.0	.01160	.580	2.4×10^{-10}
7,115.3	.01160	.580	2.3×10^{-10}
7,137.1	.01165	.582	2.3×10^{-10}
7,161.1	.01170	.585	2.3×10^{-10}
7,185.1	.01170	.585	2.6×10^{-10}
7,209.0	.01180	.590	1.5×10^{-10}
7,281.3	.01190	.595	1.7×10^{-10}
7,305.0	.01190	.595	1.2×10^{-10}
7,329.1	.01190	.595	2.2×10^{-10}
7,353.0	.01190	.595	1.4×10^{-10}
7,377.0	.01190	.595	2.0×10^{-10}
7,449.2	.01190	.595	1.5×10^{-10}
7,472.9	.01190	.595	1.3×10^{-10}
7,497.3	.01195	.598	1.3×10^{-10}
7,521.1	.01190	.595	1.2×10^{-10}
7,545.1	.01195	.598	1.6×10^{-10}
7,617.5	.01195	.598	1.2×10^{-10}
7,641.0	.01190	.595	1.5×10^{-10}
7,665.0	.01190	.595	1.2×10^{-10}
7,688.9	.01195	.598	1.3×10^{-10}
7,713.2	.01195	.598	1.4×10^{-10}
7,785.1	.01200	.600	1.5×10^{-10}
7,810.1	.01200	.600	1.3×10^{-10}
7,833.0	.01205	.602	1.4×10^{-10}
7,857.5	.01205	.602	2.1×10^{-10}
7,881.9	.01205	.602	1.3×10^{-10}
7,978.0	.01205	.602	1.6×10^{-10}
8,001.1	.01210	.605	1.4×10^{-10}
8,025.0	.01215	.608	1.7×10^{-10}
8,049.5	.01220	.610	1.2×10^{-10}
8,121.6	.01230	.615	1.3×10^{-10}
8,145.7	.01230	.615	1.1×10^{-10}

TABLE 4 (Continued)

Time	Length Change Δ L (inch) (2" G. L.)	Creep (%)	Pressure (Torr)
8,169.4 Hours	.01230	.615	1.1×10^{-10}
8,193.1	.01240	.620	1.3×10^{-10}
8,217.2	.01250	.625	1.3×10^{-10}
8,289.3	.01265	.632	1.2×10^{-10}
8,313.2	.01265	.632	1.2×10^{-10}
8,337.0	.01265	.632	1.2×10^{-10}
8,361.0	.01270	.635	1.2×10^{-10}
8,385.1	.01270	.635	1.3×10^{-10}
8,459.1	.01270	.635	1.3×10^{-10}
8,480.9	.01270	.635	1.3×10^{-10}
8,505.7	.01275	.638	1.2×10^{-10}
8,528.9	.01280	.640	1.3×10^{-10}
8,536.5	.01280	.640	1.3×10^{-10}

Test terminated - sufficient data obtained
Specimen B-36

TABLE 5

Creep test data, TZC, Heat No. 4345, Stress Relieved at 2400°F (1315°C) 1 Hour, Tested at 2000°F (1093°C), 22,000 psi ($1.52 \times 10^8 N/m^2$)

Time	Length Change Δ L (inch) (2" G. L.)	Creep (%)	Pressure (Torr)
1 Minute	.00000	.000	1.2×10^{-7}
2	.00000	.000	
3	.00005	.002	
4	.00005	.002	
5	.00005	.002	
6	.00005	.002	
7	.00010	.005	
8	.00010	.005	
9	.00015	.008	
10	.00015	.008	
15	.00020	.010	
30	.00015	.008	
45	.00015	.008	
60	.00015	.008	
1.0 Hours	.00015	.008	1.2×10^{-7}
70.5	.00080	.040	3.9×10^{-9}
93.0	.00110	.055	3.1×10^{-9}
117.1	.00125	.062	2.5×10^{-9}
141.3	.00135	.068	2.5×10^{-9}
165.3	.00155	.078	1.8×10^{-9}
237.3	.00180	.090	1.7×10^{-9}
261.0	.00190	.095	1.6×10^{-9}
284.8	.00195	.098	1.5×10^{-9}
309.3	.00205	.102	1.6×10^{-9}
333.0	.00220	.110	1.5×10^{-9}
405.0	.00255	.128	1.3×10^{-9}
429.4	.00255	.128	1.2×10^{-9}
453.0	.00260	.130	1.2×10^{-9}
477.1	.00260	.130	1.2×10^{-9}
502.9	.00260	.130	1.1×10^{-9}
572.4	.00265	.132	8.2×10^{-10}
596.3	.00265	.132	9.0×10^{-10}
620.9	.00270	.135	9.2×10^{-10}
644.4	.00275	.138	9.1×10^{-10}
668.0	.00280	.140	9.2×10^{-10}
789.6	.00305	.152	8.0×10^{-10}

TABLE 5 (Continued)

Time	Length Change Δ L (inch) (2" G. L.)	Creep (%)	Pressure (Torr)
814.2 Hours	.00305	.152	7.8×10^{-10}
835.8	.00315	.158	8.0×10^{-10}
908.5	.00320	.160	7.8×10^{-10}
932.2	.00325	.162	7.0×10^{-10}
956.4	.00335	.168	7.2×10^{-10}
980.0	.00345	.172	6.9×10^{-10}
1,006.2	.00350	.175	7.1×10^{-10}
1,076.0	.00355	.178	6.8×10^{-10}
1,100.0	.00360	.180	7.2×10^{-10}
1,123.8	.00365	.182	8.0×10^{-10}
1,148.7	.00375	.188	6.9×10^{-10}
1,172.7	.00380	.190	6.5×10^{-10}
1,246.4	.00405	.202	6.0×10^{-10}
1,292.8	.00410	.205	6.4×10^{-10}
1,316.2	.00410	.205	6.8×10^{-10}
1,340.3	.00410	.205	6.3×10^{-10}
1,412.1	.00410	.205	6.5×10^{-10}
1,436.1	.00420	.210	6.6×10^{-10}
1,460.7	.00415	.208	6.0×10^{-10}
1,486.3	.00415	.208	6.9×10^{-10}
1,508.0	.00425	.212	6.5×10^{-10}
1,579.0	.00425	.212	5.5×10^{-10}
1,604.4	.00430	.215	5.4×10^{-10}
1,628.4	.00430	.215	6.0×10^{-10}
1,652.9	.00430	.215	6.4×10^{-10}
1,676.0	.00435	.218	6.2×10^{-10}
1,748.5	.00435	.218	5.7×10^{-10}
1,772.0	.00435	.218	5.6×10^{-10}
1,795.9	.00435	.218	5.9×10^{-10}
1,820.2	.00440	.220	5.5×10^{-10}
1,843.8	.00450	.225	5.6×10^{-10}
1,917.4	.00455	.228	5.3×10^{-10}
1,940.3	.00455	.228	5.2×10^{-10}
1,963.9	.00455	.228	5.2×10^{-10}
1,987.9	.00465	.232	5.2×10^{-10}
2,011.8	.00465	.232	5.3×10^{-10}
2,083.8	.00470	.235	5.0×10^{-10}

TABLE 5 (Continued)

Time	Length Change Δ L (inch) (2" G. L.)	Creep (%)	Pressure (Torr)
2,131.8 Hours	.00475	.238	5.0×10^{-10}
2,155.9	.00480	.240	5.1×10^{-10}
2,180.0	.00480	.240	6.2×10^{-10}
2,252.3	.00490	.245	5.0×10^{-10}
2,275.9	.00490	.245	5.2×10^{-10}
2,300.5	.00490	.245	5.0×10^{-10}
2,324.7	.00495	.248	6.2×10^{-10}
2,348.9	.00500	.250	3.9×10^{-10}
2,420.6	.00505	.252	4.8×10^{-10}
2,444.0	.00505	.252	4.8×10^{-10}
2,468.2	.00515	.258	4.9×10^{-10}
2,492.0	.00515	.258	5.0×10^{-9}
2,516.1	.00520	.260	6.0×10^{-10}
2,590.0	.00520	.260	3.3×10^{-10}
2,612.3	.00530	.265	4.0×10^{-10}
2,641.2	.00540	.270	6.1×10^{-10}
2,660.2	.00550	.275	6.0×10^{-10}
2,683.9	.00560	.280	4.7×10^{-10}
2,758.3	.00565	.282	4.6×10^{-10}
2,780.0	.00565	.282	3.2×10^{-10}
2,804.1	.00570	.285	3.2×10^{-10}
2,828.0	.00575	.288	4.8×10^{-10}
2,851.9	.00575	.288	4.4×10^{-10}
2,924.2	.00575	.288	6.0×10^{-10}
2,947.8	.00575	.288	4.0×10^{-10}
2,972.1	.00575	.288	6.0×10^{-10}
2,995.9	.00580	.290	4.5×10^{-10}
3,019.9	.00580	.290	5.0×10^{-10}
3,092.2	.00585	.292	3.7×10^{-10}
3,115.8	.00590	.295	4.0×10^{-10}
3,140.2	.00600	.300	2.7×10^{-10}
3,164.0	.00600	.300	4.2×10^{-10}
3,188.0	.00600	.300	4.6×10^{-10}
3,260.4	.00600	.300	5.5×10^{-10}
3,283.9	.00600	.300	3.5×10^{-10}
3,307.9	.00600	.300	2.4×10^{-10}
3,331.8	.00600	.300	4.0×10^{-10}
3,356.1	.00600	.300	2.8×10^{-10}
3,428.0	.00605	.302	2.8×10^{-10}
3,453.1	.00605	.302	3.9×10^{-10}

TABLE 5 (Continued)

Time	Length Change Δ L (inch) (2" G. L.)	Creep (%)	Pressure (Torr)
3,475.9 Hours	.00605	.302	5.0×10^{-10}
3,500.5	.00605	.302	3.6×10^{-10}
3,524.8	.00605	.302	2.8×10^{-10}
3,620.9	.00615	.308	4.3×10^{-10}
3,643.9	.00615	.308	4.3×10^{-10}
3,667.9	.00615	.308	3.4×10^{-10}
3,692.4	.00620	.310	5.6×10^{-10}
3,764.5	.00620	.310	5.2×10^{-10}
3,788.7	.00625	.312	2.6×10^{-10}
3,812.3	.00625	.312	2.7×10^{-10}
3,836.0	.00630	.315	2.8×10^{-10}
3,860.1	.00635	.318	2.4×10^{-10}
3,932.2	.00635	.318	2.6×10^{-10}
3,956.0	.00635	.318	4.0×10^{-10}
3,979.8	.00640	.320	4.8×10^{-10}
4,003.9	.00640	.320	2.8×10^{-10}
4,028.2	.00645	.322	3.4×10^{-10}
4,102.0	.00650	.325	2.6×10^{-10}
4,123.8	.00655	.328	2.5×10^{-10}
4,148.6	.00660	.330	2.4×10^{-10}
4,171.8	.00665	.332	4.6×10^{-10}
4,195.7	.00660	.330	2.5×10^{-10}
4,268.0	.00670	.335	2.5×10^{-10}
4,291.9	.00670	.335	2.5×10^{-10}
4,316.7	.00695	.338	3.0×10^{-10}
4,339.9	.00680	.340	2.5×10^{-10}
4,364.0	.00685	.342	4.2×10^{-10}
4,435.9	.00685	.342	2.3×10^{-10}
4,459.9	.00685	.342	2.3×10^{-10}
4,484.1	.00690	.345	3.2×10^{-10}
4,508.5	.00690	.345	3.6×10^{-10}
4,532.6	.00695	.348	3.0×10^{-10}
4,604.8	.00695	.348	4.5×10^{-10}
4,628.1	.00700	.350	4.1×10^{-10}
4,651.8	.00700	.350	3.4×10^{-10}
4,676.1	.00700	.350	3.5×10^{-10}

TABLE 5 (Continued)

Time	Length Change Δ L (inch) (2" G. L.)	Creep (%)	Pressure (Torr)
4,700.0 Hours	.00700	.350	4.5×10^{-10}
4,772.4	.00700	.350	5.6×10^{-10}
4,797.0	.00700	.350	3.7×10^{-10}
4,820.7	.00705	.352	3.2×10^{-10}
4,844.8	.00710	.355	4.1×10^{-10}
4,869.0	.00705	.352	3.2×10^{-10}
4,941.3	.00710	.355	3.8×10^{-10}
4,988.9	.00720	.360	3.4×10^{-10}
5,013.5	.00720	.360	3.0×10^{-10}
5,036.8	.00720	.360	3.0×10^{-10}
5,111.2	.00720	.360	4.6×10^{-10}
5,132.8	.00725	.362	4.0×10^{-10}
5,157.5	.00730	.365	3.2×10^{-10}
5,180.7	.00735	.368	3.3×10^{-10}
5,205.5	.00735.	.368	3.2×10^{-10}
5,300.9	.00740	.370	3.2×10^{-10}
5,325.6	.00745	.372	2.9×10^{-10}
5,349.1	.00745	.372	3.2×10^{-10}
5,373.2	.00750	.375	3.2×10^{-10}
5,445.2	.00765	.382	3.0×10^{-10}
5,469.0	.00765	.382	3.2×10^{-10}
5,493.3	.00770	.385	3.1×10^{-10}
5,612.9	.00775	.388	3.0×10^{-10}
5,636.8	.00775	.388	3.0×10^{-10}
5,661.4	.00780	.390	3.2×10^{-10}
5,685.6	.00780	.390	2.7×10^{-10}
5,708.9	.00785	.392	2.8×10^{-10}
5,781.1	.00795	.398	4.1×10^{-10}
5,804.9	.00790	.395	2.9×10^{-10}
5,829.0	.00800	.400	4.0×10^{-10}
5,853.6	.00800	.400	3.8×10^{-10}
5,877.1	.00805	.402	4.0×10^{-10}
5,949.0	.00815	.408	2.8×10^{-10}
5,973.0	.00815	.408	2.9×10^{-10}

TABLE 5 (Continued)

Time	Length Change Δ L (inch) (2" G. L.)	Creep (%)	Pressure (Torr)
5,996.9	.00815	.408	3.4×10^{-10}
6,020.9	.00815	.408	3.0×10^{-10}
6,045.0	.00820	.410	3.0×10^{-10}
6,116.9	.00825	.412	3.1×10^{-10}
6,141.0	.00820	.410	3.0×10^{-10}
6,164.8	.00825	.412	2.8×10^{-10}
6,188.9	.00830	.415	2.8×10^{-10}
6,213.1	.00840	.420	2.6×10^{-10}
6,333.3	.00840	.420	3.5×10^{-10}

Test in progress
Specimen B-37

TABLE 6

Creep Test Data, TZM Forged Disc Heat KDTZM 1175, Stress Relieved 2300°F (1260°C) 1 Hour, Tested at 1800°F (982°C) and 44,000 psi ($3.03 \times 10^8 N/m^2$)

Time	Length Change Δ L (inch) (2" G. L.)	Creep (%)	Pressure (Torr)
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	.00100	.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 6 (Continued)

Time	Length Change Δ L (inch) (2" G. L.)	Creep (%)	Pressure (Torr)
736.8 Hours	.00150	.075	8.8×10^{-10}
761.7	.00150	.075	8.6×10^{-10}
785.0	.00150	.075	5.0×10^{-10}
808.8	.00155	.078	9.0×10^{-10}
833.8	.00155	.078	5.0×10^{-10}
904.7	.00160	.080	8.4×10^{-10}
928.8	.00160	.080	8.9×10^{-10}
953.1	.00160	.080	7.0×10^{-10}
977.0	.00165	.082	6.0×10^{-10}
1001.0	.00180	.090	9.2×10^{-10}
1073.0	.00180	.090	9.1×10^{-10}
1144.9	.00175	.088	8.2×10^{-10}
1240.7	.00175	.088	7.5×10^{-10}
1313.2	.00180	.090	9.0×10^{-10}
1409.5	.00180	.090	5.8×10^{-10}
1484.2	.00180	.090	4.4×10^{-10}
1577.2	.00185	.092	4.0×10^{-10}
1650.2	.00185	.092	3.5×10^{-10}
1746.9	.00190	.095	4.5×10^{-10}
1822.5	.00200	.100	4.0×10^{-10}
1913.6	.00215	.108	4.9×10^{-10}
1984.0	.00210	.105	3.5×10^{-10}
2080.1	.00215	.108	3.0×10^{-10}
2152.2	.00215	.108	4.0×10^{-10}
2247.9	.00220	.110	3.5×10^{-10}
2319.8	.00225	.112	2.8×10^{-10}
2416.7	.00235	.118	3.5×10^{-10}
2489.7	.00230	.115	2.4×10^{-10}
2584.3	.00235	.118	2.2×10^{-10}
2655.9	.00240	.120	2.4×10^{-10}
2776.3	.00250	.125	3.8×10^{-10}
2824.0	.00250	.125	4.6×10^{-10}
2922.9	.00250	.125	4.4×10^{-10}
2991.8	.00245	.122	4.0×10^{-10}

TABLE 6 (Continued)

Time	Length Change Δ L (inch) (2" G. L.)	Creep (%)	Pressure (Torr)
3015.8 Hours	.00245	.122	4.0×10^{-10}
3088.0	.00245	.122	3.7×10^{-10}
3160.4	.00245	.122	4.0×10^{-10}
3256.0	.00250	.125	4.4×10^{-10}
3328.7	.00255	.128	4.1×10^{-10}
3424.5	.00255	.128	3.4×10^{-10}
3496.0	.00255	.128	4.5×10^{-10}
3615.9	.00260	.130	4.0×10^{-10}
3664.8	.00255	.128	3.5×10^{-10}
3760.4	.00255	.128	4.2×10^{-10}
3831.9	.00255	.128	3.5×10^{-10}
3928.0	.00255	.128	3.4×10^{-10}
4002.1	.00260	.130	3.9×10^{-10}
4096.6	.00260	.130	3.4×10^{-10}
4168.7	.00255	.128	4.0×10^{-10}
4265.1	.00265	.132	3.6×10^{-10}
4338.1	.00270	.135	3.1×10^{-10}
4432.3	.00260	.130	3.2×10^{-10}
4503.7	.00270	.135	3.5×10^{-10}
4600.0	.00290	.145	2.6×10^{-10}
4671.7	.00270	.135	3.5×10^{-10}
4770.2	.00270	.135	3.6×10^{-10}
4840.1	.00275	.138	3.5×10^{-10}
4936.8	.00275	.138	3.9×10^{-10}
5008.0	.00280	.140	3.8×10^{-10}
5128.5	.00285	.142	3.2×10^{-10}
5175.7	.00290	.145	3.0×10^{-10}
5272.4	.00290	.145	3.0×10^{-10}
5343.8	.00290	.145	3.5×10^{-10}
5440.5	.00290	.145	3.0×10^{-10}
5512.1	.00295	.148	3.0×10^{-10}
5607.9	.00295	.148	3.2×10^{-10}
5680.2	.00300	.150	3.0×10^{-10}
5776.1	.00300	.150	3.0×10^{-10}
5849.9	.00300	.150	2.5×10^{-10}
5943.9	.00300	.150	4.1×10^{-10}

TABLE 6 (Continued)

Time	Length Change Δ L (inch) (2" G. L.)	Creep (%)	Pressure (Torr)
6016.0 Hours	.00300	.150	3.0×10^{-10}
6111.9	.00300	.150	3.0×10^{-10}
6184.0	.00300	.150	3.0×10^{-10}
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}
7865.1	.00330	.165	3.8×10^{-10}
7985.2	.00330	.165	3.7×10^{-10}
8033.4	.00330	.165	3.0×10^{-10}
8130.3	.00330	.165	3.8×10^{-10}
8201.2	.00335	.168	3.5×10^{-10}
8298.4	.00335	.168	3.0×10^{-10}
8369.5	.00335	.168	3.0×10^{-10}
8465.2	.00335	.168	3.7×10^{-10}
8537.6	.00335	.168	3.6×10^{-10}
8633.4	.00340	.170	3.7×10^{-10}

TABLE 6 (Continued)

Time	Length Change Δ L (inch) (2" G. L.)	Creep (%)	Pressure (Torr)
8705.7 Hours	.00340	.170	3.0×10^{-10}
8803.1	.00340	.170	3.0×10^{-10}
8873.7	.00340	.170	3.2×10^{-10}
8969.4	.00350	.175	3.0×10^{-10}
9041.2	.00345	.172	3.2×10^{-10}
9137.6	.00345	.172	3.2×10^{-10}
9209.8	.00350	.175	3.3×10^{-10}
9305.6	.00355	.178	3.4×10^{-10}
9377.0	.00355	.178	3.4×10^{-10}
9473.0	.00355	.178	3.0×10^{-10}
9544.8	.00360	.180	3.4×10^{-10}
9640.8	.00360	.180	3.3×10^{-10}
9712.9	.00360	.180	3.3×10^{-10}
9808.9	.00350	.175	3.2×10^{-10}
9881.2	.00355	.178	3.4×10^{-10}
9977.5	.00365	.182	3.2×10^{-10}
10048.9	.00365	.182	3.3×10^{-10}
10145.3	.00365	.182	3.5×10^{-10}
10151.7	.00365	.182	3.5×10^{-10}

Test terminated - sufficient data obtained
Specimen B-25

TABLE 7

Creep Test Data, TZM , Heat No. KDTZM-1175, Stress Relieved at 2300°F (1260°C) for 1 hour, Tested at 2000°F (1093°C), 22,000 psi (1.52×10^2 N/m^2)

Time	Length Change Δ L (inch) (2" G. L.)	Creep (%)	Pressure (Torr)
1 Minute	-.00005	-.002	9.7×10^{-8}
2	-.00005	-.002	
3	.00005	-.002	
4	.00010	.005	
5	.00010	.005	
6	.00010	.005	
7	.00010	.005	
8	.00005	.002	
9	.00015	.008	
10	.00020	.010	
15	.00015	.008	
30	.00020	.010	
45	.00015	.008	
60	.00015	.008	
19.0 Hours	.00025	.012	1.2×10^{-8}
91.4	.00055	.028	5.5×10^{-9}
114.8	.00075	.038	5.0×10^{-9}
139.0	.00125	.062	4.6×10^{-9}
162.8	.00140	.070	4.3×10^{-9}
186.9	.00150	.075	4.1×10^{-9}
260.8	.00150	.075	3.7×10^{-9}
283.1	.00150	.075	3.6×10^{-9}
312.0	.00150	.075	3.8×10^{-9}
330.4	.00150	.075	3.6×10^{-9}
354.7	.00150	.075	3.4×10^{-9}
429.0	.00155	.078	3.3×10^{-9}
450.8	.00150	.075	3.2×10^{-9}
474.8	.00150	.075	3.2×10^{-9}
498.8	.00150	.075	3.2×10^{-9}
522.7	.00155	.078	3.2×10^{-9}
595.0	.00160	.080	5.2×10^{-9}
618.6	.00155	.078	3.2×10^{-9}
642.8	.00155	.078	3.2×10^{-9}
666.7	.00155	.078	3.2×10^{-9}
690.7	.00155	.078	3.2×10^{-9}
763.0	.00155	.078	3.5×10^{-9}
786.6	.00155	.078	3.0×10^{-9}
811.0	.00160	.080	3.3×10^{-9}
834.8	.080	.00160	3.1×10^{-9}
858.8	.00160	.080	3.3×10^{-9}
931.2	.00165	.082	3.1×10^{-9}

TABLE 7 (Continued)

Time	Length Change Δ L (inch) (2" G. L.)	Creep (%)	Pressure (Torr)
954.6 Hours	.00165	.082	2.9×10^{-9}
978.7	.00170	.085	3.1×10^{-9}
1,002.6	.00170	.085	3.0×10^{-9}
1,026.9	.00175	.088	3.3×10^{-9}
1,098.7	.00185	.092	3.4×10^{-9}
1,123.8	.00190	.095	3.4×10^{-9}
1,146.7	.00200	.100	3.3×10^{-9}
1,171.2	.00200	.100	3.4×10^{-9}
1,195.5	.00200	.100	3.2×10^{-9}
1,291.6	.00205	.102	3.4×10^{-9}
1,314.7	.00205	.102	3.2×10^{-9}
1,338.6	.00205	.102	3.0×10^{-9}
1,363.2	.00205	.102	3.1×10^{-9}
1,435.3	.00205	.102	3.1×10^{-9}
1,459.5	.00200	.100	3.0×10^{-9}
1,483.0	.00205	.102	3.0×10^{-9}
1,506.8	.00210	.105	3.1×10^{-9}
1,530.8	.00210	.105	3.1×10^{-9}
1,603.0	.00210	.105	3.1×10^{-9}
1,626.8	.00215	.108	3.2×10^{-9}
1,650.6	.00220	.110	2.9×10^{-9}
1,674.7	.00215	.108	2.8×10^{-9}
1,698.8	.00220	.110	2.8×10^{-9}
1,772.7	.00220	.110	2.8×10^{-9}
1,794.6	.00225	.112	3.0×10^{-9}
1,819.4	.00225	.112	2.8×10^{-9}
1,842.6	.00225	.112	2.7×10^{-9}
1,866.5	.00225	.112	2.4×10^{-9}
1,938.8	.00235	.118	1.2×10^{-9}
1,962.7	.00245	.122	2.9×10^{-9}
1,987.5	.00245	.122	2.9×10^{-9}
2,010.7	.00245	.122	3.0×10^{-9}
2,034.8	.00250	.125	2.8×10^{-9}
2,106.7	.00250	.125	2.9×10^{-9}
2,130.7	.00245	.122	2.9×10^{-9}
2,154.9	.00250	.125	2.8×10^{-9}

TABLE 7 (Continued)

Time	Length Change Δ L (inch) (2" G. L.)	Creep (%)	Pressure (Torr)
2,178.7 Hours	.00250	.125	2.9×10^{-9}
2,203.4	.00245	.122	2.3×10^{-9}
2,275.6	.00245	.122	2.8×10^{-9}
2,298.9	.00245	.122	2.9×10^{-9}
2,322.6	.00250	.125	2.7×10^{-9}
2,346.9	.00255	.128	2.8×10^{-9}
2,370.8	.00255	.128	2.8×10^{-9}
2,443.1	.00255	.128	2.9×10^{-9}
2,467.8	.00255	.128	3.0×10^{-9}
2,491.5	.00245	.122	2.8×10^{-9}
2,515.5	.00250	.125	2.9×10^{-9}
2,539.8	.00255	.128	2.8×10^{-9}
2,612.1	.00260	.130	3.0×10^{-9}
2,636.5	.00260	.130	2.5×10^{-9}
2,659.7	.00265	.132	2.6×10^{-9}
2,684.3	.00265	.132	2.6×10^{-9}
2,707.6	.00260	.130	2.6×10^{-9}
2,782.0	.00265	.132	2.8×10^{-9}
2,803.5	.00260	.130	2.7×10^{-9}
2,828.3	.00265	.132	2.8×10^{-9}
2,851.5	.00265	.132	3.0×10^{-9}
2,876.3	.00275	.138	2.9×10^{-9}
2,948.0	.00295	.148	2.9×10^{-9}
2,971.6	.00290	.145	3.0×10^{-9}
2,996.4	.00295	.148	2.6×10^{-9}
3,019.8	.00295	.148	3.1×10^{-9}
3,043.9	.00295	.148	2.6×10^{-9}
3,116.0	.00295	.148	3.0×10^{-9}
3,139.7	.00305	.152	3.1×10^{-9}
3,164.0	.00310	.155	2.5×10^{-9}
3,283.7	.00315	.158	2.5×10^{-9}
3,307.6	.00320	.160	2.6×10^{-9}
3,332.2	.00320	.160	2.9×10^{-9}
3,356.4	.00325	.162	2.8×10^{-9}
3,379.7	.00315	.158	2.8×10^{-9}
3,451.9	.00325	.162	2.8×10^{-9}
3,475.7	.00330	.165	2.8×10^{-9}
3,499.8	.00335	.168	2.9×10^{-9}
3,524.4	.00340	.170	2.8×10^{-9}

TABLE 7 (Continued)

Time	Length Change Δ L (inch) (2" G. L.)	Creep (%)	Pressure (Torr)
3,547.9 Hours	.00340	.170	2.9×10^{-9}
3,619.8	.00345	.172	2.6×10^{-9}
3,643.9	.00345	.172	2.7×10^{-9}
3,667.7	.00340	.170	2.5×10^{-9}
3,691.7	.00340	.170	2.6×10^{-9}
3,715.7	.00345	.172	2.6×10^{-9}

Test in progress
Specimen B-38

TABLE 8

Creep Test Data, TZM Forged Disc, Heat 7502, Stress Relieved 2200°F (1204°C)
Tested at 1800°F (982°C), and 44,000 psi (3.03×10^8 N/m^2)

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

TABLE 8 (Continued)

Time	Length Change Δ L (inch) (2" G. L.)	Creep (%)	Pressure (Torr)
615.7 Hours	.00275	.138	2.6×10^{-9}
639.8	.00280	.140	2.7×10^{-9}
663.6	.00290	.145	2.6×10^{-9}
735.6	.00300	.150	2.6×10^{-9}
759.8	.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}

TABLE 8 (Continued)

Time	Length Change Δ L (inch) (2" G. L.)	Creep (%)	Pressure (Torr)
1816.5 Hours	.00485	.242	2.4×10^{-9}
1840.5	.00485	.242	2.4×10^{-9}
1912.7	.00495	.248	2.5×10^{-9}
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	2.9×10^{-9}
2825.1	.00575	.288	3.0×10^{-9}
2945.2	.00585	.292	2.6×10^{-9}

TABLE 8 (Continued)

Time	Length Change Δ L (inch) (2" G. L.)	Creep (%)	Pressure (Torr)
2969.0 Hours	.00585	.292	2.6×10^{-9}
2992.8	.00585	.292	2.7×10^{-9}
3017.2	.00590	.295	2.7×10^{-9}
3112.9	.00605	.302	2.6×10^{-9}
3137.8	.00600	.300	2.6×10^{-9}
3161.4	.00600	.300	2.5×10^{-9}
3185.0	.00600	.300	2.6×10^{-9}
3257.9	.00605	.302	2.7×10^{-9}
3282.9	.00610	.305	2.6×10^{-9}
3305.2	.00615	.308	2.5×10^{-9}
3328.8	.00620	.310	2.7×10^{-9}
3353.0	.00620	.310	2.6×10^{-9}
3426.1	.00640	.320	2.3×10^{-9}
3448.7	.00645	.322	2.4×10^{-9}
3473.1	.00645	.322	2.5×10^{-9}
3497.1	.00655	.328	2.6×10^{-9}
3521.0	.00655	.328	2.2×10^{-9}
3592.9	.00665	.332	2.6×10^{-9}
3616.9	.00660	.330	2.6×10^{-9}
3641.1	.00665	.332	2.6×10^{-9}
3665.3	.00675	.338	2.4×10^{-9}
3689.2	.00685	.342	2.4×10^{-9}
3761.1	.00695	.348	2.4×10^{-9}
3784.7	.00695	.348	2.0×10^{-9}
3808.8	.00690	.345	2.8×10^{-9}
3833.4	.00695	.348	2.1×10^{-9}
3857.1	.00695	.348	2.6×10^{-9}
3930.8	.00695	.348	2.5×10^{-9}
3953.0	.00690	.345	2.0×10^{-9}
3977.0	.00700	.350	2.3×10^{-9}

TABLE 8 (Continued)

Time	Length Change Δ L (inch) (2" G. L.)	Creep (%)	Pressure (Torr)
4001.4 Hours	.00700	.350	2.6×10^{-9}
4027.6	.00700	.350	2.0×10^{-9}
4097.0	.00705	.352	2.3×10^{-9}
4121.1	.00705	.352	2.1×10^{-9}
4144.5	.00710	.355	2.4×10^{-9}
4168.9	.00705	.352	2.1×10^{-9}
4192.9	.00710	.355	2.4×10^{-9}
4265.3	.00710	.355	2.0×10^{-9}
4289.0	.00715	.358	2.4×10^{-9}
4313.5	.00715	.358	2.1×10^{-9}
4337.5	.00720	.360	2.2×10^{-9}
4361.2	.00730	.265	2.2×10^{-9}
4433.3	.00735	.368	2.2×10^{-9}
4457.4	.00740	.370	2.2×10^{-9}
4481.0	.00760	.380	2.4×10^{-9}
4504.7	.00755	.378	2.3×10^{-9}
4528.7	.00755	.378	2.3×10^{-9}
4600.7	.00760	.380	2.3×10^{-9}
4625.0	.00760	.380	2.3×10^{-9}
4648.5	.00765	.382	2.4×10^{-9}
4672.5	.00770	.385	2.2×10^{-9}
4696.4	.00770	.385	2.2×10^{-9}
4768.5	.00775	.388	2.2×10^{-9}
4792.6	.00785	.392	2.1×10^{-9}
4817.1	.00790	.395	2.3×10^{-9}
4840.6	.00790	.395	2.2×10^{-9}
4864.7	.00800	.400	2.2×10^{-9}

TABLE 8 (Continued)

Time	Length Change Δ L (inch) (2" G. L.)	Creep (%)	Pressure (Torr)
4,936.6 Hours	.00810	.405	2.3×10^{-9}
4,960.9	.00815	.408	2.3×10^{-9}
5,008.9	.00810	.405	2.3×10^{-9}
5,105.2	.00820	.410	2.3×10^{-9}
5,129.0	.00820	.410	2.2×10^{-9}
5,152.7	.00825	.412	2.2×10^{-9}
5,176.6	.00825	.412	2.2×10^{-9}
5,201.2	.00825	.412	2.2×10^{-9}
5,273.0	.00825	.412	2.2×10^{-9}
5,296.7	.00830	.415	2.5×10^{-9}
5,320.7	.00830	.415	2.4×10^{-9}
5,344.5	.00835	.418	2.1×10^{-9}
5,368.5	.00845	.422	2.2×10^{-9}
5,442.2	.00850	.425	2.2×10^{-9}
5,464.6	.00850	.425	2.1×10^{-9}
5,488.7	.00855	.428	2.2×10^{-9}
5,513.0	.00855	.428	2.1×10^{-9}
5,536.9	.00860	.430	2.3×10^{-9}
5,608.9	.00860	.430	2.2×10^{-10}
5,632.6	.00865	.432	2.3×10^{-9}
5,656.5	.00865	.432	2.3×10^{-9}
5,680.9	.00870	.435	2.4×10^{-9}
5,704.6	.00875	.438	2.1×10^{-9}
5,776.7	.00890	.445	2.5×10^{-9}
5,801.0	.00900	.450	2.1×10^{-9}
5,824.7	.00900	.450	2.0×10^{-9}
5,848.8	.00905	.452	2.0×10^{-9}
5,872.9	.00905	.452	2.0×10^{-9}
5,944.0	.00910	.455	2.4×10^{-9}
5,968.0	.00910	.455	2.2×10^{-9}
5,992.6	.00905	.452	2.2×10^{-9}
6,016.1	.00905	.452	2.3×10^{-9}
6,039.7	.00900	.450	2.1×10^{-9}
6,161.3	.00915	.458	2.3×10^{-9}
6,185.8	.00920	.460	2.2×10^{-9}
6,207.5	.00925	.462	2.3×10^{-9}

TABLE 8 (Continued)

Time	Length Change Δ L (inch) (2" G. L.)	Creep (%)	Pressure (Torr)
6,280.2 Hours	.00935	.468	2.1×10^{-9}
6,303.9	.00940	.470	2.0×10^{-9}
6,328.0	.00945	.472	2.0×10^{-9}
6,351.6	.00950	.475	2.1×10^{-9}
6,377.9	.00950	.475	2.2×10^{-9}
6,447.7	.00955	.478	2.3×10^{-9}
6,471.7	.00960	.480	2.2×10^{-9}
6,495.5	.00965	.482	2.4×10^{-9}
6,520.4	.00965	.482	2.2×10^{-9}
6,544.3	.00965	.482	2.0×10^{-9}
6,618.1	.00965	.482	2.0×10^{-9}
6,664.5	.00970	.485	2.0×10^{-9}
6,687.9	.00970	.485	2.3×10^{-9}
6,711.9	.00975	.488	2.1×10^{-9}
6,783.7	.00980	.490	2.4×10^{-9}
6,807.7	.00980	.490	2.3×10^{-9}
6,832.4	.00980	.490	2.0×10^{-9}
6,857.9	.00985	.492	2.3×10^{-9}
6,879.7	.00995	.498	2.2×10^{-9}
6,951.4	.00995	.498	2.0×10^{-9}
6,976.0	.01005	.502	2.0×10^{-9}
7,000.0	.01000	.500	2.1×10^{-9}
7,024.6	.01000	.500	2.2×10^{-9}
7,047.7	.01000	.500	2.3×10^{-9}
7,120.1	.01010	.505	2.0×10^{-9}
7,143.6	.01005	.502	2.1×10^{-9}
7,167.5	.01015	.608	3.3×10^{-9}
7,191.9	.01025	.512	2.1×10^{-9}
7,215.5	.01025	.512	2.3×10^{-9}
7,289.0	.01035	.518	2.2×10^{-9}
7,311.9	.01045	.522	2.2×10^{-9}
7,335.4	.01045	.522	2.2×10^{-9}
7,359.5	.01050	.525	2.1×10^{-9}
7,383.4	.01050	.525	2.1×10^{-9}
7,455.4	.01060	.530	2.3×10^{-9}
7,503.4	.01065	.532	2.1×10^{-9}

TABLE 8 (Continued)

Time	Length Change Δ L (inch) (2" G. L.)	Creep (%)	Pressure (Torr)
7,527.5 Hours	.01075	.538	2.2×10^{-9}
7,551.6	.01075	.538	2.1×10^{-9}
7,623.9	.01070	.535	2.3×10^{-9}
7,647.5	.01070	.535	
7,659.5	.01070	.535	2.2×10^{-9}

Test terminated - sufficient data obtained
Specimen B-35

TABLE 9

Creep Test Data, Pure Ta, Annealed at 1832°F (1000°C) for 1 hour, Tested at 1100°F (596°C), 13,600 psi ($9.37 \times 10^7 N/m^2$)

Time	Length Change Δ L (inch) (2" G. L.)	Creep (%)	Pressure (Torr)
1 Minutes	.00010	.005	1.0×10^{-7}
2	.00005	.002	1.0×10^{-7}
3	.00005	.002	1.0×10^{-7}
4	.00015	.008	1.0×10^{-7}
5	.00015	.008	1.0×10^{-7}
6	.00020	.010	1.0×10^{-7}
7	.00015	.008	1.0×10^{-7}
8	.00020	.010	1.0×10^{-7}
9	.00030	.015	1.0×10^{-7}
10	.00030	.015	1.0×10^{-7}
15	.00030	.015	1.0×10^{-7}
30	.00040	.020	1.0×10^{-7}
45	.00050	.025	1.0×10^{-7}
60	.00080	.040	1.0×10^{-8}
1.0 Hours	.00080	.040	9.0×10^{-8}
18.6	.01440	.720	
20.0	.01470	.735	
20.9	.01505	.752	1.9×10^{-8}
22.9	.01575	.788	1.9×10^{-8}
25.1	.01720	.860	1.9×10^{-8}
26.5	.01810	.905	1.9×10^{-8}
31.8	.02040	1.02	2.2×10^{-8}

Test terminated - sufficient data obtained
Specimen B-39A

TABLE 10

Creep Test Data, Pure Ta, Annealed at 1832°F (1000°C) for 1/4 hour, Tested at 1100°F (596°C), H,600 psi ($7.99 \times 10^7 N/m^2$)

Time	Length Change Δ L (inch) (2" G. L.)	Creep (%)	Pressure (Torr)
1 Minutes	.00005	.002	9.2×10^{-9}
2	.00005	.002	9.2×10^{-9}
3	.00005	.002	9.2×10^{-9}
4	.00005	.002	9.2×10^{-9}
5	.00010	.005	9.2×10^{-9}
6	.00005	.002	9.2×10^{-9}
7	.00010	.005	9.2×10^{-9}
8	.00005	.002	9.2×10^{-9}
9	.00005	.002	9.2×10^{-9}
10	.00005	.002	9.2×10^{-9}
15	.00010	.005	9.2×10^{-9}
30	.00010	.005	9.2×10^{-9}
45	.00015	.008	9.2×10^{-9}
60	.00015	.008	9.2×10^{-9}
1.0 Hours	.00015	.008	
16.4	.00028	.014	4.4×10^{-9}
28.1	.00126	.063	
41.9	.00167	.084	
53.3	.00285	.143	
65.1	.00365	.182	6.1×10^{-9}
72.8	.00470	.235	5.5×10^{-9}
77.9	.00510	.255	
89.1	.00560	.280	4.8×10^{-9}
96.8	.00615	.308	4.6×10^{-9}
102.2	.00640	.320	
113.3	.00675	.338	4.3×10^{-9}
121.3	.00690	.345	3.1×10^{-9}
126.1	.00715	.357	2.0×10^{-9}
137.2	.00740	.370	3.6×10^{-9}
148.4	.00765	.382	3.4×10^{-9}
161.8	.00800.	.400	2.7×10^{-9}
186.4	.00900	.450	2.3×10^{-9}
210.5	.00920	.460	3.4×10^{-9}
234.0	.01010	.505	3.1×10^{-9}
241.1	.01030	.515	3.0×10^{-9}
257.3	.01070	.535	2.9×10^{-9}
264.3	.01085	.542	

Test terminated - sufficient data obtained
Specimen B-39B

TABLE 11

Creep Test Data, Pure Ta, Annealed at 1832°F (1000°C) for 1/4 hour, Tested at 1183°F (639°C), 10,100 psi ($6.95 \times 10^7 N/m^2$)

Time	Length Change Δ L (inch) (2" G. L.)	Creep (%)	Pressure (Torr)
1 Minutes	.00005	.002	2.9×10^{-9}
2	.00000	.000	2.9×10^{-9}
3	.00000	.000	2.9×10^{-9}
4	.00000	.000	2.9×10^{-9}
5	.00000	.000	2.9×10^{-9}
6	-.00005	-.002	2.9×10^{-9}
7	.00000	.000	2.9×10^{-9}
8	.00000	.000	2.9×10^{-9}
9	.00005	.002	2.9×10^{-9}
10	.00000	.000	2.9×10^{-9}
15	.00005	.002	2.9×10^{-9}
30	.00005	.002	2.9×10^{-9}
45	.00005	.002	2.9×10^{-9}
60	.00005	.002	2.9×10^{-9}
1.0 Hours	.00005	.002	2.6×10^{-9}
17.5	.00155	.078	3.4×10^{-9}
24.8	.00215	.108	2.7×10^{-9}
41.3	.00310	.155	3.1×10^{-9}
48.9	.00350	.175	2.7×10^{-9}
68.0	.00400	.200	2.6×10^{-9}
91.9	.00500	.250	2.2×10^{-9}
113.7	.00610	.305	3.0×10^{-9}
123.6	.00650	.325	2.2×10^{-9}
138.4	.00710	.355	2.0×10^{-9}
146.3	.00735	.368	2.2×10^{-9}
162.0	.00805	.402	2.7×10^{-9}
186.1	.00890	.445	2.8×10^{-9}
210.3	.01010	.505	2.8×10^{-9}
282.4	.01270	.635	2.3×10^{-9}

Test terminated - sufficient data obtained
Specimen B-39C

TABLE 12

Creep Test Data, Pure Ta, Annealed at 1832°F (1000°C) for 1 hour, Tested at 1350°F (720°C), 7,000 psi ($4.83 \times 10^7 N/m^2$)

Time	Length Change Δ L (inch) (2" G. L.)	Creep (%)	Pressure (Torr)
1 Minutes	.00050	.025	7.0×10^{-8}
2	.00125	.063	7.0×10^{-8}
3	.00170	.085	7.0×10^{-8}
4	.00210	.105	7.0×10^{-8}
5	.00225	.113	7.0×10^{-8}
6	.00235	.118	7.0×10^{-8}
8	.00260	.130	7.0×10^{-8}
9	.00300	.150	7.0×10^{-8}
10	.00330	.165	7.0×10^{-8}
15	.00370	.185	7.0×10^{-8}
30	.00490	.245	7.0×10^{-8}
45	.00615	.308	7.0×10^{-8}
60	.00680	.340	7.0×10^{-8}
1.25	.00815	.408	7.0×10^{-8}
1.50	.00905	.453	7.0×10^{-8}
1.75	.00950	.475	7.0×10^{-8}
2.0	.01040	.520	7.0×10^{-8}
2.25	.01095	.548	7.0×10^{-8}
2.50	.01175	.588	7.0×10^{-8}
2.75	.01220	.610	7.0×10^{-8}
3.25	.01305	.657	7.0×10^{-8}
3.75	.01395	.698	7.0×10^{-8}
5.83	.01655	.828	7.0×10^{-8}
6.5	.01740	.870	7.0×10^{-8}
7.0	.01780	.890	7.0×10^{-8}
7.5	.01835	.918	7.0×10^{-8}
8.0	.01905	.953	7.0×10^{-8}
8.5	.01935	.968	7.0×10^{-8}
9.0	.0200	1.000	7.0×10^{-8}

Test terminated - sufficient data obtained
Specimen B-40A

TABLE 13

Creep Test Data, Pure Ta, Annealed at 1832°F (1000°C) for 1/4 hour, Tested at 1350°F (720°C), 4,900 psi ($3.38 \times 10^7 N/m^2$)

Time	Length Change Δ L (inch) (2" G. L.)	Creep (%)	Pressure (Torr)
1 Minutes	.00000	.000	7.6×10^{-9}
2	.00005	.002	7.6×10^{-9}
3	.00005	.002	7.6×10^{-9}
4	.00005	.002	7.6×10^{-9}
5	.00010	.005	7.6×10^{-9}
6	.00005	.002	7.6×10^{-9}
7	.00005	.002	7.6×10^{-9}
8	.00000	.000	7.6×10^{-9}
9	.00000	.000	7.6×10^{-9}
10	.00005	.002	7.6×10^{-9}
15	.00005	.002	7.6×10^{-9}
30	.00010	.005	7.6×10^{-9}
45	.00010	.005	7.6×10^{-9}
60	.00010	.005	7.6×10^{-9}
1.0 Hours	.00010	.005	7.6×10^{-9}
19.0	.00020	.010	5.8×10^{-9}
43.1	.00025	.012	4.6×10^{-9}
115.1	.00055	.028	3.4×10^{-9}
138.9	.00075	.038	3.0×10^{-9}
163.2	.00085	.042	3.0×10^{-9}
282.9	.00125	.062	2.6×10^{-9}
306.7	.00135	.068	2.5×10^{-9}
331.3	.00140	.070	2.1×10^{-9}
355.5	.00145	.072	2.0×10^{-9}
378.8	.00155	.078	2.0×10^{-9}
451.0	.00170	.085	1.6×10^{-9}
474.8	.00180	.090	1.6×10^{-9}
498.9	.00190	.095	1.6×10^{-9}
523.5	.00195	.098	2.1×10^{-9}
547.1	.00200	.100	2.1×10^{-9}
618.9	.00225	.112	1.3×10^{-9}
643.0	.00235	.118	1.3×10^{-9}
666.8	.00245	.122	1.4×10^{-9}
690.8	.00255	.128	1.2×10^{-9}
714.9	.00260	.130	1.3×10^{-9}
786.9	.00340	.170	1.2×10^{-9}
811.0	.00365	.182	1.2×10^{-9}

TABLE 13 (Continued)

Time	Length Change Δ L (inch) (2" G. L.)	Creep (%)	Pressure (Torr)
834.6 Hours	.00390	.195	9.4×10^{-10}
858.9	.00390	.195	1.2×10^{-9}
883.0	.00390	.195	1.2×10^{-9}
1,003.2	.00405	.202	1.2×10^{-9}
1,027.3	.00455	.228	8.3×10^{-10}
1,051.1	.00460	.230	9.6×10^{-10}
1,147.0	.00525	.262	9.2×10^{-10}
1,171.0	.00535	.268	9.3×10^{-10}
1,195.1	.00555	.278	8.0×10^{-10}
1,219.1	.00545	.272	7.3×10^{-10}
1,291.2	.00595	.298	9.4×10^{-10}
1,315.5	.00575	.288	8.6×10^{-10}
1,339.7	.00580	.290	7.0×10^{-10}
1,363.2	.00595	.298	8.1×10^{-10}
1,386.1	.00600	.300	8.2×10^{-10}

Test terminated - sufficient data obtained
Specimen B-40B

TABLE 14

Creep Test Data, ASTAR 811C Sheet, Recrystallized 3600°F (1982°C) 0.5 Hour, Tested at 2600°F (1427°C), and 2000 PSI ($1.38 \times 10^7 N/m^2$)

Time	Length Change Δ L (inch) (2" G. L.)	Creep (%)	Pressure (Torr)
1 Minute	.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}
667.6	.00045	.022	1.8×10^{-9}
691.0	.00050	.025	1.6×10^{-9}

TABLE 14 (Continued)

Time	Length Change Δ L (inch) (2" G. L.)	Creep (%)	Pressure (Torr)
715.3 Hours	.00050	.025	1.7×10^{-9}
739.4	.00050	.025	1.5×10^{-9}
859.3	.00060	.030	1.4×10^{-9}
883.1	.00065	.032	1.4×10^{-9}
907.0	.00065	.032	1.3×10^{-9}
931.3	.00070	.035	1.4×10^{-9}
1,027.0	.00075	.038	1.4×10^{-9}
1,051.6	.00075	.038	1.4×10^{-9}
1,075.3	.00080	.040	1.3×10^{-9}
1,099.1	.00080	.040	1.2×10^{-9}
1,171.2	.00085	.042	1.4×10^{-9}
1,195.2	.00085	.042	1.4×10^{-9}
1,219.1	.00085	.042	1.4×10^{-9}
1,242.8	.00085	.042	1.4×10^{-9}
1,266.9	.00090	.045	1.2×10^{-9}
1,339.5	.00095	.048	1.2×10^{-9}
1,362.8	.00100	.050	1.2×10^{-9}
1,387.0	.00100	.050	1.2×10^{-9}
1,410.8	.00100	.050	1.0×10^{-9}
1,434.9	.00100	.050	1.2×10^{-9}
1,506.9	.00110	.055	1.2×10^{-9}
1,530.9	.00110	.055	1.3×10^{-9}
1,555.2	.00115	.058	1.2×10^{-9}
1,579.4	.00120	.060	1.3×10^{-9}
1,603.3	.00125	.062	1.2×10^{-9}
1,674.9	.00125	.062	1.1×10^{-9}
1,698.8	.00130	.065	1.0×10^{-9}
1,722.9	.00130	.065	1.1×10^{-9}
1,746.9	.00130	.065	1.1×10^{-9}
1,771.1	.00140	.070	1.0×10^{-9}
1,845.0	.00145	.072	1.0×10^{-9}
1,867.1	.00150	.075	1.0×10^{-9}
1,891.0	.00150	.075	1.0×10^{-7}
1,915.4	.00155	.078	1.0×10^{-9}
1,941.8	.00160	.080	1.0×10^{-9}
2,010.9	.00170	.085	1.0×10^{-9}

TABLE 14 (Continued)

Time	Length Change Δ L (inch) (2" G. L.)	Creep (%)	Pressure (Torr)
2,035.2 Hours	.00175	.088	1.0×10^{-9}
2,058.6	.00175	.088	1.1×10^{-9}
2,083.0	.00175	.088	1.1×10^{-9}
2,107.0	.00180	.090	1.0×10^{-9}
2,179.3	.00195	.098	1.1×10^{-9}
2,203.1	.00195	.098	1.1×10^{-9}
2,227.7	.00195	.098	1.0×10^{-9}
2,251.7	.00195	.098	1.0×10^{-9}
2,275.3	.00195	.098	1.0×10^{-9}
2,374.4	.00200	.100	9.1×10^{-10}
2,371.6	.00200	.100	9.7×10^{-10}
2,395.0	.00205	.102	9.4×10^{-10}
2,418.7	.00205	.102	9.4×10^{-10}
2,442.8	.00210	.105	9.1×10^{-10}
2,514.8	.00210	.105	9.9×10^{-10}
2,538.9	.00210	.105	9.1×10^{-10}
2,562.5	.00210	.105	1.1×10^{-9}
2,586.5	.00215	.108	9.3×10^{-10}
2,754.6	.00220	.110	1.1×10^{-9}
2,778.8	.00220	.110	8.2×10^{-10}
2,850.6	.00220	.110	9.2×10^{-10}
2,874.8	.00220	.110	8.2×10^{-10}
2,898.9	.00220	.110	8.2×10^{-10}
2,923.0	.00225	.112	8.8×10^{-10}
3,019.3	.00230	.115	9.4×10^{-10}
3,043.1	.00235	.118	1.1×10^{-9}
3,066.8	.00230	.115	9.6×10^{-10}
3,081.8	.00240	.120	9.6×10^{-10}
3,115.1	.00235	.118	8.9×10^{-10}
3,187.1	.00240	.120	9.1×10^{-10}
3,210.8	.00245	.122	9.6×10^{-10}
3,234.8	.00245	.122	1.0×10^{-9}
3,258.6	.00250	.125	8.2×10^{-10}
3,282.7	.00255	.128	9.0×10^{-10}
3,355.7	.00255	.128	8.0×10^{-10}
3,378.7	.00260	.130	9.0×10^{-10}
3,402.8	.00265	.132	9.0×10^{-10}

TABLE 14 (Continued)

Time	Length Change Δ L (inch) (2" G. L.)	Creep (%)	Pressure (Torr)
3,427.0 Hours	.00270	.135	9.0×10^{-10}
3,451.0	.00270	.135	9.1×10^{-10}
3,522.8	.00270	.135	9.7×10^{-10}
3,546.7	.00265	.132	9.5×10^{-10}
3,570.6	.00265	.132	9.8×10^{-10}
3,594.9	.00270	.135	9.4×10^{-10}
3,618.6	.00280	.140	9.3×10^{-10}
3,690.8	.00285	.142	9.8×10^{-10}
3,715.1	.00285	.142	9.3×10^{-10}
3,738.8	.00285	.142	8.9×10^{-9}
3,762.8	.00280	.140	1.3×10^{-9}
3,786.8	.00285	.142	1.2×10^{-10}
3,858.1	.00280	.140	9.9×10^{-9}
3,881.7	.00290	.145	1.2×10^{-9}
3,906.8	.00290	.145	1.1×10^{-9}
3,930.1	.00290	.145	1.0×10^{-9}
3,953.7	.00295	.148	1.0×10^{-9}
4,074.5	.00305	.152	1.2×10^{-9}
4,099.8	.00305	.152	1.2×10^{-9}
4,121.5	.00310	.155	1.2×10^{-9}
4,194.2	.00320	.160	1.1×10^{-9}
4,217.9	.00320	.160	1.2×10^{-9}
4,241.6	.00320	.160	1.2×10^{-9}
4,265.6	.00315	.158	1.1×10^{-9}
4,291.9	.00320	.160	1.0×10^{-9}
4,361.7	.00330	.165	1.1×10^{-9}
4,385.7	.00335	.168	1.1×10^{-9}
4,409.6	.00340	.170	1.1×10^{-9}
4,434.4	.00340	.170	1.0×10^{-10}
4,458.2	.00350	.175	9.8×10^{-10}
4,532.1	.00350	.175	8.7×10^{-10}
4,578.5	.00360	.180	9.2×10^{-9}
4,601.6	.00360	.180	1.1×10^{-9}
4,626.0	.00365	.182	1.1×10^{-10}
4,697.7	.00365	.182	9.2×10^{-10}
4,721.8	.00360	.180	$1.0 \times 10^{-}$

TABLE 14 (Continued)

Time	Length Change Δ L (inch) (2" G. L.)	Creep (%)	Pressure (Torr)
4,746.2 Hours	.00370	.185	1.0×10^{-9}
4,771.8	.00370	.185	1.1×10^{-9}
4,793.7	.00375	.188	1.1×10^{-9}
4,865.5	.00380	.190	9.8×10^{-10}
4,889.9	.00380	.190	1.3×10^{-9}
4,914.0	.00385	.192	1.4×10^{-9}
4,938.7	.00385	.192	1.2×10^{-9}
4,961.7	.00390	.195	1.2×10^{-9}
5,034.0	.00390	.195	1.2×10^{-9}
5,057.5	.00385	.192	1.1×10^{-9}
5,081.5	.00390	.195	1.1×10^{-9}
5,105.8	.00390	.195	1.0×10^{-9}
5,129.5	.00395	.198	1.2×10^{-9}
5,203.0	.00425	.212	1.0×10^{-9}
5,225.6	.00405	.202	1.1×10^{-9}
5,249.3	.00415	.208	9.5×10^{-10}
5,273.3	.00420	.210	9.3×10^{-10}
5,297.4	.00420	.210	1.2×10^{-9}
5,369.4	.00425	.212	1.1×10^{-9}
5,417.4	.00430	.215	8.4×10^{-10}
5,441.4	.00430	.215	9.0×10^{-10}
5,465.6	.00430	.215	8.0×10^{-10}
5,537.9	.00440	.220	1.0×10^{-9}
5,561.6	.00440	.220	1.0×10^{-9}
5,610.3	.00450	.225	8.6×10^{-10}
5,634.5	.00450	.225	7.8×10^{-10}
5,706.1	.00460	.230	9.8×10^{-10}
5,729.6	.00450	.225	9.5×10^{-10}
5,753.9	.00450	.225	9.7×10^{-10}
5,777.5	.00450	.225	7.9×10^{-10}
5,801.4	.00455	.228	1.7×10^{-10}
5,897.4	.00460	.230	9.4×10^{-10}
5,926.9	.00460	.230	9.7×10^{-10}
5,945.3	.00460	.230	8.4×10^{-10}
5,969.4	.00460	.230	8.2×10^{-10}
6,043.3	.00475	.238	8.4×10^{-10}
6,065.5	.00480	.240	9.2×10^{-10}
6,089.6	.00480	.240	8.4×10^{-10}
6,065.5	.00480	.240	9.2×10^{-10}
6,089.6	.00480	.240	8.4×10^{-10}
6,113.6	.00480	.240	8.8×10^{-10}
6,137.4	.00475	.238	9.0×10^{-10}

TABLE 14 (Continued)

Time	Length Change Δ L (inch) (2" G. L.)	Creep (%)	Pressure (Torr)
6,209.6 Hours	.00475	.238	7.7×10^{-10}
6,233.6	.00480	.240	7.8×10^{-10}
6,257.6	.00475	.238	8.5×10^{-10}
6,281.6	.00475	.238	8.2×10^{-10}
6,305.5	.00475	.238	9.6×10^{-10}
6,377.6	.00480	.240	9.4×10^{-10}
6,401.5	.00485	.242	9.0×10^{-10}
6,425.9	.00490	.245	8.2×10^{-10}
6,449.6	.00490	.245	9.4×10^{-10}
6,473.6	.00490	.245	9.8×10^{-10}
6,546.1	.00495	.248	7.8×10^{-10}
6,569.5	.00500	.250	8.6×10^{-10}
6,593.5	.00500	.250	8.6×10^{-10}
6,617.4	.00500	.250	9.4×10^{-10}
6,641.7	.00505	.252	9.3×10^{-10}
6,713.5	.00510	.255	9.6×10^{-10}
6,738.6	.00505	.252	8.0×10^{-10}
6,761.5	.00505	.252	9.0×10^{-10}
6,786.0	.00505	.252	8.0×10^{-10}
6,810.4	.00510	.255	8.4×10^{-10}
6,906.5	.00510	.255	9.8×10^{-10}
6,929.6	.00515	.258	9.7×10^{-10}
6,953.4	.00515	.258	8.3×10^{-10}
6,978.0	.00515	.258	8.0×10^{-10}
7,049.8	.00520	.260	9.1×10^{-10}
7,074.1	.00520	.260	8.8×10^{-10}
7,097.6	.00525	.262	8.0×10^{-10}
7,121.5	.00525	.262	8.7×10^{-10}
7,145.4	.00535	.268	9.3×10^{-10}
7,217.7	.00540	.270	9.2×10^{-10}
7,241.5	.00545	.272	8.9×10^{-10}
7,265.4	.00545	.272	8.8×10^{-10}
7,289.4	.00545	.272	8.5×10^{-10}
7,313.5	.00550	.275	8.4×10^{-10}
7,386.4	.00555	.278	8.4×10^{-10}
7,409.4	.00555	.278	9.4×10^{-10}
7,434.0	.00555	.278	8.2×10^{-10}
7,457.4	.00555	.278	8.1×10^{-10}
7,481.3	.00555	.278	8.0×10^{-10}

TABLE 14 (Continued)

Time	Length Change Δ L (inch) (2" G. L.)	Creep (%)	Pressure (Torr)
7,553.6 Hours	.00565	.282	8.4×10^{-10}
7,577.4	.00560	.280	8.1×10^{-10}
7,602.3	.00565	.282	7.5×10^{-10}
7,625.4	.00-65	.282	7.6×10^{-10}
7,649.5	.00565	.282	8.0×10^{-10}
7,721.4	.00570	.285	8.4×10^{-10}
7,745.4	.00570	.285	8.2×10^{-10}
7,769.5	.00575	.288	7.8×10^{-10}
7,793.4	.00575	.288	8.1×10^{-10}
7,818.0	.00585	.292	6.5×10^{-10}
7,890.3	.00585	.292	8.6×10^{-10}
7,913.5	.00595	.298	8.5×10^{-10}
7,937.4	.00595	.298	7.6×10^{-10}
7,961.6	.00600	.300	7.5×10^{-10}
7,985.6	.00600	.300	7.5×10^{-10}
8,057.8	.00595	.298	6.0×10^{-10}
8,082.5	.00605	.302	9.2×10^{-10}
8,106.2	.00615	.308	7.6×10^{-10}
8,129.8	.00615	.308	8.8×10^{-10}
8,154.0	.00620	.310	9.5×10^{-10}
8,226.8	.00620	.310	7.6×10^{-10}
8,250.1	.00625	.312	8.0×10^{-10}
8,274.2	.00625	.312	7.8×10^{-10}
8,298.9	.00625	.312	8.0×10^{-10}
8,322.3	.00635	.318	8.0×10^{-10}
8,394.7	.00630	.315	7.5×10^{-10}
8,418.2	.00630	.315	7.4×10^{-10}
8,442.9	.00630	.315	9.0×10^{-10}
8,466.2	.00630	.315	9.4×10^{-10}
8,490.3	.00635	.318	9.9×10^{-10}
8,562.7	.00640	.320	7.2×10^{-10}
8,586.2	.00640	.320	9.8×10^{-10}
8,610.5	.00640	.320	7.7×10^{-10}
8,634.4	.00645	.322	9.5×10^{-10}
8,658.5	.00655	.328	1.1×10^{-9}
8,730.7	.00655	.328	9.8×10^{-10}

TABLE 14(Continued)

Time	Length Change Δ L (inch) (2" G. L.)	Creep (%)	Pressure (Torr)
8,754.4 Hours	.00660	.330	7.7×10^{-10}
8,778.7	.00665	.332	7.6×10^{-10}
8,898.4	.00695	.348	9.8×10^{-10}
8,922.2	.00700	.350	9.7×10^{-10}
8,946.8	.00695	.348	9.2×10^{-10}
8,970.9	.00705	.352	9.2×10^{-9}
8,994.3	.00720	.360	1.1×10^{-10}
9,066.5	.00730	.365	7.6×10^{-10}
9,090.3	.00720	.360	9.2×10^{-10}
9,114.2	.00720	.360	8.0×10^{-9}
9,138.7	.00730	.365	1.0×10^{-10}
9,162.6	.00735	.368	8.5×10^{-10}
9,234.4	.00740	.370	7.6×10^{-9}
9,258.3	.00750	.375	1.0×10^{-10}
9,282.3	.00750	.375	9.2×10^{-9}
9,306.4	.00750	.375	1.1×10^{-10}
9,330.3	.00755	.378	9.8×10^{-9}
9,402.3	.00755	.378	1.2×10^{-9}

Test in progress
Specimen S-29

TABLE 15

Creep Test Data, T-111 Sheet Heat D-1670, Recrystallized 3000°F (1649°C) 1 Hour, Tested at 1800°F (982°C), and 17,000 PSI ($1.17 \times 10^8 N/m^2$)

Time	Length Change Δ L (inch) (2" G. L.)	Creep (%)	Pressure (Torr)
1 Minute	.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^{-9}
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}
617.1	.00085	.042	8.8×10^{-10}
641.6	.00090	.045	8.8×10^{-10}
665.7	.00095	.048	8.6×10^{-10}

TABLE 15 (Continued)

Time	Length Change Δ L (inch) (2" G. L.)	Creep (%)	Pressure (Torr)
736.9 Hours	.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}
1,000.2	.00110	.055	7.0×10^{-10}
1,074.0	.00110	.055	7.3×10^{-10}
1,096.5	.00120	.060	6.8×10^{-10}
1,120.7	.00120	.060	6.8×10^{-10}
1,144.7	.00120	.060	6.9×10^{-10}
1,168.5	.00115	.058	6.9×10^{-10}
1,240.5	.00120	.060	6.6×10^{-10}
1,264.7	.00115	.058	6.5×10^{-10}
1,288.7	.00125	.062	6.5×10^{-10}
1,312.7	.00125	.062	6.4×10^{-10}
1,336.6	.00130	.065	6.2×10^{-10}
1,433.2	.00145	.072	5.9×10^{-10}
1,456.7	.00155	.078	6.1×10^{-10}
1,480.4	.00155	.078	6.1×10^{-10}
1,504.5	.00155	.078	6.0×10^{-10}
1,577.0	.00160	.080	6.0×10^{-10}
1,600.6	.00165	.082	7.1×10^{-10}
1,624.6	.00165	.082	7.2×10^{-10}
1,648.4	.00165	.082	7.0×10^{-10}
1,673.1	.00170	.085	6.9×10^{-10}
1,745.2	.00175	.088	5.4×10^{-10}
1,768.7	.00180	.090	5.4×10^{-10}
1,792.7	.00175	.088	5.4×10^{-10}
1,816.8	.00190	.095	5.4×10^{-10}
1,840.5	.00195	.098	5.4×10^{-10}
1,912.6	.00200	.100	5.4×10^{-10}
1,936.8	.00205	.102	5.3×10^{-10}

TABLE 15 (Continued)

Time	Length Change Δ L (inch) (2" G. L.)	Creep (%)	Pressure (Torr)
1,960.6 Hours	.00210	.105	5.6×10^{-10}
1,985.0	.00205	.102	5.2×10^{-10}
2,008.8	.00210	.105	5.3×10^{-10}
2,104.5	.00210	.105	5.0×10^{-10}
2,128.6	.00220	.110	5.0×10^{-10}
2,154.6	.00225	.112	5.4×10^{-10}
2,176.9	.00230	.115	5.0×10^{-10}
2,248.6	.00235	.118	7.0×10^{-10}
2,272.7	.00230	.115	5.1×10^{-10}
2,296.6	.00240	.120	5.2×10^{-10}
2,320.7	.00245	.122	5.0×10^{-10}
2,344.8	.00245	.122	5.1×10^{-10}
2,416.6	.00255	.128	4.9×10^{-10}
2,440.6	.00260	.130	4.9×10^{-10}
2,464.9	.00260	.130	4.8×10^{-10}
2,488.7	.00265	.132	5.0×10^{-10}
2,512.6	.00265	.132	5.0×10^{-10}
2,584.6	.00270	.135	5.0×10^{-10}
2,611.7	.00275	.138	5.2×10^{-10}
2,632.7	.00275	.138	5.1×10^{-10}
2,657.1	.00280	.140	4.9×10^{-10}
2,680.7	.00285	.142	5.0×10^{-10}
2,753.6	.00290	.145	4.8×10^{-10}
2,777.6	.00300	.150	4.9×10^{-10}
2,801.7	.00305	.152	4.8×10^{-10}
2,825.9	.00310	.155	4.9×10^{-10}
2,849.7	.00320	.160	5.0×10^{-10}
2,921.6	.00335	.168	4.7×10^{-10}
2,945.7	.00340	.170	4.6×10^{-10}
2,970.1	.00350	.175	4.6×10^{-10}
2,993.6	.00350	.175	4.7×10^{-10}
3,017.5	.00360	.180	4.7×10^{-10}
3,089.7	.00365	.182	4.8×10^{-10}
3,114.1	.00370	.185	4.8×10^{-10}
3,138.2	.00390	.195	4.7×10^{-10}
3,161.8	.00390	.195	4.8×10^{-10}

TABLE 15 (Continued)

Time	Length Change Δ L (inch) (2" G. L.)	Creep (%)	Pressure (Torr)
3,185.6 Hours	.00400	.200	4.7×10^{-10}
3,257.8	.00430	.215	4.7×10^{-10}
3,281.6	.00435	.218	4.7×10^{-10}
3,305.8	.00445	.222	4.7×10^{-10}
3,353.6	.00445	.222	4.6×10^{-10}
3,425.7	.00450	.225	4.4×10^{-10}
3,449.6	.00455	.228	4.2×10^{-10}
3,473.7	.00460	.230	4.2×10^{-10}
3,498.2	.00470	.235	4.3×10^{-10}
3,522.1	.00465	.232	4.5×10^{-10}
3,594.1	.00475	.238	4.4×10^{-10}
3,617.8	.00475	.238	4.4×10^{-10}
3,641.7	.00490	.245	4.4×10^{-10}
3,665.8	.00490	.245	4.2×10^{-10}
3,689.7	.00500	.250	4.1×10^{-10}
3,762.0	.00505	.252	4.1×10^{-10}
3,785.7	.00515	.257	4.3×10^{-10}
3,809.7	.00530	.265	4.2×10^{-10}
3,833.9	.00530	.265	4.3×10^{-10}
3,857.7	.00540	.270	4.3×10^{-10}
3,930.4	.00540	.270	4.3×10^{-10}
3,953.9	.00545	.272	4.0×10^{-10}
3,978.1	.00545	.272	4.2×10^{-10}
4,002.2	.00550	.275	4.2×10^{-10}
4,122.1	.00565	.282	4.1×10^{-10}
4,146.0	.00580	.290	4.2×10^{-10}
4,169.7	.00590	.295	4.0×10^{-10}
4,194.0	.00590	.295	4.1×10^{-10}
4,289.9	.00605	.302	4.2×10^{-10}
4,314.5	.00610	.305	4.3×10^{-10}
4,338.2	.00620	.310	4.4×10^{-10}
4,361.9	.00640	.320	4.3×10^{-10}
4,434.5	.00665	.332	4.2×10^{-10}
4,458.1	.00670	.335	4.2×10^{-10}
4,482.1	.00680	.340	4.0×10^{-10}
4,505.8	.00700	.350	4.2×10^{-10}

TABLE 15 (Continued)

Time	Length Change Δ L (inch) (2" G. L.)	Creep (%)	Pressure (Torr)
4,529.9 Hours	.00710	.355	4.3×10^{-10}
4,602.5	.00725	.362	4.0×10^{-10}
4,625.8	.00730	.365	4.0×10^{-10}
4,649.9	.00730	.365	4.2×10^{-10}
4,674.2	.00740	.370	4.2×10^{-10}
4,698.0	.00750	.375	4.2×10^{-10}
4,770.0	.00775	.388	3.9×10^{-10}
4,793.9	.00780	.390	4.1×10^{-10}
4,818.2	.00780	.390	4.0×10^{-10}
4,842.3	.00785	.392	3.9×10^{-10}
4,866.3	.00785	.392	3.9×10^{-10}
4,938.2	.00785	.392	3.9×10^{-10}
4,961.7	.00790	.395	4.0×10^{-10}
4,985.8	.00795	.398	4.7×10^{-10}
5,009.8	.00800	.400	4.1×10^{-10}
5,034.1	.00800	.400	3.9×10^{-10}
5,108.0	.00800	.400	4.0×10^{-10}
5,130.1	.00810	.405	3.8×10^{-10}
5,154.0	.00810	.405	4.0×10^{-10}
5,178.4	.00820	.410	4.0×10^{-10}
5,204.7	.00825	.412	4.0×10^{-10}
5,273.9	.00835	.418	3.4×10^{-10}
5,298.2	.00840	.420	4.0×10^{-10}
5,321.6	.00850	.425	3.8×10^{-10}
5,345.9	.00855	.428	4.0×10^{-10}
5,369.9	.00865	.432	3.5×10^{-10}
5,442.3	.00880	.440	4.0×10^{-10}
5,466.0	.00890	.445	3.8×10^{-10}
5,490.6	.00890	.445	4.0×10^{-10}
5,514.6	.00895	.448	3.9×10^{-10}
5,538.3	.00900	.450	3.8×10^{-10}
5,610.3	.00920	.460	3.6×10^{-10}
5,634.5	.00930	.465	3.8×10^{-10}
5,658.0	.00940	.470	3.8×10^{-10}
5,681.7	.00940	.470	3.9×10^{-10}
5,705.8	.00945	.472	3.8×10^{-10}
5,777.7	.00965	.482	3.8×10^{-10}
5,802.0	.00975	.488	3.7×10^{-10}
5,825.5	.00975	.488	3.9×10^{-10}
5,849.5	.00985	.492	3.8×10^{-10}
5,873.5	.00985	.492	4.1×10^{-10}

TABLE 15 (Continued)

Time	Length Change Δ L (inch) (2" G. L.)	Creep (%)	Pressure (Torr)
5,945.6 Hours	.00985	.492	3.6×10^{-10}
5,969.6	.01000	.500	3.9×10^{-10}
5,994.2	.01005	.502	3.7×10^{-10}
6,017.6	.01020	.510	4.0×10^{-10}
6,041.8	.01035	.518	3.6×10^{-10}
6,113.6	.01060	.530	4.0×10^{-10}
6,137.8	.01065	.532	3.6×10^{-10}
6,161.9	.01075	.538	4.0×10^{-10}
6,185.9	.01090	.545	3.6×10^{-10}
6,282.3	.01100	.550	3.6×10^{-10}
6,306.1	.01115	.558	3.9×10^{-10}
6,329.8	.01110	.555	3.8×10^{-10}
6,353.8	.01120	.560	3.9×10^{-10}
6,378.2	.01120	.560	3.6×10^{-10}
6,450.1	.01125	.562	3.9×10^{-10}
6,473.8	.01150	.575	3.7×10^{-10}
6,497.8	.01160	.580	3.9×10^{-10}
6,521.5	.01160	.580	3.5×10^{-10}
6,545.6	.01170	.585	3.6×10^{-10}
6,619.3	.01170	.585	3.5×10^{-10}
6,641.7	.01195	.598	3.8×10^{-10}
6,665.8	.01205	.602	3.6×10^{-10}
6,690.0	.01215	.608	3.8×10^{-10}
6,714.0	.01225	.612	3.8×10^{-10}
6,785.8	.01235	.618	3.8×10^{-10}
6,809.7	.01235	.618	3.6×10^{-10}
6,833.5	.01240	.620	3.8×10^{-10}
6,857.9	.01250	.625	3.6×10^{-10}
6,881.7	.01260	.630	3.7×10^{-10}
6,953.8	.01275	.638	3.8×10^{-10}
6,978.1	.01285	.642	3.9×10^{-10}
7,001.8	.01290	.645	3.8×10^{-10}
7,025.8	.01290	.645	3.9×10^{-10}
7,049.8	.01300	.650	4.0×10^{-10}
7,121.0	.01300	.650	3.5×10^{-10}
7,144.8	.01320	.660	3.7×10^{-10}
7,169.7	.01325	.662	3.9×10^{-10}
7,193.1	.01325	.662	3.7×10^{-10}
7,216.7	.01335	.668	3.7×10^{-10}
7,338.2	.01375	.688	3.7×10^{-10}
7,362.8	.01390	.695	4.0×10^{-10}
7,384.5	.01410	.705	3.8×10^{-10}

TABLE 15 (Continued)

Time	Length Change Δ L (inch) (2" G. L.)	Creep (%)	Pressure (Torr)
7,457.2	.01415	.708	4.0×10^{-10}
7,480.9	.01415	.708	3.6×10^{-10}
7,504.6	.01415	.708	3.7×10^{-10}
7,528.6	.01425	.712	3.7×10^{-10}
7,554.9	.01445	.722	3.7×10^{-10}
7,624.7	.01455	.728	3.9×10^{-10}
7,648.7	.01465	.732	3.8×10^{-10}
7,672.5	.01465	.732	3.7×10^{-10}
7,697.3	.01495	.748	3.9×10^{-10}
7,721.2	.01505	.752	3.8×10^{-10}
7,795.1	.01515	.752	3.8×10^{-10}
7,841.6	.01520	.760	3.6×10^{-10}
7,864.6	.01540	.770	3.8×10^{-10}
7,889.0	.01545	.772	3.4×10^{-10}
7,960.7	.01555	.778	3.6×10^{-10}
7,984.8	.01560	.780	3.6×10^{-10}
8,009.3	.01570	.785	3.5×10^{-10}
8,034.8	.01580	.790	3.6×10^{-10}
8,056.7	.01585	.795	3.6×10^{-10}
8,128.5	.01600	.800	3.6×10^{-10}
8,153.1	.01605	.802	3.4×10^{-10}
8,177.1	.01615	.808	3.9×10^{-10}
8,201.7	.01620	.810	3.7×10^{-10}
8,224.7	.01625	.812	3.8×10^{-10}
8,297.2	.01640	.812	3.8×10^{-10}
8,320.6	.01650	.825	3.8×10^{-10}
8,344.5	.01655	.828	3.8×10^{-10}
8,368.9	.01660	.830	3.6×10^{-10}
8,392.5	.01675	.838	3.7×10^{-10}
8,466.1	.01685	.842	3.8×10^{-10}
8,488.9	.01695	.848	3.8×10^{-10}
8,512.4	.01695	.848	3.6×10^{-10}
8,536.4	.01710	.855	3.6×10^{-10}
8,560.5	.01725	.862	3.6×10^{-10}
8,632.5	.01730	.865	3.7×10^{-10}
8,680.5	.01770	.885	3.7×10^{-10}

TABLE 15 (Continued)

Time	Length Change Δ L (inch) (2" G. L.)	Creep (%)	Pressure (Torr)
8,704.6	.01770	.885	3.6×10^{-10}
8,728.7	.01775	.888	3.5×10^{-10}
8,801.0	.01780	.890	3.5×10^{-10}
8,824.6	.01775	.888	3.6×10^{-10}
8,849.3	.01780	.890	3.5×10^{-10}
8,873.4	.01790	.895	3.6×10^{-10}
8,897.7	.01795	.898	3.7×10^{-10}
8,969.2	.01820	.910	3.9×10^{-10}
8,992.7	.01835	.918	3.6×10^{-10}
9,017.0	.01850	.925	4.2×10^{-10}
9,040.6	.01860	.930	4.1×10^{-10}
9,064.8	.01875	.938	3.7×10^{-10}
9,138.4	.01875	.938	3.6×10^{-10}
9,161.0	.01885	.942	3.6×10^{-10}
9,189.9	.01890	.945	3.6×10^{-10}
9,208.4	.01905	.952	3.7×10^{-10}
9,232.6	.01905	.952	3.9×10^{-10}
9,306.5	.01930	.965	3.7×10^{-10}
9,328.7	.01935	.968	3.8×10^{-10}
9,352.8	.01950	.975	3.8×10^{-10}
9,376.7	.01960	.980	3.9×10^{-10}
9,400.6	.01970	.985	3.8×10^{-10}
9,472.9	.01985	.992	3.8×10^{-10}
9,496.6	.01985	.992	4.0×10^{-10}
9,520.7	.01995	.998	3.6×10^{-10}
9,544.7	.02005	1.002	3.5×10^{-10}
9,568.6	.02010	1.005	3.6×10^{-10}
9,624.2	.02060	1.030	3.5×10^{-10}

Test terminated - sufficient data obtained
Specimen S-26

TABLE 16

Creep Test Data, T-111 Sheet Heat D-1670, Recrystallized 3000°F (1649°C) 1 Hour, Tested at 2600°F (1427°C), and 500 PSI (3.45×10^{6} N/m^2)

Time	Length Change Δ L (inch) (2" G. L.)	Creep (%)	Pressure (Torr)
1 Minute	.00005	.002	2.6×10^{-8}
2	.00005	.002	2.6×10^{-8}
3	.00000	.000	2.6×10^{-8}
4	.00005	.002	2.6×10^{-8}
5	.00000	.000	2.6×10^{-8}
6	.00005	.002	2.6×10^{-8}
7	.00005	.002	2.6×10^{-8}
8	.00005	.002	2.6×10^{-8}
9	.00010	.005	2.6×10^{-8}
10	.00005	.002	2.6×10^{-8}
15	-.00005	-.002	2.6×10^{-8}
30	-.00010	-.005	2.6×10^{-8}
45	-.00010	-.005	2.6×10^{-8}
60	-.00010	-.005	2.6×10^{-8}
16.4 Hours	-.00010	-.005	1.6×10^{-9}
40.4	.00005	.002	8.0×10^{-9}
64.4	.00050	.025	8.4×10^{-9}
83.3	.00075	.038	7.9×10^{-9}
160.3	.00180	.090	5.5×10^{-9}
184.5	.00205	.102	5.5×10^{-9}
208.3	.00235	.118	5.3×10^{-9}
232.7	.00245	.122	5.0×10^{-9}
256.5	.00260	.130	4.2×10^{-9}
328.5	.00325	.162	3.8×10^{-9}
352.3	.00335	.168	3.6×10^{-9}
376.4	.00345	.172	4.6×10^{-9}
402.4	.00345	.172	6.0×10^{-9}
424.5	.00350	.175	3.6×10^{-9}
496.4	.00370	.185	3.3×10^{-9}
520.4	.00375	.188	3.4×10^{-9}
544.3	.00385	.192	3.9×10^{-9}
568.4	.00385	.192	3.5×10^{-9}
592.5	.00385	.192	3.7×10^{-9}
664.3	.00395	.198	4.2×10^{-9}
688.3	.00395	.198	4.0×10^{-9}
712.6	.00400	.200	3.2×10^{-9}
736.4	.00405	.202	3.8×10^{-9}

TABLE 16 (Continued)

Time	Length Change Δ L (inch) (2" G. L.)	Creep (%)	Pressure (Torr)
760.3 Hours	.00410	.205	3.1×10^{-9}
832.3	.00430	.215	3.0×10^{-9}
859.4	.00435	.218	4.0×10^{-9}
880.4	.00435	.218	5.4×10^{-9}
904.7	.00445	.222	5.4×10^{-9}
928.5	.00460	.230	5.2×10^{-9}
1,001.3	.00465	.232	5.0×10^{-9}
1,025.4	.00465	.232	4.9×10^{-9}
1,049.5	.00475	.238	5.2×10^{-9}
1,073.6	.00490	.245	5.6×10^{-9}
1,097.4	.00505	.252	5.3×10^{-9}
1,169.4	.00535	.268	4.9×10^{-9}
1,193.4	.00550	.275	4.9×10^{-9}
1,217.8	.00555	.278	4.8×10^{-9}
1,241.3	.00565	.282	4.0×10^{-9}
1,265.3	.00570	.285	4.9×10^{-9}
1,337.5	.00585	.292	5.0×10^{-9}
1,361.4	.00590	.295	2.8×10^{-9}
1,385.9	.00590	.295	4.5×10^{-9}
1,409.5	.00595	.298	2.9×10^{-9}
1,433.3	.00600	.300	4.5×10^{-9}
1,505.5	.00605	.302	4.9×10^{-9}
1,529.4	.00615	.308	5.0×10^{-9}
1,553.5	.00620	.310	4.6×10^{-9}
1,601.2	.00615	.308	4.7×10^{-9}
1,673.5	.00625	.312	4.6×10^{-9}
1,697.4	.00625	.312	4.4×10^{-9}
1,721.4	.00625	.312	4.1×10^{-9}
1,745.9	.00625	.312	4.6×10^{-9}
1,769.8	.00635	.318	4.5×10^{-9}
1,841.8	.00635	.318	2.9×10^{-9}
1,865.6	.00640	.320	4.3×10^{-9}
1,889.5	.00645	.322	4.1×10^{-9}
1,913.5	.00645	.322	4.1×10^{-9}
1,937.5	.00650	.325	2.4×10^{-9}
2,009.7	.00660	.330	4.4×10^{-9}

TABLE 16 (Continued)

Time	Length Change Δ L (inch) (2" G. L.)	Creep (%)	Pressure (Torr)
2,033.4 Hours	.00665	.332	4.1×10^{-9}
2,057.5	.00665	.332	4.0×10^{-9}
2,081.4	.00675	.338	4.2×10^{-9}
2,105.4	.00675	.338	4.1×10^{-9}
2,178.2	.00680	.340	4.9×10^{-9}
2,201.6	.00685	.342	2.8×10^{-9}
2,225.8	.00685	.342	3.0×10^{-9}
2,249.9	.00690	.345	3.8×10^{-9}
2,369.8	.00695	.348	3.6×10^{-9}
2,369.8	.00695	.348	3.6×10^{-9}
2,393.6	.00695	.348	4.0×10^{-9}
2,417.5	.00695	.348	3.8×10^{-9}
2,441.8	.00705	.352	4.1×10^{-9}
2,537.6	.00705	.352	4.1×10^{-9}
2,562.2	.00705	.352	3.8×10^{-9}
2,585.9	.00710	.355	4.0×10^{-9}
2,609.7	.00710	.355	4.0×10^{-9}
2,682.1	.00705	.352	2.0×10^{-9}
2,705.9	.00705	.352	3.7×10^{-9}
2,729.8	.00705	.352	2.2×10^{-9}
2,753.5	.00705	.352	3.6×10^{-9}
2,777.6	.00710	.355	3.7×10^{-9}
2,850.2	.00685	.342	3.8×10^{-9}
2,873.5	.00685	.342	4.1×10^{-9}
2,897.7	.00695	.348	3.8×10^{-9}
2,921.5	.00705	.352	3.6×10^{-9}
2,945.7	.00705	.352	3.9×10^{-9}
3,017.7	.00705	.352	3.5×10^{-9}
3,041.6	.00700	.350	4.6×10^{-9}
3,065.9	.00710	.355	3.8×10^{-9}
3,090.1	.00710	.355	4.0×10^{-9}
3,114.0	.00715	.358	3.6×10^{-9}
3,185.6	.00710	.355	3.9×10^{-9}
3,209.5	.00710	.355	4.0×10^{-9}
3,233.6	.00710	.355	4.0×10^{-9}
3,257.6	.00715	.358	3.8×10^{-9}

TABLE 16(Continued)

Time	Length Change Δ L (inch) (2" G. L.)	Creep (%)	Pressure (Torr)
3,281.8 Hours	.00715	.358	3.8×10^{-9}
3,355.7	.00720	.360	3.3×10^{-9}
3,377.8	.00720	.360	4.0×10^{-9}
3,401.7	.00710	.355	4.0×10^{-9}
3,426.2	.00710	.355	3.7×10^{-9}
3,452.5	.00715	.358	3.7×10^{-9}
3,521.6	.00715	.358	3.2×10^{-9}
3,545.9	.00710	.355	3.9×10^{-9}
3,569.3	.00715	.358	3.4×10^{-9}
3,593.7	.00710	.355	3.9×10^{-9}
3,617.7	.00710	.355	3.6×10^{-9}
3,690.0	.00720	.360	3.7×10^{-9}
3,713.8	.00715	.358	3.4×10^{-9}
3,738.3	.00725	.362	3.6×10^{-9}
3,762.4	.00720	.360	3.6×10^{-9}
3,786.0	.00720	.360	3.5×10^{-9}
3,858.1	.00725	.362	3.4×10^{-9}
3,882.2	.00725	.362	3.4×10^{-9}
3,905.7	.00725	.362	3.5×10^{-9}
3,929.4	.00725	.362	3.8×10^{-9}
3,953.5	.00725	.362	3.2×10^{-9}
4,025.5	.00725	.362	3.4×10^{-9}
4,049.6	.00715	.358	3.1×10^{-9}
4,073.2	.00725	.362	3.8×10^{-9}
4,097.3	.00715	.358	3.7×10^{-9}
4,121.2	.00720	.360	4.0×10^{-9}
4,193.3	.00730	.365	3.0×10^{-9}
4,217.3	.00725	.362	3.2×10^{-9}
4,241.9	.00720	.360	3.5×10^{-9}
4,265.3	.00720	.360	3.6×10^{-9}
4,289.5	.00730	.365	3.8×10^{-9}

TABLE 16 (Continued)

Time	Length Change Δ L (inch) (2" G. L.)	Creep (%)	Pressure (Torr)
4,361.3	.00730	.365	4.0×10^{-9}
4,385.6	.00735	.368	3.6×10^{-9}
4,409.6	.00735	.368	3.7×10^{-9}
4,433.7	.00730	.365	3.6×10^{-9}
4,530.0	.00735	.368	3.3×10^{-9}
4,553.8	.00735	.368	3.6×10^{-9}
4,577.5	.00730	.365	3.4×10^{-9}
4,601.5	.00730	.365	3.7×10^{-9}
4,625.9	.00740	.370	3.5×10^{-9}
4,697.8	.00745	.372	3.6×10^{-9}
4,721.5	.00755	.378	3.3×10^{-9}
4,745.5	.00755	.378	3.5×10^{-9}
4,769.3	.00755	.378	3.0×10^{-9}
4,793.4	.00750	.375	3.5×10^{-9}
4,867.0	.00765	.382	3.7×10^{-9}
4,913.5	.00760	.380	3.4×10^{-9}
4,889.4	.00760	.380	3.7×10^{-9}
4,937.7	.00765	.382	3.5×10^{-9}
4,961.7	.00775	.388	3.4×10^{-9}
5,033.5	.00770	.385	3.4×10^{-9}
5,057.4	.00770	.385	3.2×10^{-9}
5,081.3	.00780	.390	3.4×10^{-9}
5,105.6	.00775	.388	3.9×10^{-9}
5,129.5	.00780	.390	3.1×10^{-9}
5,201.5	.00775	.358	3.0×10^{-9}
5,225.8	.00785	.392	3.4×10^{-9}
5,249.5	.00785	.392	3.5×10^{-9}
5,273.5	.00785	.392	3.8×10^{-9}
5,297.5	.00785	.392	3.7×10^{-9}
5,368.8	.00785	.392	3.5×10^{-9}
5,392.6	.00795	.398	3.3×10^{-9}
5,417.5	.00805	.402	3.5×10^{-9}
5,440.8	.00800	.400	3.4×10^{-9}
5,464.4	.00800	.400	3.7×10^{-9}
5,585.2	.00800	.400	2.0×10^{-9}

TABLE 16 (Continued)

Time	Length Change Δ L (inch) (2" G. L.)	Creep (%)	Pressure (Torr)
5,610.5 Hours	.00805	.402	2.0×10^{-9}
5,632.2	.00810	.405	3.3×10^{-9}
5,705.0	.00800	.400	3.1×10^{-9}
5,752.3	.00790	.395	3.3×10^{-9}
5,776.3	.00800	.400	3.1×10^{-9}
5,802.7	.00800	.400	3.0×10^{-9}
5,872.5	.00800	.400	3.1×10^{-9}
5,896.5	.00800	.400	3.2×10^{-9}
5,920.3	.00795	.398	3.2×10^{-9}
5,945.1	.00800	.400	3.2×10^{-9}
5,968.9	.00805	.402	2.9×10^{-9}
6,042.8	.00825	.412	2.7×10^{-9}
6,089.2	.00825	.412	3.2×10^{-9}
6,112.3	.00825	.412	2.0×10^{-9}
6,136.7	.00825	.412	3.1×10^{-9}
6,208.4	.00815	.408	3.0×10^{-9}
6,232.5	.00825	.412	3.2×10^{-9}
6,257.0	.00815	.408	3.1×10^{-9}
6,282.5	.00815	.408	3.3×10^{-9}
6,304.5	.00805	.402	3.1×10^{-9}
6,376.2	.00815	.408	3.0×10^{-9}
6,400.8	.00815	.408	3.0×10^{-9}
6,424.8	.00820	.410	3.1×10^{-9}
6,449.4	.00820	.410	3.2×10^{-9}
6,472.3	.00815	.408	3.2×10^{-9}
6,544.9	.00815	.408	3.3×10^{-9}
6,568.4	.00805	.402	2.4×10^{-9}
6,592.3	.00805	.402	2.0×10^{-9}
6,616.7	.00815	.408	3.0×10^{-9}
6,640.3	.00816	.408	1.9×10^{-9}
6,713.8	.00795	.398	3.2×10^{-9}
6,736.5	.00815	.408	3.3×10^{-9}
6,760.1	.00820	.410	3.6×10^{-9}
6,784.1	.00805	.402	3.2×10^{-9}
6,808.2	.00815	.408	3.9×10^{-9}

TABLE 16 (Continued)

Time	Length Change Δ L (inch) (2" G. L.)	Creep (%)	Pressure (Torr)
6,880.2 Hours	.00810	.405	3.8×10^{-9}
6,929.2	.00805	.402	3.2×10^{-9}
6,952.2	.00815	.408	3.4×10^{-9}
6,976.4	.00815	.408	3.3×10^{-9}
7,048.8	.00815	.408	4.0×10^{-9}
7,072.4	.00815	.408	2.9×10^{-9}
7,097.0	.00815	.408	2.9×10^{-9}
7,121.0	.00815	.408	3.3×10^{-9}
7,145.4	.00815	.408	3.3×10^{-9}
7,216.9	.00820	.410	3.5×10^{-9}
7,240.4	.00805	.402	3.0×10^{-9}
7,264.7	.00810	.405	3.0×10^{-9}
7,288.4	.00815	.408	3.1×10^{-9}
7,312.5	.00815	.408	3.3×10^{-9}
7,386.1	.00835	.418	2.7×10^{-9}
7,408.2	.00835	.418	2.9×10^{-9}
7,437.7	.00835	.418	3.1×10^{-9}
7,456.1	.00840	.420	3.3×10^{-9}
7,480.3	.00840	.420	3.3×10^{-9}
7,554.3	.00845	.422	2.9×10^{-9}
7,576.4	.00845	.422	2.9×10^{-9}
7,600.5	.00850	.425	2.9×10^{-9}
7,624.4	.00855	.428	2.9×10^{-9}
7,648.3	.00860	.430	2.9×10^{-9}
7,720.6	.00860	.430	3.4×10^{-9}
7,744.4	.00860	.430	3.0×10^{-9}
7,768.4	.00860	.430	3.4×10^{-9}
7,792.4	.00860	.430	3.0×10^{-9}
7,816.3	.00860	.430	3.0×10^{-9}
7,888.5	.00860	.430	3.0×10^{-9}
7,912.3	.00860	.430	2.8×10^{-9}
7,936.7	.00860	.430	3.0×10^{-9}
7,960.4	.00860	.430	2.8×10^{-9}
7,984.5	.00865	.432	2.4×10^{-9}
8,056.9	.00860	.430	3.2×10^{-9}
8,080.3	.00865	.432	3.0×10^{-9}

TABLE 16 (Continued)

Time	Length Change Δ L (inch) (2" G. L.)	Creep (%)	Pressure (Torr)
8,104.4 Hours	.00865	.432	3.1×10^{-9}
8,128.3	.00865	.432	3.0×10^{-9}
8,152.5	.00865	.432	2.8×10^{-9}
8,224.4	.00860	.430	3.0×10^{-9}
8,249.5	.00855	.428	2.8×10^{-9}
8,272.4	.00855	.428	3.9×10^{-9}
8,296.8	.00850	.425	3.4×10^{-9}
8,321.2	.00845	.422	2.8×10^{-9}
8,417.3	.00855	.428	3.1×10^{-9}
8,440.4	.00855	.428	3.0×10^{-9}
8,464.2	.00860	.430	2.8×10^{-9}
8,488.9	.00855	.428	3.3×10^{-9}
8,560.8	.00845	.422	3.3×10^{-9}
8,585.0	.00850	.425	2.9×10^{-9}
8,608.5	.00865	.432	3.0×10^{-9}
8,632.4	.00875	.438	2.9×10^{-9}
8,656.4	.00875	.438	2.9×10^{-9}
8,728.6	.00860	.430	2.7×10^{-9}
8,752.5	.00865	.432	2.9×10^{-9}
8,776.3	.00875	.438	2.8×10^{-9}
8,800.3	.00870	.435	2.8×10^{-9}
8,824.5	.00875	.438	3.2×10^{-9}
8,898.4	.00865	.452	3.0×10^{-9}
8,920.3	.00865	.432	3.0×10^{-9}
8,944.9	.00875	.438	2.8×10^{-9}
8,968.3	.00885	.442	2.9×10^{-9}
8,992.2	.00880	.440	2.8×10^{-9}
9,064.5	.00885	.442	2.8×10^{-9}
9,088.3	.00875	.438	2.8×10^{-9}
9,113.2	.00875	.438	3.2×10^{-9}
9,136.3	.00880	.440	3.2×10^{-9}
9,160.4	.00880	.440	3.0×10^{-9}
9,232.3	.00885	.442	2.7×10^{-9}
9,256.3	.00885	.442	2.6×10^{-9}
9,280.4	.00885	.442	3.3×10^{-9}
9,304.5	.00895	.448	3.2×10^{-9}

TABLE 16 (Continued)

Time	Length Change Δ L (inch) (2" G. L.)	Creep (%)	Pressure (Torr)
9,328.9 Hours	.00890	.445	4.6×10^{-9}
9,401.2	.00885	.442	2.7×10^{-9}
9,424.5	.00885	.442	2.8×10^{-9}
9,448.3	.00890	.445	3.1×10^{-9}
9,472.5	.00885	.442	2.7×10^{-9}
9,496.5	.00890	.445	3.1×10^{-9}
9,568.8	.00875	.438	3.0×10^{-9}
9,593.5	.00885	.442	2.8×10^{-9}
9,617.2	.00885	.442	3.0×10^{-9}
9,640.8	.00885	.442	2.9×10^{-9}
9,665.1	.00890	.445	2.8×10^{-9}
9,737.8	.00885	.442	3.4×10^{-9}
9,761.1	.00890	.445	2.9×10^{-9}
9,785.2	.00885	.442	3.3×10^{-9}
9,810.0	.00890	.445	2.8×10^{-9}
9,833.3	.00890	.445	2.9×10^{-9}
9,906.0	.00885	.442	3.2×10^{-9}
9,929.2	.00885	.442	2.8×10^{-9}
9,954.0	.00890	.445	3.2×10^{-9}
9,977.2	.00885	.442	3.1×10^{-9}
10,001.3	.00890	.445	3.1×10^{-9}
10,073.7	.00885	.442	3.1×10^{-9}
10,097.3	.00885	.442	3.1×10^{-9}
10,121.5	.00895	.448	3.2×10^{-9}
10,145.4	.00900	.450	3.0×10^{-9}
10,169.5	.00895	.448	3.2×10^{-9}
10,241.7	.00890	.445	3.1×10^{-9}
10,265.5	.00890	.445	3.1×10^{-9}
10,289.7	.00885	.442	3.1×10^{-9}
10,409.4	.00900	.450	2.7×10^{-9}
10,433.2	.00895	.448	2.8×10^{-9}
10,457.8	.00895	.448	3.1×10^{-9}
10,482.0	.00900	.450	3.1×10^{-9}
10,505.4	.00895	.448	3.1×10^{-9}
10,577.5	.00900	.450	3.2×10^{-9}
10,601.3	.00895	.448	3.3×10^{-9}

TABLE 16 (Continued)

Time	Length Change Δ L (inch) (2" G. L.)	Creep (%)	Pressure (Torr)
10,625.2 Hours	.00900	.450	2.8×10^{-9}
10,649.8	.00895	.448	2.1×10^{-9}
10,673.6	.00895	.448	2.8×10^{-9}
10,745.5	.00905	.452	2.9×10^{-9}
10,769.4	.00900	.450	3.0×10^{-9}
10,793.4	.00905	.452	2.8×10^{-9}
10,817.4	.00905	.452	3.0×10^{-9}
10,841.4	.00900	.450	2.8×10^{-9}
10,913.4	.00915	.458	3.0×10^{-9}

Test in progress
Specimen S-28

TABLE 17

Creep Test Data, T-111 Sheet Heat D-1102, Recrystallized 3000°F (1649°C) 1 Hour, Tested at 2200°F (1204°C), and 5,000 psi ($3.45 \times 10^7 N/m^2$)

Time	Length Change Δ L (inch) (2" G. L.)	Creep (%)	Pressure (Torr)
1 Minute	-.00005	-.002	5.8×10^{-8}
2	.00000	.000	5.8×10^{-8}
3	+.00005	+.002	5.8×10^{-8}
4	.00010	.005	5.8×10^{-8}
5	.00005	.002	5.8×10^{-8}
6	.00005	.002	5.8×10^{-8}
7	.00005	.002	5.8×10^{-8}
8	.00010	.005	5.8×10^{-8}
9	.00005	.002	5.8×10^{-8}
10	.00010	.005	5.8×10^{-8}
15	.00005	.002	5.8×10^{-8}
30	.00005	.002	5.8×10^{-8}
45	.00010	.005	5.8×10^{-8}
60	.00010	.005	5.8×10^{-8}
19.1 Hours	.00030	.015	2.3×10^{-9}
91.0	.00100	.050	8.1×10^{-9}
115.2	.00115	.058	4.6×10^{-9}
139.5	.00130	.065	3.9×10^{-9}
163.5	.00145	.072	3.3×10^{-9}
283.6	.00160	.080	2.7×10^{-9}
307.4	.00165	.082	2.4×10^{-9}
331.2	.00175	.088	2.3×10^{-9}
355.6	.00190	.095	2.2×10^{-9}
451.3	.00320	.160	2.0×10^{-9}
476.2	.00315	.158	1.9×10^{-9}
499.5	.00315	.158	1.9×10^{-9}
523.4	.00350	.175	2.0×10^{-9}
596.4	.00365	.182	1.9×10^{-9}
621.3	.00370	.185	1.8×10^{-9}
643.6	.00420	.210	1.6×10^{-9}
667.3	.00425	.212	1.8×10^{-9}
691.4	.00425	.212	1.8×10^{-9}
764.5	.00480	.240	1.8×10^{-9}
787.2	.00490	.245	1.9×10^{-9}
811.5	.00495	.248	1.8×10^{-9}
835.6	.00500	.250	1.8×10^{-9}

TABLE 17 (Continued)

Time	Length Change Δ L (inch) (2" G. L.)	Creep (%)	Pressure (Torr)
859.4 Hours	.00510	.255	1.6×10^{-9}
931.3	.00555	.278	1.7×10^{-9}
955.3	.00565	.282	1.6×10^{-9}
979.5	.00575	.288	1.6×10^{-9}
1,003.7	.00580	.290	1.5×10^{-9}
1,027.6	.00585	.292	1.8×10^{-9}
1,099.5	.00610	.305	1.7×10^{-9}
1,123.1	.00625	.312	1.5×10^{-9}
1,147.2	.00630	.315	1.9×10^{-9}
1,171.8	.00655	.328	1.4×10^{-9}
1,195.5	.00665	.332	1.6×10^{-9}
1,269.2	.00710	.355	1.5×10^{-9}
1,291.4	.00725	.362	1.4×10^{-9}
1,315.4	.00735	.368	1.5×10^{-9}
1,339.8	.00745	.372	1.5×10^{-9}
1,366.0	.00755	.378	1.3×10^{-9}
1,435.5	.00795	.398	1.6×10^{-9}
1,459.5	.00805	.402	1.4×10^{-9}
1,482.9	.00830	.415	1.5×10^{-9}
1,507.3	.00840	.420	1.3×10^{-9}
1,531.3	.00860	.430	1.6×10^{-9}
1,603.7	.00920	.460	1.3×10^{-9}
1,627.4	.00945	.472	1.5×10^{-9}
1,651.9	.00950	.475	1.4×10^{-9}
1,675.9	.00955	.478	1.4×10^{-9}
1,699.6	.00965	.482	1.4×10^{-9}
1,771.7	.01000	.500	1.5×10^{-9}
1,795.8	.01015	.508	1.4×10^{-9}
1,819.4	.01030	.515	1.6×10^{-9}
1,843.1	.01035	.518	1.6×10^{-9}
1,867.2	.01040	.520	1.4×10^{-9}
1,939.2	.01080	.540	1.5×10^{-9}
1,963.4	.01080	.540	1.5×10^{-9}
1,987.0	.01090	.545	1.4×10^{-9}
2,010.9	.01100	.550	1.4×10^{-9}

TABLE 17 (Continued)

Time	Length Change Δ L (inch) (2" G. L.)	Creep (%)	Pressure (Torr)
2,034.8 Hours	.01100	.550	1.4×10^{-9}
2,106.9	.01110	.555	1.6×10^{-9}
2,131.0	.01115	.558	1.6×10^{-9}
2,155.5	.01130	.565	1.5×10^{-9}
2,178.9	.01155	.578	1.6×10^{-9}
2,203.3	.01165	.582	1.6×10^{-9}
2,274.9	.01200	.600	1.5×10^{-9}
2,299.3	.01210	.605	1.4×10^{-9}
2,323.3	.01230	.615	1.7×10^{-9}
2,347.3	.01255	.628	1.5×10^{-9}
2,443.6	.01315	.658	1.4×10^{-9}
2,467.4	.01325	.662	1.5×10^{-9}
2,491.1	.01330	.665	1.4×10^{-9}
2,515.0	.01345	.672	1.4×10^{-9}
2,539.6	.01350	.675	1.6×10^{-9}
2,611.4	.01375	.688	1.5×10^{-9}
2,635.1	.01375	.688	1.6×10^{-9}
2,659.1	.01385	.692	1.5×10^{-9}
2,682.9	.01400	.700	1.3×10^{-9}
2,706.9	.01420	.710	1.6×10^{-9}
2,780.6	.01460	.730	1.6×10^{-9}
2,803.0	.01470	.735	1.4×10^{-9}
2,827.1	.01475	.738	1.4×10^{-9}
2,851.4	.01485	.742	1.5×10^{-9}
2,875.3	.01495	.748	1.5×10^{-9}
2,947.3	.01540	.770	1.4×10^{-9}
2,971.0	.01545	.772	1.5×10^{-9}
2,994.9	.01555	.778	1.5×10^{-9}
3,019.3	.01565	.782	1.5×10^{-9}
3,043.0	.01570	.785	1.4×10^{-9}
3,115.1	.01610	.805	1.6×10^{-9}
3,139.5	.01620	.810	1.6×10^{-9}
3,163.1	.01640	.820	1.4×10^{-9}
3,187.2	.01650	.825	1.5×10^{-9}
3,213.0	.01650	.825	1.6×10^{-9}
3,282.4	.01675	.383	1.7×10^{-9}
3,306.4	.01690	.845	1.5×10^{-9}
3,331.0	.01710	.855	1.5×10^{-9}
3,354.5	.01705	.852	1.4×10^{-9}
3,378.1	.01710	.855	1.5×10^{-9}

TABLE 17 (Continued)

Time	Length Change Δ L (inch) (2" G. L.)	Creep (%)	Pressure (Torr)
3,499.7 Hours	.01830	.915	1.4×10^{-9}
3,524.2	.01835	.918	1.4×10^{-9}
3,545.9	.01840	.920	1.4×10^{-9}
3,618.6	.01850	.925	1.4×10^{-9}
3,642.3	.01855	.928	1.3×10^{-9}
3,666.4	.01870	.935	1.4×10^{-9}
3,690.0	.01875	.938	1.4×10^{-9}
3,716.3	.01875	.938	1.3×10^{-9}
3,786.1	.01890	.945	1.4×10^{-9}
3,810.1	.01895	.948	1.4×10^{-9}
3,833.9	.01900	.950	1.4×10^{-9}
3,858.8	.01915	.958	1.4×10^{-9}
3,882.8	.01930	.965	1.4×10^{-9}
3,956.5	.01960	.980	1.3×10^{-9}
4,002.9	.01970	.985	1.3×10^{-9}
4,026.3	.01990	.995	1.3×10^{-9}
4,050.3	.02000	1.000	1.3×10^{-9}
4,127.1	.02015	1.008	1.6×10^{-9}
4,146.1	.02025	1.012	1.3×10^{-9}
4,170.8	.02040	1.020	1.3×10^{-9}
4,196.4	.02065	1.032	1.4×10^{-9}
4,218.1	.02070	1.035	1.4×10^{-9}
4,289.8	.02080	1.040	1.2×10^{-9}
4,321.8	.02085	1.042	1.3×10^{-9}

Test terminated - sufficient data obtained
Specimen S-31

TABLE 18

Creep Test Data, T-111, Heat No. D-1102, Annealed at 3000°F (1649°C) for 1 hour, Tested at 1800°F (1982°C), 17,000 psi ($1.17 \times 10^8 N/m^2$)

Time	Length Change Δ L (inch) (2" G. L.)	Creep (%)	Pressure (Torr)
1 Minutes	.00005	.002	3.4×10^{-9}
2	.00005	.002	3.4×10^{-9}
3	.00000	.000	3.4×10^{-9}
4	.00005	.002	3.4×10^{-9}
5	.00010	.005	3.4×10^{-9}
6	.00010	.005	3.4×10^{-9}
7	.00010	.005	3.4×10^{-9}
8	.00010	.005	3.4×10^{-9}
9	.00010	.005	3.4×10^{-9}
10	.00015	.008	3.4×10^{-9}
15	.00010	.005	3.4×10^{-9}
30	.00005	.002	3.4×10^{-9}
45	.00005	.002	3.4×10^{-9}
60	.00010	.005	3.4×10^{-9}
69.9 Hours	.00035	.017	2.1×10^{-9}
93.7	.00045	.022	2.0×10^{-9}
117.6	.00060	.030	1.8×10^{-9}
141.9	.00070	.035	1.7×10^{-9}
165.6	.00070	.035	1.6×10^{-9}
239.1	.00075	.038	1.6×10^{-9}
262.0	.00080	.040	1.6×10^{-9}
285.6	.00090	.045	1.4×10^{-9}
309.5	.00095	.048	1.4×10^{-9}
333.5	.00100	.050	1.3×10^{-9}
405.5	.00105	.052	1.4×10^{-9}
453.5	.00105	.052	1.3×10^{-9}
477.6	.00115	.058	1.4×10^{-9}
501.7	.00120	.060	1.4×10^{-9}
574.0	.00125	.062	1.4×10^{-9}
597.6	.00120	.060	1.4×10^{-9}
622.3	.00125	.062	1.4×10^{-9}
646.4	.00125	.062	1.3×10^{-9}
670.6	.00130	.065	2.0×10^{-9}
742.3	.00140	.070	1.2×10^{-9}
765.7	.00140	.070	1.2×10^{-9}
790.0	.00150	.075	1.2×10^{-9}
813.6	.00150	.075	1.2×10^{-9}
837.8	.00150	.075	1.2×10^{-9}
911.8	.00150	.075	1.2×10^{-9}
934.0	.00150	.075	1.2×10^{-9}
963.0	.00160	.080	1.2×10^{-9}

TABLE 18 (Continued)

Time	Length Change Δ L (inch) (2" G. L.)	Creep (%)	Pressure (Torr)
982.0 Hours	.00160	.080	1.3×10^{-9}
1,005.6	.00160	.080	1.2×10^{-9}
1,080.0	.00180	.090	1.2×10^{-9}
1,101.8	.00180	.090	1.2×10^{-9}
1,125.8	.00190	.095	1.2×10^{-9}
1,149.8	.00195	.098	1.3×10^{-9}
1,173.6	.00195	.098	1.2×10^{-9}
1,246.0	.00200	.100	1.2×10^{-9}
1,269.6	.00200	.100	1.1×10^{-9}
1,293.8	.00200	.100	1.1×10^{-9}
1,317.7	.00210	.105	1.2×10^{-9}
1,341.6	.00210	.105	1.2×10^{-9}
1,413.9	.00210	.105	1.1×10^{-9}
1,437.5	.00220	.110	1.3×10^{-9}
1,461.9	.00225	.112	1.2×10^{-9}
1,485.7	.00230	.115	1.2×10^{-9}
1,509.8	.00235	.118	1.2×10^{-9}
1,582.2	.00240	.120	1.2×10^{-9}
1,605.6	.00245	.122	1.1×10^{-9}
1,629.6	.00260	.130	1.2×10^{-9}
1,653.6	.00270	.135	1.2×10^{-9}
1,677.8	.00275	.138	1.2×10^{-9}
1,749.7	.00285	.142	1.2×10^{-9}
1,774.8	.00285	.142	1.3×10^{-9}
1,797.6	.00290	.145	1.2×10^{-9}
1,822.2	.00295	.148	1.2×10^{-9}
1,846.5	.00295	.148	1.2×10^{-9}
1,942.6	.00295	.148	1.3×10^{-9}
1,965.7	.00305	.152	1.2×10^{-9}
1,989.7	.00315	.158	1.1×10^{-9}
2,014.2	.00320	.160	1.2×10^{-9}
2,086.2	.00335	.168	1.3×10^{-9}
2,110.4	.00345	.172	1.2×10^{-9}
2,134.0	.00370	.185	1.3×10^{-9}
2,157.7	.00370	.185	1.2×10^{-9}
2,181.8	.00370	.185	1.3×10^{-9}

TABLE 18 (Continued)

Time	Length Change Δ L (inch) (2" G. L.)	Creep (%)	Pressure (Torr)
2,253.9 Hours	.00380	.190	1.2×10^{-9}
2,277.8	.00380	.190	1.2×10^{-9}
2,301.6	.00385	.192	1.2×10^{-9}
2,325.6	.00385	.192	1.1×10^{-9}
2,349.9	.00395	.198	1.2×10^{-9}
2,423.7	.00405	.202	1.2×10^{-9}
2,445.6	.00410	.205	1.2×10^{-9}
2,470.3	.00420	.210	1.1×10^{-9}
2,493.5	.00425	.212	1.1×10^{-9}
2,517.5	.00435	.218	1.2×10^{-9}
2,589.8	.00455	.228	1.2×10^{-9}
2,613.6	.00460	.230	1.2×10^{-9}
2,638.5	.00460	.230	1.2×10^{-9}
2,661.6	.00470	.235	1.3×10^{-9}
2,685.8	.00470	.235	1.2×10^{-9}
2,757.6	.00485	.242	1.1×10^{-9}
2,781.6	.00495	.248	1.2×10^{-9}
2,805.8	.00490	.245	1.2×10^{-9}
2,829.7	.00490	.245	1.3×10^{-10}
2,854.3	.00505	.252	7.8×10^{-9}
2,926.5	.00510	.255	1.2×10^{-9}
2,949.9	.00515	.258	1.1×10^{-9}
2,973.5	.00530	.265	1.2×10^{-9}
2,997.9	.00540	.270	1.3×10^{-9}
3,021.7	.00545	.272	1.4×10^{-9}
3,094.1	.00550	.275	1.2×10^{-9}
3,118.7	.00570	.285	2.2×10^{-9}
3,142.4	.00580	.290	1.1×10^{-9}
3,166.5	.00585	.292	1.2×10^{-9}
3,190.7	.00585	.292	1.2×10^{-9}
3,263.0	.00595	.298	2.0×10^{-9}
3,287.4	.00595	.298	1.0×10^{-9}
3,310.6	.00605	.302	1.2×10^{-9}
3,335.2	.00610	.305	1.0×10^{-9}
3,358.5	.00630	.315	1.1×10^{-9}
3,432.9	.00635	.318	1.1×10^{-9}

TABLE 18 (Continued)

Time	Length Change Δ L (inch) (2" G. L.)	Creep (%)	Pressure (Torr)
3,454.5 Hours	.00640	.320	1.1×10^{-9}
3,479.3	.00640	.320	1.9×10^{-9}
3,502.5	.00645	.322	1.8×10^{-9}
3,527.3	.00655	.328	2.7×10^{-9}
3,599.0	.00655	.328	2.8×10^{-9}
3,622.6	.00660	.330	2.8×10^{-9}
3,647.4	.00675	.338	1.1×10^{-9}
3,670.8	.00690	.345	1.8×10^{-9}
3,694.9	.00695	.348	1.6×10^{-9}
3,767.0	.00700	.350	2.8×10^{-9}
3,790.7	.00720	.360	2.2×10^{-9}
3,815.0	.00750	.375	1.1×10^{-10}
3,934.7	.00765	.382	9.9×10^{-9}
3,958.5	.00765	.382	1.1×10^{-9}
3,983.2	.00765	.382	1.8×10^{-9}
4,007.4	.00780	.390	2.4×10^{-9}
4,030.6	.00785	.392	1.9×10^{-9}
4,102.9	.00865	.412	1.0×10^{-9}
4,126.6	.00830	.415	1.9×10^{-9}
4,150.7	.00830	.415	1.1×10^{-10}
4,175.4	.00840	.420	9.8×10^{-10}
4,198.9	.00850	.425	9.8×10^{-9}
4,270.7	.00870	.435	1.8×10^{-9}
4,294.8	.00880	.440	1.9×10^{-9}
4,318.6	.00800	.440	1.0×10^{-9}
4,342.6	.00885	.442	2.6×10^{-9}
4,366.7	.00895	.448	1.1×10^{-9}

Test in progress
Specimen S-40

TABLE 19

Creep Test Data, T-111, Heat No. MCN-02A-065, Annealed at 3000°F (1649°C) for 1 hour, Tested at 2200°F (1204°C), 8,000 psi ($5.51 \times 10^7 N/m^2$)

Time	Length Change Δ L (inch) (2" G. L.)	Creep (%)	Pressure (Torr)
1 Minutes	.00000	.000	1.7×10^{-7}
2	.00000	.000	1.7×10^{-7}
3	.00005	.002	1.7×10^{-7}
4	.00000	.000	1.7×10^{-7}
5	.00000	.000	1.7×10^{-7}
6	.00005	.002	1.7×10^{-7}
7	.00005	.002	1.7×10^{-7}
8	.00005	.002	1.7×10^{-7}
9	.00000	.000	1.7×10^{-7}
10	.00005	.002	1.7×10^{-7}
15	.00000	.000	1.7×10^{-7}
30	.00000	.000	1.7×10^{-7}
45	.00000	.000	1.7×10^{-7}
60	.00000	.000	1.7×10^{-7}
1.0 Hours	.00000	.000	1.4×10^{-7}
17.2	.00010	.005	4.0×10^{-8}
41.3	.00020	.010	1.6×10^{-8}
65.4	.00030	.015	6.2×10^{-9}
138.0	.00070	.035	7.0×10^{-9}
161.3	.00090	.045	5.6×10^{-9}
185.5	.00100	.050	5.4×10^{-9}
209.3	.00130	.065	5.9×10^{-9}
233.4	.00145	.072	6.2×10^{-9}
305.4	.00200	.100	4.8×10^{-9}
329.4	.00215	.108	4.8×10^{-9}
353.7	.00220	.110	4.2×10^{-9}
377.9	.00225	.112	4.2×10^{-9}
401.8	.00240	.120	4.0×10^{-9}
473.4	.00250	.125	3.6×10^{-9}
497.3	.00310	.155	3.8×10^{-9}
521.4	.00330	.165	3.3×10^{-9}
545.4	.00380	.190	2.3×10^{-9}
569.6	.00390	.195	3.1×10^{-9}
643.5	.00440	.220	3.0×10^{-9}
665.5	.00435	.218	3.0×10^{-9}
689.5	.00445	.222	2.9×10^{-9}
713.9	.00455	.228	2.6×10^{-9}
740.3	.00470	.235	2.6×10^{-9}
809.4	.00505	.252	2.4×10^{-9}
833.7	.00515	.258	2.4×10^{-9}
857.1	.00540	.270	2.2×10^{-9}

TABLE 19 (Continued)

Time	Length Change Δ L (inch) (2" G. L.)	Creep (%)	Pressure (Torr)
881.5 Hours	.00570	.285	2.4×10^{-9}
905.5	.00575	.288	2.4×10^{-9}
977.8	.00600	.300	2.2×10^{-9}
1,001.5	.00605	.302	2.1×10^{-9}
1,026.1	.00615	.308	2.2×10^{-9}
1,050.2	.00620	.310	2.1×10^{-9}
1,073.8	.00640	.320	2.1×10^{-9}
1,145.9	.00730	.365	1.8×10^{-9}
1,170.0	.00745	.372	2.0×10^{-9}
1,193.5	.00765	.382	2.0×10^{-9}
1,217.2	.00780	.390	2.0×10^{-9}
1,241.3	.00800	.400	1.9×10^{-9}
1,313.3	.00820	.410	2.0×10^{-9}
1,337.4	.00835	.418	2.0×10^{-9}
1,361.0	.00845	.422	2.0×10^{-9}
1,385.0	.00855	.428	2.0×10^{-9}
1,409.0	.00870	.435	2.1×10^{-9}
1,481.1	.00930	.465	1.9×10^{-9}
1,505.1	.00945	.472	2.0×10^{-9}
1,529.7	.00955	.478	2.6×10^{-9}
1,553.1	.00970	.485	2.0×10^{-9}
1,553.1	.00970	.485	2.0×10^{-9}
1,577.3	.00985	.492	1.9×10^{-9}
1,649.1	.01040	.520	1.9×10^{-9}
1,673.3	.01060	.530	1.8×10^{-9}
1,697.4	.01080	.540	1.8×10^{-9}
1,721.4	.01095	.548	1.8×10^{-9}
1,817.8	.01180	.590	1.8×10^{-9}
1,841.6	.01195	.598	1.8×10^{-9}
1,865.3	.01220	.610	1.8×10^{-9}
1,889.3	.01230	.615	1.7×10^{-9}
1,913.7	.01240	.620	1.8×10^{-9}
1,985.6	.01315	.658	1.9×10^{-9}
2,009.3	.01320	.660	1.8×10^{-9}
2,033.3	.01335	.668	1.8×10^{-9}
2,057.1	.01345	.672	1.7×10^{-9}
2,081.1	.01360	.680	1.7×10^{-9}

TABLE 19 (Continued)

Time	Length Change Δ L (inch) (2" G. L.)	Creep (%)	Pressure (Torr)
2,154.8 Hours	.01420	.710	1.6×10^{-9}
2,177.2	.01430	.715	1.7×10^{-9}
2,201.3	.01455	.728	1.7×10^{-9}
2,225.5	.01470	.735	1.8×10^{-9}
2,249.5	.01510	.755	1.8×10^{-9}
2,321.3	.01570	.785	1.7×10^{-9}
2,345.2	.01590	.795	1.6×10^{-9}
2,369.1	.01615	.808	1.6×10^{-9}
2,393.4	.01635	.818	1.7×10^{-9}
2,417.3	.01635	.818	1.7×10^{-9}
2,489.3	.01715	.858	1.6×10^{-9}
2,513.6	.01735	.868	1.8×10^{-9}
2,537.3	.01745	.872	1.7×10^{-9}
2,561.3	.01780	.890	1.9×10^{-9}
2,585.3	.01800	.900	1.9×10^{-9}
2,656.6	.01840	.920	1.7×10^{-9}
2,680.2	.01860	.930	1.8×10^{-9}
2,705.3	.01885	.942	1.8×10^{-9}
2,728.6	.01895	.948	1.7×10^{-9}
2,752.2	.01905	.952	1.7×10^{-9}
2,873.0	.02020	1.010	1.4×10^{-9}
2,898.3	.02030	1.015	1.3×10^{-9}
2,920.0	.02060	1.030	1.4×10^{-9}
2,975.9	.02095	1.048	1.4×10^{-9}

Test terminated - sufficient data obtained
Specimen S-33

TABLE 20

Creep Test Data, T-111, Heat No. MCN-02A-065, Annealed at 3000°F (1649°C) for 1 hour, Tested at 2000°F (1093°C), 11,000 psi ($7.58 \times 10^7 N/m^2$)

Time	Length Change Δ L (inch) (2" G. L.)	Creep (%)	Pressure (Torr)
1 Minutes	.00000	.000	2.0×10^{-8}
2	.00005	.002	2.0×10^{-8}
3	.00010	.005	2.0×10^{-8}
4	.00015	.005	2.0×10^{-8}
5	.00025	.012	2.0×10^{-8}
6	.00020	.010	2.0×10^{-8}
7	.00020	.010	2.0×10^{-8}
8	.00020	.010	2.0×10^{-8}
9	.00020	.010	2.0×10^{-8}
10	.00025	.012	2.0×10^{-8}
15	.00020	.010	2.0×10^{-8}
30	.00025	.012	2.0×10^{-8}
45	.00020	.010	2.0×10^{-8}
60	.00020	.010	2.0×10^{-8}
3.3 Hours	.00020	.010	1.8×10^{-9}
26.7	.00025	.012	8.4×10^{-9}
52.0	.00025	.012	6.0×10^{-9}
67.6	.00030	.015	4.8×10^{-9}
91.4	.00045	.022	4.1×10^{-9}
115.5	.00050	.025	3.9×10^{-9}
139.5	.00060	.030	3.7×10^{-9}
163.8	.00065	.032	3.3×10^{-9}
237.7	.00100	.050	3.0×10^{-9}
259.7	.00105	.052	2.9×10^{-9}
283.7	.00115	.058	3.0×10^{-9}
308.1	.00115	.058	2.8×10^{-9}
334.4	.00115	.058	2.6×10^{-9}
403.6	.00115	.058	2.3×10^{-9}
427.9	.00115	.058	2.4×10^{-9}
451.3	.00120	.060	2.4×10^{-9}
475.6	.00130	.065	2.4×10^{-9}
499.6	.00130	.065	2.3×10^{-9}
572.0	.00135	.068	2.3×10^{-9}
595.7	.00145	.072	2.3×10^{-9}
620.3	.00145	.072	2.1×10^{-9}
644.4	.00155	.078	2.2×10^{-9}
668.0	.00165	.082	2.2×10^{-9}
740.1	.00165	.082	2.0×10^{-9}
764.2	.00170	.085	2.1×10^{-9}
787.7	.00170	.085	2.1×10^{-9}
811.4	.00170	.085	2.1×10^{-9}

TABLE 20 (Continued)

Time	Length Change Δ L (inch) (2" G. L.)	Creep (%)	Pressure (Torr)
835.5 Hours	.00175	.088	2.0×10^{-9}
907.5	.00185	.092	2.0×10^{-9}
931.7	.00190	.095	2.1×10^{-9}
955.2	.00200	.100	2.1×10^{-9}
979.2	.00205	.102	2.1×10^{-9}
1,003.2	.00210	.105	2.1×10^{-9}
1,075.3	.00225	.112	2.0×10^{-9}
1,099.3	.00230	.115	2.0×10^{-9}
1,123.9	.00230	.115	1.9×10^{-9}
1,147.3	.00235	.118	2.0×10^{-9}
1,171.5	.00235	.118	1.9×10^{-9}
1,243.3	.00240	.120	2.0×10^{-9}
1,267.5	.00245	.122	1.9×10^{-9}
1,291.6	.00250	.125	1.9×10^{-9}
1,315.6	.00260	.130	1.8×10^{-9}
1,412.0	.00280	.140	1.9×10^{-9}
1,435.8	.00280	.140	1.9×10^{-9}
1,459.5	.00285	.142	1.9×10^{-9}
1,483.5	.00300	.150	1.8×10^{-9}
1,507.9	.00305	.152	1.8×10^{-9}
1,579.8	.00310	.155	1.9×10^{-9}
1,603.5	.00310	.155	1.9×10^{-9}
1,627.5	.00320	.160	1.9×10^{-9}
1,651.3	.00320	.160	1.8×10^{-9}
1,675.3	.00325	.162	1.8×10^{-9}
1,749.0	.00335	.168	1.8×10^{-9}
1,771.4	.00345	.172	2.0×10^{-9}
1,795.5	.00355	.178	1.8×10^{-9}
1,819.7	.00360	.180	1.9×10^{-9}
1,843.7	.00365	.182	1.9×10^{-9}
1,915.5	.00375	.188	1.8×10^{-9}
1,939.4	.00380	.190	1.8×10^{-9}
1,963.3	.00380	.190	1.9×10^{-9}
1,987.6	.00385	.192	1.8×10^{-9}
2,011.5	.00385	.192	1.8×10^{-9}
2,083.5	.00410	.205	1.3×10^{-9}

TABLE 20 (Continued)

Time	Length Change L (inch) (2" G. L.)	Creep (%)	Pressure (Torr)
2,107.8 Hours	.00410	.205	2.0×10^{-9}
2,131.5	.00410	.205	2.0×10^{-9}
2,155.5	.00420	.210	1.8×10^{-9}
2,179.5	.00425	.212	1.9×10^{-9}
2,250.7	.00425	.212	1.7×10^{-9}
2,274.5	.00435	.218	1.8×10^{-9}
2,299.4	.00435	.218	2.0×10^{-9}
2,322.8	.00445	.222	1.9×10^{-9}
2,346.4	.00450	.225	1.8×10^{-9}
2,467.9	.00475	.238	1.9×10^{-9}
2,492.5	.00480	.240	1.9×10^{-9}
2,514.2	.00480	.240	1.9×10^{-9}
2,586.9	.00490	.245	2.0×10^{-9}
2,610.4	.00490	.245	1.8×10^{-9}
2,634.3	.00495	.248	2.0×10^{-9}
2,658.3	.00505	.252	1.9×10^{-9}
2,684.6	.00515	.258	1.8×10^{-9}
2,754.4	.00520	.260	2.0×10^{-9}
2,778.4	.00520	.260	1.9×10^{-9}
2,802.3	.00520	.262	1.9×10^{-9}
2,827.0	.00525	.262	1.8×10^{-9}
2,850.9	.00535	.268	1.9×10^{-9}
2,924.8	.00570	.285	1.7×10^{-9}
2,971.2	.00570	.285	1.9×10^{-9}
2,994.3	.00575	.288	2.0×10^{-9}
3,018.7	.00575	.288	2.0×10^{-9}
3,090.4	.00580	.290	1.8×10^{-9}
3,114.5	.00580	.290	1.7×10^{-9}
3,139.0	.00590	.295	1.8×10^{-9}
3,164.5	.00600	.300	1.8×10^{-9}
3,186.5	.00610	.305	1.8×10^{-9}
3,258.2	.00610	.305	1.8×10^{-9}
3,282.8	.00615	.308	1.7×10^{-9}
3,306.7	.00625	.312	2.0×10^{-9}
3,331.4	.00625	.312	1.9×10^{-9}
3,354.4	.00630	.315	1.8×10^{-9}

TABLE 20 (Continued)

Time	Length Change L (inch) (2" G. L.)	Creep (%)	Pressure (Torr)
3,426.9 Hours	.00640	.320	2.0×10^{-9}
3,450.3	.00645	.322	1.9×10^{-9}
3,474.2	.00650	.325	2.0×10^{-9}
3,498.6	.00655	.328	1.8×10^{-9}
3,522.3	.00655	.328	2.0×10^{-9}
3,595.8	.00665	.332	1.9×10^{-9}
3,618.4	.00675	.338	2.0×10^{-9}
3,642.1	.00685	.342	1.8×10^{-9}
3,666.1	.00705	.352	1.8×10^{-9}
3,690.2	.00710	.355	1.8×10^{-9}
3,762.2	.00725	.362	1.9×10^{-9}
3,810.2	.00735	.368	1.7×10^{-9}
3,834.2	.00735	.368	1.8×10^{-9}
3,858.4	.00740	.370	1.8×10^{-9}
3,930.7	.00750	.375	1.8×10^{-9}
3,954.3	.00750	.375	1.8×10^{-9}
3,979.0	.00755	.378	1.7×10^{-9}
4,003.1	.00760	.380	1.7×10^{-9}
4,027.4	.00760	.380	1.6×10^{-9}
4,098.9	.00760	.380	1.8×10^{-9}
4,122.4	.00765	.382	1.7×10^{-9}
4,146.7	.00775	.388	1.7×10^{-9}
4,170.3	.00775	.388	1.7×10^{-9}
4,194.5	.00775	.388	1.8×10^{-9}
4,268.1	.00790	.395	1.8×10^{-9}
4,290.8	.00790	.395	1.7×10^{-9}
4,319.7	.00790	.395	1.7×10^{-9}
4,338.1	.00800	.400	1.7×10^{-9}
4,362.3	.00805	.402	1.8×10^{-9}
4,436.2	.00810	.405	1.8×10^{-9}
4,436.2	.00810	.405	1.8×10^{-9}
4,458.4	.00815	.408	1.7×10^{-9}
4,482.5	.00835	.418	1.8×10^{-9}
4,506.4	.00835	.418	1.8×10^{-9}
4,530.3	.00825	.412	1.7×10^{-9}
4,602.5	.00825	.412	1.7×10^{-9}
4,626.3	.00840	.420	1.7×10^{-9}

TABLE 20 (Continued)

Time	Length Change Δ L (inch) (2" G. L.)	Creep (%)	Pressure (Torr)
4,650.4 Hours	.00855	.428	1.6×10^{-9}
4,674.4	.00855	.428	1.6×10^{-9}
4,698.3	.00860	.430	1.7×10^{-9}
4,770.5	.00860	.430	1.7×10^{-9}
4,794.3	.00865	.432	1.7×10^{-9}
4,818.8	.00870	.435	1.8×10^{-9}
4,842.4	.00875	.438	1.8×10^{-9}
4,866.4	.00875	.438	1.9×10^{-9}
4,938.9	.00885	.442	1.6×10^{-9}
4,962.3	.00890	.445	1.8×10^{-9}
4,986.4	.00895	.448	1.7×10^{-9}
5,010.2	.00905	.452	1.6×10^{-9}
5,034.5	.00915	.458	1.7×10^{-9}
5,106.4	.00925	.462	1.7×10^{-9}
5,131.4	.00935	.468	1.8×10^{-9}
5,154.3	.00940	.470	1.9×10^{-9}
5,178.8	.00955	.478	2.0×10^{-9}
5,203.2	.00955	.478	1.8×10^{-9}
5,299.3	.00965	.482	1.9×10^{-9}
5,322.4	.00975	.488	2.0×10^{-9}
5,346.1	.00985	.492	1.8×10^{-9}
5,370.9	.00990	.495	2.0×10^{-9}
5,442.8	.01000	.500	1.8×10^{-9}
5,467.0	.01000	.500	1.8×10^{-9}
5,490.5	.01010	.505	1.9×10^{-9}
5,514.4	.01010	.505	1.9×10^{-9}
5,538.4	.01015	.508	2.0×10^{-9}
5,610.6	.01035	.518	1.8×10^{-9}
5,634.4	.01040	.520	1.9×10^{-9}
5,658.3	.01040	.520	1.8×10^{-9}
5,682.3	.01050	.525	1.8×10^{-9}
5,706.5	.01050	.525	1.8×10^{-9}
5,780.4	.01065	.532	1.8×10^{-9}
5,802.3	.01075	.538	1.9×10^{-9}
5,826.9	.01090	.545	1.6×10^{-9}

TABLE 20 (Continued)

Time	Length Change Δ L (inch) (2" G. L.)	Creep (%)	Pressure (Torr)
5,850.3 Hours	.01105	.552	1.8×10^{-9}
5,874.3	.01100	.550	1.8×10^{-9}
5,946.5	.01105	.552	1.6×10^{-9}
5,970.4	.01100	.550	1.6×10^{-9}
5,995.2	.01110	.555	1.5×10^{-9}
6,018.3	.01120	.560	1.5×10^{-9}
6,042.5	.01135	.568	1.7×10^{-9}
6,114.2	.01145	.572	1.5×10^{-9}
6,138.3	.01145	.572	1.4×10^{-9}
6,162.3	.01150	.575	1.7×10^{-9}
6,186.4	.01155	.578	1.6×10^{-9}
6,211.1	.01160	.580	1.3×10^{-9}
6,283.2	.01160	.580	1.6×10^{-9}
6,306.5	.01170	.585	1.7×10^{-9}
6,330.3	.01180	.590	1.6×10^{-9}
6,354.5	.01190	.595	1.6×10^{-9}
6,378.4	.01190	.595	1.6×10^{-9}
6,450.8	.01190	.595	1.7×10^{-9}
6,475.5	.01190	.595	1.5×10^{-9}
6,499.2	.01205	.602	1.8×10^{-9}
6,522.8	.01210	.605	1.5×10^{-9}
6,547.1	.01210	.605	1.6×10^{-9}
6,619.8	.01210	.605	1.6×10^{-9}
6,643.1	.01220	.610	1.6×10^{-9}
6,691.9	.01235	.618	1.6×10^{-9}
6,715.3	.01255	.628	1.7×10^{-9}
6,788.0	.01275	.638	1.7×10^{-9}
6,811.2	.01280	.640	1.8×10^{-9}
6,836.0	.01275	.638	1.6×10^{-9}
6,859.2	.01285	.642	1.6×10^{-9}
6,883.3	.01280	.640	1.6×10^{-9}
6,955.7	.01300	.650	1.6×10^{-9}
6,979.3	.01300	.650	1.4×10^{-9}
7,003.9	.01300	.650	1.6×10^{-9}
7,027.4	.01310	.655	1.4×10^{-9}

TABLE 20 (Continued)

Time	Length Change Δ L (inch) (2" G. L.)	Creep (%)	Pressure (Torr)
7,051.5 Hours	.01325	.662	1.4×10^{-9}
7,123.7	.01315	.658	1.5×10^{-9}
7,147.4	.01330	.665	1.6×10^{-9}
7,171.7	.01340	.670	1.5×10^{-9}
7,291.4	.01380	.690	1.8×10^{-9}
7,315.2	.01390	.695	1.7×10^{-9}
7,339.8	.01395	.698	1.8×10^{-9}
7,364.0	.01390	.695	1.6×10^{-9}
7,387.3	.01395	.698	1.5×10^{-9}
7,459.4	.01415	.708	1.6×10^{-9}
7,483.3	.01410	.705	1.8×10^{-9}
7,507.5	.01415	.708	1.6×10^{-9}
7,531.7	.01410	.705	1.8×10^{-9}
7,555.6	.01410	.705	1.7×10^{-9}
7,627.4	.01450	.725	1.8×10^{-9}
7,651.3	.01450	.725	1.5×10^{-9}
7,675.3	.01465	.732	$15. \times 10^{-9}$
7,699.4	.01465	.732	1.4×10^{-9}
7,723.3	.01455	.728	1.7×10^{-9}
7,795.3	.01460	.730	1.4×10^{-9}
7,819.5	.01460	.730	1.4×10^{-9}
7,819.5	.01455	.728	1.4×10^{-9}
7,843.2	.01465	.732	1.1×10^{-9}
7,867.4	.01475	.738	1.3×10^{-9}
7,891.5	.01490	.745	1.3×10^{-9}
8,011.8	.01485	.742	1.5×10^{-9}
8,035.8	.01490	.745	1.5×10^{-9}
8,059.5	.01495	.748	1.5×10^{-9}

Test in progress
Specimen S-34

TABLE 21

Creep Test Data, T-111 Sheet Heat 65079, Recrystallized 3000°F (1649°C) 1 Hour, Tested at 2200°F (1204°C), and 5000 psi (3.45×10^7 N/m^2)

Time	Length Change Δ L (inch) (2" G. L.)	Creep (%)	Pressure (Torr)
1 Minute	.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}
547.3	.00215	.108	4.4×10^{-9}
571.1	.00220	.110	2.8×10^{-9}
595.4	.00230	.115	2.9×10^{-9}
691.2	.00260	.130	3.3×10^{-9}
715.7	.00260	.130	2.7×10^{-9}
739.4	.00270	.135	5.4×10^{-9}
763.2	.00275	.138	3.7×10^{-9}

TABLE 21 (Continued)

Time	Length Change Δ L (inch) (2" G. L.)	Creep (%)	Pressure (Torr)
836.3 Hours	.00290	.145	3.0×10^{-9}
859.4	.00300	.150	8.6×10^{-9}
883.4	.00310	.155	2.4×10^{-9}
907.0	.00320	.160	2.4×10^{-9}
931.3	.00325	.162	3.6×10^{-9}
1,004.4	.00340	.170	5.5×10^{-9}
1,027.0	.00350	.175	5.2×10^{-9}
1,051.2	.00355	.178	3.4×10^{-9}
1,075.4	.00360	.180	3.5×10^{-9}
1,099.3	.00370	.185	3.6×10^{-9}
1,171.2	.00395	.198	2.2×10^{-9}
1,195.1	.00400	.200	2.3×10^{-9}
1,219.4	.00405	.202	3.4×10^{-9}
1,243.6	.00410	.205	2.1×10^{-9}
1,267.5	.00420	.210	2.1×10^{-9}
1,339.4	.00435	.218	4.4×10^{-9}
1,363.0	.00450	.225	3.0×10^{-9}
1,387.1	.00455	.228	2.8×10^{-9}
1,411.6	.00475	.238	4.4×10^{-9}
1,435.4	.00475	.238	3.0×10^{-9}
1,509.2	.00485	.242	3.5×10^{-9}
1,531.3	.00490	.245	4.6×10^{-9}
1,555.2	.00500	.250	3.5×10^{-9}
1,579.7	.00510	.255	3.4×10^{-9}
1,605.9	.00525	.262	4.6×10^{-9}
1,675.1	.00540	.270	4.3×10^{-9}
1,675.1	.00540	.270	4.3×10^{-9}
1,699.4	.00545	.272	4.4×10^{-9}
1,722.8	.00560	.280	4.3×10^{-9}
1,747.2	.00570	.285	3.6×10^{-9}
1,771.2	.00590	.295	4.0×10^{-9}
1,843.6	.00630	.315	4.1×10^{-9}
1,867.3	.00630	.315	3.2×10^{-9}
1,891.8	.00635	.318	4.1×10^{-9}
1,915.8	.00645	.322	3.8×10^{-9}
1,939.5	.00650	.325	3.6×10^{-9}

TABLE 21 (Continued)

Time	Length Change Δ L (inch) (2" G. L.)	Creep (%)	Pressure (Torr)
2,011.6 Hours	.00655	.328	3.6×10^{-9}
2,035.7	.00660	.330	3.8×10^{-9}
2,059.3	.00660	.330	3.7×10^{-9}
2,083.0	.00670	.335	3.8×10^{-9}
2,107.1	.00680	.340	3.0×10^{-9}
2,179.0	.00685	.342	3.7×10^{-9}
2,203.2	.00685	.342	3.6×10^{-9}
2,226.8	.00695	.348	3.8×10^{-9}
2,250.8	.00705	.352	3.8×10^{-9}
2,274.7	.00715	.358	3.9×10^{-9}
2,346.9	.00735	.368	3.8×10^{-9}
2,370.9	.00740	.370	3.9×10^{-9}
2,395.4	.00750	.375	2.8×10^{-9}
2,418.9	.00755	.378	3.2×10^{-9}
2,443.0	.00770	.385	3.0×10^{-9}
2,514.8	.00780	.390	2.1×10^{-9}
2,539.1	.00800	.400	2.8×10^{-9}
2,563.1	.00830	.415	3.9×10^{-9}
2,587.2	.00830	.415	3.6×10^{-9}
2,683.5	.00840	.420	2.8×10^{-9}
2,707.3	.00850	.425	2.9×10^{-9}
2,731.0	.00845	.422	2.9×10^{-9}
2,755.0	.00860	.430	3.0×10^{-9}
2,779.4	.00860	.430	2.8×10^{-9}
2,851.3	.00875	.438	3.0×10^{-9}
2,875.0	.00885	.442	2.9×10^{-9}
2,899.0	.00890	.445	3.0×10^{-9}
2,922.8	.00905	.452	2.8×10^{-9}
2,946.9	.00915	.458	2.8×10^{-9}
3,020.5	.00935	.468	2.7×10^{-9}
3,042.9	.00945	.472	2.9×10^{-9}
3,067.0	.00955	.478	2.7×10^{-9}
3,091.2	.00960	.480	2.9×10^{-9}
3,115.2	.00970	.485	2.7×10^{-9}

TABLE 21 (Continued)

Time	Length Change Δ L (inch) (2" G. L.)	Creep (%)	Pressure (Torr)
3,187.1 Hours	.00975	.488	2.9×10^{-9}
3,210.9	.00990	.495	2.6×10^{-9}
3,234.8	.01000	.500	2.8×10^{-9}
3,259.1	.01020	.510	2.8×10^{-9}
3,283.0	.01025	.512	2.6×10^{-9}
3,355.0	.01050	.515	1.9×10^{-9}
3,379.4	.01055	.528	2.8×10^{-9}
3,403.0	.01065	.532	2.7×10^{-9}
3,427.1	.01075	.538	2.8×10^{-9}
3,451.1	.01075	.538	2.8×10^{-9}
3,522.3	.01095	.548	2.8×10^{-9}
3,546.1	.01100	.550	2.7×10^{-9}
3,570.9	.01105	.550	2.6×10^{-9}
3,594.4	.01105	.552	2.6×10^{-9}
3,618.0	.01105	.552	2.0×10^{-9}
3,739.5	.01160	.580	2.5×10^{-9}
3,764.1	.01170	.585	2.6×10^{-9}
3,785.8	.01180	.590	2.6×10^{-9}
3,858.5	.01190	.595	2.6×10^{-9}
3,882.2	.01205	.602	2.5×10^{-9}
3,906.3	.01215	.608	2.5×10^{-9}
3,929.9	.01220	.610	2.6×10^{-9}
3,956.2	.01230	.615	2.6×10^{-9}
4,026.0	.01240	.620	1.1×10^{-9}
4,050.0	.01255	.628	2.7×10^{-9}
4,073.8	.01265	.632	2.6×10^{-9}
4,098.7	.01270	.635	2.8×10^{-9}
4,122.7	.01285	.642	2.4×10^{-9}
4,196.3	.01320	.660	2.5×10^{-9}
4,242.8	.01330	.665	2.6×10^{-9}
4,266.2	.01350	.675	1.5×10^{-9}
4,290.2	.01355	.678	1.4×10^{-9}
4,361.9	.01375	.688	2.7×10^{-9}
4,386.0	.01375	.688	2.4×10^{-9}
4,410.5	.01375	.688	2.4×10^{-9}

TABLE 21 (Continued)

Time	Length Change Δ L (inch) (2" G. L.)	Creep (%)	Pressure (Torr)
4,436.1 Hours	.01380	.690	2.6×10^{-9}
4,458.0	.01400	.700	2.5×10^{-9}
4,529.7	.01415	.708	2.6×10^{-9}
4,554.4	.01425	.712	2.4×10^{-9}
4,578.3	.01430	.715	2.5×10^{-9}
4,602.9	.01440	.720	2.5×10^{-9}
4,625.9	.01455	.728	2.6×10^{-9}
4,698.4	.01480	.740	2.6×10^{-9}
4,721.9	.01490	.745	2.5×10^{-9}
4,745.8	.01500	.750	2.0×10^{-9}
4,770.2	.01505	.752	2.6×10^{-9}
4,793.8	.01520	.760	2.4×10^{-9}
4,867.3	.01550	.775	2.4×10^{-9}
4,890.1	.01570	.785	2.5×10^{-9}
4,913.7	.01575	.788	2.6×10^{-9}
4,937.7	.01580	.790	2.6×10^{-9}
4,961.7	.01595	.798	1.0×10^{-9}
5,033.7	.01605	.802	2.3×10^{-9}
5,081.7	.01610	.805	2.6×10^{-9}
5,105.8	.01625	.812	2.8×10^{-9}
5,129.9	.01640	.820	2.6×10^{-9}
5,202.2	.01650	.825	1.6×10^{-9}
5,225.9	.01670	.835	1.1×10^{-9}
5,250.5	.01675	.838	2.6×10^{-9}
5,274.6	.01680	.840	1.8×10^{-9}
5,298.9	.01680	.840	1.6×10^{-9}
5,370.4	.01705	.852	2.7×10^{-9}
5,393.9	.01730	.865	2.6×10^{-9}
5,418.2	.01720	.860	2.6×10^{-9}
5,441.9	.01730	.865	2.6×10^{-9}
5,466.0	.01745	.872	2.5×10^{-9}
5,539.6	.01770	.885	2.4×10^{-9}
5,562.3	.01780	.890	2.6×10^{-9}
5,591.2	.01780	.890	2.5×10^{-9}
5,609.6	.01810	.905	2.6×10^{-9}
5,633.8	.01810	.905	2.6×10^{-9}

TABLE 21 (Continued)

Time	Length Change Δ L (inch) (2" G. L.)	Creep (%)	Pressure (Torr)
5,707.8 Hours	.01835	.918	2.6×10^{-9}
5,730.0	.01840	.920	3.6×10^{-9}
5,754.0	.01850	.925	2.6×10^{-9}
5,777.9	.01855	.928	2.6×10^{-9}
5,801.8	.01870	.935	2.5×10^{-9}
5,874.1	.01895	.948	2.6×10^{-9}
5,897.8	.01905	.952	2.6×10^{-9}
5,922.0	.01915	.958	2.6×10^{-9}
5,945.9	.01935	.968	2.5×10^{-9}
5,969.8	.01950	.975	2.5×10^{-9}
6,042.0	.01970	.985	2.7×10^{-9}
6,065.7	.01970	.985	2.6×10^{-9}
6,090.1	.01975	.988	2.6×10^{-9}
6,113.9	.01980	.990	2.4×10^{-9}
6,137.9	.01985	.992	2.4×10^{-9}
6,210.4	.02005	1.002	2.6×10^{-9}
6,233.8	.02010	1.005	2.6×10^{-9}
6,257.9	.02025	1.012	2.6×10^{-9}
6,281.8	.02035	1.018	2.3×10^{-9}
6,306.0	.02010	1.020	2.6×10^{-9}
6,377.9	.02060	1.030	2.6×10^{-9}
6,403.0	.02075	1.038	2.6×10^{-9}
6,425.8	.02085	1.042	2.5×10^{-9}
6,450.4	.02105	1.052	1.7×10^{-9}
6,474.7	.02125	1.062	2.5×10^{-9}
6,570.8	.02170	1.085	1.0×10^{-9}
6,593.9	.02185	1.092	2.4×10^{-9}

Test terminated - sufficient data obtained
Specimen S-31

TABLE 22

Creep Test Data, T-111, Heat No. 65079, Annealed at 3000°F (1649°C) for 1 hours, Tested at 2200°F (1204°C), 5,000 psi ($3.44 \times 10^7 N/m^2$)

Time	Length Change Δ L (inch) (2" G. L.)	Creep (%)	Pressure (Torr)
1 Minutes	.00010	.005	5.6×10^{-9}
2	.00020	.010	5.6×10^{-9}
3	.00025	.012	5.6×10^{-9}
4	.00035	.018	5.6×10^{-9}
5	.00035	.018	5.6×10^{-9}
6	.00030	.015	5.6×10^{-9}
7	.00030	.015	5.6×10^{-9}
8	.00030	.015	5.6×10^{-9}
9	.00025	.012	5.6×10^{-9}
10	.00030	.015	5.6×10^{-9}
15	.00050	.025	5.6×10^{-9}
30	.00040	.020	5.6×10^{-9}
45	.00055	.028	5.6×10^{-9}
60	.00050	.025	5.6×10^{-9}
19.5 Hours	.00050	.025	5.0×10^{-9}
91.6	.00070	.035	2.5×10^{-9}
115.8	.00090	.045	2.5×10^{-9}
139.3	.00105	.052	2.1×10^{-9}
163.0	.00115	.058	2.1×10^{-9}
187.1	.00115	.058	2.0×10^{-9}
259.0	.00135	.068	1.9×10^{-9}
283.3	.00140	.070	1.9×10^{-9}
306.8	.00155	.078	1.9×10^{-9}
330.8	.00175	.088	1.7×10^{-9}
354.8	.00190	.095	1.6×10^{-9}
426.9	.00200	.100	1.5×10^{-9}
450.8	.00205	.102	1.6×10^{-9}
475.5	.00215	.108	1.5×10^{-9}
498.9	.00230	.115	1.7×10^{-9}
523.1	.00250	.125	1.4×10^{-9}
594.9	.00290	.145	1.6×10^{-9}
619.1	.00290	.145	1.5×10^{-9}
643.2	.00295	.148	1.5×10^{-9}
667.2	.00305	.152	1.3×10^{-9}
763.6	.00350	.175	1.3×10^{-9}
787.4	.00350	.175	1.4×10^{-9}
811.1	.00360	.180	1.5×10^{-9}
835.1	.00370	.185	1.5×10^{-9}
859.5	.00370	.185	1.5×10^{-9}
931.4	.00405	.202	1.5×10^{-9}

TABLE 22 (Continued)

Time	Length Change Δ L (inch) (2" G. L.)	Creep (%)	Pressure (Torr)
955.1 Hours	.00405	.202	1.4×10^{-9}
979.1	.00420	.210	1.5×10^{-9}
1,002.9	.00425	.212	1.3×10^{-9}
1,026.9	.00425	.212	1.3×10^{-9}
1,100.5	.00450	.225	1.3×10^{-9}
1,122.9	.00450	.225	1.4×10^{-9}
1,147.1	.00455	.228	1.2×10^{-9}
1,171.3	.00455	.235	1.4×10^{-9}
1,195.3	.00485	.242	1.4×10^{-9}
1,267.1	.00495	.248	1.4×10^{-9}
1,290.9	.00510	.255	1.3×10^{-9}
1,314.8	.00520	.260	1.3×10^{-9}
1,339.2	.00525	.262	1.2×10^{-9}
1,363.0	.00530	.265	1.4×10^{-9}
1,435.1	.00555	.278	1.3×10^{-9}
1,459.4	.00560	.280	1.4×10^{-9}
1,483.0	.00565	.282	1.3×10^{-9}
1,507.1	.00570	.285	1.2×10^{-9}
1,531.1	.00575	.288	1.2×10^{-9}
1,602.3	.00590	.295	1.2×10^{-9}
1,626.1	.00615	.308	1.4×10^{-9}
1,651.0	.00620	.310	1.3×10^{-9}
1,674.4	.00625	.312	1.2×10^{-9}
1,696.9	.00630	.315	1.3×10^{-9}
1,819.5	.00670	.335	1.3×10^{-9}
1,844.1	.00690	.345	1.3×10^{-9}
1,865.8	.00695	.348	1.2×10^{-9}
1,938.5	.00740	.370	1.3×10^{-9}
1,962.2	.00740	.370	1.2×10^{-9}
1,985.9	.00745	.372	1.3×10^{-9}
2,009.9	.00750	.375	1.2×10^{-9}
2,036.2	.00760	.380	1.2×10^{-9}
2,106.0	.00780	.390	1.2×10^{-9}
2,130.0	.00785	.392	1.2×10^{-9}
2,153.8	.00785	.392	1.1×10^{-9}
2,178.6	.00810	.405	1.2×10^{-9}
2,202.5	.00830	.415	1.2×10^{-9}

TABLE 22 (Continued)

Time	Length Change Δ L (inch) (2" G. L.)	Creep (%)	Pressure (Torr)
2,276.4 Hours	.00870	.435	1.2×10^{-9}
2,322.7	.00895	.448	1.2×10^{-9}
2,345.9	.00895	.448	1.2×10^{-9}
2,370.2	.00900	.450	1.2×10^{-9}
2,442.0	.00900	.450	1.2×10^{-9}
2,466.1	.00905	.452	1.1×10^{-9}
2,490.6	.00905	.452	1.3×10^{-9}
2,516.1	.00910	.455	1.3×10^{-9}
2,538.0	.00920	.460	1.2×10^{-9}
2,609.8	.00955	.478	1.3×10^{-9}
2,634.4	.00960	.480	1.3×10^{-9}
2,658.3	.00970	.485	1.3×10^{-9}
2,705.9	.00985	.492	1.2×10^{-9}
2,778.4	.01005	.502	1.2×10^{-9}
2,801.9	.01015	.508	1.2×10^{-9}
2,825.8	.01025	.512	1.3×10^{-9}
2,850.2	.01040	.520	1.2×10^{-9}
2,873.8	.01050	.525	1.2×10^{-9}
2,947.4	.01095	.548	1.1×10^{-9}
2,970.0	.01095	.548	1.1×10^{-9}
2,993.7	.01100	.550	1.0×10^{-9}
3,017.7	.01115	.558	1.0×10^{-9}
3,113.8	.01130	.565	9.7×10^{-10}
3,161.8	.01165	.582	1.0×10^{-9}
3,185.8	.01165	.582	1.1×10^{-9}
3,210.0	.01175	.588	1.1×10^{-9}
3,282.3	.01200	.600	1.1×10^{-9}
3,305.9	.01205	.602	1.2×10^{-9}
3,330.6	.01210	.605	1.2×10^{-9}
3,354.6	.01215	.608	1.2×10^{-9}
3,378.9	.01215	.608	1.1×10^{-9}
3,450.5	.01225	.612	1.1×10^{-9}
3,474.0	.01250	.625	1.1×10^{-9}

TABLE 22 (Continued)

Time	Length Change Δ L (inch) (2" G. L.)	Creep (%)	Pressure (Torr)
3,498.2 Hours	.01270	.635	1.0×10^{-9}
3,521.9	.01275	.638	1.0×10^{-9}
3,546.1	.01275	.638	1.0×10^{-9}
3,619.6	.01280	.640	1.2×10^{-9}
3,642.3	.01290	.645	1.1×10^{-9}
3,671.2	.01315	.658	1.1×10^{-9}
3,689.7	.01315	.658	1.2×10^{-9}
3,713.9	.01330	.665	1.2×10^{-9}
3,787.8	.01360	.680	1.2×10^{-9}
3,810.0	.01370	.685	1.1×10^{-9}
3,834.1	.01395	.698	1.1×10^{-9}
3,858.0	.01395	.698	1.1×10^{-9}
3,881.9	.01395	.698	1.1×10^{-9}
3,954.1	.01400	.700	1.1×10^{-9}
3,977.9	.01415	.708	1.1×10^{-9}
4,002.0	.01430	.715	1.1×10^{-9}
4,025.9	.01450	.725	1.0×10^{-9}
4,049.9	.01455	.728	1.0×10^{-9}
4,122.1	.01480	.740	1.1×10^{-9}
4,145.8	.01495	.748	1.1×10^{-9}
4,170.2	.01500	.750	1.2×10^{-10}
4,194.0	.01510	.755	9.6×10^{-9}
4,218.0	.01515	.758	1.0×10^{-9}
4,290.4	.01530	.765	1.1×10^{-9}
4,313.9	.01540	.770	1.1×10^{-9}
4,337.9	.01550	.775	1.0×10^{-9}
4,361.8	.01560	.780	1.1×10^{-9}
4,386.1	.01570	.785	1.1×10^{-9}
4,458.0	.01600	.800	1.1×10^{-9}
4,483.0	.01615	.808	1.2×10^{-9}
4,505.9	.01620	.810	1.1×10^{-9}
4,530.3	.01630	.815	1.1×10^{-9}
4,554.8	.01645	.822	1.1×10^{-9}
4,650.8	.01645	.822	1.1×10^{-9}
4,674.0	.01700	.850	1.0×10^{-10}
4,697.7	.01715	.858	9.8×10^{-10}

TABLE 22 (Continued)

Time	Length Change Δ L (inch) (2" G. L.)	Creep (%)	Pressure (Torr)
4,722.4 Hours	.01730	.865	1.1×10^{-9}
4,794.4	.01745	.872	1.2×10^{-9}
4,818.7	.01755	.878	1.0×10^{-9}
4,842.1	.01775	.882	1.2×10^{-9}
4,866.0	.01785	.892	1.1×10^{-9}
4,890.0	.01795	.898	1.2×10^{-9}
4,962.2	.01830	.915	1.0×10^{-9}
4,986.0	.01840	.920	1.0×10^{-9}
5,009.9	.01860	.930	1.1×10^{-9}
5,033.9	.01875	.938	9.7×10^{-10}
5,058.0	.01885	.942	1.2×10^{-9}
5,132.0	.01895	.948	9.4×10^{-10}
5,153.9	.01895	.948	9.5×10^{-10}
5,178.5	.01910	.955	9.8×10^{-10}
5,201.8	.01925	.962	1.1×10^{-9}
5,225.8	.01935	.968	1.0×10^{-9}
5,298.1	.01955	.978	1.0×10^{-9}
5,321.9	.01965	.982	9.5×10^{-10}
5,346.7	.01975	.988	9.6×10^{-10}
5,369.9	.01995	.998	9.6×10^{-10}
5,394.0	.02015	1.008	1.0×10^{-9}
5,465.8	.02065	1.032	9.7×10^{-10}
5,489.9	.02075	1.038	9.4×10^{-10}
5,513.9	.02090	1.045	1.1×10^{-9}
5,522.1	.02095	1.048	1.1×10^{-9}

Test terminated - sufficient data obtained
Specimen S-35

TABLE 23

Creep Test Data, T-111, Heat No. 65079, Annealed at 3000°F (1649°C) for 1 hour, Tested at 2300°F (1263°C), 3500 psi ($2.41 \times 10^7 N/m^2$)

Time	Length Change Δ L (inch) (2" G. L.)	Creep (%)	Pressure (Torr)
1 Minutes	.00010	.005	7.8×10^{-8}
2	.00010	.005	7.8×10^{-8}
3	.00025	.013	7.8×10^{-8}
4	.00030	.015	7.8×10^{-8}
5	.00030	.015	7.8×10^{-8}
6	.00025	.013	7.8×10^{-8}
7	.00030	.015	7.8×10^{-8}
8	.00040	.020	7.8×10^{-8}
9	.00035	.018	7.8×10^{-8}
10	.00035	.018	7.8×10^{-8}
15	.00030	.015	7.8×10^{-8}
30	.00020	.010	7.8×10^{-8}
45	.00025	.013	7.8×10^{-8}
60	.00025	.013	7.8×10^{-8}
19.1 Hours	.00040	.020	2.0×10^{-8}
43.2	.00070	.035	1.4×10^{-8}
67.1	.00075	.035	1.2×10^{-9}
91.0	.00075	.038	8.3×10^{-9}
163.3	.00115	.058	5.5×10^{-9}
187.0	.00115	.058	4.9×10^{-9}
211.1	.00130	.065	4.7×10^{-9}
235.0	.00145	.072	4.2×10^{-9}
259.0	.00150	.075	4.0×10^{-9}
331.2	.00180	.090	3.6×10^{-9}
354.9	.00205	.102	2.2×10^{-9}
379.3	.00210	.105	3.2×10^{-9}
403.1	.00215	.108	3.0×10^{-9}
427.1	.00220	.110	3.0×10^{-9}
499.5	.00240	.120	2.6×10^{-9}
522.0	.00250	.125	1.6×10^{-9}
547.0	.00255	.128	1.6×10^{-9}
570.9	.00265	.132	1.6×10^{-9}

TABLE 23 (Continued)

Time	Length Change Δ L (inch) (2" G. L.)	Creep (%)	Pressure (Torr)
595.2 Hours	.00265	.132	2.6×10^{-9}
667.1	.00290	.145	1.6×10^{-9}
692.1	.00305	.152	1.5×10^{-9}
715.0	.00310	.155	2.2×10^{-9}
739.5	.00310	.155	2.1×10^{-9}
763.9	.00380	.190	1.4×10^{-9}
859.9	.00415	.208	2.1×10^{-9}
883.1	.00425	.212	1.2×10^{-9}
907.0	.00440	.220	1.6×10^{-9}
431.5	.00445	.222	1.9×10^{-9}
1,003.6	.00450	.225	1.8×10^{-9}
1,027.8	.00450	.225	1.2×10^{-9}
1,051.3	.00465	.232	1.2×10^{-9}
1,075.1	.00470	.235	1.2×10^{-9}
1,099.2	.00475	.238	1.2×10^{-9}
1,171.3	.00475	.238	1.2×10^{-9}
1,195.1	.00485	.242	1.2×10^{-9}
1,219.0	.00525	.262	1.6×10^{-9}
1,243.0	.00540	.270	1.4×10^{-9}
1,267.1	.00555	.278	1.5×10^{-9}
1,341.0	.00625	.312	1.4×10^{-9}
1,362.9	.00645	.322	1.2×10^{-9}
1,387.7	.00660	.330	1.6×10^{-9}
1,410.9	.00670	.335	1.4×10^{-9}
1,434.8	.00685	.342	1.2×10^{-9}
1,507.1	.00735	.368	1.2×10^{-9}
1,531.0	.00740	.370	1.4×10^{-9}
1,555.8	.00745	.372	1.4×10^{-9}
1,579.0	.00755	.378	1.4×10^{-9}
1,603.1	.00765	.382	1.2×10^{-9}
1,675.0	.00745	.398	1.1×10^{-9}
1,699.0	.00800	.400	1.3×10^{-9}
1,723.2	.00810	.405	1.3×10^{-9}
1,747.0	.00815	.408	1.4×10^{-9}
1,771.7	.00830	.415	9.5×10^{-10}
1,843.9	.00875	.438	1.4×10^{-9}

TABLE 23 (Continued)

Time	Length Change Δ L (inch) (2" G. L.)	Creep (%)	Pressure (Torr)
1,867.2 Hours	.00895	.448	1.1×10^{-9}
1,890.9	.00915	.458	1.3×10^{-9}
1,915.2	.00930	.465	1.3×10^{-9}
1,939.1	.00935	.468	1.4×10^{-9}
2,011.5	.00940	.470	1.4×10^{-9}
2,036.1	.00950	.475	1.2×10^{-9}
2,059.8	.00985	.492	1.1×10^{-9}
2,083.9	.00995	.498	1.1×10^{-9}
2,108.1	.01015	.508	1.1×10^{-9}
2,180.4	.01045	.522	1.2×10^{-9}
2,204.8	.01045	.522	1.2×10^{-9}
2,228.0	.01055	.528	1.2×10^{-9}
2,252.6	.01070	.535	1.4×10^{-9}
2,275.9	.01090	.545	1.2×10^{-9}
2,348.7	.01125	.562	1.2×10^{-9}
2,371.8	.01155	.578	1.2×10^{-9}
2,396.7	.01175	.588	1.1×10^{-10}
2,419.8	.01235	.618	9.2×10^{-10}
2,444.6	.01275	.638	9.8×10^{-10}
2,516.3	.01295	.648	9.6×10^{-10}
2,539.9	.01305	.652	9.3×10^{-9}
2,564.5	.01315	.658	1.1×10^{-9}
2,588.1	.01320	.660	1.2×10^{-10}
2,612.3	.01320	.660	8.2×10^{-10}
2,684.3	.01330	.665	8.2×10^{-9}
2,708.1	.01340	.670	1.2×10^{-9}
2,732.3	.01350	.675	1.1×10^{-9}
2,852.0	.01415	.708	1.0×10^{-9}
2,875.9	.01440	.720	1.1×10^{-9}
2,900.5	.01445	.722	1.1×10^{-10}
2,924.7	.01470	.735	8.8×10^{-9}
2,948.0	.01485	.742	1.0×10^{-9}
3,020.2	.01545	.772	1.1×10^{-10}
3,044.0	.01565	.782	9.0×10^{-10}
3,068.1	.01570	.785	9.8×10^{-10}
3,102.6	.01585	.792	7.6×10^{-10}

TABLE 23 (Continued)

Time	Length Change Δ L (inch) (2" G. L.)	Creep (%)	Pressure (Torr)
3,126.2 Hours	.01605	.802	7.8×10^{-10}
3,208.1	.01655	.822	8.6×10^{-10}
3,232.2	.01650	.825	8.2×10^{-10}
3,256.0	.01660	.830	8.2×10^{-10}
3,280.0	.01665	.832	8.6×10^{-10}
3,304.0	.01685	.842	9.8×10^{-10}
3,376.0	.01755	.878	8.2×10^{-10}
3,400.2	.01775	.888	8.4×10^{-10}
3,423.8	.01770	.885	7.4×10^{-10}

Test in progress
Specimen S-42

TABLE 24

Creep Test Data, T-111, Heat No. 65079, Annealed at 3000°F (1649°C), for 1 hour, Tested at 1750°F (954°C), 24,000 psi ($1.65 \times 10^8 N/m^2$)

Time	Length Change Δ L (inch) (2" G. L.)	Creep (%)	Pressure (Torr)
1 Minutes	.00000	.000	2.0×10^{-8}
2	.00000	.000	2.0×10^{-8}
3	.00005	.002	2.0×10^{-8}
4	.00000	.000	2.0×10^{-8}
5	.00005	.002	2.0×10^{-8}
6	.00005	.002	2.0×10^{-8}
7	.00000	.000	2.0×10^{-8}
8	.00000	.000	2.0×10^{-8}
9	.00000	.000	2.0×10^{-8}
10	.00005	.002	2.0×10^{-8}
15	.00005	.002	2.0×10^{-8}
30	.00010	.005	2.0×10^{-8}
45	.00005	.002	2.0×10^{-8}
60	.00005	.002	2.0×10^{-9}
1.0 Hours	.00005	.002	5.1×10^{-9}
13.6	.00030	.015	4.2×10^{-9}
37.9	.00030	.015	2.8×10^{-9}
61.1	.00015	.008	2.5×10^{-9}
84.4	.00015	.008	2.3×10^{-9}
108.2	.00015	.008	2.0×10^{-9}
132.4	.00015	.008	2.0×10^{-9}
156.3	.00020	.010	1.8×10^{-9}
228.7	.00030	.015	2.0×10^{-9}
253.4	.00030	.015	1.4×10^{-9}
277.1	.00030	.015	1.6×10^{-9}
300.7	.00030	.015	1.5×10^{-9}
325.0	.00035	.018	1.6×10^{-9}
397.7	.00040	.020	1.5×10^{-9}
421.1	.00040	.020	1.4×10^{-9}
445.1	.00040	.020	1.6×10^{-9}
469.9	.00045	.022	1.4×10^{-9}
493.2	.00045	.022	1.4×10^{-9}
566.0	.00045	.022	1.4×10^{-9}
589.1	.00045	.022	1.5×10^{-9}
613.9	.00045	.022	1.4×10^{-9}
637.1	.00045	.022	1.4×10^{-9}
661.2	.00050	.025	1.4×10^{-9}
733.6	.00045	.022	1.3×10^{-9}

TABLE 24 (Continued)

Time	Length Change Δ L (inch) (2" G. L.)	Creep (%)	Pressure (Torr)
757.2 Hours	.00045	.022	1.3×10^{-9}
781.9	.00050	.025	1.4×10^{-9}
805.3	.00055	.028	1.2×10^{-9}
829.5	.00055	.028	1.2×10^{-9}
901.6	.00060	.030	1.3×10^{-9}
925.3	.00055	.028	1.4×10^{-9}
949.6	.00060	.030	1.2×10^{-9}
1,069.3	.00090	.045	1.1×10^{-9}
1,117.7	.00080	.040	1.4×10^{-9}
1,141.9	.00080	.040	1.4×10^{-9}
1,165.3	.00080	.040	1.1×10^{-9}
1,237.3	.00080	.040	1.2×10^{-9}
1,261.3	.00070	.035	1.3×10^{-9}
1,285.4	.00075	.038	1.2×10^{-9}
1,309.8	.00070	.035	1.2×10^{-9}
1,333.5	.00075	.038	1.1×10^{-9}
1,405.3	.00080	.040	1.2×10^{-9}
1,429.3	.00075	.038	1.2×10^{-9}
1,453.2	.00080	.040	1.3×10^{-9}
1,477.3	.00080	.040	1.2×10^{-9}
1,501.3	.00085	.042	1.3×10^{-9}
1,573.3	.00080	.040	1.3×10^{-9}
1,597.5	.00085	.042	1.4×10^{-9}
1,621.1	.00090	.045	7.8×10^{-10}
1,645.3	.00095	.048	1.3×10^{-9}
1,669.4	.00090	.045	1.1×10^{-9}
1,789.7	.00100	.050	1.3×10^{-9}
1,813.7	.00100	.050	1.2×10^{-9}
1,837.4	.00100	.050	1.1×10^{-9}

Test in progress
Specimen S-47

TABLE 25

Creep Test Data, T-111, Heat No. 65079, Annealed at 3000°F (1649°C) for 1 hour, Tested at 2350°F (1288°C), 2400 psi ($1.65 \times 10^7 N/m^2$)

Time	Length Change Δ L (inch) (2" G. L.)	Creep (%)	Pressure (Torr)
1 Minutes	-.00005	-.002	1.0×10^{-8}
2	.00000	.000	1.0×10^{-8}
3	.00000	.000	1.0×10^{-8}
4	.00005	.002	1.0×10^{-8}
5	.00005	.002	1.0×10^{-8}
6	.00010	.005	1.0×10^{-8}
7	.00005	.002	1.0×10^{-8}
8	.00005	.002	1.0×10^{-8}
9	.00005	.002	1.0×10^{-8}
10	.00010	.005	1.0×10^{-8}
15	-.00015	-.008	1.0×10^{-8}
30	-.00015	-.008	1.0×10^{-8}
45	.00005	.002	1.0×10^{-8}
60	.00010	.005	1.0×10^{-8}
1.0 Hours	.00010	.005	1.0×10^{-8}
21.4	.00010	.005	2.0×10^{-9}
55.0	.00015	.008	7.0×10^{-9}
66.5	.00020	.010	6.5×10^{-9}
90.3	.00020	.010	6.0×10^{-9}
140.9	.00015	.008	6.3×10^{-9}
163.3	.00015	.008	4.7×10^{-9}
234.8	.00025	.012	5.3×10^{-9}
258.4	.00025	.012	3.6×10^{-9}
282.4	.00075	.038	3.4×10^{-9}
306.5	.00050	.025	3.1×10^{-9}
331.0	.00055	.028	3.1×10^{-9}
403.2	.00085	.042	3.0×10^{-9}
426.3	.00085	.042	2.6×10^{-9}
450.5	.00085	.042	3.1×10^{-9}
570.6	.00135	.068	2.5×10^{-9}
594.6	.00135	.068	2.4×10^{-9}
618.6	.00135	.068	2.3×10^{-9}
642.3	.00145	.072	2.2×10^{-9}
667.1	.00150	.075	2.2×10^{-9}
738.6	.00155	.078	2.0×10^{-9}
768.0	.00175	.088	1.9×10^{-9}
786.3	.00180	.090	1.9×10^{-9}
810.1	.00210	.105	1.9×10^{-9}
835.3	.00210	.105	1.9×10^{-9}
906.9	.00210	.105	1.8×10^{-9}

TABLE 25 (Continued)

Time	Length Change Δ L (inch) (2" G. L.)	Creep (%)	Pressure (Torr)
930.3 Hours	.00240	.120	1.7×10^{-9}
954.4	.00255	.128	1.7×10^{-9}
981.7	.00265	.132	1.6×10^{-9}
1,075.1	.00270	.135	1.5×10^{-9}
1,100.5	.00275	.138	1.4×10^{-9}
1,124.0	.00275	.138	1.4×10^{-9}
1,148.0	.00280	.140	1.5×10^{-9}
1,170.7	.00290	.145	1.5×10^{-9}

Test in progress
Specimen S-48

TABLE 26

Creep Test Data, T-111, Heat No. 65079, Annealed at 3000°F (1649°C) for 1 hour, Tested at 2000°F (1093°C), 8500 psi ($7.22 \times 10^7 N/m^2$)

Time	Length Change Δ L (inch) (2" G. L.)	Creep (%)	Pressure (Torr)
1 Minutes	.00000	.000	2.8×10^{-7}
2	.00005	.002	2.8×10^{-7}
3	.00005	.002	2.8×10^{-7}
4	.00005	.002	2.8×10^{-7}
5	.00010	.005	2.8×10^{-7}
6	.00010	.005	2.8×10^{-7}
7	.00015	.008	2.8×10^{-7}
8	.00015	.008	2.8×10^{-7}
9	.00015	.008	2.8×10^{-7}
10	.00015	.008	2.8×10^{-7}
15	.00015	.008	2.8×10^{-7}
30	.00015	.008	2.8×10^{-7}
45	.00010	.005	2.8×10^{-7}
60	.00005	.002	2.8×10^{-7}
1.0 Hours	.00005	.002	2.7×10^{-8}
17.7	.00005	.002	6.1×10^{-8}
42.8	.00015	.008	3.6×10^{-8}
114.3	.00015	.008	1.8×10^{-8}
137.9	.00015	.008	1.4×10^{-8}
162.0	.00020	.010	1.3×10^{-8}
189.3	.00020	.010	1.1×10^{-8}
210.0	.00020	.010	1.0×10^{-8}
282.7	.00035	.018	8.8×10^{-9}
308.1	.00040	.020	8.5×10^{-9}
331.6	.00030	.015	7.4×10^{-9}
355.7	.00035	.018	7.2×10^{-9}
378.2	.00035	.018	6.6×10^{-9}
503.7	.00040	.020	5.3×10^{-9}
522.7	.00040	.020	4.9×10^{-9}
546.0	.00045	.022	4.8×10^{-9}
642.3	.00060	.030	4.2×10^{-9}
665.8	.00060	.030	4.0×10^{-9}

Test in progress
Specimen S-50

TABLE 27

Creep Test Data, T-111, Heat No. 65080, Annealed at 3000°F (1649°C) for 1 hour, Tested at 2200°F (1204°C), 8000 psi ($5.51 \times 10^7 N/m^2$)

Time	Length Change Δ L (inch) (2" G. L.)	Creep (%)	Pressure (Torr)
1 Minutes	.00005	.002	1.2×10^{-8}
2	.00005	.002	1.2×10^{-8}
3	.00015	.008	1.2×10^{-8}
4	.00015	.008	1.2×10^{-8}
5	.00020	.010	1.2×10^{-8}
6	.00025	.012	1.2×10^{-8}
7	.00025	.012	1.2×10^{-8}
8	.00030	.015	1.2×10^{-8}
9	.00035	.018	1.2×10^{-8}
10	.00045	.022	1.2×10^{-8}
15	.00040	.020	1.2×10^{-8}
30	.00035	.018	1.2×10^{-8}
45	.00035	.018	1.2×10^{-8}
60	.00040	.020	1.2×10^{-8}
1.0 Hours	.00040	.020	1.1×10^{-8}
2.8	.00055	.028	1.1×10^{-8}
21.2	.00245	.122	1.0×10^{-9}
29.5	.00285	.142	9.2×10^{-9}
47.6	.00425	.212	6.7×10^{-9}
117.4	.00930	.465	4.0×10^{-9}
141.4	.01075	.538	3.9×10^{-9}
165.2	.01225	.612	3.4×10^{-9}
190.0	.01425	.712	3.1×10^{-9}
213.8	.01570	.785	2.8×10^{-9}
250.4	.01820	.910	
274.2	.02560	1.230	3.1×10^{-9}

Test terminated - sufficient data obtained
Specimen S-37

TABLE 28

Creep Test Data, T-111, Heat No. 65080, Annealed at 3000°F (1649°C) for 1 hour, Tested at 1800°F (982°C), 13,000 psi ($8.95 \times 10^7 N/m^2$)

Time	Length Change Δ L (inch) (2" G. L.)	Creep (%)	Pressure (Torr)
1 Minutes	.00000	.000	4.0×10^{-9}
2	.00000	.000	4.0×10^{-9}
3	.00005	.002	4.0×10^{-9}
4	.00000	.000	4.0×10^{-9}
5	.00000	.000	4.0×10^{-9}
6	.00005	.002	4.0×10^{-9}
7	.00000	.000	4.0×10^{-9}
8	.00000	.000	4.0×10^{-9}
9	.00000	.000	4.0×10^{-9}
10	.00000	.000	4.0×10^{-9}
15	.00000	.000	4.0×10^{-9}
30	.00000	.000	4.0×10^{-9}
45	.00000	.000	4.0×10^{-9}
60	.00000	.000	4.0×10^{-9}
7.0 Hours	.00000	.000	4.0×10^{-9}
17.0	.00005	.002	2.6×10^{-9}
41.6	.00005	.002	1.9×10^{-9}
64.6	.00005	.002	1.7×10^{-9}
137.1	.00015	.008	1.5×10^{-9}
160.6	.00015	.008	1.0×10^{-9}
184.5	.00020	.010	9.0×10^{-10}
208.9	.00025	.012	9.0×10^{-10}
232.5	.00030	.015	8.4×10^{-10}
306.0	.00050	.025	8.0×10^{-10}
328.7	.00065	.032	8.0×10^{-10}
352.4	.00060	.030	7.4×10^{-10}
376.4	.00070	.035	7.1×10^{-10}
400.5	.00065	.032	7.1×10^{-10}
472.5	.00065	.032	6.4×10^{-10}
520.5	.00070	.035	6.3×10^{-10}
544.4	.00070	.035	6.1×10^{-10}
568.6	.00070	.035	5.9×10^{-10}
641.0	.00075	.038	6.4×10^{-10}
664.6	.00085	.042	6.0×10^{-10}
689.3	.00085	.042	6.0×10^{-10}
713.3	.00085	.042	5.2×10^{-10}
737.6	.00090	.045	4.9×10^{-10}
809.1	.00100	.050	5.4×10^{-10}
832.6	.00105	.052	5.3×10^{-10}
856.9	.00110	.055	5.1×10^{-10}
880.6	.00120	.060	5.0×10

TABLE 28 (Continued)

Time	Length Change Δ L (inch) (2" G. L.)	Creep (%)	Pressure (Torr)
904.8 Hours	.00125	.062	5.5×10^{-10}
978.3	.00120	.060	5.4×10^{-10}
1,000.4	.00135	.068	4.9×10^{-10}
1,029.9	.00135	.068	5.1×10^{-10}
1,048.3	.00140	.070	5.1×10^{-10}
1,072.5	.00140	.070	5.1×10^{-10}
1,146.3	.00140	.070	4.8×10^{-10}
1,168.6	.00155	.078	5.0×10^{-10}
1,192.7	.00175	.088	4.6×10^{-10}
1,216.6	.00190	.095	4.9×10^{-10}
1,240.5	.00210	.105	4.7×10^{-10}
1,312.6	.00215	.108	4.6×10^{-10}
1,336.6	.00210	.105	4.6×10^{-10}
1,360.6	.00210	.105	4.9×10^{-10}
1,384.6	.00205	.102	4.7×10^{-10}
1,408.6	.00205	.102	4.8×10^{-10}
1,480.7	.00215	.108	4.7×10^{-10}
1,504.5	.00215	.108	4.6×10^{-10}
1,528.9	.00220	.110	4.6×10^{-10}
1,552.6	.00220	.110	4.7×10^{-10}
1,576.7	.00225	.112	4.6×10^{-10}
1,649.1	.00225	.112	4.2×10^{-10}
1,672.5	.00235	.118	4.6×10^{-10}
1,696.6	.00230	.115	4.5×10^{-10}
1,720.5	.00235	.118	4.6×10^{-10}
1,744.7	.00235	.118	4.7×10^{-10}
1,816.6	.00245	.122	4.5×10^{-10}
1,841.7	.00250	.125	4.5×10^{-10}
1,864.6	.00260	.130	4.4×10^{-10}
1,889.0	.00275	.138	4.3×10^{-10}
1,913.4	.00275	.138	4.3×10^{-10}
2,009.5	.00300	.150	4.5×10^{-10}
2,032.6	.00305	.152	4.5×10^{-10}
2,056.4	.00305	.152	3.9×10^{-10}
2,081.0	.00305	.152	4.6×10^{-10}
2,153.0	.00325	.162	4.4×10^{-10}

TABLE 28 (Continued)

Time	Length Change Δ L (inch) (2" G. L.)	Creep (%)	Pressure (Torr)
2,177.3 Hours	.00335	.168	4.7×10^{-10}
2,200.8	.00345	.172	4.4×10^{-10}
2,224.6	.00355	.178	4.4×10^{-10}
2,248.6	.00360	.180	4.8×10^{-10}
2,320.8	.00380	.190	4.7×10^{-10}
2,344.7	.00385	.192	4.4×10^{-10}
2,368.5	.00395	.198	4.4×10^{-10}
2,392.6	.00395	.198	4.2×10^{-10}
2,416.7	.00400	.200	4.2×10^{-10}
2,490.6	.00410	.205	4.3×10^{-10}
2,512.5	.00415	.208	4.6×10^{-10}
2,537.1	.00430	.215	4.2×10^{-10}
2,560.5	.00440	.220	4.2×10^{-10}
2,584.4	.00440	.220	4.3×10^{-10}
2,656.8	.00475	.238	4.1×10^{-10}
2,680.6	.00490	.245	4.0×10^{-10}
2,705.4	.00495	.248	4.0×10^{-10}
2,728.6	.00505	.252	4.0×10^{-10}
2,752.6	.00510	.255	4.1×10^{-10}
2,824.5	.00530	.265	4.0×10^{-10}
2,848.6	.00535	.268	3.9×10^{-10}
2,872.6	.00550	.275	4.0×10^{-10}
2,896.7	.00550	.275	4.0×10^{-10}
2,921.0	.00560	.280	2.6×10^{-10}
2,993.5	.00580	.290	5.9×10^{-10}
3,016.7	.00585	.292	4.6×10^{-10}
3,040.5	.00585	.292	4.1×10^{-10}
3,064.7	.00590	.295	4.1×10^{-10}
3,088.7	.00590	.295	4.0×10^{-10}
3,161.0	.00615	.308	5.0×10^{-10}
3,185.7	.00620	.310	4.0×10^{-10}
3,209.4	.00625	.312	4.0×10^{-10}
3,233.1	.00635	.318	4.1×10^{-10}
3,257.3	.00635	.318	4.1×10^{-10}
3,330.0	.00655	.328	4.0×10^{-10}
3,353.4	.00660	.330	4.0×10^{-10}

TABLE 28 (Continued)

Time	Length Change Δ L (inch) (2" G. L.)	Creep (%)	Pressure (Torr)
3,377.4 Hours	.00675	.338	3.9×10^{-10}
3,402.2	.00680	.340	4.0×10^{-10}
3,425.5	.00680	.340	3.6×10^{-10}
3,498.1	.00680	.340	3.8×10^{-10}
3,521.4	.00690	.345	3.2×10^{-10}
3,546.1	.00690	.345	4.0×10^{-10}
3,569.4	.00705	.352	3.8×10^{-10}
3,593.5	.00710	.355	3.9×10^{-10}
3,666.0	.00725	.362	3.7×10^{-10}
3,689.5	.00725	.362	3.7×10^{-10}
3,713.7	.00725	.362	3.8×10^{-10}
3,737.6	.00750	.368	3.5×10^{-10}
3,761.8	.00750	.375	3.4×10^{-10}
3,833.9	.00765	.382	3.9×10^{-10}
3,857.7	.00780	.390	4.3×10^{-10}
3,881.9	.00795	.398	3.8×10^{-10}
4,001.7	.00845	.422	3.9×10^{-10}
4,025.4	.00840	.420	4.4×10^{-10}
4,050.0	.00840	.420	4.3×10^{-10}
4,074.2	.00850	.425	4.2×10^{-10}
4,097.6	.00865	.432	3.7×10^{-10}
4,169.7	.00885	.442	4.0×10^{-10}
4,193.6	.00890	.445	4.0×10^{-10}
4,217.4	.00905	.452	3.9×10^{-10}
4,242.0	.00915	.458	4.0×10^{-10}
4,265.9	.00925	.462	4.1×10^{-10}
4,337.7	.00940	.470	4.0×10^{-10}
4,361.6	.00955	.478	3.8×10^{-10}
4,385.6	.00960	.480	4.4×10^{-10}
4,409.6	.00970	.485	3.9×10^{-10}
4,433.6	.00970	.485	4.3×10^{-10}
4,505.6	.00980	.490	3.8×10^{-10}
4,529.7	.00985	.492	3.8×10^{-10}
4,553.4	.00980	.490	2.9×10^{-10}
4,577.6	.00985	.492	3.7×10^{-10}
4,601.7	.00995	.498	3.6×10^{-10}

Test in progress
Specimen S-39

TABLE 29

Creep Test Data, T-111, Heat No. 65080A, Annealed at 3000°F (1649°C) for 1 hour, Tested at 2200°F (1204°C), 3000 psi ($2.07 \times 10^7 N/m^2$)

Time	Length Change Δ L (inch) (2" G. L.)	Creep (%)	Pressure (Torr)
2 Minutes	.00020	.010	3.4×10^{-8}
3	.00030	.015	3.4×10^{-8}
4	.00035	.018	3.4×10^{-8}
5	.00040	.020	3.4×10^{-8}
6	.00065	.033	3.4×10^{-8}
7	.00065	.033	3.4×10^{-8}
8	.00065	.033	3.4×10^{-8}
9	.00060	.030	3.4×10^{-8}
10	.00070	.035	3.4×10^{-8}
15	.00075	.038	3.4×10^{-8}
30	.00065	.033	3.4×10^{-8}
45	.00030	.015	3.4×10^{-8}
60	.00040	.020	3.4×10^{-8}
17.4 Hours	.00080	.040	2.2×10^{-9}
41.2	.00190	.095	6.4×10^{-9}
46.2	.00200	.100	6.3×10^{-9}
65.2	.00305	.152	4.0×10^{-9}
137.3	.00580	.290	3.9×10^{-9}
161.2	.00755	.378	3.9×10^{-9}
185.0	.00780	.390	4.4×10^{-9}
209.0	.00890	.445	4.2×10^{-9}
233.2	.01010	.505	4.6×10^{-9}
307.1	.01280	.640	3.7×10^{-9}
329.0	.01350	.675	3.2×10^{-9}
353.6	.01420	.710	3.8×10^{-9}
377.0	.01495	.748	2.9×10^{-9}
400.9	.01560	.780	3.1×10^{-9}
473.2	.01720	.860	2.8×10^{-9}
497.1	.01850	.925	2.4×10^{-9}
521.9	.01925	.962	1.8×10^{-9}
545.1	.01980	.990	2.4×10^{-9}
569.2	.02020	1.010	1.7×10^{-9}
641.0	.02175	1.088	2.5×10^{-9}
665.1	.02240	1.120	2.4×10^{-9}
689.2	.02300	1.150	2.4×10^{-9}
697.2	.02330	1.165	1.4×10^{-9}

Test terminated - sufficient data obtained
Specimen S-45

TABLE 30

Creep Test Data, T-111, Heat No. 65079, Annealed at 3000°F (1649°C) for 1/4 hour, Tested at 2000°F (1093°C), 18,000 psi ($1.24 \times 10^8 N/m^2$)

Time	Length Change Δ L (inch) (2" G. L.)	Creep (%)	Pressure (Torr)
1	.00000	.000	1.1×10^{-8}
2	.00005	.002	1.1×10^{-8}
3	.00000	.000	1.1×10^{-8}
4	.00005	.002	1.1×10^{-8}
5	.00010	.005	1.1×10^{-8}
6	.00010	.005	1.1×10^{-8}
7	.00015	.008	1.1×10^{-8}
8	.00015	.008	1.1×10^{-8}
9	.00010	.005	1.1×10^{-8}
10	.00015	.008	1.1×10^{-8}
15	.00020	.010	1.1×10^{-8}
30	.00020	.010	1.1×10^{-8}
45	.00020	.010	1.1×10^{-8}
60	.00020	.010	1.1×10^{-8}
3.0 Hours	.00020	.010	1.3×10^{-8}
19.3	.00025	.012	8.1×10^{-9}
43.4	.00025	.012	5.1×10^{-9}
115.8	.00035	.018	2.4×10^{-9}
139.2	.00035	.018	2.3×10^{-9}
163.3	.00045	.022	1.8×10^{-9}
187.2	.00060	.030	1.6×10^{-9}
211.4	.00070	.035	1.5×10^{-9}
283.4	.00115	.058	1.4×10^{-9}
308.4	.00130	.065	1.4×10^{-9}
331.3	.00170	.085	1.1×10^{-9}
355.7	.00210	.105	1.2×10^{-9}
360.6	.00215	.108	1.2×10^{-9}

Test Terminated - Sufficient Data Obtained
Specimen S-43

TABLE 31

Creep Test Data, T-111, Heat No. 61079, Annealed at 3000°F (1649°C) for 1 hour, Tested at 2172°F (1189°C), 9500 psi ($6.55 \times 10^7 N/m^2$)

Time	Length Change Δ L (inch) (2" G. L.)	Creep (%)	Pressure (Torr)
1 Minutes	.00000	.000	2.6×10^{-8}
2	.00005	.003	2.6×10^{-8}
3	.00005	.003	2.6×10^{-8}
4	.00010	.005	2.6×10^{-8}
5	.00010	.005	2.6×10^{-8}
6	.00010	.005	2.6×10^{-8}
7	.00010	.005	2.6×10^{-8}
8	.00010	.005	2.6×10^{-8}
9	.00015	.008	2.6×10^{-8}
10	.00015	.008	2.6×10^{-8}
15	.00015	.008	2.6×10^{-8}
30	.00010	.005	2.6×10^{-8}
45	.00015	.008	2.6×10^{-8}
60	.00015	.008	2.6×10^{-8}
1.0 Hours	.00015	.008	3.2×10^{-8}
7.0	.00030	.015	2.0×10^{-8}
33.2	.00040	.020	1.1×10^{-9}
56.6	.00050	.025	7.2×10^{-9}
79.0	.00060	.030	5.0×10^{-9}
102.1	.00075	.038	3.9×10^{-9}
125.9	.00090	.045	2.8×10^{-9}
154.0	.00110	.055	3.1×10^{-9}
222.6	.00140	.070	2.5×10^{-9}
246.9	.00155	.078	2.5×10^{-9}
270.3	.00170	.085	2.2×10^{-9}
294.1	.00185	.092	2.1×10^{-9}
318.3	.00205	.128	1.4×10^{-9}
414.2	.00275	.138	1.3×10^{-9}
438.0	.00295	.148	1.2×10^{-9}
462.1	.00305	.152	1.2×10^{-9}
467.3	.00305	.152	1.2×10^{-9}

Test terminated - sufficient data obtained
Specimen S-44A

TABLE 32

Creep Test Data, T-111, Heat No. 65079, Annealed at 3000°F (1649°C) for 44 hours, Tested at 2371°F (1299°C), 3300 psi ($2.27 \times 10^7 N/m^2$)

Time	Length Change Δ L (inch) (2" G. L.)	Creep (%)	Pressure (Torr)
1 Minutes	-.00005	-.002	4.0×10^{-8}
2	-.00005	-.002	4.0×10^{-8}
3	.00000	.000	4.0×10^{-8}
4	.00005	.002	4.0×10^{-8}
5	.00005	.002	4.0×10^{-8}
6	.00010	.005	4.0×10^{-8}
7	.00010	.005	4.0×10^{-8}
8	.00015	.008	4.0×10^{-8}
9	.00010	.005	4.0×10^{-8}
10	.00010	.005	4.0×10^{-8}
15	.00005	.002	4.0×10^{-8}
30	.00005	.002	4.0×10^{-8}
45	.00005	.002	4.0×10^{-8}
60	.00010	.005	4.0×10^{-8}
1.0 Hours	.00010	.005	3.3×10^{-8}
16.9	.00020	.010	1.0×10^{-8}
41.5	.00030	.015	4.0×10^{-9}
64.9	.00055	.028	3.2×10^{-9}
88.8	.00095	.048	3.1×10^{-9}
161.1	.00175	.088	2.1×10^{-9}
185.0	.00185	.092	1.8×10^{-9}
209.8	.00200	.100	1.8×10^{-9}
232.9	.00215	.108	1.6×10^{-9}
257.1	.00255	.128	1.6×10^{-9}
328.9	.00295	.148	1.3×10^{-9}
334.6	.00335	.168	1.3×10^{-9}

Test terminated - sufficient data obtained
Specimen S-44B

TABLE 33

Creep Test Data, T-111, Heat No. 65079, Annealed at 3000°F (1649°C) for 1/4 hour, Tested at 2000°F (1093°C), 18,000 psi (1.24×10^8 N/m²)

Time	Length Change Δ L (inch) (2" G. L.)	Creep (%)	Pressure (Torr)
1 Minutes	.00000	.000	2.8×10^{-9}
2	.00000	.000	2.8×10^{-9}
3	.00005	.002	2.8×10^{-9}
4	.00010	.005	2.8×10^{-9}
5	.00010	.005	2.8×10^{-9}
6	.00010	.005	2.8×10^{-9}
7	.00015	.008	2.8×10^{-9}
8	.00015	.008	2.8×10^{-9}
9	.00015	.008	2.8×10^{-9}
10	.00015	.008	2.8×10^{-9}
15	.00015	.008	2.8×10^{-9}
30	.00010	.005	2.8×10^{-9}
45	.00015	.008	2.8×10^{-9}
60	.00015	.008	2.8×10^{-9}
2.0 Hours	.00015	.008	3.2×10^{-9}
3.9	.00020	.010	3.8×10^{-9}
17.6	.00135	.068	2.6×10^{-9}
41.8	.00155	.078	3.2×10^{-9}
65.4	.00095	.048	2.6×10^{-9}
88.7	.00130	.065	2.5×10^{-9}
112.4	.00145	.072	2.0×10^{-9}
136.6	.00155	.078	1.9×10^{-9}
160.6	.00160	.080	1.8×10^{-9}
233.0	.00175	.088	2.1×10^{-9}
257.6	.00175	.088	1.6×10^{-9}
281.3	.00185	.092	1.6×10^{-9}
305.0	.00190	.095	1.5×10^{-9}
329.2	.00210	.105	1.3×10^{-9}
401.9	.00255	.128	1.0×10^{-9}
426.3	.00270	.135	1.1×10^{-9}
449.4	.00295	.148	1.2×10^{-9}
474.1	.00315	.158	1.2×10^{-9}
497.4	.00345	.172	1.3×10^{-9}
570.2	.00380	.190	1.0×10^{-9}
593.3	.00420	.210	1.1×10^{-10}
618.1	.00435	.218	9.7×10^{-10}
641.3	.00470	.235	8.6×10^{-10}
665.4	.00510	.255	9.1×10^{-10}
737.9	.00595	.298	8.3×10^{-10}
761.4	.00605	.302	8.1×10^{-10}
786.1	.00640	.320	8.0×10^{-10}

TABLE 33 (Continued)

Time	Length Change Δ L (inch) (2" G. L.)	Creep (%)	Pressure (Torr)
809.2 Hours	.00675	.338	7.4×10^{-10}
833.7	.00710	.355	7.8×10^{-10}
905.8	.00795	.398	8.3×10^{-10}
929.6	.00840	.420	8.2×10^{-10}
953.9	.00865	.432	1.0×10^{-9}
1,073.5	.01175	.588	8.0×10^{-10}
1,076.5	.01120	.560	
1,097.3	.01180	.590	8.0×10^{-10}
1,121.8	.01200	.600	7.8×10^{-10}
1,146.1	.01245	.622	7.4×10^{-10}
1,169.4	.01265	.632	7.0×10^{-10}
1,241.5	.01375	.688	7.2×10^{-10}

Test terminated - sufficient data obtained
Specimen S-44C

TABLE 34

Creep Test Data, T-111. Heat No. 65079, Annealed at 3000°F (1649°C) for 1/4 hour, Tested at 1800°F (982°C), 23,000 psi ($1.58 \times 10^8 N/m^2$)

Time	Length Change Δ L (inch) (2" G. L.)	Creep (%)	Pressure (Torr)
1 Minutes	.00000	.000	7.1×10^{-10}
2	.00000	.000	7.1×10^{-10}
3	.00000	.000	7.1×10^{-10}
4	.00005	.002	7.1×10^{-10}
5	.00005	.002	7.1×10^{-10}
6	.00010	.005	7.1×10^{-10}
7	.00010	.005	7.1×10^{-10}
8	.00015	.008	7.1×10^{-10}
9	.00010	.005	7.1×10^{-10}
10	.00015	.008	7.1×10^{-10}
15	.00010	.005	7.1×10^{-10}
30	.00010	.005	7.1×10^{-10}
45	.00015	.008	7.1×10^{-10}
60	.00010	.005	7.1×10^{-10}
15.5 Hours	.00015	.008	6.9×10^{-10}
39.6	.00015	.008	6.9×10^{-10}
64.1	.00035	.018	7.0×10^{-10}
87.8	.00045	.022	6.8×10^{-10}
159.6	.00035	.018	6.9×10^{-10}
183.5	.00055	.028	6.8×10^{-10}
207.5	.00065	.032	7.2×10^{-10}
231.5	.00065	.032	6.4×10^{-10}
255.6	.00070	.035	6.4×10^{-10}
327.5	.00070	.035	6.4×10^{-10}
351.7	.00065	.032	6.3×10^{-10}
375.4	.00060	.030	5.3×10^{-10}
399.6	.00075	.038	6.2×10^{-10}
423.7	.00085	.042	6.0×10^{-10}
568.0	.00070	.035	6.3×10^{-10}
591.8	.00065	.032	6.2×10^{-10}
687.7	.00095	.048	6.2×10^{-10}
711.3	.00095	.048	6.1×10^{-10}
735.8	.00125	.062	6.4×10^{-10}
759.8	.00135	.068	6.2×10^{-10}
831.9	.00160	.080	6.3×10^{-10}
856.2	.00160	.080	5.4×10^{-10}
880.3	.00165	.082	6.1×10^{-10}
903.9	.00180	.090	5.7×10^{-10}
927.2	.00185	.092	5.8×10^{-10}
1.002.6	.00200	.100	5.8×10

Test in progress
Specimen S-44D

TABLE 35

Creep Test Data, T-111, Heat No. 65080, Annealed at 3000°F (1649°C) for 1 hour, Tested at 2200°F (1204°C), 16 psi/hr. continuous loading rate

Time	Length Change Δ L (inch) (2" G. L.)	Creep (%)	Pressure (Torr)
1.0 Hours	.00000	.000	9.6×10^{-9}
17.3	.00010	.005	8.9×10^{-9}
41.3	.00080	.040	3.6×10^{-9}
112.6	.00140	.070	5.8×10^{-9}
136.5	.00190	.095	5.4×10^{-9}
161.2	.00220	.110	5.3×10^{-9}
184.6	.00255	.128	5.0×10^{-9}
208.2	.00300	.150	4.6×10^{-9}
231.9	.00390	.195	4.2×10^{-9}
258.4	.00460	.230	4.0×10^{-9}
297.4	.00540	.270	3.3×10^{-9}
319.9	.00610	.305	2.8×10^{-9}
328.5	.00655	.328	3.4×10^{-9}
354.3	.00750	.375	3.4×10^{-9}
376.0	.00855	.428	3.4×10^{-9}
399.9	.00955	.478	
431.7	.01055	.528	3.1×10^{-9}
448.7	.01135	.568	2.8×10^{-9}
472.4	.01250	.625	2.6×10^{-9}
496.6	.01365	.682	2.8×10^{-9}
520.2	.01510	.755	2.8×10^{-9}
546.4	.01695	.848	2.8×10^{-9}
575.6	.01850	.925	2.7×10^{-9}
605.7	2.02140	1.070	2.6×10^{-9}
616.2	.02200	1.100	2.8×10^{-9}
623.8	.02240	1.120	2.8×10^{-9}

Test terminated - sufficient data obtained
Specimen S-36

TABLE 36

Creep Test Data, T-111, Heat No. 65080, Annealed at 3000°F (1649°C) for 1 hour, Tested at 2200°F (1204°C), 1 psi/hr. - continuous loading rate

Time	Length Change Δ L (inch) (2" G. L.)	Creep (%)	Pressure (Torr)
4.0 Hours	.00000	.000	2.0×10^{-8}
20.4	.00000	.000	1.0×10^{-8}
92.1	.00000	.000	5.3×10^{-9}
116.2	.00000	.000	4.4×10^{-9}
140.8	.00000	.000	3.7×10^{-9}
166.4	.00000	.000	4.1×10^{-9}
188.2	.00005	.002	3.8×10^{-9}
259.9	.00000	.000	3.1×10^{-9}
284.6	.00000	.000	2.8×10^{-9}
308.5	.00000	.000	2.7×10^{-9}
333.1	.00005	.002	2.8×10^{-9}
356.2	.00000	.000	2.8×10^{-9}
428.6	.00010	.005	2.0×10^{-9}
452.1	.00005	.002	2.1×10^{-9}
476.0	.00010	.005	2.2×10^{-9}
500.4	.00015	.008	2.0×10^{-9}
524.0	.00015	.008	1.9×10^{-9}
597.4	.00010	.005	1.7×10^{-9}
621.4	.00005	.002	1.7×10^{-9}
645.4	.00005	.002	1.6×10^{-9}
669.4	.00005	.002	1.5×10^{-9}
691.9	.00010	.005	1.6×10^{-9}
764.0	.00010	.005	1.6×10^{-9}
812.0	.00010	.005	1.4×10^{-9}
836.0	.00015	.008	1.3×10^{-9}
860.1	.00015	.008	1.4×10^{-9}
932.4	.00020	.010	1.6×10^{-9}
956.1	.00015	.008	1.4×10^{-9}
980.6	.00015	.008	1.5×10^{-9}
1,004.8	.00025	.012	1.3×10^{-9}
1,029.1	.00025	.012	1.2×10^{-9}
1,100.7	.00050	.025	1.2×10^{-9}
1,124.2	.00060	.030	1.3×10^{-9}
1,148.4	.00065	.032	1.2×10^{-9}
1,172.1	.00070	.035	1.2×10^{-9}

TABLE 36 (Continued)

Time	Length Change Δ L (inch) (2" G. L.)	Creep (%)	Pressure (Torr)
1,196.3 Hours	.00080	.040	1.2×10^{-9}
1,269.8	.00115	.058	1.3×10^{-9}
1,292.5	.00145	.072	1.2×10^{-9}
1,321.4	.00170	.085	1.2×10^{-9}
1,339.8	.00170	.085	1.2×10^{-9}
1,364.0	.00180	.090	1.1×10^{-9}
1,438.4	.00195	.098	1.1×10^{-9}
1,460.2	.00195	.098	1.1×10^{-9}
1,484.2	.00210	.105	1.0×10^{-9}
1,508.1	.00225	.112	1.2×10^{-9}
1,532.0	.00220	.110	1.1×10^{-9}
1,604.3	.00240	.120	1.1×10^{-9}
1,630.4	.00240	.120	1.1×10^{-9}
1,654.4	.00250	.125	9.6×10^{-10}
1,678.4	.00260	.130	9.6×10^{-10}
1,702.4	.00285	.142	9.6×10^{-10}
1,774.4	.00305	.152	9.3×10^{-10}
1,798.4	.00320	.160	9.0×10^{-10}
1,822.4	.00320	.160	9.2×10^{-10}
1,846.4	.00325	.162	8.8×10^{-10}
1,870.4	.00325	.162	1.0×10^{-9}
1,942.4	.00355	.178	9.0×10^{-10}
1,966.4	.00385	.192	8.4×10^{-10}
1,990.4	.00430	.125	8.9×10^{-10}
2,014.4	.00440	.220	8.8×10^{-10}
2,038.4	.00450	.225	9.2×10^{-10}
2,110.4	.00480	.240	9.0×10^{-10}
2,134.4	.00490	.245	8.8×10^{-10}
2,158.4	.00530	.265	9.0×10^{-10}
2,182.4	.00545	.272	8.3×10^{-10}
2,206.4	.00565	.282	8.3×10^{-10}
2,302.4	.00615	.308	8.5×10^{-10}
2,326.4	.00645	.322	8.1×10^{-10}
2,350.4	.00665	.332	7.7×10^{-10}
2,374.4	.00675	.338	8.2×10^{-10}
2,447.9	.00695	.348	7.6×10^{-10}

TABLE 36 (Continued)

Time	Length Change Δ L (inch) (2" G. L.)	Creep (%)	Pressure (Torr)
2,470.4 Hours	.00715	.358	7.8×10^{-10}
2,494.4	.00725	.362	8.0×10^{-10}
2,518.4	.00745	.372	7.9×10^{-10}
2,542.4	.00760	.380	8.6×10^{-10}
2,614.4	.00815	.408	7.8×10^{-10}
2,638.4	.00840	.420	8.2×10^{-10}
2,662.4	.00855	.428	8.0×10^{-10}
2,686.4	.00870	.435	8.0×10^{-10}
2,710.4	.00895	.448	7.5×10^{-10}
2,782.4	.00940	.470	7.4×10^{-10}
2,806.4	.00955	.478	7.5×10^{-10}
2,830.4	.00995	.498	7.8×10^{-10}
2,854.4	.01010	.505	7.2×10^{-10}
2,878.4	.01020	.510	7.2×10^{-10}
2,950.4	.01065	.532	7.0×10^{-10}
2,974.4	.01085	.542	7.2×10^{-10}
2,998.4	.01115	.558	7.2×10^{-10}
3,022.4	.01125	.562	6.9×10^{-10}
3,046.4	.01150	.575	6.4×10^{-10}
3,118.4	.01195	.598	7.1×10^{-10}
3,142.4	.01235	.618	6.6×10^{-10}
3,166.4	.01-70	.635	6.8×10^{-10}
3,190.4	.01285	.642	6.8×10^{-10}
3,214.4	.01310	.655	4.8×10^{-10}
3,286.4	.01365	.682	6.7×10^{-10}
3,310.4	.01385	.692	6.9×10^{-10}
3,334.4	.01410	.705	6.6×10^{-10}
3,358.4	.01425	.712	6.4×10^{-10}
3,382.4	.01450	.725	6.6×10^{-10}
3,454.4	.01505	.752	6.8×10^{-10}
3,478.4	.01645	.822	6.2×10^{-10}
3,502.4	.01620	.810	6.8×10^{-10}
3,526.4	.01615	.808	6.8×10^{-10}
3,550.4	.01655	.828	6.8×10^{-10}
3,622.4	.01765	.882	6.5×10^{-10}
3,646.4	.01795	.898	6.5×10^{-10}
3,670.4	.01835	.918	6.9×10^{-10}

TABLE 36 (Continued)

Time	Length Change Δ L (inch) (2" G. L.)	Creep (%)	Pressure (Torr)
3,694.4 Hours	.01880	.940	6.8×10^{-10}
3,718.4	.01895	.948	6.8×10^{-10}
3,790.4	.01965	.982	6.6×10^{-10}
3,814.4	.01980	.990	6.6×10^{-10}
3,838.4	.02005	1.002	6.4×10^{-10}
3,862.4	.02020	1.010	6.1×10^{-10}
3,886.4	.02055	1.028	6.4×10^{-10}
3,958.4	.02115	1.058	6.0×10^{-10}
3,982.4	.02140	1.070	5.9×10^{-10}
4,006.4	.02175	1.088	5.6×10^{-10}
4,030.4	.02230	1.115	5.4×10^{-10}
4,054.4	.02265	1.132	4.8×10^{-10}
4,126.4	.02330	1.165	5.8×10^{-10}
4,150.4	.02395	1.198	6.0×10^{-10}
4,174.4	.02455	1.228	6.0×10^{-10}
4,294.4	.02590	1.295	6.4×10^{-10}
4,318.4	.02615	1.308	6.0×10^{-10}
4,342.4	.02635	1.318	6.0×10^{-10}
4,366.4	.02655	1.328	5.0×10^{-10}
4,390.4	.02685	1.342	5.4×10^{-10}
4,462.4	.02745	1.372	6.1×10^{-10}
4,486.4	.02785	1.392	5.8×10^{-10}
4,510.4	.02855	1.428	6.1×10^{-10}
4,534.4	.02870	1.435	7.0×10^{-10}
4,558.4	.02905	1.452	7.1×10^{-10}
4,630.4	.03005	1.502	6.1×10^{-10}
4,654.4	.03065	1.532	6.4×10^{-10}
4,678.4	.03105	1.552	6.9×10^{-10}
4,685.9	.03125	1.562	6.1×10^{-10}

Test terminated - sufficient data obtained
Specimen S-38

TABLE 37

Creep Test Data, T-111, Heat No. 65079, Annealed at 3000°F (1649°C) for 1 hour, Tested at 2200°F (1204°C), 16 psi/hr. continuous loading rate.

Time	Length Change Δ L (inch) (2" G. L.)	Creep (%)	Pressure (Torr)
2.4 Hours	.00000	.000	1.6×10^{-8}
15.2	.00010	.005	1.8×10^{-8}
39.4	.00005	.002	3.8×10^{-9}
64.5	.00005	.002	5.2×10^{-9}
88.5	.00000	.000	4.6×10^{-9}
112.5	.00000	.000	2.0×10^{-9}
136.5	.00000	.000	4.2×10^{-9}
160.5	.00005	.002	1.6×10^{-9}
232.5	.00005	.002	4.0×10^{-9}
256.5	.00015	.008	1.6×10^{-9}
280.5	.00020	.010	3.4×10^{-9}
304.5	.00040	.020	2.1×10^{-9}
328.5	.00035	.018	2.0×10^{-9}
400.5	.00040	.020	3.1×10^{-9}
424.5	.00050	.025	3.0×10^{-9}
448.5	.00040	.020	1.4×10^{-9}
472.5	.00050	.025	3.0×10^{-9}
496.5	.00050	.025	2.4×10^{-9}
568.5	.00160	.080	2.8×10^{-9}
592.5	.00250	.125	3.1×10^{-9}
616.5	.00330	.165	1.5×10^{-9}
640.5	.00330	.165	1.6×10^{-9}
663.1	.00415	.208	1.5×10^{-9}
736.5	.00425	.212	1.5×10^{-9}
760.5	.00450	.225	1.4×10^{-9}

Test terminated - sufficient data obtained
Specimen S-46

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