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HOT BLEED-PORT NOZZLE-PRESSURE VESSEL
STRUCTURAL TEST

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RN-TM-0412

HOT BLEED-PORT NOZZLE-PRESSURE VESSEL
STRUCTURAL TEST

D. White

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ABSTRACT

The Hot Bleed Port Nozzle-Pressure Vessel Structural Test (Test 1343N) was successfully conducted in the Structural Test Laboratory, Solid Rocket Operations, Aerojet-General Corporation, Sacramento, California. The test item utilized an aluminum alloy development pressure vessel, S/N 0000003, and AGC Steel Nozzle S/N 008, which incorporates a hot bleed port. The test objectives were to (1) evaluate the Hot Bleed Port Nozzle-Pressure Vessel compatibility at an ambient pressure vessel proof pressure of 740 psig, and a nozzle chamber pressure of 560 psig; (2) measure deflections and rotations of the nozzle hot bleed port; (3) evaluate the Hot Bleed Port Nozzle-Pressure Vessel Assembly, and; (4) record strains at critical areas.

The measured deflections, rotations, and strains were all within the experimental limits of the theoretical predictions. The pressure vessel ruptured at 1380 psig (versus a theoretical rupture pressure of 1370 psig) thus demonstrating a safety margin of .87, as related to the ambient proof pressure of 740 psig. The apparent bi-axial gain was 14.2% for this aluminum alloy pressure vessel. For this specific test, the stress concentration factor was 1.23 for the two 0.5-in. instrumentation passthrough holes with a center-to-center spacing of 2 in. This hole location proved to be the point of failure.

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I. INTRODUCTION

This report describes the pressure tests conducted using a Hot Bleed Port Nozzle/Pressure Vessel Assembly and includes the experimental results, a comparison of these results with the theoretical analysis, and the conclusions and recommendations derived from the test results. The testing was conducted at the Structural Test Laboratory, Solid Rocket Operations, Aerojet-General Corporation, Sacramento, California beginning 25 October 1965 and terminating 3 December 1965.

The primary purpose of the testing was to demonstrate the compatibility of an AGC stainless steel hot bleed port type nozzle with an NRX 6061-T6 aluminum pressure vessel and to qualify the Hot Bleed Port Nozzle for use on the NRX/EST test hardware.

Instrumentation and testing were performed in accordance with AGC Report 7456:R2577, Test Plan for Hot Bleed Port Nozzle/Pressure Vessel Hydrostatic Proof and Failure Test, dated June 1965. The testing was performed at ambient temperature using a two-zone pressure system simulating reactor core pressure drop. The pressure vessel (Zone 1) was subjected to a proof pressure of 740 psig and the nozzle chamber (Zone 2) to a pressure of 560 psig. During the burst test, the pressures in the two zones were maintained at a constant ratio of 76 psig in Zone 2 to each 100 psig in Zone 1 until failure occurred.

Specific objectives of the test were to evaluate the hot bleed port nozzle/pressure vessel compatibility and to determine:

- a. Strains about the nozzle hot bleed port.
- b. Strains in the nozzle shell.
- c. Strains in the pressure vessel closure.
- d. Strains in the pressure vessel cylinder.

e. The deflections and rotations of the cylinder/nozzle and cylinder/closure joints.

f. The mode of failure.

II. DESCRIPTION OF TEST

A. TEST UNIT

The test unit consisted of an NRX-A pressure vessel cylinder (S/N 003), a forward closure (S/N 007), and a steel jacket nozzle (S/N 008).

AGC drawings 703888, 703887 and 707270 describe the pressure vessel cylinder, the forward closure, and the nozzle, respectively. The pressure vessel and forward closure are made of 6061-T6 aluminum alloy and the nozzle is made of 347 stainless steel. The pressure vessel cylinder used for this test had been subjected to twelve 645-psig pressurization cycles during Test 909N. The nozzle was fabricated to AGC drawing 285950 and used in a chemical firing. The tubes were removed and the nozzle jacket subjected to six pressurization cycles to 645 psig during Test 1070N. The nozzle jacket was then reworked to AGC Drawing 707270 to include a hot bleed port boss.

The cylinder and forward closure were joined together with 120 high-strength A-286 steel bolts (AGC drawing 286664) with SPS W39969-WC22-10 washers. This joint was sealed with a metallic seal, P/N 286766. The nozzle/cylinder joint consisted of 96 A-286 bolts (AGC drawing 265233) with Harrison "K" seals, P/N 121268. The seal at this joint was also provided by a metallic seal, P/N 286767.

B. TEST ASSEMBLY

The pressure vessel cylinder, forward closure and steel nozzle were assembled, with associated tooling, as shown in Figure 1 and installed in

Figure 1 - Test Setup Assembly

Test Cell 1 as shown in Figure 2. An internal thrust reaction fixture (T-417188) was installed in the test assembly to divide the unit into two pressure zones to simulate the distribution of actual operational loads for a forward-supported reactor. One pressure zone was in the pressure vessel (Zone 1) and the other in the nozzle chamber (Zone 2). The nozzle chamber was sealed at the exit by a steel plug welded into the nozzle throat as shown in Figure 1.

A detailed list of component test parts, test unit identification, and tooling parts is presented in Table 1.

The bolts for the nozzle and forward closure were torqued in diametrically opposite pairs starting at 0° and 180° locations. The next two pairs of bolts torqued were located adjacent and clockwise to the first pair. All bolts were torqued to a specific increment level before proceeding to the next torque level. Torque was applied in increments of 50, 100, 150, and 200 ft-lb to both bolt sets. Neolube was used to lubricate the threads and under the heads of all bolts.

C. INSTRUMENTATION

The type and locations of all strain gages installed are presented in Figure 3. Post-yield strain gages were installed in areas where the failure strains were expected to be in excess of 15,000 microin./in. Strain gages were located on the pressure vessel cylinder and nozzle at $153^\circ 30'$ and $333^\circ 30'$ meridians and on the forward closure at $160^\circ 30'$ and $340^\circ 30'$ meridians. The plane of the strain gage locations was shifted 7° from the pressure vessel cylinder to the forward closure as indicated in Figure 3. This shift was made so the plane of the strain gages would lie between a control port and an instrumentation port on the forward closure. The instrumentation planes of $153^\circ 30'$ and $330^\circ 30'$ were based on the location of the hot bleed port boss ($153^\circ 30'$ meridian). Strain gages were also installed in

Figure 2 - Test Setup in Test Cell

TABLE I

COMPONENT TEST PARTS

	<u>Description</u>	<u>No. Req'd</u>	<u>Part Number</u>
1.	Pressure Vessel Cylinder	(1)	703888
2.	Forward Closure	(1)	703887
3.	AGC Nozzle	(1)	707270
4.	Nozzle - Cylinder Bolts	(96)	265233
5.	K-Seal (Harrison)	(96)	121268
6.	Nozzle - Cylinder Seal	(1)	287767
7.	Forward Closure - Cylinder Bolts	(120)	286664
8.	Washers	(120)	W39969-W22-10
9.	Forward Closure - Cylinder Seal	(1)	286766

TOOLING PARTS

1.	Chamber Test Stand	(1)	T-417210
2.	Thrust Reaction Structure	(1)	279555
3.	Lower Thrust Structure Simulator	(1)	T-417199
4.	Chamber to Test Stand Clamp	(1)	T-417201
5.	Internal Thrust Reaction Fixture	(1)	T-417188
6.	Control Rod Port Plugs	(10)	T-417202-2
7.	Control Rod Port Fittings	(2)	T-417202-1
8.	"O" Ring	(12)	AN6290-32
9.	Instrumentation Port Plug	(10)	T-417191-9
10.	Instrumentation Port Fitting	(2)	T-417191-1
11.	"O" Ring	(10)	T-417191-2
12.	"O" Ring (Parker)	(2)	2-150
13.	Marman Clamp	(12)	30773-H-250

GAGE NO.	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42	43	44	45	46	47	48
TYPE	A	A	A	B	B	A	A	A	A	A	A	A	A	A	B	B	B	B	A	A	B	B	B	A	A	A	B	B	B	A	A	A	A	A	A	B	B	B	A	A	A	A	A	A	A			
THICKNESS	675	675	675	1015	1015	1015	1015	1015	1015	1015	1015	1015	1015	1015	1015	1015	1015	1015	1015	1015	1015	1015	1015	1015	1015	1015	1015	1015	1015	1015	1015	1015	1015	1015	1015	1015	1015	1015	1015	1015	1015	1015	1015	1015	1015	1015	1015	

A 0.1 IN. TYPICAL GAGE TYPE PA 1 7
B 0.1 IN. TYPICAL GAGE TYPE PA 1 12

49	50	51	52	53	54	55	56	57
B	B	B	B	A	A	A	A	A
352	354	356	358	360	362	364	366	368

NOTES:
1. GAGES #1 THRU #6 ARE AT 11 CATI 120° JO
2. GAGES #34 THRU #39 ARE AT 11 CATI 120° JO
3. GAGES #7 THRU #12 ARE AT 11 CATI 120° JO
4. GAGES #40 THRU #45 ARE AT 11 CATI 120° JO
5. THICKNESS IS IN INCHES

Figure 3 - Strain Gage Locations

a radial pattern around the hot bleed port boss as shown in Figure 3. Gage locations adjacent to the hot bleed port boss on the nozzle were selected at random because the removal of the coolant tubes from the inside of the nozzle left a rough inner surface. Gages were located in areas where the nozzle was smooth enough for the required back to back installation.

The nozzle and forward closure joints were instrumented to measure flange separation, rotation, and radial displacement. The locations of the deflection transducers for the pressure vessel cylinder forward closure joint are shown in Figure 4 and Figure 5 shows the transducer locations for the pressure vessel cylinder nozzle joint. The hot bleed port boss was instrumented to measure rotation and radial displacement as shown in Figure 6.

The locations of breakwires and accelerometers installed to determine the point of origin of rupture on the pressure vessel cylinder are shown in Figures 7 and 8, respectively.

Three nozzle bolts and three closure bolts were instrumented to determine the pressure at which the bolt operational load exceeds the bolt pre-torque load to further study the mechanics of the two joints, with specific attention to the effect of operational loads on the bolt. Four uniaxial strain gages were installed on each bolt, as shown in Figure 9.

A total of 297 channels of instrumentation were utilized as follows:

<u>MEASUREMENT</u>	<u>TYPE TRANSDUCER</u>	<u>LOCATION</u>	<u>NO. OF CHANNELS</u>
Strain	Biaxial Strain Gage	Forward Closure	48
Strain	Biaxial Strain Gage	Cylinder	72
Strain	Biaxial Strain Gage	Nozzle	100
Strain	Circumferential Strain Gage	Cylinder	1
Strain	Uniaxial Strain Gage	Nozzle and Closure Bolts	24

Figure 4 - Cylinder-Closure Joint Deflection Instrumentation Locations

GAGE LOCATION & NO's	A	B	C	D	E
153°30' - 7,8,9,10	8.00	0.50	0.56	-	-
143°30' - 11, 12	-	-	-	1.04	0.56
333°30' - 19, 20, 21,22	8.00	0.50	0.56	-	-
323°30' - 23, 24	-	-	-	1.04	0.56

Figure 5 - Cylinder-Nozzle Joint Deflection Instrumentation Locations

Figure 6 - Hot Bleed Port Boss Deflection Locations

Figure 7 - Breakwire and Circumferential Strain Gage Locations

Figure 8 - SWAT Accelerometer Locations

NOTE:

1. INSTRUMENTED BOLT NO's 1, 2, AND 3 WERE INSTALLED ON THE FORWARD CLOSURE AT 0°, 120° AND 240° RESPECTIVELY.
2. INSTRUMENTED BOLT NO's 4, 5, AND 6 WERE INSTALLED ON THE NOZZLE CLOSURE AT 0°, 120° AND 240° RESPECTIVELY.

PART NUMBER	A DIM	B DIM	USED ON
26533-9	2.56	.63	NOZZLE
286664	2.80	.95	FWD CLOSURE

Figure 9 - Closure Bolt Instrumentation

<u>MEASUREMENT</u>	<u>TYPE TRANSDUCER</u>	<u>LOCATION</u>	<u>NO. OF CHANNELS</u>
Deflection	Strain Gaged Cantilever Beam	Closure Joint	12
Deflection	Strain Gaged Cantilever Beam	Nozzle Joint	12
Deflection	Strain Gaged Cantilever Beam	Hot Bleed Port	12
Rupture Origin	Breakwires	Cylinder	6
Rupture Origin	Accelerometers	Cylinder	6
Pressure	Strain-Gaged Diaphragm	Pressure Vessel	2
Pressure	Strain-Gaged Diaphragm	Nozzle	2

Data acquisition was accomplished utilizing CEC Type 5-123 recording oscillographs, an SR-4 strain indicator, and a Honeywell LAR 7400 tape recorder.

D. TEST PROCEDURES

Thickness measurements were made at the locations shown in Figure 3, Baldwin Hamilton FABX-25-12 and PAR-7 strain gages were bonded to the test structure with Eastman 910 and SR-4 post yield cement respectively. After the wiring was soldered to the gages, Epoxylite was applied to waterproof each gage. In addition to the Epoxylite, all inside gages were coated with a combination of beeswax and bowl wax.

The internal thrust reaction fixture (T-417188) was assembled and checked for proper mating of the T-417188-10 piston with the nozzle core support flange.

The test stand (T-417210) was placed in the test cell and the forward closure was attached to the test stand with the T-417201 clamp. The plugs for the instrumentation and control ports were then assembled in the forward closure. The internal thrust reaction fixture was installed in the test assembly with the reaction plate (T-417188-1) resting on the forward closure. The cylinder-forward closure seal (P/N 286766) was installed in the cylinder groove.

The pressure vessel cylinder was then placed over the internal thrust reaction fixture, while the inside cylinder strain gage lead wires were simultaneously threaded through the forward closure port plugs. The wires were then potted in the port plugs with Devcon A. The forward closure bolts and washers were installed and torqued as described in Section II B of this report. The insert threads in the cylinder were washed with trichloroethylene before bolt installation. The nozzle-cylinder seal (P/N 286767) was installed and the nozzle was placed on the pressure vessel cylinder. The lead wires from strain gages located on the outside of the nozzle core support flange were threaded through the forward closure port plug and potted with Devcon A. All strain gage lead wires from gages located inside pressure Zone 2 were brought out through ports in the nozzle throat plug and potted with Devcon A. The nozzle bolts were installed and torqued as described in Section II B of this report. The cleaning and lubrication of the nozzle bolts was identical to the procedure used for the forward closure bolts.

When the cylinder was pressurized to 90 psig, leakage between zones occurred through the nozzle core support flange coolant tube grooves. The nozzle was removed and reworked. After rework, the nozzle was reinstalled on the cylinder with a new seal (P/N 286767) and the nozzle bolts were again installed and torqued as described above. No leakage was observed between the two zones under the 90 psig check pressure. The Nozzle Hot Bleed Port Insert was installed and capped as shown in Figures 1 and 6.

All hydraulic plumbing was assembled to the test unit, including the Marginator Load Maintainer and the pressure supply system. Air was vented from the two pressure zones while the system was being filled with oil.

All deflection transducers were calibrated prior to installation. After the transducers were installed, all instrumentation was connected to the CEC Type 5-123 recording oscillograph (except for the several channels of strain gages which were connected to an SR-4 strain indicator to allow visual monitoring during the test).

The instrumented bolts were installed at 0°, 120°, and 240° in both the forward and aft flanges and the strain gage traces were "zeroed" after the torquing procedure.

The test was conducted as follows:

Phase I - Proof Pressure Tests (Runs 1, 2, and 3)

All instrumentation on the oscillograph was zeroed and balanced and the graph paper feed rate set at 0.1 in./sec. Both zones were pressurized simultaneously to 20% proof pressure to exercise the strain gages and check out the setup. After the exercise cycle, the test assembly was pressurized to 100% proof pressure (740 psig in Zone 1 and 560 psig in Zone 2) stopping at 20% increments to record data. Except for the first increment, the two pressure zones were allowed to stabilize at each 20% increment, and the instrumentation data was recorded. (The 20% of proof pressure measurements would be invalid because stabilization of nozzle and pressure vessel pressures did not occur until the 40% point was reached). The system was allowed to stabilize and data was recorded at 60% and 20% increments, during depressurization, to check repeatability of data and this phase of the test was performed three times.

Phase II - First Burst Test (Run 4)

All instrumentation was connected to oscillographs, and those strain gages located in areas where large strains were predicted were reranged. The hydraulic pressurization system was modified to maintain the pressurization rate after the chamber started yielding. The pressurization rate in both pressure zones was controlled by a hand valve and monitored by a pressure transducer connected to an X-Y plotter. The pressure vessel cylinder was pressurized at 200 psig/min until failure occurred. At 1400 psig one of the AN815-4 fittings installed in the pressure vessel cylinder to seal the AND 10050-4 instrumentation bosses was ejected. The instrumentation boss that

failed was located at the 112° 30' meridian and 11.00 inches aft of the pressure vessel cylinder/forward closure joint. The instrumentation boss was enlarged and apparently the fitting sheared the threads in the cylinder wall, allowing ejection when the thread interlock was sufficiently reduced. The pressure was dropped to zero and both zones drained. Posttest inspection revealed that the AN-815-4 fittings installed in the eighteen instrumentation ports in the cylinder had a thread engagement of only 0.25 in.

Phase II - Second Burst Pressure Test (Run 5)

All eighteen AN 815-4 fittings were removed from the cylinder and sixteen were replaced with 7/16-in. dia. by .75-in. long bolts with an "O" ring under the head of each to maintain sealing. Both the forward instrumentation port that failed and the one aft of it, located at the 112° 30' meridian and 13.00 in. aft of the flange, were drilled and tapped for 1/2-30 UNF thread and plugged with two 1/2-in. dia by .75-in. long bolts with an "O" ring under the head. All deflection transducers were removed from the test unit and this second burst test was conducted in the same manner as Phase II - Run 4, above.

III. EXPERIMENTAL RESULTS

The pressure vessel cylinder failed at 1380 psig in Run 5. The origin of failure was at the 112° 30' Meridian at the forward of the two instrumentation ports that were increased to 1/2-in. diameter. This location was determined by visual inspection and substantiated by the accelerometer data only because the breakwire data was inconclusive. At the time of failure the pressures in Zone 1 and Zone 2 were 1380 psig and 1045 psig, respectively.

The accelerometers were placed on the pressure vessel for determination of the change in the speed of sound as a function of stress in an aluminum part, and to verify the point of origin of the rupture. Aerojet is developing this technique to determine the origin of failure and the "kill" parameter for firings prior to vessel failure. The method of rupture origin determination is called Stress-Wave Analysis Technique (SWAT).

The method uses accelerometer outputs recorded on a high-speed magnetic tape recorder to determine the origin of chamber failure through use of seismic techniques. Accelerometer data recordings are time-base-expanded so that one inch of oscillograph trace represents 10^{-4} seconds. High resolution time interval measurements may then be made for the arrival of the chamber failure shock signals at the various accelerometers. This seismic technique determines the origin of failure location within a 3 in. circle.

During Phase II - Run 4, three significant stress waves were recorded by the accelerometers. They occurred at 899, 917, and 1400 psig cylinder pressure. The origin of the stress waves emitted at 899, 917 and 1130 psig are shown in Figure 8. The 1400 psig stress wave originated at the instrumentation port plug that was ejected. Two significant stress waves were recorded during Phase II - Run 5 one at 1130 psig and another at the origin of failure location (at 1380 psig) shown on Figure 8.

The stress wave occurrences at 899 and 917 psig during Run 4, and 1130 psig during Run 5, were attributed to residual stresses or subcritical flaw growth. This conclusion is based on a comparison with stress waves recorded during tests on subcritical flaw growth which were run prior to this burst test using flaw-induced steel specimens. The steel tensile tests are documented in preliminary form only and no formal publication is available at this time. Only number one and two breakwires were severed and because of the nature of the failure did not furnish any significant information. The rupture emanated from the forward instrumentation port, where bulging occurred, (Figure 10) ripping aft through the weld band and then circumferentially. The failure was not sufficiently catastrophic to sever enough breakwires to locate the precise origin of the failure. Breakwire number one failed first and number two failed 0.0022 seconds later.

Photographs of the forward closure and failed chamber are presented as Figures 10 through 16.

The test data obtained from all five runs are presented in Appendix B of this report. The tabulated data presented are identified as Phase I - Runs 1, 2 and 3 - Proof Pressure Test; Phase II - Run 4 - First Burst Pressure Test; and Phase II - Run 5 - Second Burst Pressure Test. All strain data recorded during Phase II - Run 4 were plotted as a function of pressure vessel cylinder pressure and are also presented in Appendix B.

Stress values for the cylinder and closure at proof pressure are given in Table 2. The tabulated stresses are the averages of consistent values obtained for Runs 1, 2, 3 and 4. The stress obtained during the fifth run (rupture test) were not included in the average, because material yielding had been observed during Phase II, Run 4. Examination of the surface around the forward instrumentation boss showed a definite yield pattern. The pattern was elliptical with the major axis oriented on the longitudinal axis of the cylinder.

Figure 10 - Failed Cylinder in Test Cell

Figure 11 - Lower Section of Failed Cylinder

Figure 12 - Failed Cylinder Close Up

Figure 13 - Close Up of Rupture Edge

Figure 14 - Cylinder Failure - View from Inside

Figure 15 - Cylinder Failure - View Looking Aft at Forward Closure Flange

Figure 16 - Damaged Area of Forward Closure

TABLE 2

PRESSURE VESSEL STRESSES (PSI)

STA.	TOTAL STRESS				MEMBRANE STRESS		BENDING STRESS	
	MO	HO	MI	HI	M	H	M	H
1	28,950	25,065	19,623	17,668	24,262	21,366	4,642	3,696
2	25,431	18,842	18,990	11,638	22,211	15,222	3,222	3,579
3	25,145	13,821	17,990	7,008	21,444	10,415	3,702	3,406
4	11,445	- 587	17,306	- 1,618	14,376	- 1,108	- 2,930	515
5	3,284	- 3,327	24,835	5,260	14,059	942	-10,775	-4,307
6	2,735	-12,298	17,315	- 3,890	9,984	- 8,094	- 7,248	-3,025
7	27,516	23,952	- 7,064	13,878	10,528	19,122	17,345	5,033
8	20,646	24,144	- 72	21,141	10,288	22,644	10,360	1,500
9	10,408	23,661	7,890	23,894	9,149	23,776	1,256	- 117
10	10,880	24,322	9,846	24,959	10,384	24,644	496	- 319
11	4,690	19,939	13,091	23,598	8,891	21,770	- 4,200	-1,824
12	11,699	24,250	8,522	25,310	10,118	25,029	1,595	- 280
13	16,036	21,051	5,156	18,982	10,585	20,019	5,440	1,034
14	1,449	1,144	17,326	6,736	9,390	3,939	- 7,941	-2,798
15	6,612	2,825	12,692	4,142	9,651	3,485	- 3,041	- 658

Stations 1 through 6 are the average values for the gages located 180° apart and at the same axial position on the forward closure.

Stations 7 through 15 are the average values for the gages located 180° apart and at the same axial position on the Pressure Vessel Cylinder.

Stress values for the stainless steel nozzle at the 560 psig proof pressure are given in Table 3. These stresses are the average of the stresses obtained during proof cycles 2, 3, and Phase II Run 4. Data from the first proof cycle was not included in the averages because of inconsistencies in the data when compared with subsequent cycles. These aberrations in data were apparently caused by inadequate exercising of the assembly prior to the tests. Data from Run 5 were not used because of the yielding that had occurred during Phase II, Run 4.

Comparisons of theoretical and experimental stresses for the proof pressure conditions, (pressure vessel assembly 740 psig and nozzle chamber 560 psig) are given in the following figures:

Pressure Vessel Cylinder	Figures 17 and 18
Forward Closure	Figures 19 and 20
Nozzle	Figures 21 and 22

The experimental radial stresses around the hot bleed port and the opposite side of the nozzle at 560 psig are shown in Figures 23, 24, and 25. The rotations and hot bleed port radial movement measured for the proof pressure conditions are given in the following figures:

Nozzle and Pressure Vessel Flange	Figure 26
Pressure Vessel Cylinder/Forward Closure Flange	Figure 27
Hot Bleed Port	Figures 28 and 29

The stresses were averaged for the $150^{\circ}30'$ and $333^{\circ}30'$ meridians on the cylinder and closure. The stresses on the nozzle are shown separately to allow comparison of the hot bleed port boss stresses to the theoretical stresses of the opposite side where no discontinuity exists. The nozzle strains at gage 25 are shown on Figure 30.

A comparison of theoretical and experimental stresses in the pressure vessel cylinder and closure is given in Figures 17 through 20. The forward closure to pressure vessel cylinder joint rotation at proof pressure, 740 psig, is shown in Figure 26. Nozzle to pressure vessel rotations are shown for both the $153^{\circ} 30'$ and $333^{\circ} 30'$ meridians in Figure 27.

Rotations and movement of the nozzle hot bleed port boss at proof pressure are given in Figures 28 and 29. A comparison of the theoretical and experimental meridional and hoop stresses for the $330^{\circ} 30'$ meridian and the hot bleed port meridian ($153^{\circ} 30'$) are shown in Figures 13 and 14.

TABLE 3

NOZZLE STRESSES (PSI)								
STA.	MO	TOTAL			MEMBRANE		BENDING	
		HO	MI	HI	M	H	M	H
16	-5,743	-9,687	5,420	-4,773	- 158	-7,230	-5,580	-2,457
17	-6,186	-5,703	6,733	2,367	273	-1,668	-6,460	-4,036
18	2,330	3,997	-1,938	2,670	202	3,333	2,127	662
19	6,730	6,270	-	-	-	-	-	-
20	23,003	18,810	-	-	-	-	-	-
21	23,387	14,035	-8,653	19,327	7,867	16,663	16,517	-2,647
22	29,027	19,903	-4,149	10,530	12,437	15,213	16,587	4,683
23	17,553	16,267	2,077	10,243	9,817	13,257	7,737	3,013
24	14,310	14,677	3,904	7,787	9,123	11,230	5,183	3,446
25	32,710	21,230	-8,503	2,623	12,460	11,927	20,963	9,307
26	21,737	21,417	1,170	2,960	11,925	12,275	10,175	7,840
27	13,783	16,257	8,667	4,787	11,220	10,520	2,555	5,733
28	27,683	23,510	-1,094	11,177	13,297	17,343	14,387	6,167
29	21,277	17,210	6,227	8,317	13,750	12,763	7,527	4,450
30	12,920	12,100	12,610	8,450	12,763	10,227	156	1,827
31	21,163	20,723	4,830	28,080	12,993	24,403	8,163	-3,679
32	5,043	9,013	14,923	24,800	9,647	16,910	-4,654	-7,892
33	2,757	9,187	13,820	20,540	8,290	14,863	-5,531	-5,675
49	-3,888	-7,160	4,507	-6,120	309	-6,640	-4,196	- 520
50	-4,676	-5,305	3,533	-2,236	- 571	-3,772	-4,105	-1,536
51	1,773	1,557	-2,676	328	- 452	942	2,227	614
52	4,547	4,523	-	-	-	-	-	-
53	-	-	-	-	-	-	-	-
54	14,170	13,590	-2,620	8,957	5,773	11,273	8,397	2,313
55	-	-	5,147	17,473	-	-	-	-
56	6,953	12,063	-	-	-	-	-	-
57	11,520	32,020	-	-	-	-	-	-

Figure 17 - Comparison of Theoretical and Experimental Cylinder Meridional Stresses

Figure 18 - Comparison of Theoretical and Experimental Cylinder Hoop Stresses

NOTE: EXPERIMENTAL DATA PLOTTED IS THE AVERAGE OF 153°30' AND 333°30' MERIDIAN LOCATIONS

Figure 19 - Comparison of Theoretical and Experimental Forward Closure Meridional Stresses

NOTE: EXPERIMENTAL DATA PLOTTED IS THE AVERAGE OF 153° AND 333° MERIDIAN LOCATIONS

Figure 20 - Comparison of Theoretical and Experimental Forward Closure Hoop Stresses

Figure 21 - Comparison of Theoretical and Experimental Nozzle Meridional Stresses

Figure 22 - Comparison of Theoretical and Experimental Nozzle Hoop Stresses

——— OUTSIDE SURFACE STRESS
 - - - INSIDE SURFACE STRESS

EXPERIMENTAL VALUES
 ● 153°30' MERIDIAN
 HOT BLEED PORT
 ▲ 333°30' MERIDIAN

Figure 23 - Experimental Radial Stresses About the Nozzle Hot Bleed Port - 6" Radius

——— OUTSIDE SURFACE STRESS
 - - - INSIDE SURFACE STRESS

EXPERIMENTAL VALUES

- 153°30' MERIDIAN
HOT BLEED PORT
- ▲ 333°30' MERIDIAN

Figure 24 - Experimental Radial Stresses About the Nozzle Hot Bleed Port - 7.5" Radius

——— OUTSIDE SURFACE STRESS
 - - - INSIDE SURFACE STRESS

EXPERIMENTAL VALUES

- 153°30' MERIDIAN
HOT BLEED PORT
- ▲ 333°30' MERIDIAN

Figure 25 - Experimental radial stresses About the Nozzle Hot Bleed Port - 9.0" Radius

Figure 26 - Experimental Nozzle Pressure Vessel Flange Rotations

RECORDED FLANGE ROTATIONS
740 PSIG AT 153°30' MERIDIAN

RECORDED FLANGE ROTATIONS
740 PSIG AT 333°30' MERIDIAN

Figure 27 - Experimental Forward Closure Pressure Vessel Cylinder
Flange Rotations

NOTE: NOZZLE CHAMBER
INTERNAL PRESSURE: 560 PSIG

ROTATIONS		
0°	.0003 RAD.	OUTBOARD
90°	.0004 RAD.	INBOARD
180°	.0001 RAD.	OUTBOARD
270°	.0017 RAD.	INBOARD

Figure 28 - Hot Bleed Port Boss Rotations vs Pressure

Figure 29 - Hot Bleed Port Boss Radial Deflections vs Pressure

Figure 30 - Hot Bleed Port Boss Strain vs Pressure at Gage 25

IV. DISCUSSION

A. STRUCTURAL INTEGRITY

The structural integrity of the NRX-A aluminum pressure vessel and hot bleed port nozzle assembly was fully demonstrated when the test assembly successfully withstood three proof pressurization test cycles to 740 psig in the pressure vessel and 560 psig in the nozzle chamber.

Stresses computed from the strains recorded at full proof pressure, 740 psig, on the pressure vessel cylinder and forward closure were well below the yield point for the 6061-T6 aluminum.

The stress computed for the 560-psig proof pressure using the gages at Station 25 near the hot bleed port on the outside of the nozzle indicate that the design minimum yield point of the 347 stainless steel had been exceeded. However, the high stress was the result of local bending and an examination of the strain versus pressure plots of the affected strain gages does not indicate the presence of yielding at proof pressure.

B. EXPERIMENTAL DATA ANALYSIS

1. Nozzle

The highest stress measured on the nozzle was 32,710 psi on the outer surface at strain gage 25, which was oriented 6-in. radially outboard at the 270° position of the hot bleed port. The high stress at this location is attributed to two factors: (1) a normal bending stress caused by discontinuities between the bleed port boss and the nozzle wall membrane; and (2) an abnormal mismatch discontinuity at the boss-membrane weld joint caused by weld distortion. All NERVA nozzles delivered for nuclear testing have integrally-machined bleed port bosses, which eliminate the weld joint mismatch. A comparison of stress distribution around the bleed port boss, and that of the nozzle wall without a boss may be seen in Figures 21 through 25.

Although the computed stress for strain gage 25 exceeds the / design minimum room temperature yield stress for CRES 347 steel (30,000 psi)⁽¹⁾ plots of strain vs. internal pressure indicate that no yielding took place until a pressure in excess of 560 psig in the nozzle chamber had been attained. A plot of the strain versus internal pressure may be seen in Figure 29.

The pairs of deflection gages used to determine hot bleed port boss rotation indicated asymmetrical rotation of the boss with respect to its axial centerline. (Figure 28). The magnitudes of these rotations are very small, ranging from 0.0001 to 0.0017 radians, showing that the boss rotations were insignificant in this test (See Appendix B). In addition, the $\pm 3\%$ of full scale accuracy of the data acquisition system exceeds the values calculated for the differential deflections used to determine the rotations shown in Figure 28. The apparent asymmetrical rotations around the periphery of the boss may have been caused by the stress distribution contributed by weld joint mismatch; however, as stated the rotations are insignificant.

The effect of the discontinuity caused by the hot bleed port boss with insert can be seen in the high meridional and hoop stresses shown on Figures 21 and 22 and Table 3. Damping of these discontinuity stresses at the nozzle flange and their negligible effect on the core support flange is readily discernible by cross-comparison of the two graphs shown on Figures 21 and 22. Comparison of the nozzle flange rotation at the 153°30' meridian to that at the 330°30' meridian demonstrates the minor effect of the hot bleed port boss with insert on the compatibility of the nozzle/pressure vessel joint, Figure 26.

The changes in the characteristic of the nozzle jacket caused by the hot bleed port boss with insert can be seen in Figures 23, 24, and 25. Increased bending and associated higher stresses at the 6 in. radius can be compared to equivalent locations on the opposite side in Figure 23.

Damping of the discontinuity caused by the hot bleed port assembly is almost complete at a 9.0 in. radius, Figure 25. The combined effects of the throat plug and port discontinuities apparently cause the deviation at the 180° (aft) position on Figure 25. Changes in mechanical characteristics of the hot bleed port nozzles are essentially damped out at 9.0 in. from the axial center of the port.

2. Nozzle/Pressure Vessel Cylinder Joint

Compatibility of the hot bleed port nozzle with the pressure vessel assembly was fully demonstrated when the test assembly withstood three proof pressure cycles without detrimental effects on any portion of the assembly. The deflection data showed good repeatability. Based on the repetition of the values, Runs 1, 2 and 3 were averaged to compute the nozzle and pressure vessel flange rotations. At the 153° 30' meridian, hot bleed port location, the aft pressure vessel cylinder flange rotated .0018 radian outboard and the nozzle flange rotated .0056 radian (Figure 28). The differential rotation computed for this location was .0038 radian (see Appendix B). The data for the rotation of the nozzle flange at 330° 30' showed a reverse in the direction of rotation. The strain profiles for test 1070 N-1⁽²⁾ were compared to similar strain data available in this test to establish whether the channels for the data used to determine the nozzle flange rotation had been reversed. This comparison showed no significant change in strain. Based on the comparison it was established that the channel numbers had been reversed. The average rotation of the nozzle flange was then computed to be .0025 radian outboard which agrees in direction to the rotation given in Reference (2), and also in direction and order of magnitude with the rotation calculated at the hot bleed port (153° 30' meridian). The pressure vessel rotation at 333° 30' was the same, as at the hot bleed port location, 0.0018 radian. The resulting differential rotation, opposite the bleed port, was .0007 radian (Figure 28).

The resulting differential rotations indicated a .007-in. gap at $153^{\circ} 30'$ and a .001-in. gap at $333^{\circ} 30'$. Gapping would indicate that the bolt preload had been overcome and the nozzle and pressure vessel flanges were acting independently. However, nozzle flange compression and pressure vessel flange deformation due to bolt preload were calculated to total approximately .008 in. Therefore, separation of the mating surfaces would not occur until the chamber pressure was approximately 990 psig. A graph of nozzle flange rotation versus pressure for the $153^{\circ} 30'$ and $333^{\circ} 30'$ meridians is shown in Figure 26 and indicates, by a change in slope, that mating surface separation and independent flange rotation occurred at approximately 980 psig chamber pressure.

3. Pressure Vessel Cylinder

The highest stress recorded in the cylinder at the 740-psig proof pressure was 27,516 psi in the meridional direction on the outer surface at the gage location nearest the forward closure flange. Membrane stress at the same location was 10,528 psi with the balance of the stress due to the discontinuity moment introduced by the closure flange. The maximum membrane stress was 25,029 psi in the hoop direction 18 in. forward of the nozzle closure joint. Maximum hoop stress was 25,310 psi on the inside surface indicating only an insignificant amount of bending.

It was found that hoop and meridional membrane stresses in the weld area were reduced by from 12 to 13%, correlating excellently with the 14% increase in wall thickness at the weld area. Total stress on the inside meridional surface, however, was 13,091 psi, which is 50% greater than that in the adjacent area, clearly showing the discontinuity stresses caused by the increase in thickness. Such stress increases, while of significant magnitude, are not considered detrimental to the pressure vessel unless they reach the magnitude of the hoop stresses which currently dictate the design margin of safety for this location.

Of significance is the comparison of membrane stresses at the aft end, just forward of the nozzle adapter portion, and at the forward end of the pressure vessel cylinder. The maximum hoop membrane stress of 25,029 psi occurs at the aft end, while the membrane stresses at the forward end are: hoop 19,122 psi and meridional 10,528 psi. This relationship of membrane stresses shows that the hoop membrane at the aft barrel section of the cylinder is critical and therefore the primary design consideration for the pressure vessel should be the maximum hoop stress calculation; i.e., pressure times radius divided by material thickness. Using the test conditions and nominal pressure vessel thickness, the hoop membrane stress was calculated to be 25,300 psi, which agrees with the maximum membrane stress determined from the empirical data.

4. Pressure Vessel Cylinder-Closure Joint

Based on information obtained in previous pressure tests (2) it was established that a closure bolt preload of 26,000 lb would be required to minimize gapping of the closure and pressure vessel flanges at a satisfactory margin of safety above proof pressure, 740 psig. Therefore, it was established that the forward closure bolts would be torqued to 200 ft-lb (3) which would provide an approximate 26,000 lb bolt preload. During the pressure test series, there were indications that flange compression under the bolt was relieved between 550 and 650 psig. Three closure bolts, spaced at 120° intervals, were instrumented with four strain gages each. The data obtained indicated that the bolts were bending and that flange compression under the bolt was relieved. The differential rotation of the cylinder and closure flanges indicates that the compression on the flanges at the bolt circle will be overcome between 450 and 650 psig. The effect of the differential rotation of the flanges can be seen in the bending imposed on the bolts, as shown in the bolt strain versus pressure plot Figures 31, 32 and 33. Similar strain data is available in Reference 2, Page 135.

The effect of differential rotation of the cylinder-closure flanges is to overcome the precompression at the center line of the bolt circle. This is accomplished by the inside of the joint tending to separate while the outside tends to increase in compression. A conservative quantity for the compression caused by bolt preload was calculated to be .0036 in. Assuming this value to be reasonable, the tendency to gap at a point 1.125 in. inside the bolt circle would be equal to this value at a pressure of 565 psig, Appendix B. The 1.125-in. dimension is the distance from the bolt circle centerline to the inside diameter of the pressure vessel cylinder. A pressure of 565 psig is reasonably close to the pressure at which the bolt strain shows a significant change in slope (Figures 31, 32 and 33).

The change in location of the maximum compressive deformation would normally occur over a range of pressures moving from the bolt circle toward the shear lip. The increase in compression near the shear lip caused by the differential rotation produces a prying action causing the flange deformation to shift from the bolt circle toward the shear lip. Figure 20 shows that the rotation of the flanges remains linear as a function of pressure indicating that the effect of bolt preload for the joint has not been overcome while the point of maximum compression is tending to travel toward the shear lip. Reference 4 shows shear lip engagement and radial displacement which occurs in a transition region between 450 and 650 psig, which corresponds to the change in bolt strains shown in Figures 23, 24, and 25. This correlation shows the possibility of attributing the change in slope of the bolt strain gages to the engagement of the shear lip with joint compression at only one point. The fact that the ring rotations are linear indicates that the effect of bolt preload is overcome on the inside of the flange interfaces, but that the preload effect for the total joint has not been overcome.

The average experimental values for rotation were .0099 radian for the pressure vessel forward flange and .0051 radian for the forward

Figure 31 - Closure Bolt, Pressure vs Strain - 0°

Figure 32 - Closure Bolt, Pressure vs Strain - 120°

Figure 33 - Closure Bolt, Pressure vs Strain - 240°

closure at the 740 psig proof pressure. The differential rotation based on these averages was .0048 radian which would give a gap of 0.0102-in. This gap, less the 0.0036-in. flange compression caused by bolt preload, would give an experimental related opening at the inside diameter of 0.0066 in. Gap is calculated as shown in Appendix B.

5. Pressure Vessel Forward Closure

The highest stress recorded on the pressure vessel closure at the 740 psig proof pressure was 28,950 psi on the outside shell surface in the meridional direction at the strain gage position nearest the centerline of the assembly. The corresponding outer surface hoop stress was 25,065 psi. Both of these stresses were almost pure membrane stresses containing little bending. The calculated margin of safety based on the 0.2% offset yield point for the 6061-T6 material was +0.21. The highest bending stress recorded was 17,345 psi in the meridional direction one inch outboard of the lower thrust structure attachment surface and was the result of discontinuities induced by the thrust structure attachment ring. Total stress at this location was 27,516 psi and also the maximum stress recorded outboard of the attachment ring.

C. BURST TEST EVALUATION

The predicted origin of failure of the pressure vessel would be in the middle portion of the cylinder at a pressure of 1460 psig. This pressure was derived using the maximum distortion energy theory of failure (Appendix B). The inclusion of instrumentation ports in the forward portion of the cylinder cause local stresses which analysis show would change the origin of failure to their proximity. The pressure at which failure would occur with 3/8-in. instrumentation ports is 1450 psig, while 1/2-in. ports reduce the predicted pressure value to 1370 psig.

Two attempts were made to rupture the pressure vessel. On the first attempt an AN fitting used to plug an instrument passthrough hole was ejected at 1400 psig causing termination of the pressurization. The ejection occurred at a pressure 50 psi lower than the predicted wall rupture pressure of 1450 psig (Appendix B). Ejection of the fitting was caused by the short (0.25-in.) thread engagement and local yielding of the pressure vessel because of the stress concentration at the passthrough hole. All AN fittings were removed and replaced with 7/16-in. bolts providing full thread engagement. The instrument port from which the fitting was ejected and the one adjacent to it were refitted with 1/2-in. dia 20 x .75-in. long bolts, because of the enlargement of these ports. The pressure vessel assembly was then repressurized until failure occurred at 1380 psig.

Two techniques for experimental determination of the origin of the rupture were used. The breakwires did not provide any significant information because the failure did not propagate rapidly enough to fail more than two of the wires. With only two wires broken, there was insufficient data to use this method of determining the failure origin. The accelerometer (SWAT) method of determining incipient failure indicated that the initial rupture occurred at or between the two enlarged instrument ports. The accuracy of the SWAT technique is a three inch circle; therefore, a specific point of failure origin is indeterminate.

The pictures (Figures 11 through 15) show that the maximum deformation of the cylinder occurred at the instrumentation ports, which correlates with the theoretical and empirical techniques used to analyze the failure point. Figure 16 shows that the shear lip was fully engaged at failure and also, shows the Keenserts that were pulled out of the vessel.

The surface surrounding the instrumentation bosses, near the forward end of the pressure vessel cylinder, exhibited the classic stress concentration pattern caused by holes. The surface of the metal on the inside

and outside of cylinder had the "orange peel" appearance associated with yielding of a ductile material. The stress intensification caused by the instrumentation holes was calculated to be 1.23 (Appendix B).

An analysis of the effects of increasing the instrument passthrough hole diameter is included in Appendix B and indicates that the increase in hole size reduces the expected burst pressure to 1370 psig. The analysis also shows that, excluding the local stress concentration caused by the instrument holes, the pressure vessel could be expected to fail near the mid-point of the cylinder at approximately 1460 psig. Based on the strains recorded at gage 10 and assuming a linear extrapolation of the pressure versus strain plots obtained during the first burst attempt and using the expression:

$$\sigma_h = \frac{E}{1 - \mu^2} (\epsilon_h + \mu \epsilon_m) \quad \text{the hoop stress is found to be:}$$

$$\sigma_h = 10^7 / 0.91 \quad (.004300 + .3 \times .000525) = 49,000 \text{ psi}$$

Although the preceding is an extrapolation of elastic theory into the plastic range it indicates that at 1400 psig the chamber was approaching its ultimate capability. Therefore, there is a high degree of statistical confidence that the assembly demonstrated a margin of safety of not less than + .89 over the maximum expected proof pressure of 740 psig.

The biaxial gain of the material was determined by comparing the actual pressure at failure to the pressure required to cause failure at the empirical value of 47,000 psi for the aluminum 6061-T6 material used to fabricate the cylinder. The theoretical failure pressure of 1472 psig was reduced by the reciprocal of the stress intensification factor, and the biaxial gain was computed to be 14.2% (Appendix B).

V. CONCLUSIONS AND RECOMMENDATIONS

1. Compatibility of the NRX-A aluminum pressure vessel and stainless steel nozzle with hot bleed port was fully demonstrated when the test assembly withstood three pressure cycles to maximum expected operating pressure and further demonstrated adequate margins of safety by attaining a pressure of 1400 psig before the AN fitting was ejected.

2. Experimental and theoretical stress on the pressure vessel show excellent agreement.

3. Stresses in the nozzle were generally low except for one location near the hot bleed port where the data indicated that the design minimum yield strength of the material had been reached at the 560 psig proof pressure; however, plots of stress versus pressure indicated that elastic behavior existed at that pressure. Since the data obtained during the second and third proof cycles and the first burst cycle were in close agreement, the data was assumed correct and the high stresses attributed to discontinuities adjacent to the hot bleed port boss.

4. The effect of bolt preload at the forward joint is to cause initial maximum compression on the flanges at the centerline of the bolt circle. The combined effects, which are flange rotation and radial displacement, caused by pressure, lead to a transition in the location of maximum compression from the bolt circle to the shear lip. The transition occurs between 450 and 650 psig. Based on the current seal location (Reference 4), a net compression of .002-in. would exist at the outboard seal gland at the 750 psig proof pressure condition.

5. In tests on future designs, the interrelated effects of the bolt torque, preload, etc., at the pressure cylinder/closure flange should be established.

6. To provide a more complete understanding of the interaction between the hot bleed port boss and insert, the following additional data should be obtained and recorded for the deflection and rotation on the flange of the hot bleed port insert, and on torque values for the nuts used in the assembly. The measurement technique should be changed to minimize the system error imposed on the deflection and rotation instruments located on the hot bleed port boss.

7. All future nozzles should be fabricated with an integrally-forged and machined hot bleed port boss to eliminate the possibility of weld joint mismatch.

BLANK

REFERENCES

1. AGC Report No. RN-S-0158, Pressure Vessel-Nozzle Seal Assembly Confirmation Test 1070N Evaluation Report, June 1965
2. AGC Report No. RN-TM-0359, NRX-A5 Aluminum Pressure Vessel S/N 00000010 Structural Evaluation of Redesigned Cylinder/Closure Joint, July 1966
3. AGC Report No. RN-S-0161, NRX-A Bolt Test and Lubricant Evaluation Report, December 1964
4. AGC Report No. 2275 Revised, Materials Properties Data Book, January 1967

APPENDIX A
TEST DATA

FOREWORD

All test data from Test 1343N are presented in this Appendix. The data include instrumentation locations, photographs of the instrumentation, strains and deflections of the test unit.

The test was conducted in three phases and the test data are identified as follows:

Phase I - Runs 1, 2, and 3 Proof pressure test with three runs.

Phase II - Run 4 First burst pressure test.

Phase II - Run 5 Second burst pressure test.

The strain data for Phase II were plotted as a function of Zone 1 pressure and are presented as Figures A-3 through A-15.

Figure A-1 is included to assist the reader in converting from the percent of proof pressure values given for Phase I, runs 1, 2, and 3 to the pressures in Zone 1 (Pressure Vessel) and Zone 2 (Nozzle). Figure A-2 is provided to allow the reader the basis of converting the Zone 1 (Pressure Vessel) pressures to Zone 2 (Nozzle) pressures. All pressures are given in pounds per square inch gage (psig).

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Figure A-1 - Pressure Versus Percent Proof Pressure -
Phase I, Runs 1, 2 and 3

A-2

Figure A-2 - Zone 1 Pressure Versus Zone 2 Pressure -
Phases II, Runs 4 and 5

Gage No	Symbol	Thickness
7	○	.770
8	●	.770
9	□	.775

NOTE: For exact locations of strain gages refer to Figure 3.

Figure A-3

Forward Cylinder Pressure-Strain Curves, 153° 30' Location

Gage No	Symbol	Thickness
10	○	.680
11	●	.780
12	□	.680
13	■	.690
14	△	.780
15	▲	.885

NOTES:
For exact locations of strain gages
refer to Figure 3.

Figure A-4
Aft Cylinder Pressure-Strain Curves, 153° 30' Location
A-4

Gage No	Symbol	Thickness
40	○	.770
41	●	.770
42	□	.775

NOTE:
For exact locations of strain gages
refer to Figure 3.

Figure A-5
Forward Cylinder Pressure-Strain Curves, 333° 30' Location

Gage No	Symbol	Thickness
43	○	.680
44	●	.780
45	▲	.680
46	△	.680
47	□	.780
48	■	.885

NOTE:
For exact locations of strain gages
refer to Figure 3.

Figure A-6
Aft Cylinder Pressure-Strain Curves, 333° 30' Location
A-6

Gage No	Symbol	Thickness
1	○	.675
2	●	.676
3	◻	.676
4	■	1.015
5	△	1.015
6	▲	1.010

NOTE:
For exact locations of strain gages
refer to Figure 3.

Figure A-7

Forward Closure Pressure-Strain Curves, 160° 30' Location

Gage No	Symbol	Thickness
34	○	.675
35	●	.676
36	□	1.020
37	■	1.010
38	△	1.004
39	▲	1.004

NOTE:
For exact locations of strain gages
refer to Figure 3.

Figure A-8
Forward Closure Pressure-Strain Curves, 340° 30' Location
A-8

Gage No	Symbol	Thickness
16	○	.382
17	□	.350
18	△	.520

NOTES:

1. For exact location of strain gages refer to Figure 3.
2. See Figure A-2 for Zone 2 pressure.

Figure A-9

Nozzle Core Support Pressure-Strain Curves, 153° 30' Location

Gage No	Symbol
19	○
20	□

NOTES:

1. For exact locations of strain gages refer to Figure 3.
2. See Figure A-2 for Zone 2 pressure.

Figure A-10

Nozzle Attachment Flange Pressure-Strain Curves, 153° 30' Location

Gage No	Symbol	Thickness
22	○	.470
23	●	.520
24	◻	.520
25	◼	.466
26	△	.376
27	▲	.379
28	○	.518
29	●	.378
30	◇	.368

NOTES:

1. For exact locations of strain gage refer to Figure 3.
2. See Figure A-2 for Zone 2 pressure.

Figure A-11
Nozzle Hot-Bleed Port Pressure-Strain Curve
A-11

Gage No	Symbol	Thickness
21	○	.480
31	●	.523
32	□	.510
33	■	.528

- NOTES:
1. For exact locations of strain gages refer to Figure 3.
 2. See Figure A-2 for Zone 2 pressure.

Figure A-12
Nozzle Entrance Cone Pressure-Strain Curves, 153° 30' Location
A-12

Gage No	Symbol	Thickness
49	○	.352
50	□	.354
51	▲	

NOTES:

1. For exact locations of strain gages refer to Figure 3.
2. See Figure A-2 for Zone 2 pressure.

Figure A-13

Nozzle Core Support Pressure-Strain Curves, 333° 30' Location

<u>Gage No</u>	<u>Symbol</u>
52	○
53	□

- NOTES:
1. For exact locations of strain gages refer to Figure 3.
 2. See Figure A-2 for Zone 2 pressure.

Figure A-14
Nozzle Attachment Flange Pressure-Strain Curves, 333° 30' Location
A-14

Gage No	Symbol	Thickness
54	○	.440
55	●	.448
56	◻	.490
57	■	.492

NOTES:

1. For exact location of strain gages refer to Figure 3.
2. See Figure A-2 for Zone 2 pressure.

Figure A-15

Nozzle Entrance Cone Pressure-Strain Curves, 333° 30' Location

PRESSURE VS DEFLECTION

TEST NO. DATE TESTED RUN PHASE
1343 11 19 65 1 1

PRESSURE									
	0	20	40	60	80	100	60	20	0
DEFLECTION									
1	.000	-.058	-.126	-.195	-.267	-.383	-.217	-.083	-.029
2	.000	.030	.055	.066	.063	-.052	-.016	-.035	-.051
3	.000	.036	.069	.113	.138	.193	.124	.055	.011
4	.000	-.104	-.227	-.354	-.491	-.576	-.571	-.576	-.576
5	.000	-.020	-.047	-.073	-.098	-.149	-.098	-.029	-.020
6	.000	.012	.020	.028	.038	.063	.046	.043	.042
7	.000	.131	.165	.399	.545	.686	.370	.088	-.024
8	.000	-.113	-.223	-.290	-.309	-.422	-.151	.094	.181
9	.000	.145	.280	.425	.555	.705	.377	.068	-.048
10	.000	.090	.205	.296	.271	.246	.000	-.115	-.115
11	.000	-.001	.001	.055	.000	.000	.000	.000	-.000
12	.000	.004	.004	-.007	-.026	-.038	-.036	-.035	-.036
13	.000	-.058	-.128	-.205	-.280	-.370	-.218	-.066	-.021
14	.000	.028	.050	.064	.073	.060	.056	.032	.010
15	.000	.031	.066	.110	.141	.180	.110	.031	.002
16	.000	-.113	-.241	-.368	-.481	-.633	-.348	-.118	-.029
17	.000	.009	.017	.024	.029	.037	.020	.007	.002
18	.000	-.010	-.021	-.031	-.043	-.055	-.033	-.010	-.004
19	.000	.142	.274	.405	.542	.695	.400	.121	.000
20	.000	-.107	-.218	-.318	-.418	-.529	-.282	-.054	.032
21	.000	.135	.274	.414	.554	.714	.434	.150	.035
22	.000	.141	.300	.484	.690	.942	.578	.214	.081
23	.000	.010	.021	.040	.053	.081	.055	.029	.017
24	.000	.007	.014	.021	.029	.046	.026	.005	-.004
25	.000	.117	.000	.000	.000	.000	.000	.079	-.019
26	.000	.111	.214	.266	.418	.503	.240	.023	-.067
27	.000	-.103	-.213	.000	.000	.000	.000	-.047	.047
28	.000	.135	.256	.419	.577	.726	.447	.167	.056
29	.000	.145	.187	.231	.279	.335	.247	.162	.113
30	.000	.015	.015	.010	.002	.015	.015	.015	.015
31	.000	.102	.200	.309	.000	.000	.000	.118	.012
32	.000	.078	.403	.000	.000	.000	.000	.316	.060
33	.000	.051	.000	.000	.000	.000	.000	.074	.029
34	.000	.133	.000	.000	.000	.000	.000	.160	.048
35	.000	.155	.299	.476	.664	.830	.515	.177	.111
36	.000	-.002	.009	.022	.035	.024	.028	.002	-.003

NOTES:

1. Multiply all deflections by 10^{-1} to get actual values.
2. Measurements of oscillograph trace deflections are accurate to ± 0.01 inches. The last column in this table correlates the transducer movement to 0.01 inches of trace deflection and therefore defines the reading accuracy for each channel.
3. All positive and negative deflection readings denote Retraction and Extension of the transducer respectively.
4. The locations and positions of all deflection transducers are shown in Figures 4, 5 and 6.

Figure A-16
Tabulated Deflection Data, Phase 1 Run 1
A-16

PRESSURE VS STRAIN

TEST NO. DATE TESTED RUN PHASE
1343 11 19 65 1 1

PRESSURE

GAGE	0	20	40	60	80	100	60	20	0	1
14	0	269	558	846	1154	1442	865	288	0	19
17	0	419	819	1257	1581	2019	1295	419	57	19
18	0	345	669	953	1297	1601	892	345	61	20
24	0	264	588	872	1216	1500	872	264	20	20
27	0	396	764	1217	1613	1783	1245	425	85	28
28	0	187	417	625	875	1062	667	229	83	21
34	0	294	588	863	1157	1412	765	216	-20	20
35	0	-19	-19	-9	37	65	37	28	0	9
37	0	358	811	1283	1736	2151	1377	453	57	19
38	0	93	224	346	467	598	383	140	28	9
44	0	305	667	1029	1390	1714	1048	381	19	19
45	0	-156	-294	-440	-560	-670	-431	-156	-9	9
47	0	229	457	695	914	1152	638	200	19	10
48	0	-93	-187	-271	-327	-402	-243	-93	0	9
54	0	444	926	1389	1870	2296	1370	444	19	19
55	0	-48	-77	-135	-173	-231	-144	-48	0	10
57	0	72	130	217	290	406	203	58	0	14
58	0	-77	-183	-269	-337	-385	-250	-77	10	10
64	0	451	922	1373	1765	2059	1275	392	-20	20
65	0	-204	-393	-583	-728	-947	-597	-233	-58	15
67	0	75	189	311	434	717	387	151	75	0
68	0	-278	-556	-815	-1074	-1333	-852	-296	-56	19
74	0	-160	-408	-641	-888	-1180	-583	-160	15	15
75	0	262	553	830	1107	1427	816	291	58	15
77	0	355	710	1121	1514	1944	1065	299	-19	19
78	0	275	592	908	1225	1555	894	303	41	14
84	0	-88	-228	-333	-447	-561	-281	-79	26	9
85	0	358	755	1208	1774	2302	1396	509	75	19
87	0	239	451	704	942	1195	690	186	-27	13
88	0	319	673	1027	1381	1752	1027	319	18	18
94	0	9	9	9	18	35	18	9	0	9
95	0	393	804	1271	1701	2150	1252	430	19	19
97	0	86	133	210	276	362	219	57	-10	10
98	0	374	766	1196	1626	2056	1178	355	0	19

NOTES:

- The last digit of the gage number is coded as follows:
1 = Meridional Strain
2 = Hoop Strain
4 = Inside Meridional Strain
5 = Inside Hoop Strain
7 = Outside Meridional Strain
8 = Outside Hoop Strain
- Gages malfunctioned where values are not shown.
- Negative values are compressive strain and positive values are tensile strain.
- Measurements of oscillograph trace deflections are accurate to ± 0.01 inches. The last column in this table correlates the magnitude of strain to 0.01 inches of trace deflection and therefore defines the reading accuracy for each channel

Figure A-17
Tabulated Strain Data, Phase I Run I
A-17

PRESSURE VS STRAIN

TEST NO. DATE TESTED RUN PHASE
1343 11 19 65 1 1

PRESSURE

GAGE	0	20	40	60	80	100	60	20	0	1
104	0	57	95	133	171	219	133	29	-10	10
105	0	393	841	1290	1738	2187	1290	393	0	28
107	0	81	144	225	297	378	234	54	-9	9
108	0	393	785	1234	1654	2047	1206	364	0	28
114	0	120	231	352	481	602	352	93	-19	9
115	0	389	796	1241	1685	2093	1241	389	19	19
117	0	-37	-83	-119	-156	-202	-128	-64	-28	9
118	0	357	732	1107	1482	1857	1107	357	18	18
124	0	19	28	47	66	85	66	19	9	9
125	0	425	876	1354	1832	2283	1354	398	27	27
127	0	71	152	241	321	411	232	45	-27	9
128	0	382	791	1227	1664	2073	1200	327	-27	27
134	0	-27	-64	-73	-82	-91	-55	-27	-9	9
135	0	301	655	991	1345	1699	973	283	-35	18
137	0	200	371	571	757	943	557	129	-43	14
138	0	313	626	974	1322	1687	957	278	0	17
144	0	283	566	920	1257	1575	973	336	71	18
145	0	9	36	100	182	200	127	64	55	9
147	0	17	35	0	-78	-61	-122	-191	-200	9
148	0	-18	-9	62	159	168	124	106	-27	9
154	0	261	468	606	702	1032	509	-55	-55	14
155	0	-26	-35	61	226	252	270	270	287	9
157	0	115	231	327	375	452	183	-96	-202	10
158	0	-18	-9	155	418	418	418	418	418	9
164	0	37	75	131	159	224	131	56	19	9
165	0	-28	-83	-156	-229	-294	-174	-101	-55	9
167	0	-28	-37	-37	-18	-37	46	55	64	9
168	0	-24	-95	-143	-238	-333	-155	-83	-36	12
174	0	38	66	160	292	377	302	245	198	9
175	0	0	9	-27	-118	-136	-118	-127	-136	9
177	0	-36	-72	-108	-126	-171	-81	-9	9	9
178	0	-28	-37	-112	-215	-271	-224	-196	-178	9
184	0	-19	-37	28	178	168	262	280	299	0
185	0	27	45	18	-36	-45	-82	-100	-127	0
187	0	0	9	-36	-126	-153	-171	-162	-162	9
188	0	9	37	0	-92	-101	-138	-183	-193	9

NOTES:

- The last digit of the gage number is coded as follows:
1 = Meridional Strain
2 = Hoop Strain
4 = Inside Meridional Strain
5 = Inside Hoop Strain
7 = Outside Meridional Strain
8 = Outside Hoop Strain
- Gages malfunctioned where values are not shown.
- Negative values are compressive strain and positive values are tensile strain.
- Measurements of oscillograph trace deflection are accurate to ± 0.01 inches. The last column in this table correlates the magnitude of strain to 0.01 inches of trace deflection and therefore defines the reading accuracy for each channel.

Figure A-17

Tabulated Strain Data, Phase 1 Run 1 (Continued)

PRESSURE VS STRAIN

TEST NO. DATE TESTED RUN PHASE
1343 11 19 65 1 1

PRESSURE	0	20	40	60	80	100	60	20	0	1
GAGE										
191	0	19	29	-19	-95	-67	-114	-162	-181	10
192	0	37	56	37	-28	-28	-83	-139	-167	9
201	0	91	209	318	455	627	427	218	100	9
202	0	57	142	198	255	340	208	66	-9	9
214	0	-112	-224	-355	-542	-654	-449	-262	-159	9
215	0	128	294	440	633	826	569	266	138	9
217	0	124	286	486	714	876	629	343	219	10
218	0	37	93	112	150	196	103	9	-9	9
224	0	-56	-112	-215	-346	-439	-336	-224	-178	9
225	0	55	145	191	236	327	191	27	-36	9
227	0	155	318	564	818	1018	745	436	282	9
228	0	56	120	231	315	398	278	111	46	9
234	0	0	-9	-45	-109	-136	-127	-91	-109	9
235	0	48	105	152	171	286	152	19	-29	10
237	0	75	170	274	425	519	377	217	142	9
238	0	57	132	198	283	358	170	75	19	9
244	0	0	0	0	-30	-40	-30	-50	-60	10
245	0	18	64	92	101	183	101	0	-37	9
247	0	47	121	215	308	374	262	131	84	9
248	0	59	139	188	238	307	188	50	-10	10
254	0	-67	-154	-250	-356	-471	-327	-192	-125	10
255	0	37	75	93	93	131	56	0	-47	9
257	0	165	359	602	864	1126	796	427	262	10
258	0	56	140	243	336	458	327	150	84	9
264	0	0	0	0	57	57	10	0	10	10
265	0	10	30	60	50	60	0	-50	-70	10
267	0	98	216	353	520	725	324	294	186	10
268	0	80	160	310	450	610	420	220	140	10
274	0	0	86	157	200	300	157	29	14	14
275	0	0	12	12	12	12	-36	-60	-71	12
277	0	85	151	264	368	472	226	170	94	9
278	0	75	189	340	491	642	358	264	189	9
284	0	-29	-67	-87	-163	-221	-183	-125	-87	10
285	0	76	143	257	333	429	276	124	48	10
287	0	133	267	429	610	810	429	248	114	10
288	0	98	206	333	490	657	500	265	157	10

NOTES:

1. The last digit of the gage number is coded as follows:

- 1 = Meridional Strain
- 2 = Hoop Strain
- 4 = Inside Meridional Strain
- 5 = Inside Hoop Strain
- 7 = Outside Meridional Strain
- 8 = Outside Hoop Strain

2. Gages malfunctioned where values are not shown.

3. Negative values are compressive strain and positive values are tensile strain.

4. Measurements of oscillograph trace deflection are accurate to ± 0.01 inches. The last column in this table correlates the magnitude of strain to 0.01 inches of trace deflection and therefore defines the reading accuracy for each channel.

Figure A-17

Tabulated Strain Data, Phase 1 Run 1 (Continued)

PRESSURE VS STRAIN

TEST NO. DATE TESTED RUN PHASE
1343 11 19 65 1 1

PRESSURE	0	20	40	60	80	100	60	20	0	1
GAGE										
294	0	38	57	105	133	152	86	38	0	10
295	0	46	83	157	176	213	111	28	-28	9
297	0	105	200	333	486	714	524	314	219	10
298	0	78	147	245	333	451	294	39	78	10
304	0	80	140	230	300	380	250	120	70	10
305	0	29	58	106	144	183	77	29	-29	10
307	0	56	111	185	231	324	231	74	9	9
308	0	47	94	176	247	353	235	129	71	12
314	0	-32	-53	-53	-96	-160	-43	-32	-64	11
315	0	170	340	570	830	1140	600	120	-30	10
317	0	99	198	307	515	614	406	198	99	10
318	0	130	230	350	490	690	450	250	150	10
324	0	28	57	123	198	236	160	104	57	9
325	0	140	290	480	660	900	640	140	200	10
327	0	19	37	65	93	150	93	56	37	9
328	0	67	124	181	238	324	219	114	67	10
334	0	49	98	196	294	402	304	206	157	10
335	0	93	234	439	514	654	421	131	0	9
337	0	9	27	27	27	36	9	0	36	9
338	0	50	139	198	257	356	248	149	99	10
344	0	261	565	870	1174	1478	870	304	22	22
345	0	202	442	692	923	1163	721	250	48	10
347	0	430	903	1333	1763	2194	1312	452	43	22
348	0	370	678	1007	1336	1582	1007	390	62	21
355	0	95	219	352	467	600	390	162	38	10
358	0	239	447	718	941	1165	734	287	48	16
364	0	309	673	964	1255	1564	891	327	55	18
365	0	0	55	138	193	294	248	165	92	9
367	0	319	723	1170	1553	1936	1213	404	64	21
368	0	102	237	390	525	661	424	153	68	17
374	0	333	706	1059	1431	1784	1137	431	98	20
375	0	-143	-286	-429	-571	-684	-429	-153	-10	10
377	0	219	457	676	886	1114	619	190	10	10
378	0	-89	-188	-257	-327	-386	-248	-89	10	10

NOTES:

- The last digit of the gage number is coded as follows:
1 = Meridional Strain
2 = Hoop Strain
4 = Inside Meridional Strain
5 = Inside Hoop Strain
7 = Outside Meridional Strain
8 = Outside Hoop Strain
- Gages malfunctioned where values are not shown.
- Negative values are compressive strain and positive values are tensile strain.
- Measurements of oscillograph trace deflection are accurate to ± 0.01 inches. The last column in this table correlates the magnitude of strain to 0.01 inches of trace deflection and therefore defines the reading accuracy for each channel.

Figure A-17

Tabulated Strain Data, Phase 1 Run 1 (Continued)

PRESSURE VS STRAIN

TEST NO. DATE TESTED RUN PHASE
 1343 11 19 65 1 1

PRESSURE

	0	20	40	60	80	100	60	20	0	1
GAGE										
384	0	449	918	1388	1837	2306	1367	469	82	20
385	0	-39	-78	-136	-184	-214	-126	-39	10	10
387	0	79	158	228	327	436	228	79	20	10
388	0	-95	-190	-276	-362	-438	-286	-114	0	10
394	0	269	577	846	1115	1346	827	269	58	19
395	0	-180	-375	-555	-735	-900	-555	-210	0	15
397	0	87	191	304	435	609	322	104	35	9
398	0	-262	-524	-801	-1063	-1311	-816	-291	0	15
405	0	317	661	1005	1335	1693	977	317	28	14
408	0	270	595	905	1216	1527	892	324	54	14
414	0	-101	-257	-376	-532	-688	-376	-138	-18	9
415	0	352	759	1148	1537	1944	1148	407	56	19
417	0	292	559	839	1131	1436	839	280	38	13
418	0	343	724	1124	1486	1829	1105	381	76	19
424	0	0	9	27	109	182	164	100	64	9
425	0	404	826	1284	1725	2128	1248	404	37	18
428	0	381	800	1219	1619	2019	1200	400	19	19
434	0	68	114	159	205	239	148	45	0	11
437	0	73	138	202	266	330	202	64	0	9
438	0	416	832	1307	1723	2139	1248	416	30	30
444	0	136	255	373	500	609	373	109	-9	0
445	0	360	721	1081	1459	1838	1081	324	18	18
447	0	-35	-70	-105	-149	-184	-105	-44	-9	9
448	0	364	745	1127	1491	1855	1091	364	36	18
454	0	27	45	73	91	109	73	9	-9	9
457	0	101	183	266	349	440	266	83	0	9
464	0	-10	-10	-19	-29	-29	-19	-19	-10	10
465	0	348	697	1045	1409	1758	1045	348	30	15
467	0	212	398	597	757	956	584	173	0	13
468	0	321	661	982	1304	1625	964	321	18	18

NOTES:

1. The last digit of the gage number is coded as follows:

- 1 = Meridional Strain
- 2 = Hoop Strain
- 4 = Inside Meridional Strain
- 5 = Inside Hoop Strain
- 7 = Outside Meridional Strain
- 8 = Outside Hoop Strain

2. Gages malfunctioned where values are not shown.

3. Negative values are compressive strain and positive values are tensile strain.

4. Measurements of oscillograph trace deflection are accurate to + 0.01 inches. The last column in this table correlates the magnitude of strain to 0.01 inches of trace deflection and therefore defines the reading accuracy for each channel.

Figure A-17

Tabulated Strain Data, Phase 1 Run 1 (Continued)

PRESSURE VS STRAIN

TEST NO. DATE TESTED RUN PHASE
1343 11 17 65 1 1

PRESSURE										
GAGE	0	20	40	60	80	100	60	20	0	1
474	0	304	607	929	1232	1518	929	304	18	18
475	0	18	54	80	116	152	71	18	-9	9
477	0	22	45	67	90	112	56	-11	-34	11
484	0	221	412	632	853	1059	632	206	15	29
485	0	0	0	15	29	74	59	44	44	15
487	0	112	215	327	402	495	290	37	-75	9
488	0	9	28	46	83	120	93	65	56	9
494	0	42	83	135	187	240	146	83	52	10
495	0	-40	-99	-158	-208	-267	-158	-69	-10	10
497	0	-10	-20	-30	-40	-60	-30	0	10	10
498	0	-30	-60	-110	-170	-230	-120	-40	-20	10
504	0	18	45	80	125	170	116	54	27	36
505	0	-21	-41	-72	-103	-144	-103	-62	-31	10
507	0	-21	-41	-72	-93	-113	-72	-21	10	10
508	0	-21	-42	-84	-105	-168	-105	-63	-32	11
514	0	-22	-32	-43	-54	-54	22	22	54	11
515	0	10	21	31	31	31	10	0	-10	10
517	0	10	20	30	30	30	0	-10	-10	10
518	0	10	20	20	20	20	0	-10	-20	10
521	0	20	49	69	78	98	39	0	-29	10
522	0	31	52	72	93	113	52	10	-10	10
532	0	57	114	171	229	295	190	67	29	10
544	0	-36	-72	-135	-198	-252	-180	-117	-72	9
545	0	69	157	245	333	441	284	127	59	10
547	0	70	150	240	330	430	280	130	70	10
548	0	62	135	219	260	375	229	104	42	10
554	0	10	30	51	71	91	81	71	61	10
555	0	112	255	408	561	735	510	296	194	10
557	0	32	74	116	158	200	126	53	21	11
565	0	98	159	244	341	415	268	110	37	12
567	0	13	27	53	67	67	40	13	-13	13
568	0	82	134	196	268	330	196	93	31	10

NOTES:

- The last digit of the gage number is coded as follows:
1 = Meridional Strain
2 = Hoop Strain
4 = Inside Meridional Strain
5 = Inside Hoop Strain
7 = Outside Meridional Strain
8 = Outside Hoop Strain
- Gages malfunctioned where values are not shown.
- Negative values are compressive strain and positive values are tensile strain.
- Measurements of oscillograph trace deflection are accurate to ± 0.01 inches. The last column in this table correlates the magnitude of strain to 0.01 inches of trace deflection and therefore defines the reading accuracy for each channel.

Figure A-17

Tabulated Strain Data, Phase 1 Run 1 (Continued)

PRESSURE VS STRAIN

TEST NO.	DATE TESTED	RUN	PHASE
1343	11 19 65	1	1

PRESSURE										
	0	20	40	60	80	100	60	20	0	1
GAGE										
574	0	24	49	73	110	207	98	61	37	12
577	0	26	39	53	79	92	79	39	26	13
578	0	179	403	582	806	1030	627	269	45	45
11	0	119	310	476	786	1286	500	190	48	24
12	0	43	86	129	214	429	107	0	-86	21
14	0	157	336	560	851	1410	537	157	67	22
21	0	100	125	200	375	275	-150	-350	-375	25
22	0	175	277	481	743	1209	408	117	29	15
23	0	190	429	690	1143	2143	738	476	333	24
24	0	69	254	415	715	1223	415	92	-46	23
31	0	98	268	488	780	1561	610	244	98	24
32	0	71	95	190	310	405	-24	-167	-214	24
33	0	69	160	298	435	664	115	-115	-183	23
34	0	169	339	605	968	1839	798	363	194	24
41	0	-22	-44	-88	-199	-397	-397	-397	-397	22
42	0	0	-22	-65	-109	-283	-304	-304	-348	22
43	0	39	39	39	39	39	-59	-59	-138	20
44	0	22	22	-66	-88	-109	-175	-197	-241	22
51	0	22	0	0	43	87	43	0	-22	22
53	0	0	0	0	-127	-203	-229	-254	-280	25
54	0	-29	-57	-200	-857	-1200	-1143	-1143	-1143	29
61	0	26	53	132	211	132	26	0	-26	26
62	0	0	-67	-111	-111	-111	-133	-133	-133	22
63	0	0	-85	-213	-404	-447	-426	-426	-468	21
64	0	0	0	-28	-85	-198	-311	-340	-396	28

NOTES:

- The last digit of the gage number is coded as follows:
 - 1 = Meridional Strain
 - 2 = Hoop Strain
 - 4 = Inside Meridional Strain
 - 5 = Inside Hoop Strain
 - 7 = Outside Meridional Strain
 - 8 = Outside Hoop Strain
- Gages malfunctioned where values are not shown.
- Negative values are compressive strain and positive values are tensile strain.
- Measurements of oscillograph trace deflection are accurate to + 0.01 inches. The last column in this table correlates the magnitude of strain to 0.01 inches of trace deflection and therefore defines the reading accuracy for each channel.

Figure A-17

Tabulated Strain Data, Phase 1 Run 1 (Continued)

PRESSURE VS DEFLECTION

TEST NO. DATE TESTED RUN PHASE
1343 11 19 65 2 1

PRESSURE	0	40	60	80	100	60	20	0	1
DEFLECTION									
1	.000	-.139	-.210	-.281	-.366	-.196	-.053	-.004	.004
2	.000	.055	.065	.061	.024	.058	.033	.007	.001
3	.000	.072	.107	.148	.177	.115	.035	.005	.003
4	.000	.000	.000	.000	.000	.000	.000	.000	.005
5	.000	-.043	-.070	-.093	-.120	-.070	-.017	.000	.002
6	.000	.026	.036	.046	.053	.034	.021	.011	-.000
7	.000	.274	.407	.549	.691	.397	.104	-.009	.005
8	.000	-.238	-.359	-.484	-.609	-.348	-.103	-.015	.004
9	.000	.289	.429	.583	.741	.429	.126	-.009	.005
10	.000	.073	.129	.218	.339	.121	.004	.000	.004
11	.000	-.007	-.009	-.011	-.012	.000	.007	.012	-.000
12	.000	.005	.007	.007	.007	.007	.005	.003	-.000
13	.000	-.131	-.208	-.279	-.362	-.208	-.060	-.006	.002
14	.000	.052	.068	.077	.070	.067	.034	.006	.001
15	.000	.067	.101	.137	.173	.103	.030	.004	.002
16	.000	-.251	-.379	-.511	-.644	-.360	-.123	-.019	.005
17	.000	.018	.023	.032	.038	.023	.009	.000	.002
18	.000	-.020	-.031	-.042	-.053	-.030	-.009	.000	-.000
19	.000	.284	.418	.563	.702	.413	.134	.010	.005
20	.000	-.222	-.342	-.461	-.574	-.335	-.109	-.024	.003
21	.000	.274	.409	.548	.692	.413	.135	.014	.005
22	.000	.319	.491	.671	.875	.519	.164	.025	.004
23	.000	.017	.032	.044	.058	.034	.008	-.002	-.000
24	.000	.017	.025	.034	.044	.025	.001	-.004	-.000
25	.000	.000	.000	.000	.000	.000	.110	.007	-.000
26	.000	.225	.329	.445	.549	.318	.093	-.011	.005
27	.000	.000	.000	.000	.000	.000	-.086	.014	.001
28	.000	.278	.411	.556	.695	.411	.133	.006	.006
29	.000	.272	.412	.527	.000	.000	.142	.018	.002
30	.000	.024	.016	.006	-.002	-.016	-.004	-.008	.002
31	.000	.198	.299	.427	.000	.296	.096	.012	.002
32	.000	.201	.304	.401	.511	.298	.097	.012	.006
33	.000	.104	.000	.000	.000	.000	.059	.010	.001
34	.000	.000	.000	.000	.000	.000	.130	.015	.001
35	.000	.310	.473	.631	.800	.473	.158	.006	.006
36	.000	-.005	.006	.020	.029	.034	.009	.004	-.000

NOTES:

1. Multiply all deflections by 10^{-1} to get actual values.
2. Measurements of oscillograph trace deflections are accurate to ± 0.01 inches. The last column in this table correlates the transducer movement to 0.01 inches of trace deflection and therefore defines the reading accuracy for each channel.
3. All positive and negative deflection readings denote Retraction and Extension of the transducer respectively.
4. The locations and positions of all deflection transducers are shown in Figures 4, 5 and 6.

Figure A-18

Tabulated Deflection Data, Phase 1 Run 2

PRESSURE VS STRAIN

TEST NO. DATE TESTED RUN PHASE
 1343 11 19 65 2 1

PRESSURE									
GAGE	0	40	60	80	100	60	20	0	1
14	0	596	885	1192	1481	904	308	38	19
17	0	838	1238	1657	2057	1200	400	57	19
18	0	689	1014	1358	1642	993	365	61	20
24	0	628	912	1297	1561	912	304	20	20
27	0	821	1217	1642	1840	1245	425	-28	28
28	0	437	625	896	1104	687	250	42	21
34	0	608	902	1118	1490	804	235	20	20
35	0	0	9	37	75	47	9	-9	9
37	0	811	1264	1736	2170	1377	472	19	19
38	0	215	336	449	598	393	121	19	9
44	0	724	1067	1410	1733	1124	381	0	19
45	0	-321	-468	-596	-688	-459	-174	-46	9
47	0	467	695	943	1171	657	210	19	10
48	0	-206	-280	-355	-411	-252	-93	-37	9
54	0	963	1407	1889	2333	1463	481	74	19
55	0	-58	-115	-154	-202	-106	-19	-48	10
57	0	130	203	290	391	203	58	-14	14
58	0	-202	-288	-346	-413	-279	-106	-10	10
64	0	980	1431	1824	2137	1412	510	39	20
65	0	-393	-568	-743	-888	-583	-204	-58	15
67	0	198	311	453	642	311	85	9	9
68	0	-574	-815	-1056	-1296	-852	-315	-93	19
74	0	-408	-626	-888	-1209	-626	-189	-44	15
75	0	553	830	1136	1456	801	248	15	15
77	0	766	1178	1589	2037	1159	374	37	19
78	0	592	894	1225	1583	894	289	41	14
84	0	-219	-333	-456	-579	-316	-105	-18	9
85	0	868	1340	1868	2377	1434	491	94	19
87	0	504	757	1009	1274	743	252	27	13
88	0	673	1027	1398	1788	1027	301	18	18
94	0	9	18	26	35	18	0	-9	9
95	0	860	1290	1720	2187	1271	411	37	19
97	0	143	219	295	371	219	67	0	10
98	0	822	1252	1682	2112	1215	393	37	19

NOTES:

- The last digit of the gage number is coded as follows:
 1 = Meridional Strain
 2 = Hoop Strain
 4 = Inside Meridional Strain
 5 = Inside Hoop Strain
 7 = Outside Meridional Strain
 8 = Outside Hoop Strain
- Gages malfunctioned where values are not shown.
- Negative values are compressive strain and positive values are tensile strain.
- Measurements of oscillograph trace deflection are accurate to ± 0.01 inches. The last column in this table correlates the magnitude of strain to 0.01 inches of trace deflection and therefore defines the reading accuracy for each channel.

Figure A-19
 Tabulated Strain Data, Phase 1 Run 2

PRESSURE VS STRAIN

TEST NO.	DATE TESTED	RUN	PHASE
1343	11 19 65	2	1

PRESSURE

	0	40	60	80	100	60	20	0	=0
GAGE									
104	0	95	133	181	229	133	38	0	10
105	0	897	1346	1794	2243	1318	393	56	28
107	0	162	243	324	405	234	81	9	9
108	0	897	1290	1738	2131	1262	421	56	28
114	0	259	389	509	639	389	130	19	9
115	0	852	1278	1741	2167	1259	407	74	19
117	0	-73	-110	-147	-174	-110	-37	-9	9
118	0	750	1107	1500	1893	1107	357	36	18
124	0	28	47	66	85	66	28	0	9
125	0	929	1381	1858	2336	1381	425	27	27
127	0	179	259	348	438	268	89	9	9
128	0	873	1282	1745	2182	1255	409	27	27
134	0	-55	-73	-100	-118	-73	-27	-9	9
135	0	708	1062	1434	1752	1044	336	35	18
137	0	400	600	800	1000	600	186	0	14
138	0	696	1009	1357	1704	1009	313	35	17
144	0	619	920	1204	1522	920	301	0	18
145	0	55	82	127	164	82	18	0	9
147	0	52	78	104	139	78	17	0	0
148	0	18	27	53	71	35	0	0	9
154	0	550	812	1060	1335	784	261	41	14
155	0	-35	-43	-43	-35	-26	-17	-9	9
157	0	269	404	529	663	385	125	0	10
158	0	-27	-27	-27	-18	-9	-9	-9	9
164	0	56	121	168	224	121	19	-19	9
165	0	-92	-138	-183	-229	-138	-55	0	9
167	0	-37	-55	-64	-101	-46	-28	0	9
168	0	-107	-179	-250	-298	-167	-60	-12	12
174	0	66	104	132	208	113	19	9	9
175	0	18	27	18	27	27	18	18	9
177	0	-45	-81	-117	-144	-81	-36	9	9
178	0	-37	-56	-75	-84	-65	-28	0	9
184	0	-19	-37	-75	-84	-28	9	37	9
185	0	55	73	91	109	64	9	9	0
187	0	27	27	36	45	9	9	0	9
188	0	46	55	73	101	55	0	0	9

NOTES:

- The last digit of the gage number is coded as follows:
 1 = Meridional Strain
 2 = Hoop Strain
 4 = Inside Meridional Strain
 5 = Inside Hoop Strain
 7 = Outside Meridional Strain
 8 = Outside Hoop Strain
- Gages malfunctioned where values are not shown.
- Negative values are compressive strain and positive values are tensile strain.
- Measurements of oscillograph trace deflection are accurate to ± 0.01 inches. The last column in this table correlates the magnitude of strain to 0.01 inches of trace deflection and therefore defines the reading accuracy for each channel.

Figure A-19

Tabulated Strain Data, Phase 1 Run 2 (Continued)

PRESSURE VS STRAIN

TEST NO. DATE TESTED RUN PHASE
 1343 11 19 65 2 1

PRESSURE	0	40	60	80	100	60	20	0	1
GAGE									
191	0	57	67	95	133	57	10	10	0
192	0	56	93	111	148	93	9	9	9
201	0	209	327	436	545	336	100	18	9
202	0	132	208	274	387	217	66	9	9
214	0	-206	-308	-411	-505	-308	-112	-9	9
215	0	275	422	560	734	440	147	18	9
217	0	286	419	552	695	429	124	29	10
218	0	75	131	159	224	131	19	9	9
224	0	-84	-140	-196	-243	-150	-56	0	9
225	0	145	236	309	391	236	64	9	9
227	0	300	464	609	782	491	164	36	9
228	0	139	222	306	380	231	56	0	9
234	0	-36	-36	-45	-45	-36	-36	-36	9
235	0	133	181	238	324	200	57	19	10
237	0	151	236	321	425	255	85	9	9
238	0	151	208	292	377	217	75	19	9
244	0	10	10	20	50	20	-10	0	10
245	0	83	119	165	229	138	37	0	9
247	0	131	178	262	346	187	75	19	9
248	0	139	198	287	347	228	59	10	10
254	0	-144	-212	-269	-327	-192	-58	29	10
255	0	75	103	131	178	121	28	-9	9
257	0	350	524	689	903	553	184	29	10
258	0	150	234	318	402	262	84	9	9
264	0	0	0	10	10	0	-19	-29	10
265	0	80	90	100	140	80	30	0	10
267	0	206	304	402	520	324	108	10	10
268	0	170	260	350	460	270	100	10	10
274	0	100	114	186	214	129	43	-14	14
275	0	48	60	83	119	48	12	0	12
277	0	151	226	302	377	226	85	9	9
278	0	179	255	358	453	264	94	0	9
284	0	-58	-77	-115	-154	-96	-29	-19	10
285	0	162	219	305	400	229	76	19	10
287	0	276	400	571	686	419	152	10	10
288	0	196	294	392	510	304	108	10	10

NOTES:

1. The last digit of the gage number is coded as follows:

- 1 = Meridional Strain
- 2 = Hoop Strain
- 4 = Inside Meridional Strain
- 5 = Inside Hoop Strain
- 7 = Outside Meridional Strain
- 8 = Outside Hoop Strain

2. Gages malfunctioned where values are not shown.

3. Negative values are compressive strain and positive values are tensile strain.

4. Measurements of oscillograph trace deflection are accurate to + 0.01 inches. The last column in this table correlates the magnitude of strain to 0.01 inches of trace deflection and therefore defines the reading accuracy for each channel.

Figure A-19

Tabulated Strain Data, Phase 1 Run 2 (Continued)

PRESSURE VS STRAIN

TEST NO. DATE TESTED RUN PHASE
1343 11 19 65 2 1

PRESSURE									
	0	40	60	80	100	60	20	0	1
GAGE									
294	0	57	86	105	124	67	10	-10	10
295	0	74	139	167	204	120	19	-9	9
297	0	229	324	419	533	333	133	38	10
298	0	137	225	284	343	225	69	20	10
304	0	140	210	280	340	220	80	0	10
305	0	58	96	135	154	96	19	0	10
307	0	130	185	241	315	185	83	9	9
308	0	118	165	212	294	165	59	12	12
314	0	-43	-64	-96	-117	-64	-43	-11	11
315	0	350	530	700	920	570	190	30	10
317	0	198	317	386	505	327	89	0	10
318	0	210	300	400	540	310	100	10	10
324	0	57	85	132	179	94	38	0	9
325	0	250	400	520	690	410	140	0	10
327	0	37	56	93	121	65	28	9	9
328	0	114	171	210	276	152	48	0	10
334	0	98	137	196	245	147	49	0	10
335	0	234	336	467	617	393	140	19	9
337	0	-9	-9	9	-9	-9	-9	-9	9
338	0	99	149	198	257	149	40	0	10
344	0	609	913	1217	1543	913	304	43	22
345	0	442	673	913	1154	712	240	0	10
347	0	925	1269	1785	2215	1312	409	0	22
348	0	658	986	1377	1685	1007	329	0	21
355	0	200	324	467	590	381	133	0	10
358	0	431	654	910	1069	718	223	0	16
364	0	655	1000	1291	1600	927	345	18	18
365	0	73	138	202	303	211	110	18	9
367	0	745	1149	1553	1936	1213	404	0	21
368	0	220	373	492	644	407	136	-34	17
374	0	745	1098	1451	1804	1157	412	59	20
375	0	-296	-439	-571	-684	-439	-143	-10	10
377	0	457	686	914	1143	648	200	29	10
378	0	-198	-267	-347	-396	-257	-99	0	10

NOTES:

1. The last digit of the gage number is coded as follows:

- 1 = Meridional Strain
- 2 = Hoop Strain
- 4 = Inside Meridional Strain
- 5 = Inside Hoop Strain
- 7 = Outside Meridional Strain
- 8 = Outside Hoop Strain

2. Gages malfunctioned where values are not shown.

3. Negative values are compressive strain and positive values are tensile strain.

4. Measurements of oscillograph trace deflection are accurate to + 0.01 inches. The last column in this table correlates the magnitude of strain to 0.01 inches of trace deflection and therefore defines the reading accuracy for each channel.

Figure A-19

Tabulated Strain Data, Phase 1 Run 2 (Continued)

PRESSURE VS STRAIN

TEST NO. DATE TESTED RUN PHASE
 1343 11 19 65 2 1

PRESSURE									
GAGE	0	40	60	80	100	60	20	0	1
384	0	939	1408	1878	2327	1429	449	41	20
385	0	-97	-136	-184	-233	-136	-39	0	10
387	0	168	257	347	455	257	89	20	10
388	0	-190	-286	-362	-448	-286	-95	0	10
394	0	577	846	1115	1346	846	288	19	19
395	0	-360	-540	-720	-885	-540	-180	0	15
397	0	209	322	452	609	330	104	35	9
398	0	-568	-830	-1092	-1325	-830	-291	-29	15
405	0	674	1032	1376	1734	1018	344	55	14
408	0	622	919	1243	1554	919	324	41	14
414	0	-266	-385	-532	-688	-394	-128	-9	9
415	0	741	1130	1537	1963	1148	370	37	19
417	0	559	852	1157	1462	852	280	38	13
418	0	705	1067	1448	1810	1067	362	57	19
424	0	45	82	127	173	145	100	45	9
425	0	844	1284	1725	2165	1284	422	37	18
428	0	819	1219	1657	2057	1219	419	38	19
434	0	91	136	193	227	136	45	0	11
437	0	138	202	275	330	202	73	0	9
438	0	832	1277	1723	2139	1248	416	30	30
444	0	245	364	491	609	364	118	0	9
445	0	721	1099	1495	1856	1081	342	18	18
447	0	-79	-123	-149	-184	-114	-35	-9	9
448	0	727	1109	1473	1836	1073	345	18	18
454	0	45	64	91	118	64	27	9	9
457	0	183	257	349	422	257	92	0	9
464	0	-19	-29	-38	-38	-19	-10	-10	10
465	0	682	1030	1394	1742	1030	333	30	15
467	0	398	611	823	956	611	199	13	13
468	0	643	946	1304	1625	946	304	18	18

NOTES:

1. The last digit of the gage number is coded as follows:
 1 = Meridional Strain
 2 = Hoop Strain
 4 = Inside Meridional Strain
 5 = Inside Hoop Strain
 7 = Outside Meridional Strain
 8 = Outside Hoop Strain
2. Gages malfunctioned where values are not shown.
3. Negative values are compressive strain and positive values are tensile strain.
4. Measurements of oscillograph trace deflection are accurate to ± 0.01 inches. The last column in this table correlates the magnitude of strain to 0.01 inches of trace deflection and therefore defines the reading accuracy for each channel.

Figure A-19

Tabulated Strain Data, Phase 1 Run 2 (Continued)

PRESSURE VS STRAIN

TEST NO. DATE TESTED RUN PHASE
 1343 11 19 65 2 1

PRESSURE	0	40	60	80	100	60	20	0	1
GAGE									
474	0	607	911	1232	1482	893	36	18	18
475	0	36	63	116	143	63	18	0	9
477	0	34	56	90	112	56	0	-22	11
484	0	412	603	809	1000	588	176	0	15
485	0	-15	-15	-15	0	0	0	0	15
487	0	234	327	439	551	327	103	-9	9
488	0	9	19	37	65	28	9	0	9
494	0	94	135	177	229	135	52	10	10
495	0	-109	-158	-208	-267	-158	-50	-10	10
497	0	-10	-30	-40	-60	-30	0	0	10
498	0	-50	-100	-160	-220	-110	-10	-10	10
504	0	54	80	107	134	80	27	-9	9
505	0	-52	-72	-93	-124	-82	-31	-10	10
507	0	-41	-62	-82	-103	-62	-21	0	10
508	0	-42	-74	-105	-137	-84	-42	-11	11
514	0	-43	-65	-86	-108	-65	-22	0	11
515	0	21	31	31	31	21	0	-10	10
517	0	30	40	50	60	20	0	0	10
518	0	10	20	20	31	10	0	-10	10
521	0	59	69	98	118	59	10	0	10
522	0	31	52	72	93	41	-10	-31	10
532	0	105	171	210	257	162	48	10	10
544	0	-72	-108	-144	-180	-117	-36	0	9
545	0	157	235	304	382	235	78	0	10
547	0	140	210	280	360	210	70	10	10
548	0	135	198	260	333	187	62	10	10
554	0	10	10	10	10	10	0	-10	10
555	0	224	337	439	551	337	112	10	10
557	0	74	116	158	200	116	42	11	11
565	0	134	220	293	378	220	61	-24	12
567	0	27	40	53	93	40	13	0	13
568	0	124	186	237	309	186	52	-10	10

NOTES:

- The last digit of the gage number is coded as follows:
 1 = Meridional Strain
 2 = Hoop Strain
 4 = Inside Meridional Strain
 5 = Inside Hoop Strain
 7 = Outside Meridional Strain
 8 = Outside Hoop Strain
- Gages malfunctioned where values are not shown.
- Negative values are compressive strain and positive values are tensile strain.
- Measurements of oscillograph trace deflection are accurate to + 0.01 inches. The last column in this table correlates the magnitude of strain to 0.01 inches of trace deflection and therefore defines the reading accuracy for each channel.

Figure A-19
 Tabulated Strain Data, Phase 1 Run 2 (Continued)

PRESSURE VS STRAIN

TEST NO.	DATE TESTED	RUN	PHASE
1343	11 19 65	2	1

PRESSURE	0	40	60	80	100	60	20	0	1
GAGE									
574	0	49	61	85	122	73	24	0	12
577	0	13	26	53	66	26	13	0	13
578	0	358	537	761	985	582	134	0	45
582	0	873	1364	1745	2291	1364	545	0	55
11	0	262	452	738	1262	452	95	-24	24
12	0	43	129	214	450	129	0	-43	21
14	0	269	537	806	1388	537	112	0	22
21	0	100	175	350	600	125	0	-25	25
22	0	262	437	786	1267	437	102	0	15
23	0	381	643	1119	1810	643	119	-48	24
24	0	208	438	715	1246	438	92	-23	23
31	0	244	488	780	1390	488	73	-49	24
32	0	48	143	262	524	143	-24	-71	24
33	0	115	229	435	779	252	0	-46	23
34	0	315	556	944	1573	556	97	-48	24
41	0	-66	-66	-66	-88	-66	-66	-110	22
42	0	-43	0	-43	-43	-65	-87	-87	22
43	0	0	59	79	79	0	-20	-39	20
44	0	0	0	0	22	0	-22	-44	22
51	0	-22	-22	-22	22	0	-22	-65	22
53	0	0	-25	-25	0	-25	-25	-25	25
54	0	-86	-86	-114	-114	-86	-86	-86	29
61	0	0	26	26	53	0	-53	-79	26
62	0	-44	-67	-67	-44	-67	-67	-67	22
63	0	213	213	191	213	213	213	213	21
64	0	-340	-396	-340	-340	-396	-453	-425	28

NOTES:

- The last digit of the gage number is coded as follows:
 1 = Meridional Strain
 2 = Hoop Strain
 4 = Inside Meridional Strain
 5 = Inside Hoop Strain
 7 = Outside Meridional Strain
 8 = Outside Hoop Strain
- Gages malfunctioned where values are not shown.
- Negative values are compressive strain and positive values are tensile strain.
- Measurements of oscillograph trace deflection are accurate to ± 0.01 inches. The last column in this table correlates the magnitude of strain to 0.01 inches of trace deflection and therefore defines the reading accuracy for each channel.

Figure A-19

Tabulated Strain Data, Phase 1 Run 2 (Continued)

PRESSURE VS DEFLECTION

TEST NO. DATE TESTED RUN PHASE
1343 11 0 65 3 1

PRESSURE	0	40	60	80	100	60	20	0	1
DEFLECTION									
1	.000	-.139	-.217	-.288	-.370	-.199	-.057	-.004	.004
2	.000	.050	.062	.058	.023	.058	.034	.008	.001
3	.000	.067	.102	.137	.175	.107	.030	.000	.003
4	.000	.000	.000	.000	.000	.000	.000	.000	.005
5	.000	-.043	-.070	-.095	-.123	-.070	-.018	.000	.002
6	.000	.025	.034	.043	.052	.031	.017	.008	-.000
7	.000	.274	.402	.549	.705	.407	.123	.000	.005
8	.000	-.238	-.363	-.484	-.612	-.341	-.103	-.011	.004
9	.000	.289	.433	.592	.746	.424	.131	.000	.005
10	.000	.052	.121	.202	.274	.105	.004	.004	.008
11	.000	-.008	-.011	-.014	-.016	-.004	.003	.006	-.000
12	.000	.004	.006	.007	.005	.005	.003	.003	-.000
13	.000	-.133	-.204	-.279	-.364	-.206	-.058	-.004	.002
14	.000	.051	.066	.076	.067	.063	.030	.006	.001
15	.000	.065	.101	.137	.171	.101	.027	.002	.002
16	.000	-.246	-.369	-.492	-.644	-.346	-.114	-.014	.005
17	.000	.018	.021	.029	.038	.021	.009	.002	.002
18	.000	-.020	-.031	-.041	-.051	-.030	-.008	.000	-.000
19	.000	.284	.418	.563	.707	.418	.129	.015	.005
20	.000	-.219	-.331	-.455	-.571	-.328	-.103	-.014	.003
21	.000	.274	.409	.548	.692	.413	.130	.010	.005
22	.000	.323	.491	.679	.879	.515	.155	.016	.004
23	.000	.022	.033	.046	.059	.035	.011	-.001	-.000
24	.000	.018	.027	.036	.046	.027	.008	-.002	-.000
25	.000	.000	.000	.000	.000	.000	.112	.008	-.000
26	.000	.220	.329	.456	.560	.324	.099	-.011	.005
27	.000	.000	.000	.000	.000	.000	-.097	.003	.002
28	.000	.267	.398	.540	.682	.409	.131	.006	.006
29	.000	.272	.416	.569	.716	.427	.144	.017	.003
30	.000	.028	.020	.010	.004	-.016	-.004	-.008	.002
31	.000	.202	.303	.405	.500	.302	.098	.012	.002
32	.000	.207	.301	.413	.526	.301	.094	.019	.009
33	.000	.100	.000	.000	.000	.000	.054	.006	.001
34	.000	.000	.000	.000	.000	.000	.130	.013	.001
35	.000	.290	.460	.600	.760	.450	.150	.010	.010
36	.000	-.006	.009	.022	.031	.040	.016	.012	-.000

NOTES:

1. Multiply all deflections by 10^{-1} to get actual values.
2. Measurements of oscillograph trace deflections are accurate to ± 0.01 inches. The last column in this table correlates the transducer movement to 0.01 inches of trace deflection and therefore defines the reading accuracy for each channel.
3. All positive and negative deflection readings denote Retraction and Extension of the transducer respectively.
4. The locations and positions of all deflection transducers are shown in Figures 4, 5 and 6.

Figure A-20

Tabulated Deflection Data, Phase 1 Run 3

PRESSURE VS STRAIN

TEST NO. DATE TESTED RUN PHASE
1343 11 19 65 3 1

PRESSURE									
	0	40	60	80	100	60	20	0	-0
GAGE									
14	0	577	865	1154	1462	865	288	19	19
17	0	857	1257	1657	2057	1219	438	57	19
18	0	628	973	1297	1622	932	324	20	20
24	0	649	953	1257	1581	912	304	20	20
27	0	849	1274	1670	1925	1274	453	57	28
28	0	437	667	875	1083	667	250	42	21
34	0	667	941	1235	1529	843	275	59	20
35	0	-9	28	37	65	47	28	9	9
37	0	868	1264	1698	2132	1358	472	19	19
38	0	196	327	439	579	383	131	9	9
44	0	743	1086	1429	1771	1124	400	57	19
45	0	-303	-440	-578	-679	-431	-138	-9	9
47	0	495	733	952	1210	676	229	38	10
48	0	-187	-271	-346	-402	-243	-84	0	9
54	0	944	1426	1852	2333	1389	481	56	19
55	0	-67	-106	-163	-202	-106	-38	0	10
57	0	145	188	304	377	188	58	-29	14
58	0	-183	-260	-346	-413	-260	-87	10	10
64	0	1000	1451	1804	2157	1392	510	78	20
65	0	-379	-539	-728	-888	-553	-175	-15	15
67	0	217	330	481	651	349	123	38	9
68	0	-537	-796	-1056	-1259	-796	-259	-19	19
74	0	-393	-626	-888	-1209	-597	-175	-44	15
75	0	539	830	1121	1442	786	218	0	15
77	0	748	1140	1570	2019	1121	355	37	19
78	0	592	894	1225	1569	881	275	28	14
84	0	-219	-333	-439	-561	-298	-88	-18	9
85	0	868	1358	1849	2340	1377	491	75	19
87	0	478	730	982	1235	717	239	27	13
88	0	673	1009	1398	1770	991	301	18	18
94	0	0	9	18	26	9	0	-9	9
95	0	841	1252	1720	2150	1234	393	37	19
97	0	133	210	286	362	219	67	-10	10
98	0	804	1234	1645	2093	1196	374	37	19

NOTES:

1. The last digit of the gage number is coded as follows:

- 1 = Meridional Strain
- 2 = Hoop Strain
- 4 = Inside Meridional Strain
- 5 = Inside Hoop Strain
- 7 = Outside Meridional Strain
- 8 = Outside Hoop Strain

2. Gages malfunctioned where values are not shown.

3. Negative values are compressive strain and positive values are tensile strain.

4. Measurements of oscillograph trace deflection are accurate to ± 0.01 inches. The last column in this table correlates the magnitude of strain to 0.01 inches of trace deflection and therefore defines the reading accuracy for each channel.

Figure A-21

Tabulated Strain Data, Phase 1 Run 3

PRESSURE VS STRAIN

TEST NO.	DATE TESTED	RUN	PHASE
1343	11 19 65	3	1

PRESSURE									
GAGE	0	40	60	80	100	60	20	0	1
104	0	86	124	181	219	133	48	-10	10
105	0	841	1262	1766	2215	1262	364	28	28
107	0	153	225	306	378	225	81	0	9
108	0	785	1234	1682	2075	1206	364	0	28
114	0	241	370	500	611	370	130	0	9
115	0	815	1241	1685	2093	1204	370	19	19
117	0	92	-128	-156	-202	-110	-46	-18	9
118	0	714	1071	1464	1839	1054	321	18	18
124	0	9	28	47	66	47	19	-9	9
125	0	876	1327	1858	2283	1301	372	0	27
127	0	152	232	339	420	250	71	-9	9
128	0	818	1227	1691	2100	1200	355	0	27
134	0	-73	-91	-109	-127	-82	-36	-27	9
135	0	673	1027	1398	1699	991	301	18	18
137	0	371	571	771	971	571	171	-14	14
138	0	643	974	1322	1687	957	296	35	17
144	0	584	867	1168	1469	885	265	0	18
145	0	27	55	100	145	55	0	-18	9
147	0	35	61	96	122	61	9	-17	9
148	0	0	9	27	44	9	0	0	9
154	0	509	771	1032	1280	729	206	-28	14
155	0	-43	-43	-43	-52	-43	-26	-9	9
157	0	240	375	510	625	356	106	-10	10
158	0	-45	-45	-36	-27	-27	-27	-27	9
164	0	93	140	187	271	140	47	9	9
165	0	-92	-138	-183	-220	-110	-28	0	9
167	0	-46	-55	-92	-101	-55	-9	-9	9
168	0	-95	-143	-238	-262	-143	-36	0	12
174	0	75	113	160	217	142	75	28	9
175	0	18	18	9	9	27	18	9	9
177	0	36	-90	-126	-144	-81	-27	0	9
178	0	-19	-37	-65	-65	-37	0	0	9
184	0	-65	-84	-121	-121	-47	-19	-19	9
185	0	55	73	91	118	73	27	9	9
187	0	36	45	45	72	27	9	18	9
188	0	73	83	92	128	83	37	28	9

NOTES:

- The last digit of the gage number is coded as follows:
 1 = Meridional Strain
 2 = Hoop Strain
 4 = Inside Meridional Strain
 5 = Inside Hoop Strain
 7 = Outside Meridional Strain
 8 = Outside Hoop Strain
- Gages malfunctioned where values are not shown.
- Negative values are compressive strain and positive values are tensile strain.
- Measurements of oscillograph trace deflection are accurate to ± 0.01 inches. The last column in this table correlates the magnitude of strain to 0.01 inches of trace deflection and therefore defines the reading accuracy for each channel.

Figure A-21

Tabulated Strain Data, Phase 1 Run 3 (Continued)

PRESSURE VS STRAIN

TEST NO. DATE TESTED RUN PHASE
 1343 11 19 65 3 1

PRESSURE	0	40	60	80	100	60	20	0	1
GAGE									
191	0	57	95	105	152	76	38	10	10
192	0	74	120	139	176	102	46	28	9
201	0	218	318	436	564	336	118	27	9
202	0	151	236	283	387	236	94	19	9
214	0	-196	-290	-411	-477	-290	-84	0	9
215	0	284	431	578	734	450	174	37	9
217	0	286	429	562	705	438	171	38	10
218	0	84	159	178	252	140	75	28	9
224	0	-84	-131	-187	-234	-140	-37	0	9
225	0	155	245	309	427	255	109	18	9
227	0	300	473	618	800	491	191	36	9
228	0	139	231	296	380	231	93	9	9
234	0	0	0	-18	-27	-18	0	0	9
235	0	143	200	257	343	219	95	38	10
237	0	170	264	340	453	274	113	28	9
238	0	151	217	292	387	245	104	28	9
244	0	10	30	30	70	40	10	10	10
245	0	83	138	174	229	147	64	9	9
247	0	140	206	262	336	206	93	37	9
248	0	99	218	297	366	228	99	40	10
254	0	-58	-183	-250	-298	-173	-10	38	0
255	0	75	121	150	196	121	56	9	9
257	0	359	544	709	903	563	214	39	10
258	0	178	243	327	421	271	112	47	9
264	0	19	0	19	19	0	0	0	10
265	0	70	70	120	130	70	30	10	10
267	0	284	343	490	588	382	186	88	10
268	0	190	240	380	470	290	110	30	10
274	0	100	100	186	229	100	14	-14	14
275	0	48	36	83	107	48	0	0	12
277	0	151	198	292	377	226	66	0	9
278	0	198	255	368	472	292	104	19	9
284	0	-48	-96	-125	-144	-96	-48	-19	10
285	0	152	200	295	381	229	76	0	10
287	0	286	390	571	686	419	143	19	10
288	0	196	265	392	510	304	98	10	10

NOTES:

- The last digit of the gage number is coded as follows:
 1 = Meridional Strain
 2 = Hoop Strain
 4 = Inside Meridional Strain
 5 = Inside Hoop Strain
 7 = Outside Meridional Strain
 8 = Outside Hoop Strain
- Gages malfunctioned where values are not shown.
- Negative values are compressive strain and positive values are tensile strain.
- Measurements of oscillograph trace deflection are accurate to ± 0.01 inches. The last column in this table correlates the magnitude of strain to 0.01 inches of trace deflection and therefore defines the reading accuracy for each channel.

Figure A-21

Tabulated Strain Data, Phase 1 Run 3 (Continued)

PRESSURE VS STRAIN

TEST NO.	DATE TESTED	RUN	PHASE
1343	11 19 65	3	1

PRESSURE

	0	40	60	80	100	60	20	0	1
GAGE									
294	0	57	57	95	114	57	10	-10	10
295	0	102	111	176	213	139	28	0	9
297	0	200	286	410	524	314	105	10	10
298	0	147	186	284	363	216	59	0	10
304	0	130	180	270	330	210	60	0	10
305	0	67	77	144	154	96	38	0	10
307	0	130	176	259	315	194	83	28	9
308	0	94	129	188	247	141	47	0	12
314	0	-43	-96	-96	-106	-85	-43	0	11
315	0	340	500	700	880	540	190	10	10
317	0	198	257	386	485	277	99	10	10
318	0	210	300	420	530	310	110	10	10
324	0	85	85	142	179	123	38	28	9
325	0	250	390	550	700	420	150	10	10
327	0	37	47	93	121	75	28	0	9
328	0	114	143	200	286	143	48	0	10
334	0	108	137	206	255	157	59	10	10
335	0	243	355	495	626	402	150	28	9
337	0	9	0	9	9	9	0	0	9
338	0	119	149	238	267	149	50	10	10
344	0	565	870	1152	1478	870	304	0	22
345	0	452	683	913	1154	692	240	19	10
347	0	925	1355	1742	2172	1247	387	65	22
348	0	678	1027	1356	1685	1027	349	62	21
355	0	200	324	457	581	371	133	10	10
358	0	447	702	926	1181	718	239	32	16
364	0	709	1000	1255	1600	891	345	55	18
365	0	83	138	183	248	211	101	37	9
367	0	745	1149	1532	1957	1255	447	64	21
368	0	237	390	525	678	424	169	51	17
374	0	706	1059	1412	1804	1098	353	39	20
375	0	-306	-439	-571	-694	-439	-143	-20	10
377	0	457	676	905	1133	619	190	-10	10
378	0	-198	-277	-337	-406	-248	-89	0	10

NOTES:

- The last digit of the gage number is coded as follows:
 1 = Meridional Strain
 2 = Hoop Strain
 4 = Inside Meridional Strain
 5 = Inside Hoop Strain
 7 = Outside Meridional Strain
 8 = Outside Hoop Strain
- Gages malfunctioned where values are not shown.
- Negative values are compressive strain and positive values are tensile strain.
- Measurements of oscillograph trace deflection are accurate to + 0.01 inches. The last column in this table correlates the magnitude of strain to 0.01 inches of trace deflection and therefore defines the reading accuracy for each channel.

Figure A-21

Tabulated Strain Data, Phase 1 Run 3 (Continued)

PRESSURE VS STRAIN

TEST NO. DATE TESTED RUN PHASE
 1343 11 19 65 3 1

PRESSURE	0	40	60	80	100	60	20	0	1
GAGE									
384	0	918	1388	1857	2306	1367	429	41	20
385	0	-97	-136	-184	-233	-136	-39	0	10
387	0	149	248	347	446	238	79	10	10
388	0	-210	-295	-381	-457	-286	-105	-10	10
394	0	558	827	1077	1327	808	269	19	19
395	0	-375	-540	-720	-900	-540	-180	-15	15
397	0	191	304	435	600	304	96	17	9
398	0	-553	-816	-1078	-1325	-816	-262	-29	15
405	0	661	1005	1349	1720	991	330	55	14
408	0	622	919	1216	1541	919	311	54	14
414	0	-275	-404	-532	-688	-385	-119	-9	9
415	0	759	1148	1537	1963	1148	370	74	19
417	0	547	839	1131	1449	852	280	51	13
418	0	686	1029	1410	1790	1029	343	57	19
424	0	18	55	82	127	100	55	9	9
425	0	844	1284	1725	2183	1266	422	73	18
428	0	800	1219	1619	2038	1181	381	57	19
434	0	91	136	182	239	148	57	11	11
437	0	128	202	257	330	202	73	9	9
438	0	861	1277	1723	2168	1277	416	89	30
444	0	245	373	500	618	382	127	18	9
445	0	721	1099	1477	1856	1081	324	36	18
447	0	-88	-123	-158	-193	-105	-35	-9	9
448	0	673	1109	1491	1891	1091	364	55	18
454	0	64	91	118	145	100	55	27	9
457	0	174	257	339	431	266	83	9	9
464	0	-19	-29	-29	-29	-19	-10	-10	10
465	0	697	1061	1424	1788	1061	348	61	15
467	0	398	611	810	1009	611	199	13	13
468	0	679	964	1304	1643	964	304	36	18

NOTES:

- The last digit of the gage number is coded as follows:
 1 = Meridional Strain
 2 = Hoop Strain
 4 = Inside Meridional Strain
 5 = Inside Hoop Strain
 7 = Outside Meridional Strain
 8 = Outside Hoop Strain
- Gages malfunctioned where values are not shown.
- Negative values are compressive strain and positive values are tensile strain.
- Measurements of oscillograph trace deflection are accurate to + 0.01 inches. The last column in this table correlates the magnitude of strain to 0.01 inches of trace deflection and therefore defines the reading accuracy for each channel.

Figure A-21
 Tabulated Strain Data, Phase 1 Run 3 (Continued)

PRESSURE VS STRAIN

TEST NO. DATE TESTED RUN PHASE
 1343 11 19 65 3 1

PRESSURE									
GAGE	0	40	60	80	100	60	20	0	1
474	0	571	893	1196	1482	893	286	0	18
475	0	54	89	116	161	89	27	18	9
477	0	34	67	101	124	79	22	0	11
484	0	397	618	809	1015	588	191	15	15
485	0	0	0	15	29	15	15	15	15
487	0	215	327	439	551	346	112	0	9
488	0	9	19	37	56	28	9	0	9
494	0	73	125	167	208	115	31	0	10
495	0	-99	-158	-208	-267	-149	-50	-10	10
497	0	-20	-30	-40	-70	-30	-10	0	10
498	0	-60	-110	-160	-220	-90	-10	0	10
504	0	45	71	98	134	80	27	0	9
505	0	-41	-62	-93	-113	-72	-21	0	10
507	0	-41	-62	-82	-103	-72	-31	0	10
508	0	-63	-84	-105	-147	-84	-42	-11	11
514	0	-43	-65	-86	-108	-43	-11	-11	11
515	0	10	21	31	41	21	0	-10	10
517	0	30	40	50	60	20	10	0	10
518	0	10	20	20	31	10	0	0	10
521	0	39	69	98	118	59	20	10	10
522	0	52	72	93	113	62	10	0	10
532	0	95	152	210	257	152	48	10	10
544	0	-81	-117	-153	-189	-117	-45	-9	9
545	0	147	225	304	382	225	69	10	10
547	0	140	210	280	360	220	80	20	10
548	0	125	187	250	323	177	52	10	10
554	0	-10	-20	-20	-20	-20	-20	-10	10
555	0	204	306	418	531	316	92	0	10
557	0	74	105	147	189	105	42	11	11
565	0	146	220	305	390	232	73	12	12
567	0	27	40	53	80	67	27	0	13
568	0	103	175	216	309	175	41	0	10

NOTES:

- The last digit of the gage number is coded as follows:
 1 = Meridional Strain
 2 = Hoop Strain
 4 = Inside Meridional Strain
 5 = Inside Hoop Strain
 7 = Outside Meridional Strain
 8 = Outside Hoop Strain
- Gages malfunctioned where values are not shown.
- Negative values are compressive strain and positive values are tensile strain.
- Measurements of oscillograph trace deflection are accurate to + 0.01 inches. The last column in this table correlates the magnitude of strain to 0.01 inches of trace deflection and therefore defines the reading accuracy for each channel.

Figure A-21

Tabulated Strain Data, Phase 1 Run 3 (Continued)

PRESSURE VS STRAIN

TEST NO. DATE TESTED RUN PHASE
1343 11 19 65 3 1

PRESSURE

	0	40	60	80	100	60	20	0	1
GAGE									
574	0	61	73	61	122	85	24	0	12
577	0	13	39	39	66	39	0	-13	13
578	0	358	582	761	985	582	224	0	45
582	0	873	1255	1691	2182	1255	382	109	55
11	0	310	476	762	1262	476	95	24	24
12	0	43	129	214	450	129	0	-43	21
14	0	269	470	784	1388	493	90	0	22
21	0	75	175	350	600	150	75	-25	25
22	0	248	451	772	1252	422	87	0	15
23	0	333	643	1095	1810	619	95	0	24
24	0	208	415	715	1246	392	69	0	23
31	0	244	488	829	1463	488	98	0	24
32	0	71	143	286	548	167	0	-24	24
33	0	115	252	435	779	252	23	0	23
34	0	315	532	968	1597	532	73	-48	24
41	0	-22	-22	-22	-44	-22	-22	0	22
42	0	0	-22	0	0	-22	-22	-22	22
43	0	20	59	79	118	59	20	0	20
44	0	0	0	44	66	44	-22	-22	22
51	0	0	-22	0	0	0	-22	-22	22
53	0	25	0	0	0	0	0	0	25
54	0	0	-29	-57	-29	-29	-29	0	29
61	0	0	0	26	53	26	-26	-53	26
62	0	0	-22	0	0	0	0	-22	22
63	0	-21	-21	-21	-21	-21	-21	-21	21
64	0	28	0	0	0	-57	-85	-113	28

NOTES:

- The last digit of the gage number is coded as follows:
1 = Meridional Strain
2 = Hoop Strain
4 = Inside Meridional Strain
5 = Inside Hoop Strain
7 = Outside Meridional Strain
8 = Outside Hoop Strain
- Gages malfunctioned where values are not shown.
- Negative values are compressive strain and positive values are tensile strain.
- Measurements of oscillograph trace deflection are accurate to + 0.01 inches. The last column in this table correlates the magnitude of strain to 0.01 inches of trace deflection and therefore defines the reading accuracy for each channel.

Figure A-21

Tabulated Strain Data, Phase 1 Run 3 (Continued)

PRESSURE VS DEFLECTION

TEST NO. DATE TESTED RUN PHASE
1343 11 0 65 4 2

PRESSURE	0	200	400	500	600	700	800	900	1000	1100	1200	1300	1350	1375	1400	0
DEFLECTION	0	200	400	500	600	700	800	900	1000	1100	1200	1300	1350	1375	1400	0
1	.000	-.099	-.194	-.241	-.296	-.352	-.407	-.486	-.557	-.628	-.692	-.787	.000	.000	.000	.083
2	.000	.033	.059	.062	.051	.029	-.008	-.060	-.037	-.172	.000	.000	.000	.000	.000	.000
3	.000	.048	.096	.119	.141	.164	.189	.212	.251	.278	.299	.299	.285	.267	.239	-.148
4	.000	-.155	-.335	-.412	-.514	-.529	-.529	-.534	-.529	-.529	-.529	-.529	-.529	-.529	-.529	-.529
5	.000	-.035	-.066	-.082	-.101	-.119	-.145	-.171	-.194	-.218	-.239	-.270	-.300	-.316	-.326	-.003
6	.000	.013	.028	.033	.037	.041	.049	.056	.065	.072	.080	.100	.120	.000	.000	.107
7	.000	.223	.381	.476	.589	.698	.817	.906	1.025	1.134	.000	.000	.000	.000	.000	-.084
8	.000	-.169	-.330	-.403	-.491	-.579	-.671	-.744	-.807	-.869	-.898	-.939	-.924	-.843	-.726	.616
9	.000	.227	.415	.502	.613	.729	.855	.966	1.077	1.207	1.352	1.497	1.560	1.555	1.531	-.227
10	.000	.042	.121	.176	.251	.334	.418	.502	.481	.109	.008	.008	.004	.004	.004	.004
11	.000	-.006	-.009	-.013	-.017	-.020	-.021	-.000	.007	.016	.022	.026	.025	.026	.028	.019
12	.000	.007	.006	.005	.004	.002	.000	.016	.020	.025	.027	.025	.021	.021	.023	.003
13	.000	-.098	-.187	-.235	-.291	-.349	-.416	-.553	-.653	-.749	-.848	-.950	-1.011	.000	.000	.029
14	.000	.031	.065	.072	.077	.074	.054	-.090	-.173	-.247	-.318	.000	.000	.000	.000	.000
15	.000	.049	.091	.116	.140	.163	.190	.259	.302	.346	.452	.384	.368	.346	.315	-.075
16	.000	-.156	-.341	-.417	-.502	-.601	-.720	-.715	-.776	-.871	-.909	-.909	-.914	-.914	-.914	-.909
17	.000	.010	.025	.030	.034	.041	.045	.054	.080	.093	.102	.114	.126	.136	.148	.061
18	.000	-.014	-.027	-.035	-.040	-.048	-.055	-.081	-.091	-.105	-.116	-.128	-.136	-.142	-.144	-.025
19	.000	.237	.397	.490	.594	.702	.805	.924	1.027	1.146	1.260	1.373	1.425	1.440	1.425	-.139
20	.000	-.153	-.306	-.379	-.456	-.543	-.633	-.737	-.817	-.890	-.936	-1.016	-1.019	-.984	-.922	.403
21	.000	.231	.385	.481	.582	.687	.793	.909	1.034	1.163	1.298	1.452	1.529	1.582	1.572	-.005
22	.000	.244	.462	.586	.714	.854	1.024	1.234	1.440	1.709	1.981	.000	.000	.000	.000	.264
23	.000	.013	.035	.043	.054	.064	.077	.074	.084	.097	.116	.139	.157	.170	.177	.045
24	.000	.014	.027	.035	.043	.051	.058	.053	.054	.064	.074	.077	.086	.093	.094	.016
25	.000	.200	.323	.405	.494	.581	.675	.769	.827	.861	.873	.871	.871	.871	.871	.104
26	.000	.193	.310	.386	.473	.559	.646	.743	.836	.952	1.086	1.215	1.275	1.305	1.295	-.087
27	.000	-.134	-.234	-.301	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.060
28	.000	.243	.385	.482	.590	.695	.816	.961	1.130	.000	.000	.000	.000	.000	.000	.486
29	.000	.252	.399	.501	.608	.725	.854	1.007	.000	.000	.000	.000	.000	.000	.000	.903
30	.000	.004	.000	-.002	-.003	-.005	-.007	-.009	-.008	-.007	-.004	.001	.006	.011	.016	.031
31	.000	.176	.276	.347	.421	.498	.580	.691	.799	.000	.000	.000	.000	.000	.000	.327
32	.000	.178	.278	.346	.428	.492	.570	.691	.805	.000	.000	.000	.000	.000	.000	.552
33	.000	.088	.157	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	-.023
34	.000	.227	.365	.460	.560	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.502
35	.000	.261	.413	.522	.631	.745	.876	1.039	.000	.000	.000	.000	.000	.000	.000	.718
36	.000	-.002	.014	.021	.026	.034	.040	.048	.050	.055	.059	.062	.061	.061	.060	.007

NOTES:

1. Multiply all deflections by 10^{-1} to get actual values.
2. Measurements of oscillograph trace deflections are accurate to + 0.01 inches. The last column in this table correlates the transducer movement to 0.01 inches of trace deflection and therefore defines the reading accuracy for each channel.
3. All positive and negative deflection readings denote Retraction and Extension of the transducer respectively.
4. The locations and positions of all deflection transducers are shown in Figures 4, 5 and 6.

Figure A-22

Tabulated Deflection Data, Phase 2 Run 4

A-40

PRESSURE VS STRAIN

TEST NO. DATE TESTED RUN PHASE
1343 11 22 65 4 2

PRESSURE

GAGE	0	200	400	500	600	700	800	900	1000	1100	1200	1300	1350	1375	1400	0
14	0	513	855	1026	1197	1368	1538	1709	2051	2222	2564	2906	3248	3590	3761	1197
17	0	636	1255	1527	1818	2091	2418	2727	3109	3509	4018	4709	5200	5727	5909	2073
18	0	434	867	1084	1283	1482	1699	1898	2151	2440	2801	3470	3994	4410	4753	1807
24	0	388	776	988	1182	1394	1624	1818	2029	2400	2647	3035	3265	3494	3600	1024
27	0	633	1294	1624	1927	2229	2560	2917	3303	3743	4211	4651	4844	4927	4982	661
28	0	442	664	885	885	1106	1327	1549	1770	1991	2434	2655	2655	2655	2655	664
34	0	485	913	1107	1320	1534	1767	1981	2194	2447	2757	3107	3340	3437	3631	835
35	0	-18	-9	18	36	45	63	90	126	171	216	297	342	396	432	9
37	0	641	1301	1612	1922	2252	2660	3068	3573	4097	4680	5223	5437	5515	5534	913
38	0	152	313	402	482	571	661	759	875	1009	1134	1313	1455	1536	1607	232
44	0	509	1018	1255	1473	1709	1964	2164	2436	2709	2964	3218	3382	3436	3509	273
45	0	-228	-421	-509	-596	-684	-754	-816	-877	-939	-1000	-1070	-1105	-1114	-1123	-228
47	0	353	681	836	991	1155	1328	1466	1595	1733	1862	2000	2078	2103	2121	-34
48	0	-148	-259	-315	-361	-398	-435	-463	-491	-509	-537	-574	-574	-574	-574	-148
54	0	673	1308	1607	1925	2224	2561	2860	3140	3495	3850	4224	4411	4542	4617	336
55	0	-59	-119	-136	-169	-203	-229	-254	-288	-314	-339	-356	-364	-364	-364	17
57	0	129	243	300	343	414	500	571	629	686	771	829	886	914	929	-71
64	0	699	1340	1592	1845	2058	2272	2466	2660	2835	3010	3184	3262	3282	3301	563
65	0	-283	-552	-665	-778	-892	-1019	-1132	-1245	-1358	-1458	-1599	-1670	-1726	-1769	-269
67	0	149	297	386	505	634	772	950	1119	1287	1475	1673	1812	1911	1970	-267
68	0	-404	-758	-927	-1096	-1247	-1399	-1551	-1702	-1854	-2006	-2208	-2309	-2410	-2444	-354
75	0	517	862	1034	1207	1379	1724	1897	2069	2241	2414	3103	3793	4138	4828	1897
77	0	536	1071	1339	1607	1964	2232	2589	2946	3304	3750	4286	4732	5089	5179	446
78	0	444	889	1037	1185	1481	1778	1926	2074	2370	2815	3259	3704	3852	4148	1481
84	0	-150	-301	-451	-451	-602	-752	-902	-902	-1053	-1203	-1353	-1353	-1353	-1353	-301
85	0	171	684	1026	1368	2051	2051	2222	2393	2735	3248	4444	5812	6667	7521	3077
87	0	410	718	923	1026	1128	1436	1538	1641	1744	1949	2359	2564	2769	2667	410
88	0	545	909	1273	1455	1636	2000	2364	2545	2909	3273	3818	4909	5273	5636	2182
94	0	0	0	0	0	0	0	0	133	0	-133	-133	-267	-667	-400	-400
95	0	367	1101	1284	1468	1835	2202	2569	2936	3119	3486	4954	6055	6972	7706	3670
97	0	0	268	268	268	403	537	537	537	537	537	537	671	805	805	0
98	0	336	1008	1345	1513	1849	2185	2353	2689	3025	3529	5378	7395	9076	10588	6555

NOTES:

1. The last digit of the gage number is coded as follows:

- 1 = Meridional Strain
- 2 = Hoop Strain
- 4 = Inside Meridional Strain
- 5 = Inside Hoop Strain
- 7 = Outside Meridional Strain
- 8 = Outside Hoop Strain

2. Gages malfunctioned where values are not shown.

3. Negative values are compressive strain and positive values are tensile strain

4. For data reduction accuracy refer to Note 4 of Phase 1 Run 5 data tables.

Figure A-23
Tabulated Strain Data, Phase 2 Run 4

PRESSURE VS STRAIN

TEST NO. DATE TESTED RUN PHASE
1343 11 22 65 4 2

PRESSURE

	0	200	400	500	600	700	800	900	1000	1100	1200	1300	1350	1375	1400	0
GAGE																
104	0	0	122	244	244	244	244	366	366	366	244	122	-244	-854	-1463	-1951
105	0	472	1102	1417	1732	1890	2362	2677	2992	3307	3780	4882	8031	13701	20945	16220
107	0	0	136	272	272	272	408	408	408	408	408	680	992	1224	1497	680
108	0	556	1111	1481	1667	1852	2407	2593	2963	3333	3704	5000	8148	12963	19074	14815
114	0	134	268	403	403	537	671	671	805	940	1074	1342	1879	2416	2953	1879
115	0	241	843	1205	1446	1687	2169	2410	2771	2892	3373	4337	6747	11205	16867	12289
117	0	-176	-176	-176	-264	-264	-264	-264	-264	-352	-441	-617	-793	-1057	-1674	-1410
118	0	360	901	1081	1441	1622	1982	2162	2523	2703	2883	3784	5766	8649	11892	8108
124	0	-132	-132	-132	-132	-132	0	0	132	132	132	132	132	132	132	-132
125	0	360	1081	1441	1622	1982	2523	2703	3063	3423	3964	4685	5766	7207	9009	4505
127	0	0	138	138	138	276	414	414	552	690	690	1103	1379	1517	1517	690
128	0	531	1062	1416	1770	1947	2301	2655	3009	3186	3540	4248	4956	6018	7080	2832
134	0	-214	-214	-214	-214	-214	-214	-214	-107	-107	-107	-107	107	321	428	428
135	0	545	909	1273	1455	1636	2000	2182	2364	2727	2909	3455	3818	4364	4364	909
137	0	177	531	708	708	885	1062	1239	1239	1239	1416	1416	1416	1239	708	-1239
138	0	154	769	1077	1231	1385	1692	1846	2154	2308	2615	2923	3538	3846	4154	615
145	0	-43	86	103	112	121	147	172	207	224	224	241	233	207	155	-267
147	0	36	63	99	117	135	171	189	207	225	216	207	189	135	27	-252
148	0	-63	18	27	9	9	36	45	54	36	27	18	0	-36	-90	-306
154	0	417	722	931	1111	1292	1514	1736	1986	2306	2681	3056	3306	3500	3653	972
155	0	-89	-44	-56	-67	-78	-67	-67	-56	-44	-33	-22	0	-11	-56	-122
157	0	216	351	459	559	640	730	766	793	766	739	667	649	613	577	-604
158	0	-71	-27	-27	-35	-35	-18	-9	9	18	35	71	97	97	62	-80
164	0	17	137	154	171	197	239	274	316	385	436	530	564	573	547	120
165	0	-19	-121	-159	-168	-196	-234	-252	-308	-364	-421	-495	-533	-551	-542	-121
167	0	-9	-53	-70	-79	-88	-96	-105	-132	-158	-193	-228	-254	-254	-228	-61
168	0	-25	-157	-190	-207	-248	-289	-322	-388	-438	-488	-554	-587	-603	-603	-91
174	0	64	92	119	156	183	220	275	349	450	633	872	1055	1248	1404	945
175	0	0	0	0	0	0	0	-18	-54	-98	-161	-250	-321	-375	-411	-321
177	0	-77	-87	-115	-144	-163	-192	-212	-248	-346	-462	-596	-731	-856	-952	-577
178	0	-53	-140	-193	-211	-228	-281	-333	-491	-649	-877	-1175	-1386	-1561	-1632	-1140
184	0	34	-77	-103	-77	-77	-77	-68	-60	-9	85	179	265	359	444	590
185	0	26	61	70	88	105	114	123	132	140	140	140	140	132	123	-61
187	0	-83	37	18	0	0	-9	-18	-83	-147	-257	-376	-477	-569	-642	-587
188	0	27	63	72	90	108	117	126	117	108	90	63	36	18	0	-198

NOTES:

1. The last digit of the gage number is coded as follows:

1 = Meridional Strain
2 = Hoop Strain
4 = Inside Meridional Strain
5 = Inside Hoop Strain
7 = Outside Meridional Strain
8 = Outside Hoop Strain

2. Gages malfunctioned where values are not shown.

3. Negative values are compressive strain and positive values are tensile strain.

4. For data reduction accuracy refer to Note 4 of Phase 1 Run 5 data tables.

Figure A-23

Tabulated Strain Data, Phase 2 Run 4 (Continued)

A-42

PRESSURE VS STRAIN

TEST NO. DATE TESTED RUN PHASE
 1343 11 22 65 4 2

PRESSURE

	0	200	400	500	600	700	800	900	1000	1100	1200	1300	1350	1375	1400	0
GAGE																
191	0	0	86	86	86	105	124	152	181	219	257	286	286	276	267	48
192	0	35	88	105	123	140	158	175	175	175	175	167	158	149	149	-123
201	0	0	469	469	469	625	781	781	938	1250	1563	1875	2188	2500	2813	1563
202	0	153	305	305	305	458	458	458	611	763	916	1069	1069	1221	1374	611
214	0	-153	-305	-458	-458	-458	-611	-611	-763	-1069	-1374	-1679	-1985	-2290	-2443	-1374
215	0	0	182	364	545	727	909	1091	1273	1455	1818	2182	2545	2909	3273	1636
217	0	313	469	469	625	625	781	938	938	1094	1250	1406	1563	1719	1875	469
218	0	0	156	156	156	156	313	313	313	469	625	625	781	781	938	313
224	0	-95	-138	-172	-224	-259	-310	-379	-466	-552	-672	-828	-948	-1052	-1138	-517
225	0	121	210	258	315	371	444	524	637	790	1024	1315	1532	1726	1887	1081
227	0	263	412	518	640	754	877	1000	1149	1351	1614	1947	2202	2439	2632	1105
228	0	139	209	252	313	374	435	504	574	678	809	991	1122	1252	1374	565
234	0	-9	-9	-9	-19	-28	-37	-56	-93	-121	-159	-206	-243	-262	-262	-168
235	0	93	167	204	259	306	361	426	509	639	824	1046	1222	1389	1528	870
237	0	128	220	275	339	404	477	569	697	881	1147	1459	1670	1872	2018	1156
238	0	111	204	250	306	352	407	463	519	593	694	815	907	1009	1083	352
244	0	10	21	31	42	42	52	62	73	104	146	187	208	240	260	167
245	0	63	117	135	171	207	252	297	378	477	622	793	910	1036	1126	631
247	0	104	189	226	274	321	377	425	491	566	698	821	906	1000	1057	434
248	0	165	183	239	294	339	394	450	514	606	697	844	954	1055	1128	431
254	0	-168	-168	-168	-168	-336	-336	-504	-504	-672	-672	-840	-1008	-1008	-1008	-336
255	0	0	0	161	161	161	161	323	323	484	645	645	645	806	968	645
257	0	292	438	584	730	876	1168	1314	1460	1752	2628	3212	3796	4088	4964	3066
258	0	0	140	140	280	280	420	420	559	699	979	1259	1399	1538	1818	979
264	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
265	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
267	0	317	317	317	476	476	476	952	1111	1270	1905	2698	3333	3651	4127	2857
268	0	458	458	458	458	611	611	916	916	1069	1221	1832	2137	2595	1985	1679
274	0	0	153	153	305	305	0	305	305	458	611	763	1069	1221	1221	763
275	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
277	0	167	0	0	167	167	167	333	500	667	667	833	1167	1500	1833	833
278	0	0	137	137	274	274	411	548	685	959	1370	1644	1918	2055	2192	1370
284	0	-44	-74	-103	-118	-147	-184	-213	-257	-324	-397	-507	-596	-706	-772	-441
285	0	138	215	269	338	385	446	538	662	815	1000	1231	1415	1592	1738	900
287	0	250	404	485	618	721	824	971	1140	1375	1706	2140	0	0	0	0
288	0	185	267	356	437	511	615	778	1007	1319	1719	2281	0	0	0	556

NOTES:

1. The last digit of the gage number is coded as follows:

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- 8 = Outside Hoop Strain

2. Gages malfunctioned where values are not shown.

3. Negative values are compressive strain and positive values are tensile strain.

4. For data reduction accuracy refer to Note 4 of Phase 1 Run 5 data tables.

Figure A-23

Tabulated Strain Data, Phase 2 Run 4 (Continued)

PRESSURE VS STRAIN

TEST NO. DATE TESTED RUN PHASE
1343 11 22 65 4 2

PRESSURE

	0	200	400	500	600	700	800	900	1000	1100	1200	1300	1350	1375	1400	0
GAGE																
294	0	61	87	96	130	148	139	148	165	183	252	357	435	548	600	261
295	0	96	130	174	209	243	261	270	287	304	348	400	470	522	557	948
297	0	193	284	367	468	550	651	963	1385	2147	0	0	0	0	0	0
298	0	134	214	259	339	393	446	563	750	1000	1375	1875	0	0	0	0
304	0	138	193	239	303	358	394	450	532	661	844	1147	1404	1697	1936	1183
305	0	63	90	117	144	171	180	180	180	180	180	189	198	234	261	-72
307	0	124	181	219	276	324	362	438	552	733	1000	1314	1648	1895	1962	1476
308	0	90	140	200	250	290	340	430	550	620	950	1200	1410	1560	1860	1160
314	0	0	-149	-149	-149	-149	-149	-299	-448	-896	-1493	-2090	-2388	-2985	-3134	-2836
315	0	341	455	568	795	909	1023	1364	1591	2386	3750	5000	5795	6591	7386	5455
317	0	278	139	139	417	556	556	556	1111	1667	1944	2639	3333	3611	4028	3056
318	0	139	139	139	417	417	417	833	1250	1944	3472	5417	6667	7639	8472	7222
324	0	119	0	0	357	0	357	119	119	0	-119	-119	-238	-357	-595	-714
325	0	270	270	541	676	676	811	1081	1351	2027	2838	4189	5270	5811	6757	5135
327	0	0	0	0	0	0	154	308	308	615	769	923	1385	1538	1538	1538
328	0	0	0	0	153	153	305	305	305	763	1527	2290	2748	3206	3817	3053
334	0	0	0	0	146	292	292	292	292	438	584	584	730	730	730	584
335	0	145	290	145	290	435	580	725	870	1304	2029	3043	3768	4348	4928	3623
337	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
338	0	227	227	227	341	341	341	455	455	909	1477	2159	2955	3295	3636	3295
344	0	335	626	772	917	1078	1223	1383	1558	1762	2010	2359	2636	2854	3015	1107
345	0	325	650	813	976	1138	1301	1463	1626	1789	1951	2114	2276	2276	2439	813
347	0	630	1220	1496	1811	2047	2362	2638	2992	3386	3858	4567	5079	5472	5787	1890
348	0	477	925	1150	1402	1626	1879	2103	2383	2720	3140	3925	4542	5047	5411	2187
354	0	442	853	1042	1232	1453	1674	1895	2147	2463	2779	3221	3474	3600	3758	1074
355	0	154	317	404	490	577	673	779	904	1038	1192	1413	1587	1712	1808	433
357	0	651	1330	1613	1925	2264	2575	2915	3283	3679	4047	4387	4557	4585	4642	396
358	0	306	611	750	903	1056	1194	1361	1528	1722	1944	2278	2528	2722	2889	694
364	0	519	981	1173	1385	1596	1827	2058	2308	2558	2904	3268	3519	3673	3808	962
365	0	48	114	152	190	229	276	343	410	514	629	800	914	1000	1048	210
367	0	553	1128	1404	1702	2000	2255	2489	2745	2979	3213	3362	3383	3319	3277	1021
368	0	159	333	429	524	619	714	841	1000	1159	1317	1524	1667	1746	1825	429
374	0	775	1027	1261	1477	1712	1964	2144	2378	2613	2865	3117	3243	3351	3387	306
375	0	-212	-394	-485	-576	-652	-727	-773	-833	-909	-970	-1030	-1045	-1061	-1061	-182
377	0	337	651	791	930	1081	1256	1395	1535	1663	1791	1907	1953	1977	2000	-47
378	0	-135	-252	-297	-342	-387	-423	-441	-459	-486	-505	-523	-532	-532	-523	-144

NOTES:

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- 8 = Outside Hoop Strain

2. Gages malfunctioned where values are not shown.

3. Negative values are compressive strain and positive values are tensile strain.

4. For data reduction accuracy refer to Note 4 of Phase 1 Run 5 data tables.

Figure A-23

Tabulated Strain Data, Phase 2 Run 4 (Continued)

A-44

PRESSURE VS STRAIN

TEST NO. DATE TESTED RUN PHASE
1343 11 22 65 4 2

PRESSURE

	0	200	400	500	600	700	800	900	1000	1100	1200	1300	1350	1375	1400	0
GAGE																
384	0	649	1279	1604	1892	2216	2541	2775	3045	3351	3676	4018	4198	4306	4396	306
385	0	-55	-110	-147	-174	-211	-239	-275	-312	-349	-376	-404	-413	-422	-431	18
387	0	127	235	304	373	441	520	627	706	784	882	961	1010	1039	1059	-59
388	0	-145	-273	-327	-382	-436	-491	-509	-527	-564	-600	-618	-636	-645	-636	-127
394	0	655	1291	1582	1836	2109	2345	2418	2527	2655	2745	2836	2964	3018	3073	527
395	0	-261	-523	-619	-743	-853	-963	-1115	-1225	-1321	-1417	-1528	-1596	-1638	-1665	-275
397	0	139	278	365	452	557	722	1026	1243	1461	1687	1861	2009	2157	2243	-209
398	0	-389	-764	-923	-1111	-1269	-1442	-1615	-1774	-1947	-2048	-2264	-2365	-2423	-2452	-389
404	0	-147	-441	-588	-735	-882	-1176	-1324	-1471	-1618	-1765	-2353	-2500	-2647	-2941	294
405	0	597	1045	1194	1493	1642	1940	2239	2388	2687	2985	3433	3881	4478	4776	1642
407	0	661	992	1322	1653	1983	2314	2479	2645	3140	3636	3967	4298	4793	4793	331
408	0	571	1000	1143	1429	1571	1714	2000	2286	2429	2714	3143	4000	4857	5143	2286
414	0	-141	-282	-423	-563	-704	-704	-704	-845	-986	-1268	-1549	-1549	-1690	-1690	141
415	0	563	1221	1408	1596	1878	2160	2441	2723	3099	3380	4038	4601	5352	5728	1784
417	0	526	921	1053	1184	1316	1579	1711	1842	1974	2237	2632	2895	3158	3289	658
418	0	533	1067	1200	1467	1733	2000	2133	2400	2800	3200	3733	4400	5067	5333	1733
424	0	132	132	132	132	132	132	265	265	265	265	132	0	-132	-397	-662
425	0	533	1067	1333	1733	2133	2267	2533	2933	3200	3600	4400	5333	6267	6800	2667
427	0	-182	-182	-182	-182	-182	-182	0	0	0	0	0	0	0	0	364
428	0	545	1273	1455	1636	2000	2182	2545	2727	3091	3455	4909	6364	7818	8545	4727
434	0	305	305	305	305	305	305	458	458	458	458	458	458	611	458	-153
435	0	602	1203	1504	1805	2105	2406	2857	3158	3459	3759	4511	5263	6015	6917	2556
437	0	98	195	293	293	390	390	488	488	585	488	390	293	0	-390	-976
438	0	556	1204	1481	1759	2037	2130	2593	2963	3241	3704	4815	6296	8704	12037	7778
444	0	120	241	361	482	482	602	723	723	843	964	1205	1446	1687	1928	723
445	0	763	1221	1527	1679	1832	2137	2443	2748	3053	3359	3969	5038	6718	8550	4885
447	0	0	0	0	0	0	0	0	-120	-120	-241	-361	-482	-723	-1205	-964
448	0	565	1130	1356	1582	1808	2034	2373	2712	2938	3164	3729	4520	6102	7458	4068
454	0	136	136	136	136	136	136	136	136	136	136	136	136	136	-136	-408
457	0	315	472	472	472	472	630	630	630	787	945	945	1417	1575	1575	630
458	0	635	1270	1587	1905	2063	2381	2698	3016	3333	3651	4444	5397	6508	6825	3175
464	0	0	0	0	0	0	0	0	0	0	0	0	313	469	625	313
465	0	541	1081	1351	1486	1622	1892	2162	2432	2703	2973	3243	3649	4054	4054	676
467	0	400	533	667	800	933	1067	1333	1467	1600	1600	1600	1600	1333	-533	
468	0	541	1081	1261	1261	1441	1622	1982	2342	2523	2703	3063	3423	3784	3964	901

NOTES:

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- 8 = Outside Hoop Strain

2. Gages malfunctioned where values are not shown.

3. Negative values are compressive strain and positive values are tensile strain.

4. For data reduction accuracy refer to Note 4 of Phase 1 Run 5 data tables.

Figure A-23

Tabulated Strain Data, Phase 2 Run 4 (Continued)

A-45

PRESSURE VS STRAIN

TEST NO. DATE TESTED RUN PHASE
1343 11 22 65 4 2

PRESSURE	0	200	400	500	600	700	800	900	1000	1100	1200	1300	1350	1375	1400	0
GAGE																
474	0	552	862	1103	1207	1517	1724	1931	2121	2345	2569	2793	3155	3224	3241	414
475	0	-34	94	103	111	120	154	188	222	248	265	274	291	265	222	-145
477	0	57	80	115	195	184	195	195	195	207	207	207	161	103	46	-241
484	0	333	583	722	847	986	1167	1292	1444	1625	1833	2083	2278	2417	2514	528
485	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
487	0	203	316	398	481	564	647	707	744	767	752	699	654	609	556	-474
488	0	0	43	43	43	43	78	113	148	209	261	339	391	426	426	209
494	0	19	130	148	176	204	241	278	315	352	426	546	620	648	667	241
495	0	-19	-150	-168	-196	-224	-262	-299	-355	-411	-477	-598	-654	-710	-720	-262
497	0	9	-28	-37	-37	-46	-55	-64	-73	-92	-110	-138	-165	-156	-138	-18
498	0	28	-92	-119	-147	-165	-202	-248	-294	-358	-422	-550	-624	-678	-679	-266
504	0	67	76	105	133	152	190	229	286	371	514	771	933	1029	1171	800
505	0	-19	-58	-67	-77	-96	-115	-144	-183	-250	-327	-433	-490	-558	-587	-385
507	0	-67	-48	-67	-86	-105	-124	-152	-181	-229	-295	-400	-486	-600	-695	-438
508	0	-19	-65	-75	-93	-112	-131	-159	-206	-271	-355	-467	-551	-617	-673	-430
514	0	44	-71	-71	-71	-71	-71	-53	-27	35	133	248	336	442	540	655
515	0	0	27	36	36	45	45	45	45	9	-36	-90	-126	-171	-198	-279
517	0	-75	47	37	28	19	9	0	-19	-65	-150	-234	-299	-355	-430	-458
518	0	11	33	33	44	44	44	33	0	-33	-89	-144	-178	-211	-289	
521	0	-45	63	72	81	90	99	108	117	117	117	117	108	99	90	-99
522	0	27	63	81	99	117	126	135	135	144	144	153	153	153	153	-90
532	0	0	194	194	194	194	194	388	388	388	388	583	777	777	971	388
544	0	-180	-180	-180	-180	-180	-180	-360	-360	-360	-360	-541	-541	-541	-541	-180
545	0	0	0	174	174	174	348	348	348	522	696	870	1043	1217	1391	522
547	0	0	135	135	270	270	405	405	405	541	541	676	676	811	811	135
548	0	97	159	204	248	292	336	389	460	558	690	867	1009	1044	1221	611
554	0	0	0	0	0	0	0	0	-160	-160	-320	-320	-320	-320	-320	-320
555	0	209	314	419	419	524	628	733	942	1152	1466	2094	2513	2932	3246	1990
557	0	53	80	106	133	159	186	221	274	354	460	611	708	805	858	513
558	0	58	83	108	133	158	183	208	250	300	392	500	600	700	767	442
565	0	174	348	348	348	348	522	522	696	696	870	1043	1391	1565	1739	870
567	0	0	0	0	172	172	172	172	172	172	172	172	172	172	345	0
568	0	172	172	345	345	345	517	517	690	690	862	1034	1207	1379	1724	1034

NOTES:

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- Gages malfunctioned where values are not shown.
- Negative values are compressive strain and positive values are tensile strain
- For data reduction accuracy refer to Note 4 of Phase 1 Run 5 data tables.

Figure A-23
Tabulated Strain Data, Phase 2 Run 4 (cont.)

PRESSURE VS STRAIN

TEST NO. DATE TESTED RUN PHASE
1343 11 22 65 4 2

PRESSURE

	0	200	400	500	600	700	800	900	1000	1100	1200	1300	1350	1375	1400	0
GAGE																
574	0	0	0	0	0	0	0	174	174	174	174	174	348	348	522	174
577	0	0	0	110	110	110	110	220	220	220	220	220	220	220	220	0
578	0	374	374	374	561	561	748	748	935	935	1121	1308	1495	1495	1495	748
582	0	638	1064	1489	1702	1915	2340	2766	2979	3404	3830	4468	5745	7021	8723	4681
11	0	196	424	587	783	1141	1598	2446	3130	3880	4793	6163	7272	8283	0	587
12	0	78	157	209	287	417	652	600	835	1148	1591	2374	3209	4096	4878	809
14	0	216	486	649	892	1243	1811	2757	3459	4243	5135	6459	0	0	0	-27
22	0	163	419	535	791	1116	1535	1953	2395	2930	3581	4791	5860	6791	7326	1535
23	0	243	649	865	1216	1703	2405	3135	3811	4514	5324	0	0	0	0	946
24	0	143	400	543	771	1114	1543	1971	2457	2971	3657	4800	3143	7143	7800	686
31	0	186	451	611	876	1274	1779	2283	2894	3478	4142	5018	5735	6292	6717	-1009
32	0	56	167	222	361	528	778	1000	1333	1694	2056	2556	3000	3417	3778	-583
33	0	81	243	324	486	730	1027	1297	1622	1973	2351	2919	3432	3919	4324	-811
34	0	229	571	743	1029	1486	2057	2600	3171	3714	4371	5314	6057	6629	7086	-1229
41	0	0	-28	-28	-28	-56	-56	-194	-389	-694	-1056	-1444	-1611	-1722	-1806	-1722
42	0	26	26	26	52	52	52	-52	-181	-362	-621	-931	-1060	-1164	-1241	-1448
44	0	0	27	53	80	80	106	106	80	27	0	-53	-80	-106	-133	-531
51	0	26	53	53	53	79	79	105	158	158	105	-53	-158	-211	-263	-579
52	0	0	0	28	28	28	28	-57	-170	-311	-509	-651	-792	-849	-1075	
54	0	0	-28	-28	-28	-55	-83	-220	-413	-633	-908	-1183	-1376	-1514	-1596	-1459
61	0	27	54	80	107	107	134	161	188	80	-27	-187	-295	-348	-375	-991
62	0	0	29	29	29	29	29	29	-57	-171	-286	-486	-629	-686	-743	-829
63	0	0	0	27	27	27	27	-54	-134	-268	-429	-643	-750	-804	-750	-857
64	0	0	28	28	56	56	84	84	56	-56	-224	-364	-505	-561	-617	-1093

NOTES:

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2. Gages malfunctioned where values are not shown.

3. Negative values are compressive strain and positive values are tensile strain

4. For data reduction accuracy refer to Note 4 of Phase 1 Run 5 data tables.

Figure A-23
Tabulated Strain Data, Phase 2 Run 4 (cont.)

PRESSURE VS STRAIN

TEST NO. DATE TESTED RUN PHASE
1348 12 7 65 5 2

PRESSURE		0	200	300	400	500	600	700	800	900	1000	1100	1200	1300	1350	1386	1
GAGE																	
14	0	190	381	571	762	952	1143	1333	1333	1524	1714	1905	2095	2095	2286	190	
15	0	213	426	638	851	851	1064	1277	1277	1489	1702	1915	2128	2128	2340	213	
17	0	556	926	1111	1296	1667	1852	2037	2222	2407	2778	3148	3333	3519	3704	185	
18	0	561	748	935	1121	1308	1495	1682	1869	2056	2243	2430	2617	2804	3178	187	
24	0	571	571	762	952	1143	1333	1524	1524	1714	2095	2286	2476	2476	2667	190	
27	0	755	943	1132	1509	1698	2075	2264	2642	2830	3019	3396	3585	3774	3962	189	
28	0	364	545	727	909	1091	1091	1273	1455	1455	1636	1818	1818	2000	2182	182	
34	0	374	561	748	935	1121	1308	1495	1682	1869	2056	2243	2430	2617	2804	187	
35	0	0	187	187	187	187	187	187	187	374	374	374	374	374	374	187	
37	0	748	935	1121	1495	1682	2056	2243	2617	2804	2991	3364	3738	3925	4112	187	
38	0	185	370	370	556	556	741	741	741	926	1111	1296	1481	1481	185		
44	0	423	673	923	1154	1385	1615	1827	2038	2269	2481	2712	2923	3000	3096	19	
45	0	-149	-230	-310	-379	-437	-506	-563	-632	-701	-747	-793	-839	-862	-885	11	
47	0	294	456	603	750	897	1044	1191	1338	1500	1662	1809	1956	2029	2074	15	
48	0	-101	-130	-174	-188	-217	-246	-275	-304	-333	-362	-377	-391	-391	-406	14	
54	0	579	879	1215	1495	1776	2112	2374	2654	2972	3290	3589	4000	0	0	19	
55	0	-58	-77	-106	-135	-163	-202	-231	-260	-288	-317	-346	-365	-385	-394	10	
57	0	118	191	265	338	412	485	559	632	706	779	853	926	971	1000	15	
58	0	-88	-132	-176	-206	-250	-294	-338	-368	-397	-426	-471	-500	-515	-515	15	
65	0	-198	-311	-425	-524	-623	-764	-877	-991	-1090	-1160	-1245	-1344	-1373	-1415	14	
67	0	284	455	625	773	966	1170	1318	1489	1625	1773	1920	2080	2159	2216	11	
68	0	-281	-442	-603	-737	-911	-1058	-1205	-1339	-1500	-1634	-1768	-1888	-1942	-1996	13	
75	0	367	734	917	1101	1284	1468	1651	1835	2018	2202	2385	2569	2752	2936	183	
77	0	727	1091	1455	1818	2182	2364	2727	3091	3273	3636	4000	4364	4727	4909	182	
78	0	374	561	748	935	1121	1308	1495	1682	1869	2243	2430	2617	2617	2804	187	
84	0	-370	-370	-556	-556	-741	-741	-926	-926	-1111	-1111	-1111	-1111	-1111	-1111	185	
85	0	522	870	1043	1391	1739	1913	2261	2609	2957	3130	3478	3826	4000	4174	174	
87	0	187	561	748	748	748	748	935	935	1121	1308	1495	1682	2056	2430	187	
88	0	357	714	893	1071	1429	1607	1786	2143	2321	2679	3036	3393	3571	3571	179	
94	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	179	
95	0	545	727	1091	1273	1636	2000	2364	2545	2909	3273	3636	4000	4182	4364	182	
97	0	0	109	109	109	219	219	219	328	328	328	437	437	437	437	109	
98	0	342	684	855	1197	1538	1709	2051	2222	2564	2906	3248	3419	3761	3932	171	

NOTES:

1. The last digit of the gage number is coded as follows:

1 = Meridional
2 = Hoop
4 = Inside Meridional Strain
5 = Inside Hoop Strain
7 = Outside Meridional Strain
8 = Outside Hoop Strain

2. Gage malfunctioned where values are not shown.

3. Negative values are compressive strain and positive values are tensile strain.

4. Measurements of oscillograph trace deflection are accurate to ± 0.01 inches. The last column in this table correlates the magnitude of strain to 0.01 inches of trace deflection and therefore defines the reading accuracy for each channel. The accuracy of each channel during Phase 1 Run 4 is the same as shown on this table.

Figure A-24

Tabulated Strain Data, Phase 2 Run 5

A-48

PRESSURE VS STRAIN

TEST NO. DATE TESTED RUN PHASE
1343 12 7 65 5 2

PRESSURE	0	200	300	400	500	600	700	800	900	1000	1100	1200	1300	1350	1386	1
GAGE																
104	0	0	0	0	182	182	182	364	364	364	364	364	364	364	364	182
105	0	561	748	935	1308	1682	2056	2430	2804	2991	3178	3738	4299	4486	4673	187
107	0	0	0	187	187	187	187	187	187	187	187	374	374	374	561	187
108	0	367	550	917	1284	1651	1835	2018	2385	2569	2752	3119	3486	4037	4404	183
114	0	0	0	0	194	388	388	388	388	388	388	583	583	583	777	194
115	0	531	885	1062	1416	1770	1947	2301	2655	2832	3186	3540	3894	4071	4248	177
117	0	-187	-187	-374	-374	-374	-561	-561	-561	-561	-561	-561	-561	-561	-561	187
118	0	360	541	721	901	1261	1441	1622	1982	2162	2523	2883	3063	3243	3243	180
124	0	0	0	-182	-182	-182	-182	-182	-182	-182	-182	-182	-182	-182	-182	182
125	0	541	901	1081	1441	1802	1982	2342	2703	2883	3243	3604	3964	4144	4505	180
127	0	-187	-187	-187	0	0	0	187	187	187	187	374	374	561	561	187
128	0	351	702	877	1228	1579	1754	2105	2456	2632	2982	3333	3684	3860	4035	175
134	0	-180	-180	-180	-180	-180	-360	-360	-360	-360	-360	-360	-360	-360	-360	180
135	0	360	541	721	901	1261	1441	1622	1982	2162	2342	2703	3063	3243	3423	180
137	0	0	177	354	354	531	708	708	885	885	1062	1239	1416	1416	177	177
138	0	180	360	541	721	1081	1441	1622	1802	1982	2162	2523	2883	3063	3243	180
145	0	186	71	97	133	186	221	292	345	389	451	513	558	575	602	9
147	0	9	46	55	73	92	110	119	128	147	165	183	202	211	220	9
148	0	150	35	44	71	97	124	177	212	239	283	319	354	363	372	9
154	0	186	491	650	810	982	1142	1288	1460	1619	1779	1978	2164	2217	2296	13
155	0	79	-18	-18	-9	9	26	44	61	79	114	140	158	167	167	9
157	0	63	241	321	402	491	563	634	714	786	857	929	1009	1036	1071	9
158	0	61	0	9	26	43	61	78	96	113	139	157	174	191	200	9
164	0	163	88	125	163	200	288	313	338	388	475	588	738	813	900	13
165	0	-152	-87	-109	-152	-196	-239	-293	-326	-370	-435	-500	-587	-630	-674	11
167	0	-69	-40	-59	-79	-99	-119	-129	-139	-158	-218	-277	-347	-396	-416	10
168	0	-175	-112	-150	-200	-237	-300	-375	-425	-475	-525	-600	-687	-750	-775	13
174	0	-12	60	83	107	131	155	167	190	214	226	214	202	202	202	12
175	0	-49	0	0	0	0	-12	-25	-37	-49	-62	-74	-99	-111	-123	12
177	0	0	-55	-73	-92	-110	-138	-156	-165	-183	-165	-147	-101	-73	-55	9
178	0	-46	-37	-46	-64	-73	-92	-110	-128	-147	-174	-202	-229	-248	-266	9
184	0	-165	-47	-71	-94	-118	-141	-176	-212	-235	-282	-341	-400	-424	-435	12
185	0	30	40	60	70	90	100	110	130	140	160	170	180	190	200	10
187	0	177	21	21	31	52	62	83	115	156	208	260	333	385	406	10
188	0	12	37	49	61	73	85	98	110	122	134	146	159	171	171	12

NOTES:

- The last digit of the gage number is coded as follows:
 - Meridional
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 - Inside Meridional Strain
 - Inside Hoop Strain
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 - Outside Hoop Strain
- Gage malfunctioned where values are not shown.
- Negative values are compressive strain and positive values are tensile strain.
- Measurements of oscillograph trace deflection are accurate to ± 0.01 inches. The last column in this table correlates the magnitude of strain to 0.01 inches of trace deflection and therefore defines the reading accuracy for each channel. The accuracy of each channel during Phase 1 Run 4 is the same as shown on this table.

Figure A-24
Tabulated Strain Data, Phase 2 Run 5
A-49

PRESSURE VS STRAIN

TEST NO. DATE TESTED RUN PHASE
 1343 12 7 65 5 2

PRESSURE	0	200	300	400	500	600	700	800	900	1000	1100	1200	1300	1350	1386	1
GAGE																
191	0	99	42	56	85	99	127	155	183	211	254	282	310	324	338	14
192	0	27	54	68	95	108	122	135	149	176	203	230	243	257	257	14
201	0	0	0	180	180	360	360	360	541	541	721	721	901	901	1081	180
202	0	0	0	0	0	190	190	190	381	381	381	381	571	571	762	190
214	0	-182	-364	-364	-545	-545	-727	-727	-727	-727	-727	-909	-909	-1091	-1091	182
215	0	183	183	367	367	550	550	734	734	917	917	1101	1284	1284	1468	183
217	0	0	189	377	377	377	566	566	755	755	943	943	1132	1132	1132	189
218	0	0	0	0	0	0	182	182	182	182	182	182	364	364	364	182
224	0	-25	-101	-152	-177	-215	-253	-291	-316	-354	-405	-456	-506	-532	-557	13
225	0	37	134	195	244	293	341	390	439	500	549	610	671	707	732	12
227	0	76	278	392	506	595	684	772	861	962	1051	1165	1278	1329	1392	13
228	0	25	125	188	250	300	338	388	438	488	538	600	663	700	738	13
234	0	-12	-24	-24	-35	-35	-47	-47	-59	-71	-71	-82	-94	-106	-118	12
235	0	11	112	157	191	236	281	315	348	393	438	483	528	551	573	11
237	0	33	150	200	250	317	367	417	467	517	567	633	700	750	800	17
238	0	44	111	178	244	289	333	378	422	467	511	578	644	667	711	22
244	0	0	0	0	23	23	23	23	47	47	47	47	70	70	70	23
245	0	22	67	89	133	156	178	200	244	267	289	333	378	400	422	22
247	0	51	128	179	231	282	308	359	410	462	487	538	590	615	667	26
248	0	42	125	167	208	271	312	354	396	437	479	521	583	625	646	21
254	0	-190	-381	-381	-571	-571	-571	-571	-571	-571	-571	-571	-571	-571	-571	190
255	0	-190	-190	0	0	0	0	0	0	0	0	0	0	190	381	190
257	0	0	163	325	488	650	650	650	813	976	976	1138	1301	1463	1626	163
258	0	0	0	0	0	187	187	187	374	374	374	561	561	748	748	187
264	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	171
265	0	0	168	168	168	168	168	168	168	168	168	168	336	336	336	168
267	0	0	194	194	388	388	388	583	583	583	583	777	777	971	971	194
268	0	167	333	333	500	500	500	500	667	667	833	833	1000	1000	1000	167
274	0	167	167	333	333	333	333	333	500	500	500	667	667	667	667	167
275	0	500	500	500	500	667	667	667	667	667	667	667	667	667	667	167
277	0	0	0	169	169	339	339	339	508	508	508	678	678	678	847	169
278	0	0	165	331	496	496	661	826	992	661	661	826	826	992	992	165
284	0	-8	-49	-66	-74	-90	-115	-131	-148	-172	-197	-230	-254	-279	-287	8
285	0	40	145	202	258	306	363	395	444	492	540	605	661	694	726	8
287	0	56	262	355	449	542	636	701	785	879	972	1075	1178	1215	1271	9
288	0	50	188	267	347	396	475	535	604	673	752	842	921	980	1030	10

NOTES:

1. The last digit of the gage number is coded as follows:

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- 8 = Outside Hoop Strain

2. Gage malfunctioned where values are not shown.

3. Negative values are compressive strain and positive values are tensile strain.

4. Measurements of oscillograph trace deflection are accurate to ± 0.01 inches. The last column in this table correlates the magnitude of strain to 0.01 inches of trace deflection and therefore defines the reading accuracy for each channel. The accuracy of each channel during Phase 1 Run 4 is the same as shown on this table.

Figure A-24

Tabulated Strain Data, Phase 2 Run 5

A-50

PRESSURE VS STRAIN

TEST NO. DATE TESTED RUN PHASE
1343 12 7 65 5 2

PRESSURE	0	200	300	400	500	600	700	800	900	1000	1100	1200	1300	1350	1386	1
GAGE																
294	0	20	71	112	143	163	173	194	214	245	265	286	306	316	327	10
295	0	31	94	135	167	198	219	240	271	323	344	365	385	406	427	10
297	0	19	57	67	76	76	86	86	95	105	114	133	143	143	152	10
298	0	29	59	78	88	98	98	108	118	127	127	137	147	147	157	10
304	0	29	126	184	233	282	320	369	417	456	505	553	612	631	660	10
305	0	10	68	97	126	155	175	194	214	252	262	282	301	320	330	10
307	0	20	118	157	206	235	275	314	343	382	422	471	510	529	559	10
308	0	20	109	158	218	238	267	297	337	386	436	475	525	545	574	10
314	0	0	0	0	163	163	0	-163	-163	-163	-163	-163	-163	-163	-163	163
315	0	165	331	496	661	826	992	992	1157	1157	1322	1488	1653	1653	1818	165
317	0	-241	0	241	482	482	241	241	482	482	482	723	723	723	964	241
318	0	0	161	323	484	645	645	645	645	806	968	1129	1129	1129	1290	161
324	0	0	0	163	325	325	325	325	325	325	325	325	325	325	488	163
325	0	0	140	280	420	559	699	839	839	979	1119	1259	1399	1538	1678	140
327	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	165
328	0	0	167	167	167	167	167	167	333	333	333	500	500	500	667	167
334	0	0	167	167	167	167	333	333	333	333	333	333	333	333	500	167
335	0	0	194	388	583	583	583	583	777	777	971	971	1165	1165	1359	194
337	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	167
338	0	0	0	0	167	167	167	167	167	333	333	333	500	500	500	167
344	0	190	381	571	762	952	952	1143	1333	1524	1714	1905	2095	2286	2095	190
345	0	325	488	650	813	976	1138	1301	1463	1626	1789	1951	2114	2276	2439	163
347	0	374	748	1121	1308	1682	1869	2056	2243	2617	2991	3178	3364	3551	3738	187
348	0	187	561	748	935	1121	1308	1495	1682	1869	2056	2243	2430	2617	2804	187
354	0	313	469	625	781	938	1094	1250	1406	1561	1719	1875	2031	2188	2344	156
355	0	190	190	381	381	571	571	571	762	762	952	1143	1333	1333	1333	190
357	0	381	762	1143	1333	1524	1905	2095	2286	2667	3048	3238	3429	3619	3810	190
358	0	374	374	561	748	748	935	1121	1308	1495	1682	1869	2056	2056	2056	187
364	0	367	550	734	917	1101	1284	1468	1651	1835	2018	2202	2385	2385	2569	183
365	0	0	0	0	0	0	0	187	187	374	374	561	561	748	748	187
367	0	388	583	777	1165	1359	1748	1942	2136	2330	2718	2913	3107	3301	3495	194
368	0	0	189	377	377	566	566	755	755	943	1132	1132	1132	1321	1321	189
374	0	416	656	912	1136	1360	1584	1808	2032	2240	2448	2688	2880	2976	3040	16
375	0	-148	-216	-295	-352	-420	-489	-534	-602	-659	-716	-784	-830	-852	-875	11
377	0	276	448	586	736	874	1034	1184	1310	1471	1609	1770	1931	1977	2034	11
378	0	-105	-132	-171	-211	-237	-263	-276	-303	-329	-355	-382	-395	-408	-408	13

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- 8 = Outside Hoop Strain

2. Gage malfunctioned where values are not shown.

3. Negative values are compressive strain and positive values are tensile strain.

4. Measurements of oscillograph trace deflection are accurate to ± 0.01 inches. The last column in this table correlates the magnitude of strain to 0.01 inches of trace deflection and therefore defines the reading accuracy for each channel. The accuracy of each channel during Phase 1 Run 4 is the same as shown on this table.

Figure A-24
Tabulated Strain Data, Phase 2 Run 5
A-51

PRESSURE VS STRAIN

TEST NO. DATE TESTED RUN PHASE
1343 12 7 65 5 2

PRESSURE

GAGE	0	200	300	400	500	600	700	800	900	1000	1100	1200	1300	1350	1386	1
384	0	543	874	1166	1457	1722	2040	2331	2623	2901	3219	3523	3841	3960	4079	13
385	0	-71	-82	-106	-141	-188	-224	-247	-282	-318	-353	-376	-412	-424	-435	12
387	0	134	209	284	358	433	522	597	687	776	851	925	1000	1045	1090	15
388	0	-115	-149	-195	-230	-264	-310	-333	-368	-402	-448	-483	-506	-517	-529	11
394	0	377	574	770	951	1115	1295	1459	1623	1803	2033	2213	2426	2492	2541	16
395	0	-193	-297	-416	-520	-639	-743	-832	-936	-1025	-1129	-1218	-1292	-1337	-1351	15
397	0	263	461	618	803	1000	1197	1382	1566	1737	1895	2053	2224	2303	2368	13
398	0	-309	-456	-603	-765	-926	-1103	-1235	-1368	-1515	-1676	-1794	-1926	-1985	-2029	15
404	0	-696	-870	-1043	-1391	-1565	-1739	-1913	-2087	-2435	-2609	-2783	-2957	-3130	-3478	174
405	0	348	696	1043	1217	1391	1739	1913	2087	2261	2609	2783	3130	3304	3478	174
407	0	645	1129	1613	1935	2258	2581	2903	3226	3548	3871	4194	4516	4839	5000	161
408	0	508	678	1017	1186	1356	1695	1864	2203	2373	2542	2712	2881	3220	3390	169
414	0	-336	-504	-504	-672	-840	-840	-1008	-1176	-1345	-1513	-1513	-1681	-1849	-2017	168
415	0	513	684	1026	1368	1709	2051	2393	2564	2735	3077	3419	3761	3932	4103	171
417	0	351	702	1053	1228	1404	1579	1754	1930	2105	2281	2456	2632	2807	2982	175
418	0	522	696	1043	1217	1565	1913	2087	2435	2609	2783	3130	3304	3478	3826	174
424	0	0	0	174	174	174	348	348	348	348	348	348	348	348	348	174
425	0	348	696	1217	1739	1913	2087	2261	2435	2609	2783	2957	3304	3652	4000	174
428	0	522	696	1043	1391	1739	2087	2261	2435	2783	3130	3478	3652	3826	4000	174
434	0	0	0	174	174	174	174	174	174	174	174	348	348	348	348	174
437	0	-351	-175	0	0	175	351	175	175	175	351	351	351	351	351	175
438	0	345	690	1034	1379	1724	2069	2241	2586	2759	3103	3448	3621	3793	3966	172
444	0	168	168	336	504	504	672	672	672	672	840	840	840	1008	1008	168
445	0	500	833	1167	1333	1500	1833	2000	2333	2500	2833	3167	3500	3667	3833	167
447	0	-169	-169	-169	-169	-169	-169	-339	-339	-339	-339	-339	-339	-339	-508	169
448	0	522	870	1043	1217	1565	1913	2087	2261	2435	2783	3304	3478	3652	3652	174
454	0	-342	-171	0	0	0	171	171	171	171	171	171	171	171	171	171
455	0	508	847	1186	1525	1864	2203	2542	2881	3220	3390	3898	4068	4237	4407	169
457	0	0	179	179	357	357	536	536	536	536	714	714	714	714	714	179
458	0	513	855	1197	1538	1709	2051	2393	2564	2906	3248	3590	3932	4103	4274	171
464	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	171
465	0	171	513	684	855	1197	1709	1880	2051	2222	2564	3077	3248	3419	3590	171
467	0	168	336	504	672	840	840	1008	1008	1008	1176	1176	1345	1345	1513	168
468	0	531	708	885	1239	1416	1593	1770	2124	2301	2655	2832	3009	3186	3363	177

NOTES: 1. The last digit of the gage number is coded as follows:

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- 8 = Outside Hoop Strain

2. Gage malfunctioned where values are not shown.

3. Negative values are compressive strain and positive values are tensile strain.

4. Measurements of oscillograph trace deflection are accurate to ± 0.01 inches. The last column in this table correlates the magnitude of strain to 0.01 inches of trace deflection and therefore defines the reading accuracy for each channel. The accuracy of each channel during Phase 1 Run 4 is the same as shown on this table.

Figure A-24

Tabulated Strain Data, Phase 2 Run 5

STRAIN, DEFLECTION AND STRESS DATA REDUCTION

PRESSURE VS STRAIN

TEST NO. DATE TESTED RUN PHASE
1348 12 7 65 5 2

PRESSURE	0	200	300	400	500	600	700	800	900	1000	1100	1200	1300	1350	1386	1
GAGE																
474	0	185	588	807	1008	1210	1412	1563	1731	1916	2034	2269	2454	2538	2622	17
475	0	178	68	102	136	169	220	280	322	373	432	475	500	508	525	8
477	0	17	52	70	96	113	130	139	157	174	183	209	235	243	243	9
484	0	179	410	564	705	846	987	1103	1218	1346	1462	1615	1756	1821	1872	13
487	0	51	212	305	381	441	525	576	644	703	763	831	890	915	941	8
494	0	154	167	141	154	192	231	282	321	372	462	615	782	872	949	13
495	0	-160	-160	-160	-173	-222	-259	-321	-370	-407	-481	-580	-691	-741	-790	12
497	0	-62	-25	-37	-50	-62	-75	-100	-112	-125	-175	-237	-312	-350	-387	13
498	0	-150	-75	-100	-150	-175	-225	-287	-350	-412	-462	-575	-725	-775	-850	13
504	0	-41	41	68	82	96	110	123	137	151	151	137	123	110	96	14
505	0	-62	-49	-74	-86	-111	-123	-148	-173	-185	-210	-247	-272	-309	-321	12
507	0	30	-40	-59	-69	-79	-79	-89	-89	-99	-69	-10	40	69	89	10
508	0	-62	-62	-72	-93	-113	-134	-165	-175	-196	-227	-268	-320	-340	-371	10
514	0	-206	-59	-88	-103	-118	-147	-176	-221	-250	-309	-368	-412	-456	-471	15
515	0	27	27	27	27	41	41	54	68	81	81	81	81	81	81	14
517	0	184	23	34	46	69	103	138	161	184	253	322	391	437	460	11
518	0	43	43	43	43	43	43	43	64	85	85	85	64	64	64	21
521	0	117	65	65	91	117	143	169	195	234	260	286	325	338	351	13
522	0	50	50	63	88	100	113	125	138	163	175	188	188	200	200	13
531	0	0	0	167	167	167	167	167	333	500	500	500	500	667	667	167
532	0	0	0	0	0	155	155	155	155	310	310	310	310	310	310	155
544	0	0	0	0	0	0	0	-180	-180	-180	-360	-360	-360	-360	-360	180
545	0	0	163	163	325	325	325	488	488	488	488	650	650	650	650	163
547	0	0	157	157	157	157	315	315	315	472	472	472	630	630	630	157
548	0	0	160	160	160	160	320	320	480	480	480	480	480	480	640	160
554	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	161
555	0	284	284	426	426	567	567	709	851	851	851	993	993	1135	1135	142
557	0	0	142	142	142	142	142	284	284	426	426	426	426	426	426	142
558	0	0	0	0	146	146	146	292	292	292	438	438	584	730	730	146
564	0	0	0	0	0	0	190	190	190	190	381	381	381	381	381	190
565	0	0	0	180	180	180	180	360	360	360	541	541	541	541	541	180
567	0	0	0	183	183	183	183	183	183	183	183	183	183	183	183	183
568	0	190	190	190	190	381	381	381	571	571	571	571	571	762	762	190

NOTES: 1. The last digit of the gage number is coded as follows:

- 1 = Meridional
- 2 = Hoop
- 4 = Inside Meridional Strain
- 5 = Inside Hoop Strain
- 7 = Outside Meridional Strain
- 8 = Outside Hoop Strain

2. Gage malfunctioned where values are not shown.

3. Negative values are compressive strain and positive values are tensile strain.

4. Measurements of oscillograph trace deflection are accurate to ± 0.01 inches. The last column in this table correlates the magnitude of strain to 0.01 inches of trace deflection and therefore defines the reading accuracy for each channel. The accuracy of each channel during Phase 1 Run 4 is the same as shown on this table.

Figure A-24

Tabulated Strain Data, Phase 2 Run 5

A-53

STRAIN, DEFLECTION AND STRESS DATA REDUCTION

PRESSURE VS STRAIN

TEST NO. DATE TESTED RUN PHASE
1348 12 7 65 5 2

PRESSURE																
	0	200	300	400	500	600	700	800	900	1000	1100	1200	1300	1350	1386	1
GAGE																
574	0	180	180	180	180	360	360	360	360	360	360	360	360	360	360	180
575	0	0	192	192	192	192	385	385	577	577	577	577	577	577	577	192
578	0	0	0	0	0	182	182	182	182	182	364	364	364	364	545	182
582	0	721	901	1261	1441	1802	2162	2523	2883	3243	3604	4144	4505	4865	5045	180
11	0	935	1484	2032	2645	3290	3968	4581	5226	5645	6258	7129	7839	8226	8645	32
12	0	382	627	873	1091	1336	1582	1827	2100	2427	2809	3191	3600	3764	3982	27
14	0	1032	1613	2258	2935	3677	4419	5097	5774	6419	7065	7742	8419	9065	9194	32
21	0	500	781	1063	1250	1438	1625	1813	2063	2313	2625	3000	3375	3563	3875	31
22	0	832	1337	1842	2376	2911	3475	4040	4634	5198	5733	6624	0	0	0	30
23	0	1083	1667	2333	3056	3972	4611	5333	6111	6833	0	0	0	0	0	28
24	0	678	1043	1383	1748	2139	2557	2870	3209	3600	3991	4383	4774	5296	5400	26
31	0	835	1330	1904	2426	2948	3522	4096	4670	5217	0	0	0	0	0	26
32	0	433	711	990	1299	1608	1948	2258	2598	2938	3309	3680	4082	4299	4515	31
33	0	247	557	928	1268	1639	2041	2412	2814	3186	3619	4052	4485	4701	4918	31
34	0	928	1454	2041	2567	3155	3773	4299	4887	5474	6093	6711	7330	7639	7979	31
41	0	0	0	0	0	0	-32	-32	-32	-32	-32	-63	-95	-95	-126	32
42	0	0	31	61	61	61	92	92	122	122	122	122	122	122	122	31
44	0	31	31	63	63	94	125	156	188	219	250	281	313	344	344	31
51	0	0	0	0	31	31	62	93	124	155	186	216	216	216	247	31
52	0	0	0	0	0	32	32	65	97	97	129	129	161	161	161	32
54	0	0	0	-31	-31	-31	-31	-62	-62	-62	-94	-125	-156	-156	-187	31
61	0	30	61	91	121	152	212	273	333	394	455	515	545	576	606	30
62	0	0	0	0	0	32	32	32	63	63	63	95	95	95	95	32
63	0	0	0	0	0	33	33	66	99	132	198	297	396	429	462	33
64	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

NOTES: 1. The last digit of the gage number is coded as follows:

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- 8 = Outside Hoop Strain

2. Gage malfunctioned where values are not shown.

3. Negative values are compressive strain and positive values are tensile strain.

4. Measurements of oscillograph trace deflection are accurate to + 0.01 inches. The last column in this table correlates the magnitude of strain to 0.01 inches of trace deflection and therefore defines the reading accuracy for each channel. The accuracy of each channel during Phase 1 Run 4 is the same as shown on this table.

Figure A-24

Tabulated Strain Data, Phase 2 Run 5

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Figure A-25 - Strain Gages - Inside View of Cylinder
(Photograph No. 1265-SP-762)

Figure A-26 - Strain Gages - Inside View of Forward Closure
(Photograph No. 1265-SP-767)

Figure A-27 - Deflection Instrumentation - Forward Closure Joint (Photograph No. 1165-SP-1470)

Figure A-28 - Deflection Instrumentation - Hot Bleed Port
(Photograph No. 1165-SP-1467)

Figure A-29 - Deflection and Strain Gage Instrumentation
of Upper Cylinder and Nozzle at 152°30'
(Photograph No. 1165-SP-1466)

APPENDIX B
CALCULATIONS

NOZZLE HOT BLEED PORT BOSS ROTATIONS

The arrows show the calculated direction of rotation at 530 psig

The rotation in radians of the hot bleed port boss is calculated by the following method.

$$\beta = \text{Rotation in radians} = \frac{\text{Deflection at the inboard gage} - \text{Deflection at the outboard gage}}{\text{Distance Between Gages}}$$

Given: Deflection = 0.0200" at gage 25, Pressure 150 psig
 Deflection = 0.0193" at gage 26, Pressure 150 psig
 Deflection = 0.0176" at gage 31, Pressure 150 psig
 Deflection = 0.0178" at gage 32, Pressure 150 psig
 Deflection = 0.0559" at gage 25, Pressure 530 psig
 Deflection = 0.0581" at gage 26, Pressure 530 psig
 Deflection = 0.048" at gage 31, Pressure 530 psig
 Deflection = 0.0492" at gage 32, Pressure 530 psig

Determine the rotation described by gages 25, 26 and 31, 32 at 150 psig.

$$\beta = \frac{0.0193 - 0.0200}{4.86} = \frac{-0.0007}{4.86} = 0.00014 \text{ radians, at gages 25, 26}$$

$$\beta = \frac{0.0178-0.0176}{8.00} = \frac{0.0002}{8.00} = 0.00002 \text{ radians, at gages 31, 32}$$

Determine the rotation described by gages 25, 26 and 31, 32

$$\beta = \frac{0.0581-0.0559}{4.86} = \frac{0.0022}{4.86} = 0.0004 \text{ radians, at gages 25, 26}$$

$$\beta = \frac{0.0492-0.0498}{8.00} = \frac{-0.0006}{8.00} = 0.000075 \text{ radians, at gages 31, 32}$$

NOZZLE-PRESSURE VESSEL CYLINDER FLANGE ROTATIONS

Figure Gage numbers are given for the 153° 30' Meridian. Equivalent numbers for the 333° 30' Meridian are as follows: 7 = 19, 8 = 20, 9 = 21, and 10 = 22.

The rotation in radians of the nozzle is calculated by the following method.

Rotation in radians =

$$\frac{\text{Deflection at inboard gage} - \text{Deflection at outboard gage}}{\text{Distance Between Gages}}$$

Determine the nozzle flange rotation (β)

At 153° 30'

Given: Deflection at 9 = 0.0731 in.
 Deflection at 10 = 0.0283 in.
 Pressure in Nozzle = 560 psig
 Pressure in Pressure Vessel = 740 psig
 Distance Between Gages = 8.00 in.
 Deflection at 21 = 0.0899 in.
 Deflection at 22 = 0.0700 in.

$$\beta_{153^\circ 30'} = \frac{0.0731 - 0.0283}{8.00} = \frac{0.0448}{8.00} = 0.0056 \text{ radians}$$

At $333^{\circ} 30'$

$$\beta_{333^{\circ} 30'} = \frac{0.0899 - 0.0700}{8.00} = 0.0025 \text{ radians}$$

Show direction of flange rotation about its center of gravity.

This direction is shown by the values of gages 10 and 22 being less than gages 7 and 19, showing that the beam tends to move down at the outboard gage.

Determine the pressure vessel cylinder aft flange rotations

Given: Deflection at 7 = 0.0694 in.
Deflection at 8 = -0.0548 in.
Deflection at 19 = 0.0694 in.
Deflection at 20 = -0.0558 in.

Find: The rotation at the Pressure Vessel Cylinder Aft Flange

Change the sign on gages 8 and 20 to + because the negative reading is caused by gage position, while the beam tends to move upward at both gages

At $153^{\circ} 30'$

$$\beta_{153^{\circ} 30'} = \frac{0.0694 - 0.0548}{8.00} = \frac{0.0146}{8.00} = 0.0018 \text{ radians}$$

At $333^{\circ} 30'$

$$\beta_{333^{\circ} 30'} = \frac{0.0701 - 0.0558}{8.00} = \frac{0.143}{8} = 0.0018 \text{ radians}$$

Show the flange rotation about its center of gravity

This direction is shown by the values of gages 8 and 20 being less than gages 9 and 21, indicating that the beam tends to move down at the outboard gage.

Determine the differential rotation of the Nozzle/Pressure Vessel Cylinder Flanges.

$\Delta\beta$ = Nozzle Flange β - Pressure Vessel Cylinder Flange β because the rotation is in the same direction

At $153^\circ 30'$

$$\Delta\beta_{153^\circ 30'} = 0.0056 - 0.0018 = 0.0038 \text{ radians}$$

At $333^\circ 30'$

$$\Delta\beta_{333^\circ 30'} = 0.0025 - 0.0018 = 0.0007 \text{ radians}$$

Determine the Gap at the Nozzle/Pressure Vessel Joint

Given: $\Delta\beta_{153^\circ 30'} = 0.0038$ radians
 $\Delta\beta_{333^\circ 30'} = 0.0007$ radians
 Values shown in figure

40.380" P.V. Aft Flange I.D.
 42.000" Bolt Circle ϕ Diameter
 44.000" P.V. Aft Flange O.D. and Shear Lip I.D.

Find the:

Width of the P.V. flange

$$W_{\text{flange}} = \frac{44,000 - 40,380}{2} = \frac{3,620}{2} = 1.81''$$

Distance from the Q_L of the Bolt Circle to the I.D. of the flange

$$D_{Q_L \text{ Bolt}} = \frac{42,000 - 40,380}{2} = \frac{1,620}{2} = 0.81''$$

Gap if differential rotation pivots at the Q_L of the bolt circle

$$G = D \times \Delta\beta$$

$$G_{153^\circ 30'} = 0.81 (0.0038) = 0.003078''$$

$$G_{333^\circ 30'} = 0.81 (0.0007) = 0.000567''$$

Gap if differential rotation pivots at the shear lip

$$G = W \times \Delta\beta$$

$$G_{153^\circ 30'} = 1.81 (0.0038) = 0.006878''$$

$$G_{333^\circ 30'} = 1.81 (0.0007) = 0.001267''$$

Determine the effect of bolt preload at ambient temperature

Given: $A_{VF} = 0.994 \text{ in.}^2$, effective area on cylinder flange

$L_{VF} = 1.955 \text{ in.}$, length of Keensert

$E_{VF} = 10 \times 10^6 \text{ psi}$, E Value for Aluminum (4)

$P_i = 33,800 \text{ lb}$, bolt preload

$A_{NF} = 1.4 \text{ in.}^2$, effective area nozzle flange

$L_{NF} = 1.290 \text{ in.}$, nozzle bolt grip length

$E_{NF} = 29 \times 10^6 \text{ psi}$, E Value for 347 Stainless Steel (4)

$$\delta_T = \frac{P_i L_{NF}}{A_{NF} E_{NF}} + \frac{P_i L_{VF}}{A_{VF} E_{VF}}$$

Find the compression of the nozzle flange and deformation of the pressure vessel flange

$$\delta_T = \frac{33,800 (1.290)}{1.4 (29) (10^6)} + \frac{33,800 (1.955)}{0.994 (10) (10^6)}$$

$$\delta_T = 0.00107 + 0.00665$$

$$\delta_T = 0.00772''$$

Determine if the initial δ is exceeded

Given: If $\delta - G$ is positive δ has not been exceeded

If $\delta - G$ is negative δ has been exceeded

Find the $\delta - G$ relation

$$\delta - G_{153^\circ 30'} = 0.00772 - 0.00688 = 0.00084'' \text{ at Port Meridian}$$

$$\delta - G_{333^\circ 30'} = 0.00772 - 0.00127 = 0.00645'' \text{ opposite the Port}$$

PRESSURE VESSEL CYLINDER/CLOSURE FLANGE ROTATION CALCULATIONS

Figure Gage Numbers are given for the 153° 30' Meridian. Equivalent numbers for the 333° 30' Meridian are as follows:

1 = 13, 2 = 14, 3 = 15, and 4 = 16

The rotation in radians of the pressure vessel cylinder and forward closure flanges are calculated by the same method used for the nozzle/pressure vessel cylinder flanges. Therefore, one calculation is shown for example at 740 psig.

Given: Deflection at 3 = -0.0576 in.

Deflection at 4 = 0.0193 in.

Deflection at 1 = -0.0370 in.

Deflection at 2 = 0.0023 in.

Determine cylinder and closure flange rotation (β).

$$\beta_{153^\circ 30'} = \frac{-0.0576 - 0.0193}{8.00} = \frac{-0.0769}{8.00} = -0.0096 \text{ radians, cylinder}$$

$$\beta_{153^\circ 30'} = \frac{-0.0370 - 0.0023}{8.00} = \frac{-0.0393}{8.00} = -0.0049 \text{ radians, closure}$$

Find the differential rotation of the flanges ($\Delta\beta$).

$$\Delta\beta = -0.0096 - (-0.0049) = 0.0047 \text{ radians}$$

The values for the differential flange rotations were average for both sides because of the similarity of the rotation values.

Determine the gap at the pressure vessel forward joint.

Given: $\Delta\beta = 0.0016$ radians at 300 psig
 $\Delta\beta = 0.0025$ radians at 450 psig
 $\Delta\beta = 0.0035$ radians at 600 psig
 $\Delta\beta = 0.0048$ radians at 740 psig

Assumptions:

1. The pressure vessel cylinder is solid at A.
2. Assume pivot point to occur at the bolt circle centerline or at the shearlip point B.

Find:

The tendency to gap at the inside diameter ID of the joint pivoting at the bolt circle.

$$\begin{aligned} \text{Gap} &= \Delta\beta(\text{distance from pivot point to joint ID}) \\ \text{Gap} &= 0.0016 (1.125) = 0.0020" \text{ at 300 psig} \\ \text{Gap} &= 0.0025 (1.125) = 0.0027" \text{ at 450 psig} \\ \text{Gap} &= 0.0035 (1.125) = 0.0039" \text{ at 600 psig} \\ \text{Gap} &= 0.0048 (1.125) = 0.0054" \text{ at 740 psig} \end{aligned}$$

The tendency to compress (C) at B with rotation at bolt circle C_L .

$$C = \Delta\beta(\text{distance from pivot point to B})$$

$$C = 0.0016 (0.995) = 0.0015 \text{ in. at 300 psig}$$

$$C = 0.0025 (0.995) = 0.0025 \text{ in. at 450 psig}$$

$$C = 0.0035 (0.995) = 0.0035 \text{ in. at 600 psig}$$

$$C = 0.0048 (0.995) = 0.0048 \text{ in. at 740 psig}$$

The flange compression δ (in) for ambient temperature preload conditions

$$\delta = \frac{P_I L_F}{A_F E_F}$$

$$P_I = 33,800 \text{ lb--Preload}$$

$$L_F = 1.4 \text{ in.--Bolt Grip length}$$

$$A_F = 1.33 \text{ in.}^2\text{--assumed area over which preload is initially distributed.}$$

$$E_F = 10 \times 10^6 \text{ psi--for Aluminum Ref (4)}$$

$$\delta = \frac{33,800 (1.4)}{1.33 (10) (10^6)} = 0.0036"$$

The pressure at which preload compression and compression at B are equal is 565 psig as shown in the figure below:

The gap at the ID of the pressure vessel assuming pivoting occurs at B.

$$\text{Gap} = 0.0048 (2.120) = 0.0102 \text{ in.}$$

$$\Delta\text{Gap} = \text{Gap because of rotation} - \text{Bolt preload flange compression.}$$

$$\Delta\text{Gap} = 0.0102 - 0.0036 = 0.0066 \text{ in.}$$

APPENDIX B-2

FAILURE ANALYSIS SUMMATION OF CALCULATIONS

The following calculations predict a burst pressure of 1460 psi chamber pressure for the original pressure vessel design with failure occurring in the midbarrel position. The predicted failure pressure due to local stresses at the tapped holes in the thick portion of the cylinder was 1450 psi for the original 3/8 inch diameter holes and 1370 psi for the enlarged 1/2 inch diameter holes.

PRESSURE VESSEL BURST PRESSURE

The maximum distortion energy theory of failure is best fitted for hydrostatic tests assuming this theory is applicable at failure gives:

$$(\sigma_1 - \sigma_2)^2 + (\sigma_2 - \sigma_3)^2 + (\sigma_3 - \sigma_1)^2 = 2 F_{TU}^2$$

For thin shells $\sigma_3 = 0$

$$\sigma_1^2 - 2 \sigma_1 \sigma_2 + \sigma_2^2 + \sigma_2^2 + \sigma_1^2 = 2 F_{TU}^2$$

$$\sigma_1 = 2 \sigma_2$$

$$4 \sigma_2^2 - 2 \cdot 2 \sigma_2^2 + \sigma_2^2 + \sigma_2^2 + 4 \sigma_2^2 = 2 F_{TU}^2$$

$$(4 - 4 + 1 + 1 + 4) \sigma_2^2 = 2 F_{TU}^2$$

$$\sigma_2^2 = \frac{F_{TU}^2}{3}$$

$$\sigma_2 = \frac{F_{TU}}{\sqrt{3}} = \frac{pr}{2t}$$

$$\therefore P_{burst} = \frac{2 F_{TU} t}{\sqrt{3} R} = 1.154 \frac{F_{TU} t}{R}$$

Cylindrical Section

Using the maximum distortion energy theorem of failure.

$$P_{burst} = 1.154 \frac{F_{TU} t}{R}$$

For $\therefore F_{TU_{Min}} = 42 \text{ ksi}$ $t = 0.67 \text{ in.}$

$$R = 24.875 \text{ in.}$$

$$P_{burst} = \frac{1.154 (42,000) (.67)}{24.875} = 1305 \text{ psi}$$

for $F_{TU} = 47,000 \text{ psi}^*$

$$P_{burst} = 1460 \text{ psi}$$

*This value obtained from test on material from same lot as burst unit.

Cylindrical Section with Tapped Holes

Flat plate theory will be used for local web stresses

The stress concentration factor on yield for a plate with a hole varies from 2.0 to 3.0 depending upon the loading. However, when yielding does occur redistribution of the local peak stress will begin and as load continues to increase the presence of inelastic action penetrates to a greater distance into the as yet unyielded material. The peak stress level remains at the material yield allowable until the entire section is yielded. Now the stress concentration factor would be reduced to unity, and the only reduction in the allowable loading due to the holes would be the decrease in area. However, this assumes an unlimited amount of material over which redistribution may occur. In the case at hand the distance is limited to the distance between holes and the stress concentration factor may not be as low as 1.0.

Stress level at which yielding occurs across the full web width

$$F_{TY} = \frac{\sigma_o}{2} \left[2 + \left(\frac{R}{X} \right)^2 + 3 \left(\frac{R}{X} \right)^4 \right]$$

where: X = distance of penetration of inelastic strain

For the stress to be $> F_{TY}$ across full distance between holes

$$X \geq 1.0 \text{ in. } R = 3/16$$

$$X \geq 5.34R$$

$$\therefore F_{TY} = \frac{\sigma_o}{2} \left[2 + \left(\frac{1}{5.34} \right)^2 + 3 \left(\frac{1}{5.34} \right)^4 \right]$$

$$\therefore F_{TY} = \frac{\sigma_o}{2} [2 + .035 + .003] = \frac{2.038}{2} \quad \sigma_o = 1.017 \quad \sigma_o$$

$$\therefore \sigma_o = .983 F_{TY}$$

$\therefore$ Web yields slightly before that part away from hole area.

$\therefore$ It will be assumed that the same stress concentration occurs at failure

$$\text{i.e. } K_T = \frac{1}{.983} = 1.017$$

Considering the meridional direction the distance for the effect of the hole to become negligible, i.e., the distance from the hole that its effect has diminished, will be 5.34R.

$\therefore$ The net section width will be:

$$2(5.34R) - 2R = 8.68R$$

$$\therefore \text{Area Ratio} = \frac{8.68}{10.68} = 81.3\%$$

$$\therefore \sigma_{NET} = \frac{pr}{2t} \times \frac{1}{.813} = \frac{p^R}{1.63t} < \sigma_{HOOP}$$

Therefore the hoop direction is definitely the critical direction.

Considering the hoop direction only we have two holes on a meridian two inches apart. The web, or material, between the holes is the critical area.

Yielding will occur at the edge of the hole and penetrate into the web as the load increases. The effect of one hole on the other will meet at a stress level of 98% of the material yield allowable. Since this is so close to 100% it is felt that, for failure to occur, the effect of one hole must

have penetrated across the full web width or for a distance of $(2 - d)$ inches. Also a net section width should be chosen such that the effect of the holes is negligible at the edge of the section. This section width must then be $(6 - d)$ inches as shown in the following diagram.

In section with tapped holes $t_{CYL} = 0.78$

For cylinder W/O holes

$$P_{burst} = 1460 \times \frac{.78}{.67} = 1700 \text{ psi}$$

However holes will reduce area from $(6 - d)t$ to $(6 - 3d)t$.

$$\therefore P_{burst} = \frac{6 - 3d}{6 - d} \left(\frac{1700}{K_T} \right) \quad d = 3/8$$

$$\therefore P_{burst} = \frac{4.875}{5.625} \left(\frac{1700}{1.017} \right) = 1450 \text{ psi}$$

During burst test the plugs in these holes were ejected at 1400 psi chamber pressure. The holes were enlarged to $d = 1/2$ in. and the chamber was repressurized to burst. Burst pressure was 1380 psi.

for $d = 1/2$ in.

$$P_{\text{burst}} = \left(\frac{6 - 1.5}{6 - .5} \right) \left(\frac{1700}{1.017} \right) = 1370 \text{ psi.}$$

BIAXIAL GAIN-STRESS

Determine the change (Bi-axial gain) when comparing theoretical stress versus actual stress at ultimate.

$$\sigma_H = \frac{pr}{t}$$

$$\sigma_H = 47,000 \text{ psi determined experimentally for 6061-T6 vessel used}$$

$$t = 0.78 \text{ inch}$$

$$r = 24,875$$

$$\therefore P_t = \frac{47,000 (.78)}{24,875} = 1472 \text{ psig theoretical}$$

$$P_{k_t} = P_t \left(\frac{1}{K_t} \right) = 1472 \left(\frac{1}{1.23} \right) = 1200$$

$$P_{Act} = 1380 \text{ psig}$$

$$K_{B.G.} = \frac{P_{Act}}{P_{K_t}} = \frac{1380}{1200} = \underline{\underline{1.142}}$$

$$\text{Biaxial Gain \%} = (K_{BG} - 1) 100 = (1.142 - 1) 100 = 14.2\%$$

STRESS INTENSIFICATION FACTOR--CAUSED
BY THE INSTRUMENTATION BOSSES

Determine the stress intensification caused by the instrumentation bosses at the forward end of the pressure vessel cylinder.

Given: F_{ult} = 47,000 psi determined experimentally
 P_f = 1380 psig at failure with holes
 $P_{f,the}$ = 1700 psig failure without holes, theoretical
 d = 1/2 inch diameter holes

Let $K_t = \frac{P_{f,the}}{P_f}$ = the stress intensification factor

$$\therefore K_t = \frac{1700}{1380} = \underline{\underline{1.23}}$$

The percent of initial theoretically determined pressure is reduced at the 1/2 in. hole to the following:

$$\% = \frac{1}{K_t} = \frac{1}{1.23} = 81.3\%$$

APPENDIX C
THEORETICAL ANALYSIS

APPENDIX C

THEORETICAL ANALYSIS

The pressure vessel was analyzed with a computerized finite element method which determines displacements and stresses within axisymmetric solids. The continuous body (nozzle closure or cylinder) is replaced by a system of elements with triangular or quadrilateral cross sections. The points at the intersecting sides of these elements are called nodal points and are positioned by radial and axial coordinates. Displacements are calculated for the nodal points and stresses are calculated for the elements.

The pressure vessel was analyzed for the two zone hydrotest condition.

The pressure vessel and nozzle are proof pressure hydrotested to 740 and 560 psig respectively in the attitude and configuration shown below.

PRESSURE VESSEL PROOF TEST CONFIGURATION AND ATTITUDE

The aft ring of the cylinder is bolted to the nozzle. The pressure vessel components and the nozzle are theoretically separated at the bolted interfaces and each component is analyzed separately. The interactions are accommodated by applying discontinuity moments and shears as well as axial loads to the bolted face of each component so that the compatibility of the entire structure is maintained. The discontinuity moments must be determined to obtain bolt loads.

The forward joint compatibility must also be established. The axial loads and discontinuities are applied in the following figure.

PRESSURE VESSEL FORWARD JOINT FREE BODY

The values of the discontinuity moment M_1 and shear Q_1 are determined by applying chamber pressure, unit moment and unit shear to both the closure and the cylinder to obtain influence coefficients for each loading condition for each structural component. From these six computer runs, equations for rotation and radial deflection are written for each pressure vessel component. These equations are in terms of the unknown discontinuities, influence coefficients and pressure. The following equations are given as examples:

1. Cylinder radial deflection at the cylinder to closure interface,

$$\omega_{\text{cyl.}} = K_1 M_1 + K_2 Q_1 + K_3$$

2. Cylinder rotation at the interface,

$$\theta_{\text{cyl.}} = K_4 M_1 + K_5 Q_1 + K_6$$

3. Closure radial deflection at the interface,

$$\omega_{\text{clos.}} = K_7 M_1 + K_8 Q_1 + K_9$$

4. Closure rotation at the interface

$$\theta_{\text{clos.}} = K_{10} M_1 + K_{11} Q_1 + K_{12}$$

where:

ω	=	radial deflection
θ	=	rotation
Q_1	=	discontinuity shear
M_1	=	discontinuity moment
K 's	=	influence coefficients

The unknown discontinuities are then determined by equating the radial deflection and rotation of the cylinder to the radial deflection and rotation of the closure,

$$\text{i.e., } \omega_{\text{cyl.}} = \omega_{\text{clos.}}$$

$$\text{a) } K_1 M_1 + K_2 Q_1 + K_3 = K_7 M_1 + K_8 Q_1 + K_9$$

$$\theta_{\text{cyl.}} = \theta_{\text{clos.}}$$

$$\text{b) } K_4 M_1 + K_5 Q_1 + K_6 = K_{10} M_1 + K_{11} Q_1 + K_{12}$$

Simultaneous solution of equations a) and b) above yields values for M_1 and Q_1 .

The discontinuity moment and shear and pressure loading are now applied to the pressure vessel components for a complete solution.

The computer runs for the theoretical portion of this report "B" are on file in the REON Stress Department.

CALCULATION OF LOADS IN
FWD CLOSURE - CYLINDER JOINT

$$A = 5.286 \text{ in.}^2$$

$$I = 3.01 \text{ in.}^4$$

$$N_{34} = 12.44 p$$

From I.B.M. Program No. 663 Solution:

$$M_{34} = -1.389 p$$

$$\omega_{34} = -.0000362 p$$

$$Q_{34} = .1783 p$$

$$\theta_{32} = \theta_{34} = .00001295 p$$

$$\Sigma M_{cg} R_{cg} = \Sigma M_i R_i$$

$$= -M_{33} \times 26 + Q_{33} \times 1.18 \times 27.13 + [M_{34} + Q_{34} \times 1.61 + N_{34} \times .73]$$

$$25.27 + 2.92 p \quad (.15) \quad 24.88 + .45 p \quad (.90) \quad 25.1$$

$$= -26 M_{33} + 32 Q_{33} + \frac{-35.13 p}{25.27 (-1.389 p)} + \frac{7.25 p}{40.67 \times .1783 p}$$

$$+ \frac{229.5 p}{18.45 \times 12.44 p} + 10.92 p + 10.16 p$$

$$= -26 M_{33} + 32 Q_{33} + 222.7 p$$

$$\theta = \frac{R_{cg}}{EI} \sum M_i R_i = \frac{26}{(10)^7} 3.01 \quad \sum M_i R_i = \frac{.864}{(10)^6} \sum M_i R_i$$

$$\theta = (10)^{-6} [-22.45 M_{33} + 27.63 Q_{33} + 192.5p]$$

$$R_{cg}^2 \sum Q_{cg} = R_{cg}^2 \sum Q_i \frac{R_i}{R_{cg}}$$

$$\sum Q_i R_i = Q_{33} \times 27.13 - Q_{34} \times 25.27 - 2.92p \times 24.88$$

$$= 27.13 Q_{33} - \frac{4.5p}{.1783p \times 25.27} - 72.6p$$

$$= 27.13 Q_{33} - 77.1p$$

$$\omega_{CG} = \frac{R_{cg}}{AE} \sum Q_i R_i - A_{CG_c - CG_1} \times \theta$$

$$= \frac{26}{5.286(10)^7} (27.13 Q_{33} - 77.1p) - 1.23 \times .00001295p$$

$$= (10)^{-6} [.492 (27.13 Q_{33} - 77.1p) - 1.23 \times 12.95p]$$

$$= (10)^{-6} (13.34 Q_{33} - 53.88p)$$

$$\omega_{34} = \omega_{CG} - A_{CG_1 - 34} \times \theta$$

$$= (10)^{-6} (13.34 Q_{33} - 53.88p) - 1.61 (10)^{-6} 12.95p$$

$$= (10)^{-6} (13.34 Q_{33} - 74.72p)$$

$$p = -(10)^{-6} 36.2 (13.34 Q_{33} - 74.72 p$$

$$Q_{33} = \frac{-36.2 p + 74.72 p}{13.34} = \frac{38.52 p}{13.34} = 2.888 p$$

Using rotation equation, previous page

$$\theta(10)^6 = -22.45 M_{33} + 27.63 Q_{33} + 192.5 p$$

$$12.95 p = \frac{-22.45 M_{33} + 27.63 \times 2.888 p + 192.5 p}{79.9 p + 272.4 p} + 192.5$$

$$M_{33} = \frac{27.63 \times 2.888 p + 192.5 p - 12.95 p}{22.45} = 12.14 p$$

CALCULATION OF CLOSURE
BOLT LOADS, HYDROTEST CONDITION

$$M_{33} = 12.14p \frac{\text{in.-lb}}{\text{in.}}$$

$$P_p = \frac{R_s^2 p}{2 R_{B.C.}} = \frac{(26.65)^2 p}{2 \times 26} = 13.66 p \text{ lb/in.}$$

$$P_m = M_{33}/e = 12.14/1.0 = 12.14 p \text{ lb/in.}$$

$$P_b = P_p + P_m = (13.66 + 12.14) p = 25.80 p \text{ lb/in.}$$

$$P = \frac{2\pi R_{B.C.} P_b}{N} = \frac{2\pi \times 26 \times 25.8p}{120} = 35.1p \text{ lb/bolt}$$

REQUIRED PRELOAD:

Pt. No. 286664 (702999 for A4) for A1, A2, and A3*

A 286 Bolt, $E = 29 (10)^6$ psi, $D_G = .520$ " min., 120 bolts, equally spaced.

$F_{ty} = 180,000$ psi

6061-T6, $E = (10)^7$

0.83 in. Washer (K-seal) ID

* -11, -13, and -21 are drilled--
used only where instrumentation
required

Spring constant of compressed material (closure flange and K-seal):

Take washer (K-seal) OD and washer "Solid" ID for the washer, and washer OD and bolt hole D. in the flange, as the effective compression area limits.

$$\begin{aligned}\frac{1}{K_c} &= \frac{1}{K_{\text{washer}}} + \frac{1}{K_{\text{flange}}} = \left(\frac{L}{AE} \right)_{\text{washer}} + \left(\frac{L}{AE} \right)_{\text{flange}} \\ &= \frac{1}{\frac{\pi}{4} (10)^6} \left[\frac{.084}{\frac{(1.34^2 - .95^2) 29}{.893}} + \frac{1.44}{\frac{(1.34^2 - .65^2) 10}{1.373}} \right] \\ &= \frac{4}{\pi} (10)^{-6} \left[\frac{.10804}{.00324 + .1048} \right] = .1376 (10)^{-6}\end{aligned}$$

$$K_c = (10)^6 7.27$$

Spring constant of bolt:

Take effective spring length as length of grip from head to first thread = 1.5 in. approximately.

$$K_b = \frac{AE}{L} = \frac{\pi (.520)^2 29 (10)^6}{4 \cdot 1.5} = 4.10 (10)^6$$

Relative stiffness parameters:

$$\frac{K_c}{K_c + K_B} = \frac{7.27}{7.27 + 4.10} = .64$$

$$\frac{K_B}{K_B + K_C} = \frac{4.10}{11.37} = .36$$

Required Preload (min. for sealing at maximum extension load),

$$P_{i_{\min.}} = \frac{K_C}{K_C + K_B} \times P = .64 \times 35.1p = 22.45p \text{ lb/bolt}$$

Because of the difficulty in attaining accurate tensile preload values through use of torque wrenches, assume that the tensile loads may deviate $\pm 25\%$ from the specified (nominal) value.

$$P_{i_{\text{nom.}}} - .25 P_{i_{\text{nom.}}} = P_{i_{\min.}} = 22.45p$$

$$P_{i_{\text{nom.}}} = \frac{22.45p}{.75} = 29.93p$$

$$P_{i_{\max.}} = 29.93p \times 1.25 = 37.4p$$

Bolt Loads, Stresses and Maximum Stresses

Total maximum bolt load,

$$\begin{aligned} P_{\max.} &= P_{i_{\max.}} + \frac{K_B}{K_B + K_C} P \\ &= 37.4p + (.36) 35.1p \\ &= (37.4 + 12.64)p = 50.04p \end{aligned}$$

Maximum bolt stress,

$$\sigma = \frac{P_{\max.}}{\pi D^2/4} = \frac{50.04p}{\pi (.520)^2/4} = \frac{50.40p}{.2123} = 236p$$