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LIQUID ROCKET PLANT

FINAL TEST REPORT NO. 1.9.5-1E

VOLUME 4

MECHANICAL IRRADIATION TEST

8/L001

STATIC FLANGE SEAL ASSEMBLY

16 March 1964

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FINAL TEST REPORT NO. 1.9.5-1E

VOLUME 4

MECHANICAL IRRADIATION TEST

No. 8/1001

STATIC FLANGE SEAL ASSEMBLY

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ABSTRACT

Mechanical Irradiation Test 8/1001 was designed to determine the effects of radiation on seals and flanges at LH₂ temperatures. The test was conducted in a test reactor at General Dynamics Aerospace Systems, Fort Worth, Texas, on 17 July 1963.

Three combinations of stainless steel and aluminum flanges with aluminum or stainless steel gaskets were exposed to between 3.7×10^{13} and 9.0×10^{12} n/cm² of fast neutrons ($E > 2.9$ Mev) and a gamma radiation of from 1.3×10^7 to 8.1×10^7 ergs/gm(c). Temperature and pressure of the H₂ was monitored during the test, and leak checks and visual inspections were conducted during pre- and post-irradiation tests. No apparent damage to seals or flanges resulted from the irradiation test. There was an apparent change of bolt torque values on joints between pre- and post-irradiation tests accompanied by an increase in leak rate for the joints affected. This anomaly is not attributed to radiation effects.

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I. INTRODUCTION

The radiation effects test program is designed to obtain preliminary information regarding the effects of a combined radiation and cryogenic environment on NERVA engine non-nuclear components. The first experiment on flanges and seals, as reported herein, was to evaluate the performance and integrity of various combinations of stainless steel and aluminum flanges and seals in a radiation and cryogenic environment, representative of the NERVA engine operation.

The NERVA engine is a rocket engine using hydrogen as the propulsion fluid and a controlled nuclear reaction as a heat source. The use of many flange and seal applications in the engine dictates the need for developing reliable radiation resistant hardware. It is felt that the flange and seal problems will not be great, but in view of the scarcity of radiation effects information in a combined cryogenic and radiation environment, a program to provide such information is necessary.

II. EXPERIMENT IDENTIFICATION

A. TEST PLAN REFERENCE

8/1001 Static Flange Seal Assembly

B. SPONSOR

NERVA Rocket Operations
Liquid Rocket Plant (LRP)
Aerojet-General Corporation
Sacramento, California

II, Experiment Identification (cont.)

C. TEST FACILITIES

1. Pre- and Post-Irradiation Tests

NERVA Rocket Operations
Liquid Rocket Plant (LRP)
Aerojet-General Corporation
Sacramento, California

2. Irradiation Test

Aerospace Systems Test Reactor
Nuclear Aerospace Research Facility
General Dynamics Corporation (GD/FW)
Fort Worth, Texas

D. TEST DATES

1. Pre-irradiation test, 13 March 1963
2. Irradiation test, 17 July 1963
3. Post-irradiation test, August 1963

III. PURPOSE OF THE EXPERIMENT

This experiment was designed to provide early preliminary information on the performance and integrity of various seal and flange combinations in a combined cryogenic and radiation environment. The first test maintained H₂ in the static flange and seal assembly (SFSA) under 220 psi and a low-flow rate (approximately 0.1 lb/sec). Possible permanent deformation and resulting increase in leakage rate would be determined by comparison between the pre and posttest examination and leak tests.

IV. TEST DESCRIPTION

An assembly of Aeroquip Corporation Conoseal-type flanges made of stainless steel and aluminum was designed to include a 6-in. aluminum-to-aluminum joint with an aluminum Conoseal, a 6-in. aluminum-to-stainless steel joint with an aluminum Conoseal, a 6-in. stainless steel-to-stainless steel joint with a stainless steel Conoseal, a 2-in. aluminum-to-stainless steel joint with an aluminum seal, and a 2-in. aluminum-to-aluminum joint with an aluminum seal. This test assembly, PN 263685 (Figure A-1), was mounted on a test pallet, P/N 255802-19, and subjected to the sequence of tests in Section II,D. The pre-irradiation test was a functional checkout conducted at LRP Test Zone G-7. (See Figure A-2.) Hydrogen was flowed through this assembly and then through an orifice into the tank shut-off valve (TSOV) cryostat (Figure C-1). By design, the flow was to be controlled by the liquid level sensors in the TSOV cryostat; this was only sufficient to replace the boil-off. The GH_2 in the cryostat was ducted to an atmospheric vent.

Instrumentation of the SFSA included a Rosemont 134-CT RTT at the inlet end, a CEC 170209-0100 pressure transducer at the outlet end, and a chromel-alumel thermocouple on the pressure transducer case.

The test pallet was positioned so that the SFSA was to the left of the reactor center line when extended through the pallet. A detailed description of the test pallet and special test equipment provided is included in Volume V of this report. Briefly, the test pallet consisted of an aluminum structural portion designed to support the SFSA in the desired position relative to the reactor radiation field and to contain the necessary valves, regulators, filters, relief systems, and instrumentation. The pallet controlled the fluid and electrical supplies to the test components. Liquid hydrogen pressure at the test pallet was controlled at the LH_2 supply Dewar. The Dewar was provided with pressurization, purge, vent, and water deluge systems (Figure A-3). A gas distribution system supplied gaseous helium and hydrogen to the pallet for containment vessel purging and valve actuation of the containing vessel (Figure A-4).

IV, Test Description (cont.)

Control of this test equipment was accomplished through a master sequencer checker mounted in a control console along with an event recorder, a power panel, an output amplifier, and a signal conditioning unit.

The data acquisition system consisted of an analog magnetic tape system, video tape system, visual meter panels, and four 4-channel Sanborn recorders. Critical parameters were monitored visually on the meter panels. In addition, all critical and "kill" parameters were wired directly to the Sanborn recorders. All test measurements were recorded on analog tapes. The analog magnetic tape system included twenty-four tape channels, each of which could record six separate parameters.

V. TEST PROCEDURES

Report No. 9440-1SA, Test Procedure No. 1.9.5-1D presents the data handling requirements and the detailed irradiation test operating procedures, including the pre and post ones. Briefly, the following sequence of major events was followed at GD/FW. The test pallet and associated control equipment was set up and functionally tested in the laboratory prior to its installation at the reactor site. Once the test equipment was installed at ASTR, electrical checks, system leak checks, functional tests, and a liquid nitrogen flow test were performed to ascertain that all systems were operational. At this point the storage Dewar was loaded with liquid hydrogen, a cooldown sequence was followed and a 10 sec control run was initiated. Normal shut down procedures were then followed and preparations were made for the irradiation test. When the Dewar was refilled, the cooldown sequence was repeated, the reactor was elevated into position, the reactor power was increased to 10 Mw, and the irradiation test was started. The reactor was turned off after 327 sec of operation and a normal shut down procedure followed.

As soon as practicable after the conclusion of the irradiation test the shroud cover was removed and all pressure transducers were recalibrated using the same Heise

V, Test Procedures (cont.)

gage that was used for the original calibrations. All irradiation test parameters were plotted using the posttest calibration data because the conditions existing during the posttest calibration were more nearly like those during the irradiation test. Appendix E presents the calibration curves used in conjunction with the oscillograph charts.

The SFSA was removed from the pallet and shipped to the Liquid Rocket Plant. Proof and bubble chamber leak tests were performed on the SFSA. Flange couplings were checked for residual torque, retorqued as necessary to design values, and again leak tested. The test cell was then disassembled, measured, and inspected for damage. Thicker Conoseals (.040 in. vs .032 in.) were installed and another leak check was performed.

A complete materials analysis of the irradiated SFSA was planned, but had not been completed prior to the cessation of the NERVA static flange and seal development program.

It was also planned to run a test with .032 x .280 in. Conoseals in these flanges, but this was also cut off by the stoppage of the development program.

VI. NUCLEAR MEASUREMENTS

A. NEUTRON

The neutron flux was monitored during the test at 19 locations (Table B-II). Neutron flux measurements were made with the threshold detectors: sulfur for energy >2.9 Mev and aluminum for energy >8.1 Mev; phosphorus pellets (bare and cadmium) were used to measure the thermal flux. (See Table B-I.)

VI, A, Neutron (cont.)

Detectors were mounted on 3-1/2 x 3 in. aluminum holders, which in turn were mounted on or near the components. All foils were counted and the data reduced by an IBM 7090 digital computer program.

B. GAMMA

The gamma dose measurements were made with nitrous oxide (N_2O) dosimeters, chemical dosimeters, and cobalt glass.

1. Nitrous Oxide Dosimeters

The nitrous oxide dosimeters used at GD/FW consist of a quartz shell forming a volume of about 24 cc which is filled with a measured quantity of N_2O gas before the dosimeter is flame-sealed. Upon exposure to gamma radiation, the following reaction is produced in the gas:

The dose is determined by measuring the moles of $N_2 + O_2$ produced per mole of original N_2O , and then relating this quantity to dose on a calibration curve.

Energy dependence of the N_2O system is air-equivalent (within 10%) from 150 kev to 5 Mev. The dosimeters are usable in the dose and temperature ranges of from 10^8 to 10^{12} ergs/gm(C) and -90° to $+120^\circ C$, respectively. The dosimeters have a reproducibility of 7% to 9%.

2. Chemical Dosimeters

The chemical dosimeters are the chlorinated hydrocarbon type developed originally by Taplin-Sigaloff and modified at GD/FW. They consist of 0.8 ml of tetrachloroethylene overlaid with 0.2 ml of water. The dosimeters,

VI, B, Gamma (cont.)

sensitive to gamma energies from 65 kev to 10 Mev, have a usable gamma dose range from 10^5 to 10^8 ergs/gm(C), a temperature range from 5 to 50°C, and a precision of 5 to 6% at the 95% confidence level.

3. Cobalt Glass Dosimeters

These dosimeters are cobalt-activated borosilicate glass plates, 15 by 6 by 1.5 mm, manufactured by Bausch and Lomb Inc. Exposure to ionizing radiation darkens the glass. The change in optical density measured at 390 mμ versus the dose was plotted; the plot was compared with similar plots of calibrated glass plates to obtain the dose. The recommended range of the dosimeters is from 10^6 to 2.6×10^8 ergs/gm(C).

These dosimeters were enclosed in a 1/16 in.-thick thermal neutron shield of the following composition: 33% by weight B_4C (92% enriched B^{10}), 33% Epon 828, and 33% Versamid¹⁴⁰.

VII. TEST RESULTS

As described in Section IV, provisions were made for measurement of various parameters during pre- and post-irradiation tests; the pressure, temperature, and radiation dosages were monitored during the irradiation test.

Comparisons of the pre-irradiation test leak checks, which were performed with a mass spectrometer having a sniffer attachment, and the post-irradiation test leak checks, which were performed with a bubble chamber, are as follows:

VII, Test Results (cont.)

<u>Joint</u>	<u>Test</u>	<u>Test Fluid Pressure (psig)</u>	<u>Test Fluid</u>	<u>Bolt Torque (in.-lb)</u>	<u>Leakage</u>
<u>6 in.</u>					
Alum-Alum	Pre-	630	G He	260	$< 1.27 \times 10^6$ scc/sec
	1st Post-	500	"	240	No bubbles*
	2nd Post-	500	"	260	No bubbles**
	3rd Post-	500	"	260	Thicker Conoseal. $< 10^{-3}$ xxx scc/sec
<u>6 in.</u>					
Al-CRES	Pre-	630	"	260	$< 1.27 \times 10^{-6}$ scc/sec
	1st Post-	500	"	280	Excessive*
	2nd Post-	500	"	260	Excessive**
	3rd Post-	500	"	260	Thicker Conoseal. 4.6×10^{-2} scc/sec***
<u>6 in.</u>					
CRES-CRES	Pre-	630	"	430	$< 1.27 \times 10^{-6}$ scc/sec
	1st Post-	500	"	310	Excessive*
	2nd Post-	500	"	430	Excessive**
	3rd Post-	500	"	430	Thicker Conoseal. $< 10^{-3}$ scc/sec***
<u>2 in.</u>					
Al-CRES	Pre-	630	"	80	$< 1.27 \times 10^{-6}$ scc/sec
	1st Post-	500	"	65	No bubbles*
	2nd Post-	500	"	80	No bubbles**
	3rd Post-	500	"	80	$< 10^{-3}$ scc/sec***

*, **, ***, See next page for footnotes.

VII, Test Results (cont.)

<u>Joint</u>	<u>Test</u>	<u>Test Fluid Pressure (psig)</u>	<u>Test Fluid</u>	<u>Bolt Torque (in.-lb)</u>	<u>Leakage</u>
<u>2 in.</u>					
Al-Al	Pre-	630	G He	60	$< 1.27 \times 10^{-6}$ scc/sec
	1st Post-	500	"	50	No bubbles*
	2nd Post-	500	"	60	No bubbles**
	3rd Post-	500	"	60	$< 10^{-3}$ scc/sec***

NOTES:

*Entire cell was immersed and bubbles were observed only from 6 in. Al-CRES and 6 in. CRES-CRES joints. Total leakage was 60 scc/sec.

**Entire cell was immersed and bubbles were observed only from 6 in. Al-CRES and 6 in. Al-CRES and 6 in. CRES-CRES joints. Total leakage was again 60 scc/sec.

***Leakage from 6 in. Al-CRES joint determined from bubble count. Leakage from all other joints in 3rd post irradiation test totaled less than 10^{-3} scc/sec.

During the irradiation test, the temperature of the H₂ in the SFSA averaged -395°F. (See Figure D-2.) The pressure remained at approximately 230 psig until the LH₂S valve was manually closed at FS₁ + 241 sec, (See Figure D-1.)

Integrated doses received were; (1) from 9.0×10^{-12} to 3.7×10^{-13} n/cm² fast neutrons ($E > 2.9$ Mev), and (2) from 1.3×10^7 to 8.1×10^7 ergs/gm(C) gamma. These values (see Appendix B) are interpreted and adjusted in Reference 5.

No leakage measurement was planned nor accomplished during the irradiation test.

The dimensional check of flange diameters and groove depths indicated that all dimensions were within design tolerances. No measurements of flange flatness, bolt length, nor clamp dimensions were taken.

VIII. DISCUSSION OF TEST RESULTS

The test data tabulation of Section VII indicates a reduction of flange coupling bolt torque values on four of the five joints and an increase on one. There was no detailed procedure for inspection of these torque values before or after each of the several functional or system leak tests which were conducted. It is therefore difficult to assess when or how coupling bolt torque relaxation occurred.

The reduction of leakage during the post-irradiation testing after the .032 in. Conoseals were replaced by .040 in. Conoseals supports the Aeroquip Corporation recommendation to use the .040 x .275 in. Conoseals in flange line sizes of 6 to 10 in. However, the leak rate after the heavier Conoseals were installed was still greater than that prior to the irradiation test series.

Insufficient data was obtained upon which to base any conclusion concerning the cause of the increased leakage. This is partly because of the design of the SFSA, partly to lack of radiation qualified instrumentation, and partly to incomplete detail in test planning.

IX. CONCLUSIONS AND RECOMMENDATIONS

A. It is concluded that:

1. A static flange seal assembly leakage rate increase may have been caused by a combined radiation and cryogenic environment, or by the radiation environment imposed.

2. Further static flange seal testing should be delayed until instrumentation can be properly evaluated in a radiation environment and the accuracy and reliability of such instruments during irradiation are known.

IX, Conclusions and Recommendations (cont.)

3. Test planning did not provide for sufficient information to isolate the causes of the failure of static flanges and seals.

B. It is recommended that:

1. Additional nonradiation and radiation testing of static flange seals be undertaken.

2. Test planning should ensure that data is obtained at appropriate intervals during a complicated test series to permit isolation of effects and causes.

3. Further testing of static flanges and seals be accomplished when instrumentation capabilities in a combined cryogenic and radiation environment are better defined.

4. The flange and seal test cell be redesigned to provide for in-test monitoring of leak rates and critical stresses.

5. Pre and posttest materials properties tests should be conducted.

REFERENCES

1. Test Procedures No. 1.9.5-1, Mechanical Irradiation Test No. 901,
Aerojet-General Corporation Reports 9440-1S and 9440-1SA.
2. Final Test Specifications for ASTR Mechanical Pallet Tests of 15 June 1963,
Aerojet-General Corporation Report 2569.
3. Preliminary Report ASTR-1 Irradiation Test, 17 July 1963, General Dynamics,
Fort Worth.
4. NERVA Components Irradiation Program Volume 2: ASTR Test 1, General Dynamics,
Fort Worth, Report FZK-170-2.
5. Radiation Analysis of Mechanical Irradiation Tests 901 thru 904 (U), Aerojet-
General Corporation, Report No. RN-S-0050, January 1964 (Conf. Restricted Data).
6. Preliminary Report SCR #159, Mechanical Controls Department Report, Systems
and Controls Division, Aerojet-General Corporation.

APPENDIX A

PHOTOGRAPHS

FIGURE LIST

	<u>Figure</u>
Static Flange Seal Assembly	A-1
Test Pallet on Test Stand at G-7	A-2
LH ₂ Supply Dewar with Pressurization, Water Deluge, and Vent Systems	A-3
Gas Distribution System	A-4

Figure A-1

Static Flange Seal Assembly

Test Pallet on Test Stand at G-7

Figure A-2

Figure A-3

LH₂ Supply Dewar with Pressurization, Water Deluge, and Vent Systems

Figure A-4

Gas Distribution System

APPENDIX B

DOSIMETRY

TABLE LIST

	<u>Table</u>
Dosimetry Results	B-1
Dosimetry Locations	B-2

DOSIMETRY

Nineteen dosimetry packets were attached to the various components on the test pallet to measure the integrated dose received by each component. Table 1 contains the dose measured by each of the dosimetry packets. Table 2 contains the location description and number of the dosimetry packets for each of the components.

TABLE B-1

Dosimetry Results				
Packet	Gamma ergs/gm(C)	Neutrons/cm ² E>8.1 Mev	Neutrons/cm ² E>2.9 Mev	Thermal Neutrons/cm ² E<0.48 ev
1.	8.1 (7)*	6.2 (11)	1.8 (13)	2.8 (12)
2.	3.8 (7)	3.5 (11)	1.1 (13)	2.5 (12)
3.	1.3 (7)	1.3 (12)	3.7 (13)	
4.	1.4 (8)	2.3 (12)	8.3 (13)	
5.	2.1 (6)	2.5 (12)	9.2 (13)	
6.	3.8 (8)	2.4 (12)	8.1 (13)	
7.	1.8 (8)	1.1 (12)	3.5 (13)	
8.	1.7 (7)	1.8 (11)	5.2 (12)	3.2 (12)
9.	1.4 (7)	1.8 (11)	5.2 (12)	3.1 (12)
10.	1.7 (7)	1.0 (11)	3.6 (12)	2.7 (12)
11.	8.1 (6)	6.0 (10)	1.7 (12)	2.1 (12)
12.	5.4 (6)	1.3 (10)	6.0 (11)	1.6 (12)
13.	7.4 (7)	7.9 (11)	2.5 (13)	
14.	2.2 (7)	3.2 (11)	1.0 (13)	2.4 (12)
15.	8.1 (7)	7.9 (11)	2.5 (13)	
17.	5.4 (7)	8.0 (11)	2.8 (13)	
18.	7.0 (6)	2.6 (11)	1.3 (12)	2.1 (12)
19.	4.0 (7)	1.7 (11)	9.0 (12)	2.5 (12)
20.	2.9 (7)	2.7 (11)	8.6 (12)	2.8 (12)

*8.1 (7) denoted 8.1×10^7

Table B-1

TABLE B-2

Dosimetry Locations

Static Flange Seal Assembly

Packet No. 1	On horizontal centerline, 6 inches from left end, on front face.
Packet No. 3	On horizontal centerline, 12 inches from left end, on front face.
Packet No. 19	On horizontal centerline, $8\frac{1}{2}$ inches from left end, on back face.

Tank Shut-Off Valve

Packet No. 19	On vertical centerline, front face, directly behind Static Flange Seal Assembly.
Packet No. 20	Directly behind No. 19 on back face of TSOV.

Bearing Tester

Packet No. 4	On front face, vertical and horizontal centerlines.
Packet No. 17	Mounted on rear surface of flange at top.
Packet No. 18	Mounted on rear surface of Bearing Tester Motor

Turbine Pump Control Valve Actuator

Packet No. 13	On front face
Packet No. 14	On rear face

Turbine Pump Control Valve

Packet No. 15	On front face
Packet No. 2	On rear face

Shroud (outside dosimetry 6" up from base)

Front face left to right distance from left side of shroud

$18\frac{1}{2}$ " 25" 34"

2

APPENDIX C

TEST DATA--10 SEC RUN

FIGURE LIST

	<u>Figure</u>
Flow Diagram MIT #901 Pallet	C-1
Pressure of LH ₂ in the Static Flange Seal Assembly	C-2

- NOTES: 1 SYMBOLS PER MIL-STD-12
2 ALL SECONDARY LINES ARE 1/2 INCH DIA
3 TO BE USED IN CONJUNCTION WITH ASSY DWG
255802 & 255830
4 FOR CONTROL SYSTEM SCHEMATIC SEE DWG NO 255801
5 FOR ALL RADIATION EFFECTS PALLET ELE TYPICAL
SCHEMATIC SEE DWG NO 255811
6 FOR AGC ELECTRICAL HARNESS INTERFACE SEE UNK
NO 255815
△ DENOTES NERVA ENGINE COMPONENT TO BE
TESTED (NOT PART OF TEST PALLET).

SYSTEM COMPONENTS					
COMPONENT SYMBOL	DESCRIPTION	UNIT NO	VENDOR NAME CODE IDENT NO	HYDRAULIC RANGE	LOC NO
①	PRESSURE GAGE	TYPE 100 35	MAFACH 3A'08	0-600 PSIG	1
②	HAND LOADER	LV 10	VICTOR 43026	0-600 PSIG	2
③	DOWN LOADED REGULATOR	GD 96		0-7000 PSIG	3
④		GD 96		0-7000 PSIG	4
⑤		GD 96	VICTOR 43026	0-3600 PSIG	5
⑥		GD 96		0-3600 PSIG	6
⑦		GD 96		0-3600 PSIG	7
⑧		GD 96	VICTOR 43026	0-3600 PSIG	8
⑨		GD 96		0-3600 PSIG	9
⑩		GD 96		0-3600 PSIG	10
⑪		GD 96	VICTOR 43026	0-3600 PSIG	11
⑫		GD 96		0-3600 PSIG	12
⑬		GD 96		0-3600 PSIG	13
⑭		GD 96	VICTOR 43026	0-3600 PSIG	14
⑮		GD 96		0-3600 PSIG	15
⑯		GD 96		0-3600 PSIG	16
⑰		GD 96	VICTOR 43026	0-3600 PSIG	17
⑱		GD 96		0-3600 PSIG	18
⑲		GD 96		0-3600 PSIG	19
⑳		GD 96	VICTOR 43026	0-3600 PSIG	20
㉑		GD 96		0-3600 PSIG	21
㉒		GD 96		0-3600 PSIG	22
㉓		GD 96	VICTOR 43026	0-3600 PSIG	23
㉔		GD 96		0-3600 PSIG	24
㉕		GD 96		0-3600 PSIG	25
㉖		GD 96	VICTOR 43026	0-3600 PSIG	26
㉗		GD 96		0-3600 PSIG	27
㉘		GD 96		0-3600 PSIG	28
㉙		GD 96	VICTOR 43026	0-3600 PSIG	29
㉚		GD 96		0-3600 PSIG	30
㉛		GD 96		0-3600 PSIG	31
㉜		GD 96	VICTOR 43026	0-3600 PSIG	32
㉝		GD 96		0-3600 PSIG	33
㉞		GD 96		0-3600 PSIG	34
㉟		GD 96	VICTOR 43026	0-3600 PSIG	35
㊱		GD 96		0-3600 PSIG	36
㊲		GD 96		0-3600 PSIG	37
㊳		GD 96	VICTOR 43026	0-3600 PSIG	38
㊴		GD 96		0-3600 PSIG	39
㊵		GD 96		0-3600 PSIG	40
㊶		GD 96	VICTOR 43026	0-3600 PSIG	41
㊷		GD 96		0-3600 PSIG	42
㊸		GD 96		0-3600 PSIG	43
㊹		GD 96	VICTOR 43026	0-3600 PSIG	44
㊺		GD 96		0-3600 PSIG	45
㊻		GD 96		0-3600 PSIG	46
㊼		GD 96	VICTOR 43026	0-3600 PSIG	47
㊽		GD 96		0-3600 PSIG	48
㊾		GD 96		0-3600 PSIG	49

HYDRAULIC DATA	
SYMBOL	DESCRIPTION
①	TURBINE POWER CONTROL VALVE
②	TANK SHUT OFF VALVE
③	MAJOR FLANGE COUPLING
④	HYDROGEN GAS LINE PRIMARY
⑤	HELIUM LINE PRIMARY
⑥	VENT RETURN LINE
⑦	LIQUID HYDROGEN LINE PRIMARY
⑧	EXPANSION BEND
⑨	HELIUM LINE SECONDARY
⑩	HYDROGEN GAS LINE SECONDARY
⑪	LIQUID HYDROGEN LINE SECONDARY
⑫	FLEX HOSE LINE
⑬	VENT PORT
⑭	VENT
⑮	VENT
⑯	VENT
⑰	VENT
⑱	VENT
⑲	VENT
⑳	VENT
㉑	VENT
㉒	VENT
㉓	VENT
㉔	VENT
㉕	VENT
㉖	VENT
㉗	VENT
㉘	VENT
㉙	VENT
㉚	VENT
㉛	VENT
㉜	VENT
㉝	VENT
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㊾	VENT
㊿	VENT

PARAMETRIC DATA		
SYMBOL	DESCRIPTION	FUNCTION
①	TEMPERATURE LIQUID HYDROGEN INLET TO BEARING TESTER	TLH ₂₁
②	BEARING HOUSING	TBH ₁
③	BEARING HOUSING	TBH ₂
④	ROLLER BEARING RACE	TRB ₁
⑤	SPLIT BEARING RACE	TSB ₁
⑥	SPLIT BEARING RACE	TSB ₂
⑦	MOTOR	TFB ₁
⑧	LIQUID HYDROGEN IN STATIC FLANGE	TSFSA ₁
⑨	LIQUID HYDROGEN IN TANK SHUT OFF VALVE TANK	TSOV ₁
⑩	ACTUATOR GAS TANK SHUT OFF VALVE	TSOV ₂
⑪	HYDROGEN GAS INLET TO TURBINE POWER CONTROL VALVE HOUSING	TGH ₁
⑫	TURBINE POWER CONTROL VALVE HOUSING	TGH ₂
⑬	COMPONENT CONTAINER MULTICASE SIDE	T ₁
⑭	COMPONENT CONTAINER TOP	T ₂
⑮	TEMPERATURE COMPONENT CONTAINER SHADED SIDE	T ₃
⑯	PRESSURE LIQUID HYDROGEN INLET OF BEARING TESTER	PLH ₂₁
⑰	LIQUID HYDROGEN HOUSING OF BEARING TESTER	PLH ₂₂
⑱	LIQUID HYDROGEN OUTLET OF BEARING TESTER	PLH ₂₃
⑲	LIQUID HYDROGEN IN STATIC FLANGE	PSFSA ₁
⑳	LIQUID HYDROGEN IN TANK SHUT OFF VALVE TANK	PTSOV ₁
㉑	TURBINE POWER CONTROL VALVE GAS INLET	Pg ₁ TPCV
㉒	TURBINE POWER CONTROL VALVE GAS OUTLET	Pg ₂ TPCV
㉓	TURBINE POWER CONTROL VALVE ACTUATOR GAS INLET	Pg ₃ TPCVA
㉔	TURBINE POWER CONTROL VALVE ACTUATOR GAS OUTLET	Pg ₄ TPCVA
㉕	VALVE POSITION TSOV	LTSOV
㉖	VALVE POSITION TPCV	LTPCV
㉗	MOTOR SPEED	MTFB

Flow Diagram 1 MIT No. 901

Figure C-1, Sheet 2 of 2

Figure C-2

Preirradiation Run: Pressure of H_2 in the Static
Flange Seal

APPENDIX D

TEST DATA--300 SEC IRRADIATION TEST

FIGURE LIST

	<u>Figure</u>
Pressure of LH_2 in the Static Flange Seal Assembly	D-1
Temperature of LH_2 in the Static Flange Seal Assembly	D-2

Figure D-1

Pressure of H_2 in the Static Flange Seal Assembly

Temperature of H_2 in the Static Flange Seal Assembly

Figure D-2

Figure D-1

Pressure of H_2 in the Static Flange Seal Assembly

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APPENDIX E

CALIBRATION DATA

FIGURE LIST

	<u>Figure</u>
Calibration Curve--Static Flange Seal Assembly Pressure Transducer	E-1
Calibration Curve--Static Flange Seal Assembly Temperature Transducer	E-2

Calibration Curve--Static Flange Seal
Assembly Pressure Transducer

Figure E-1

Figure E-2

Calibration Curve--Static Flange Seal
Assembly Temperature Transducer