~~TID/SNA--2052~~

GESp-723

TID/SNG--17

MASTER

FINAL REPORT
CREEP OF 347 STAINLESS STEEL IN HYDROGEN

March 15, 1972

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Work Performed for
Aerojet Nuclear Systems Company
A Division of Aerojet-General Corporation
Customer Order No. N-900104

By
General Electric Company
Nuclear Systems Programs
Space Division
Cincinnati, Ohio 45215

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Subject: Final Report - "Creep of AISI Type 347 Stainless Steel in Hydrogen"

References:

1. ANSC Request for Quotation L-0174, May 4, 1970.
2. GE-NSP Quotation No. A22041, May 18, 1970.
3. ANSC Purchase Order No. N-900104, August 4, 1970.
4. ANSC TWX 20019 - To Stop Further Testing, April 20, 1971.
5. ANSC TWX 05014 - Resume Testing at 1400 F, May 5, 1971.
6. ANSC Telegram DF Johns to ES Collins, Resume Testing at 1600⁰ F, July 30, 1971.
7. ANSC TWX 28005 - Further Test Definition at 1200⁰ F, December 28, 1971.
8. ANSC TWX 21012 - Final Test Definition at 1400⁰ F, January 21, 1972.

This is the final report for the work performed on Aerojet Nuclear Systems Company Purchase Order N-900104, "Creep of AISI 347 Stainless Steel in Gaseous Hydrogen." The program consisted of performing creep tests on three lots of 347 stainless steel sheet specimens, 0.016-inch-thick; the material for which was supplied by the Aerojet Nuclear Systems Company. The lots were identified as Lots A, B, and C and represented material initially produced by Washington, Republic, and Jones & Laughlin Steel Companies, respectively. All three lots were then rolled from 1/8-inch stock to 0.016-inch sheet by a different vendor, and all were subjected to a final heat treat schedule by a single vendor. Fifteen sheets of the above sheet stock from each lot were received by GE-NSP on August 12, 1970. The sheets were 0.016 inch thick x 4 inches wide by 10 inches long.

Two hundred-forty specimens (80 from each lot) were fabricated according

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to GE-NSP Drawing No. 125B8100, Rev. H, Part 1. Inspection for dimensional conformance and dye penetrant inspection for flaws (MIL-I-6866, Type 1, Method B) were performed prior to testing. To assure no mix-up in material lots during fabrication of the specimens, only one lot of material was released at a time to the shop. Each sheet of material submitted to specimen fabrication had an A, B, or C identification mark scribed in one corner of the sheet prior to receipt of the material by GE-NSP. After specimen fabrication and inspection, each test specimen was marked on one tab end with a lot letter, A, B, or C, and a sequential number. Therefore, there was no chance for a material mix-up at GE-NSP.

The test program consisted of performing a total of 194 tests of the three lots of material at 1200° , 1400° , and 1600° F. Table I shows the temperature-stress level conditions used in the program and the number of specimens from each lot tested at these conditions. As can be seen in Table I, 194 tests were run that totaled 20,107 test hours for an average test time of 104 hours each. Six tests were of no value because of extensometers either sticking or the spot weld breaking loose. Tables 2 through 8 list the tests that were run on this program with the hours required to reach 0.5%, 1.0%, and 3.0% total strain. In addition, the test conditions, the starting data, the test stand, the total test time, and the final strain are shown.

Because of the low stress levels required for the 1600° F and 1400° F tests, three different types of creep stands were employed in this test program. All tests were dead-weight loaded, and the stands used were equipped with bellows-sealed Marshall Muffle Furnaces. However, two stands were modified to include the weight pans within the furnace lower bellows for the 1600° F tests since the loads were so low for the required stress level that the bellows correction required for an external load pan would be too great. For the intermediate stress levels, mostly the 1400° F tests, two test stands were used that were equipped with a tank extension below the bellows in which a heavier load could be sealed within the hydrogen atmosphere thus eliminating a bellows correction. The high-stress level tests at 1200° F were run in two test stands that had external load pans and these tests required that a bellows correction be made.

In all cases the furnace hydrogen atmospheres were established by first evacuating the muffle furnaces to about 1×10^{-5} torr, and after assuring an acceptable leak rate (remain on 10^{-4} torr scale after one minute), the muffle was backfilled with hydrogen. The hydrogen flow rate was established and continued at least overnight before starting to heat the specimen to the test temperature. After test temperatures reached the equilibrium test condition, the load was gradually applied and creep readings were begun.

The hydrogen used for the tests was commercial-grade hydrogen, -60°F D.P. , that was passed through a Serfass Hydrogen Purifier (Milton Ray Company, Model C-50D), Palladium-Silver Alloy Diffuser in the supply line to the creep stands. This unit is capable of purifying 50 SCFH of hydrogen to a level where there are no detectable impurities in the output of the purifier including moisture. Periodically, a sample bottle was placed in a furnace exhaust line while a test was in progress and a gas chromatograph analysis made of the furnace exhaust gases after several hours (> 24 hours) of through-flow in the bottle. A typical analysis of the hydrogen gas samples taken in the above manner was:

<u>Impurity</u>	<u>Typical Amount</u>	<u>Precision</u>
$\text{O}_2 + \text{Ar}$	1.5 ppm	± 0.5 ppm
N_2	0.8 ppm	± 0.5 ppm
CO	12 ppm	± 5 ppm
CH_4	3 ppm	± 1 ppm

Argon gas was used at the conclusion of the tests to displace hydrogen from the furnaces prior to opening the muffle. Therefore, some argon is present in the system and probably accounts for the majority of the $\text{O}_2 + \text{Ar}$ peak observed as a sum of the two gases by the gas chromatography method used.

The initial tests run on the program were attempted using a static hydrogen atmosphere with the furnace sealed off and the hydrogen pressure maintained at slightly above atmospheric pressure. The specimens at all test temperatures, however, showed a significant amount of surface oxidation;

some were tarnished blue, straw, or even an allover oxide surface. To reduce this discoloration, a short series of tests were run at various hydrogen flow rates, and it was found that there was less discoloration of the 347 stainless steel at a flow rate of about $500 \text{ cm}^3/\text{min}$ ($\sim 1 \text{ SCFH}$) than at either no flow or at a flow rate of $100 \text{ cm}^3/\text{min}$ (0.2 SCFH).

Therefore, all of the tests after the first few were run at a hydrogen flow rate through the furnace of about $500 \text{ cm}^3/\text{min}$ ($\sim 1 \text{ SCFH}$). The results were that the 1600°F tests were very clean showing no signs of tarnish, the 1400°F tests showed a slight bluish surface color while the 1200°F tests were a darker blue color on the surface. Increasing the flow rate further did not seem to affect the discoloration at the lower temperatures; therefore, the $500 \text{ cm}^3/\text{min}$ flow rate was maintained throughout the remainder of the program at a furnace pressure of 8 inches - H_2O above atmospheric pressure.

In the initial 1600°F tests in the highly purified hydrogen atmosphere, the platinum strip extensometers were sticking. To solve this problem, it was necessary to switch to stainless steel extensometer strips at 1600°F .

Metallography mounts were prepared from pieces that were cut from Lots A, B, and C plates as previously identified in an attempt to understand why the creep behavior of the three lots was different and to explain some wide ranges of creep strength within a single lot.

Lot A metallographic samples indicated a relatively uniform grain structure having a grain size $< \text{ASTM } 8$ on both transverse and longitudinal mounts. Six microhardness readings ranged from 171 to 179 VHN.

Lot B metallographic samples indicated a relatively uniform grain structure having a grain size $\text{ASTM } 7-8$ on both transverse and longitudinal mounts. Six microhardness readings ranged from 147 to 171 VHN.

Lot C metallographic samples indicated a duplex structure having some large grains ASTM 6-7 and some small grains ASTM < 8. Six hardness readings taken on Lot C material ranged from 158 to 196 VHN.

The creep results of the three lots appeared to be consistent with the grain size observations; i.e., the larger grain material had a greater resistance to creep than fine-grain material under the same test conditions, particularly at the higher temperatures.

Summary curves of the creep tests performed on this contract indicating the relationship between stress and time required for 1 percent total creep at 1200^o, 1400^o, and 1600^oF are shown as Figures 1, 2, and 3, respectively, for ANSC Lots A, B, and C. Also shown as closed points are the results of some earlier tests performed for ANSC by the Battelle Memorial Institute, Columbus, Ohio. The data from Battelle generally fall within the range of scatter observed from the greater number of tests performed at GE-NSP.

Percent Creep - Time curves for each material lot at each stress level tested and each temperature tested are shown as Figures 4 through 57. The individual creep curves for each test and the early tabular data were forwarded to ANSC as they were completed through the program. In Figures 4 through 57, all creep curves were redrawn to the same scale of strain and time for ease of comparison. The data points shown on these curves are not necessarily a measured creep point. The points shown were taken from the smooth original curve that best fit the measured creep data. They are shown here only to help identify the individual tests.

Temperatures were measured using three Type K (Chromel-Alumel) thermocouples wired in position on the specimen so that they gave an indication of the top, middle, and bottom temperatures of the specimen gage length. Temperatures were controlled to the desired test temperature to within $\pm 3^{\circ}\text{F}$, and the position of the specimens in the furnaces and/or furnace shunts were adjusted so that the longitudinal temperature variation within the gage length was centered on the middle of the specimen and did not exceed $\pm 3^{\circ}\text{F}$, in accordance with ASTM Designation E139-69.

Figure 58 is General Electric Drawing No. 125B8100, Rev. H, to which the specimens on this program were fabricated. The specimens were fabricated according to Part No. 1 of the drawing. For most of the specimens tested, a small corner was clipped off of the specimen at a tab end and taped to the inside of the specimen envelope so that at a later date, if desirable to explain an anomaly, a pretest microstructure sample would be available for each specimen to compare with the posttest microstructure.

All tested and untested specimens, and all spare sheet stock will be packaged and shipped prepaid to the Aerojet Nuclear Systems Company: Attention D. F. Johns, Jr.

B. A. Chandler
Materials Technology Section

cak

TABLE I

NUMBER OF SPECIMENS OF LOTS A, B, & C TESTED AT 1200°, 1400°, 1600°F
WITH CORRESPONDING STRESS LEVELS

Stress Level, psi	Test Temperature									Totals
	1200°F			1400°F			1600°F			
	A	B	C	A	B	C	A	B	C	
17,000	3	3	3							9
18,000	-	-	5							5
19,000	3	3	8							14
20,000	3	3	3							9
22,000	3	3	3*							9
24,000	3	3	2							8
3,000				-	-	-				-
3,500				1	-	12				13
4,000				-	-	-				-
5,000				2	2	2				6
7,000				5	6	7				18
8,500				5	4	5**				14
10,000				5	6	5				16
13,000				-	1	-				1
15,000				-	1	-				1
200							-	-	-	-
250							-*	-	-	-
500							5*	3	3	11
700							4	2	-	6
800							2	-	1*	3
1,000							3	4	5*	12
1,300							-*	-	2	2
1,500							3*	3	3	9
2,000							-	3	1	4
3,000							3	3	3	9
4,500							3	3	3	9
Totals	15	15	24	18	20	31	23	21	21	188

* In addition 1 test - extensometer strip stuck, no data)

** In addition 2 tests - extensometer strip stuck, no data)

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Total Tests Run 194

Total Test Hours 20,107

Average Test Time, Hrs. 104

Original Test Matrix Stress Levels Underlined

TABLE 2
ORIGINAL 1200°F TEST MATRIX

Test No.	Std. No.	Start Date	Specimen No.	Stress psi	Time in Hours to				Final Strain %
					0.5%	1.0%	3.0%	Cplt.	
1	36	9-14-70	A-1	24.0	0.2	1.5	25.5	122	33.1 ^a
2	37	9-14-70	A-2	24.0	0.3	1.4	16.2	82	35.8 ^a
3	37	9-21-70	A-4	19.0	3.6	8.3	34	167	10.0
4	36	9-22-70	A-5	20.0	0.5	19.2	106.8	142	4.7
5	37	9-30-70	C-171	24.0	0.0	0.3	27.8	43	3.8
6	36	10-1-70	A-7	19.0	1.6	6.1	38.0	98	4.5
7	37	10-7-70	B-85	17.0	94.0	160.0	377.5	387	3.1
8	36	10-7-70	C-172	19.0	2.7	18.6	92.3	101	3.4
9	36	10-16-70	B-86	24.0	4.0	50.0	109.5	163	6.4
10	36	10-28-70	C-173	17.0	52.8	86.4	159.2	170	3.4
11	37	10-29-70	A-13	17.0	27.8	71.0	216.7	260	4.2
12	36	11-5-70	B-93	20.0	3.8	85.3	245.0	312	4.2
13	37	11-11-70	B-94	24.0	0.0	0.3	96.5	118	3.6
14	37	11-18-70	C-179	17.0	12.	68.	188.	290	5.8
15	36	12-2-70	A-14	20.0	5.6	18.9	112.6	122	3.4
16	37	12-3-70	B-95	19.0	13.0	96.5	267.5	286	3.3
17	36	12-11-70	A-16	17.0	49.	141.	298.	310	3.2
18	37	12-17-70	C-180	19.0	2.8	16.5	115.5	121	3.2
19	36	1-6-71	C-181	17.0	39.	98.	209.	260	4.2
20	37	1-7-71	B-96	17.0	80.	147.	384.	432	3.6
21	36	1-19-71	B-107	20.0	3.5	53.5	168.5	192	3.5
22	37	1-26-71	C-192	20.0	3.0	14.2	84.0	120	4.5
23	36	2-4-71	B-108	22.0	0.2	10.0	127.5	142	3.4
24	37	2-3-71	C-193	24.0	(b)				
25	37	2-10-71	C-194	22.0	0.1	1.5	73.5	75	3.0
26	36	2-24-71	C-195	22.0	0.3	4.2	63.2	79	4.1
27	37	2-24-71	A-23	22.0	2.2	6.6	65.6	79	3.5
28	37	3-2-71	C-196	24.0	0.1	0.7	42.2	49	3.3
29	36	3-3-71	B-109	22.0	0.0	2.2	128.6	163	3.8
30	37	3-10-71	A-24	22.0	2.0	8.9	88.5	89	3.0
31	36	3-29-71	A-30	22.0	1.3	4.6	53.0	73	3.8
32	37	4-1-71	B-113	19.0	12.5	70.0	195.5	209	3.3
33	36	4-8-71	B-114	19.0	1.3	113.5	252.5	288	3.5
34	37	4-20-71	C-199	20.0	2.4	11.6	83.1	89	3.2
35	36	5-20-71	B-130	20.0	8.0	88.0	213.0	218	3.1
36	37	6-1-71	A-31	20.0	5.8	33.0	177.8	194	3.5
37	36	6-9-71	C-200	20.0	1.0	13.8	103.9	122	3.5
38	37	6-11-71	B-116	22.0	0.1	3.8	145.0	146	3.0
39	36	7-12-71	A-32	24.0	0.5	2.8	15.3	25	4.0
40	37	7-12-71	B-117	24.0	0.0	0.1	71.0	96	4.0
41	36		B-118	17.0	95.0	-	-	140	0.8
42	37	8-2-71	C-201	22.0	0.0	0.6	58.7	91	3.6
43	36	8-2-71	A-33	17.0	87.5	(177)	-	167	0.9
44	37	8-17-71	A-34	19.0	15.0	75.0	-	171	1.8
45	36	8-17-71	C-202	19.0	6.5	35.3	102	140	4.5

- Completed -

^aSpecimens tested to Rupture

^bBad test

TABLE 3

ORIGINAL 1400°F TEST MATRIX

Test No.	Std. No.	Start Date	Specimen No.	Stress ksi	Time in Hours to				Final Strain %
					0.5%	1.0%	3.0%	Cplt.	
1	41	10-7-70	A-6	3.5	7.5	36.0	189.5	195.9	3.2
2	40	10-21-70	B-87	5.0	114	192	424	451	3.2
3	41	10-22-70	A-8	5.0	16.5	38	117	120	3.1
4	41	10-29-70	B-88	5.0	140	234	519	601	4.0
5	41	11-30-70	B-90	7.0	16.3	43.8	115	122	3.2
6	41	12-9-70	B-91	7.0	15.7	36	89	118	4.6
7	40	12-10-70	C-174	7.0	23.0	73.8	167	193	4.1
8	41	12-16-70	C-175	7.0	7.0	23.4	81	92	3.4
9	41	1-5-71	C-187	10.0	-----Bad Test-----				
10	40	1-7-71	B-105	10.0	6.0	21.4	57.2	93	7.4
11	41	1-12-71	B-106	10.0	3.2	12.7	57.0	66	3.7
12	40	1-13-71	A-20	10.0	1.1	2.4	6.5	24	16.9
13	40	1-19-71	C-188	10.0	0.7	2.5	15.7	22	3.7
14	41	1-19-71	C-189	10.0	0.8	2.0	7.3	21	7.4
15	41	1-27-71	C-190	8.5	2.2	5.3	20.8	24	3.3
16	41	2-3-71	A-21	8.5	1.5	3.1	8.7	24	10.3
17	41	2-10-71	A-25	7.0	3.7	7.9	21.1	25	3.8
18	41	2-23-71	B-110	15.0	0.08	0.25	3.2	20	14.3
19	41	3-2-71	A-27	5.0	10.8	22.6	65.4	73	3.4
20	41	3-11-71	C-197	5.0	17.5	42.5	123.8	144	3.5
21	41	4-6-71	C-198	7.0	5.7	14.8	48	68	4.4
22	40	4-6-71	B-111	13.0	.35	1.25	18.8	26	3.9
23	41	6-11-71	C-203	5.0	27.0	60	158	167	3.2
24	36	10-6-71	C-209	10.0	Extensometer Stuck				

- End -

See New 1400°F Matrix

TABLE 4

ORIGINAL 1600°F TEST MATRIX

Test No.	Std. No.	Start Date	Specimen No.	Stress ksi	Time in Hours to				Final Strain %
					0.5%	1.0%	3.0%	Cplt.	
1	35	9-15-70	A-3	0.5	(B)	-	-	169	-
2	35	9-24-70	C-170	1.0	16	36.2	217	263	3.3
3	35	10-8-70	B-92	1.5	(A)	-	-	53	-
4	41	10-13-70	C-169	2.0	-----Strip Stuck-----			140	4.0
5	35	10-15-70	C-176	1.5	5.2	13.4	-	121	3.5
6	35	10-21-70	A-11	1.5	-	(A)	-	21	3.2
7	35	10-26-70	A-12	1.5	4.7	(A)	-	50	3.1
8	35	11-3-70	A-15	0.5	111	225	(B)	384	1.8
9	35	11-25-70	C-177	1.0	6.8	15.1	54.8	73	3.8
10	40	12-1-70	B-89	2.0	5.5	23.2	107.7	122	3.3
11	35	12-8-70	A-10	1.0	3.1	7.8	28.9	45	4.7
12	35	12-15-70	C-178	0.8	19.5	46.9	208.1	212	3.0
13	35	1-5-71	A-9	0.8	9.1	19.3	56.6	71	4.0
14	35	1-13-71	C-182	1.0	14.5	35.0	61.0	169	3.1
15	35	1-26-71	B-97	1.0	31.0	67.5	225.5	240	3.2
16	40	1-27-71	C-191	1.5	7.2	16.8	60.5	96	4.5
17	40	2-4-71	A-22	0.7	17.0	38.9	115	122	3.2
18	35	2-11-71	C-183	1.3	4.8	10.2	36.2	53	4.1
19	40	2-23-71	A-26	1.5	3.9	6.5	23.5	24	3.1
20	35	2-25-71	B-98	1.5	5.0	14.8	56.5	96	4.7
21	40	3-2-71	A-28	1.5	2.9	6.0	19.0	46	7.3
22	35	3-4-71	B-99	1.5	10.0	21.2	68.5	97	4.0
23	35	3-10-71	B-100	2.0	7.5	17.0	56.0	96	5.0
24	35	3-11-71	C-184	1.3	6.4	15.3	69.8	89	3.6
25	40	3-18-71	A-29	0.7	15.4	36.3	118.7	141	3.5
26	35	4-5-71	A-17	0.8	8.8	21.1	56.5	71	3.9
27	35	4-12-71	A-18	1.0	3.9	8.7	27.1	45	5.2
28	40	6-11-71	B-112	2.0	7.4	16.0	51.3	64	3.7

(A) Platinum strip extensometer stuck - no creep data obtained.

(B) Test terminated prior to reaching strain level indicated.

TABLE 5
NEW 1400°F TEST MATRIX
Ref. TWX 5-5-71

Test No.	Std. No.	Start Date	Specimen No.	Stress ksi	0.5%	1.0%	3.0%	Cplt.	Final Strain %
1	40	4-29-71	B-115	7.0	35.0	75.2	157.0	169	3.7
2	41	5-3-71	A-46	↓	3.1	6.7	20.2	24	3.7
3	40	5-14-71	C-216		10.2	20.3	56.7	68	3.9
4	41	5-17-71	C-214		5.5	12.9	41.7	49	3.6
5	41	6-2-71	B-131		14.4	29.3	61.4	96	6.1
6	40	6-3-71	B-133		21.5	37.8	83.8	97	4.0
7	41	6-9-71	C-215		5.7	10.7	27.3	45	5.2
8	40	6-11-71	A-48		3.7	7.9	20.1	21	3.3
9	41	6-15-71	B-132		22.0	36.5	75.4	116	6.1
10	40	6-16-71	A-49		6.8	13.5	29.3	42	5.3
11	41	7-13-71	A-47		6.3	12.1	24.1	25	-
12	40	7-13-71	C-217		7.1	17.0	51.0	67	4.3
13	41	7-19-71	C-204	8.5	2.9	7.6	21.7	23	3.3
14	40	7-21-71	B-119	↓	6.9	16.1	41.6	45	3.3
15	41	8-3-71	A-35		2.2	4.9	13.6	21	5.9
16	40	8-3-71	B-120		7.1	16.4	41.4	47	3.1
17	41	8-16-71	B-121		5.6	19.5	58.0	74	4.3
18	40	8-16-71	A-36		2.2	4.8	13.3	22	5.5
19	41	8-23-71	C-205		2.5	6.9	24.6	26	3.1
20	40	8-23-71	C-206		3.0	5.3	19.7	25	4.0
21	41	9-1-71	B-122		5.7	11.6	33.4	37	3.4
22	40	9-1-71	C-207		4.0	8.5	26.3	26	3.0
23	41	9-8-71	A-37		2.1	4.3	12.5	19	4.9
24	40	9-8-71	A-38		1.3	2.7	8.3	18	6.8
25	36	9-7-71	A-39	10.0	1.3	2.8	8.4	18	6.9
26	37	9-8-71	C-208	↓	0.8	2.3	9.5	17	5.4
27	41	9-13-71	B-123		1.0	5.8	32.8	43	4.1
28	40	9-14-71	A-40		0.9	1.9	5.8	20	16.0
29	41	8-23-71	A-41		0.9	1.7	5.1	19	12.7
30	40	9-29-71	C-209		- Extensometer Broke Loose -				
31	36	10-13-71	B-124		- Extensometer strip stuck 100				Rupt.
32	40	10-5-71	A-42		<0.1	1.0	4.1	4	3.1
33	37	10-22-71	C-210		0.3	1.6	9.3	25	7.8
34	36	10-20-71	B-125		3.0	8.0	25.3	26	3.1
35	37	10-27-71	C-211		0.7	0.9	7.8	22	8.2
36	36	11-8-71	B-126		1.8	7.7	28.0	28	3.1

TABLE 6
NEW 1600°F TEST MATRIX
(Ref. TWX 7-30-71)

Test No.	Std. No.	Start Date	Specimen No.	Stress ksi	0.5%	1.0%	3.0%	Cplt.	Final Strain %
1	41	9-13-71	C186	4.5	0.1	0.4	1.2	14	42
2	40	9-14-71	B103		0.3	0.9	3.2	19	17
3	40	9-20-71	C212		0.1	0.3	1.1	1	3.2
4	41	9-16-71	A45		0.1	0.3	1.1	2	4.0
5	40	9-27-71	A43		0.2	0.4	1.1	1	3.2
6	41	9-29-71	B128		0.5	1.0	3.3	18	16.4
7	40	10-4-71	C219		0.2	0.5	1.9	2	3.2
8	41	10-5-71	B104		0.5	1.0	3.3	18	13.7
9	40	10-7-71	A44		<0.1	0.3	0.9	1	3.3
10	41	10-11-71	A50	3.0	0.4	0.8	2.9	3	3.0
11	40	10-15-71	C220		0.8	1.9	7.4	19	6.4
12	38	11-1-71	A53		0.5	1.1	3.1	3	3.2
13	40	11-8-71	B136		1.3	3.0	11.1	20	5.0
14	41	12-17-71	B134		1.6	3.5	13.3	19	4.0
15	41	11-10-71	C225		0.7	1.5	5.2	20	9.8
16	40	11-11-71	B137		1.6	3.3	11.4	20	5.0
17	41	11-15-71	A55		0.5	1.0	3.5	3	2.8
18	40	11-15-71	C226		0.4	1.0	3.4	20	10.5
19	41	10-16-71	C221	1.5	5.8	15.0	65.8	73	3.3
20	35	9-1-71	B101	1.0	23.0	44.0	(187)	155	2.7
21	35	9-9-71	C185		7.5	16.7	73.2	94	3.7
22	35	9-16-71	B102		17.5	43	(170)	147	2.7
23	35	9-27-71	A19		8.8	16.0	39.2	46	3.7
24	38	9-30-71	C213		8.8	19.5	86.3	139	4.2
25	38	10-14-71	C218		Extensometer strip problem				
26	35	10-7-71	B127		11.8	39.0	146.0	143	2.9
27	35	10-16-71	A51	0.7	9.0	21.5	73.0	77	3.2
28	40	10-20-71	A52		10.8	30.7	87.3	118	4.2
29	41	10-25-71	B129		65.5	166.0	-	167	1.0
30	35	12-16-71	B138		27.0	78.0	-	121	1.4
31	40	10-27-71	C223	0.5	33.5	87.0	-	142	1.4
32	35	11-1-71	C224		20.0	62.3	-	168	1.7
33	41	11-3-71	A54		35.7	79.5	-	123	1.6
34	35	11-10-71	B135		66.0	180 (EST)	-	125	0.8
35	40	12-16-71	A56		21.0	41.0	-	120	1.9
36	41	12-21-71	C227		49.0	149.0	-	146	1.0
37	41	1-6-72	B139		145.0 (Est)	-	-	120	0.5
38	40	1-5-72	A57		32.0	66.5	140 (Est)	120	2.1
39	35	1-5-72	B140		94.5	-	-	125	0.6

TABLE 7

NEW 1200°F TEST MATRIX

(Ref: TWX 28005)

<u>Test No.</u>	<u>Std. No.</u>	<u>Start Date</u>	<u>Specimen No.</u>	<u>Stress, psi</u>	<u>0.5%</u>	<u>1.0%</u>	<u>3.0%</u>	<u>Hours Cplt.</u>	<u>Final Strain, %</u>
1	36	1-11-72	C228	18.0	13.0	48.0	120.0	140	3.4
2	37	1-10-72	C222	19.0	4.5	31.0	131.0	162	3.5
3	37	1-19-72	C229	18.0	19.0	68.0	-	120	1.8
4	36	1-19-72	C230	19.0	9.0	38.5	119.0(Est)	115	2.7
5	36	1-26-72	C231	18.0	10.0	51.8	-	119	2.1
6	37	1-26-72	C232	19.0	5.0	35.5	120.0	122	3.0
7	37	2-2-72	C237	18.0	19.8	70.0	-	122	2.1
8	36	2-2-72	C235	19.0	9.8	41.3	114.5	115	3.0
9	37	2-9-72	C236	18.0	5.5	34.8	104.5	122	3.6
10	36	2-9-72	C238	19.0	25.0	59.0	-	122	2.6

TABLE 8
NEW 1400^o F TEST MATRIX
(Ref: TWX 21012)

Test No.	Std. No.	Start Date	Specimen No.	Stress, psi	0.5%	1.0%	3.0%	Hours, Cplt.	Final Strain, %
1	41	1-27-72	C233	3.5	51.5	105	-	122	1.2
2	40	1-27-72	C234	3.5	55.0	118	-	115	1.0
3	41	2-3-72	C247	3.5	98.8	-	-	116	0.7
4	40	2-3-72	C248	3.5	39.4	90	-	122	1.3
5	40	2-10-72	C245	3.5	38.5	75	-	122	1.7
6	41	2-10-72	C246	3.5	80.2	-	-	114	0.8
7	40	2-17-72	C240	3.5	61.8	119	-	123	1.1
8	41	2-17-72	C239	3.5	57.0	116	-	116	1.0
9	40	2-24-72	C241	3.5	40.0	83	-	123	1.6
10	41	2-24-72	C242	3.5	52.8	103	-	115	1.2
11	41	3-2-72	C243	3.5	49.0	97	-	123	1.3
12	40	3-7-72	C244	3.5	48.6	90	-	123	1.5

Figure 1. Time for 1% Total Creep, hrs.

Figure 2. Time for 1% Total Creep, hrs.

Figure 3. Time for 1% Total Creep, hrs.

○	A 23	78.8	3.5%	37
□	A 24	89.1	3.03	37
◇	A 30	73.2	3.8	36

Figure 7. A Lot 1200°F, 22,000 psi.

○ A1	122.05 MTS RUP	33.1%	36
□ A2	82.35 RUP	35.8%	37
◇ A32	25	3.9%	36

Figure 8. A Lot 1200°F, 24,000 psi.

○	B85	387.1	HOURS	37
□	B96	431.6	3.55%	37
◇	B112	140.4	0.75	36

5.0
4.0
3.0
2.0
1.0

%
STRAIN

TIME HOURS

Figure 9. B Lot 1200° F, 17,000 psi.

Figure 29. B Lot 1400°F, 13,000 psi.

Figure 42. A Lot 1600°F, 4500 psi.

ON HS 125B8100
REV 125B8100

REVISIONS		SIZE	125B8100	REV
SYM	DESCRIPTION	DATE	APPROVAL	
A	WTC WAS 125 ± .002	12-6-62	JHR	
B	WTC PWT	12-11-62	JHR	
	B1 WAS 3.00 ± .04			
	B2 WAS .38 ± .01			
	B3 WAS 2.25 ± .04			
C	WTC	12-17-62	JHR	
	C1 WAS .250 ± .0005			
D	JHR	12-26-62	JHR	
	D1 1.000 ± .005 WAS 1.000 ± .003			
E	EMB	5-9-63	JRM	
	E1 .250 ± .001 DIA WAS .2510 ± .0010 DIA			
F	WTC	1-2-64	JHR	
	F1 ADDED NOTE #8 & 9			
H	WTC	3-31-64	JHR	
	H1 ADDED PT #2

SECTION A-A

9. ZYGLO & MICROSCOPICALLY INSPECT AT 30X FOR CRACKS, LAMINATIONS, AND FLAKING.
8. NO LAMINATIONS OR SEPARATIONS TO BE VISIBLE ON MACHINED EDGES OF GAUGE SECTION. NO FLAKING OF [F1] EDGES AT MACHINED SURFACE TO BE VISIBLE (SEE NOTE #9)
7. TO FIT FIXTURE FOR GRINDING "GAUGE SECTION"
6. DIM. "B" AND MATERIAL TO BE SPECIFIED BY ENGR.
5. "GAUGE SECTION" TO BE FREE OF ALL NICKS AND SCRATCHES ON SIDES & EDGES
4. DEBURR & LONGITUDINALLY POLISH EDGES & SIDES OF "GAUGE SECTION" WITH #400 EMERY CLOTH SO FINISH IS "V" OR BETTER
3. RADII MUST BLEND WITH EDGES OF "GAUGE SECTION" WITH NO UNDERCUT
2. WIDTH OF "GAUGE SECTION" MUST BE UNIFORM WITHIN .0005 OVER FULL 1.00 LENGTH.
1. .250 DIA HOLES MUST BE WITHIN .0005 OF CENTER LINE OF "GAUGE SECTION."

NOTES

PART NO	"X" DIM	"Y" DIM
1	.75 ± .04	.38 ± .02
2	.750 ± .005	.375 ± .0025

UNLESS OTHERWISE SPECIFIED DIMENSIONS ARE IN INCHES	
FRACTIONS	DECIMALS
±	±
ALL SURFACES	✓
MATERIAL	GOVT. OR COML.
G-E	AS NOTED
DRAWN	DATE
10-31-62	
APPD	ISSUED
11-1-62	
APPROVED	DATE
11-1-62	
ENGR	MFG
JRM	12-20-62
MATL	

TEST SPECIMEN,
HIGH TEMPERATURE
CREEP, STRESS
RUPTURE, & TENSILE

GENERAL ELECTRIC	
NMEPO	
DIV OR DEPT	
EVENDALE PLANT	
LOCATION	
SIZE	125B8100H
CONT ON SHEET	SH NO.

PRINTS TO

March 29, 1972

Mr. D. F. Johns, Jr., Buyer
Aerojet Nuclear Systems Company
Aerojet General Corporation
Building 2019-A1
P. O. Box 13070
Sacramento, California 95813

Dear Sir:

Enclosed are two copies of the Final Report, GESP 723, "Creep of 347 Stainless Steel in Hydrogen," March 15, 1972. All testing that was requested by Aerojet Nuclear Systems Company has been completed; therefore, this final report and the return of specimens and unused specimen material sheets fulfills all the requirements of ANSC Purchase Order Number 900104 and supplementary TWX's, the latest of which (TWX No. 21012 dated 1-21-72) identified the last twelve tests to be run on the program and requested that a final report be submitted.

All tested and untested specimens fabricated by GE-NSP and the unused specimen material sheets furnished by ANSC are being returned prepaid to your attention under separate cover.

GE-NSP was pleased to be able to perform this service for the Aerojet Nuclear Systems Company. If any questions arise with regard to this program, please contact E. S. Collins, Manager NSR Marketing.

Original Signed By

S. J. Saksa for
A. A. Gayuski
Manager - Contracts
Nuclear Systems Programs

cak

cc: T. A. Redfield - ANSC

Enclosures (2)

THIS COPY FOR