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PHOEBUS 2 CF/2A PRESSURE VESSEL REDESIGNED MAIN CLOSURE STRUCTURAL PROOF TEST SPECIFICATION — PROCEDURE

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1. INTRODUCTION

- 1.1 This report specifies the requirements for conducting a structural test on the Phoebus 2 CF/2A Pressure Vessel Redesigned Main Closure in conjunction with the Phoebus 2 Hydrostatic Test Nozzle. The Pressure Vessel was designed and fabricated by the Albuquerque Division of ACF Industries; the Nozzle was designed and fabricated by the REON Division of Aerojet General Corporation of Sacramento, California.
- 1.2 The test will be conducted in three phases. The First Phase is a hydrostatic structural proof test in which the test assembly will be loaded to simulate the 115% Nuclear Steady State load and extensive structural measurements will be made to determine the elastic behavior of the Main Closure. Internal loading will be simulated, where practical, through the use of differential pressure plenums designated P₁, P₂, P₃, and P₄, as shown in Figure 1. No attempt will be made to simulate the thrust loads. No attempt will be made to simulate thermal loads as the testing will be performed under room temperature conditions. The loading condition was derived as shown in Phoebus 2 Interface Analysis - Part 1, Load Analysis, (Report Number P2-65-6, Rev. B). The Second Phase is a hydrostatic cycling test in which the test assembly will be loaded to simulate 100% of the Nuclear Steady State load for a total of ten cycles. Structural measurements will also be made during the test. The Third Phase will be conducted with the test assembly proof tested while chilled to liquid nitrogen temperatures at a loading which simulates the 100% Nuclear Steady State load. This test will more closely simulate the actual operational temperatures.
- 1.3 The test will be conducted during the month of January 1967 at the test facilities of the Albuquerque Division, ACF Industries, Incorporated.

2. OBJECTIVES

- 2.1 The primary objectives of the test are (1) to verify the structural analysis of the Phoebus 2 CF/2A Pressure Vessel Redesigned Main Closure and to ensure that structural compatibility exists between the Pressure Vessel and the Clamp, and (2) to prove the structural integrity of the design and evaluate the performance of the 7039 material under simulated operational temperatures.

3. RESPONSIBILITIES

- 3.1 H. T. Ried of Department 431 will act as Test Coordinator. Any requested changes or inquiries concerning the test should be directed to him. Deviations from this test specification must be approved by him or his designee. He is also responsible for arranging test schedules and informing interested parties of pertinent information concerning the test.
- 3.2 Department 411, Test Operations, will be responsible for conducting the test.
- 3.3 The Analytical Support Group of Department 431 will assist in evaluating the "raw" data during testing and will complete evaluation of the Pressure Vessel Redesigned Main Closure performance within six weeks after completion of testing. Los Alamos Scientific Laboratory, N-7 Division, will witness all testing and will determine when all test objectives have been accomplished.

Figure 1. Phobos 2 CF/ΔA Structural Test Components

4. DESCRIPTION OF TEST UNITS

- 4.1 Listed below are the items required to conduct the test. Following the nomenclature of each item is the respective contractor's drawing number. The drawing number shall be the latest issue in effect. When more than one of an item is required, the quantity is shown in parentheses following the drawing number. Refer to Figure 1 for the assembly of the test components.
- 4.2 Aerojet General Corporation has provided the following Phoebus 2 test items:
- (a) Pressure Test Nozzle, 1115307
 - (b) Nozzle Bolt, 1115487-5 (126)
 - (c) Nozzle Bolt-Modified, 1115487-7 (18)
 - (d) Nozzle Bolt Seal (144)
- 4.3 ACF Department 431 will provide the following Phoebus 2 test items:
- (a) Pressure Vessel Forward Section, 3-517054
 - (b) Pressure Vessel Aft Section, 3-517053
 - (c) Clamp Ring, 3-515666
 - (d) Clamp Ring Segment, 3-517852 (12)
 - (e) Guide Tube Dummy, 3-516193 (18)
 - (f) Nozzle Omega Seal, 3-515359
 - (g) Wave Ring Seal, 3-516358
 - (h) Support Leg, 3-516308 (6)
 - (i) V-seal, 6-556510 (18)
 - (j) Plug, 3-516289 (72)
 - (k) K-seal, 6-556490 (72)
 - (l) Structural Chamber, 3-516353
 - (m) Test Stand Assembly, 3-516280
 - (n) Lift Band, 3-516326
 - (o) Support Bolt, 3-516535 (18)
 - (p) Nozzle Skirt Seal, 3-516998
 - (q) Seal, Interplenum, P-2

5. DETERMINATION OF LOADS

5.1 General

The following calculations are made to determine the required static test pressures for the Phoebus 2 CF/2A Vessel under the conditions of:

- (a) 3 - Plenum Test - no thrust
- (b) 2 - Plenum Test - no thrust (applies to both hydrostatic and cryogenic tests)

The attempt is made to simulate nuclear steady state (NSS) loads and pressures wherever possible. However, the elimination of thrust from the test results in one or more pressures and/or loads to be different from the NSS value. The correct NSS values, together with certain dimensions, are as described in Reference (1), below. Remaining dimensions are recorded in Reference (2).

5.2 3-Plenum Test

- 5.2.1 Using 100% NSS values from Reference (1), determine total separating force in P. V. wall (= F_{PV}), treating the vessel as a free body:

$$F_N = \text{nozzle separating force} = 1,511,608 \text{ lbs}$$

$$F_c = \text{bolt/core pre-load} = 40,000 \text{ lbs.}$$

F_C = net core load on nozzle skirt (including F_S) = 354,019 lbs.

$$P_1 = \text{reflector inlet pressure} = 842.3 \text{ psig}$$

$$F_{PV} = F_C + F_N + P_1 \pi (R_V^2 - R_C^2) - F_S$$

$$= 354,019 + 1,511,608 + 842.3 (39.7425^2 - 30.45^2) - 40,000$$

$$= 354,019 + 1,511,608 + 1,725,995.2 - 40,000$$

$$F_{pV} = 3,551,622 \text{ lbs, at 100\% NSS condition.}$$

then: For 115% NSS simulation:

$$F_{PV} = 1.15 (3,551.622) = 4,084,365 \text{ lbs, at 115\% NSS simulation}$$

and $P_1 = 1.15 (842.3) = 968.645$ psig at 115% NSS simulation.

- 5.2.2 Determine required test pressure P_2 in dome and lower cylinder section of vessel, such that F_{PV} at the main closure = 100% NSS, or 3,551,622 pounds:

$$F_{pV} = P_2 \pi R_V^2$$

$$P_2 = \frac{F_P V}{\pi R_V^2}$$

$$P_2 = \frac{3,551,622}{\pi (39.7425)^2} = \underline{715.759 \text{ psig}} \text{ (at 100\% NSS simulation)} = \frac{715.759}{782.3} =$$

91% of NSS pressure at main closure.

and for 115% of NSS simulation:

$$P_2 = 1.15 (715.759) = \underline{823.123 \text{ psig}} \text{ (at 115\% NSS simulation)} \approx \frac{823.123}{782.3} =$$

105% of NSS pressure at main closure.

Reference (1) Rev. "B" (2-1-66) to "P2-65-6, Part I - Load Analysis, Phoebus 2 Pressure Vessel/Nozzle Interface Analysis," dated March 26, 1965.

Reference (2) ACF Dwg. 3-517054-000, Rev. D - "P. V. Fwd. Section, C. F."
ACF Dwg. 3-517053-000, Rev. E - "P. V. Aft Section, C. F."

- 5.2.3 Determine F_C core load obtained during test when P_1 , F_{PV} , and P_3 are at required values for 100% NSS simulation:

then: $P_1 = 842.3$ psig
 $P_2 = 715.759$ psig
 $P_3 = 612.3$ psig (Ref (1))

$$F_C = P_2 \pi R_V^2 + F_S - P_1 \pi (R_V^2 - R_C^2) - P_3 \pi R_C^2$$

$$= 715.759 \pi (39.7425)^2 + 40,000 - 842.3 \pi (39.7425^2 - 30.45^2) - 612.3 \pi (30.45)^2$$

$$F_C = 3,551,622 + 40,000 - 1,725,995.2 - 1,783,562.6$$

$$F_C = \underline{82,064.2 \text{ lbs @ 100\% NSS simulation}} = 82,064.2 / 354,019 = \underline{23\% \text{ of NSS value}}$$

For 115% of NSS simulation:

$$F_C = (82,064 - 40,000) (1.15) + 40,000 = \underline{88,373.8 \text{ lbs @ 115\% NSS simulation}}$$

$$= 88,373.8 / 354,019 = \underline{25\% \text{ of NSS value}}$$

- 5.2.4 Determine F_I nozzle interface load obtained during test when P_1 , F_{PV} , and P_3 are at required values for 100% NSS simulation:

$$F_I = F_C - F_S + P_3 \pi R_C^2 + P_1 \pi (R_S^2 - R_C^2)$$

$$F_I = 82,064 - 40,000 + 612.3 \pi (30.45)^2$$

$$+ 842.3 \pi (32.875^2 - 30.45^2) = 82,064 - 40,000 + 1,783,562.6 + 406,352.8$$

$$F_I = \underline{2,231,979 \text{ lbs at 100\% NSS simulation.}}$$

Per Ref. (1), F_I at 100% NSS = 2,232,077 lbs.

therefore, $F_I = \underline{100\% \text{ NSS value at 100\% NSS simulation.}}$

For 115% NSS simulation:

$$F_I = (2,231,979) (1.15) = \underline{2,566,776 \text{ lbs}} = \underline{115\% \text{ NSS value at 115\% NSS simulation.}}$$

5.3 2-Plenum TestHydrostatic

at 100% and 115% NSS simulation

Cryogenic

at 100% NSS simulation

- 5.3.1 In the 3-Plenum Test calculations of Paragraph 5.2, the 100% NSS simulation was arbitrarily defined as when P_1 , F_{PV} , and P_3 were at their true 100% NSS values; similarly for the 115% NSS simulation.

For the 2-Plenum Test, since $P_1 = P_2$ at all conditions, then the % NSS simulation will be defined as when P_1 and P_3 only are at their true % NSS values.

F_{PV} at 100% NSS simulation:

$$P_2 = P_1 = 842.3 \text{ psig}$$

$$F_{PV} = 842.3 \pi (39.7425)^2 = \underline{4,179,523 \text{ lbs}} = 4,179,523/3,551,622 = \underline{118\% \text{ NSS value at 100\% simulation.}}$$

at 115% NSS simulation:

$$P_2 = P_1 = (842.3) (1.15) = 968.645 \text{ psig}$$

$$F_{PV} = 968.6 \pi (39.7425)^2 = \underline{4,806,451 \text{ lbs}} = \underline{135\% \text{ NSS value at 115\% simulation.}}$$

- 5.3.2 Determine F_C (See sketch in Paragraph 5.2.3). This equation simplifies to:

$$F_C = (P_2 - P_3) R_C^2 + 40,000$$

at 100% NSS simulation:

$$F_C = (842.3 - 612.3) \pi (30.45)^2 + 40,000$$

$$F_C = \underline{709,964.7 \text{ lbs}} \text{ at 100\% NSS simulation} = \underline{201\% \text{ NSS value}} \text{ at 100\% NSS simulation.}$$

at 115% NSS simulation:

$$P_2 = P_1 = 968.645 \text{ psig}$$

$$P_3 = 612.3 (1.15) = 704.145 \text{ psig}$$

$$F_C = (968.645 - 704.145) \pi (30.45)^2 + 40,000 = \underline{810,459 \text{ lbs}} \text{ at 115\% NSS simulation} = \underline{229\% \text{ NSS value}} \text{ at 115\% NSS simulation.}$$

5.3.3 Determine F_I (See sketch in Paragraph 5.2.4). Since $P_1 = P_2$, the equation simplifies to:

$$F_I = P_1 \pi R_S^2$$

at 100% NSS simulation:

$$F_I = 842.3 \pi (32.875)^2 = \underline{2,859,880 \text{ lbs}} \text{ at 100\% NSS simulation} = 2,859,880 / 2,232,077 = \underline{128\% \text{ NSS value at 100\% NSS simulation.}}$$

at 115% NSS simulation:

$$F_I = (2,859,880) (1.15) = \underline{3,288,862 \text{ lbs}} \text{ at 115\% NSS simulation} = 3,288,862 / 2,232,077 = \underline{147\% \text{ NSS value at 115\% NSS simulation.}}$$

5.4 Summary

Following is a summary of loads and pressures. Values are rounded off to the nearest whole number.

Test Condition	Pressure or Load	@ 100% NSS Simulation		@115% NSS Simulation	
		Test Value	% True NSS Value	Test Value	% True NSS Value
3 Plenum Hydrostatic Test	P_1 (psig)	842	100	969	115
	P_2 (psig)	716	~ 91	823	~ 105
	P_3 (psig)	612	100	704	115
	F_{PV} (lbs)	3,551,622	100	4,084,365	115
	F_C (lbs)	82,064	23	88,374	25
	F_I (lbs)	2,231,979	100	2,566,776	115
	Thrust	0	0	0	0
2 Plenum Hydrostatic or Cryogenic Test	P_1 (psig)	842	100	969	115
	P_2 (psig)	842	~ 108	969	~ 124
	P_3 (psig)	612	100	704	115
	F_{PV} (lbs)	4,179,523	118	4,806,451	135
	F_C (lbs)	709,965	201	801,459	229
	F_I (lbs)	2,859,880	128	3,288,862	147
	Thrust	0	0	0	0

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6. INSTRUMENTATION REQUIREMENTS

6.1 Strains

- 6.1.1 Foil-type electrical resistance strain gages capable of indicating strains to 0.005000 inch-per-inch shall be installed as shown in Figures 2 through 4. All dimensions given in the figures are in inches. For two gage rosettes, low-numbered gages are circumferential, and high-numbered gages are axial unless otherwise noted. For three gage rosettes, the lowest numbered gage will be considered circumferential and the highest numbered gage axial. When a two gage rosette is specified, one gage axis is to be located in the circumferential (hoop) direction with respect to the vessel and the second gage axis (axial) is perpendicular to the first. Strain gage positional tolerance will be ± 0.060 " (axially and circumferentially). Gage lengths shall be 0.250" maximum unless otherwise noted.
- 6.1.2 Four of the nozzle bolts shall be instrumented with strain gages to give tensile and bending loads. Each bolt shall have four axial strain gages bonded at quadrants on the bolt shanks. The instrumented bolts shall be calibrated (load versus strain) prior to use in the testing. The bolt gages shall be numbered B1 through B16.

6.2 Deflection and Rotation

- 6.2.1 Any laboratory type instrument capable of measuring deflections within 0.001 inch may be used. Suggested types are: dial indicators, ACF-designed strain gage linear transducers, LVDT'S, and autocollimators. The required measurements for deflections and rotations of the Nozzle and Pressure Vessel are shown in Figures 5 and 6.

6.3 Pressures

Bourdon tube-type pressure gages and/or transducers may be used. The instruments must have a repeatable accuracy of $\pm 0.5\%$ of reading. Differential pressure tolerances must be maintained within ± 2.0 psi except for the Clamp Ring (P4) plenum which may vary ± 30 psi. All instruments must be certified prior to testing without intervening usage.

7. TEST PROCEDURE

7.1 Unit Assembly

The assembly procedure described in this section is based on previous Pressure Vessel-Nozzle tests. Alternate assembly techniques may be used when they are considered more feasible. The test units will be visually inspected prior to assembly. All seal grooves and sealing surfaces must be cleaned prior to installing the seals. Install coffer dams or seal leakage collectors (such as those shown in Figure 1) on the test units. The purpose of the individual collector is to differentiate between sources of any leakage. All seals except the Nozzle and Wave Ring Seals (3-515359 and 3-516358, respectively) shall be lightly coated with Dow Corning No. 11 Silicone grease prior to installation.

A member of the Analytical Support Group, Department 431, must be present during all assembly operations. Assemble the unit of testing as follows:

- (a) Mount strain gages to Pressure Vessel and components as shown in Figures 2 through 4 and the Instrumentation List, Appendix A. Data will be recorded on Gilmore Recorders.
- (b) Mount six Support Leg Assemblies and Spacers to Mounting Ring. Torque bolts to 80 ft-lbs.
- (c) Center Pressure Vessel Forward Section on the six Support Legs. Torque leg dogs to 20 ft-lbs.
- (d) Plug all holes in the Pressure Vessel Forward Section (Dome) with K-seals and plugs specified in Figure 1. Torque plugs to 60 ft-lbs.
- (e) Install 18 Dummy Guide Tubes with metal V-seals into Forward Section of Pressure Vessel. A torque of 60 in-lbs is required.
- (f) Make the required dimensional checks on the Seals, Nozzle, and Vessel as follows:
 - (1) Shear Lip. The following physical dimensions of the Aft Section and Nozzle are required before and after the testing at 0, 90, 180, and 270°:
 - (a) ID of the Nozzle Shear Lip at Station 68.5
 - (b) OD of the Pressure Vessel at Station 68.5

NOTE: Reference marks should be marked on the test units to ensure that dimensional measurements are made at the same locations.

- (2) Wave Ring Seal. Measure the OD of each lobe before assembly. After inserting the Seal in the Pressure Vessel Forward Section Groove, measure the exposed or top OD of the lobe. Upon completion of the structural test, measure both lobe OD's after removal from the Pressure Vessel. Mark orientation as to the forward and aft lobe with respect to the Pressure Vessel.
- (3) Omega Seal. After testing, measure the height of the Seal, i.e., from lobe to lobe and the gap between the legs.
- (4) Pressure Vessel Aft Section Seal Groove. Measure the depth of the seal groove at eight (8) equally-spaced locations beginning at 0°.
- (5) Test Assembly. Dye penetrant check all welds and highly stressed areas prior to and after testing. These inspections must be witnessed by Department 431 personnel.
- (6) Clamp Segments. A visual inspection will be performed by Department 431 personnel on each clamp segment and its specific mating location on the Pressure Vessel before final assembly.

- (g) Install Wave Ring Seal into the Pressure Vessel Forward Section.
- (h) Assemble Pneumatic Seal to Pressure Vessel Aft Section with six seal clamps. Install Seal Clamps, taking care that seal has no wavers or puckers when tightening screws.
- (i) Center Structural Chamber on wooden guide rack.
- (j) Attach Lifting Band and lower Pressure Vessel Aft Section over Structural Chamber taking care not to damage Pneumatic Seal or Seal Clamps. Adjust section radially for proper angular orientation with Structural Chamber.
- (k) Install O-ring in Structural Chamber.
- (l) Install Nozzle Omega Seal in Pressure Vessel Aft Section.
- (m) Position Nozzle over Pressure Vessel Assembly. Angularly orientate Nozzle with respect to Pressure Vessel and Structural Chamber Assemblies and lower into position.
- (n) Install modified nozzle bolts with K-seals.
- (o) Install nozzle bolts with K-seals so that the four instrumented bolts are 90° apart. See Figure 3 and Appendix A. Torque all nozzle bolts to a preload of 34,000 pounds in diametrically opposed pairs.
- (p) Assemble 18 support bolts with K-seals through special nozzle bolts to support Structural Chamber. Torque support bolts to 15 ft-lbs (equivalent to 40,000 lbs, total load).
- (q) Install internal gap deflection gages as shown in Figure 6.
- (r) Center Pressure Vessel Aft Section - Nozzle Assembly over Dome and lower down around Wave Ring Seal.
- (s) Ensure that the mating surfaces between the pressure vessel and the clamp segments are clean and unlubricated. Install the 12 Clamp Ring Segments starting at 0°. Pull the Clamp Ring into position, and measure the load required.
- (t) Install Nozzle Bolt Leak Collector as shown in Figure 1.
- (u) Fill the Clamp Ring (P₄), Nozzle (P₃), Structural Chamber Annulus (P₁), and Forward Section (P₂) with softened water taking care that all air is bled from the vessel.
- (v) Install deflection gages as shown in Figures 5 and 6, and make connection to the Gilmore Recorder per the Instrumentation List, Appendix A.
- (w) Connect the pressurization system as shown in Figure 7.
- (x) Install hydraulic jack as shown in Figure 1.

Figure 2. Pressure Vessel Strain Gage Locations

Figure 3. Strain Gage Locations on Nozzle Bolts

NOTE: All strain gages to be placed on inside surface of Segment #4.

Figure 4. Strain Gage Locations on Clamp Segment

Figure 5. Interface Rotations and Gap Separations

NOTES:

1. Dimensions indicated are to be measured within ± 0.010 inch.
2. Radial growth of vessel to have positive indication of output.
3. Gap gages to have positive indication from gap opening.

Figure 6. Pressure Vessel Main Closure Rotations and Deflections

Figure 7. Hydrostatic Pressurization System

7.2 Phase 1 - Hydrostatic Structural Test

- 7.2.1 Apply approximately 10 psig to the hydraulic jack to stabilize the Pressure Vessel Assembly.
- 7.2.2 Apply pressure in stepped increments and release after each application as shown in Table 1. Maintain the jack load as specified by Paragraph 7.2.1. In agreement with a memorandum¹ from J. W. Neudecker to J. R. Stucki the hydrostatic pressure test will be scheduled as follows: The three plenum test setup is much preferred over the two plenum arrangement. However, since the time available for conducting the test is extremely limited, the two plenum test setup should be selected without delay in the event that trouble is encountered in effecting a seal with the three plenum arrangement. The two plenum test setup will be run utilizing Table 2 loading schedule. After exercising the instrumentation (initial 30% pressure steps), re-zero the instrumentation. To maintain a complete computerized data history of the Phase 1 and 2 tests, the recorders shall not be zeroed after this point. Record the data at each pressure increment.

NOTE: If an interruption occurs, testing will resume with the initial zero load being the starting point.
- 7.2.3 Record the data from the instrumentation at each increment of pressure.
- 7.2.4 After the Phase 1 testing has been completed, verify the documentation on locations of all deflection gages and visually inspect the Pressure Vessel Assembly for evidence of deformation.

7.3 Phase 2 - Hydrostatic Structural Proof Test

- 7.3.1 Install additional instrumentation, if determined necessary. The type and location will be specified by Department 431, depending upon test results.
- 7.3.2 Assemble the Pressure Vessel and Test System as described in Paragraph 7.1(b) through (x) on pages 14 and 15.
- 7.3.3 Make dimensional checks to insure that the Nozzle is completely seated on the Pressure Vessel.
- 7.3.4 Apply approximately 10 psig to the hydraulic jack to stabilize the Pressure Vessel Assembly. Apply pressure in stepped increments as shown in Table 3. Alternate two-chamber test is shown in Table 4. Record the data at each pressure increment. Repeat the above procedure for a minimum of ten pressure cycles.

NOTE: If an interruption occurs, testing will resume with the initial zero load being the starting point.
- 7.3.5 Drain, disassemble, and dry Pressure Vessel Assembly. Record the nozzle bolt breakaway torque values and the final strain indications. Obtain the required dimensional measurements as stated in Paragraph 7.1(f), Items 1 through 4 (page 14).
- 7.3.6 Visually inspect the Pressure Vessel Assembly for evidence of deformation. Dye penetrant inspect weld areas.

¹Memorandum from J. W. Neudecker to J. R. Stucki, titled Proof Test Pressures, Phoebus 2 Pressure Vessel Proof Test.

Table 1. Phase 1 Structural Test Loading Schedule

Step	Load	P ₁	P ₂	P ₃	P ₄	Step	Load	P ₁	P ₂	P ₃	P ₄
	%	psig	psig	psig	psig		%	psig	psig	psig	psig
0*	0*	0	0	0	0	20	10*				126
1		253	253	253		21			84		
2				184		22				84	
3			215			23		168	168	168	
4	30*				378	24				122	
5			253			25			143		
6				253		26	20*				252
7		0	0	0		27			168		
8	0*				0	28				168	
9		253	253	253		29		253	253	253	
10				184		30				184	
11			215			31			215		
12	30*				378	32	30*				378
13			253			33			253		
14				253		34				253	
15		0	0	0		35		0	0	0	
16	0*				0	36	0*				0
17		84	84	84		37		421	421	421	
18				61		38				306	
19			72			39			358		
*Record Instrumentation											

Table 1. Phase I Structural Test Loading Schedule (Continued)

Step	Load %	P ₁ psig	P ₂ psig	P ₃ psig	P ₄ psig	Step	Load %	P ₁ psig	P ₂ psig	P ₃ psig	P ₄ psig
40	50*				630	60				612	
41			420			61	100*				1260
42		505				62			788		
43				367		63		926			
44			430			64				673	
45	60*				756	65	110*				1386
46			501			66			823		
47		589				67		969			
48				428		68				704	
49	70*				882	69	115*				1449
50			573			70		840			
51		674				71			760		
52				490		72				600	
53	80*				1008	73			704		
54			644			74		704			
55		758				75				704	
56				551		76		0	0	0	
57	90*				1134	77	0*				0
58			716								
59		842									
*Record Instrumentation											

Table 2. Alternate Phase 1 Structural Test Loading Schedule

Step	Load	P ₁ =P ₂	P ₃	P ₄	Step	Load	P ₁ = P ₂	P ₃	P ₄
	%	psig	psig	psig		%	psig	psig	psig
0*	0*	0	0	0	20			168	
1		253	253		21		253	253	
2			184		22			184	
3	30*			378	23	30*			378
4			253		24			253	
5		0	0		25		0	0	
6	0*			0	26	0*			0
7		253	253		27		421	421	
8			184		28			306	
9	30*			378	29	50*			630
10			253		30			367	
11		0	0		31		505		
12	0*			0	32	60*			756
13		84	84		33			428	
14			61		34		589		
15	10*			126	35	70*			882
16			84		36			490	
17		168	168		37		674		
18			122		38	80*			1008
19	20*			253	39			551	
*Record Instrumentation									

Table 2. Alternate Phase 1 Structural Test Loading Schedule (continued)

Step	Load %	P ₁ = P ₂ psig	P ₃ psig	P ₄ psig	Step	Load %	P ₁ = P ₂ psig	P ₃ psig	P ₄ psig
40		756			47	110*			1386
41	90*			1134	48			704	
42			612		49		969		
43		842			50	115*			1149
44	100*			1260	51		704		
45			673		52		0	0	
46		926			53	0	0	0	0

Table 3. Phase 2 Structural Proof Test Loading Schedule

Step	Load %	P ₁ psig	P ₂ psig	P ₃ psig	P ₄ psig	Step	Load %	P ₁ psig	P ₂ psig	P ₃ psig	P ₄ psig
1	0*	0	0	0	0	12				551	
2		501	501	501		13					1134
3				428		14			716		
4		589				15		842			
5	70*				882	16				612	
6			573			17	100*				1260
7		674				18			704		
8				490		19		704			
9	80				1008	20				704	
10			644			21		0	0	0	
11		758				22	0*				0

*Record Instrumentation

Table 4. Alternate Phase 2 Structural Proof Test Loading Schedule

Step	Load %	P ₁ =P ₂ psig	P ₃ psig	P ₄ psig	Step	Load %	P ₁ =P ₂ psig	P ₃ psig	P ₄ psig
1	0*	0	0	0	7		842		
2		589	589		8	100*			1260
3			428		9		612		
4	70*			882	10		0	0	
5			589		11	0*			0
6		612	612		*Record Instrumentation				

7.4 Phase 3 - Cryogenic Structural Proof Test

- 7.4.1 Install thermocouples on the Pressure Vessel at Station 44.5, 180° apart, and on the Nozzle 180° apart.
- 7.4.2 Assemble the vessel with the Structural Chamber, using new Omega and Wave Ring Seals. Install metal Nozzle Skirt Seal in lieu of O-ring noted in Paragraph 7.1(k). Assemble vessel as described in Paragraphs 7.1 (b), (c), (e), (f), (g), (i), (j), (l), (m), (n), (o), (p), (r), and (s). Plug all instrumentation holes with cryogenic seals.
- 7.4.3 Transport the Pressure Vessel Assembly to the ACF explosives test site at Sandia Base.
- 7.4.4 Connect the LN₂ fill and pressurization systems to the Pressure Vessel Assembly as shown in Figure 8 and place insulation around vessel.
- 7.4.5 Fill the Pressure Vessel and Clamp Ring with LN₂ until thoroughly chilled. Monitor thermocouples to determine temperature stabilization.

CAUTION: Open all relief valves mounted on the Pressure Vessel during filling procedure to prevent gas pressure buildup.

- 7.4.6 After temperature stabilization, pressurize P₁P₂ to 400 psig, P₃ to 350 psig and P₄ to 400 psig with helium. Visually inspect the assembly for leakage and seal any significant leaks.

Figure 8. Phoebus 2 CF/2A Cryogenic Test Setup

- 7.4.7 Perform final instrumentation check.
- 7.4.8 Top off the Pressure Vessel and Clamp Ring with LN₂ until thoroughly chilled and boiling of LN₂ has ceased. Monitor thermocouples to determine temperature stabilization at $-300^{\circ} \pm 20^{\circ}\text{F}$.
- 7.4.9 After temperature stabilization, pressurize Pressure Vessel and Clamp Ring per the Phase 3 loading schedule, Table 5. Record the test data at each pressure increment. Bleed GN₂ as necessary to maintain as much LN₂ as possible.
- 7.4.10 Depressurize Pressure Vessel Assembly and allow it to warm to ambient temperature. Check torque value on 12 nozzle bolts (4 sets of 3 bolts) 90° apart. Record test data.
- 7.4.11 Perform the operations specified in Paragraphs 7.4.5 through 7.4.10 for a total of three pressurization cycles. Dye penetrant inspect weld areas after each cycle.
- 7.4.12 Disassemble Pressure Vessel Assembly and visually inspect for evidence of deformation. Dye penetrant inspect and X-ray weld areas.

Table 5. Cryogenic Proof Test Loading Schedule

Step	Pressure Vessel and Clamp Ring Load (psig)		
	P ₁ = P ₂	P ₃	P ₄
1	0	0	0
2	612	612	0
3	842	612	0
4	842*	612*	1260*
5	612	612	1260
6	0	0	1260
7	0	0	0
Repeat Steps 1 through 7 for a total of 3 pressure cycles.			
*Pressure maintained for 5 minutes @ $-300^{\circ} \pm 20^{\circ}\text{F}$			

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8. REPORT REQUIREMENTS

- 8.1 Department 411 (ACF) will issue a preliminary test data report within five working days following completion of each test phase. These reports shall include strain and deflection data as reduced by the ACF IBM D-115 Computer Program and copies of the test log. A formal data report will be issued four weeks after completion of testing. It shall include (1) descriptions of unusual occurrences, (2) miscellaneous information required in this specification, (3) variations from the test specification, (4) strain, stress, deflection, and rotational data graphed as functions of load, and (5) pertinent photographs.
- 8.2 The Analytical Support Group of Department 431 (ACF) will publish separate test reports within six weeks after completion of testing. The reports shall contain a complete evaluation of the Pressure Vessel Main Closure performance based on a comparison with hydrostatic proof test conditions to the Phoebus 2 redesigned main closure analysis.

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Appendix A
INSTRUMENTATION LIST

INSTRUMENTATION LIST

GAGE NO	MEASUREMENT DESCRIPTION	MEASUREMENT LOCATION	MEASUREMENT RANGE (μ IN/IN)
B1	AXIAL STRAIN	NOZZLE BOLT 1	0 DEGREE 0 TO 5000
B2	AXIAL STRAIN	NOZZLE BOLT 1	90 DEGREE 0 TO 5000
B3	AXIAL STRAIN	NOZZLE BOLT 1	180 DEGREE 0 TO 5000
B4	AXIAL STRAIN	NOZZLE BOLT 1	270 DEGREE 0 TO 5000
B5	AXIAL STRAIN	NOZZLE BOLT 2	0 DEGREE 0 TO 5000
B6	AXIAL STRAIN	NOZZLE BOLT 2	90 DEGREE 0 TO 5000
B7	AXIAL STRAIN	NOZZLE BOLT 2	180 DEGREE 0 TO 5000
B8	AXIAL STRAIN	NOZZLE BOLT 2	270 DEGREE 0 TO 5000
B9	AXIAL STRAIN	NOZZLE BOLT 3	0 DEGREE 0 TO 5000
B10	AXIAL STRAIN	NOZZLE BOLT 3	90 DEGREE 0 TO 5000
B11	AXIAL STRAIN	NOZZLE BOLT 3	180 DEGREE 0 TO 5000
B12	AXIAL STRAIN	NOZZLE BOLT 3	270 DEGREE 0 TO 5000
B13	AXIAL STRAIN	NOZZLE BOLT 4	0 DEGREE 0 TO 5000
B14	AXIAL STRAIN	NOZZLE BOLT 4	90 DEGREE 0 TO 5000
B15	AXIAL STRAIN	NOZZLE BOLT 4	180 DEGREE 0 TO 5000
B16	AXIAL STRAIN	NOZZLE BOLT 4	270 DEGREE 0 TO 5000
1	CIRC. STRAIN	DOME OUTSIDE STA 0.438	90 DEGREE 0 TO 5000
2	AXIAL STRAIN	DOME OUTSIDE STA 0.438	90 DEGREE 0 TO 5000
3	CIRC. STRAIN	DOME OUTSIDE STA 2.375	90 DEGREE 0 TO 5000
4	AXIAL STRAIN	DOME OUTSIDE STA 2.375	90 DEGREE 0 TO 5000
5	CIRC. STRAIN	VESSEL OUTSIDE STA 9.625	90 DEGREE 0 TO 5000
6	AXIAL STRAIN	VESSEL OUTSIDE STA 9.625	90 DEGREE 0 TO 5000
7	CIRC. STRAIN	VESSEL OUTSIDE STA 23.000	90 DEGREE 0 TO 5000
8	AXIAL STRAIN	VESSEL OUTSIDE STA 23.000	90 DEGREE 0 TO 5000
9	CIRC. STRAIN	VESSEL INSIDE STA 23.000	90 DEGREE 0 TO 5000

INSTRUMENTATION LIST

GAGE NO	GAGE IDENTIFICATION	GAGE INSTALLATION	RECORDING INSTRUMENT	REFERENCE FIGURE
B1	BUDD C 6-121	ACF-1S-10,11,12	GILMORE M114 1-2	3
B2	BUDD C 6-121	ACF-1S-10,11,12	GILMORE M114 1-3	3
B3	BUDD C 6-121	ACF-1S-10,11,12	GILMORE M114 1-4	3
B4	BUDD C 6-121	ACF-1S-10,11,12	GILMORE M114 1-5	3
B5	BUDD C 6-121	ACF-1S-10,11,12	GILMORE M114 1-6	3
B6	BUDD C 6-121	ACF-1S-10,11,12	GILMORE M114 1-7	3
B7	BUDD C 6-121	ACF-1S-10,11,12	GILMORE M114 1-8	3
B8	BUDD C 6-121	ACF-1S-10,11,12	GILMORE M114 1-9	3
B9	BUDD C 6-121	ACF-1S-10,11,12	GILMORE M114 1-10	3
B10	BUDD C 6-121	ACF-1S-10,11,12	GILMORE M114 1-11	3
B11	BUDD C 6-121	ACF-1S-10,11,12	GILMORE M114 1-12	3
B12	BUDD C 6-121	ACF-1S-10,11,12	GILMORE M114 1-13	3
B13	BUDD C 6-121	ACF-1S-10,11,12	GILMORE M114 1-14	3
B14	BUDD C 6-121	ACF-1S-10,11,12	GILMORE M114 1-15	3
B15	BUDD C 6-121	ACF-1S-10,11,12	GILMORE M114 1-16	3
B16	BUDD C 6-121	ACF-1S-10,11,12	GILMORE M114 1-17	3
1	BUDD C 12-121-R2VC	ACF-1S-9,11,12	GILMORE M114 1-18	2
2	BUDD C 12-121-R2VC	ACF-1S-9,11,12	GILMORE M114 1-19	2
3	BUDD C 12-121-R2VC	ACF-1S-9,11,12	GILMORE M114 1-20	2
4	BUDD C 12-121-R2VC	ACF-1S-9,11,12	GILMORE M114 1-21	2
5	BUDD C 12-121-R2VC	ACF-1S-9,11,12	GILMORE M114 1-22	2
6	BUDD C 12-121-R2VC	ACF-1S-9,11,12	GILMORE M114 1-23	2
7	BUDD C 12-121-R2VC	ACF-1S-9,11,12	GILMORE M114 1-25	2
8	BUDD C 12-121-R2VC	ACF-1S-9,11,12	GILMORE M114 1-26	2
9	BUDD C 12-121-R2VC	ACF-1S-9,11,12	GILMORE M114 1-27	2

INSTRUMENTATION LIST

GAGE NO	MEASUREMENT DESCRIPTION	MEASUREMENT LOCATION	MEASUREMENT RANGE (μ IN/IN)
10	AXIAL STRAIN	VESSEL INSIDE STA 23.000	90 DEGREE 0 TO 5000
11	CIRC. STRAIN	VESSEL OUTSIDE STA 50.500	90 DEGREE 0 TO 5000
12	AXIAL STRAIN	VESSEL OUTSIDE STA 50.500	90 DEGREE 0 TO 5000
13	CIRC. STRAIN	VESSEL INSIDE STA 50.500	90 DEGREE 0 TO 5000
14	AXIAL STRAIN	VESSEL INSIDE STA 50.500	90 DEGREE 0 TO 5000
15	CIRC. STRAIN	VESSEL INSIDE STA 9.625	90 DEGREE 0 TO 5000
16	AXIAL STRAIN	VESSEL INSIDE STA 9.625	90 DEGREE 0 TO 5000
17	CIRC. STRAIN	VESSEL INSIDE STA 7.912	90 DEGREE 0 TO 5000
18	AXIAL STRAIN	VESSEL INSIDE STA 7.912	90 DEGREE 0 TO 5000
19	CIRC. STRAIN	DOME INSIDE STA 4.088	90 DEGREE 0 TO 5000
20	AXIAL STRAIN	DOME INSIDE STA 4.088	90 DEGREE 0 TO 5000
21	CIRC. STRAIN	DOME INSIDE STA 2.375	90 DEGREE 0 TO 5000
22	AXIAL STRAIN	DOME INSIDE STA 2.375	90 DEGREE 0 TO 5000
23	CIRC. STRAIN	DOME INSIDE STA 0.438	90 DEGREE 0 TO 5000
24	AXIAL STRAIN	DOME INSIDE STA 0.438	90 DEGREE 0 TO 5000
25	CIRC. STRAIN	CLAMP SEGMENT BOT CORNER	0 TO 5000
26	DIAG. STRAIN	CLAMP SEGMENT BOT CORNER	0 TO 5000
27	AXIAL STRAIN	CLAMP SEGMENT BOT CORNER	0 TO 5000
28	CIRC. STRAIN	CLAMP SEGMENT TOP CORNER	0 TO 5000
29	DIAG. STRAIN	CLAMP SEGMENT TOP CORNER	0 TO 5000
30	AXIAL STRAIN	CLAMP SEGMENT TOP CORNER	0 TO 5000
31	CIRC. STRAIN	CLAMP SEGMENT CENTER	105 DEGREE 0 TO 5000
32	DIAG. STRAIN	CLAMP SEGMENT CENTER	105 DEGREE 0 TO 5000
33	AXIAL STRAIN	CLAMP SEGMENT CENTER	105 DEGREE 0 TO 5000
34	CIRC. STRAIN	DOME OUTSIDE STA 0.438	270 DEGREE 0 TO 5000

INSTRUMENTATION LIST

GAGE NO	GAGE IDENTIFICATION	GAGE INSTALLATION	RECORDING INSTRUMENT	REFERENCE FIGURE
10	BUDD C 12-121-R2VC	ACF-1S-9,11,12	GILMORE M114 1-28	2
11	BUDD C 12-121-R2VC	ACF-1S-9,11,12	GILMORE M114 1-29	2
12	BUDD C 12-121-R2VC	ACF-1S-9,11,12	GILMORE M114 1-30	2
13	BUDD C 12-121-R2VC	ACF-1S-9,11,12	GILMORE M114 1-31	2
14	BUDD C 12-121-R2VC	ACF-1S-9,11,12	GILMORE M114 1-32	2
15	BUDD C 12-121-R2VC	ACF-1S-9,11,12	GILMORE M114 1-33	2
16	BUDD C 12-121-R2VC	ACF-1S-9,11,12	GILMORE M114 1-34	2
17	BUDD C 12-121-R2VC	ACF-1S-9,11,12	GILMORE M114 1-35	2
18	BUDD C 12-121-R2VC	ACF-1S-9,11,12	GILMORE M114 1-36	2
19	BUDD C 12-121-R2VC	ACF-1S-9,11,12	GILMORE M114 1-37	2
20	BUDD C 12-121-R2VC	ACF-1S-9,11,12	GILMORE M114 1-38	2
21	BUDD C 12-121-R2VC	ACF-1S-9,11,12	GILMORE M114 1-39	2
22	BUDD C 12-121-R2VC	ACF-1S-9,11,12	GILMORE M114 1-40	2
23	BUDD C 12-121-R2VC	ACF-1S-9,11,12	GILMORE M114 1-41	2
24	BUDD C 12-121-R2VC	ACF-1S-9,11,12	GILMORE M114 1-42	2
25	BUDD EC 12-121-R3TS	ACF-1S-9,11,12	GILMORE M114 1-43	2
26	BUDD EC 12-121-R3TS	ACF-1S-9,11,12	GILMORE M114 1-44	2
27	BUDD EC 12-121-R3TS	ACF-1S-9,11,12	GILMORE M114 1-45	2
28	BUDD EC 12-121-R3TS	ACF-1S-9,11,12	GILMORE M114 1-46	2
29	BUDD EC 12-121-R3TS	ACF-1S-9,11,12	GILMORE M114 1-47	2
30	BUDD EC 12-121-R3TS	ACF-1S-9,11,12	GILMORE M114 1-49	2
31	BUDD EC 12-121-R3TS	ACF-1S-9,11,12	GILMORE M114 1-50	4
32	BUDD EC 12-121-R3TS	ACF-1S-9,11,12	GILMORE M114 1-51	4
33	BUDD EC 12-121-R3TS	ACF-1S-9,11,12	GILMORE M114 1-52	4
34	BUDD C 12-121-R2VC	ACF-1S-9,11,12	GILMORE M114 1-53	2

INSTRUMENTATION LIST

GAGE NO	MEASUREMENT DESCRIPTION	MEASUREMENT LOCATION			MEASUREMENT RANGE (μ IN/IN)		
35	AXIAL STRAIN	DOME	OUTSIDE	STA 0.438	270 DEGREE	0 TO 5000	
36	CIRC. STRAIN	DOME	OUTSIDE	STA 2.375	270 DEGREE	0 TO 5000	
37	AXIAL STRAIN	DOME	OUTSIDE	STA 2.375	270 DEGREE	0 TO 5000	
38	CIRC. STRAIN	VESSEL	OUTSIDE	STA 9.625	270 DEGREE	0 TO 5000	
39	AXIAL STRAIN	VESSEL	OUTSIDE	STA 9.625	270 DEGREE	0 TO 5000	
40	CIRC. STRAIN	VESSEL	OUTSIDE	STA 23.000	270 DEGREE	0 TO 5000	
41	AXIAL STRAIN	VESSEL	OUTSIDE	STA 23.000	270 DEGREE	0 TO 5000	
42	CIRC. STRAIN	VESSEL	INSIDE	STA 23.000	270 DEGREE	0 TO 5000	
43	AXIAL STRAIN	VESSEL	INSIDE	STA 23.000	270 DEGREE	0 TO 5000	
44	CIRC. STRAIN	VESSEL	OUTSIDE	STA 50.000	270 DEGREE	0 TO 5000	
45	AXIAL STRAIN	VESSEL	OUTSIDE	STA 50.000	270 DEGREE	0 TO 5000	
46	CIRC. STRAIN	VESSEL	INSIDE	STA 50.000	270 DEGREE	0 TO 5000	
47	AXIAL STRAIN	VESSEL	INSIDE	STA 50.000	270 DEGREE	0 TO 5000	
48	CIRC. STRAIN	VESSEL	INSIDE	STA 9.625	270 DEGREE	0 TO 5000	
49	AXIAL STRAIN	VESSEL	INSIDE	STA 9.625	270 DEGREE	0 TO 5000	
50	CIRC. STRAIN	VESSEL	INSIDE	STA 7.912	270 DEGREE	0 TO 5000	
51	AXIAL STRAIN	VESSEL	INSIDE	STA 7.912	270 DEGREE	0 TO 5000	
52	CIRC. STRAIN	DOME	INSIDE	STA 4.088	270 DEGREE	0 TO 5000	
53	AXIAL STRAIN	DOME	INSIDE	STA 4.088	270 DEGREE	0 TO 5000	
54	CIRC. STRAIN	DOME	INSIDE	STA 2.375	270 DEGREE	0 TO 5000	
55	AXIAL STRAIN	DOME	INSIDE	STA 2.375	270 DEGREE	0 TO 5000	
56	CIRC. STRAIN	DOME	INSIDE	STA 0.438	270 DEGREE	0 TO 5000	
57	AXIAL STRAIN	DOME	INSIDE	STA 0.438	270 DEGREE	0 TO 5000	
58	CIRC. STRAIN	CLAMP SEGMENT	BOT CORNER	120 DEGREE	0 TO 5000		
59	DIAG. STRAIN	CLAMP SEGMENT	BOT CORNER	120 DEGREE	0 TO 5000		

INSTRUMENTATION LIST

GAGE NO	GAGE IDENTIFICATION	GAGE INSTALLATION	RECORDING INSTRUMENT	REFERENCE FIGURE
35	BUDD C 12-121-R2VC	ACF-1S-9,11,12	GILMORE M114 1-54	2
36	BUDD C 12-121-R2VC	ACF-1S-9,11,12	GILMORE M114 1-55	2
37	BUDD C 12-121-R2VC	ACF-1S-9,11,12	GILMORE M114 1-56	2
38	BUDD C 12-121-R2VC	ACF-1S-9,11,12	GILMORE M114 1-57	2
39	BUDD C 12-121-R2VC	ACF-1S-9,11,12	GILMORE M114 1-58	2
40	BUDD C 12-121-R2VC	ACF-1S-9,11,12	GILMORE M114 1-59	2
41	BUDD C 12-121-R2VC	ACF-1S-9,11,12	GILMORE M114 1-60	2
42	BUDD C 12-121-R2VC	ACF-1S-9,11,12	GILMORE M114 1-61	2
43	BUDD C 12-121-R2VC	ACF-1S-9,11,12	GILMORE M114 1-62	2
44	BUDD C 12-121-R2VC	ACF-1S-9,11,12	GILMORE M114 1-63	2
45	BUDD C 12-121-R2VC	ACF-1S-9,11,12	GILMORE M114 1-64	2
46	BUDD C 12-121-R2VC	ACF-1S-9,11,12	GILMORE M114 1-65	2
47	BUDD C 12-121-R2VC	ACF-1S-9,11,12	GILMORE M114 1-66	2
48	BUDD C 12-121-R2VC	ACF-1S-9,11,12	GILMORE M114 1-67	2
49	BUDD C 12-121-R2VC	ACF-1S-9,11,12	GILMORE M114 1-68	2
50	BUDD C 12-121-R2VC	ACF-1S-9,11,12	GILMORE M114 1-69	2
51	BUDD C 12-121-R2VC	ACF-1S-9,11,12	GILMORE M114 1-70	2
52	BUDD C 12-121-R2VC	ACF-1S-9,11,12	GILMORE M114 1-71	2
53	BUDD C 12-121-R2VC	ACF-1S-9,11,12	GILMORE M114 1-73	2
54	BUDD C 12-121-R2VC	ACF-1S-9,11,12	GILMORE M114 1-74	2
55	BUDD C 12-121-R2VC	ACF-1S-9,11,12	GILMORE M114 1-75	2
56	BUDD C 12-121-R2VC	ACF-1S-9,11,12	GILMORE M114 1-76	2
57	BUDD C 12-121-R2VC	ACF-1S-9,11,12	GILMORE M114 1-77	2
58	BUDD EC 12-121-R3TS	ACF-1S-9,11,12	GILMORE M114 1-78	2
59	BUDD EC 12-121-R3TS	ACF-1S-9,11,12	GILMORE M114 1-79	2

INSTRUMENTATION LIST

GAGE NO	MEASUREMENT DESCRIPTION	MEASUREMENT LOCATION			MEASUREMENT RANGE (μIN/IN)	
60	AXIAL STRAIN	CLAMP SEGMENT	BOT CORNER	120 DEGREE	0 TO 5000	
61	C IRC . STRAIN	CLAMP SEGMENT	TOP CORNER	120 DEGREE	0 TO 5000	
62	DIAG . STRAIN	CLAMP SEGMENT	TOP CORNER	120 DEGREE	0 TO 5000	
63	AXIAL STRAIN	CLAMP SEGMENT	TOP CORNER	120 DEGREE	0 TO 5000	
64	C IRC . STRAIN	CLAMP SEGMENT	CENTER	275 DEGREE	0 TO 5000	
65	DIAG . STRAIN	CLAMP SEGMENT	CENTER	275 DEGREE	0 TO 5000	
66	AXIAL STRAIN	CLAMP SEGMENT	CENTER	275 DEGREE	0 TO 5000	
67	C IRC . STRAIN	CLAMP RING	STA 3.800	95 DEGREE	0 TO 5000	
68	AXIAL STRAIN	CLAMP RING	STA 3.800	95 DEGREE	0 TO 5000	
69	C IRC . STRAIN	CLAMP RING	STA 8.200	95 DEGREE	0 TO 5000	
70	AXIAL STRAIN	CLAMP RING	STA 8.200	95 DEGREE	0 TO 5000	
71	C IRC . STRAIN	CLAMP RING	STA 3.800	275 DEGREE	0 TO 5000	
72	AXIAL STRAIN	CLAMP RING	STA 3.800	275 DEGREE	0 TO 5000	
73	C IRC . STRAIN	CLAMP RING	STA 8.200	275 DEGREE	0 TO 5000	
74	AXIAL STRAIN	CLAMP RING	STA 8.200	275 DEGREE	0 TO 5000	
75	C IRC . STRAIN	CLAMP RING	STA 3.700	45 DEGREE	0 TO 5000	
76	C IRC . STRAIN	CLAMP RING	STA 3.700	135 DEGREE	0 TO 5000	
77	C IRC . STRAIN	CLAMP RING	STA 3.700	225 DEGREE	0 TO 5000	
78	C IRC . STRAIN	CLAMP RING	STA 3.700	315 DEGREE	0 TO 5000	
79	C IRC . STRAIN	CLAMP RING	STA 6.000	45 DEGREE	0 TO 5000	
80	C IRC . STRAIN	CLAMP RING	STA 6.000	225 DEGREE	0 TO 5000	
81	C IRC . STRAIN	CLAMP RING	STA 8.300	315 DEGREE	0 TO 5000	
82	C IRC . STRAIN	CLAMP RING	STA 8.300	225 DEGREE	0 TO 5000	
83	C IRC . STRAIN	CLAMP RING	STA 8.300	135 DEGREE	0 TO 5000	
84	C IRC . STRAIN	CLAMP RING	STA 8.300	45 DEGREE	0 TO 5000	

INSTRUMENTATION LIST

GAGE NO	GAGE IDENTIFICATION	GAGE INSTALLATION	RECORDING INSTRUMENT	REFERENCE FIGURE
60	BUDD EC 12-121-R3TS	ACF-1S-9,11,12	GILMORE M114 1-80	2
61	BUDD EC 12-121-R3TS	ACF-1S-9,11,12	GILMORE M114 1-81	2
62	BUDD EC 12-121-R3TS	ACF-1S-9,11,12	GILMORE M114 1-82	2
63	BUDD EC 12-121-R3TS	ACF-1S-9,11,12	GILMORE M114 1-83	2
64	BUDD EC 12-121-R3TS	ACF-1S-9,11,12	GILMORE M114 1-84	2
65	BUDD EC 12-121-R3TS	ACF-1S-9,11,12	GILMORE M114 1-85	2
66	BUDD EC 12-121-R3TS	ACF-1S-9,11,12	GILMORE M114 1-86	2
67	BUDD C 12-121-R2VC	ACF-1S-9,11,12	GILMORE M114 1-87	2
68	BUDD C 12-121-R2VC	ACF-1S-9,11,12	GILMORE M114 1-88	2
69	BUDD C 12-121-R2VC	ACF-1S-9,11,12	GILMORE M114 1-89	2
70	BUDD C 12-121-R2VC	ACF-1S-9,11,12	GILMORE M114 1-90	2
71	BUDD C 12-121-R2VC	ACF-1S-9,11,12	GILMORE M114 1-91	2
72	BUDD C 12-121-R2VC	ACF-1S-9,11,12	GILMORE M114 1-92	2
73	BUDD C 12-121-R2VC	ACF-1S-9,11,12	GILMORE M114 1-93	2
74	BUDD C 12-121-R2VC	ACF-1S-9,11,12	GILMORE M114 1-94	2
75	BLH PA-18	SR-4 CEMENT	GILMORE M114 2-73	2
76	BLH PA-18	SR-4 CEMENT	GILMORE M114 2-74	2
77	BLH PA-18	SR-4 CEMENT	GILMORE M114 2-75	2
78	BLH PA-18	SR-4 CEMENT	GILMORE M114 2-76	2
79	BLH PA-18	SR-4 CEMENT	GILMORE M114 2-77	2
80	BLH PA-18	SR-4 CEMENT	GILMORE M114 2-78	2
81	BLH PA-18	SR-4 CEMENT	GILMORE M114 2-79	2
82	BLH PA-18	SR-4 CEMENT	GILMORE M114 2-80	2
83	BLH PA-18	SR-4 CEMENT	GILMORE M114 2-81	2
84	BLH PA-18	SR-4 CEMENT	GILMORE M114 2-82	2

INSTRUMENTATION LIST

GAGE NO	MEASUREMENT DESCRIPTION	MEASUREMENT LOCATION	MEASUREMENT RANGE (μ IN/IN)
85	CIRC. STRAIN	DOME SHEAR LIP STA 6.000	90 DEGREE 0 TO 5000
86	AXIAL STRAIN	DOME SHEAR LIP STA 6.000	90 DEGREE 0 TO 5000
87	RADIAL DEF.	DOME FLANGE BOTTOM	0 DEGREE 0 TO 2000
88	RADIAL DEF.	DOME FLANGE TOP	0 DEGREE 0 TO 2000
89	RADIAL DEF.	BOT CLAMP SEG. BOTTOM	0 DEGREE 0 TO 2000
90	RADIAL DEF.	BOT CLAMP SEG. TOP	0 DEGREE 0 TO 2000
91	RADIAL DEF.	CLAMP RING BOTTOM	0 DEGREE 0 TO 2000
92	RADIAL DEF.	CLAMP RING CENTER	0 DEGREE 0 TO 2000
93	RADIAL DEF.	CLAMP RING TOP	0 DEGREE 0 TO 2000
94	RADIAL DEF.	TOP CLAMP SEG. BOTTOM	0 DEGREE 0 TO 2000
95	RADIAL DEF.	TOP CLAMP SEG. TOP	0 DEGREE 0 TO 2000
96	RADIAL DEF.	VESSEL FLANGE BOTTOM	0 DEGREE 0 TO 2000
97	RADIAL DEF.	VESSEL FLANGE TOP	0 DEGREE 0 TO 2000
98	RADIAL DEF.	DOME FLANGE BOTTOM	180 DEGREE 0 TO 2000
99	RADIAL DEF.	DOME FLANGE TOP	180 DEGREE 0 TO 2000
100	RADIAL DEF.	BOT CLAMP SEG. BOTTOM	180 DEGREE 0 TO 2000
101	RADIAL DEF.	BOT CLAMP SEG. TOP	180 DEGREE 0 TO 2000
102	RADIAL DEF.	CLAMP RING BOTTOM	180 DEGREE 0 TO 2000
103	RADIAL DEF.	CLAMP RING CENTER	180 DEGREE 0 TO 2000
104	RADIAL DEF.	CLAMP RING TOP	180 DEGREE 0 TO 2000
105	RADIAL DEF.	TOP CLAMP SEG. BOTTOM	180 DEGREE 0 TO 2000
106	RADIAL DEF.	TOP CLAMP SEG. TOP	180 DEGREE 0 TO 2000
107	RADIAL DEF.	VESSEL FLANGE BOTTOM	180 DEGREE 0 TO 2000
108	RADIAL DEF.	VESSEL FLANGE TOP	180 DEGREE 0 TO 2000
109	GAP SEPARATION	INSIDE VESSEL TO DOME	30 DEGREE 0 TO 2000

INSTRUMENTATION LIST

GAGE NO	GAGE IDENTIFICATION	GAGE INSTALLATION	RECORDING INSTRUMENT	REFERENCE FIGURE
85	BUDD C 12-121-R2VC	ACF-1S-9,11,12	GILMORE M114 2-83	2
86	BUDD C 12-121-R2VC	ACF-1S-9,11,12	GILMORE M114 2-84	2
87	AC F TYPE C		GILMORE M114 2-41	6
88	AC F TYPE C		GILMORE M114 2-42	6
89	AC F TYPE C		GILMORE M114 2-43	6
90	AC F TYPE C		GILMORE M114 2-44	6
91	AC F TYPE C		GILMORE M114 2-45	6
92	AC F TYPE C		GILMORE M114 2-46	6
93	AC F TYPE C		GILMORE M114 2-47	6
94	AC F TYPE C		GILMORE M114 2-49	6
95	AC F TYPE C		GILMORE M114 2-50	6
96	AC F TYPE C		GILMORE M114 2-51	6
97	AC F TYPE C		GILMORE M114 2-52	6
98	AC F TYPE C		GILMORE M114 2-53	6
99	AC F TYPE C		GILMORE M114 2-54	6
100	AC F TYPE C		GILMORE M114 2-55	6
101	AC F TYPE C		GILMORE M114 2-56	6
102	AC F TYPE C		GILMORE M114 2-57	6
103	AC F TYPE C		GILMORE M114 2-58	6
104	AC F TYPE C		GILMORE M114 2-59	6
105	AC F TYPE C		GILMORE M114 2-60	6
106	AC F TYPE C		GILMORE M114 2-61	6
107	AC F TYPE C		GILMORE M114 2-62	6
108	AC F TYPE C		GILMORE M114 2-63	6
109	AC F TYPE C		GILMORE M114 2-64	6

INSTRUMENTATION LIST

GAGE NO	MEASUREMENT DESCRIPTION	MEASUREMENT LOCATION	MEASUREMENT RANGE (μ IN/IN)
110	GAP SEPARATION	OUTSIDE VESSEL TO DOME	30 DEGREE 0 TO 2000
111	GAP SEPARATION	INSIDE VESSEL TO DOME	210 DEGREE 0 TO 2000
112	GAP SEPARATION	OUTSIDE VESSEL TO DOME	210 DEGREE 0 TO 2000
113	VESSEL ROT.	NOZZEL-VESSEL INTERFACE	90 DEGREE 0-5 MIN ARC
114	NOZZLE ROT.	NOZZEL-VESSEL INTERFACE	90 DEGREE 0-5 MIN ARC
115	VESSEL ROT.	NOZZEL-VESSEL INTERFACE	270 DEGREE 0-5 MIN ARC
116	NOZZLE ROT.	NOZZEL-VESSEL INTERFACE	270 DEGREE 0-5 MIN ARC
117	GAP SEPARATION	NOZZEL-VESSEL INTERFACE	0 DEGREE 0 TO 2000
118	GAP SEPARATION	NOZZEL-VESSEL INTERFACE	90 DEGREE 0 TO 2000
119	GAP SEPARATION	NOZZEL-VESSEL INTERFACE	180 DEGREE 0 TO 2000
120	GAP SEPARATION	NOZZEL-VESSEL INTERFACE	270 DEGREE 0 TO 2000
121	CIRC. STRAIN	DOMESHEAR LIP STA 6.000	270 DEGREE 0 TO 5000
122	AXIAL STRAIN	DOMESHEAR LIP STA 6.000	270 DEGREE 0 TO 5000
123	CIRC. STRAIN	CLAMP SEGMENT CENTER	98 DEGREE 0 TO 5000
124	DIAG. STRAIN	CLAMP SEGMENT CENTER	98 DEGREE 0 TO 5000
125	AXIAL STRAIN	CLAMP SEGMENT CENTER	98 DEGREE 0 TO 5000
126	CIRC. STRAIN	CLAMP SEGMENT CENTER	91 DEGREE 0 TO 5000
127	DIAG. STRAIN	CLAMP SEGMENT CENTER	91 DEGREE 0 TO 5000
128	AXIAL STRAIN	CLAMP SEGMENT CENTER	91 DEGREE 0 TO 5000

INSTRUMENTATION LIST

GAGE NO	GAGE IDENTIFICATION	GAGE INSTALLATION	RECORDING INSTRUMENT	REFERENCE FIGURE
110	AC F TYPE C		GILMORE M114 2-65	6
111	AC F TYPE C		GILMORE M114 2-66	6
112	AC F TYPE C		GILMORE M114 2-67	6
113	AUTOCOLLIMATOR		MANUAL RECORDING	5
114	AUTOCOLLIMATOR		MANUAL RECORDING	5
115	AUTOCOLLIMATOR		MANUAL RECORDING	5
116	AUTOCOLLIMATOR		MANUAL RECORDING	5
117	AC F TYPE C		GILMORE M114 2-68	5
118	AC F TYPE C		GILMORE M114 2-69	5
119	AC F TYPE C		GILMORE M114 2-70	5
120	AC F TYPE C		GILMORE M114 2-71	5
121	BUDD C 12-121-R2VC	ACF-1S-9,11,12	GILMORE M114 2-85	2
122	BUDD C 12-121-R2VC	ACF-1S-9,11,12	GILMORE M114 2-86	2
123	BUDD EC 12-121-R3TS	ACF-1S-9,11,12	GILMORE M114 2-87	4
124	BUDD EC 12-121-R3TS	ACF-1S-9,11,12	GILMORE M114 2-88	4
125	BUDD EC 12-121-R3TS	ACF-1S-9,11,12	GILMORE M114 2-89	4
126	BUDD EC 12-121-R3TS	ACF-1S-9,11,12	GILMORE M114 2-90	4
127	BUDD EC 12-121-R3TS	ACF-1S-9,11,12	GILMORE M114 2-91	4
128	BUDD EC 12-121-R3TS	ACF-1S-9,11,12	GILMORE M114 2-92	4

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