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REPORT NO. CASD-NAS-75-006

THERMAL PERFORMANCE OF A CUSTOMIZED MULTILAYER INSULATION (MLI) CONTRACT NAS 3-17756

FINAL REPORT FOR TASK II

Design and Fabrication of Test Facility Hardware

(NASA-CR-135051) THERMAL PERFORMANCE OF A CUSTOMIZED MULTILAYER INSULATION (MLI). DESIGN AND FABRICATION OF TEST FACILITY HARDWARE Final Report (General Dynamics/Convair) 67 p HC A04/MF A01 N78-20257 Unclas G3/24 15213

By
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Submitted to
National Aeronautics and Space Administration
LEWIS RESEARCH CENTER
Cleveland, Ohio

15 August 1975

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THERMAL PERFORMANCE OF A CUSTOMIZED MULTILAYER INSULATION (MLI)

CONTRACT NAS3-17756

FINAL REPORT FOR TASK II

DESIGN AND FABRICATION OF TEST FACILITY HARDWARE

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Submitted to

National Aeronautics and Space Administration
Lewis Research Center
Cleveland, Ohio 44135

General Dynamics Convair Division
San Diego, CA 92138

FOREWORD

This report was prepared by General Dynamics Convair Division under Contract NAS3-17756, "Thermal Performance of a Customized Multilayer Insulation." The work was administered under the technical direction of Mr. J. R. Barber, Fluid System Section of Chemical Energy Division of the Space Technology and Material Directorate and Mr. W. R. Johnson, Thermal Technology Section, Propulsion Technology Branch, Chemical Propulsion Division, NASA/Lewis Research Center.

In addition to the project leader, K. E. Leonhard, the following Convair personnel were major contributors to the study:

Thermodynamics	M. D. Walter G. B. Yates
Manufacturing Research	H. E. Kobrich E. Catton V. V. Sowinski
Test Laboratory	B. A. Ganoe H. G. Brittain

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SUMMARY

Task II of the program "The Performance of a Customized Multilayer Insulation (MLI)" consisted of the design, fabrication and assembly of the test facility hardware. A schematic of the major, assembled system components including the thermal payload simulator and the modified cryoshroud is shown in Figure S-1. A tank back pressure control device designed to maintain a constant liquid boiling point during the thermal evaluation of the multilayer insulation (Task V) is also a major component of the test system. Auxiliary hardware to operate the test apparatus was designed and fabricated.

THERMAL PAYLOAD SIMULATOR (TPS)

The thermal payload simulator was designed and fabricated to provide a constant temperature surface in the range of 20.5 to 417K (37 to 750R) for the insulated tank to view. It consists of a 1.83m (72 in) diameter 0.953 cm (0.375 in) thick, highly polished aluminum disc. An emissivity of 0.03 was measured utilizing the Lion emissometer Model 25 B-7. The thermal payload simulator is cooled by liquid hydrogen flowing through circumferential, aluminum coils. The TPS heaters were designed for an operating range of 0.01 to 55 watts. Due to the radially nonuniform heat load on the TPS, individual heaters were mounted in the inner, mid and outer zone.

CRYOSHROUD ASSEMBLY MODIFICATION

The objective of the modification of the NASA/LeRC furnished cryoshroud, 2.44 m (8.0 ft) in diameter, was to establish a low temperature black body cavity while limiting liquid hydrogen usage to a minimum feasible rate. The modification of the cryoshroud was performed in six subtasks:

1. Cryoshroud shell modification
2. Cryoshroud thermal analysis
3. Cryoshroud baffle design and fabrication
4. Thermal payload simulator and baffle positioning mechanism design and fabrication
5. Guard tank design and fabrication
6. Assembly of the cryoshroud components

The cryoshroud shell modification consisted of reworking the top cover to accommodate the guard tank, removal of the existing baffles and preparing the bottom cover for the baffle positioning mechanism. An analysis was performed to determine the number and location of the liquid hydrogen cooled baffles required to intercept the thermal

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NOTE: ALL FILL AND VENT LINES ARE INSULATED WITH 10 LAYERS OF MLI

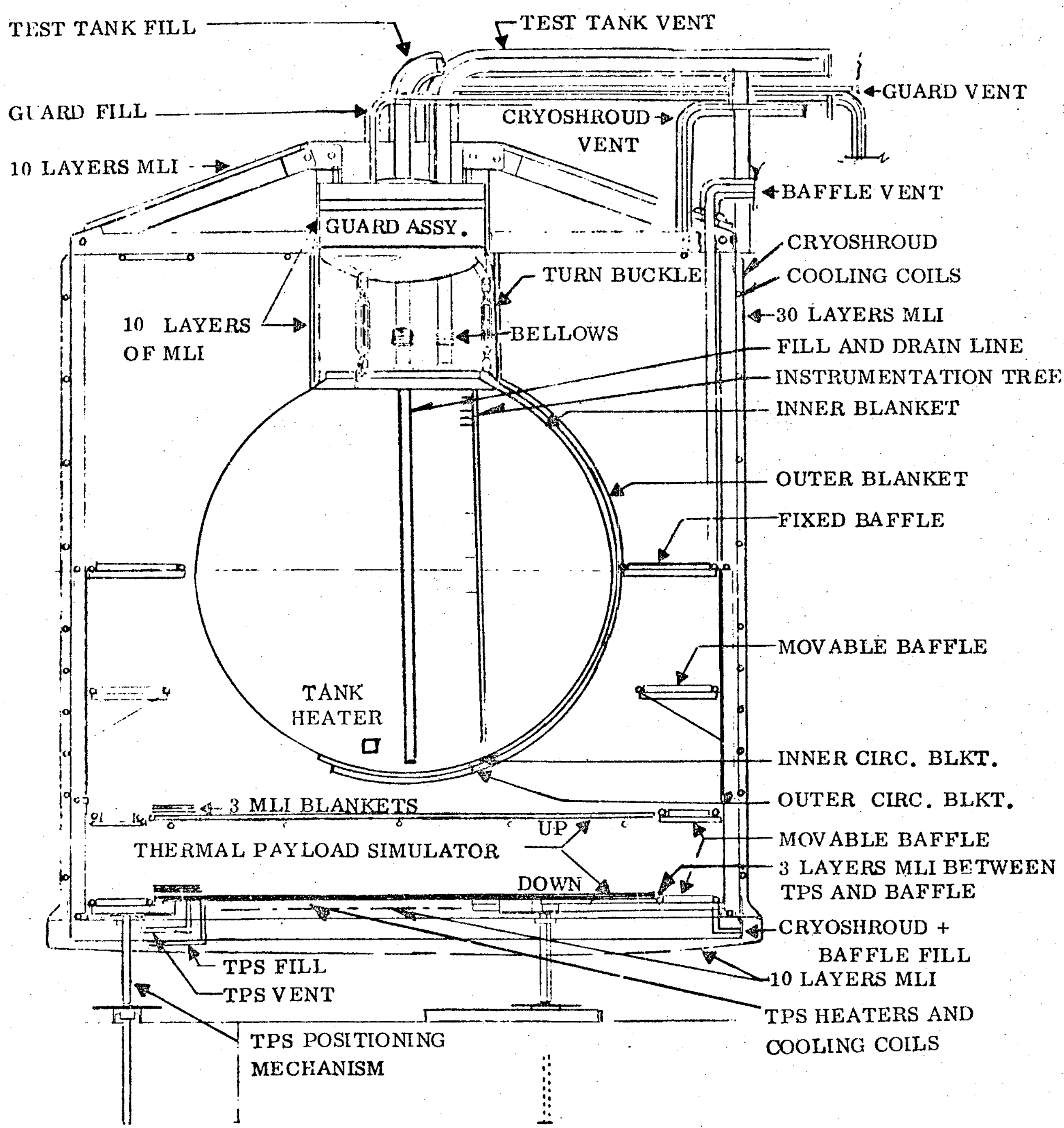


Figure S-1. Apparatus for Testing the Thermal Performance of the 60 Inch Tank Customized MLI radiation within the cryoshroud. The analysis revealed that three baffles are required, one fixed baffle located at the test tank equator, one baffle in the same plane as the thermal payload simulator and one baffle between the thermal payload simulator and fixed baffle. The baffle structure is a sandwich consisting of a flat plate with cooling coils welded to its upper surface as the main structural element and honeycomb bonded to one or both of the surfaces. The lower two baffles and the thermal payload simulator are designed to move together. The bottom baffle remains in the same plane with the payload simulator as it is positioned by the jack screw mechanism.

All lines going to the test tank pass through the 60.96 cm (24 in) diameter liquid hydrogen guard tank as shown in Figure S-1 in order to prevent entry of extraneous heat to the test tank. All instrumentation lines into the test tank are passed through the vent line.

The assembly sequence of the modified cryoshroud was as follows:

1. Attachment of the guard tank to the shroud top.
2. Mating of the test tank to the guard tank/shroud top assembly.
3. Mating of the baffle assembly to the shroud-side.
4. Installation of the multilayer insulation on the guard and test tank assembly.
5. Instrumentation of tank/baffle/shroud and thermal payload simulator.
6. Mating of thermal payload simulator to the baffle/shroud assembly.
7. Installation of the insulation on the bottom of the TPS.
8. Mating of shroud bottom to TPS/baffle assembly/shroud assembly.
9. Joining of test tank to the shroud assembly.
10. Installation of the test assembly into the vacuum chamber.
11. Installation of the baffle positioning jack screws.
12. Installation of the MLI on the outside of the cryoshroud assembly.

Before installing the test tank all interior surfaces including cryoshroud, baffles, and attachment hardware viewing the test package were painted with 3M "Nextel" Black Velvet paint to achieve the highest emissivity possible. Single and double Conoseals were used for tubing joints, where welding was not possible. Single Conoseals were utilized for stainless steel joints while double Conoseals were applied for bi-metal joints.

PRESSURE CONTROL SYSTEMS

Back pressure control devices are used for both the test tank and the guard tank to maintain a constant liquid boiling point. The back pressure of the test tank is controlled within ± 1.38 N/m^2 (± 0.0002 psia) of the set point. The MKS Baratron Differential Capacitance Manometer senses very small pressure variations relative to the absolute pressure of a fixed volume of gas maintained at a constant temperature. The output of this instrument is fed to a controller which activates one of two valves in the vent line to control the tank pressure within the desired tolerance. The NBS Barostat is used to control the pressure of the guard tank at ±13.8 N/m^2 (±0.002 psi).

AUXILIARY HARDWARE

Design and fabrication of auxiliary hardware was required to support the test operation. These systems include LH_2 fill and drain and vent lines for the test tank and guard tank, the LH_2 supply and recovery system for the cryoshroud, baffles and payload simulator. Welding and silver brazing was used as the principal means of joining fluid system components inside the chamber in addition to the Conoseals. All components were individually leak checked. After assembly and installation of the test tank into the vacuum chamber a complete section by section leak check was performed and repairs made as necessary. A 1500 gallon tank is used to supply liquid hydrogen to all systems. The supply tank is supplied from the 13,000 gallon site storage tank and the 1,000 gallon recovery tank.

An electric heater installed in the test tank is used to supply a known heat input to the test tank during the null test (Task V of contract).

1

INTRODUCTION

This program report covers the work performed under task II of NASA contract NAS3-17756, "Thermal Performance of a Customized Multilayer Insulation (MLI)." The major objective of the total program is to build up a test facility and to design, fabricate, and experimentally evaluate the thermal performance of a selected, customized MLI system. NASA/LeRC provided the basic design of the MLI configuration to be tested, the test tank to be insulated, and the cryoshroud for simulating a deep space environment. The test tank was modified in Task I (Reference 3-2) to establish the required smooth spherical contour over most of the tank surface area. Task II is the design and fabrication of the Test Facility Hardware. Multilayer insulation systems for the thermal payload simulator and test tank were designed and fabricated during task III and IV, (Ref. 4-2). Task V is the experimental evaluation of the multilayer insulation system.

THERMAL PAYLOAD SIMULATOR

The purpose of the thermal payload simulator (TPS) is to provide a constant temperature surface for the insulated 1.52 m(60 in) tank to view (Figure S-1). The TPS configuration consists of a 1.83 m (72 in) dia. aluminum plate supported by the cryoshroud assembly. A schematic of the payload simulator is shown in Figure 2-1.

2.1 THERMAL REQUIREMENTS

The following provisions were incorporated in the design of the TPS to meet the thermal conditions during the Null test, the thermal testing of the tank installed system and thermal testing of the customized MLI configuration:

1. Provisions for establishing and maintaining any uniform steady-state temperature in the range of 20.5 to 417K (37 to 750R) over the surface of the payload simulator.

2. Provisions for varying the tank-payload simulator spacing to any value between 15.24 cm (6 in) and 45.72 cm (18 in).

3. Surface viewing the tank must be flat and free of penetrations.

4. Total hemispherical emittance less than 0.04.

The temperature, < 27.8K (50R) required during the test operation is achieved by circulating LH_2 through cooling coils welded to the bottom surface of the aluminum plate. Since the TPS is completely surrounded by a LH_2 cold wall, two coils (Figure 2-1) will reduce the plate temperature below the required 27.8K (50R) in less than an hour. During the thermal tests electric heaters are used to produce the required surface temperatures. The highest test temperature required is 389K (700R), however, the maximum heat load of approximately 58.6W (200 Btu per hour) will be at 289K (520R) during the tank thermal test without the insulation on the plate. Assuming a 103.8 W/mK (60 Btu/hr-ft R) thermal conductivity for the aluminum plate, a heater element spacing of 15.2 cm (6 in) produces a temperature variation less than 0.055K (0.1R) at the maximum heat load. There should be no circumferential variation in the normal thermal flux. However, there will be a radial variation due to the shape of the tank bottom and edge loading by the cryoshroud and baffles. This is corrected by dividing the heater into suitable annular sections, which are independently controlled as shown in Figure 2-1.

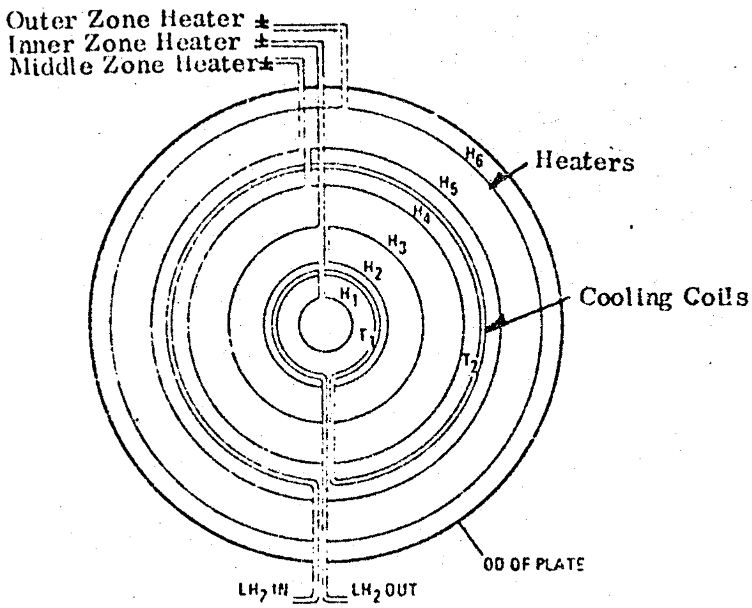


Figure 2-1. Thermal Payload Simulator Schematic

The inner edge of the lower baffle next to the simulator is shielded by three layers of aluminized Mylar to reduce the thermal load on the outer heater band. Further thermal protection for the simulator is provided by a 10-layer aluminized Mylar insulation blanket placed between the simulator and the bottom of the shroud.

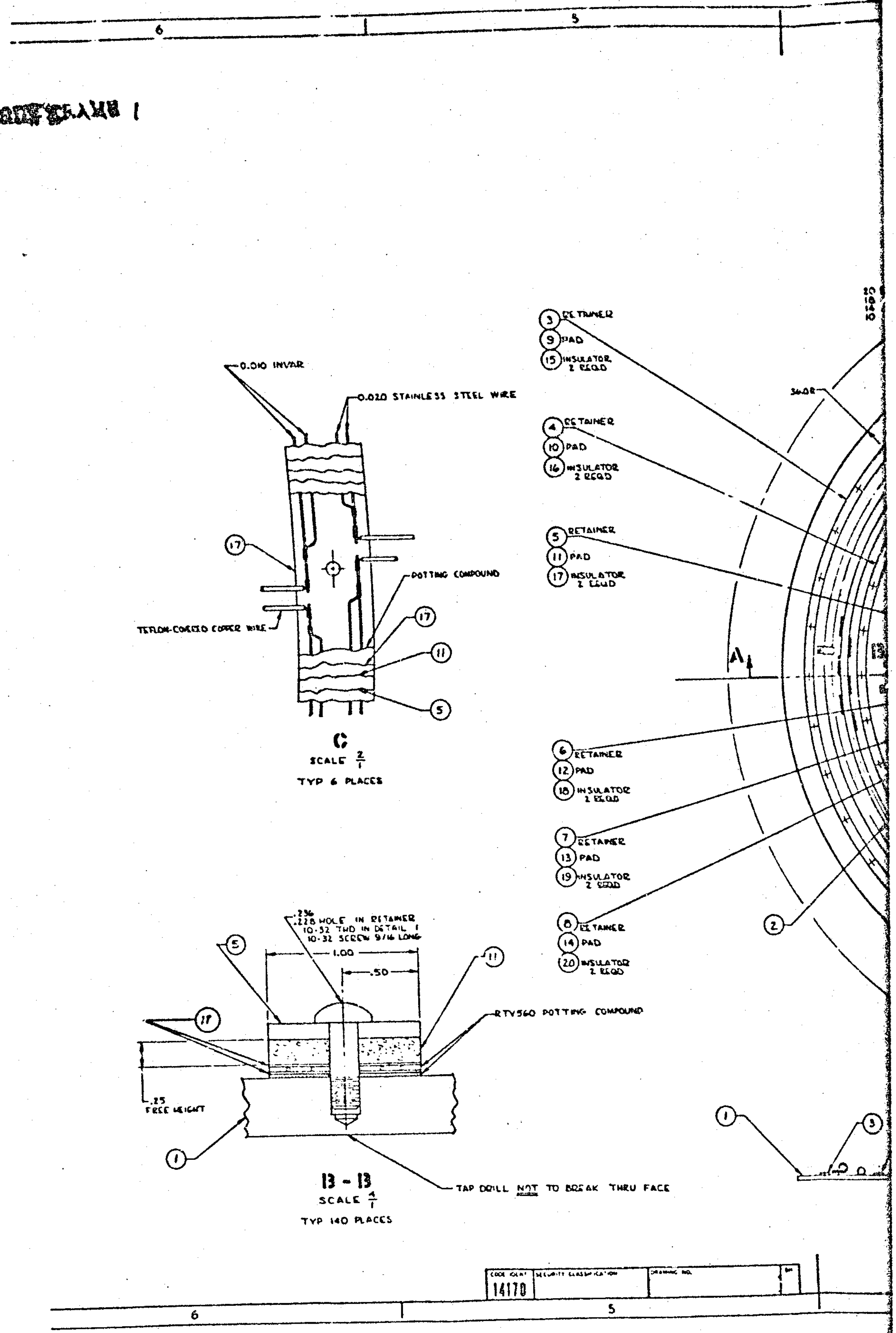
The simulator is positioned along with the lower baffle by moving the TPS adjustment mechanism (Figure S-1). This baffle is moved by three jackscrews which are controlled from outside the chamber. A linear displacement transducer is used to determine the platform position. Positioning accuracy is ±0.25 cm (0.1 in).

2.2 TPS Design and Fabrication

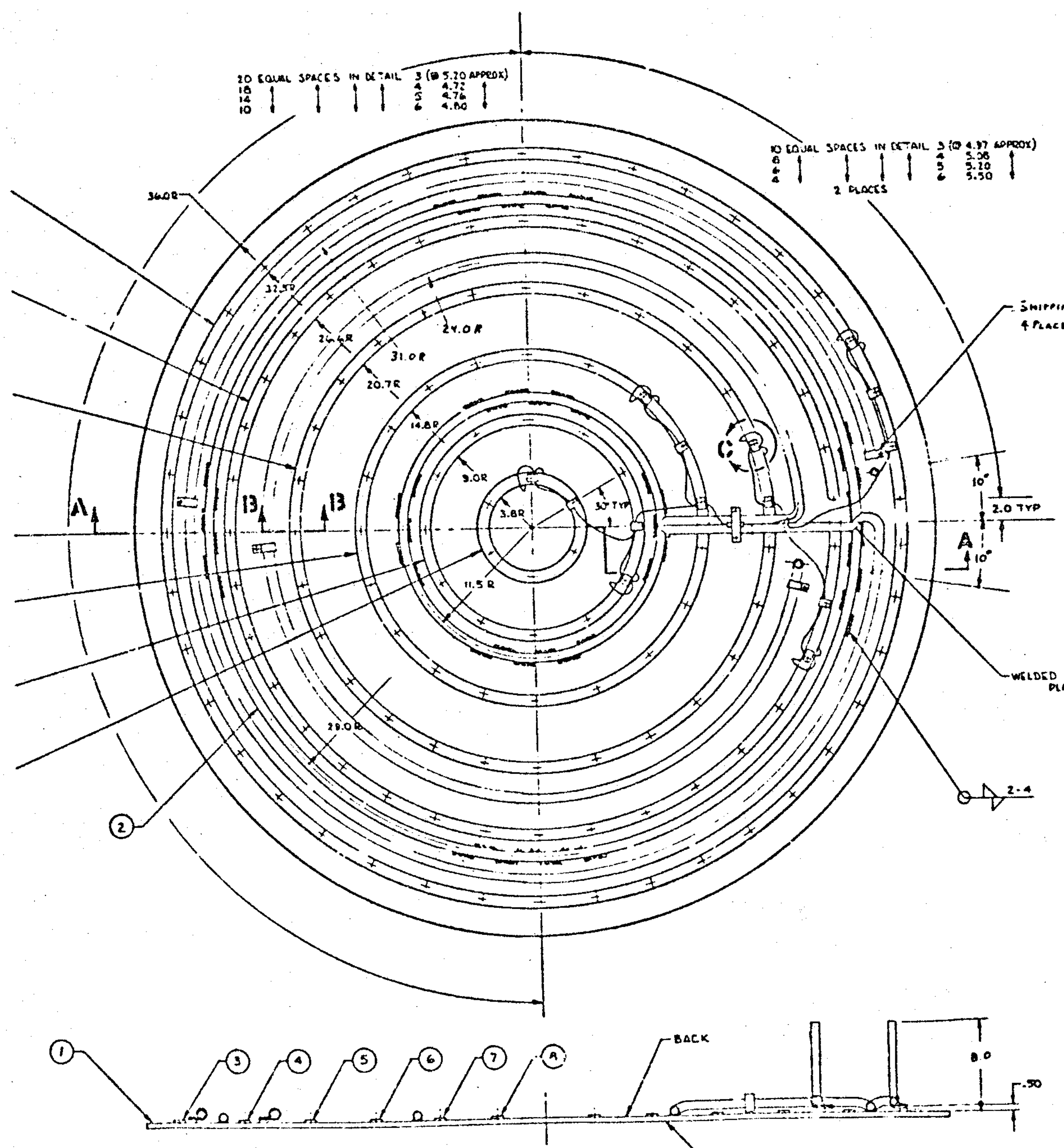
The TPS design configuration is presented in Figure 2-2. The base plate consists of a disk 0.953 cm (0.375 in) thick and 1.83 m (72 in) in diameter. It was fabricated from a highly polished 6061-T-6 Alclad aluminum material. There are no penetrations on the surface facing the tank. An emissivity of 0.03 was measured by a Lion emissometer Model 25B-7. During installation of the cooling coils and electrical heaters the polished surface was protected with a strippable plastic film, called Spraylab, which could be easily removed after installation of all components.

2.2.1 <u>COOLING COILS.</u> The cooling coils were designed and fabricated utilizing 1.90 cm (0.75 in) O.D. × 0.152 cm (0.060 in) thick, 6061-T6 aluminum tubing. The

FOLDOUT FRAME 1



FOLDOUT FRAME 2



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REVISIONS

ZONE	LTR	DESCRIPTION	DATE	APPROVED

FOLDOUT FRAME 3

NOTES –
1. REMOVE ALCLAD ON BACK IN AREA OF COOLING TUBES
2. WELD 3/4 DIA COOLING TUBES IN PLACE
3. FLATTEN PLATE AND TUBE ASSEMBLY AFTER WELDING (IF NECESSARY) TO ± 1/8 INCH.
4. DRILL AND TAP ALL BLIND HOLES IN BACK SIDE OF PLATE.
5. PLACE IN HOLDING FIXTURE FACE UP.
6. POLISH FACE, CHECK EMISSIVITY; RE-POLISH AS NECESSARY TO OBTAIN EMISSIVITY LESS THAN 0.04. SPRAY WITH STRIP PLASTIC.
7. TURN PLATE ASSEMBLY FACE DOWN IN HOLDING FIXTURE
8. INSTALL HEATERS

JOINT

QTY	DETAIL / PART NO.	PART NAME	SIZE	MATERIAL
8		SCREW	10-32 x 1-1/2	
140		SCREW	10-32 x 3/16	
AR		WIRE	.020 DIA	STAINLESS STEEL
AR		WIRE	.010 DIA	INVAR
AR	RTY560	POTTING COMPOUND		
3	24	CLAMP	.75 x 1.3 x 2.8	MICARTA
3	23	BLOCK	.38 x .6 x 2.8	MICARTA
1	22	CLAMP	.75 x 1.3 x 2.8	MICARTA
1	21	BLOCK	.50 x .8 x 2.8	6061-T6
1	20	INSULATOR	.002 x 1.0	TEFLON
1	19			
1	18			
1	17			
1	16			
1	15	INSULATOR	.002 x 1.0	TEFLON
1	14	PAD	1/4 x 1.0	SILICONE FOAM RUBBER - OPEN CELL
1	13			
1	12			
1	11			
1	10			
1	9	PAD	1/4 x 1.0	SILICONE FOAM RUBBER - OPEN CELL
1	8	RETAINER	[illegible] x 1.0	AL ALY
1	7			
1	6			
1	5			
1	4			
1	3	RETAINER	.10 x 1.0	AL ALY
1	2	TUBE	.75 OD x 0.040	6061-T6
1	1	PLATE	.375 x 72.0 x 72.0	6061-T6

PARTS LIST

UNLESS OTHERWISE SPECIFIED

MACHINED SURFACES √

SEE 0-1000 FOR ABBREVIATION CODE AND SYMBOL REQUIREMENTS

SEE 0-10002 FOR STANDARD MANUFACTURING AND INSTALLATION REQUIREMENTS

ASSOCIATED LIST REQUIRED SEE DOCUMENT SAME NUMBER PREFIXED
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DESIGN
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CONTRACT NO

CONVAIR DIVISION OF GENERAL DYNAMICS
SAN DIEGO CALIFORNIA

THERMAL PAYLOAD SIMULATOR

SIZE J | CODE IDENT 14170 | DRAWING NO PD73-0086-1

Figure 2-2. Thermal Payload Simulator Design circumferential coils were welded in place as shown in Figure 2-2. Welds, 2.54 cm (1.0 in) long, spaced at 2.54 cm (1.0 in) were applied on alternate sides of the tubing to ensure good heat conduction between the LH_2 tubing and the TPS plate. Radial feed lines were not fastened to the plate to minimize thermal nonuniformity circumferentially. The tubing loop was leak checked with gaseous helium and a helium mass spectrometer. It was necessary to replace a welded portion of the LH_2 tubing, after a leakage problem could not be resolved. The replacement section was re-checked and found to be free of any leakage.

2.2.2 ELECTRICAL HEATERS. The heat load on the plate at equilibrium temperature was expected to range from 0.01 to 55 watts. To improve the reliability each of the heater rings consists of one high power and one low power heater. Each heater was equipped with two parallel elements.

Due to the radially nonuniform heat load on the TPS, the heaters were divided into three annular zones: 1) an inner zone consisting of three inner rings connected in series; 2) a mid zone consisting of two rings connected in series, and 3) an outer zone consisting of the outer ring. For versatility, each heater element lead wire was extended individually to the outside of the chamber to facilitate regrouping if necessary. The heater design connections are shown in Figure 2-2 and 2-3 .

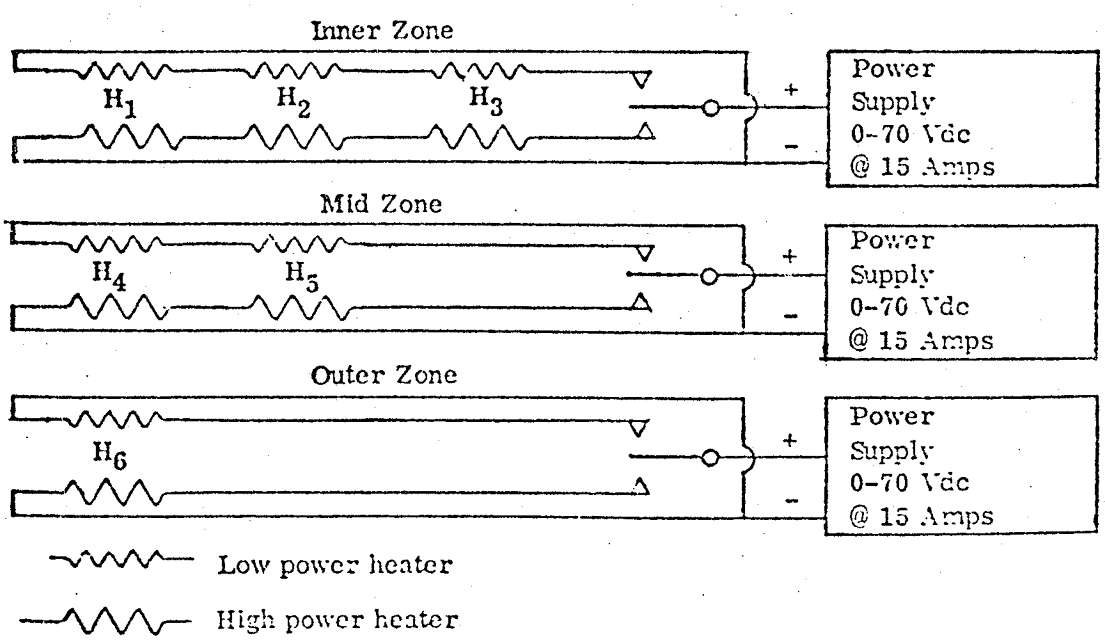


Figure 2-3. Sketch of Electrical Heater Connections

The material selection to construct the electrical heaters was based primarily on the required temperature limits of 20.5K (37R) and 417K (750R) with second consideration being thermal conductivity. The heater was constructed utilizing 0.0254 cm (0.010 in) invar and 0.058 cm (0.020 in) thick stainless steel wires. The Teflon film between the TPS and heater wires was required for electrical insulation. The Teflon film behind the heater wire reduces the area loading on the silicone rubber foam while limiting the force on the wire to prevent its cutting through the insulating Teflon. The silicone foam is a resiliant filler to provide good mechanical contact between the heater and the TPS and some thermal insulation between the heater and the aluminum back-up strip. RTV 560 potting compound is used primarily for thermal conductivity and also as a mechanical bond. A photo of the completed thermal payload simulator in its protective holding fixture is shown in Figure 2-4.

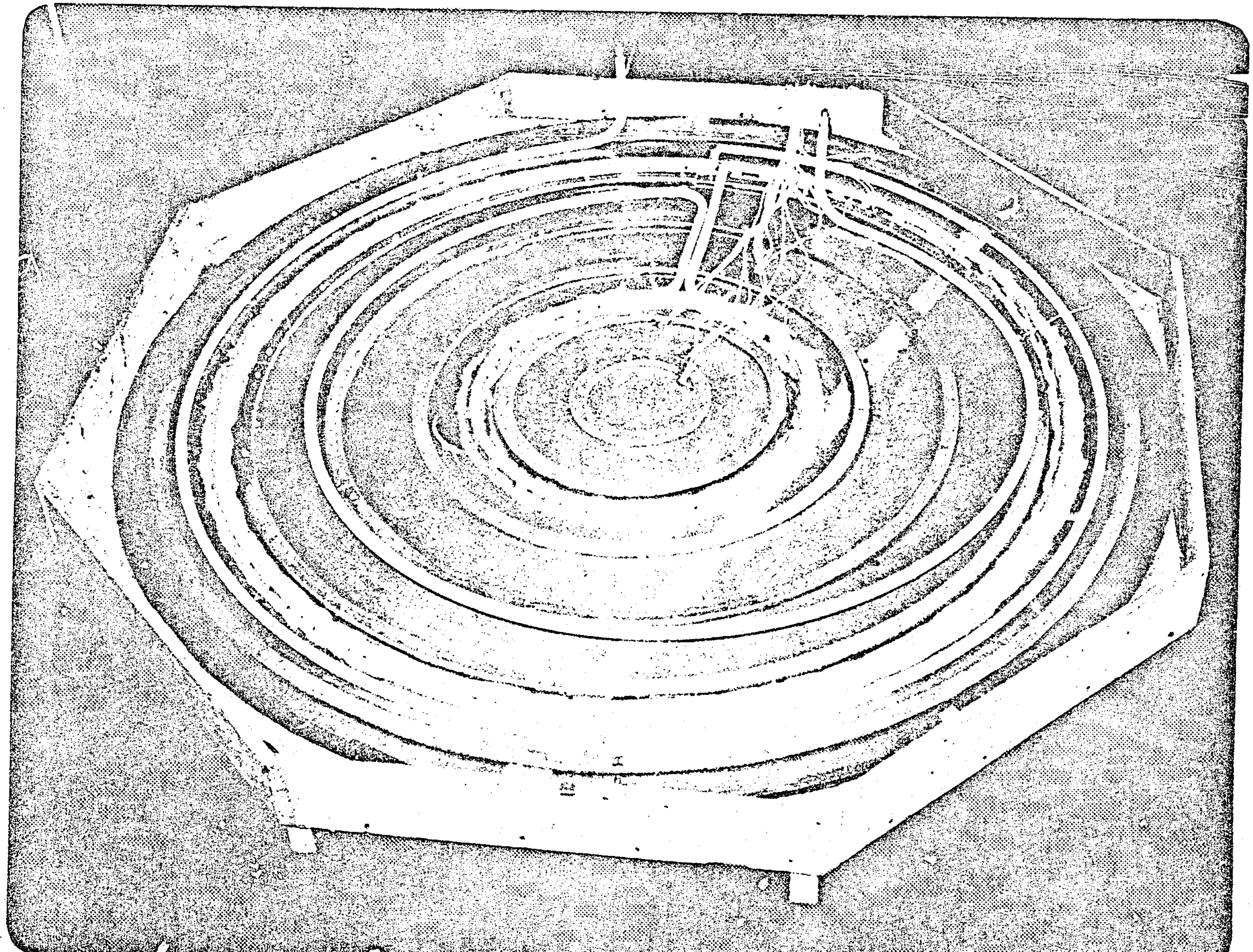


Figure 2-4. Thermal Payload Simulator Assembly

3

CRYOSHROUD ASSEMBLY MODIFICATION

The modification of the cryoshroud was initiated by evaluating the design of the cryoshroud assembly which was furnished by the NASA LeRC to simulate the environment of deep space. The cryoshroud was required to be cooled by liquid hydrogen and to have a high surface emittance on those surfaces viewing the test tank. The objective of the modification was to establish as near a low temperature black body cavity as feasible, and minimize cryoshroud hydrogen usage.

The cryoshroud assembly modification effort was subdivided into five tasks:

1. Cryoshroud modification
2. Cryoshroud baffle thermal analysis
3. Cryoshroud baffle design and fabrication
4. Guard tank design and fabrication
5. Thermal payload simulator and baffle positioning mechanism design and fabrication
6. Assembly of the cryoshroud components

3.1 CRYOSHROUD MODIFICATION

The cryoshroud is a 2.44 m (8 ft) diameter by 2.44 m (8 ft) high cylindrical shell with top and bottom covers. Cooling coils are welded to all surfaces. A schematic of the cryoshroud is shown in Figure S-1. The material used in the construction of the cryoshroud is principally 6061 aluminum alloy. The basic method of construction is a framework of 7.62 × 7.62 × 0.63 cm (3 × 3 × 0.25 in) angle and 7.62 × 0.63 cm (3 × 0.25 in) bar stock material with 0.32 cm (1/8 in) sheet covering. The top cover has a heavy 5.08 cm (2 in) thick mounting ring attached by a 63.5 cm (25 in) diameter 25.4 cm (10 in) high sleeve. The ring is braced by four radial struts. The cylindrical shell has eight baffle guides which also provide support for the sidewall structure.

The cryoshroud is mounted in the vacuum chamber on pads under the bottom cover rather than supported from the mounting ring in the top. Thus the radial strut load is compression rather than tension. Aluminum angles 7.62 × 7.62 × 0.63 cm (3 × 3 × 0.25 in) are attached to each side of each radial strut (Figure 3-1). The top cover (NASA Drawing CR 62191) was also modified by the addition of a 7.62 (3 in) hole for the baffle vent line to exit the cryoshroud.

The bottom cover (NASA Drawing CF 621922) was modified by the addition of holes for cooling tubes and for the payload simulator lifting jack screws. The new bottom

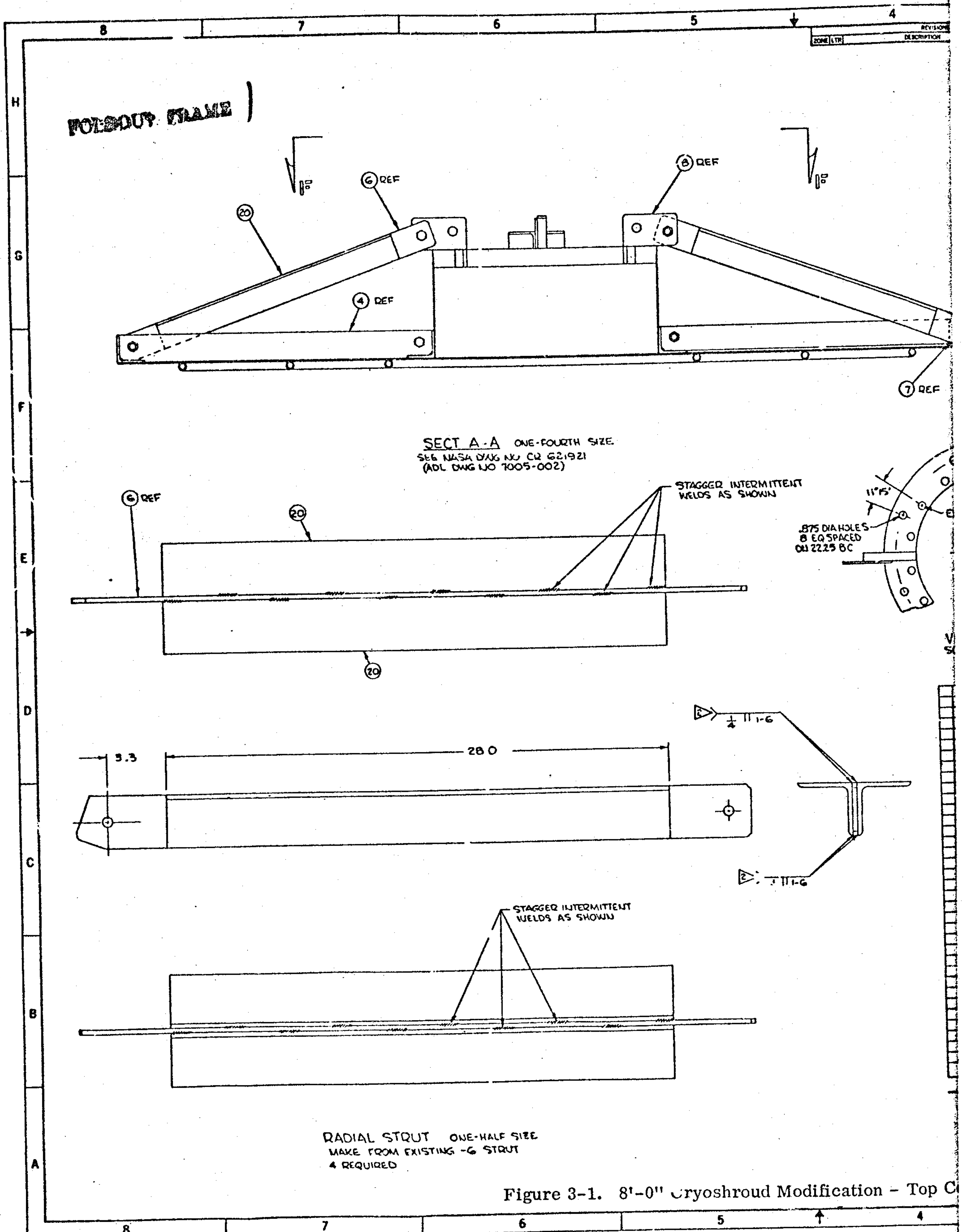


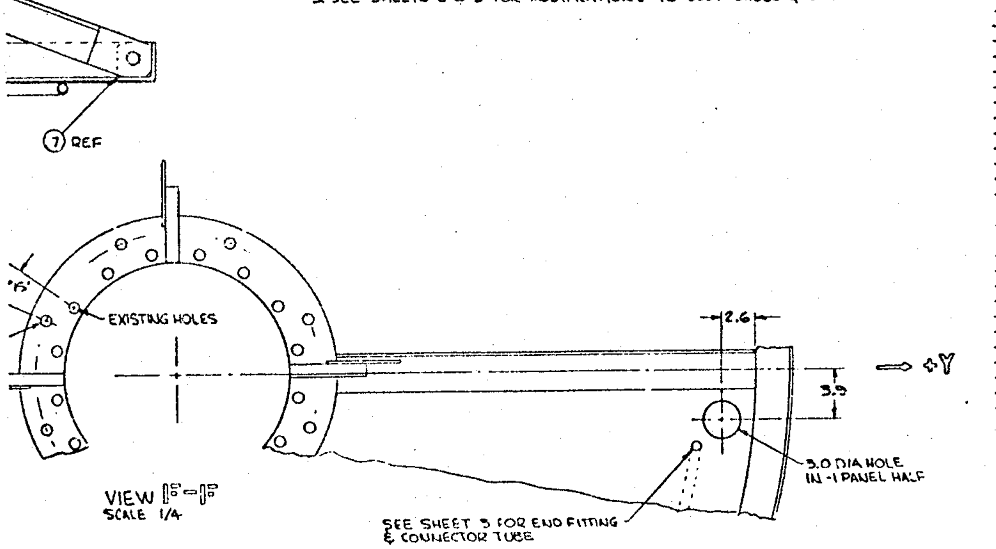
Figure 3-1. 8'-0" Cryoshroud Modification - Top C

4	3	2	1

REVISIONS DESCRIPTION	DATE	APPROVED	ZONE	LTR	REVISIONS DESCRIPTION	DATE	APPROVED	ZONE	LTR	REVISIONS DESCRIPTION	DATE	APPROVED

NOTES: UNLESS OTHERWISE SPECIFIED

1. MODIFY THE 8' CRYO-SHROUD MOUNTING STRUCTURE AND TOP COVER (NASA DWG CR621921) BY REWORKING THE FOUR RADIAL STRUTS AS SHOWN
2. WELD PER MIL-W-8604
3. SEE SHEETS 2 & 3 FOR MODIFICATIONS TO BODY SHELL & BOTTOM COVER



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REQ PER ASSY / INSTL	UNIT OF MEAS	ITEM OR FIND NO	CODE IDENT NO.	PART OR IDENTIFYING NUMBER	NOMENCLATURE OR DESCRIPTION	ZONE	NO	NOTE TEXT (STOCK SIZE, MATERIAL, SPECIFICATION, TYPE (TEMPER, ETC), HEAT TREAT)
1				-32	TUBE, CONNECTOR	E	38	.75 OD X .062 X 22.0 TUBE 6061-T4 AL
1				-31	TUBE, CONNECTOR	C	33	.75 OD X .062 X 67.0 TUBE 6061-T4 AL
1				-30	TUBE, FILL-BAFFLE	C	24	.75 OD X .062 X 23.0 TUBE 6061-T4 AL
1				-29	TUBE FILL	D	24	.75 OD X .062 X 50.0 TUBE 6061-T4 AL
1				-28	TEE	D	25	1.0 X 2.0 X 2.1 PLATE 6061-T6 AL
2				NAS1003-20A	BOLT	E	24	
14				MS21045-3	NUT	C	22	
12				AN960C10	WASHER	C	22	
12				NAS1005-14A	BOLT	C	22	
3		27		59190-12AA	FITTING, TUBE	H	27	PRODUCT OF AEROQUIP/MARMAN DIVISION
1		26		-26	TUBE, CONNECTOR	E	25	.75 OD X .062 X 95.0 TUBE 6061-T4 AL
1		25		-25	TUBE, FILL-C/S	D	25	.75 OD X .062 X 23.0 TUBE 6061-T4 AL
1		24		59161-100A	FLANGE, FEMALE	C	24	PRODUCT OF AEROQUIP/MARMAN DIVISION
1		23		-23	ADAPTER	C	24	1.0 OD X .87 X 5.0 TUBE 6061-T4 AL
1		22		AN742F12	CLAMP	D	24	
3		21		-21	BLOCK	C	25	1.0 X 4.0 X 4.0 TEFLON
3		20		-20	STRUT BRACE	E	5	3 X 3 X ¼ X 26.0 ANGLE 6061-T6 AL

NOTE SYMBOL: E–END ITEM, G–GENERAL NOTE, L–LIMIT, M–MATERIAL, R–REFERENCE DESIGNATION, S–STOCK NO, U–USAGE DATA

PARTS LIST

UNLESS OTHERWISE SPECIFIED: ALL MACHINED SURFACES √
RIVET BASIC CODE NAS523
BB–MS20426AD
BJ–MS20470AD

SEE 0-71914 FOR ABBREVIATION CODE AND SYMBOL REQUIREMENTS
SEE 0-70902 FOR STANDARD MANUFACTURING AND INSTALLATION REQUIREMENTS
ASSOCIATED LIST REQUIRED SEE DOCUMENT SAME NUMBER PREFIXED
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CONVAIR AEROSPACE DIVISION OF GENERAL DYNAMICS
SAN DIEGO, CALIFORNIA

8'-0" CRYO-SHROUD MODIFICATION

SIZE E | CODE IDENT 14170 | DRAWING NO P073-0085
SHEET 1 OF

– Top Cover

SECURITY CLASSIFICATION

FOLDOUT FRAME 2

cover drawing is presented in Figure 3-2. The only modification to the cylindrical sidewalls was the removal of the existing baffles and replacement of the joints between the upper and lower cooling tubes, Figure 3-3. "Double-Seal" Conoseal fittings were attached to the cryoshroud cooling tube fill and vent lines.

The entire inner surface of the cryoshroud was repainted with low outgassing 3M Nextel Velvet (3M 401-C10) to achieve as high an emissivity as possible.

3.2 CRYOSHROUD BAFFLE THERMAL ANALYSIS

The major objective of the cryoshroud thermal analysis was to determine the number and location of the liquid hydrogen cooled baffles, required to intercept and absorb both direct and reflected thermal radiation within the cryoshroud. The location of the baffles must be thermally acceptable for all three "Tank-TPS" spacings (Section 2.1), required during the testing of the customized MLI (Task V).

3.2.1 THERMAL ANALYSIS. An analysis was performed on the radiation interchange and heat transfer inside the lower half of the cryoshroud with the thermal payload simulator and insulated cryogenic tank. Two basic radiation interchange models were considered. The reflecting node model is a segment of the axially symmetric installation with boundary nodes having zero emissivity, Figure 3-4. The complete node model, Figure 3-5, includes all the radiative surface areas inside the cryoshroud.

3.2.2 REFLECTING NODE MODEL. The model consists of 19 flat plates and represents a 1/15 segment (24°) of the total installation. Since, in actual practice, the energy exchange will be symmetrical about the vertical tank axis, reflecting nodes (5, 6, 7, 8, 9, 10) with an emissivity, $\epsilon = 10^{-5}$, were placed on the sides of the segment section analyzed. The value, $\epsilon = 10^{-5}$, was used because the computer will not operate with a zero value. Use of reflecting boundaries reduces the number of nodes analyzed from 195 to 19 with a corresponding saving in setup and computer time. The cost of computing view factors and Script F values for radiation increases approximately as the 2.5 power of the number of nodes so that minimizing the number of nodes is significant. It is noted that the node size has been increased from a 1/16 segment to a 1/15 segment in order to reduce the maximum possible number of nodes in the complete model case to less than 200; a computer program limitation.

Four geometrical configurations were evaluated, (1) open-to-space, (2) the cryoshroud only, (3) the cryoshroud and lower baffle, and (4) the cryoshroud and two baffles. The thermal payload simulator in all cases was at its lowest position since this is the location where the greatest amount of reflected energy from the shroud/baffle surface will occur. The emissivity of the thermal payload simulator (node 1) was $\epsilon_{TPS} = 0.04$ and the MLI surface on the tank (nodes 2, 3, 4) was $\epsilon_T = 0.03$. The emissivity on the shroud (nodes 13, 14, 15) and baffles (nodes 11, 12 and 16, 17, 18, 19) was varied from 0.85 to 0.96 to simulate different surface coatings.

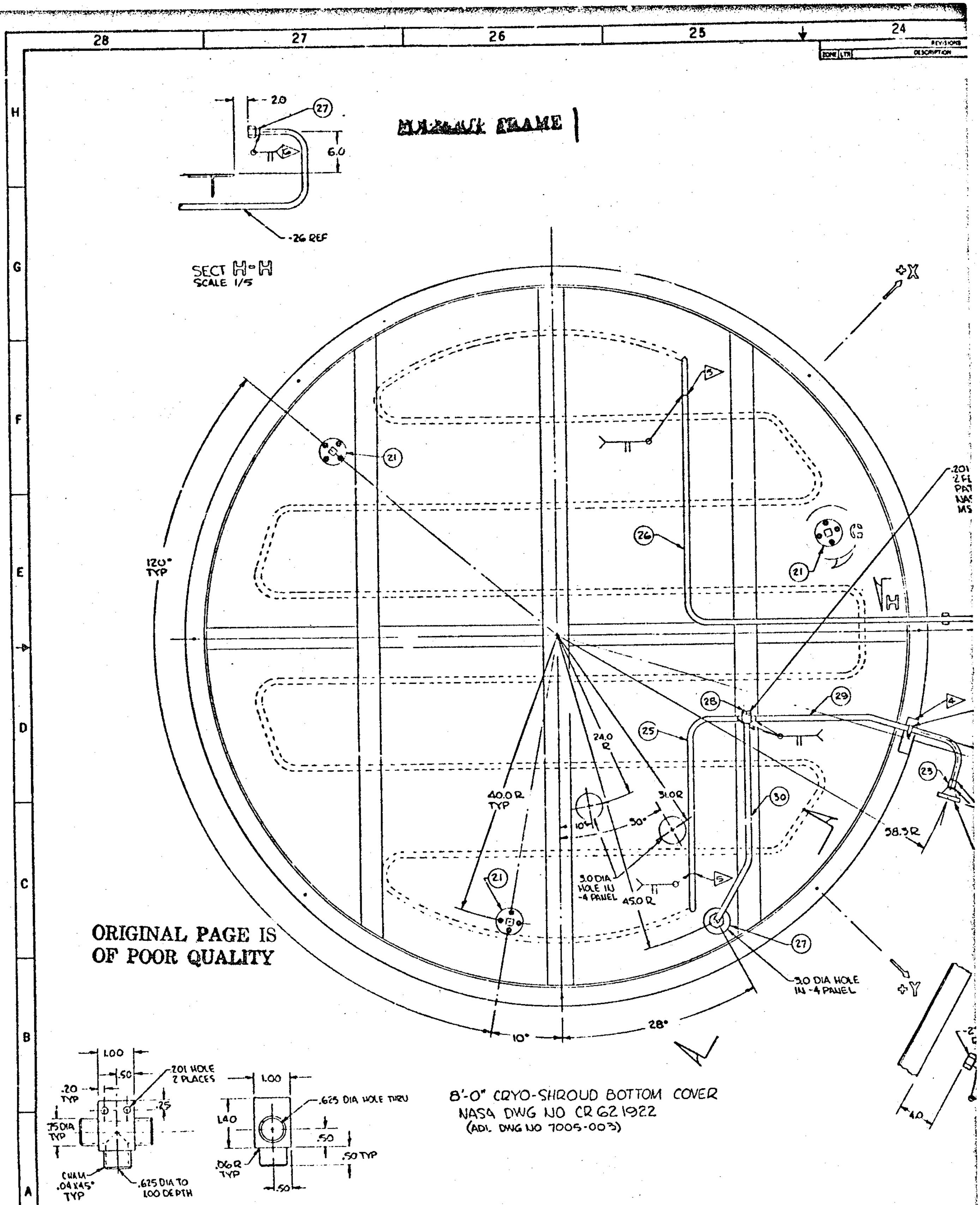

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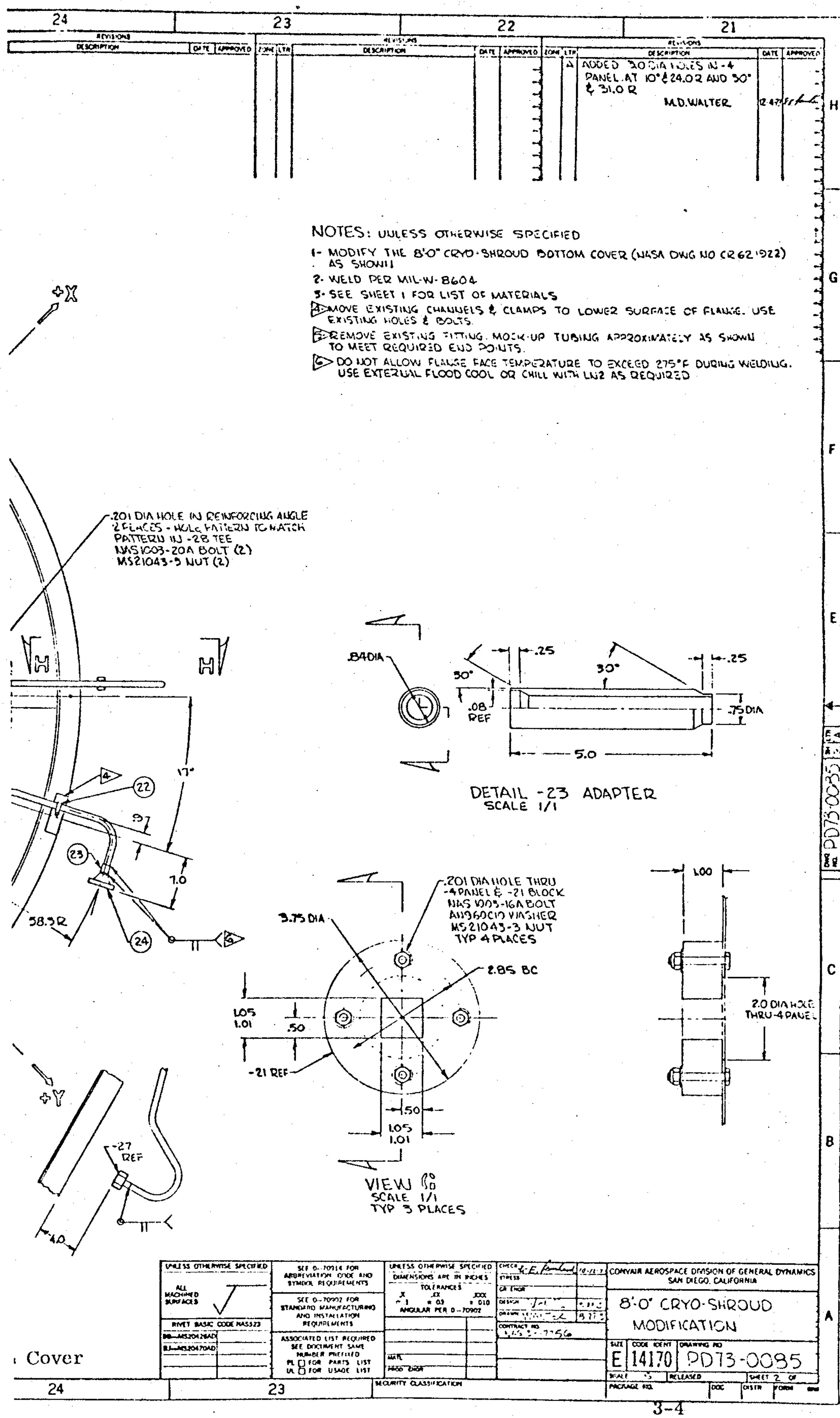
Figure 3-2. 8'-0" Cryoshroud Modification - Bottom Cover

FOLDOUT FRAME 2



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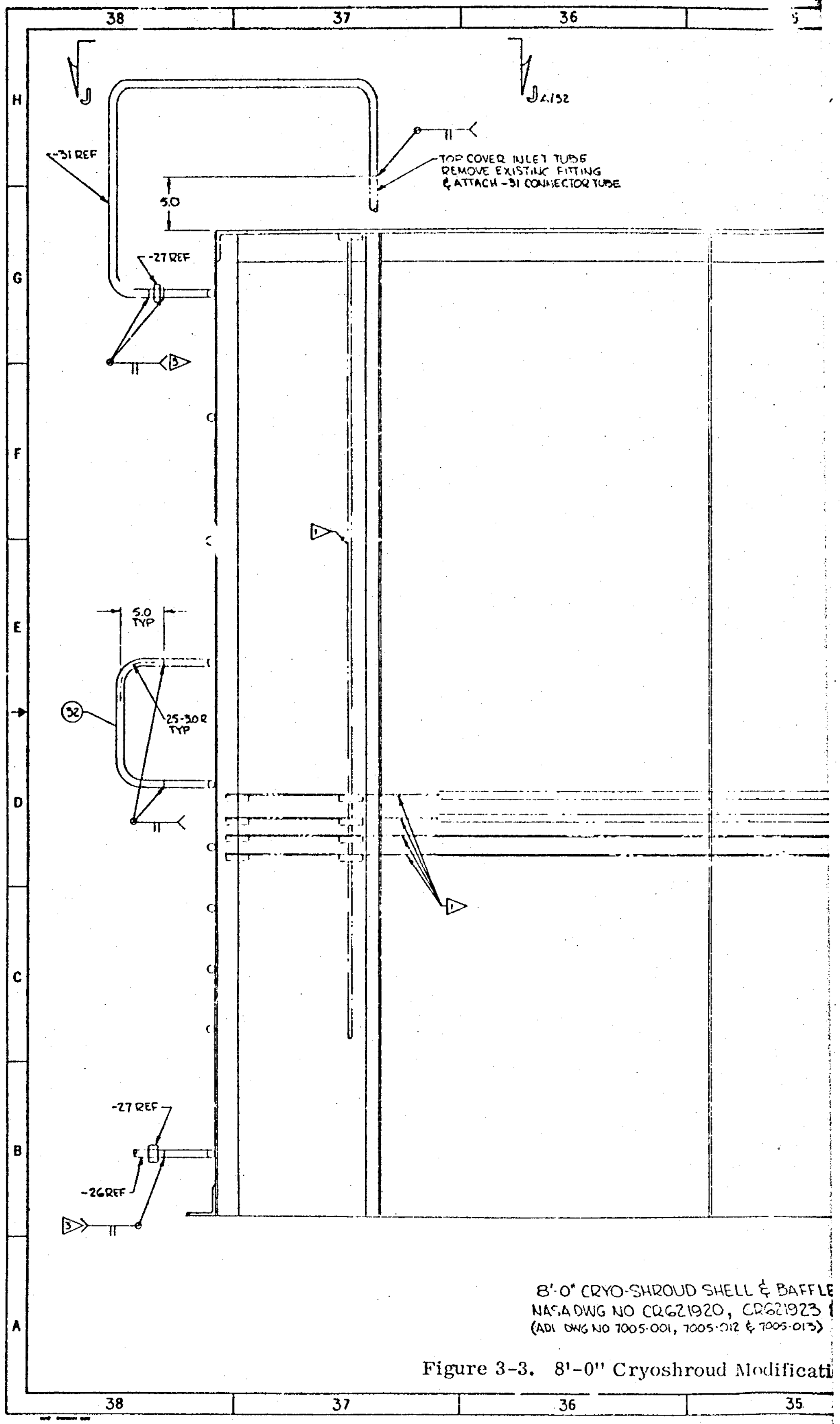
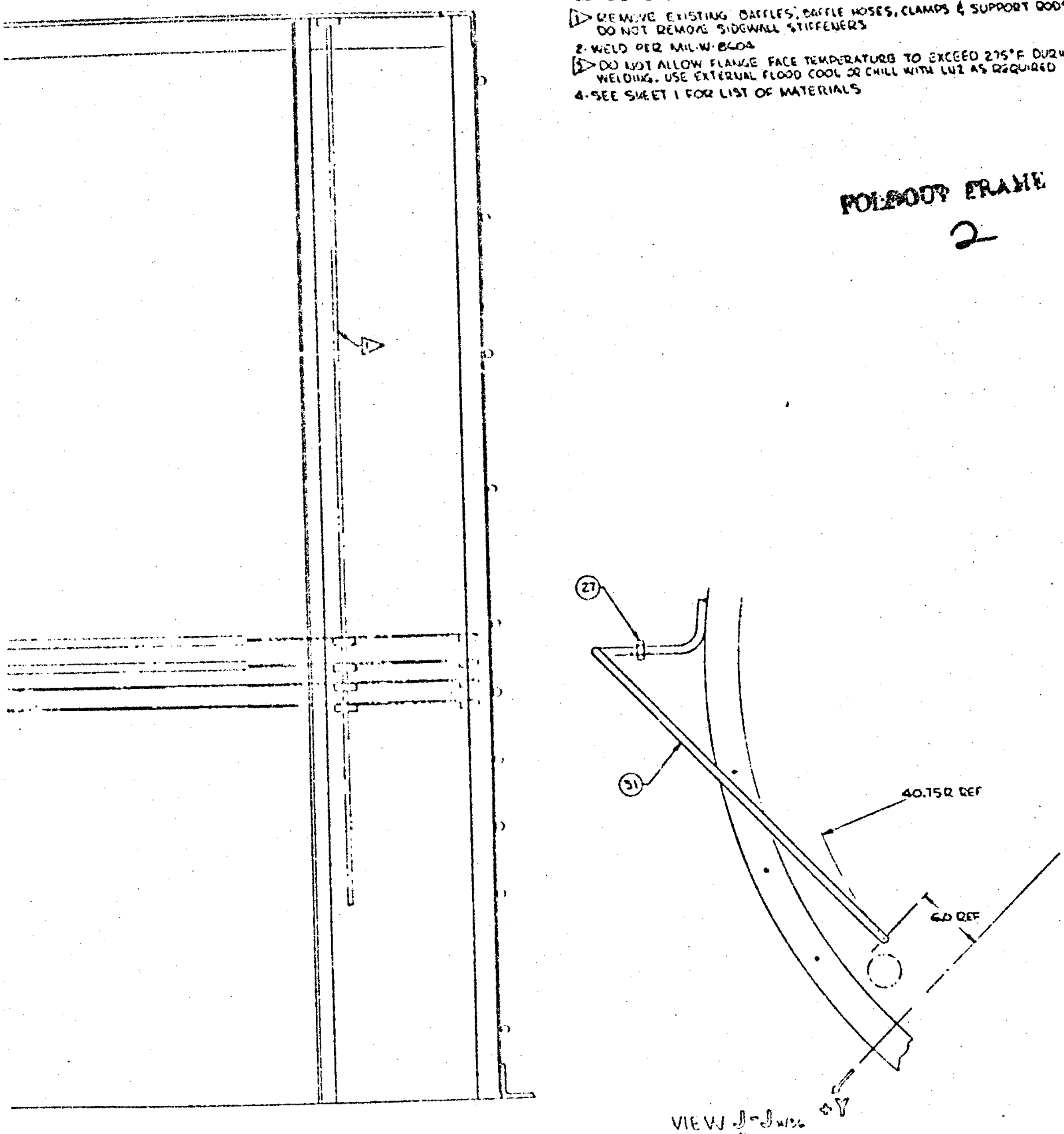


Figure 3-3. 8'-0" Cryoshroud Modificati

NOTES: UNLESS OTHERWISE SPECIFIED

1. REMOVE EXISTING BAFFLES, BAFFLE HOSES, CLAMPS & SUPPORT RODS. DO NOT REMOVE SIDEWALL STIFFENERS
2. WELD PER MIL-W-8604
3. DO NOT ALLOW FLANGE FACE TEMPERATURE TO EXCEED 275°F DURING WELDING. USE EXTERNAL FLOOD COOL OR CHILL WITH LN2 AS REQUIRED
4. SEE SHEET 1 FOR LIST OF MATERIALS

FOLDOUT FRAME 2



. & BAFFLES
CR621923 & CR621924
7005-013)

odification - Cylindrical Shell

CONVAIR AEROSPACE DIVISION OF GENERAL DYNAMICS
SAN DIEGO CALIFORNIA

8'-0" CRYO-SHROUD MODIFICATION

E | 14170 | PD73-0085

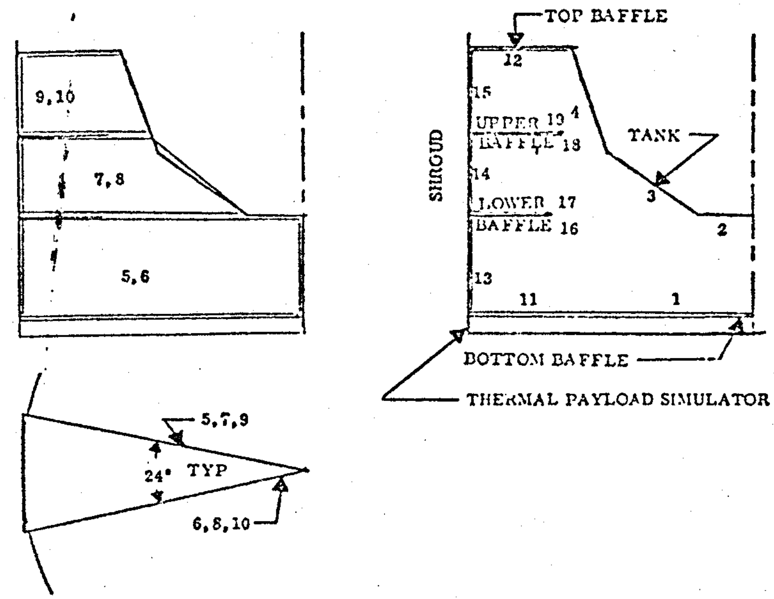


Figure 3-4. Reflecting Node Model of Cryoshroud Illustrating Node Numbers

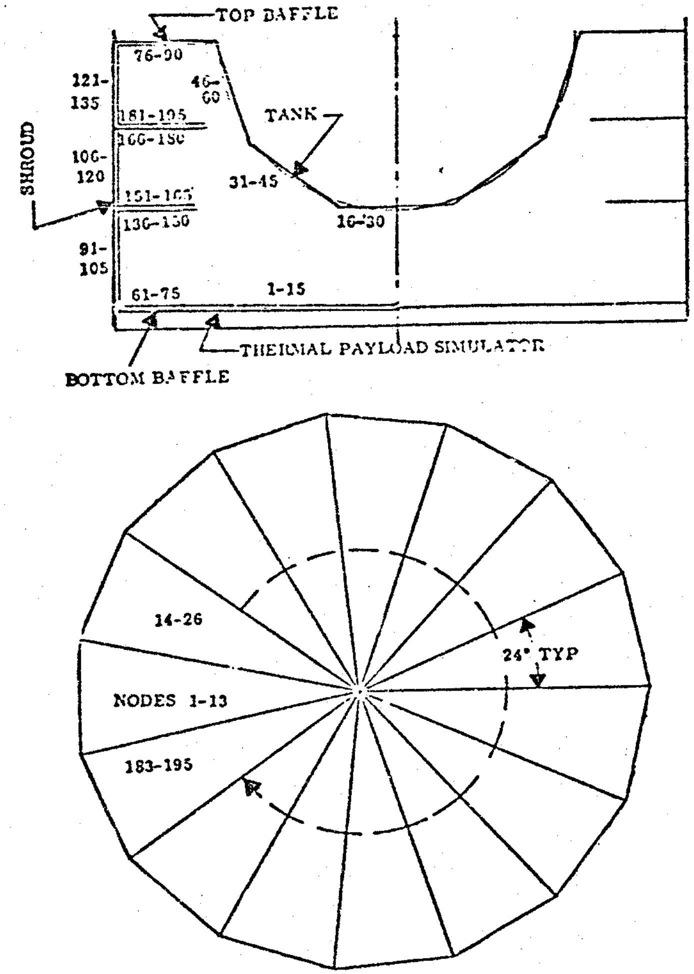


Figure 3-5. Complete Node Model of Cryoshroud Illustrating Node Numbers

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3.2.3 COMPLETE NODE MODEL. There is some uncertainty in the accuracy of the thermal model using reflecting boundary nodes. The Gebhart technique (Reference 3-1) for determining Script F assumes diffuse reflection from all surfaces according to the Lambert cosine law, whereas specular hemispherical reflection is more representative of the actual case.

The differences are indeterminate except by generating a complete open model with no reflecting nodes. Therefore, for (1) the open-to-space and (2) the cryoshroud with lower baffle configurations, a complete model analysis was made.

The analysis used the same basic node sizes, Figure 3-5, as the reflecting model with each individual segment being 1/15 of the total installation. The directly transmitted and reflected energy from each emitting segment to a 1/15 receiving segment was computed, then the results multiplied by 15 to determine the heat exchange to the entire circumferential surface. This technique reduced the number of nodes actually analyzed in the complete model configuration.

3.2.4 FINITE NUMERICAL APPROXIMATION. The node models consist entirely of flat plates to simulate the curved surfaces. The modeled flat plate surface areas and the actual curved surface areas are listed in Table 3-1. The view factors were determined by breaking each node into smaller finite elements. The node areas and elemental breakdown is listed in Table 3-1. The view factors were computed for the cases of a smaller node to a larger node and the calculated reciprocal used for interchange from large to small nodes. The view factor projection was computed in finite 5 sweep angle increments. All node sizes and finite element breakdowns were identical in the reflecting and complete node cases, therefore view factors within a segment were also identical. View factors from the payload plate to the three tank nodes are given in Table 3-1.

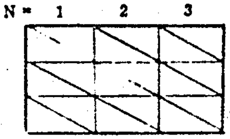
3.2.5 RESULTS. Heat flow values are plotted in Figure 3-6 for the shroud, $\epsilon = 0.85$, and lower baffle, $\epsilon = 0.96$, configuration for both the reflecting node and complete node models. Emissivity of the fixed top and bottom baffles is also 0.96. The complete node model for the case where the emissivities are 1.00, open-to-space, is also plotted in Figure 3-6. Accurate numerical values of the plotted data are listed in Table 3-2. There is a difference of almost 60% between the reflecting and complete node models indicating the reflecting node model is not a suitable representation of the actual installation. It is also noted that the heat flow to the shroud and lower baffle configuration is within approximately 6% of the open-to-space case. For example, at a TPS surface temperature of 500R and a shroud and baffle emissivity of 0.85 and 0.96 respectively, the heat flow from the thermal payload simulator to the cryogenic tank is 1.296 BTU/hr utilizing one baffle between the top baffle and the bottom baffle. Using the same temperature for the "Open-to-Space" case, the calculated heat flow is 1.219 BTU/hr, resulting in a difference of 0.077 BTU/hr or

Table 3-1. Model Node Description

Node Description	Node Number: Reflecting Model	Node Number: Complete Model	Area Sq. Ft.	No. * Divisions	No. * Elements
Payload Plate	1	1-15	1.9130	3	18
Tank Bottom	2	16-30	.1335	2	8
Tank Mid	3	31-45	.9658	3	18
Tank Upper	4	46-60	1.5627	3	18
Reflect. Bottom	5	N/A	5.9774	3	18
Reflect. Bottom	6	N/A	5.9774	3	18
Reflect. Mid	7	N/A	3.0153	2	8
Reflect. Mid	8	N/A	3.0153	2	8
Reflect. Upper	9	N/A	2.0383	2	8
Reflect. Upper	10	N/A	2.0383	2	8
Baffle Bottom	11	61-75	1.4110	3	18
Baffle Top	12	76-90	1.9293	3	18
Shroud Bottom	13	91-105	2.4856	3	18
Shroud Mid	14	106-120	1.9994	3	18
Shroud Upper	15	121-135	2.10[illegible]3	3	18
Baffle Lower (lower surface)	16	136-150	1.6081	3	18
Baffle Lower (upper surface)	17	151-165	1.6081	3	18
Baffle Upper (lower surface)	18	166-180	1.7736	3	18
Baffle Upper (upper surface)	19	181-195	1.7736	3	18

* Divisions

N = 1 2 3



1. Elements = $2N^2$
2. Finite Elements in a Node
3. For computing view factors

SURFACE AREAS SQ. FT.

Name	Modeled	Actual	Percent Deviation
Payload Plate	28.695	28.274	1.5
Tank	39.930	39.270	1.7
Shroud	96.8095	96.437	0.4
Baffle, Bottom	21.210	21.991	3.6
Baffle, Top	28.940	30.6305	5.5
Baffle Lower	24.1200	24.464	1.4
Baffle Upper	26.604	26.565	0.2

VIEW FACTORS

Nodes: Reflecting Model	Nodes: Complete Model	VF
1 → 2	1 → 16	.09128
· → 3	1 → 31	.03845
1 → 4	1 → 46	.01439

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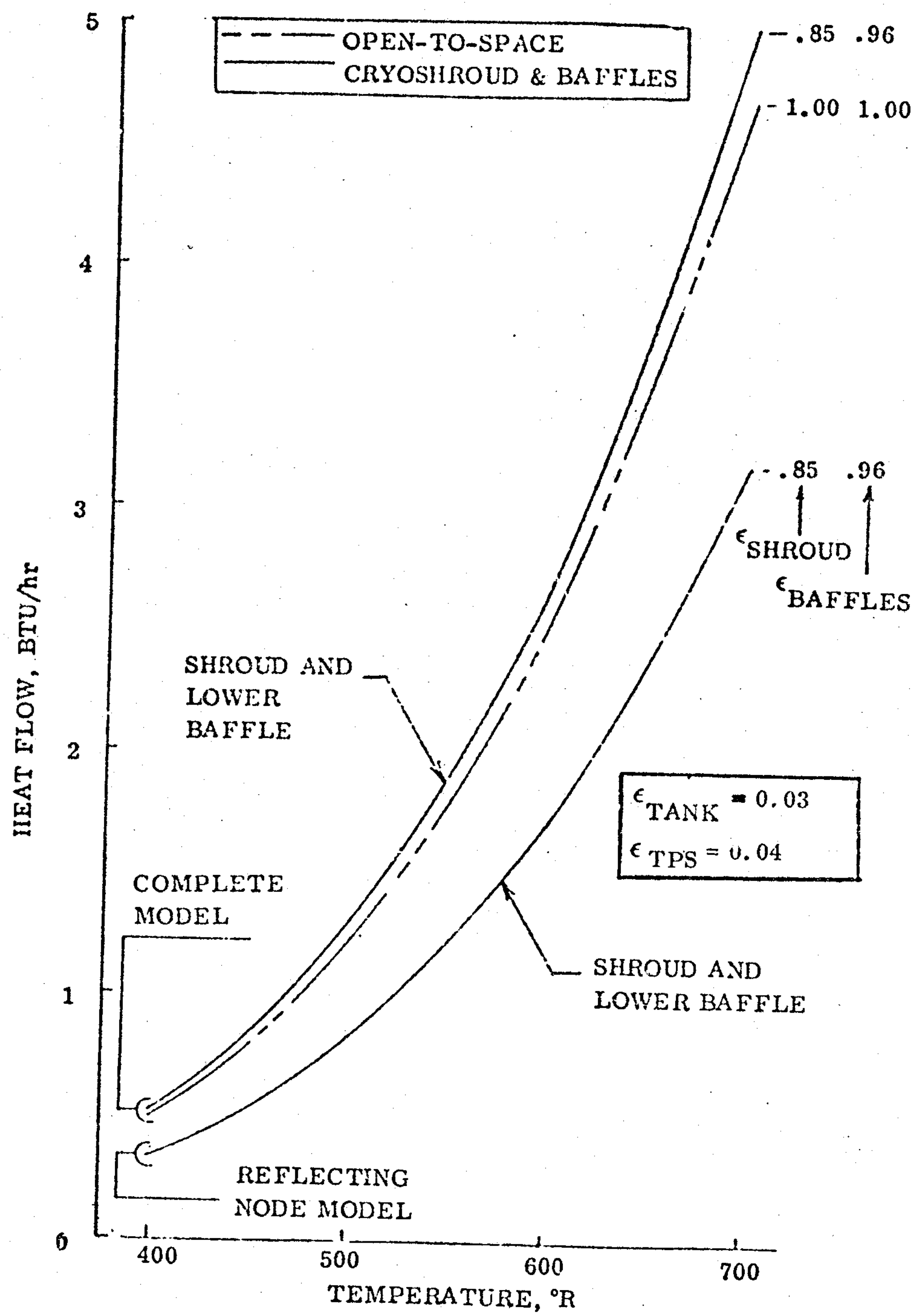


Figure 3-6. Heat Flow From Thermal Payload Simulator (Node 1) to Cryogenic Tank (Nodes 2, 3, 4) vs Thermal Payload Simulator Surface Temperature

Table 3-2. Heat Transfer From Thermal Payload Simulator to Tank Bottom Hemisphere

Configuration	Model	ϵ shroud	ϵ baffle	$B_{ij} \times 10^{-4}$ Node 1 → 72	Node 1 → 73	Node 1 → 74	Total P/L → Tk
1. Open to Space	Complete	1.00	1.00	1.4230	5.3513	0.8165	7.5908
2. Shroud-Lower Baffle	Complete	0.85	0.96	1.4526	5.5456	1.0702	8.0684
3. Shroud-Lower Baffle	Reflecting	0.85	0.96	0.7147	3.2417	1.1883	5.1447

Configuration	Q BTU/hr $T_{P/L}$ = 700	600	500	400	300	200
1. Open to Space	3.4958	1.8869	0.9099	0.3726	0.1178	0.0232
2. Shroud-Lower Baffle	4.9776	2.6867	1.2956	0.5306	0.1678	0.0330
3. Shroud-Lower Baffle	3.1739	1.7131	0.8261	0.3383	0.1070	0.0211

T_{TPS} = thermal payload simulator temperature (variable)

TT = tank insulation surface temperature, 50R

$\epsilon P/L$ = payload plate emissivity, 0.04

ϵ_{Tk} = tank insulation emissivity, 0.03

$Q = 15\,\sigma\, B_{ij}\,(T_{P/L}^4 - T_{Tk}^4)$ BTU/hr

15 = number model segments

$\sigma = 0.1713 \times 10^{-8}$ Stephan-Boltzman

B_{ij} - $A\mathfrak{F}_{kj}$ script $\mathfrak{F}$x area

6.3%. Additional baffles within this narrow band are not justified or practical for such a small and largely indeterminate gain. The combined accuracy of the finite element analysis for radiation, the known accuracy of the surface emissivities and α/ϵ, and the test measurements are also not considered to be within the 6% band. It was therefore decided to use only one intermediate baffle between the top baffle and the thermal payload simulator.

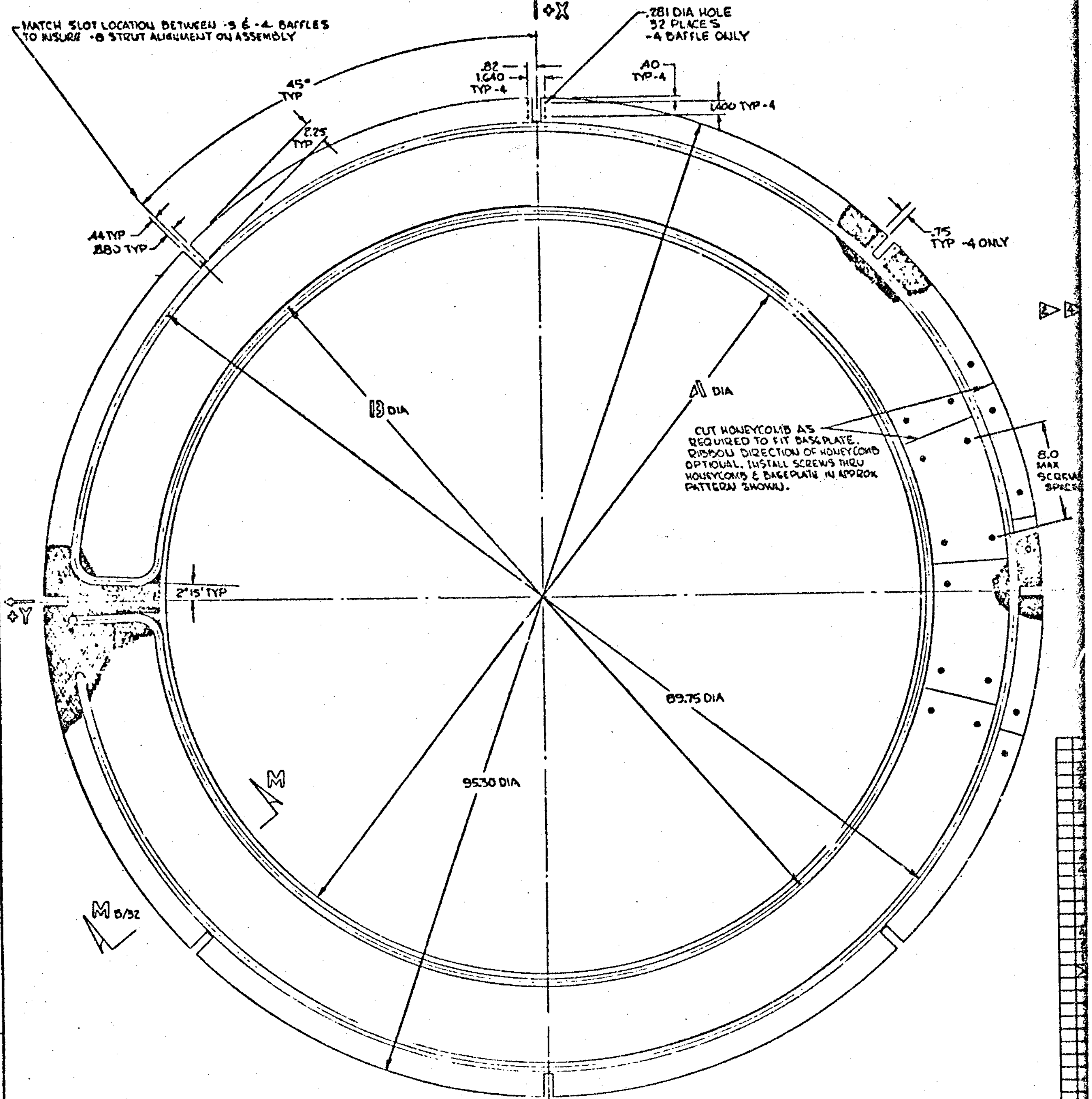
3.3 BAFFLE DESIGN AND FABRICATION

The existing internal baffles which were furnished with the cryoshroud by NASA-LeRC were too small to accommodate the 1.52 m (60 in) diameter test tank. In order to enlarge this inside diameter it would have been necessary to remove the baffle surface cooling coil, making it impractical to rework these baffles into the design required for the test program. Three new annular-shaped liquid hydrogen cooled baffles for attachment to the internal surface of the cryoshroud were designed and fabricated.

3.3.1 BAFFLE LOCATION. The first baffle is located at the test tank equatorial plane and is rigidly attached to the cryoshroud. It will intercept and prevent thermal payload simulator radiant energy from entering into the region of the test tank upper hemisphere (Figure S-1). The lower baffle is aligned with the very top surface of the thermal payload simulator. This baffle was designed to move as a unit with the TPS. It will remain in that relationship at all positions of the thermal payload simulator to prevent back surface radiation emission and TPS-MLI interlayer tunneling radiation from entering into the tank lower hemisphere region. The intermediate baffle is rigidly connected to the lower baffle. It moves with the lower baffle at a distance of 46.99 cm (18.5 in).

3.3.2 DESIGN. The fundamental baffle structure is a sandwich of annular shape whose main structural element is a flat, 6061-T-6 aluminum plate, 0.317 cm (0.125 in) thick. The annular aluminum base plate has 6061-T4 aluminum cooling coils welded to its upper surface. Aluminum honeycomb with 0.318 cm (0.125 in) cells is bonded with APCO 1252 urethane adhesive and additionally bolted to one or both surfaces. This configuration was selected to produce good thermal contacts allowing all baffle surfaces to attain the same temperature as the cryoshroud walls. The design is presented in Figures 3-7, 3-8 and 3-9.

The bottom surface of the honeycomb on the bottom baffle has a faceplate bonded to it to make a sandwich construction for stiffening. Six phenolic blocks are bolted to the lower surface of the movable baffle to provide a means of supporting the thermal payload simulator as well as reducing the load concentration of the baffle positioning mechanism. This mechanism allows the lower two baffles to move with respect to the cryoshroud and the fixed upper baffle, while still maintaining continuous LH_2 cooling. It consists



	-2	-3	-4
A	64.00	68.20	72.25
B	65.25	69.45	73.50

SECT E-E -2 BAFFLE
SECT F-F -3 BAFFLE ROTATED 45° CCW
SECT G-G -4 BAFFLE
SCALE 1/4

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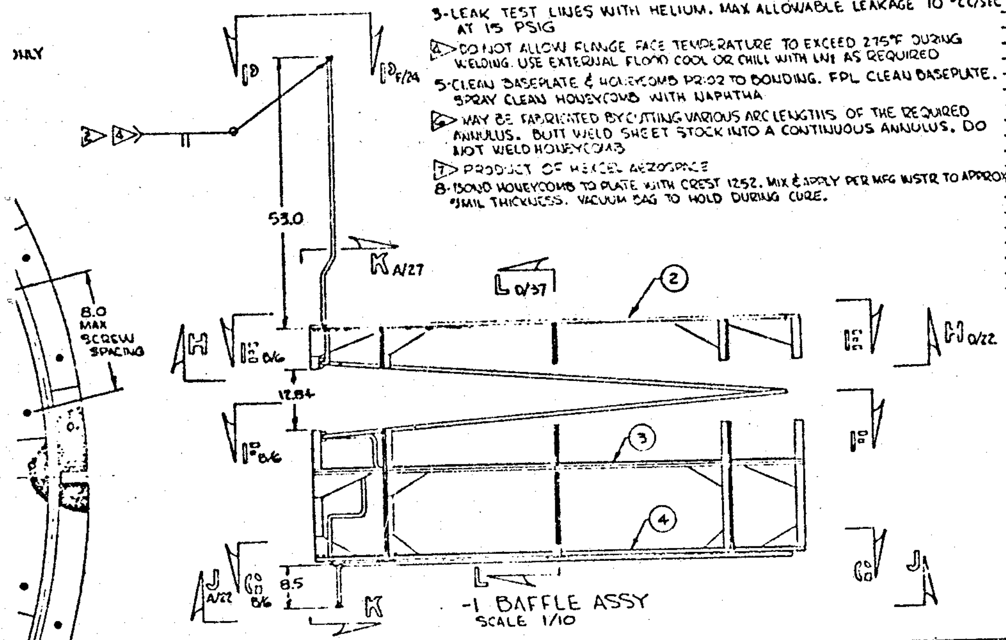
Figure 3-7. Baffle Assembly - Sandwich Construction

REVISIONS					
ZONE	LTR	DESCRIPTION		DATE	APPROVED
	A	ADDED WELD ... BETWEEN COOLING TUBE & BAFFLE BASEPLATE. ... AL SCRIMS TO BE ... HONEYCOMB. REMOVED HONEYCOMB FROM TOP SURFACE OF UPPER BAFFLE. CHANGED ADHESIVE TO CREST 1252, REMOVED SCRIM.	M.D.WALTER	3/5/4	

NOTES: UNLESS OTHERWISE SPECIFIED

1. WELD PER MIL-W-8604
2. DYE PENETRANT INSPECT WELDS NOTED PER MIL-I-6866. 100% INSPECTION REQUIRED. NO CRACKS PERMITTED
3. LEAK TEST LINES WITH HELIUM. MAX ALLOWABLE LEAKAGE 10^{-6}CC/SEC AT 15 PSIG
4. DO NOT ALLOW FLANGE FACE TEMPERATURE TO EXCEED 275°F DURING WELDING. USE EXTERNAL FLOOD COOL OR CHILL WITH LN2 AS REQUIRED
5. CLEAN BASEPLATE & HONEYCOMB PRIOR TO BONDING. FPL CLEAN BASEPLATE. SPRAY CLEAN HONEYCOMB WITH NAPHTHA
6. MAY BE FABRICATED BY CUTTING VARIOUS ARC LENGTHS OF THE REQUIRED ANNULUS. BUTT WELD SHEET STOCK INTO A CONTINUOUS ANNULUS. DO NOT WELD HONEYCOMB
7. PRODUCT OF HEXCEL AEROSPACE
8. BOND HONEYCOMB TO PLATE WITH CREST 1252. MIX & APPLY PER MFG INSTR TO APPROX. 5 MIL THICKNESS. VACUUM BAG TO HOLD DURING CURE.



PARTS LIST

17	4	3	2	1	UNIT OF MEAS	ITEM OR FIND NO	CODE IDENT NO	PART OR IDENTIFYING NUMBER	NOMENCLATURE OR DESCRIPTION	L	ZONE	STOCK SIZE, MATERIAL, SPECIFICATION TYPE (TEMPER ETC.) HEAT TREAT / NOTE TEXT
				64				MS...24-6	SCREW			
	24							MS2...60L4	NUT PLATE			
4								MS21043-6	NUT			
2				32				MS21043-4	NUT			
	48							MS20470AD3-4	RIVET			
2								NAS1004-64A	BOLT			
	24							NAS1004-20A	BOLT			
				8				NAS1004-12A	BOLT			
				32				NAS1004-4A	BOLT			
4								AN960C616	WASHER			
4	24			100				AN960C416	WASHER			
				16		21		-21	BRACKET	A	37	.25 X 1.1 X 2.5 PLATE 6061-T6 AL
				8		20		-20	BRACKET		36	.040 X 5.0 X 15.5 SHEET 6061-T6 AL
	1							AL 1/8 5052 .002P-8.1	HONEYCOMB			[illegible] AL HONEYCOMB, PERFORATED; NOTES 6 & 7
	1	2	2					AL 1/8 5052 .002U-8.1	HONEYCOMB			.5 X 42.0 X [illegible] AL HONEYCOMB, [illegible] NOTES 6 & 7
4								NAS1006-24A	BOLT		35	
2								-19	CLAMP BLOCK			1.35 X 2.1 X 4.1 PHENOLIC BLOCK
1								-18	CLAMP PLATE			.25 X 4.1 X 4.1 PLATE 304 CRES
X				1		17		-17	CLAMP ASSY	A	34	
				20				NAS1081C4A12	SETSCREW	A	35	
				20				-16	U-CLAMP			.62 X 1.4 X 2.3 PLATE 304 CRES
	6					15		-15	BLOCK			.75 X 6.0 X 11.0 PHENOLIC BLOCK
	1					14		-14	BASE PLATE		24	.040 X 96.0 X 96.0 SHEET 6061-T6 AL SEE NOTE 6
		1				13		-13	BASE PLATE	C	24	.040 X 96.0 X 96.0 SHEET 6061-T6 AL SEE NOTE 6
			1			12		-12	BASE PLATE		24	.040 X [illegible] SHEET 6061-T6 AL SEE NOTE 6
	1					11		-11	FACE SHEET	A	26	.040 X 96.0 X 96.0 SHEET 6061-T6 AL SEE NOTE 6
				1		10		-10	TUBE		24	.7500 X .062 X 2240.0 TUBE 6061-T6 AL
				2		9		-9	CLAMP		23	1.0 X 1.0 X 2.0 BAR 6061-T6 AL
				8		8		-8	STRUT	D	37	.875 X 2.3 X 27.5 PLATE 6061-T6 AL
				8		7		-7	BRACKET	C	37	.040 X 5.0 X 11.0 SHEET 6061-T6 AL
				8		6		-6	BRACKET	D	37	.040 X 5.0 X 13.5 SHEET 6061-T6 AL
				8		5		-5	STRUT		37	.875 X 2.3 X 8.5 PLATE 6061-T6 AL
	X			1		4		-4	BAFFLE		1	
		X		1		3		-3	BAFFLE		2	
			X	1		2		-2	BAFFLE		2	
				X				-1	ASSY			

REQ PER ASSY / INSTL

NOTE SYMBOL: E—END ITEM, G—GENERAL NOTE, L—LIMIT, M—MATERIAL, R—REFERENCE DESIGNATION, S—STOCK NO, U—USAGE DATA

UNLESS OTHERWISE SPECIFIED ALL MACHINED SURFACES √

RIVET BASIC CODE NAS523

SEE 0-70914 FOR ABBREVIATION CODE AND SYMBOL REQUIREMENTS

SEE 0-70002 FOR STANDARD MANUFACTURING AND INSTALLATION REQUIREMENTS

ASSOCIATED LIST REQUIRED SEE DOCUMENT SAME NUMBER PREFIXED

UNLESS OTHERWISE SPECIFIED DIMENSIONS ARE IN INCHES

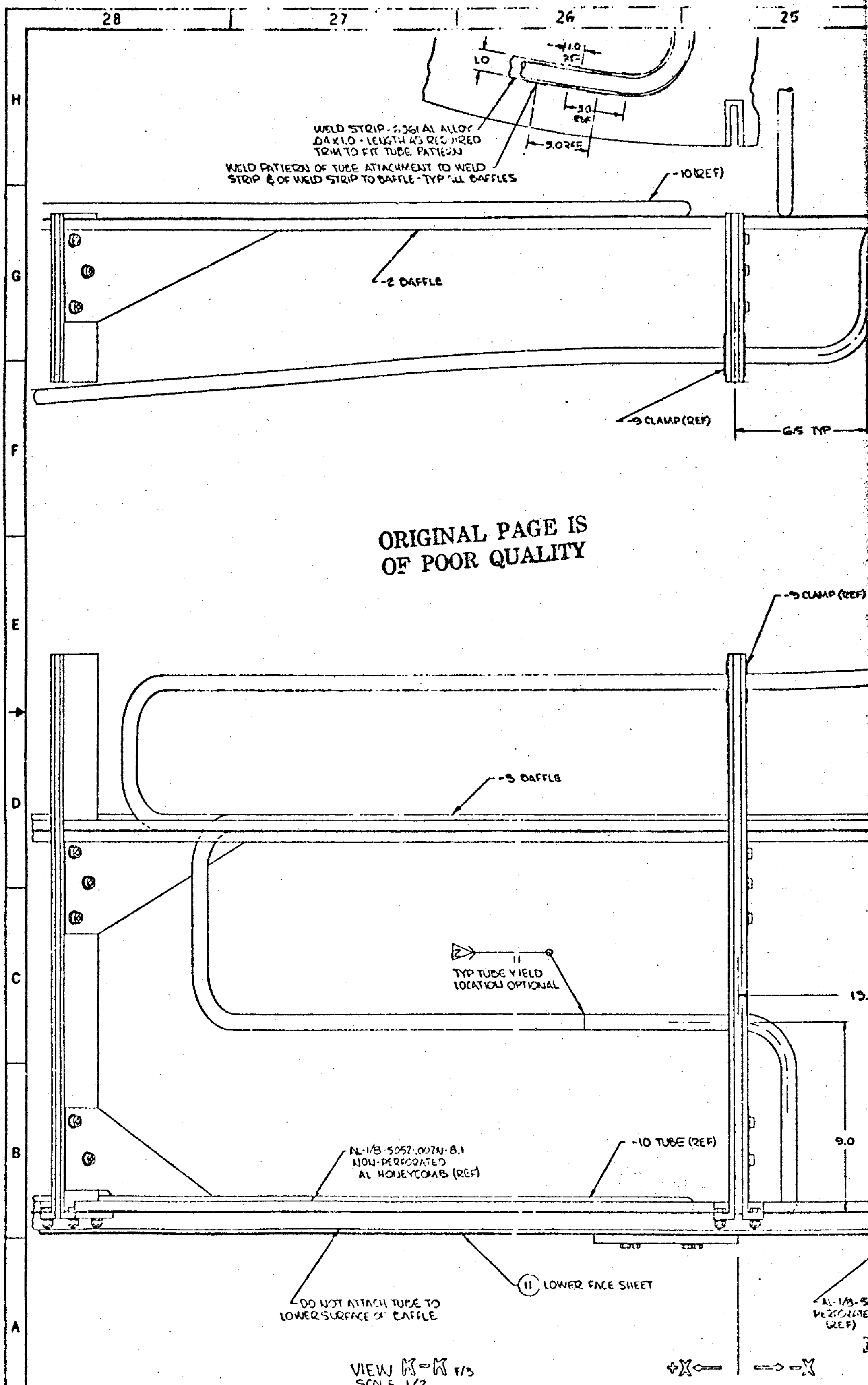
TOLERANCES .X ±.1 .XX ±.03 .XXX ±.010 ANGULAR PER 0-70902

CONVAIR AEROSPACE DIVISION OF GENERAL DYNAMICS SAN DIEGO CALIFORNIA

BAFFLE ASSY

SIZE E | CODE IDENT 14170 | DRAWING NO. PD73-0084

SECURITY CLASSIFICATION



28
27
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1.0
WELD STRIP - 5361 AL ALLOY
.04 X 1.0 - LENGTH AS REQUIRED
TRIM TO FIT TUBE PATTERN
WELD PATTERN OF TUBE ATTACHMENT TO WELD STRIP & OF WELD STRIP TO BAFFLE - TYP ALL BAFFLES
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-9 CLAMP (REF)
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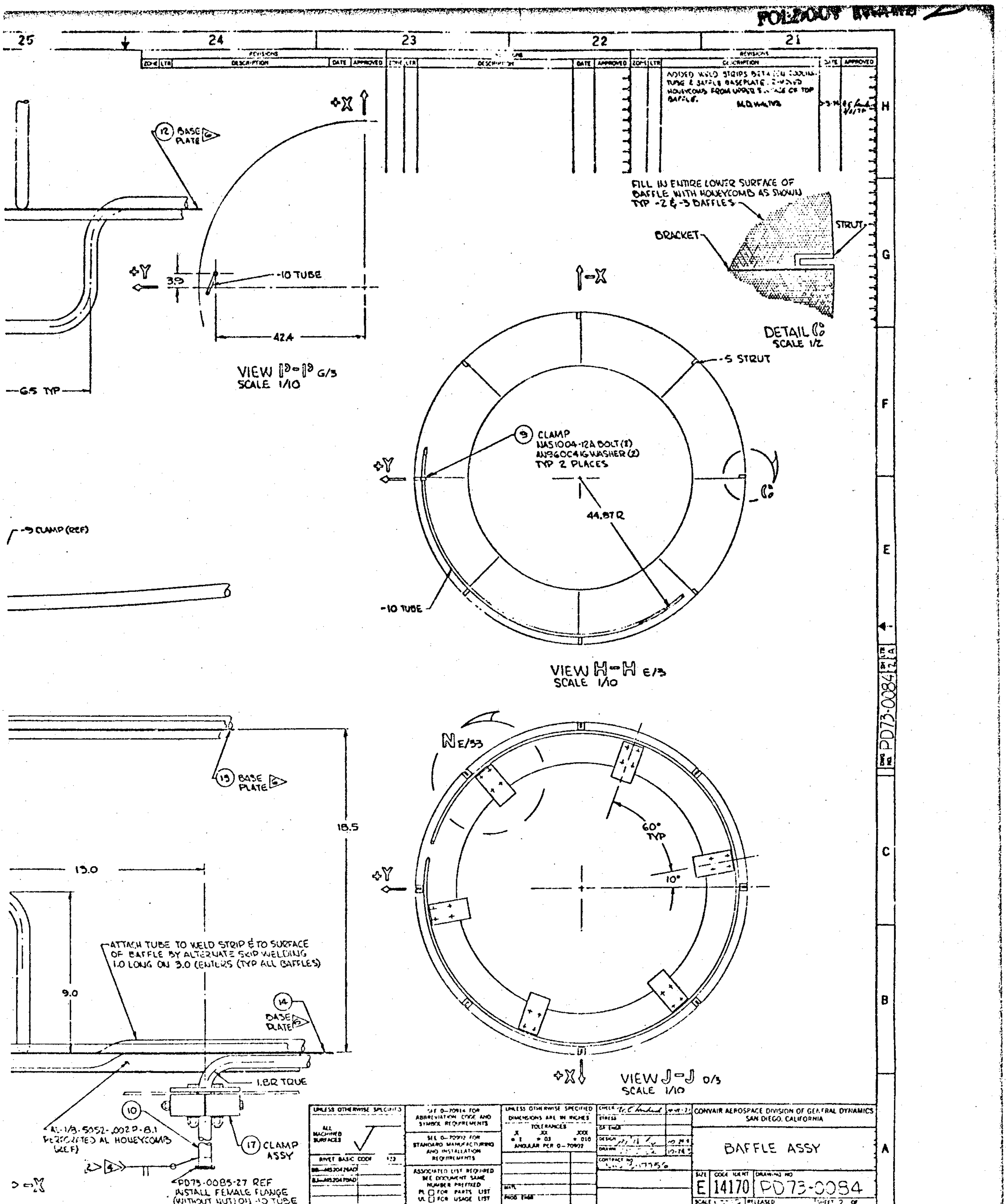
NON-PERFORATED
AL HONEYCOMB (REF)
-10 TUBE (REF)
11 LOWER FACE SHEET
DO NOT ATTACH TUBE TO
LOWER SURFACE OF BAFFLE
VIEW K-K
SCALE 1/2
+X
-X

Figure



2 Figure 3-8. Baffle Assembly - Cooling Coil Arrangement

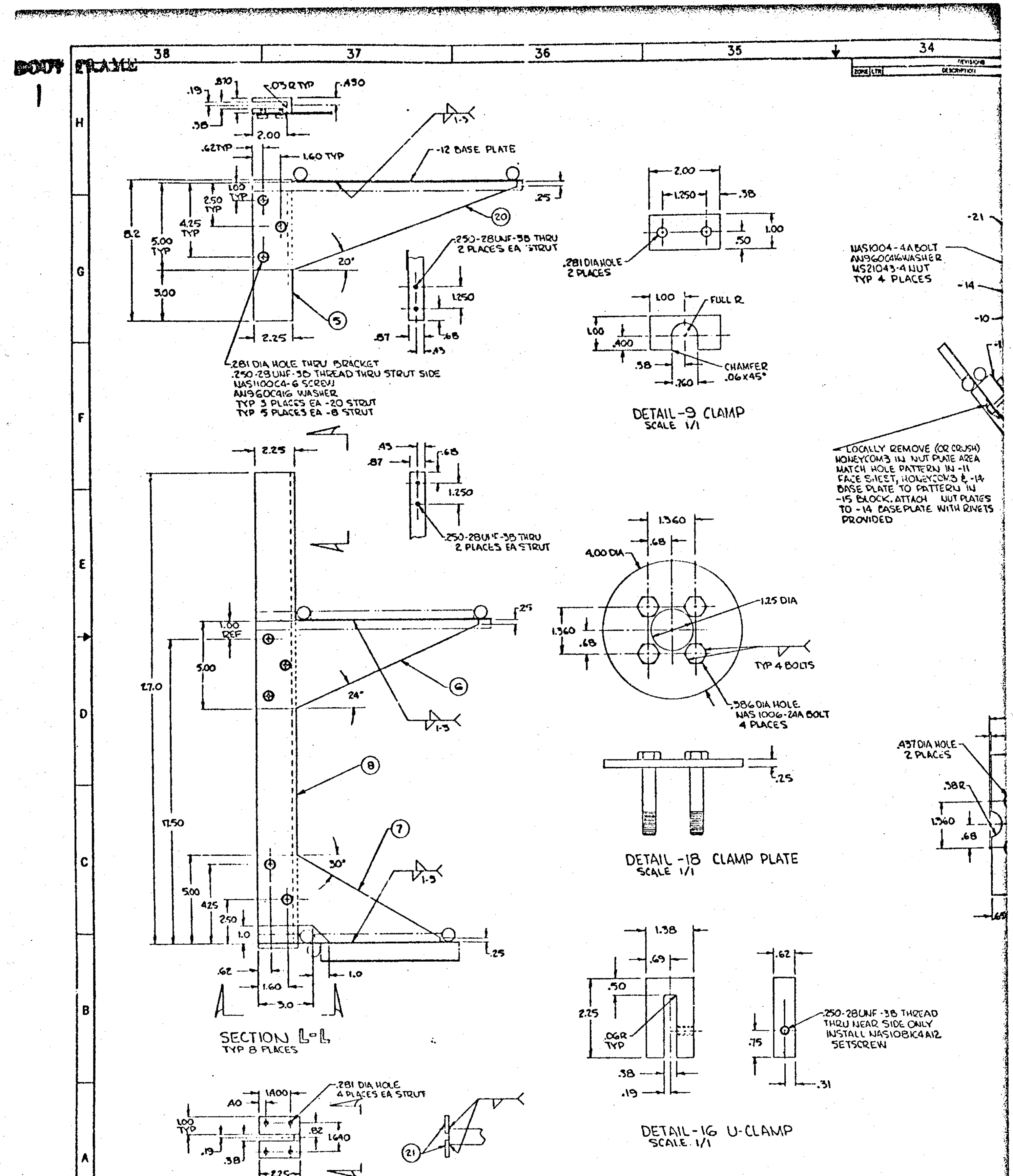


Figure 3-9. Baffle Assembly - Honeycomb Arrangement

FOLDOUT FRAME

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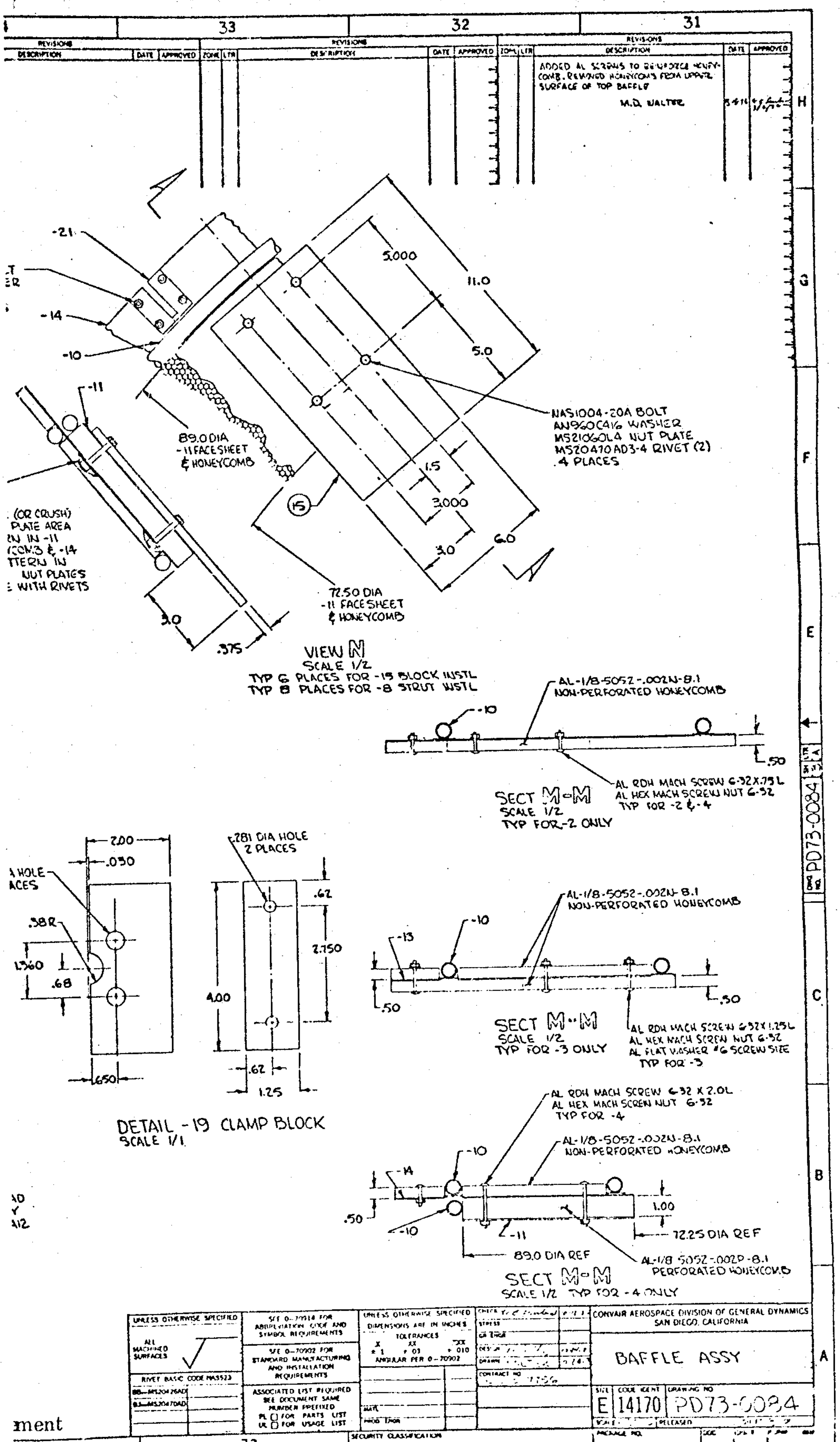

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of two cooling tube coils extending around the outside edge of the baffles. One of these coils is below the lower two movable baffles and the other coil is between the upper fixed baffle and the lower two movable baffles (Figures 3-7 and 3-8). These two coils extend and compress like coils in a spring as the two movable baffles are adjusted up and down. With this method, there is no high spot in the cooling tubes for vapor entrapment. In the same manner, two coils are used between TPS and bottom of the cryoshroud to provide movement for the TPS. At the upper baffle, the tube is vented up through a hole in the cryoshroud upper cover. Eight slotted struts are provided at the outside edge of both the single upper fixed baffle and of the two lower movable baffles. These position and guide the baffles as they are moved in the shroud. "U" clamps lock the upper baffle in position and prevent the lower baffles from falling out during removal of the thermal payload simulator.

3.3.3 FABRICATION. Prior to fabricating the cryoshroud baffles, a sandwich sample consisting of 0.102 cm (0.040 in) thick 6061 aluminum with 1.587 cm (0.625 in) honeycomb attached to both sides was immersed in liquid nitrogen for 2 minutes. The sample was removed from liquid nitrogen and allowed to return to ambient temperature. This test was repeated 19 times for a total of 20 cycles. Twenty additional tests of the same kind were conducted using liquid hydrogen. There was no apparent failure of the joint.

All base plate sections, tubing and honeycomb materials were cut and chemically cleaned. The tubing was provided with an additional 2.54 cm (1.0 in) wide aluminum base plate to avoid warping of the 2.41 m (96 in) O.D. annular baffle base plates. Welds of 2.54 cm (1.0 in) length at 7.62 cm (3 in) centers were applied on each side of the tube to ensure good heat conduction between tubing and base plates. All liquid hydrogen tubing was leak checked and repaired as necessary after the welding operation. Unforeseen distortions of the 0.102 cm (0.040 in) aluminum baffle base plates were encountered during welding of the liquid hydrogen tubing onto the baffle sheet material. Since proper bonding of the honeycomb to the base plates could not be assured under these circumstances, the 0.102 cm (0.040 in) thick aluminum plate was replaced by 0.317 cm (0.125 in) thick plate material. Welding of the tubing to the new baffle sheet material was completed without distortions. The honeycomb material type AL-1/8-5052-002P-8.1 perforated, was purchased from HEXCEL Aerospace Company. This material was utilized on the lower surface of the upper baffle, on both surfaces of the intermediate baffle and on the top surface of the lower baffle (Figure 3-9). The honeycomb material on the lower surfaces of the bottom plate was Hexcel Type AL-1/8-5052-002 N-8.1 Non-Perforated. A face plate was bonded to it to make a rigid sandwich construction for the movable baffle. The plate was cut in sections and prefitted to blue print dimensions. It was then bonded to the baffle base plate under vacuum pressure for 18 hours utilizing APCO 1252 urethane adhesive. The honeycomb was additionally bolted to the plate with 6-32 aluminum bolts to achieve good thermal conductance and a better mechanical joint.

3.4 BAFFLE AND THERMAL PAYLOAD SIMULATOR POSITIONING MECHANISM

The thermal performance test of the customized multilayer insulation during Task V requires that the spacing between test tank and thermal payload simulator can be adjusted from 45.72 cm (18 in) to 15.14 cm (6 in). The lower two baffles and the thermal payload simulator are designed to move together; the bottom baffle remaining in the same plane as the payload simulator as they are adjusted up and down. This is provided for by resting the thermal payload simulator on six phenolic blocks bolted to the bottom of the lowest baffle and resting three of the phenolic blocks on three 2.54 cm (1.0 in) diameter screw-jacks extending through the bottom of the cryoshroud, Figure S-1. The rotating nuts for the jack screws are fabricated from Teflon. A bicycle-chain sprocket is attached to the Teflon nut at the bottom of each of the screw-jacks and all three sprockets are driven simultaneously by a single chain. By changing chain position on the sprocket, very minute adjustments to thermal payload simulator heights can be made to level the thermal payload simulator during installation. The chain is driven by a small sprocket and hand crank on a shaft that passes through the bottom of the chamber. As a back up to the positioning transducer, the sprocket tooth ratio and jack screw threads/inch combined, require 166.5 turns of the hand crank to produce 15.24 cm (6.0 in) of travel.

Drawings of the positioning mechanism with all details are shown in Figures 3-10 through 3-16. The selection of the material for the positioning mechanism parts was based on low heat transfer considerations.

3.5 GUARD TANK DESIGN AND FABRICATION

In order to prevent entry of extraneous heat to the test tank, fluid lines going to the test tank pass through the liquid hydrogen guard tank as shown in Figure S-1. The test tank is also suspended from the guard tank which is attached to a support ring in the top cover of the cryoshroud.

The guard tank was fabricated from 304 CRES material. Its construction (Figures 3-17 and 3-18) consisted of two formed 60.96 cm (24 in) diameter tank heads connected by a 14.22 cm (5.6 in) high cylinder. The material gauge is 0.317 cm (0.125 in). A heavy mounting ring was welded to the top of the guard tank to transfer loads from the test tank to the cryoshroud structure. Three lugs were welded to the bottom of the tank at its periphery for attachment of the test tank support struts (Ref. 3-2).

The test tank fill/drain line and vent line, consisting of 5.08 cm (2.0 in) O.D., 0.09 cm (0.035 in) wall, 304 CRES tubing, penetrate the guard tank. Both of these lines pass with a "U" bend through the guard tank to prevent radiation tunneling and to allow for thermal contraction. The guard tank fill and vent lines were fabricated from 1.91 cm (0.75 in) O.D. CRES-304 tubing. The instrumentation lines going into the test tank pass into the tank through the vent line. This eliminated an electrical pass-thru in the test tank door and an additional line through the guard tank.

-1, Basic Drawing
-3, Nut (3) - Teflon
-5, Washer (3) - 0.317 cm (0.125 in.) 6061 T6 Aluminum
-7, Angle (12) - 0.317 cm (0.125 in.) 6061 T6 Aluminum
-9, Adapter Ring (3) - 0.317 cm (0.125 in) 6061 T6 Aluminum
-11, Sprocket
-13, Jackscrew (3) - 1-8 NC, 40.64 cm (16 in) Screw
Thread 2.54 cm (1.0 in) Dia Epoxy Fiberglass
-15, Guide (3) - Teflon
-17, Angle (12) - 0.317 cm (0.125) 6061 T6 Aluminum

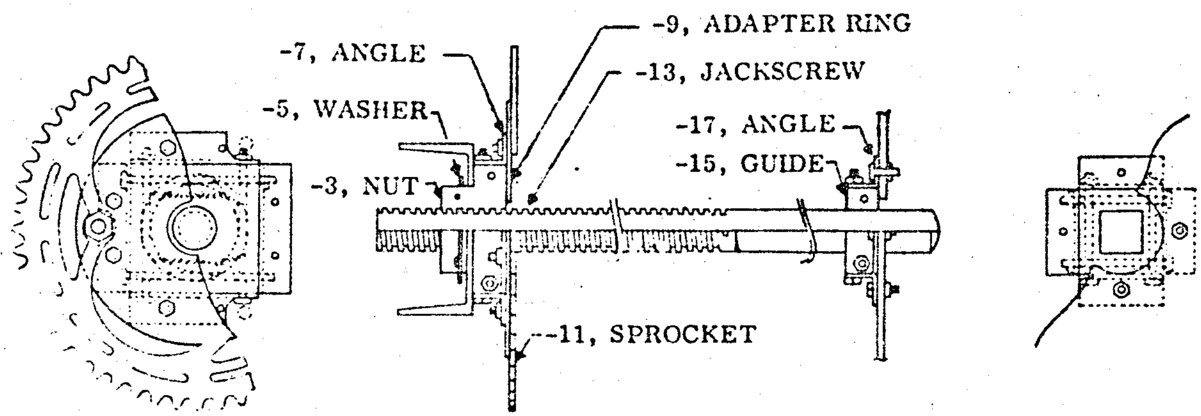

Figure 3-10. Thermal Payload Simulator and Cryoshroud Baffle Positioning Mechanism

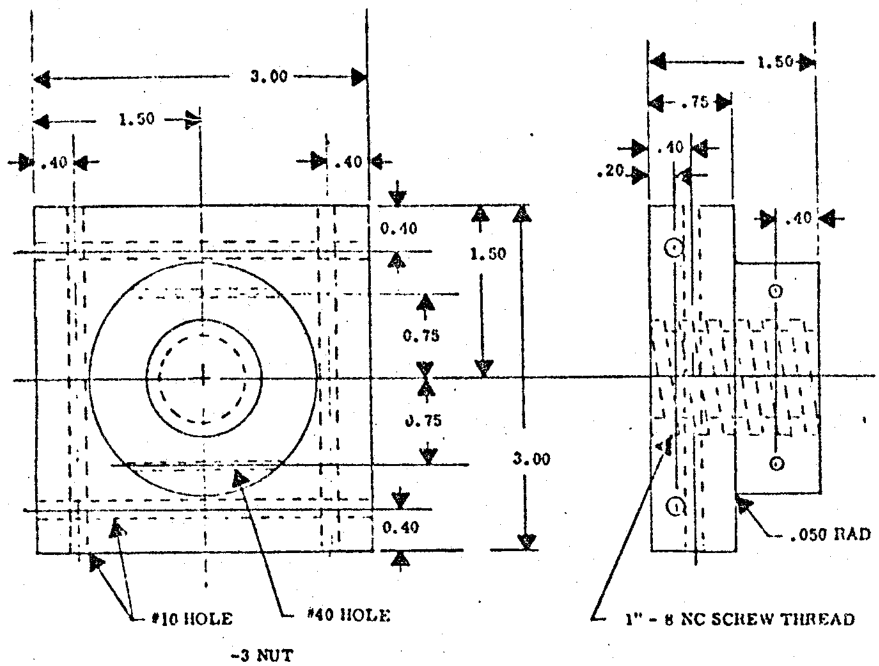

Figure 3-11. Positioning Screw-Nut

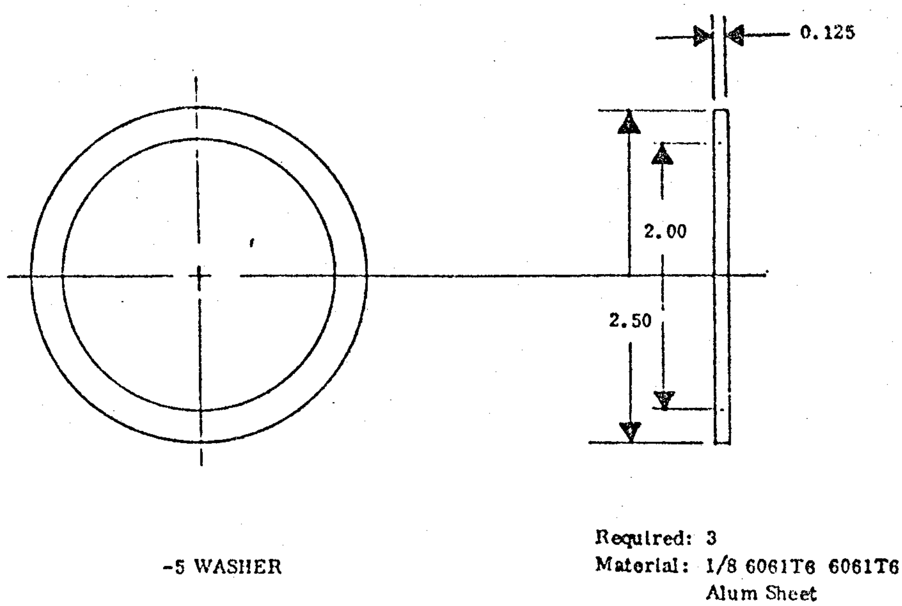

Figure 2-12. Positioning Screw-Washer

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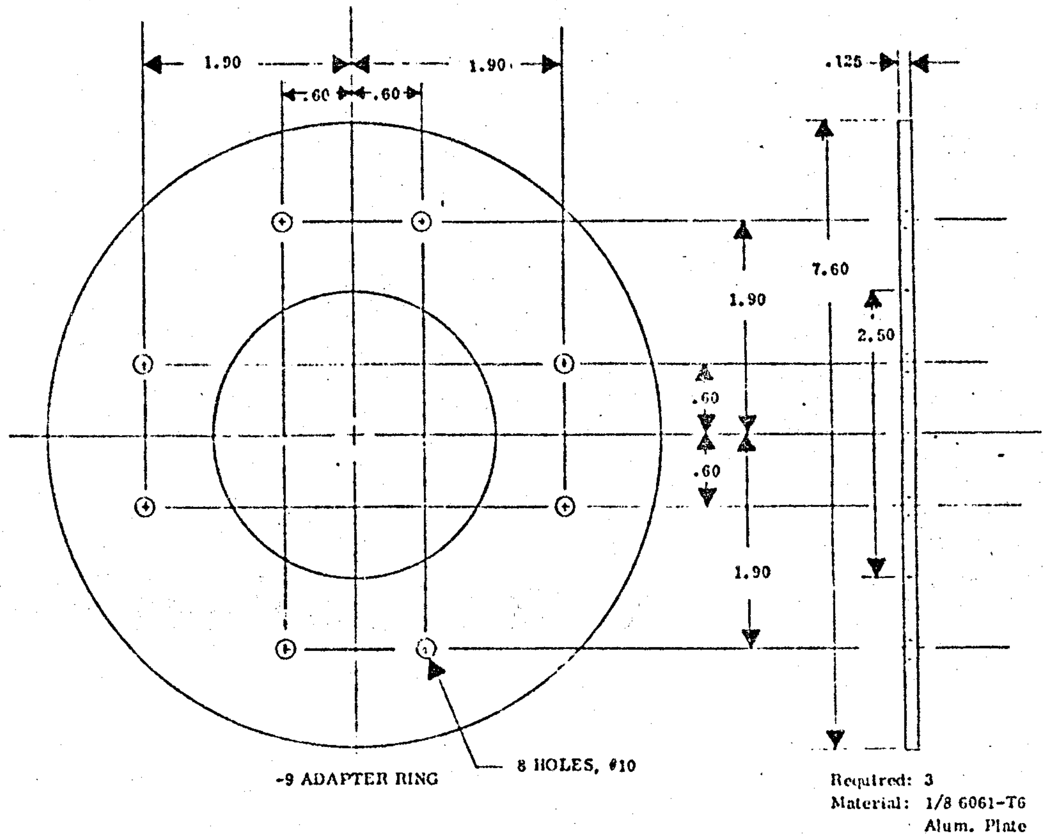


Figure 3-13. Positioning Screw - Adapter Ring

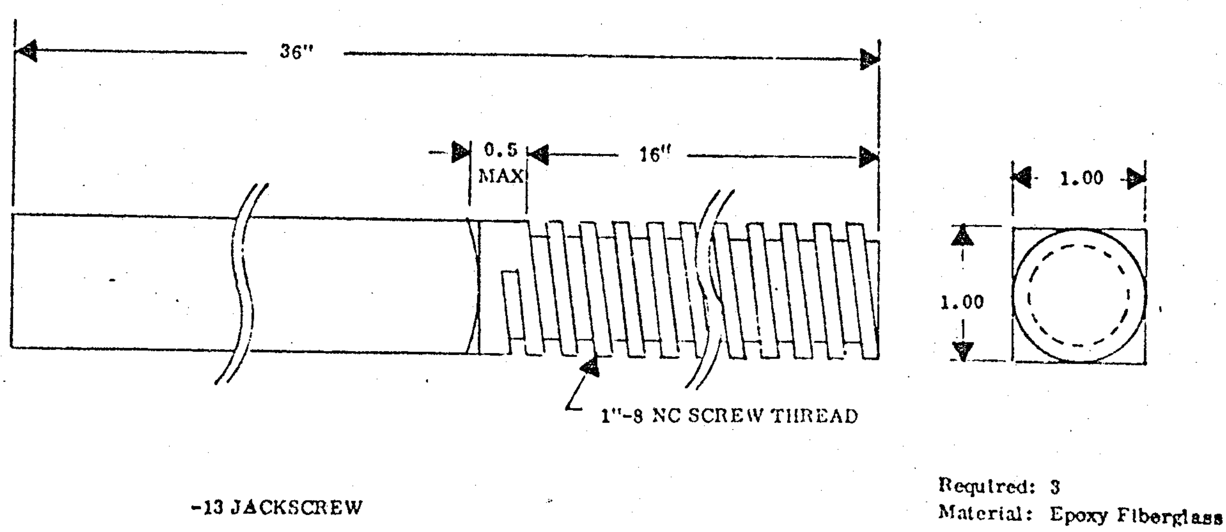
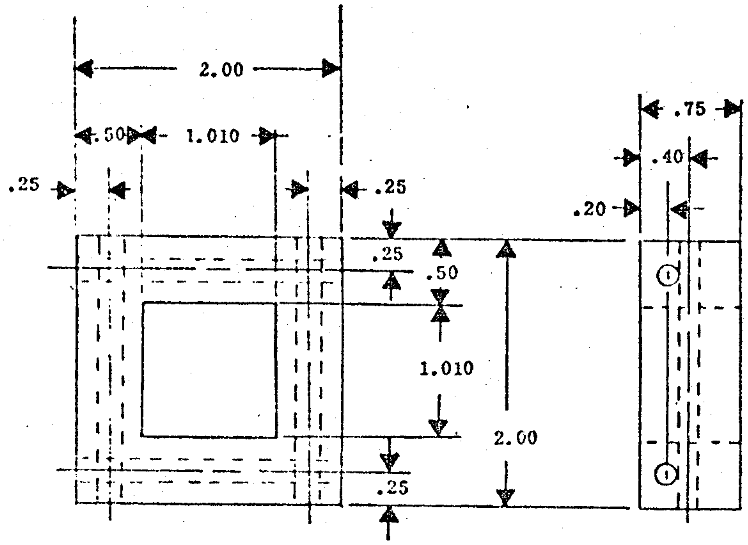


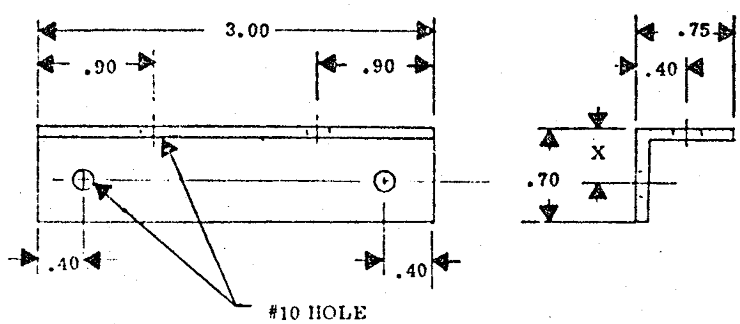
Figure 3-14. Positioning Mechanism - Jack Screw



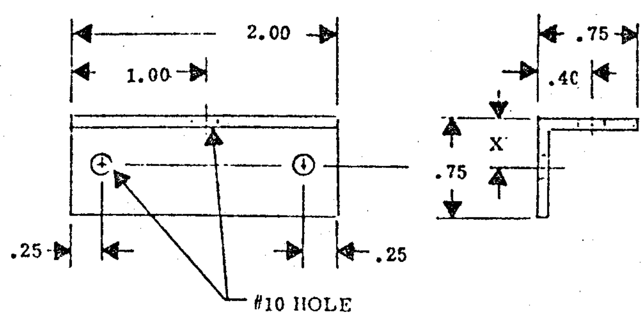
-15 GUIDE

Required: 3
Material: Teflon

Figure 3-15. Positioning Mechanism - Guide



-7 ANGLE



-17 ANGLE

Required: Six (6) each -7 & -17 with x = .35
Six (6) each -7 & -17 with x = .55
Material: 3/4 × 3/4 × 3/32 or 1/8 6061 T6 Alum Angle

Figure 3-16. Positioning Mechanism - Angle

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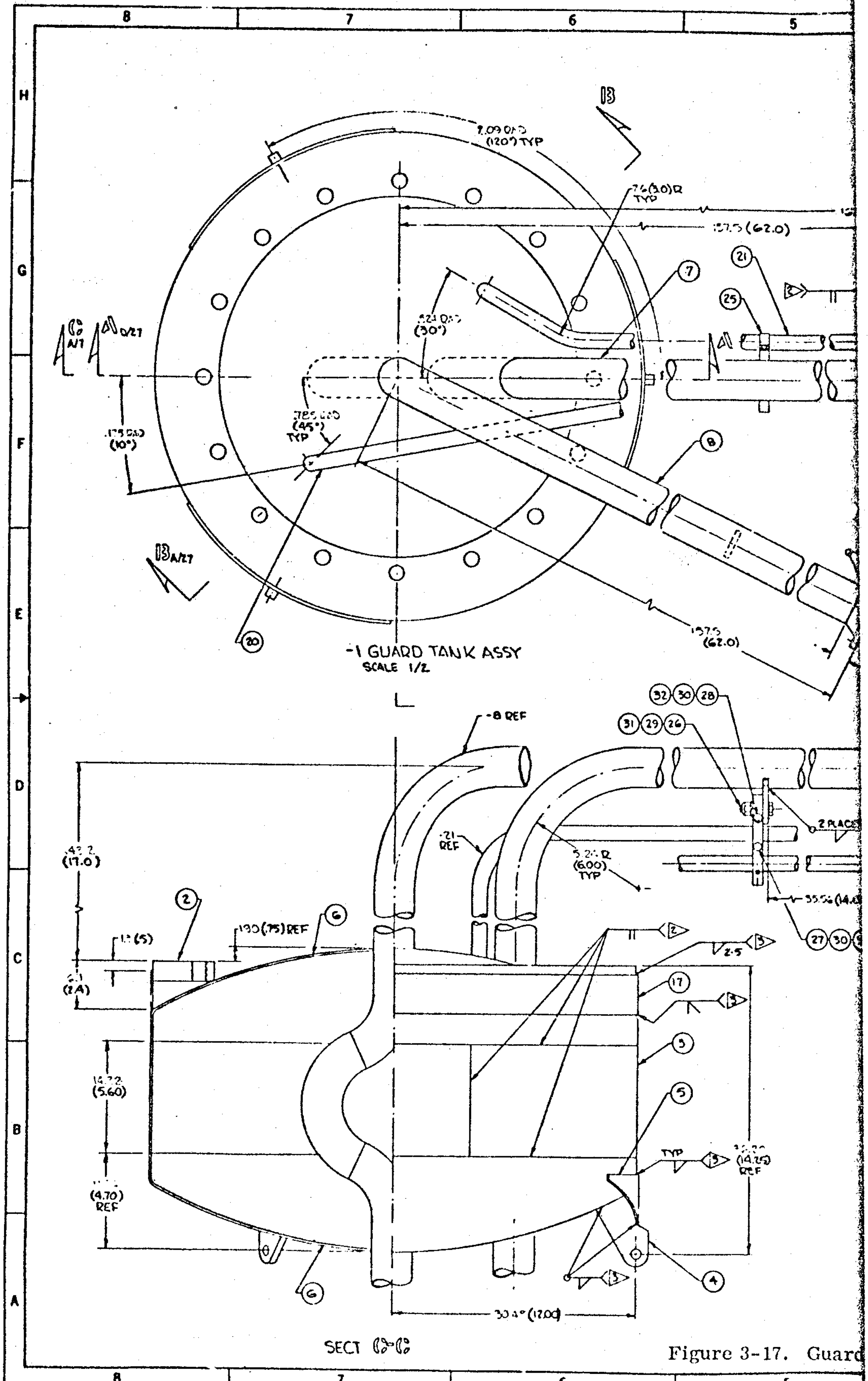

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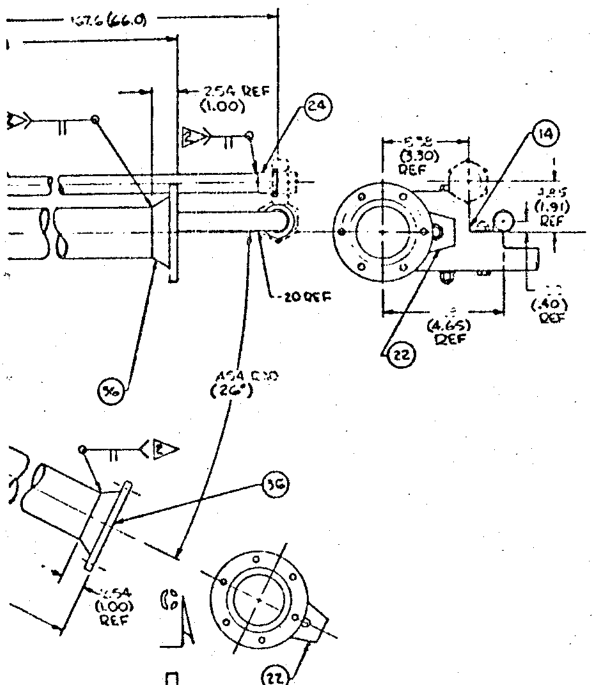
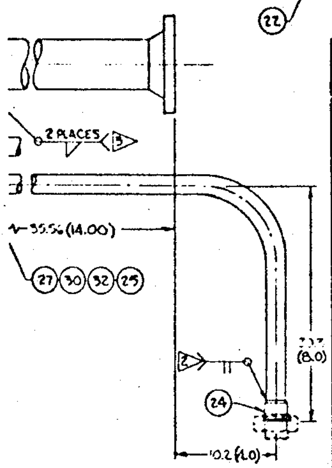
Figure 3-17. Guard





NOTES: UNLESS OTHERWISE SPECIFIED

1- WELD PER MIL-W-8611
2> 100% RADIOGRAPHIC INSPECT WELDS NOTED PER MIL-STD-453. ACCEPTANCE STANDARD PER 0-77008
3> DYE PENETRANT INSPECT WELDS NOTED PER MIL-I-6866. 100% INSPECTION REQUIRED NO CRACKS PERMITTED
4- IDENTIFY PER 0-70042 AS REQUIRED. LOCATION OPTIONAL
5- IMPRESSION MARKING OF PARTS NOT PERMITTED
6> WELD AFTER INSTALLATION OF GUARD TANK INTO CRYO-SHROUD COVER
7- PROOF PRESSURE TEST THE TEST TANK FILL & DRAIN (-8) AND VENT (-7) LINES TO (50 PSIG)
8- PROOF PRESSURE TEST THE GUARD TANK ASSY TO (30 PSIG)
9- LEAK TEST LINES & GUARD TANK ASSY WITH HELIUM. MAX ALLOWABLE LEAKAGE 1X10⁻⁶ CC/SEC AT (15 PSIG)
10> PRODUCT OF MINI-FLEX CORP, VAN NUYS, CA
11- CLEAN TEST TANK FILL & DRAIN (-8) & VENT (-7) LINES TO 0-75192-2
12- CLEAN GUARD TANK & LINES TO REMOVE LARGE PARTICLES & CHIPS
13> PRODUCT OF AEROQUIP/MARMAN DIVISION
14- TEST FACILITY REQUIREMENTS
15> SIZE WELD BANDS & DUCT AS REQUIRED TO FIT BELLOWS NECK
16> SEAM WELD & INSPECT PER 0-75175-1
17> CLEAN LOCALLY PRIOR TO RESISTANCE WELDING PER 0-73509-1
18> INSPECT INSIDE OF SMALL ELECTRICAL HARNESS TUBE AFTER WELDING FOR BURN-THRU OR BLISTERS. REMOVE ANY PROTURBANCES
19 ALL DIMENSIONS IN SI UNITS (ENGLISH UNITS IN PARENTHESIS FOLLOWING)
20> COORDINATE WELDING OF TUBES INTO GUARD TANK & TANK CLOSURE WELD WITH TEST ENGINEERING
21> FLARE END OF INNER TUBE TO (2.01) OD. FLARE ANGLE TO BE (30-50°)
22> FLARE END OF TUBE TO (30-50°) X (.63) OD
23> PRODUCT OF ORANGE COUNTY MACHINE WORKS, ORANGE, CA. HEAD CONFIGURATION: DISHED & FLANKED, DIE-FORMED STANDARD, NON-CODE, 100% CROWN RADIUS, (24 IN) OD, NO 10 GAGE, 304 CRES
24> TRIM FLANGE SKIRT TO (.040) WALL THICKNESS. MAINTAIN INSIDE DIA

REQ PER ASSY / INSTL	UNIT OF MEAS	ITEM OR FIND NO	CODE IDENT NO.	PART OR IDENTIFYING NUMBER	NOMENCLATURE OR DESCRIPTION	ZONE	NO	NOTE TEXT (STOCK SIZE, MATERIAL, SPECIFICATION, TYPE (TEMPER, ETC.), HEAT TREAT)
2		–		56991-2005	FLANGE, MALE			SEE NOTES 13 & 14
2		36		56932-2005	FLANGE, FEMALE	E	4	SEE NOTE 13
2		35		59162-2005	FLANGE, MALE	D	26	SEE NOTE 13
2		34		55-2000-120-85A	BELLOWS	C	27	SEE NOTE 10
4		33		-33	BAND, WELD	E	26	(.028X.5X6.5) SHEET 304 CRES
2		32		AN960C10	WASHER	E	6	
2		31		AN960C616	WASHER	D	6	
2		30		MS21043-3	NUT	E	5	
2		29		MS21043-6	NUT	D	6	
1		28		NAS1003-18A	BOLT	E	5	
1		27		NAS1003-14A	BOLT	C	5	
2		26		NAS1006-7A	BOLT	D	6	
2		25		AN742F12	CLAMP	F	5	
2		24		59190-1255	TUBING JOINT	C	4	SEE NOTE 13
1		23		-23	TUBE	G	26	(50.00X.029X43.0) TUBE 304 CRES
2		22		-22	LUG, SUPPORT	F	4	(.25X2.0X2.5) PLATE 304 CRES
1		21		-21	TUBE, VENT	G	5	(.75X.035X20.0) TUBE 304 CRES
1		20		-20	TUBE, FILL	E	7	(.75X.035X13.0) TUBE 304 CRES
2		19		-19	TUBE		27	(2.000X.035X2.7) TUBE 304 CRES
1		18		-18	TUBE, FILL & DRAIN		27	(1.500X.035X57.0) TUBE 304 CRES
1		17		-17	BAND		8	(.125X2.0X77.0) SHEET 304 CRES
1		16		-16	CLIP	B	27	(.04X.75X1.6) SHEET 304 CRES
1		15		-15	DEFLECTOR	B	28	(.025X.5X.3) SHEET 304 CRES
2		14		-14	BLOCK, SUPPORT		5	(.5X3.2X5.0) TEFLON
1		13		-13	ELBOW	C	27	(2.000X.035X.3) TUBE 304 CRES
1		12		-12	ELBOW	H	27	(2.000X.035X12.0) TUBE 304 CRES
1		11		-11	ELBOW	F	27	(2.000X.035X13.0) TUBE 304 CRES
1		10		-10	ELBOW	H	27	(2.000X.035X12.0) TUBE 304 CRES
2		9		-9	U TUBE	F	27	(2.000X.035X7.0) TUBE 304 CRES
1		8		-8	TUBE, FILL & DRAIN	E	5	(2.000X.035X69.0) TUBE 304 CRES
1		7		-7	TUBE, VENT	G	5	(2.000X.035X63.0) TUBE 304 CRES
2		6			HEAD, TANK	A	7	SEE NOTE 23
3		5		-5	STRIP		5	(.125X2.5X12.0) SHEET 304 CRES
3		4		-4	LUG, MOUNTING	A	5	(.50X1.5X5.7) PLATE 304 CRES
1		3		-3	SHELL	C	8	(.125X12.5X77.0) SHEET 304 CRES
1		2		-2	RING	C	8	(1.0X24.5X24.5) PLATE 304 CRES
X				-1	GUARD TANK ASSY	E	7	

NOTE SYMBOL: E–END ITEM, G–GENERAL NOTE, L–LIMIT, M–MATERIAL, R–REFERENCE DESIGNATION, S–STOCK NO, U–USAGE DATA

PARTS LIST

UNLESS OTHERWISE SPECIFIED — ALL MACHINED SURFACES √
RIVET BASIC CODE NAS523
SEE 0-70914 FOR ABBREVIATION CODE AND SYMBOL REQUIREMENTS
SEE 0-70962 FOR STANDARD MANUFACTURING AND INSTALLATION REQUIREMENTS
ASSOCIATED LIST REQUIRED SEE DOCUMENT SAME NUMBER PREFIXED UL ☐ FOR USAGE LIST
UNLESS OTHERWISE SPECIFIED DIMENSIONS ARE IN INCHES. TOLERANCES .X ±.1 .XX ±.03 .XXX ±.010 ANGULAR PER 0-70902
CONTRACT NO NAS 3-17756

CONVAIR AEROSPACE DIVISION OF GENERAL DYNAMICS
SAN DIEGO, CALIFORNIA

TANK ASSY- GUARD

SIZE E | CODE IDENT 14170 | DRAWING NO PD73-0083 | SHEET 1 OF 2

SECURITY CLASSIFICATION

Guard Tank Assembly

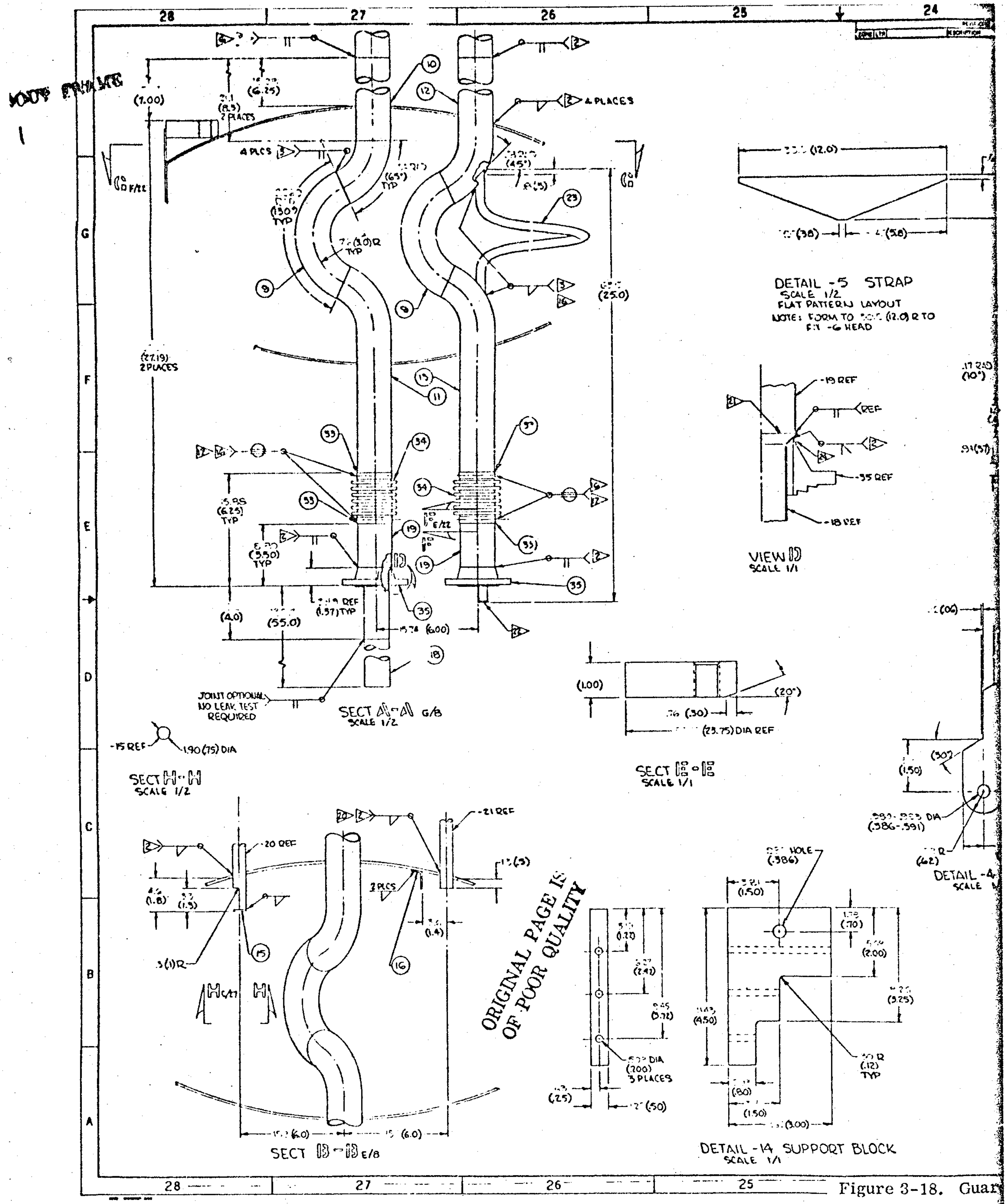
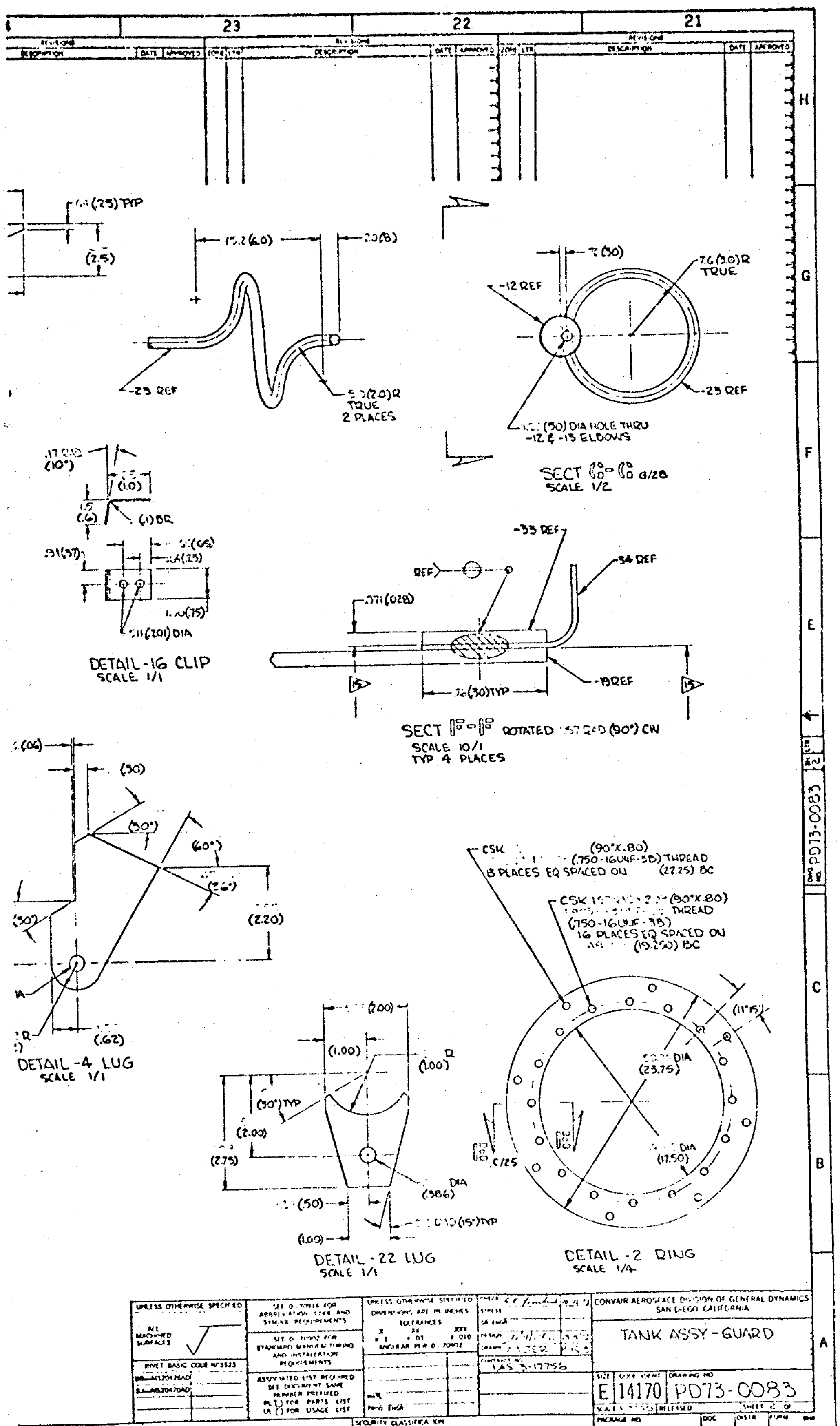


Figure 3-18. Guar



8. Guard Tank - Facility Lines

The electrical harness was fed through a separate tube in the guard tank to provide good thermal contact and to assure complete heat removal. Bellows (SS-2000-120-85A, Mini-Flex Corp., Van Nuys, CA) were provided in both the lines between the test tank and guard tank for ease of installation and to assure that the loads caused by movement of the test tank were not transmitted through these lines.

3.6 MODIFIED CRYOSHROUD ASSEMBLY

Figure 3-19 shows the assembly of the cryoshroud cover including the fill and vent lines of the test tank, guard tank, thermal payload simulator, cryoshroud and baffles. The assembly of the cryoshroud and baffles with the guard tank, test tank, thermal payload simulator and Baffle/TPS positioning mechanism is presented in Figure 3-20.

3.6.1 ASSEMBLY SEQUENCE. The assembly sequence of all components was as follows:

1. Mate guard tank to shroud top.
2. Mate test tank to guard tank/shroud top (tank assembly), (Fig. 3-21 to 3-23).
3. Leak check tank assembly.
4. Mate baffles to shroud-side, (Figure 3-24).
5. Temporarily mate tank assembly to shroud-side, adjust test tank supports, unmate tank assembly from shroud-side.
6. Install MLI on test tank.
7. Install instrumentation on tank assembly.
8. Add plumbing to baffle/shroud-side assembly and leak check.
9. Install instrumentation on baffle/shroud-side assembly, shroud-bottom and thermal payload simulator.
10. Mate TPS to baffle/shroud-side assembly.
11. Install MLI on bottom of TPS.
12. Mate shroud-bottom to TPS/baffle/shroud-side assembly (shroud assembly).
13. Add plumbing to shroud assembly and leak check.
14. Mate tank assembly to shroud assembly (test assembly).
15. Place test assembly in chamber and install support legs.
16. Add test assembly plumbing between test assembly and chamber and leak check.
17. Install baffle/TPS jack screw assembly.
18. Install MLI on outside of test assembly.

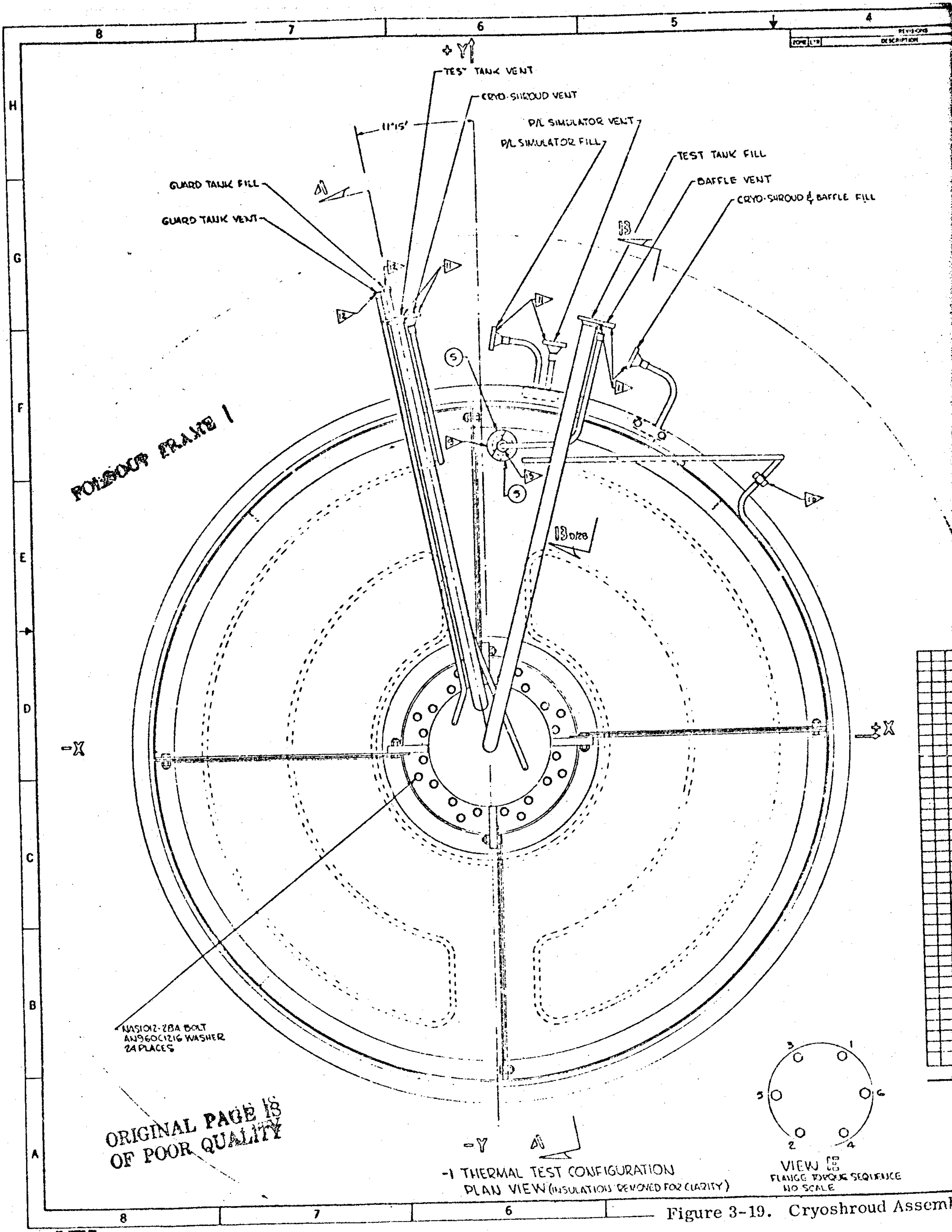


Figure 3-19. Cryoshroud Assemb

NOTES: UNLESS OTHERWISE SPECIFIED

1- DO NOT FILL TEST TANK WITH LN2 WITHOUT A STRUCTURAL ANALYSIS OF THE CRYO-SHROUD, GUARD TANK & TEST TANK

2- INSTALL MLI AS SHOWN IN SECTION A-A. USE ALUMINIZED MYLAR TAPE & VELCRO FASTENERS TO ATTACH INSULATION TO STRUCTURE & TO EFFECT CLOSURE OF BLANKETS. USE .125 THICK FOAM STRIPS FOR SEPARATORS

3- INSTALL TEST TANK IN CRYO-SHROUD COVER & LEAK TEST PRIOR TO INSTALLATION IN THE CRYO-SHROUD SHELL

4- LEAK TEST WITH HELIUM. MAX ALLOWABLE LEAKAGE IS 1×10^{-6} CC/SEC AT 15 PSIG

5▷ DIM "D" IS NOMINALLY 17.19. ON INSTALLATION OF TEST TANK (PD73-0072) TO GUARD TANK (PD73-0085), ADJUST STRUTS (PD73-0077) TO ADJUST BELLOWS IN PD73-0085 ASSY TO AS NEAR THEIR FREE LENGTH AS POSSIBLE WITH THE TANK LID PARALLEL TO THE CRYO-SHROUD COVER

6▷ ADJUST INDIVIDUAL STRUTS AS REQUIRED TO CENTER THE TEST TANK WITHIN THE CRYO-SHROUD SHELL. DIM "C" (FROM TEST TANK TO WALL STIFFENER) SHOULD BE CONSTANT WITHIN ±.62 AT ALL STIFFENERS. DO NOT ALLOW DIM "D" TO DEVIATE MORE THAN ±.1 OVER THE SURFACE OF TANK COVER FROM THE BELLOWS FREE LENGTH POSITION ESTABLISHED IN NOTE 5

7- REMOVE -2 SHIPPING STRUTS & -7 CLAMP ON CRYOSHROUD VENT LINE PRIOR TO TEST

8▷ DO NOT ALLOW FLANGE FACE TEMPERATURE TO EXCEED 275°F DURING WELDING. USE EXTERNAL FLOOD COOL OR CHILL WITH LN2 AS REQUIRED

9▷ PAINT ONE SIDE OF -5 COVERS PER NOTES 10, 18 & 20

10▷ PREPARE UNPAINTED SURFACES WITH "ANEW-X" METAL BRIGHTENER (PRODUCT OF A.C. FERGUSON CO. PHIL., PA). RINSE WITH DE-IONIZED WATER. PROTECT TREATED SURFACES AGAINST CONTAMINATION. DO NOT HANDLE

11▷ TORQUE FLANGE BOLTS TO 80-90 IN-LB AS FOLLOWS: TIGHTEN ALL BOLTS FINGER TIGHT. THEN TIGHTEN ALL BOLTS 1/2 TURN IN SEQUENCE SHOWN IN VIEW "E". CONTINUE IN THIS SEQUENCE UNTIL SPECIFIED TORQUE IS REACHED

12▷ TORQUE CRES TUBE FITTINGS TO 700-1050 IN-LB

13▷ TORQUE ALUMINUM TUBE FITTINGS TO 490-730 IN-LB

14- WELD PER MIL-W-8604

15- TEST FACILITY REQUIREMENT

16▷ 3 STRUTS ARE USED FOR TEST & 3 STRUTS ARE USED FOR GROUND HANDLING. INSTALL ONE JAM NUT ON EACH STRUT USED FOR TEST. LOCK IN PLACE AFTER ADJUSTMENT

17 INSTALL -5 COVERS WITH PAINTED SURFACES DOWN. USE ALUMINIZED MYLAR TAPE TO ATTACH COVERS TO SHROUD

18▷ PRIME UNPAINTED SURFACES WITH 3M NEXTEL 901-T1 BLACK PRIMER

19▷ CLEAN PREVIOUSLY PAINTED SURFACES OF GREASE, WAX & SIMILAR STAINS WITH A NAPHTHA DAMPENED CLOTH OR SPONGE. RUB LIGHTLY & CHANGE CLOTHS FREQUENTLY TO REMOVE AS MUCH STAIN AS POSSIBLE WITHOUT SPREADING. REMOVE DIRT WITH A DAMP CLOTH, SPONGE OR SOFT BRISTLE BRUSH

20▷ PAINT INTERIOR SURFACES DESIGNATED WITH 3M NEXTEL VELVET COATING (3M 401-C10). MIX & APPLY PER MANUFACTURERS DIRECTIONS.

REQ PER ASSY / INSTL (-1)	UNIT OF MEAS	ITEM OR FIND NO	CODE IDENT NO.	PART OR IDENTIFYING NUMBER	NOMENCLATURE OR DESCRIPTION	ZONE	NO	NOTE TEXT (STOCK SIZE, MATERIAL, SPECIFICATION TYPE (TEMPER, ETC) & HEAT TREAT)
12				AN960C416	WASHER			
AR				3M 901-T1	PRIMER			PRODUCT OF 3M CO, ST PAUL, MINN
AR				3M 401-C10	PAINT			PRODUCT OF 3M CO, ST. PAUL, MINN
12				[illegible]	GASKET			PRODUCT OF AEROQUIP/MARMAN DIVISION
24				[illegible]	GASKET			PRODUCT OF AEROQUIP/MARMAN DIVISION
30				50587-150A	GASKET			PRODUCT OF AEROQUIP/MARMAN DIVISION
30				50887-100A	GASKET			PRODUCT OF AEROQUIP/MARMAN DIVISION
36				50507-12A	GASKET			PRODUCT OF AEROQUIP/MARMAN DIVISION
20				PD73-0084-15	CLAMP			
2				PD73-0085-23	ADAPTER			
1				PD73-0087-1	BAFFLE ADJ MECH	G	22	
1				PD73-0086-1	PLUS[illegible]ATOR	G	22	
1				PD73-0085	MOD. FEU. CRYO-SHROUD	G	25	
1				PD73-0084-1	BAFFLE ASSY	G	24	
1				PD73-0083-1	GUARD TANK ASSY	D	26	
6		16		[illegible]	[illegible]	G	24	PRODUCT OF MERRILL BROS, MASPETH, N.Y. SEE NOTE 16
1				PD73-0070-1	TEST TANK	G	25	
8				MS[illegible]	NUT	F	25	
72				AN960C[illegible]	WASHER	F	25	
22				ANEW-X	METL. BRIGHTENER			PRODUCT OF A.C. FERGUSON CO, PHILADELPHIA, PA
12				NAS1004-6A	BOLT	C	25	
24				[illegible]	WASHER	F	[illegible]	
[illegible]				NAS1006-[illegible]	BOLT	F	[illegible]	
1		15		59159-12AA	[illegible] FITTING	[illegible]	27	PRODUCT OF AEROQUIP/MARMAN DIVISION
[illegible]				59162-100S	FLANGE, MALE			PRODUCT OF AEROQUIP/MARMAN DIVISION SEE NOTE 15
AR		13		-13	INSULATION			1/4 MIL ALUMINIZED MYLAR. SEE NOTE 17
2		12		MS21043-4	NUT	[illegible]	26	
2		11		NAS1004-6A	BOLT	G	26	
2		10		AN960C10	WASHER	F	26	
2		9		MS21043-3	NUT	F	26	
2		8		NAS1003-12A	BOLT	C	26	
2		7		AN742E12	CLAMP	F	26	
1		6		-6	TUBE	D	28	.75 OD X .062 X 40.0 TUBE 6061-T4 AL
2		5		-5	COVER	F	26	.040 X [illegible] X 4.5 SHEET 6061-T6 AL
2		4		59161-100A	FLANGE, FEMALE	F	26	PRODUCT OF AEROQUIP/MARMAN DIVISION
1		3		-3	TUBE	[illegible]	26	.75 OD X .062 X 75.0 TUBE 6061-T4 AL
2		2		-2	SHIPPING STRUT	G	26	.125 X 2 X 2 ANGLE CARBON STEEL
				-1	ASSY	A	6	

NOTE SYMBOL: E—END ITEM, G—GENERAL NOTE, L—LIMIT, M—MATERIAL, R—REFERENCE DESIGNATION, S—STOCK NO, U—USAGE DATA

PARTS LIST

UNLESS OTHERWISE SPECIFIED — ALL MACHINED SURFACES √	SEE 0-70914 FOR ABBREVIATION, CODE AND SYMBOL REQUIREMENTS	UNLESS OTHERWISE SPECIFIED DIMENSIONS ARE IN INCHES. TOLERANCES .X ±.1, .XX ±.03, .XXX ±.010. ANGULAR PER 0-70902	CONVAIR AEROSPACE DIVISION OF GENERAL DYNAMICS, SAN DIEGO, CALIFORNIA
RIVET BASIC CODE NAS523	SEE 0-70902 FOR STANDARD MANUFACTURING AND INSTALLATION REQUIREMENTS	CONTRACT NO. NAS 3-17756	THERMAL TEST CONFIGURATION CUSTOMIZED MLI
	ASSOCIATED LIST REQUIRED. SEE DOCUMENT SAME NUMBER PREFIXED UL FOR USAGE LIST	SIZE E; CODE IDENT 14170; DRAWING NO PD73-0080	SCALE 1/5; SHEET 1 OF 2

Assembly - Top View 3

FOLDOUT FRAME 2

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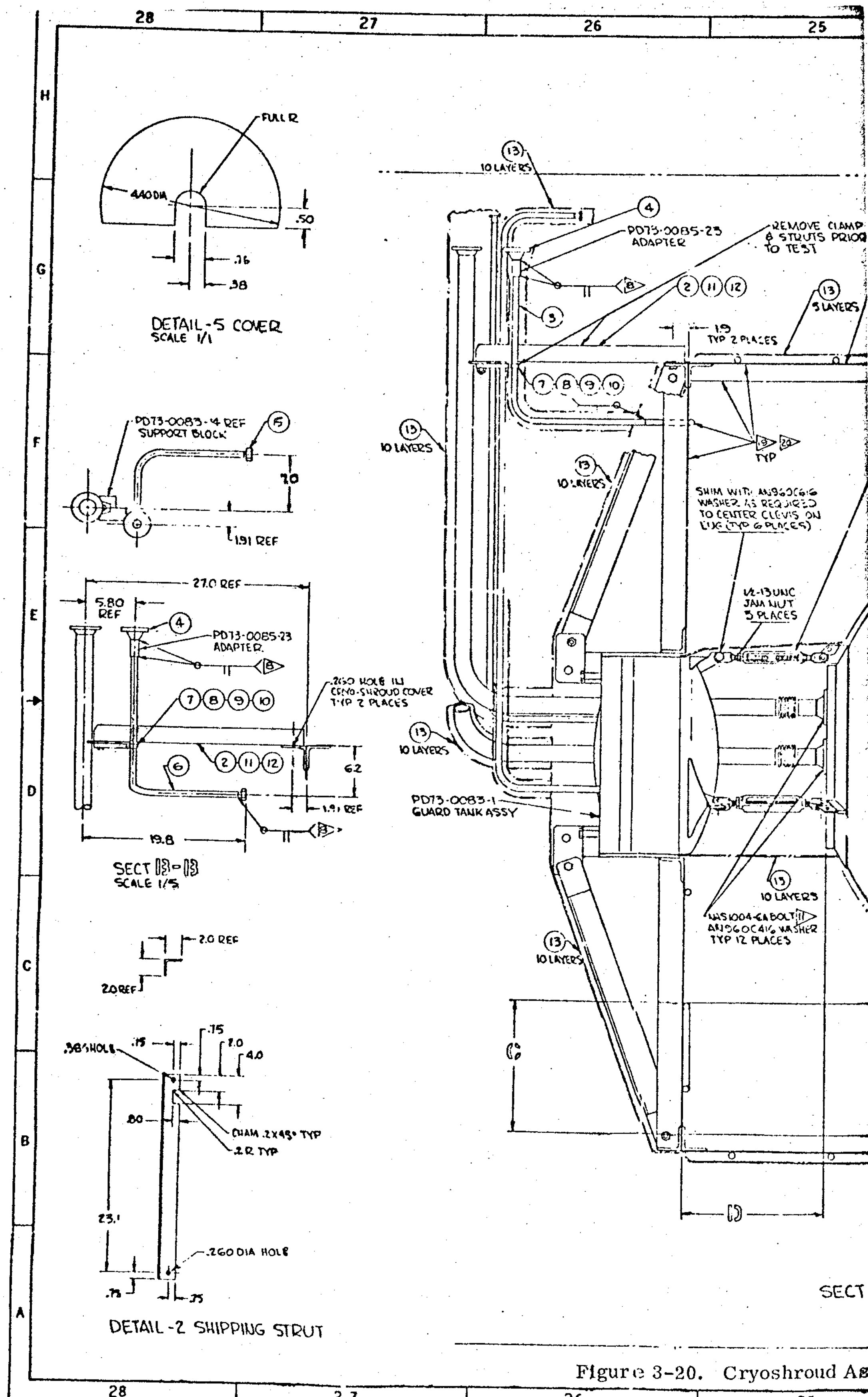

Figure 3-20. Cryoshroud Ass

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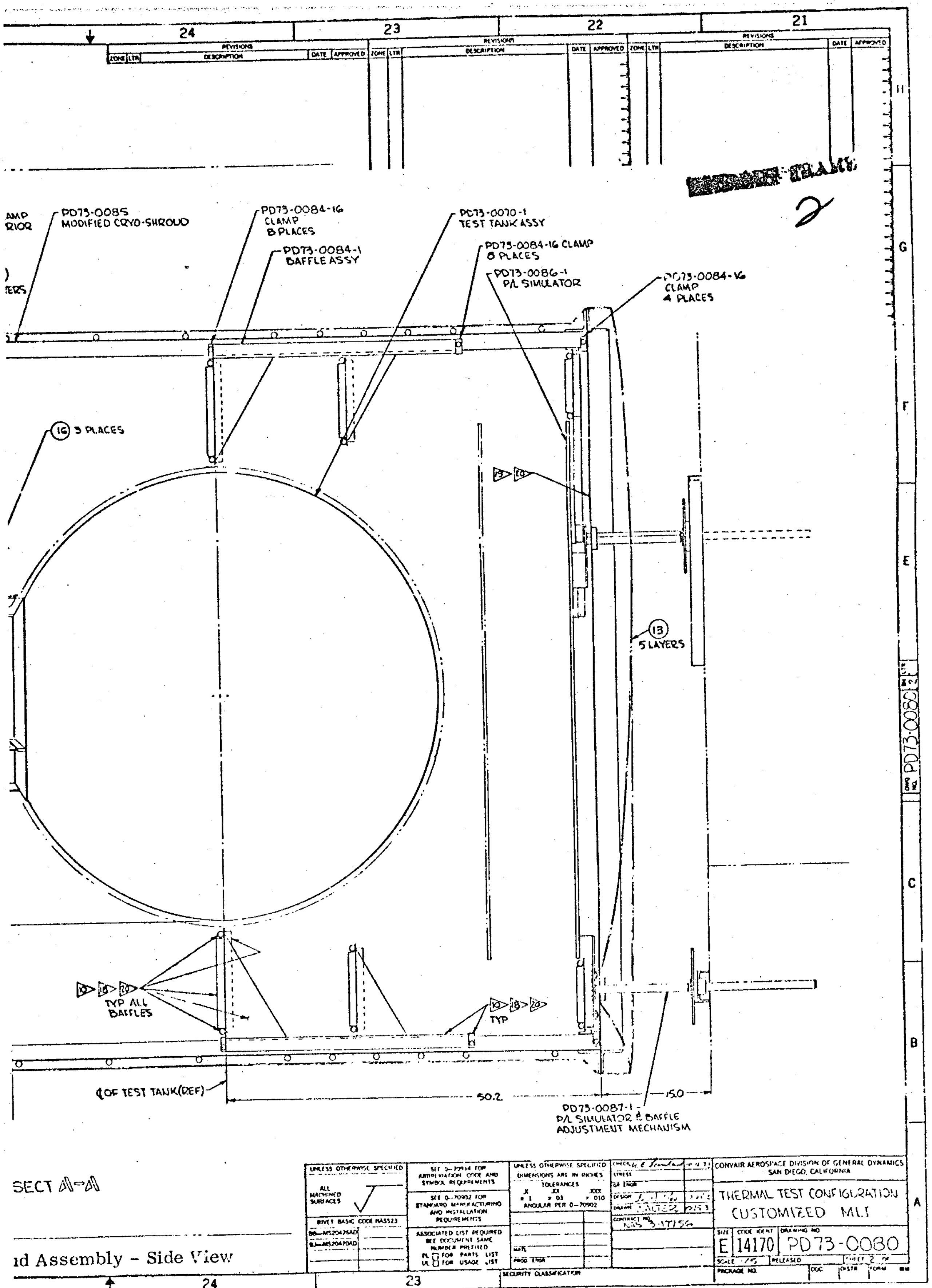


…ld Assembly - Side View

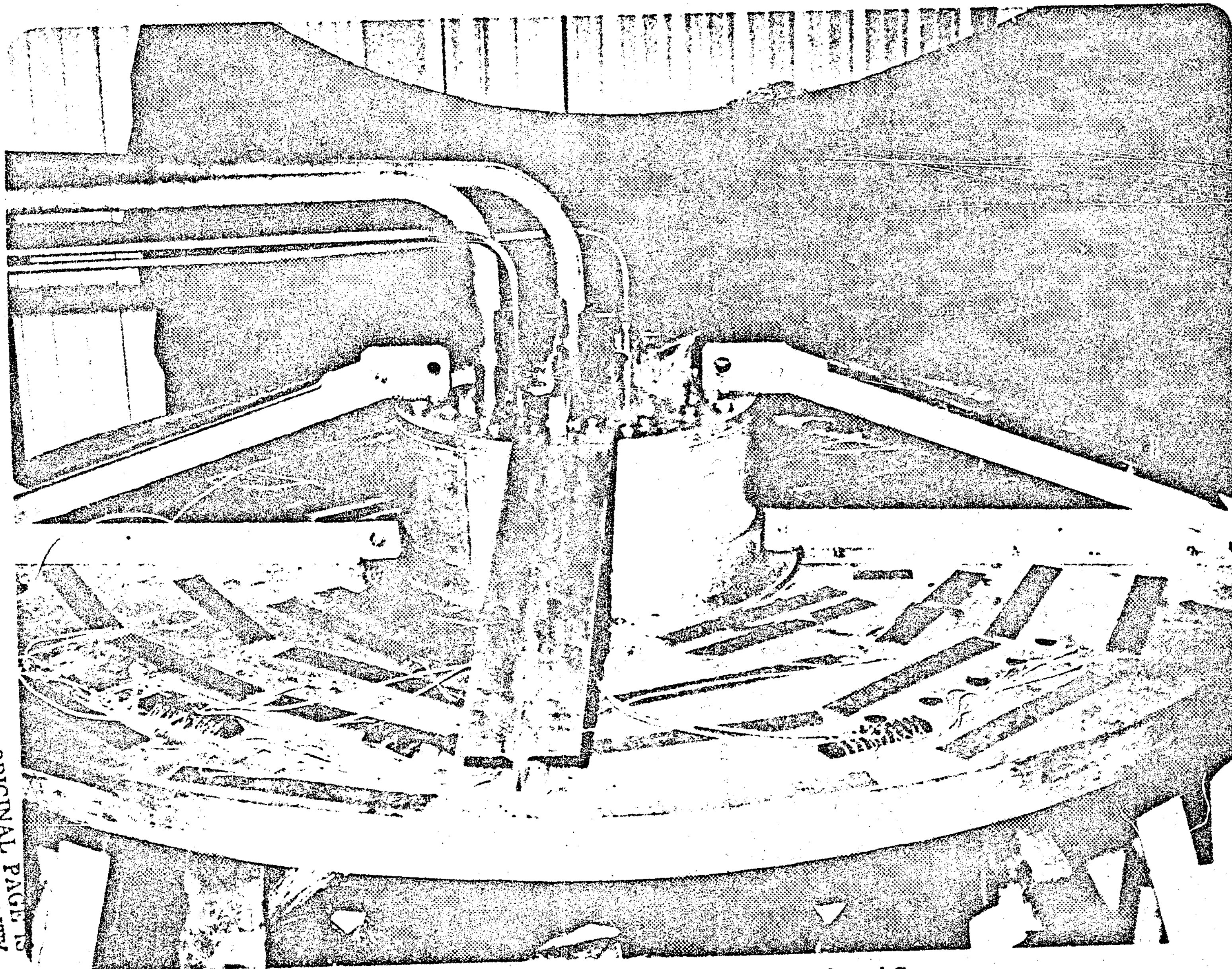


Figure 3-21. Assembly of the Guard Tank and Cryoshroud Cover

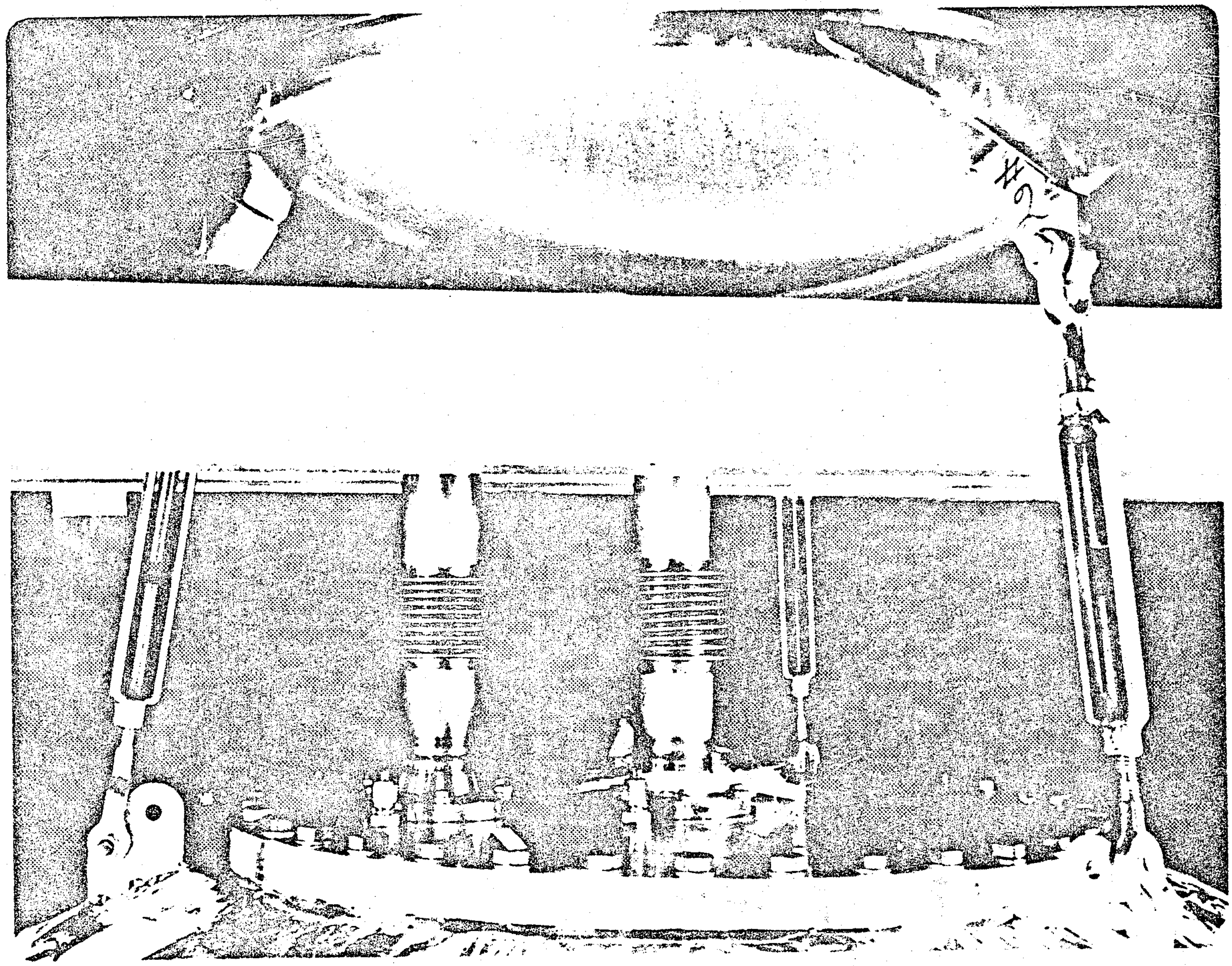


Figure 3-22. Assembly of Cryoshroud Cover/Guard Tank and Test Tank, Side View

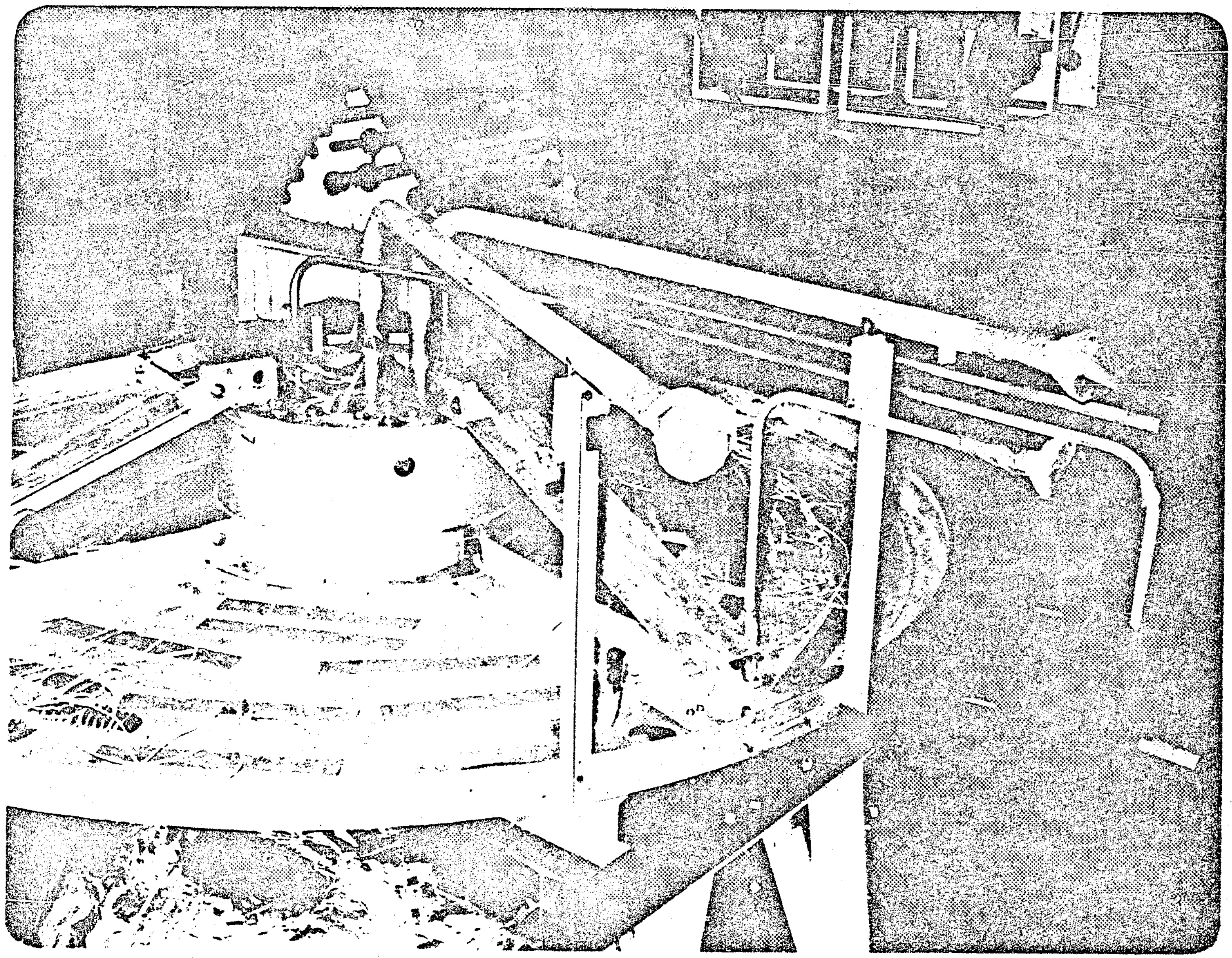


Figure 3-23. Assembly of Cryoshroud Cover/Guard Tank and Test Tank - Top View

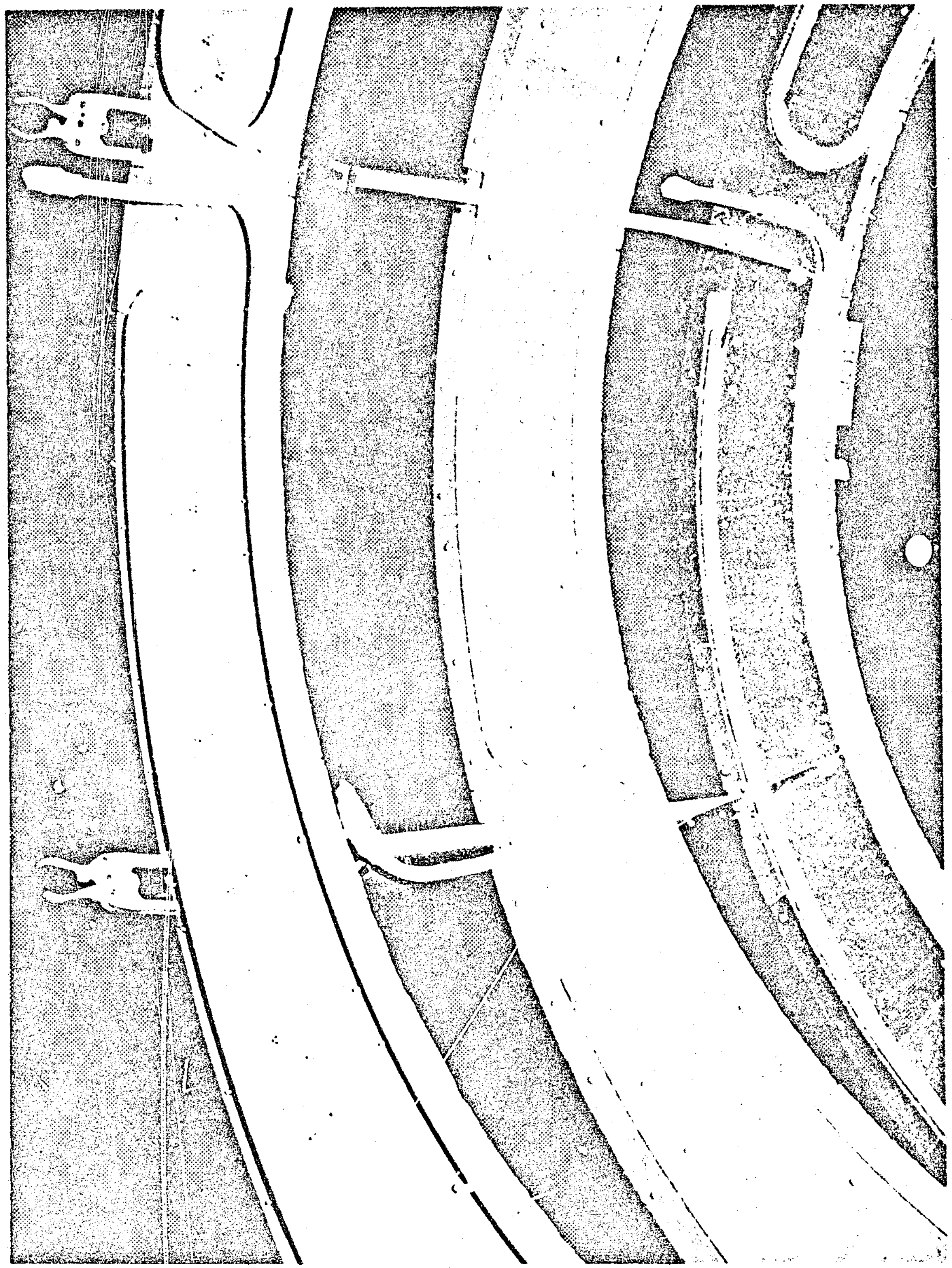


Figure 3-24. Cryoshroud and Baffle Assembly

Prior to mounting the baffles on the cryoshroud, all baffle supports were fabricated and attached to the wall as shown in Figure 3-9. The baffle cooling coils were externally cleaned with Freon solvent, then leak checked with helium and repaired as necessary.

As shown in Figure 3-20, the guard tank is supported from the cryoshroud lifting structure.. This arrangement permitted assembly and installation of the cryoshroud cover and test tank as a unit.

The cryoshroud assembly support consists of 6 micarta and aluminum legs, bolted to the cryoshroud and resting on the bottom of the vacuum chamber. The micarta material is used to minimize heat transfer.

3.6.2 THERMAL PAINT REQUIREMENTS. After assembly, all interior surfaces including the cryoshroud, baffles, and attachment hardware viewing the test package were completely covered with 3M "Nextel" Black Velvet (3M401C10) paint to achieve the highest emissivity possible. This paint is designed for surfaces requiring high emissivities and low outgassing in a vacuum.

3.6.3 MLI REQUIREMENTS. Multilayer radiation shields were used to thermally protect:

1. All lines between the test configuration and vacuum chamber wall (10 layers).

2. The cover of the cryoshroud (10 layers).

3. The guard tank assembly (10 layers).

4. The TPS from the bottom of cryoshroud (10 layers).

5. The TPS to reduce the thermal load on the outer heater band (3 layers). This insulation was attached to the inner diameter of the lower baffle assembly.

6. The cryoshroud along the side wall, top and bottom (30 layers).

All shields were attached to the surfaces by taping or the use of Velcro fasteners.

3.6.4 FLUID TUBING. Single and double Conoseals were used for flange and tubing joints where welding was not feasible or desirable. Single Conoseals were utilized for stainless steel joints while double Conoseals were applied where a bi-metal (i.e., Al + Cres) joint could cause a possible leak. The Conoseals and Conoseal groove information were provided by Aeroquip Marman Corporation. The cryoshroud and baffle filling operation was accomplished through a single fill line at the bottom panel.

The thermal payload simulator has its own fill and vent line. The baffle cooling line is a continuous aluminum tube which makes a circle around the baffle on the lower side (not attached), goes through the movable baffle plate and makes a double circuit on the upper surface of the movable baffle. It continues with a spiral around the cryoshroud from the lower movable baffle to the fixed baffle. The coil then exits through a hole in the shroud. The Conoseal flanges, tubing, joints and gaskets used for the cryoshroud assembly are shown in Table 3-3.

Table 3-3. Conoseal Flanges, Tubing Joints and Gaskets

Item	Location	Seal No.	No.	Material
Tube Joint	Guard Fill/Vent	59190-12SS	2	Cres
Double Seal Flange	TPS, Baffles	59162-100S	5	Cres Male
	Cryoshroud	59161-100A	5	Al Female
Double Seal Flange	Test Tank Fill/Vent*	59162-200S	2	Cres Male
Single Seal Flange	Test Facility	56331-200S	2	Cres Male
	Test Tank Fill/Vent	56332-220S	2	Cres Female
Gasket**		59307-12A		Al Alloy
		50887-100A		↓
		50887-150A		
		50887-200A		
		50887-250A		

* The mating female flange was machined as a part of the test tank lid.

** All gaskets were Teflon coated before installation.

4

TANK PRESSURE CONTROL SYSTEMS

Pressure control devices are required for the test tank and guard tank to maintain a constant liquid boiling point.

4.1 TEST TANK PRESSURE CONTROL

The pressure control system shown in Figure 4-1, is used during testing to control the back pressure of the liquid hydrogen test tank. The system is designed to maintain the test tank pressure within ± 1.38 N/m^2 (0.0002 psi) of the set point. The MKS Baratron, Differential Capacitance Manometer, Model 145 AH-1 (±1 mm Hg diff.) is utilized to sense very small positive or negative pressure variations in the test tank relative to a constant reference pressure of a fixed volume of gas, maintained at a constant temperature. The electrical output of the Baratron transducer is fed to the pressure regulating valve, Controller, Dahl Model C601B, which actuates the Hammel-Dahl vent valves Model A40A located in the test tank vent line, thereby controlling the pressure in the cyrogenic tank. A brief description of the major components is given in the following paragraph.

1. Capacitance Manometer MKS Baratron No. 145 AH-1, ±1 mm Hg pressure differential. The MKS Baratron Type 145A capacitance manometer head is a tensioned diaphragm pressure/vacuum gauge designed for performing highly accurate measurements of gas pressures. It is mounted inside a temperature controlled chamber and attached to a 12000 lb mass block to eliminate vibrations. The MKS Baratron Head support plate and reference pressure container is shown in Figure 4-2.

2. Signal Conditioner, MKS Model 170 M-7A. This type of electronic unit provides excitation to the Head, and converts the Head output to a proportional DC output of ± 10 VDC full scale.

3. Pressure Indicator, MKS Model 170M-26A. This unit is a 12.7 cm (5 in) precision mirror scale meter, readout unit, calibrated directly in pressure units. It has a center-zero meter for reading both positive and negative pressures.

4. Balance Digital Offset MKS Model 170 M-29. The instrument monitors minute variations about a fixed pressure that has been applied to the Head.

5. Controller, Dahl Model C-601B. The C601B is a three mode analog controller which permits full time automatic control. It accepts all standard transmitter

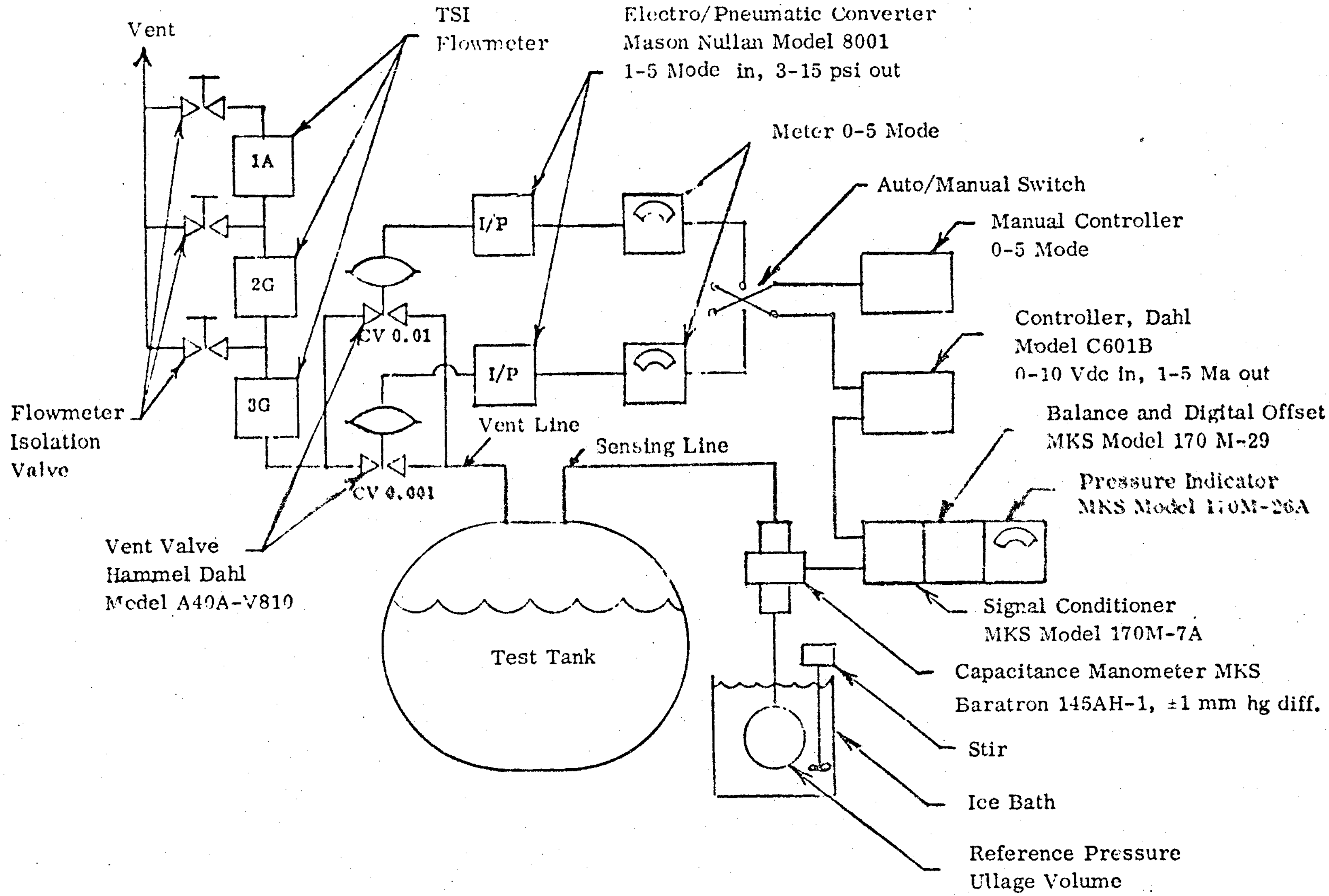


Figure 4-1. Customized Multilayer Insulation System Back Pressure Control System Schematic

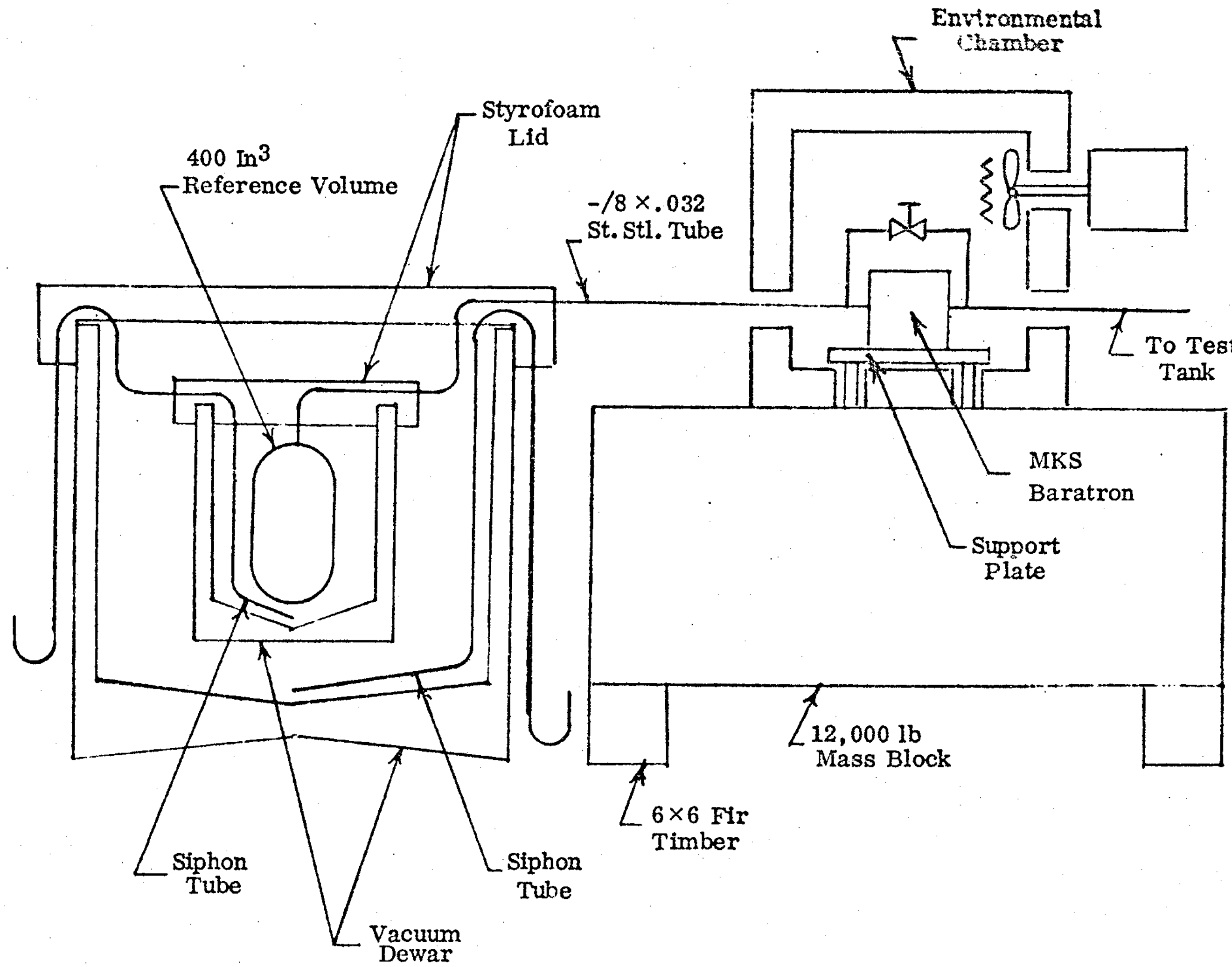


Figure 4-2. MKS Baratron Head Mounting and Reference Pressure Container

and remote set-point signals. Power supply: 105-130 volts, 50/60 Hz, 33 VA maximum.

6. Hammel-Dahl Valve, CV = 0.001, A-40A, V810 DGE 42, P4SG8. This is an air to open actuator, globe design, 316 S. steel, screwed ends, plain bonnet, spline trim, with teflon packing valve positioners and hand jack actuator to close.

7. Hammel-Dahl Valve, CV=0.01, V810 DGE 42 PWSG8. Same as Spec. No. 6.

8. TSI Flowmeter. The TSI (Thermo Systems Inc.) flowmeters which measure boiloff rates are hot film anemometers.

   a. Model 1352-1A measures flowrates between .000039 - .00196 g/sec (0.000312-0.0156 lb/hr) ±2% accuracy, F.S.

   b. Model 1352-2G measures flowmeters between 1.6-46.6 mg/sec (0.013-0.37 lb/hr) ±2% accuracy, full scale.

   c. Model 1352-3G measures flowmeters between 16.4-466.2 mg/sec (0.13-3.7 lb/hr) ±2% accuracy F.S.

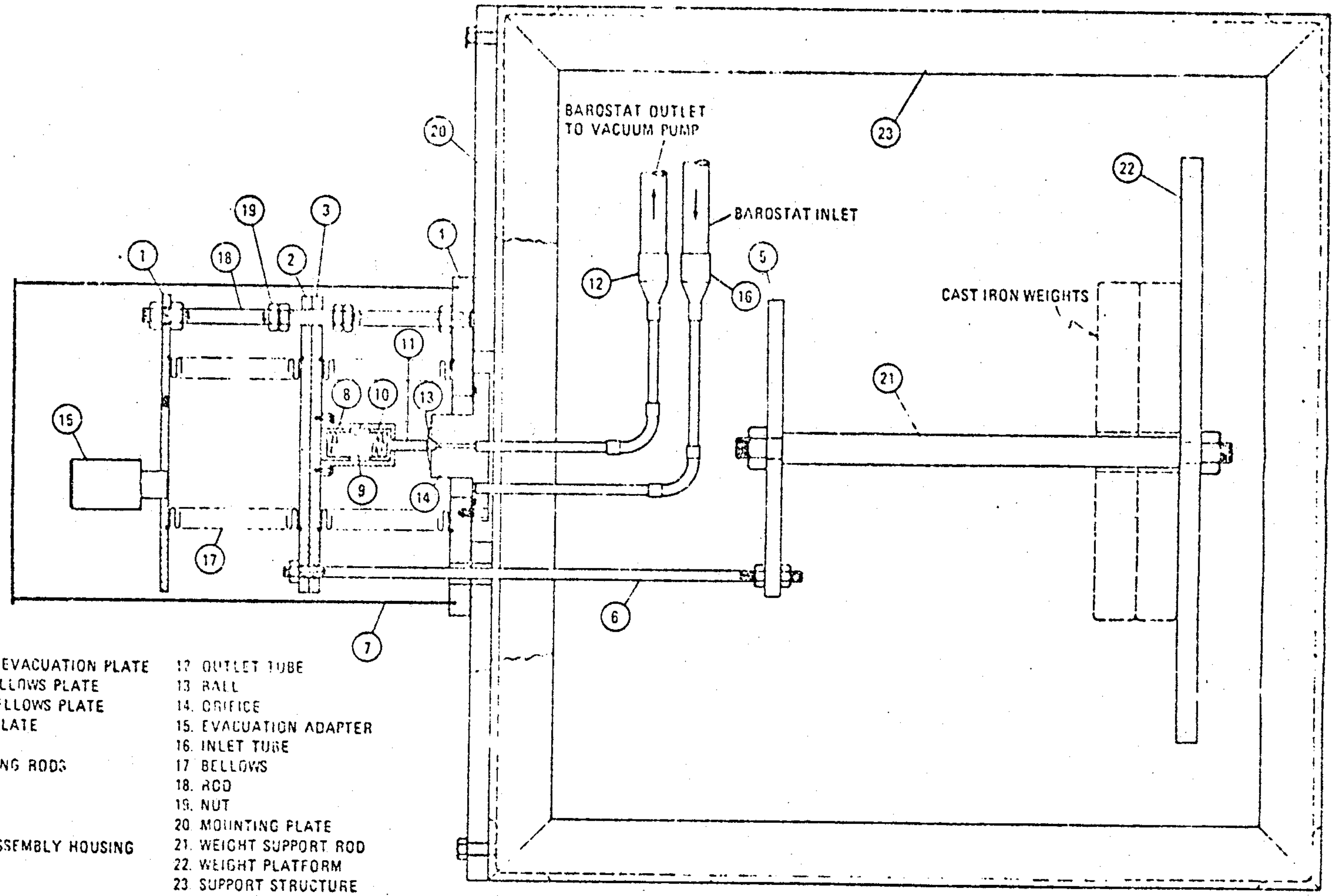
9. Reference Pressure Container Ice Bath. The reference pressure container ice bath (Figure 4-2) consists of a 15.24 cm (6 in) diameter, 30.48 (12 in) long stainless steel vessel containing hydrogen gas. This vessel is mounted within the inner vacuum jacketed dewar, 25.40 cm (10 in) diameter and 45.72 cm (18 in) deep. The assembly is contained within an outer dewar, 76.2 cm (30 in) diameter and 72.2 cm (30 in) deep. Both dewars are filled with ice, covered with foam lids and equipped with tubes to siphon water away. The reference pressure vessel is connected with the Baratron Head by a 0.318 cm (0.125 in) diameter, 0.081 cm (0.032 in) wall, 244 cm (96 in) long stainless steel tube.

4.2 GUARD TANK PRESSURE CONTROL

The NBS barostat device is used to control the pressure of the guard tank. The NBS barostat was developed by the National Bureau of Standards (NBS), Washington, to maintain constant tank back pressure with small variations in vent gas flow rate. The barostat has been used successfully at NASA/MSFC and at Convair on a 2.21 m (87 in) diameter test tank thermal test program (Reference 4-1). Convair's experience in calibration of the unit indicates that pressure control was maintained over a band of ± 13.8 N/m^2 (±0.002 psi), provided the flow rate does not change more than 94 cm^3/sec (±0.2 scfm).

Figure 4-3 is a schematic of the NBS barostat. The basic principle of operation of the unit is balance between the pressure in the lower cavity and weights suspended from this bellows assembly. In order in reach equilibrium, the bellows respond to the pressure from the tank and open or close the orifice by moving the ball and plunger assembly. This plunger is spring loaded to prevent damage to the lapped orifice seat when the unit closes. The amount of weight placed on the weight platform determines the pressure at which the unit will control. The upper bellows section is evacuated to provide a constant pressure reference for the controlling bellows that is not affected by changes in atmospheric pressure. As is noted on the drawing, a vacuum pump is connected to the barostat outlet port. This is done to ensure a critical pressure ratio across the orifice over a wide range of flow rates.

During testing, the guard tank pressure will be maintained at 111.8 kN/m^2 (16.2 psia). The upper evacuated bellows on the Barostat will be maintained at a pressure of less than 13.32 N/m^2 (100 microns) during all thermal equilibrium testing.



1. BELLOWS EVACUATION PLATE
2. UPPER BELLOWS PLATE
3. LOWER BELLOWS PLATE
4. ORIFICE PLATE
5. PLATE
6. CONNECTING RODS
7. COVER
8. CUP
9. SPRING
10. SPRING ASSEMBLY HOUSING
11. PLUNGER
12. OUTLET TUBE
13. BALL
14. ORIFICE
15. EVACUATION ADAPTER
16. INLET TUBE
17. BELLOWS
18. ROD
19. NUT
20. MOUNTING PLATE
21. WEIGHT SUPPORT ROD
22. WEIGHT PLATFORM
23. SUPPORT STRUCTURE

Figure 4-3. NBS Barostat Assembly

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AUXILIARY HARDWARE

5.1 FLUID SYSTEM

Figure 5-1 is an overall schematic of the fluid systems required for the thermal test. Table 5-1 presents each fluid system and the work which was necessary for the performance of this test.

Table 5-1. Test Apparatus Fluid Systems

	System	Fabrication Requirement
1.	Test Tank LH_2 Fill and Drain	New installation.
2.	Test Tank Vent	New installation.
3.	Vacuum System	Existed with the exception of a 10 inch diffusion fore-pump located between the mechanical pumps and the 32 inch diffusion pump.
4.	Guard Tank and TPS Cooling	New installation.
5.	Cryoshroud and Baffle Cooling	New installation.

The systems for the guard tank, payload simulator, cryoshroud, and baffles were fabricated and leak checked before test tank installation. Welding and silver brazing was used as the principal means of joining parts of the system. After assembly and installation of the test tank a complete section by section leak check was performed.

To assure adequate performance of the vacuum system during the testing phase, a total systems leak check was performed. Several leaks were found and repaired. No leakage could be measured by the mass spectrometer leak detector.

The fill line for the test tank extends to the bottom of the tank primarily as a safety measure. Since the fill line is guarded at LH_2 temperature, there was no need to terminate the line in the ullage space. In an emergency, the tank may be emptied through the fill line by pressurizing the tank, opening the fill valve, and forcing the

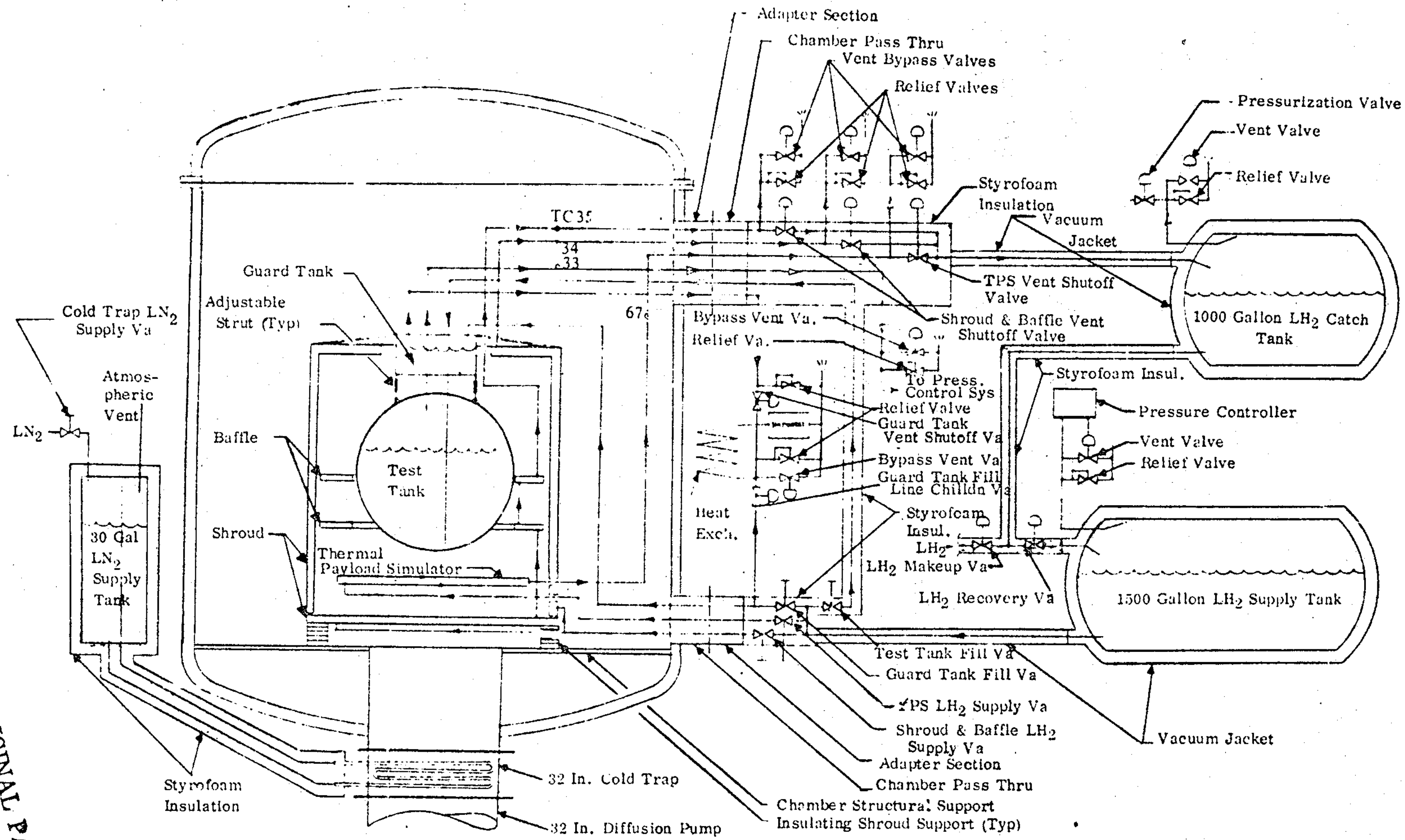

Figure 5-1. Schematic of Test Apparatus and Fluid System

liquid back into the site storage tank. The fill valve is located immediately outside the chamber wall. The valve is a proportionally controlled globe valve permitting metering of the LH_2 supply during filling operations.

The vent line terminates at the tank door. This line is also guarded and penetrates the chamber wall at a level just above the cryoshroud (Figure 5-1). The primary tank vent valve that is used during filling and initial childown is also a proportionally controlled valve.

A 1500 gallon supply tank is used to fill the test tank and guard tank with liquid hydrogen and to supply LH_2 flow to the TPS, cryoshroud and baffles. The pressure controller and vent valve maintain an approximate pressure of 41.4 kN/m^2 (6 psig) in the supply tank. The supply tank is filled from the 1000 gallon catch tank or from the 13000 gallon site storage tank. Vent flow from the shroud, baffles and TPS is passed through the recovery valve into the catch tank. The schematic in Figure 5-1 shows that each tank and line segment is protected by a relief valve.

The majority of the instrumentation and switches to control the system components are located in the blockhouse located approximately 23.00 m (75 ft) from the vacuum chamber.

5.2 TEST TANK HEATER

An electrical heater (Figure 5-2) is used to simulate payload thermal input to the test tank during the null test. The heater was designed to provide a maximum heat flow of one watt into the tank. The resistance of this heater is less than 10 ohms, for accuracy in power measurement and the desirability of low current to minimize unknown I^2R heating in the leads. In order to provide a large enough area to eliminate nucleate boiling on the heater surface, the heater was fabricated from Nichrom Ribbon 119.4 cm (47 in) long, 0.0051 cm (0.002 in) thick by 0.317 cm (0.125 in) wide. The ribbon is mounted on two pieces of terminal board as shown in Figure 5-2. The ribbon is divided into eight segments. It is installed in a parallel/series circuit and has a total resistance of approximately one ohm.

The terminal board is mounted to the lower end of the instrumentation tree as shown in Figure 5-3. The transition from the heater ribbon to a minimum 16-gage power lead was made at the bottom of the tank.

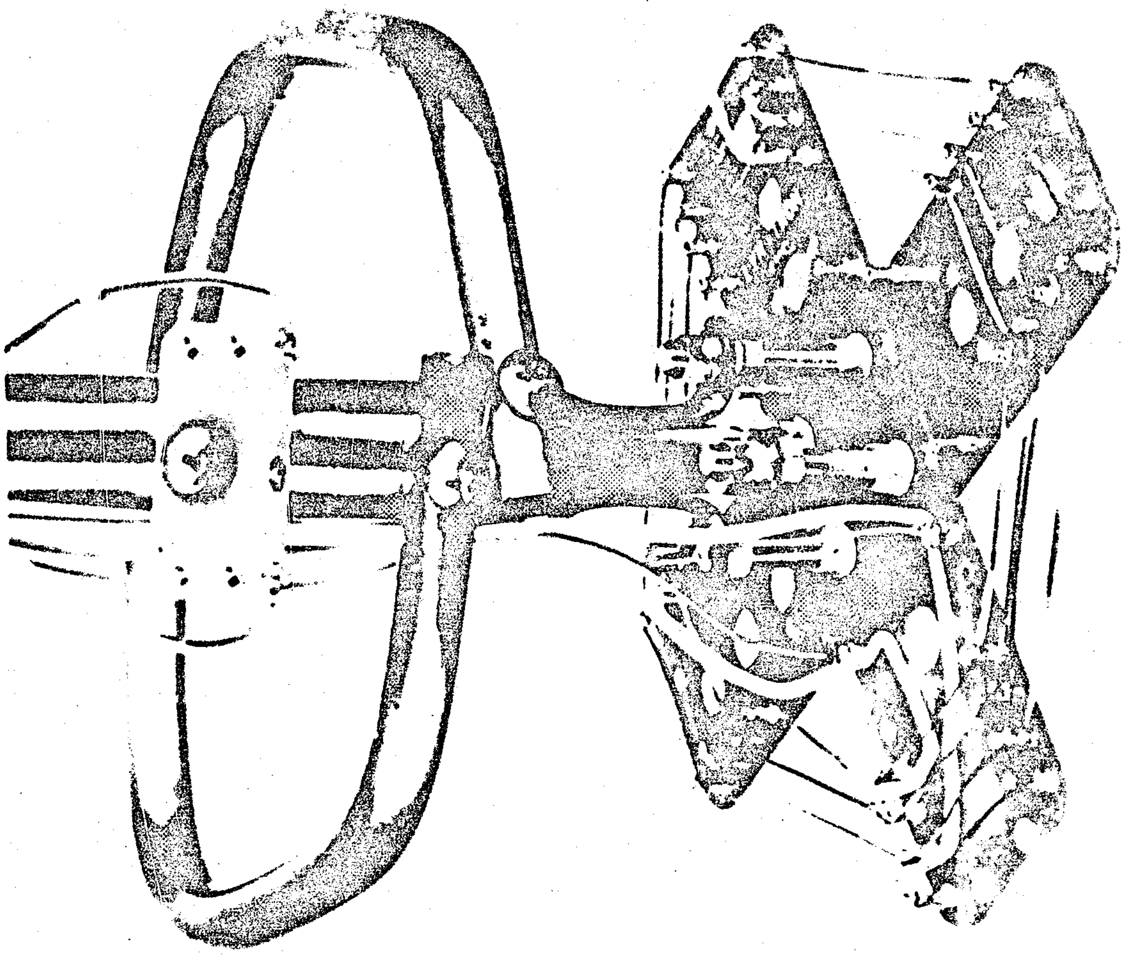

Figure 5-2. Test Tank Heater

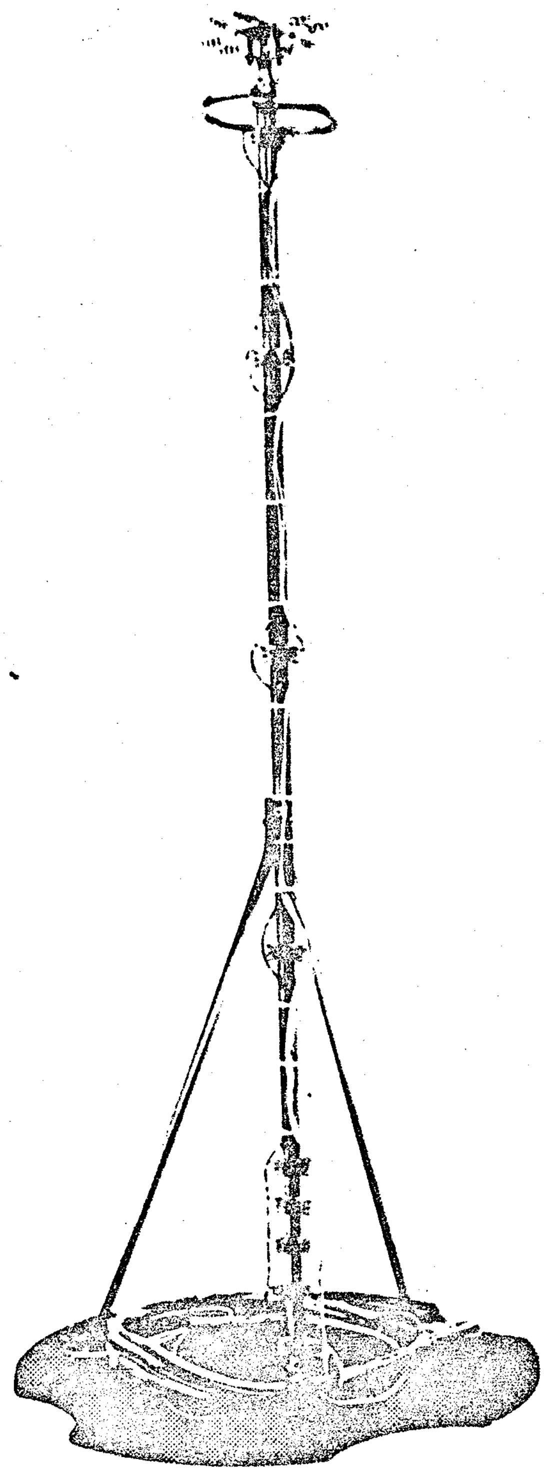

Figure 5-3. Test Tank Heater - Attached to Instrumentation Tree

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