

NASA CR 134760

①

VOLUME II
LIGHTWEIGHT VACUUM JACKET FOR
CRYOGENIC INSULATION

APPENDICIES TO FINAL REPORT

By

D. L. Barclay, J. E. Bell, E. W. Brogen & J. W. Straayer

BOEING AEROSPACE COMPANY

BOEING TECHNICAL LIBRARY
ST. LOUIS
MAILCODE: S111-1025

Prepared for
NATIONAL AERONAUTICS AND SPACE ADMINISTRATION
NASA Lewis Research Center

CONTRACT NAS3-15848

J. R. Barber, Project Manager

NASA-CR-134760

M75-15280-cl

1. Report No. NASA CR 134760	2. Government Accession No.	3. Recipient's Catalog No.	
4. Title and Subtitle VACUUM JACKET FOR CRYOGENIC INSULATION		5. Report Date Apr 11 1975	6. Performing Organization Code
		8. Performing Organization Report No. D180-18476-2	
7. Author(s) D. L. BARCLAY, J. E. BELL, E. W. BROGREN, & J. W. STRAAYER		10. Work Unit No.	
9. Performing Organization Name and Address BOEING AEROSPACE COMPANY (A Division of The Boeing Company) P.O. BOX 3999 SEATTLE, WASHINGTON 98124		11. Contract or Grant No. NAS3-15848	
		13. Type of Report and Period Covered Final Contractor Report	
12. Sponsoring Agency Name and Address National Aeronautics & Space Administration Lewis Research Center		14. Sponsoring Agency Code	
		15. Supplementary Notes J. R. BARBER, PROJECT MANAGER	
16. Abstract This program demonstrated the feasibility of producing a Lightweight Vacuum Jacket using state-of-the-art technology and materials. Design and analytical studies were made on a full scale, i.e., 4.57 m (15 ft.) inside diameter with a volume of 65.1 m ³ (2300 ft. ³), oms fuel (LH ₂) tank. Preliminary design details were completed for the tank assembly which included an optimized vacuum jacket and MLI system. A half scale LH ₂ test model was designed and fabricated. A force/stiffness (F/S) proof test was conducted on the vacuum jacket. The vacuum jacket designed and fabricated on this program achieved a vacuum leak rate of 1 x 10 ⁻⁵ atmosphere ml of helium per second, sustained approximately 1500 hours of vacuum pressure and experienced 29 vacuum pressure cycles prior to failure. * KEY WORDS Evaluated MLI System, Vacuum Jacket Space Shuttle Orbiter Oms Fuel (LH ₂) Tank Force/Stiffness (F/S) Proof Test Vacuum Annulus Preconditioning			
17. Key Words (Suggested by Author(s)) *		18. Distribution Statement UNCLASSIFIED-UNLIMITED	
19. Security Classif. (of this report) Unclassified	20. Security Classif. (of this page) Unclassified	21. No. of Pages	22. Price* \$3.00

* For sale by the National Technical Information Service, Springfield, Virginia 22151

TABLE OF CONTENTS

	<u>Page</u>
APPENDIX A OMS FUEL TANK DRAWINGS	1
APPENDIX B MODIFIED THEORETICAL EFFECTIVE GAS CONDUCTIVITY	23
APPENDIX C ANALYTICAL THERMAL MODELS	30
APPENDIX D HALF SCALE LH ₂ TEST MODEL ASSEMBLY DRAWINGS	44
APPENDIX E THERMAL INSTRUMENTATION PLAN FOR THE LH ₂ TEST MODEL	87
APPENDIX F SYSTEM EVALUATION TEST PLAN FOR THE LH ₂ TEST MODEL	100

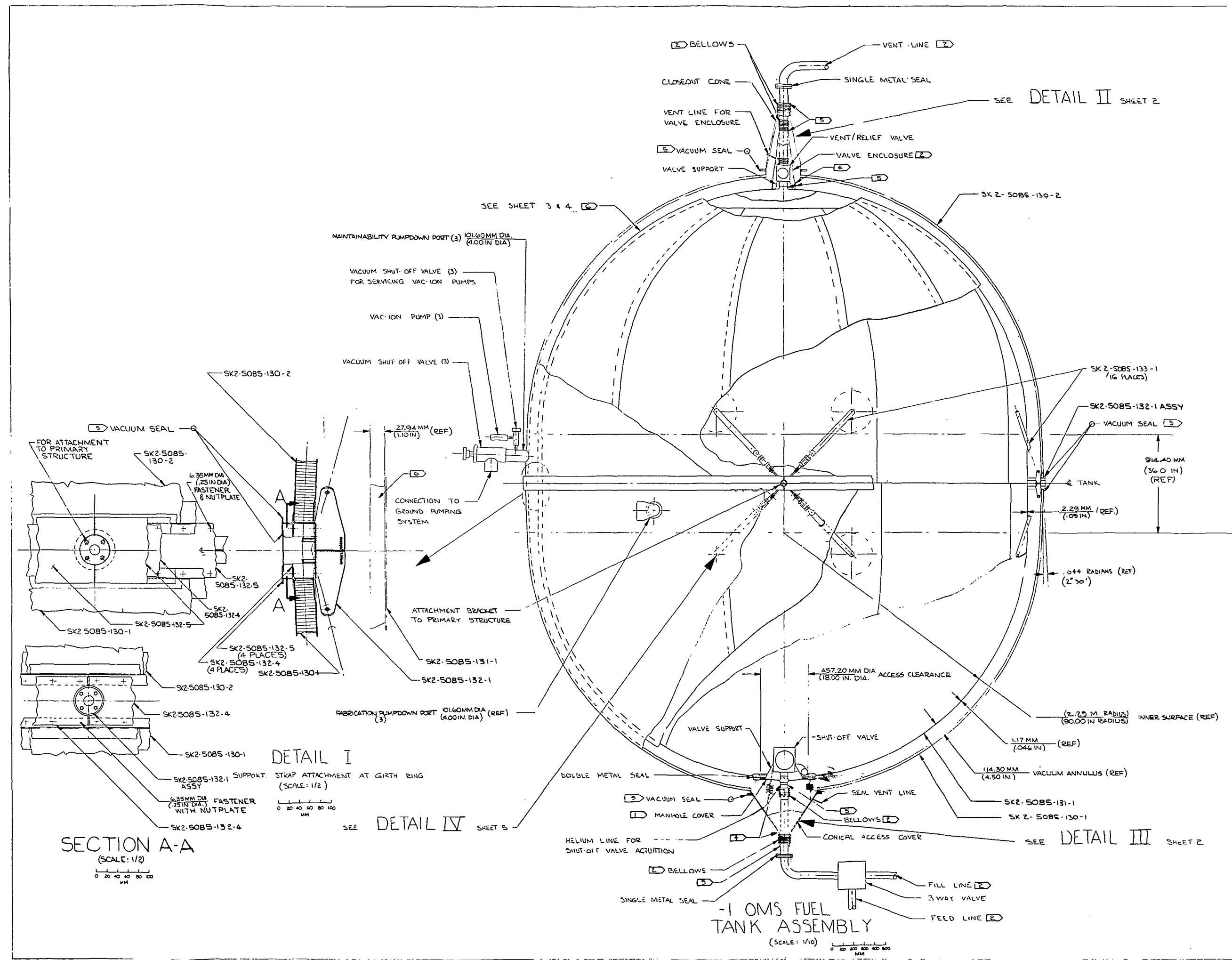
INTRODUCTION

This is a companion document to Volume I, NASA CR 134759, "Final Report."
The appendices contained herein supplement the technical discussion in that document.

APPENDIX A

OMS FUEL TANK PRELIMINARY DESIGN DRAWINGS

REVISIONS	
9/11/72	10/10/72
11/10/72	12/10/72
1/10/73	



ASSEMBLY AND QUALIFICATION PROCEDURES

- 10 DETAILS AND SUBASSEMBLIES
 - a) PRESSURE VESSEL WELD ASSEMBLY. LN₂ COLD SHOCK, PROOF PRESSURE TEST, AND HELIUM LEAK CHECK
 - b) SUPPORT STRAP DETAILS
 - c) GIRTH RING WELD ASSEMBLY AND MACHINING
 - d) VACUUM JACKET SUBASSEMBLIES
 - e) MLI BLANKET SUBASSEMBLIES
 - f) MANHOLE COVER ASSEMBLY (COVER, SHUT-OFF VALVE, AND FEED LINE)
- 20 ASSEMBLE PRESSURE VESSEL, SUPPORT STRAPS, GIRTH RING, VENT LINE, AND VENT RELIEF VALVE.
- 30 INSTALL MLI BLANKET ON PRESSURE VESSEL. INSULATE SUPPORT STRAPS AND VENT LINE.
- 40 INSTALL VACUUM JACKET SUBASSEMBLIES. SEAL JOINTS AT GIRTH RING AND VENT LINE OUTLET FOR VACUUM.
- 50 INSTALL MANHOLE COVER, FEED LINE, AND SEAL VENT LINE. INSULATE THE AREA. INSTALL VACUUM JACKET COVER. SEAL JACKET COVER AND FEED LINE OUTLET FOR VACUUM.
- 60 HELIUM LEAK CHECK ASSEMBLY. REPAIR AS NECESSARY. PUMPDOWN VACUUM ANNULUS TO 5×10^{-5} TORR. CONDUCT VACUUM DECAY TEST. PRECONDITION WITH HEAT AND VACUUM PUMPING AS NECESSARY TO REACH REQUIRE DECAY RATE. PINCH OFF AND SEAL THE THREE FABRICATION PUMPDOWN PORTS. CLOSE VACUUM VALVES ON THE MAINTAINABILITY PUMPDOWN PORTS.
- 70 CONDUCT BOIL-OFF TEST.

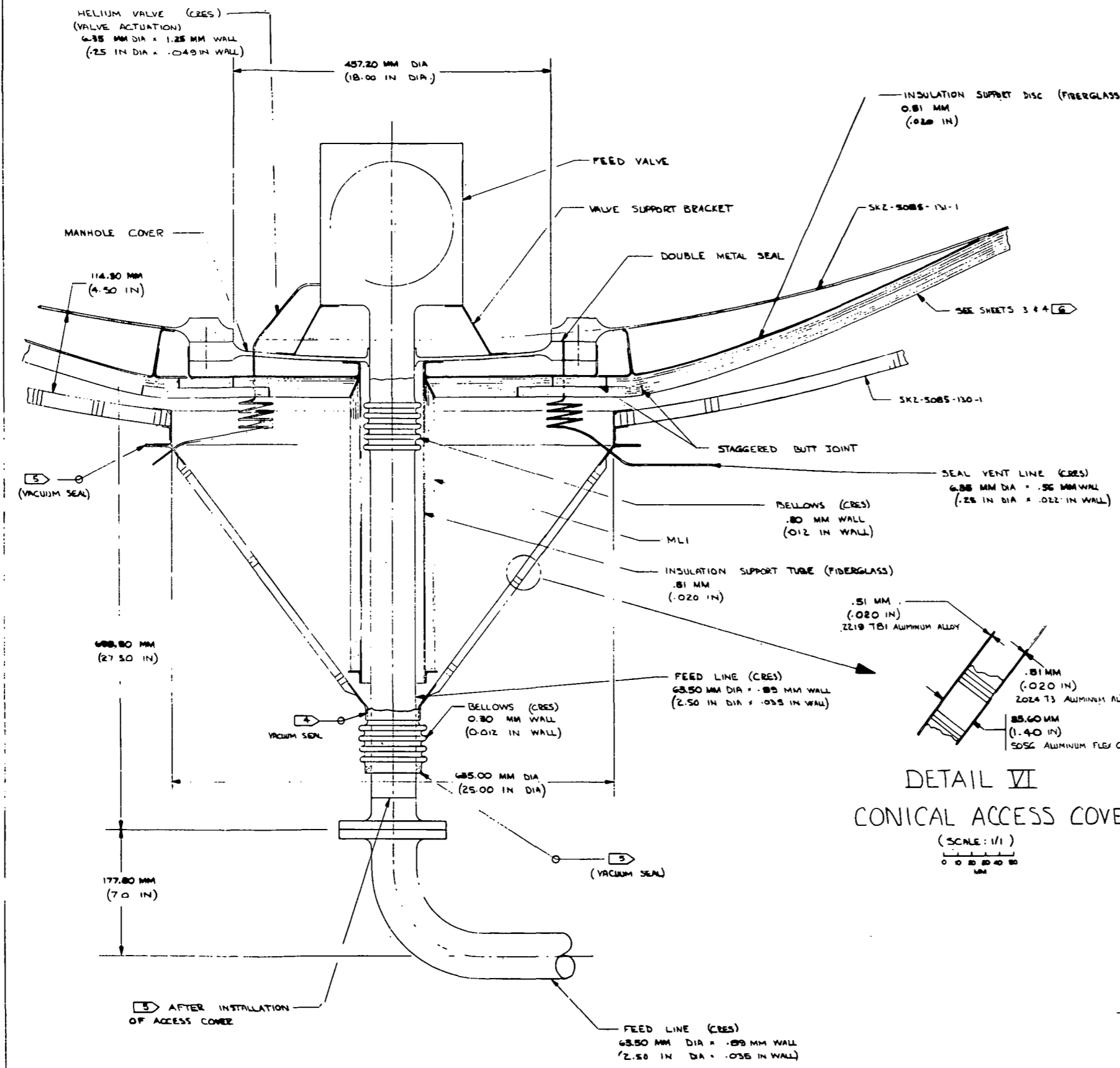
NOTES

- 1 ALUMINUM ALLOY 2219-T81
- 2 STAINLESS STEEL
- 3 DIFFUSION BOND
- 4 WELD
- 5 MULTILAYER INSULATION (MLI)
 - a) ALUMINIZED MYLAR (.15 MIL)/DACRON NET (B4A) - 2.95 LAYERS/MM (.75 LAYERS/INCH)
 - b) OUTER 2.54MM (.10 IN) LAYER - ALUMINIZED KAPTON (0.30 MIL)/DACRON NET (B4A) - 2.95 LAYERS/MM (.75 LAYERS/INCH)
- 6 HOOK & PILE FASTENER - VELCRO OR EQUIVALENT
- 7 DACRON THREAD
- 8 Z-YTEL 103 HS-L NYLON RESIN

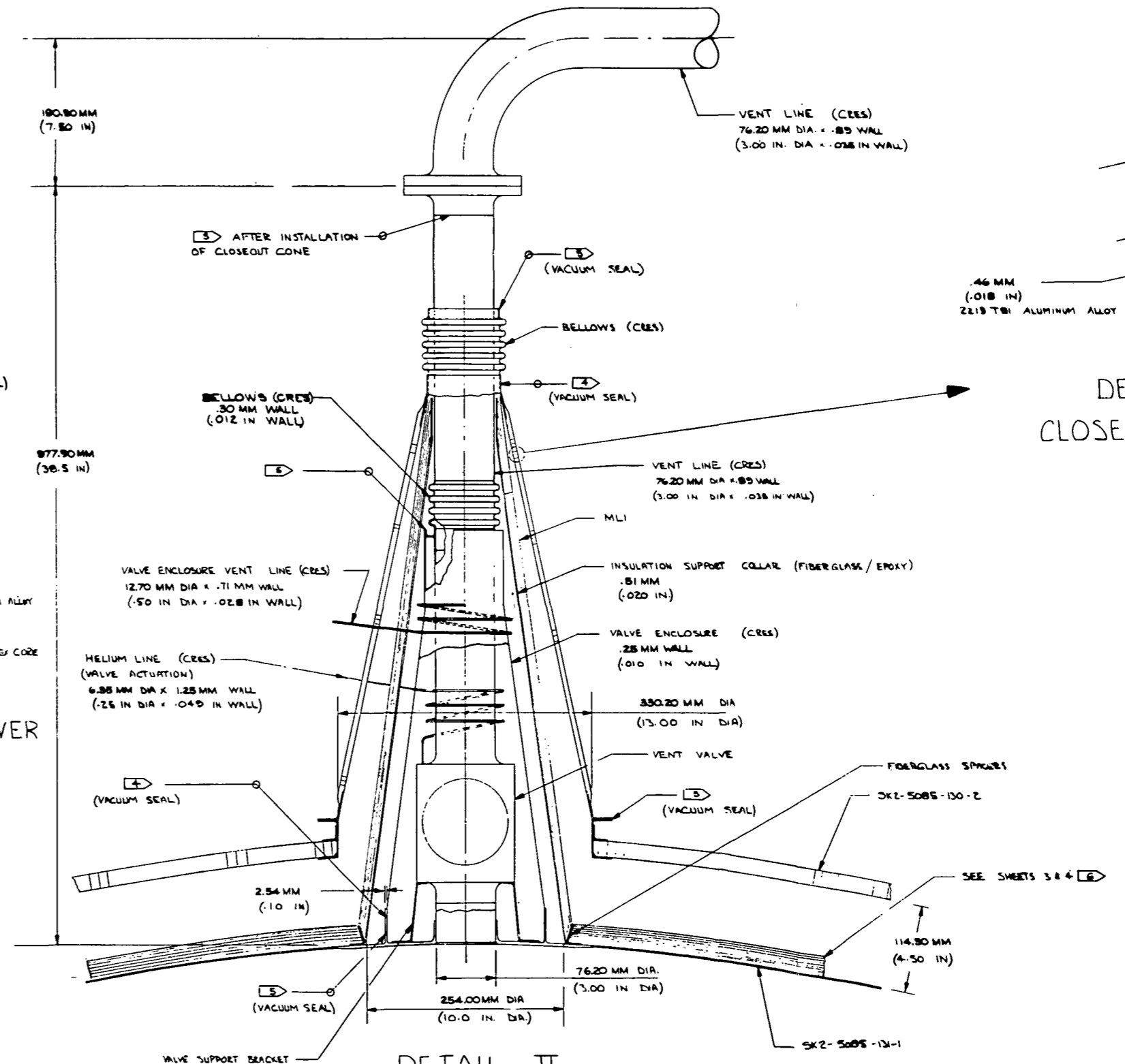
Figure A-1

ASSEMBLY
 81205 SK 2-5085-129

REVISIONS	
5/11/72	11/10/72
12/10/72	1/10/73



DETAIL III
MANHOLE ACCESS & FEED VALVE
(SCALE: 1/2)
0 20 40 60 80 100
MM



DETAIL II
VENT VALVE
(SCALE: 1/2)
0 20 40 60 80 100
MM

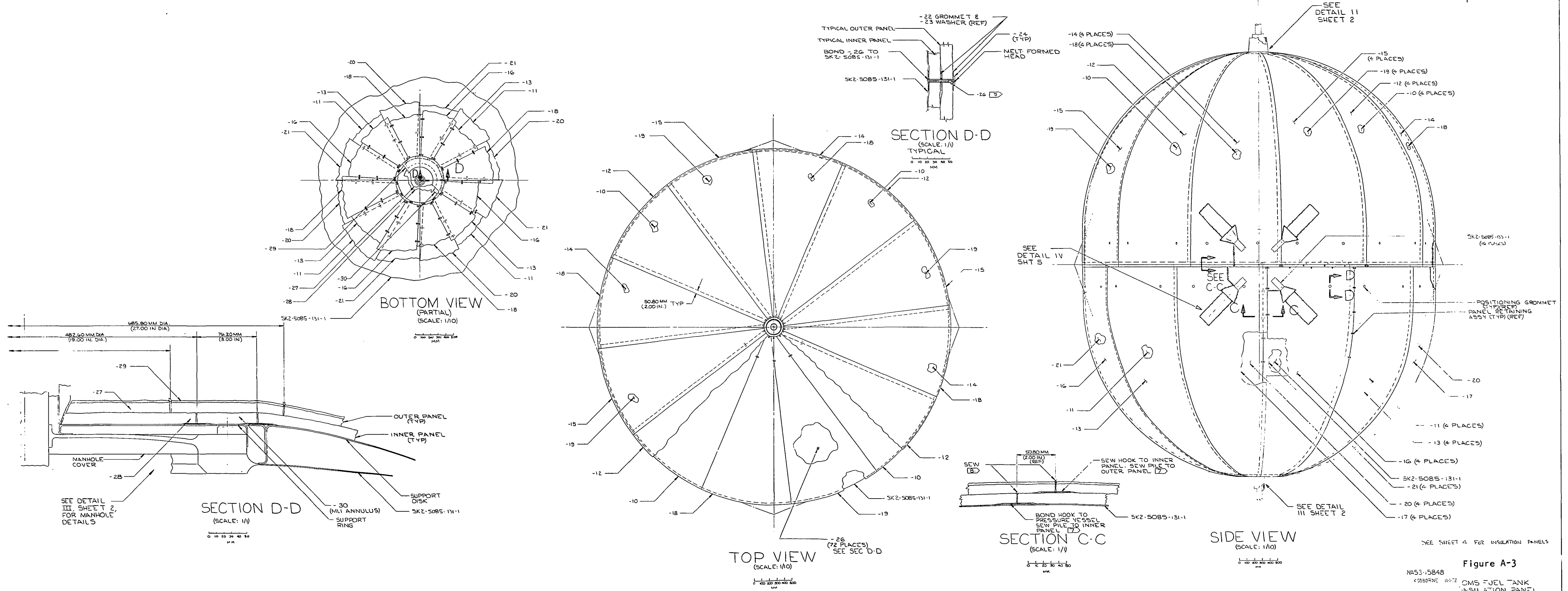
DETAIL VI
CONICAL ACCESS COVER
(SCALE: 1/1)
0 20 40 60 80 100
MM

DETAIL V
CLOSE OUT CONE
(SCALE: 1/1)
0 20 40 60 80 100
MM

Figure A-2

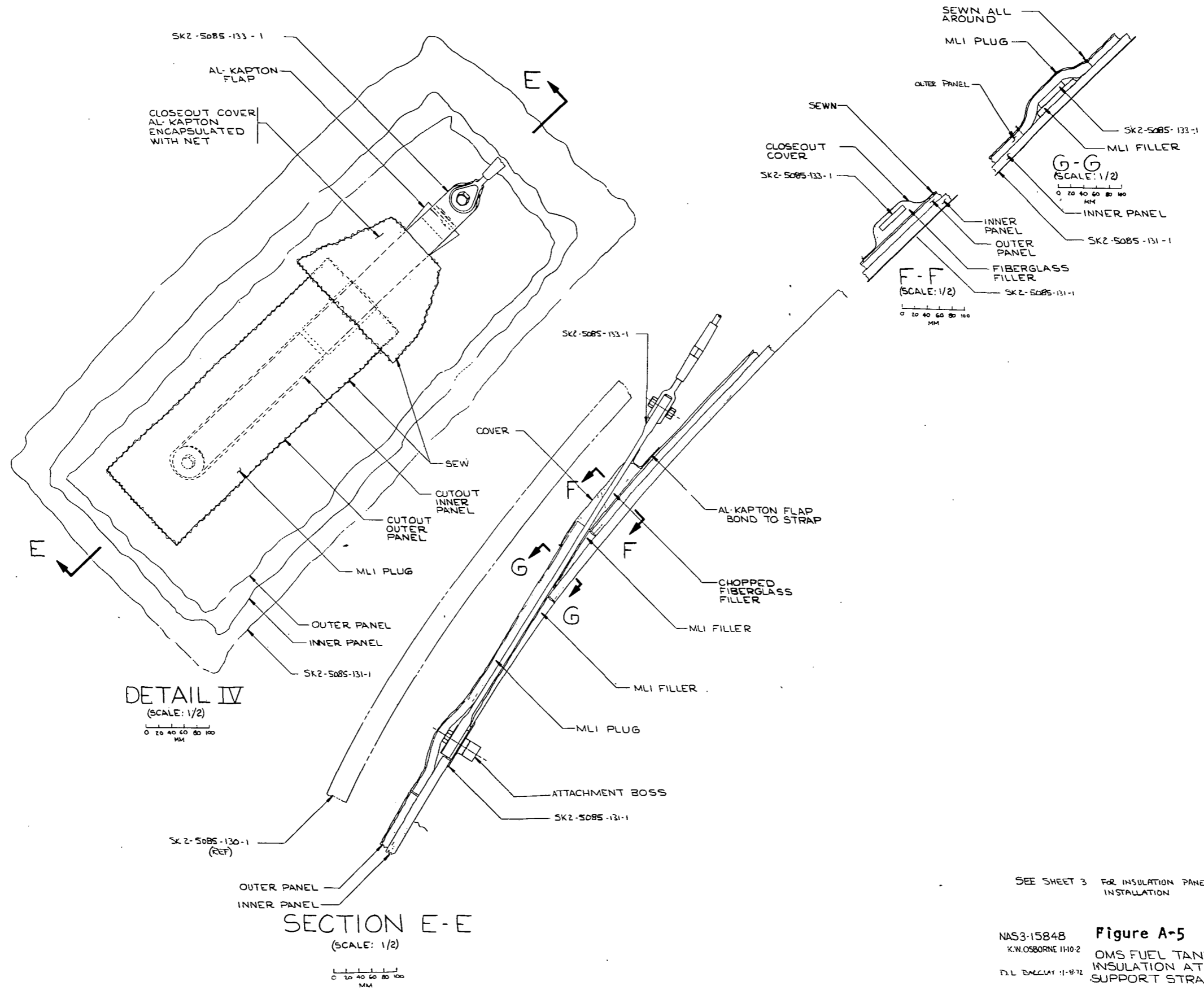
NAS3-15848
DL DARLAY DESIG
DL DARLAY DESIG
OMS FUEL TANK
MANHOLE & PLUMBING
PENETRATIONS
21205SK2-5085-129
HOTEL 2

REVISIONS
12/10/72



SEE SHEET 4 FOR INSULATION PANELS

Figure A-3
 NAS 15848
 OMS FUEL TANK
 INSULATION PANEL
 INSTALLATION
 SK2-5085-129



SEE SHEET 3 FOR INSULATION PANEL INSTALLATION

NAS3-15848
 K.W.OSBORNE 11102
 D.L. BUCKLEY 11-872

Figure A-5
 OMS FUEL TANK
 INSULATION AT
 SUPPORT STRAP

21205SK2-5085-129
 5

CS-2082-153 2H12

FIGURE A-6

PARTS LIST		THE BOEING COMPANY CORPORATE OFFICES SEATTLE, WASHINGTON 98124							CONTRACT NUMBER NAS 3-15848		CODE IDENT NUMBER 81205		PL SK2-5085-130		SHEET 1	REV LTR
EAWR NUMBER	FIND NUMBER	QTY RECD	QTY RECD	QTY RECD	QTY RECD	QTY RECD	QTY RECD	QTY RECD	CODE IDENT NUMBER	PART OR IDENTIFYING NUMBER	NOMENCLATURE OR DESCRIPTION	ZONE	MATERIAL AND SPECIFICATION	TRACE	NOTES	REV LTR
							-2	-1								
								-		-1	HEAD ASSEMBLY					
								-		-2	HEAD ASSEMBLY					
							1	1		-3	CORE	2				
								-	3	-4	GORE-INNER	1				
							3	-		-5	GORE-INNER					
								-	5	-6	GORE-INNER					
							5	-		-7	GORE-INNER					
								-	3	-8	GORE-OUTER					
							3	-		-9	GORE-OUTER					
								-	5	-10	GORE-OUTER					
							5	-		-11	GORE-OUTER					
								-	1	-12	ANNULUS					
								-	1	-13	ANNULUS					
							1	-		-14	ANNULUS					
							1	-		-15	ANNULUS					
								-	8	-16	FILLER					
							8	-		-17	FILLER	1				
								-	1	-18	FLANGE	7				
							1	-		-19	FLANGE	7				
								-	8	-20	STRIP-INNER	1				
							8	-		-21	STRIP-INNER	1				

ADDITIONAL QTY RECD COLUMNS MAY BE SHOWN ON CONTINUATION SHEET IMMEDIATELY FOLLOWING

FIGURE: A-7

PARTS LIST		THE BOEING COMPANY CORPORATE OFFICES SEATTLE, WASHINGTON 98124								CONTRACT NUMBER NAS3-15848	CODE IDENT NUMBER 81205	PLSK2-5080-130	SHEET 2	REV LTR		
EAWR NUMBER	FIND NUMBER	QTY	QTY	QTY	QTY	QTY	QTY	QTY	CODE IDENT NUMBER	PART OR IDENTIFYING NUMBER	NOMENCLATURE OR DESCRIPTION	ZONE	MATERIAL AND SPECIFICATION	TRACE	NOTES	REV LTR
		REQD	REQD	REQD	REQD	REQD	REQD	REQD								
						-34	-27	-2	-1							
									8	-22	STRIP-OUTER	1				
									8	-23	STRIP-OUTER	1				
									8	-24	STRIP-EXTERNAL	1				
									8	-25	STRIP-EXTERNAL	1				
									3	-27	TUBE ASSY	10				
									1	-28	TUBE	7				
									1	-29	FLANGE	7				
									3	-30	COLLAR	1				
									8	-31	DOUBLER	1				
										-32	ANGLE-CLOSEOUT	1				
									3	-33	ANGLE-CLOSEOUT	1				
									1	-34	RING ASSY	10				
									3	-35	SEGMENT	7				
									8	-36	DOUBLER	1				
									8	-38	FILLER	1				
										-39	FILLER	1				
									8	-40	FILLER	1				
										464HE1032-16	INSERT, POTTED					
										-41						

ADDITIONAL QTY REQD COLUMNS MAY BE SHOWN ON CONTINUATION SHEET IMMEDIATELY FOLLOWING

ASSEMBLY AND QUALIFICATION PROCEDURES
- 1 & - 2, HEAD ASSEMBLY

REV
STD

1.0 ASSEMBLE INNER GORES - 4, - 5, - 6, - 7; INNER STRIPS - 20, - 21; CLOSE OUT FLANGE - 18, - 19; ANNULI - 12, - 13, - 14, - 15; FILLERS - 16, - 17 & - 38; TUBE ASSY - 27; GIRTH RING ASSY - 34.
PER [8]

2.0 HELIUM LEAK CHECK INNER SKIN ASSY AT 1.333 cN/m^2 (1×10^{-5} TORR)

3.0 FILL GORE SEAM GAPS FLUSH WITH XA3919 (3MCo)

4.0 BOND STRIPS - 22, - 23; - 36 DOUBLERS PER [8]

5.0 HELIUM LEAK CHECK (2.0)

6.0 APPLY METLBOND 329 TO THE OUTER SURFACE OF THE INNER SKIN PER [4]

ASSEMBLE INNER ANGLE SEG - 36; CORE - 3; APPLY METLBOND 329 TO - 36

INNER ANGLE SEG FAYING SURFACES & CONTACT SURFACES WITH - 3.

WIRE CORE (- 3) TOGETHER AT SEAMS. SPLICE CORE WITH [5] THEN BOND PER [4].

7.0 HELIUM LEAK CHECK (2.0)

8.0 REINFORCE GIRTH CORE WITH [5] COMPLETELY AROUND CIRCUMFERENCE AS SHOWN.

9.0 APPLY METLBOND 329 TO THE INNER SURFACE OF THE OUTER SKIN GORES - 8, - 9, - 10, - 11; OUTER STRIPS - 24 - 25; APPLY TO - 31 DOUBLERS, INNER CONTACT SURFACES. PER [4] ASSEMBLE TO CORE THEN BOND PER [4].

10.0 HELIUM LEAK CHECK (2.0)

FIGURE: A-8

SIZE B	CODE IDENT NO. 81205	SK2-5085-130
SCALE		SHEET 3 OF 5

USE FOR DRAWINGS AND HAND PRINTED MATERIAL ONLY - NO TYPEWRITTEN MATERIAL

USE FOR DRAWINGS AND HAND PRINTED MATERIAL ONLY - NO TYPEWRITTEN MATERIAL

REV
B/R

1 2024-T81 ALUM PER QQ-A-250/4 3

2 FLEX-CORE 5056/F40-.0014, 33.6kg/m³
(2.1# FT³) ALUMINUM HONEYCOMB- HEXCEL
PRODUCTS INC - SPLICE CORE GORE'S
WITH 5

3 CLEAN PER BAC 5514

4 CLEAN & BOND PER DOC DG-23841 TN.
METLBOND 329 ADHESIVE (NARMCO
MATERIALS DIV., WHITTACER CORP.) SHALL BE
APPLIED TO FAYING SURFACES NOTED:

5 STRUCTURAL FOAMING ADHESIVE PER BAC
5-90, TYPE 2, CLASS 350, GRADE 50.

6 ALL RAW MATERIALS, SUBASSEMBLIES
& ASSEMBLYS SHALL BE PROTECTED
FROM OIL & PARTICLE CONTAMINATION.
ASSEMBLY SHALL BE DONE IN A DUST FREE
ROOM.

7 ALUMINUM 2219-T6 OR T62, PER BMS7-110B
OR BMS7-108

8 BOND WITH XA3919 (3MCo) APPLY BY
BRUSH COATING BOTH SURFACES.
AIR DRY THE SURFACES FOR 15 MIN.
FOLLOWED BY A 45 MIN. DRYING CYCLE
AT 380°K (225°F). CURE BOND AT 450°K
(350°F) FOR 3600 SEC AT 344.74 kN/m²
(50 PSI).

9 DEVIATION FROM RADIUS ±.051cm
(.02 IN) PROVIDED THE DISCONTINUITIES
DO NOT EXCEED ±.051cm IN 25.4cm
(10.0 IN) LENGTH IN ANY DIRECTION ALONG
THE SURFACE

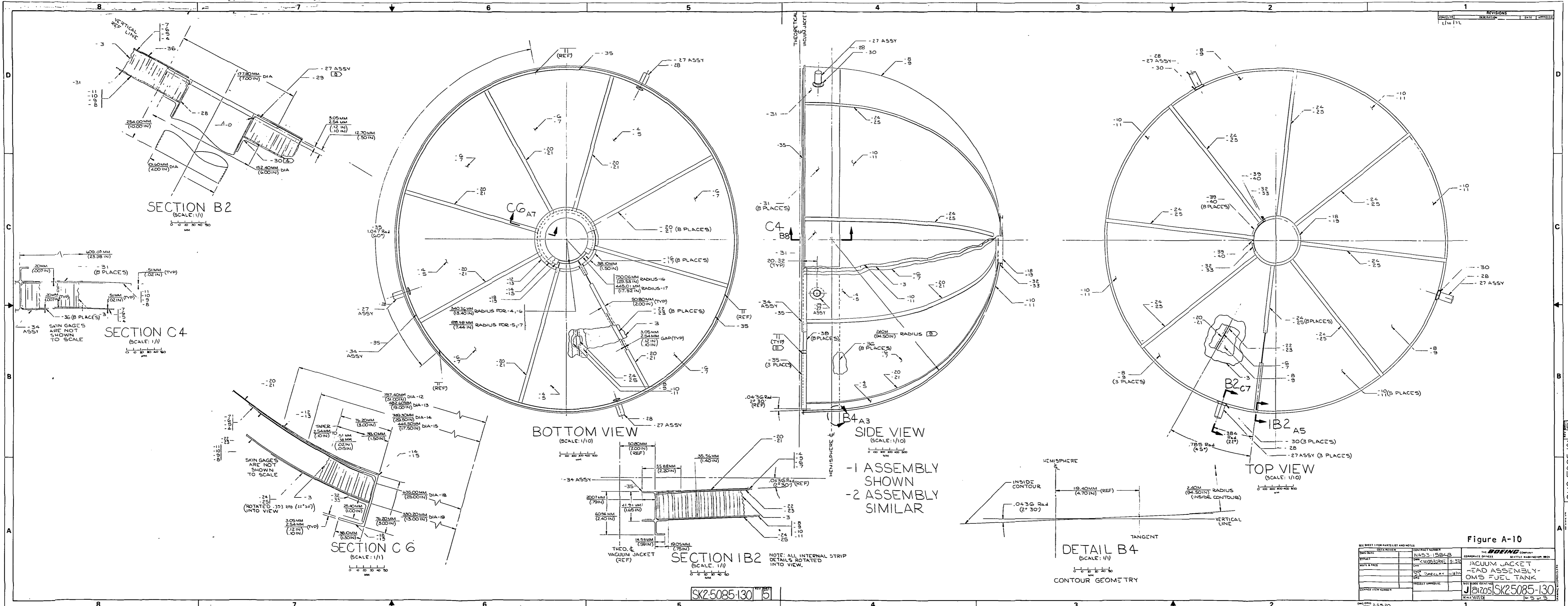
10 BMS 5-25 GRADE 3, APPLY PER BAC
5514-590.

11 FUSION WELD PER BAC 5935, CLASS A.
EXCEPT RADIOGRAPHIC INSPECTION IS WAIVED.
PENETRANT INSPECT PER BAC 5423.
HELIUM LEAK CHECK 1.393cN/m² (1x10⁻⁵ TORR)

FIGURE: A-9

SIZE B	CODE IDENT NO. 81205	SK2-5085-130
SCALE		SHEET 4 OF 5

REVISIONS		
NO.	DESCRIPTION	DATE
1		



SK2-5085-130

SEE SHEET FOR PARTS LIST AND NOTES		CONTRACT NUMBER	
DWG. NO.	011-111	NAS 3-1584-B	THE BOEING COMPANY
PROJECT	011-111	0-371	CORPORATE OFFICES
DATE & PRICE	011-111	0-371	SEATTLE WASHINGTON 98104
DWG. NO.	011-111	0-371	PROJECT APPROVAL
CHANGE ITEM NUMBER	011-111	0-371	DATE

Figure A-10
VACUUM JACKET HEAD ASSEMBLY - OMS FUEL TANK
JTB:ms SK25085-130
SCALE: 1/10

SK2-5085-130

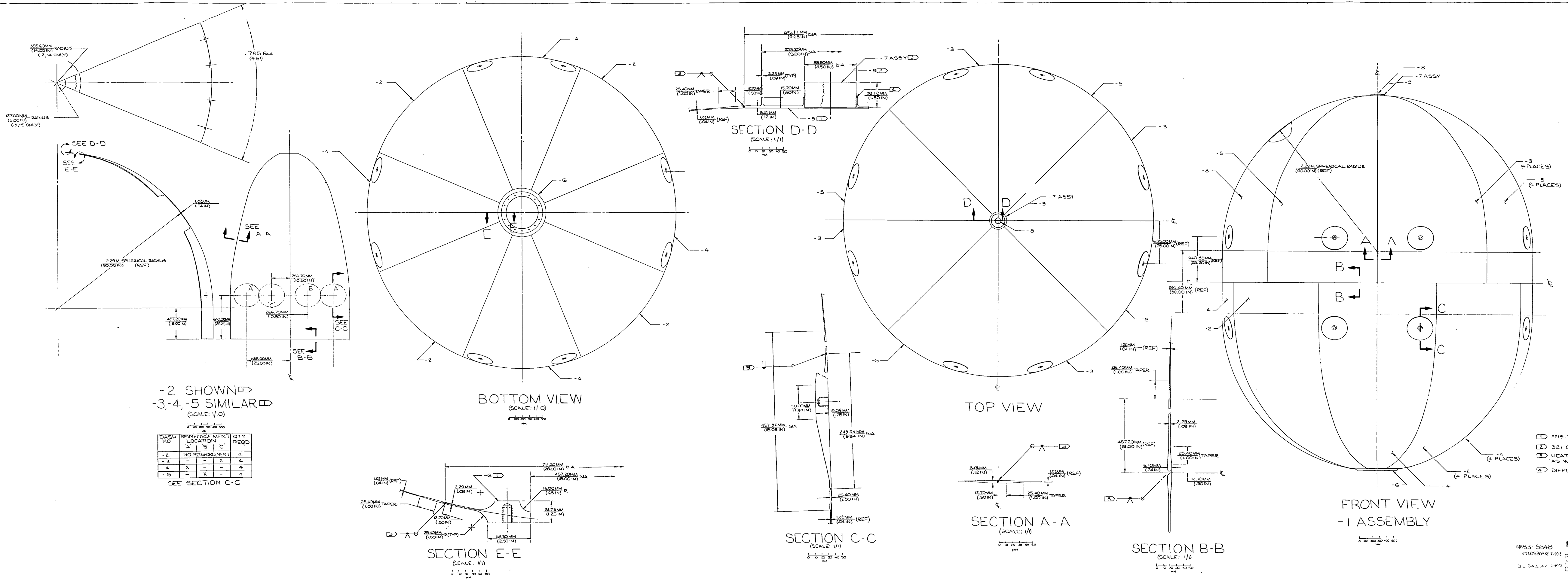
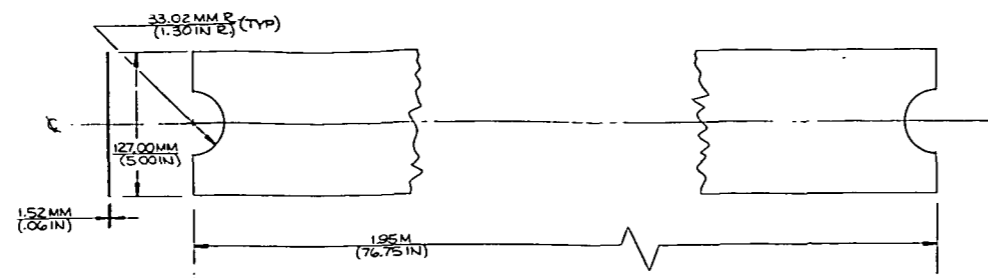
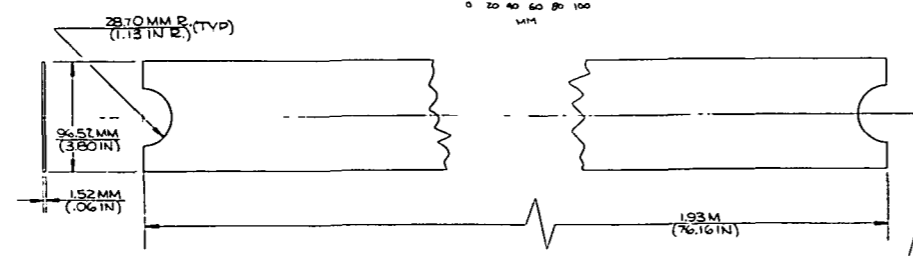


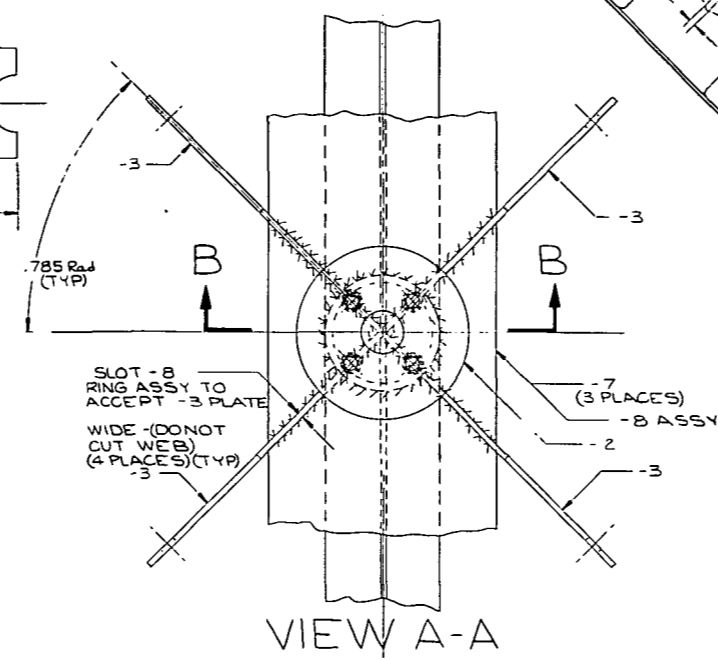
Figure A-11
NAS3-5848
PRESSURE VESSEL
ASSEMBLY
OMS FUEL TANK
812.05 SK2-5085-131



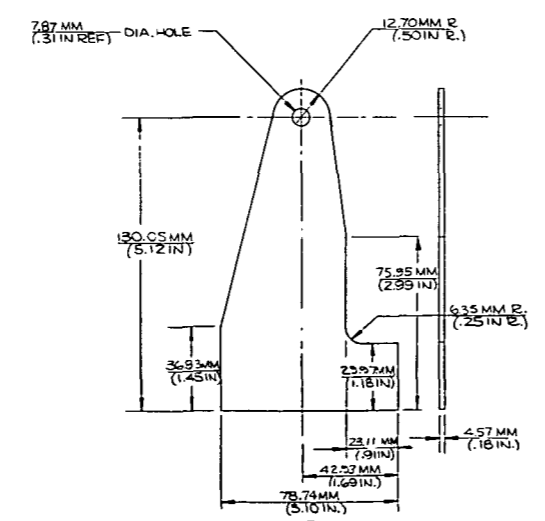
-5
(SCALE: 1/2)
(4 REQ'D)
2219-T0 AL SHEET



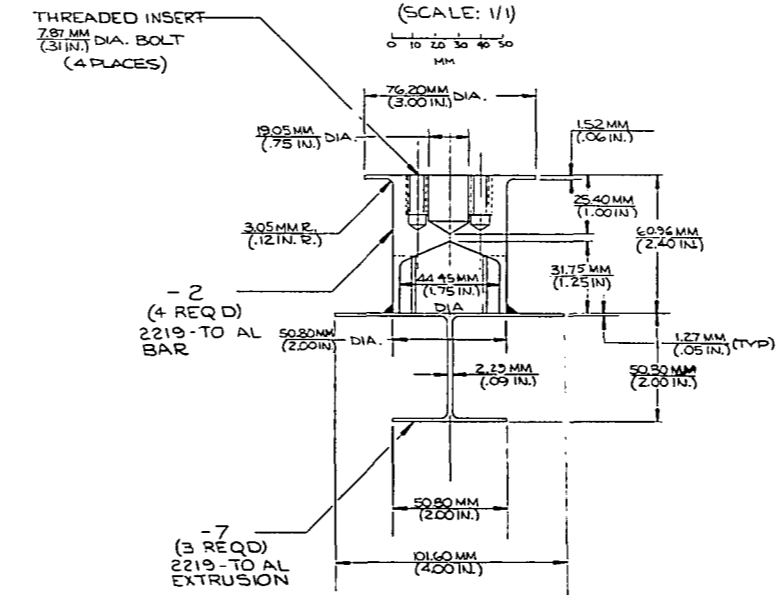
-4
(SCALE: 1/2)
(4 REQ'D)
2219-T62 AL SHEET



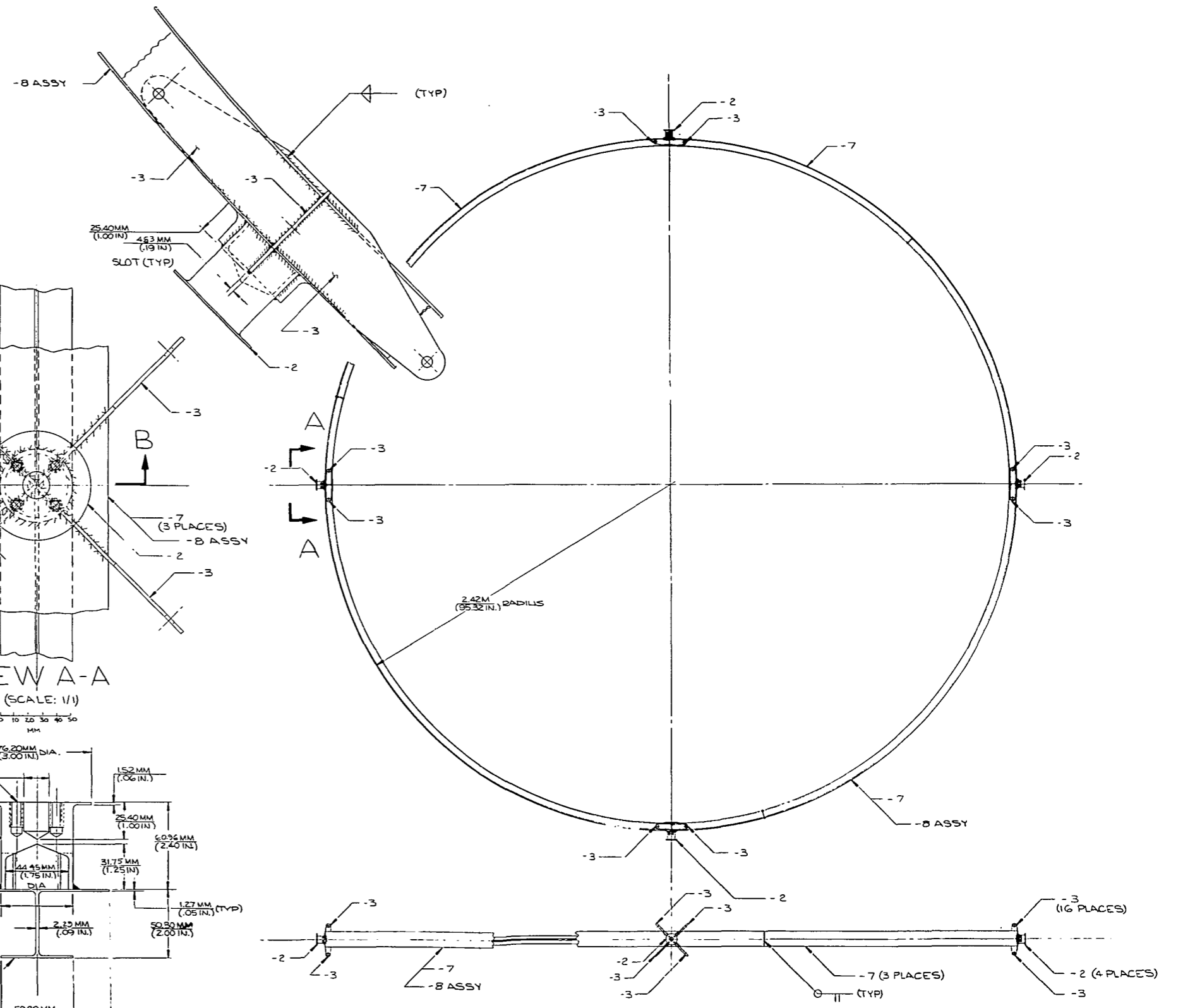
VIEW A-A
(SCALE: 1/1)



-3
(SCALE: 1/1)
(16 REQ'D)
2219-T0 AL PLATE



SECTION B-B
(SCALE: 1/1)



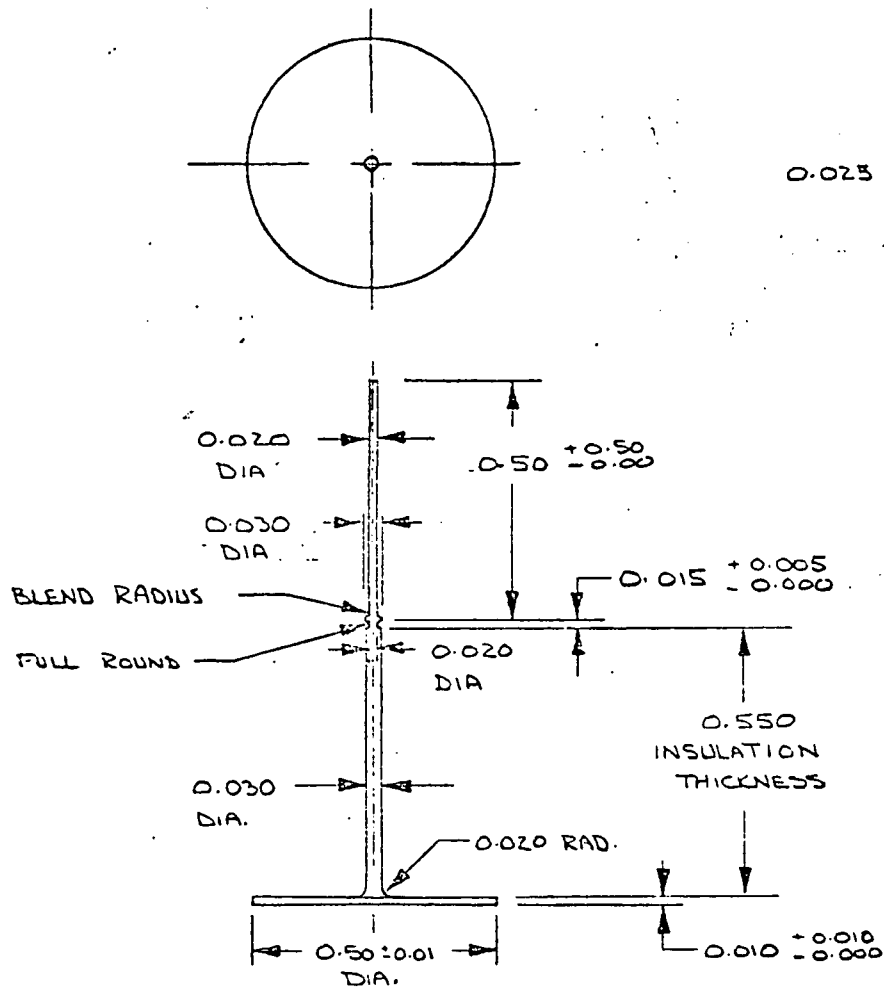
-1 ASSEMBLY
(SCALE: 1/10)

SOLUTION HEAT TREAT AND ARTIFICIALLY AGE, -1 ASSY, TO T62 AFTER WELDING.

NAS3-15848
KWO5BORNE 11272
DL BARCLAY R-8-X
GIRTH RING ASSEMBLY
OMS FUEL TANK

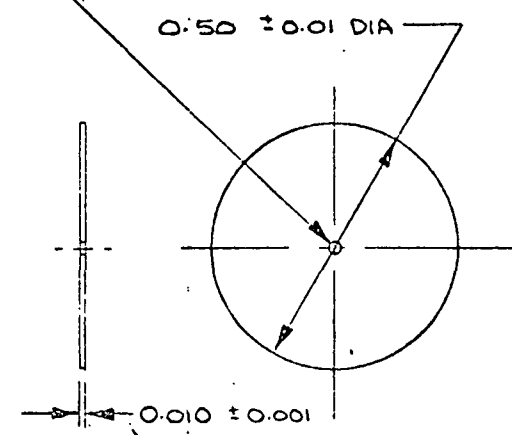
Figure A-14

81205 SK2-5085-132



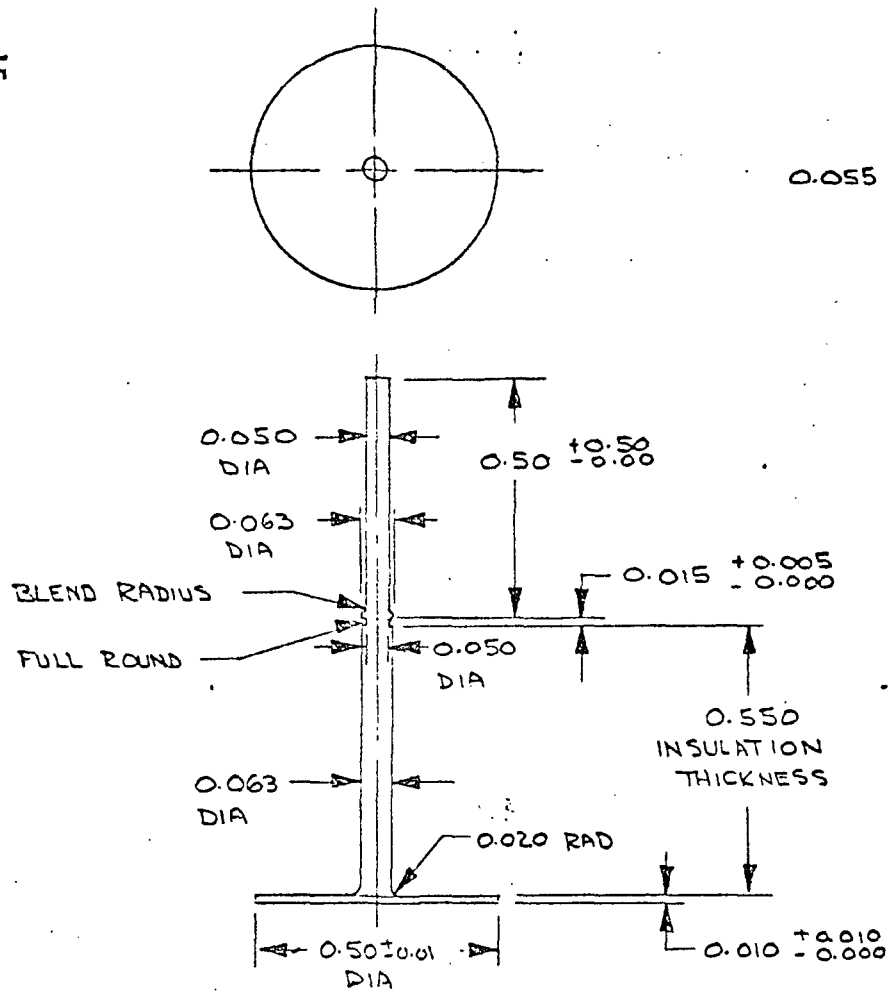
- 1
 BUTTON - PIN STUD
 MAT'L: ZYTEL 103HS1-L NYLON RESIN
 TOLERANCE ON X.XXX IS ± 0.002
 (SCALE 4/1)

0.025 DIA ± 0.002



- 2
 BUTTON
 MAT'L: ZYTEL 103HS1-L NYLON RESIN
 (SCALE 4/1)

FIGURE A-13
 SK 2-5085-147 — MLI FASTENERS

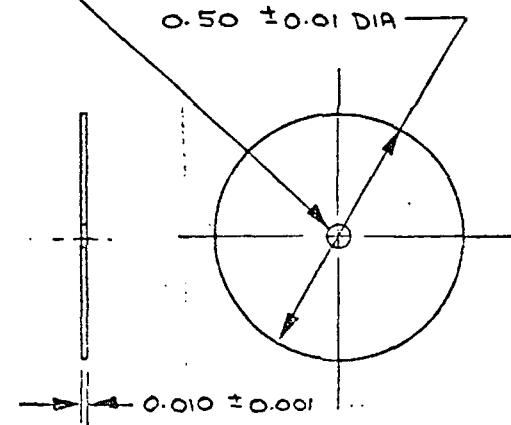


-3

BUTTON - PIN STUD
 MAT'L: ZYTEL 103 HSI-L NYLON RESIN
 TOLERANCE ON X.YXX IS ± 0.002

(SCALE 4/1)

0.055 DIA ± 0.002



-4

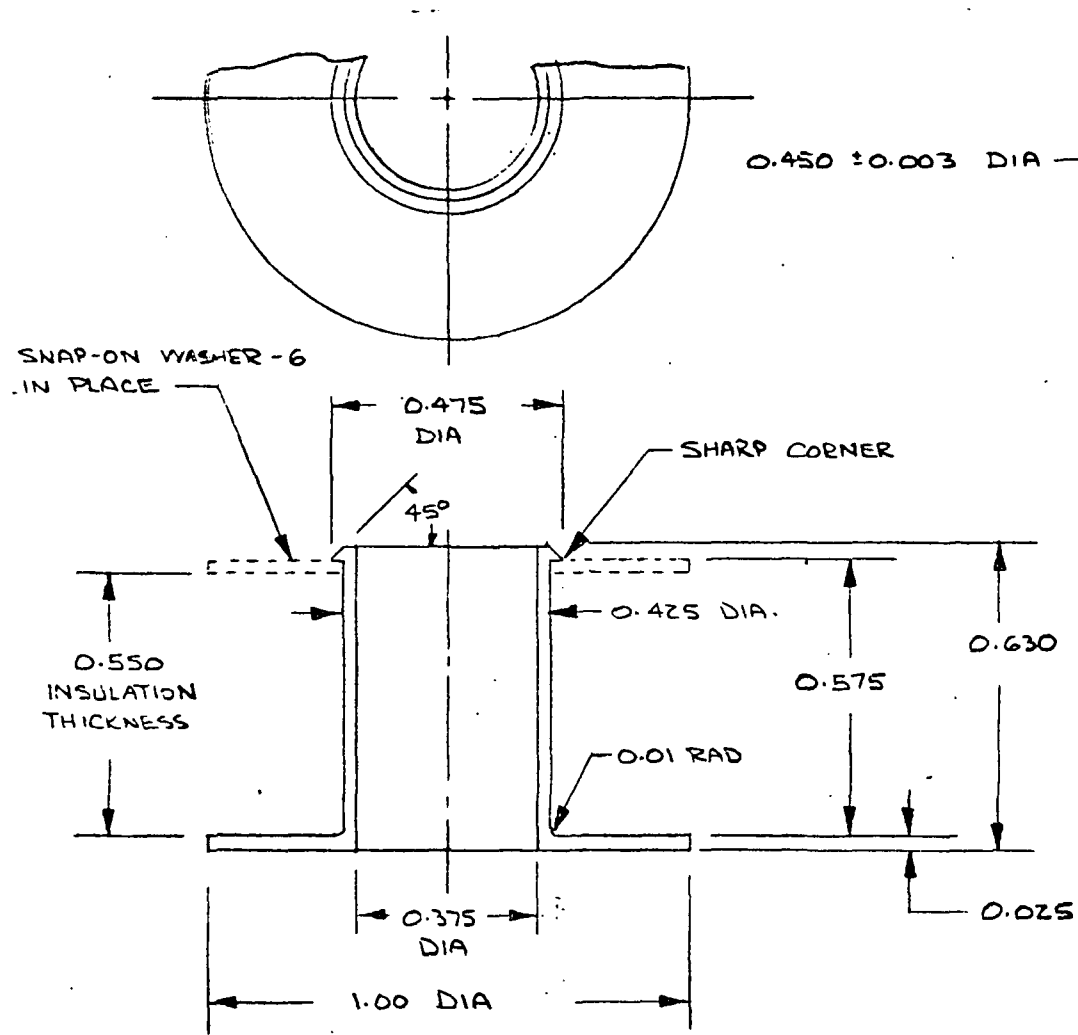
BUTTON

MAT'L: ZYTEL 103 HSI-L NYLON RESIN

(SCALE 4/1)

FIGURE A-14

SKZ-5085-147-MLI FASTENERS



-5

POSITIONING GROMMET

MAT'L: ZYTEL 103 HSI-L NYLON RESIN

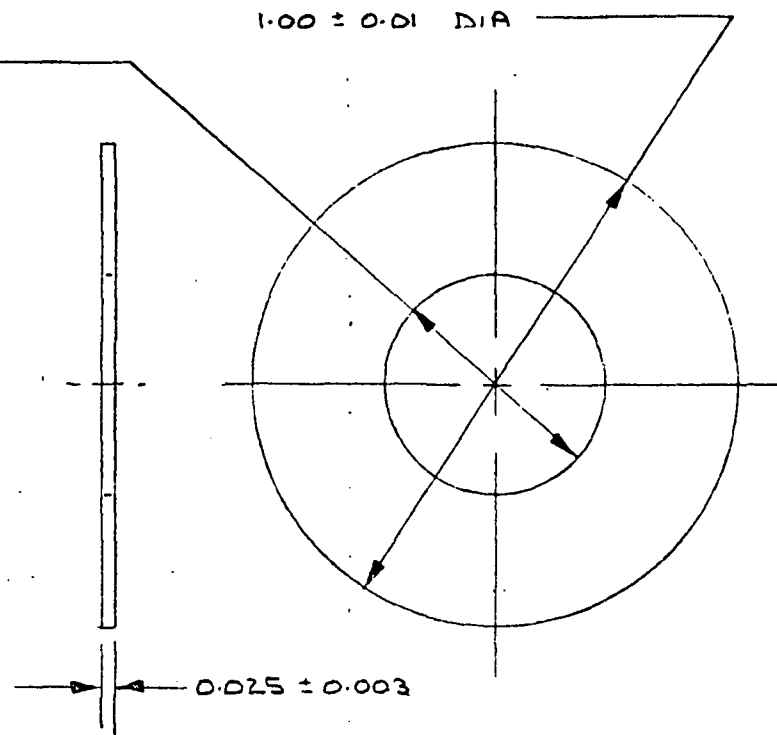
TOLERANCE ON X.XX IS ± 0.01

ON X.XXX IS ± 0.003

(SCALE 4/1)

0.450 ± 0.003 DIA

1.00 ± 0.01 DIA



-6

SNAP-ON WASHER

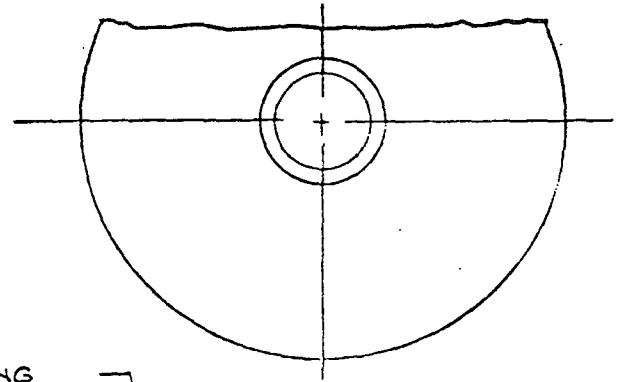
MAT'L: ZYTEL 103 HSI-L NYLON RESIN

(SCALE 4/1)

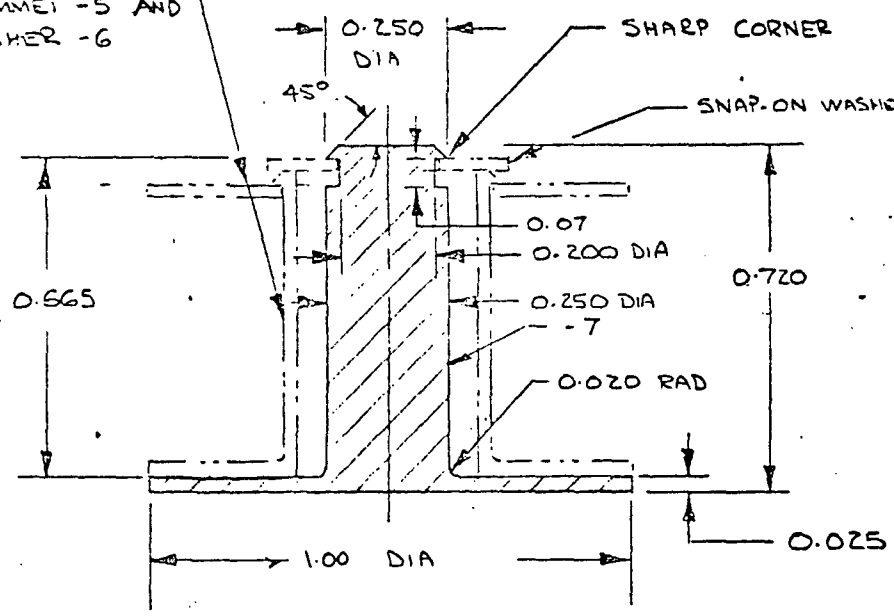
FIGURE A-15

SK2-5085-147—MLI FASTENERS

17



POSITIONING GROMMET -5 AND WASHER -6



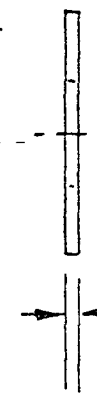
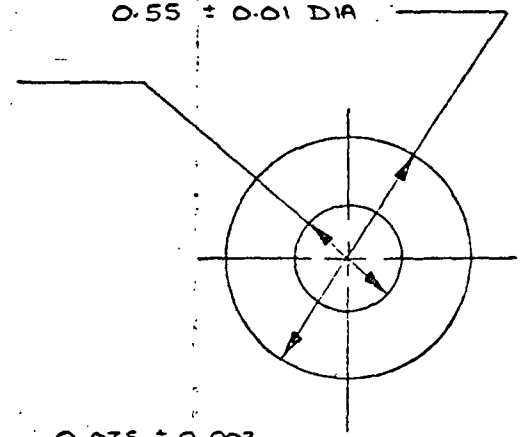
-7

LOCATING PIN

MAT'L: ZYTEL 103 HSI-L NYLON RESIN
 TOLERANCE ON X.XX IS ± 0.01
 ON X.XXX IS ± 0.003
 (SCALE 4/1)

0.225 ± 0.003 DIA.

0.55 ± 0.01 DIA



0.025 ± 0.003

-8

SNAP-ON WASHER
 MAT'L: ZYTEL 103 HSI-L NYLON RESIN
 (SCALE 4/1)

FIGURE A-16
 SK2-5085-147-MLI FASTENERS

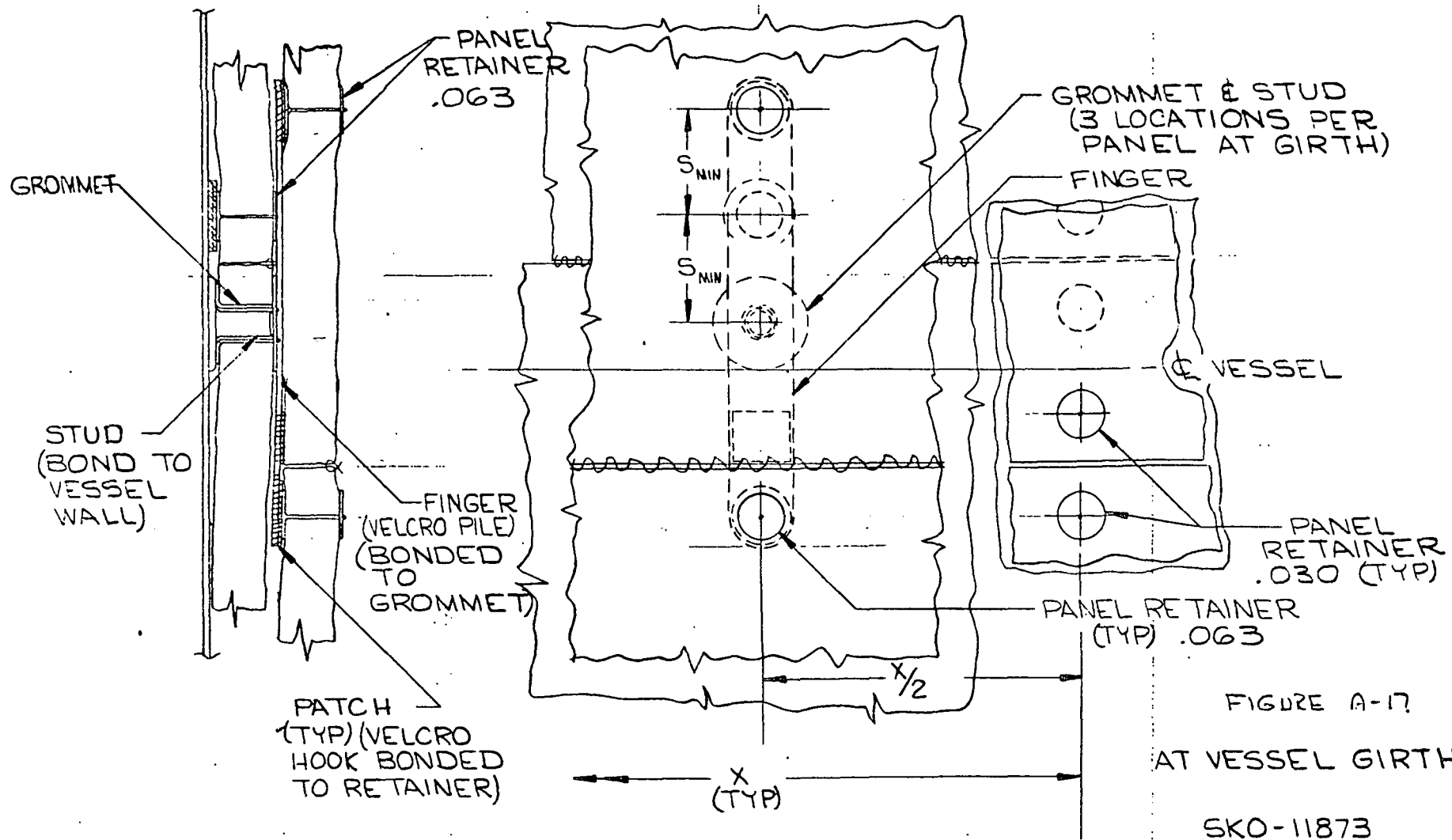


FIGURE A-17
AT VESSEL GIRTH

SKO-11873

INSULATION PANEL
RETENTION SYSTEM

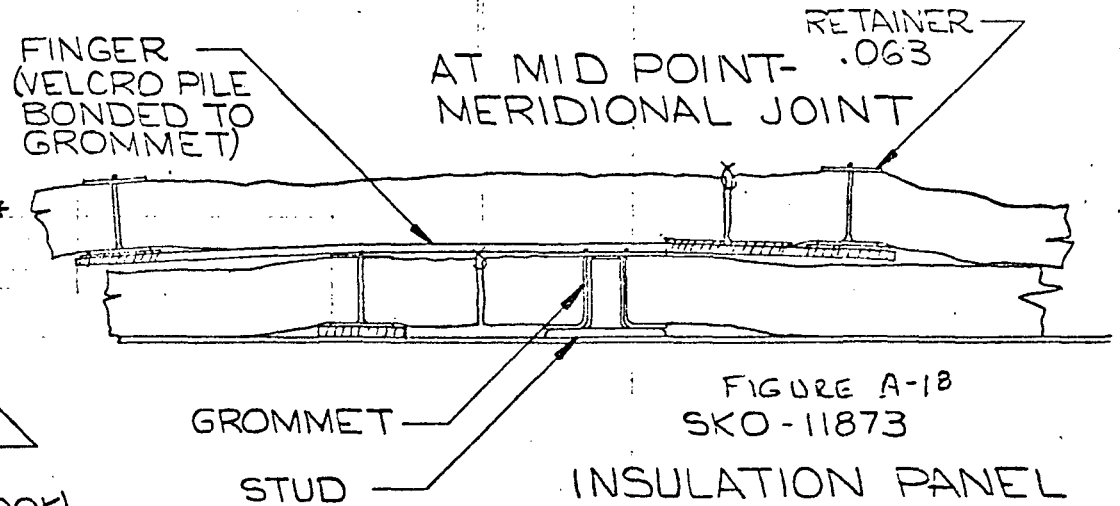
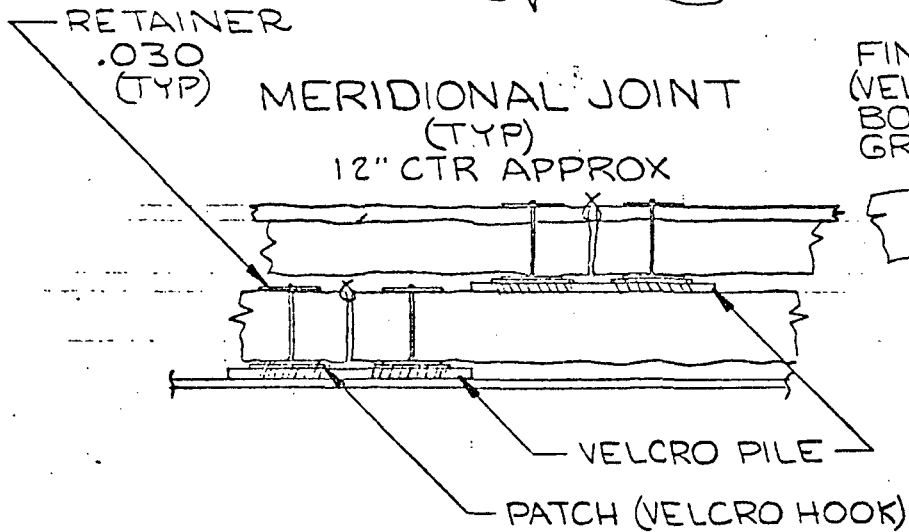
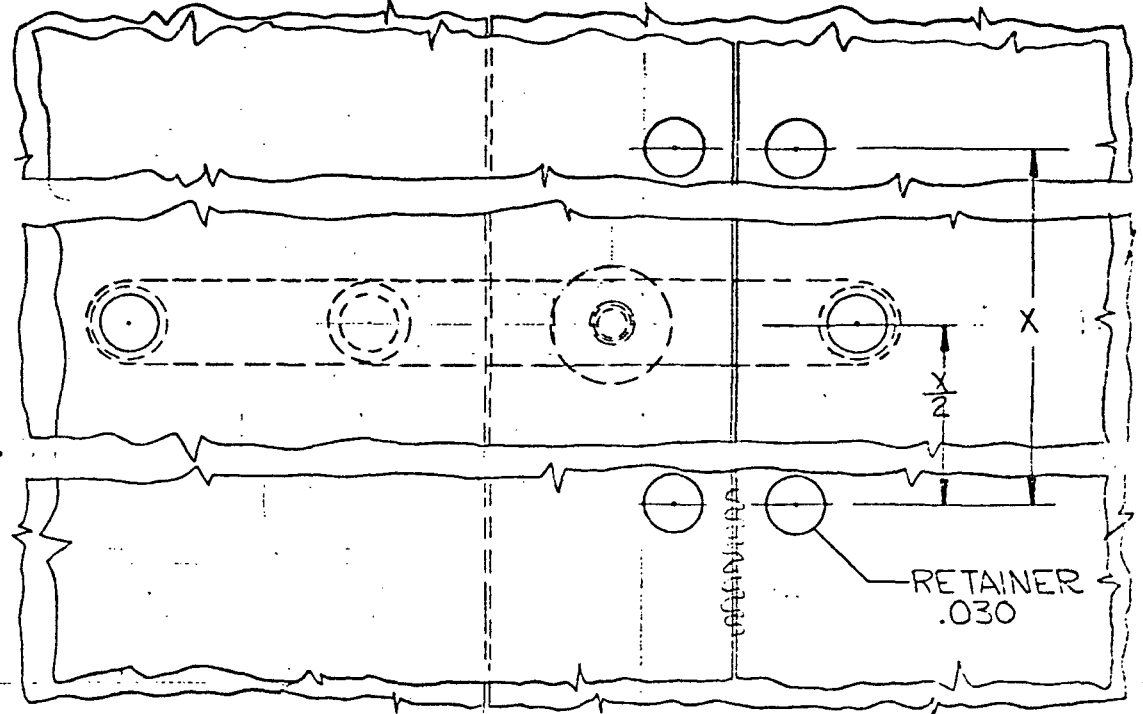
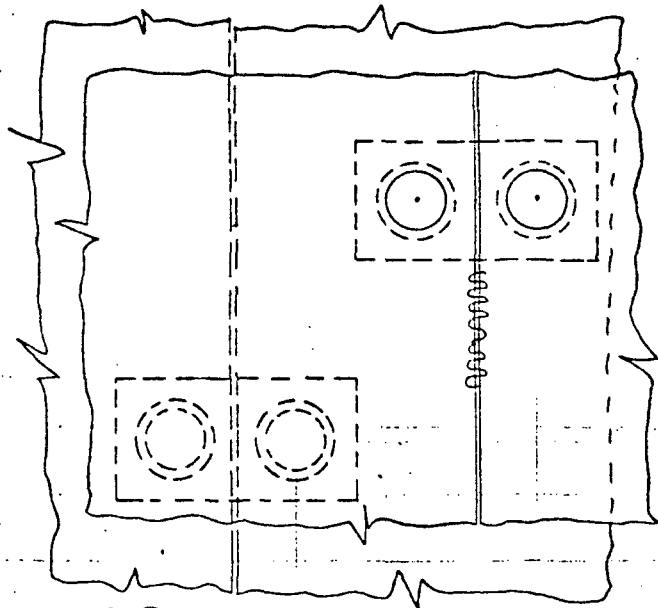


FIGURE A-18
SKO-11873
INSULATION PANEL
RETENTION SYSTEM

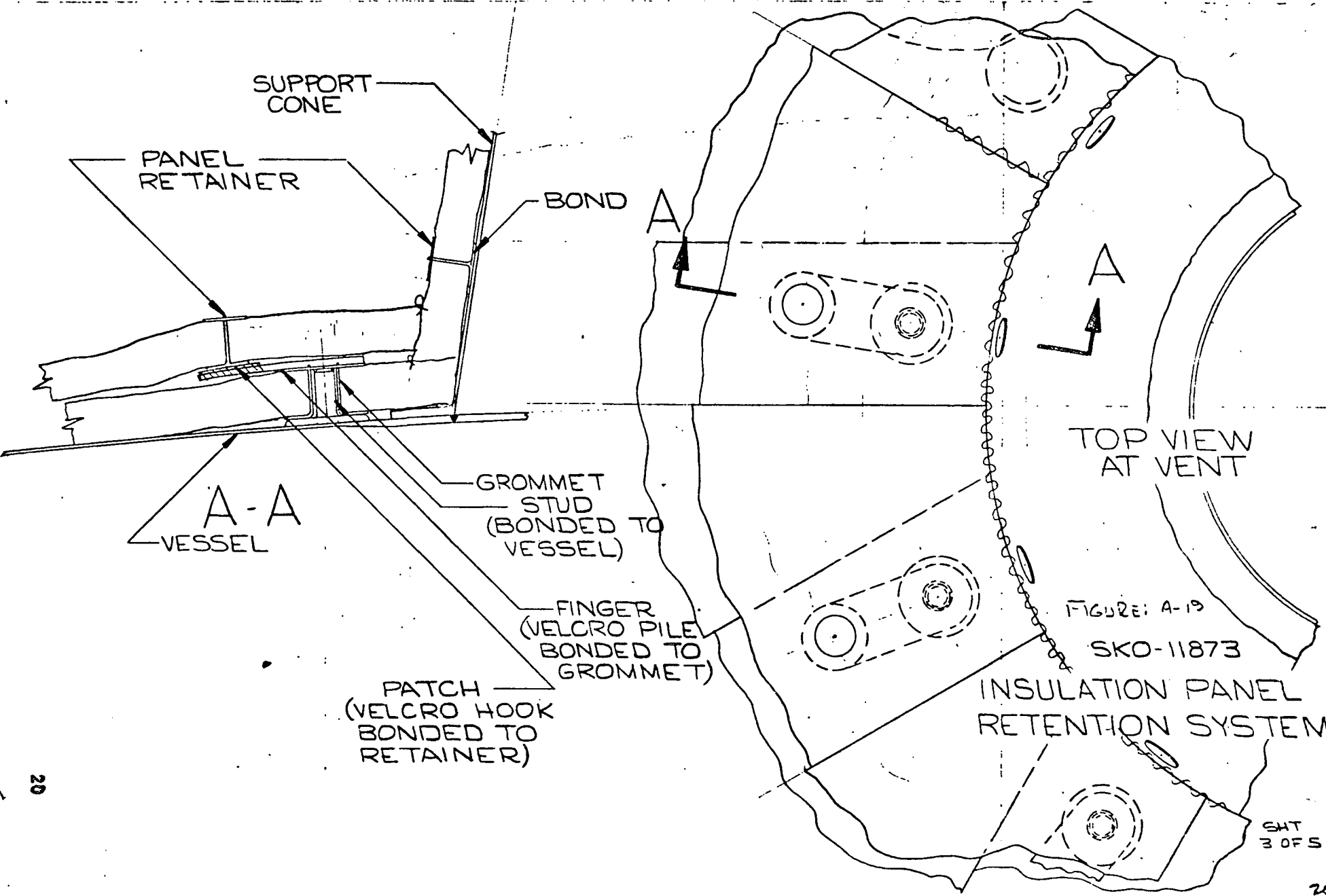
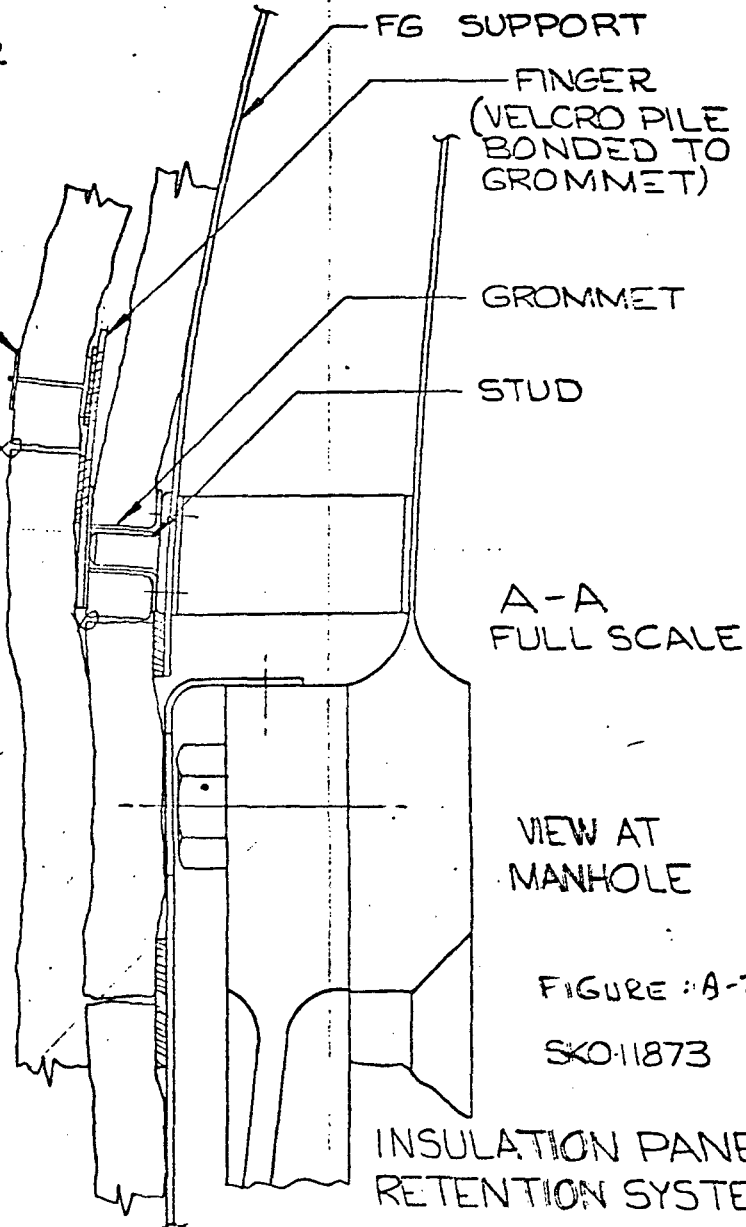
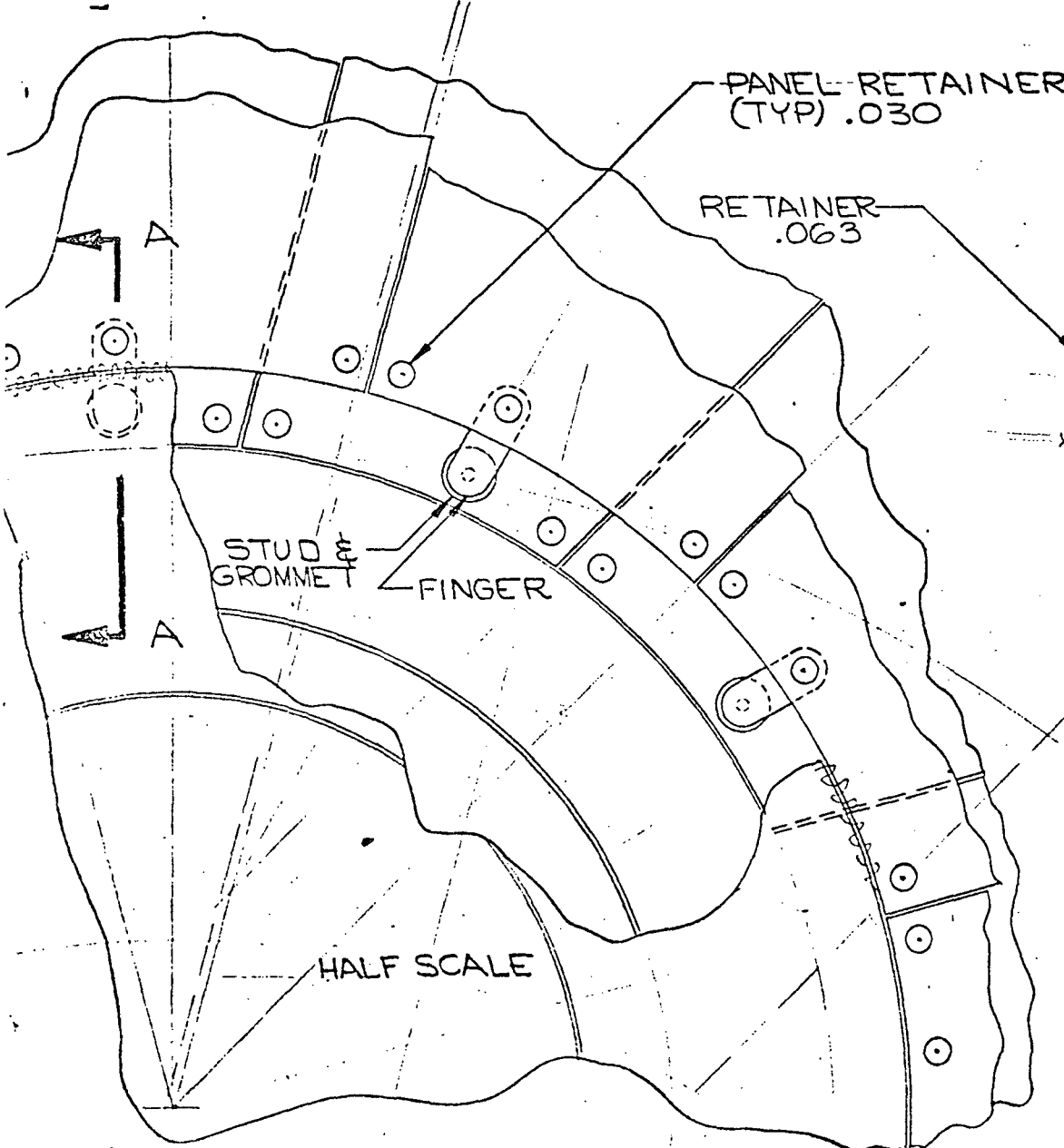


FIGURE: A-19

SKO-11873

INSULATION PANEL
RETENTION SYSTEM

SAT
3 OF 5

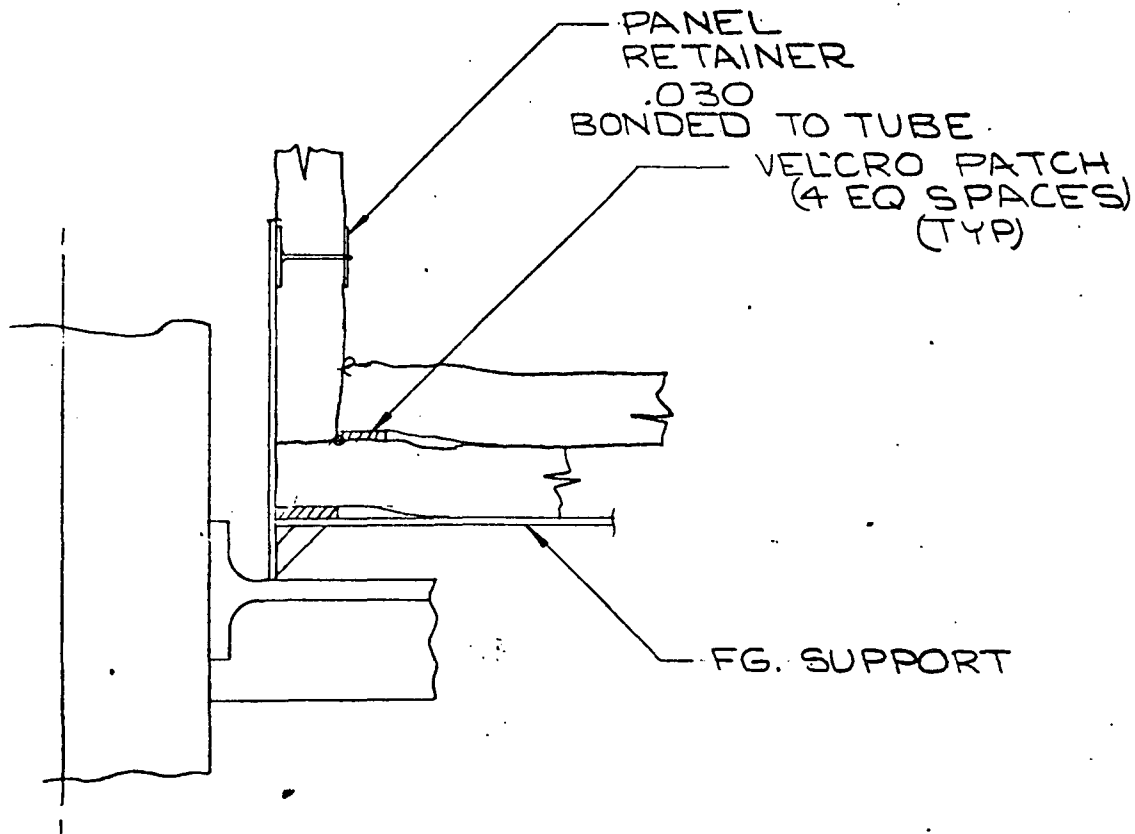


VIEW AT MANHOLE

FIGURE A-20

SKO-11873

INSULATION PANEL RETENTION SYSTEM



VIEW AT MANHOLE
 FEED LINE PENATRATION

FIGURE: A-21
 SKO-11873

INSULATION PANEL
 RETENTION SYSTEM

SHT 50FS

APPENDIX B

MODIFIED THEORETICAL EFFECTIVE GAS CONDUCTIVITY

APPENDIX B
MODIFIED THEORETICAL EFFECTIVE GAS CONDUCTIVITY

In Reference 1 an expression for elemental heat transfer due to free molecule gas conduction was derived for open net MLI systems employing layer densities from 2.0 to 4.0 layers per mm (51 to 102 layers per inch). That expression is

$$q_x = \alpha k_g \left(\frac{h}{h + \lambda} \right) \frac{dT^*}{dx} \quad (8)^*$$

where

q_x = heat flux in the x direction

α = accommodation coefficient

k_g = true gas conductivity

h = thickness of one shield plus one space (layer interval)

λ = mean free path

T = temperature

x = MLI thickness dimension

After substitution of curve-fit formulas expressing the gas property parameters of Equation (8) in terms pressure, temperature and molecular weight, the equation becomes

$$q_x = \frac{a_0 T^n a_1 T^m h}{\left[\frac{8.6 a_2 T^{0.5}}{pM^{.5}} \right]} = \frac{dT}{dx} \quad (10)$$

*Equation numbers, units and nomenclature (except where conflicting with symbols used elsewhere in this report) are those of Reference 1.

for which the gas-dependent constants are:

Gas	a_0	n	a_1	m	a_2	o	M
H ₂	2.66	-.42	$.971 \times 10^{-5}$.92	1.5×10^{-6}	.7	2.016
He	1.17	-.333	2.35×10^{-5}	.74	5.0×10^{-6}	.65	4.003
N ₂	1.0	0	1.38×10^{-6}	.92	1.2×10^{-6}	.9	28.013

The values for a_2 and o (gas viscosity constants) were not listed directly in Reference 2 but were derived here from the curves of the reference.

With $h \ll \lambda$ (free molecule regime), Equation (10) may be simplified to

$$q_x = \left[C(T)^S \rho h \right] \frac{dT}{dx} \quad (12)$$

or

$$q_x = \frac{C \rho T^S}{\bar{N}} \frac{dT}{dx}$$

where

$$C = f(a_0, a_1, a_2, M)$$

$$S = f(n, m, o)$$

$$\bar{N} = \text{number of layers per unit of thickness}$$

$$\bar{N} = 1/h$$

In Reference 1, Equation (12) was integrated under the assumption that T varied with x but p was independent of x. The result was

$$q_g = \frac{C_p}{N_o(S+1)} \left[T_H^{S+1} - T_C^{S+1} \right] \quad (13)$$

or

$$q_g = \frac{C_p}{x\bar{N}(S+1)} \left[T_H^{S+1} - T_C^{S+1} \right]$$

For the free molecule regime, however, Knudsen's principle (Reference 3) states that

$$\frac{\partial}{\partial x} \left(\frac{\rho}{T^{.5}} \right) = 0$$

If it can be assumed that

$$\frac{\partial}{\partial x} (pT^S) \approx \frac{\partial}{\partial x} (pT^{-.5}) = 0$$

then from Equation (12)

$$q_g = \frac{C}{N_x} pT^S (T_H - T_C)$$

Because of the independence of (pT^S) of x , the non-subscripted p and T may be evaluated at any consistent location within the MLI, usually most conveniently at the hot surface. The effective gas conductivity, which follows directly from the preceding expression, has exactly the same form as the previously used semi-empirical formula,

$$k_g = \frac{C}{N} pT^S \quad (A)$$

The gas-dependent constants of Equation (10) were used to evaluate C and S for use in the above formula. The values, along with the corresponding values for the previous, semi-empirical effective conductivity expression are shown below.

Gas	$\frac{C, \text{ watt-m}}{\text{mm-N-K}^{S+1}}$	$\left(\frac{C, \text{ Btu}}{\text{ft}^2\text{-hr-Torr-R}^{S+1}} \right)$	S
H ₂	.244	(7610)	-.70
He	.111	(3460)	-.74
N ₂	.0575	(1790)	-.48
N ₂ , He	.0266	(828)	-.5

(Previous Semi-Emp. Formula)

The newly derived theoretical values of S fail to satisfy exactly the assumption that

$$\frac{\partial}{\partial x} (pT^S) \approx \frac{\partial}{\partial x} (pT^{.5})$$

but are close enough to the ideal value of 0.5 to offer hope as to the validity of the theoretical formula for k_g . In order to test this validity predictions were made for comparison with effective gas conductivity test data of reference 4. Results of this comparison, shown in Figure A-1, support the validity of the theoretical expression, Equation (A), at least for N_2 . On the basis of this correlation, the validity for H_2 was assumed and Equation (A) was adopted for subsequent thermal analyses in the current program.

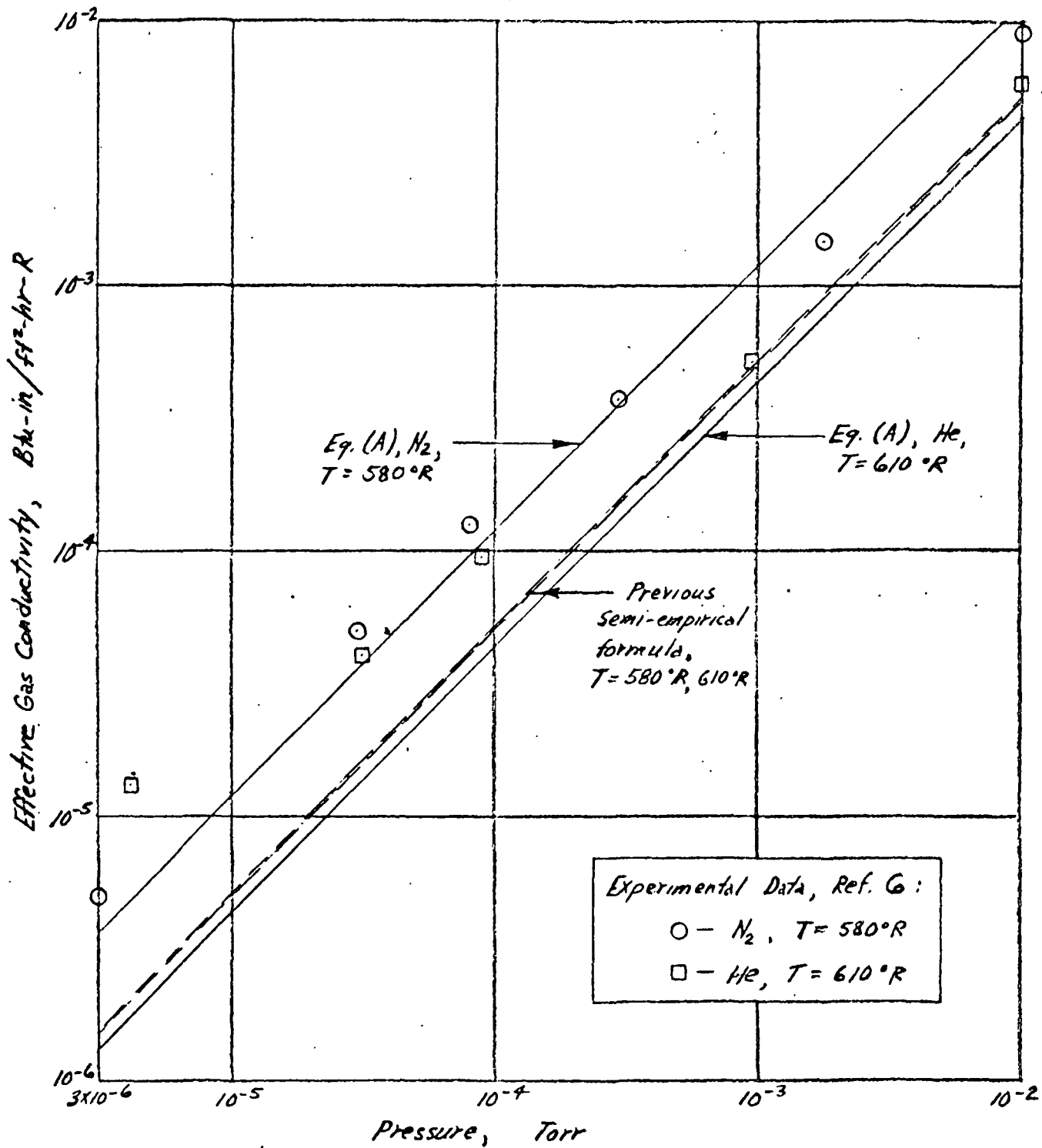


FIGURE B-1

EFFECTIVE GAS CONDUCTIVITY THEORY-EXPERIMENT COMPARISONS

REFERENCES

1. Keller, C. W., "Thermal Performance of Multilayer Insulation," Sixth Quarterly Activity Report, 1 October - 31 December 1972, Contract NAS3-14377, LMSC/D337102, Lockheed Missiles and Space Company.
2. Vance, R. W., and Duke, W. M., Applied Cryogenic Engineering, John Wiley and Sons, N.Y., 1962.
3. Kennard, E. H., "Kinetic Theory of Gases," McGraw Hill, New York, 1938.
4. Ottestad, J. T., "Cryogenic Tank Insulation Properties Measurement," D2-113369-1, The Boeing Company, September 1971.

APPENDIX C

ANALYTICAL THERMAL MODELS

APPENDIX C
ANALYTICAL THERMAL MODELS

The analytical models used in the detailed thermal analysis are illustrated in Figures C-1 through C-7. Symbols employed in the illustrations are explained in Table C-1. The figures show the network of thermal conductors for each case treated, in order to provide an indication of the degree of detail to which the conduction heat paths were considered. Radiation heat paths, which in the analyses connected each pair of terminal nodes between which radiation interchange was significant, have been omitted from the figures for clarity. Although the analytical models, as currently defined, represent details of the full scale design, most of them can be easily adapted to analysis of the subscale design. The following paragraphs describe features of the individual models.

1. Idealized MLI Blankets

The basic heat flow across the idealized MLI, i.e., blankets having no discontinuities or penetrations, was computed with the aid of the one-dimensional model illustrated in Figure C-1. The total heat path included conduction across the vacuum jacket skins, coupled radiation and conduction across the vacuum jacket core, radiation across the vacuum annulus, effective conduction across the MLI, and conduction across the pressure vessel wall. For the steady state analysis, representing the 30-day LH₂ storage condition, constant boundary temperatures at T₁ and T₁₀ of 311.0K (560R) and 20.5K (37R), respectively, were assumed. For the transient analysis, representing response to an assumed orbiter reentry with an empty tank, the temperature at T₁ was defined to follow a prescribed history while all other nodes were free to respond. The interface between the two MLI blankets was effectively ignored with the assumption of continuous properties through the entire MLI thickness. The MLI thickness was varied parametrically in the basic heat flow analysis in order to develop data required for thermal optimization.

2. Typical Lap Joint

Figure C-2 shows the model used to compute the incremental heat leak per unit length of single-step lap joint in the MLI. The two-dimensional model represented a 65.0 cm (26.6 in) wide section of blanket perpendicular to the joint. It was assumed that this section was wide enough to effectively isolate the influence of the joint on the basic heat flow. The gap at the butt interfaces in the joint, which had an important effect on the magnitude of the joint incremental heat leak, was assumed as .0127 cm (.050 in). As in the basic heat flow analysis, the MLI thickness was varied parametrically.

Unlike the basic heat flow model of Figure C-1, the joint analytical model did not include the vacuum jacket or the vacuum annulus. Instead, the temperatures at the outer surface of the MLI (T1, T8, T15, T22, ..., T85 in Figure C-2) were defined as fixed at the value derived from the corresponding point (T5, Figure C-1) from the basic heat flow analysis. The temperatures along the pressure vessel wall (T7, T14, T21, T28, ..., T91) were fixed at the cold boundary condition of 20.5K (37R).

3. Pin-and-Grommet Fastener

The model used for analyzing the pin-and-grommet (MLI panel installation) type fastener is shown in Figure C-3. This is the design for which alternatives having lower heat leaks are being considered. As in the case of the lap joint, the model includes an area of MLI assumed sufficient to isolate the thermal influence of the fastener. The analytical model is two-dimensional but, by virtue of assumed axial symmetry, represents the fastener and a surrounding circular area of MLI 52.07 cm (20.5 in) in diameter. In a manner similar to the previously described models, the MLI thickness and the affected lengths of pin shaft and grommet wall were varied parametrically. For the purpose of computing radiation interchange in the annular space between the pin and the grommet, the pin was assumed to be positioned concentric with the grommet.

The high temperature boundary condition, at T61, T60, T63, T21, T27, T33, T39, and T45, was set at the computed value for T5 from Figure C-1. The

cold (20.5°K) boundary condition was assumed to exist at T65, T64, T67, T26, T32, T38, T44, and T50.

4. Pin Fasteners

Figure C-4 shows the model used for analyzing the pin-type (MLI panel assembly) fasteners. Because of the alternating positions of the fasteners in the two blankets and the possibility of thermal interactions between pairs of fasteners, it was necessary to employ a three-dimension analytical model. For the fastener pattern assumed, the minimum size recurring cell is the triangular area shown in the figure. The validity of such a recurring cell for an analytical model depends upon infinite repetition of the pattern. Its use here assumes no interactions between the pin-type fasteners and the pin-and-grommet fasteners, MLI lap joints, or other penetrations. For analysis of the pin-type fasteners, both the MLI thickness (Dimension "B" in the figure) and the pin spacing (dimension "A") were varied parametrically. Boundary temperatures were prescribed on the MLI surfaces and the surfaces of exposed pin heads in a manner similar to that used for the pin-and-grommet and lap joint analyses.

5. Structural Support Strap

Figure C-5 illustrates the model used to analyze the incremental heat flow due to a typical support strap penetration. This penetration was actually treated in two parts: the strap itself, as a direct conductor of heat to the pressure vessel; and the MLI in the vicinity of the strap attachment on the pressure vessel wall. Both components of the model are shown in the figure.

The actual MLI blanket design at the strap penetration includes a number of cuts, seams, and joints. The modelling of these details, especially in view of the difficulties in estimating the dimensions of gaps and spaces at joints and the effects of compression of the MLI, appeared to be a formidable task and one of questionable value. It was observed that the design provided total MLI thicknesses at least equal to the basic thickness everywhere around the strap except in the vicinity of the attachment boss.

It was therefore assumed that the total heat leak due to the strap penetration could be estimated as the sum of the heat flow through the strap and the increased heat flow through the MLI due to the reduced thickness over the strap attachment bolt.

The strap was considered a one-dimensional conductor between the point where it emerged from the insulation cover to the thickened lug on its pressure vessel end. Those two points, designated at T51 and T20 on Figure C-5, were fixed at 311.0°K (560°R) and 20.5°K (37°R), respectively.

The MLI analysis employed a two-dimensional model of an axially symmetric area 52.07 cm (20.5 in) in diameter, centered on the strap attachment bolt. No interaction between the strap and the MLI was assumed. As in previous cases, the MLI thickness was varied parametrically.

Warm side boundary temperatures, at T1, T8, T15, T21, ..., T45 were again set at the value for MLI outer surface from the basic heat flow analysis. The cold side boundary temperature, at T20, T26, T32, T38, T44, and T50, were set at 20.5°K (37°R).

6. Manhole Access and Feed Valve Assembly

The model for analysis of the manhole and feed valve penetration is shown in Figure C-6. The heat flow through this region was expected to be a complex combination of conduction and radiation with the thermal influence extending well beyond the periphery of the assembly.

With the exception of the two small vent and valve actuator tubes, the network shown in the figure was treated as axisymmetric. Heat flow through the two small tubes was computed on an independent, one-dimensional basis and added to the heat flow resulting from the axisymmetric model analysis. Radiation interchange between the small tubes and other surfaces was thus ignored, but all other possible radiant exchanges permitted by the nodal network, including radiation through the main feed line interior, were

considered. The conductor values for the two small coiled tubes were based on their true length, although the figure shows shorter lengths for clarity.

The model for manhole and feed valve penetration analysis included pressure vessel, MLI blanket, vacuum annulus, and vacuum jacket area out to a radius of 107 cm (42 in) from the feed line. The thickness of the main MLI blanket was taken as 2.79 cm (1.10 in) and the feed line MLI as 1.27 cm (0.50 in) rather than being varied as in some of the other component analyses. It was assumed that within the range of MLI thicknesses of interest for optimization purposes, the incremental heat leak associated with the manhole and feed valve penetration would be little affected by variations in thickness. The joints in the main MLI providing access to the manhole cover bolts were not included as part of this model but were included as part of the total length of joint in the computation of total joint heat leak.

Boundary temperatures for the model of Figure C-6 were 311.0°K (560°R) at T1, the outer, warm surface, and 20.5°K (37°R) at T2, at the cold boundary.

7. Vent Valve Assembly

Figure C-7 shows the analytical model for the vent valve assembly penetration. Although the model was developed as illustrated, the analysis of this penetration, as described in the discussion of predicted heat flow results, did not incorporate all details of the model. Specifically, radiation within the valve enclosure and its vacuum jacket housing, and lateral heat flow in the pressure vessel MLI and the entire vacuum jacket were ignored. The analysis did include conduction through the main vent line, valve enclosure, insulation support collar, valve enclosure MLI (laterally only), and the valve enclosure vent and valve actuator tubes, as well as radiation through the main vent line interior. Boundary temperatures for the analysis were 20.5°K (37°R) at T70 and 311.0°K (560°R) at T1 and T69.

TABLE C-1

SYMBOLS FOR ANALYTICAL THERMAL
MODEL DIAGRAMS



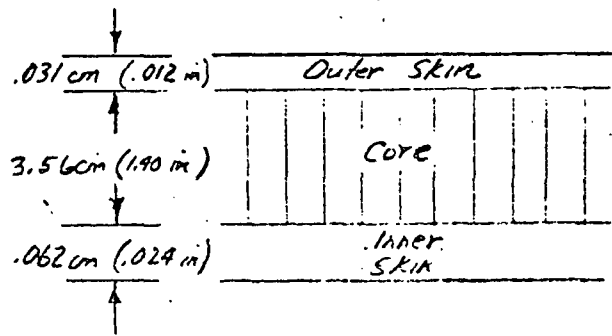
— Terminal Node: Terminus for thermal conductors, point at which temperatures are evaluated, point at which surface area (for radiation interchange) and thermal capacitance (for transient thermal diffusion) are assumed concentrated.



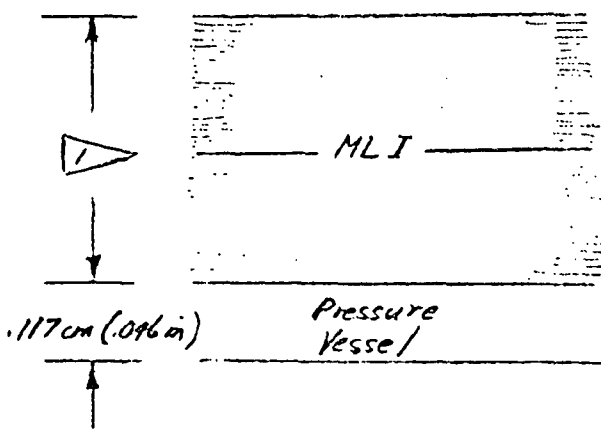
— Thermal Conductor: Connects two terminal nodes, incorporating properties of material conductivity, conduction path length and conduction path effective cross section area.



— Zero Resistance Conductor: Connects terminal nodes whose temperatures are assumed identical.



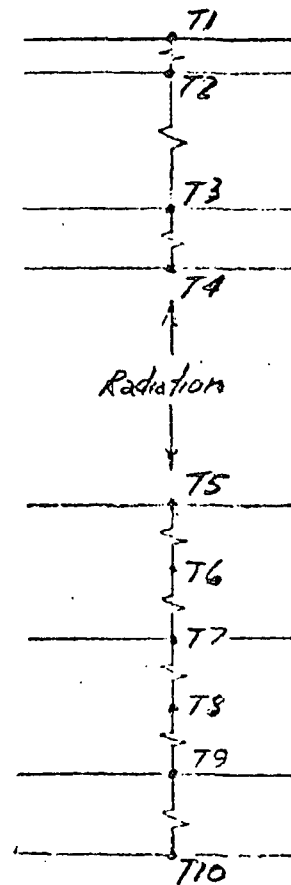
Vacuum Annulus



Section

△ MLI thickness varied parametrically

FIGURE C-1



Model

(NO TO SCALE)

ANALYTICAL THERMAL MODEL - AREAS REMOTE FROM PENETRATIONS OR DISCONTINUITIES

38

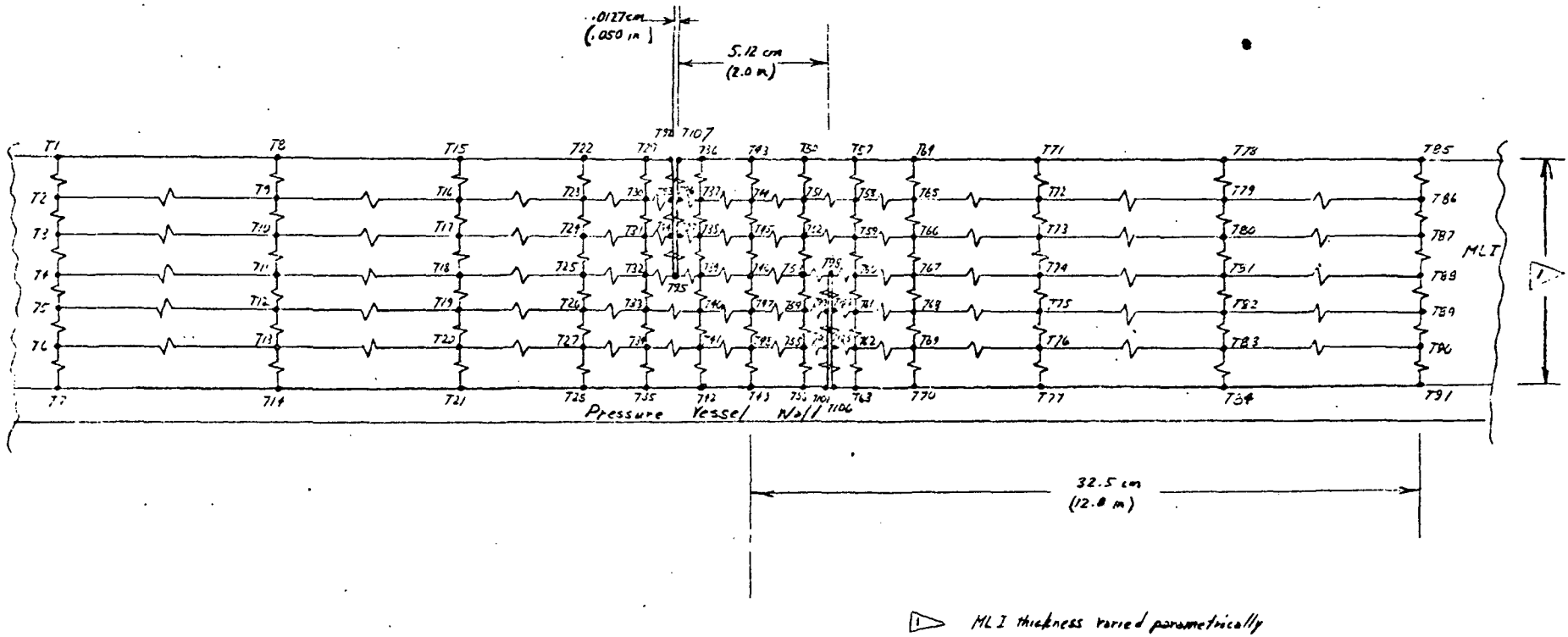
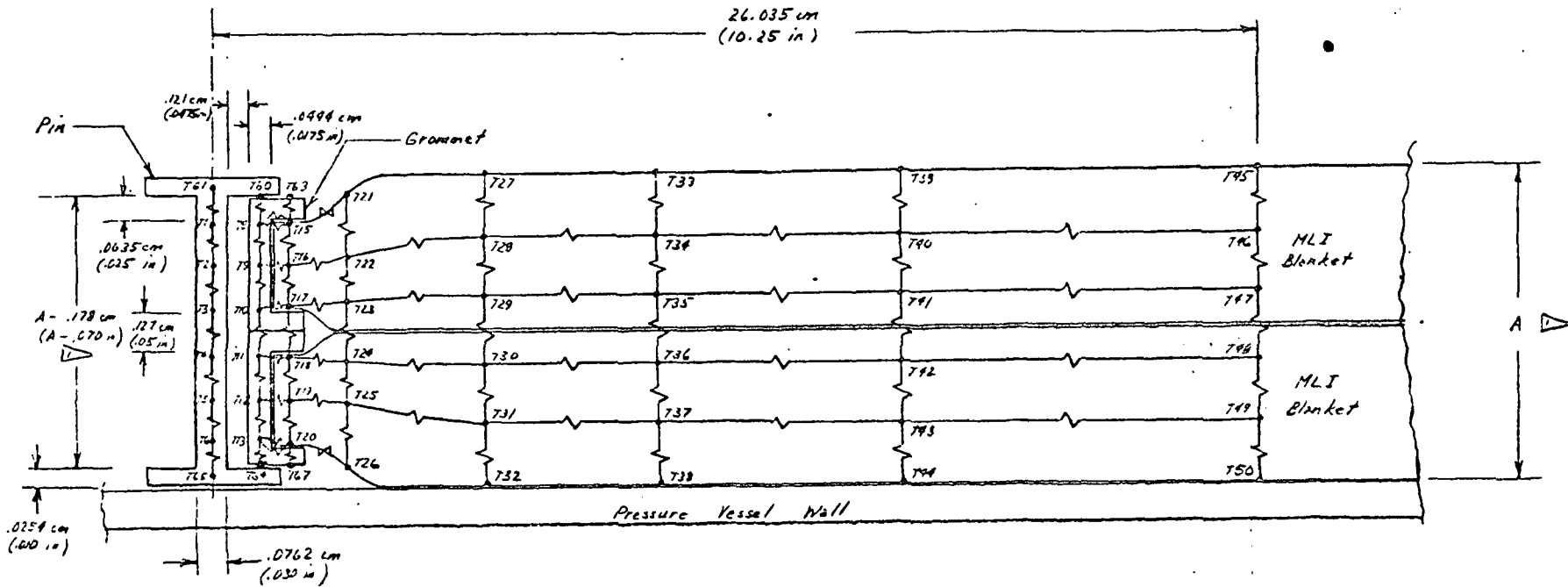


FIGURE C-2

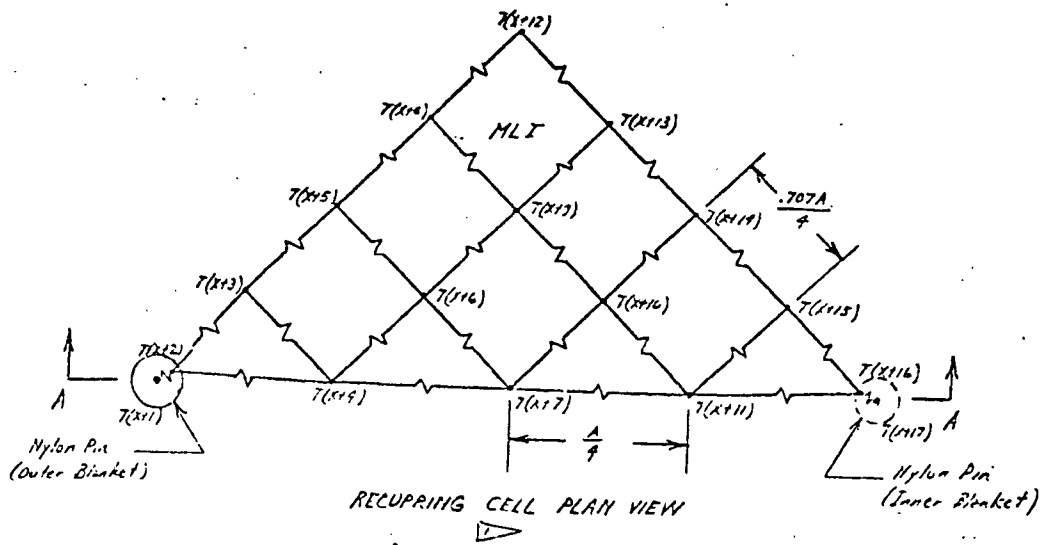
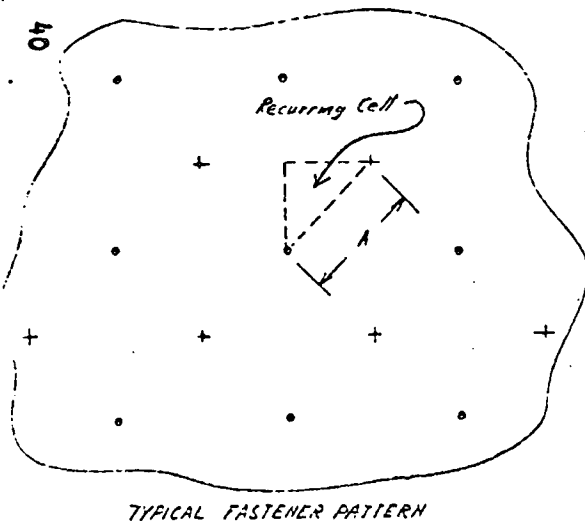
ANALYTICAL THERMAL MODEL - TYPICAL SECTION THROUGH SINGLE-STEP LAP JOINT
(NOT TO SCALE)



▷ MLI Thickness varied parametrically

FIGURE C-3

ANALYTICAL THERMAL MODEL - TYPICAL NYLON PIN-AND-GROMMET FASTENER & SURROUNDING MLI.
(NOT TO SCALE)



- ▽ $x = 0, 50, 100, \dots, 450$
- ▽ MLI thickness and fastener pitch varied parametrically
- ▽ Many node designations omitted for clarity

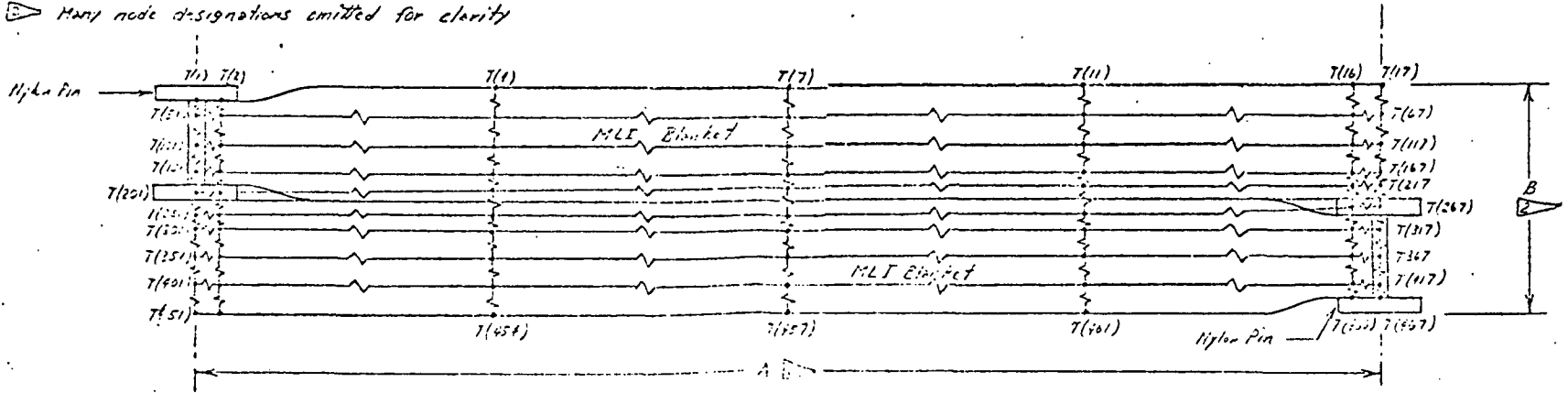


FIGURE C-4
ANALYTICAL THERMAL MODEL - PIN-TYPE FASTENERS & ASSOCIATED MLI (Not to Scale)

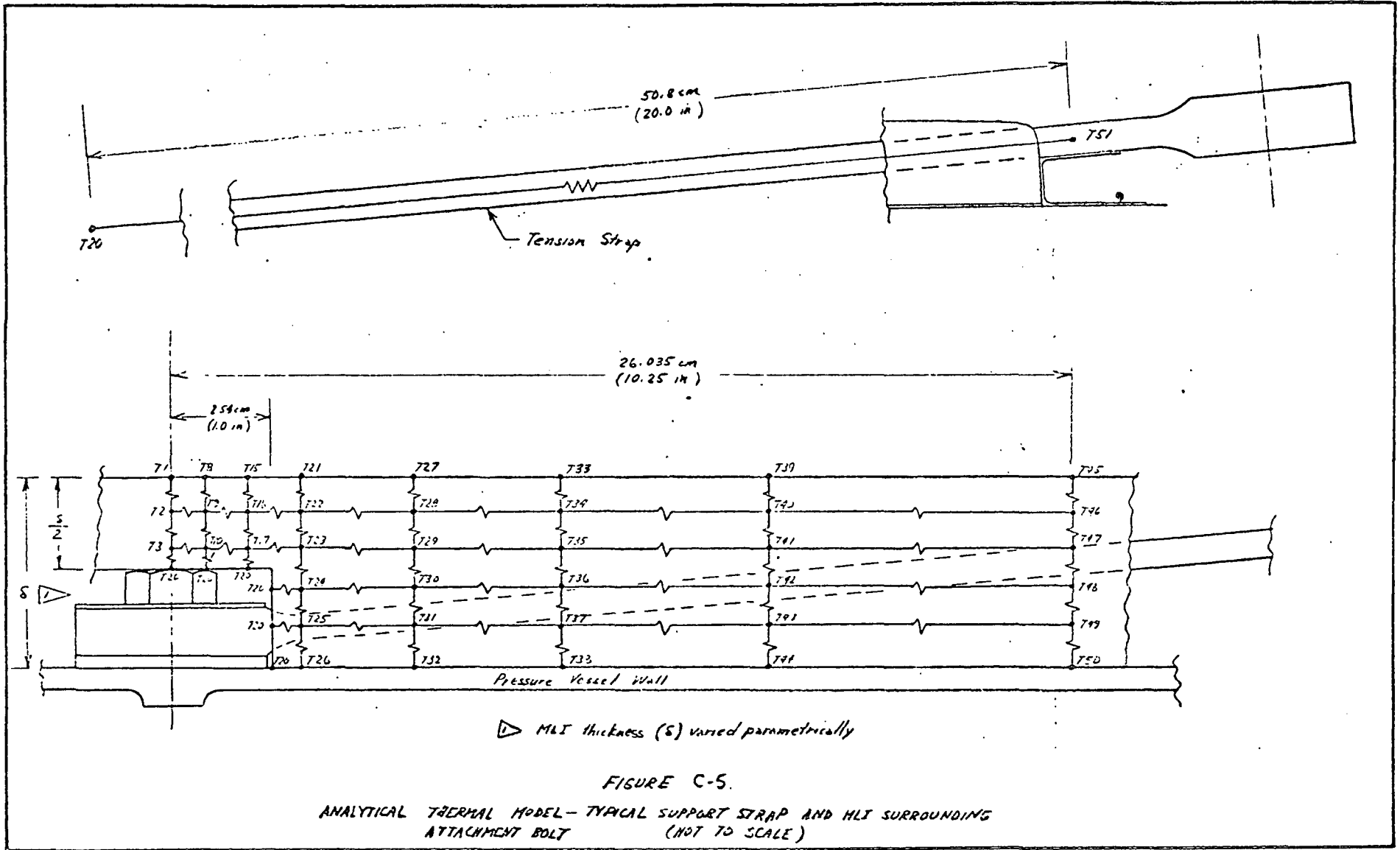
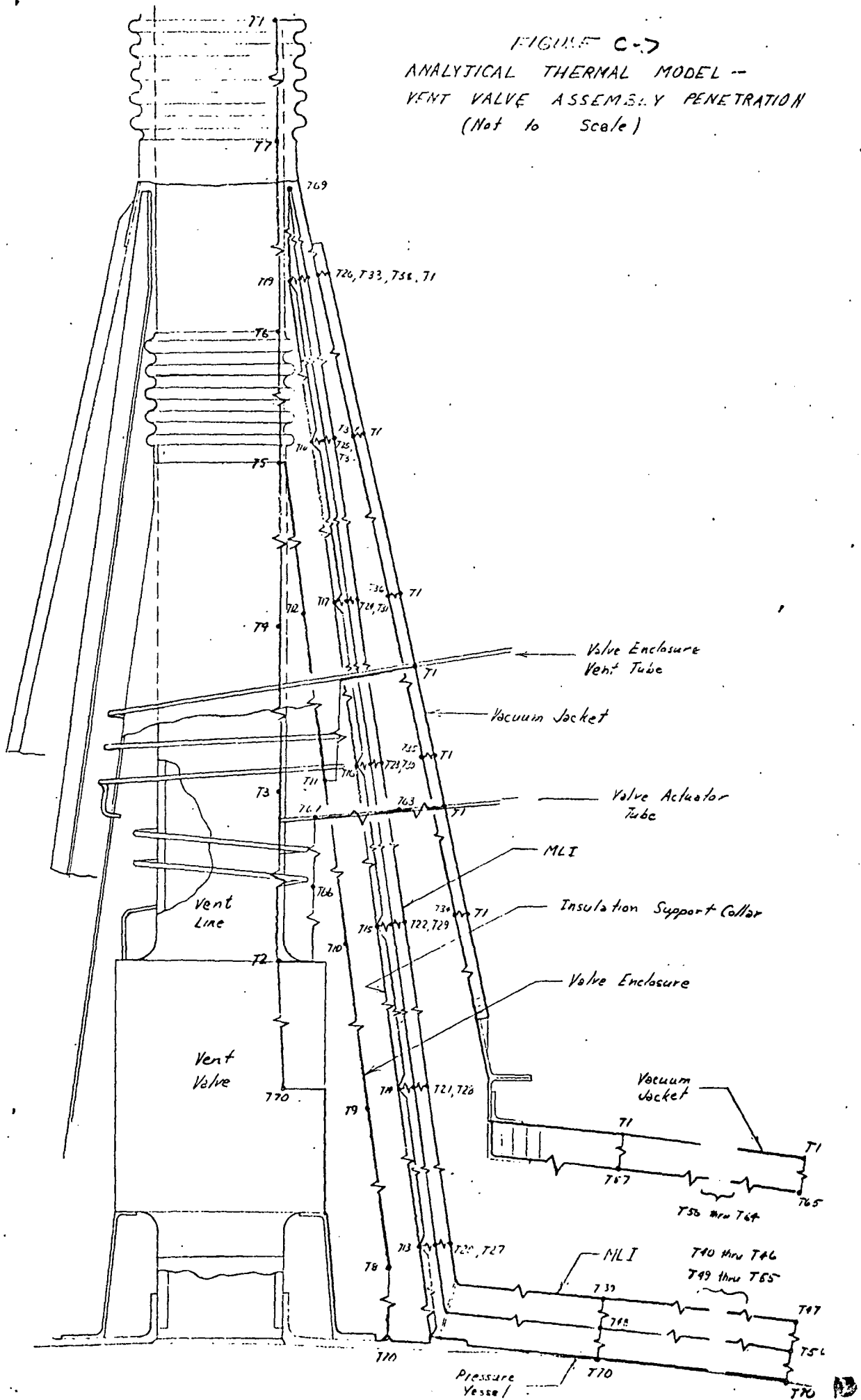


FIGURE C-7
 ANALYTICAL THERMAL MODEL --
 VENT VALVE ASSEMBLY PENETRATION
 (Not to Scale)



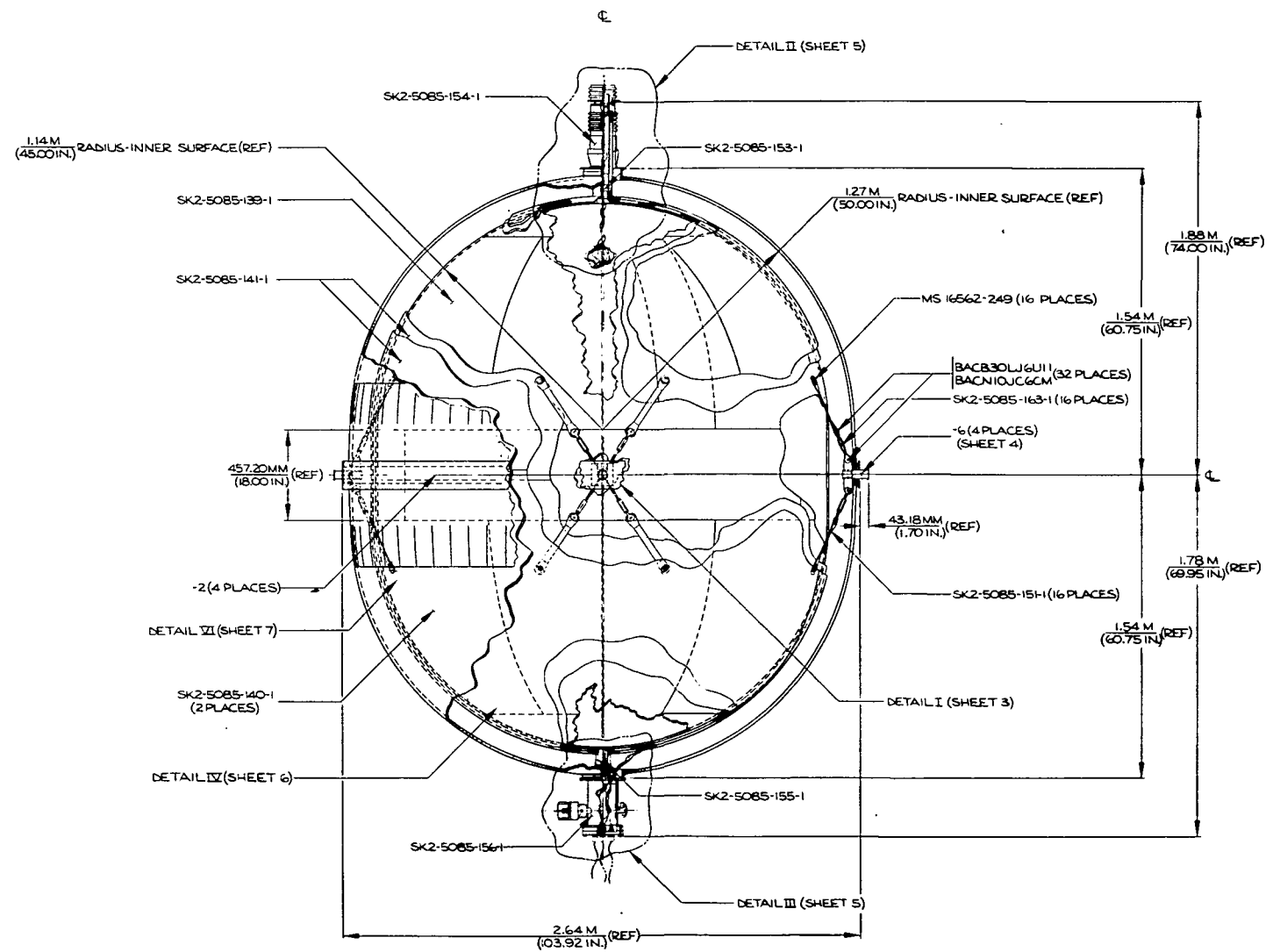
APPENDIX D

HALF SCALE LH₂ TEST MODEL DRAWINGS

2KS-2082-131S

112

REVISIONS				
NO.	LETTER	DESCRIPTION	DATE	APPROVED
1	A	RE-DRAWN	8/30/74	SWP/S



-1 HALF SCALE
LH₂ TEST MODEL
ASSEMBLY

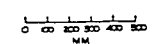


Figure D-2

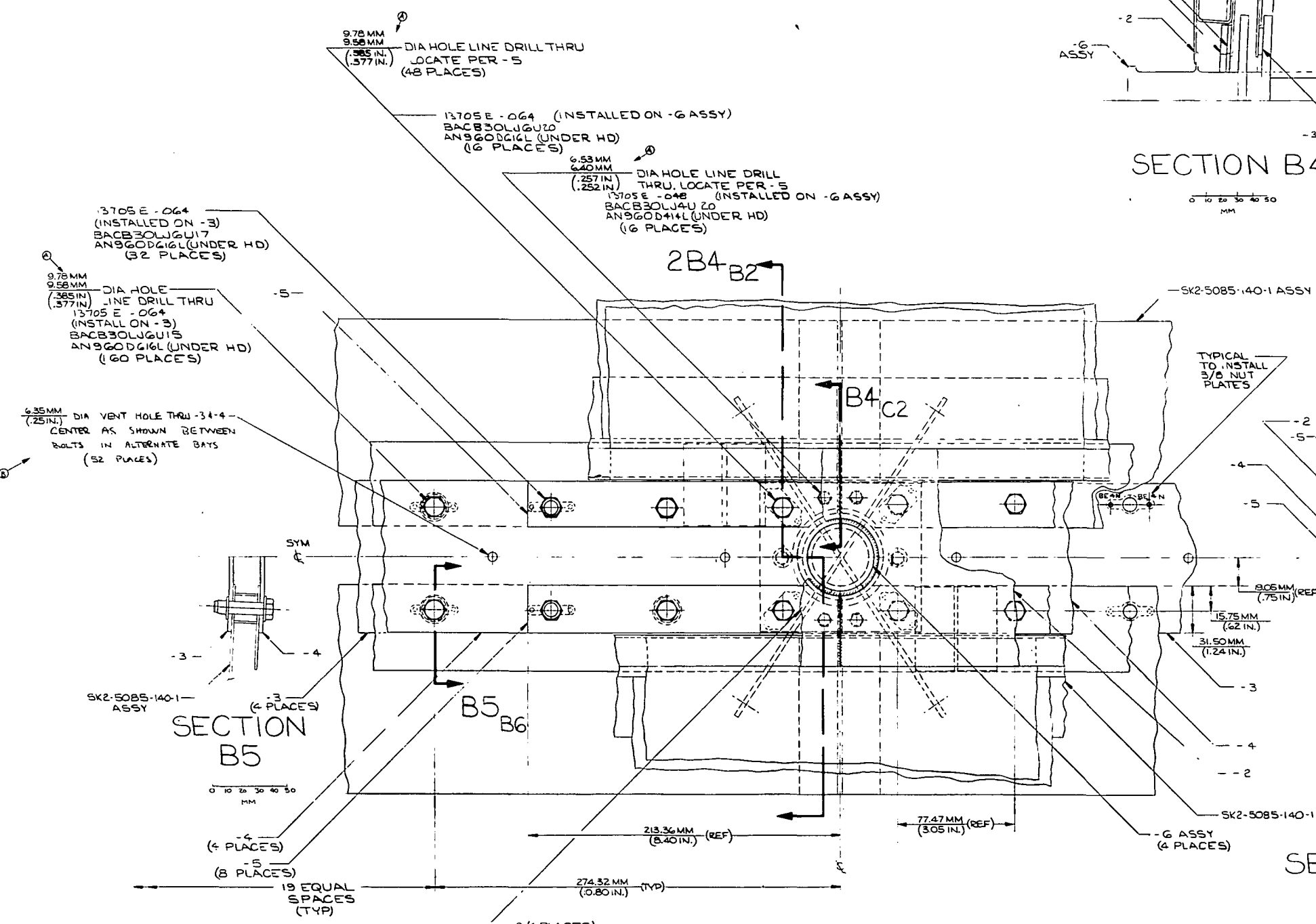
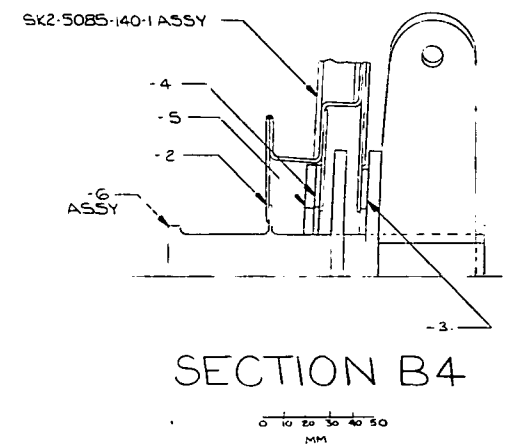
SEE SHEET 1 FOR PARTS LIST AND NOTES		CONFIDENTIAL NUMBER	
DRWG NO.	DATE REVIEW	NAS3-15848	
PROJECT	DESIGNED BY	PLANNING	8/30/74
DRAWN BY	CHECKED BY		
SCALE	DATE		
ORG.	PROJECT APPROVAL		
CHARACTER NUMBER	DATE CODE IDENT NO.	J81205	SK2-5085-137
	SCALE 1/0		OF 4

SK2-5085-137 A2

2KS-2082-131S

PKS 2082-131 3

REV	DESCRIPTION	DATE	APPROVED
A	257 DIA HOLES WERE 252 DIA HOLES WERE	254 250	1/18/74 <i>DM</i>
B	385 DIA HOLES WERE 377	379 375	2/11/74 <i>DM</i>
	ADDED .25 DIA VENT HOLES		



13705 E-064
(INSTALLED ON -3)
BACB30LJG17
AN960D41L (UNDER HD)
(52 PLACES)

13705 E-064 (INSTALLED ON -G ASSY)
BACB30LJG20
AN960D41L (UNDER HD)
(6 PLACES)

13705 E-048 (INSTALLED ON -G ASSY)
BACB30LJ4U
AN960D41L (UNDER HD)
(6 PLACES)

6.35 mm DIA VENT HOLE THRU -3-4
CENTER AS SHOWN BETWEEN
BOLTS IN ALTERNATE BAYS
(52 PLACES)

SK2-5085-140-1
ASSY
(4 PLACES)
SECTION B5

SK2-5085-140-1 ASSY

SK2-5085-140-1 ASSY

SK2-5085-140-1 ASSY

SK2-5085-140-1 ASSY

SK2-5085-140-1 ASSY

SK2-5085-140-1 ASSY

TYPICAL TO INSTALL
3/8 NUT PLATES
B2
TYPICAL TO INSTALL
1/4 NUT PLATES

DETAIL I
(ROTATED 90°)

SECTION 2B4

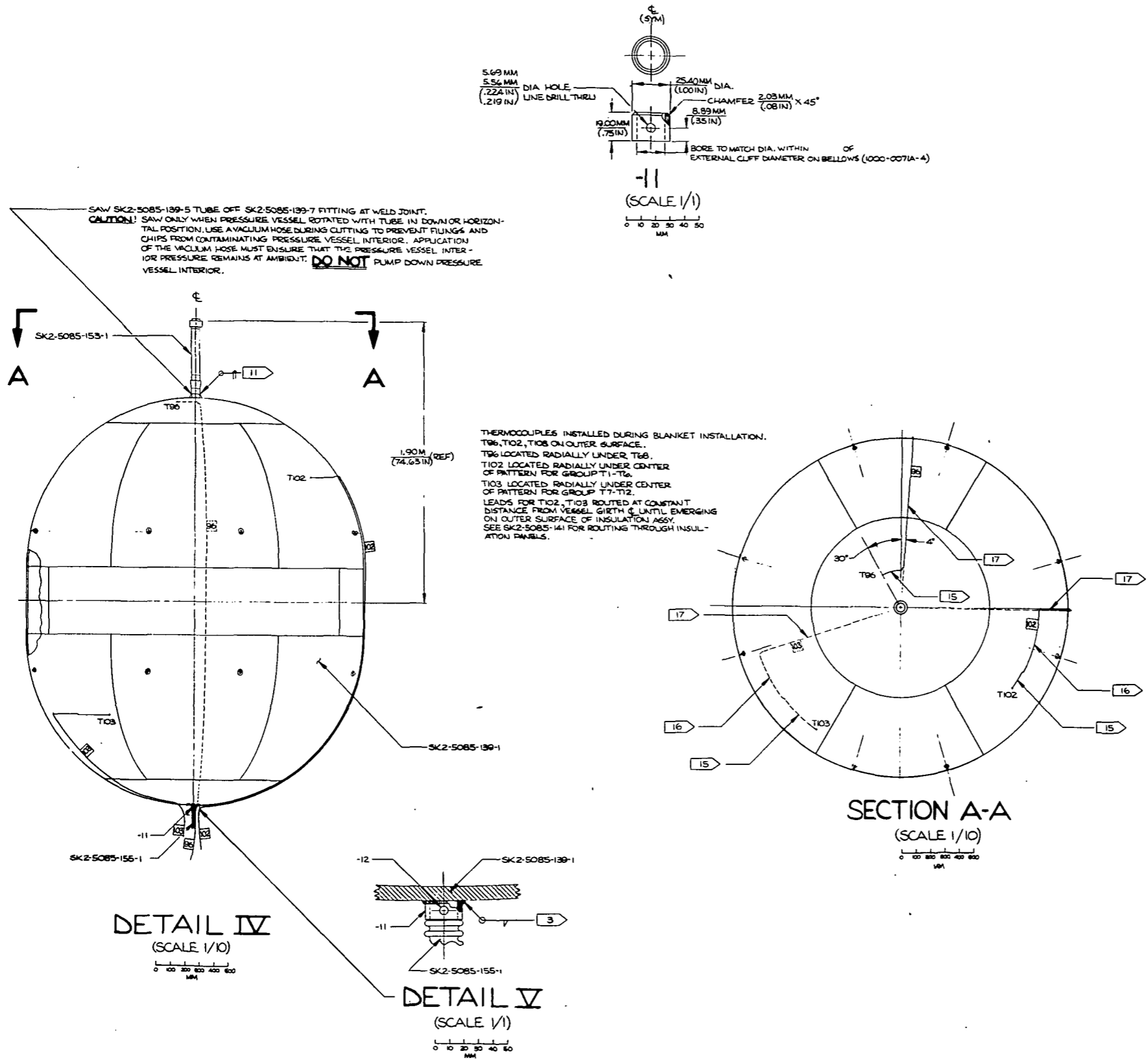
Figure D-3

DRAWING DATA		CONTRACT NUMBER		THE BOEING COMPANY	
CONTRACT NUMBER	NA53-15848	CORPORATE OFFICES		BATTLE, WASHINGTON, WASH.	
PROJECT	CHC	CORPORATE OFFICES		BATTLE, WASHINGTON, WASH.	
DATE	11/14/73	CORPORATE OFFICES		BATTLE, WASHINGTON, WASH.	
DESIGNER	SL BARCLAY	CORPORATE OFFICES		BATTLE, WASHINGTON, WASH.	
PROJECT APPROVAL		CORPORATE OFFICES		BATTLE, WASHINGTON, WASH.	
SCALE	1/1	CORPORATE OFFICES		BATTLE, WASHINGTON, WASH.	
PROJECT IDENT NO	J812.05	CORPORATE OFFICES		BATTLE, WASHINGTON, WASH.	
SCALE	1/1	CORPORATE OFFICES		BATTLE, WASHINGTON, WASH.	
SCALE	1/1	CORPORATE OFFICES		BATTLE, WASHINGTON, WASH.	

SK2-5085-131 B3

PKS 2082-131 3

2K5-2082-131 2H2



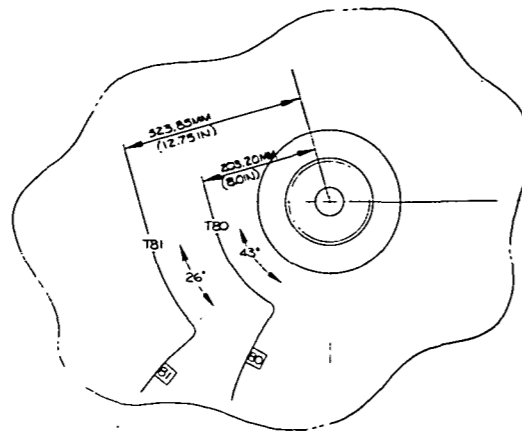
2K5-2082-131 2H2

Figure D-6

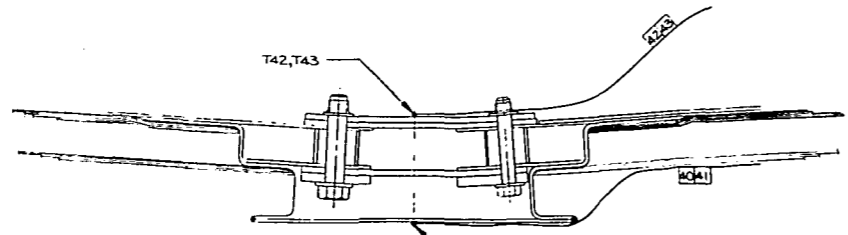
DIMENSIONING & TOLERANCING PER ANSI (UNLESS) Y14.5 UNLESS OTHERWISE SPECIFIED DIMENSIONS ARE IN INCHES TOLERANCES - ANGLES: DECIMALS .XXX DECIMALS .XXX RIVET & BOLT EDGE MARGIN: 0.50 BEND RADIUS: .01 OR .02 & .05 .02 OR .05 & GREATER SHEET METAL CORNER RADIUS: INT. .15 EXT. .25 .15	DATE	DESIGNER	CHECKER	DATE	DATE
	PROJECT	DATE	DATE	DATE	DATE
COMPANY NUMBER NAS3-15848	CORPORATE OFFICES SEATTLE, WASHINGTON, BIRMINGHAM		SCALE: HALF SCALE LH ₂ TEST MODEL ASSEMBLY		
CHANGE/ITER NUMBER	PROJECT APPROVAL		SHEET IDENTIFICATION B1205 SK2-5085-137		

2-5520

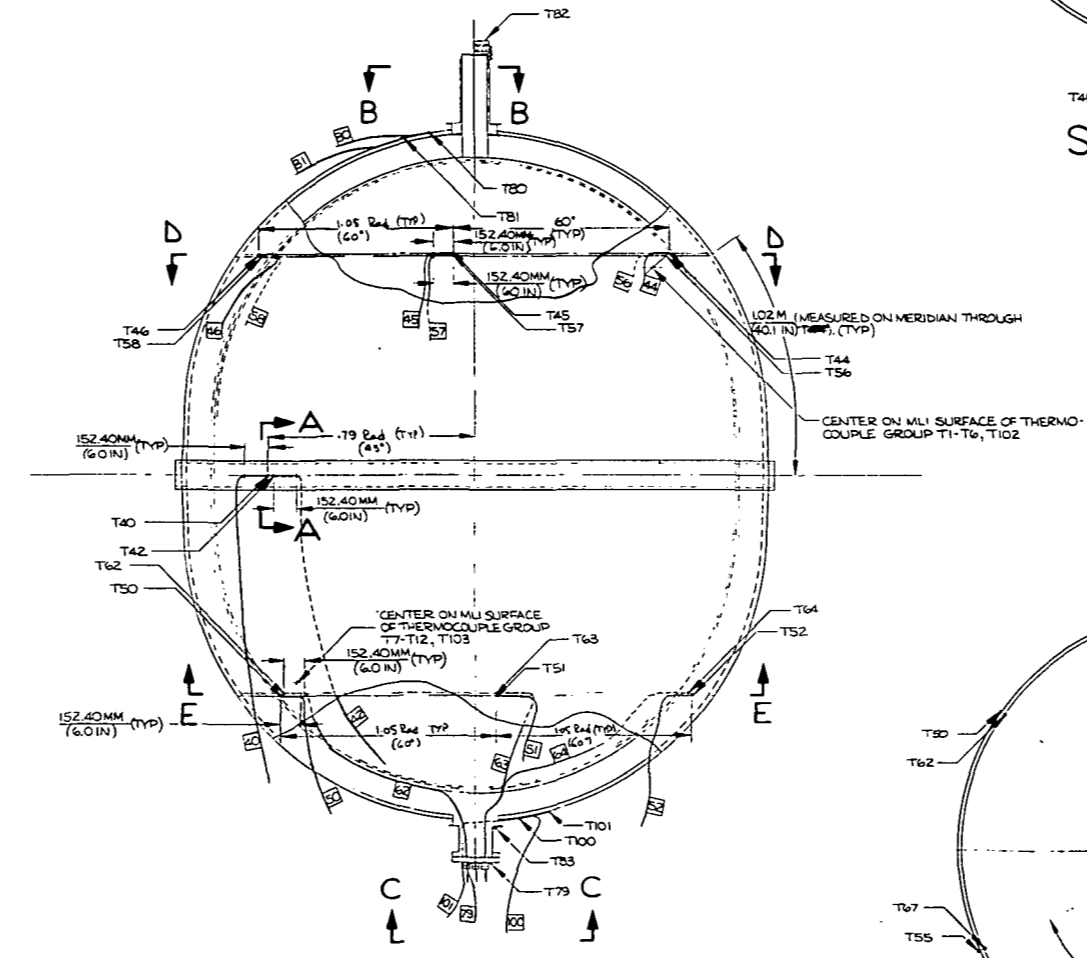
REVISIONS			
NO.	DESCRIPTION	DATE	APPROV.



VIEW B-B
(SCALE 1/4)

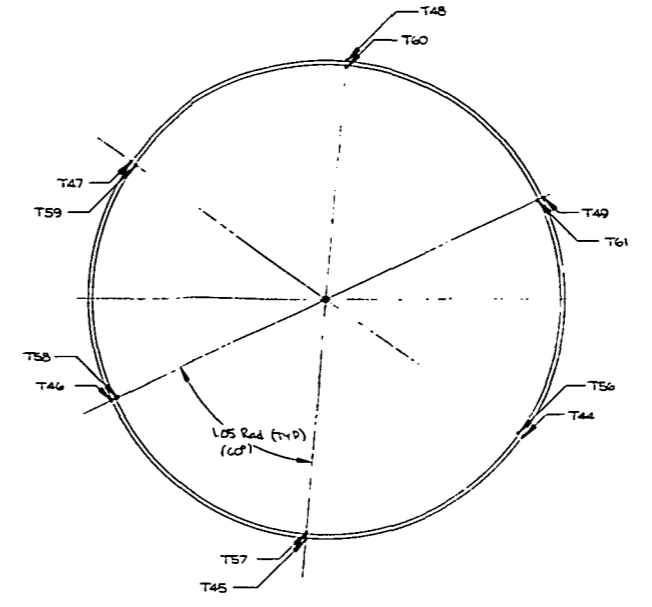


SECTION A-A
(NO SCALE)

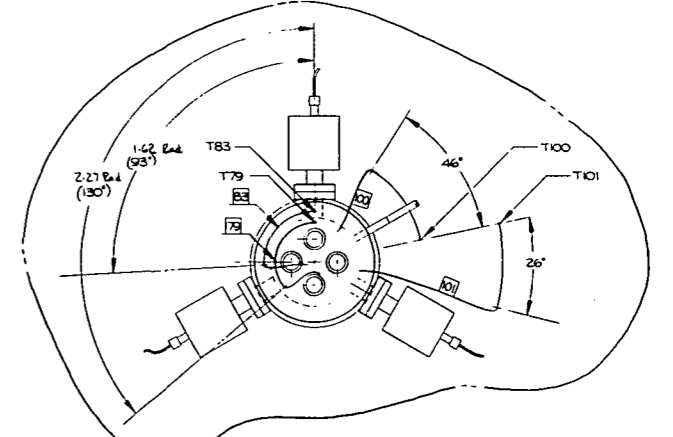


DETAIL VI
(SCALE 1/10)

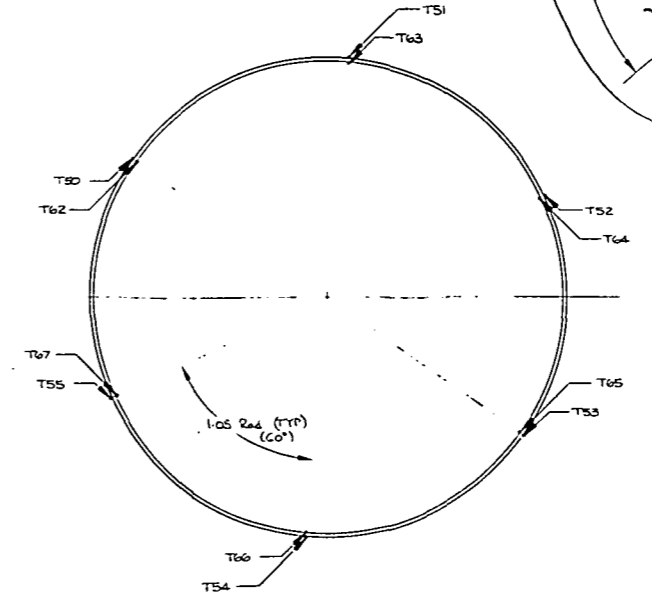
THERMOCOUPLES NOT SHOWN
 T41: 180° FROM T40
 T43: 150° FROM T42
 T44-T55 ON VACUUM JACKET OUTER SURFACE
 T56-T67 ON VACUUM JACKET INNER SURFACE
 T44, T56 LOCATED RADially OVER CENTER OF PATTERN FOR THERMOCOUPLE GROUP T1-T6, T102.
 T45-T49, T57-T61 LOCATED ON SUCCESSIVE 60° MERIDIANS FROM T44, T56, RESPECTIVELY.
 T50, T52 LOCATED RADially OVER CENTER OF PATTERN FOR THERMOCOUPLE GROUP T7-T12, T103.
 T51-T55, T63-T67 LOCATED ON SUCCESSIVE 60° MERIDIANS FROM T50, T52, RESPECTIVELY.
 T40, T42 LOCATED ON GIRTH RING MID LINE, OUTER SURFACE, INNER SURFACE, RESPECTIVELY, APPROXIMATELY 45° FROM ANY SUPPORT ASSEMBLY LOCATION, DISPLACE FROM EXACT 45° LOCATION IF NECESSARY TO LOCATE MIDWAY BETWEEN VENT HOLES ON INNER SURFACE.
 T100, T101 ON OUTER SURFACE OF VACUUM JACKET, ON SAME MERIDIAN AS T52, T51.
 LEADS FROM HIDDEN THERMOCOUPLES OMITTED FOR CLARITY.
 T80, T81 ON OUTER SURFACE OF VACUUM JACKET, ON SAME MERIDIAN AS T63 & T50.
 SEE SK2-5085 FOR T82 LEAD ROUTING



SECTION D-D
(SCALE 1/10)



SECTION C-C
(SCALE 1/4)

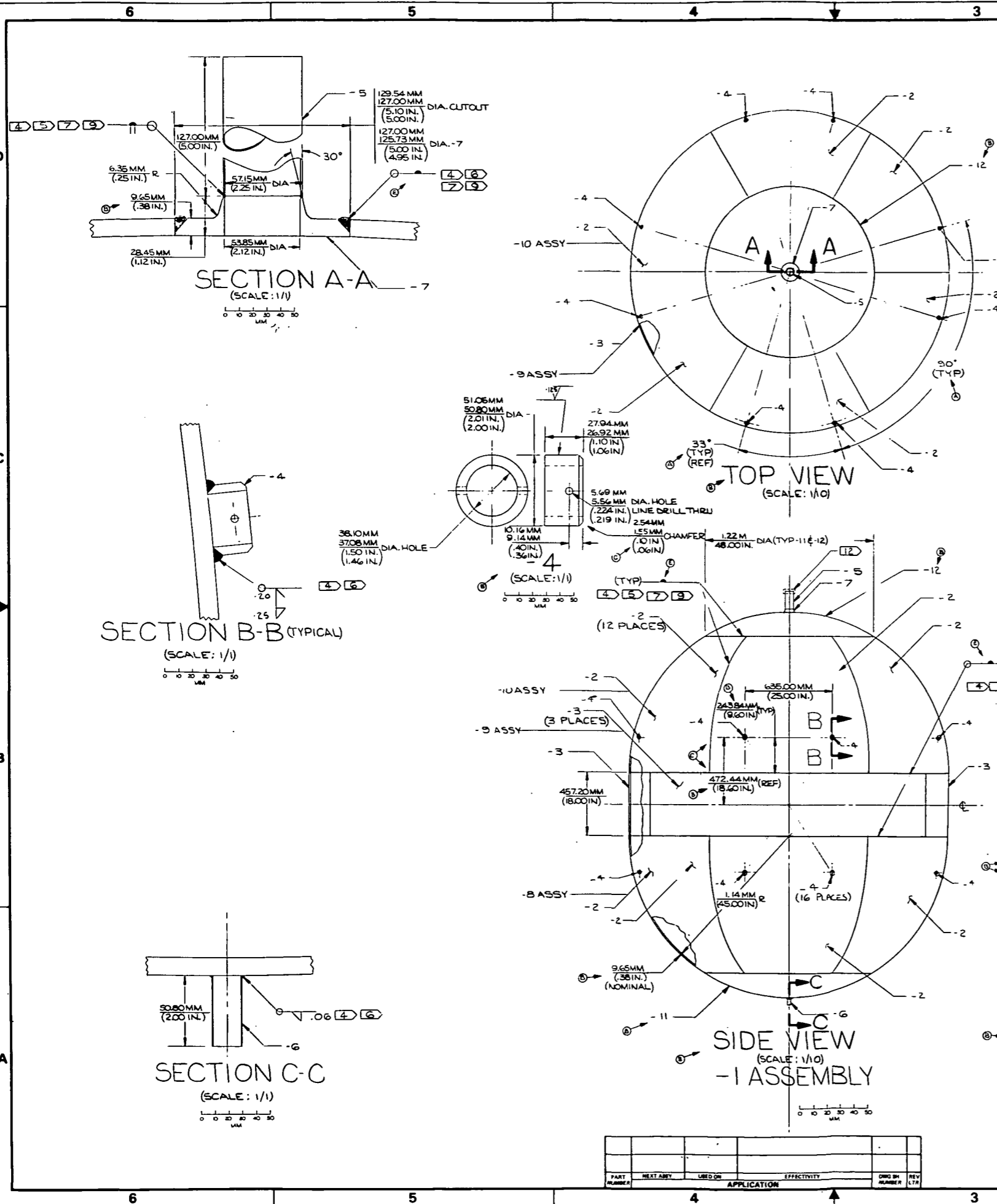


SECTION E-E
(SCALE 1/10)

Figure D-7

DIMENSIONING & TOLERANCING PER ANSI Y14.5 UNLESS OTHERWISE SPECIFIED DIMENSIONS ARE IN INCHES TOLERANCES ANGLES - DECIMALS IN ° RIVETS & BOLT EDGE MARGINS - ON BEND RADIUS - 31 ON 32 & 34 ON 35 ON OR GREATER SHEET METAL CORNER RADIUS - 1/16" 18 1/16" 22 1/16" 24 1/16" 28 1/16" 32 1/16" 36 1/16" 40 1/16" 44 1/16" 48 1/16" 52 1/16" 56 1/16" 60 1/16" 64 1/16" 68 1/16" 72 1/16" 76 1/16" 80 1/16" 84 1/16" 88 1/16" 92 1/16" 96 1/16" 100 1/16"	DATA SHEET STRIKE HALL & PREC DATE PROJECT APPROVAL	CONTRACT NUMBER NAS315848 DATE 2/23/54 PROJECT APPROVAL	THE BOEING COMPANY CORPORATE OFFICE WASHINGTON, D.C. HALF SCALE LH₂ TEST MODEL ASSEMBLY SHEET IDENT NO. E1203SK2-5085-137 SCALE LISTED SH 7 OF
--	---	---	---

SK2-5085-139



NOTES

PREPARATION AND STANDARDS FOR THE CONTROL OF MANUFACTURING OPERATIONS (AS APPLICABLE):	PART FINISHES PER SAC 5387
SURFACE ROUGHNESS PER MIL-STD-113	FINISH CODES PER MIL-STD-113
FORM, STRAIGHTNESS & SQUARENESS PER SAC 5387	RIVET INSTALLATION & SYMBOLS PER SAC 5387
GEOMETRIC TOLERANCES PER SAC 5387	

REV	DATE	APPROVED	DESCRIPTION
A	11/1/71	EWS	1. REVISED NOTES AND TEST REQUIREMENTS 2. ADDED FOUR -4 FITTINGS 3. VESSEL WALL THICKNESS WAS .50
B	6/19/71	EWS	1. ADDED -11 & -12 CAPS, AND TOLERANCES ON -4 FFG 2. ALTERED PROOF PRESSURE, GENERAL TOLERANCE, -4 LEAKING DIRECTION, AND -2 GORE QUANTITY
C	6/28/73	OWS	1. ALTERED [4], [10], AND .4 FFG AND LOCATING DIMENSIONS 2. ADDED [16]
D	9/11/73	OWS	1. ALTERED [3]
E	10/15/74	OWS	1. DELETED J WELD SYMBOL

- THIS PRESSURE VESSEL WILL BE USED FOR LIQUID HYDROGEN CONTAINMENT IN AN EVACUATED MULTILAYER INSULATION SYSTEM TEST MODEL WHERE IT FORMS THE INNER SURFACE OF THE INSULATION VACUUM ANNULUS. MAXIMUM INTERNAL PRESSURE DURING TESTS WILL BE 20 PSIA.
- 6061 CONDITION 10 ALUMINUM ALLOY PLATE PER QQ-A-250/11.
- 4043 T6 ALUMINUM ALLOY TUBE PER QQ-A-208/AC & WW-1-705/40
- WELD PER MIL-W-8088. INSPECT PER [16]. EDGE PREPARATION AS REQUIRED. FILLER WIRE ER 4043 PER QQ-A-566 TYPE 4043 OR MIL-E-14053 TYPE 4043.
- FIRST PASS GTA. SUBSEQUENT PASSES MAY BE GMA.
- GTA
- MAXIMUM OVERHEAD 0.04
- CLEAN INTERIOR OF HEADS AND CYLINDER PER [16] PRIOR TO FINAL CLOSEOUT WELD AT THE GIRTH.
- WELD SEAM MUST BE HELIUM LEAK TIGHT.
- CLEAN PER MIL-P-52111 (CE)
- GIRTH WELD IN "AS WELDED" CONDITION
- A SUITABLE CAP FOR PREVENTING CONTAMINATION OF THE VESSEL INTERIOR SHALL BE INSTALLED OVER THE OUTLET RUM. THIS CAP SHALL BE IN PLACE AT ALL TIMES EXCEPT DURING MANUFACTURING OPERATIONS AND TESTING.
- HEAD MAY BE FABRICATED BY SPINNING OR AS A WELDED GORE ASSEMBLY
- HEAT TREAT TO T6
- TOLERANCE ON PRESSURE VESSEL DIAMETER = .00
- WELD QUALITY SHALL BE DETERMINED BY 100 PERCENT VISUAL AND RADIOGRAPHIC INSPECTION. RADIOGRAPHIC INSPECT PER MIL-STD-453 TO MEET RADIOGRAPHIC QUALITY LEVEL 2 (TABLE 1). PENETRANT INSPECTION SHALL NOT BE USED. WELD QUALITY SHALL MEET REQUIREMENTS SPECIFIED FOR CLASS A WELD IN SAC 5928 TABLES 10 AND 101.

- TEST REQUIREMENTS
- THE SUPPLIER SHALL TEST THE PRESSURE VESSEL AND PROVIDE CERTIFIED TEST REPORTS TO SHOW COMPLIANCE WITH THE REQUIREMENTS LISTED BELOW. TEST SEQUENCE IS AS FOLLOWS:
- COLD SHOCK
COLD SHOCK WITH LIQUID NITROGEN
NOTE: REMOVE CAP [16] DURING TEST
 - INTERNAL PROOF PRESSURE TEST
HYDROSTATICALLY PROOF PRESSURE TEST AT ROOM TEMPERATURE TO 40 PSI WITH DEIONIZED WATER
 - WELD SEAM TEST CHECK
HELIUM LEAK CHECK WELD SEAMS INCREMENTALLY USING A VACUUM CUP ARRANGEMENT CONNECTED TO A LEAK DETECTOR. PRESSURIZE VESSEL INTERIOR TO 5 PSI WITH HELIUM/AIR MIXTURE AT ROOM TEMPERATURE. AFTER COMPLETE CHECK OF WELD SEAMS REPAIR AS NECESSARY. REPEAT TESTS 1.0, 2.0 AND 3.0 AFTER REPAIRS.

QTY	QTY	QTY	QTY	QTY	QTY	CODE	PART OR IDENTIFYING NUMBER	NOMENCLATURE OR DESCRIPTION	ZONE	MATERIAL AND SPECIFICATION	HT TR	FINISH	PT	REF	REV
REQD	REQD	REQD	REQD	REQD	REQD	REQD									
1	-	-	-	-	-	-	-12	CAP		[2]					
-	-	-	-	-	-	-	-11	CAP		[2]					
-	-	-	-	-	-	-	-10	HEAD ASSY		[8] [13] [14]					
-	-	-	-	-	-	-	-9	CYLINDER ASSY		[8] [14]					
-	-	-	-	-	-	-	-8	HEAD ASSY		[8] [13] [14]					
1	-	-	-	-	-	-	-7	FLANGE		[2]					
-	-	-	-	-	-	-	-6	TUBE		.875 DIA * .035 WALL [3]					
-	-	-	-	-	-	-	-5	TUBE		2.25 DIA * .035 WALL [2]					
8	-	-	-	-	-	-	-4	FITTING		[2]					
-	-	-	-	-	-	-	-3	PLATE		[2]					
6	-	-	-	-	-	-	-2	GORE		[2]					
-	-	-	-	-	-	-	-1	VESSEL ASSY		[15]					

FASTENER CODES

DISCREPANCY & TOLERANCING PER ANSI (UNLESS) Y 14.5	UNLESS OTHERWISE SPECIFIED DIMENSIONS ARE IN INCHES	TOLERANCES: ANGLES ± .125	DECIMALS .001	RIVET & BOLT EDGE MARGINS AS BEND RADIUS ± 0.01 ON .20 & .25	± .02 ON .20 & GREATER	SHEET METAL CORNER RADIUS INT. .16 EXT. .22	EXT. .25 .40
--	---	---------------------------	---------------	--	------------------------	---	--------------

DATE REVIEW: 2-5570

PROJECT APPROVAL: [Signature]

FASTENER CODES: [Table]

FASTENER CODES: [Table]

SK2-5085-139 E

SK2-5085-139

Figure D-8

SKS-2082-14015

REV	DATE	APPROVED	DESCRIPTION
A	4/16/75	EBM	DELETED - 9 & 5 ADDED - 15
B	7/16/75	EBM	ADDED 4 LOCATING - 17 & 18 SECTION 2C3, DETAIL C5 DETAIL 2C4, DETAIL C2 DELETED STRUT EXT - 16
C	7/16/75	EBM	DELETED - 8 & 11 - 10 SPACER WAS 10 PLACES

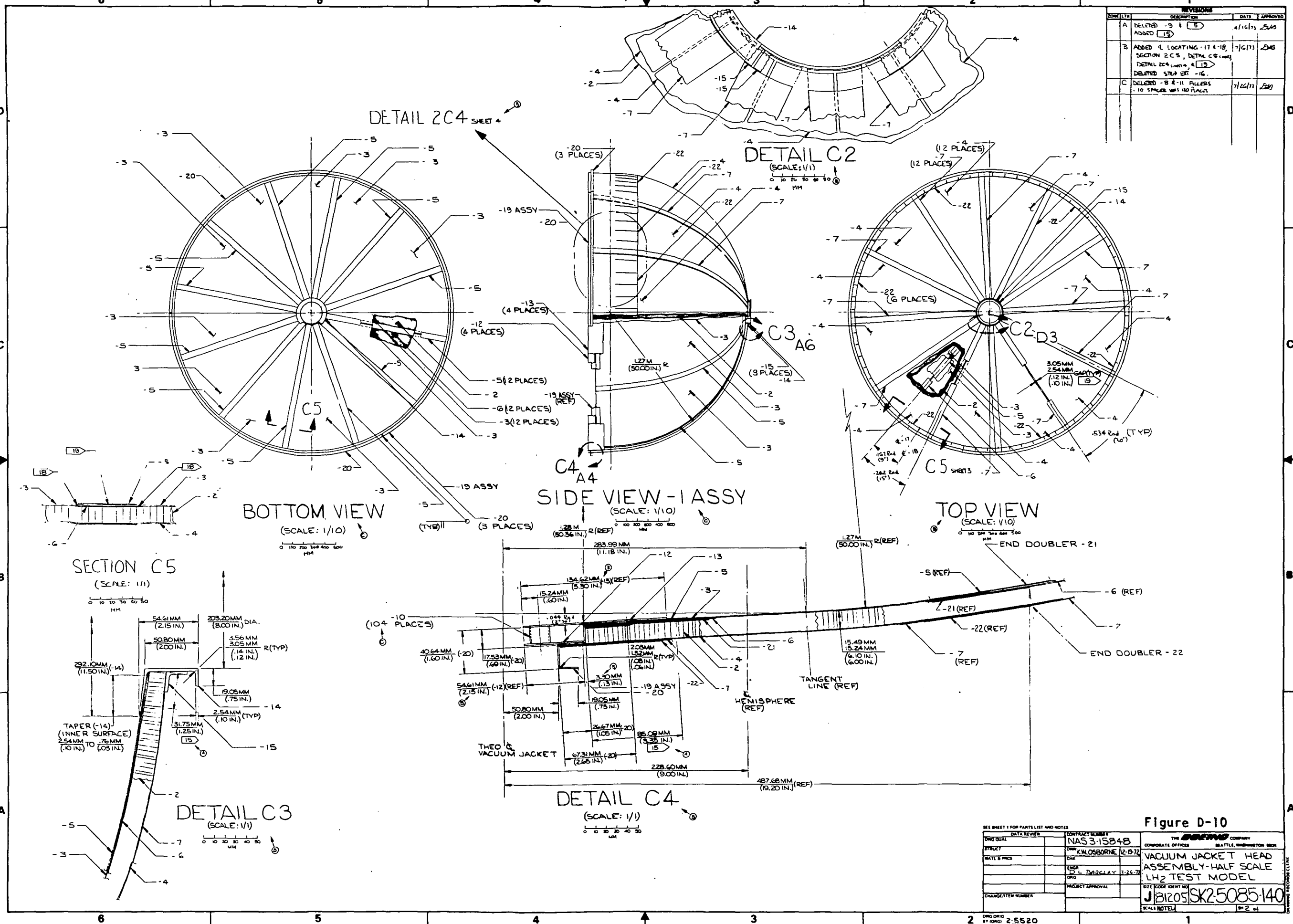
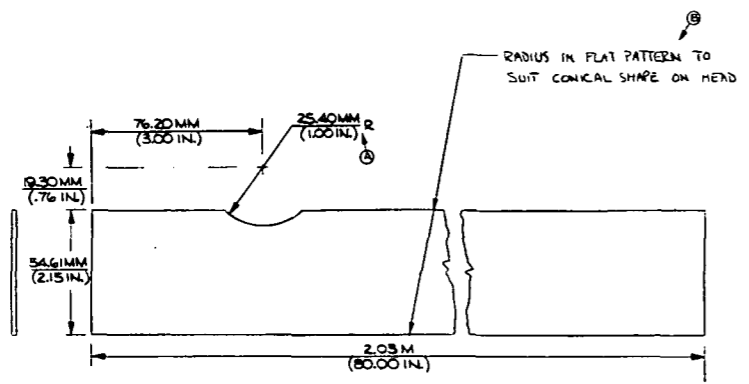


Figure D-10

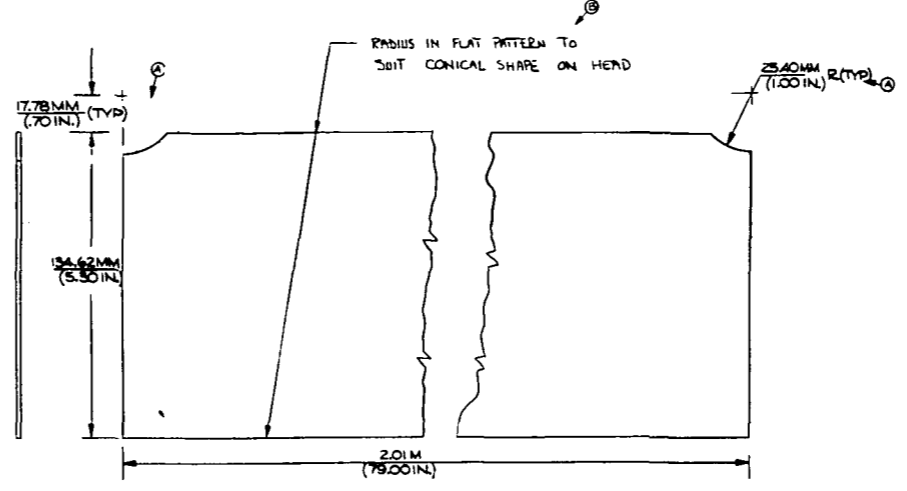
CONTRACT NUMBER	NAS 3-15848	THE OSBORN COMPANY
DATE	12-19-72	CORPORATE OFFICES SEATTLE, WASHINGTON 98108
DESIGNED BY	K.W. OSBORNE	PROJECT APPROVAL
CHECKED BY	J.P. WARE	DATE
ENGINEER	J.P. WARE	SCALE
PROJECT NUMBER	SK2-5085-140	SHEET
CHANGELIST NUMBER		OF

SKS-2082-14015 SK2-5085-14012

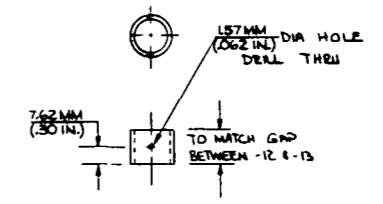
REV	DATE	DESCRIPTION	APPROVED
A	7/14/71	-10 SPACER WAS 170 PLACES 1-00 RAD WAS 1-12 RAD (42 PLACES)	CBP
B	11/18/74	ADDED DETAIL -10, 2ND NOTE FOR -12 & -13 14 WAS B IN 2B4 21 WAS 14 IN B4	CBP



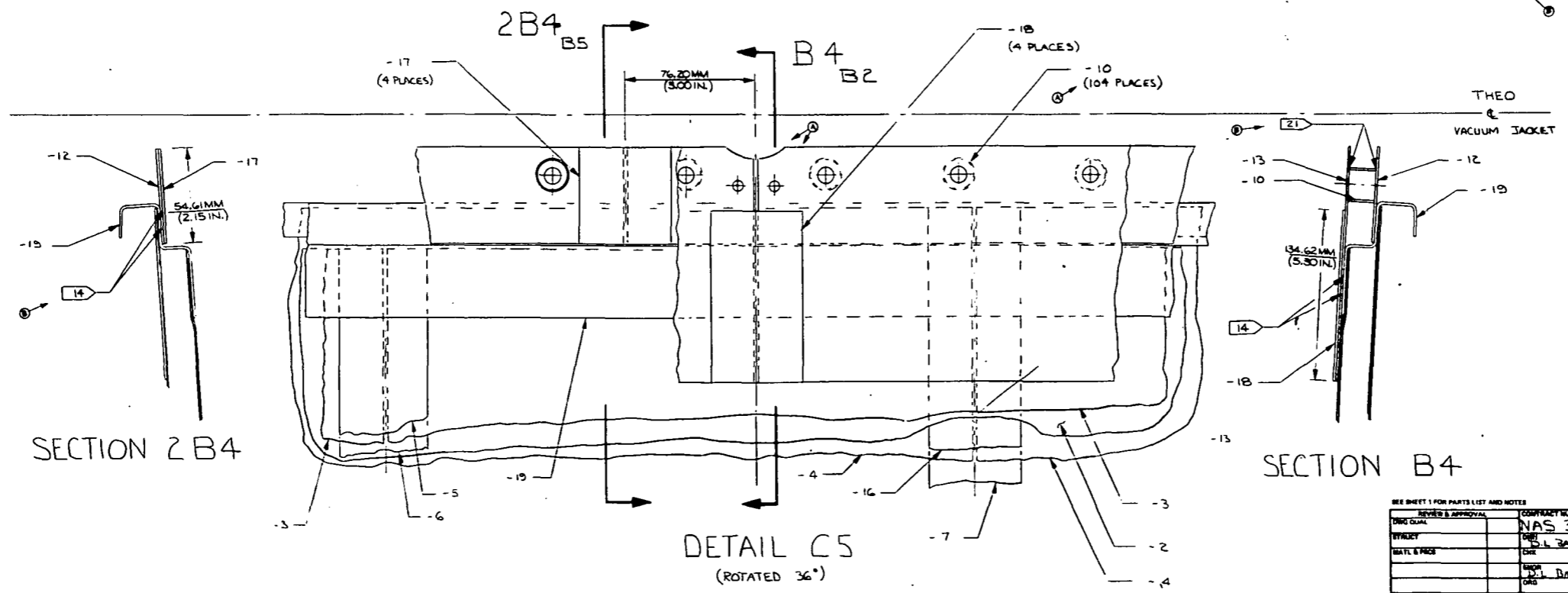
-12



-13



-10



SECTION 2 B4

SECTION B4

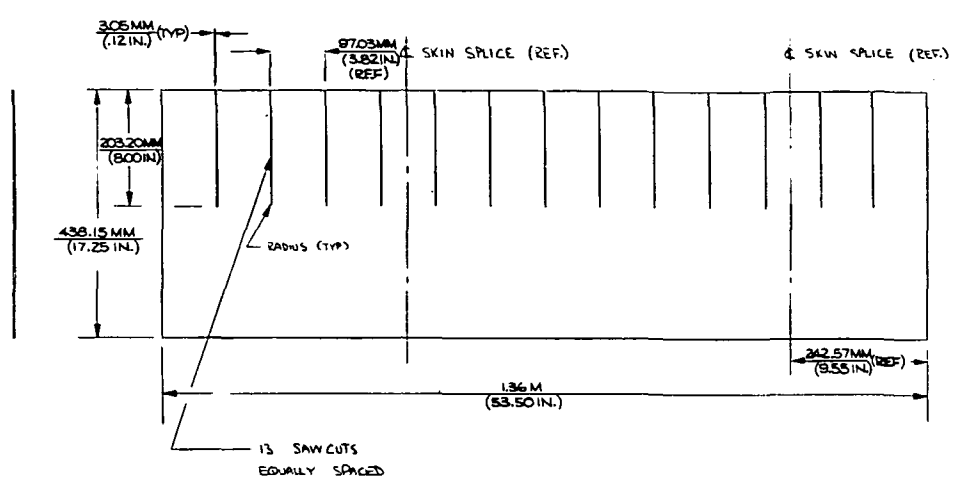
DETAIL C5
(ROTATED 36°)

Figure D-11

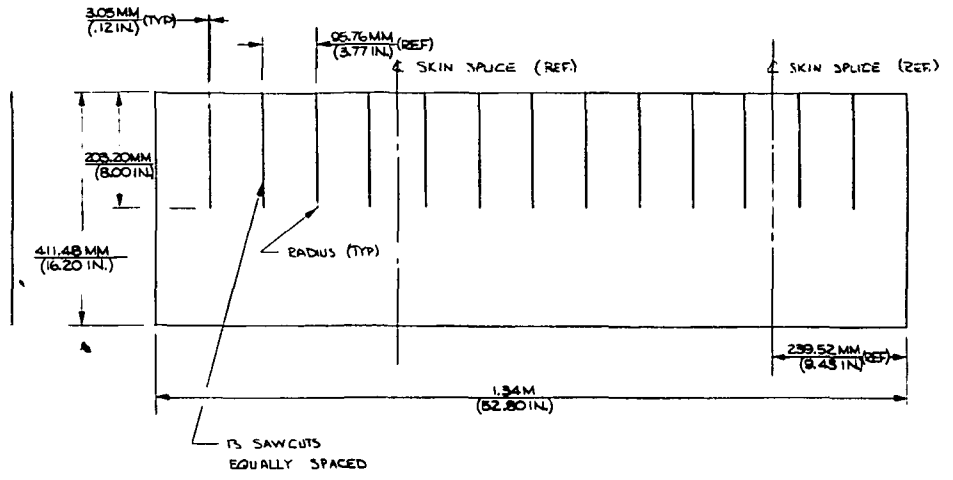
DESIGNED & APPROVED	CONTRACT NUMBER	THE BEND COMPANY CORPORATE OFFICES SEATTLE, WASHINGTON 98101
DRAWN	NAS 3-15848	
CHECKED	DATE	VACUUM JACKET HEAD ASSEMBLY - HALF SCALE LH ₂ TEST MODEL
DATE & PAGE	DATE	
PROJECT APPROVAL	PROJECT APPROVAL	J18205 SK2-5085-140 SCALE 1/1
CHANGE/ITER NUMBER	CHANGE/ITER NUMBER	

SK2-5085-140 B3

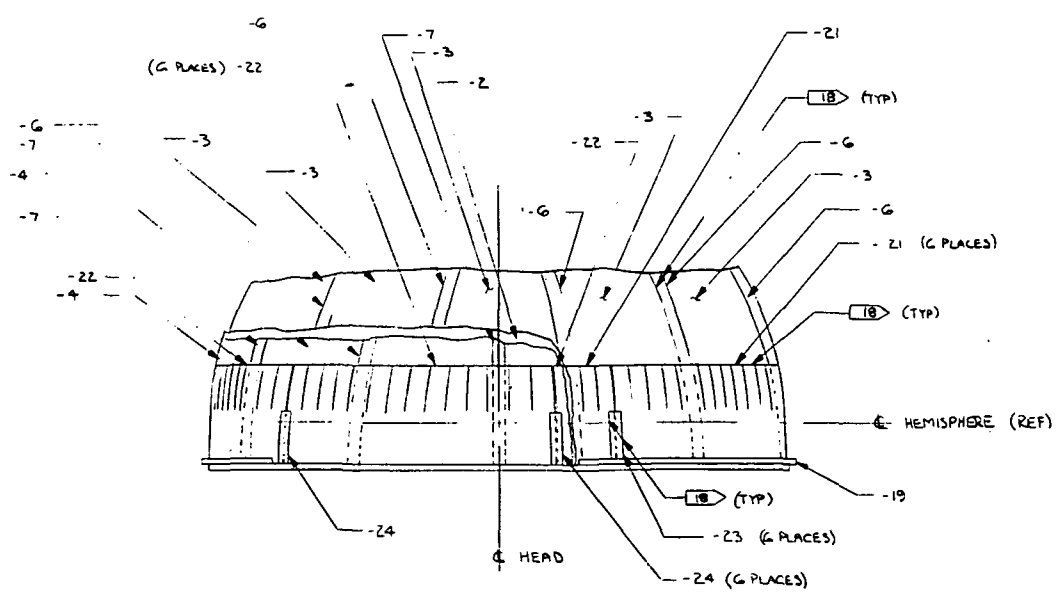
041-2802-SK2



-22
(SCALE: 1/4)
0 40 80 120 160 200
MM



-21
(SCALE: 1/4)
0 40 80 120 160 200
MM



DETAIL 2C4 (ROTATED 90°)
(SCALE: 1/10)
0 100 200 300 400 500
MM

Figure D-12

REVISIONS		CONTRACT NUMBER	
REV	DESCRIPTION	NAS 3-15848	THE SPENCER COMPANY
1			CORPORATE OFFICES SEATTLE WASHINGTON WASH
DRAWN & CHECKED		DATE	PROJECT APPROVAL
DATE: 8/19/52		DATE: 8/19/52	
DRAWN BY: ST. BARKLEY		DATE: 8/19/52	
CHECKED BY: ST. BARKLEY		DATE: 8/19/52	
PROJECT APPROVAL		DATE: 8/19/52	
CHANGE/ITEM NUMBER		SCALE IDENT NO.	
		J181205	
		SK2-5085-140	
		SCALE: 1/4	

SK2-5085-140 4

4041-2802-SK2

LIST OF MATERIAL

QTY REQD	PART OR IDENTIFYING NUMBER	NOMENCLATURE OR DESCRIPTION	MATERIAL AND SPECIFICATION
1	-21	OUTER PANEL ASSEMBLY (SHORT)	9
1	-20	↑	↑
1	-19	↑	↑
1	-18	↓	↓
1	-17	↓	↓
1	-16	OUTER PANEL ASSEMBLY (SHORT)	9
1	-15	OUTER PANEL ASSEMBLY (LONG)	8
1	-14	↑	↑
1	-13	↑	↑
1	-12	↑	↑
1	-11	↓	↓
1	-10	↓	↓
1	-9	OUTER PANEL ASSEMBLY (LONG)	8
1	-8	OUTER MLI POLAR CAP ASSEMBLY	1
1	-7	OUTER MLI POLAR CAP ASSEMBLY	1
1	-6	INNER MLI POLAR CAP ASSEMBLY	1
1	-5	INNER MLI POLAR CAP ASSEMBLY	1
	-4	OUTER MLI PANEL ASSEMBLY (SHORT)	1
	-3	OUTER MLI PANEL ASSEMBLY (LONG)	1
	-2	INNER MLI PANEL ASSEMBLY (SHORT)	1
	-1	INNER MLI PANEL ASSEMBLY (LONG)	1
QTY REQD	PART OR IDENTIFYING NUMBER	NOMENCLATURE OR DESCRIPTION	MATERIAL AND SPECIFICATION

LIST OF MATERIAL

FIGURE D-15

SIZE A	CODE IDENT NO. 81205	SK 2-5085-142
SCALE	SHEET 2	

REV
LTR A

LIST OF MATERIAL

A
A
A
A
A
A

QTY REQD	PART OR IDENTIFYING NUMBER	NOMENCLATURE OR DESCRIPTION	MATERIAL AND SPECIFICATION
1	-42	SIMULATED PLMB WRAP SUPPORT	
1	-41	SIMULATED PLMB WRAP ASSY. (LONG)	
1	-40	SIMULATED PLMB WRAP ASSY. (SHORT)	
1	-39	INLET TUBE WRAP SUPPORT	
1	-38	INLET TUBE WRAP ASSEMBLY (LONG)	
1	-37	INLET TUBE WRAP ASSEMBLY (SHORT)	
1	-36	INNER PANEL ASSEMBLY (LONG)	6
1	-35		
1	-34		
1	-33		
1	-32		
1	-31		
1	-30	INNER PANEL ASSEMBLY (LONG)	6
1	-29	INNER PANEL ASSEMBLY (SHORT)	7
1	-28		
1	-27		
1	-26		
1	-25		
1	-24		
1	-23	INNER PANEL ASSEMBLY (SHORT)	7
1	-22	OUTER PANEL ASSEMBLY (SHORT)	9
QTY REQD	PART OR IDENTIFYING NUMBER	NOMENCLATURE OR DESCRIPTION	MATERIAL AND SPECIFICATION

LIST OF MATERIAL

FIGURE D-16

SIZE

A

CODE IDENT NO.

81205

SK2-5085-142

1 BLANKET DENSITY = 75 LAYERS/INCH.
 ONE LAYER EQUALS ONE .14 MIL
 DOUBLE ALUMINIZED MYLAR SHIELD
 (OR ONE .30 MIL DOUBLE ALUMINIZED
 KAPTON, WHICHEVER IS SPECIFIED) PLUS
 ONE DACRON NET (B4A) SPACER.
 NUMBER OF SHIELDS = 42
 NUMBER OF SPACERS = 41
 OUTER PANEL SURFACES CONSIST OF
 2 DACRON NET (B4A) LAYERS.

2 VELCRO HOOK #100
 (THE HARTWELL CORP) 1.00 INCH
 WIDE POLYESTER FASTENING TAPE 11

3 VELCRO PILE (THE HARTWELL CORP.)
 2.00 INCH WIDE POLYESTER
 FASTENING TAPE 11

4 EE-6600 (PERMACEL) REFLECTIVE,
 POLYESTER, INTERLINED, PRESSURE
 SENSITIVE TAPE.

USE FOR DRAWINGS AND HAND PRINTED MATERIAL ONLY - NO TYPEWRITTEN MATERIAL

Figure D-18

SIZE A	CODE IDENT NO. 81205	SK2-5085-142
SCALE		SHEET 5

5 7402 (BORDON, MYSTIK) ALUMINUM FOIL,
SILICONE ADHESIVE, PRESSURE SENSITIVE TAPE.
POSITION TWO FOIL LAYERS TO
SANDWICH THE TWO OUTER DACRON NET
LAYERS AND THE NYLON PIN BUTTONS
BETWEEN THE ADHESIVE BACKED FOIL SURFACES.

6 MAKE FROM -1

7 MAKE FROM -2

8 MAKE FROM -3

9 MAKE FROM -4

10 ALL HOLES, EDGES, AND SLITS
CUT NORMAL TO PANEL CURVATURE

11 BOND WITH KNIFE COAT OF
EC 3532 (3M) STRUCTURAL ADHESIVE

12 FASTENER AND THERMOCOUPLE DIMENSIONS
MEASURED ALONG PANEL CURVATURE

FIGURE D-19

SIZE A	CODE IDENT NO. 81205	SK2-5085-142
SCALE		SHEET 6




- 13 HEAT FORM RETENTION BALL
- 14 LOCATIONS TO MATCH DETAIL IV
LOCATIONS ON INNER PANELS
- 15 FORM SHIELD TO CONTOUR BY DRAPING
OVER LAYUP TOOL THEN FOLDING
THE WRINKLES ALONG THE EDGES FLAT.
TAPE FOLDS IN PLACE WITH ,
1.00 x .15 IN. ARRANGE FOLDS TO AVOID
A LOCAL THICKNESS BUILDUP IN THE
BLANKET.
- 16 TAPE THERMOCOUPLES IN PLACE
WITH , 1.00 x .15 IN.
- 17 E-36-2-507-001 #36 CHROMEL
-CONSTANTAN THERMOCOUPLE WIRE,
TEFLON INSULATED.
- 18 RADIATION SHIELDS ARE NUMBERED
STARTING FROM THE INNER LAYER
OF EACH PANEL.
- 19 EXTEND OUTER SURFACE DACRON NET
(B4A), 2 LAYERS, 1.50 IN. BEYOND TRIM
EDGE OF PANEL AT EDGE SHOWN.

FIGURE D-20

SIZE 	CODE IDENT NO. 81205	5K2-5085-142
SCALE		SHEET 7

ASSEMBLY PROCEDURES

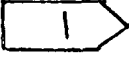



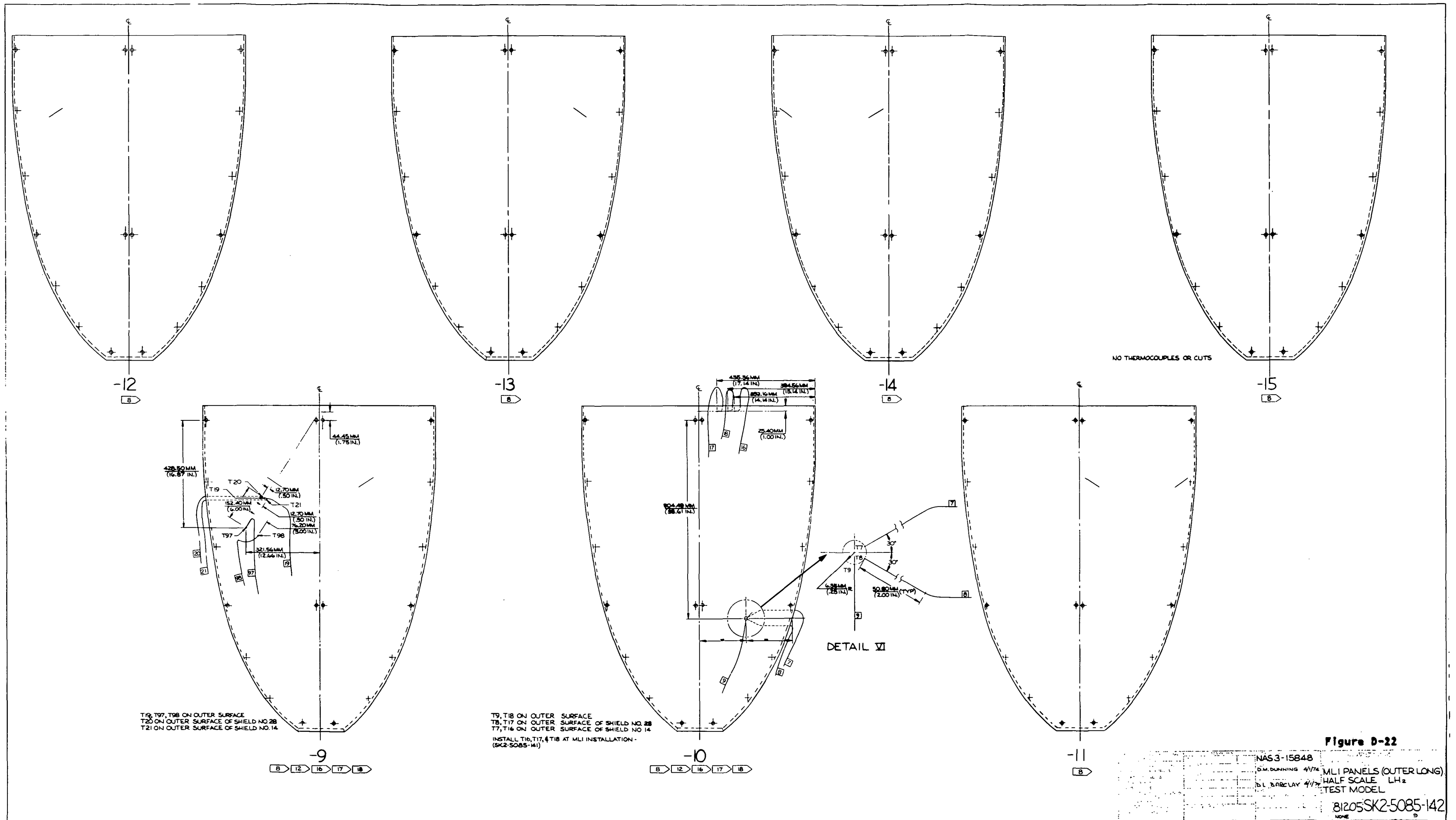
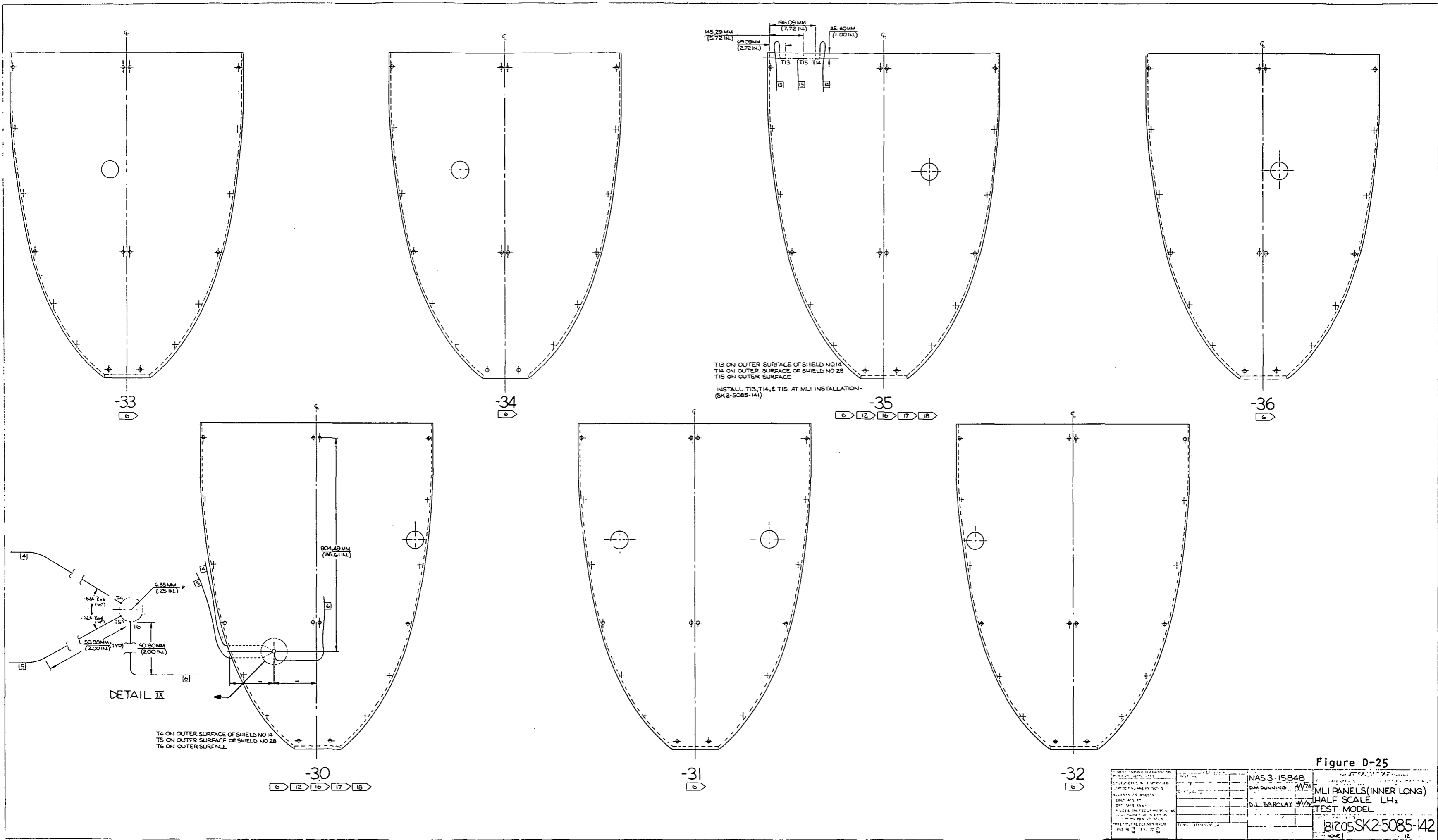
1. WHITE NYLON GLOVES OR EQUIVALENT SHALL BE USED IN HANDLING ALL MATERIAL TO INSURE CLEANLINESS. ALL MATERIALS SHALL BE FREE OF DIRT, GREASE, OR OTHER CONTAMINATION MATERIAL.
2. LAY UP ALTERNATE LAYERS OF 1 RADIATION SHIELDS AND DACRON NET PER  . CONTOUR SHIELDS PER .
3. WHEN SPECIFIED, INSTALL THERMOCOUPLES  DURING INSULATION LAY-UP. TAPE THERMOCOUPLES IN PLACE PER .
4. WHITE NYLON COATS OR EQUIVALENT SHALL BE WORN DURING FABRICATION AND INSTALLATION OF MLI PANEL ASSEMBLIES TO INSURE INSULATION CLEANLINESS.

FIGURE D-21

SIZE A	CODE IDENT NO. 81205	SK2-5085-142
SCALE		SHEET 9





T13 ON OUTER SURFACE OF SHIELD NO 14
 T14 ON OUTER SURFACE OF SHIELD NO 28
 T15 ON OUTER SURFACE
 INSTALL T13, T14, & T15 AT MLI INSTALLATION-
 (SK2-5085-141)

T4 ON OUTER SURFACE OF SHIELD NO 14
 T5 ON OUTER SURFACE OF SHIELD NO 28
 T6 ON OUTER SURFACE

Figure D-25

PROJECT: SK2-5085-142	DATE: 4/74	DESIGNER: D.L. BARCLAY	SCALE: HALF SCALE
TITLE: MLI PANELS (INNER LONG)	NO. OF SHEETS: 12	SHEET NO.: 12	TEST MODEL
81205SK2-5085-142			

SKS-2082-149

REV	DATE	DESCRIPTION	APPROVED

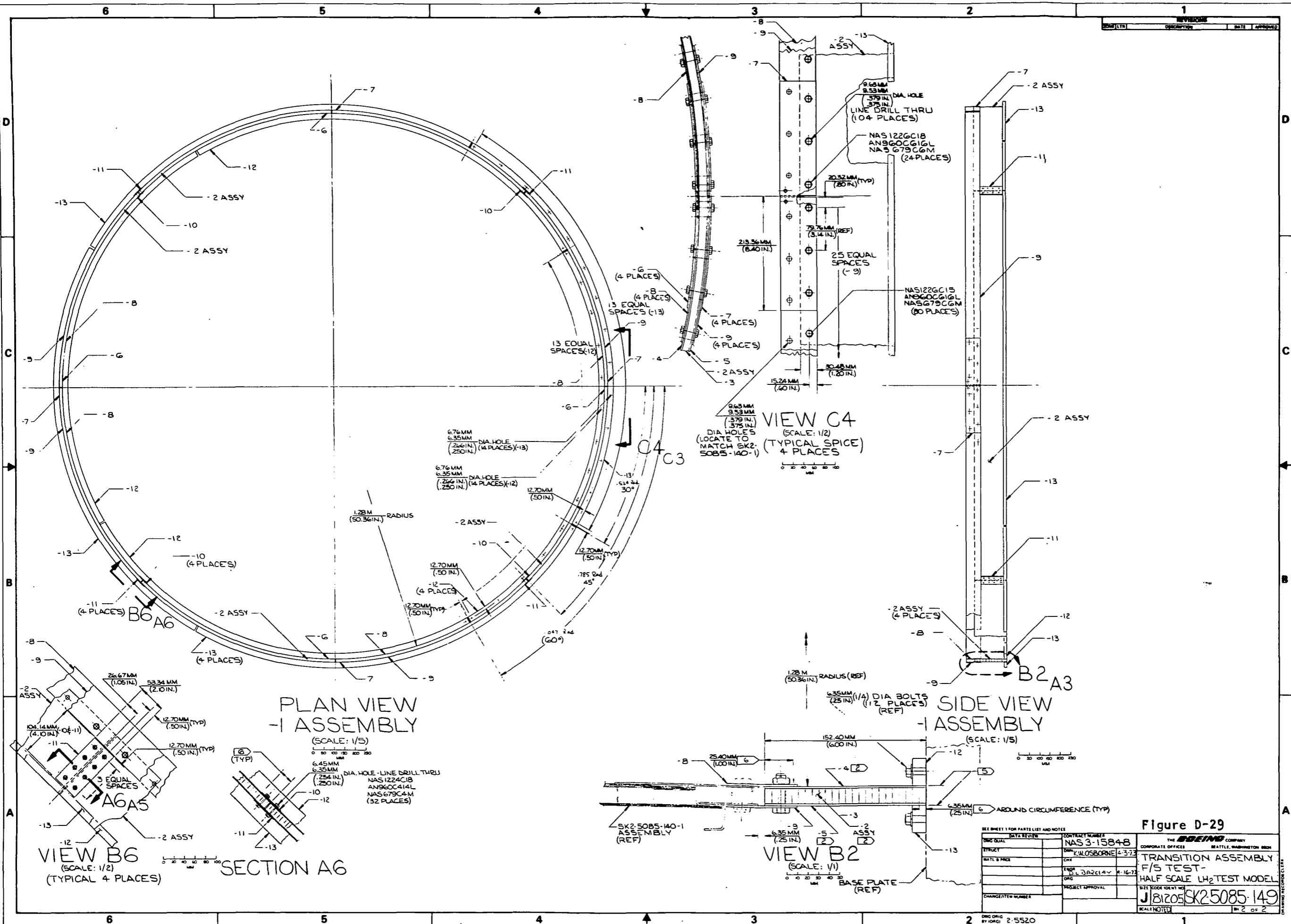


Figure D-29

DRAWING DATA		CONTRACT NUMBER	
DRG NO.	DATE	NAS 3-15848	
DATE & PRICE	CHK	K.W. OSBORNE 4-3-73	
ENGR	APP	L. JARZELAK 4-16-73	
PROJECT APPROVAL			
CHANGESTW NUMBER			

THE BOEING COMPANY	
CORPORATE OFFICES	SEATTLE, WASHINGTON 98108
TRANSITION ASSEMBLY	
F/S TEST -	
HALF SCALE LH2 TEST MODEL	
SIZE (FOR IDENT NO.)	J181205 SK25085-149
SCALE NOTED	2 OF 2

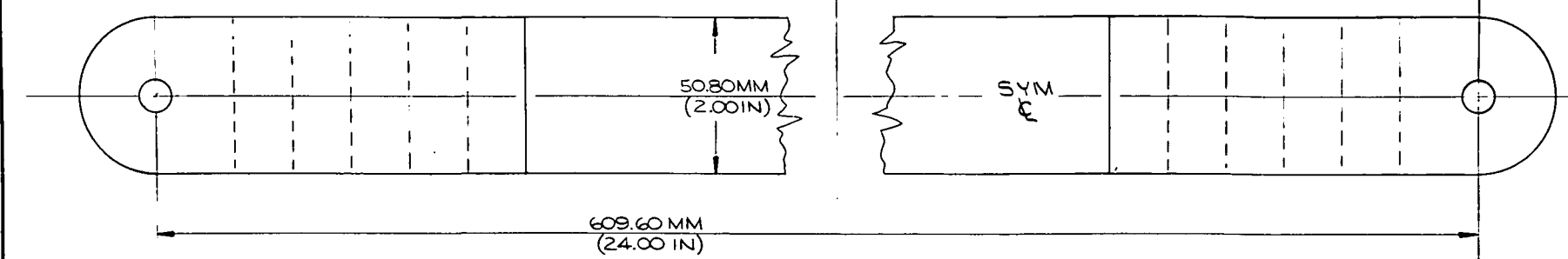
SKS-2082-149

SYM

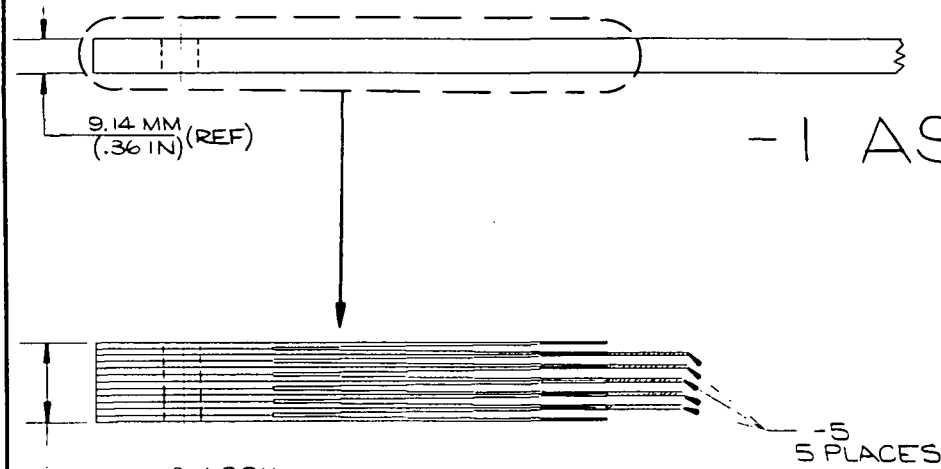
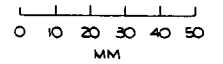
NOTES

- 1. SPECIFICATIONS AND STANDARDS FOR THE CONTROL OF MANUFACTURING OPERATIONS (AS APPLICABLE):
 SURFACE ROUGHNESS SYMBOLS PER BAC 2007 PART MARKING PER BAC 537
 WELDING AND BRAZING SYMBOLS PER BAC 2022 BOLT & NUT INSTALLATION PER BAC 5000
 FORM, STRAIGHTEN & FIT METAL PARTS PER BAC 5300 FINISH CODES PER DOCUMENT D2-5000
 MATERIAL SUBSTITUTIONS & EQUIVALENTS PER BAC 5008 RIVET INSTALLATION & SYMBOLS PER BAC 5004

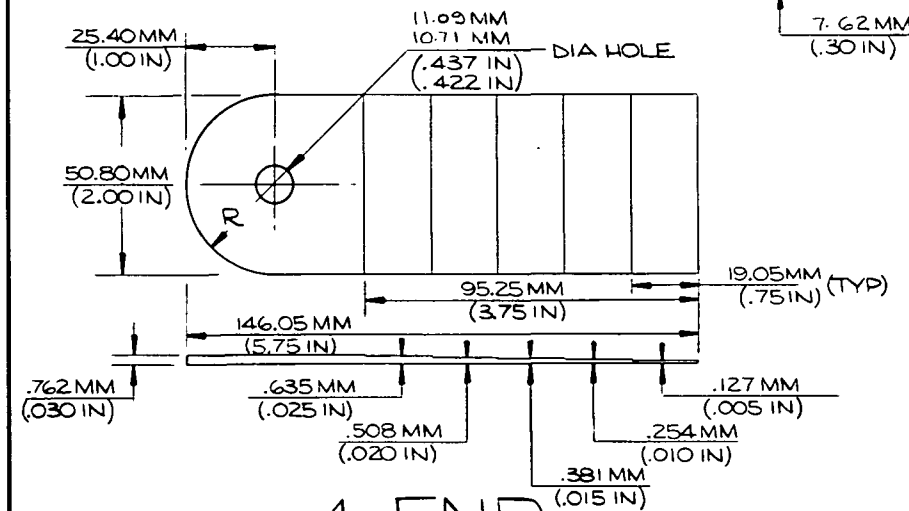
REVISIONS			
LTR	DESCRIPTION	DATE	APPROVED



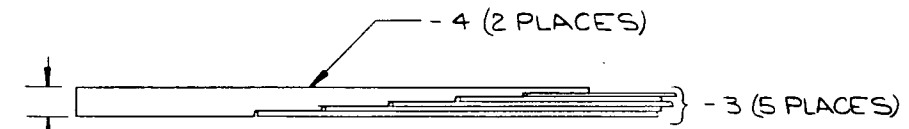
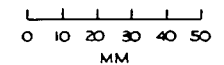
- 1 ASSEMBLY
(SCALE: 1/1)



DETAIL I
(-3's OMITTED FOR CLARITY)
(NO SCALE)



- 4 END FITTING
(SCALE: 1/1)



- 2 ASSEMBLY
(NO SCALE)
SIDE VIEW ONLY

- 1 CUT FROM 50.80MM (2.0 IN) WIDE PREPREG [2] P20 49-3 [3] TAPE
- 2 RESIN SYSTEM ERLA 4617 (UNION CARBIDE CORP.) WITH PHENYLENEDIAMINE (C) CATALYST (ALLIED CHEMICALS)
- 3 PRD-3 SINGLE END YARN - 300 DENIER - 400 FILAMENTS PER YARN - CONTINUOUS - PRODUCERS TWIST - NO FINISH (E.I. DUPONT)
- 4 GAL-4V TITANIUM SHEET PER MIL-T-9046E, TYPE III, COMP C.
- 5 FIBERGLASS EPOXY PRE PREG PER SMS B-139, TYPE 120, 2 PLY.
- 6 CURE WITH VACUUM BAG PRESSURE TWO HOURS AT 333°K (150°F) & FOUR HOURS AT 422°K (300°F)
- 7 CLEAN FAYING SURFACES OF -4 END FITTINGS PER HYSOL BULLETIN A9-123 & BOND WITH EA 934 (HYSOL DIVISION THE DEXTER CORP) WITH VACUUM BAG PRESSURE PER HYSOL BULLETIN A5-134.
- 8 CHEMICAL MILL PER BAC 5842.

QTY REQD	QTY BLD	CODE IDENT NUMBER	PART OR IDENTIFYING NUMBER	NOMENCLATURE OR DESCRIPTION	MATERIAL AND SPECIFICATION	HT TR	FINISH	PT MK	SERIALIZATION	REV LTR
-	5		-5	FILLER	50.80 MM WIDE [5]					
2	-		-4	END FITTING	.76x 50.80 x 146.08 mm [4] [8]					
5	-		-3	TAPE	50.80 MM WIDE [1]					
-	12		-2	LAMINATE ASSEMBLY	[6]					
-	-		-1	SUPPORT STRAP ASSEMBLY	[7]					

PART NUMBER	REV LTR	ISSUED ON	APPLICATION	EFFECTIVITY

FASTENER CODES

DIMENSIONING & TOLERANCING PER ANSI (UNLESS OTHERWISE SPECIFIED)	DATA REVIEW
UNLESS OTHERWISE SPECIFIED DIMENSIONS ARE IN INCHES	DRG QUAL
TOLERANCES: ANGLES: 1°	STRUCT
DECIMALS .XX: .02	MATL & PRCS
DECIMALS .XXX: .001	
RIVET & BOLT EDGE MARG: .05	
BEND RADI: .01 ON .03 & .05	
.03 ON .06 & GREATER	
SHEET METAL CORNER RADI:	
INT: .16-.18 EXT: .22-.25	

CONTRACT NUMBER: **NAS3-15848**

THE **BOEING** COMPANY
CORPORATE OFFICES SEATTLE, WASHINGTON 98108

DESIGNER: **K.W.OSBORNE 4-4-3**

ENGR: **D.L.BARCLAY 4-11-3**

PROJECT APPROVAL

CHANGE/ITEM NUMBER

SCALE NOTED

SIZE: **D** CODE IDENT NO: **SK2-5085-133**

SCALE NOTED

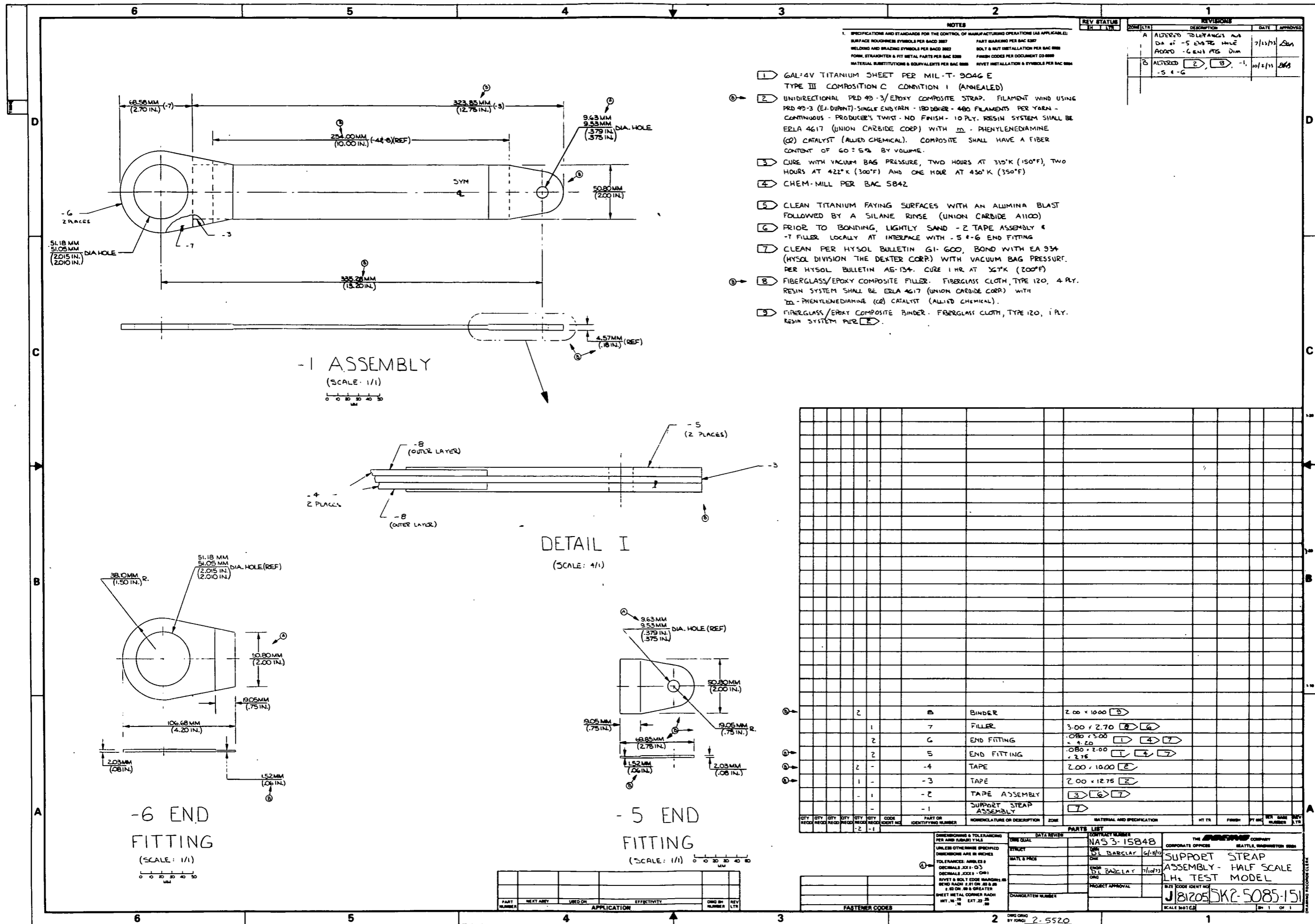
DRG ORG BY (ORG): **2.5520**

Figure D-30

SK2-5085-133

DO 6000 1225

CONTAINING UNCLASSIFIED DATA



NOTES

1. SPECIFICATIONS AND STANDARDS FOR THE CONTROL OF MANUFACTURING OPERATIONS (AS APPLICABLE):
 SURFACE ROUGHNESS SYMBOLS PER BACD 2807
 WELDING AND BRAZING SYMBOLS PER BACD 2802
 FORM, STRAIGHTEN & FIT METAL PARTS PER BAC 8200
 MATERIAL SUBSTITUTIONS & EQUIVALENTS PER BAC 8800

2. PART MARKING PER BAC 8307
 BOLT & NUT INSTALLATION PER BAC 8800
 FINISH CODES PER DOCUMENT D3-8800
 RIVET INSTALLATION & SYMBOLS PER BAC 8800

REV	STATUS	DATE	APPROVED
A	ALTERED TO LET ANGLES AND DIA OF -5 END FITTING HOLE	7/11/73	200
B	ALTERED -5 & -6	10/2/73	200

- 1 GALV 4V TITANIUM SHEET PER MIL-T-9046 E TYPE III COMPOSITION C CONDITION 1 (ANNEALED)
- 2 UNIDIRECTIONAL PED 49-3/ EPOXY COMPOSITE STRAP. FILAMENT WIND USING PRD 49-3 (E.I. DUPONT) SINGLE END YARN - 180 DENIER - 480 FILAMENTS PER YARN - CONTINUOUS - PRODUCER'S TWIST - NO FINISH - 10 PLY. RESIN SYSTEM SHALL BE ERLA 4617 (UNION CARBIDE CORP) WITH MD - PHENYLENEDIAMINE (CD) CATALYST (ALLIED CHEMICAL). COMPOSITE SHALL HAVE A FIBER CONTENT OF 60 ± 5% BY VOLUME.
- 3 CURE WITH VACUUM BAG PRESSURE, TWO HOURS AT 315°K (150°F), TWO HOURS AT 422°K (300°F) AND ONE HOUR AT 450°K (350°F)
- 4 CHEM-MILL PER BAC 5842
- 5 CLEAN TITANIUM FAYING SURFACES WITH AN ALUMINA BLAST FOLLOWED BY A SILANE RINSE (UNION CARBIDE A1100)
- 6 PRIOR TO BONDING, LIGHTLY SAND - 2 TAPE ASSEMBLY & -7 FILLER LOCALLY AT INTERFACE WITH -5 & -6 END FITTING
- 7 CLEAN PER HYSOL BULLETIN 61-600, BOND WITH EA 934 (HYSOL DIVISION THE DEXTER CORP) WITH VACUUM BAG PRESSURE. PER HYSOL BULLETIN A5-134. CURE 1 HR AT 327°K (200°F)
- 8 FIBERGLASS/EPOXY COMPOSITE FILLER. FIBERGLASS CLOTH, TYPE 120, 4 PLY. RESIN SYSTEM SHALL BE ERLA 4617 (UNION CARBIDE CORP) WITH MD - PHENYLENEDIAMINE (CD) CATALYST (ALLIED CHEMICAL).
- 9 FIBERGLASS/EPOXY COMPOSITE BINDER. FIBERGLASS CLOTH, TYPE 120, 1 PLY. RESIN SYSTEM PER 2.

QTY	QTY	QTY	QTY	QTY	QTY	CODE	PART OR IDENTIFYING NUMBER	NOMENCLATURE OR DESCRIPTION	ZONE	MATERIAL AND SPECIFICATION	HT	FR	FINISH	PT	MR	DATE	REV
2						-2	-1	BINDER		2.00 x 10.00							
1							7	FILLER		3.00 x 2.70							
2							6	END FITTING		.080 x 5.00 x 4.20							
2							5	END FITTING		.080 x 2.00 x 2.75							
2							-4	TAPE		2.00 x 10.00							
1							-3	TAPE		2.00 x 12.75							
-1							-2	TAPE ASSEMBLY		2.00 x 12.75							
-1							-1	SUPPORT STRAP ASSEMBLY									

PARTS LIST

IDENTIFYING NUMBER: NAS 3-15848

DATE & PRICE: 6/1/73

PROJECT APPROVAL: J. BARCLAY

CHANGELIST NUMBER: 1

FASTENER CODES: 2-5520

SCALE: 1/1

DATE: 7/11/73

APPROVED: 200

SK2-5081-151 B1

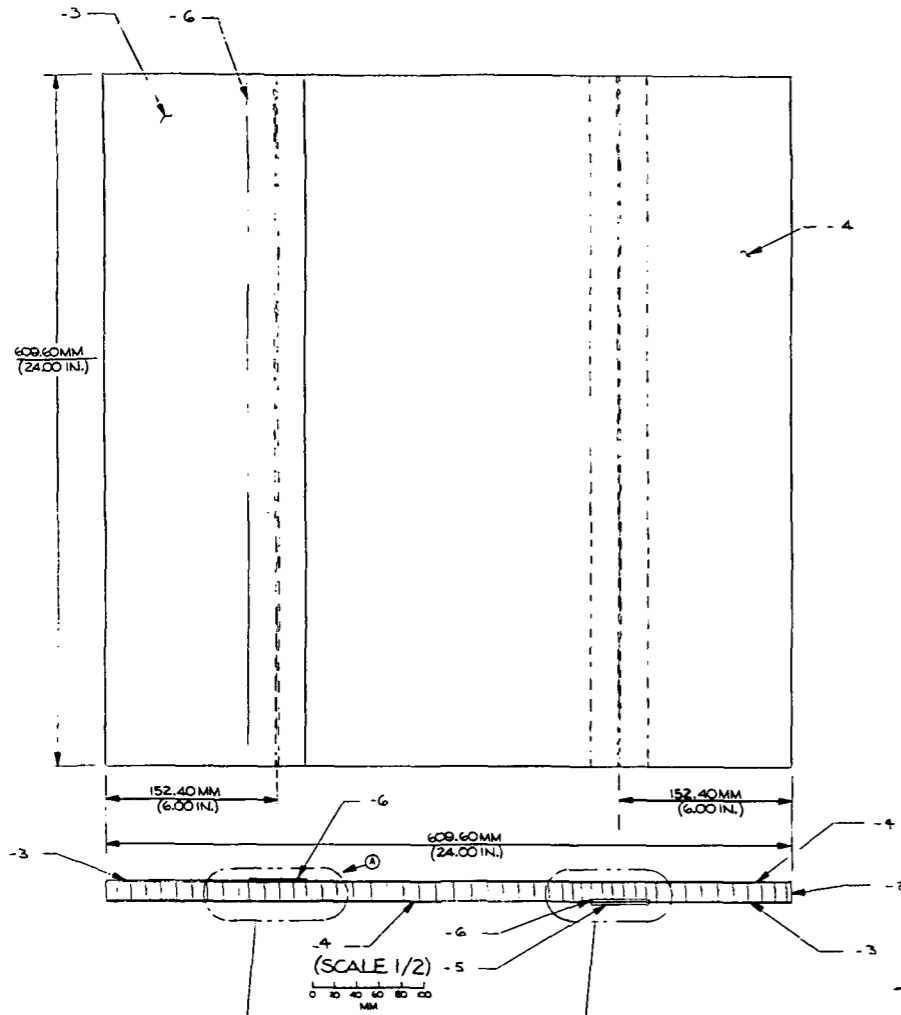
SK2-5081-1211

Figure D-31

ASSEMBLY PROCEDURE

1. ASSEMBLE INNER FACE SKINS - 3 & -4 & STRIP - 5 PER [5]
2. BOND STRIP - 6 PER [5]
3. APPLY METLBOND 329 TO OUTER SURFACE OF THE INNER SKIN PER [3] ASSEMBLE - 2 CORE & BOND PER [3] USING CAUL PLATE BETWEEN CORE & VACUUM BAG.
4. APPLY METLBOND TO OUTER SURFACE OF -2 CORE.
5. BOND STRIP - 6 TO SKINS - 3 & -4 PER [5]

REV. NO.	DESCRIPTION	DATE	APPROVED
A	DELETED - 5 STRIP ON OUTER SKIN	6/12/73	LWS
B	ALTERED [3] & [5] ADDED [8] & [10]	6/12/73	LWS
C	REVISED ASSEMBLY PROCEDURE	7/2/73	LWS

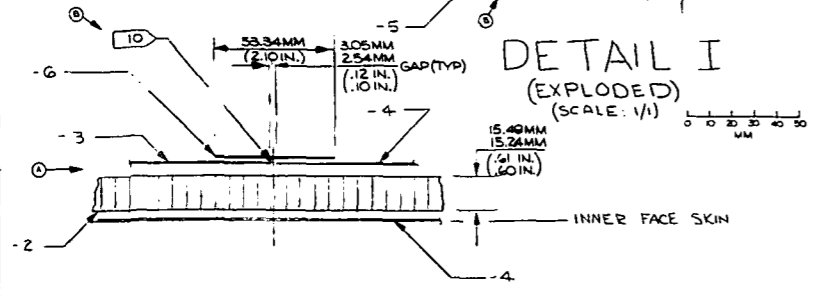


(SCALE 1/2)



DETAIL I (EXPLODED)

(SCALE: 1/1)



DETAIL II (EXPLODED)

(SCALE: 1/1)



- 10 FILL SKIN GAP WITH XA-3919 ADHESIVE (3M CO.)
- 9 FARE JOINT STEP WITH A 0.25 IN. WIDE FILLET USING EA 934 ADHESIVE (HYSOL DIVISION, THE DEXTER CORP.)
- 8 CLEAN METAL DETAILS AS FOLLOWS:
 - a) VAPOR DEGREASE FLEX-CORE.
 - b) CHEM CLEAN ALL METAL DETAILS EXCEPT CORE.
 - c) SAND WITH 400 GRIT SANDPAPER ALL SURFACES NOT FEIMED OR BONDED IMMEDIATELY AFTER CHEM CLEANING.
 - d) SOLVENT CLEAN ALL PARTS WITH BMS 11-7 PRIOR TO PRIMING OR BONDING.
- 7 CURE BOND AT 450°K (350°F) FOR 1 HOUR AT 101.4 KN/m² (14.7 PSI) VACUUM PRESSURE
- 6 ALL RAW MATERIALS & ASSEMBLY SHALL BE PROTECTED FROM OIL & PARTICLE CONTAMINATION. ASSEMBLY SHALL BE DONE IN A DUST FREE ROOM.
- 5 CLEAN PER [8]. BOND WITH XA-3919 ADHESIVE (3M CO.). APPLY BY BRUSH COATING BOTH SURFACES. AIR DRY FOR 15 MIN FOLLOWED BY A 45 MIN DRYING CYCLE AT 380°K (225°F) CURE BOND PER [7].
- 4 1100-H18 ALUM FOIL PER QQ-A-250/1
- 3 CLEAN PER [8]. PRIME WITH METLBOND 329, TYPE 2. APPLY METLBOND 329 ADHESIVE, NARMCO MATERIALS DIV, WHITTAKER CORP. CURE BOND PER [7].
- 2 FLEX-CORE 5056/FA0-0014, 33 6kg/m³ (2.116/lb/ft³) ALUMINUM HONEYCOMB, HEYCEL PRODUCTS INC.
- 1 2024-T81 ALUM PER QQ-A-250/5

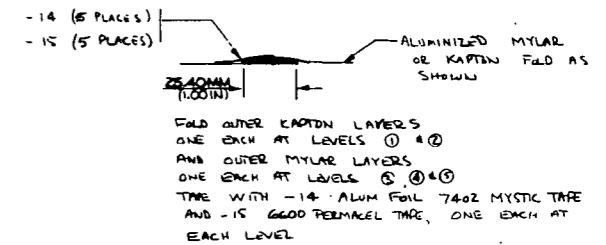
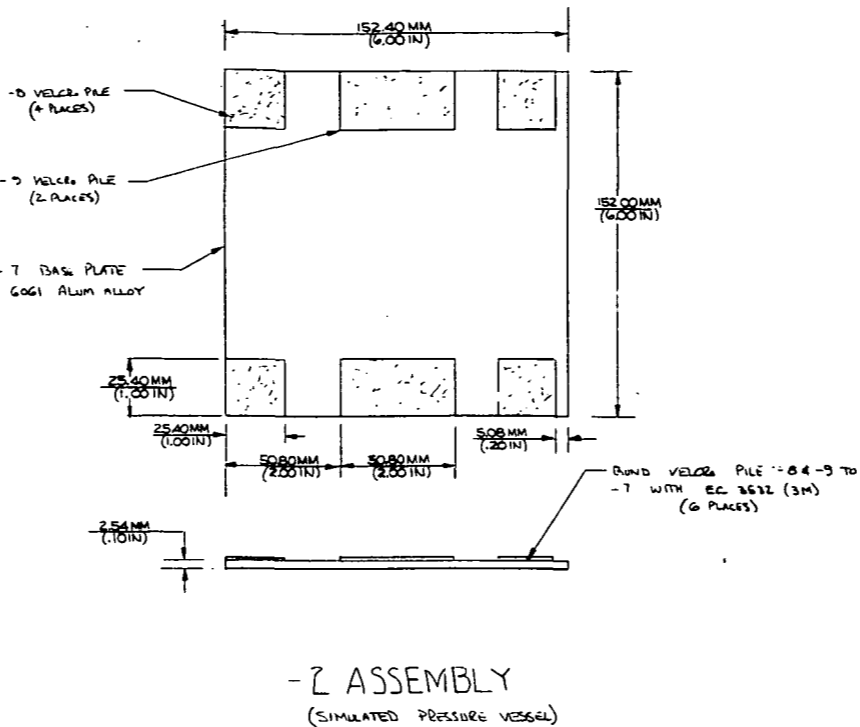
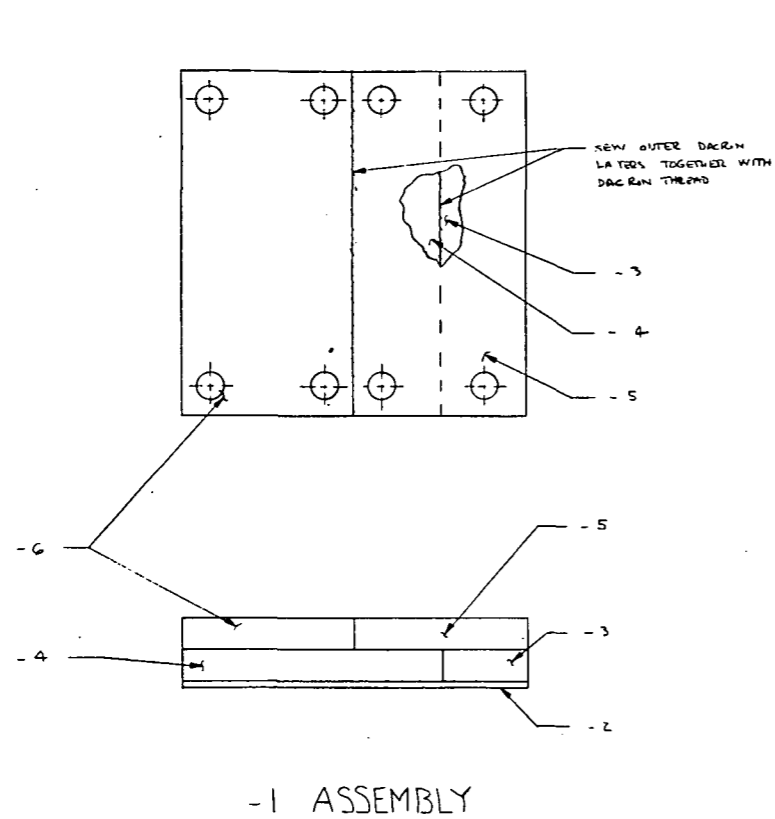
QTY	PART OR IDENTIFYING NUMBER	TEMPERATURE OR DESCRIPTION	MATERIAL AND SPECIFICATION
2	-6	STRIP	012x21x24.0 ALUM SHEET [1] [5]
1	-5	STRIP	.003x21x24.0 ALUM FOIL [4] [5]
2	-4	SKIN	.012x180x24.0 ALUM SHEET [1]
2	-3	SKIN	.012x60x24.0 ALUM SHEET [1]
1	-2	CORE	600x24.0x24.0 FLEX-CORE [2] [3]
-	-1	SPECIMEN PANEL ASSEMBLY	

UNLESS OTHERWISE SPECIFIED DIMENSIONS ARE IN INCHES TOLERANCES DECIMALS .01	REVIEW & APPROVAL	CONTRACT NUMBER NAS3-5848	THE BOEING COMPANY
	DESIGNER	DATE	CORPORATE OFFICES SEATTLE, WASHINGTON 98108
	MATERIALS	DATE	SANDWICH BEAM EDGEWISE COMPRESSION SPECIMEN HALF SCALE LH ₂ TEST MODEL
	CHANGED/ITEM NUMBER	PROJECT APPROVAL	SIZE CODE IDENT NO. J181205DK25085-152
			SCALE: NONE

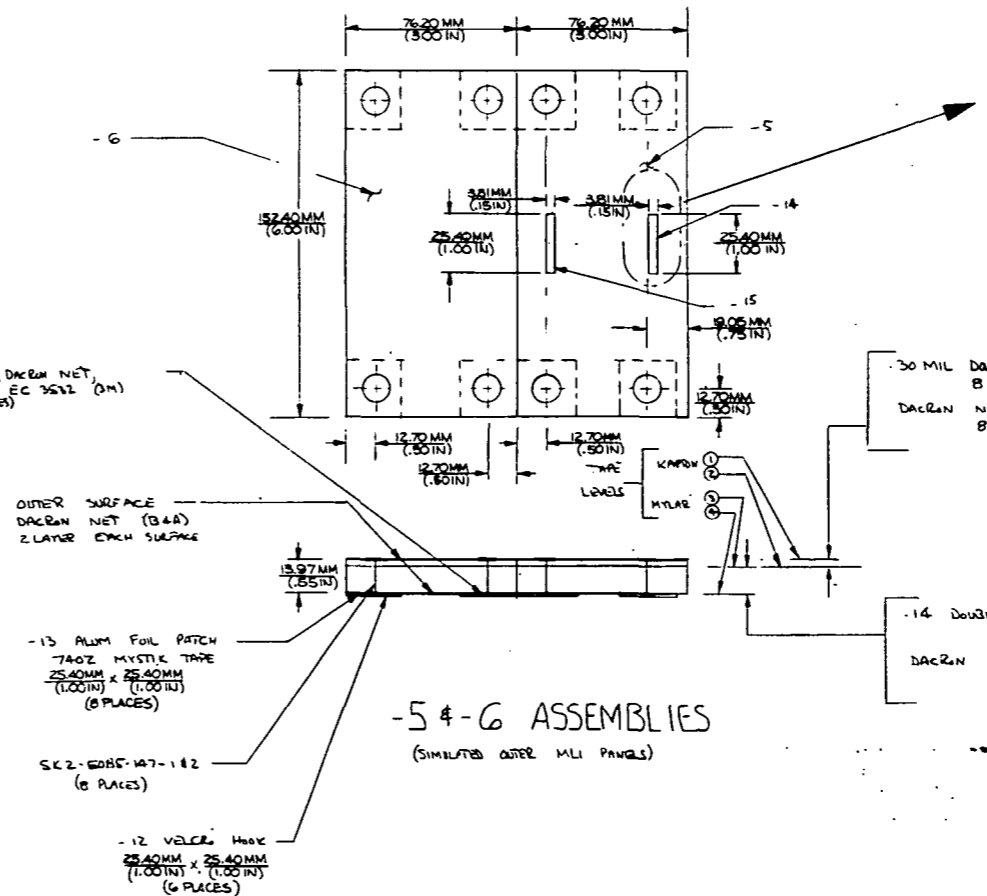
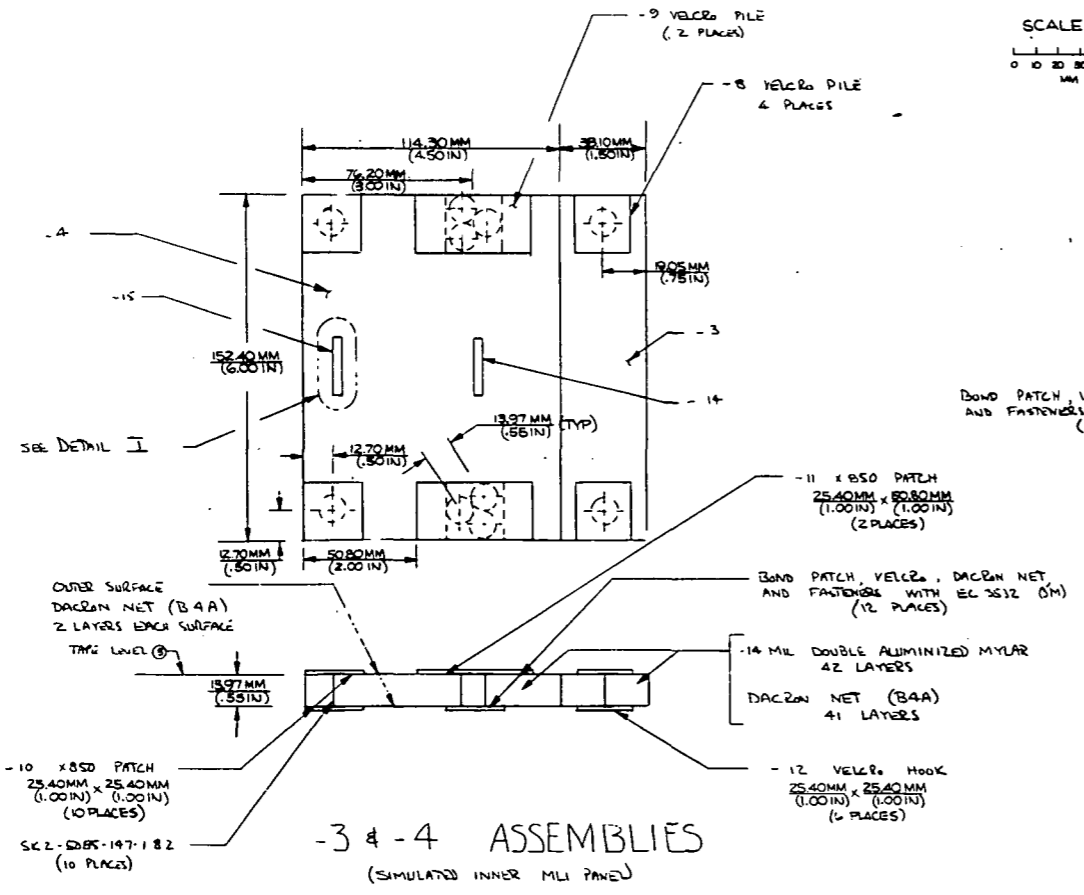
DK2-5085-152B11

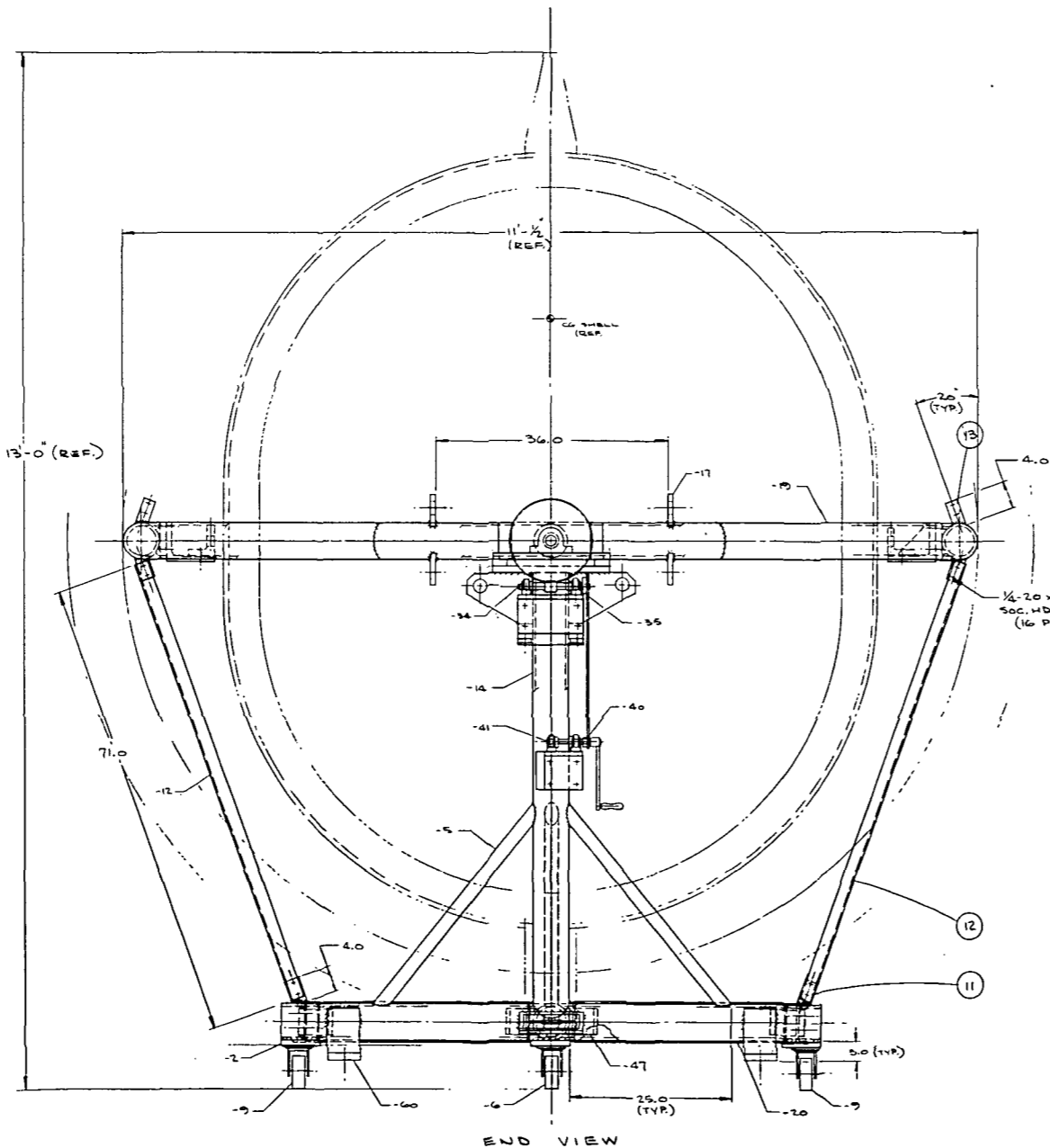
DKS-2082-1291

Figure D-32

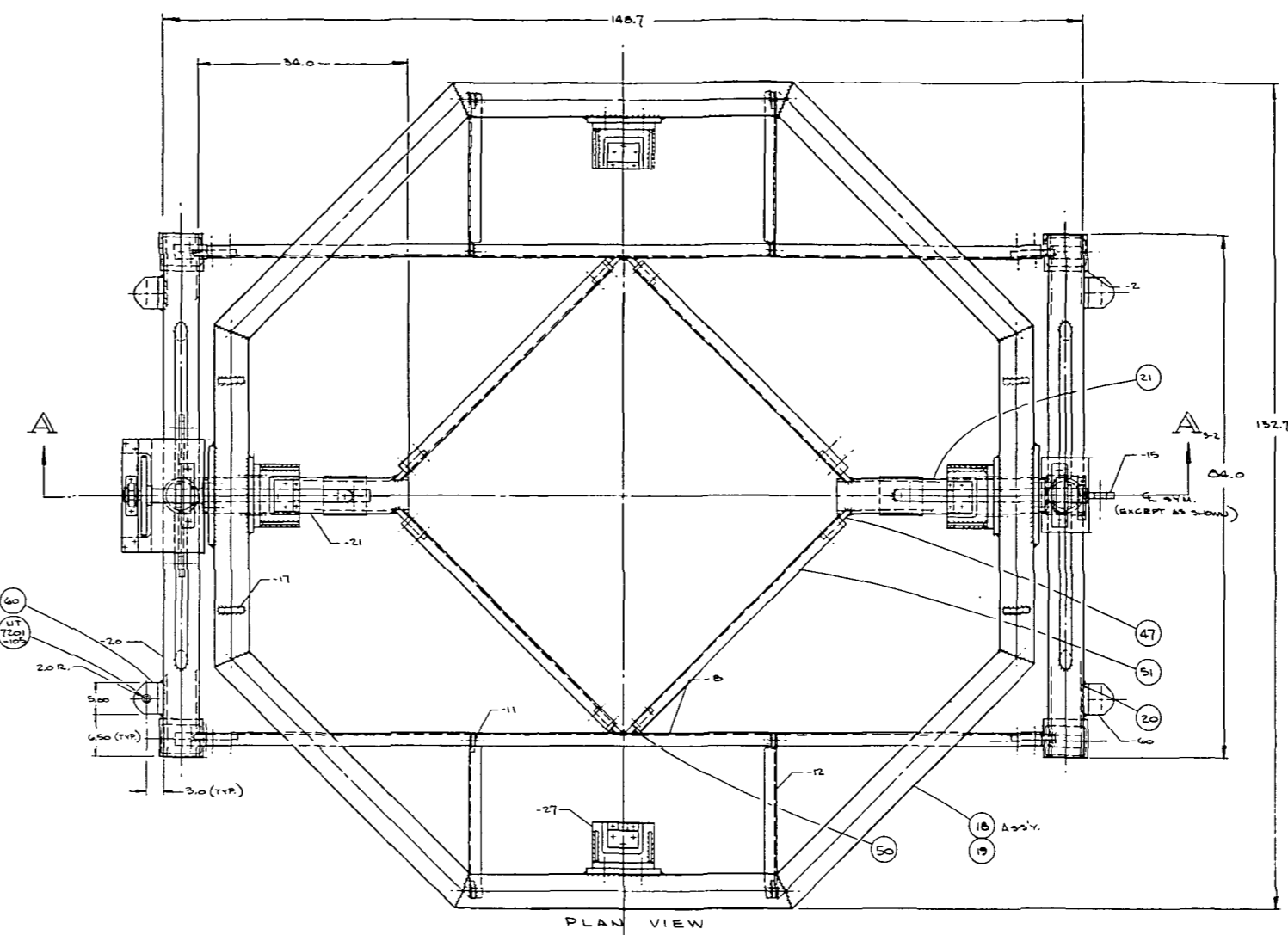


SCALE: 1/1
0 10 20 30 40 50
MM

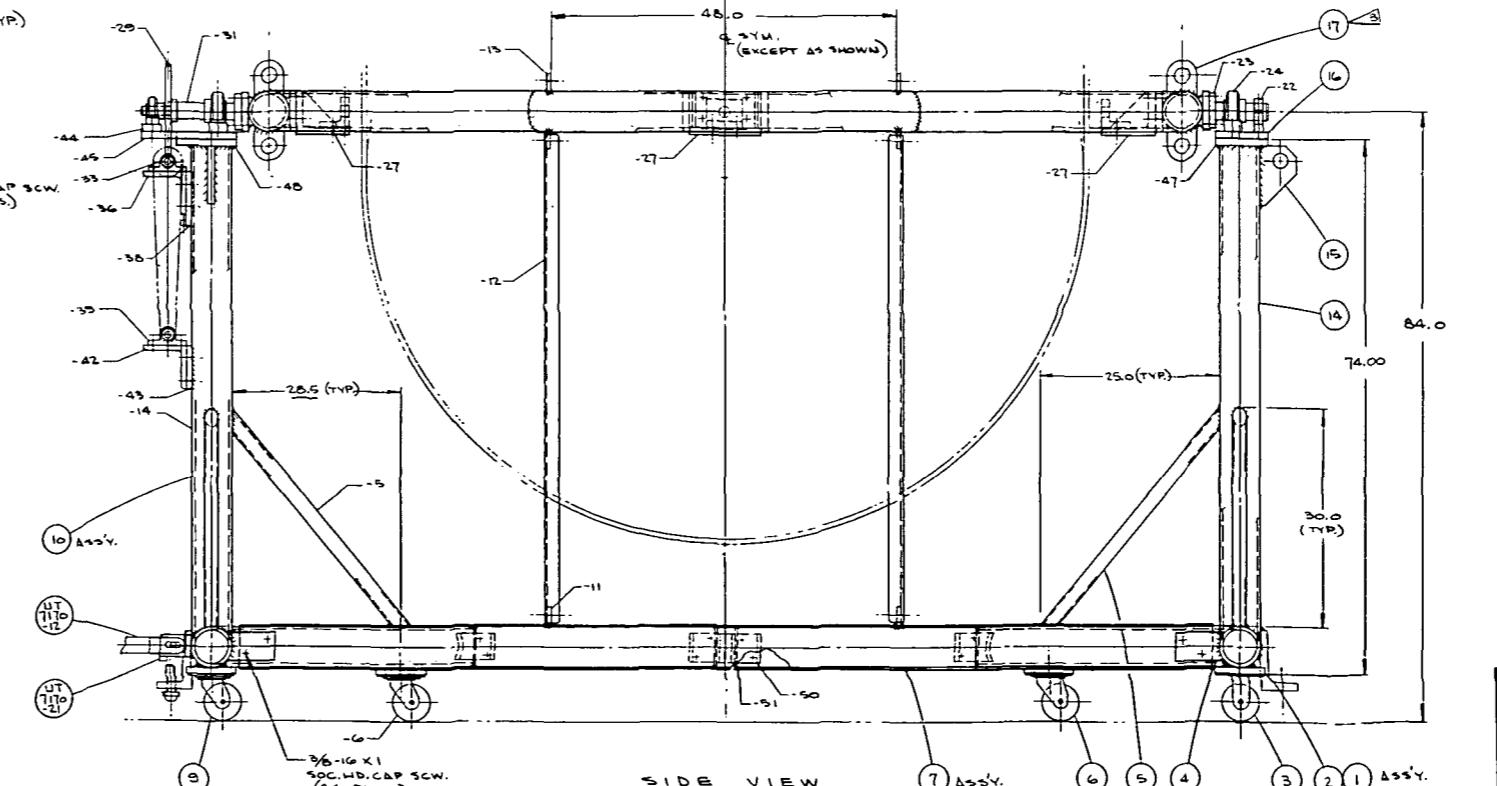




END VIEW



PLAN VIEW



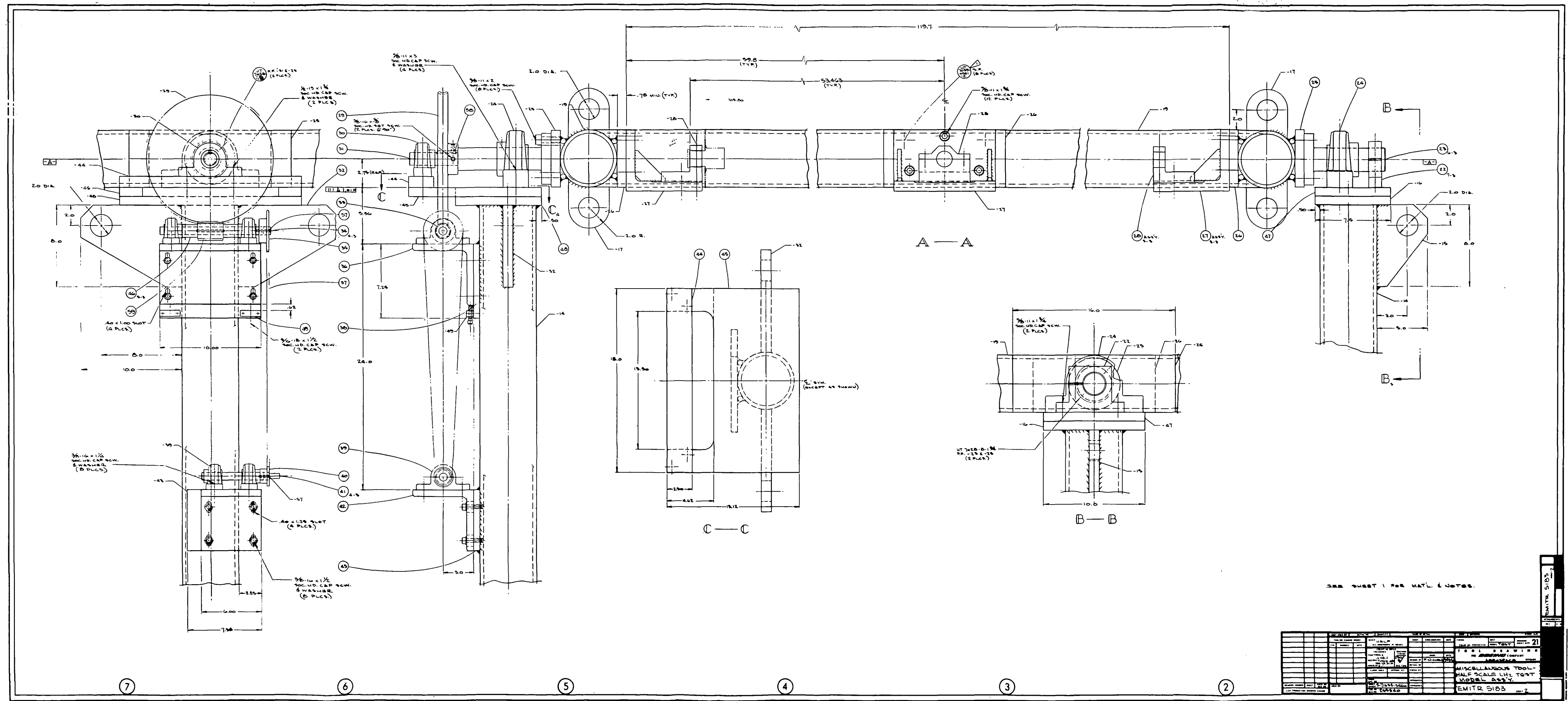
SIDE VIEW

FUNCTION OF TOOL
TO HOLD TANK FOR ASSEMBLY & TEST.

NOTES
BREAK SHARP EDGES & CORNERS.
SCALE DIMS. FOR NON-CRITICAL DIMS. NOT GIVEN.
IDENTIFY PDB TYP. 40, M 41-01.
WELD & TEST EQUIVALENT TUBS FOR TYP. 25.
WELD ALUMINUM FOR TYP. 30.
SCREWS & DOWELS AT RHP'D.
-12 & -61 DETAILS & -7 & -27 ASSYS. REMOVABLE.
ATTACH FOR TYP. 37
PRIME & PAINT STEEL STRUCTURE SEARAM GREEN,
LIFT LUGS HIGH VISIBILITY YELLOW.
STENCIL ON OR OVER LUGS. LIFT YOKES ASSY. ONLY.
IN BLACK LETTERS 1/2" HIGH.

QTY	DESCRIPTION	UNIT	REMARKS
1/10	60	2 1/2	ANGLE
1/10	UT 110	2 1/2	UNION SCREW
10	57	1	KEY
10	50	1	KEY
10	57	2	KEY
10	UT 103	4	DOWEL
10	UT 103	8	L. PIN
27	UT 103	8	DOWEL
28	50	4	WIDER PIN
20	55	4	BLOCK
20	52	4	CLIP
10	UT 110	1	TRAILER TANGENT
10	UT 110	1	MOUNTING BRACKET
27	53	8	GUSSET
27	52	4	SUPPORT ANGLE
7	50	4	PLATE
10	49	2	BLOCK
10	48	1	PLATE
1/10	47	2 1/2	PLATE
10	46	2	BRACKET
10	45	1	PLATE
10	44	1	SUPPORT
10	43	1	PLATE
10	42	1	SUPPORT
10	41	1	SHIRT
10	40	1	BRACKET
10	39	4	PILLOW BLOCK
10	38	1	PLATE
10	37	1	SHIRT
10	36	1	SHIRT
10	35	1	SHIRT
10	34	1	SHIRT
10	33	2	LIFT PLATE
10	32	1	SHIRT
10	31	1	SHIRT
10	30	1	PILLOW BLOCK
10	29	1	WHEEL CLAS
27	28	4	WIDER ASSY.
10	27	4	SUPPORT ASSY.
10	26	4	PLATE
10	25	2	PLATE
1/10	24	1 1/2	PILLOW BLOCK
10	23	1	SHIRT
10	22	1	CLAMP
1/10	21	1 1/2	LUGS
1/10	20	1 1/2	CROSS BAR
10	19	2	DRUM WHEEL
10	18	1	TANK SUPPORT ASSY.
10	17	4	LIFT LUG
10	16	1	PLATE
10	15	1	LIFT PLATE
1/10	14	1 1/2	COLUMN
10	13	4	PLATE
10	12	4	BLOCK
7	11	4	PLATE
10	10	1	STAND ASSY.
10	9	2	CASTER (SWIVEL)
7	8	2	GUSSET
10	7	1	TIE ASSY.
1/10	6	1 1/2	CASTER (SWIVEL)
1/10	5	1 1/2	BLOCK
1/10	4	1 1/2	PLATE
1/10	3	1 1/2	PLATE
1/10	2	1 1/2	PLATE

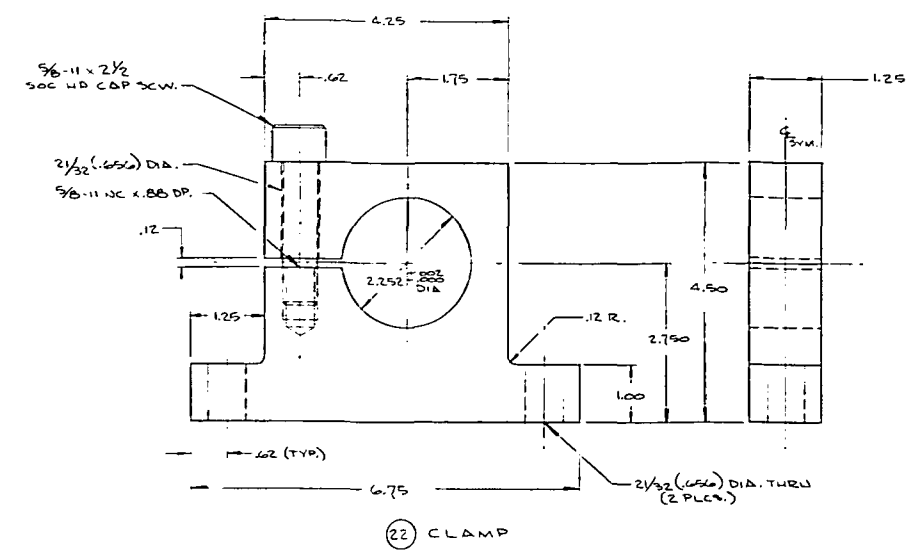
Figure D-40



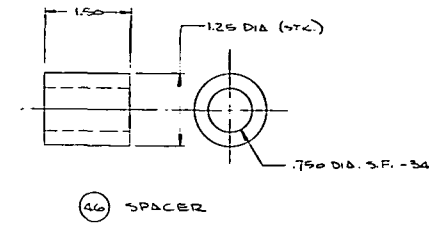
SEE SHEET 1 FOR MAT'L. & NOTES.

REV	DATE	BY	CHKD	DESCRIPTION
1				ISSUED FOR FABRICATION
2				REVISION
3				REVISION
4				REVISION
5				REVISION
6				REVISION
7				REVISION
8				REVISION
9				REVISION
10				REVISION
11				REVISION
12				REVISION
13				REVISION
14				REVISION
15				REVISION
16				REVISION
17				REVISION
18				REVISION
19				REVISION
20				REVISION
21				REVISION
22				REVISION
23				REVISION
24				REVISION
25				REVISION
26				REVISION
27				REVISION
28				REVISION
29				REVISION
30				REVISION
31				REVISION
32				REVISION

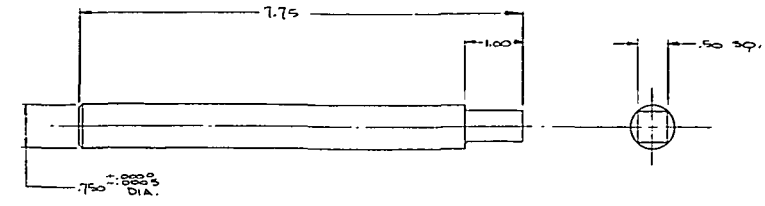
Figure D-41



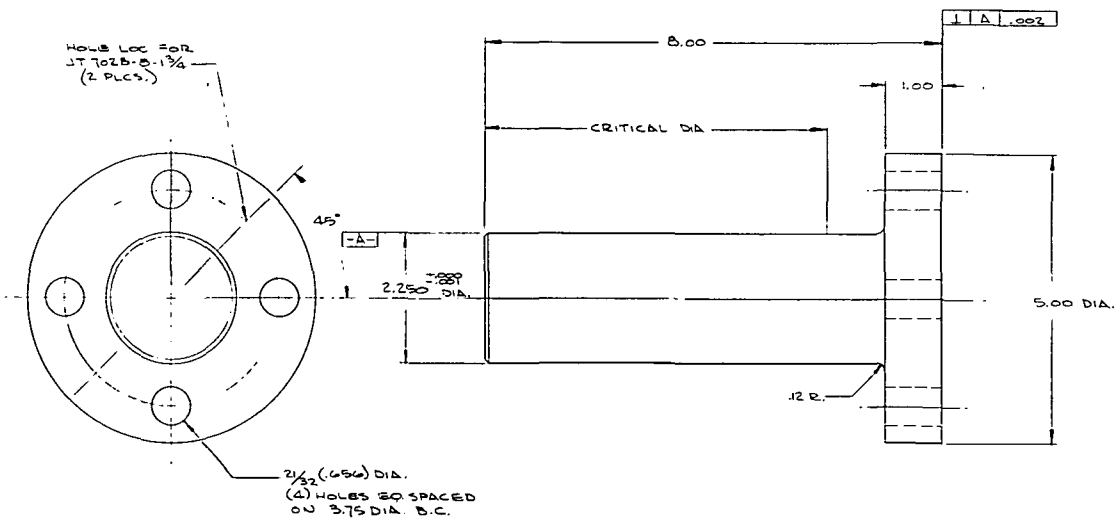
22 CLAMP



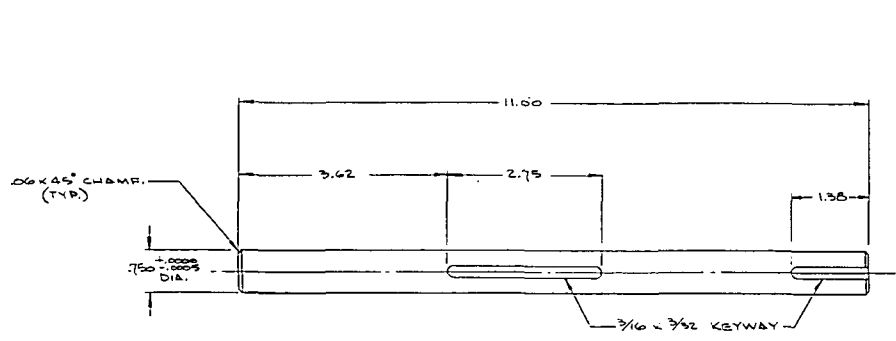
40 SPACER



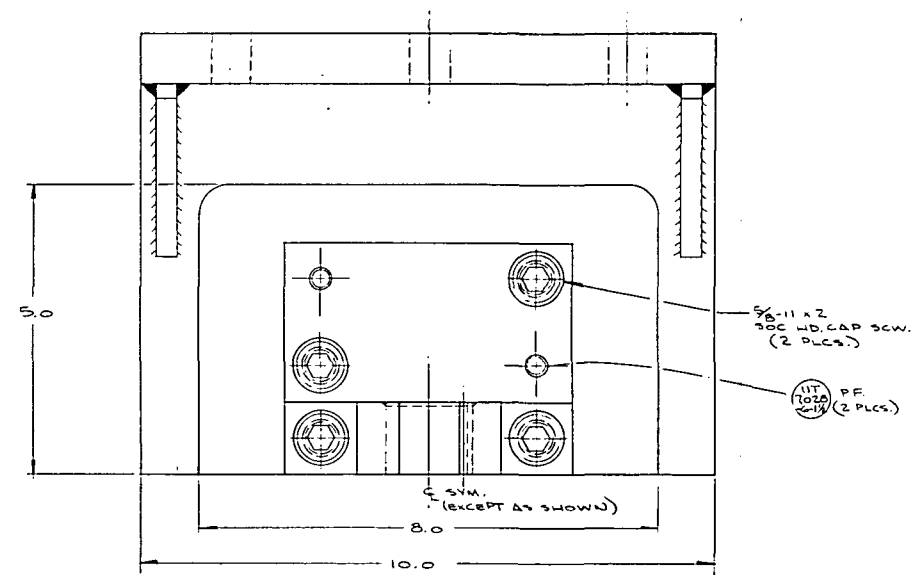
41 SHAFT



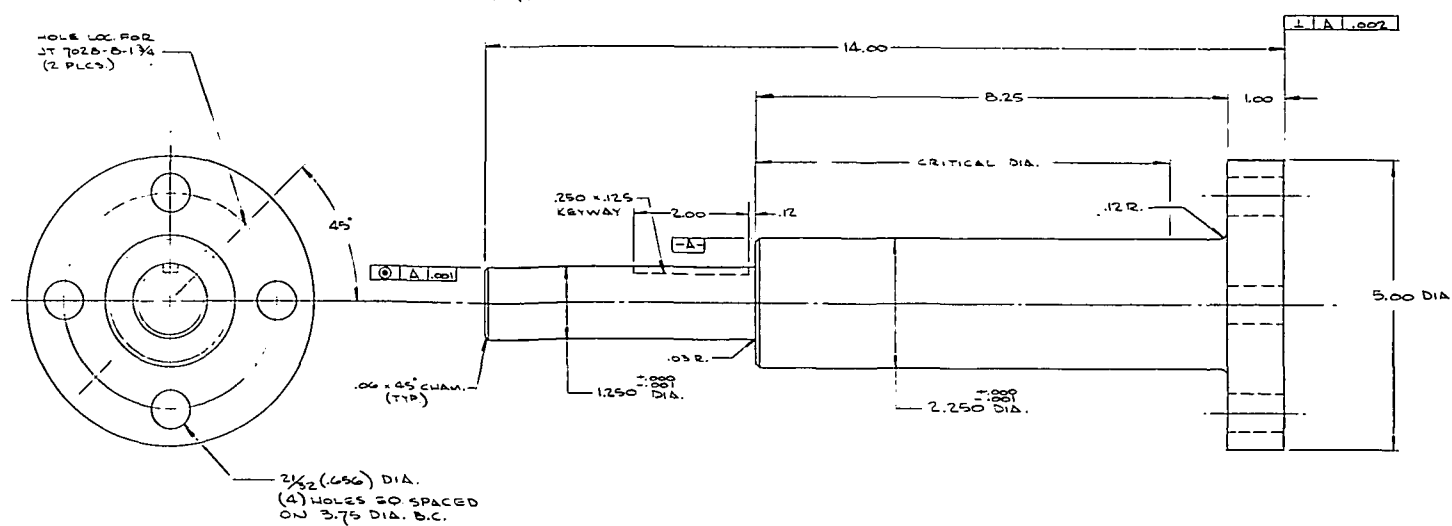
29 SHAFT
WT. 150-170 KSI



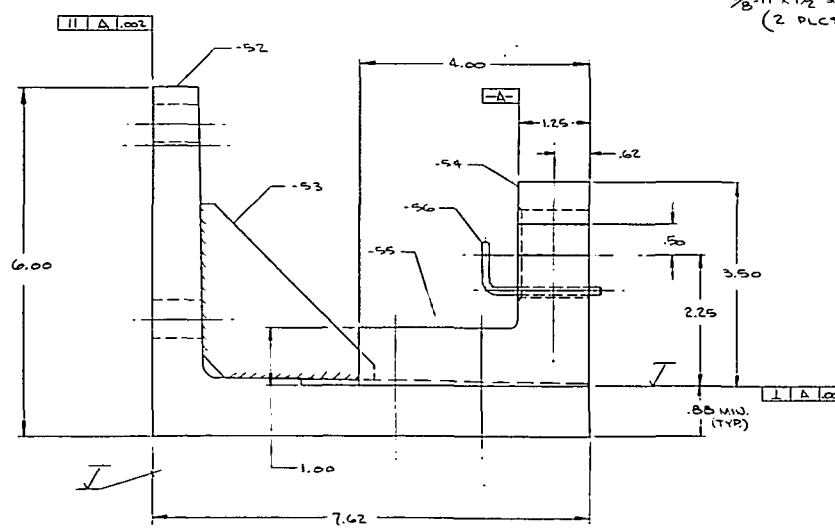
34 SHAFT



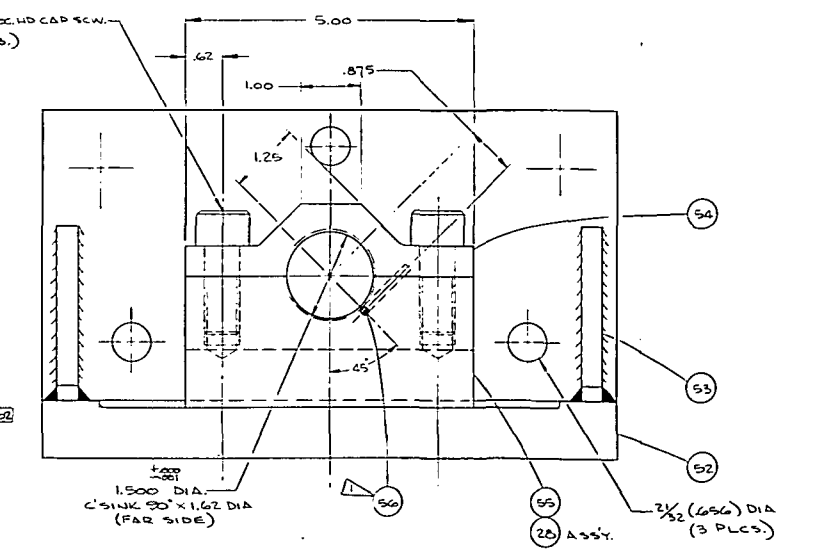
36 ASS'Y.



31 SHAFT
WT. 150-170 KSI



37 SUPPORT ASS'Y.



39 ASS'Y.

SEE SHEET 1 FOR MAT'L & NOTES

7

6

5

4

3

2

REV	DATE	BY	CHKD	DESCRIPTION
1				INITIALS
2				INITIALS
3				INITIALS
4				INITIALS
5				INITIALS
6				INITIALS
7				INITIALS
8				INITIALS
9				INITIALS
10				INITIALS
11				INITIALS
12				INITIALS
13				INITIALS
14				INITIALS
15				INITIALS
16				INITIALS
17				INITIALS
18				INITIALS
19				INITIALS
20				INITIALS
21				INITIALS
22				INITIALS
23				INITIALS
24				INITIALS
25				INITIALS
26				INITIALS
27				INITIALS
28				INITIALS
29				INITIALS
30				INITIALS
31				INITIALS
32				INITIALS
33				INITIALS
34				INITIALS
35				INITIALS
36				INITIALS
37				INITIALS
38				INITIALS
39				INITIALS
40				INITIALS
41				INITIALS
42				INITIALS
43				INITIALS
44				INITIALS
45				INITIALS
46				INITIALS
47				INITIALS
48				INITIALS
49				INITIALS
50				INITIALS

Figure D-42

APPENDIX E

THERMAL INSTRUMENTATION TEST PLAN
FOR THE LH₂ TEST MODEL

APPENDIX E
THERMAL INSTRUMENTATION TEST PLAN FOR
THE LH₂ TEST MODEL

The thermal instrumentation plan was developed from the Contract NAS 3-15848 Statement of Work instrumentation requirements. Thermocouple locations and wire routing are shown in Appendix D, Figures D-22 through D-26.

Table E-1 is a list of all thermocouples. The thermocouple entries in the list are grouped by the type of wire required and the lengths shown were used in determination of total quantities of wire required for the test. Four types of wire were used: Teflon insulated Chromel-Constantan for thermocouples in the evacuated volume; fiberglass insulated Chromel-Constantan for exterior locations; vinyl insulation Chromel-Constantan for hydrogen filled spaces; and vinyl insulated copper wire for LH₂ reference junctions and leads. The computations for required wire lengths included added length margins to facilitate component assembly and disassembly.

Table E-2 lists those thermocouples which comply with the Statement of Work requirements. In some of the areas specified, a greater number of thermocouples than the minimum required were installed; also, a number of thermocouples were installed in areas not mentioned in the reference.

A practical limitation on the number of thermocouples located in the evacuated volume exists by virtue of the available space and cost for vacuum tight connectors. Four Deutsch Series DM-5623 connectors, located in the cover plate of the simulated plumbing penetration assembly housing, as shown in Figure D-38 was used. These connectors contain 37 contacts each, providing circuit connectors for 74 thermocouples. These 74 thermocouples are listed as the first group in Table E-1.

The Deutsch connectors incorporate 18 Constantan and 19 Chromel pins each. Therefore, of the 74 thermocouples, 2 thermocouple circuits must use Chromel pins to connect their Constantan lead wires. Any temperature differences between the resulting superfluous Chromel-Constantan junctions will generate extraneous voltages, causing errors in the indicated temperatures. In order to minimize these possible errors, thermocouples in high temperature areas, i.e., thermocouples whose unaltered output voltage will be relatively high, were selected for routing through the all-Chromel connector pins. These thermocouples are T59 and T60 on the inner surface of the vacuum jacket. Any of the other thermocouples on this surface would have been suitable, except T56 or T62, for which accuracy is somewhat more important due to their association with thermocouple sets in the MIL.

Three thermocouples, T72, T73, and T74 were to be immersed in the GH_2 boil-off flow in the vent tube in an attempt to measure the temperature rise in the gas as it travels up the tube. The possibility of bonding small fins to these junctions to increase their response to changes in gas temperature was explored. Because of the need for maximum accuracy for these temperatures, relative to the saturated vapor temperature, these thermocouple circuits were to employ reference junctions within the LH_2 in the test tank rather than reference junctions in the cold box like all other thermocouples.

Thermocouple locations and wire routings were planned to achieve the best combination of accurate, useful data and minimum disruption. In some areas, these requirements conflicted and compromises were necessary. All thermocouples on or within the MLI were attached to shield layers with an aluminized Mylar tape having reflective properties very close to those of the shields themselves. When possible, the first 6 inches of wire leading to the thermocouple junction followed expected isotherm contours in order to minimize errors due to heat flow in the wires. On tubular components and support straps, loads made at least 2 turns around the component being routed away from the location of the junction.

Location and routings were planned to minimize junction and wire overlaps, avoiding the MLI thickness disruption that would result from excessive superposition. This is the reason for the rosette patterns for thermocouples T1 through T6, T7 through T12, and T25 through T30, and the staggering of groups T13 through T18 and T19 through T24.

THERMOCOUPLE LIST

T/C IDENT.	COMPONENT		LOCATION ON COMPONENT		WIRE TYPE	LENGTH "A"	LENGTH "B"	LENGTH " "	NOTES		
						(in)	(in)	(in)			
T1	MLI	-17	SHIELD	14	CHR-COH, TEFLOH	151.7	187.7		①	②	③
T2			↓	28		198.7	184.7		①		
T3			↓	OUT. SURF.		132.7	179.7				
T4		-30	SHIELD	14		165.4	201.4		①		
T5			↓	28		169.4	205.4		①		
T6			↓	OUT. SURF.		153.7	189.7				
T7		-10	SHIELD	14		78.0	114.0		①		
T8			↓	28		79.0	110.0		①		
T9			↓	OUT. SURF.		69.9	100.9				
T10		-23	SHIELD	14		91.6	127.6		①		
T11			↓	28		95.6	131.6		①		
T12			↓	OUT SURF.		80.0	116.0				
T13		-35	SHIELD	14		111.6	147.6		①		
T14			↓	28		116.6	152.6		①		
T15			↓	OUT. SURF.		110.5	146.5				
T16		-10	SHIELD	14		102.4	144.4		①		
T17			↓	28		111.5	147.5		①		
T18			↓	OUT. SURF.		109.0	145.0				
T19		-9	OUT. SURF.			86.9	122.9				
T20			SHIELD	28		94.4	130.4		①		
T21	↓	↓	↓	14		95.4	131.4		①		
T22	LOWER TEN-SION STRAP		OUT. SURF.			104.3	140.3				
T23	MLI PANEL	-23	SHIELD	28		99.4	135.4		①	✓	✓

	INITIALS	DATE	REV. BY INITIALS	DATE	TITLE	MODEL
CALC					TABLE E-1	
CHECK						
APPD						
APPD						

THERMOCOUPLE LIST

T/C IDENT.	COMPONENT		LOCATION ON COMPONENT		WIRE TYPE	LENGTH "A"	LENGTH "B"	LENGTH "C"	NOTES		
						(in)	(in)	(in)			
T 24	MLT PANEL	-23	SHIELD	14	CHR-COI, TEFLOH	98.4	134.4		①	②	③
T 25		-8	OUT. SURF.			29.5	65.5				
T 26			SHIELD	28		42.0	78.0		①		
T 27			↓	14		41.6	77.6		①		
T 28		-6	OUT. SURF.			39.5	75.5				
T 29			SHIELD	28		39.7	75.7		①		
T 30			↓	14		40.8	76.8		①		
T 31	LOWER TENSION STRAP		Q	OUT. SURF.		105.8	141.8				
T 32						102.8	138.8				
T 33						101.3	127.3				
T 34			↓			99.8	135.8				
T 35	UPPER TENSION STRAP					121.6	157.6				
T 36						120.1	156.1				
T 37						118.6	154.6				
T 38						117.1	153.1				
T 39			↓			115.6	151.6				
T 42	GIRTH RING		IN. SURF.			94.8	130.8				
T 43			↓			94.8	130.8				
T 56	VAC. JACKET UPPER HEAD		IN. SURF., OVER TI-T6			137.2	173.2				
T 57			IN. SURF., 60° FROM T56			137.2	173.2				
T 58			IN. SURF., 120° FROM T56			137.2	173.2				
T 59			IN. SURF., 180° FROM T56			137.2	173.2				
T 60			IN. SURF., 240° FROM T56		Y	137.2	173.2			Y	Y

	INITIALS	DATE	REV. BY INITIALS	DATE	TITLE	MODEL
CALC					TABLE-E1	
CHECK						
APPD						
APPD						

THERMOCOUPLE LIST

T/C IDENT.	COMPONENT	LOCATION OF COMPONENT	WIRE TYPE	LENGTH "A"	LENGTH "B"	LENGTH "C"	NOTES
				(in)	(in)	(in)	
✓ T61	W.C. JACKET UPPER HEAD	IN. SURF., 300° FROM T56	CHR-COH, TEFLOX	137.2	173.2		(2) (3)
✓ T62	VAC JACKET LOWER HEAD	IN. SURF., OVER T7-T12		57.9	93.9		
✓ T63		IN. SURF., 60° FROM T62		57.9	93.9		
✓ T64		IN. SURF., 120° FROM T62		57.9	93.9		
✓ T65		IN. SURF., 180° FROM T62		57.9	93.9		
✓ T66		IN. SURF., 240° FROM T62		57.9	93.9		
✓ T67		IN. SURF., 300° FROM T62		57.9	93.9		
✓ T68	MLI PANEL -7	SHIELD 3A		182.7	218.7		(1)
✓ T69	INLET TUBE	OUT. SURF.		209.3	245.3		
✓ T70				205.3	241.3		
✓ T71				201.3	237.3		
✓ T75	SIM. PLUMB. TUBE	OUT. SURF.		16.8	52.8		
✓ T76				15.3	51.3		
✓ T77				13.8	49.8		
✓ T78	SIM. PLUMB. ASSY	END OF FG INS. RETAINER TUBE INSL. OUT. SURF.		16.0	52.0		
✓ T86				30.6	66.6		
✓ T87				29.1	65.1		
✓ T88				27.6	63.6		
✓ T89	MLI PANEL -6	OUT. SURF.		40.3	76.3		
✓ T90				23.3	59.3		
✓ T91				36.3	72.6		
✓ T92				27.3	63.6		
✓ T96	PRESS. VESSEL	OUT. SURF. UNDER T68		182.7	218.7		✓ ✓

	INITIALS	DATE	REV. BY INITIALS	DATE	TITLE	MODEL
CALC					TABLE-E1	
CHECK						
APPD						
APPD						

THERMOCOUPLE LIST

T/C IDENT.	COMPONENT		LOCATION ON COMPONENT		WIRE TYPE	LENGTH	LENGTH	LENGTH	NOTES			
						"A"	"B"	" "				
						(in)	(in)	(in)				
T 97	MLT PANEL	-9	OUT. SURF.		CHR-CON, TEFLON	83.2	119.2				(2)(3)	
T 98		-9				81.3	117.3					
T 99		-23				92.9	128.9					
T 102	PRESS. VESSEL		UNDER T1-T6			167.4	203.4					
T 103			UNDER T7-T12			93.6	129.6					
T												
T												
TOTAL	74	T/C IN VACUUM SPACE:					7030.2	9699.2				
T						=585.25'	=807.85'					
T												
TOTAL		CHR-CON, TEFLON WIRE REQ'D:						808'				
T												
T												
T												
T												
T												
T												
T												
T												
T												
T												
T												
T												

	INITIALS	DATE	REV. BY INITIALS	DATE	TITLE	MODEL
CALC					TABLE-E1	
CHECK						
APPO						
APPO						

THERMOCOUPLE LIST

T/C IDENT.	COMPONENT	LOCATION ON COMPONENT	WIRE TYPE	LENGTH	LENGTH	LENGTH	NOTES
				"G"	"H"	"I"	
				(in)	(in)	(in)	
T 40	GIRTH RING	OUT. SURF.	CHR-COM, NYL	96.1	246.1		(8) (9)
T 41	↓	↓		96.1	246.1		
T 44	VAC. JACKET UPPER HEAD	OUT. SURF. OVER T1-T6		139.2	289.2		
T 45		OUT. SURF. 60° FROM T44		139.2	289.2		
T 46		OUT. SURF. 120° FROM T44		139.2	289.2		
T 47		OUT. SURF. 180° FROM T44		139.2	289.2		
T 48		OUT. SURF. 240° FROM T44		139.2	289.2		
T 49	↓	OUT. SURF. 300° FROM T44		139.2	289.2		
T 50	VAC. JACKET LOWER HEAD	OUT. SURF. OVER T7-T12		59.0	209.0		
T 51		OUT. SURF. 60° FROM T50		59.0	209.0		
T 52		OUT. SURF. 120° FROM T50		59.0	209.0		
T 53		OUT. SURF. 180° FROM T50		59.0	209.0		
T 54		OUT. SURF. 240° FROM T50		59.0	209.0		
T 55	↓	OUT. SURF. 300° FROM T50		59.0	209.0		
T 79	SIM. PLUMB. ASSY.	HOUSING CLOSEOUT PLATE		0.	150.0		
T 80	VAC. JACKET UPPER HEAD	NEAR VENT SAME MERIDIAN		187.0	337.0		
T 81	↓	AS T68, T96		182.0	332.0		
T 82	VENT HOUSING	CLOSEOUT EXTENSION		225.3	375.3		
T 83	SIM. PLUMB. ASSY.	HOUSING BASE FLANGE OUT. SURF.		17.2	167.2		
T 100	VAC. JACKET LOWER HEAD	NEAR SIM. PLUMB. PENETRATION		21.2	171.2		
T 101	↓	SAME MERIDIAN AS T91, T92	↓	26.7	176.7		↓ ↓
TOTAL,	21 T/C ON ASSEMBLY EXTERIOR:			2040.8	5190.8		
T				=170.07	=432.6		

	INITIALS	DATE	REV. BY INITIALS	DATE	TITLE	MODEL
CALC					TABLE - E1	
CHECK						
APPO						
APPO						

THERMOCOUPLE LIST

T/C IDENT.	COMPONENT	LOCATION OF COMPONENT	WIRE TYPE	LENGTH "D"	LENGTH "E"	LENGTH " "	NOTES
				(in)	(in)	(in)	
T72	VENT TUBE	FREE STANDING IN VENT GAS	CHR-CON, VINYL	10.0	16.0		(5) (6) (10)
T73				20.0	26.0		
T74				29.0	35.0		
T93	FILL LINE	OUT. SURF., IN VENT TUBE		28.5	34.5		
T94				24.5	30.5		
T95				20.5	26.5		V V V
T							
TOTAL,	6 T/C IN H ₂ VENT SPACE :			132.5	168.5		
T				=11.04'	=14.04'		
T							
T							
T	EXTENSION WIRE FOR T/C's				LENGTH "C"		
T	IN VACUUM SPACE, EA. :				150.0		(4)
TOTAL	EXT. WIRE, 74 T/C's :				1100.0		
T				=925.0'			
T							
T							
TOTAL	CHR-CON, VINYL WIRE REQ'D:						
T	FOR 21 EXTERIOR T/C's					432.6'	
T	FOR EXTENSIONS FOR 74 VAC. T/C's :					925.0'	
T	FOR 6 T/C's IN H ₂ VENT SPACE :					19.0'	
T					1371.6'		
T							

	INITIALS	DATE	REV. BY INITIALS	DATE	TITLE	MODEL
CALC					TABLE-E1	
CHECK						
APPD						
APPD						

REV LTR _____

BOEING

NO.

93

SH

THERMOCOUPLE LIST

T/C IDENT.	COMPONENT	LOCATION ON COMPONENT	WIRE TYPE	LENGTH "J"	LENGTH "K"	LENGTH " "	NOTES
				(in)	(in)	(in)	
TREF72		IMMERSED	Cu	63.6	69.6		(10) (11) (12)
TREF73		IN LH ₂		63.6	69.6		
TREF74		10" BELOW		63.6	69.6		
TREF93		PRESS. VESSEL		63.6	69.6		
TREF94		VENT OUTLET		63.6	69.6		
TREF95		↓		63.6	69.6		
T							
TOTAL	, 6 REF. JUNCTION LEADS				417.6		
T					=34.8'		
T							
T						LENGTH "F"	
T	EXTENSION WIRE FOR REF.						
T	JUNCTION LEADS, EA :				310.0		(7) (10)
TOTAL	, CU EXTENSION WIRE				1860.0		
T					=155.0'		
T							
T							
TOTAL	, CU WIRE REQ'D :				34.8'		
T					155.0'		
T					189.8'		
T							
T							
T							

	INITIALS	DATE	REV. BY INITIALS	DATE	TITLE	MODEL
CALC					TABLE - E1	
CHECK						
APPD						
APPD						

THERMOCOUPLE LIST NOTES

- ① Shields are numbered counting from inner surface.
- ② Length "A" is calculated min. length from T/C to Deutsch vacuum-tight connectors on closure plate of simulated plumbing housing at bottom of vac. jacket.
- ③ Length "B" = Length "A" plus 36.0".
- ④ Length "C" is length of extension required from Deutsch connectors to terminals at reference box.
- ⑤ Length "D" is calculated min. length of Chromel-Constantan wire from T/C to reference junction in LH₂.
- ⑥ Length "E" = Length "D" plus 6.0".
- ⑦ Length "F" = Length of Cu wire extension from H₂-tight connector on vent plenum to terminals at reference box.
- ⑧ Length "G" is calculated length from T/C to plane of closure plate of simulated plumbing housing at bottom of vac. jacket.
- ⑨ Length "H" = Length "G" plus 150.0 in. additional required from plane of closure plate to terminals at reference box.
- ⑩ To be installed by Tulalip Test Site personnel.
- ⑪ Length "J" is calculated min. length of Cu wire from reference junctions to H₂-tight connector.
- ⑫ Length "K" = Length "J" plus 6.0".

	INITIALS	DATE	REV BY INITIALS	DATE	TITLE	MODEL
CALC						
CHECK						
APPD.						
APPD.						

TABLE E-2

THERMOCOUPLE LOCATIONS FOR WORK STATEMENT COMPLIANCE

Work Statement Location Description	Thermocouples
"... six different depths in the MLI ... locations as follows:	
(a) Forward hemisphere on a line 45° from the centerline of the hemisphere.	T1, T2, T3, T4, T5, T6
(b) Aft hemisphere on a line 45° from the centerline of the hemisphere.	T7, T8, T9, T10, T11 T12
(c) Mid point of the cylindrical section.	T13, T14, T15, T16, T17, T18
(d) At a point where an inner tank support passes through the insulation at a constant radial distance from the support.	T19, T20, T21, T22 T23, T24
(e) The insulation within the simulated manhole access area."	T25, T26, T27, T28, T29, T30
"Twelve thermocouples ... on both the exterior of the vacuum jacket and the inner face skin of the vacuum jacket."	T44 through T55 T56 through T67
"Two thermocouples ... bonded to both exterior and interior surfaces of the girth ring."	T40, T41 T42, T43
"Two of the inner vessel supports ... (a minimum of four on each support)."	T31, T22, T32, T33, T34 T35, T36, T37, T38, T39
"The thermally modeled manhole and fluid line penetrations ... (a minimum of four on each penetration)."	T75, T76, T77, T78, T86, T87, T88: T69, T70, T71, T82, T93, T94, T95.
"The ullage gas temperature shall be measured at the outlet of the pressure vessel."	T72

APPENDIX F

SYSTEM EVALUATION TEST PLAN

TEST PLAN

LIGHTWEIGHT VACUUM JACKET FOR CRYOGENIC INSULATION

Distribution: J. Allbee 4-1720 1E-11
D. Barclay 2-5520 8C-45
R. Hanna 2-5610 86-09
R. Lominick 2-2405 1E-11
F. Olsen 2-1833 4A-20

Test Engineer: H. M. Olden Date: 11-12-73
H. M. Olden

Test Supervisor: W. A. Smith Date: 11/12/73
W. A. Smith

TTS Test No.1 7308

Test Title: Lightweight Vacuum Jacket for Cryogenic Insulation

Contract No.: NASA Contract NAS3-15848

Test Location: Area 41, Pad 3

- Reference:
- (1) Procedures Manual, Tulalip Test Site, D2-121703-1
 - (2) Engineering Laboratories Safety Manual, D2-121354-1
 - (3) SOP- 72K
 - (4) Engineering Laboratories Test Practices Manual, D180-14822-1
 - (5) EWA No. 25540, Task IV

1.0 PURPOSE

The purpose of this test is to demonstrate system performance of a half scale model of the Shuttle Orbiter OMS fuel tank with an evacuated multi-layer insulation (MLI) system. The performance of this system will be carefully evaluated in conjunction with the rigorous cyclic operational requirements of the orbiter.

This test plan describes in sufficient detail the test conditions, instrumentation, facilities, equipment, and safety and operating procedures to insure meeting the program test objectives in a safe and efficient manner.

2.0 OBJECTIVE

Testing to be accomplished under this test plan will furnish data that will be used to verify the feasibility of the evacuated MLI system design for the OMS fuel tank.

3.0 SCOPE

A half scale model of the Shuttle Orbiter OMS fuel tank will be designed, fabricated and shipped to Tulalip Test Site for testing on Pad 3, Area 41. The tank will be installed into an existing LH₂ supply, vent and disposal system with some modifications required. A radiant heat shroud will be fabricated and installed around the tank to provide temperature conditioning. A boiloff test system will be assembled and installed for determining heat flow into the tank. Three boiloff tests will be performed. The first one will be considered the baseline boil off rate. The second one will be performed after subjecting the tank to 100 external pressure cycles of 0 to 200,000 ft. equivalent altitude pressure and 100 thermal cycles of 100 to 350°F. The third boiloff test will be conducted while simulating a specified hydrogen leak into the vacuum annulus of the tanks insulation system. The test data will provide information to determine if any degradation in performance of the insulation system has occurred as a result of these operational environments.

4.0 TEST CONDITIONS

4.1 There will be three boiloff tests and two cyclic tests performed under this test plan in the sequence as follows:

- Baseline boil-off test
- Load cycling (altitude cycling) test - Area 34 .
- Thermal cycling test
- Post cycling boil-off test
- Constant GH₂ leak boil-off test.

4.2 The test conditions for the three boiloff tests will be as follows:

- Tank internal pressure 17.0 PSIA
- Tank vacuum annulus pressure $< 2.0 \times 10^{-4}$ Torr
- Tank external pressure ambient
- Tank external temperature 100°F \pm 5°F
- Tank liquid hydrogen level < 3.0 in. from Top

4.3 The test conditions for the load cycling (altitude cycling) test will be as follows:

- Tank internal pressure Same as external
- Tank vacuum annulus pressure $< 2.0 \times 10^{-4}$ Torr
- Tank external pressure ambient to 1.6×10^{-1} Torr
- Tank external temperature ambient

4.3 continued

- Tank liquid hydrogen level No hydrogen
- Number of cycles 100 cycles

4.4 The test conditions for the thermal cycling test will be as follows:

- Tank internal pressure 15.0 PSIA
- Tank vacuum annulus pressure < 2.0×10^{-4} Torr
- Tank external pressure ambient
- Tank external temperature 100°F to 350°F
- Tank liquid hydrogen level < 14.0 in. from bottom
- Number of cycles 100 cycles

4.5 The half scale tank model will be constructed of two 90.0 inch diameter hemispheres connected to an 18.0 inch long cylindrical section. This tank will hold 2150 gallons of LH₂ when full. The inner vessel will have an operating pressure of 17.0 psia, a proof pressure of 40.0 psia, and a design burst pressure of 70.0 psia.5.0 FACILITIES

All testing will be conducted at the Boeing Company's Tulalip Test Site located approximately 45 miles north of Boeing's main Plant II headquarters. This facility has several well developed permanent test areas designed to handle a wide variety of hazardous and high noise level type tests. The cryogenic structural test facility, Test Area 41, is one of these specialized areas and will be used for this program. This area is devoted to structural materials testing which involve hazardous environments. These environments involve cryogenic propellants such as LH₂, LO₂ and toxic propellants such as LP₂, N₂O₄ and Hydrazine.

In order to efficiently and safely handle this type of testing the area has three heavily reinforced concrete test cells dispersed on an arc located 130 ft. from the test control and data recording building. Each test pad is separated on this arc by 85 ft. Each pad has permanently installed wiring for remote control of the test setup and for remotely recording all test data. In addition, each pad has installed plumbing which provides He and N₂ pressurization and purge gases, plant air, water, and electrical power.

This facility has permanently installed LH₂ supply capacity of 14,000 gal. with a distribution and control system to each of the three test pads.

All testing for this program, except for altitude cycling at Area 34, will be performed on Pad 3 of Test Area 41.

6.0 TEST EQUIPMENT

A schematic of the test setup is shown in Figure F-1.

The LH₂ fill system will include a LH₂ conditioning cryostat mounted above the test tank. This vacuum insulated device will condition the LH₂ prior to entering the test tank so that the thermodynamic properties of the entering hydrogen are nearly the same as the hydrogen already in the test tank. This is to minimize the disturbance of thermal equilibrium during test tank refill operations. The pressure in this cryostat will be maintained at a constant differential pressure of 0.5 psi above the pressure in the test tank.

A radiant heat shroud will be fabricated and installed around the test tank so as to provide the required test tank external surface temperature. This shroud will be an aluminum sphere with quartz radiant heat lamps installed to the inside surface. Electrical power to the lamps will be regulated by a Research Incorporated ignitron electrical power control Unit. A closed loop temperature feedback system will be used to control the electrical power required to maintain the desired tank surface temperature. Redundant over-temperature safety circuits will be installed to prevent accidental overheating of the tank. Preheated gaseous nitrogen (GN₂) will be used as a purge gas between the shroud and the external surface of the tank. This will aid in obtaining the desired surface temperature with minimum radiant heating power and also will exclude air, minimizing the chances of ignition of hydrogen.

The test tank internal pressure control system will consist of a closed loop pressure feedback servo valve system. The servo valve will control the flow of hydrogen boiloff gas from the tank so that the desired pressure in the tank will be maintained at a constant value. An Annin globe valve with the proper sized trim and an electro-hydraulic actuator will be used as the servo valve. The tank pressure feedback will be measured with a Baratron differential pressure transducer referenced to a very stable constant pressure source. This high-resolution differential pressure transducer will be used to sense very small positive or negative pressure variations in the cryogenic tank relative to a constant reference pressure. This reference pressure source will be a fixed volume of gas maintained at a constant temperature in an ice bath. A set point controller will be used to sense the electrical output signal of the high-resolution differential pressure transducer for control of the electrohydraulic pressure regulating servo valve. This complete system results in controlling the tank pressure to a constant value with respect to the reference pressure.

The flowrate of the hydrogen boiloff gas will be measured with a Hastings-Radist HF series mass flowmeter calibrated per documented procedures prepared by the Boeing Cal.-Cert. laboratories. A copper tube heat exchanger will be used to maintain the hydrogen boiloff gas at a constant temperature before entering the pressure regulating valve and flowmeter. In addition, the entire tank pressure regulating and boiloff flow measuring system will be contained in an insulated constant temperature controlled environmental box for thermal stability purposes.

6.0 continued

The gaseous hydrogen (GH₂) leak system will consist of a needle valve, calibrated and installed to the test tank at the Kent Space Center, and a pure GH₂ pressure regulated supply system installed at Tulalip. The GH₂ leak rate needle valve will be calibrated at Kent by using helium leak rates corrected to yield the desired GH₂ leak rate. The calibrated leak will not be accessible when the LH₂ tank is loaded but final GH₂ leak rate adjustment will be provided by the remotely variable GH₂ supply pressure. Vacuum integrity will be insured by a remotely operated shut-off valve between the calibrated leak and the tank vacuum annulus. This valve will not be opened until the time of the constant GH₂ leak boil-off test. The section of plumbing between the calibrated leak and the vacuum shut-off valve will be evacuated prior to opening the annulus to the calibrated leak. This will purge this section of plumbing so as not to contaminate the tank annulus.

7.0 INSTRUMENTATION

An instrumentation list showing parameter, range, and accuracy is shown in Figure F-2. A block diagram of the instrumentation data acquisition system is shown in Figure F-3. All instrumentation equipment will have up-to-date calibration certifications issued by Boeing Quality Control Organization. These periodic calibrations are designated and performed per existing Q.C. documented standards. All calibrations are traceable to the National Bureau of Standards.

All pressures will be measured with strain gage pressure transducers. These will be located so that they will always be at ambient temperature thus requiring only an ambient calibration.

Test vessel temperatures above 0°F will be measured with chromel-constantan thermocouples with 150°F reference junction. Temperatures below 0°F will use a LN₂ reference junction. Temperatures measured in the vent tube will be set up as differential thermocouples with the LH₂ in the test tank as the reference temperature.

Hydrogen liquid level is determined by the use of carbon resistors which give a point indication as to the presence of liquid. In this application, the carbon resistor will be electrically driven so as to slightly heat up while in the presence of cold hydrogen gas. The increased heat dissipated as a result of submergence in the liquid hydrogen will cause a resistance change due to temperature which will be detected through a bridge circuit. This in turn will actuate a relay turning on an indicator light. The carbon resistor will be normally installed in a still-well (shield) to minimize false indications due to boiling liquid surface irregularities. Sufficient resistors will be installed in the test tank to adequately monitor liquid levels during thermal stabilization and boil-off testing. Power to carbon resistors will be turned off during stability period when boil-off data is taken.

R.

7.0 continued

The hydrogen boil-off gas flow rate will be measured with a Hastings-Radist, HF series, mass flowmeter. This will provide a continuous direct recording of mass flow rate from the tank. This meter with its laminar flow element will be calibrated per Boeing Cal-Cert laboratories documented procedures using hydrogen gas. The calibration will provide data as to actual standard cubic feet per minute of hydrogen gas vs millivolts output.

A MKS Baratron transducer will be used to monitor the pressure variations in the test tank. This device is a very high resolution differential pressure transducer which will be referenced to a stable constant pressure source.

The test tank vacuum annulus pressure will be monitored with the vac-ion pump current. The vac-ion pumps will be in continuous operation throughout the test program. A thermocouple gage and readout will be installed in the GH₂ leak system which could be opened to the annulus in case the annulus pressure increased beyond the effective range of the vac-ion pumps. This would provide an emergency means of monitoring the vacuum annulus pressure.

Test data will be recorded with a Non-Linear Systems (NLS) digital data recording system. This is a highly reliable, 200-channel recorder which records millivolt signal data on magnetic tape that can be listed or plotted on IBM-compatible computers. The system is designed to operate continuously 24 hours per day, seven days per week. The sample rate is 10 samples per second. System accuracy is considered to be 40 microvolts of 100 millivolts full scale. The data tape will be removed from the recording system at the end of each boil-off test for computer processing. The data and calculated values will be tabulated and/or plotted as required for each boil-off test performed.

Some of the data parameters will be displayed and recorded on potentiometer type strip chart recorders. This will provide continuous quick-look information for ease in determining system stability and satisfactory performance.

A test progress report, consisting of the test log, reduced data, brief test summary of any test deviations or anomalies, and photographs will be prepared after each of the three boil-off tests.

8.0 TEST PROCEDURES

- 8.1 Lift test tank/fixture assembly from transportation trailer with crane and place it on Pad 3, Area 41. This assembly will remain as a complete unit throughout the Task IV test program.
- 8.2 Move test tank/fixture assembly into test position and connect to LH₂ fill and conditioning cryostat.
- 8.3 Connect vac-ion pump power to facility source and monitor annulus vacuum.
- 8.4 Connect tank thermocouples to test facility instrumentation wiring.
- 8.5 Leak check tank connection by pressurizing with gaseous helium and using a helium mass spectrometer to sniff joint.
- 8.6 Install four sections of the spherical heat shroud around test tank and connect all power and control cables.
- 8.7 Connect gaseous hydrogen supply to the calibrated leak system, and purge system with gaseous hydrogen. R
- 8.8 Adjust all the test tank and cryogenic system instrumentation recorders for their proper zeros and calibration pulses with the system vent valves VH 351 and VH 354 open.
- 8.9 Purge LH₂ conditioning cryostat by flowing helium through VHe 303 and out VH 354 for 2 min.
- 8.10 Purge test tank by continuing flow as in 8.9 but open VH 363 and VH 351 and close VH 354 causing helium flow out the vent for 20 min.
- 8.11 While purging, set up thermal conditions by gradually energizing the heat shroud radiant lamps and nitrogen gas flow to slowly increase vacuum jacket external temperature to 100°F ± 5°F. Monitor vacuum annulus pressure while temperature is being increased and for a period of time after reaching final temperature until pressure is stable or decreasing. If vacuum annulus pressure exceeds 2.0×10^{-4} Torr discontinue temperature increase until pressure decreases. If vacuum annulus external surface temperature of 100°F ± 5°F cannot be reached without exceeding annulus pressure of 2.0×10^{-4} Torr, hold temperature at intermediate level until after completing tank LH₂ fill in paragraph 8.17.
- 8.12 Turn Pad 3 area condition lights to "RED" and notify Fire Department at completion of purging and after attaining external surface temperature conditions.
- 8.13 Set up the facility liquid hydrogen supply system per standard operating procedures for delivery of LH₂ to Pad 3.
- 8.14 Fill conditioning cryostat by opening vent VH 354 and pad LH₂ supply VH 301. The automatic liquid level control system will operate VH 301 as needed to maintain the cryostat full of LH₂.
- 8.15 Set conditioning cryostat pressure control VH 365 to automatic and close VH 354 which will hold its pressure to 17.5 psia.

- 8.16 Fill test tank by opening VH 351 and then slowly opening VH 363 keeping the test tank pressure below 17.0 psia.
- 8.17 Stop test tank fill by closing VH 363.
- 8.18 Monitor test tank vacuum annulus pressure during and after filling with LH₂. It should decrease during filling but should not be greater than 2.0×10^{-4} Torr. Complete temperature conditioning per para. 8.11.
- 8.19 Continue to refill test tank per 8.13 through 8.17 as tank liquid level decreases to 6.0 inches from top.
- 8.20 When time between refills approaches 6.0 hrs. then set VH 382 to automatic operation and close VH 351 which will hold test tank pressure at 17.0 psia.
- 8.21 Continue to monitor all data parameters and refilling tank per 8.19 until all data appears stabilized indicating thermal equilibrium has been obtained.
- 8.22 Boil-off data will be sampled at decreasing time intervals until considered stabilized for boil-off measurement data. At this time, 4 hrs of concentrated data will be taken. R
- 8.23 Stop conditioning cryostat fill by closing VH 301 and open vent VH 354 and drain VH 366.
- 8.24 Empty test tank by opening VH 363 and maintaining 17 to 20 psia in tank by closing VH 382 and intermittently opening helium purge valve VHE 352.
- 8.25 Test tank will be empty when LL1 light goes out and temperature TS1 begins to rise sharply.
- 8.26 Close VHE 352 and VH 363 and open VH 351. R
- 8.27 Empty conditioning cryostat by opening VH 366 and closing VH 354. It will be empty when LL9 light goes out and temperature TS2 begins rising.
- 8.28 Open VH 363 and close VH 366 and VH 354 to prepare system for helium purge and initial warmup. R
- 8.29 Open VHE 355 to purge system for 10 min. and then turn helium heater on to initiate system warmup.
- 8.30 When TS1 indicates -250°F switch purge gas supply from helium to nitrogen.
- 8.31 Continue gaseous nitrogen warmup until TS1 reaches 50°F . Then turn off heater and GN₂ and return test pad to green condition. Leave a slight positive pressure in system. R
- 8.32 Turn off radiant heat shroud and remove shroud from tank.
- 8.33 Disconnect instrumentation from test tank.
- 8.34 Disconnect vac-ion power from facility and put on portable supply.

- 8.35 Disconnect test tank/fixture assembly from conditioning cryostat and move out of test pad 3.
- 8.36 Load test tank/fixture assembly on transport trailer and move to Area 34 for altitude testing.
- 8.37 Lift test tank/fixture assembly from transport trailer at Area 34 and place on altitude chamber dolly.
- 8.38 Roll test tank/fixture assembly into altitude chamber and connect vac-ion pumps to facility power supply.
- 8.39 Close altitude chamber and evacuate to an equivalent altitude pressure of 200,000 ft. and return to ambient pressure.
- 8.40 Monitor test tank vacuum annulus pressure all during the pressure cycle. If the vacuum annulus pressure rises above the vac-ion pump capability (approximately 2.4×10^{-4} Torr) the test will be stopped. Procedures to reactivate the test will be developed at that time. R
- 8.41 Repeat this pressure cycle 100 times.
- 8.42 Open altitude chamber and remove test tank/fixture assembly for transport back to Area 41.
- 8.43 At Area 41 repeat steps 8.1 through 8.18 stopping test tank fill when liquid level reaches 14.0 inches from bottom of tank by closing VH 363.
- 8.44 Maintain this liquid level all during the succeeding thermal cycling test by opening VH 363 to refill test tank as needed. The thermal cycling will be interrupted during each refill operation.
- 8.45 Heating to 350°F must be approached cautiously. The possibility of out-gassing beyond the pumping capability of the vac-ion pumps exists. Heating should be controlled so that when the limitation of the vac-ion pump ($\approx 2.4 \times 10^{-4}$ Torr) is approached the heating system is immediately shut off and cold nitrogen gas is introduced in the shroud area to restrict further out-gassing if possible. If the vacuum annulus pressure rises above the vac-ion pump capability, the test would be stopped. Procedures to reactivate the test would be developed at that time. R
- 8.46 Slowly apply heat manually for the first 100°F to 350°F temperature cycle while observing the precautions of para. 8.45.
- 8.47 Turn heat shroud controller to thermal cycle programmer and automatically cycle test tank surface temperature from 100°F to 350°F for a total of 100 cycles. Continually monitor test tank vacuum annulus pressure for any signs of degradation or system failure.
- 8.48 At end of thermal cycle test return heat shroud control to set point of 100°F for the following post cycling boil-off test.
- 8.49 Perform the post cycling boil-off test as in Section 8.16 through 8.22.
- 8.50 Evacuate the CH₂ leak system by opening VV 360 and pumping until P₄ stabilizes in pressure.
- 8.51 Close VV 360 and open VV 357 which will meter a calibrated flow of hydrogen gas into the vacuum annulus.

- 8.52 Set hydrogen supply pressure regulator VH 386 so that P_3 is at a value TBD psia.
- 8.53 The flow rate of GH_2 leak gas will be trimmed by adjusting supply pressure, P_3 . Gradually increase P_3 in steps, monitoring vacuum annulus pressure. Final P_3 setting will be that resulting in a stable vacuum annulus pressure of TBD Torr.
- 8.54 Perform the constant GH_2 leak boil-off test per section 8.19 through 8.23.
- 8.55 Close VV 357 to stop GH_2 leak into vacuum annulus. Continue to refill test tank with LH_2 per section 8.19 until vacuum annulus pressure returns to TBD Torr or for 3 days, whichever occurs first. Monitor vacuum annulus pressure. No boil-off rate or temperature data required.
- 8.56 Empty, purge and warm up test tank per 8.24 through 8.31.
- 8.57 Prepare tank for shipment per 8.32 through 8.35.
- 8.58 Load test tank/fixture assembly on transport trailer for shipment to the Kent Space Center.

9.0 SAFETY CONSIDERATIONS

The LH_2 system to be used for this test poses no abnormal safety problem. The majority of the equipment, i.e., transfer lines, cryostats, vents and valves have all been used in past testing for several years. This specific test configuration has been used in nearly identical form for two previous test programs. The major difference for this program is in the size of the test tank. This tank will hold 2,150 gal. (1,270 lbs.) of LH_2 .

Due to the integrity of the tank design, i.e., design, proof and operating pressures, failure of the test tank is considered highly improbable as long as overpressure conditions do not occur. Therefore, redundant pressure safety devices will be installed on the test tank so that maximum pressures will not be exceeded. Also, the vent system of the test tank has been sized such that in the event the vacuum fails in the insulation annulus the resultant higher boil-off rate will not cause the tank pressure to exceed a safe value.

In order to minimize the possible ignition of hydrogen gas that may accidentally be released, all spark producing equipment will either be explosion proof or be inert-gas purged. The space between the radiant heat lamp shroud and the external surface of the test tank will also be purged with nitrogen gas in order to eliminate any possible ignition in that area.

The radiant heat system will have a redundant temperature shutoff safety system. One system will be within the temperature control unit and the backup system will be a completely independent unit and will shut off all electrical power to the heating system in the event tank temperatures exceed a safe value.

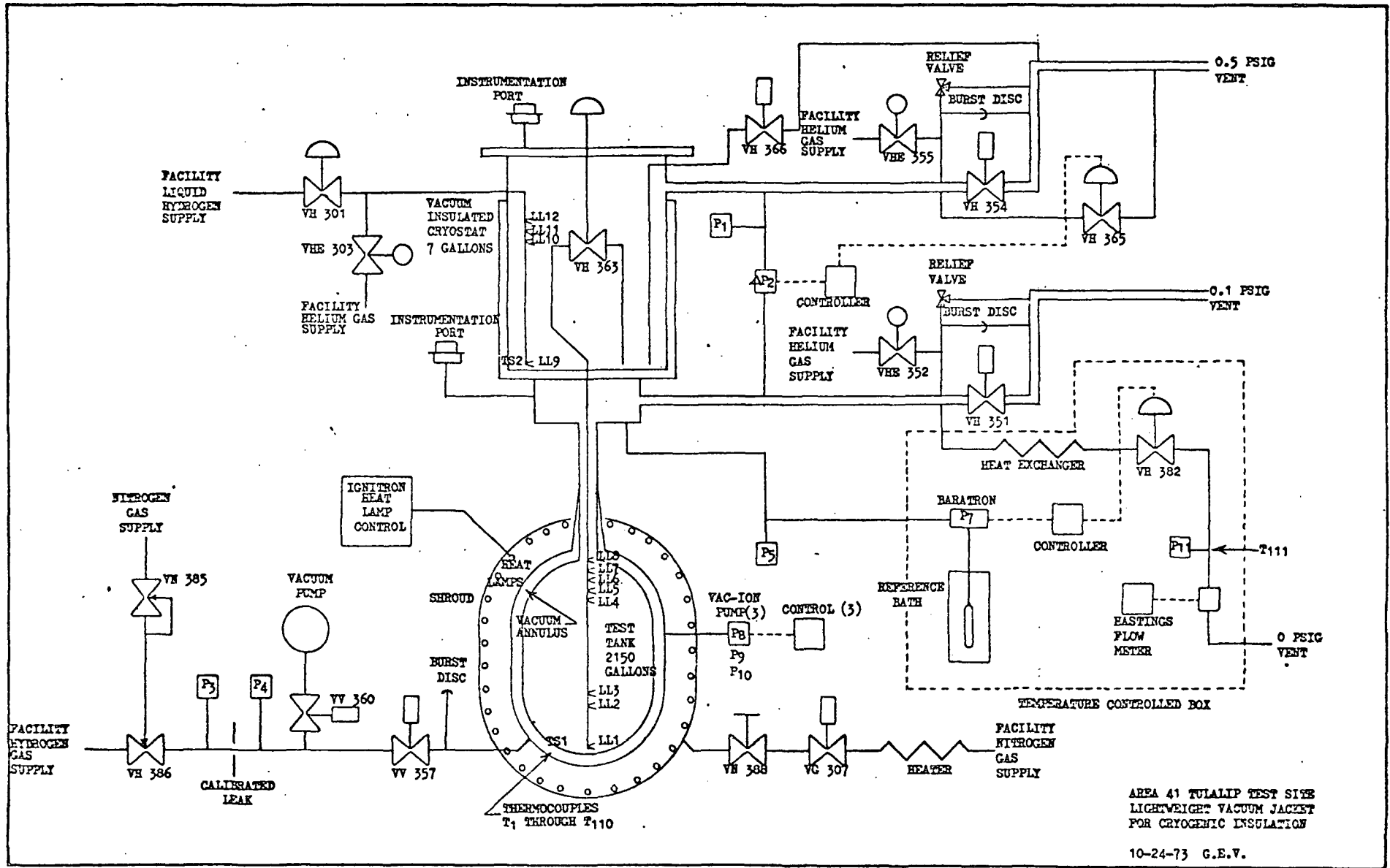
9.0 continued

In order to eliminate possible conflicts or confusion, and to increase the safety of operations, the assigned Test Area Engineer will have overall control of the test including safety procedures, cryogenic test procedures, malfunction procedures, and control of all personnel in the test area. During hydrogen test operations, all of the area of Test Area 41, east of the east end of the control house, will be excluded of all personnel.

10.0 MALFUNCTION PROCEDURES

A malfunction will be defined as any damage of equipment as a direct result of test operations conducted per this test plan. This could be caused by rupture and/or fire of/or from the test tank.

In the event of the above all hydrogen supply valves will be closed and the test tank will be emptied per 8.24 through 8.31, if possible, and the LH₂ conditioning cryostat emptied immediately after the test tank. The Fire Department will be notified and instructed to proceed to Test Area 41 and coordinate with the Test Area Engineer for further action. Helium purges of both tanks will then be turned on and maintained to warm up the test tanks and eliminate hydrogen. As soon as the hydrogen has been expelled and no over-pressurization of a tank exists the Fire Department may then be admitted to the pad area to expel any secondary fires that may exist and to cool down the test area. All main electrical power to the pad will also be turned off to eliminate electrical hazards. If a malfunction occurs the Test Area Engineer will immediately notify the Test Site Manager and the Ordnance Engineer. A written report will subsequently be prepared giving the details surrounding the incident. Corrective action will be taken before any further testing per this test plan is resumed.



REV LTR _____

BOEING NO. FIGURE F-1 Test No. 7308

Sh 12

PARAMETER			ACCURACY	RANGE		CALIBRATION			J-BOX	BALANCE PANEL	MAC PANEL	DATA SYSTEM CHAN		RECORDER CALIBRATION	
DESCRIPTION	NUMBER	S/N		RATED	USING	%	DIV	PSI							
PRESSURE															
Cryostat	P1		1% P.S.		5 psig										
Cryostat vs Test Tank	P2		1% P.S.		5 psid										
Hydrogen Gas Supply	P3		1% P.S.		50 psig										
Hydrogen Gas Vacuum	P4		1% P.S.		1x10 ⁻⁵ Torr										
Test Tank	P5		1% P.S.		5 psig										
Barometric Pressure	P6		1% Reading		0-15 psia										
Test Tank vs Reference	P7		±.0002 psi		2 psid										
Vacuum Appliance	P8		1% P.S.		1x10 ⁻⁵ Torr										
Vacuum Appliance	P9		1% P.S.		1x10 ⁻⁵ Torr										
P10															
TEMPERATURE															
Bottom Test Tank	TS 1		Indication		-423°P										
Cryostat	TS 2		"		"										
LIQUID LEVEL															
Bottom Test Tank	LL 1		.1 Inch		On/Off										
Top Test Tank	LL 2		↑		↑										
Top Test Tank	LL 3														
Top Test Tank	LL 4														
Top Test Tank	LL 5														
Top Test Tank	LL 6														
Top Test Tank	LL 7														
Top Test Tank	LL 8														
Bottom Cryostat	LL 9														
Top Cryostat	LL 10														
Top Cryostat	LL 11														
Top Cryostat	LL 12		.1 Inch		On/Off										
FLOW METER			3% of Reading		2.5 SCFM										

	INITIALS	DATE	REV BY INITIALS	DATE	TITLE	MODEL
CALC.	GEV	10/26/68			INSTRUMENTATION LIST AREA 41 LIGHTWEIGHT VACUUM JACKET FOR CRYOGENIC INSULATION	
CHECK						
APPD.						
APPD.						

113

411

PARAMETER		ACCURACY	RANGE		CALIBRATION	J-BOX	MAC PANEL	DATA SYSTEM GRAN.	RECORDER	CALIBRATION
DESCRIPTION	NUMBER				REFERENCE					
THERMOCOUPLE										
Surface &	T 1	± 2°F	-300	to +350°F						
Buried MLI	T 2									
Upper Heml	T 3									
	T 4									
	T 5									
	T 6									
Surface &	T 7	± 2°F	-300	to +350°F						
Buried MLI	T 8									
Lower Heml	T 9									
	T 10									
	T 11									
	T 12									
Surface &	T 13	± 2°F	-300	to +350°F						
Buried MLI	T 14									
Blanket	T 15									
Girth	T 16									
	T 17									
	T 18									
Surface &	T 19	± 2°F	-300	to +350°F						
Buried MLI	T 20									
Upper Strap	T 21									
	T 22									
	T 23									
	T 24									
Surface &	T 25	± 2°F	-300	to +350°F						
Buried MLI	T 26									
Lower Polar	T 27									
Cap	T 28									
	T 29									
	T 30									

	INITIALS	DATE	REV BY	DATE	TITLE	MODEL
CALC.	GEV	10/26/68			INSTRUMENTATION LIST AREA 41 LIGHTWEIGHT VACUUM JACKET FOR CRYOGENIC INSULATION	
CHECK						
APPD						
APPD						

REV LTR. _____
 US 4011 1000 REV. 2/65

BOEING NO. FIGURE F-2 - Test No. 7308
 Sh 14

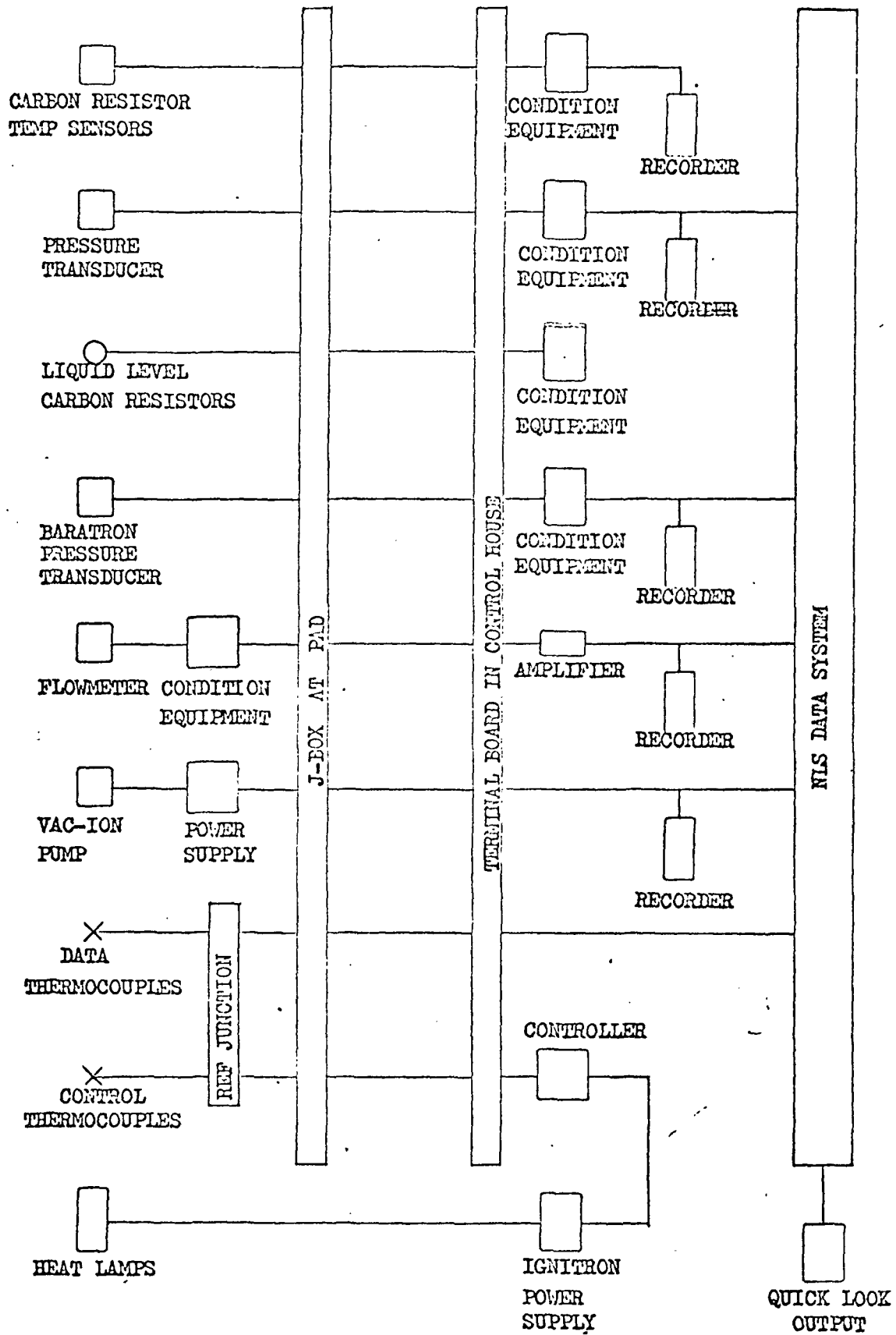
PARAMETER		ACCURACY	RANGE	CALIBRATION	J-BOX	MAC PANEL	DATA SYSTEM CHAN	RECORDER CALIBRATION
DESCRIPTION	NUMBER			REFERENCE				
THERMOCOUPLE								
Support Strip	T31	± 2°F	-300° to +350°F					
	T32							
	T33							
	T34							
Leak Strip	T35	± 2°F	-300° to +350°F					
	T36							
	T37							
	T38							
	T39							
Surface Ex	T40	± 2°F	+60° to +350°F					
Girth Ring	T41							
Surface In	T42	± 2°F	+60° to +350°F					
Girth Ring	T43							
Vac Jac	T44	± 2°F	+60° to +350°F					
Exterior	T45							
	T46							
	T47							
	T48							
	T49							
	T50							
	T51							
	T52							
	T53							
	T54							
	T55							
Vac Jac	T56	± 2°F	+60° to +350°F					
Interior	T57							
	T58							
	T59							
	T60							

	INITIALS	DATE	REV BY INITIALS	DATE	TITLE	MODEL
CALC.	GSY	10/26/5			INSTRUMENTATION LIST AREA 41 LIGHTWEIGHT VACUUM JACKETS FOR CRYOGENIC INSULATION	
CHECK						
APPD						
APPD						

115
16

PARAMETER		ACCURACY	RANGE	CALIBRATION	J-BOX	MAC PANEL	DATA SYSTEM CHAN	RECORDER CALIBRATION
DESCRIPTION	NUMBER			REFERENCE				
THERMOCOUPLES								
Vac Jac	T61	± 2°F	+60° to +350°F					
Interior	T62							
(Cont)	T63							
	T64							
	T65							
	T66							
	T67							
MLI POLAR Cap	T68	± 2°F	0 to + 275°F					
Surface	T69	± 2°F	-423° to +32°F					
Vent Tube	T70							
	T71							
Vent Tube	T72	± 1.5°F	-423° to 0					
Space	T73	Relative						
	T74							
Surface Tube	T75	± 2°F	-423° to +100°F					
Slm Pen	T76							
	T77							
	T78							
End Slm Pen	T79	± 2°F	+60° to +350°F					
Vac Jac	T80	± 2°F	+60° to +350°F					
Near Pill	T81							
Vent Line	T82	± 2°F	-423° to +32°F					
Surface Pen	T83	± 2°F	+60° to +350°F					
	T84							
MLI Pen	T86	± 2°F	-300° to +100°F					
	T87							
	T88							
MLI Surface	T89	± 2°F	-200° to +350°F					
	T90							

	INITIALS	DATE	REV BY	DATE	TITLE	MODEL
CALC.	GEY	0/26/78			INSTRUMENTATION LIST AREA 41 LIGHTWEIGHT VACUUM JACKET FOR CRYOGENIC INSULATION	
CHECK						
APPD						
APPD						



AREA 41 TULALIP TEST SITE
 LIGHTWEIGHT VACUUM JACKET
 FOR CRYOGENIC INSULATION

NAS3-15848 DISTRIBUTION LIST FOR FINAL REPORT
"LIGHTWEIGHT VACUUM JACKET FOR CRYOGENIC INSULATION". VOL. 1, NASA CR 134759;
VOL. II, NASA CR 134760.

National Aeronautics & Space Administration
Lewis Research Center
21000 Brookpark Road
Cleveland, Ohio 44135

1 Attn: Contracting Officer, MS 500-313
5 E. A. Bourke, MS 500-205
1 Technical Utilization Office, MS 3-16
1 Technical Report Control Office, MS 5-5
2 AFSC Liaison Office, MS 501-3
2 Library, MS 60-3
1 Office of Reliability & Quality Assurance, MS 500-211
3 J.R.Barber , Project Manager, MS 500- 203

National Aeronautics & Space Administration
Headquarters
Washington, D.C. 20546

1 Attn: Office of Aeronautics & Space Technology
1 Director, Manned Space Technology/RS
1 Director, Space Propulsion & Power/RP
1 Director, Materials & Structures/RW
1 F. W. Stephenson/RPI
1 Attn: Office of Manned Space Flight
1 Director, Advanced Manned Mission/MT
1 Attn: Office of Space Science
1 Director, Physics & Astronomy Programs/SG
1 Director, Planetary Programs/SL
1 Director, Launch Vehicles & Propulsion/SV
1 Attn: Office of Technology Utilization Division
Director, Technology Utilization/KT

1 National Aeronautics & Space Administration
 Ames Research Center
 Moffett Field, California 94035
 Attn: Library

1 National Aeronautics & Space Administration
 Flight Research Center
 P. O. Box 273
 Edwards, California 93523

National Aeronautics & Space Administration
 George C. Marshall Space Flight Center
 Huntsville, Alabama 35912

1 Attn: Library E. H. Hyde
 1 A. G. Orillion
 1 T. W. Barret
 1 J. M. Stuckey
 1 I. G. Yates

1 National Aeronautics & Space Administration
 Goddard Space Flight Center
 Greenbelt, Maryland 20771
 Attn: Library

National Aeronautics & Space Administration
 John F. Kennedy Space Center
 Cocoa Beach, Florida 32931

1 Attn: Library
 1 W. S. Brosier, LL-OPN-2

National Aeronautics & Space Administration
 Lyndon B. Johnson Space Center
 Houston, Texas 77001

1 Attn: Library
 1 W. Chandler

National Aeronautics & Space Administration
 Langley Research Center
 Langley Station
 Hampton, Virginia 23365

1 Attn: Library
 1 I. O. MacConochie, MS411
 1 C.D'Alutolo, MS 249A

10 - NASA Scientific & Technical Information Facility
P. O. Box 8757
Baltimore/Washington International Airport
Baltimore, MD 21240
Attn: NASA Representative

1 Office of the Director of Defense
Research & Engineering
Washington, D. C. 20301
Attn: Office of Ass't Director(Chemical Technology)

Jet Propulsion Laboratory
4800 Oak Grove Drive
Pasadena, California 91103

1 Attn: Library 1 D. Dipprey
1 J. Kelly
1 R. Breshears

1 Defense Documentation Center
Cameron Station
Building 5
5010 Duke Street
Alexandria, Virginia 22314
Attn: TISIA

1 Advanced Research Projects Agency
Washington, D. C. 20525
Attn: Library

1 Aeronautical Systems Division
Air Force Systems Command
Wright-Patterson Air Force Base
Dayton, Ohio
Attn: Library

1 Air Force Missile Test Center
Patrick Air Force Base
Florida
Attn: Library

1 Air Force Systems Command
Andrews Air Force Base
Washington, D. C. 20332
Attn: Library

Air Force Rocket Propulsion Laboratory(RPR)
Edwards, California 93523

1 Attn: Library
1 R. L. Wiswell, LKDS
1 D. A. Hart

1 Air Force Rocket Propulsion Laboratory(RPM)
Edwards, California 93523
Attn: Library

1 Air Force FTC (FTAT-2)
Edwards Air Force Base
California 93523
Attn: Library

Air Force Office of Scientific Research
Washington, D. C. 20333

Attn: Library

1 U. S. Air Force
Washington, D. C.
Attn: Library

1 Air Force Aero Propulsion Laboratory
Research & Technology Division
Air Force Systems Command
U. S. Air Force
Wright-Patterson AFB, Ohio 45433
Attn: Library (APRP)

1 Arnold Engineering Development Center
Air Force Systems Command
Tullahoma, Tennessee
Attn: Library

Space & Missile Systems Organization
Air Force Unit Post Office
Los Angeles, California 90045

1 Attn: Library(Technical Data Center)

1 Office of Research Analyses(OAR)
Holloman Air Force Base
New Mexico 88330
Attn: Library (RRRD)

1 RTD (RTNP)
Bolling Air Force Base
Washington, D. C. 20332

1 Bureau of Naval Weapons
Department of the Navy
Washington, D. C.
Attn: Library

1 Naval Research Branch Office
1030 E. Green Street
Pasadena, California 91101
Attn: Library

- 1 Picatinny Arsenal
Dover, New Jersey 07801
Attn: Library
- 1 U.S. Naval Research Laboratory
Washington, D. C. 20390
Attn: Library
- 1 U. S. Army Research Office(Durham)
Box CM, Duke Station
Durham, North Carolina 27706
Attn: Library
- 1 U. S. Army Missile Command
Redstone Scientific Information Center
Redstone Arsenal, Alabama 35808
Attn: Document Section
- 1 U. S. Naval Missile Center
Point Mugu, California 93041
Attn: Technical Library
- 1 U. S. Naval Weapons Center
China Lake, California 93557
Attn: Library
- 1 Aerojet-General Corporation
Electronics Division
P. O. Box 296
Azusa, California 91703
Attn: Library
- 1 Aerojet-General Corporation
Space Division
9200 East Flair Drive
El Monte, California 91734
Attn: Library
- 1 Aerojet-General Corporation
Aerojet Ordance & Manufacturing
11711 South Woodruff Avenue
Fullerton, California 90241
Attn: Library
- 1 Aerojet Liquid Rocket Company
P. O. Box 15847
Sacramento, California 95813
Attn: Technical Library 2484-2015A

- 1 Aerospace Corporation
2400 E. El Segundo Blvd
Los Angeles, California 90045
Attn: Library
V. H. Monteil
- 1 Garrett Corporation
Airesearch Mfg. Division
9851 Sepulveda Blvd
Los Angeles, California
Attn: Library
- 1 Garrett Corporation
Airesearch Mfg. Division
402 South 36th Street
Phoenix, Arizona 85034
Attn: Library
- 1 Aro Incorporated
Arnold Engineering Development Center
Arnold AF Station, Tennessee 37389
Attn; Library
- 1 Battelle Memorial Institute
505 King Avenue
Columbus, Ohio 43201
Attn: Library
- 1 Beech Aircraft Corporation
Boulder Facility
Box 631
Boulder, Colorado
- 1 Bell Aerosystems Inc
Box 1
Buffalo, New York 14240

Attn: Library
- 1 Bendix Corporation
Instruments & Life Support Division
P. O. Box 4508
Davenport, Iowa 52808
Attn: Library

- 1 Boeing Company
1625 K Street N. W.
Washington, D. C.
- 1 Boeing Company
P. O. Box 1680
Huntsville, Alabama 35801
- 1 Chemical Propulsion Information Agency
Applied Physics Laboratory
8621 Georgia Avenue
Silver Spring, Maryland 20910
- 1 Chrysler Corporation
Missile Division
P. O. Box 2628
Detroit, Michigan
Attn: Library
- 1 Chrysler Corporation
Space Division
P.O. Box 29200
New Orleans, Louisiana 70129
Attn: Library
- 1 Curtiss-Wright Corporation
Wright Aeronautical Division
Woodridge, New Jersey
Attn: Library
- 1 Denver Research Institute
University of Denver
P. O. Box 10127
Denver, Colorado 80210
Attn: Security Office

- 1 Fairchild Stratos Corporation
Aircraft Missile Division
Hagerstown, Maryland
Attn: Library
- 1 Fairchild Hiller Corporation
Research Center
Germantown, Maryland
Attn: Library
- 1 Fairchild Hiller Corporation
Republic Aviation
Farmington, L. I. N. Y.
- General Dynamics/Convair
P. O. Box 1128
San Diego, California 92112
- 1 Attn: Library
1 R. Tatro
- 1 General Electric Company
Missiles & Space Systems Center
Valley Forge Space Technology Center
P. O. Box 8555
Philadelphia, Pennsylvania 19101
Attn: Library
- 1 General Electric Company
Apollo Support Department
P. O. Box 2500
Daytona Beach, Florida 32015
Attn: C. Bay
- 1 Grumman Aircraft Engineering Corporation
Bethpage, L. I. N.Y.
Attn: Library
- 1 Hamilton Standard Corporation
Windsor Locks, Conn. 06096
Attn: Library

- 1 Hercules Powder Company
Allegheny Ballistics Lab
P. O. Box 210
Cumberland, Maryland 21501
Attn: Library
- 1 Honeywell Inc.
Aerospace Division
2600 Ridgeway Road
Minneapolis, Minnesota
Attn: Library
- 1 IIT Research Institute
Technology Center
Chicago, Illinois 60616
- Attn: Library
- 1 International Nickel Company
One New York Plaza
New York, N. Y. 10004
Attn: C. B. Sanborn
- 1 Kidde Aerospace Division
Walter Kidde & Company
567 Main Street
Belleville, New Jersey 07109
Attn: Library
- 1 Linde, Division of Union Carbide
P. O. Box 44
Tonawanda, N.Y. 11450
Attn: G. Nies
- 1 Ling-Temco-Vought Corporation
P. O. Box 5907
Dallas, Texas 75222
Attn: Library
- Lockheed Missiles & Space Company
P. O. Box 504
Sunnyvale, California 94087
- 1 Attn: Library
1 R. T. Parmley
- 1 Lockheed Propulsion Company
P. O. Box 111
Redlands, California 92374
Attn: Library

1 Marquardt Corporation
16555 Saticoy Street
Box 2013 South Annex
Van Nuys, California 91409

Attn: Library

1 Minnesota Mining & Manufacturing Company
900 Bush Avenue
St. Paul, Minnesota 55106
Attn: Library

Martin-Marietta Corporation
P. O. Box 179
Denver, Colorado 80201

1 Attn: Library
1 G. C. Skartvedt

1 Martin-Marietta Corporation
Box 5827
Orlando, Florida
Attn: Library

1 McDonnell Douglas Astronautics
5301 Bosa Avenue
Huntington Beach, California 92647

1 Attn: Library
1 L. Q. Westmoreland
1 P. Klevatt

McDonnell Douglas Aircraft Corporation
P. O. Box 516
Lambert Field, Missouri 63166

1 Attn: Library
1 L. F. Kohrs

1 Northrop Space Laboratories
3401 West Broadway
Hawthorne, California
Attn: Library

- 1 Philco-Ford Corporation
Aeronutronic Division
Ford Road
Newport Beach, California 92663
Attn: Library
- 1 Purdue University
Lafayette, Indiana 47907
Attn: Library
- 1 Radio Corporation of America
Astro-Electronics Products
Princeton, New Jersey
Attn: Library
- 1 Rocketdyne
A Division of Rockwell International
6633 Canoga Avenue
Canoga Park, California 91304

Attn: Library
- 1 Space Division
A Division of Rockwell International
12214 Lakewood Blvd
Downey, California

Attn: Library
- 1 Rocket Research Corporation
Willow Road At 116th Street
Redmond, Washington 98052
Attn: Library
- 1 Stanford Research Institute
333 Ravenswood Avenue
Menlo Park, California 94025
Attn: Library
- 1 Susquehanna Corporation
Atlantic Research Division
Shirley Highway & Edsall Road
Alexandria, Virginia 22314
Attn: Library

1 Thiokol Chemical Corporation
Redstone Division
Huntsville, Alabama
Attn: Library

TRW Systems Inc.
1 Space Park
Redondo Beach, California 90278

1 Attn: Library
1 A. H. Zimmerman

1 TRW
- TAPCO Division
23555 Euclid Avenue
Cleveland, Ohio 44117
Attn: Library

1 United Aircraft Corporation
Corporation Library
400 Main Street
East Hartford, Connecticut 06103

1 United Aircraft Corporation
United Technology Center
P. O. Box 358
Sunnyvale, California 94038
Attn: Library

United Aircraft Corporation
Pratt & Whitney Division
Florida Research & Development Center
P. O. Box 2691
West Palm Beach, Florida 33402

1 Attn: Library
1 G. B. Cox

1 Vickers Incorporated
Box 302
Troy, Michigan
Attn: Library

1 Vought Astronautics
Box 5907
Dallas, Texas
Attn: Library