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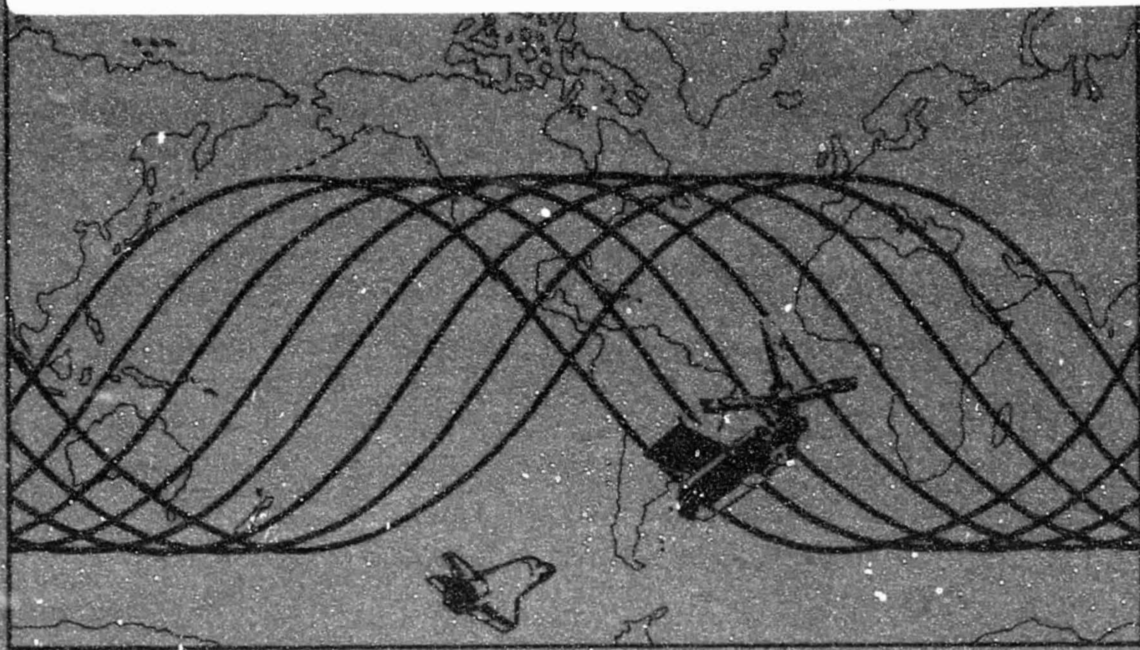

SKYLAB REUSE STUDY

FINAL REPORT AND REFERENCE DATA

Part 2 -- Appendixes

MCDONNELL DOUGLAS ASTRONAUTICS COMPANY

MCDONNELL DOUGLAS

CORPORATION

MCDONNELL DOUGLAS

SKYLAB REUSE STUDY

FINAL REPORT AND REFERENCE DATA

Part 2 – Appendixes

DECEMBER 1978

MDC G7556

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PREFACE

The Skylab Reuse Study was an 11-month effort (November 1977 to October 1978) which contributed to the Skylab Reactivation Mission and defined Skylab reuse objectives, benefits, and concepts. The study was organized into the two noted activities with emphasis on subsystems interrogation occurring during the initial two months.

The final report was prepared as both a Skylab reuse study report and a summary reference document for the Orbital Workshop and Airlock Module Mission performance. This approach was employed as a means of providing a single source of the basic information necessary for understanding the chronological flow of events and the related hardware status. As a point of departure in implementing this technical record the following information is presented in the final report: end-of-mission conditions, reactivation status, refurbishment requirements, additional mission hardware definitions, Skylab reuse concepts, and candidate payloads. An addendum volume is also provided to address special emphasis tasks and describe the original flight configuration of the Airlock Module and Orbital Workshop. Thus, should further activities be of interest at a future date, the necessary background information has been assembled in one set of documents.

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V. S. Mueller	Electrical Power System
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At MDAC-HB

A. D. Carpenter	Integrated Systems Analyses
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At MDAC-SL

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CONTENTS

Appendix A

EVALUATIONS OF THE DYSBARISM RISK ASSOCIATED WITH A SKYLAB REVISIT BY SHUTTLE

The following analytical treatment of dysbarism effects and time limitations will provide a general data base for future assessments. However, there are current test programs being conducted which will produce empirical data and factors that should be compared with the analytical baseline and appropriate adjustments made prior to final evaluations.

Test work has been recently conducted by Julian P. Cooke et al. of the Crew Environment Branch, USAF School of Aerospace Medicine, Brooks A.F.B. Texas. This current work and empirical data in denitrogenation interruptions with air should be reviewed.

EVALUATION OF THE DYSBARISM RISK ASSOCIATED WITH A SKYLAB REVISIT BY SHUTTLE

1.0 GENERAL

Dysbarism is a term normally used to describe the condition in which gas bubbles are formed in body tissues because of a reduction in the pressure to which the body is exposed. The production of bubbles depends upon the pressure reduction being of sufficient magnitude and occuring over a sufficiently short duration. Dysbarism symptoms can vary from a mild itching of the skin to coma and death but are most commonly manifested as pains in the elbow or knee joints. The nature and severity of the symptoms appear to be related to the size of the bubbles and the site of their formation.

1.1 Gases Involved:

Bubble formation is attributed to biologically inert gases in breathing mixtures, but the metabolic gases (O_2, CO_2, water vapor) are believed to contribute to bubble growth after it is formed. Nitrogen is the inert gas found in terrestrial atmospheres and in the atmosphere of most current spacecraft, although, other inert gases may be substituted in special-purpose breathing mixtures.

1.2 Dysbarism Risk

The possibility that symptoms of dysbarism will occur with a reduction in environmental pressure is usually expressed as a percentage risk and is based primarily on empirical data. Results of studies of numerous exposures to actual altitudes during flight, to simulated altitudes during low-pressure chamber tests, and to ascents from underwater dives indicate that the % risk is directly related to the ratio of the tissue gas pressure prior to pressure reduction to the environmental pressure following the change

It has been generally observed that a reduction in environmental pressure to one-half the initial pressure will produce no dysbarism symptoms in about

99% of the exposed individuals. This is identified as a 1% risk and is usually considered acceptable for most situations.

1.3 Risk Ratio Versus % Risk

The tension of the tissue gases (P_T) at sea level is about 700 torr and is comprised of nitrogen (570 torr) and the metabolic gases O_2, CO_2, and H_2O (130 torr). When the environmental pressures (P_B) is reduced by 1/2 from 760 to 380 the ratio of P_T^1/P_B^2 (700/380) = 1.8. As stated in section 1.2, this ratio is equivalent to a 1% risk. It has further been observed that a reduction of environmental pressure to 350 torr producing a P_T^1/P_B^2 ratio of 2.0 is equivalent to a 2% risk, and that a reduction to 282 torr, (P_T^1/P_B^2 = 2.5) a 5% risk. These ratios appear to be valid at any altitude or any underwater depth regardless of the initial P_T^1 or the final P_B^2. A curve relating risk ratios to % risk is presented as Figure 1. It is based on an analysis by Wamsley et. al. (reference 1) of over 80,000 exposures.

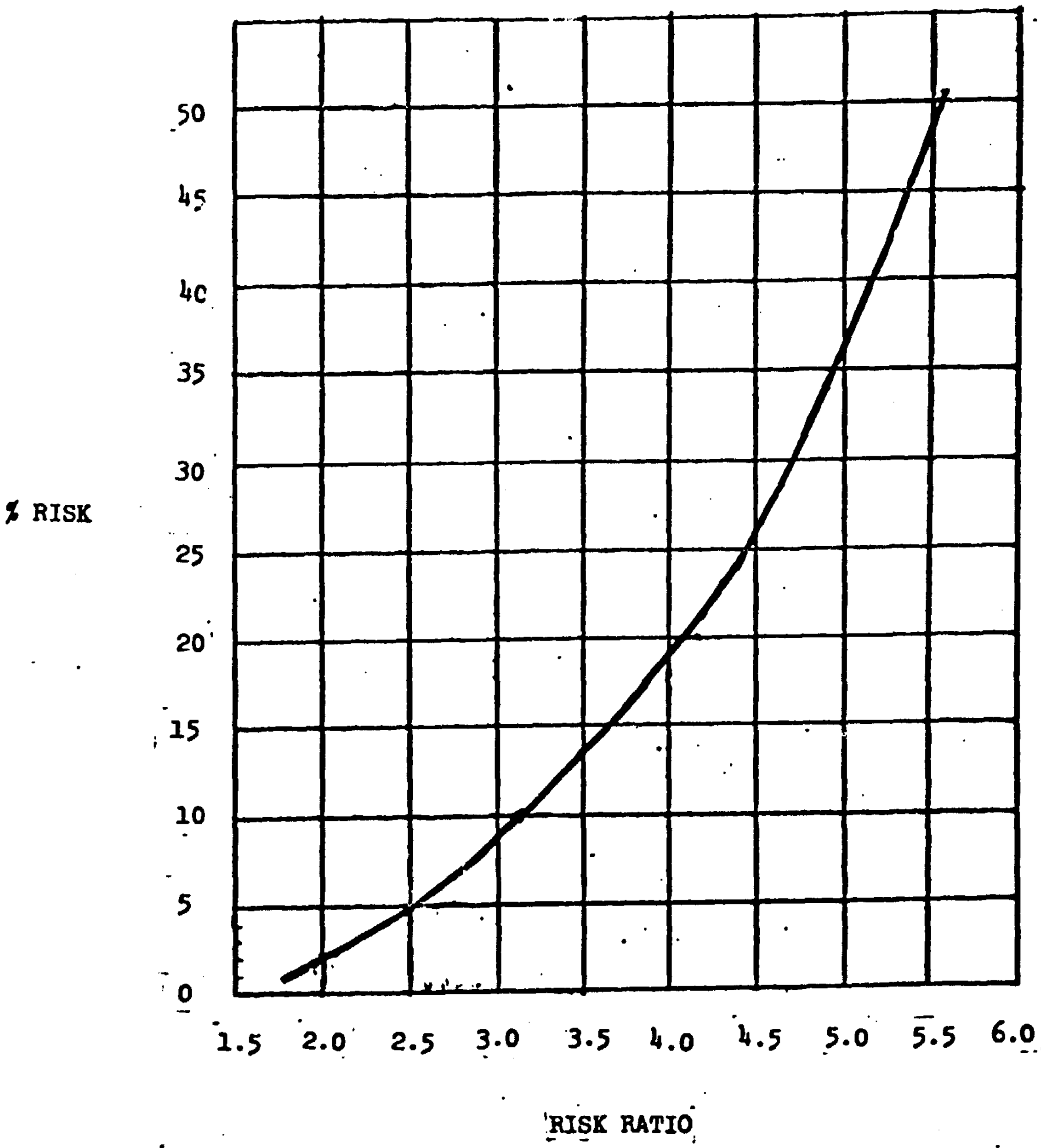
1.4 Reduction of Tissue Gas Pressure

The risk of dysbarism can be reduced by decreasing the pressure of the gases disolved in the tissues prior to exposure to a decreased environmental pressure. The pressures of the metabolic gases are fixed by metabolic characteristics and cannot be significantly changed; the amount of disolved nitrogen can, however, be reduced. The amount and, consquently, the pressure of nitrogen can be reduced by causing the subject to breath a gas mixture containing a lower nitrogen pressure than the tissue nitrogen pressure. Most commonly, 100% oxygen is used and the procedure is referred to as preoxygenation. The reduction in tissue nitrogen pressure necessary to produce a favorable P_T^1/P_B^2 ratio may be readily calculated. In the example shown below the external pressure is reduced from terrestrial pressure to 5 psia (P_B^1 = 760 torr, P_B^2 = 258 torr) and an acceptable risk is 1%.

FIGURE 1

THE RELATIONSHIP OF DYSBARISM RISK

TO THE RISK RATIO $\left(P_T^1 / P_B^2\right)$



$$P_T'/P_B^2 = 1.8 \qquad P_T = P_N + P_M$$
$$P_T' = 1.8 \times 258 \qquad P_N = 464 - 130$$
$$P_T' = 464 \text{ torr} \qquad P_N = 334 \text{ torr}$$

where P_N = pressure of disolved nitrogen and
P_M = pressure of disolved metabolic gases = 130 torr

1.5 Process of Tissue Nitrogen Saturation/Desaturation

Unfortunately, with regard to simplicity of calculation, nitrogen is not distributed evenly among the body tissues. Since the solubility of nitrogen in oils is about 5 times its solubility in water, fatty tissues have a much greater capacity for nitrogen than does the blood or muscle tissues. Further, the rate that nitrogen will enter or leave a tissue depends not only upon its solubility in the tissue but also upon the blood flow to the tissue which governs its delivery rate. Studies of nitrogen saturation and desaturation of body tissues in man and experimental animals have identified a number of body "compartments", each with its own saturation desaturation rate. The nitrogen uptake or decay curve for each compartment is generally exponential; and each identified compartment may be assigned a saturation/desaturation half-time (H) which is valid only for a specific gas. The compartment half-times used for the calculation of decompression schedules by the Navy for nitrogen-oxygen dives (reference 2) are: 5, 10, 20, 40, 80, 120, and 240 minutes. Other investigators (reference 1) have used half-times as great as 300 minutes for the slower tissues. The tissue compartment half-time is an important factor in calculations of tissue nitrogen saturation/desaturation rates.

1.6 Calculation of Tissue Nitrogen Saturation/Desaturation Times

The rate at which nitrogen enters or leaves a tissue depends upon several factors:

a. The difference in pressure between the nitrogen in the tissue (P_N) and the nitrogen pressure in the lung alveolus (P_{A_N}) which is, of course, a function of the nitrogen partial pressure in the breathing mixture. If the alveolar nitrogen pressure is lower than the tissue pressure ($P_N - P_{A_N}$), nitrogen will tend to leave the tissue; if the alveolar nitrogen pressure is higher ($P_{A_N} - P_N$) nitrogen will tend to enter the tissue.

b. The tissue compartment half-time (H) for nitrogen and the total exposure time (T) are combined into a mathematical expression or factor (F) which equals $1 - \frac{1}{(2)^{T/H}}$. The total amount of nitrogen leaving or entering a tissue compartment is the product of (F) and the pressure difference. This amount is then added to or subtracted from the amount already there.

The complete formulae for calculating the change in nitrogen concentration of a tissue compartment are:

a. For tissue saturation -

$$P_N^2 = P_N^1 + \left(1 - \frac{1}{(2)^{T/H}}\right)\left(P_{A_N}^2 - P_N^1\right)$$

b. For tissue desaturation -

$$P_N^2 = P_N^1 - \left(1 - \frac{1}{(2)^{T/H}}\right)\left(P_N^1 - P_{A_N}^2\right)$$

2.0 CALCULATIONS RELATIVE TO A SKYLAB REVISIT

The revisit to Skylab would be conducted from the Shuttle Transportation System. This discussion addresses the situation in which the Skylab has been repressurized and transfer will be made without pressurized EMU's. The Shuttle atmosphere is assumed to be:

760 TORR (14.7 psia), 21% O_2, 79% N_2

The Skylab atmosphere is assumed to be:

258 TORR (5 psia), 72% O_2, 28% N_2.

2.1 Initial Preoxygenation Requirements

Transfer from Shuttle to the Skylab without preoxygenation will involve the following dysbarism risk: P_T^1 = 700 TORR, P_B^2 = 258 TORR P_T^1 / P_B^2 = 2.7 risk ratio or a risk of about 6%. Such a risk is usually considered unacceptable for planned exposures. In order to reduce the risk to an acceptable 1% the tissue nitrogen must be reduced to approximately 334 torr:

a. A dysbarism risk of 1% = a risk ratio of 1.8

b. $P_T^1 = P_B^2 \times 1.8 = 258 \times 1.8 = 464$

c. $P_N^1 = P_T^1 - P_M^1 = 464 - 130 = 334$ TORR

The preoxygenation time required to reduce tissue nitrogen to 334 torr may be calculated:

$$P_N^1 = P_N^0 - \left(1 - \frac{1}{(2)^{T/H}}\right)\left(P_N^0 - P_{AN}^1\right)$$

When 100% O_2 is breathed P_{AN}^1 = 0. The expression then becomes $P_N^1 = P_N^0 - P_N^0 + P_N^0\left(1/(2)^{T/H}\right)$ which, when expressed in terms of "T", becomes:

$T = (H/\log 2) \times \log\left(P_N^0 / P_N^1\right)$

For the purposes of this discussion, a tissue half-time of 240 minutes will be taken to be the slowest body tissue compartment

$$T = (240/0.3) \times \log (570/334)$$

$$T = 186 \text{ minutes or about 3 hours}$$

2.2 Effects of 3 Hours Preoxygenation on Other Tissue Compartments

The calculated preoxygenation time of three hours is necessary to reduce nitrogen in the slowest considered tissue compartment to a concentration of 334 torr. While this is occurring the nitrogen concentrations in all faster compartments is being reduced at greater rates. The formula described in section 1.6 may be used to calculate the nitrogen concentration in the other compartments after three hours preoxygenation. These concentrations are:

Tissue Half-Time (H)	Nitrogen Concentration ([illegible])
5	0
10	0
20	1
40	22
80	114
120	195
240	334

2.3 Effect of a Sojourn in Skylab on Tissue Nitrogen

The Skylab atmosphere is assumed to have a pressure of 528 torr, 72% O_2 and 28% N_2. It may be calculated that under these conditions the alveolar nitrogen pressure (P_{A_N}) is 61 torr. During exposure to the Skylab atmosphere, those tissue compartments with a nitrogen tension less than 61 torr will tend to gain nitrogen and those with a greater nitrogen tension will tend to loose it. Table 2.3-1 below shows the nitrogen tension of the various tissue compartments following 1, 2, 3, and 4 hours of exposure.

Table 2.3-1

TISSUE NITROGEN CHANGES FOLLOWING EXPOSURE TO SKYLAB ATMOSPHERE

TISSUE HALF-TIME (H) IN MINUTES	P_N^1 AFTER 3 HRS PREOX	P_N^2 AFTER EXPOSURE TO SKYLAB 1 HOUR	2 HOURS	3 HOURS	4 HOURS
5	0	61	61	61	61
10	0	60	61	61	61
20	1	54	60	61	61
40	22	47	56	59	60
80	114	93	80	72	68
120	195	156	128	108	95
240	334	291	254	223	198

2.4 Effect of Return to Shuttle on Tissue Nitrogen

If after a sojourn in Skylab it is necessary for the crewmen to return to Shuttle for a short duration for meals, use of the waste management facilities, etc., his tissues will regain some of the nitrogen lost during preoxygenation and exposure to Skylab. The increases are shown for Shuttle stays of 15, 30, 60, and 120 minutes in Tables 2.4-1 through 2.4-4 for each Skylab exposure.

Table 2.4-1

TISSUE NITROGEN CHANGES IN SHUTTLE FOLLOWING A 1-HOUR SOJOURN IN SKYLAB

TISSUE HALF-TIME	P_N^2 AFTER 1 HR. IN SKYLAB	P_N^3 FOLLOWING REEXPOSURE TO SHUTTLE 15 MIN	30 MIN	60 MIN	120 MIN
5	61	506	562	570	570
10	60	390	505	561	569
20	54	263	388	506	562
40	47	167	259	385	505
80	93	151	202	286	401
120	156	190	222	277	363
240	291	306	320	347	394

Table 2.4-2

TISSUE NITROGEN CHANGES IN SHUTTLE FOLLOWING A 2-HOUR SOJOURN IN SKYLAB

TISSUE HALF-TIME	P_N^2 AFTER 2 HRS IN SKYLAB	P_N^3 AFTER EXPOSURE TO SHUTTLE 15 MIN	30 MIN	60 MIN	120 MIN
5	61	506	562	570	570
10	61	390	505	561	569
20	60	266	390	506	562
40	56	173	264	388	506
80	80	140	192	279	397
120	128	165	198	257	349
240	254	267	280	304	347

Table 2.4-3

TISSUE NITROGEN CHANGES IN SHUTTLE FOLLOWING A 3-HOUR SOJOURN IN SKYLAB

TISSUE HALF-TIME	P_N^2 AFTER 3 HRS IN SKYLAB	P_N^3 AFTER EXPOSURE TO SHUTTLE 15 MIN	30 MIN	60 MIN	120 MIN
5	61	506	562	570	570
10	61	390	505	561	569
20	61	267	390	506	562
40	59	176	266	389	506
80	72	133	186	274	394
120	103	146	182	243	339
240	223	238	252	278	325

Table 2.4-4

TISSUE NITROGEN CHANGES IN SHUTTLE FOLLOWING A 4-HOUR SOJOURN IN SKYLAB

TISSUE HALF-TIME	P_N^2 AFTER 4 HRS IN SKYLAB	P_N^3 AFTER EXPOSURE TO SHUTTLE 15 MIN	30 MIN	60 MIN	120 MIN
5	61	506	562	570	570
10	61	390	505	561	569
20	61	267	390	506	562
40	60	177	267	390	506
80	68	129	183	272	393
120	95	134	171	234	333
240	198	214	229	257	307

2.5 Preoxygenation Required Before Returning to Skylab

If the nitrogen tension in any of the tissue compartments has increased above the 334 torr originally required for a 1% risk, further preoxygenation must be conducted in order to return the nitrogen tension to this value. Preoxygenation times should be calculated for each appropriate compartment and the longest time selected for use. Preoxygenation times for all appropriate compartments are listed in Table 2.5-1. In the table the longest time for each Skylab Visit/Shuttle Exposure situation is boxed. These represent the preoxygenation times that would be required in each instance. It will be noted that if the exposure to Shuttle is relatively brief, none of the slower tissue compartments will accumulate enough nitrogen to involve them in preoxygenation requirements. The faster compartments become significantly saturated in a short time but are also desaturated rapidly during preoxygenation. The following is a summary of preoxygenation time requirements:

Table 2.5-1

PRE-OXYGENATION TIMES FOR RETURN TO SKYLAB FOLLOWING EXPOSURE TO SHUTTLE

DURATION OF INITIAL SKYLAB VISIT	DURATION OF SHUTTLE EXPOSURE	TISSUE HALF-TIMES (H) IN MINUTES							
		5		10		20		40	
		P_N [3] IN TORR	T IN MIN	P_N [3] IN TORR	T IN MIN	P_N [3] IN TORR	T IN MIN	P_N [3] IN TORR	T IN MIN
One Hour	15 Minutes	506	$\boxed{3}$	390	2	*	-	*	-
	30 Minutes	562	4	505	$\boxed{6}$	388	5	*	-
	60 Minutes	570	4	568	8	506	12	385	9
	120 Minutes	570	4	569	8	562	15	505	24
Two Hours	15 Minutes	506	$\boxed{3}$	390	2	*	-	*	-
	30 Minutes	562	4	505	$\boxed{6}$	390	5	*	-
	60 Minutes	570	4	561	8	506	$\boxed{12}$	388	9
	120 Minutes	570	4	569	8	562	15	506	$\boxed{24}$
Three Hours	15 Minutes	506	$\boxed{3}$	390	2	*	-	*	-
	30 Minutes	562	4	505	$\boxed{6}$	390	5	*	-
	60 Minutes	570	4	561	8	506	$\boxed{12}$	389	9
	120 Minutes	570	4	569	8	562	15	506	$\boxed{24}$
Four Hours	15 Minutes	506	$\boxed{3}$	390	2	*	-	*	-
	30 Minutes	562	4	505	$\boxed{6}$	390	5	*	-
	60 Minutes	570	4	561	8	506	$\boxed{12}$	390	9
	120 Minutes	570	4	569	8	562	15	506	$\boxed{24}$

* = Tissue P_N below 344 TORR, No pre-oxygenation required

Table 2.5-1 (Continued)

PRE-OXYGENATION TIMES FOR RETURN TO SKYLAB FOLLOWING EXPOSURE TO SHUTTLE

DURATION OF INITIAL SKYLAB VISIT	DURATION OF SHUTTLE EXPOSURE	TISSUE HALF-TIMES (H) IN MINUTES					
		80		120		240	
		$P_N{}^3$ IN TORR	T IN MIN	$P_N{}^3$ IN TORR	T IN MIN	$P_N{}^3$ IN TORR	T IN MIN
One Hour	15 Minutes	*	-	*	-	*	-
	30 Minutes	*	-	*	-	*	-
	60 Minutes	*	-	*	-	347	$\boxed{14}$
	120 Minutes	401	21	363	15	394	$\boxed{58}$
Two Hours	15 Minutes	*	-	*	-	*	-
	30 Minutes	*	-	*	-	*	-
	60 Minutes	*	-	*	-	*	-
	120 Minutes	397	20	349	8	347	14
Three Hours	15 Minutes	*	-	*	-	*	-
	30 Minutes	*	-	*	-	*	-
	60 Minutes	*	-	*	-	*	-
	120 Minutes	394	20	*	-	*	-
Four Hours	15 Minutes	*	-	*	-	*	-
	30 Minutes	*	-	*	-	*	-
	60 Minutes	*	-	*	-	*	-
	120 Minutes	393	19	*	-	*	-

* = Tissue P_N below 344 TORR, no pre-oxygenation required

a. Following a one-hour stay in Skylab

(1) After a 15 minute exposure to Shuttle - 3 min
(2) After a 30 minute exposure to Shuttle - 6 min
(3) After a 60 minute exposure to Shuttle - 14 min
(4) After a 120 minute exposure to Shuttle - 58 min

b. Following a two-hour stay in Skylab

(1) After a 15 minute exposure to Shuttle - 3 min
(2) After a 30 minute exposure to Shuttle - 6 min
(3) After a 60 minute exposure to Shuttle - 12 min
(4) After a 120 minute exposure to Shuttle - 24 min

c. Following a three-hour stay in Skylab

(1) After a 15 minute exposure to Shuttle - 3 min
(2) After a 30 minute exposure to Shuttle - 6 min
(3) After a 60 minute exposure to Shuttle - 12 min
(4) After a 120 minute exposure to Shuttle - 24 min

d. Following a four-hour stay in Skylab

(1) After a 15 minute exposure to Shuttle - 3 min
(2) After a 30 minute exposure to Shuttle - 6 min
(3) After a 60 minute exposure to Shuttle - 12 min
(4) After a 120 minute exposure to Shuttle - 24 min

3.0 SUMMARY OF SKYLAB REVISIT INFORMATION

a. The dysbarism risk associated with a direct transfer from Shuttle to Skylab without any preoxygenation is approximately 6%. This magnitude of risk is usually considered unacceptable for planned operations.

b. Preoxygenation for about 3 hours (186 minutes) will reduce the nitrogen pressure in the tissue compartment with the longest considered saturation/desaturation half-time (H = 240 minutes) to 334 torr. This will permit the Shuttle/Skylab transfer to be made with a 1% risk, usually considered acceptable.

c. During the period of Skylab operations the nitrogen content of those tissues with a pressure below 61 torr will tend to increase; and the nitrogen content of those tissues with a pressure above 61 torr will tend to decrease.

d. If Skylab operations are interrupted by a reexposure to the Shuttle atmosphere, some preoxygenation will be required before a return to Skylab at the initial 1% dysbarism risk. The duration of preoxygenation will depend upon both the period of initial Skylab operations and the length of exposure to Shuttle. Durations of from one to four hours of Skylab operations and Shuttle exposures of from 15 minutes to two hours were considered. Preoxygenation times varied from 3 minutes to 58 minutes for the various situations.

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2. Workman, R. D. Calculation of Decompression Schedules for Nitrogen-Oxygen Dives. Project No. SF-011-06-05, Task No. 11514, Subtask 5. U. S. Navy Experimental Diving Unit, May 1965.

Appendix B
MISSION MODEL/PAYLOAD DATA SHEETS

This appendix contains payload data sheets for the materials processing in space, the life sciences and the space construction-solar power satellite development disciplines. For each discipline a mission model describes a flight schedule and payload assignment as a function of calendar time.

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MATERIALS PROCESSING MISSION MODEL

SPACE PROCESSING PAYLOADS/MISSIONS	CY 19__ 81	82	83	84	85	86	87	88	89	90	91
SPACELAB MISSIONS											
• PALLETS	1	3	2	6	6						
• MODULES	1	1	1	1							
GROWTH MISSIONS											
• MEM (1)				4	3	3	2	2	2	2	2
• PILOT PLANT							2	2	2	2	2
• PRODUCTION PLANT								1	1	1	1
TOTAL MISSIONS PER YEAR	2	4	3	11	9	3	4	5	5	5	5

$\Sigma = 56$ MISSIONS

39952

SPACELAB PALLET PAYLOAD

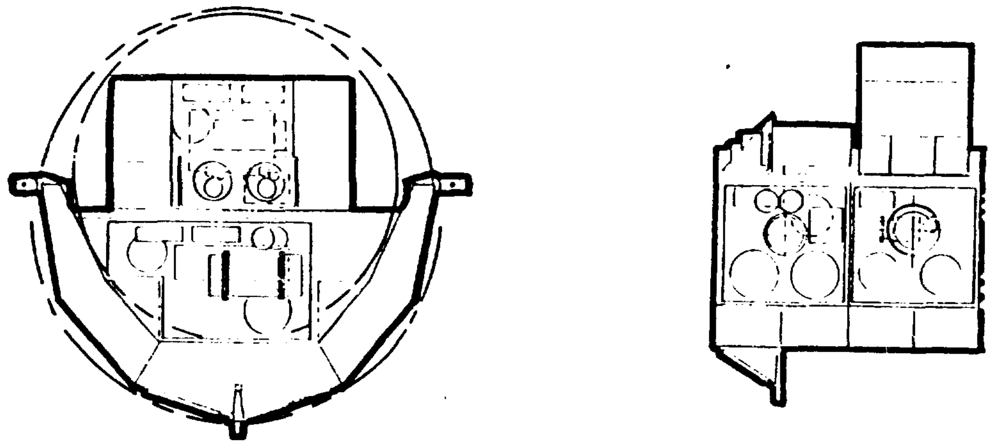
SOLIDIFICATION EXPERIMENTS

PHYSICAL CHARACTERISTICS

- WEIGHT 10,500 LBS
- DIMENSIONS 10 X 15 FT
- POWER 5 KW
- CREW 2

MISSION CHARACTERISTICS

- OBJECTIVE SCIENTIFIC R&D
- TIME FRAME 1981 - 1985
- DURATION 7 DAYS



TYPICAL EQUIPMENT

- MULTIPURPOSE FURNANCE
- ZONE REFINING SYSTEM
- ACOUSTIC LEVITATION SYSTEM

39953

SPACELAB MODULE PAYLOAD

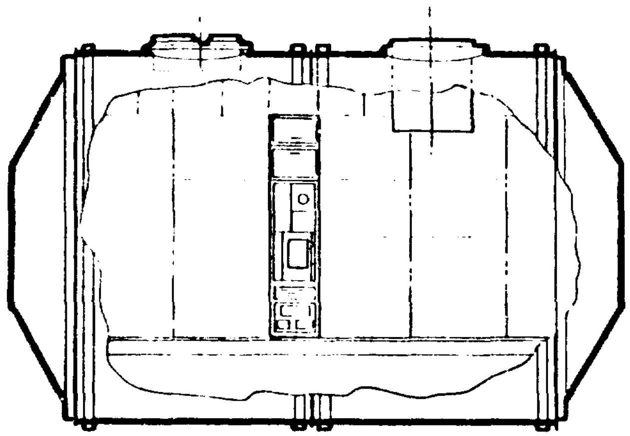
FLUIDS EXPERIMENT

PHYSICAL CHARACTERISTICS

- WEIGHT 2000 LBS
- DIMENSIONS 1/4 MODULE
- POWER 2 KW
- CREW 2

MISSION CHARACTERISTICS

- OBJECTIVE SCIENTIFIC R&D
- TIME FRAME 1981 - 1983
- DURATION 7 DAYS



TYPICAL EQUIPMENT

- MULTIPURPOSE FLUIDS RESEARCH SYSTEM

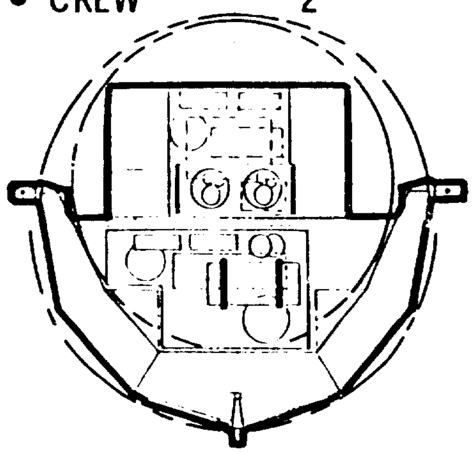
39954

SPACELAB DOUBLE PALLET

INCREASED CAPABILITY

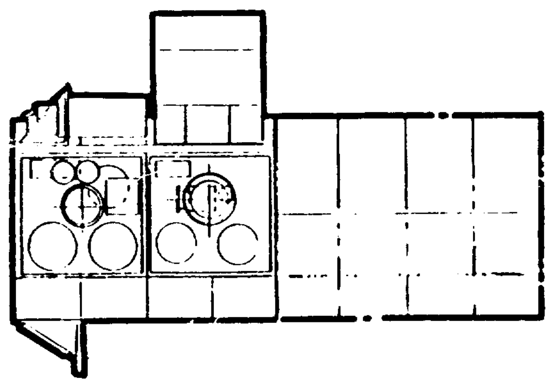
PHYSICAL CHARACTERISTICS

- WEIGHT 21,000 LBS
- DIMENSIONS 20 X 15 FT
- POWER 8 KW
- CREW 2



MISSION CHARACTERISTICS

- OBJECTIVE SCIENTIFIC R&D
- TIME FRAME 1983 - 1984
- DURATION 7 DAYS



TYPICAL EQUIPMENT

- SINGLE PALLET PLUS RESEARCH UNIQUE EQUIPMENT

39955

MATERIALS EXPERIMENTATION MODULE

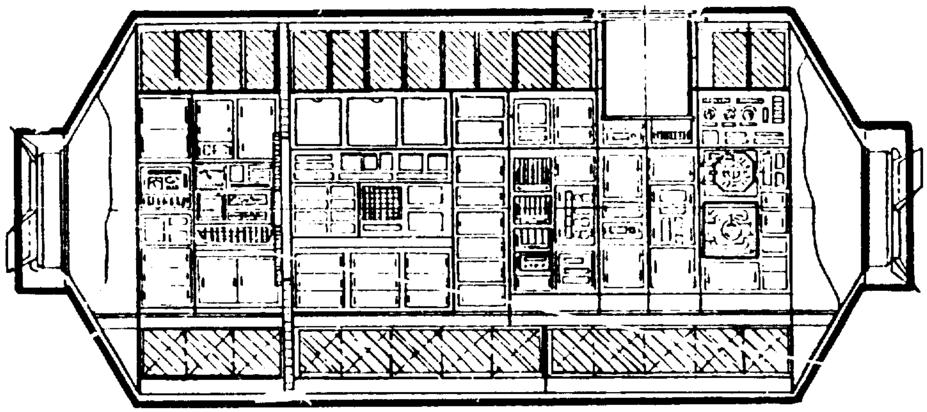
MARK I

PHYSICAL CHARACTERISTICS

- WEIGHT 22,000 LBS
- DIMENSIONS 30 X 15 FT
- POWER 8 KW
- CREW 2-3

MISSION CHARACTERISTICS

- OBJECTIVE PROCESS DEVELOPMENT
- TIME FRAME 1984 - 1985
- DURATION 14-60 DAYS



TYPICAL EQUIPMENT

- FURNANCE SYSTEMS
- ELECTROPHORESIS UNITS
- CELL CULTURING STATION
- MATERIALS CHARACTERIZATION AND ANALYTIC WORK STATION

39956

MATERIALS EXPERIMENTATION MODULE

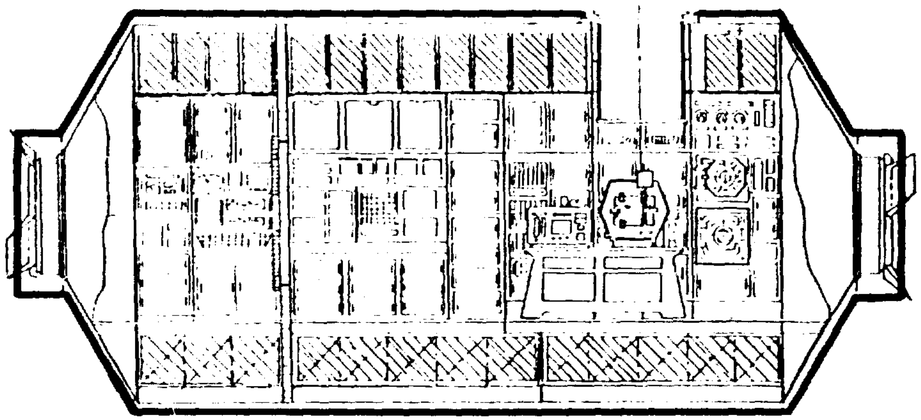
MARK II

PHYSICAL CHARACTERISTICS

• WEIGHT	25,000 LBS
• DIMENSIONS	30 X 15 FT
• POWER	15 KW
• CREW	3

MISSION CHARACTERISTICS

• OBJECTIVE	PRODUCT DEVELOPMENT
• TIME FRAME	1986 - 1991
• DURATION	90 DAYS



TYPICAL EQUIPMENT

- MEM MARK I PLUS
- HIGH TEMPERATURE FURNACE FACILITY
- BIOPROCESSING EQUIPMENT

39957

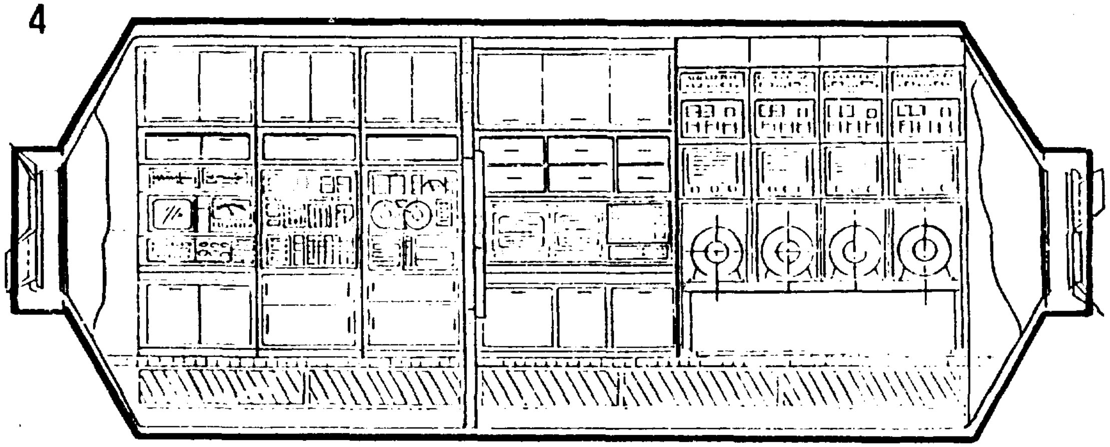
ULTRAPURE GLASSES PILOT PLANT

PHYSICAL CHARACTERISTICS

- WEIGHT 32,000 LBS
- DIMENSIONS 40 X 15 FT
- POWER 20 KW
- CREW 4

MISSION CHARACTERISTICS

- OBJECTIVE PRODUCT PROCESS
- TIME FRAME 1987 - 1991 OPTIMIZATION
- DURATION 90 DAYS



TYPICAL EQUIPMENT

- GLASS FORMING FURNACES
- GLASS ANNEALING FURNACES
- CHARACTERIZATION EQUIPMENT

39958

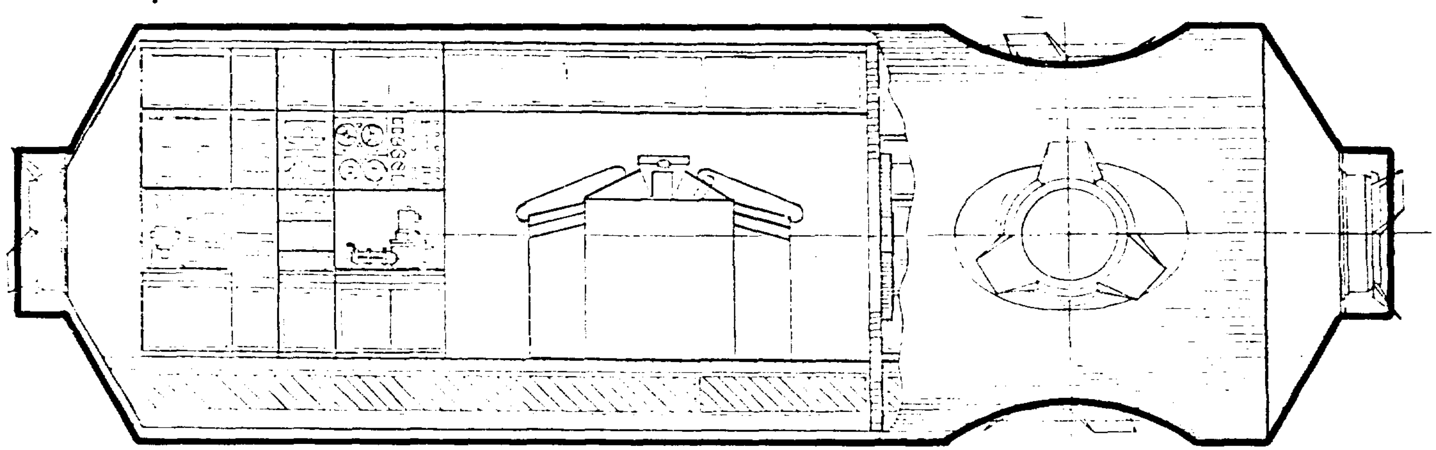
SHAPED CRYSTALS PRODUCTION PLANT

PHYSICAL CHARACTERISTICS

- WEIGHT 50,000 LBS
- DIMENSIONS 15 X 50 FT
- POWER 25 KW
- CREW 7

MISSION CHARACTERISTICS

- OBJECTIVE FULL-SCALE PRODUCTION
- TIME FRAME 1988 - 1991
- DURATION 180-360 DAYS



TYPICAL PRODUCTS

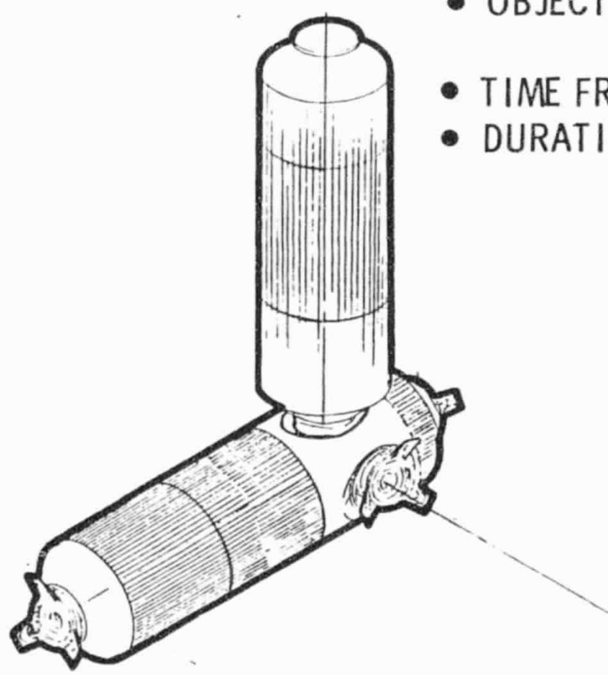
- SHAPED CRYSTAL MACHINE
- QUALITY CONTROL WORK STATION

39959

TWO MODULE SPACE MANUFACTURING PLANT

PHYSICAL CHARACTERISTICS

- WEIGHT 100, 000 LBS
- DIMENSIONS 2-15 X 50 FT
- POWER 50 KW
- CREW 14



MISSION CHARACTERISTICS

- OBJECTIVES MULTIPLE PRODUCT MANUFACTURE
- TIME FRAME 1989
- DURATION 360 DAY - CONTINUOUS

TYPICAL PRODUCTS

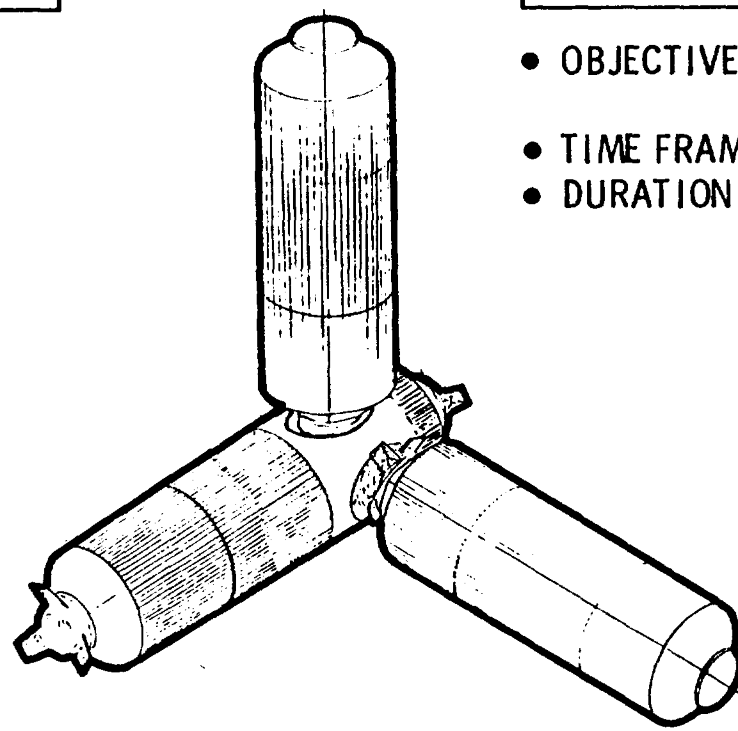
- SHAPED CRYSTALS
- PHARMACEUTICALS

39960

THREE MODULE SPACE MANUFACTURING PLANT

PHYSICAL CHARACTERISTICS

- WEIGHT 150,000 LBS
- DIMENSIONS 3-15 X 50 FT
- POWER 75 KW
- CREW 14



MISSION CHARACTERISTICS

- OBJECTIVES MULTIPLE PRODUCT MANUFACTURE
- TIME FRAME 1990
- DURATION CONTINUOUS

TYPICAL PRODUCTS

- SHAPED CRYSTALS
- PHARMACEUTICALS
- ULTRA PURE GLASSES

39961

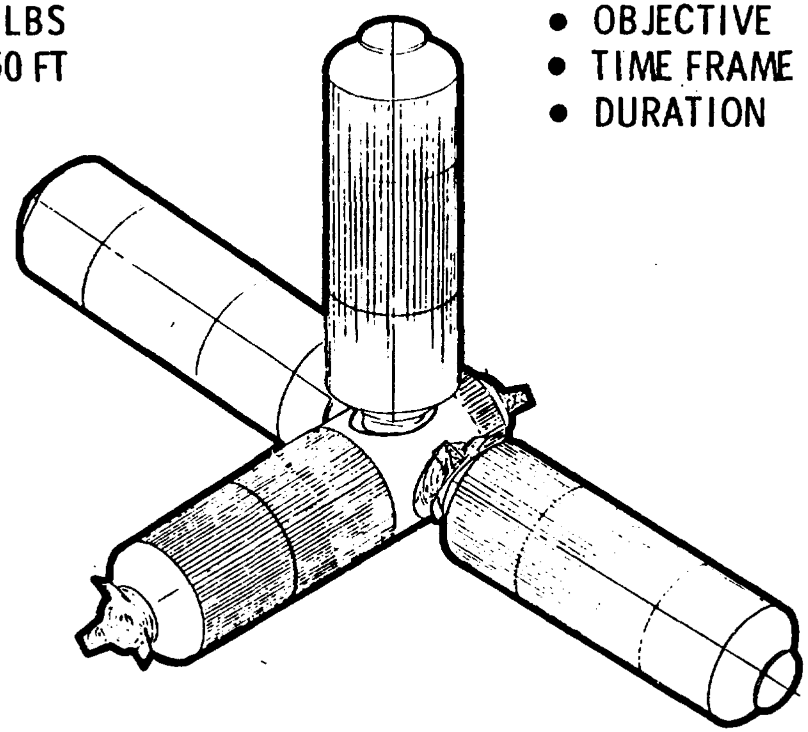
FOUR MODULE SPACE MANUFACTURING PLANT

PHYSICAL CHARACTERISTICS

- WEIGHT 200,000 LBS
- DIMENSIONS 4-15 X 50 FT
- POWER 100 KW
- CREW 14

MISSION CHARACTERISTICS

- OBJECTIVE VOLUME PRODUCTION
- TIME FRAME 1991
- DURATION CONTINUOUS



TYPICAL PRODUCTS

- PHARMACEUTICALS
- FOAMED METALS
- LARGE SIZE DEFECT FREE SEMICONDUCTORS
- PRECISION MICROSPHERES

40507

LIFE SCIENCES MISSION MODEL

LIFE SCIENCES PAYLOAD/MISSIONS	CY 19__ 80	81	82	83	84	85	86	87	88	89	90	91
CARRY ON LABS												
• MEDICAL			1	2		1		1			1	
• BIOLOGY	1	1	1		2	1	1	1	1	1	1	2
• TECHNOLOGY		1					1		1	1		
MINILABS												
• MEDICAL		1	1		2	2		1	2			1
• BIOLOGY		1	1	1		1	1	1	1	2		
• TECHNOLOGY				1			1	1	1	1		1
DEDICATED LABS												
• MEDICAL			1						1			
• MED/BIOLOGY					1	1						
• BIOLOGY								1			1	
• TECH/BIOLOGY												1
TOTAL MISSIONS PER YEAR	1	4	5	4	5	6	4	6	7	5	3	5

$\Sigma = 55$ MISSIONS

MEDICAL CARRY-ON EXPERIMENTS

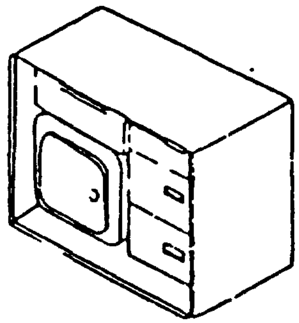
40509

PHYSICAL CHARACTERISTICS

• WEIGHT	31 LBS
• DIMENSIONS	21 X 18 X 10.5 IN.
• POWER	0.5 KW
• CREW	3 FOR 2 HOURS PER MISSION

MISSION CHARACTERISTICS

• OBJECTIVE	HUMAN RESPONSES
• TIME FRAME	1982 - 1990
• DURATION	7 DAYS
• ACCELERATION	10^{-3}G, 90% OF TIME



TYPICAL EQUIPMENT

- BLOOD AND URINE SAMPLING KITS
- HERMATOLOGY KIT
- CARDEOVASCULAR KIT
- FLUID AND ELECROLYTE BALANCE KIT

BIOLOGICAL CARRY-ON EXPERIMENTS

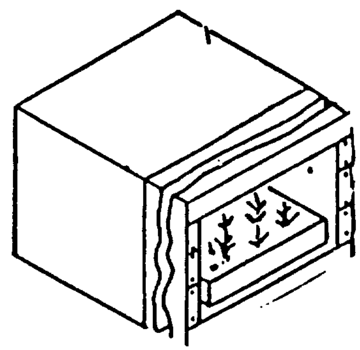
40510

PHYSICAL CHARACTERISTICS

- WEIGHT 55 LBS
- DIMENSIONS 21 X 18 X 20 IN.
- POWER 0.1 KW
- CREW 1 FOR 30 MIN PER DAY

MISSION CHARACTERISTICS

- OBJECTIVES BIOLOGICAL RESPONSES
- TIME FRAME 1980 - 1991
- DURATION 7 DAYS
- ACCELERATION 10^{-4}G, 90% OF TIME



TYPICAL EQUIPMENT

- PLANT GROWTH UNITS
- BIO/INSTRUMENTATION

TECHNOLOGY CARRY-ON EXPERIMENTS

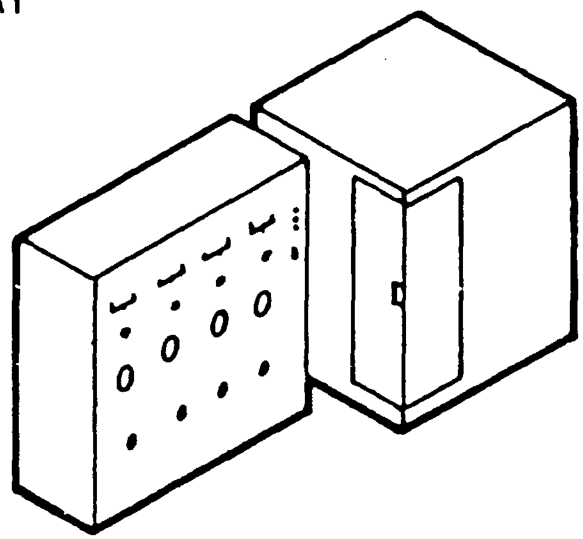
40511

PHYSICAL CHARACTERISTICS

- WEIGHT 55 LBS
- DIMENSIONS 34 X 62 X 24 IN.
- POWER 0.2 KW
- CREW 1 FOR 1.5 HOURS PER DAY

MISSION CHARACTERISTICS

- OBJECTIVE TEST DESIGNS
- TIME FRAME 1981 - 1989
- DURATION 7 DAYS
- ACCELERATION 10^{-3}G, 90% OF TIME



TYPICAL EQUIPMENT

- EXPERIMENT CONTROL CONSOLE
- EXPERIMENT MODULE

40512

MEDICAL MINILAB EXPERIMENTS

PHYSICAL CHARACTERISTICS

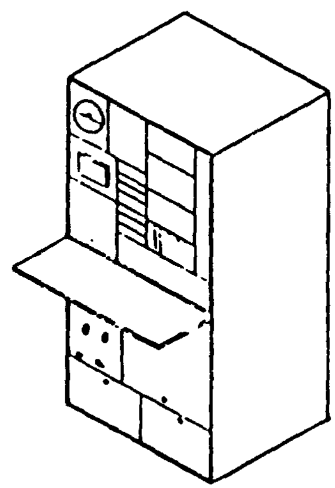
- WEIGHT 482 LBS
- DIMENSIONS 22 X 30 X 69 IN
- POWER 0.6 KW
- CREW 3 FOR 6 HOURS PER MISSION

MISSION CHARACTERISTICS

- OBJECTIVE EARLY RESPONSES - MEDICAL
- TIME FRAME 1981 - 1988
- DURATION 7 DAYS
- ACCELERATION 10^{-3}G, 90% OF TIME

TYPICAL EQUIPMENT

- BLOOD SAMPLE PROCESSOR CENTRIFUGE
- KIT, URINE ACQUISITION
- REFRIGERATOR
- GENERAL FREEZER
- MASS MEASUREMENT DEVICE



40513

BIOLOGICAL MINILAB EXPERIMENTS

PHYSICAL CHARACTERISTICS

• WEIGHT	686 LBS
• DIMENSIONS	41 X 30 X 97 IN
• POWER	0.23 KW
• CREW	1 FOR 3 HRS PER DAY

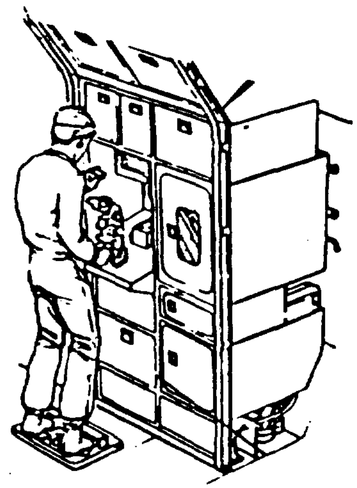
MISSION CHARACTERISTICS

• OBJECTIVE	EARLY RESPONSES - BIOLOGICAL
• TIME FRAME	1981 - 1989
• DURATION	7 DAYS
• ACCELERATION	10^{-4}G, 90% OF TIME

34

TYPICAL EQUIPMENT

- MICROSCOPE WORK STATION
- PLANT CAGE
- MASS MEASUREMENT DEVICE
- CRYOGENIC FREEZER



ADVANCED TECHNOLOGY MINILAB EXPERIMENTS

PHYSICAL CHARACTERISTICS

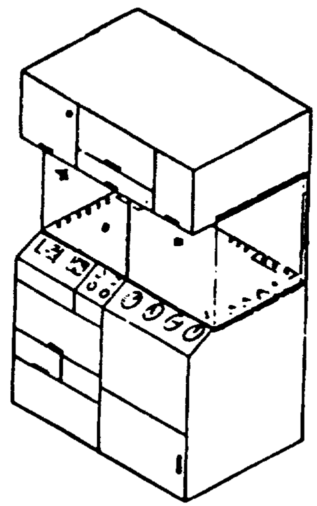
- WEIGHT 440 LBS
- DIMENSIONS 41 X 30 X 69 IN
- POWER 0.6 KW
- CREW 1 FOR 2 HRS PER DAY

MISSION CHARACTERISTICS

- OBJECTIVE CONCEPT VERIFICATION
- TIME FRAME 1983 - 1989
- DURATION 7 DAYS
- ACCELERATION 10^{-3}G, 90% OF THE TIME

TYPICAL EQUIPMENT

- GAS CHROMATOGRAPH
- MASS MEASUREMENT DEVICE
- TEST ARTICLE WORK BENCH



40515

30-DAY MEDICAL MINILAB

PHYSICAL CHARACTERISTICS

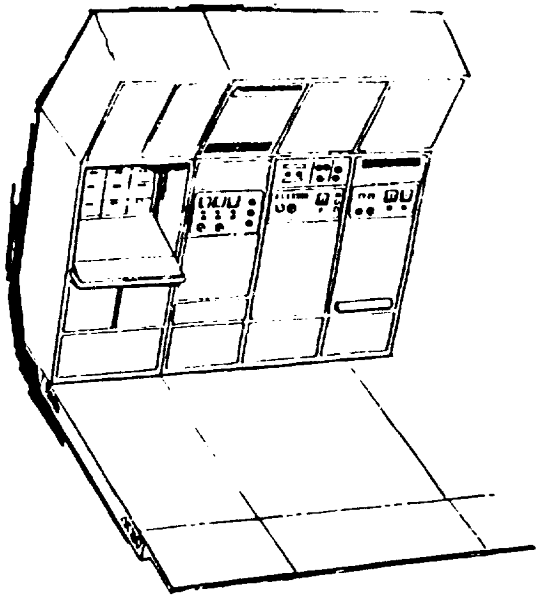
- WEIGHT 2020 LBS
- DIMENSIONS 97.5 X 30 X 105 IN
- POWER 2 KW
- CREW 3 FOR 8 HRS PER DAY

MISSION CHARACTERISTICS

- OBJECTIVE ADAPTIVE RESPONSES - HUMAN
- TIME FRAME 1985 - 1991
- DURATION 30 DAYS
- ACCELERATION 10^{-3}G, 90% OF TIME

TYPICAL EQUIPMENT

- ANALYTICAL WORK STATION
- BLOOD SAMPLING
- TABLE TOP CENTRIFUGE
- FREEZER
- MASS SPECTROMETER



40516

30-DAY BIOLOGICAL MINILAB

PHYSICAL CHARACTERISTICS

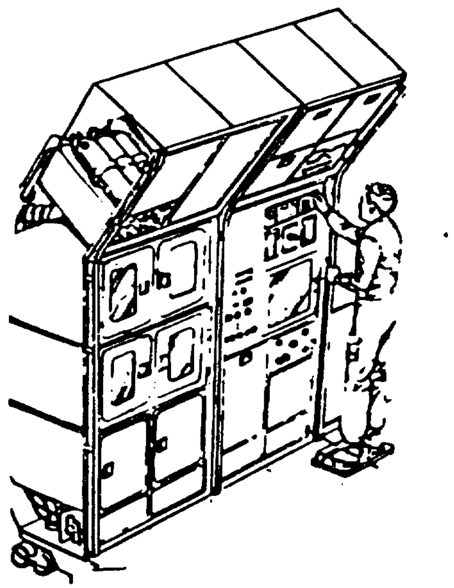
• WEIGHT	2022 LBS
• DIMENSIONS	123 X 30 X 97.5 IN
• POWER	1.1 KW
• CREW	3 FOR 8 HRS PER DAY

MISSION CHARACTERISTICS

• OBJECTIVE	ADAPTIVE RESPONSES: BIOLOGICAL
• TIME FRAME	1987 - 1991
• DURATION	30 DAYS
• ACCELERATION	10^{-4}G, 90% OF THE TIME

TYPICAL EQUIPMENT

- PLANT, CELLS AND TISSUES
- SPECIMEN HOLDING FACILITY
- BIOINSTRUMENTATION
- ANALYTIC WORK STATION



40517

30-DAY ADVANCED TECHNOLOGY MINILAB

PHYSICAL CHARACTERISTICS

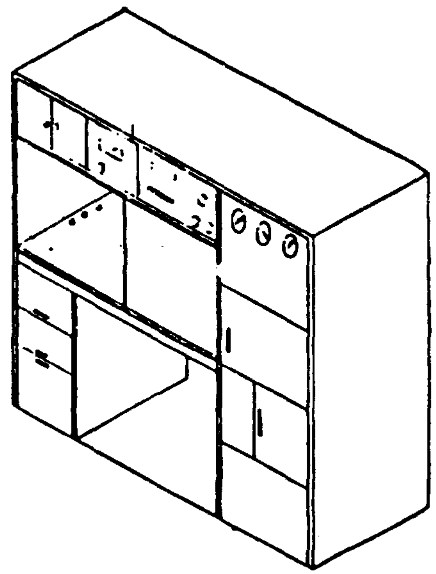
- WEIGHT — 550 LBS
- DIMENSIONS — 41 X 30 X 69 IN
- POWER — 0.6 KW
- CREW — 1 FOR 2 HRS PER DAY

MISSION CHARACTERISTICS

- OBJECTIVE — COMPONENT VERIFICATION
- TIME FRAME — 1988 - 1991
- DURATION — 30 DAYS
- ACCELERATION — AMBIENT (10^{-3}G)

TYPICAL EQUIPMENT

- MASS SPECTROMETER
- GAS CHROMATOGRAPH
- IR ANALYZER



40518

MEDICAL EMPHASIS DEDICATED LABORATORY

PHYSICAL CHARACTERISTICS

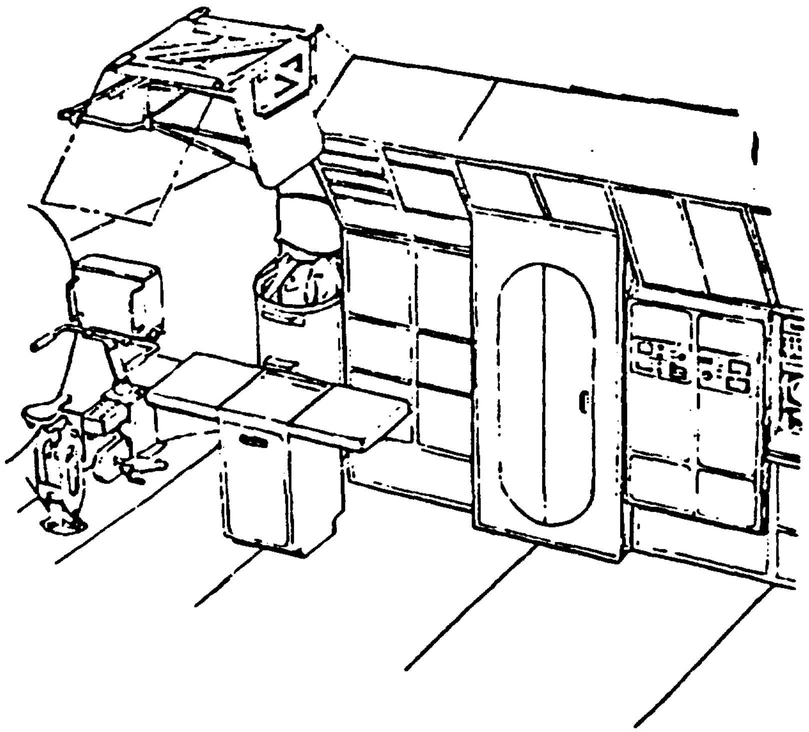
• WEIGHT	6830 LBS
• DIMENSIONS	15 X 45 FT MODULE
• POWER	2.8 KW
• CREW	3 FOR 8 HRS PER DAY

MISSION CHARACTERISTICS

• OBJECTIVE	TEST OF CONCEPT
• TIME FRAME	1982
• DURATION	7 DAYS
• ACCELERATION	10^{-3}G, 90% OF THE TIME

TYPICAL EQUIPMENT

- ERGOMETER
- MASS MEASUREMENT DEVICE
- GENERAL WORK BENCH
- KIT, MEDICAL/PHYSICAL EXAMINING
- MICROSCOPE
- FREEZER



40520

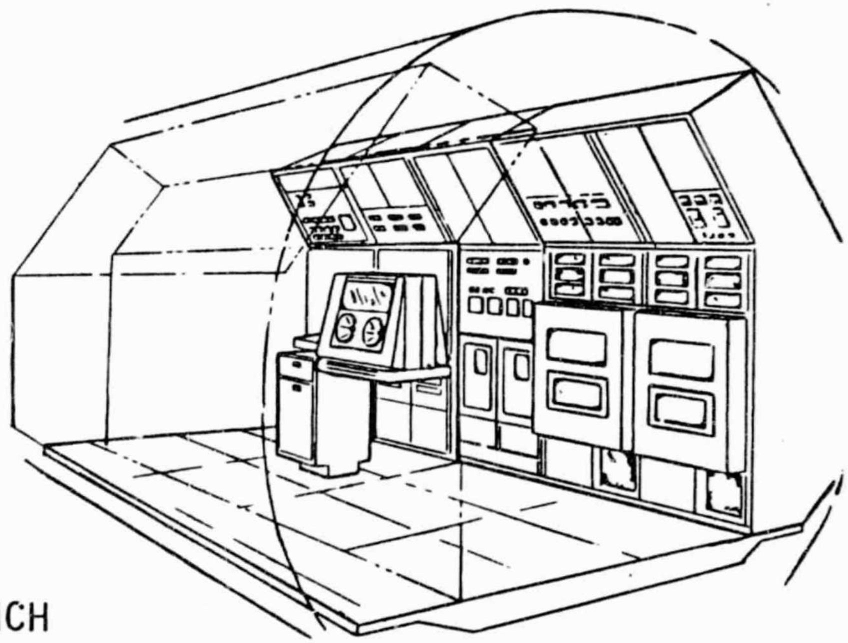
MEDICAL/BIOLOGICAL EMPHASIS DEDICATED FACILITY

PHYSICAL CHARACTERISTICS

• WEIGHT	7430 LBS
• DIMENSIONS	15 X 45 FT MODULE
• POWER	3.8 KW
• CREW	3 FOR 8 HRS PER DAY

MISSION CHARACTERISTICS

• OBJECTIVE	VERIFICATION OF ANIMAL HOLDING FACILITY
• TIME FRAME	1984
• DURATION	7 DAYS
• ACCELERATION	10^{-3}G, 90% OF TIME



TYPICAL EQUIPMENT

- SMALL VERTEBRATE HOLDING UNIT
- PRIMATE HOLDING UNIT
- GENERAL PURPOSE/SURGICAL WORK BENCH
- MEDICAL/PHYSICAL EXAMINING KIT
- VETERINARY KIT

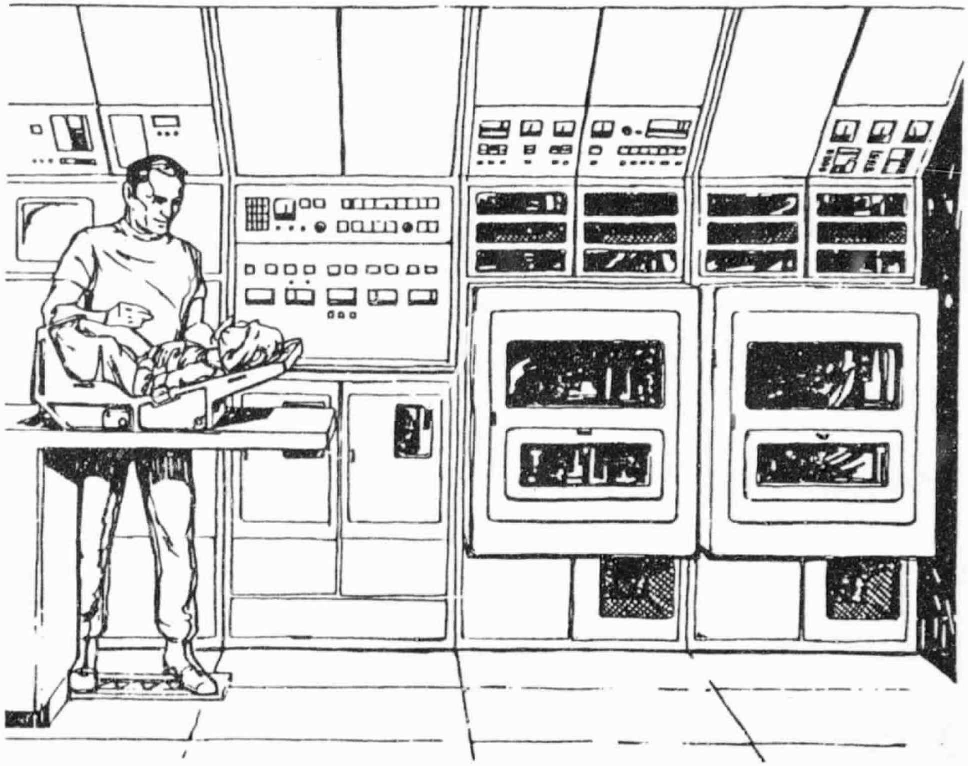
MED/BIOL EMPHASIS DEDICATED FACILITY

PHYSICAL CHARACTERISTICS

- WEIGHT 7700 LBS
- DIMENSIONS 15 X 45 FT
- POWER 3.8 KW
- CREW 3 FOR 8 HR PER DAY

MISSION CHARACTERISTICS

- OBJECTIVE STUDY ADAPTATION
- TIME FRAME 1985
- DURATION 30 DAYS
- ACCELERATION 10^{-4}G, 90% OF THE TIME



TYPICAL EQUIPMENT

- SURGICAL WORK BENCH
- PRIMATE/SMALL VERTEBRATE HOLDING UNITS
- CENTRIFUGE, TABLE TOP
- KIT, PHYSIOLOGY

40524

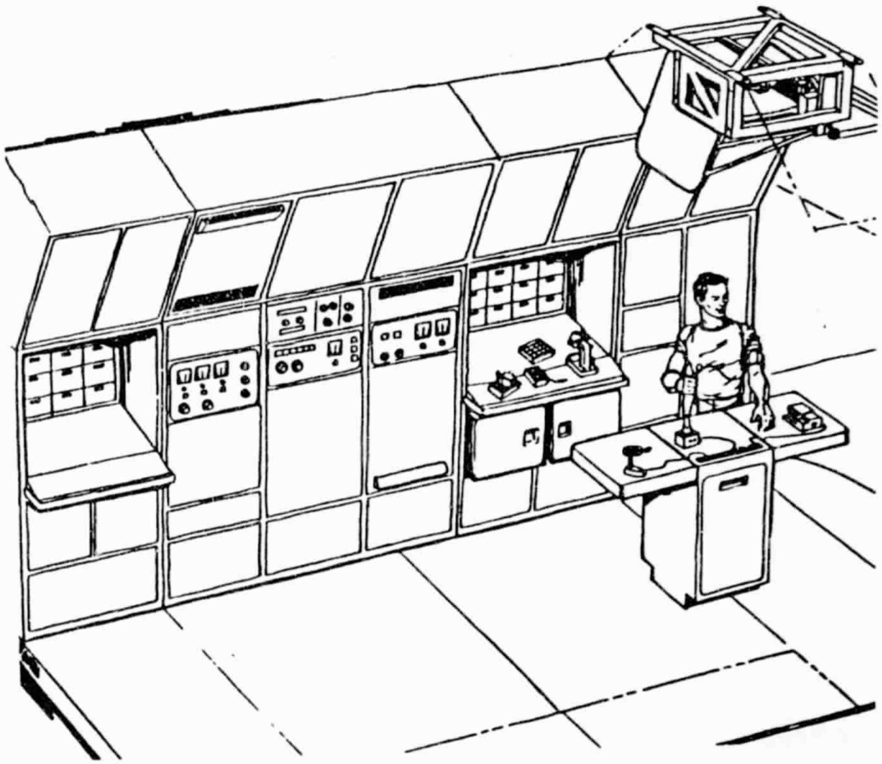
EXTENDED DURATION MEDICAL FACILITY

PHYSICAL CHARACTERISTICS

• WEIGHT	7480 LBS
• DIMENSIONS	15 X 45 FT
• POWER	2.8 KW
• CREW	3 FOR 8 HRS PER DAY

MISSION CHARACTERISTICS

• OBJECTIVE	STUDY PHYSIOLOGICAL CHANGES
• TIME FRAME	1988
• DURATION	90 DAYS
• ACCELERATION	10^{-3}G, 90% OF THE TIME



TYPICAL EQUIPMENT

- ANALYTICAL INSTRUMENTATION
- GENERAL PURPOSE WORK STATION
- ROTATING LITTER CHAIR
- LOWER BODY NEGATIVE PRESSURE UNIT

40522

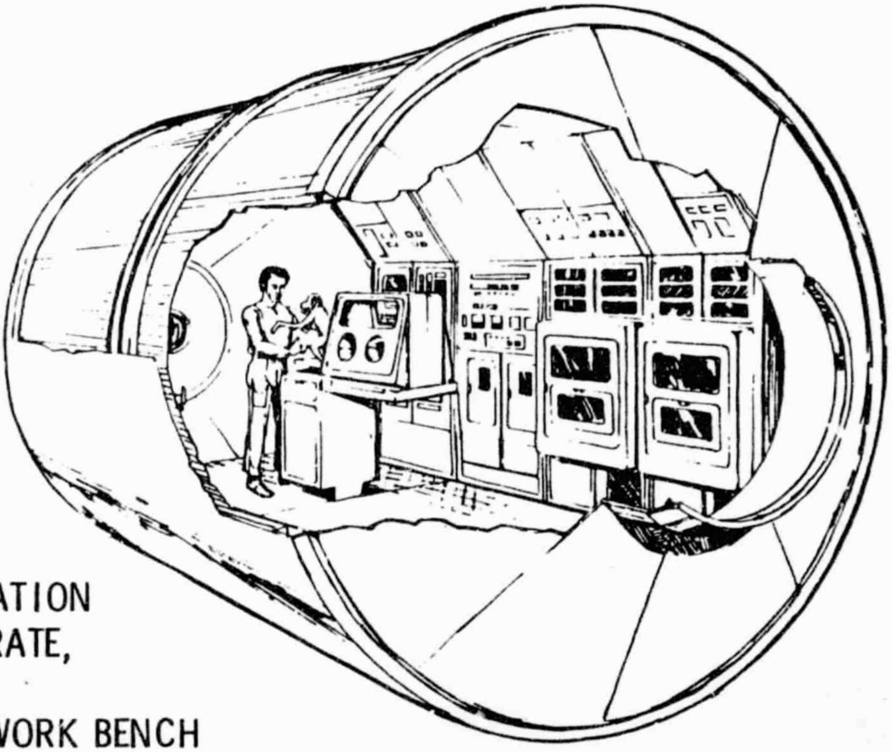
EXTENDED DURATION BIOLOGICAL FACILITY

PHYSICAL CHARACTERISTICS

- WEIGHT 6600 LBS
- DIMENSIONS 15 X 45 FT
- POWER 4 KW
- CREW 3 FOR 8 HRS PER DAY

MISSION CHARACTERISTICS

- OBJECTIVE STUDY LONG TERM EFFECTS
- TIME FRAME 1987 - 1991
- DURATION >90 DAYS
- ACCELERATION 10^{-4}G, 90% OF THE TIME



TYPICAL EQUIPMENT

- ANALYTICAL BIO-INSTRUMENTATION
- PLANT, VERTEBRATE/INVERTERRATE, CELL/TISSUES HOLDING UNITS
- GENERAL PURPOSE/SURGICAL WORK BENCH

40523

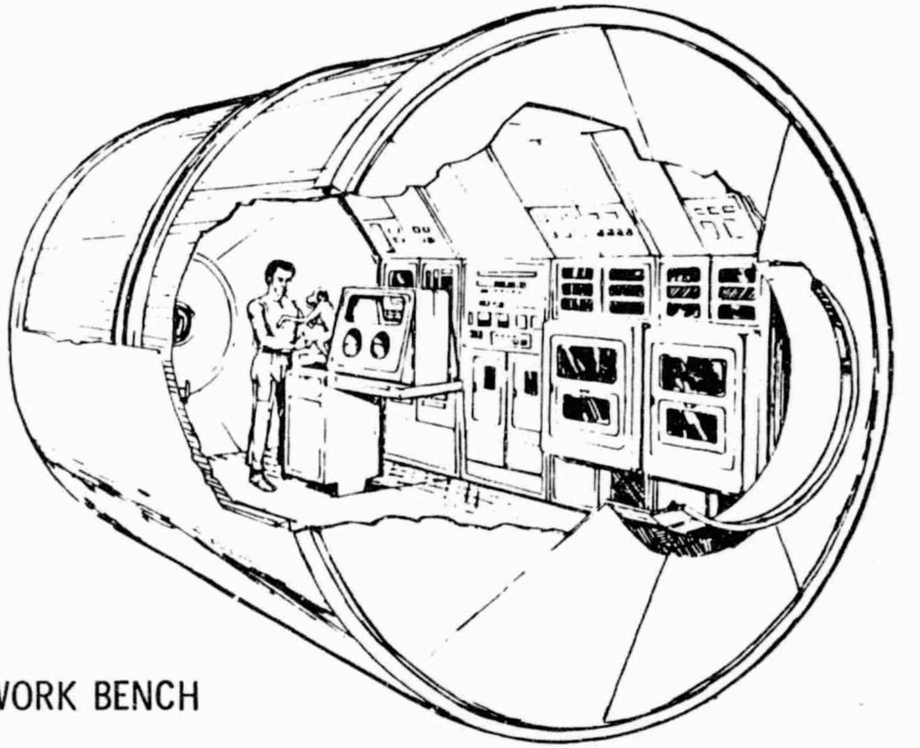
EXTENDED DURATION TECHNOLOGY/BIOLOGY FACILITY

PHYSICAL CHARACTERISTICS

- WEIGHT 8800 LBS
- DIMENSIONS 15 X 45 FT
- POWER 4 KW
- CREW 3 FOR 8 HRS PER DAY

MISSION CHARACTERISTICS

- OBJECTIVE ADVANCED LIFE SUPPORT SYSTEMS TEST
- TIME FRAME 1991
- DURATION >90 DAYS
- ACCELERATION 10^{-4}G, 90% OF THE TIME

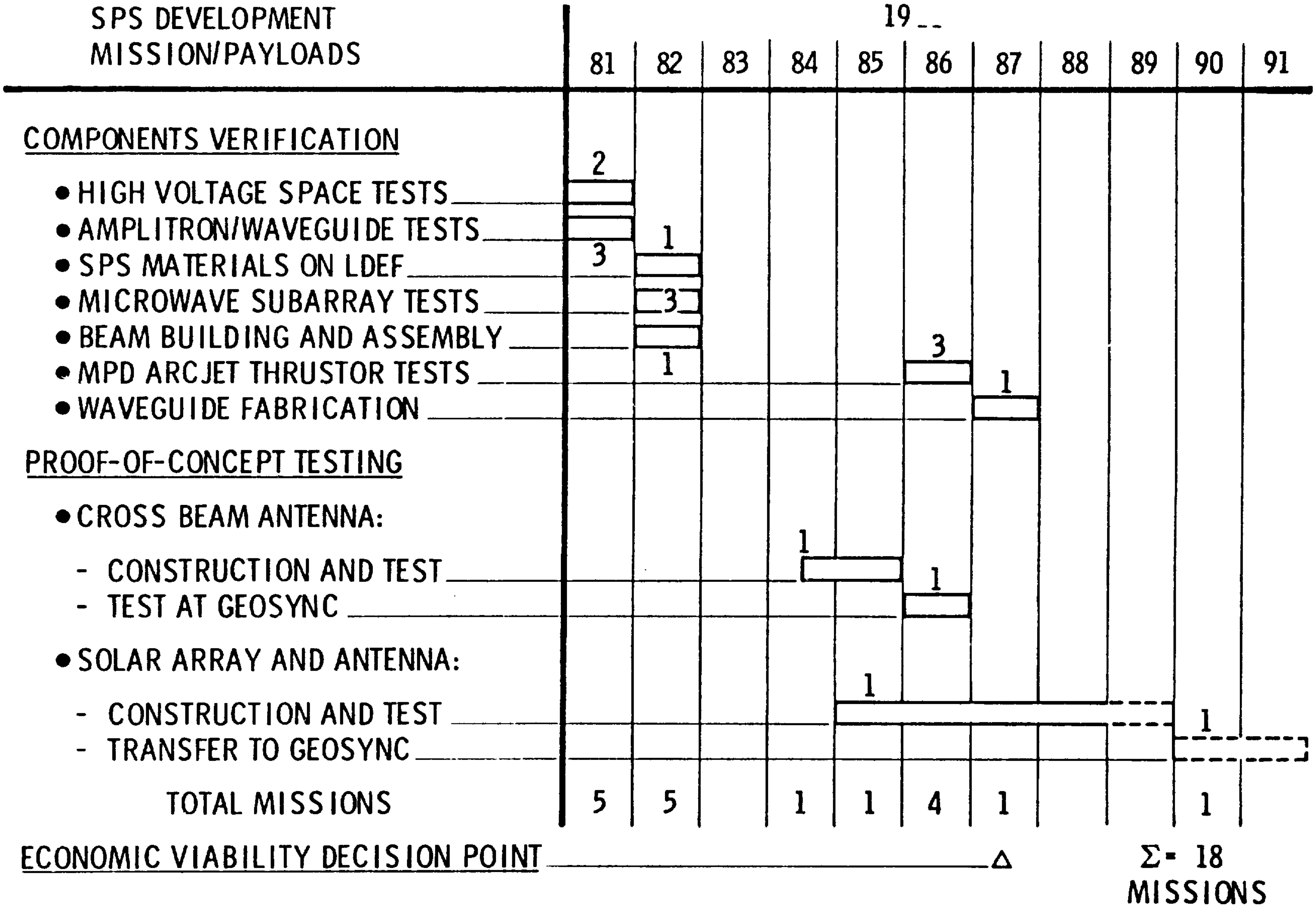


TYPICAL EQUIPMENT

- ANALYTICAL - BIO/GENERAL PURPOSE INSTRUMENTATION
- GENERAL PURPOSE/SURGICAL WORK BENCH
- HOLDING UNITS

SOLAR POWER SATELLITE DEVELOPMENT MISSION MODEL

40527

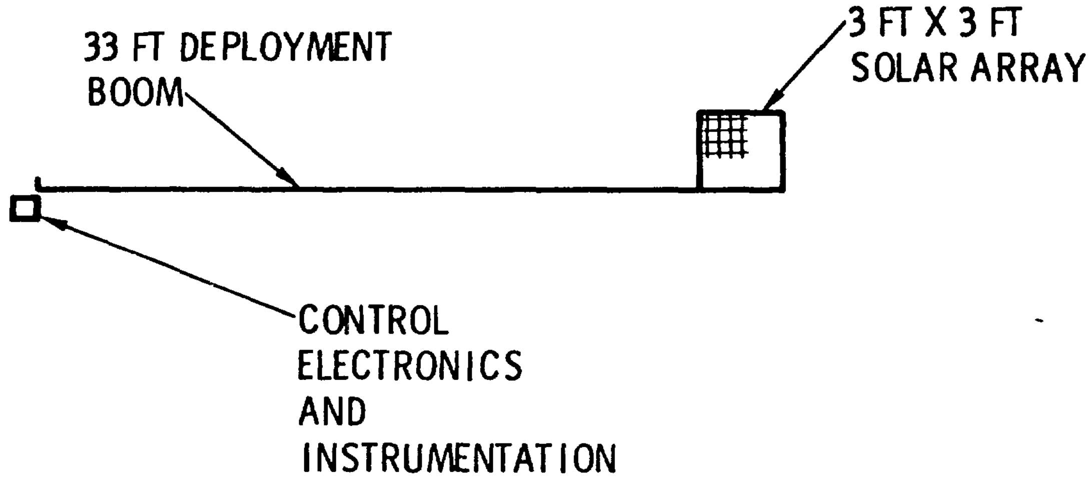


40529

HIGH VOLTAGE SPACE TESTS

PHYSICAL CHARACTERISTICS	
• WEIGHT	110 LBS
• DIMENSIONS	3 X 3 FT
• POWER	0.5 KW
• CREW	1 FOR 2 HRS PER DAY

MISSION CHARACTERISTICS	
• OBJECTIVES	ASSESS SPACE PLASMA EFFECTS
• TIME FRAME	1981
• DURATION	7 DAYS



TYPICAL EQUIPMENT

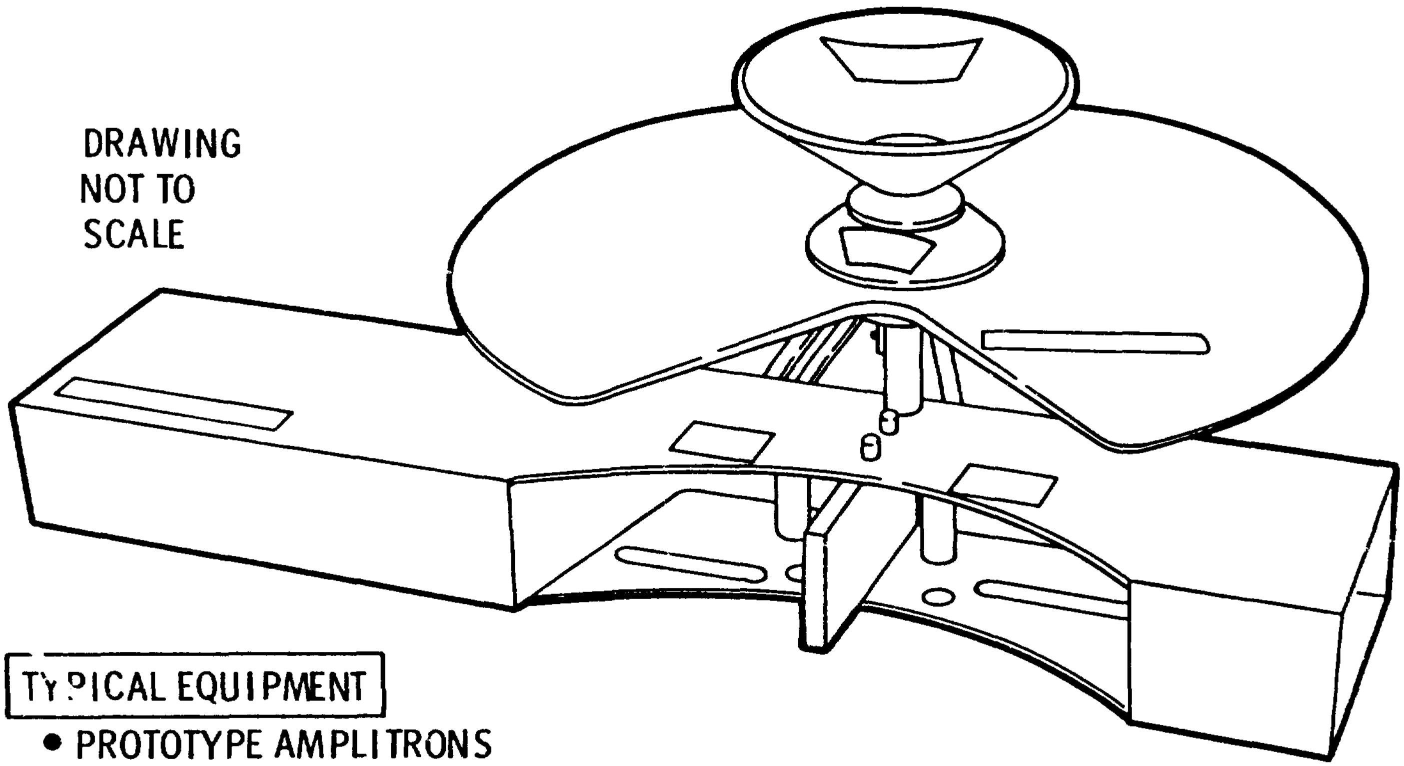
- SOLAR ARRAY SETS
- DEPLOYMENT BOOM
- CONTROL ELECTRONICS
- AND INSTRUMENTATION

AMPLITRON/WAVEGUIDE TESTS

PHYSICAL CHARACTERISTICS	
• WEIGHT	110 LBS
• DIMENSIONS	20 IN. DIA, 2 X 4 IN.
• POWER	6 KW
• CREW	1 FOR 8 HRS PER DAY

MISSION CHARACTERISTICS	
• OBJECTIVES	COMPONENT TEST AND RFI DATA
• TIME FRAME	1981
• DURATION	7 DAYS

DRAWING
NOT TO
SCALE



TYPICAL EQUIPMENT

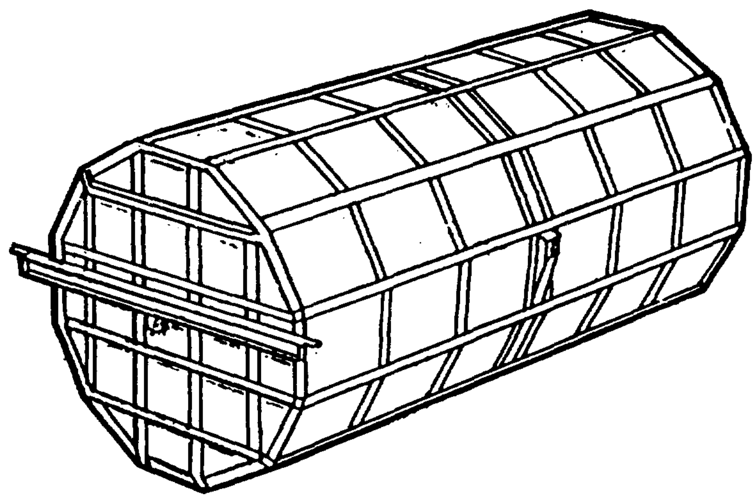
- PROTOTYPE AMPLITRONS
- WAVEGUIDE ASSEMBLY

40541

LONG DURATION EXPOSURE TESTS

PHYSICAL CHARACTERISTICS	
• WEIGHT	14,900 LB
• DIMENSIONS	14 X 30 FT
• POWER	NONE
• CREW	NONE

MISSION CHARACTERISTICS	
• OBJECTIVES	MATERIALS VERIFICATION
• TIME FRAME	1982
• DURATION	ONE YEAR



TYPICAL EQUIPMENT

- SUPPORT STRUCTURE
- ATTACH BRACKETS

40531

MICROWAVE SUBARRAY TESTS

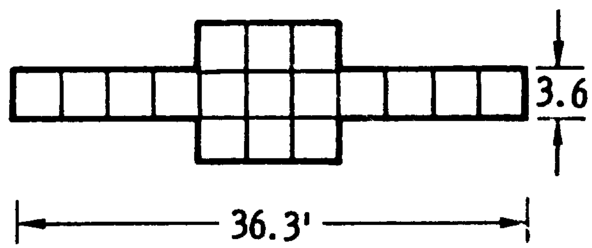
PHYSICAL CHARACTERISTICS

- WEIGHT 300 LBS
- DIMENSIONS 3.3 X 36.3 FT
- POWER 4 KW
- CREW 1

MISSION CHARACTERISTICS

- OBJECTIVES PERFORMANCE AND EMI TESTS
- TIME FRAME 1982
- DURATION 7 DAYS

TEST ARRAY DEPLOYED ON
BOOM FOR VIEWING BY BMS[1]



TYPICAL EQUIPMENT

- ANTENNA ARRAY
- KLYSTRON AND
- AMPLITRON SETS

[1] BEAM MAPPING SATELLITE. TELE OPERATOR CANDIDATE VEHICLE TO PERFORM BEAM MAPPING, PROPULSION AND MANEUVERING FUNCTIONS

40532

BEAM BUILDING AND ASSEMBLY TESTS

PHYSICAL CHARACTERISTICS

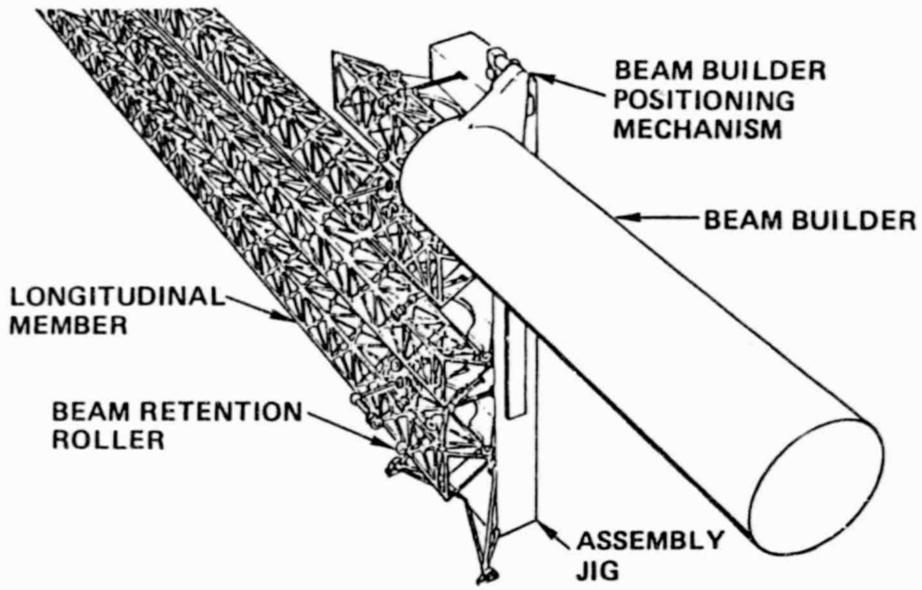
- WEIGHT: 33,000 LBS
- DIMENSIONS: 15 X 50 FT
- POWER: 5 KW
- CREW: 2 EVA FOR ~3 DAYS (24 MANHRS TOTAL)

MISSION CHARACTERISTICS

- OBJECTIVES: VERIFY N16 OPERATION
- TIME FRAME: 1982
- DURATION: 30 DAYS

TYPICAL EQUIPMENT

- BEAM BUILDER
- AND ASSEMBLY JIG



40533

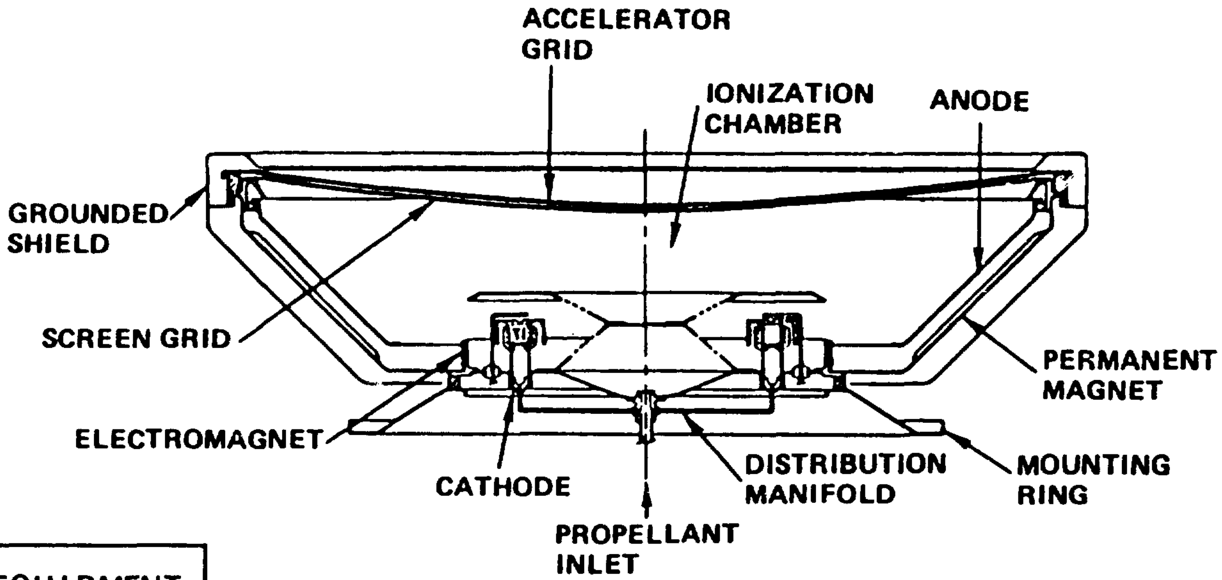
MAGNETOPLASMADYNAMIC (MPD) THRUSTOR TEST

PHYSICAL CHARACTERISTICS

- WEIGHT 5000 LBS
- DIMENSIONS
- POWER 17.5 KW
- CREW 1

MISSION CHARACTERISTICS

- OBJECTIVES PERFORMANCE VERIFICATION
- TIME FRAME 1986
- DURATION 7 DAYS



TYPICAL EQUIPMENT

CROSS BEAM ANTENNA CONSTRUCTION AND TEST

40534

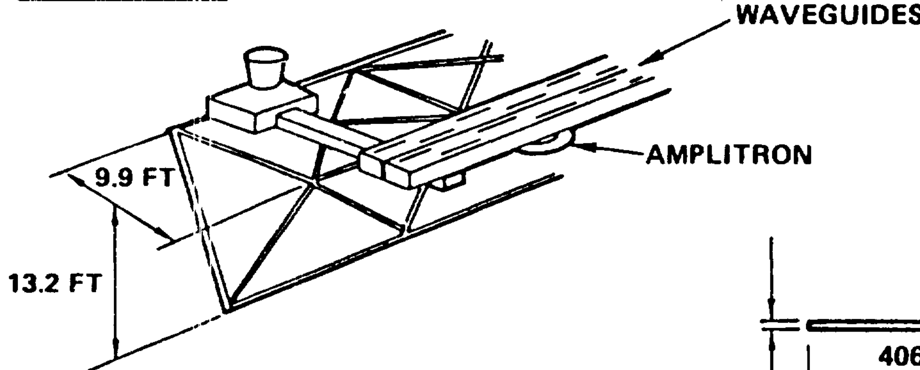
PHYSICAL CHARACTERISTICS

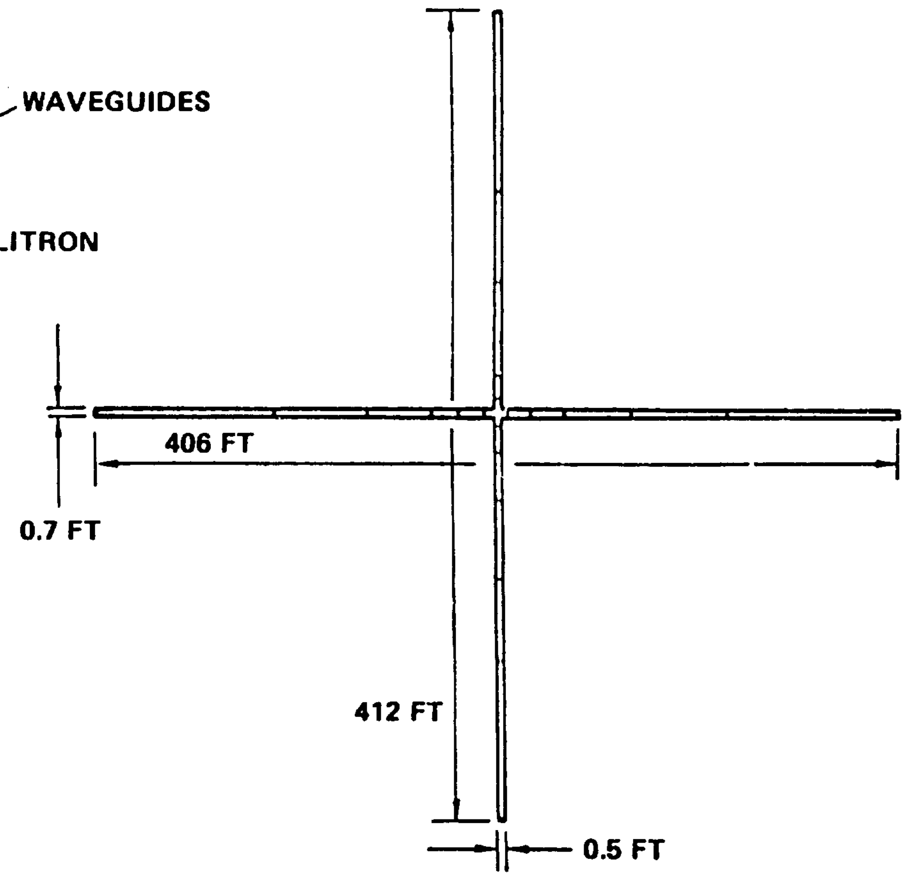
- WEIGHT 13,000 LBS
- DIMENSIONS 406 X 412 FT
- POWER 6 KW
- CREW 3 FOR 120 DAYS

MISSION CHARACTERISTICS

- OBJECTIVES FAB AND TEST X-BEAM ANTENNA
- TIME FRAME 1984 - 1985
- DURATION 485 DAYS

INSTALLATION





TYPICAL EQUIPMENT

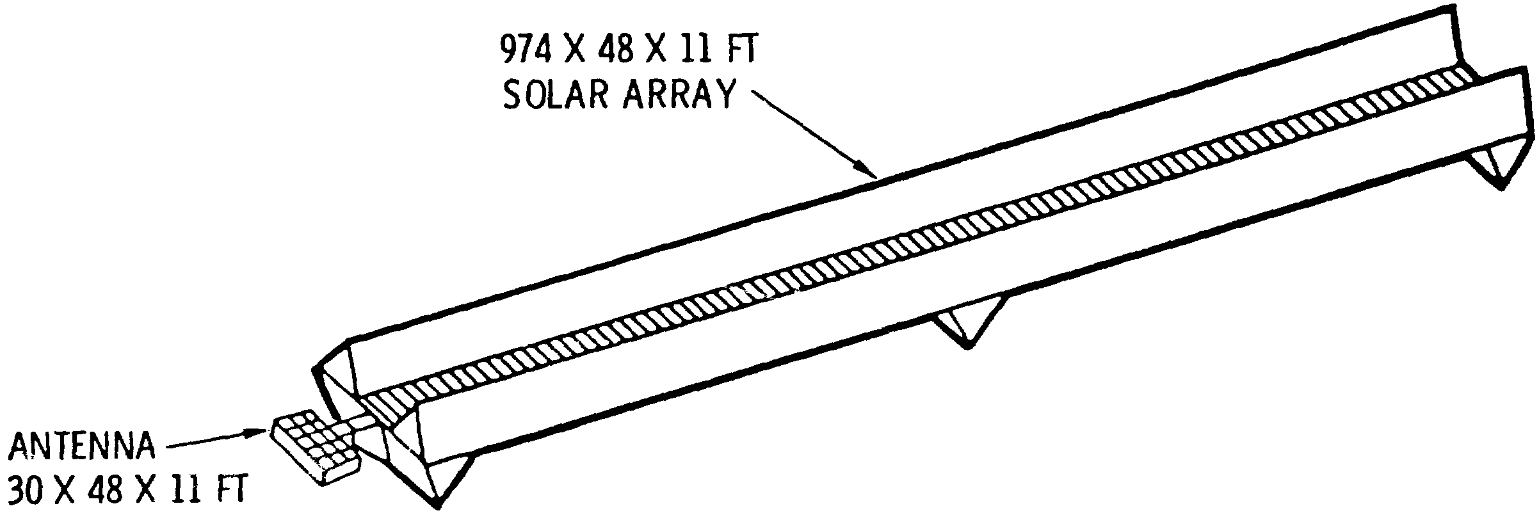
- AMPLITRON SETS
- WAVEGUIDES
- COMPOSITE MATERIAL BEAMS
- BEAM BUILDER AND ASSEMBLY JIG

40535

SOLAR ARRAY AND ANTENNA FABRICATION AND TEST

PHYSICAL CHARACTERISTICS	
WEIGHT	54,500 LBS
DIMENSIONS	974 X 48 X 11 FT
POWER	12 KW
CREW	3

MISSION CHARACTERISTICS	
OBJECTIVES	FAB AND TEST SOLAR ARRAY/ ANTENNA
TIME FRAME	1985 - 1988
DURATION	900 DAYS (TBD DAYS MANNED)



TYPICAL EQUIPMENT

MICROWAVE ANTENNA AND SOURCE
SOLAR CELL BLANKETS
BEAM BUILDER AND ASSEMBLY JIG

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APPENDIX C
LIFE SCIENCES UTILIZATION OF ON-BOARD SKYLAB MEDICAL FACILITIES

Future options have been identified for biomedical research areas which can be addressed by Skylab equipment as extensions of original Skylab. A preliminary analysis was made of the potential experiment activities that could be conducted during these future studies and the equipment and major supplies that would be required to perform these activities. In addition, a preliminary evaluation was made of the extent to which the experiment equipment used during the Skylab missions could satisfy the requirements of these candidate future studies. A summary of these analyses is contained in Table 1 along with an estimate of the equipments present status along with examples of additional equipment and supplies that could be added to satisfy or enhance experiment procedures.

It is apparent from the Table that Skylab equipment currently onboard would be able to satisfy a number of these candidate experiments with only a minimum of additional equipment and supplies to be brought up by the Orbiter.

FOLDOUT FRAME

Table 1

SKYLAB EQUIPMENT AVAILABLE FOR BIOMEDICAL EXPERIMENTATION

Candidate Future Studies Identified from Skylab Results	Equipment Items Onboard Skylab Needed to Support Studies	Skylab Equipment Status
A. Cardiovascular Studies 1. In-depth, non-invasive cardiovascular dynamics monitoring	a. Vector cardiogram b. Lower body negative pressure device c. Leg volume measurement device d. Bicycle ergometer e. Automatic blood pressure measurement system	a. Fully functional b. Fully functional c. Fully functional d. Fully functional e. Would require checkout and calibration
2. Invasive pressure/volume/flow changes in early flight (animal)	a. None	a. --
3. Demonstrate presence or absence of Gaver-Henry reflex	(NOTE: this study requires measurements during first day in orbit and is, therefore, probably impracticable for Skylab.) a. Inflight blood collection system b. Refrigerator c. Waste management urine collection system d. Body mass measurement device e. 24-hr urine volume measurement system	a. Centrifuge functional suppli required b. May require refurbishment c. Functional d. Fully functional e. Mechanical method functional indicator dilution needs sup
4. Total body exercise regimen to maintain integrity of anti-gravity as well as major muscle groups	a. Bicycle ergometer b. Skylab exercise kit c. Metabolic analyzer	a. Fully functional b. Fully functional c. May need refurbishment, requ gas supplies
5. Assess role of venous (capacitance) vessels in observed deconditioning process	a. All required equipment included in A.1.	2. See A.1.
6. Assess role of fatigue	a. Equipment requirements would depend upon experimental approach. Most required items, however, should be included in A.1, 3., and 4.	a. See A.1., 3., and 4.

Table 1

UIPMENT AVAILABLE FOR BIOMEDICAL EXPERIMENTATION

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FOLDOUT

kylab	Skylab Equipment Status	Additional Equipment Items Needed to Conduct or Support Studies
ressure device ire measure-	a. Fully functional b. Fully functional c. Fully functional d. Fully functional e. Would require checkout and calibration	a. Electrodes, paste, other supplies b. None c. None d. None e. Cuff pressure gas supply, possibly new cuff assembly f. Other: blood flowmeter and electronics, additional occlusive cuffs
	a. --	a. Animal holding facilities and all experiment equipment
s measure- orbit and mpracticable ion system collection device surement	a. Centrifuge functional supplies required b. May require refurbishment c. Functional d. Fully functional e. Mechanical method functional, indicator dilution needs supplies	a. Additional automatic sample processor kits b. Possibly some additional parts c. New supply of sample containers d. None e. Additional supply of volume indicator kits
	a. Fully functional b. Fully functional c. May need refurbishment, requires gas supplies	a. None b. None c. Calibration gas supplies, other supplies d. New exercise devices, anthropometric measurement kit, dynomometers
included	2. See A.1.	a. See A.1.
would l approach. wever, .1, 3., and	a. See A.1., 3., and 4.	a. See A.1., 3., and 4.

FOLDOUT FRAME

Table 1 (Continued)

B. Mineral/Fluid Balance Studies 1. Absolute catabolic in-flight changes in animals	a. None	a. --
2. Countermeasure evaluation - Dietary - Physical - Hormonal (?)	a. Blood sampling and storage equipment (A.3.a. and A.3.b.) b. Urine collection and storage equipment (A.3.c., A.3.b., and A.3.e.) c. Food preparation equipment d. Specimen mass measurement device e. Refrigerator g. All equipment itmes included in A.4. h. Requires animal studies--no appropriate equipment onboard	a. See A.3.a. a b. See A.3.a., c. Fully functi d. Fully funcit e. See A.3.b. g. See A.4. h. --
C. Fluid and Electrolyte Studies 1. Demonstrate Gaver-Henry reflex	a. Identical to A.3.	a. See A.3.
2. Renal hemodynamics in zero-g	a. Blood sampling and storage equipment (B.2.a.) b. Urine collection and storage equipment (B.2.b.)	a. See B.2.a. b. See B.2.b.
3. Renal response to water/salt loads, dehydration in zero-g	a. Urine collection and storage equipment (B.2.b.)	a. See B.2.b.
4. Humoral interactions involved in above	a. Same equipment as above	a. Same as abov
D. Hematology Studies 1. Ground-based marrow-suppression factors	a. Not applicable	a. --
2. Validate Skylab results on longer earth-orbital flights	a. Blood collection and storage system (B.2.a.)	a. See B.2.a.
E. Neurophysiology and Performance Studies 1. Role of altered cues: visual, kinesthetic, other sensory	a. Experimental approach unclear, it would not appear as if onboard equipment would be very useful	a. --

Table 1 (Continued)

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	a. --	a. Animal holding facilities (rodent) and all experiment equipment
storage equip- 3.b.) d storage A.3.b., and uipment rement device included in dies--no nt onboard	a. See A.3.a. and A.3.b. b. See A.3.a., A.3.b., and A.3.e. c. Fully functional d. Fully funcitonal e. See A.3.b. g. See A.4. h. --	a. See A.3.a. and A.3.b. b. See A.3.a., A.3.b., and A.3.e. Other: in-flight bone densitometer c. None d. None e. See A.3.b. f. Defined experimental diets g. See A.4. h. Animal holding facilities and 11 experiment equipment
	a. See A.3.	a. See A.3.
storage d storage	a. See B.2.a. b. See B.2.b.	a. See B.2.a. b. See B.2.b. c. Supplies and materials needed for administration of renal clearance test substances required
d storage	a. See B.2.b.	a. See B.2.b. b. Consumables associated with experiment procedures required
bove	a. Same as above	a. Same as above
	a. --	a. --
storage	a. See B.2.a.	a. See B.2.a. b. Improved blood cell processing and counting equipment
h unclear, it if onboard ery useful	a. --	a. --

Table 1 (Continued)

2. Effect of overhydration, and increased venous pressure on motion sickness threshold	a. Primarily ground-based study with in-flight verification b. Same as A.5. c. Equipment same as that used in A.3. and B.2.	a. -- b. See A.5. c. See A.3. and B.2.
3. Predictive test for zero-g space sickness susceptibility	a. Not applicable	a. --
4. Basic studies regarding etiology	a. Rotating litter chair b. Body temperature measuring system c. Vector cardiograph d. Automatic blood pressure measurement system e. Blood collection and storage equipment f. Urine collection and storage equipment g. Sleep monitoring equipment	a. Probably functional a. Fully functional c. Fully functional d. See A.1.e. e. See B.2.a. f. See B.2.b. g. Would require extensiv- tion
5. Role of one-g training in prevention	a. Not applicable	a. --
6. Improved medications for prevention/control	a. Same as E.4.	a. See E.4.

Table 1 (Continued)

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d study with n	a. --	a. --
	b. See A.5.	b. See A.5.
t used in	c. See A.3. and B.2.	c. See A.3. and B.2.
	a. --	a. --
	a. Probably functional	a. Motor nitrogen blanket should be checked
uring system	a. Fully functional	b. New probes, thermisters, and supplies
	c. Fully functional	c. None
ure measure-	d. See A.1.e.	d. See A.1.e.
storage	e. See B.2.a.	e. See B.2.a.
storage	f. See B.2.b.	f. See B.2.b.
pment	g. Would require extensive modification	g. New recorder and other equipment and supplies
	a. --	a. --
	a. See E.4.	a. See E.4. and additional consumables

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APPENDIX D

AIRLOCK MODULE DESCRIPTION

In order to provide a complete Skylab reference document, this provides sufficient description material to provide an understanding of the Airlock Module and its subsystems. It includes AM subsystem hardware descriptoins and accounts for their performance during the Skylab missions. Section 2.1.2 of Volume I, summarizes the End-of-Mission status and today's status as determined by the Reuse Study and Reactivation/Interrogation activities. Refurbishment/Resupply requirements are provided together with refurbishment kit descriptions.

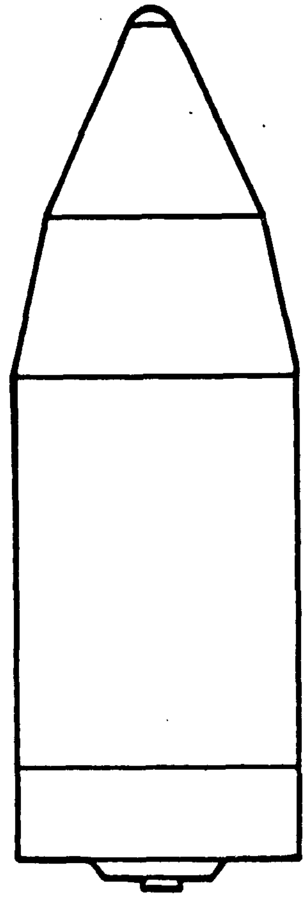
Appendix E contains similar information on the Orbital Workshop.

AIRLOCK MODULE DESCRIPTION
SKYLAB A CONFIGURATION

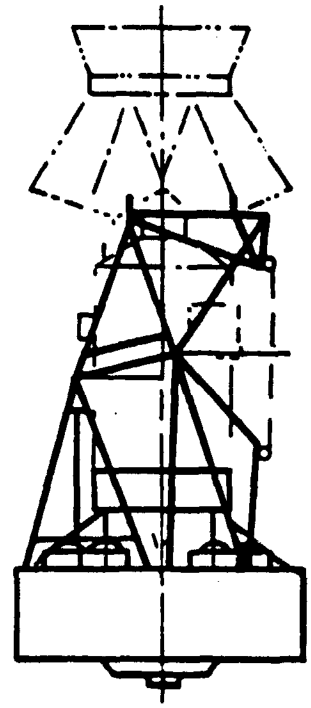
AM Configuration

The Airlock Module (AM), Fixed Airlock Shroud (FAS), and Deployment Assembly (DA), shown in Figures D-1 and D-2, and all associated trainers and Ground Support Equipment were designed, fabricated and verified under NASA contract as basic elements of the Skylab cluster. The AM provided the following features:

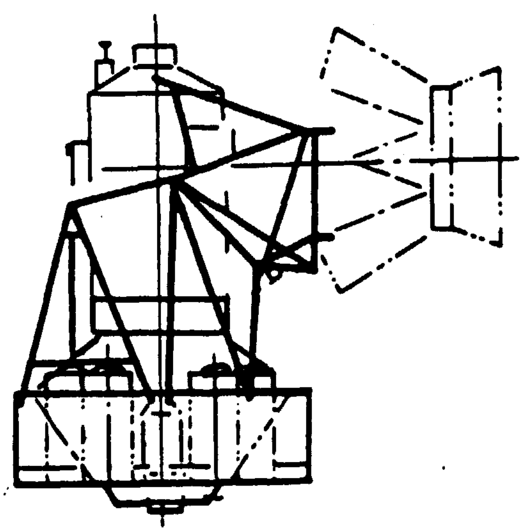
- o Interconnecting passage between MDA and OWS.
- o Lock, hatch and support system for extravehicular activity (EVA).
- o Purification of the Skylab atmosphere.
- o Thermal control of the Skylab atmosphere (cooling only for MDA and OWS).
- o Atmospheric supply and control.
- o Apollo Telescope Mount (ATM) launch support and orbital deployment.
- o Payload protection during launch (Payload Shroud).
- o Electrical power conditioning control, and distribution.
- o Real- and delayed-time data.
- o Cluster intercommunication.
- o Cluster failure warning.
- o Command system link with ground network.
- o VHF ranging link for CSM rendezvous.
- o Controls and displays.
- o Teleprinter.
- o Experiment installation of D024 sample panels.



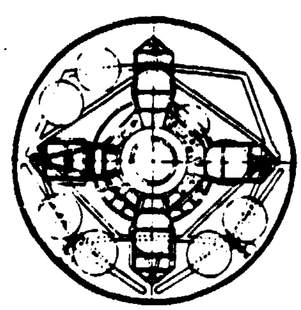
Launch Configuration



Payload Shroud Jettisoned



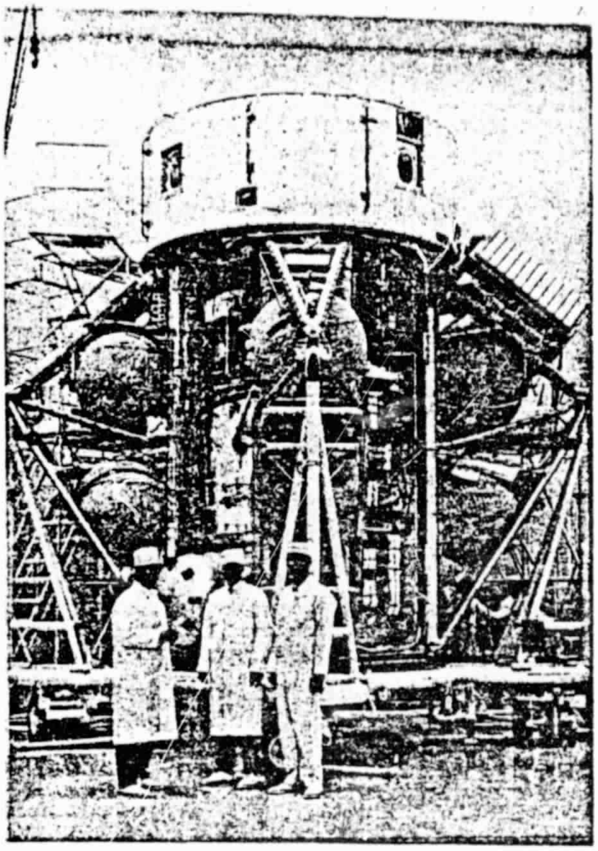
Deployment Assembly Deployed
(FAS Cutaway)

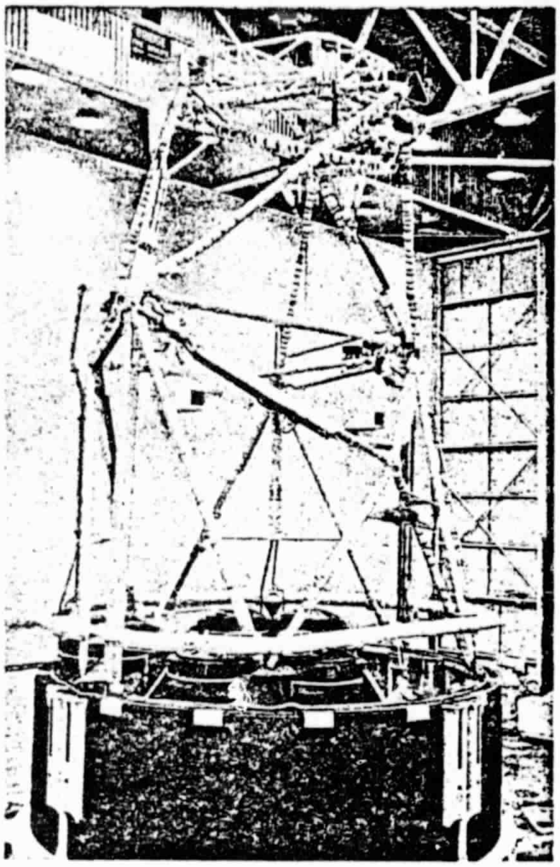


View Looking Forward

Orbital Configuration

Figure D-1 Airlock Module General Arrangement





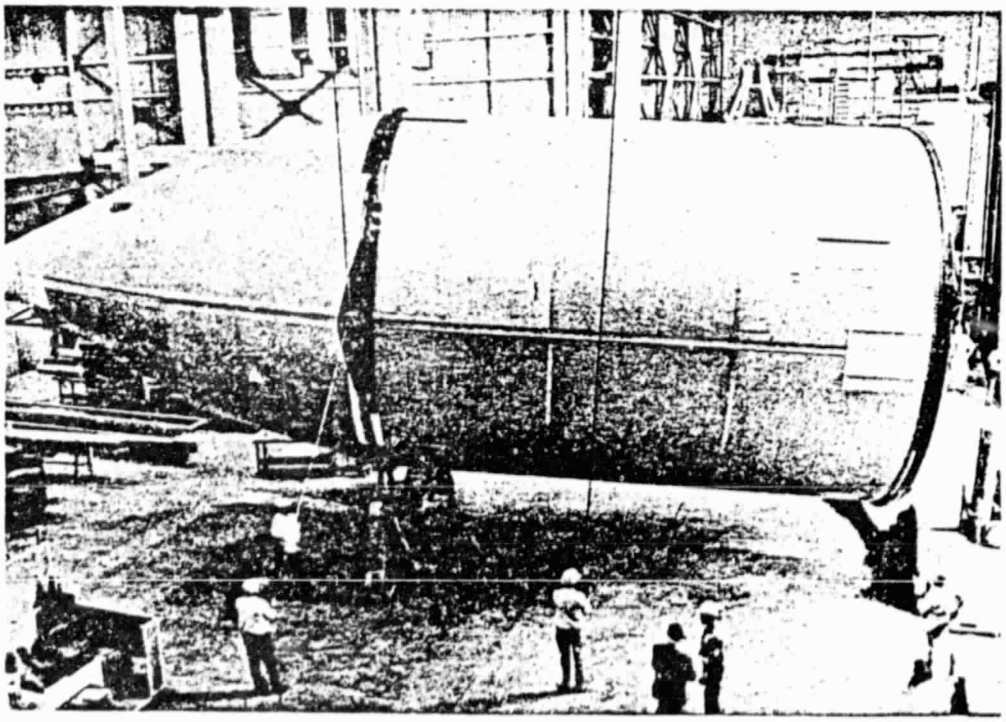


Figure D-2 Airlock Components

- o Experiment antennas (EREP and radio noise burst monitor).
- o ATM C&D Panel cooling.

Airlock Module Weight and Dimensions

o Gross AM Weight	15,166 lb.
o AM Working Volume	610 cu ft.
o AM Overall Length	211.54 in.
Tunnel Assembly	
Length	153 in.
Diameter	65 in.
Volume	322 cu ft.
Structure Transition Section (STS)	
Length	47 in.
Diameter	120 in.
Volume	288 cu ft.
Pressurized AM to OWS Passageway	
Length	11.54 in.
Diameter	42.5 in.

Structures and Mechanical Systems

The AM was required to provide a pressurized vessel to house cluster controls, allow passage between the CSM and the OWS, to permit EVA, and to be a structural support to other cluster elements. The AM was configured, as shown in Figure D-3, with four major elements.

1. Structural Transition Section (STS) and Radiators - The STS was the structural transition from the 120-inch diameter MDA to the 65-inch diameter AM tunnel section. The STS contained four windows for external viewing, with movable window covers for thermal/meteorid protection. Radiators were mounted around the periphery of the STS and portions of the MDA to provide thermal/meteoroid protection as well as perform their basic function as space radiators. The internal volume of the STS housed equipment and controls for the electrical, communication, instrumentation, thermal, environmental, and EVA/IVA systems.
2. Tunnel Assembly - The tunnel assembly was a pressure vessel providing a system of hatches that functioned as an Airlock to permit EVA. The size of the lock compartment with all hatches closed was required to accommodate two pressure suited astronauts with their EVA equipment. All hatch operations were to be designed such that they would be easily operated by a pressure suited astronaut. The internal volume of

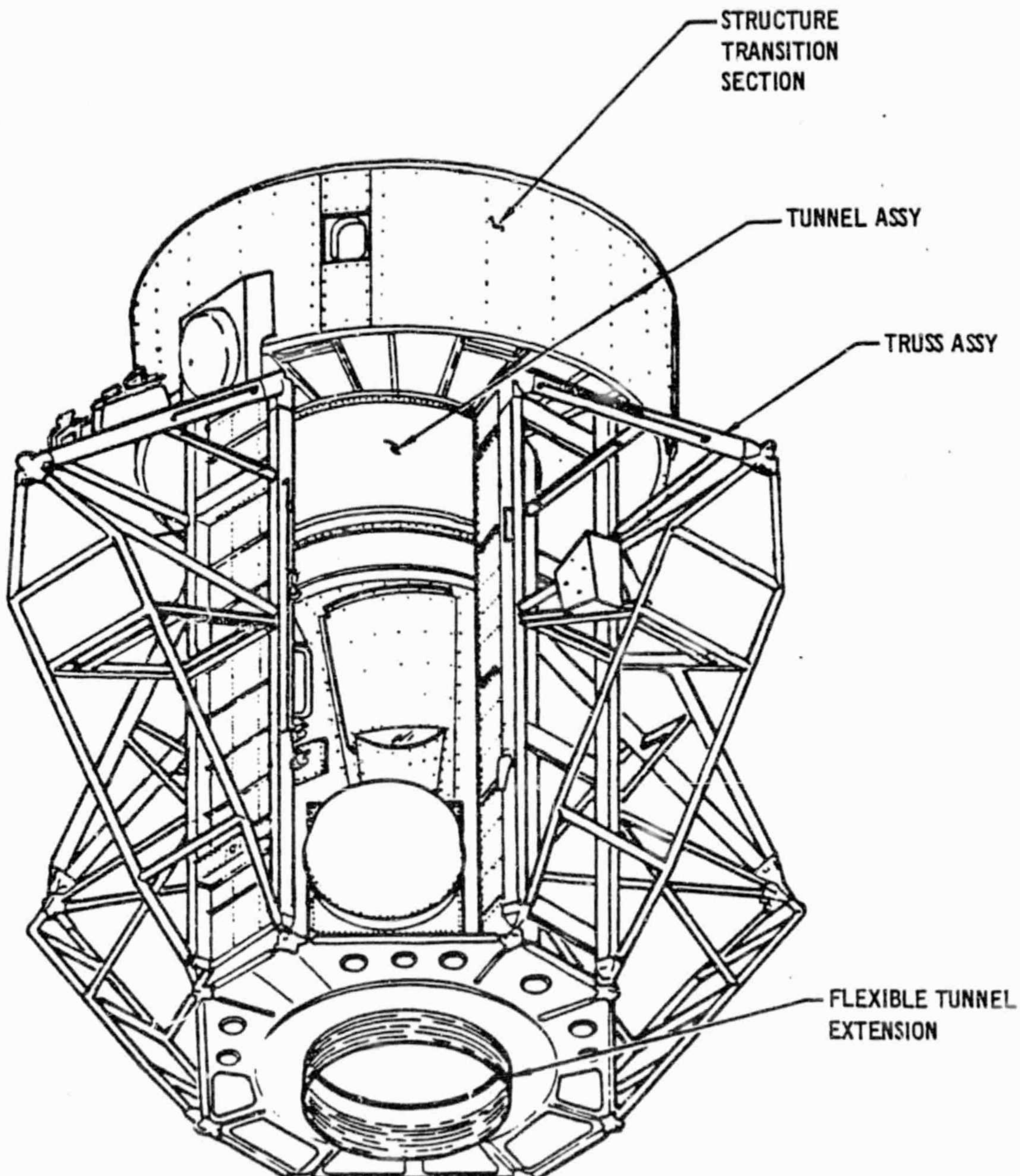


Figure D-3 Airlock Module

the tunnel assembly was sized to house and support equipment and controls for the electrical, communications, instrumentation, environmental and crew systems.

3. Flexible Tunnel Extension - The configuration of the Airlock Module and the OWS dictated the need for a pressure-tight passageway between these two modules that would accommodate relative deflections with minimum load transfer. A redundandly sealed, flexible tunnel was designed to provide this passageway.
4. Support Truss Assembly - The AM and MDA were supported by four truss assemblies that attached to the tunnel assembly and mated with four attach points on the FAS. The trusses were also used to support N_2 tanks, battery modules, experiments and miscellaneous equipment.

Thermal Control System

The Airlock Thermal Control System (TCS) provided temperature control for the Airlock and cooling to the MDA and OWS. It consisted of an active coolant system, ATM C&D Panel/EREP cooling system, battery cooling system, thermal coatings, thermal curtains, equipment insulation, AM wall heaters, and molecular sieve exhaust duct heaters. The active coolant system provided coldplates and heat exchangers for euqipment and atmospheric cooling. Primary and secondary flow paths provided the required redundancy.

The following description of the TCS subsystems reflects the as-flown configuration. The TCS subsystems made up the overall TCS to provide for temperature control of: AM structure and equipment, AM crew compartments, suit cooling system, water solution for ATM C&D/EREP cooling, and atmospheric gas for OWS and MDA cooling.

Both active and passive techniques were used in the TCS subsystems to provide the necessary temperature control. The payload shroud provided for temperature control of structure and equipment during prelaunch, launch, and ascent. The temperatures of AM structure and crew compartment surfaces were controlled during orbital operations by the thermal coatings, thermal curtains, and equipment insulation subsystems. Temperature control of suit cooling water in the EVA/IVA Suit System was provided by the coolant subsystem in conjunction with equipment insulation. Similarly, hte ATM C&D/EREP cooling water temperature was controlled through heat exchange with the coolant subsystem, and by the thermal coatings and thermal curtains subsystems. The atmospheric gas temperature control was provided by the exchange of heat between the coolant subsystem and the atmospheric control subsystem in the Environmental Control System heat exchangers.

Environmental Control System

The environmental control system provided a habitable environment for the Skylab crew. It consisted of an integrated array of systems and subsystems. Included were subsystems for O_2 and N_2 gas storage, distribution and pressure control, atmosphere cooling and circulation, CO_2 and odor removal, atmospheric condensate removal and disposal, and in-flight water systems servicing.

Gas System

The gas system permitted prelaunch purge and ascent venting, provided O_2 and N_2 storage, pressure regulation, and gas distribution for in-orbit flight operations. The gas system is shown schematically in Figure D-4.

Oxygen and ni-rogen for the Skylab missions was stored in the gaseous state and carried during launch. Design usable gas quantities were based upon a pressure range of 3000 psig to 300 psig.

Oxygen was stored in six tanks contained in three modules mounted on the Fixed Airlock Shroud. Each tank has a fill valve, a check valve, two temperature transducers, and two pressure transducers. The oxygen tanks shown in Figure D-5 are constructed with a thick fiberglass wrap on a thin welded metallic liner. Each is cylindrical shaped with elliptical ends and is 45 inches in diameter and 90 inches long.

Nitrogen was stored in six tanks contained in three modules mounted on the AM trusses. Each tank has a fill valve, a check valve, two temperature transducers, and two pressure transducers. The nitrogen tanks are 40-inch diameter spheres constructed of titanium (reference Figure D-5).

The gas system provides flows of oxygen and nitrogen at regulated pressure. The oxygen flow was used for initial pressurization of Skylab, the two-gas control system and EVA/IVA support and was regulated to 120 $\pm$10 psig. The nitrogen flow was used for initial pressurization, the two-gas control system, molecular sieve valve actuation, water systems reservoir pressurization, OWS water system pressurization, and experiment support and was regulated to 150 $\pm$10 psig.

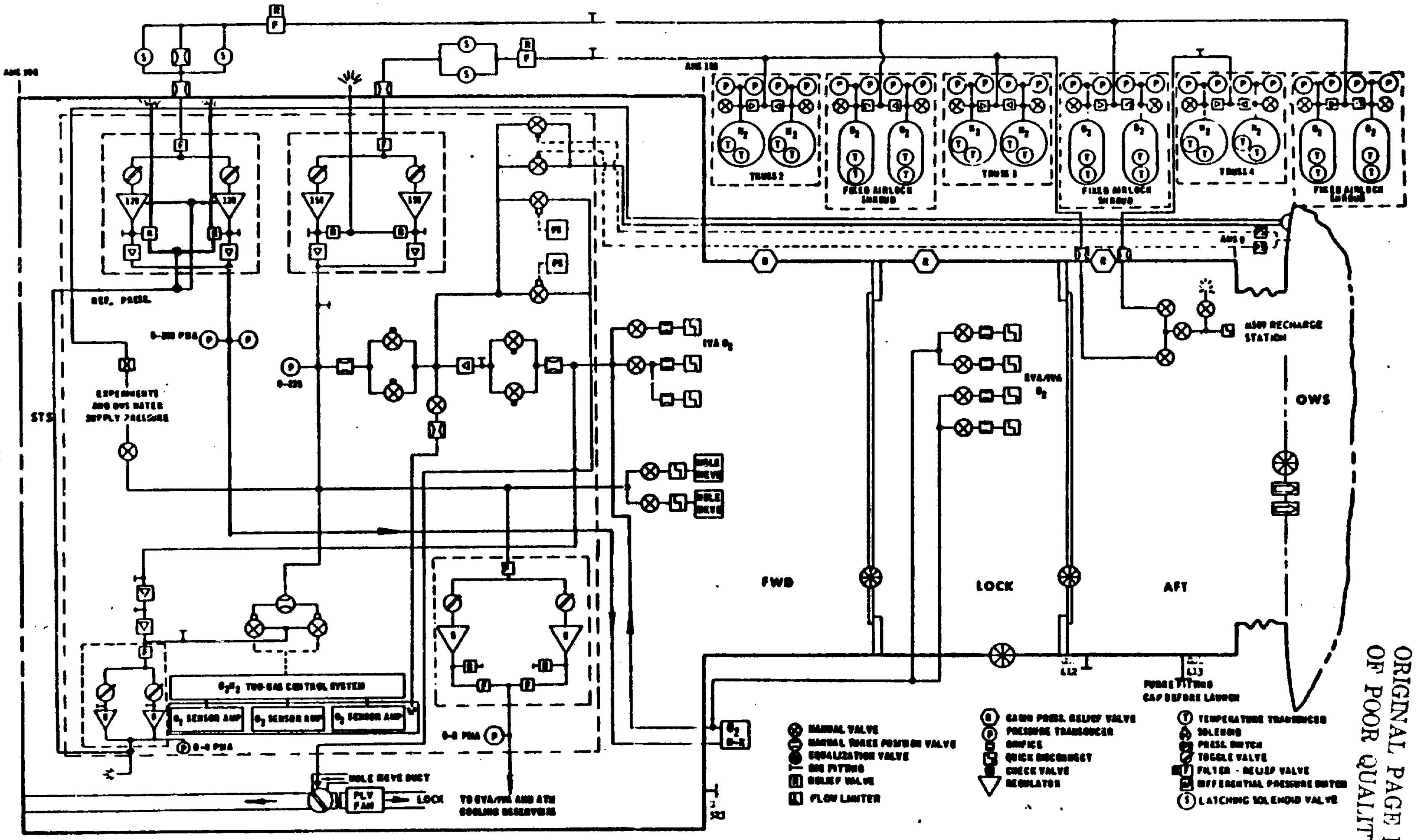


Figure D-4 Gas System

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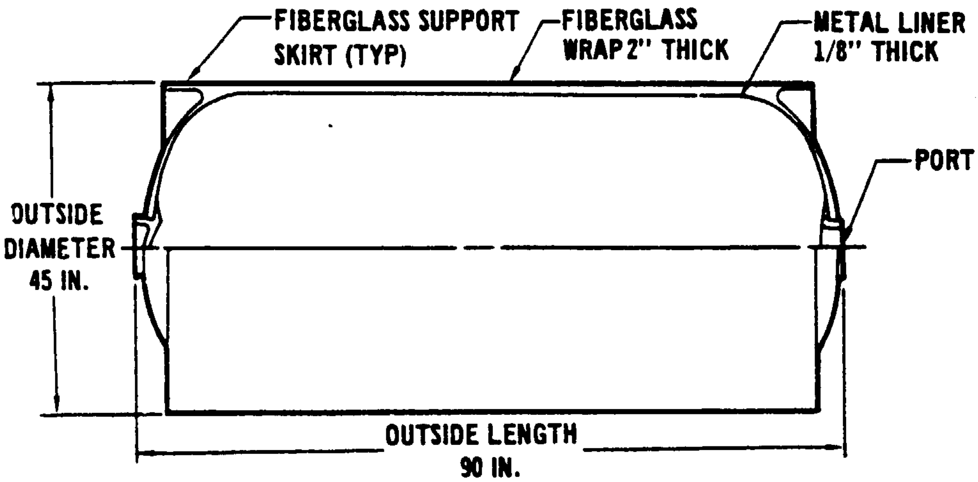
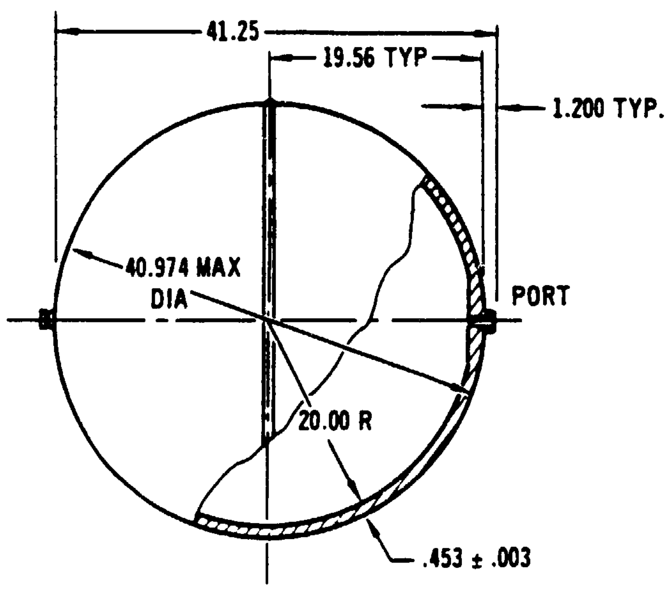
VOLUME	– 57 CU FT	936 LBS O_2 AT 3000 PSIG, 100°F (TOTAL)
WEIGHT (DRY)	– 2800 LB	822 LBS O_2 (USEABLE)
OPERATING PRESSURE	– 3000 PSIG	
RATED PRESSURE	– 4500 PSIG	
MATERIALS	– 321 ST. STL. LINER/347 ST. STL POLAR CAPS WITH FIBERGLASS WRAP	



OXYGEN TANKS



VOLUME	19.3 CU FT
WEIGHT	393 LB
OPERATING PRESSURE	3000 PSIG
MATERIAL	TITANIUM
251 LB N_2 @ 3000 PSIG, 100°F	(TOTAL)
220 LB N_2	(USABLE)

NITROGEN TANKS

Figure D-5 Oxygen and Nitrogen Tanks

During manned operation, the atmospheric total pressure was maintained between 4.8 and 6.0 psia, and O_2/N_2 composition was controlled automatically by the two-gas control system maintained atmospheric total pressure and oxygen partial pressure during manned operation. During the orbital storage, cabin pressure was maintained by the Initial Pressurization System. Overpressure protection was provided by cabin pressure relief valve assemblies located in the AM forward, lock, and aft compartments.

The atmospheric control system, shown in Figure D-6 provides humidity control, carbon dioxide and odor removal, ventilation, and cabin gas cooling. Moisture is removed from the atmosphere by condensing heat exchangers and molecular sieve systems located within the STS. Carbon dioxide and odor are removed by the molecular sieve system. Ventilation is provided by fans and molecular sieve gas compressors. Acoustic noise suppression is provided by mufflers. Gas cooling is provided by condensing and cabin heat exchangers. Solids traps upstream of the molecular sieve compressors, as well as six-mesh screens upstream of the PLV fans, provides protection from particular matter.

The condensate system provided the capability of removing, storing, and disposing of condensate from the condensing heat exchanger water separator assemblies. The system also provided the capability of removing, storing, and disposing of gas from the EVA/IVA liquid/gas separator assembly.

Provisions were made for in-flight servicing of water separator plate assemblies, and servicing/deservicing equipment as well as servicing support for ATM C&D Panel/EREP and EVA/IVA water systems. In addition, provisions were made for in-flight deservicing of the servicing/deservicing equipment.

EVA/IVA Suit System

The AM EVA/IVA system provided controlled supples of O_2 and water via GFE interfaces for astronaut cooling and pressure suit maintenance during EVA and IVA operations.

This system provides a supply of O_2, at regulated pressure and temperature, and water, at controlled temperature, flow rate, and pressure interfacing with GFE Life Support Umbilicals (LSUs) at AM EVA and IVA panels. A GFE Pressure

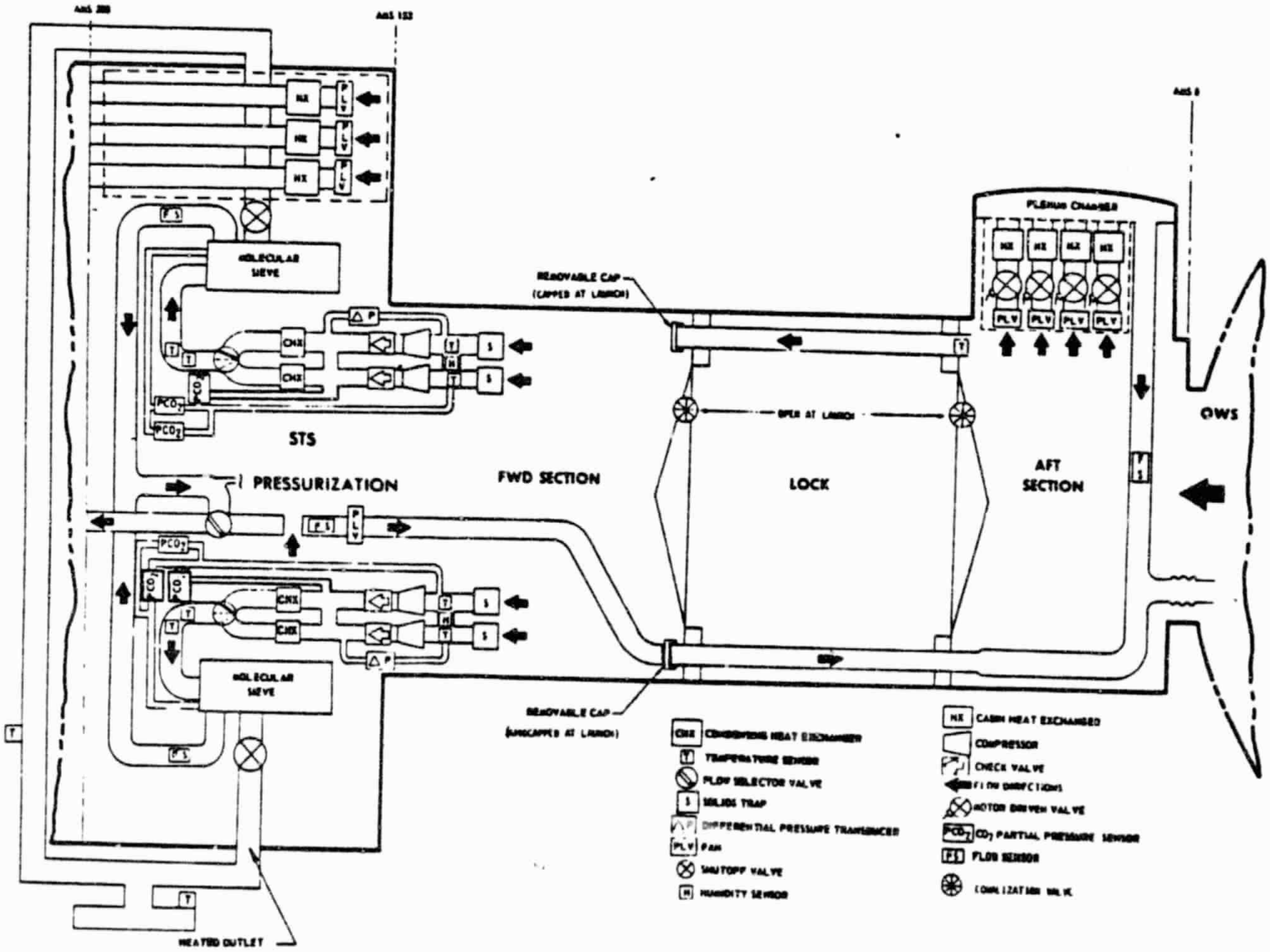


Figure D-6 Atmospheric Control System

Control Unit (PCU), attached between the LSU and pressure suit/Liquid Cooled Garment (LCG), provides control of the O_2/water flowrates delivered to each prssure suit. The AM also provides hardware for in-flight water servicing and deservicing of the LSUs and PCUs as well as controls to vent and repressurize the EVA lock compartment. The AM to LSU interface requirements are presented in ICD No. 13M07396. Additionally, the EVA/IVA Suit System provides instrumentation intelligence and procedures as a basis for system operation.

O_2 is supplied for pressure suit pressurization and ventilation during EVA/IVA operations from the ECS gas system (Figure D-4) to GFE LSUs interfacing with panel-mounted quick disconnects. O_2 flow provisions are available at three AM control panels; i.e., IVA control panel 217 in the STS (Figure D-7 and EVA control panels 317 and 323 in the lock compartment (Figures D-8 and D-9). Each of the EVA panels incorporates two O_2 connectors for redundancy during EVA, while the IVA panel has three in order to accommodate three crewmen during contingency or rescue operations.

The suit cooling system (Figure D-10) provides astronaut cooling during EVA and IVA by circulating temperature controlled water through GFE liquid cooled garments (LCGs), via GFE Life Support Umbilicals (LSUs), and pressure control designated as SUS 1 and SUS 2 and interfae with the primary and secondary coolant loops, respectively, at heat exchangers located in the suit/battery cooling modules. The interfaces with the LSUs are at water supply and return quick disconnects, mounted on IVA control panel 217 and EVA control panels 317 and 323 (Figures D-7, D-8 and D-9). The suit umbilical system controls are also provided at these panels. Astronaut cooling is regulated by adjusting the LCG water flowrates with the GFE PCU flow diverter valves.

Provisions are available for servicing the SUS loops, LSUs, and PCUs in-flight with water from the OWS tanks as well as deservicing the LSUs and PCUs. The detailed procedures for doing so are outlined in the SWS Systems Checklist. The additives initially in the SUS loops are sufficiently concentrated to tolerate dilution resulting from addition of the untreated OWS water.

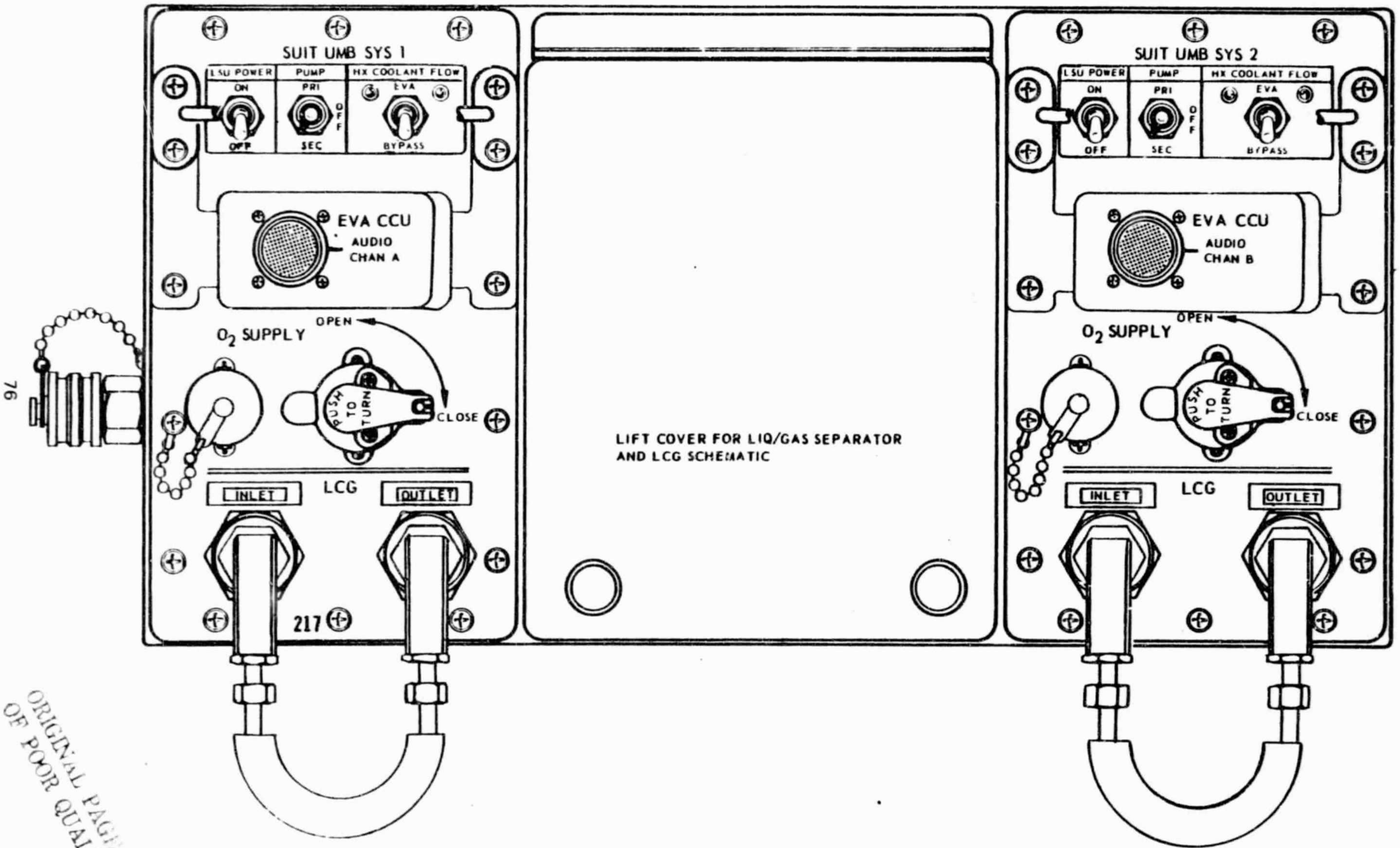


Figure D-7 IVA Control Panel 217

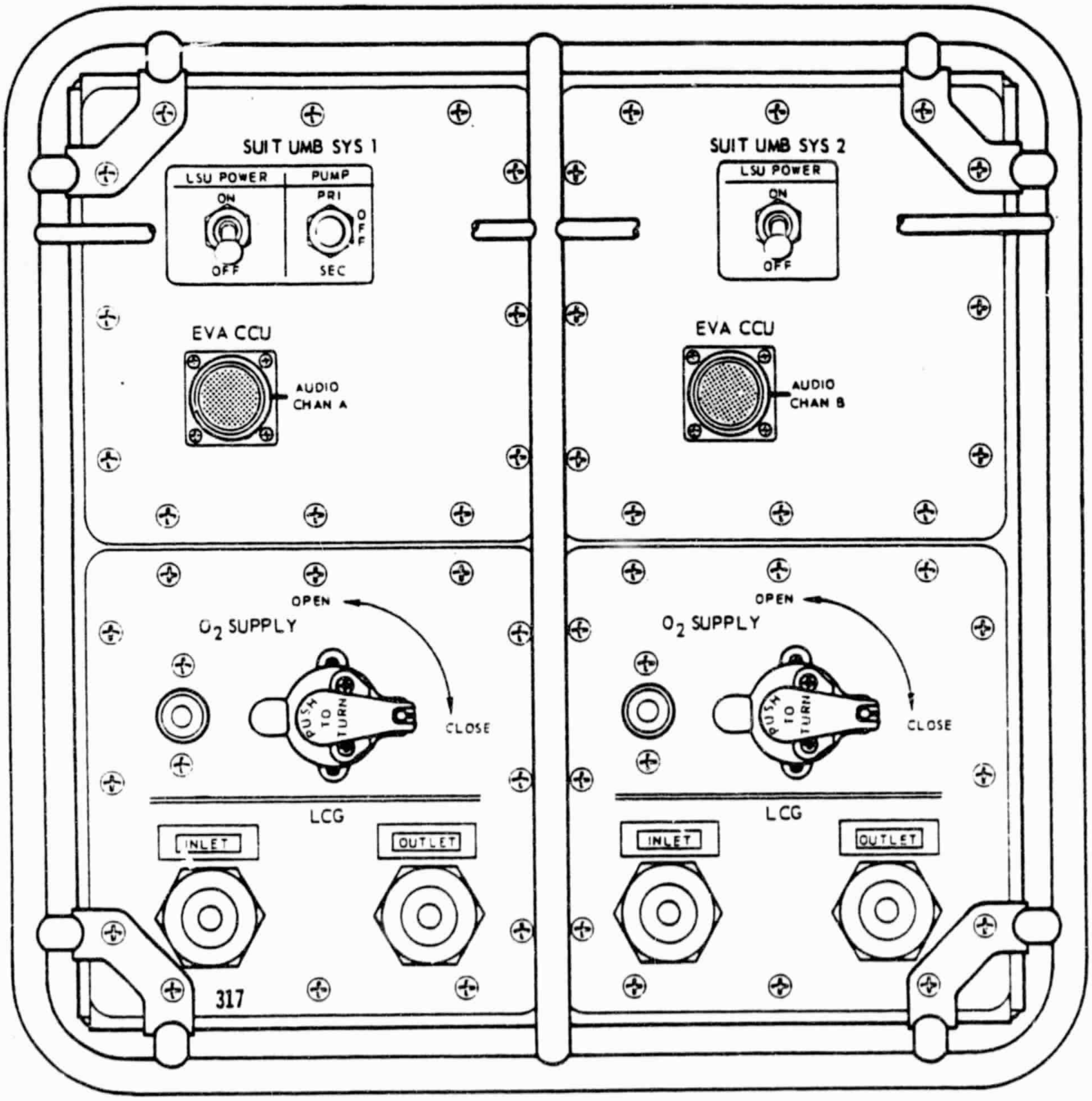


Figure D-8 EVA No. 1 Control Panel 317

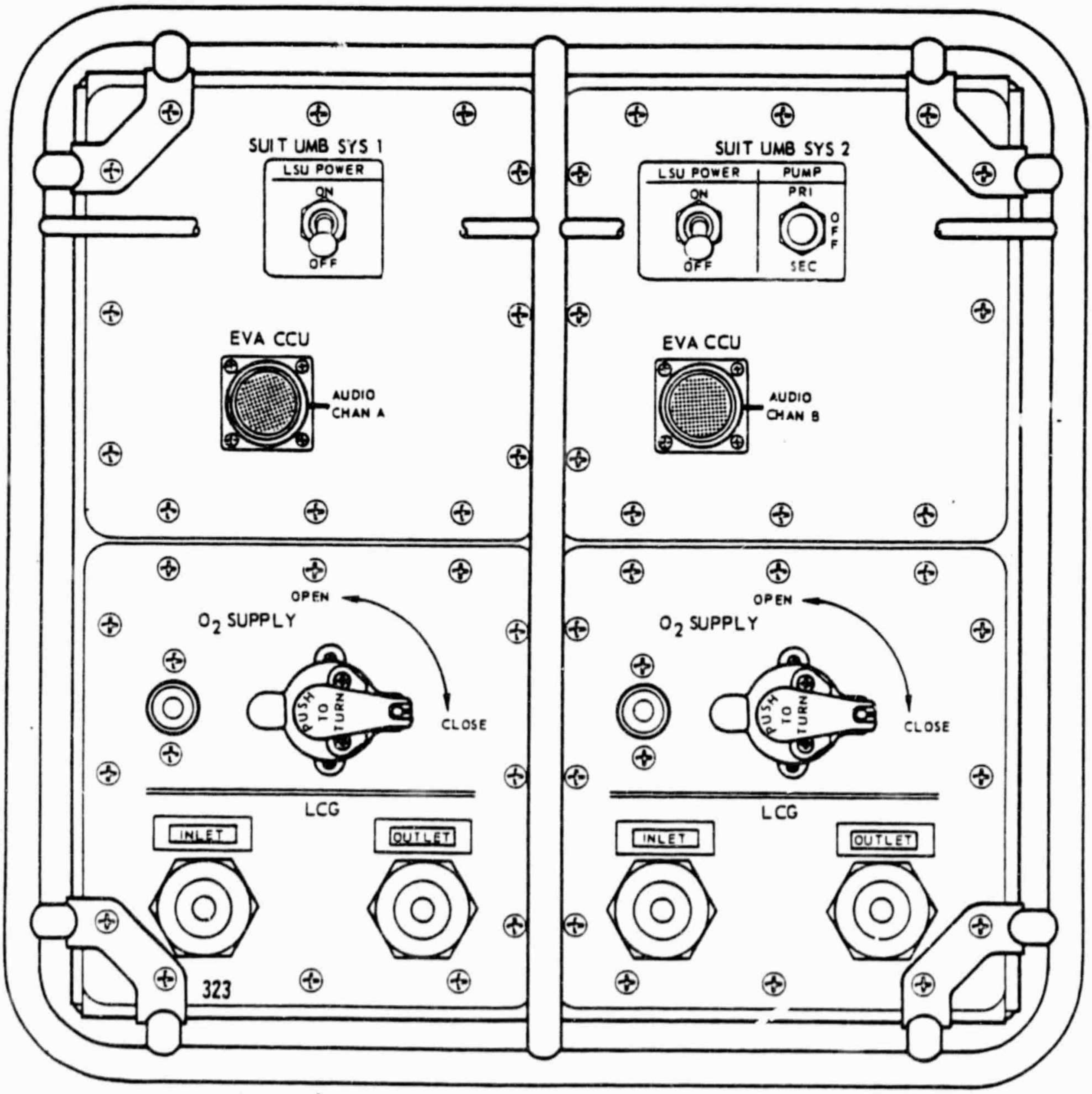


Figure D-9 EVA No. 2 Control Panel 323

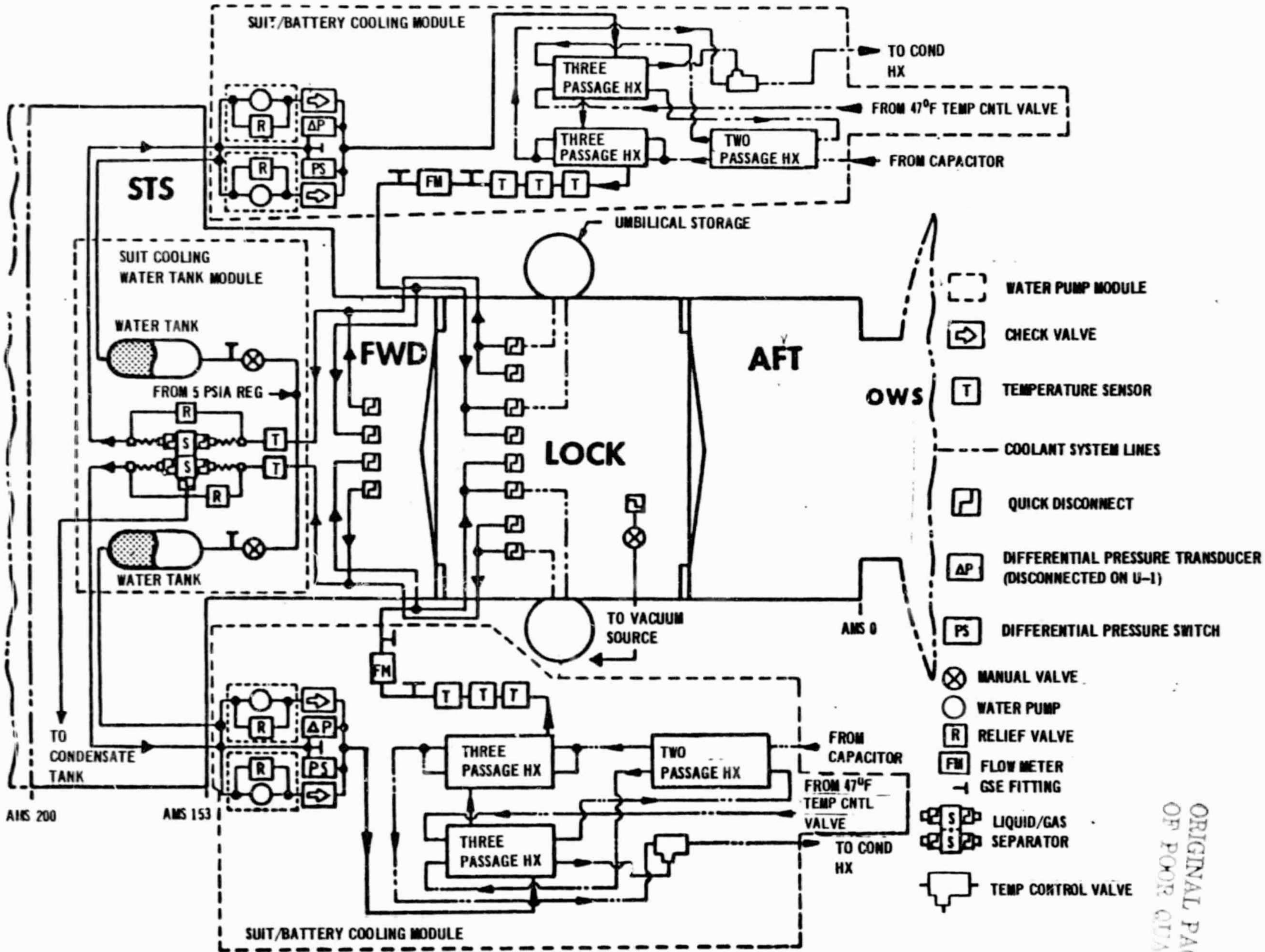


Figure D-10 Airlock Suite Cooling System

Electrical Power System

Teh AM EPS was one of three electrical power systems which provided power for the entire Orbital Assembly. The other two were ATM EOS and CSM EPS. The performance requirements of the AM EPS included compatibility with those of the other two power systems and of the consuming elements.

The AM EPS was designed to accept power from a solar array system mounted on the OWS and to condition this power for application to the AM EPS buses and to the AM EPS batteries. The OWS solar array system was divided into eight electrically identical parts called solar array groups (SAGs). Each group was composed of 30 solar modules (Figure D-11) which provided inptu power to either one of two selectable individual PCGs. Each PCG was composed of a battery, a battery charger, a voltage regulator, and the associated power distribution and control circuitry. The function of each PCG was to provide conditioned power to using equipment, and to recharge the nickel-cadmium batteries during the orbital daylight periods. Various control functions were designed into the AM EPS to effectively manage each PCG and to apply the PCG outputs to the various AM EPS buses. Appropriate control switching was provided on the STS instrument panels or by ground control via the AM Digital Command System.

The AM EPS also included the wiring and controls for power transfer between all of the various power systems and for power distribution to the electrical power loads in all of the OA modules. The AM EPS was designed to operate in parallel with the ATM EPS or CSM EPS to supply power to the AM, ATM, OWS, MDA and CSM. The distribution system was controlled by switches on the STS instrument panels or via the AM DCS. Appropriate monitoring displays for the PCGs and the distribution system were provided on the STS instrument panels and appropriate EPS parameters were instrumented for ground monitoring by the AM telemetry system.

The major equipments comprising the AM EPS consisted of eight power conditioning groups, several control panel assemblies, a dual bus distribution system, a number of relay panels, and two shunt regulators. The battery chargers, batteries, voltage regulators and relay panels for four PCGs were mounted on each of two battery modules. The location of the battery modules is shown in Figure D-12) and the equipment mounted on a battery module is shown on

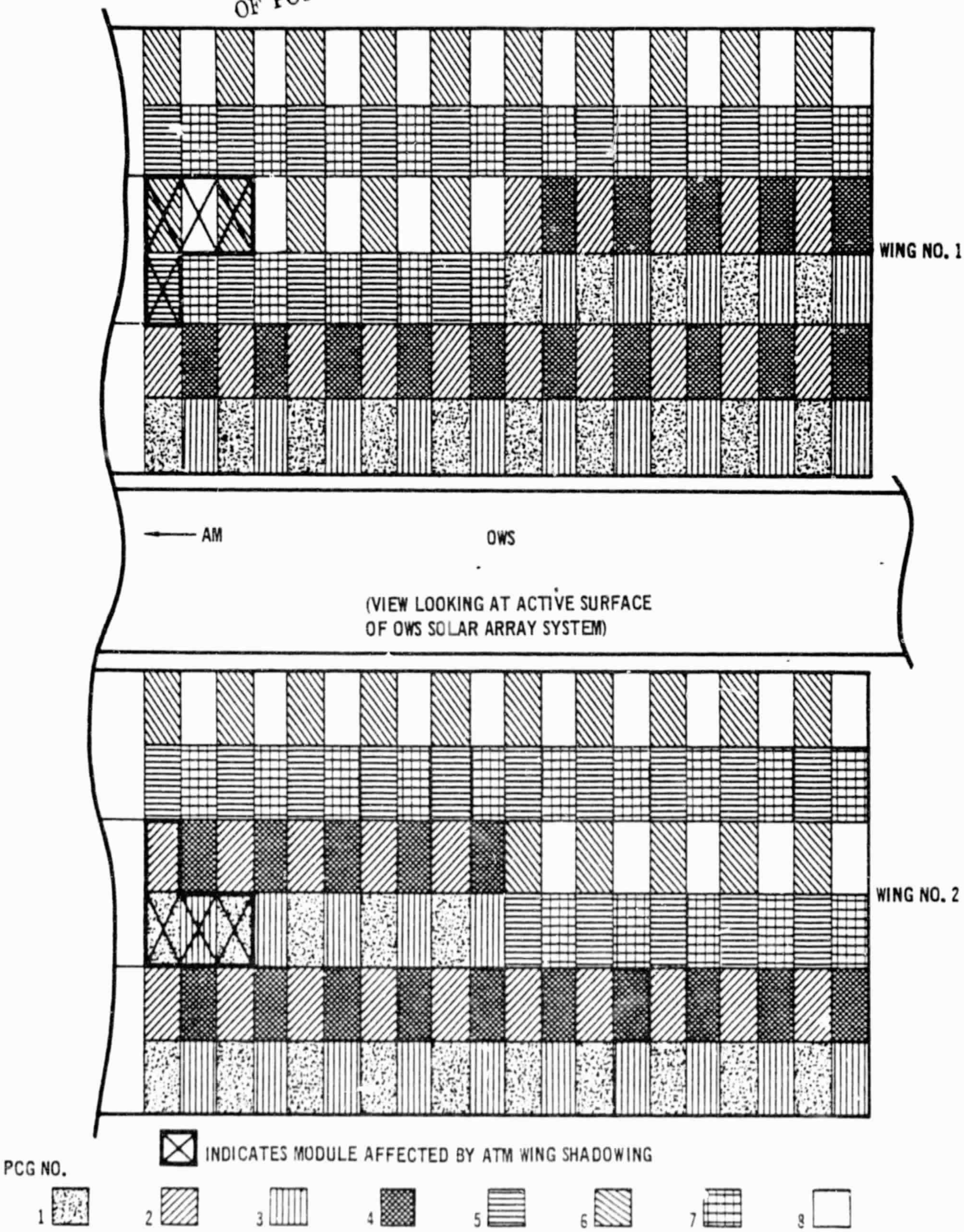


Figure D-11 , Module Layout - Solar Array Group

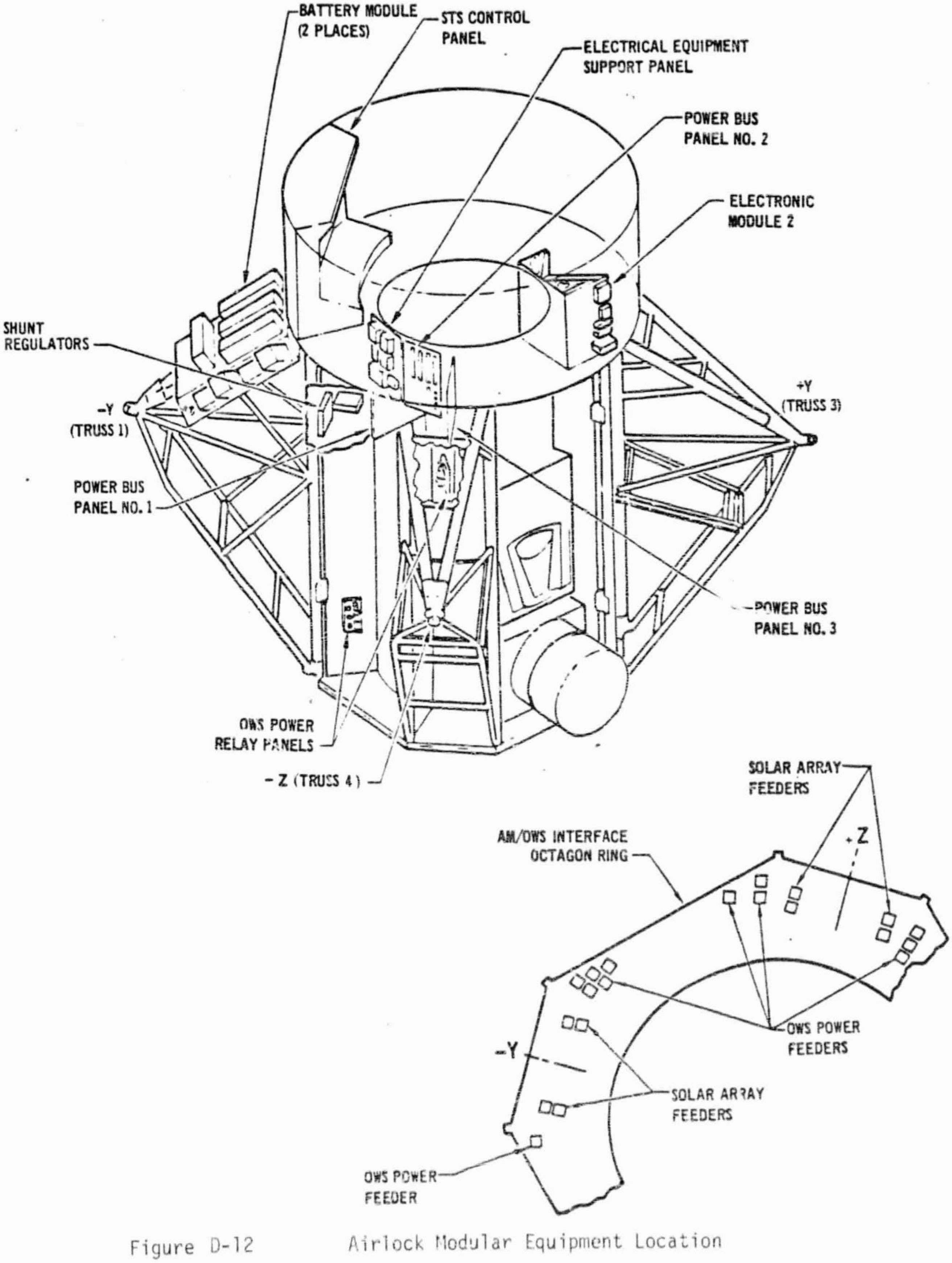


Figure D-12 Airlock Modular Equipment Location

Figure D-13. The shunt regulators were mounted on the -Y axis under truss No. 1 as shown in Figure D-12. The control panel assemblies were located in the Structural Transition Section and included the onboard controls, displays, and circuit breakers. The electrical power and distribution system included 188 relays, 90 switches, 110 circuit breakers, 166 status lights and miscellaneous other related equipment.

<u>Instrumentation System</u>

The Instrumentation System was assembled by utilizing existing Gemini Program designs where applicable and/or by modifying these and other designs to accommodate AM requirements. New designs were used only where available hardware did not satisfy needs.

The system consists of:

- Sensors/Signal Conditioners
- Regulated Power Converters
- PCM Multiplexers/Programmer/Interface Box
- Tape Recorder/Reproducers

This equipment was used to sense, condition, multiplex and encode vehicle systems, experiment and biomedical data for downlink to the Spaceflight Tracking and Data Network (STDN). Telemetry data was backed up by selected crew displays and by PCM hardline capability for prelaunch checkout. Real-time data was supplemented from onboard recordings played back for downlink in delayed time. A total of 1076 telemetry channels, 566 in the AM, 10 in the ATM, 416 in the OWS, and 84 in the MDA, were monitored by this system. Figure D-14 depicts the system in block diagram form.

System control was primarily ground command with crew backup. The Airlock Module Instrumentation System provided a portion of either sensing, multiplexing and encoding, or recording functions for the following total parameters from the AM, MDA, OWS, and ATM:

363 Temperatures
106 Pressures
15 Flows
536 Events
284 Voltages/Currents
117 Miscellaneous

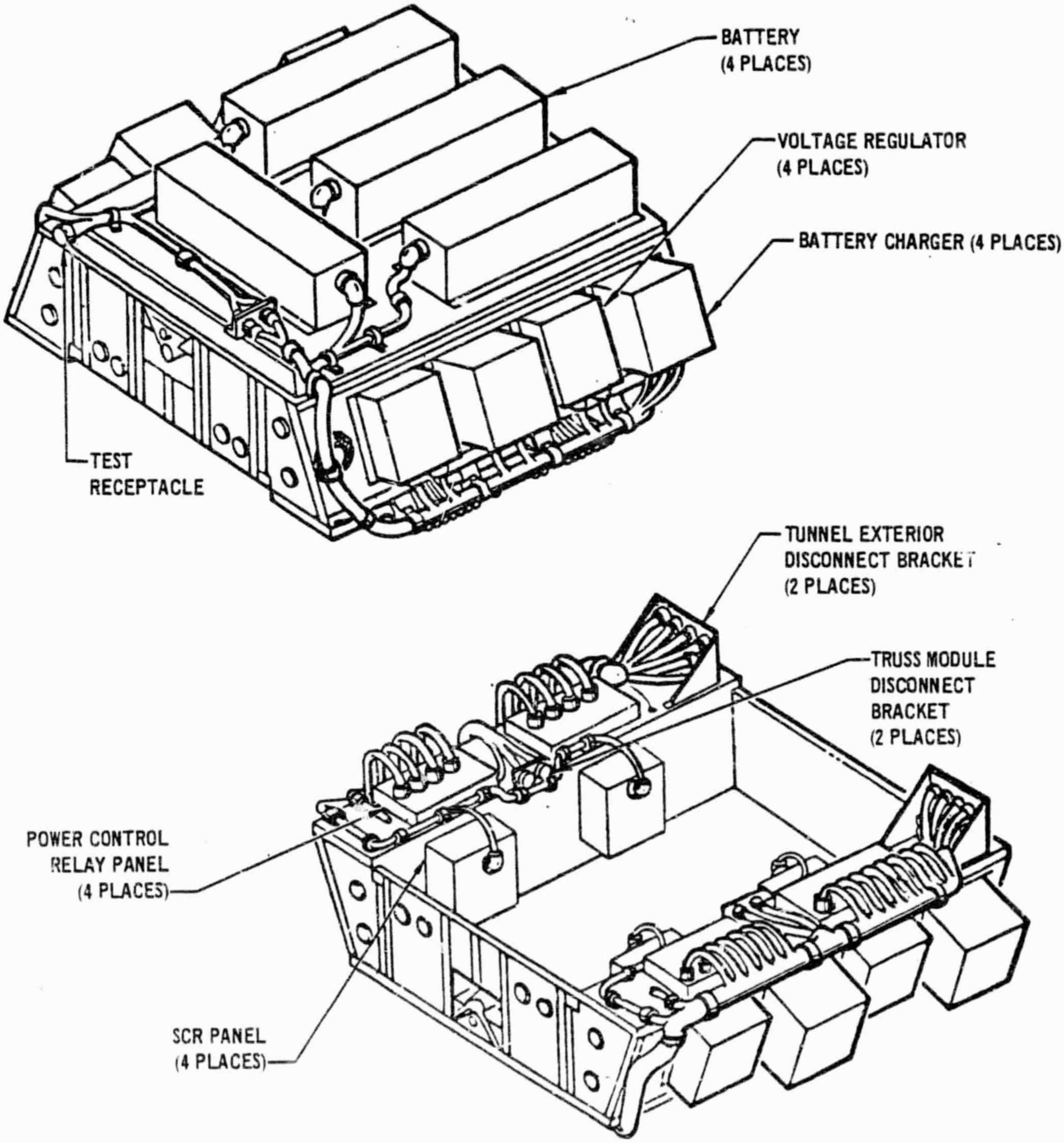


Figure D-13 PCG Component Location - Battery Module

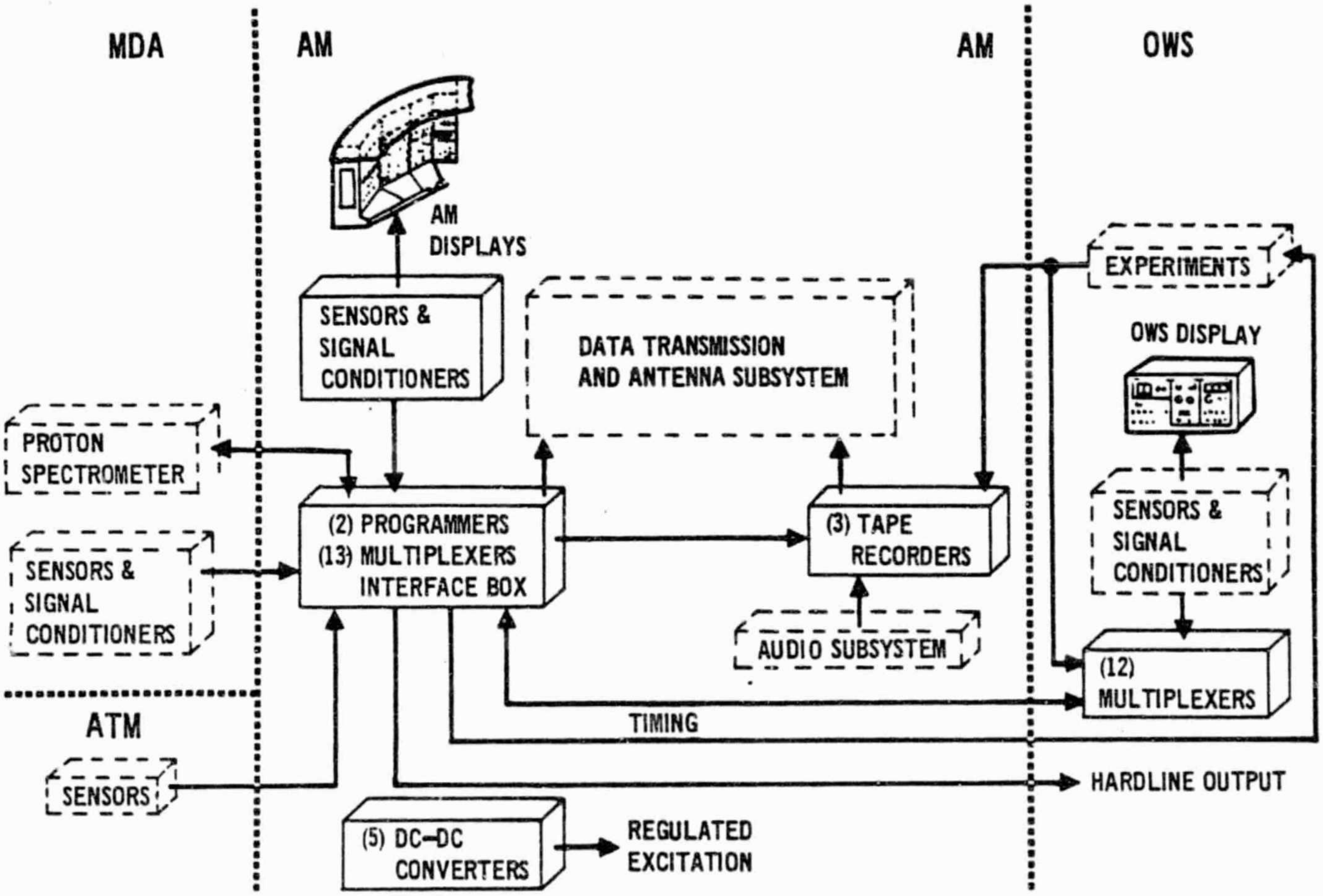


Figure D-14 Skylab Instrumentation System

The system design provided maximum data monitoring flexibility but maintained efficient operational ease for crew members as well as ground controllers.

Communications System

The equipment along with major interfaces are shown in block diagram form in Figure D-15. The system is divided into subsystems as follows:

o Audio - The Skylab audio subsystem (Figure D-16) provides voice communications to crewmen within the orbital assembly (OA) and/or while engaged in extravehicular activity. Further, it provides for air to ground duplex voice communications between the crewmen and the STDN.

o Data Transmission and Antenna (Figure D-17) - The data transmission subsystem provides RF transmission capability to the STDN for Skylab. The transmission system modulation consists of real-time PCM and delayed-time PCM. The antenna subsystem provides for reception and transmission of RF signals to and from the STDN. Figure D-18 is a block diagram showing the DCS, Teleprinter and TRS Subsystem interface relationship.

o Digital Command, Teleprinter, and Time Reference System - The DCS provides the STDN with real-time ground control of spacecraft switching functions. The tleprinter, in conjunction with the DCS, provides the capability for transmitting hard copy data from the ground to the crew. The Time Reference Subsystem (TRS) provides an elapsed time output for the Instrumentation System and a variable time delay control function for resetting command relays. A resettable timer is included to assist the crew with timekeeping functions.

o Rendezvous and Docking - The rendezvous and docking subsystems include a VHF ranging subsystem, tracking lights, and docking lights. The VHF ranging subsystem (see Figure D-19) consists of a VHF transceiver assembly and a ranging tone transfer assembly (RTTA). Four tracking lights, two primary and two secondary, are provided by the AM. Each light consists of a flash head and an electronics unit. The four flash heads are mounted on the AM Deployment Assembly, two on each side of the MDA, near the SWS Y-axis (Figure D-20), and the electronics units are mounted on Electronics Module #6. Four docking lights are mounted on the FAS and four are mounted on the MDA as shown in Figure D-21. The lights were color coded to aid the crew in orienting the CSM for final rendezvous and docking maneuvers. The discone

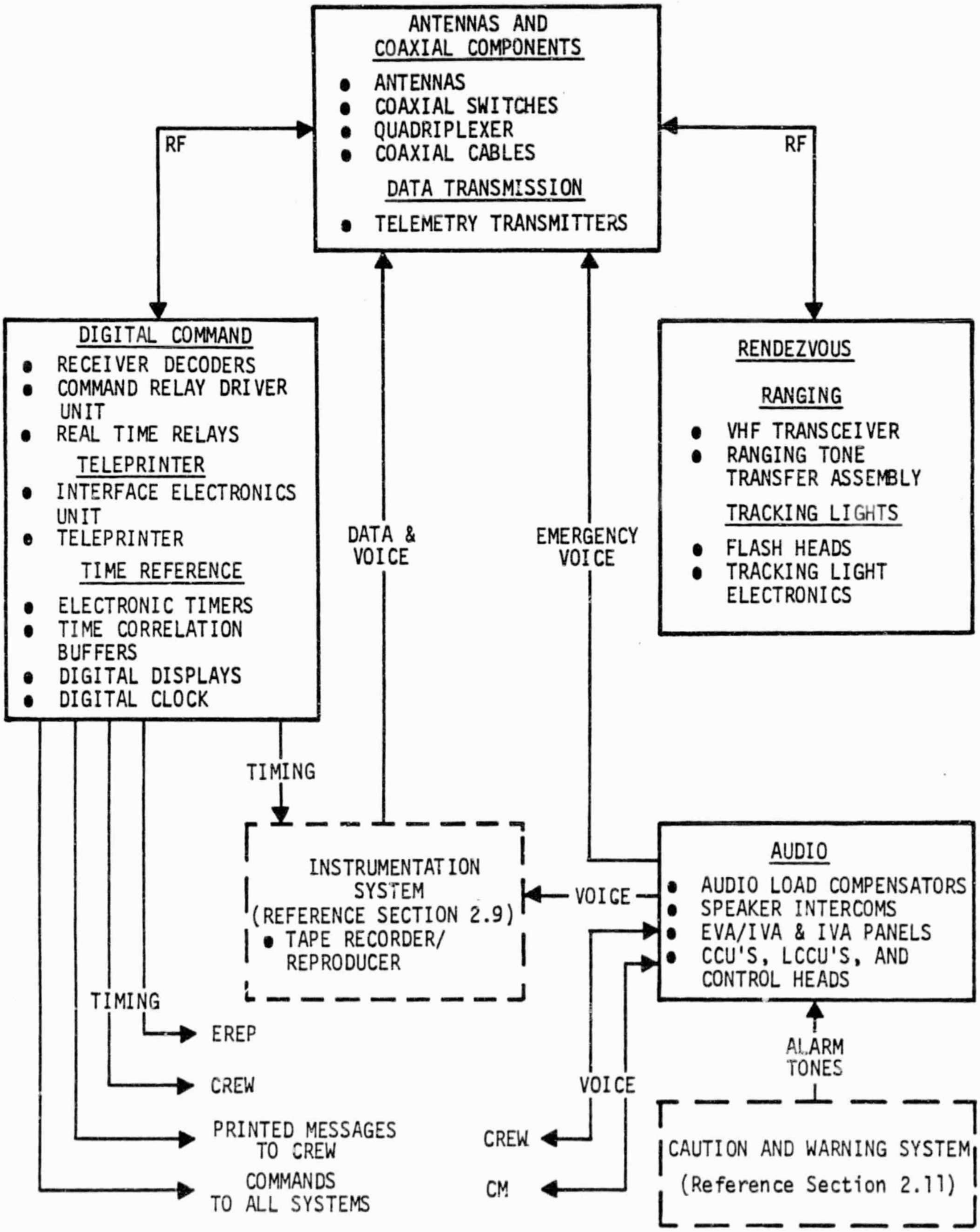


Figure D-15 Communications System

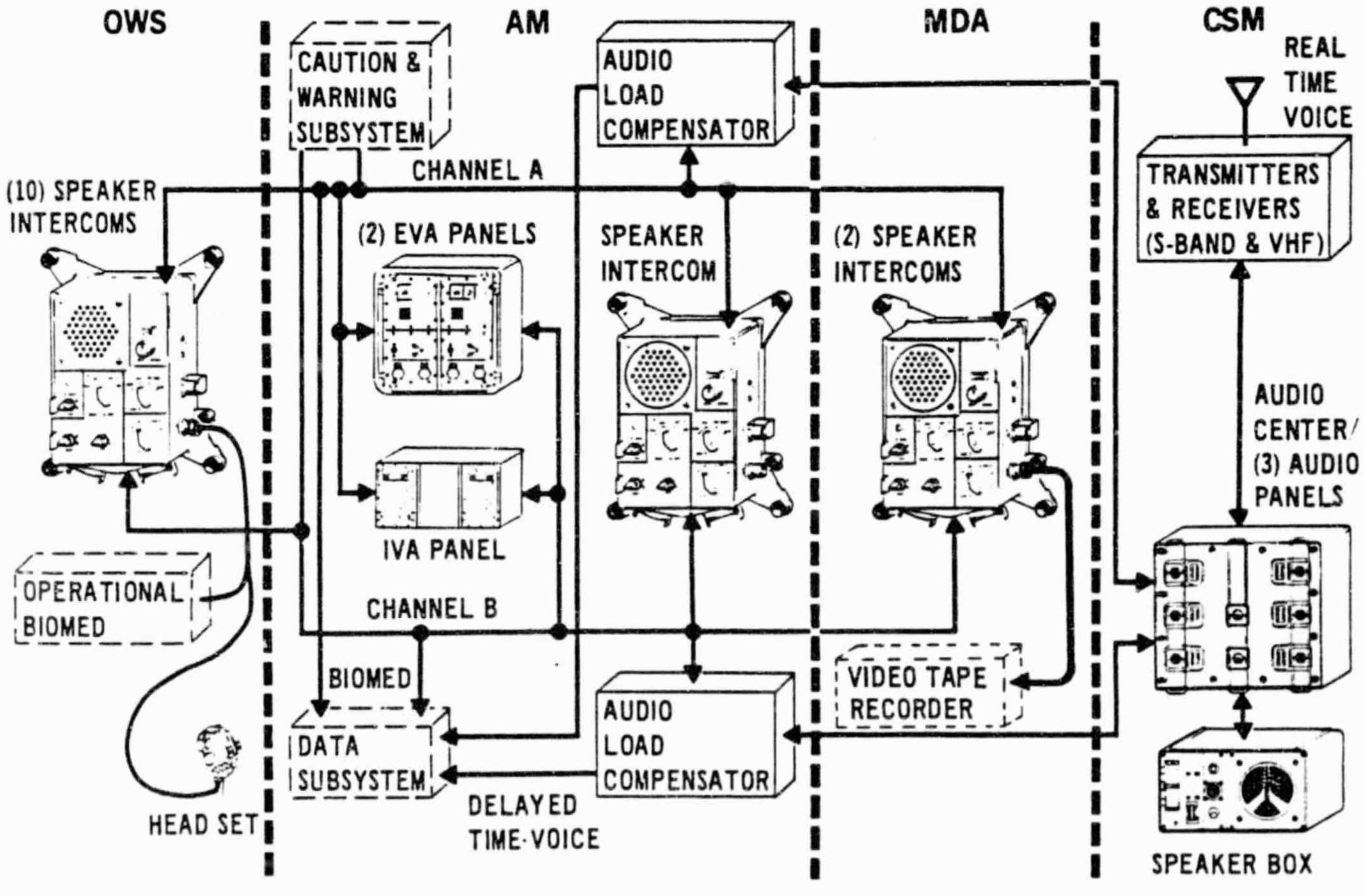


Figure D-16 Orbital Assembly Audio System

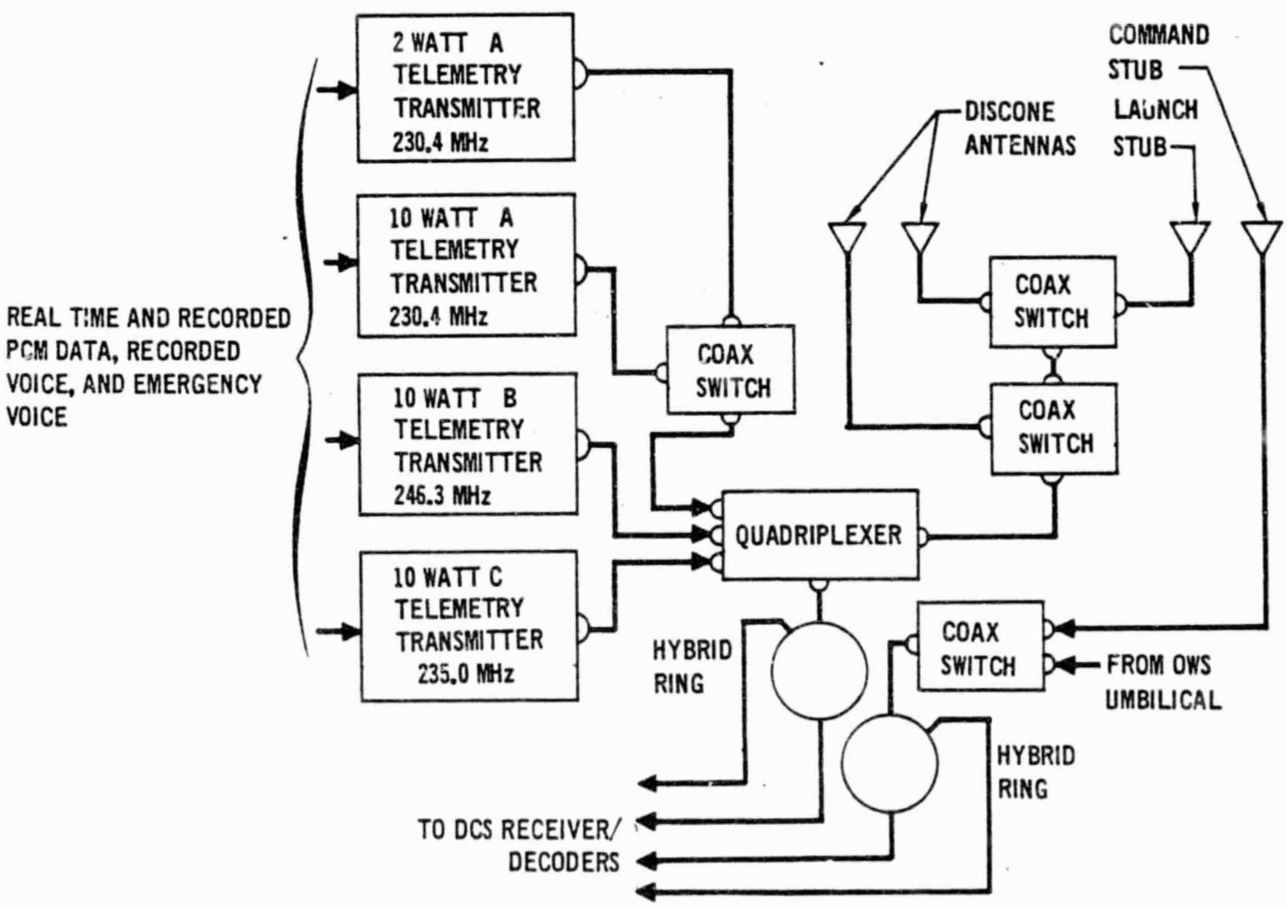


Figure D-17 Airlock Data Transmission and Antenna System

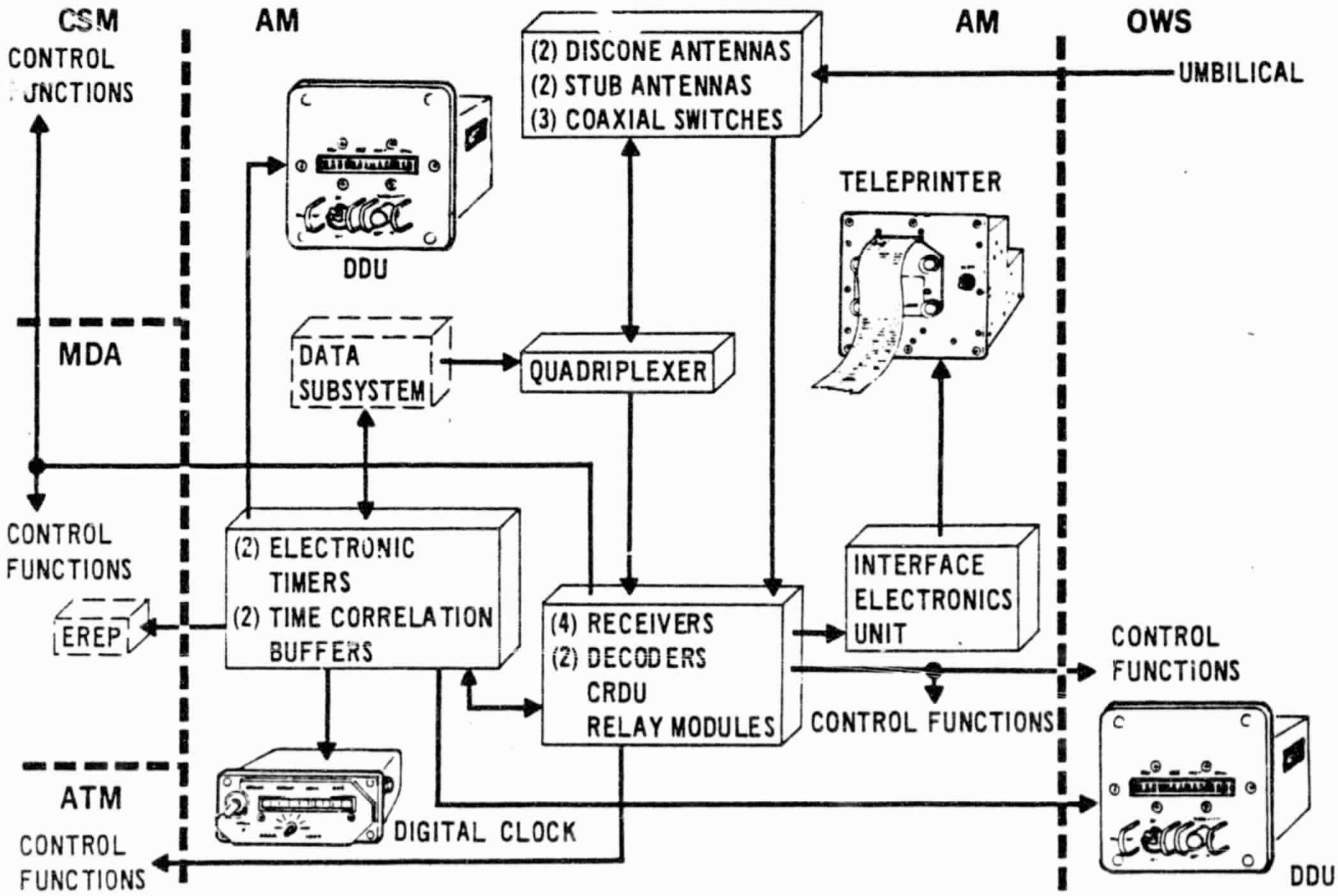


Figure D-18 DCS, Teleprinter, and TRS Subsystem

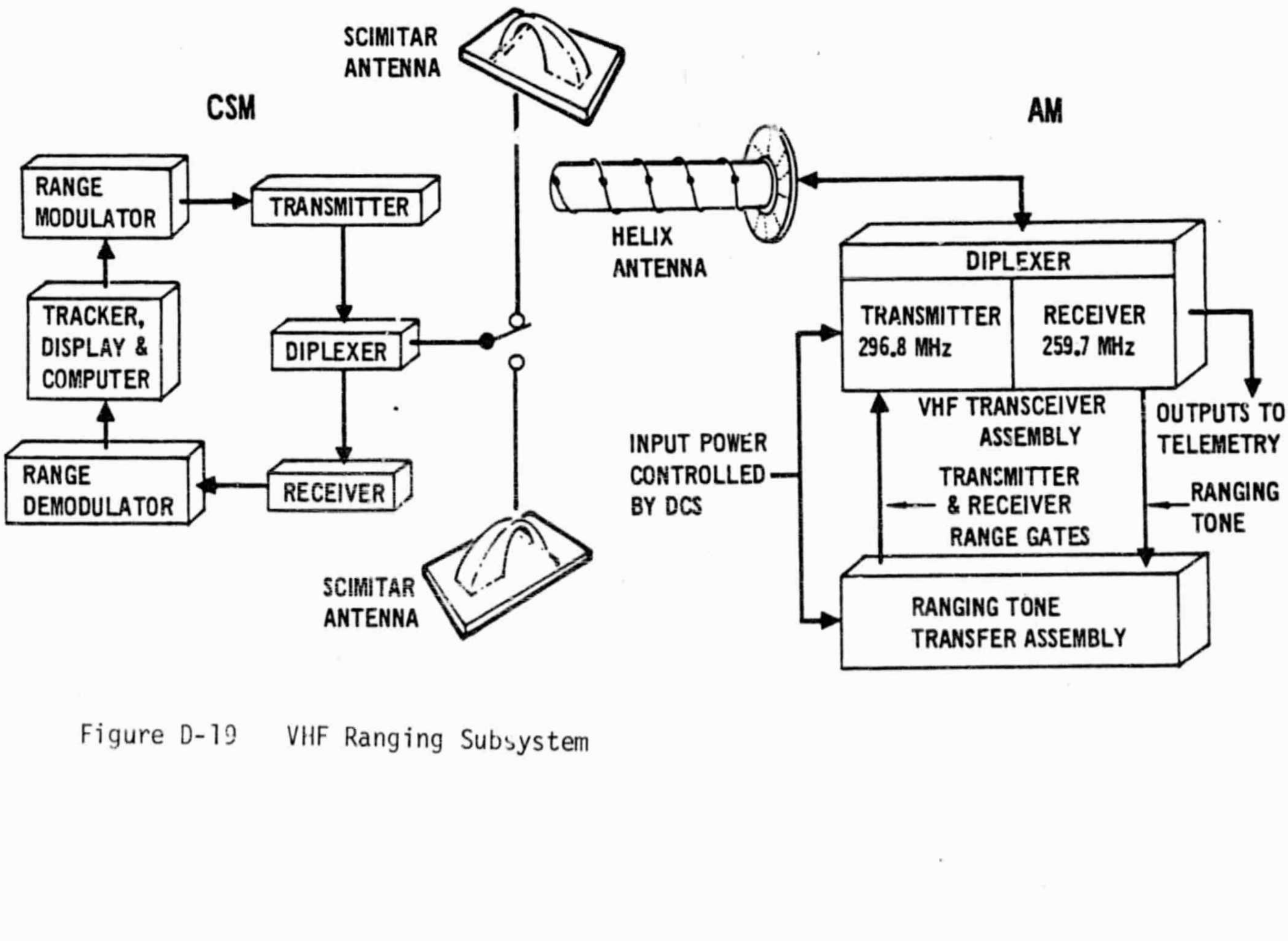


Figure D-19 VHF Ranging Subsystem

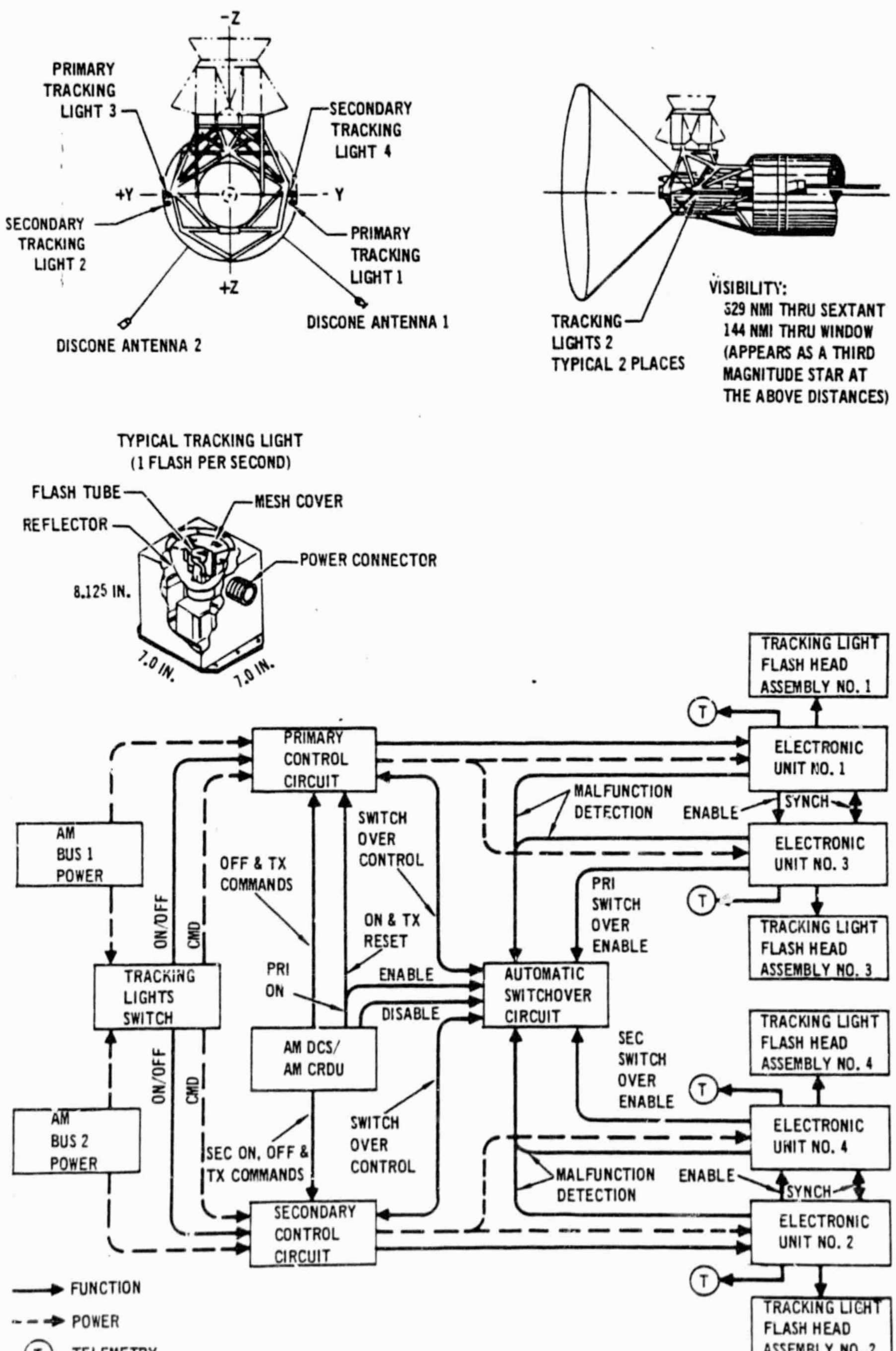


Figure D-20 Tracking Lights

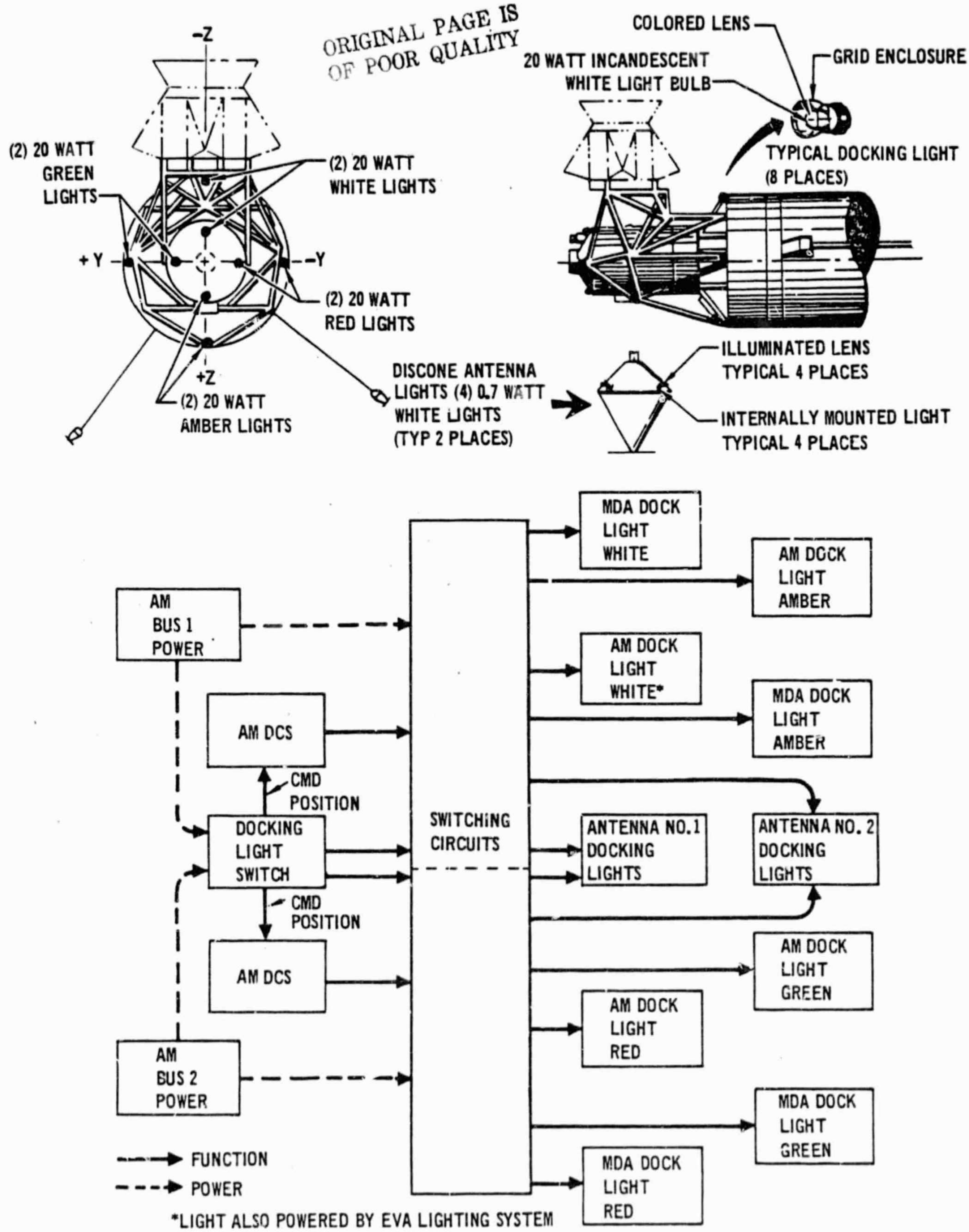


Figure D-21 Docking Lights

antenna has docking lights which act as visual locators for the crew during fly-around and docking maneuvers.

In addition to the above subsystems, a GFE-supplied television input station (RVIS) and radio noise burst monitor (RNBM) antenna were installed on the AM.

Caution and Warning System

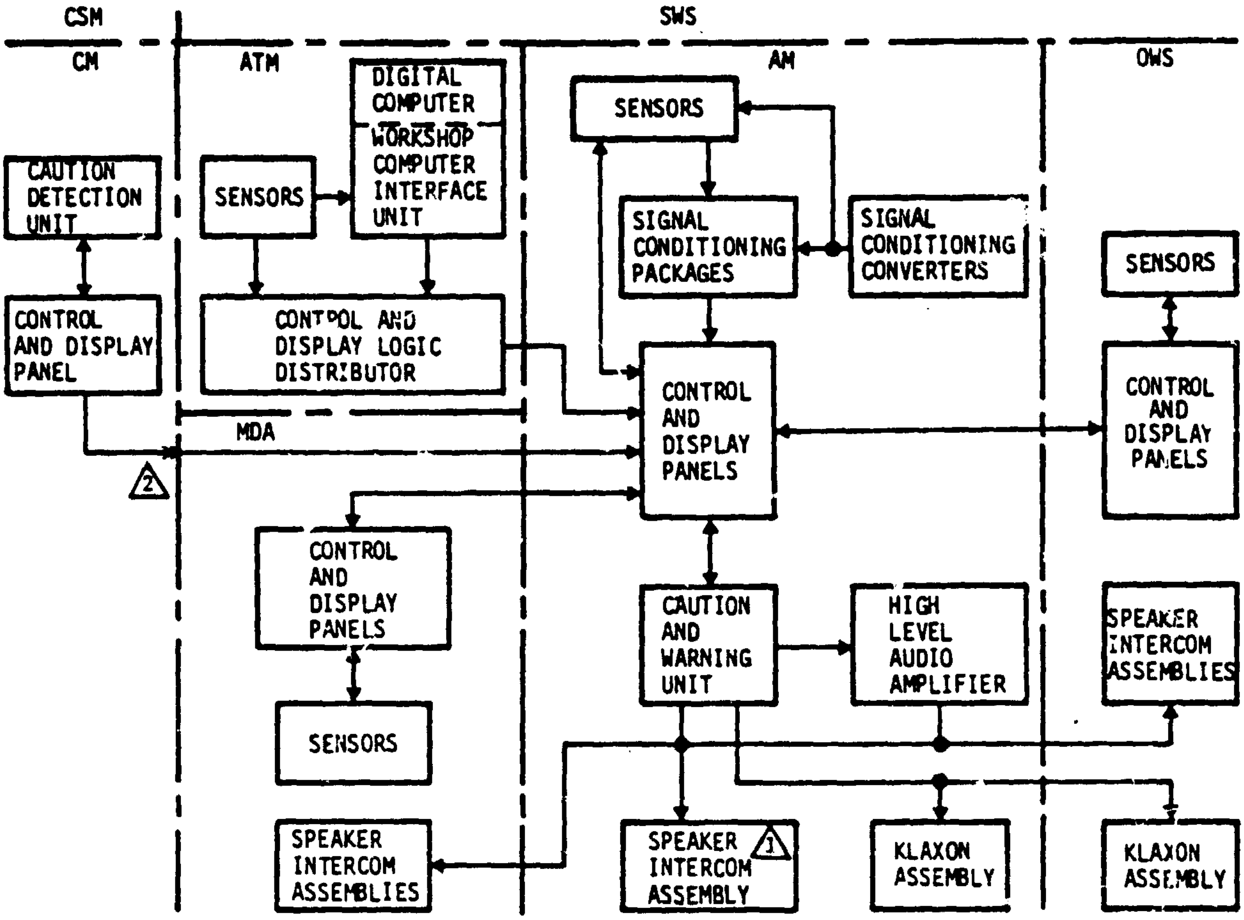
The C&W System provides the crew with visual displays and audio tones when selected parameters reach out-of-tolerance conditions. The equipment used to monitor these parameters is depicted in block diagram form in Figure D-22. The control and display panels are shown in Figure D-23. The system utilizes two independent subsystems, a caution and warning subsystem for monitoring various system parameters and an emergency subsystem for detecting fire or rapid loss of pressure.

Experiments and M509 Nitrogen Recharge Station

During the design, manufactur, test and orbital operations of the Skylab vehicle, the Airlock provided support to the Skylab experiments. Electrical power was provided to the experiments and the experiment data was recorded and transmitted to ground stations. MDAC-SL was responsible for installing four experiments outside the AM and for designing and installing an M509 RS inside the AM. Because all experiment hardware was Government Furnished Equipment (GFE), MDAC-SL was responsible only for mounting brackets, support hardware, electrical cables, crew interface, and the installation and total system tests with the integrated experiments. The four external experiments and the nitrogen recharge station locations are shown in Figure D-24. The experiments which are not described in this report are as follows:

- o Experiment S193, Microwave Radiometer/Scatterometer/Altimeter
- o Experiment D024, Thermal Control Coatings
- o Experiment S230, Magnetospheric Particle Composition
- o Radio Noise Burst Monitor (RNBM)

The function of the M509 RS was to recharge high pressure nitrogen bottles for M509 and T020 experiment operations. The high pressure gaseous nitrogen was used as a propellant for untethered flying of the astronaut maneuvering equipment (AME) in the orbital workshop. The M509 recharge station was comprised of a stowable rack for M509 bottle retention during fill and a



1. MOVED TO MDA DURING CLUSTER ACTIVATION
2. CSM DOCKED TO AXIAL PORT ONLY

Figure D-22 Cluster Caution and Warning System

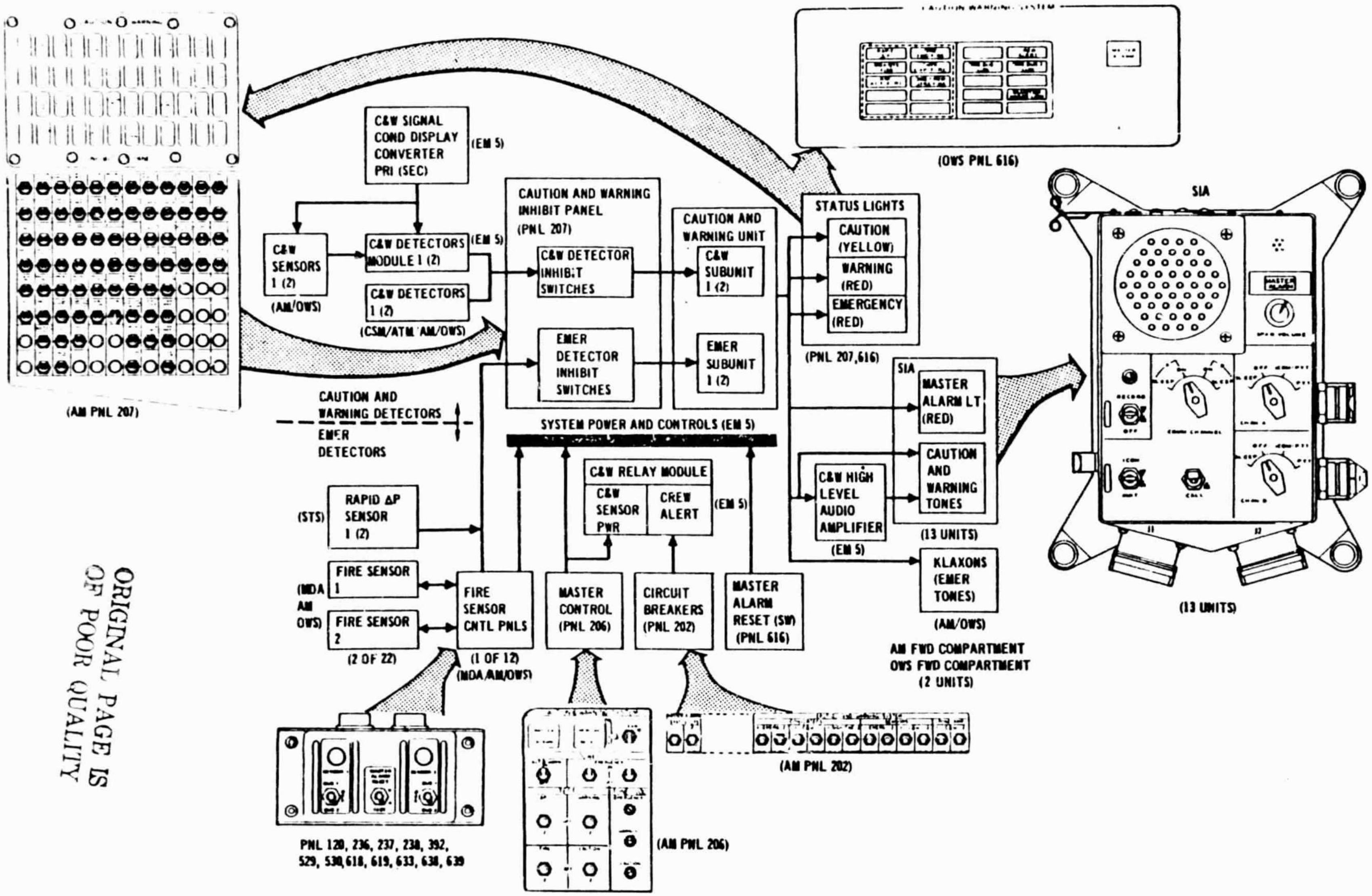


Figure D-23 Caution and Warning System Controls and Displays

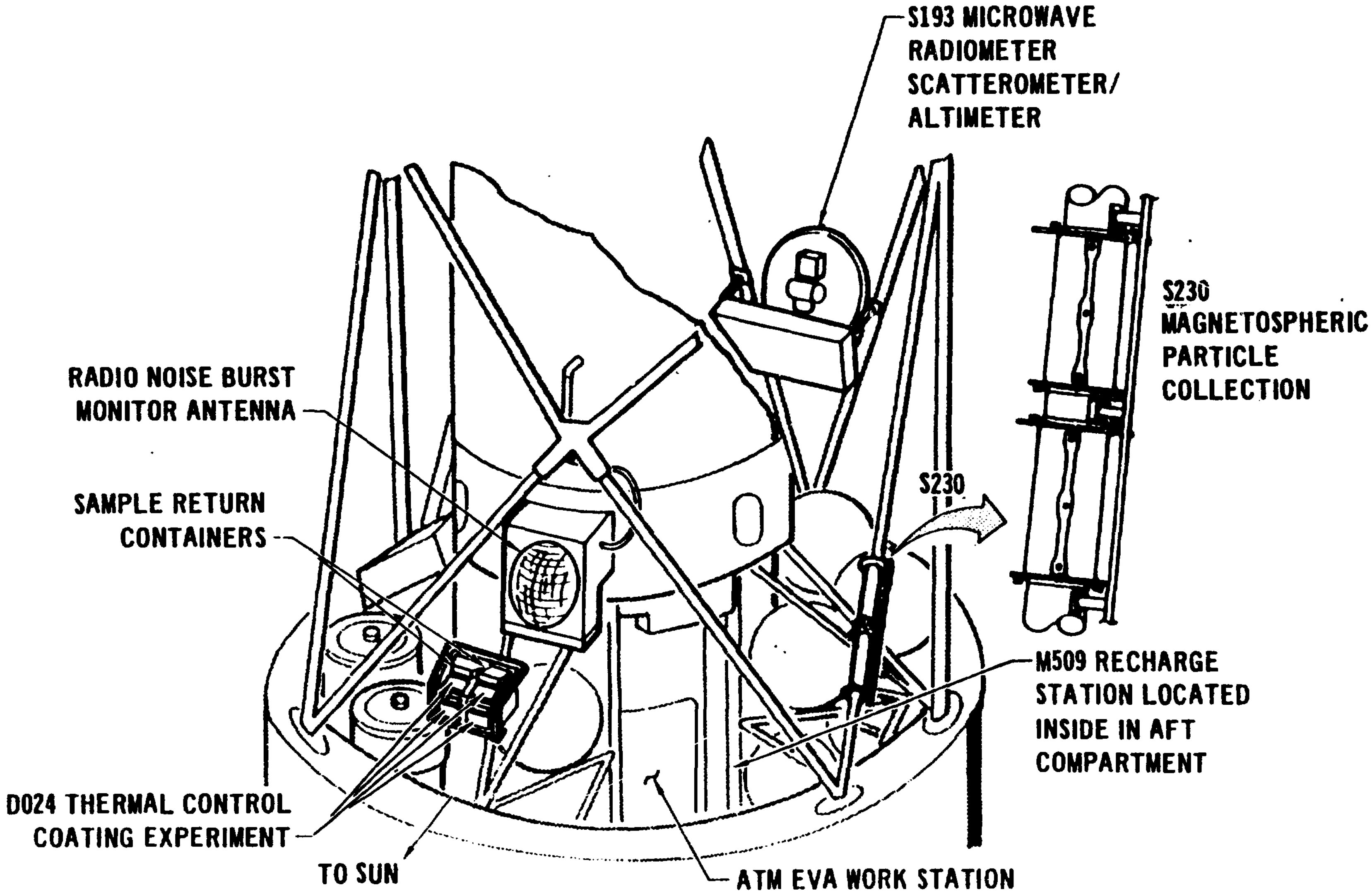


Figure D-24 Experiment Locations

control panel which provided supply valves, vent valves and a flex hose to deliver high pressure nitrogen. Figure D-25 is a photograph of the M509 recharge station in the Airlock Module aft compartment, showing the M509 bottle mounted in the recharge station rack; the bottle is approximately 14 inches in diameter including outer cover.

In use, the rack was erected, the M509 bottle clamped in place and the flex hose OD attached to the M509 bottle fill port. Control valves on M509 Recharge Station provided isolation capability for two of the six Airlock nitrogen supply tanks for bottle top-off. After filling, the flex hose was vented, decoupled, and stowed. The M509 bottle was then removed from the rack and the rack stowed. Rack stowage capability allowed easy crew passage through the aft compartment.

The valves and manifolds shown on M509 Recharge Station (Figure D-25) allowed choice of Airlock nitrogen supply tanks for M509 refill such that a high pressure nitrogen supply was available through the entire Skylab mission. Initial fills were taken from the four ECS nitrogen supply tanks with bottle top-off supplied by the two isolated tanks.

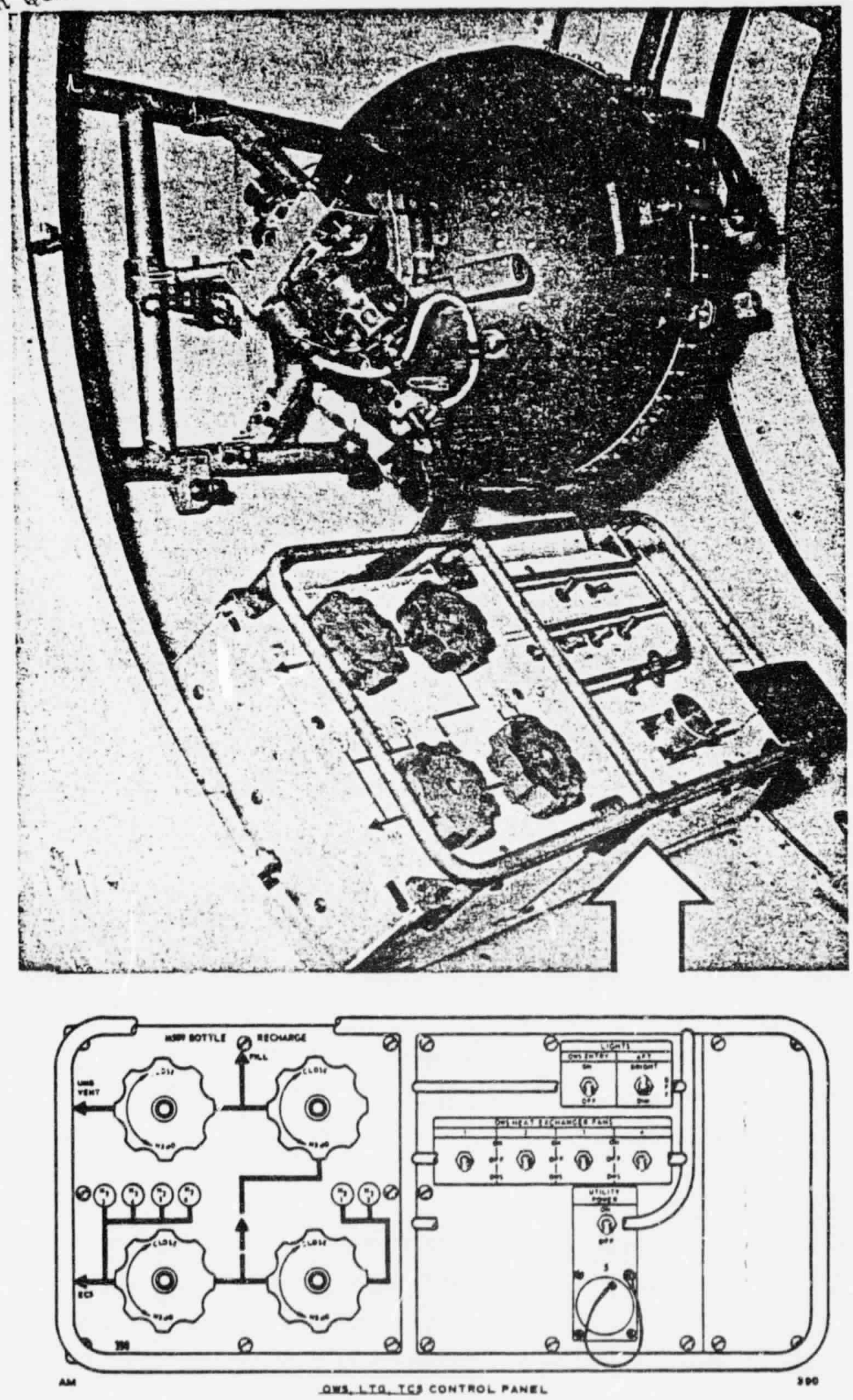


Figure D-25 M509 Recharge Station and Hold-Down Bracket

Mission Performance

The successful Airlock system performance during the Skylab Program and subsequent interrogations indicates the effectiveness of the MDAC-SL design, fabrication, and test activities that preceded the flight mission. It also indicates the effectiveness of the mission support activity in responding to discrepant conditions and providing real-time work around plans.

The major conclusion that can be drawn from a program point of view is that the Airlock program philosophy of maximum use of existing, qualified space hardware with extensive use of system engineering analysis and previous test results to identify the minimum supplemental test program required to somplete system verification was proven as a valid, economical approach to a successful mission.

The most important lesson learned, from its impact on future space system planning, is the demonstrated capability of the crewman to function as a major link in the system operation. He demonstrated the capability to function effectively in zero-g for long periods of time and to perform, with proper constraints, tools, and procedures. Additionally, the ability of the crew to perform contingency EVAs and to accomplish difficult repair/maintenance activities will be a significant input to all future manned space programs.

Structural/Mechanical

The structural integrity of the vehicle was maintained throughout the mission and mechanical systems functioned without failure. No special tests were required or conducted to support the mission. The launch loads on all the AM structural components were well within the design tolerances. Gas leakage for the entire cluster, with leakage rates well within their requirements, indicated that all the pressure vessels and joints were in excellent condition. Adequate structural support of the O_2 and N_2 bottles was also demonstrated.

Thermal Control System

The Airlock Module TCS satisfactorily performed all required functions relating to active/passive thermal control structure, systems, and equipment. The active coolant system provided cooling for interfacing systems (gas system O_2 heat exchanger, atmospheric control system heat exchangers, ATM C&D Panel/ EREP cooling system heat exchanger, and suit cooling systems heat exchangers) and temperature control for coldplate mounted electrical/electronic equipment. Radiator/thermal capacitor rejection of heat from the active cooling system was normal throughout all phases of the mission. Flow of temperature controlled water to the MDA via the ATM C&D Panel/EREP cooling system permitted normal temperature control of associated equipment. Active heating of Airlock module walls, mole sieve exhaust ducts, and condensate system overboard vents was provided as required by electrical heaters. The overall vehicle thermal balance resulted in acceptable temperatures on passively controlled structure and components.

Environment Control System

The Airlock Module ECS satisfactorily performed all required functions throughout the Skylab mission, i.e., functions relating to prelaunch purge, ascent venting, gas supply and distribution, atmospheric control, and condensate removal plus some additional functions.

In addition to performing all of the required functions, the system provided more cooling than the maximum planned to assist cooldown of the workshop crew quarters. No mid-mission molecular sieve bakeouts were required during the entire flight and none were performed during the 84-day SL-4 mission.

EVA/IVA Suit System

Airlock Module systems provided support for 12 EVA/IVA operations ranging up to a record duration of seven hours. Oxygen flow to suited crewmen was completely normal on each occasion and was utilized for cooling of the crewmen during the final EVA on SL-3 due to shutdown of the primary coolant loop. Satisfactory water cooling was supplied for all other EVA operations with up to three crewmen on one suit cooling system. Operation of the lock compartment was accomplished normally although depressurization rates were decreased as ice formed from moisture in the gas collected on the protective screen over the depress valve vent port.

Oxygen was supplied to the LSU at normal pressures and temperatures during all suited operations. Regulated O_2 pressures during these periods ranged between 122 and 127 psia while O_2 temperatures were normally controlled between 50 and and 60°F by the heat exchanger interfacing with AM coolant loops. No problems were identified with the EVA/IVA O_2 supply system.

Suit cooling systems were successfully activated on 29 separate occasions and performed in a normal manner at all times. Of this total, 11 operations were in direct support of EVA/IVA, two were to provide heat into the secondary coolant loop following a temperature control valve discrepancy, and the remainder were for normal systems checkout. Water flow rates of 225 to 296 lb/hr were obtained with SUS 1 while SUS 2 provided flow rates between 265 and 300 lb/hr depending on system configuration.

LSU/PCUs were successfully deserviced on SL-3 just prior to the DOY 265 EVA to prevent the possibility of localized freezing. Required components were again serviced prior to the first EVA on SL-4. Following loss of water in the SUS 1 reservoir the SUS 1 loop and an alternate LSU/PCU were serviced. Servicing of SUS 1 after some leakage was not required since additional system usage was not planned. No problems were encountered during any of the servicing/deservicing operations.

The Airlock Module lock and aft compartments were successfully depressurized and repressurized during the performance of EVA on nine occasions. A typical vent and pressurization profile is shown in Figure D-26 The only discrepancy reported involved the formation of ice from moisture in the lock compartment atmosphere on the screen over the depress valve opening during venting. Reports indicate that SL-2 crewmen removed ice from the screen to speed up the venting process. A second removable screen was supplied on SL-3 which permitted ready removal of the ice buildup on the second screen when pressure dropped below one psia thereby exposing the clean original screen for completion of venting. No further difficulties were encountered after use of the second screen was initiated.

Electrical Power System

The Airlock Module electrical power system performed all of its required functions and operations during the Skylab mission. Because of the mechanical problems encountered with the deployment of the OWS solar array wings, evaluation of the AM EPS performance was separated into two time periods. The first period consisted of the time frame from SL-1 luanch through DOY 159. During this period the AM EPS operated to utilize essentially all of the available

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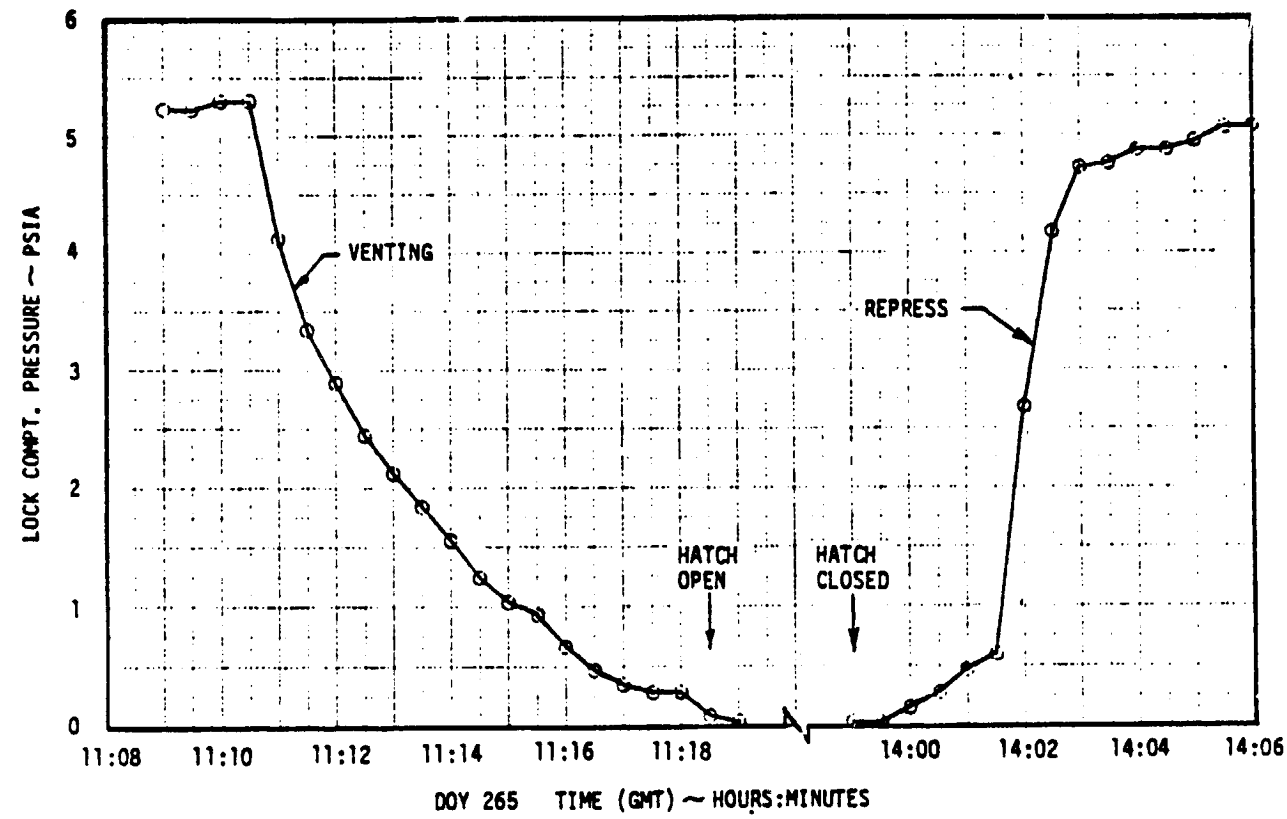

Figure D-26 Typical EVA Vent and Pressurization Profile solar power, even though signficant mission support was not possible until wing deployment. The second period started with the successful deployment of OWS solar array wing #1 on DOY 159 and continued through the end of the Skylab mission. The AM EPS was fully operational during this second time period and provided an average of 46% of the total cluster power required despite and absence of one-half of the expected OWS solar array power.

1. SL-1 Launch Through OWS SAS Deployment - OWS Solar Array Wing #2 was completely lost during the SL-1 launch. Solar Array Wing #1, which was only partially deployed, could not supply sufficient power to the EPS during this period to allow the EPS to supply any significant amount of power to the cluster load buses. The available solar array power was used, however, to charge some of the batteries at low charge rates until they reached 100% SOC. At all times, the stored energy of the AM batteries was available to supplement the ATM source when and if required. Other EPS equipments, such as battery chargers and voltage regulators, also operated under abnormal conditions during this period. All EPS equipments operated acceptably under the abnormal conditions they encountered and subsequently exhibited normal performance characteristics when higher input power levels were achieved. The flexibilities of the AM EPS control and distribution syst-m were used extensively during this period to manage the AM EPS in the most optimum manner.
2. OWS SAS Deployment Through End of SL-2 - AM EPS activation took place on DOY 159 with the full deployment of all three wing sections of Solar Array Wing #1 at 0020 GMT. All AM batteries were fully charged after only a few orbits and the system was returned to stabilized cyclic operation by DOY 160. The AM EPS performed up to expectations throughout the remainder of the Skylab missions without problems.

Instrumentation System

The Saturn Workshop Instrumentation System was activated during the SL-1 launch countdown and continued successful operation during all the remaining mission phases. A total of 6507 hours of operation was accumulated. All functions required of this system were accomplished. The functional success was marred by the failure or suspected failure of 19 instrumentation hardware items. This resulted in discrepant readings on approximately 8% of the telemetry measurements. Less than 14% of these were outright failures, the remainder were operational with minor off-nominal indications. The redundant PCM multiplexer/encoder and DC-DC converter hardware was first activated during the third mission in an attempt to clear a low level channel noise problem. Planned consumable replacement items were utilized as scheduled except for the two tape recorders which failed during the first mission due to ruptured motor drive belts. The STU/STDN and the U-2 Airlock Module were used throughout the flight for special testing and resolution of mission problems. Assuming a 30% STDN coverage, over 50 billion bits of data were sensed and encoded by this system during the three missions. This data was transmitted in both real and delayed time to the STDN by the data transmission subsystem.

Although premission planning called for an expenditure of 4327 hours of AM tape recorder operation, the nine recorders (seven original and two spares flown up on SL-3) operated for a total of 6925 flight hours. Besides the hours remaining on the three recorders operating at power down, an undefined additional capability remains in the two recorders (S/N 30 and S/N 23) that were replaced while still operating and in the recorder (S/N 28) repaired by the SL-3 crew. Two other recorders (S/N 13 and S/N 22) were repairable using the tape recorder repair kit flown up on SL-4. The average recorder flight time was 769.4 hours and the average life was greater than 1101.4 hours per recorder. What the actual life might have been cannot be determined; however, it should be noted that six of the nine recorders were operable at power down. Tables D-1, D-2, and D-3 provide a summary on instrumentation discrepancies for each of the Skylab missions.

Communication System

The Skylab audio subsystem successfully provided intercommunications, air to ground communications and voice tape recording functions throughout SL-2, 3 and 4 missions. There were instances in which the subsystem incurred a definite malfunction. All but one of these malfunctions were corrected or compensated for during flight by inflight replacement of failed components or by reconfiguration of the audio subsystem. The last audio system problem, which could not be completely corrected did not significantly degrade performance, and was partially compensated for by workaround procedures.

Table D-1

INSTRUMENTATION SYSTEM SUMMARY - FIRST MISSION

DOY	DISCREPANCY	CAUSE	MISSION EFFECT	CORRECTIVE ACTION
134	M112, M161, M162, M163 provided lower than expected values.	Meteoroid shield/solar wing problem	Nuisance.	Data was usable thru addition of correction factor
139 140	Unprogrammed automatic switchover of coolant loops (PRI to SEC) (K234).	Unknown. Assumed to be sensor(s) failure.	None. Redundant circuit available.	Redundant circuit, or RF command control used (See Sect. 2.4)
148	Mole Sieve B, $PPCO_2$ inlet - D213/tape recorder interaction.	+24V bus depression caused by recorder mode switching.	Nuisance. Disturbance lasts approx. 2 minutes.	$PPCO_2$ data ignored during tape recorder mode switching.
158	Primary coolant flow-rate measurement (F214) failed.	Unknown. Assumed to be contamination in sensor.	Minor. Alternate data available.	Flow data inferred from temp. and pressure data.
159	Tape recorder, S/N 13, Pos. 1 failed to playback recorded data.	Broken motor drive belt.	Loss of 3 hours max. of recorded data.	Crew replacement from on-board spares - S/N 22.
173	Tape recorder, S/N 22, Pos. 1 ceased operation.	Broken motor drive belt.	Loss of 3 hours max. of recorded data.	Failure occurred during unmanned period - alternate recorder selected by RF command. Recorder replaced by second crew on DOY 212, (S/N 32).

Table D-2

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INSTRUMENTATION SYSTEM SUMMARY - SECOND MISSION

DOY	DISCREPANCY	CAUSE	MISSION EFFECT	CORRECTIVE ACTION
212	Mole Sieve B, $PPCO_2$ inlet, (D213) provided erratic data after scheduled cartridge replacement.	Assumed to result from unseated O-ring in sensor detector block.	None - Alternate data source from experiment.	$PPCO_2$ O-ring repair kit designed for SL-4 mission.
212	$PPCO_2$ sensor would not lock into place - data is acceptable.	Assumed to be bent index springs in interface connector.	None - Lock position required for launch only.	None - lock position has no effect on data.
215	Low-level Multiplexer B in OWS ceased operation, subsequent operation has been on an intermittent basis.	Unknown. Problem cannot be duplicated; temperature is suspected.	Loss of Eng. evaluation data - no mission critical measurements monitored by this multiplexer.	Alternate measurements used for evaluation.
232	+X QCM contamination monitor fine output (M016) became erratic & went below scale.	Unknown. Assumed to be signal conditioner.	None - Coarse output (M015) from QCM was operative.	None - Coarse data used for contamination measurement.
251	AM transfer duct flowrate (F205) provided gradually decreasing output.	Unknown. Cleaning of associated heat exchangers did not correct problem.	Loss of Eng. evaluation data.	Other measurements used for system status assessment.
256	Tape recorder S/N 28, Pos. 3 had numerous bit errors and loss of sync.	Troubleshooting established tape path was incorrect.	Loss of 3 hours max. of recorded data.	Crew replacement from on-board spares (S/N 23). Crew repaired S/N 28 for spare pending retest.
295	MDA external CM docking port temp. measurement (C0052) exhibited intermittent operation.	Unknown.	None - Not mission critical.	Adjacent temp. measurements used for Eng. evaluation.
310	-X QCM contamination monitor (M018) & +X QCM contamination monitor (M015) provided full-scale readings.	Unknown. Assumed to result from contamination buildup.	Loss of cue for optical surface clean-up.	Past history data used for same purpose.

Table D-3

INSTRUMENTATION SYSTEM SUMMARY - THIRD MISSION

DOY	DISCREPANCY	CAUSE	MISSION EFFECT	CORRECTIVE ACTION
320	Tape recorder S/N 32, Pos. 1 motion monitor (K508) became erratic.	Unknown	None - Does not affect record/playback process.	None
326	Pri. coolant control valve A outlet flowrate (F212) failed.	Unknown - Assumed to result from contamination in sensor.	None - Not a mission critical measurement.	Temp. and pressure data used to infer flowrates.
349	Excessive noise on first 8 channels of AM low-level multiplexer P	Analytically determined to result from change in turn-on characteristics of second tier switch in multiplexer.	None - No mission critical measurements monitored by this multiplexer.	Visual inspection of strip charts was used to provide usable data.
357 359	Excessive noise on first 8 channels of all AM low-level multiplexers and first 9 channels of programmer (52 measurements total).	Unknown - Suspected to be voltage propagated on the 3MV (15%) reference line connected to the affected equip.	None - Data from all of the multiplexers except "P" recoverable by strip charting.	None
019	Tape Recorder S/N 32 (Pos. 1) Failed to dump data completely.	Unknown - tape recorder had operated for 1450 hours.	Loss of 1.5 hours of recorded data.	Replaced by on-board spare S/N 21.
011 014	OWS High Level Multiplexer "J" exhibited erroneous data output during EREP maneuvers.	Unknown - suspected to be due to high temperature.	None - data can be extrapolated.	None.

An additional problem which occurred but had been preflight identified as a potential problem was acoustical feedback occurring during operation from certain SIA locations. This feedback did not hinder communications; however, it did cause minor aggravation to the crews. This feedback problem was alleviated with the use of the anti-feedback communication network which was fabricated for the SL-4 mission.

The data transmission subsystem successfully provided real-time PCM, delayed-time PCM, and recorded voice transmissions throughout the period from SL-1 launch to SL-4 deactivation. The "A" 2-watt transmitter provided real-time telemetry transmissions from prelaunch through orbital insertion. The "A" 10-watt, "B" and "C" transmitters provided real-time PCM, delayed-PCM and recorded voice transmissions successfully throughout the Skylab orbital missions with the exception that the "A" 10-watt transmitter developed a malfunction after 29 days of operation. The loss of the "A" 10-watt transmitter did not reduce the amount of data transmission capability as the "A" 2-watt transmitter was reactivated and provided backup capability.

The antenna subsystem successfully provided the necessary spherical antenna coverage which enabled reception and transmission of RF signals to and from the STDN throughout the orbital phases of the mission. Antenna requirements were satisfied during the launch phase of the mission via the launch and command stubs. Antenna requirements during the orbital phase of the mission were satisfied via the discone antenna and command stub with occasional usage of the launch stub. The quadriplexer successfully provided isolation between the transmitters and command receivers and coupling between these units and the selected antenna. The three operational coaxial switches provided satisfactory operation throughout the entire mission. The discone antenna coaxial switch was operated approximately 18,000 times to optimize antenna coverage. The only malfunction that occurred within the antenna subsystem resulted when the 2-watt/10-watt coaxial switch microswitch instrumentation monitor circuitry ceased indicating the change from the "A" 2-watt transmitter to the "A" 10-watt transmitter. This malfunction did not affect the RF switching capability of the device and only the indicator circuitry became inoperative.

The DCS performance during the Skylab mission was considered successful with only one incident reported of the failure to execute a command message.

The teleprinter subsystem performed its intended function satisfactorily throughout the Skylab mission, with the three noted exceptions, providing the crews with retainable, hard copy messages. The high usage of the teleprinter for sending hard copy updates of flight plans, crew procedures, etc., verified the desirability of such a device on manned space missions.

The TRS met all design goals during the Skylab missions. The system was operational throughout the mission and satisfactorily provided a time base for the Instrumentation System, crew displays and EREP. In addition, all variable time delay control functions operated nominally.

The VHF ranging subsystem performed normally during the Skylab mission indicating that hardware developed for other space programs can be applied to later programs with good results. The tracking lights performed normally during this Skylab program without the utilization of backup hardware.

Caution and Warning System

The C&W System operated nominally throughout the Skylab mission and performed all required mission functions. The system successfully monitored all 76 parameters and satisfactorily detected out-of-tolerance conditions. The system was operational for a total of 4011 hours. During this time, the system activated approximately 220 times. Out of the 76 parameters monitored, the only false alarms which activated the C&W System were associated with the fire sensor assemblies. These false fire alarms were attributed to high temperature, high radiation levels and sunlight. The gas flow, $PPCO_2$ amd CMG Sat parameters activated the C&W System asn excessive number of times. The ATM CMG Sat parameter activated frequently during periods of high crew activity and/or ATM rate gyro failures while the $PPCO_2$ and gas flow alarms resulted from marginal sensing techniques utilized.

During the Skylab mission, two C&W System-related component failures occurred. They were:

FSCP - During the SL-2 mission, one component failure was identified. Side 2 of Fire Sensor Control Panel 392, S/N 10, failed to respond to self-test and was successfully replaced with an inflight spare. The removed FSCP was retained onboard as an inflight spare for reinstallation in panel locations 530 or 619 in the OWS which used only Side 1.

Pump P - During SUS Loop No. 1 activation on DOY 218, no C&W alarm was generated from the pump P sensing circuitry. This condition confirmed the loss of the EVA LCG-1 pump P sensing circuitry suspected to have failed during the SL-2 mission.

Experiment and M509 Nitrogen Recharge Station

The AM structural mounting provisions for all GFE experiments adequately satisfied the mission requirements. The functional performance of all experiments was satisfactory.

No system anomalies were noted in recharge station operation during all fill cycles performed during the three manned missions. The manifold and valving procedure used for controlling nitrogen supply was effective as shown by the 1850 psi top-off pressure available at the end of SL-4 missin. Low cluster cabin gas leak rates required preconditioning of cabin atmosphere to accommodate the nitrogen added by unsuited M509 and T020 flights and the oxygen added by suited flights. Pre-experiment atmospheric venting and oxygen enrichment countered the nitrogen added by the unsuited flights. Total cabin gas pressure increases were less tha 1 psi as predicted.

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APPENDIX E

ORBITAL WORKSHOP DESCRIPTION

In order to provide complete definition of the OWS, limited descriptive material has been drawn from the Skylab program. This material, in conjunction with the reuse study data, will assure the understanding of both capabilities and implications of refurbishment and utilization. Therefore, included in this section of the report is an Inboard Profile of OWS, Drawing Number 1B77075 (9 sheets) and a configuration description of the basic OWS vehicle and OWS subsystems. The overall system was designed to meet the requirements of Orbital Workshop Contract End Item Specification CP2080J1C. The OWS subsystems performance during the Skylab missions is reviewed and their current status is reported. Section 21.13 of Volume I summarizes the refurbishment/resupply requirements for Skylab reactivation and reuse.

Appendix D contains similar information on the Airlock Module.

ORBITAL WORKSHOP DESCRIPTION

SKYLAB A DESCRIPTION

OWS Configuration

Structural Subsystem: The OWS structural system is a modified S-IVB stage and consists of a forward skirt, propellant tanks, aft skirt, thrust structure and a main tunnel. The skirts and main tunnel serve the same function for the OWS that they did for the S-IVB; i.e., to carry structural loads and accommodate externally mounted equipment, plumbing/wiring. The thrust structure does not have engine thrust loads to transmit, but otherwise is used similarly to the S-IVB usage to accommodate installation of additional equipment and integration hardware peculiar to the OWS. The OWS structural arrangement is shown in Figure E-1.

Modification of the S-IVB propellant tanks for the OWS were more extensive. A larger, reusable entry hatch replaced the S-IVB hatch in the forward dome of the LH_2 tank. A side panel was added to the LH_2 tank for ground access and to provide entry into the tank for modifications, installations and checkout. Three other apertures are included to provide an orbital viewing window and to accommodate two scientific airlocks which provide the capability to deploy experiments external to Skylab.

Internally, the LH_2 tank modification consists first of completely lining the polyurethane tank wall insulation with aluminum foil to fireproof the habitation

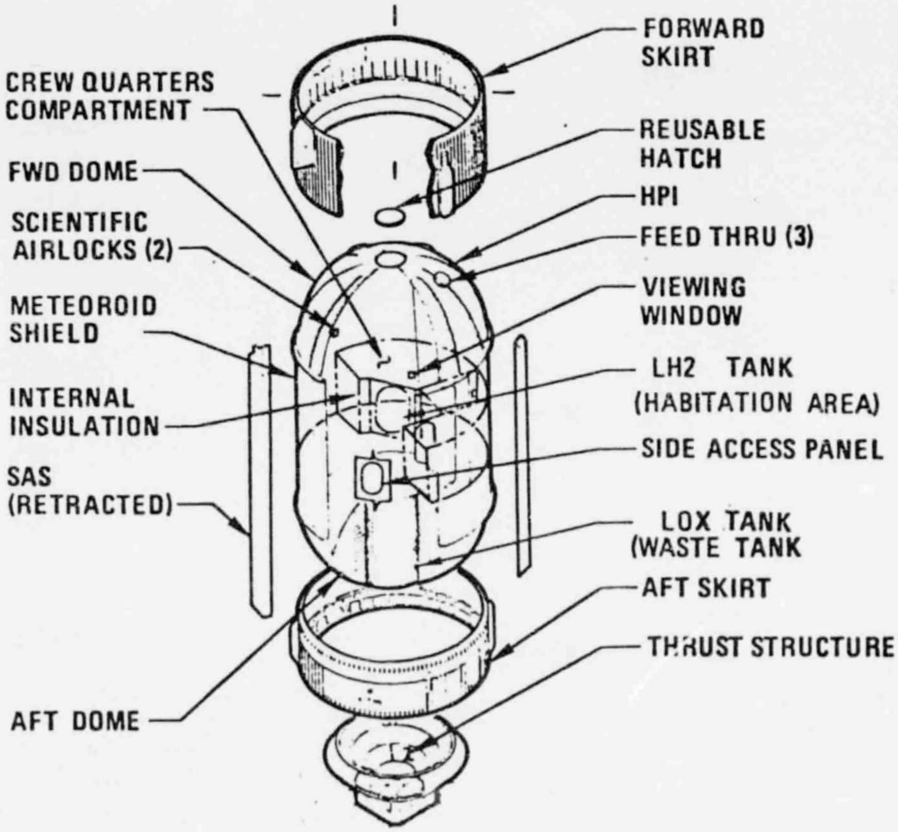
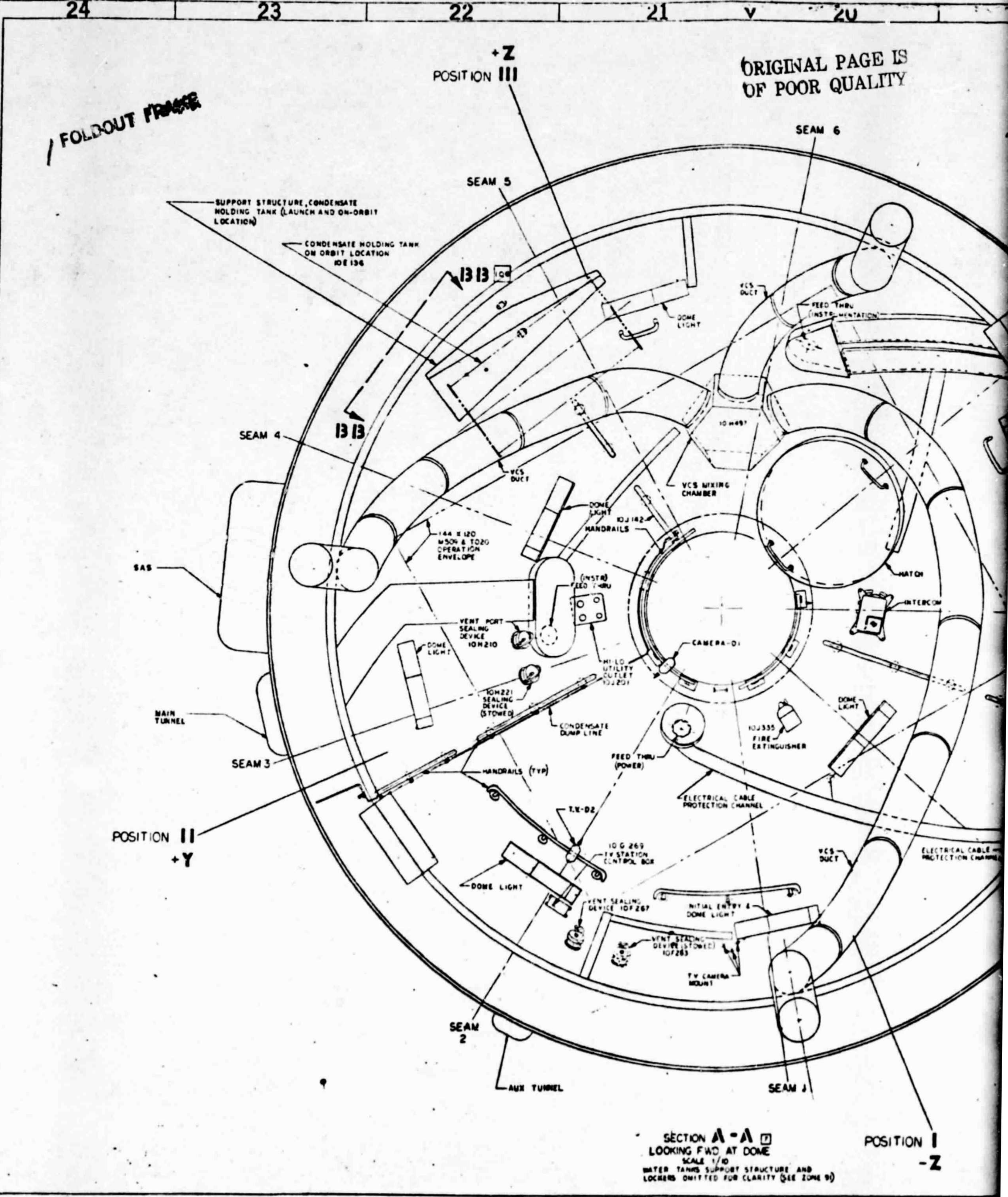


Figure E-1 Orbital Workshop Configuration



SECTION A-A
LOOKING FWD AT DOME
SCALE 1/10
WATER TANKS SUPPORT STRUCTURE AND LOCKERS OMITTED FOR CLARITY (SEE ZONE 9)

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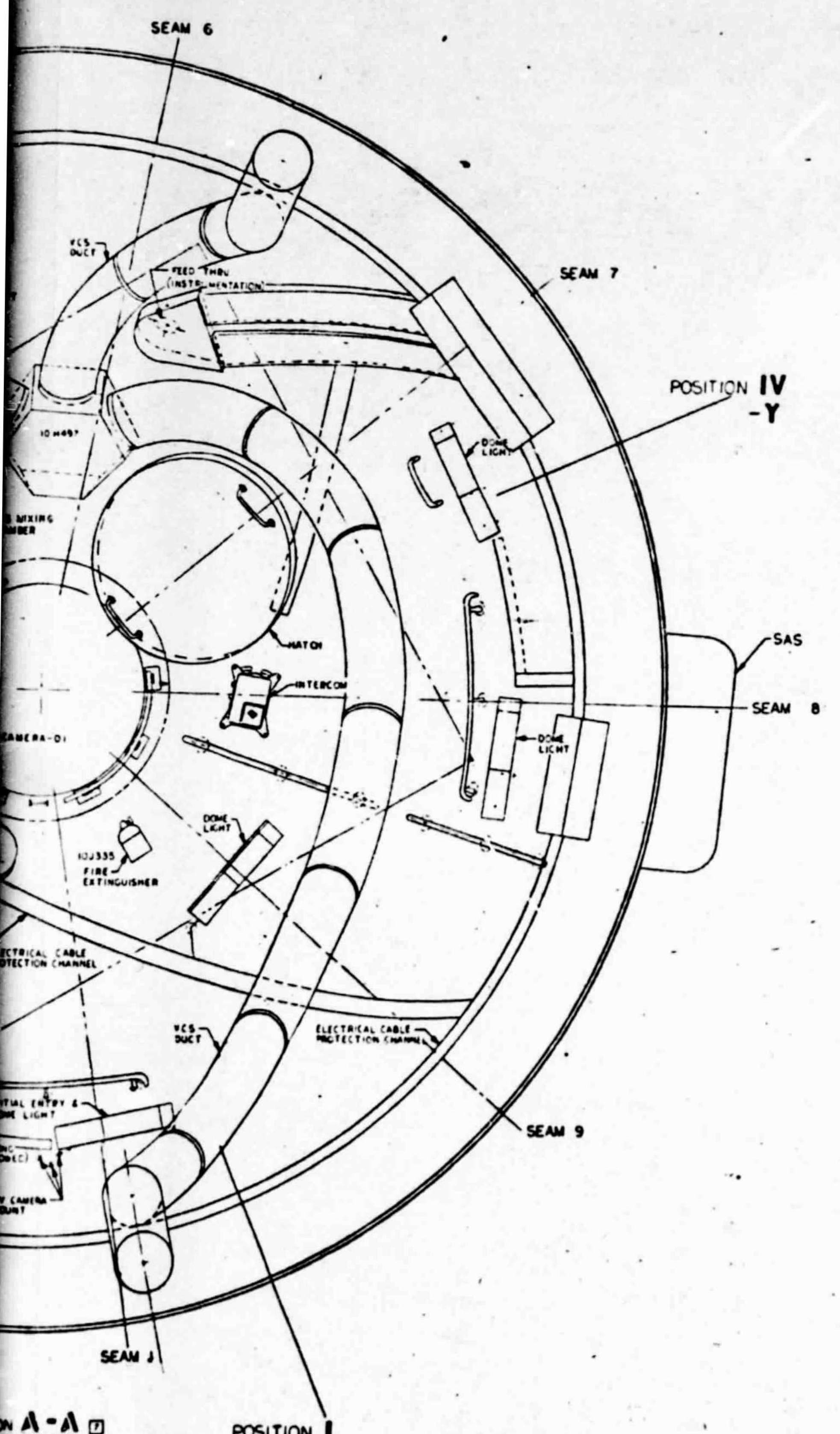
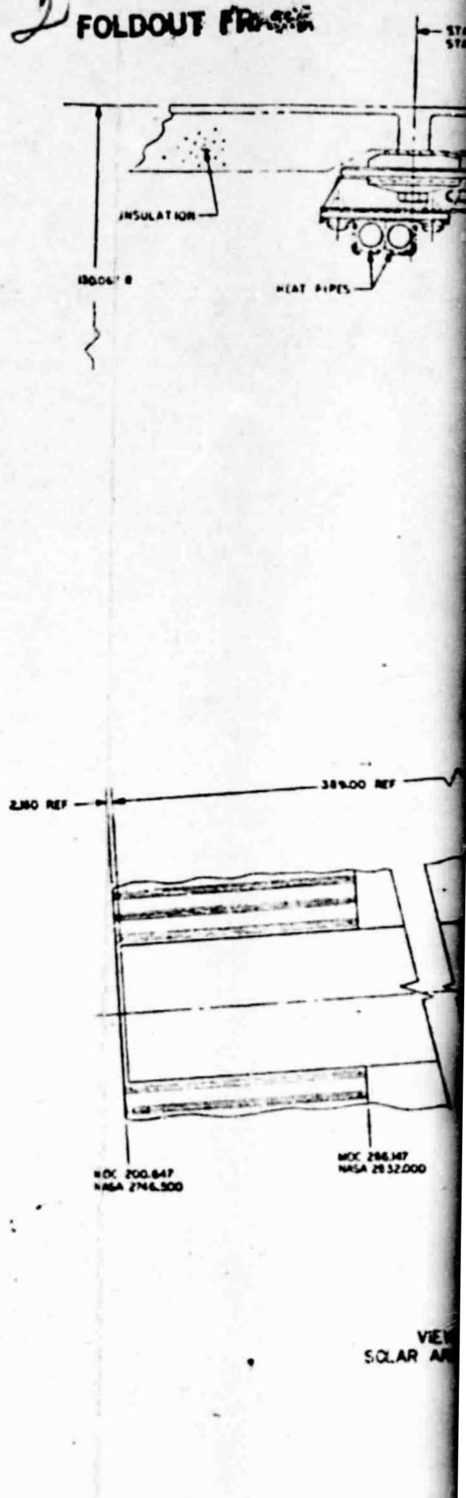


A-A
FWD AT DOME
1/10
SUPPORT STRUCTURE AND
FOR CLARITY (SEE ZONE 9)



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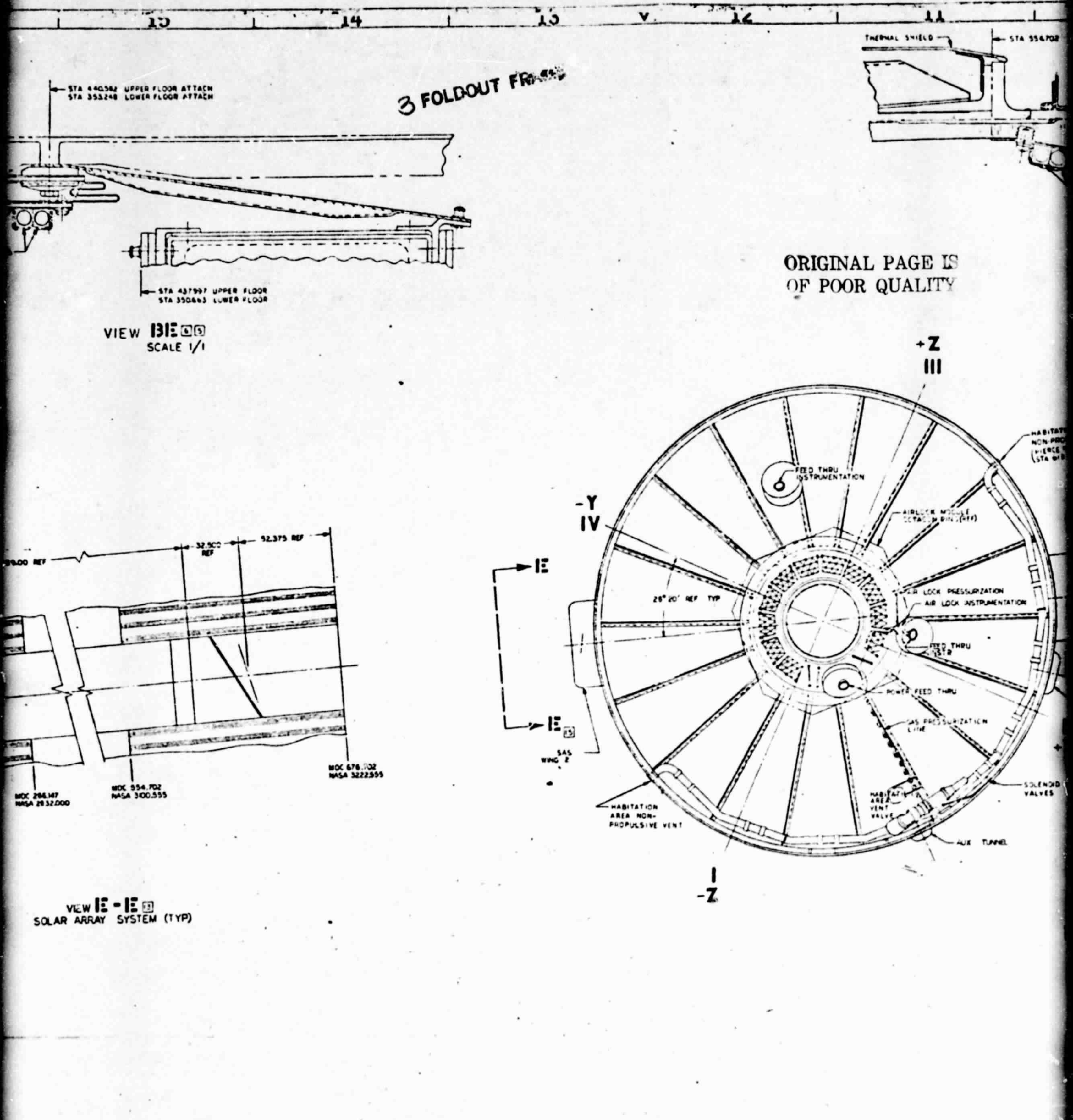
14
13
12
11
STA 440.582 UPPER FLOOR ATTACH
STA 353.248 LOWER FLOOR ATTACH
STA 437.997 UPPER FLOOR
STA 350.663 LOWER FLOOR
VIEW BE
SCALE 1/1
THERMAL SHIELD
STA 554.702
32.900 REF
52.375 REF
MDC 676.702
NASA 3222.555
MDC 554.702
NASA 3100.555
MDC 296.147
NASA 2832.000
VIEW E - E
SOLAR ARRAY SYSTEM (TYP)
E
E
SAS WING 2
+Z
III
-Y
IV
I
-Z
FEED THRU INSTRUMENTATION
AIRLOCK MODULE
28° 20' REF TYP
AIR LOCK PRESSURIZATION
AIR LOCK INSTRUMENTATION
FEED THRU
POWER FEED THRU
SAS PRESSURIZATION LINE
HABITATION AREA NON-PROPULSIVE VENT
HABITATION AREA VENT VALVE
SOLENOID VALVES
AUX TUNNEL

4

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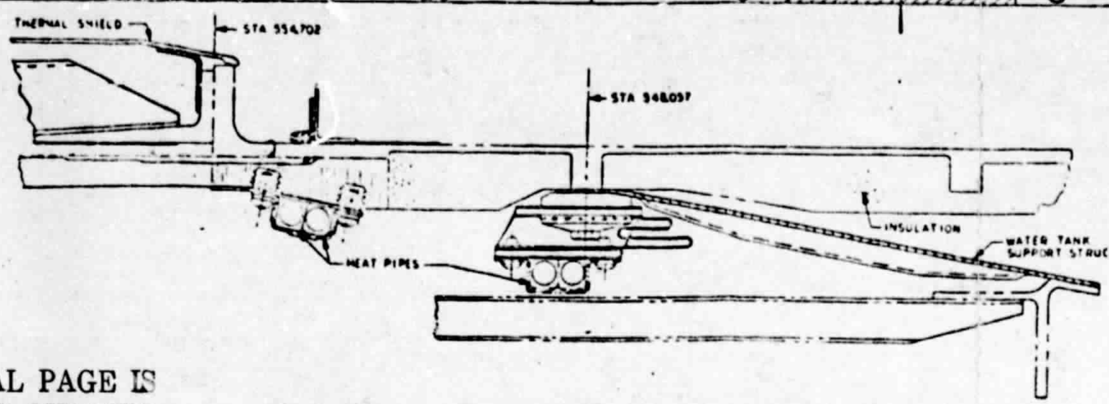

VIEW BD
SCALE 1/1

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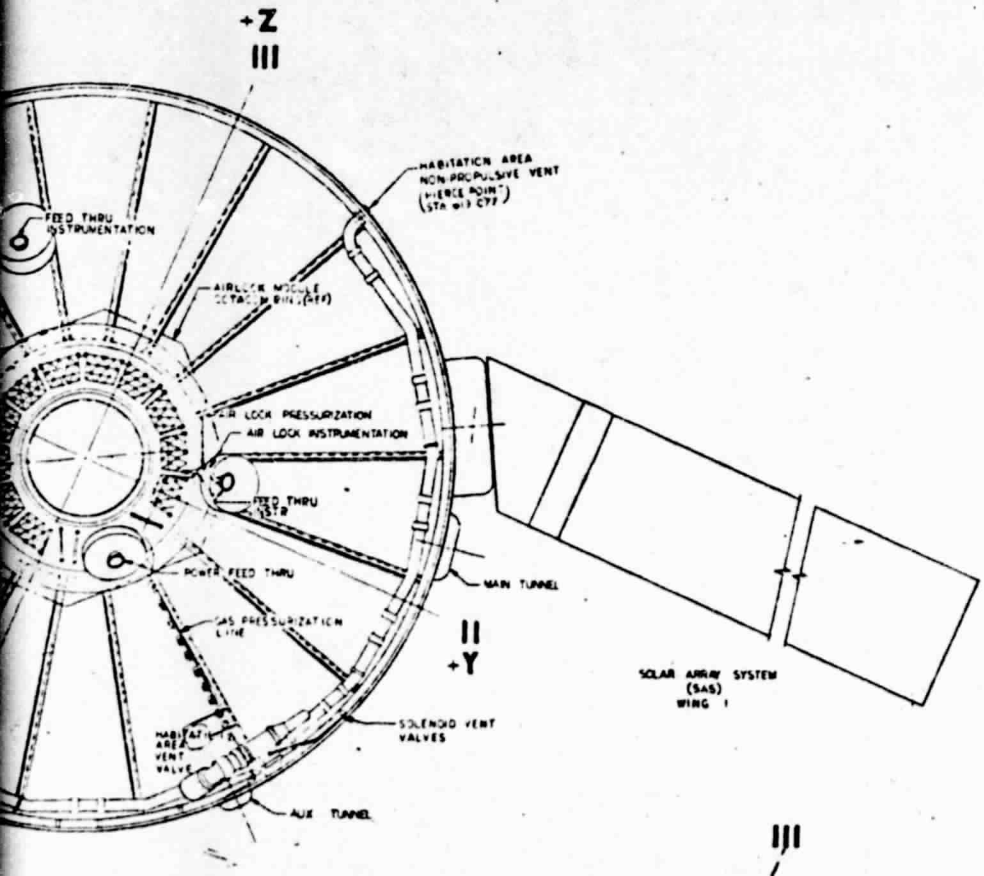
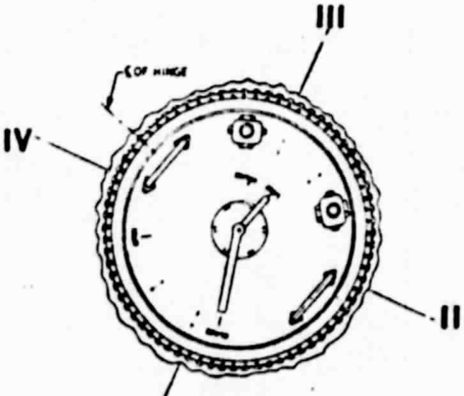
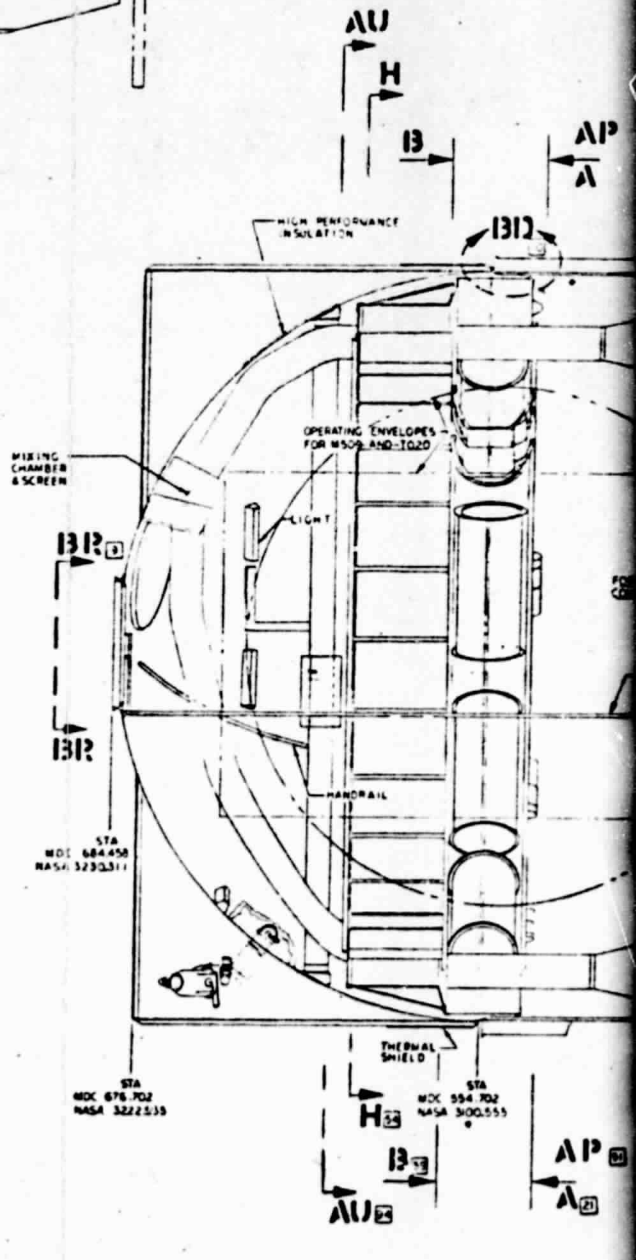




VIEW BR-BR
ENTRY HATCH IN
LAUNCH POSITION
SCALE 1/10



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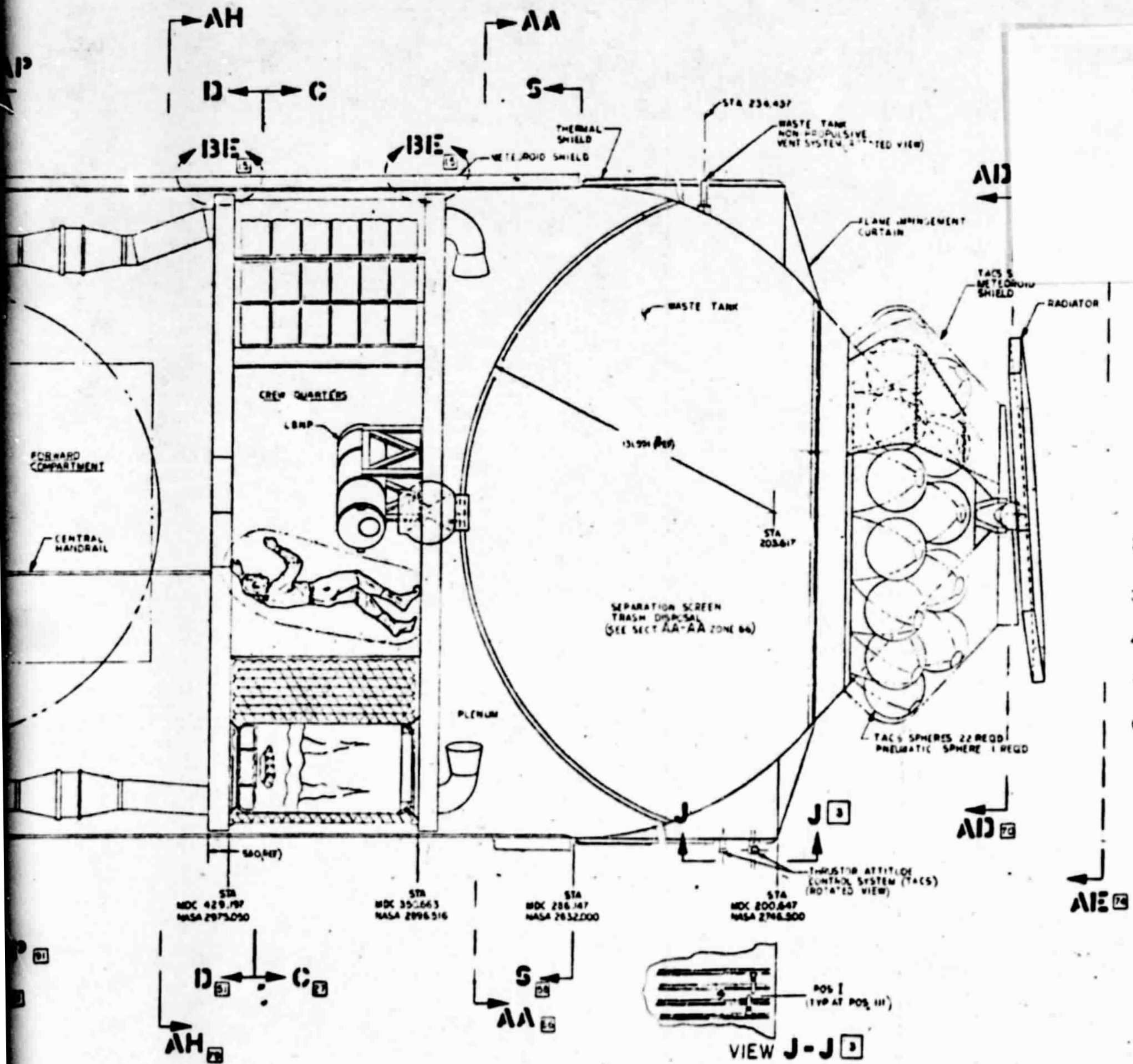

SEE SHEET #8, ZONE 98, VIEW BZ FOR NON FLIGHT GROUND SUPPORT ENVIRONMENTAL CONTROL DUCTS

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2. NUMBERS AND LETTERS NOTED THUS (17L699) ARE CREW WORK LOCATION DES
3. FOR ABBREVIATIONS NOTED ON DRAWING 1B77764
4. AXIS SYSTEM SHOWN ARE CLUSTER MA AXIS
5. NUMBERS AND LETTERS NOTED THUS (W777) ARE OWS STOWAGE NUMBERS.
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SCALE IN INCHES

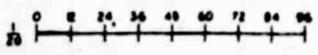

Figure E-1 (C

DOUGLAS

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DESIGN REQUIRE

J 18355

FOR ENGINEERING ASSISTANCE CONTACT M. JACK AKUNE, MDAC-W, 896-2560

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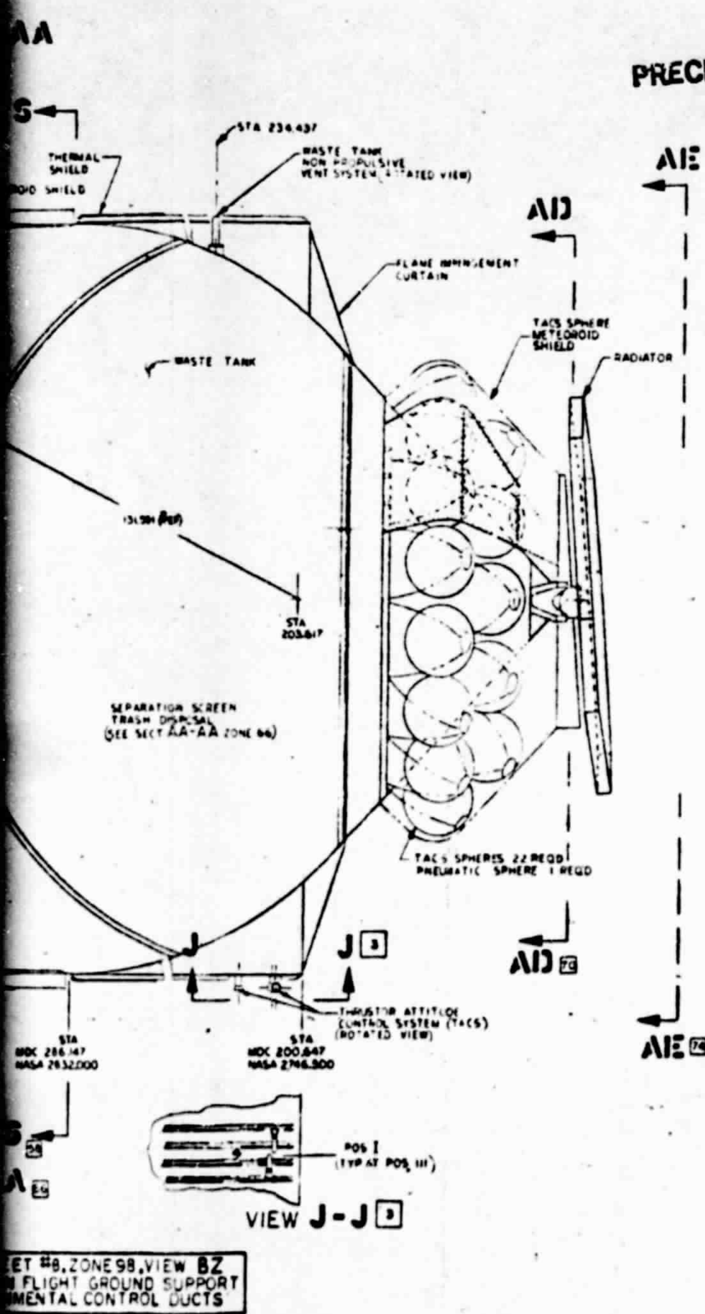

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...N FLIGHT GROUND SUPPORT
...MENTAL CONTROL DUCTS

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3. FOR ABBREVIATIONS NOTED ON DRAWING SEE 1B77764
4. AXIS SYSTEM SHOWN ARE CLUSTER MASS PROPERTIES AXIS
5. NUMBERS AND LETTERS NOTED THUS (D400) THRU (W777) ARE OWS STOWAGE NUMBERS
6. CAMERA AND PHOTOLIGHT LOCATIONS ARE TO BE RESERVED WHERE NOTED THUS ◄◯. ARROW INDICATES INSTALLATION DIRECTION OF TRIGGER ON UNIVERSAL MOUNT

Figure E-1 (Continued)

DOUGLAS

INBOARD PROFILE
ORBITAL WORKSHOP
DESIGN REQUIREMENTS DRAWING

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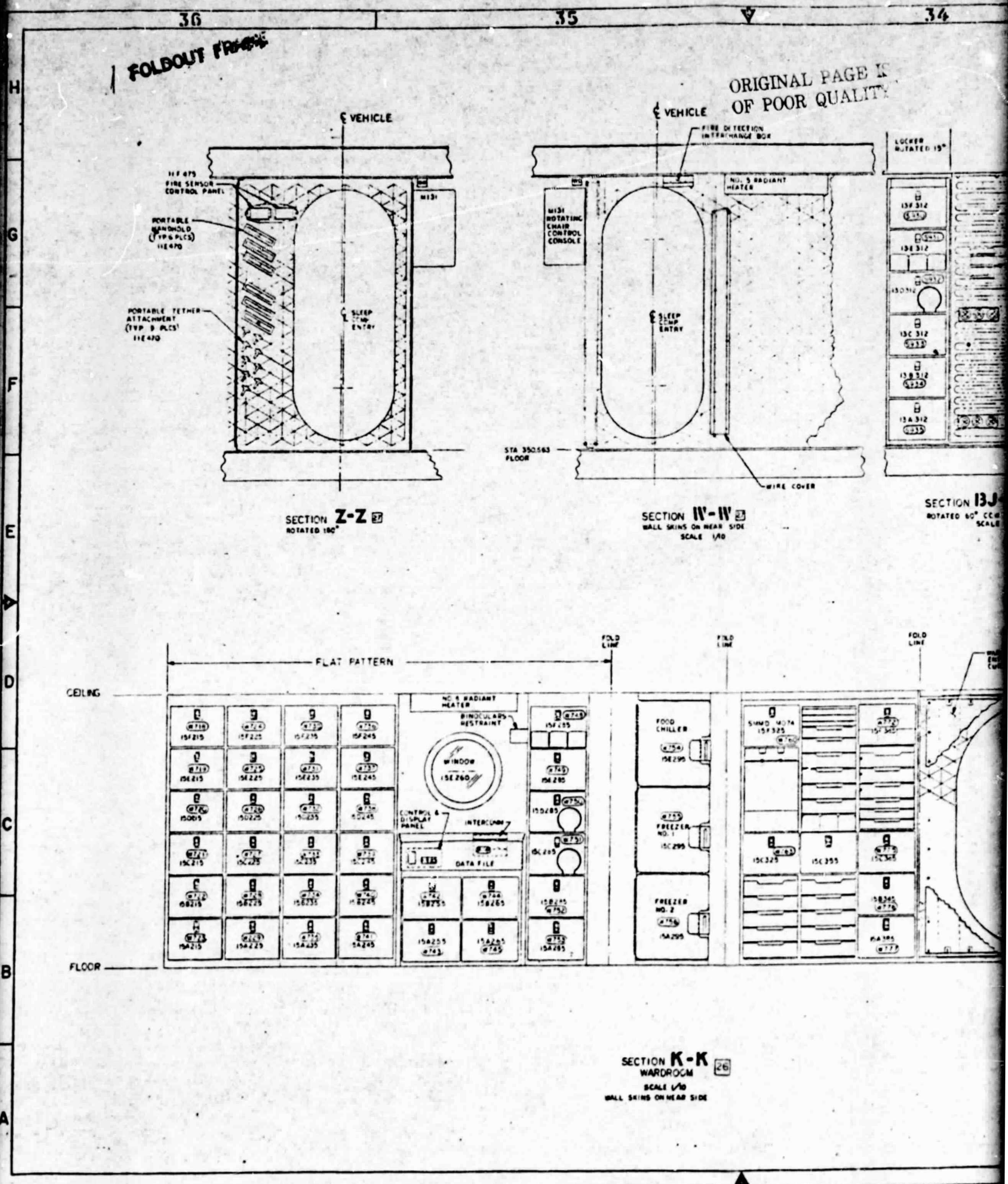
FOR ENGINEERING ASSISTANCE CONTACT:
H. JACK AKUNE, MDAC-W, 896-2560, GROUP A870, MAIL STA. 10-3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36
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H
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A
℄ VEHICLE
FIRE SENSOR CONTROL PANEL
PORTABLE HANDHOLD (TYP 6 PLCS) 11E470
PORTABLE TETHER ATTACHMENT (TYP 9 PLCS) 11E470
M131
℄ SLEEP COMP ENTRY
SECTION Z-Z 27
ROTATED 180°
FIRE DETECTION INTERCHANGE BOX
NO. 5 RADIANT HEATER
M131 ROTATING CHAIR CONTROL CONSOLE
STA 350.563 FLOOR
WIRE COVER
SECTION W-W
WALL SKINS ON NEAR SIDE
SCALE 1/10
LOCKER ROTATED 15°
SECTION BJ
FLAT PATTERN
FOLD LINE
CEILING
FLOOR
NO. 4 RADIANT HEATER
BINOCULARS RESTRAINT
WINDOW
15E260
CONTROL & DISPLAY PANEL
INTERCOM
DATA FILE
FOOD CHILLER
FREEZER NO. 1
FREEZER NO. 2
SECTION K-K 26
WARDROOM
SCALE 1/10
WALL SKINS ON NEAR SIDE

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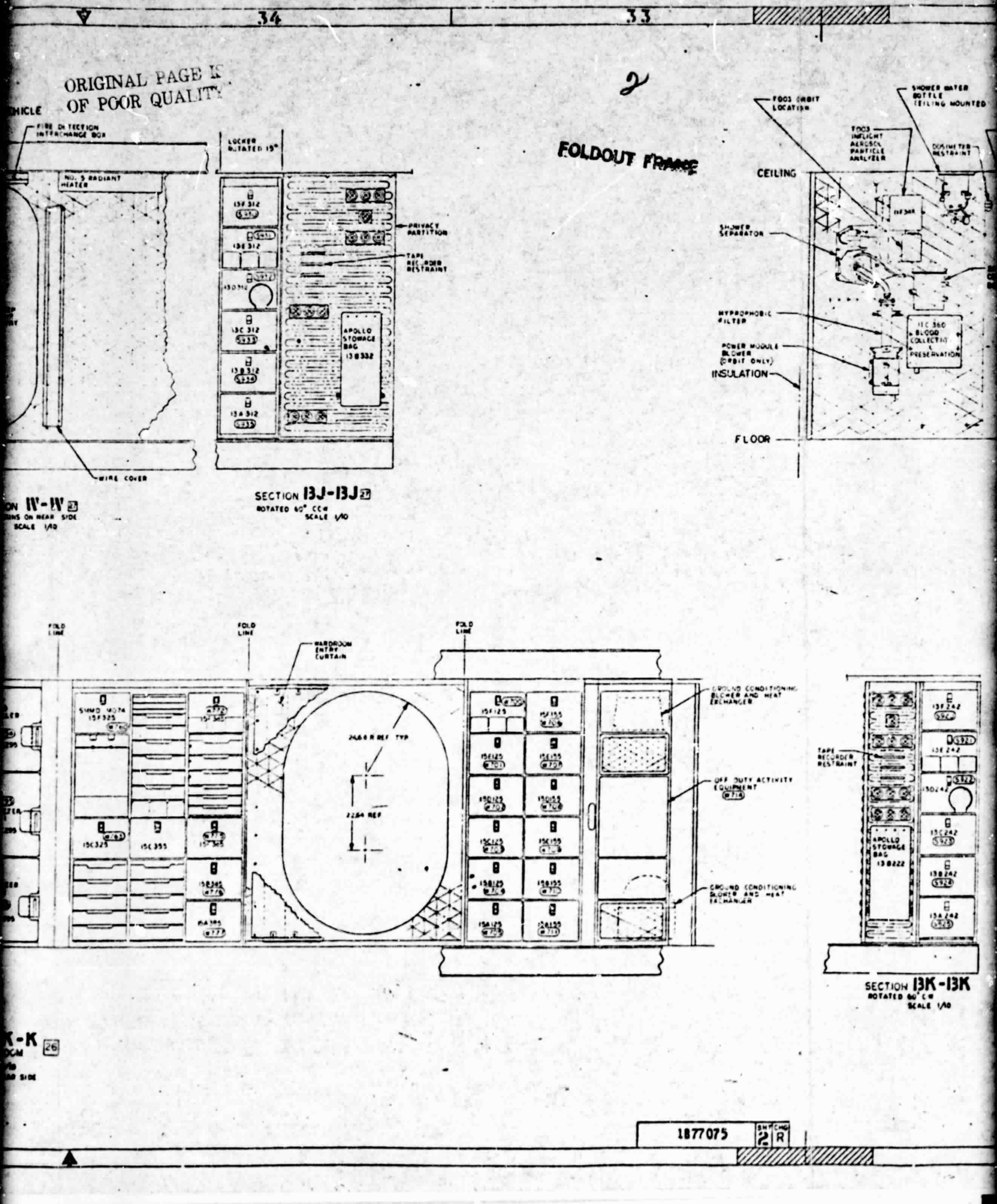

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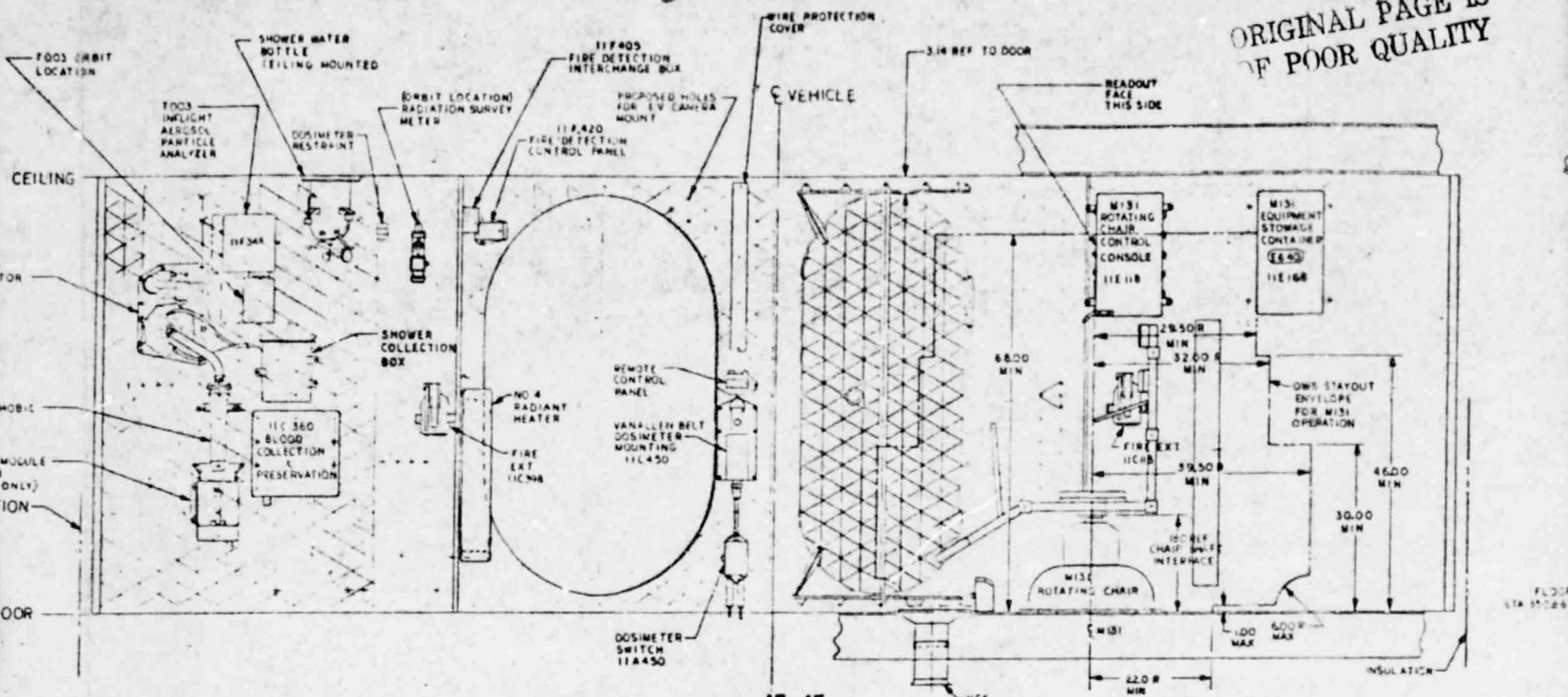

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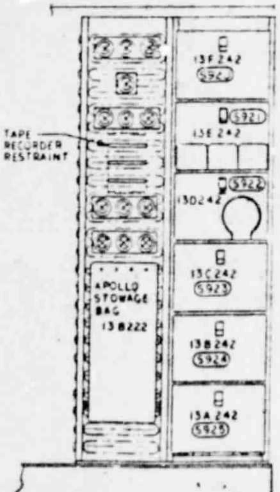

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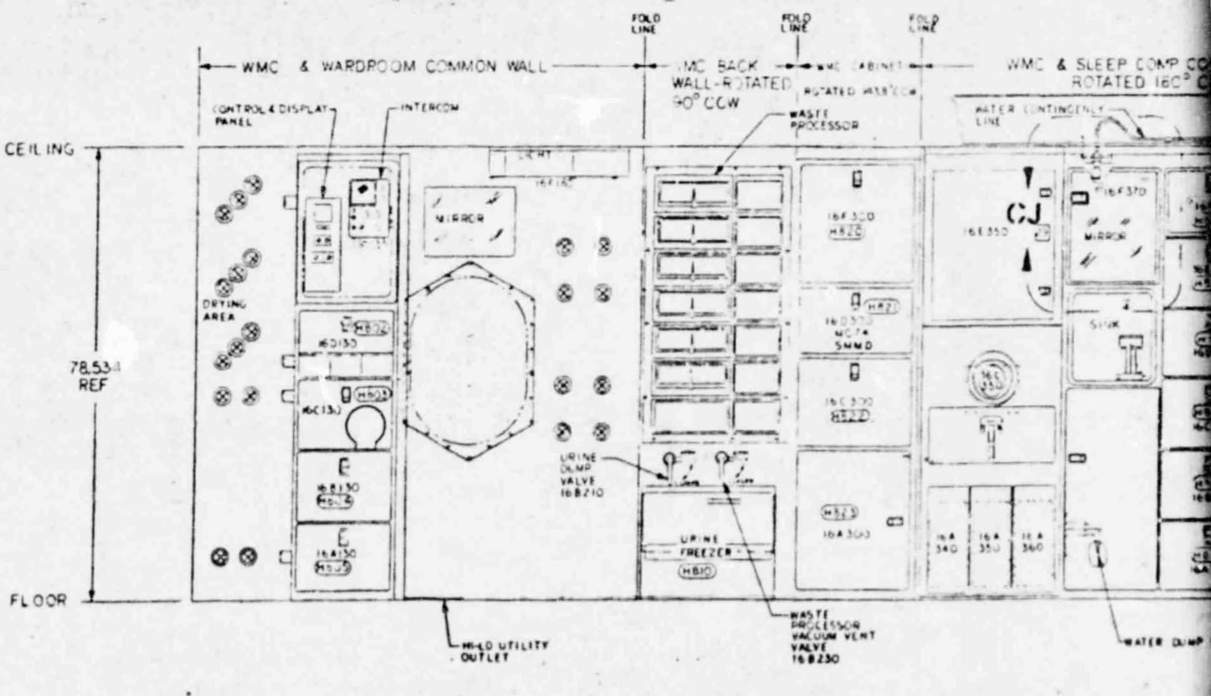
SCALE 1/10



SECTION G-G [26]
WASTE MANAGEMENT COMP
(SKINS ON NEAR SIDE)
SCALE 1/10

SHT 2 CHG R

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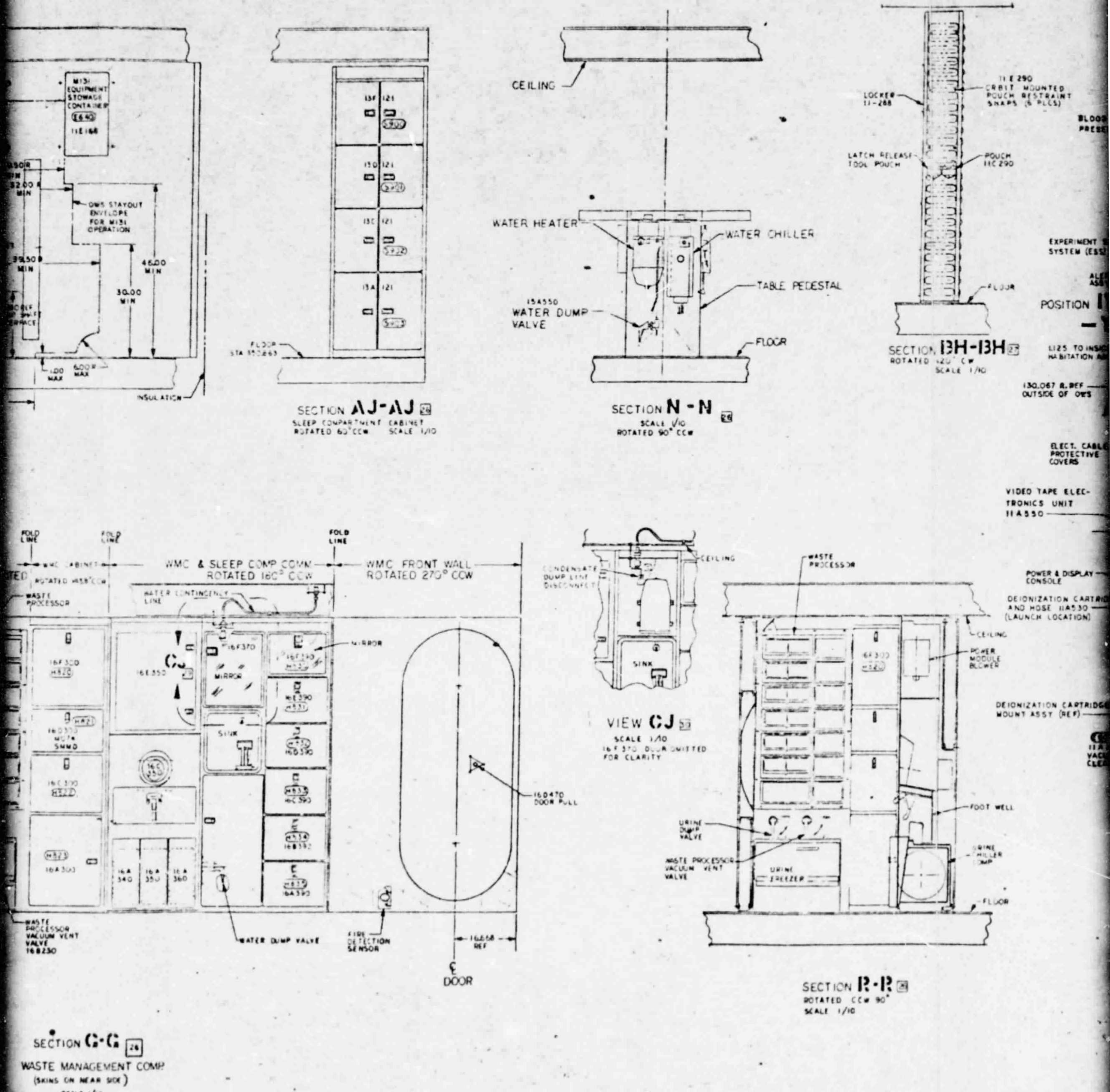

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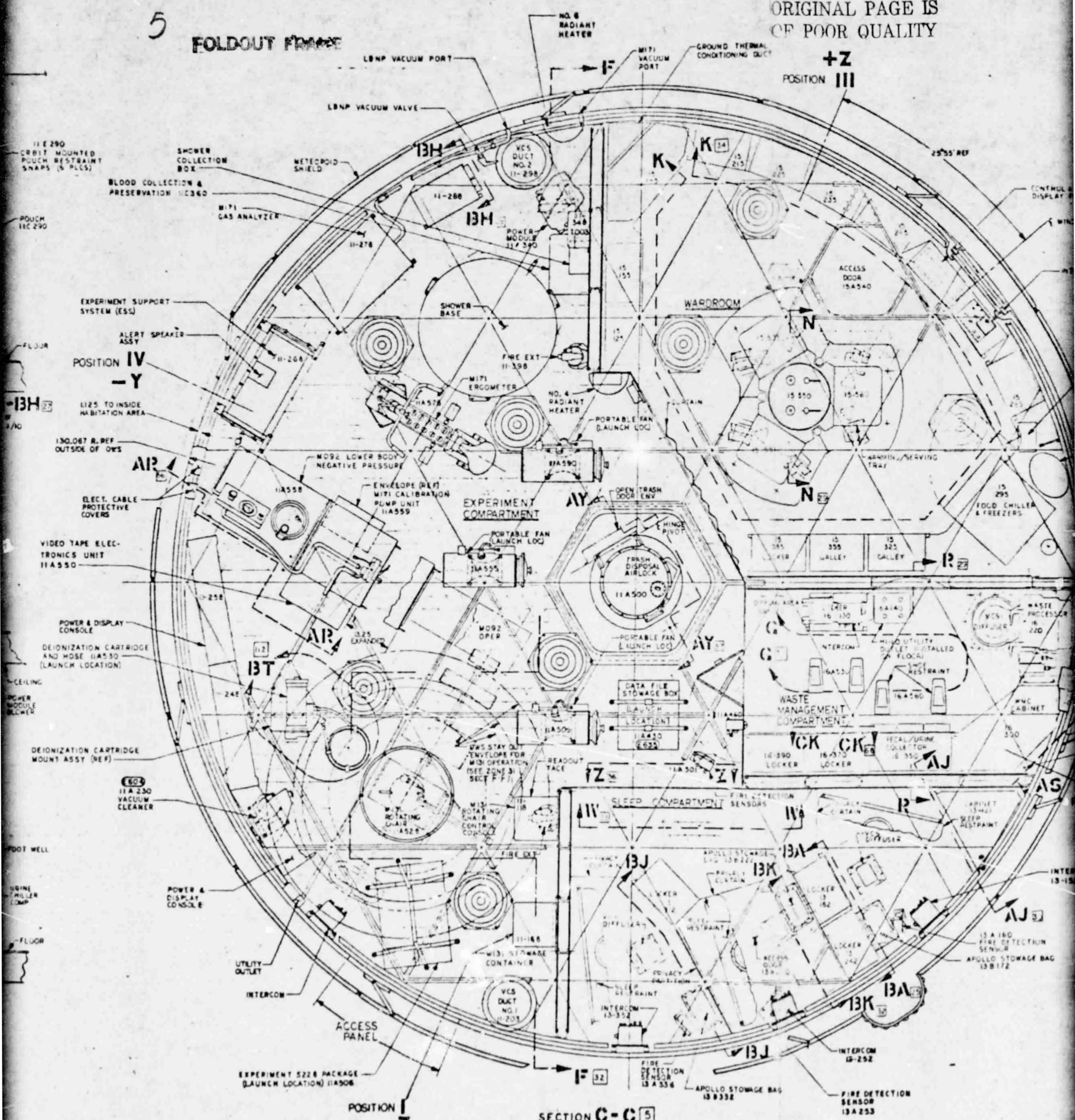

SECTION C-C 5
LOOKING AFT
SCALE 1/10

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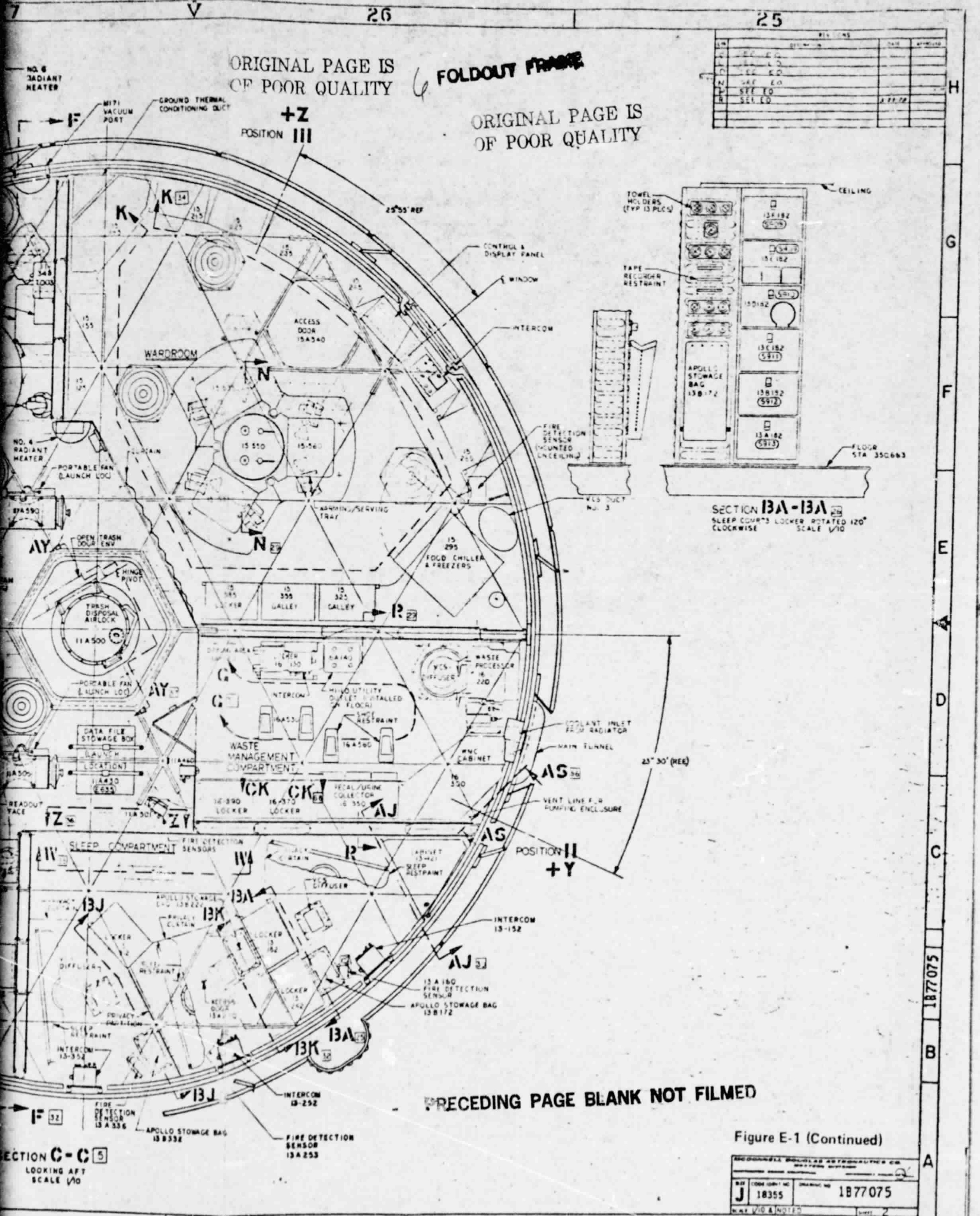

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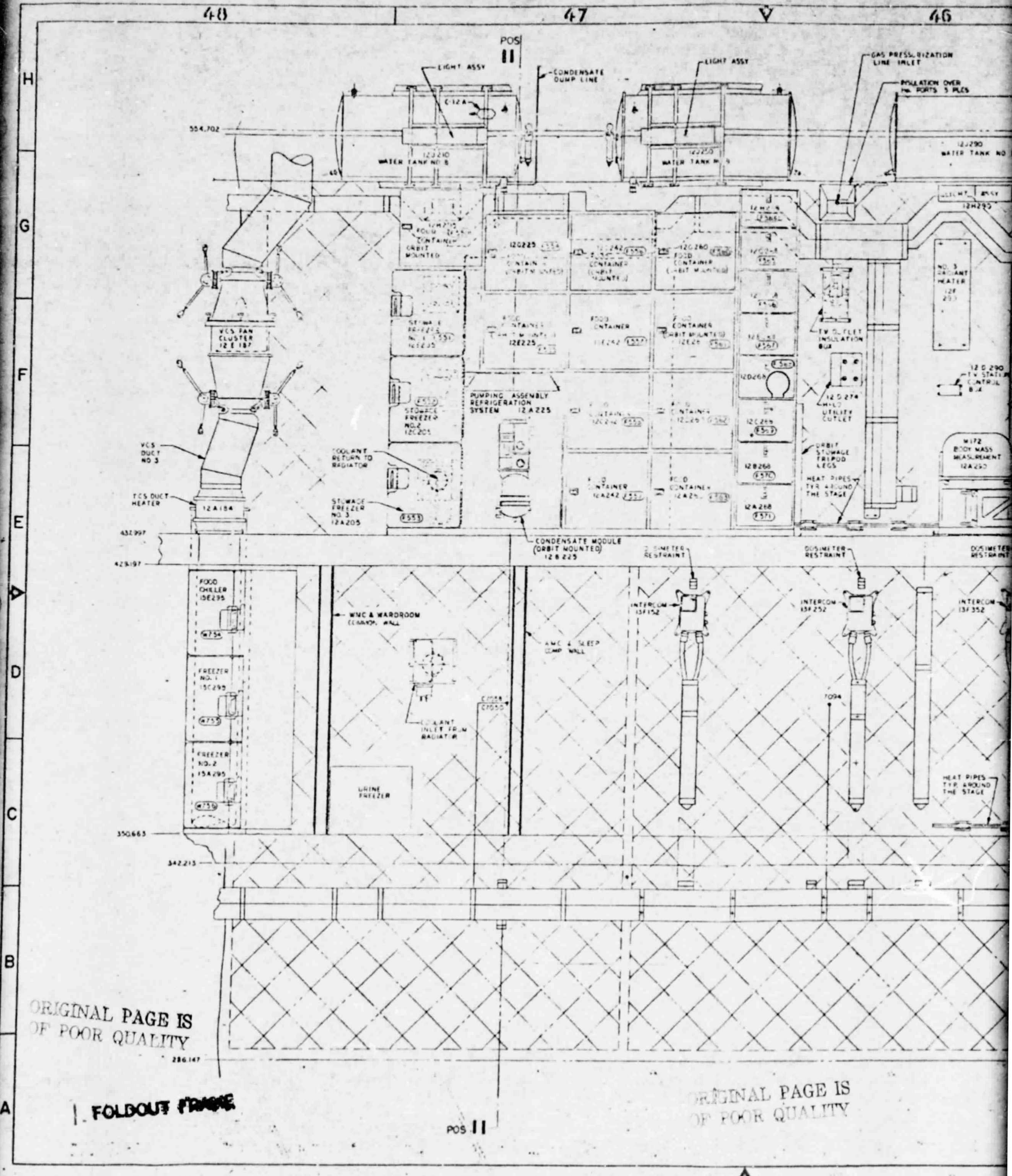

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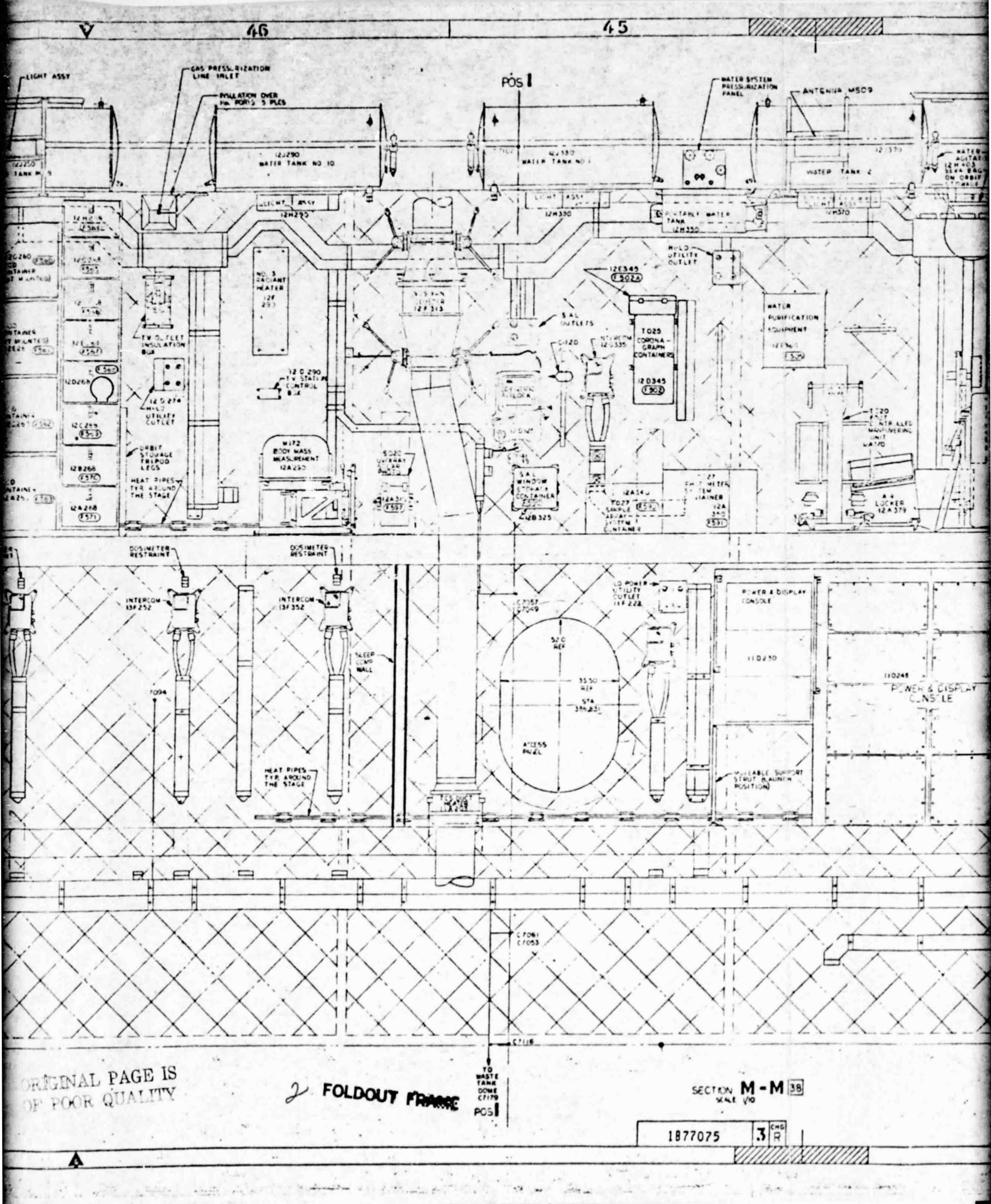

46
45
POS I
LIGHT ASSY
GAS PRESSURIZATION LINE INLET
INSULATION OVER H2O PORTS 5 PLCS
12J290 WATER TANK NO 10
WATER TANK NO 1
WATER SYSTEM PRESSURIZATION PANEL
ANTENNA M509
WATER TANK 2
12H295
12H330
PORTABLE WATER TANK 12H350
12H370
NO. 3 RADIANT HEATER
T.V. OUTLET INSULATION BUS
12 D 290 T.V. STATION CONTROL BOX
S.A.L OUTLETS
12E345
T025 CORONA-GRAPH CONTAINERS
12D345
WATER PURIFICATION EQUIPMENT
ORBIT STOWAGE TRIPOD LEGS
HEAT PIPES TYP. AROUND THE STAGE
M172 BODY MASS MEASUREMENT 12A250
S.A.L WINDOW CONTAINER
12B325
T027 SAMPLE ARRAY SYSTEM CONTAINER
T020
A-4 LOCKER 12A379
DOSIMETER RESTRAINT
INTERCOM 13F252
INTERCOM 13F352
SLEEP COMP WALL
C7057 C7049
52.0 REF
35.50 REF
STA 386.851
ACCESS PANEL
POWER & DISPLAY CONSOLE
11D230
11D245
POWER & DISPLAY CONSOLE
MOVEABLE SUPPORT STRUT (LAUNCH POSITION)
C7061 C7053
C7116
TO WASTE TANK DOME C7179
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SECTION M-M 38
SCALE 1/10
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3
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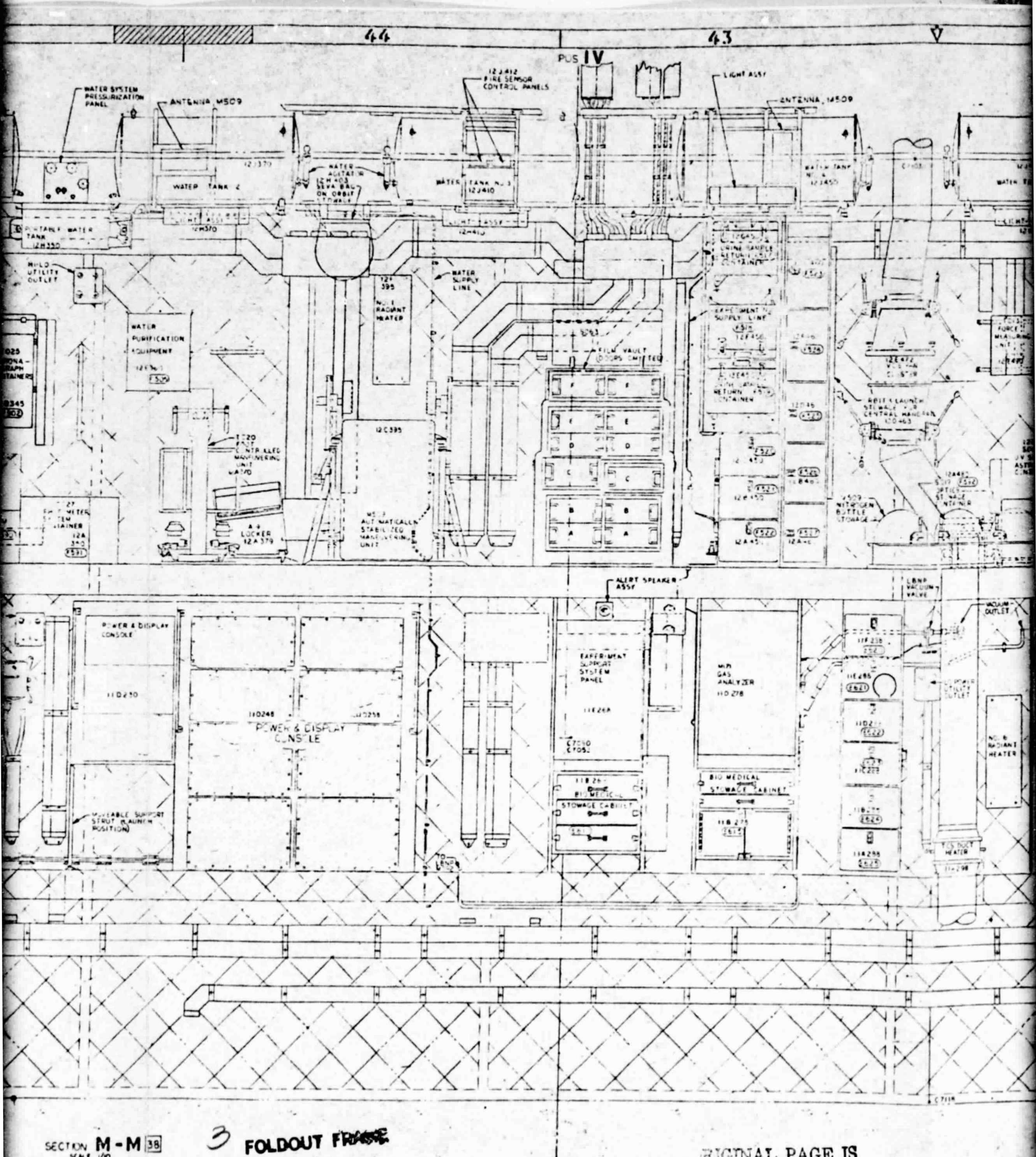

SECTION M - M 38
SCALE 1/10

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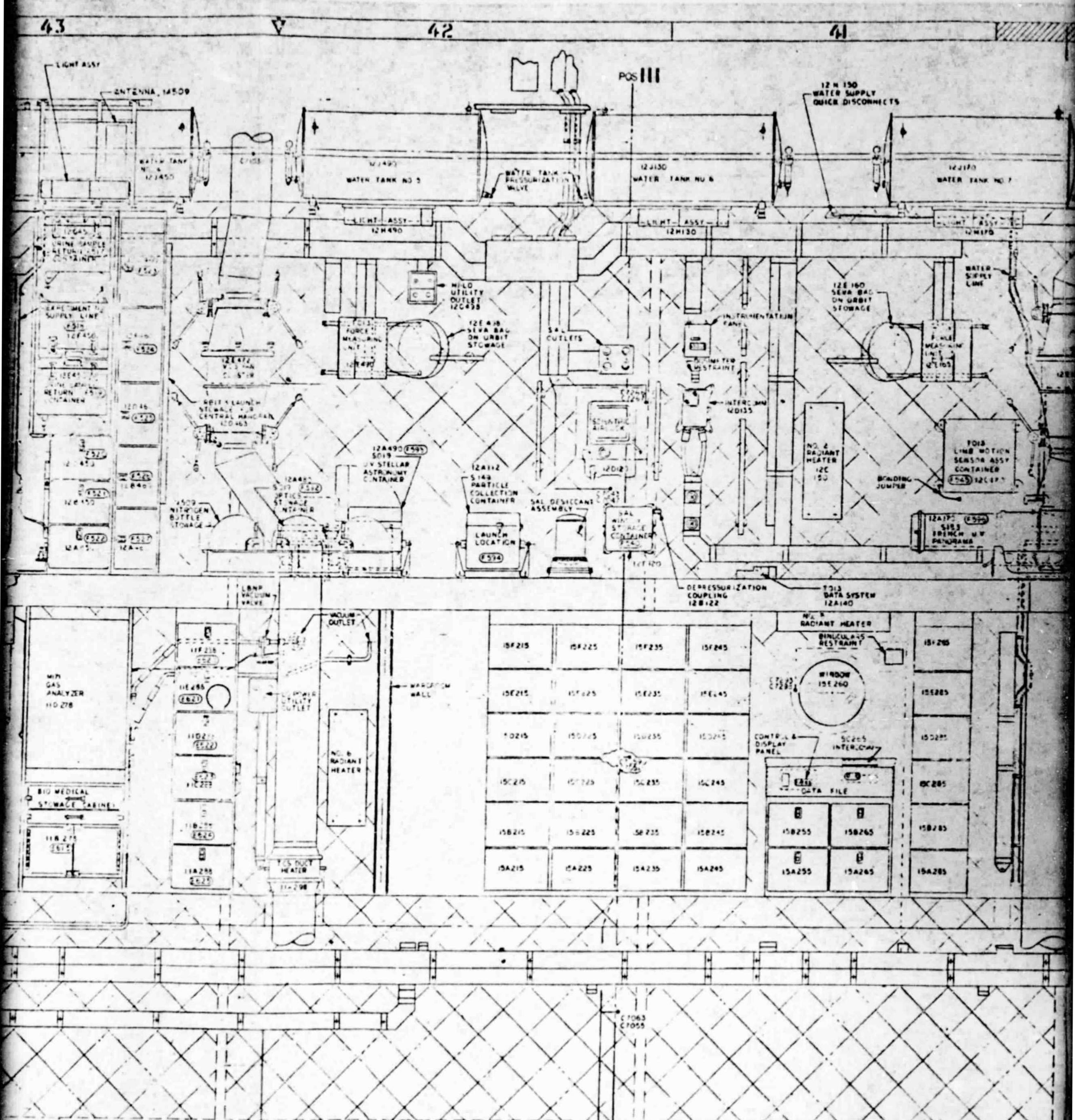

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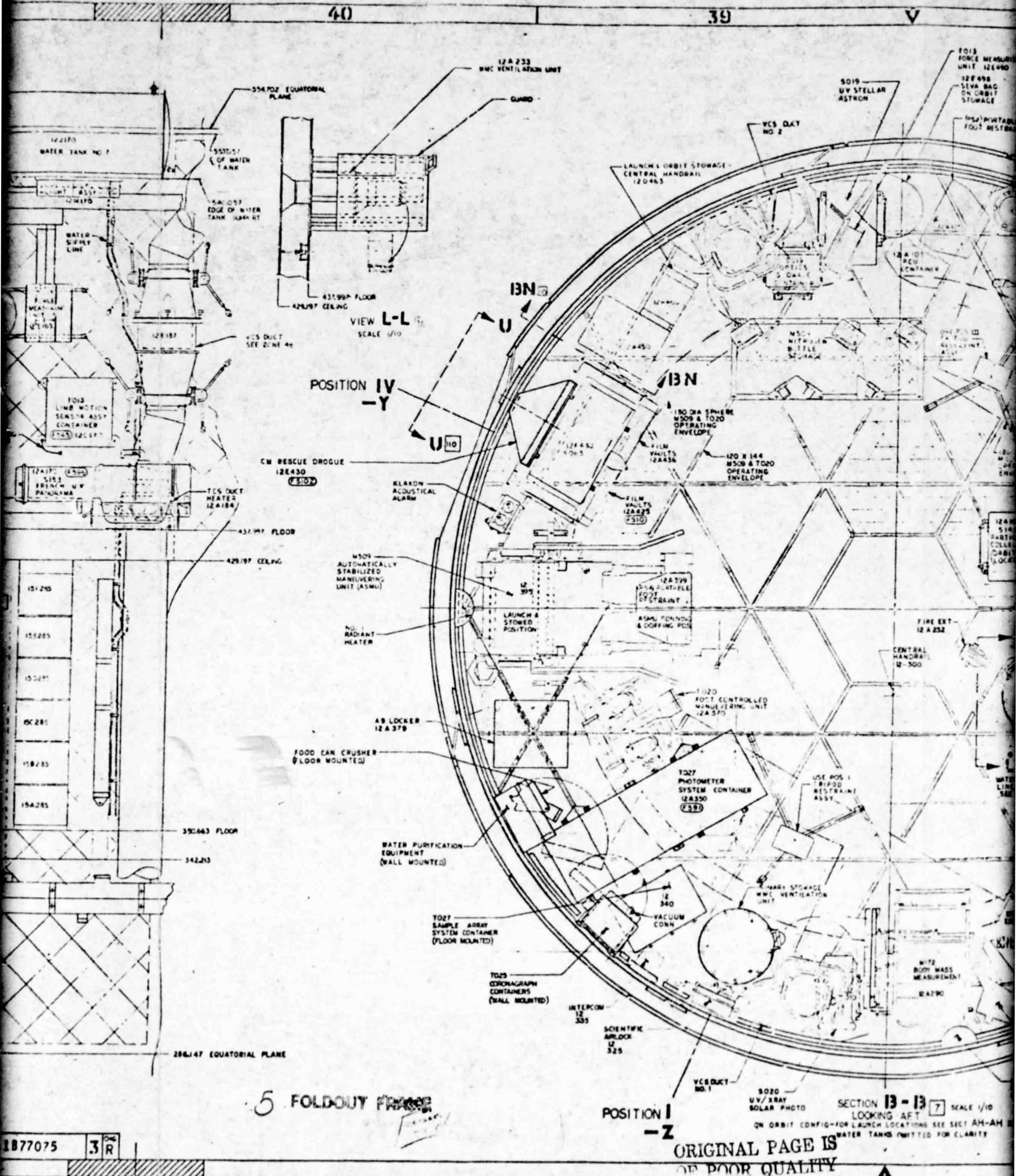

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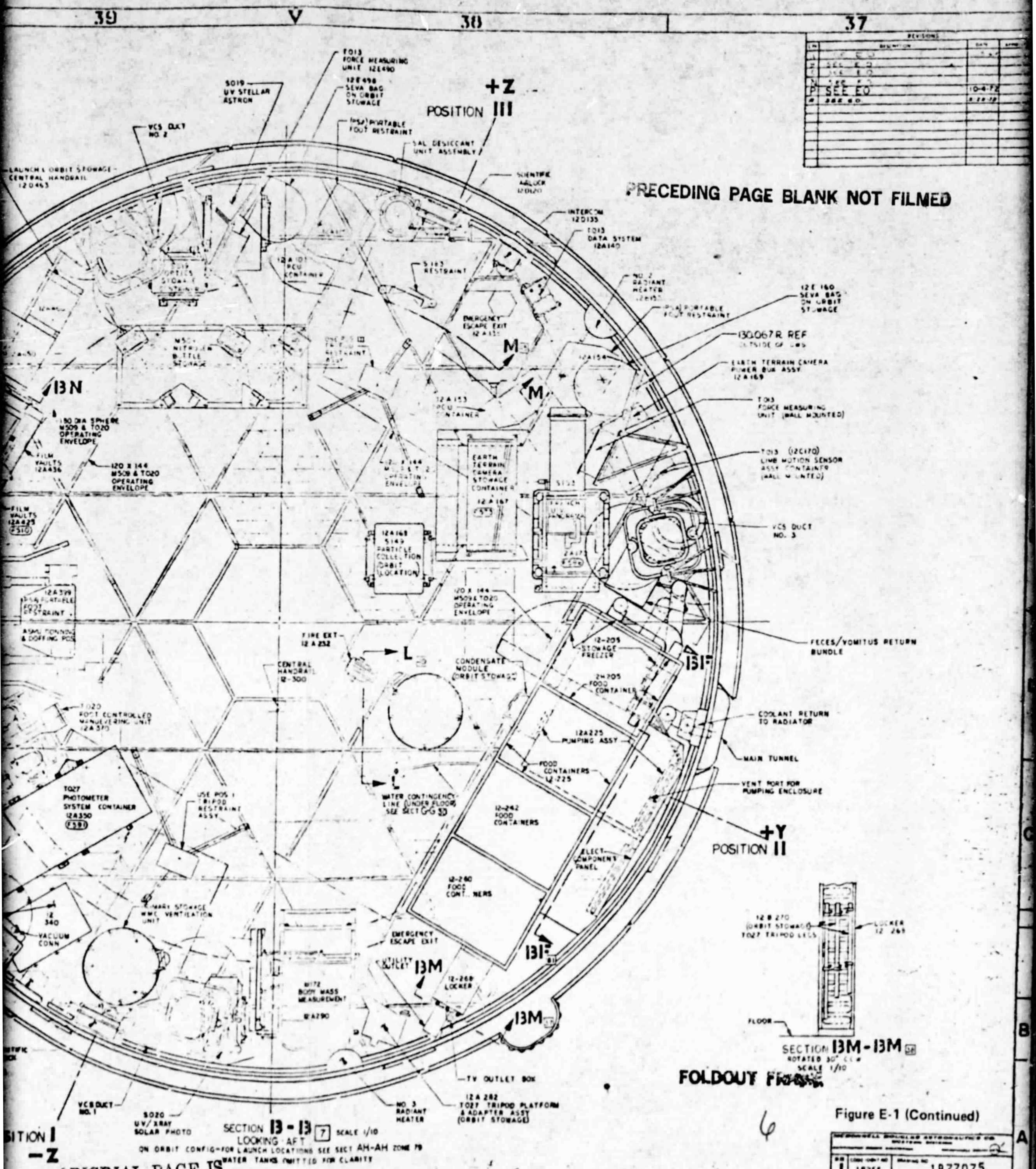

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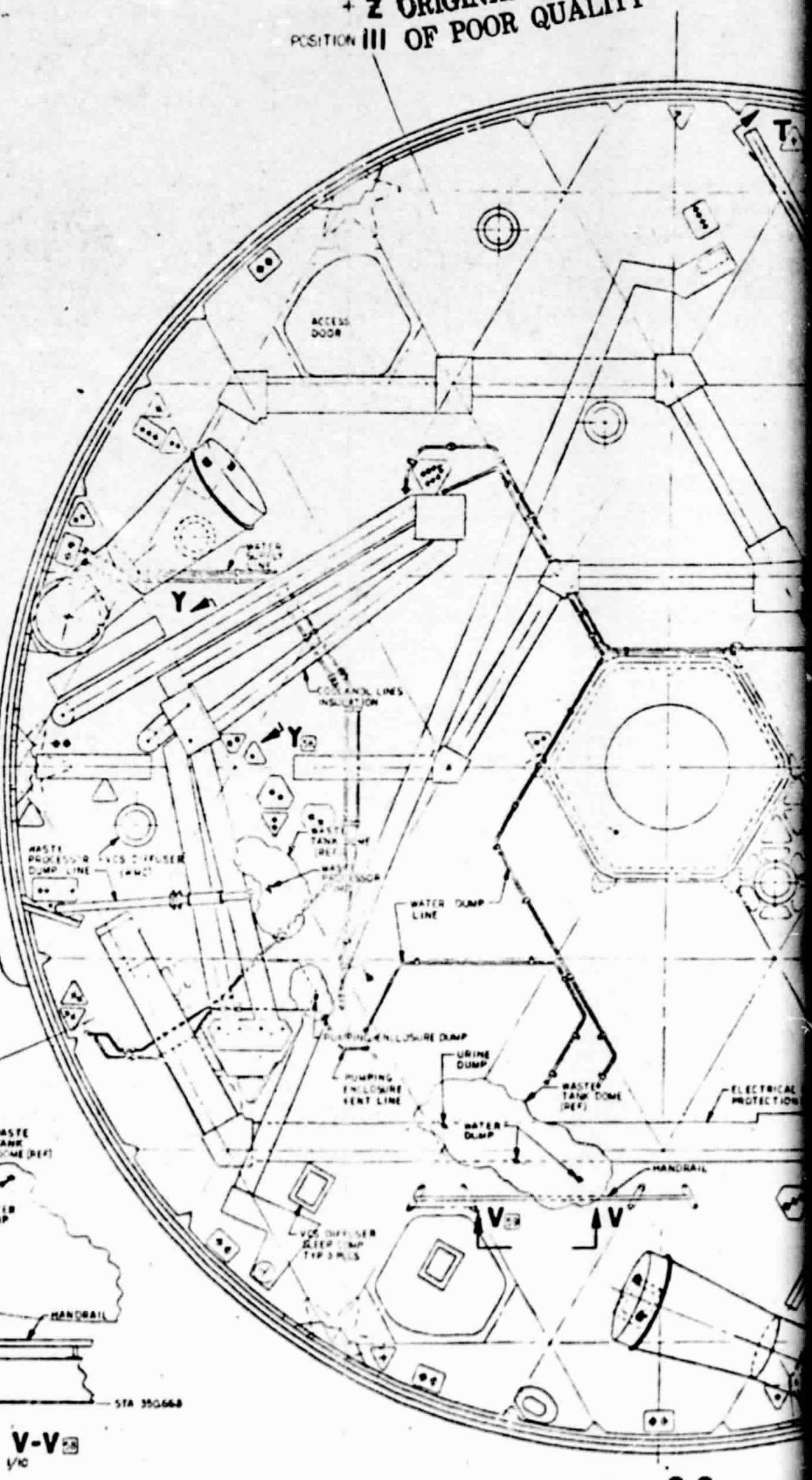
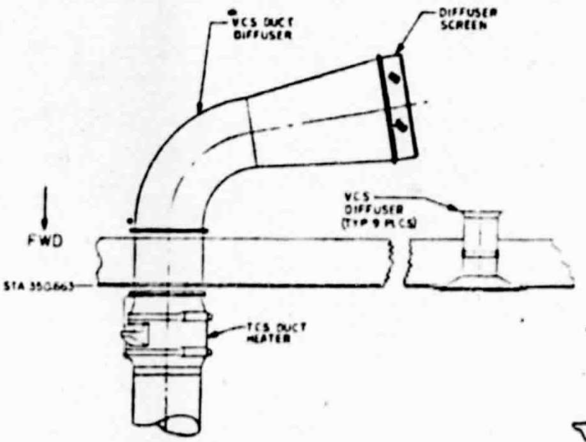
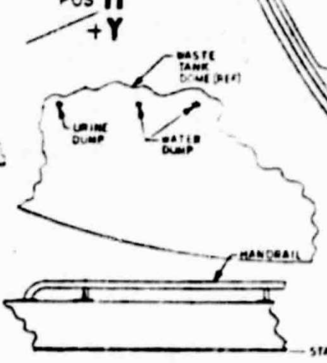




SECTION T-T
ROTATED 53° CCW
SCALE 1/10



SECTION V-V
SCALE 1/10

SECTION S-S
LOOKING FWD
SCALE 1/10
(PORTION OF WASTE TANK OMITTED FOR CLARITY)

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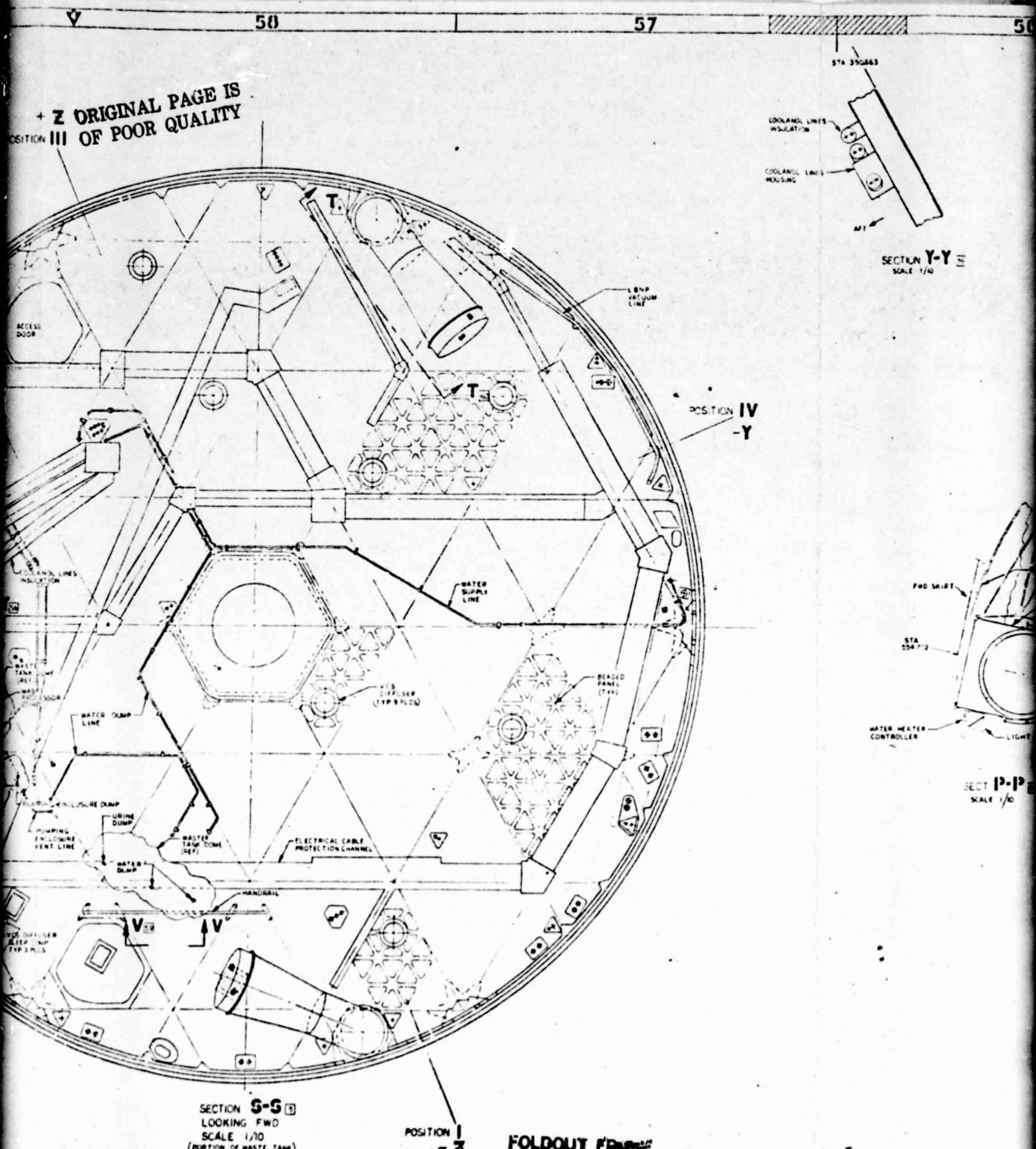

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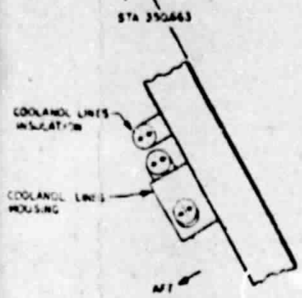
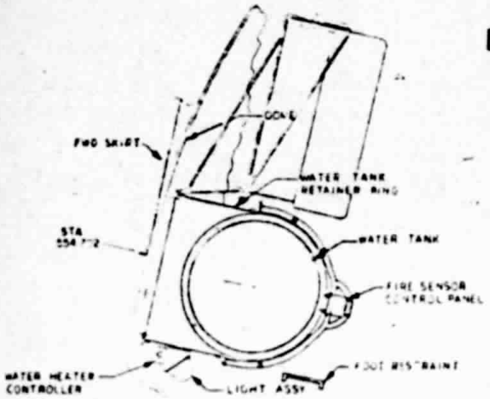
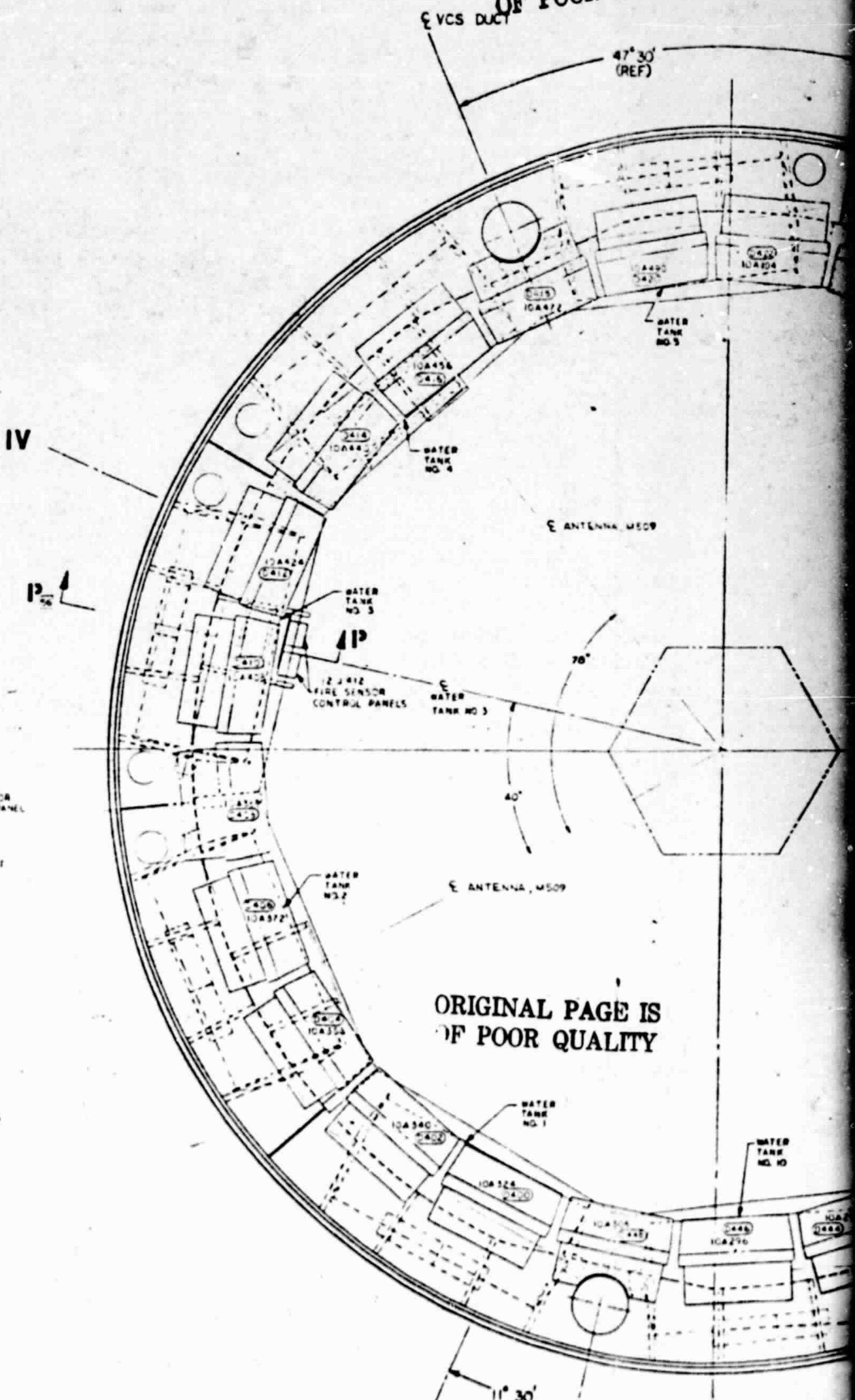


SECTION **Y-Y**
SCALE 1/10



SECT **P-P**
SCALE 1/10



SECTION **H-H**
LOOKING AFT
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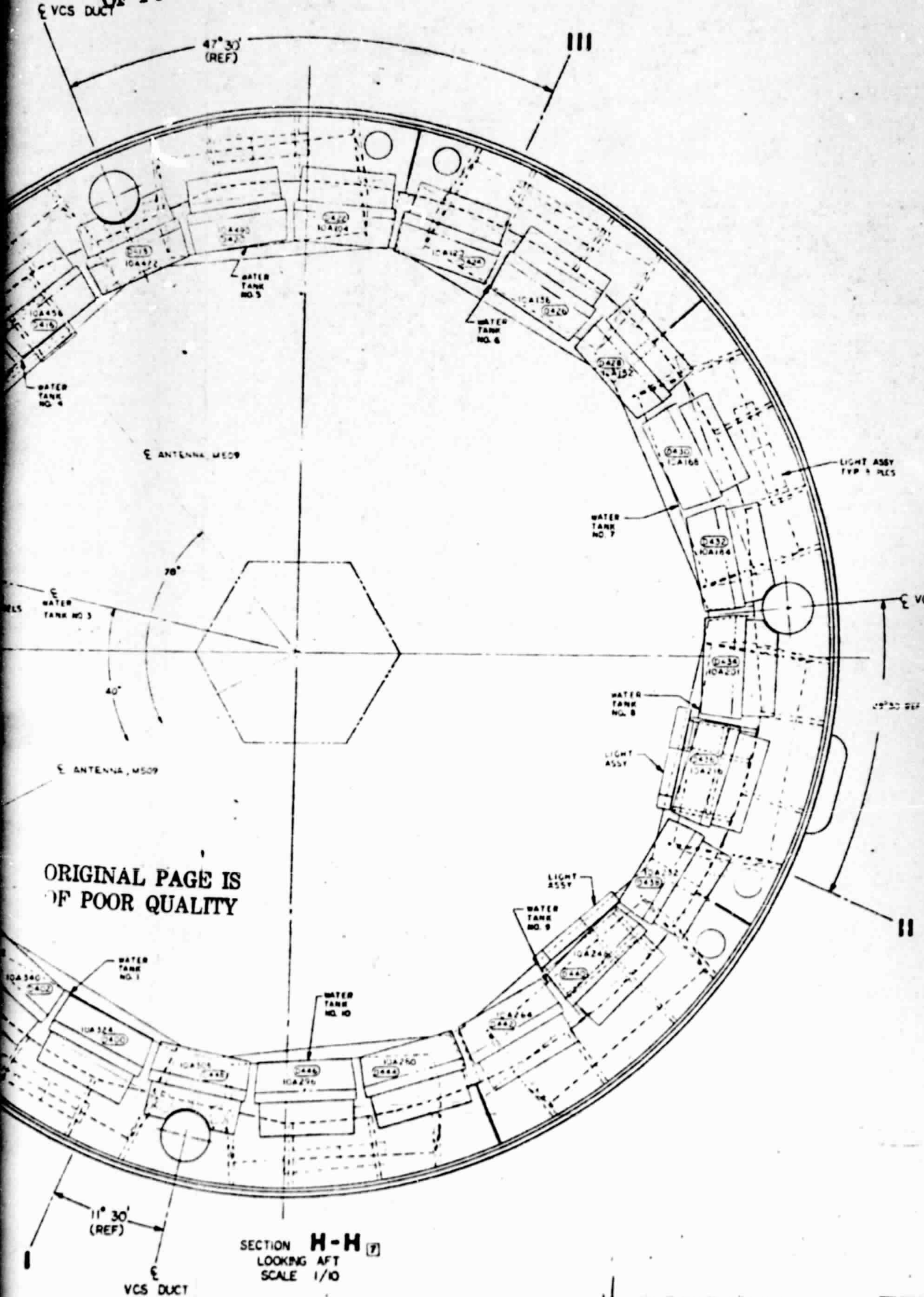

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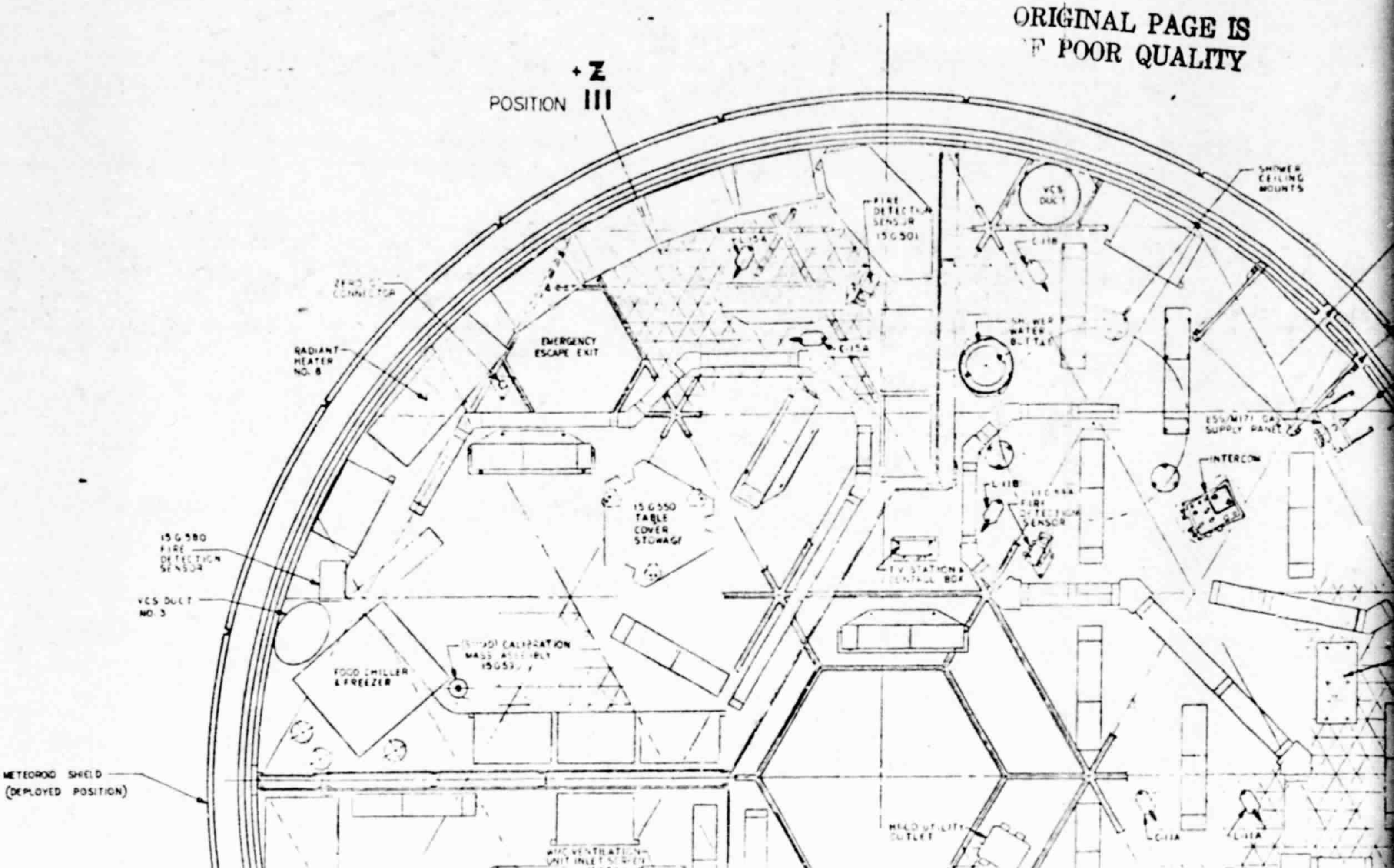

SECTION D-D
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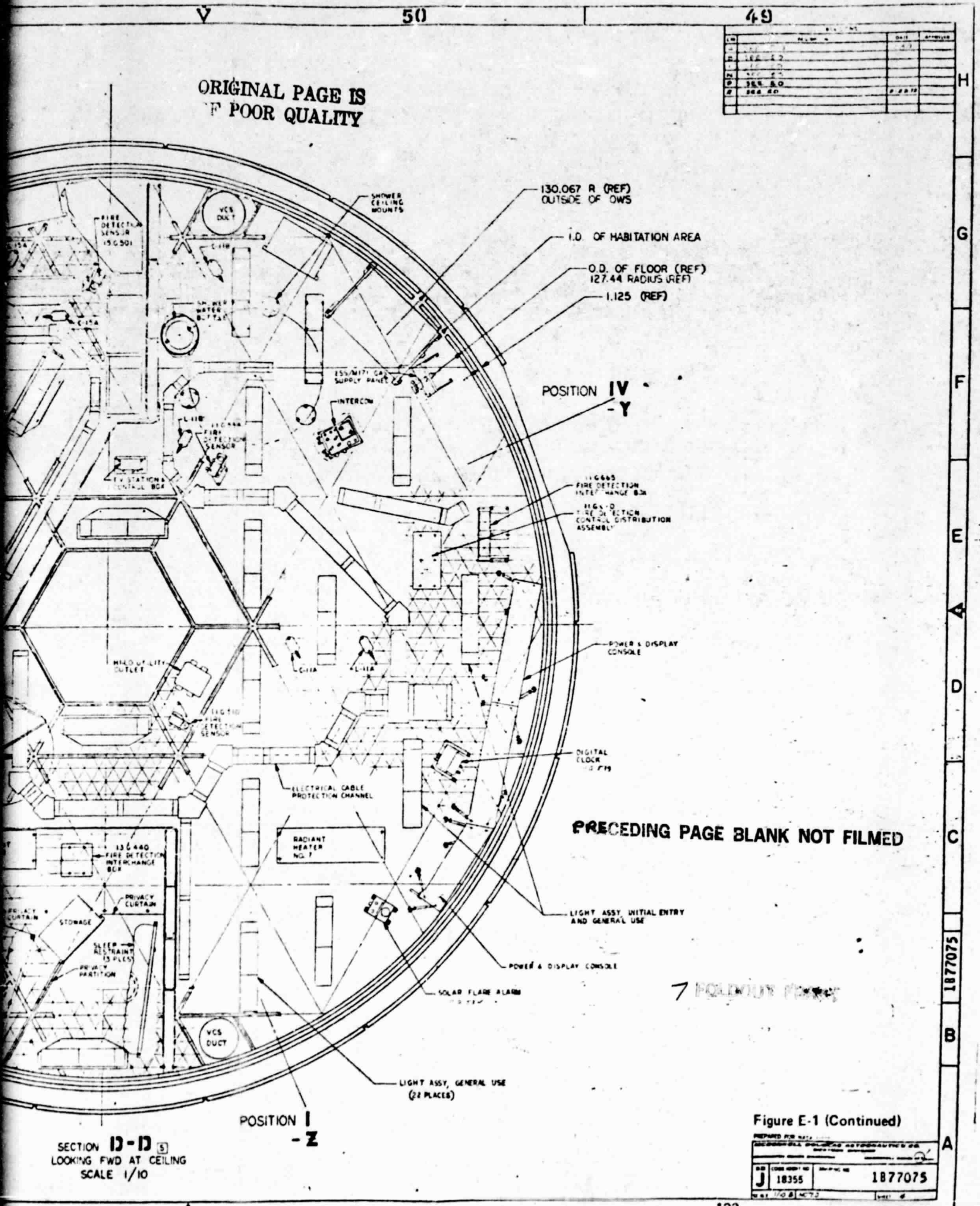

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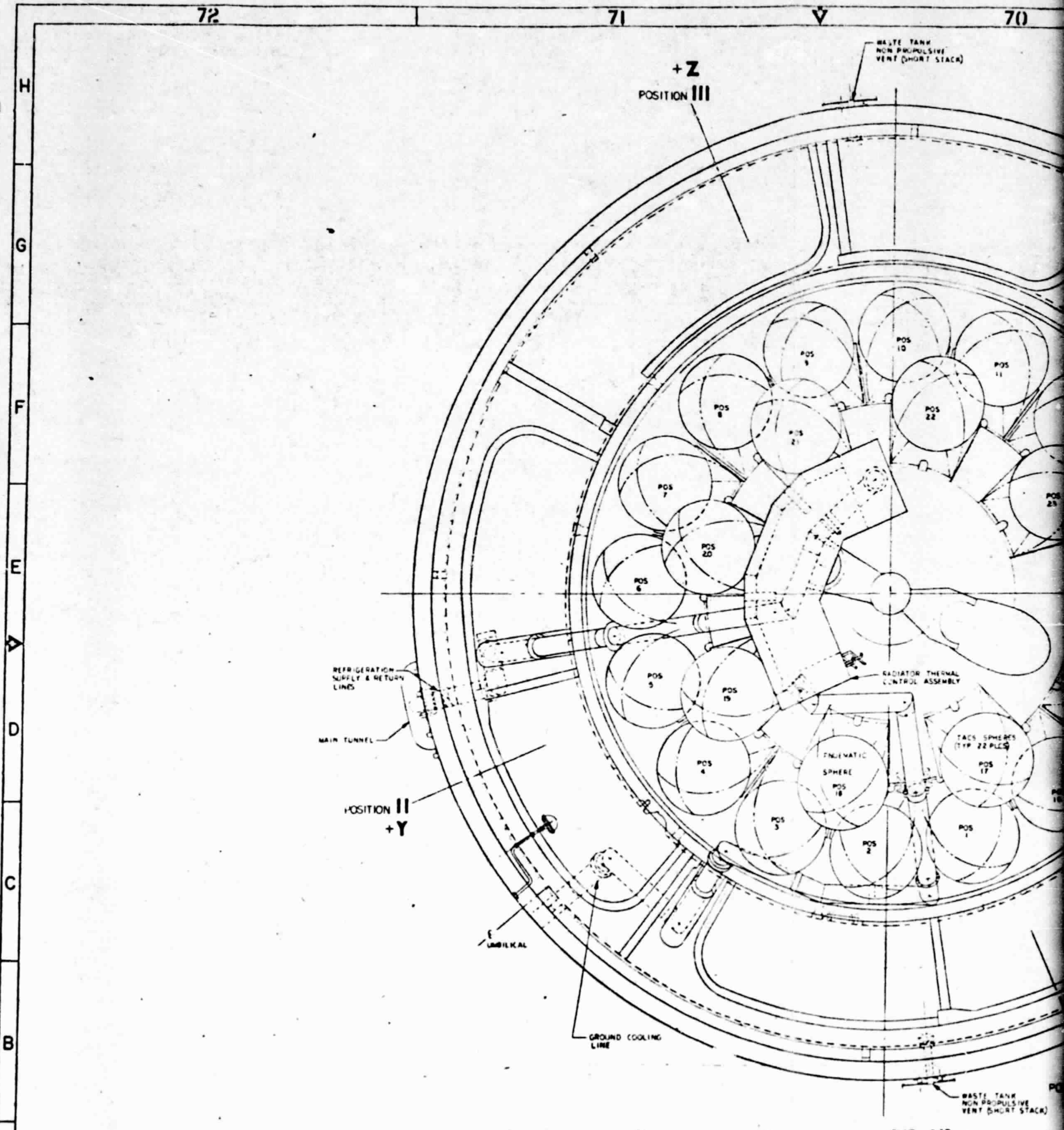

SECTION AD-AD
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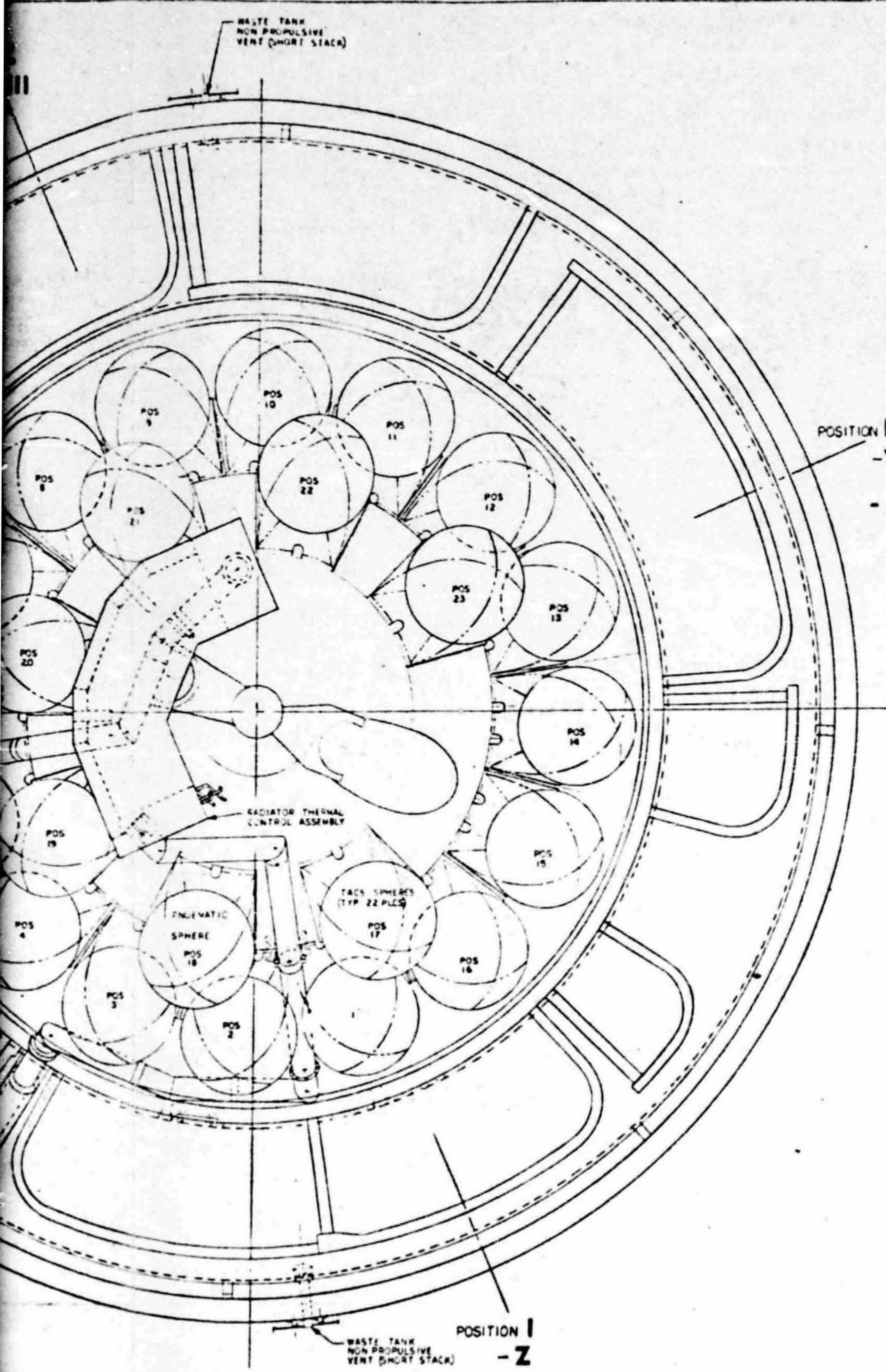

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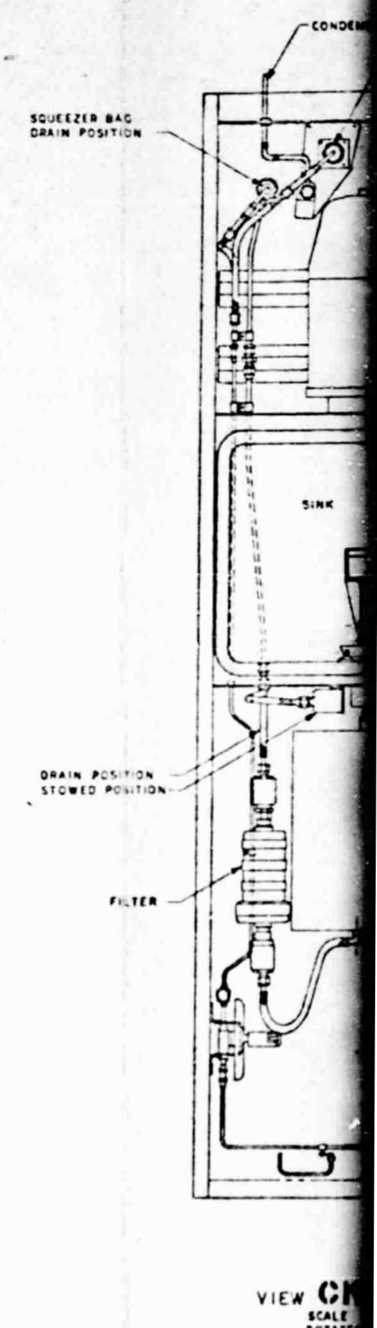

VIEW CK
SCALE
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16-370 LOCKER
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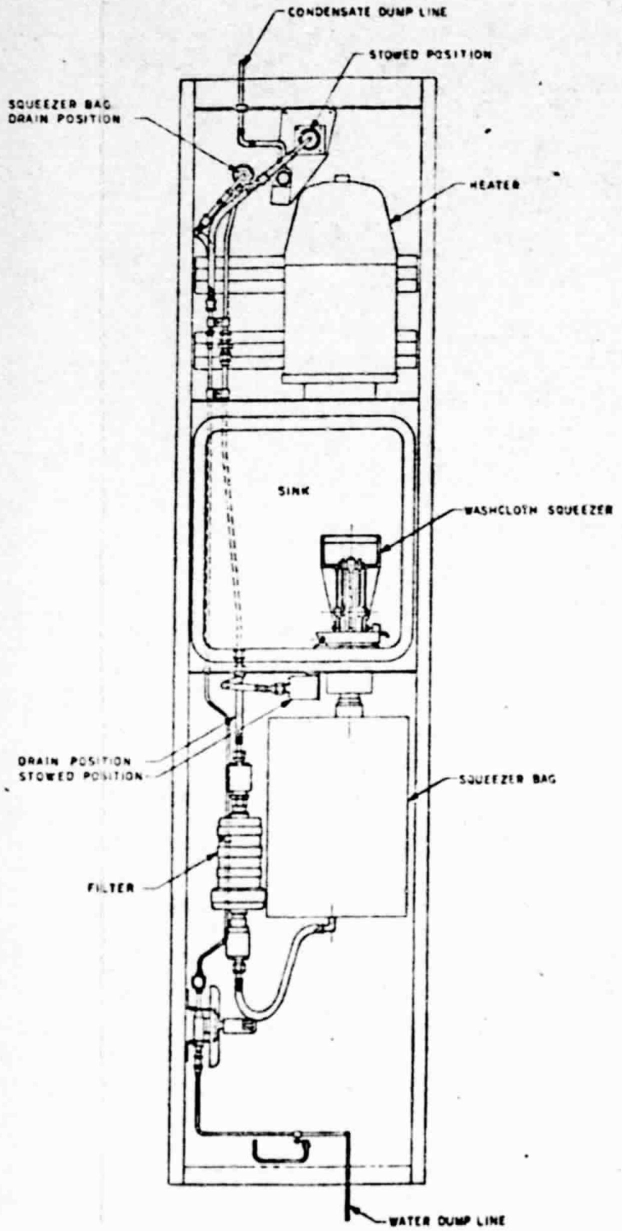

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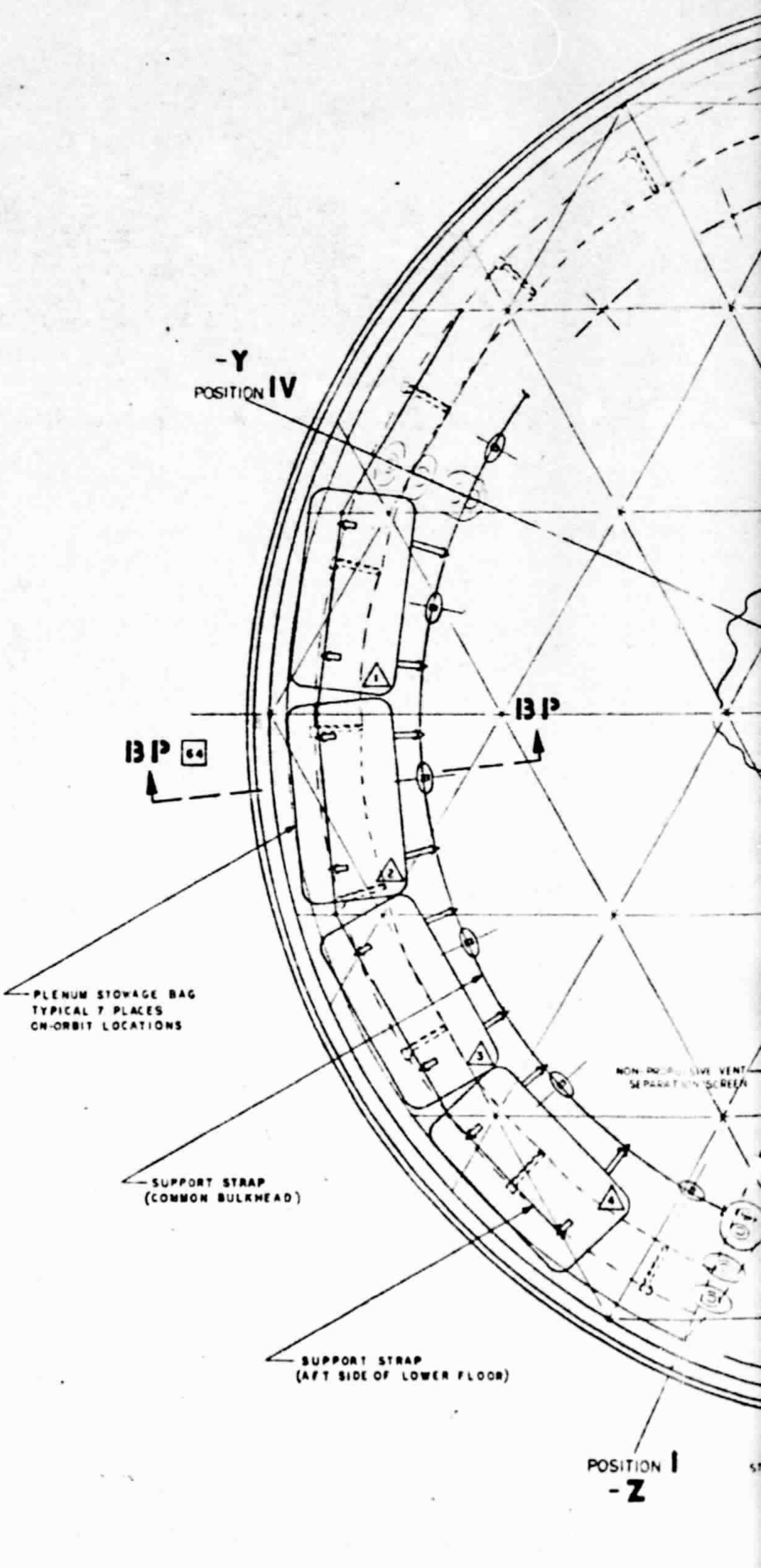
FOR CLARITY



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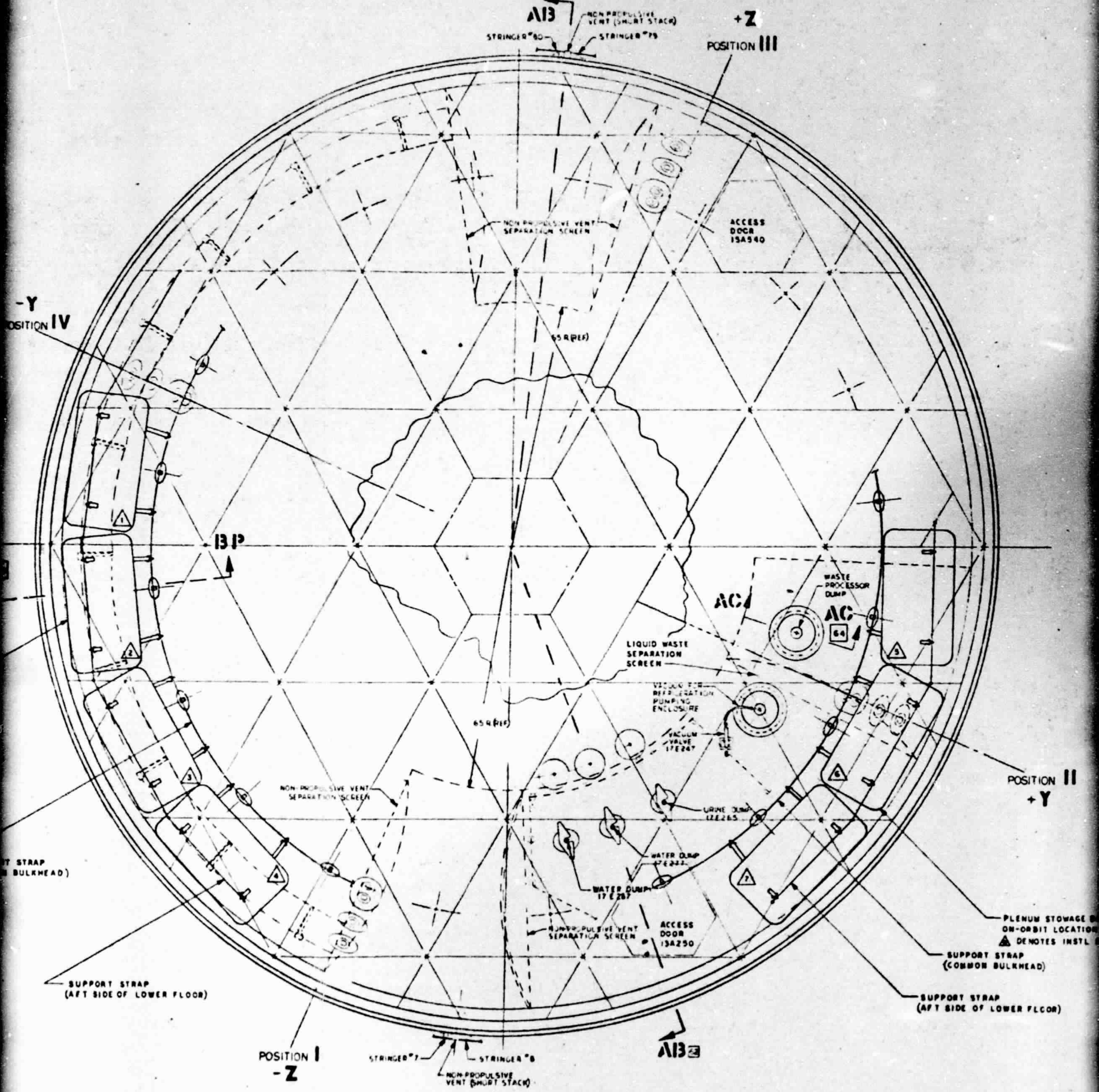

SECTION AA-AA 5
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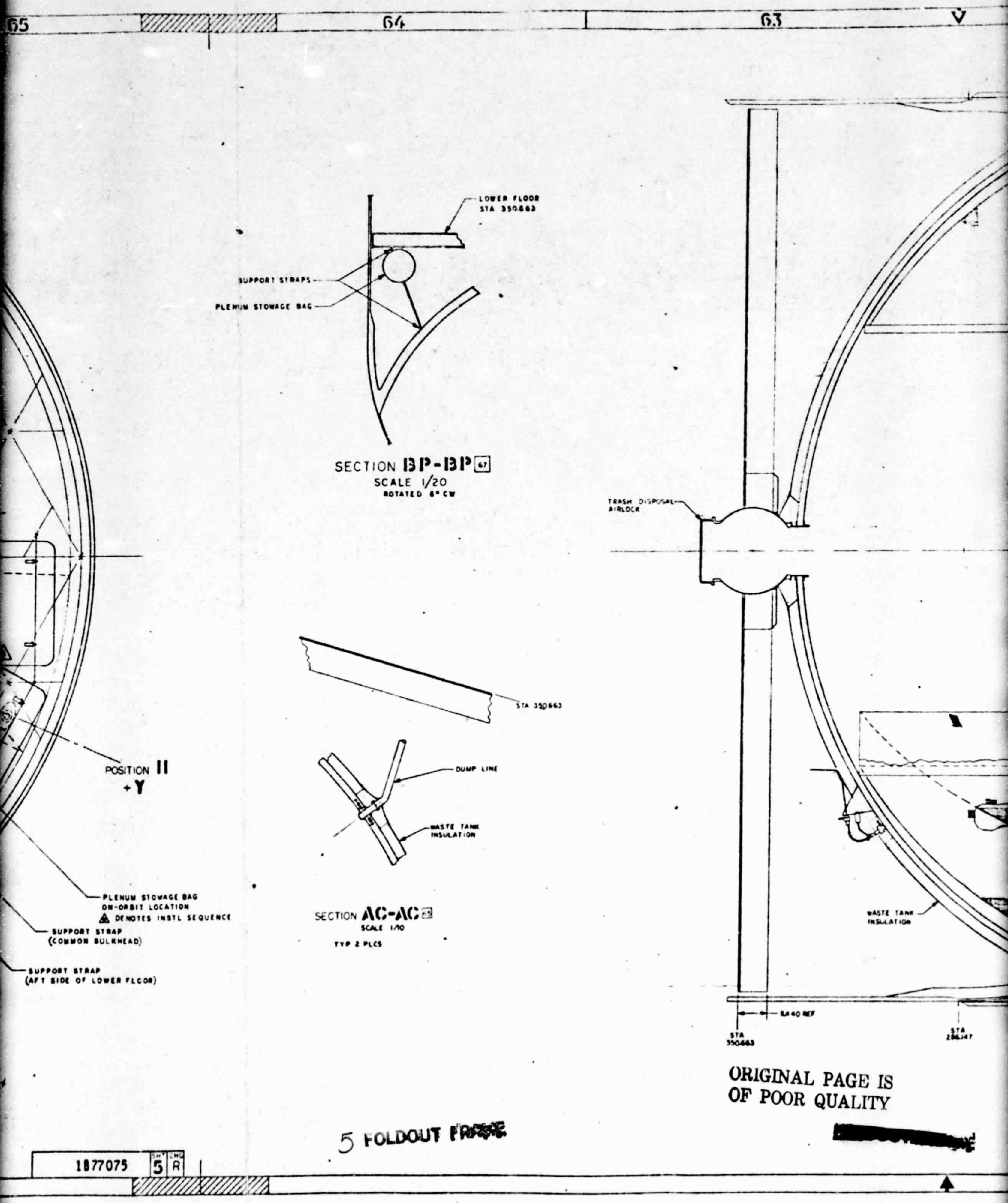

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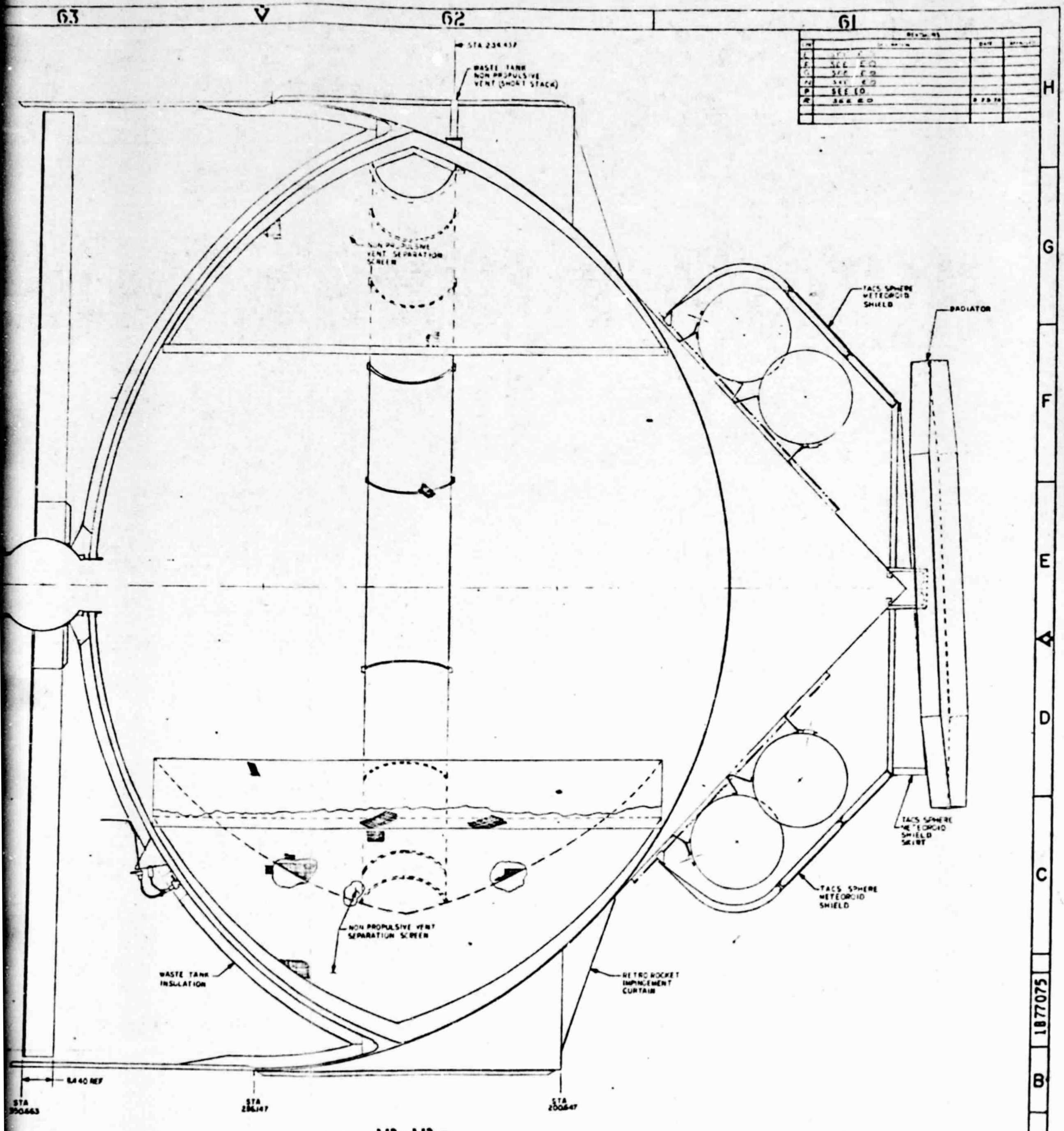

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SECTION AB-AB

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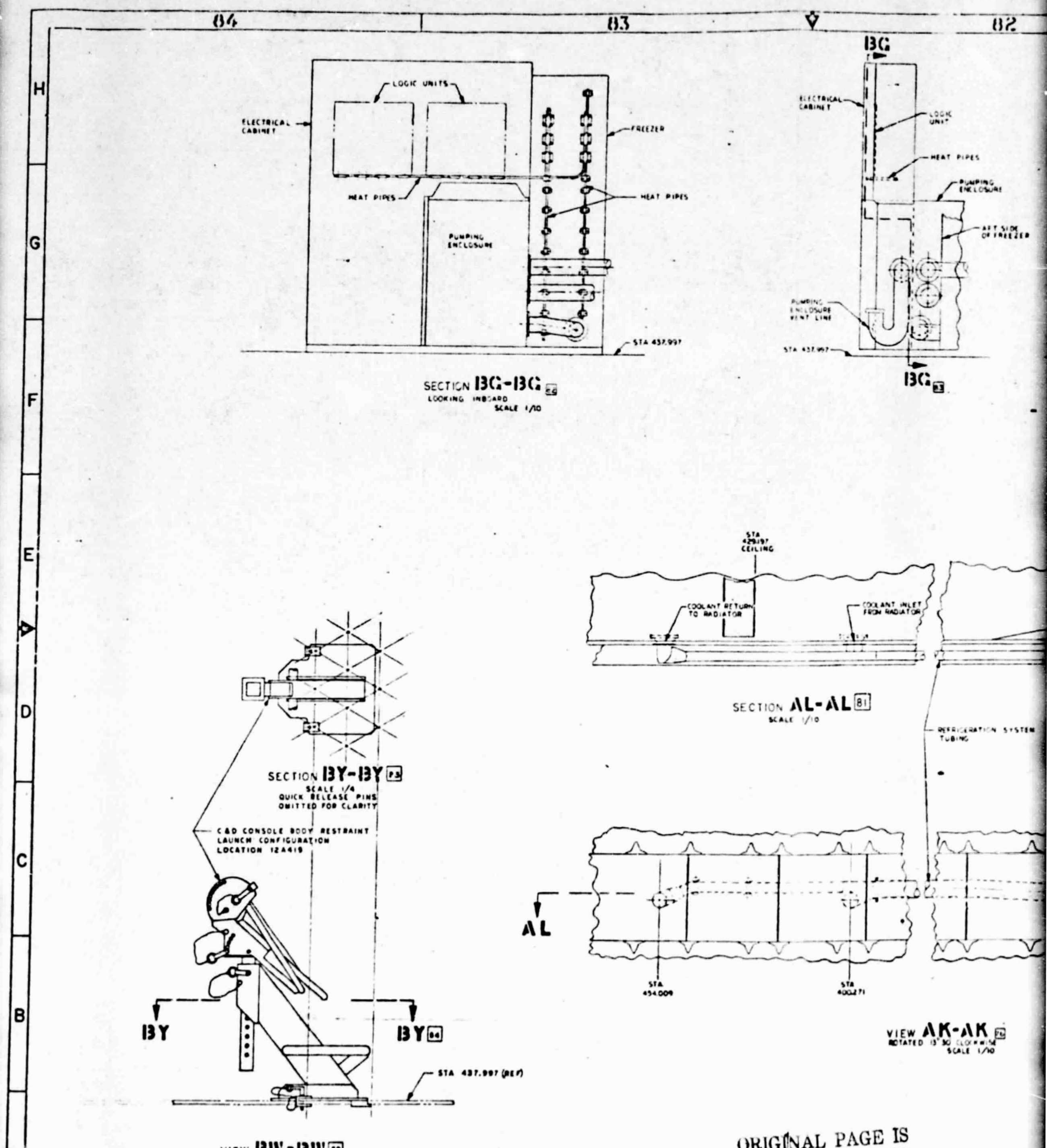

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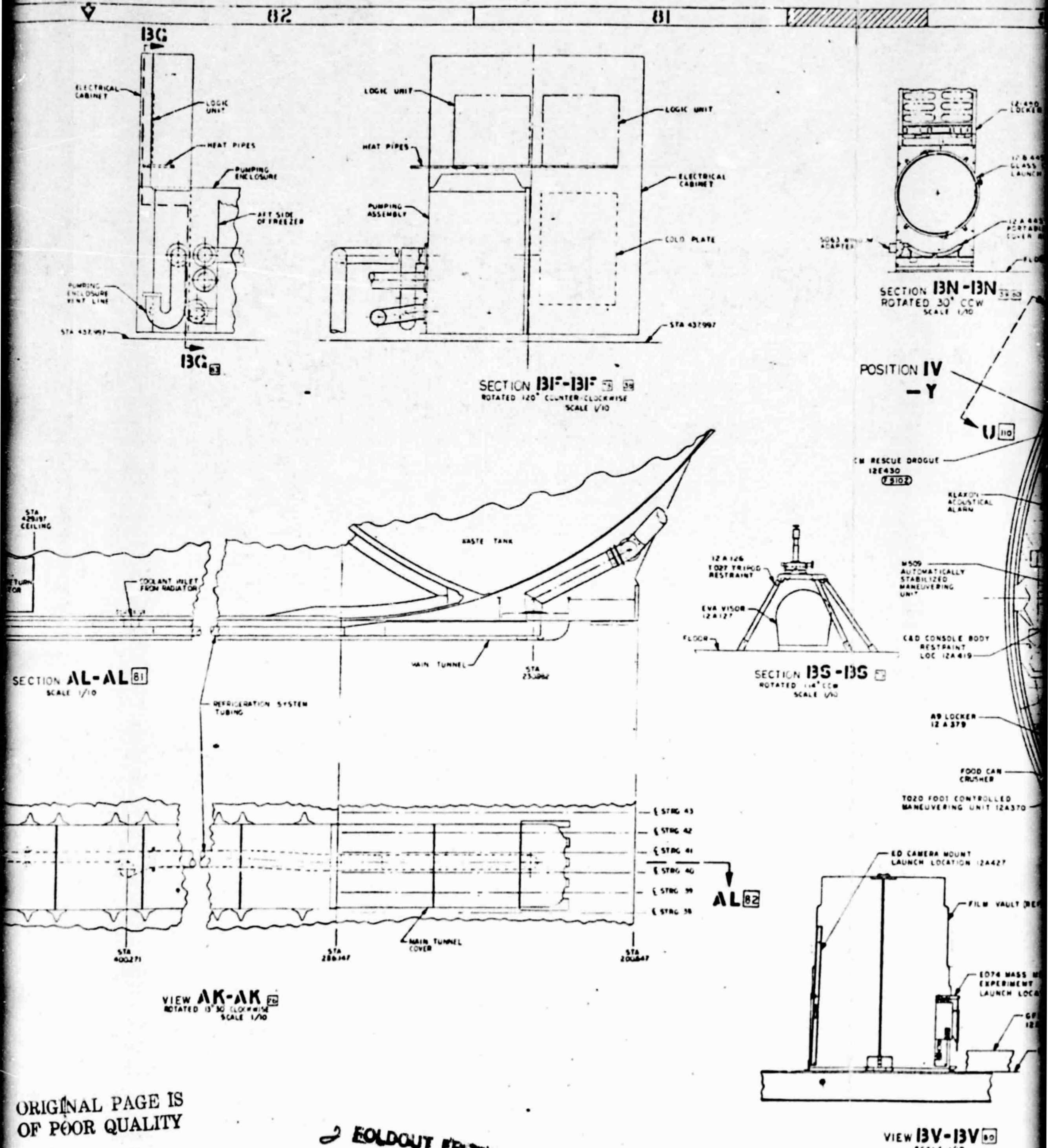

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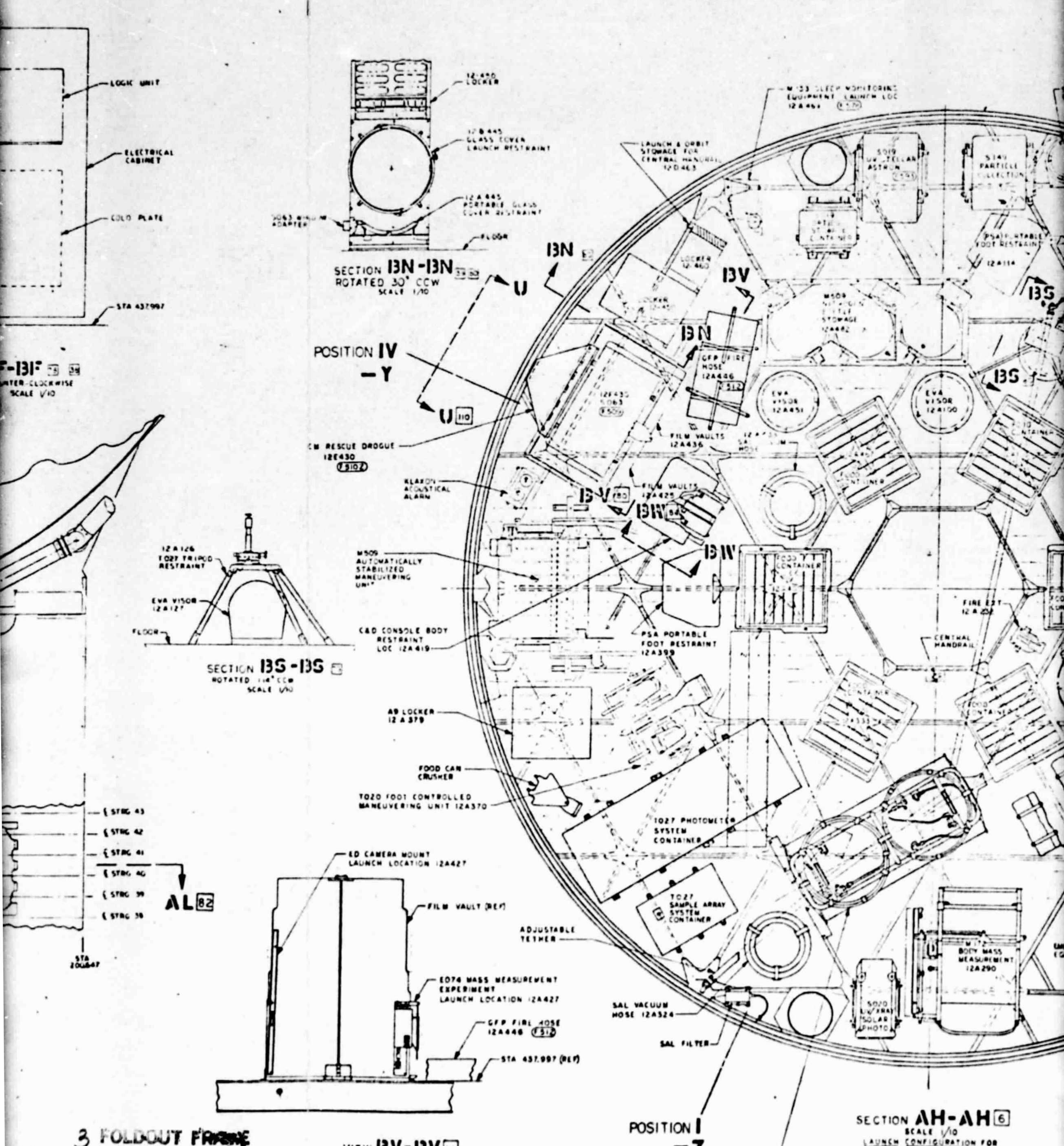

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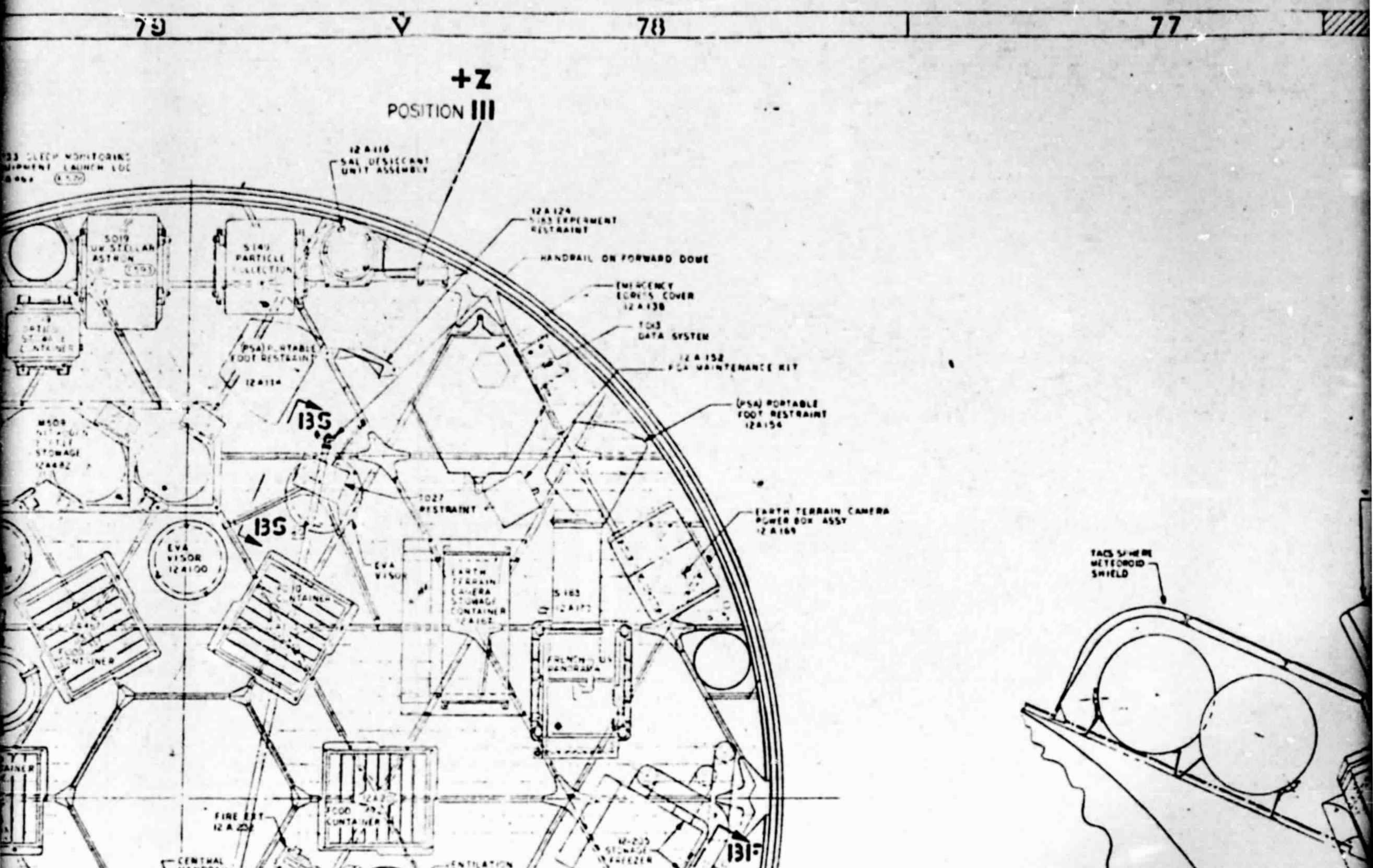

SECTION **AH-AH** 6
SCALE 1/10
LAUNCH CONFIGURATION FOR
FORWARD COMPARTMENT FLOOR
VIEW LOOKING AFT

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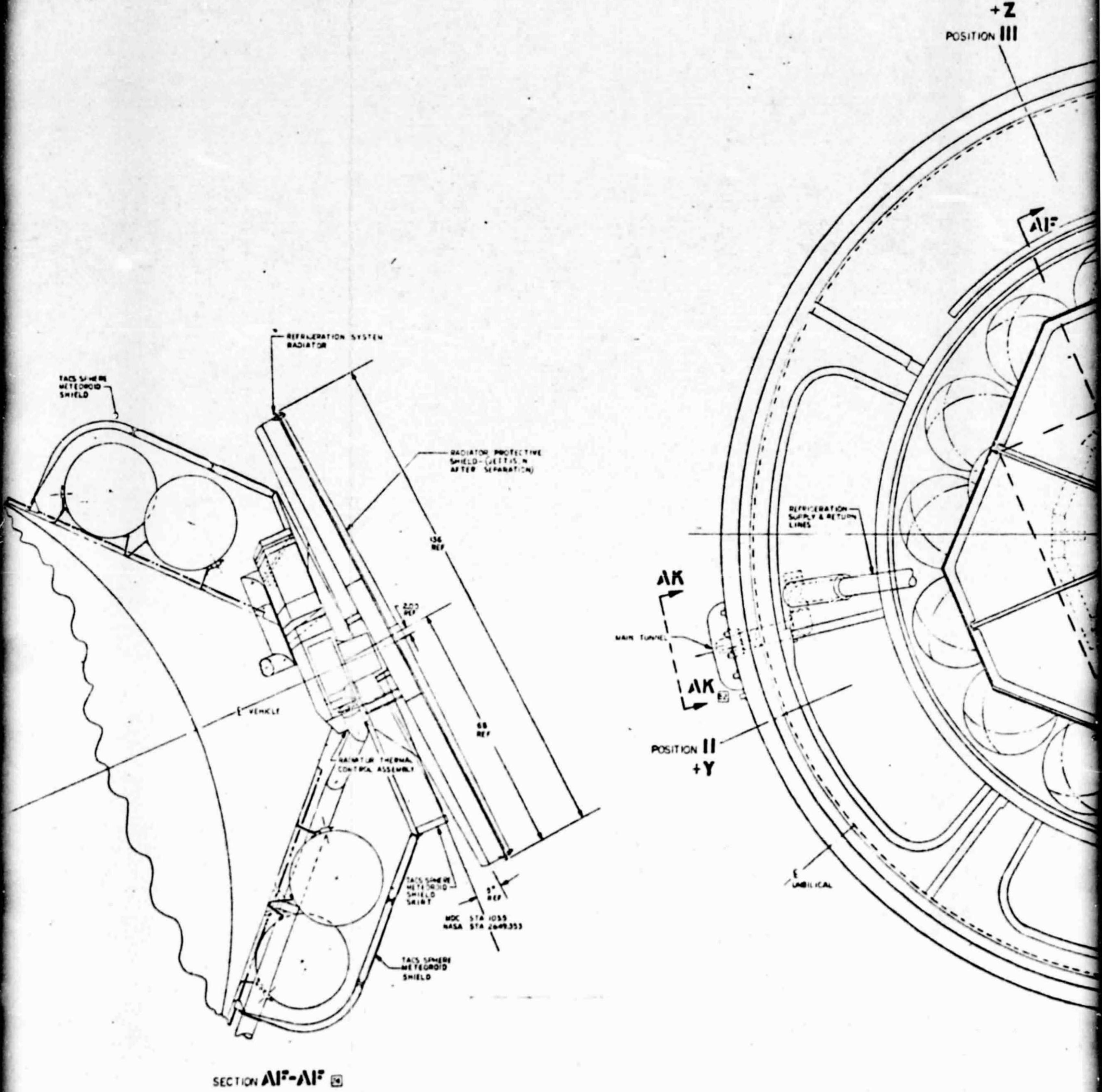

SECTION AF-AF

SCALE 1/10

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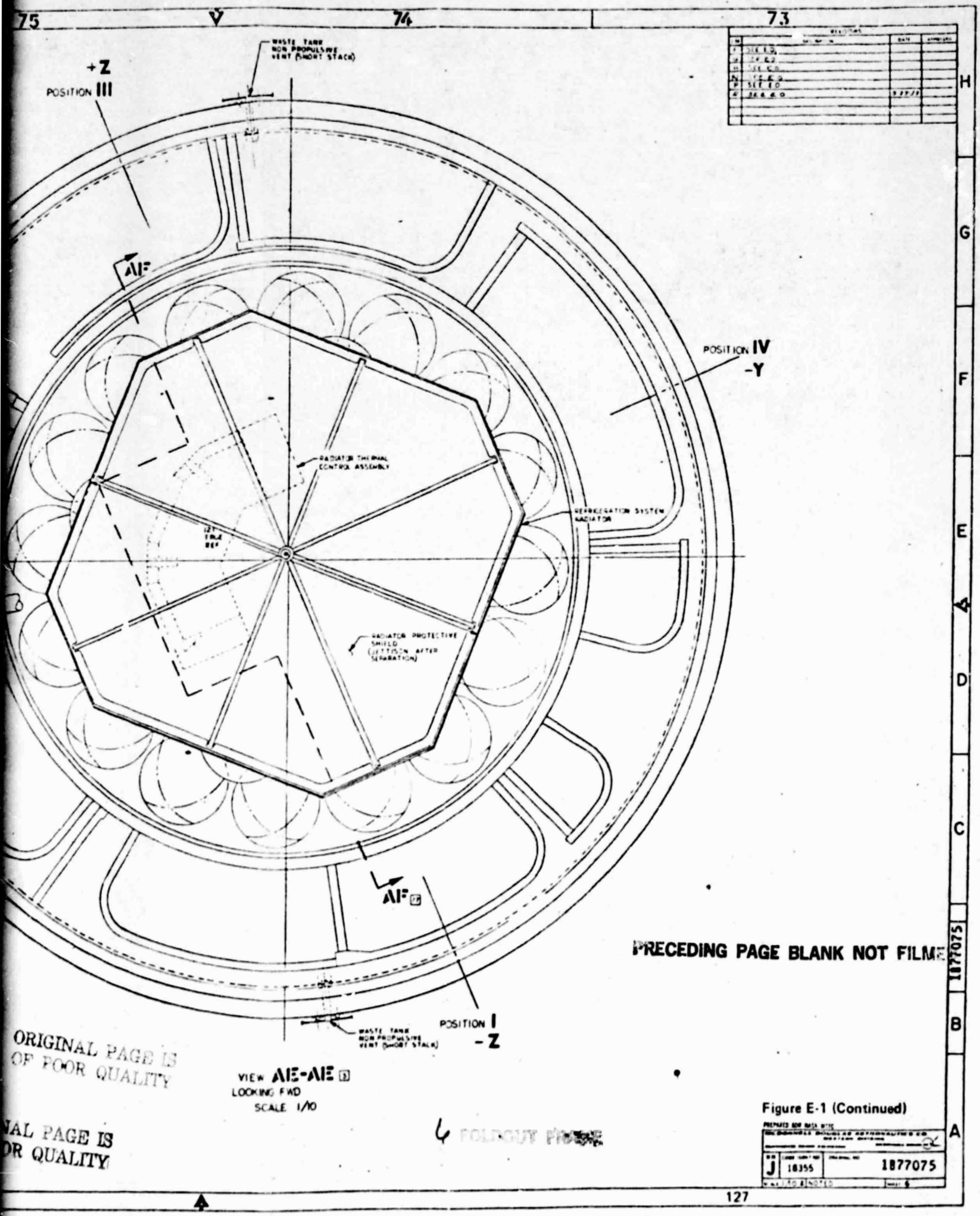

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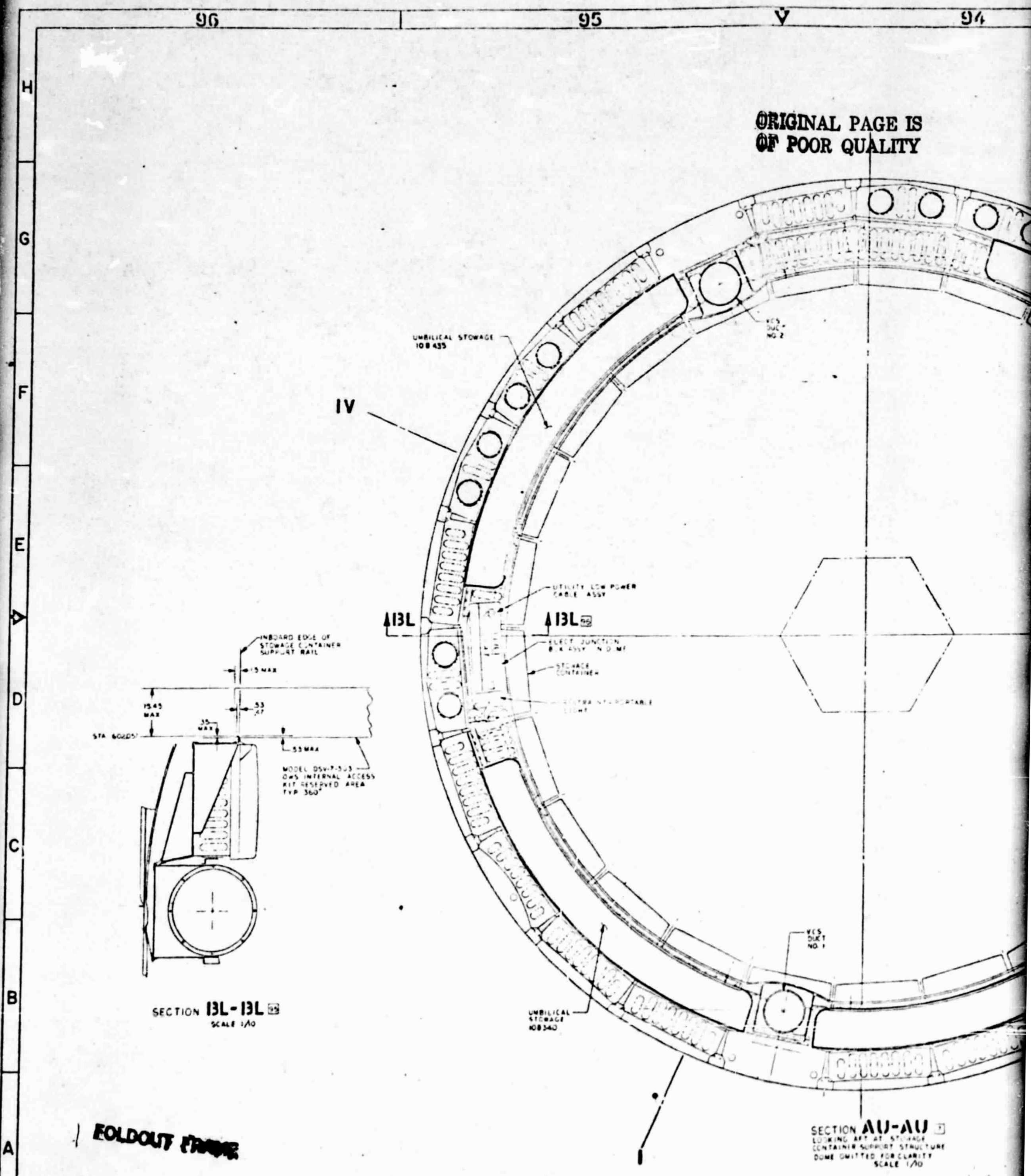

SECTION BL-BL
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SECTION AU-AU
LOOKING AFT AT STOWAGE
CONTAINER SUPPORT STRUCTURE
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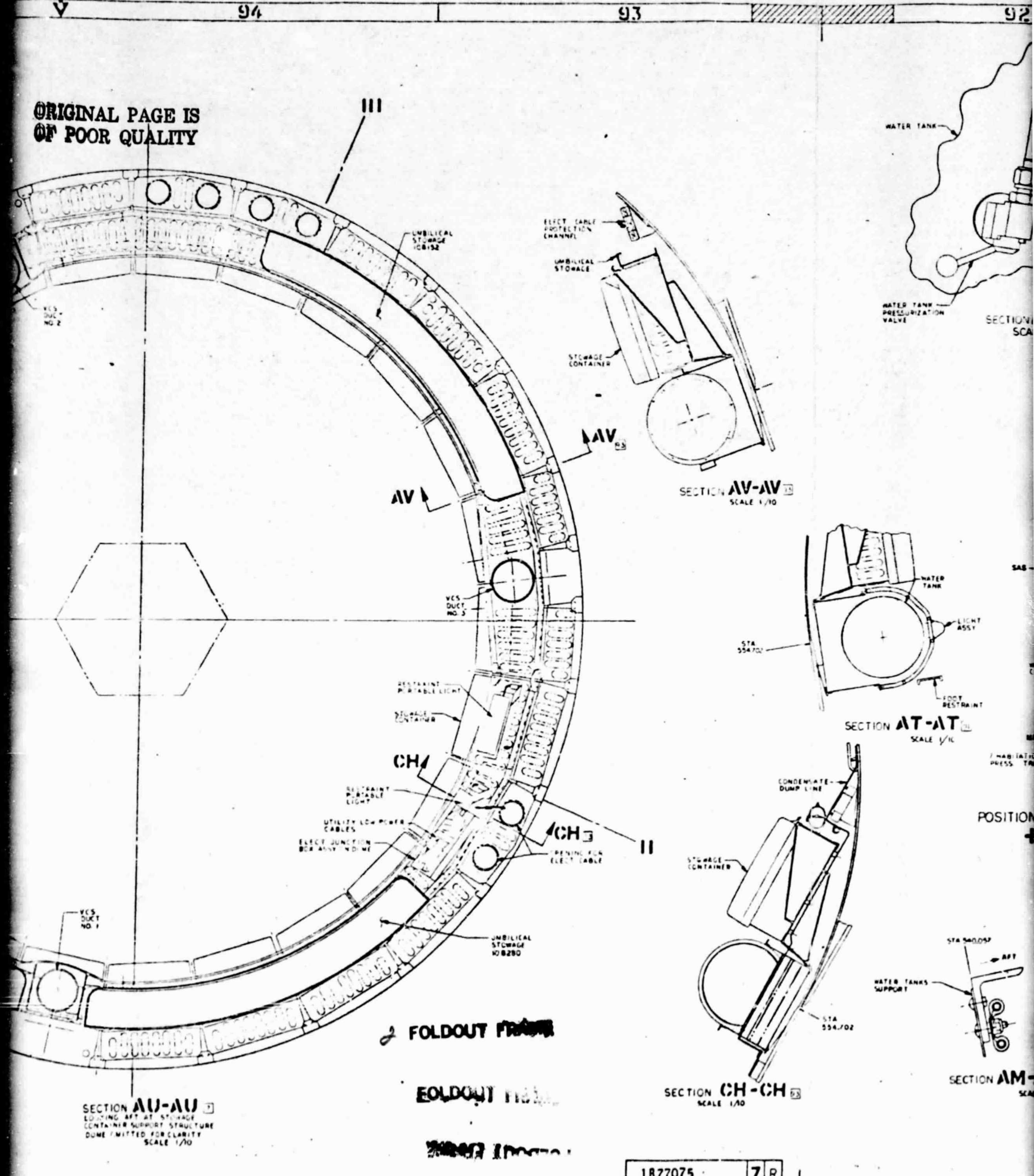

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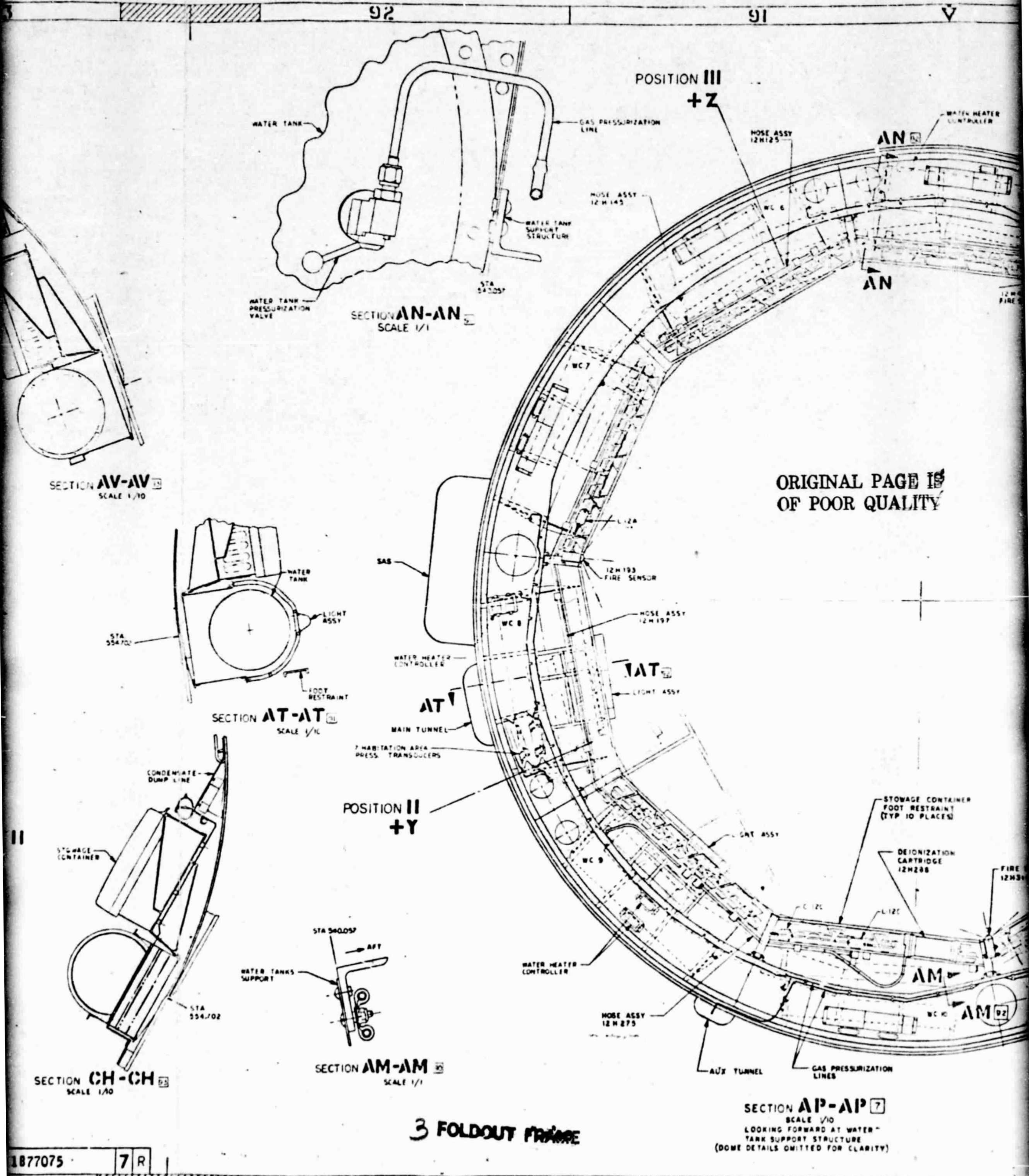

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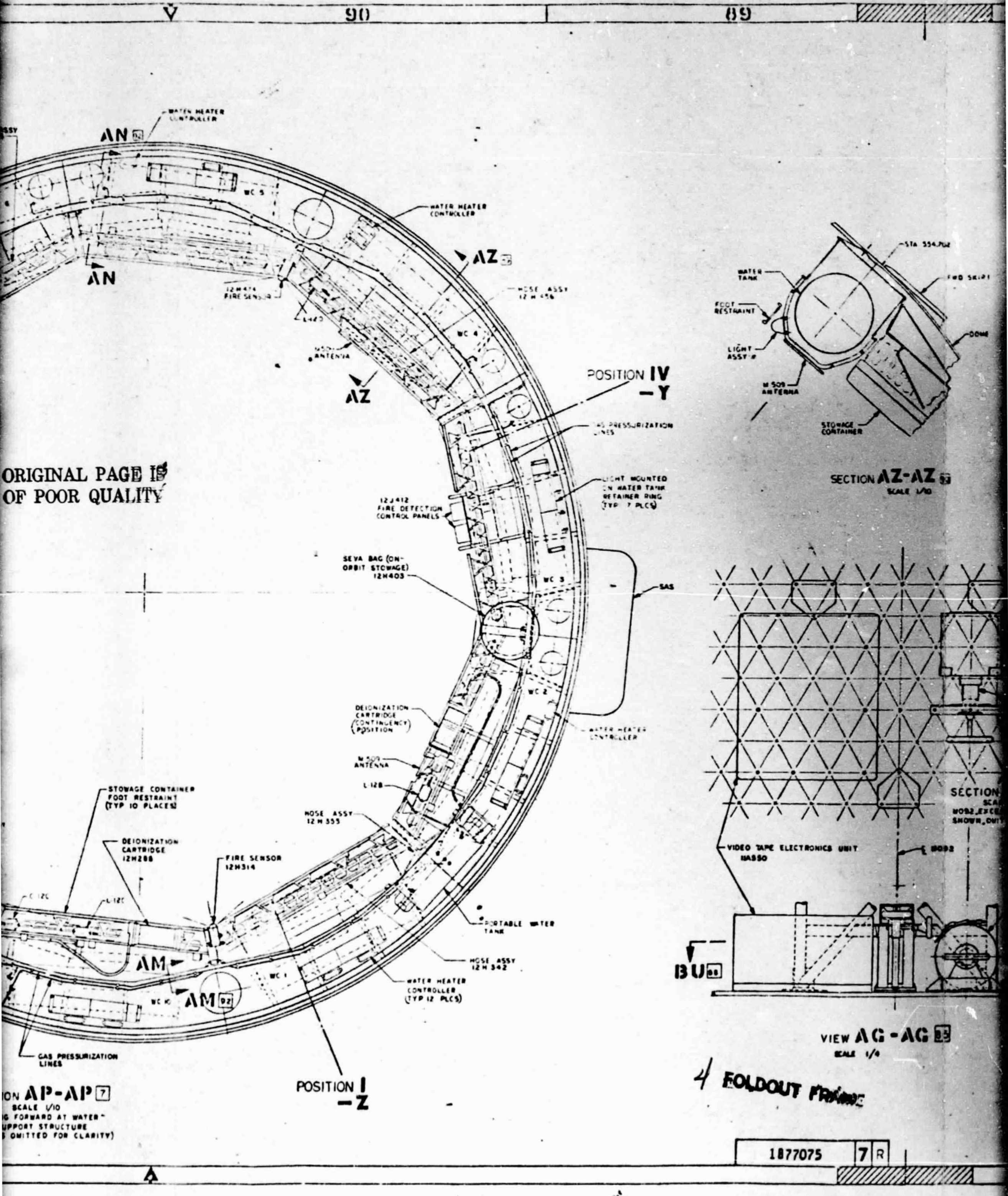

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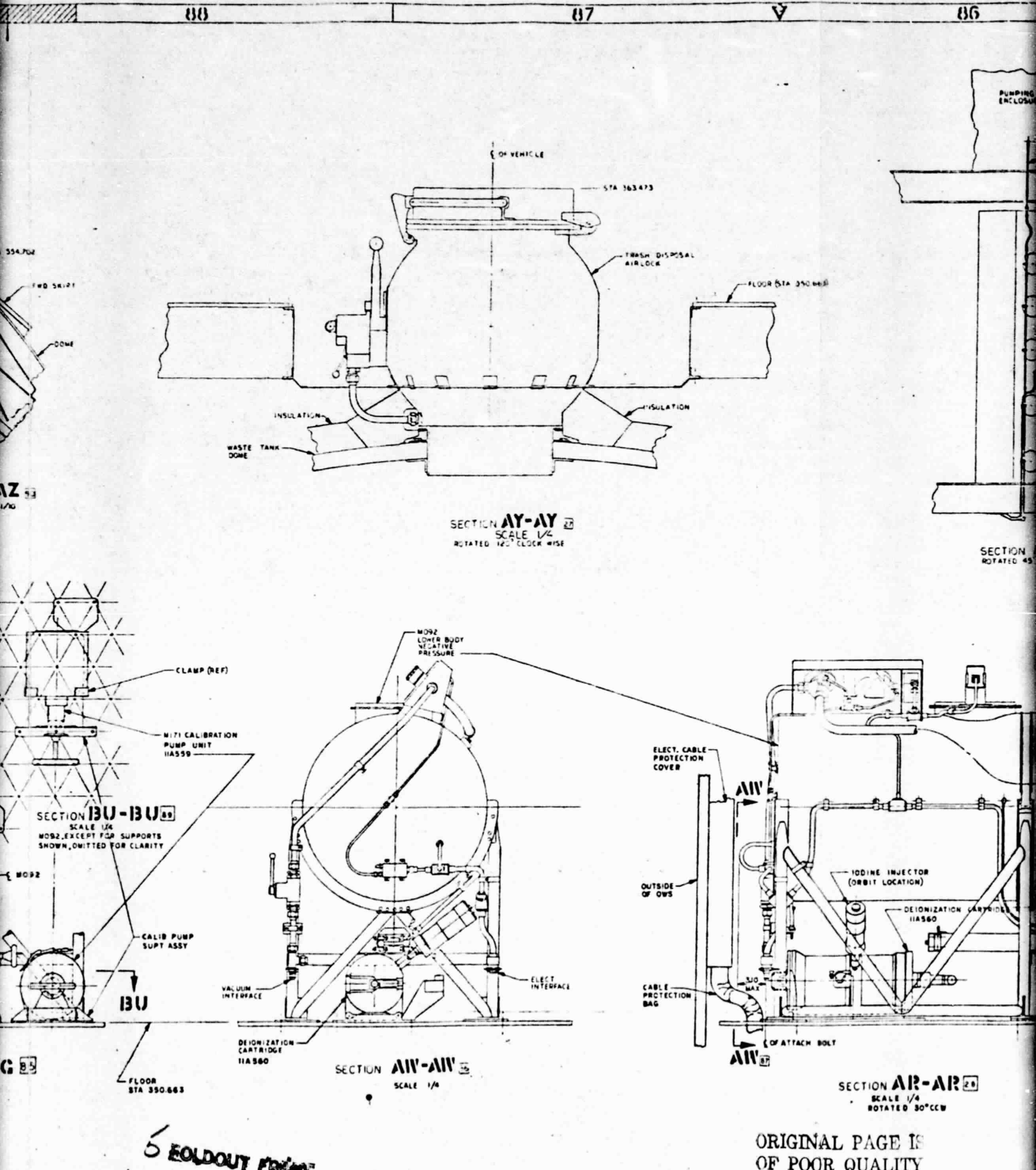

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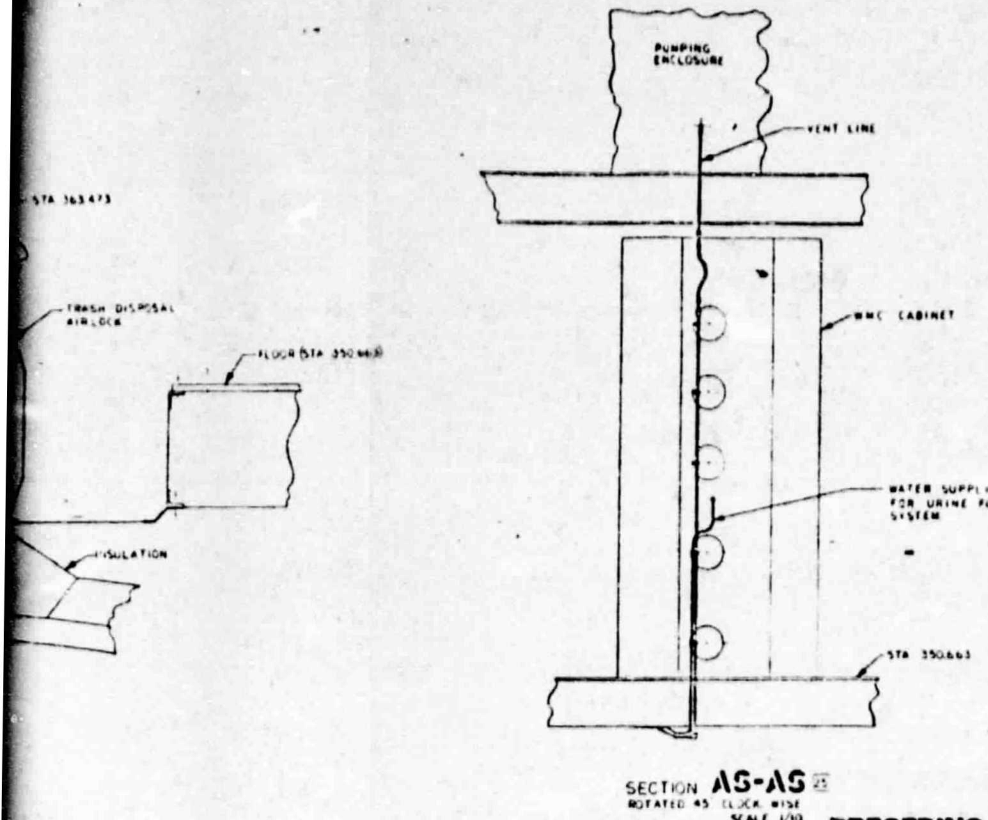

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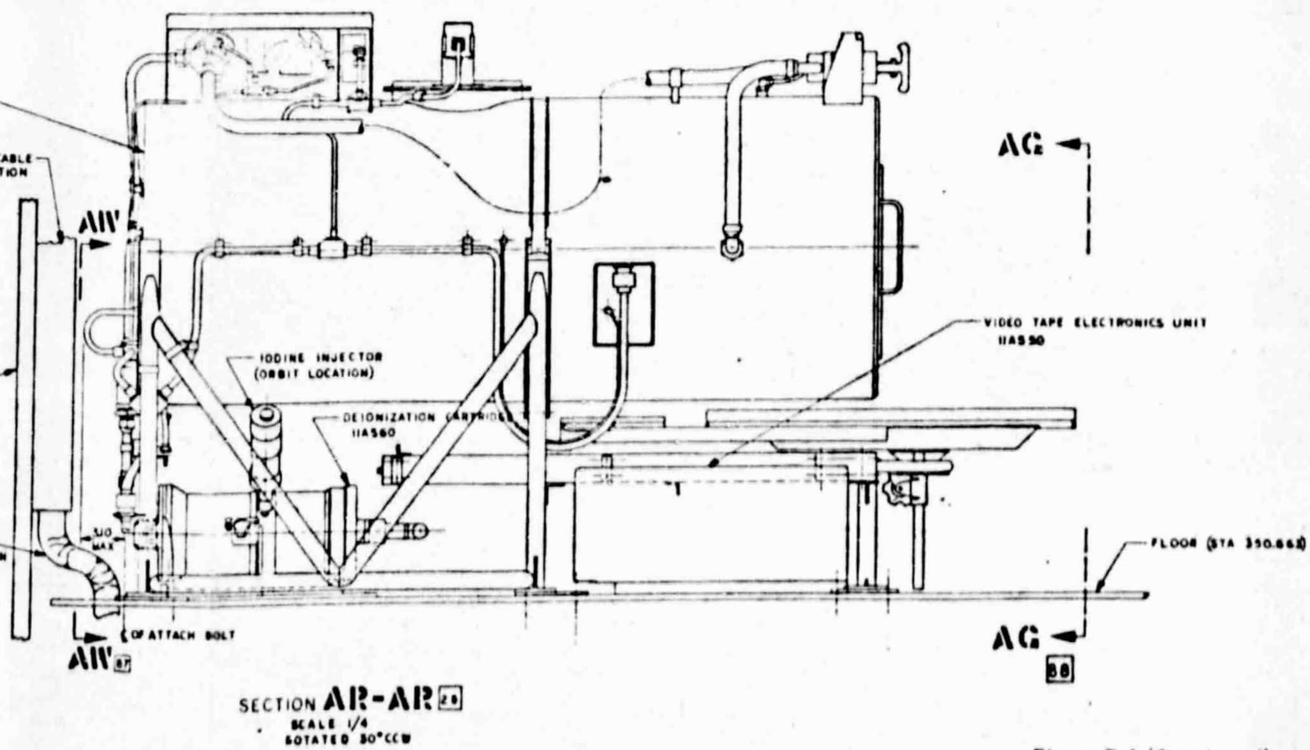

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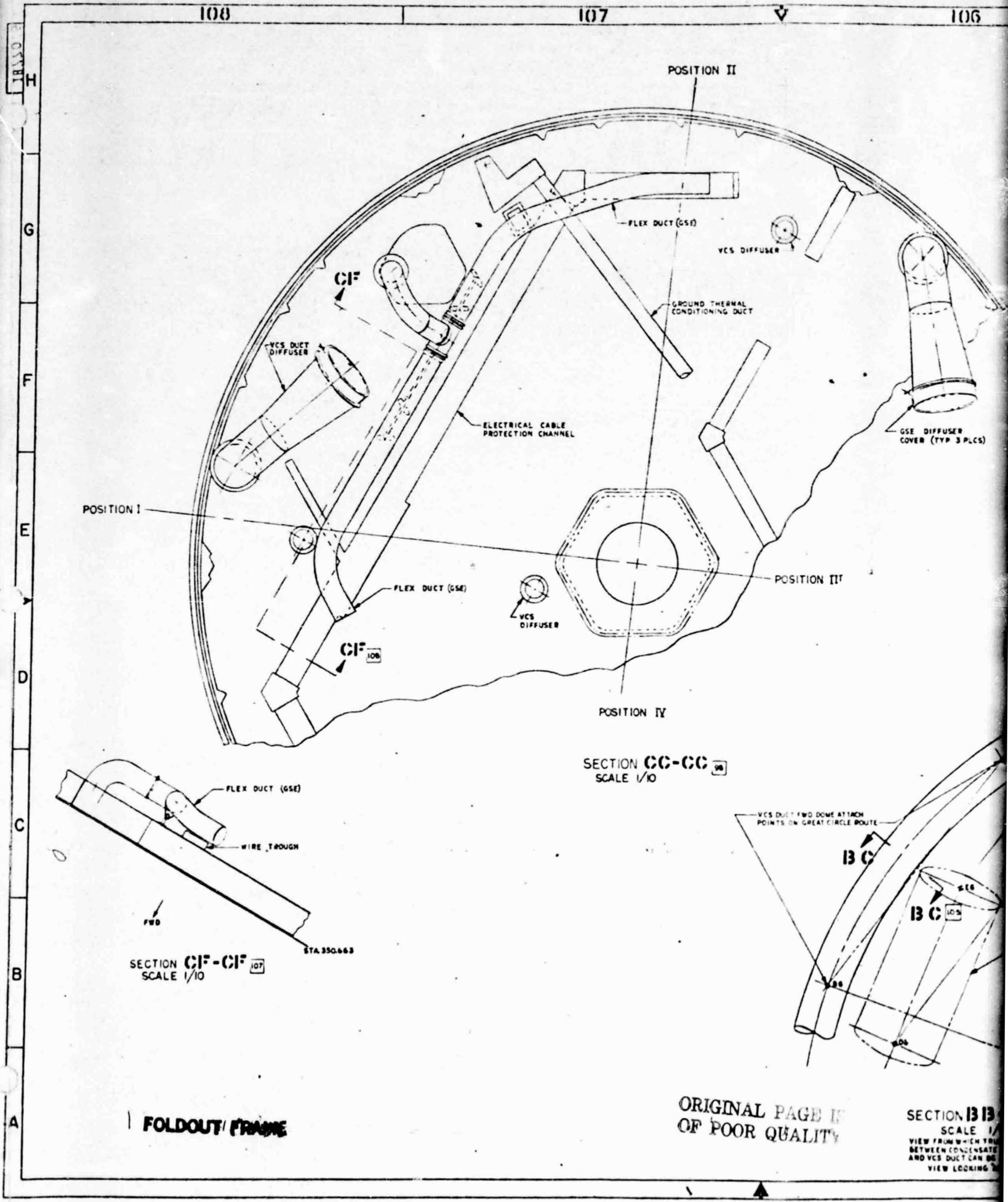

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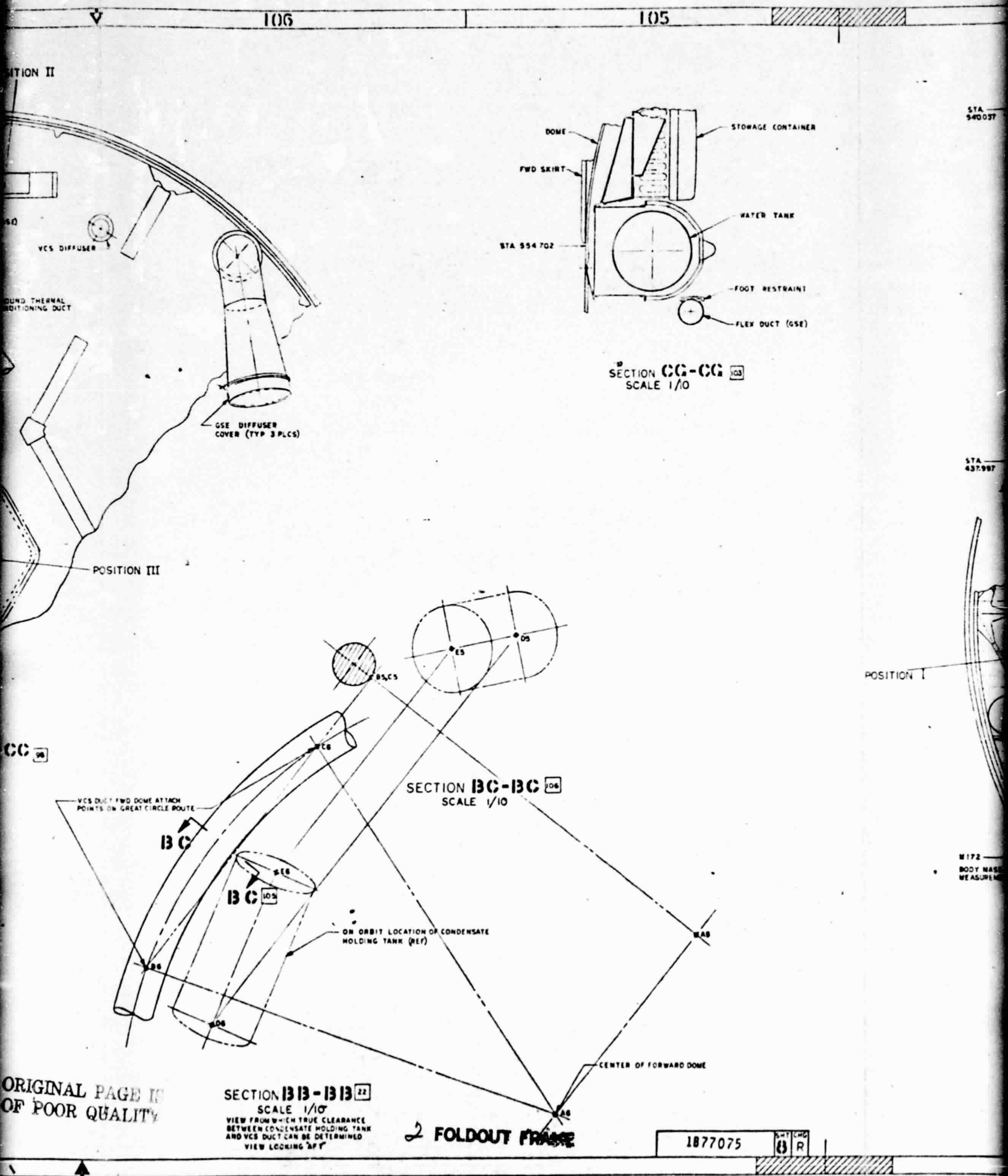
106
105
POSITION II
VCS DIFFUSER
GROUND THERMAL CONDITIONING DUCT
GSE DIFFUSER COVER (TYP 3 PLCS)
POSITION III
DOME
FWD SKIRT
STOWAGE CONTAINER
WATER TANK
STA 554.702
FOOT RESTRAINT
FLEX DUCT (GSE)
SECTION CG-CG 103
SCALE 1/10
STA 540.037
STA 437.997
POSITION I
CC 98
B5,C5
E5
D5
C6
E6
B6
D6
A6
A5
SECTION BC-BC 106
SCALE 1/10
VCS DUCT FWD DOME ATTACH POINTS ON GREAT CIRCLE ROUTE
BC
BC 105
ON ORBIT LOCATION OF CONDENSATE HOLDING TANK (REF)
CENTER OF FORWARD DOME
M172
BODY MASS MEASUREMENT
SECTION BB-BB 22
SCALE 1/10
VIEW FROM WHICH TRUE CLEARANCE BETWEEN CONDENSATE HOLDING TANK AND VCS DUCT CAN BE DETERMINED
VIEW LOOKING AFT
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SHT 8
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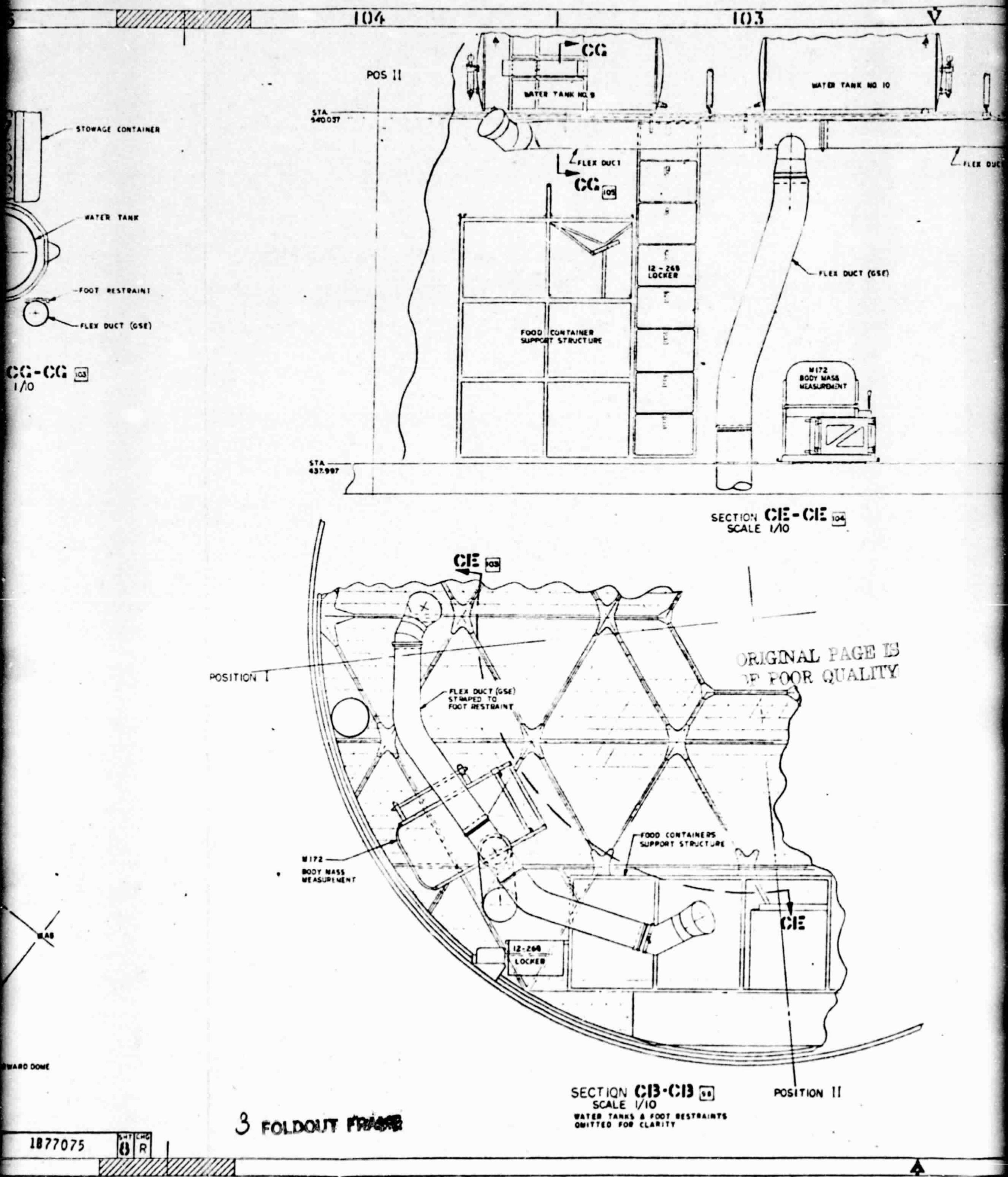

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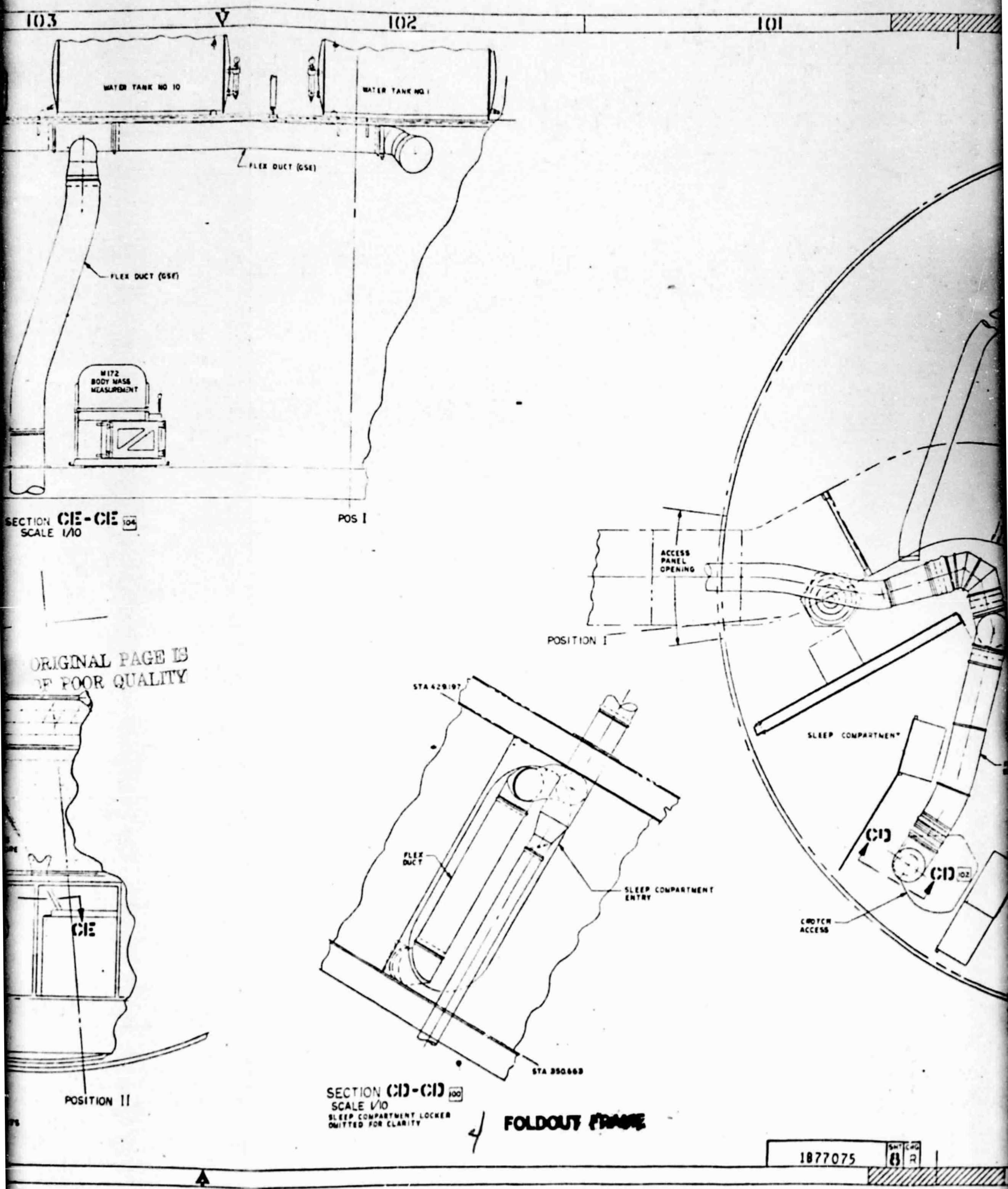

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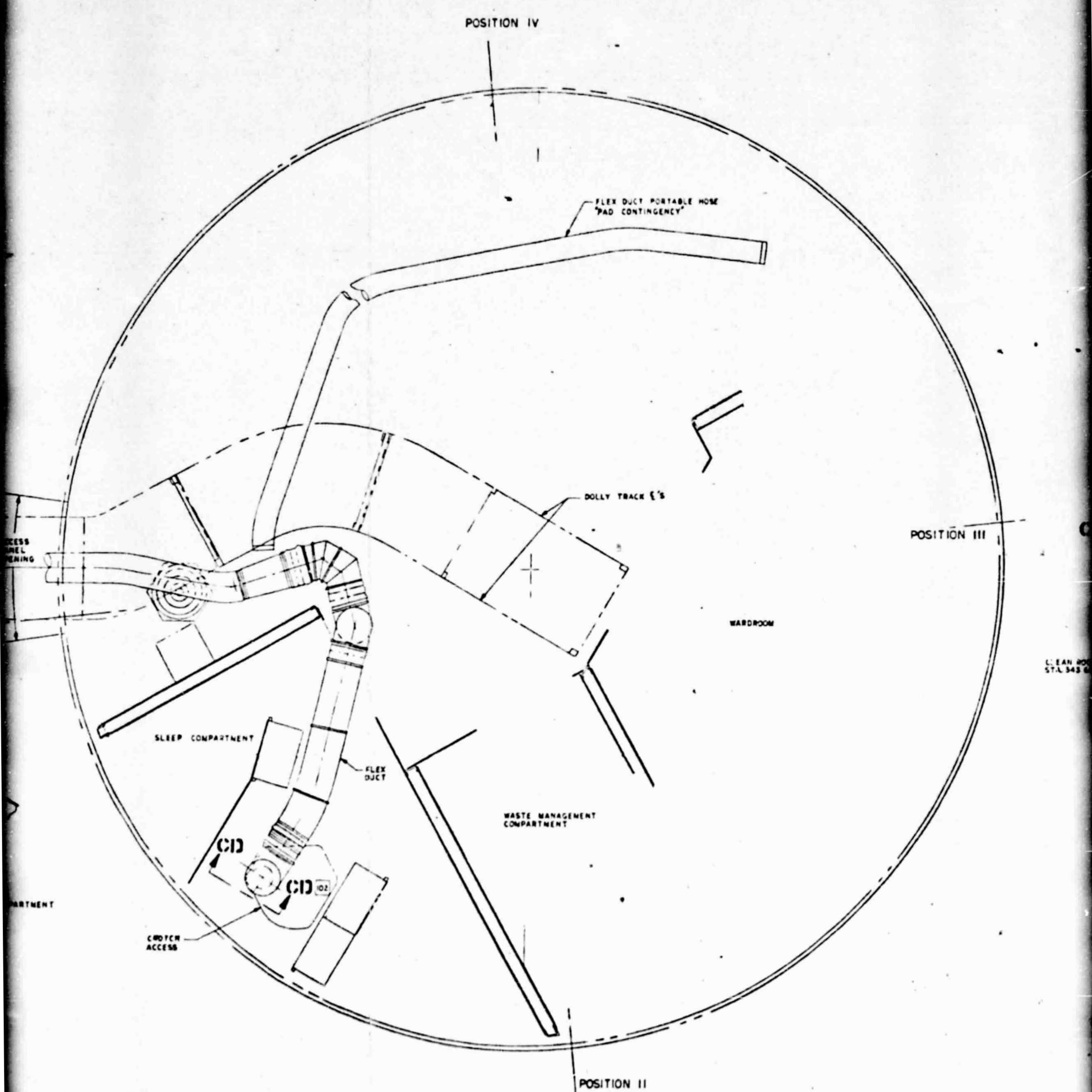

SECTION CA - CA 97
SCALE 1/10

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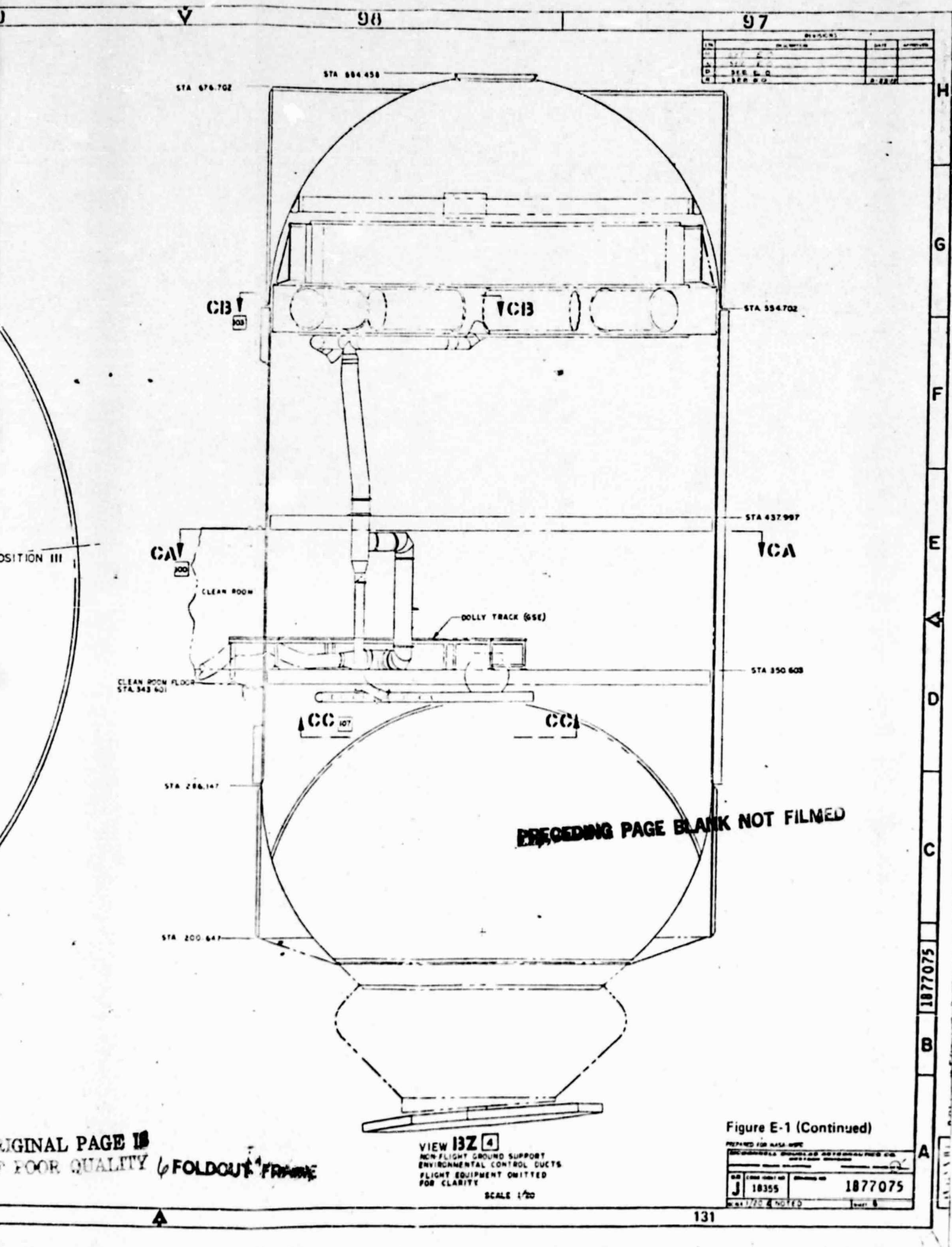

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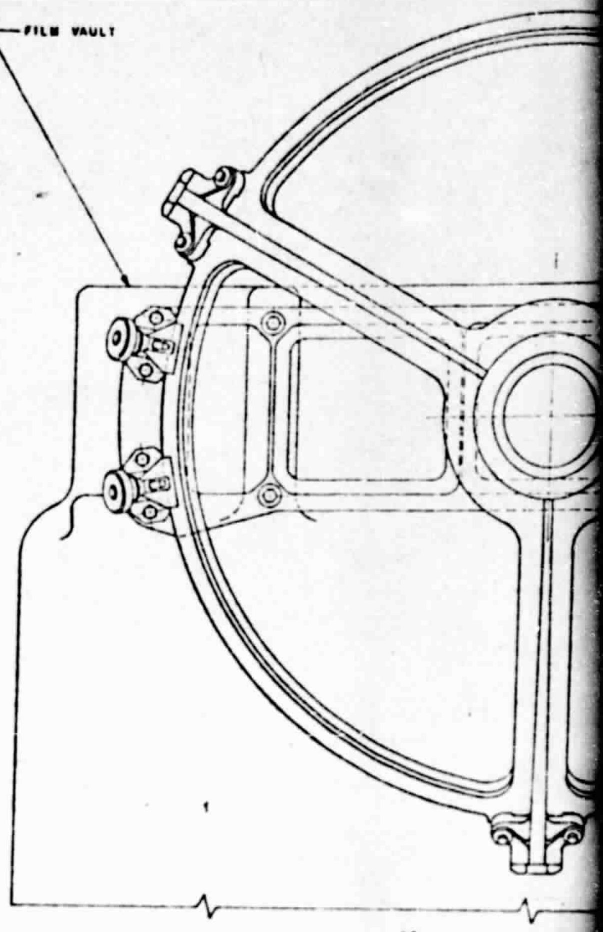

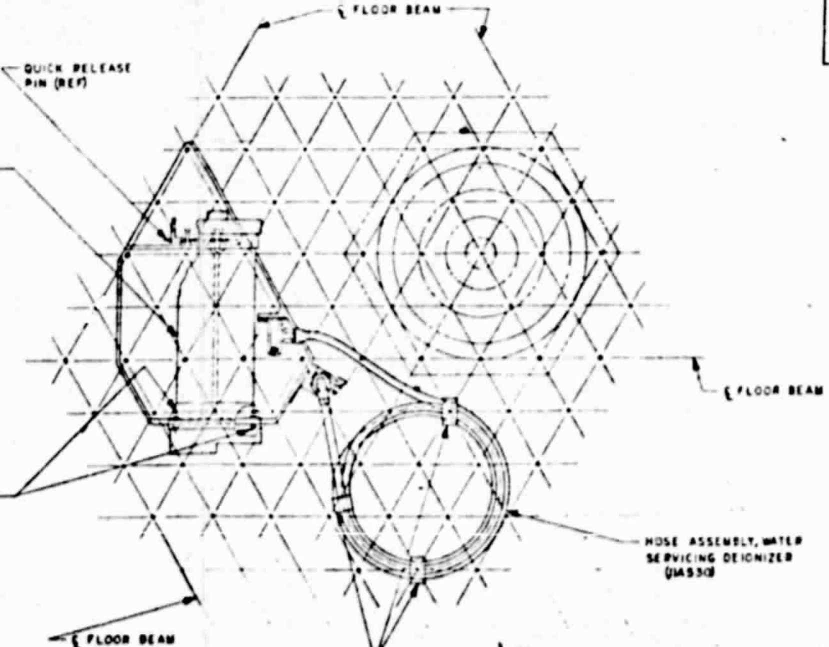

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VIEW BT [28]
SCALE 1/4
(LAUNCH CONFIGURATION)

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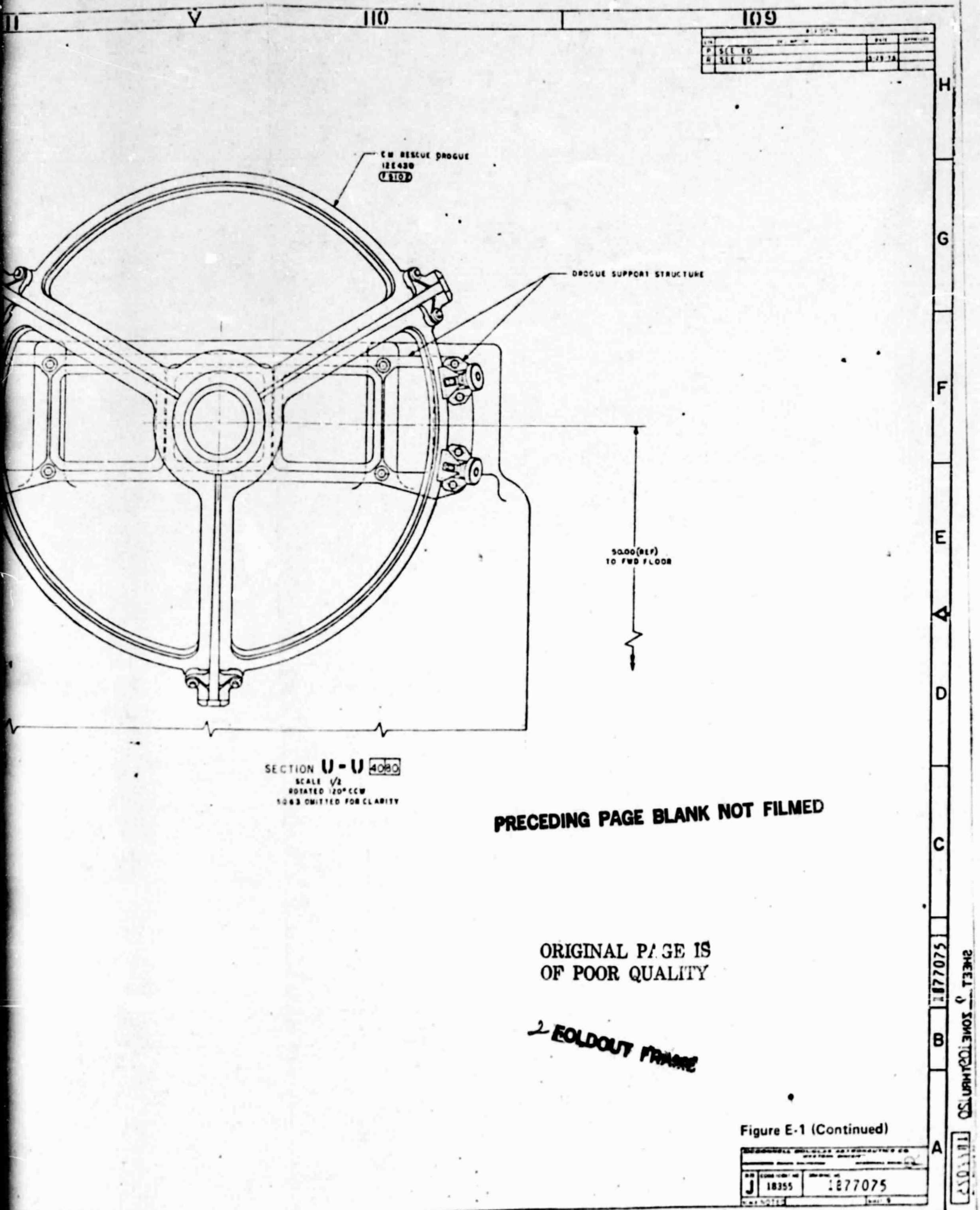

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Figure E-1 (Continued)

area. A pair of grid floors enclosing the crew quarters are installed and crew quarters consisting of a wardroom, waste management and sleep compartments and a medical experiment compartment are included.

The S-IVB LOX tank is converted to a waste tank for the disposition of Skylab trash. The tank is compartmented with screens; one compartment used to collect liquid waste which is non-propulsively vented overboard. The common bulkhead between the habitation area and the waste tank has been reworked at the center for the installation of a trash lock through which trash can be passed by the Skylab crews.

Environmental/Thermal Control Subsystem: The E/TCS design is based upon passive thermal control of the OWS environment with augmentation by convective heating and cooling of the atmosphere during manned phases and radiative heating of the internal structure during unmanned phases. The E/TCS is thus made up of two basic subsystems: an active thermal control subsystem including ventilation and a passive thermal control subsystem.

The passive thermal control subsystem consists of optical property control of the OWS interior and exterior surfaces, high performance insulation (HPI) on the forward dome, polyurethane insulation lining the inside of the OWS pressure shell and heat pipes attached to structural penetrations of the interior insulation. The exterior surface finishes and the HPI blanket control the net energy balance between the OWS and the external space environment. The heat transfer rates from the habitation area and from the forward and aft dome areas, are regulated by surface finish control. Also, the interior habitation area wall temperatures are made more uniform with optical property control of these surfaces and with the heat pipes.

The active thermal control subsystem provides continuous control of the OWS internal environment during periods of astronaut habitation. The cabin gas temperature is controlled by cabin gas heat exchangers in the airlock module (AM) and by concective heaters in the three VCS ducts. Reconstituted air from the AM is mixed with recirculated air in the OWS. Figure E-2 shows the OWS active thermal control system.

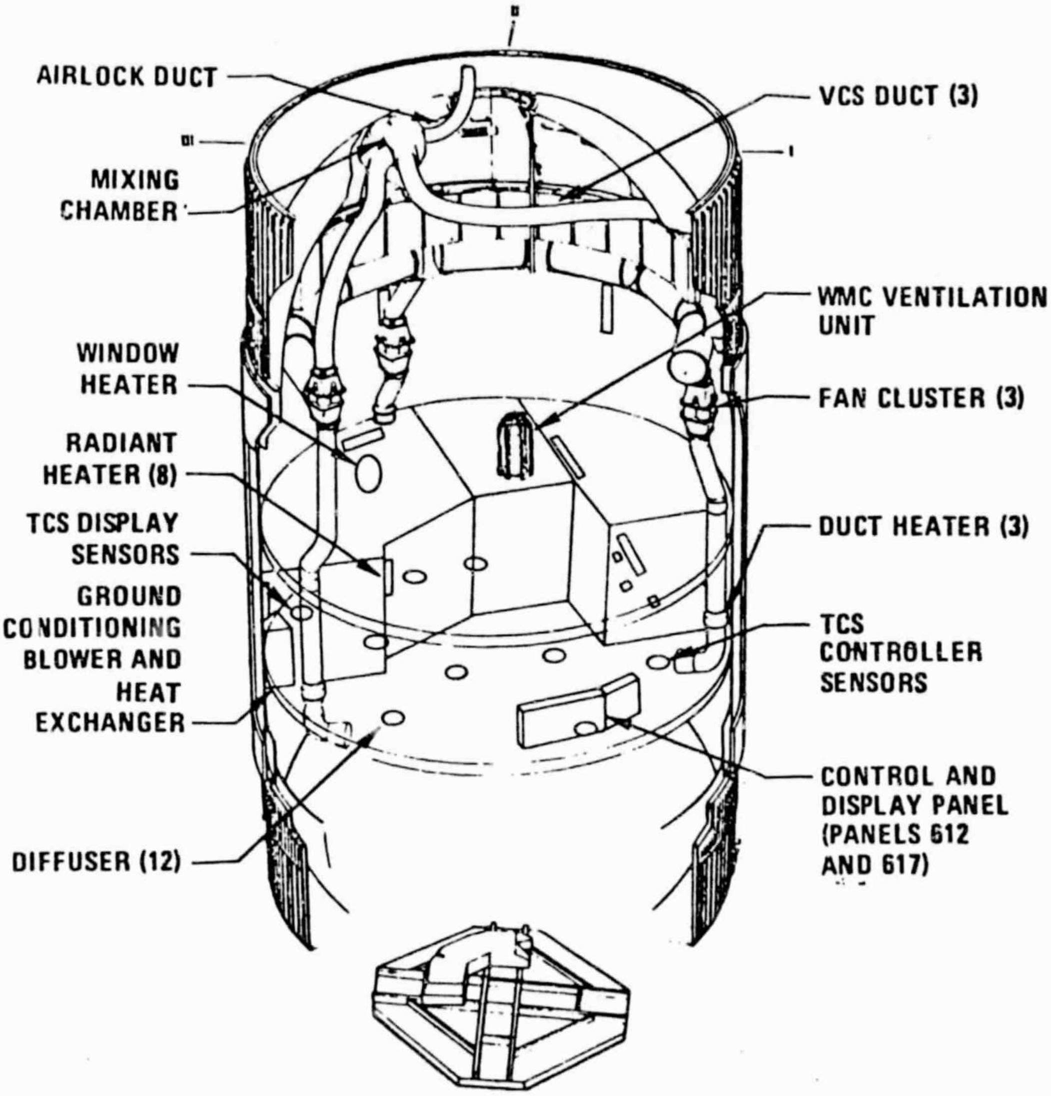


Figure E-2 Active Thermal Control System

Thruster Attitude Control Subsystem (TACS): The primary source of attitude control for Skylab is the three control moment gyros (CMG's) in the Apollo Telescope Mount which provided the pointing accuracy and stability necessary for Skylab astronomical and earth resources experiments, and which maintained the solar inertial attitude necessary for the Skylab solar arrays. A propulsive attitude control system is needed to provide control during CMG spinup, to handle docking transients and large maneuvers beyond the capability of the CMG's, to desaturate the CMG's when necessary, and to provide a contingency capability in case of CMG failure. This system designated TACS (thruster attitude control system) provided over 81,000 lb/sec (360,000 N-sec) of impulse. A high thrust level of 50 lb. (222 N) was required at the start of the mission for separation transients, a 20 lb. (90 N) thrust minimum was required for each of the three dockings with Apollo command modules, and a 10 lb. (45 N) minimum was specified for the rest of the mission.

The system is a pressure blow-down design using gaseous nitrogen as the propellant. The plumbing system joints are fully brazed. Figure E-3 shows the location of TACS equipment on OWS. Two modules of three thrusters each, 180° apart on the OWS aft skirt utilize quad-redundant valves for each thruster.

Solar Array Subsystem: SAS for OWS is a wing consisting of a beam fairing and three wing sections. Each section contains ten identical active solar panels for a total of 30 panels. The system supplies electrical power to the AM for distribution to equipment requiring power. SAS provided an average of 5250 watts between 51 and 125 volts during the sunlit portion of each orbit.

After insertion of SL-1 in orbit, the SAS beam fairing was deployed with a viscously damped spring actuator. Subsequently, the wing sections were released and deployed from the beam fairing by similar systems. The beam fairing and wing sections are mechanically latched in the deployed positions. Figure E-4 shows the deployed SAS and related equipment relative to the OWS tank structure.

Electrical Power Distribution System: The EPDS, Figure E-5 provides the means for power distribution from the AM to all OWS loads. Power is distributed externally to Thruster Attitude Control System (TACS), Instrumentation, etc.,

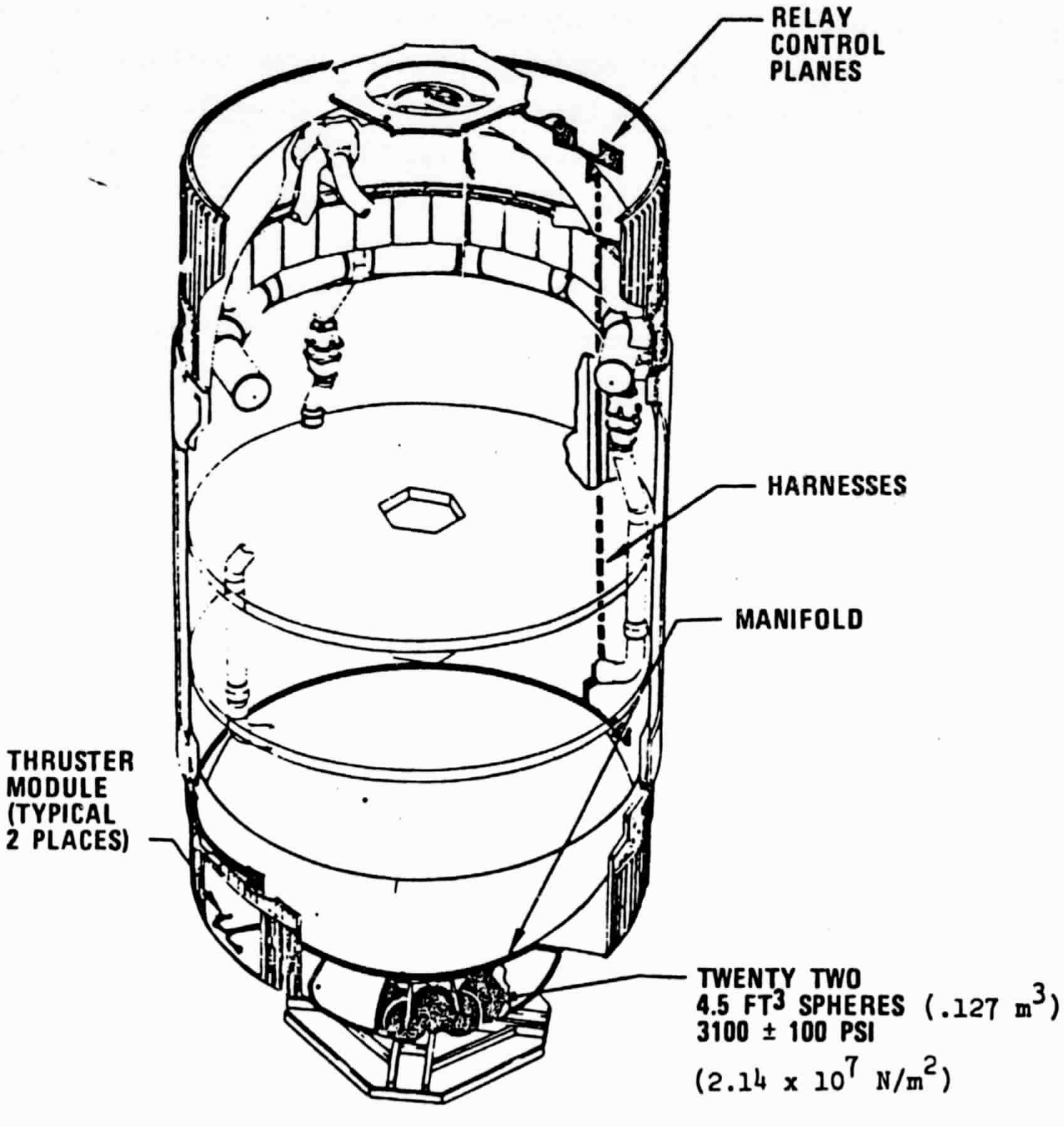
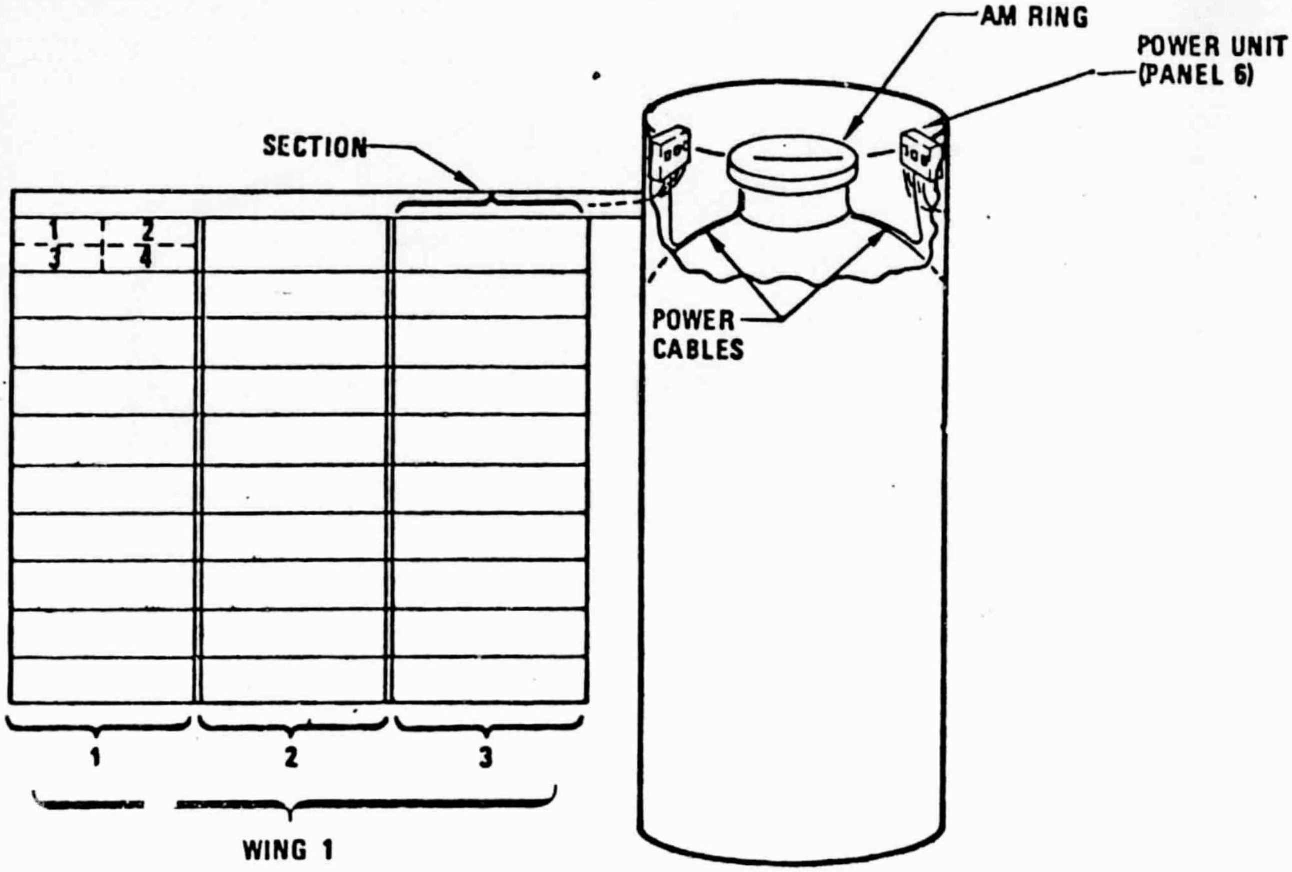


Figure E-3 Thruster Attitude Control Subsystem



NOTES:
1. (616) SOLAR CELLS MAKE UP A MODULE
2. (4) MODULES MAKE UP A PANEL
3. (10) PANELS MAKE UP A WING SECTION
4. (3) WING SECTIONS PLUS BEAM FAIRING MAKE UP A WING

Figure E-4 Solar Array

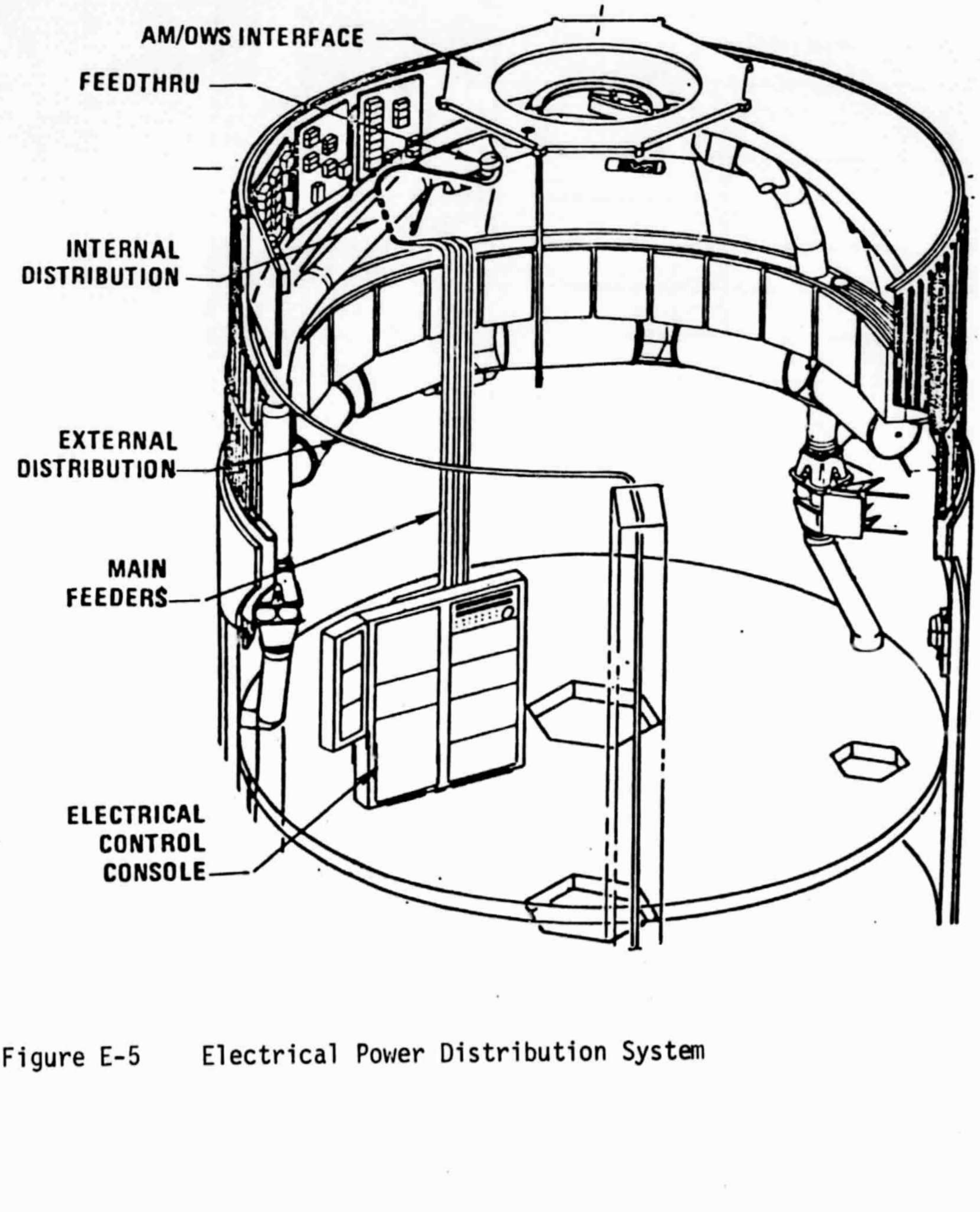


Figure E-5 Electrical Power Distribution System and through OWS feedthroughs to redundant busses routed to an electrical power and control console. In turn, the power is routed from the console to systems/equipment and experiments internal to OWS. The console in conjunction with remote control panels contains switches, circuit breakers, and indicators to permit crew control of power distribution to end items. The EPDS receives 25.5 to 30 vdc from the AM and supplies 24 to 30 vdc to the end items. Wiring to end items is electrically protected with circuit breakers and physically protected from damage and fire by metallic trough type "conduits."

Illumination System: An illumination system in OWS is provided to allow for normal and emergency crew activities and experiment operations. The system consists of light sources for general illumination, initial entry, emergency, and auxiliary.

For general illumination, there are 42 floodlights, 18 in the forward compartment with 8 on the forward dome and 10 on the forward walls, 4 in the wardroom 3 in the waste management compartment, 3 in the sleep compartment, and 14 in the experiment area. For redundancy, one-half the lights in each area are on Bus #1 and the remainder on Bus #2.

For initial crew entry into OWS and emergency, a lighting system is provided to control 8 of the 18 lights in the forward compartment. These floodlights will be illuminated, regardless of the position of their remote or integral light switch. The initial entry lighting is controlled by a single switch in the aft compartment of the Airlock Module and the emergency lighting is enabled by the simultaneous failure of both OWS busses which automatically supplies emergency power to the initial entry and emergency light system.

Two portable, high intensity lights, each containing four permanently installed fluorescent lamps, are supplied for special illumination. Figure E-6 shows the light arrangement of the OWS illumination system.

Communication System: The OWS communications system provides capability for audio communication between Skylab crewmen and between the crew and ground control. It also provides accommodations for video transmission from Skylab to ground control and the acquisition of biomedical data on the crewmen. Ten

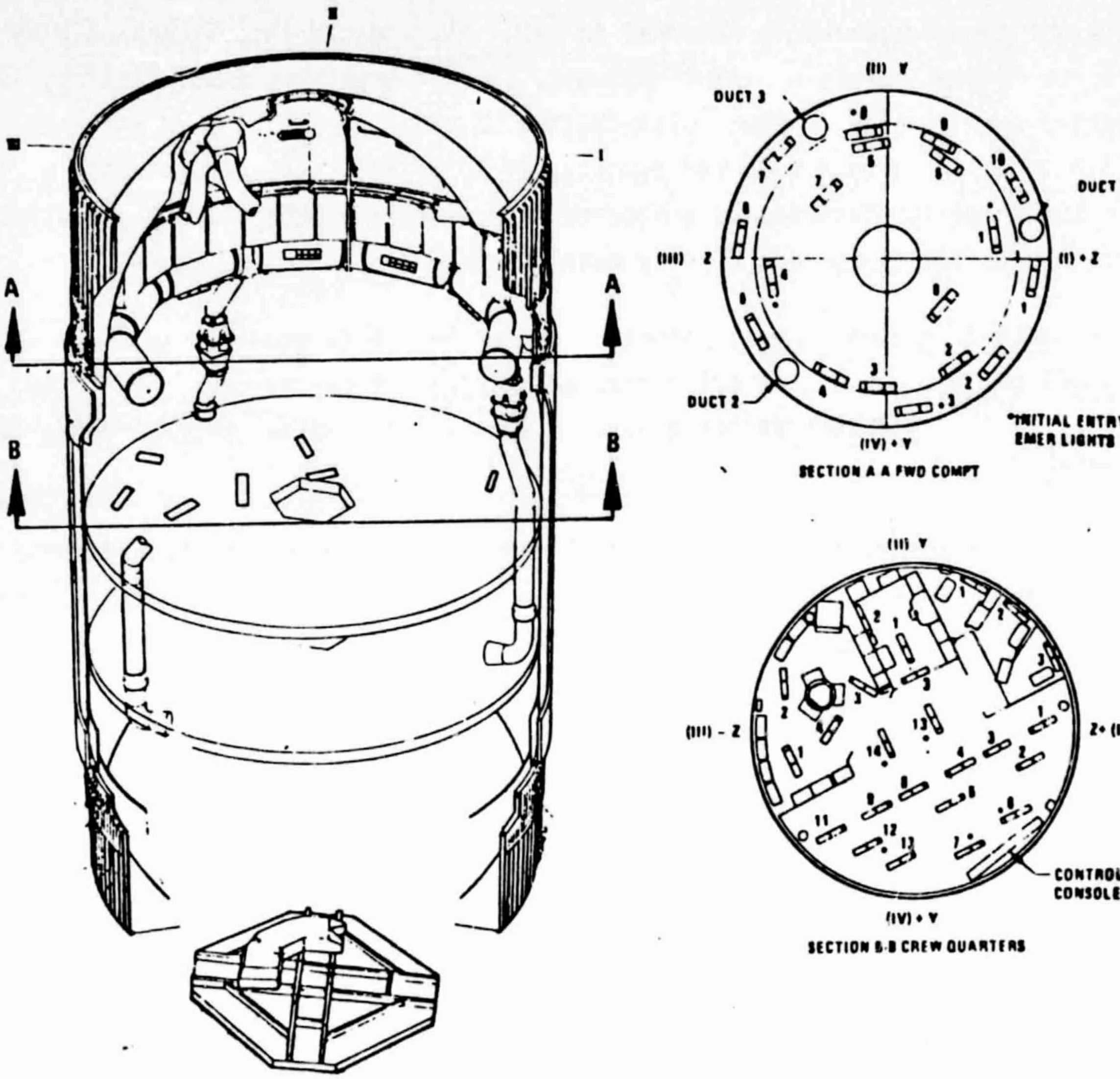


Figure E-6 Illumination System

GFP Speak Intercom Assemblies (SIAs) located throughout OWS comprise the principal hardware of the system. The SIAs utilize two channels, either of which can be connected to a crewman's communication umbilical. Further, they include the capability for push-to-talk, push-to-transmit and voice tape record selection by a crewman. Each SIA also includes an audio device for caution and warning tones. Figure E-7 shows the communication system arrangement.

Data Acquisition Systems: The OWS Data Acquisition System consists of a portion of the Saturn Workshop Pulse Code Manipulation Telemetry System, onboard displays and ground checkout support measurements. Low level and high level multiplexers, signal conditioning equipment and decoders are located in the forward skirt of the OWS. Signal conditioning equipment for transducers installed aft on OWS are mounted in the aft skirt, Figure E-8.

Command System: The OWS Command System provided automatic command capability for the first 7.5 hours of the initial mission. This was for control of tank pressures, thruster attitude control, solar array, refrigeration system radiator shield deployment, activation of the refrigeration system, and certain AM/ATM/MDA functions. The design utilizes the S-IVB mainline switch selector, which receives command input logic from the IU. The AM Digital Command System serves as backup. Figure E-9 shows the system installation on OWS.

Caution and Warning Systems (see Figure E-10): The Caution and Warning System for OWS is an integral part of the Skylab system. The system provides visual displays and audible tones when selected parameters reach out-of-tolerance conditions. The parameters selected are those which could result in jeopardizing the crew, compromising mission objectives or, if not responded to in time, could result in the loss of a system. The monitored parameters are categorized as Caution, Warning or Emergency parameters. The system is monitored in the Airlock Module; the OWS providing selected redundant displays for crew observance while in the experiment compartment. The OWS caution and warning panel is primarily a repeater station displaying the condition of selected cluster parameters. Six emergency, two caution and two warning parameters are displayed.

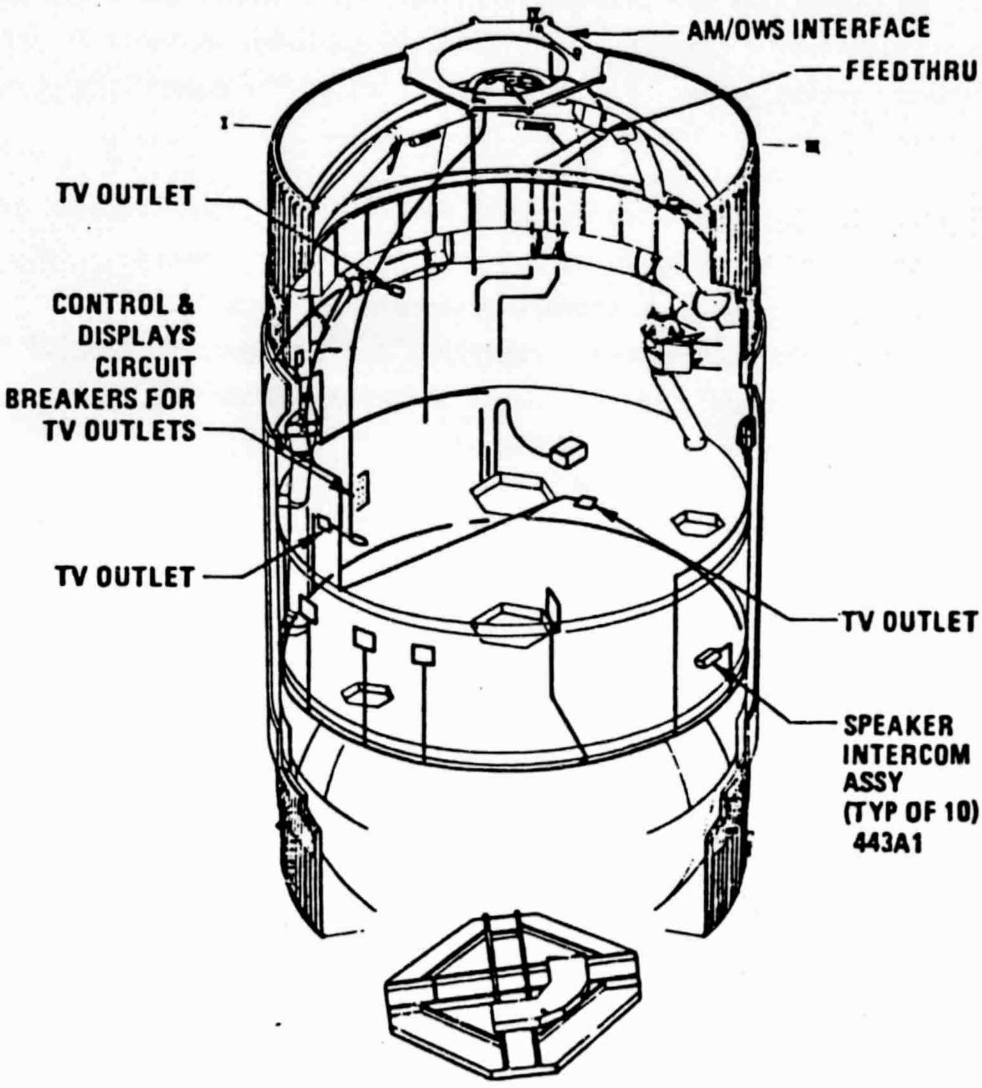


Figure E-7 Communication System

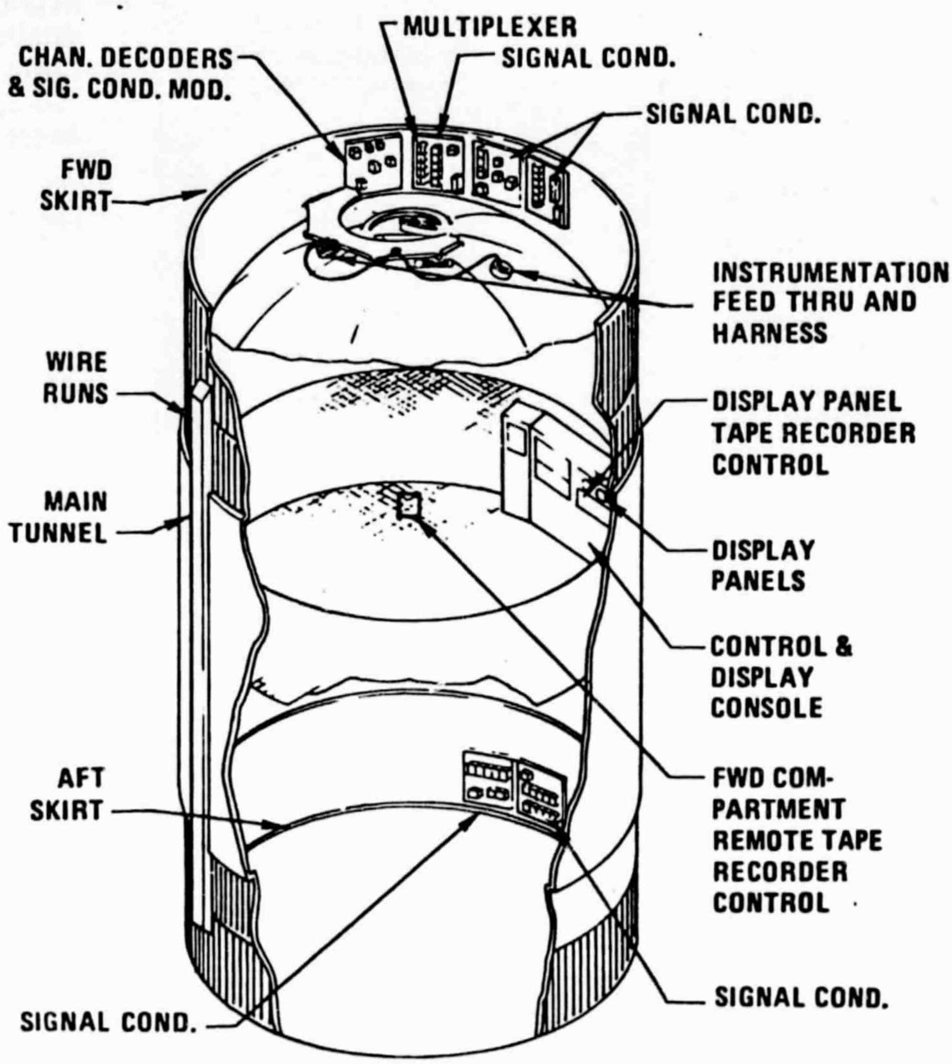


Figure E-8 Data Acquisition System

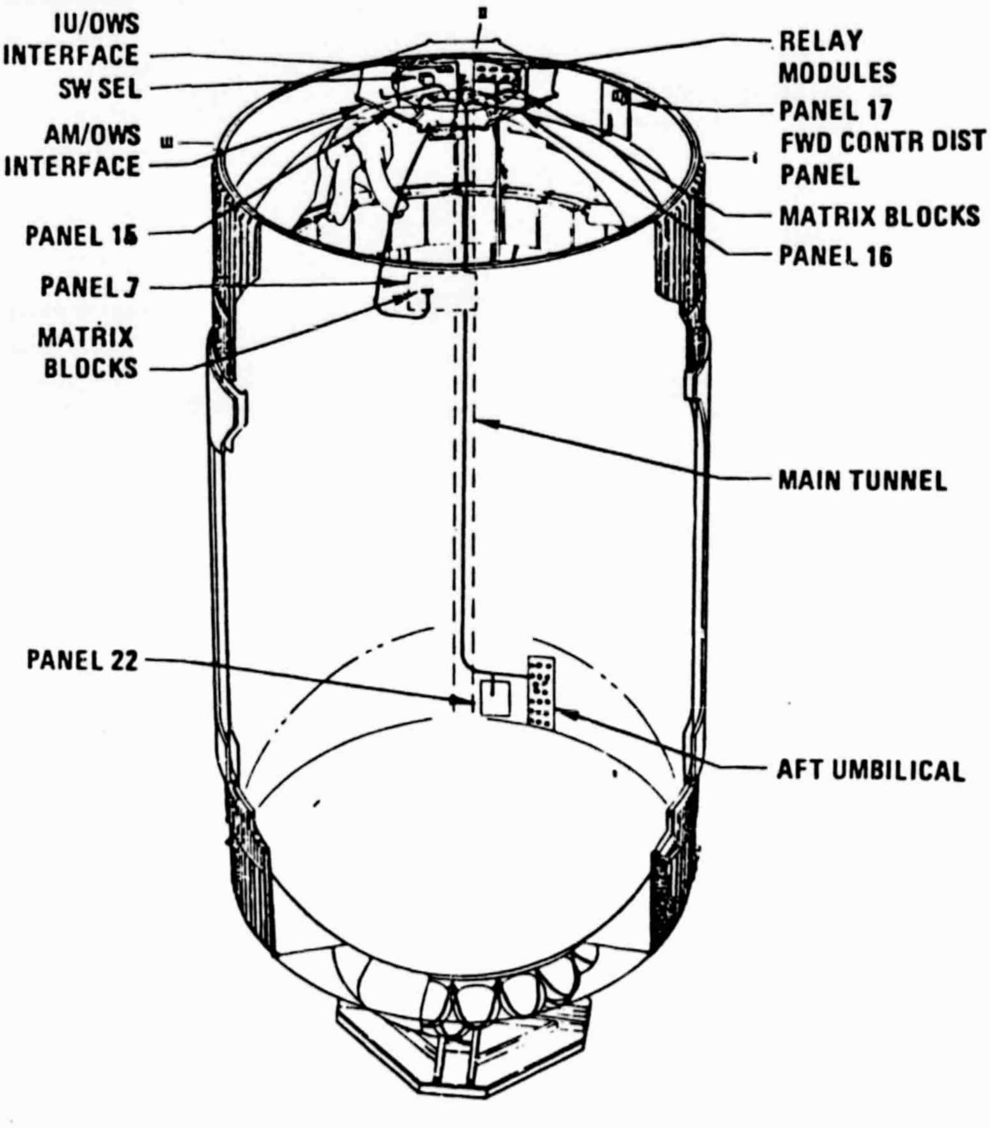


Figure E-9 Electrical Command System

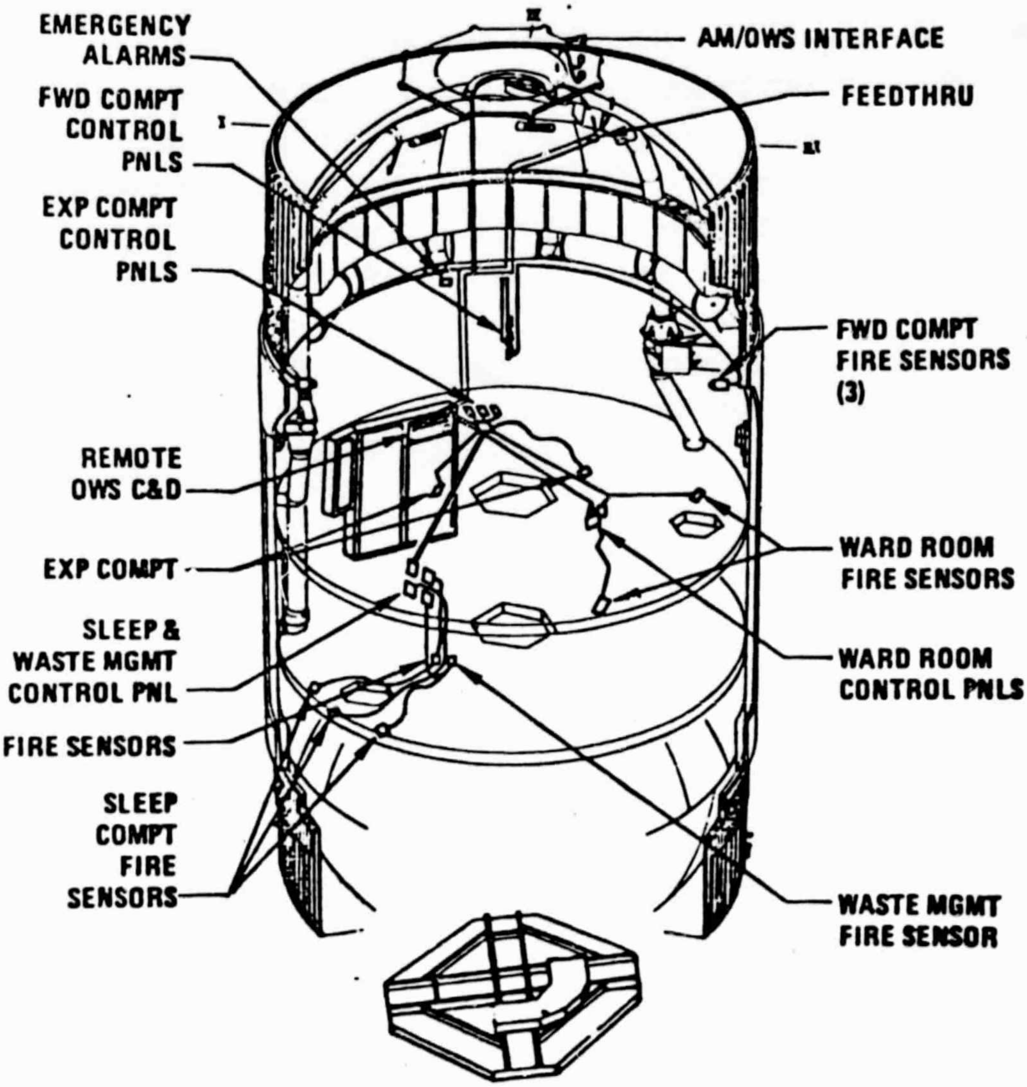


Figure E-10   Caution and Warning System

Habitability Support System: The OWS Habitability Support System consists of the following subsystems.

A. Waste Management System - WMS, Figures E-11 and E-12
The waste management compartment houses the equipment used to collect feces and urine. Feces is collected in a bag using airflow into the bag to simulate gravity. The air enters the bag, passes through a hydrophobic filter and subsequently through an odor filter and blower and exhausted into the Waste Management Compartment (WMC). Urine is collected in a receiver and hose similar to an aircraft relief tube. A centrifugal separator separates the air from the urine. Air passes through the same odor control filter and blower as does the feces collection air and the urine is pumped by the separator into a four liter storage bag. In order to obtain samples to be returned for the medical experiment, the feces is vacuum dried in a waste processor and a urine sample of 120 ml is extracted from the storage bag and then placed in a freezer for storage. A vacuum cleaner is included in the waste management equipment. The same blower as used in the collection module is used for suction. The vacuum cleaner uses a bag similar in operation to the fecal bag. The trash airlock is used to dispose of trash from the cabin into the waste tank. Trash is placed in a standard disposal bag; placed into the airlock and after closing the lid, the trash is ejected into the waste tank by a scissors mechanism.

B. Water Management System - WMS, Figure E-13
Water was stored in ten 600 pound (2721 kilogram) capacity stainless steel tanks. The tanks contain an integral stainless steel expulsion bellows, fill and drain ports, iodine and sample ports, level indicators and shutoff valves. The water is transferred by Teflon lined hoses to the wardroom for drinking water and to the WMC for personal hygiene water. In both compartments, the water is heated to the desired temperature. There is also a chiller in the WMC to supply chilled water for drinking. The hot water in the wardroom is used for food reconstitution and dispensers are available for both hot and chilled water. The water in each water storage tank is initially purified by using iodine as a biocide. The purity is maintained by periodically injecting iodine in the water. A portable water tank with a 26 pound (118 kilogram) capacity is provided for contingency water supply

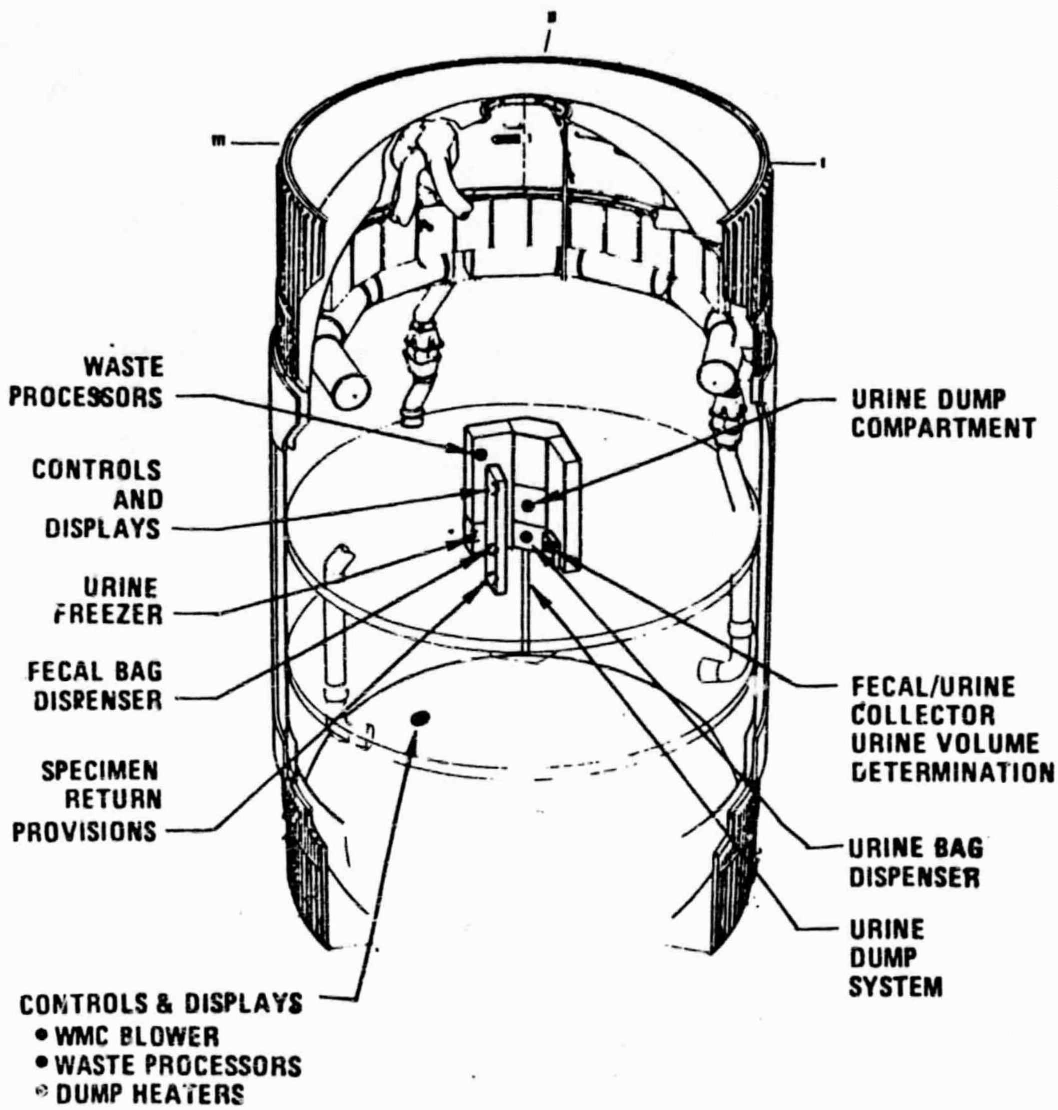


Figure E-11 Waste Management System

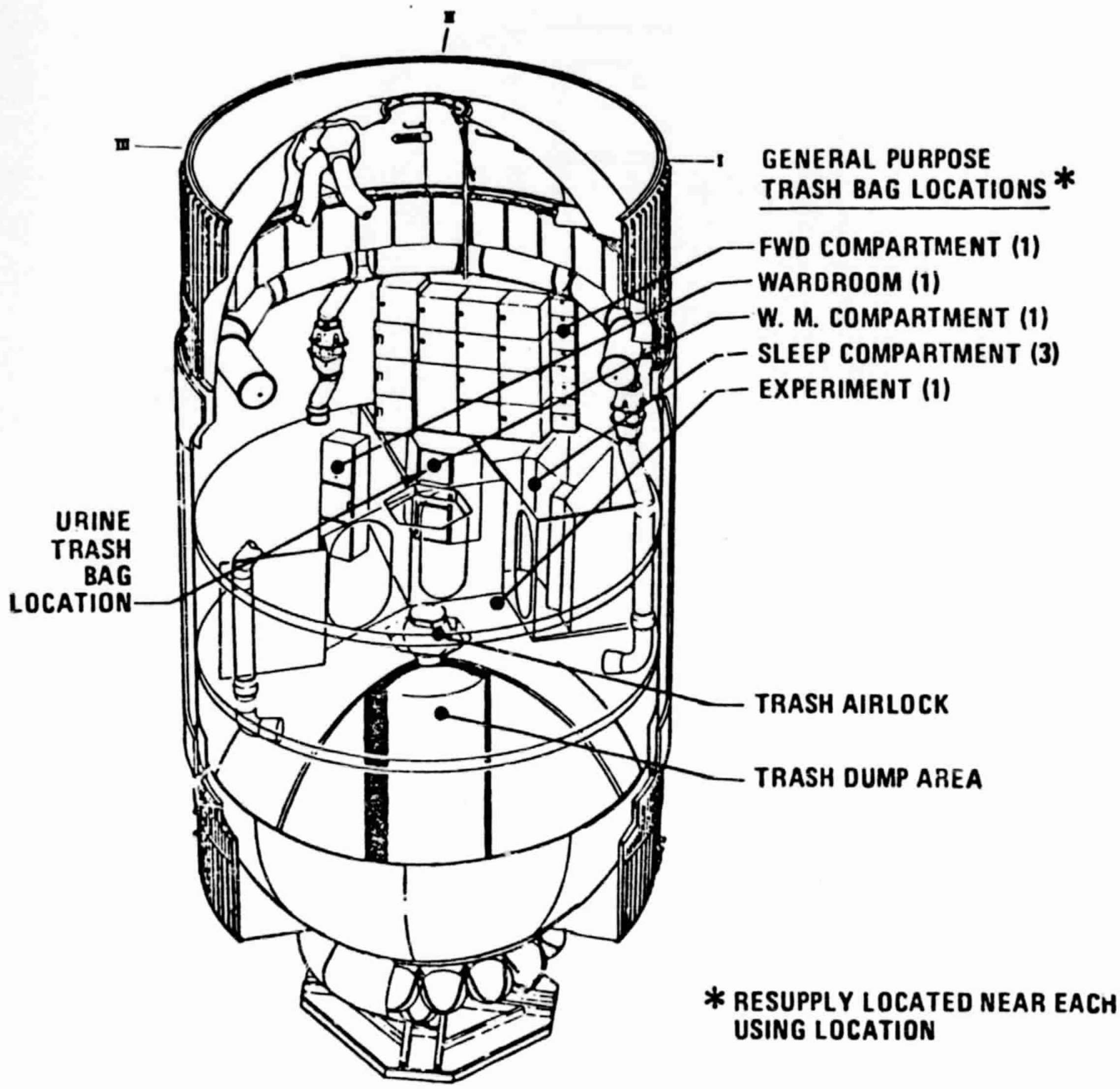


Figure E-12 Trash Disposal System

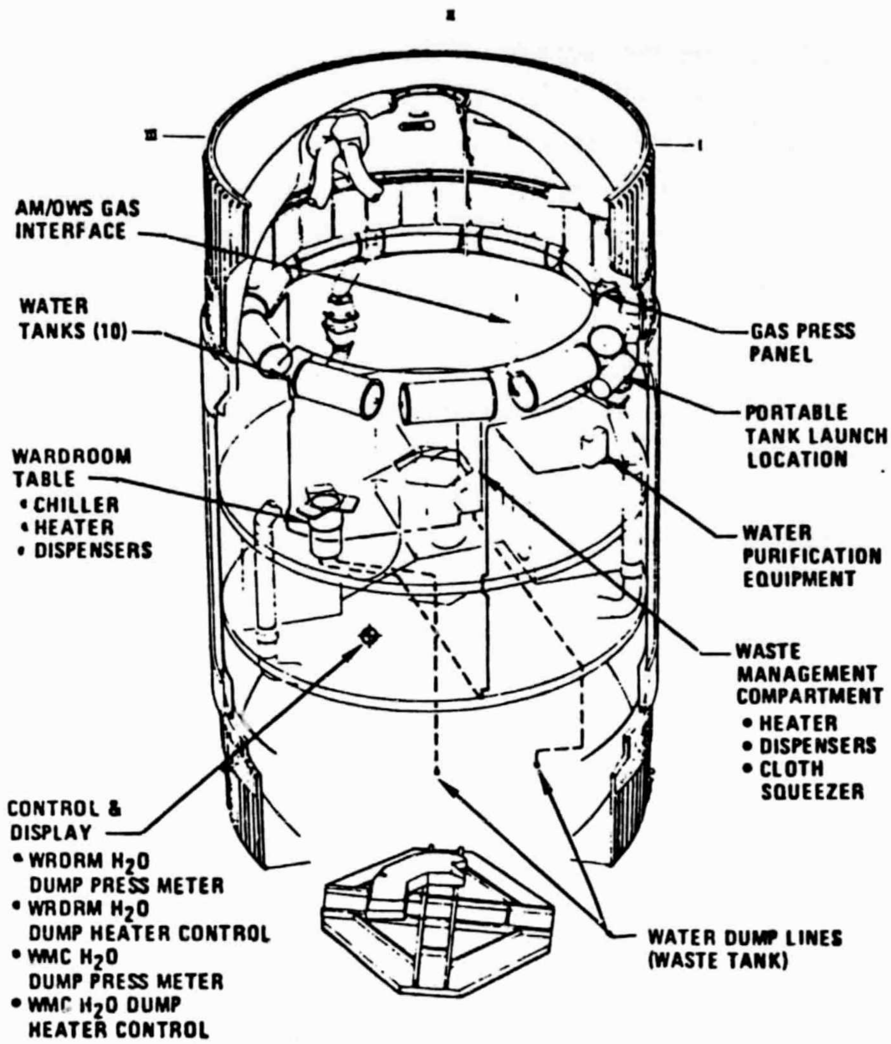


Figure E-13 Water Management System

and also to support the water netrowk fill and flush during activation.

C. Personal Hygiene System - PHS, Figure E-14

Personal hygiene equipment was provided for the maintenance of health and personal cleanliness. A personal hygiene module is proviced to store supplies required by the crewmen. Dispensers for utility tissues, wash cloths, towels, and chemically treated cotton pads were also provided. The capability to dry wash cloths and towels is available.

D. Body Cleansing System - BCS, Figure E-14

Body cleansing is accomplished both by the shower and by sponging with wash cloths. A wash cloth squeezer is provided. The shower contains an enclosure with a continuous airflow as a gravity substitute for moving water from the crewmen. A water bottle was filled from the WMC water dispenser and attached to the ceiling at the shower location. The water remaining after the shower is vacuumed and passed through a centrifugal air/liquid separator. The air is then filtered and pumped through a blower into the cabin.

E. Food Management System - FMS, Figure E-15

The food management subsystem consisted of supplies and equipment required for the storage, operation, and consumption of foods. Food was stored in food boxes, galley trays, food freezers and a food chiller. A galley food table and food trays are provided for preparation of the meals. Hot and chilled water are provided to reconstitute the dry food and chilled drinks. Food cans and beverage packs are grouped in menu form. A heater is available to heat the food during preparation of the meal.

F. Sleep Support System - SSS, Figure E-16

Sleep restraints are provided for three crewmen. They provided thermal comfort and body restraining capability. The sleep restraints are mounted on frames in the sleep compartment.

G. Suit Drying System

The EVA suit drying equipment consisting of a blower, hoses, and desiccant bags is provided to remove moisture from inside the pressure suits after

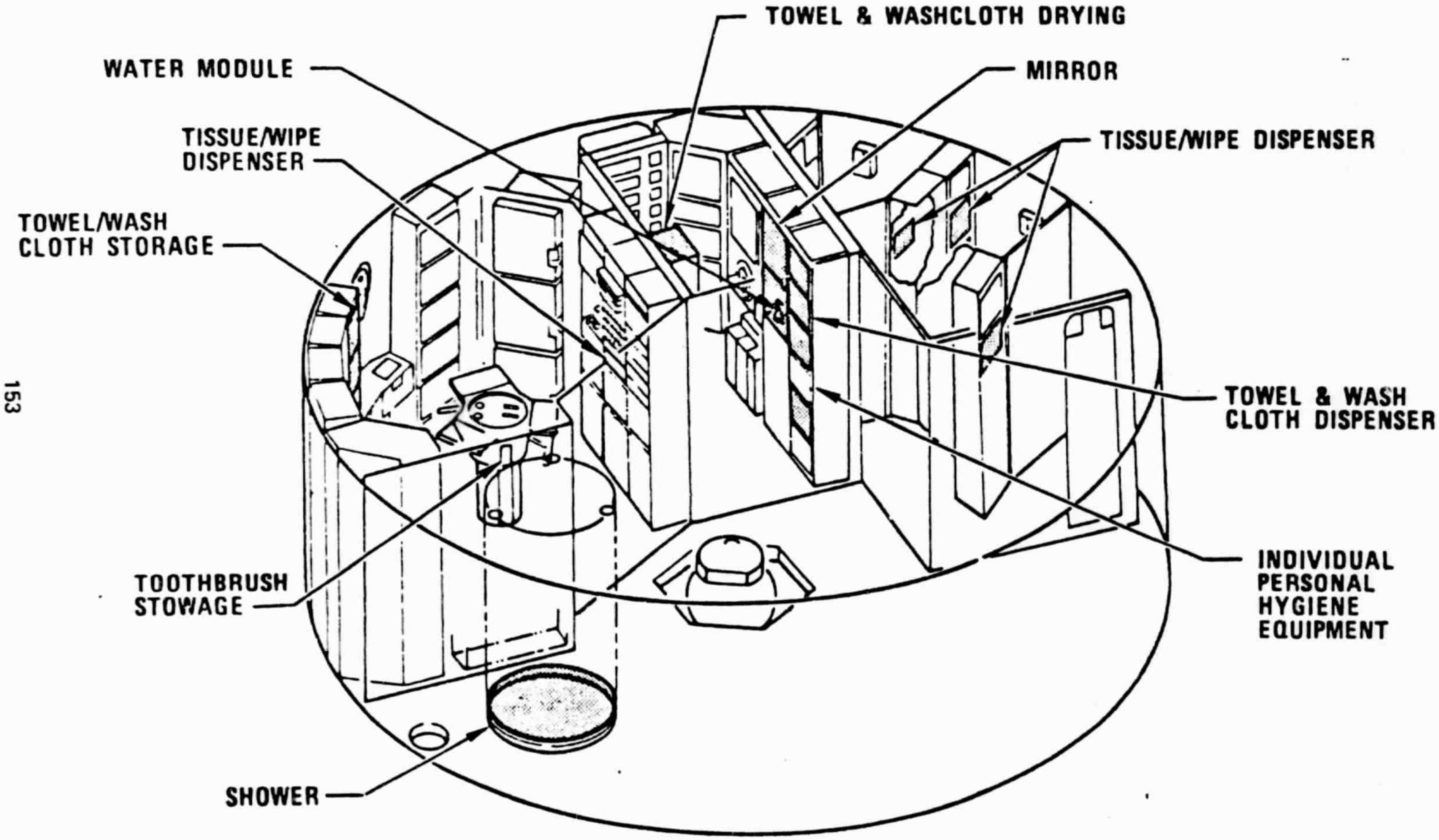


Figure E-14 Personal Hygiene and Body Cleansing System

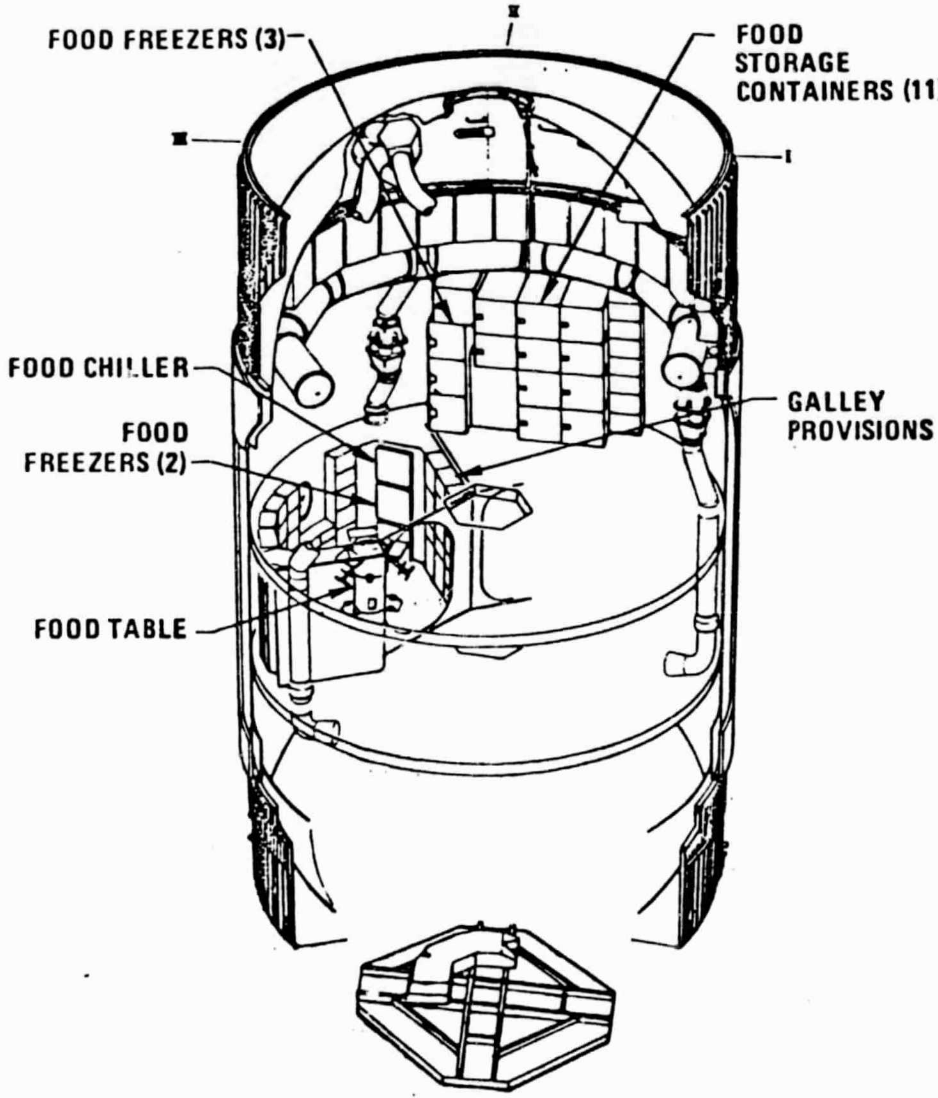


Figure E-15 Food Management System

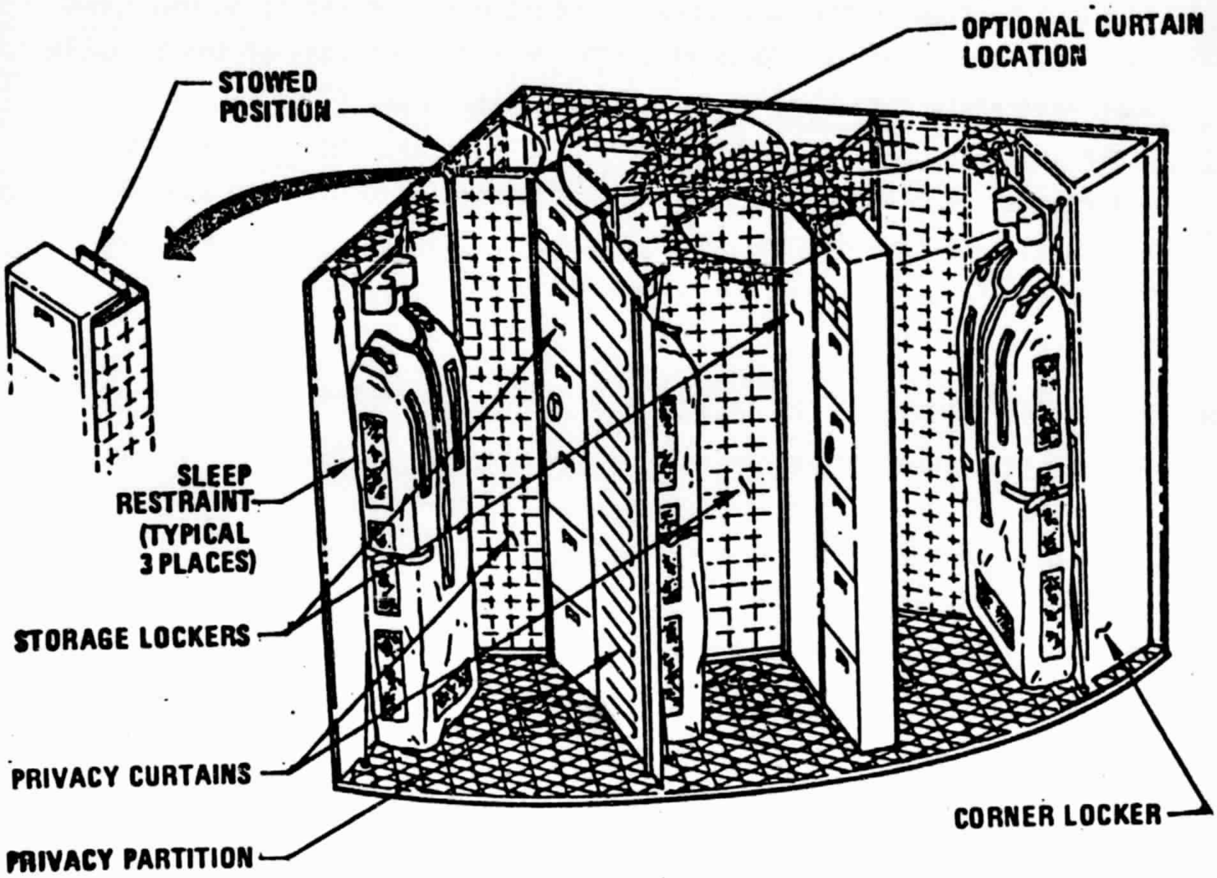


Figure E-16 OWS Sleep Station

each suited operation. Pressure suits are dried at three suit drying stations located in the OWS forward compartment. Drying is accomplished by installing a suit in the drying station which consists of the portable foot restraints (attached to the forward compartment floor) and a hangar strap which suspends the suit between the floor and the water ring foot restraints. The blower unit forces drying air through a hose and into the suit. Moisture is dried by the air and collected by the desiccant bags. The desiccant bags are subsequently dried in the WMC waste processor.

H. Refrigeration System - RS, Figure E-17

The OWS refrigeration system is a low temperature thermal control system utilizing Coolanol -15 as the refrigerant in a closed-loop circuit. Heat is dissipated through a radiator, externally mounted at the aft end of OWS, for orbital operations. The system provides food freezers and chillers for food and water in support of habitability and urine freezers and chillers in support of the biomedical experiment. The system has dual coolant loops and redundant components to provide reliability. It controls temperature through a range of +42°F to -20°F (5.6°C to -29°C).

I. Atmosphere Control System

The habitation area was pressurized to 5 psia (34.5 kN/m^2) with O_2 to provide the desired breathing atmosphere. The section on Environmental/Thermal Control discussed both the passive and active systems of control over cabin atmosphere temperatures. The active being provided by heat exchangers in the Airlock Module and convective heaters in the three OWS ventilation ducts. The circulated cabin gas was reconstituted in the Airlock Module. The ventilation ducts, each with a circulation fan cluster, route reconstituted air to a plenum chamber aft of the aft floor in OWS for diffusion through floor diffusers into the cabin.

The following ancillary accommodations/provisions for habitability support and experimentation were incorporated in OWS.

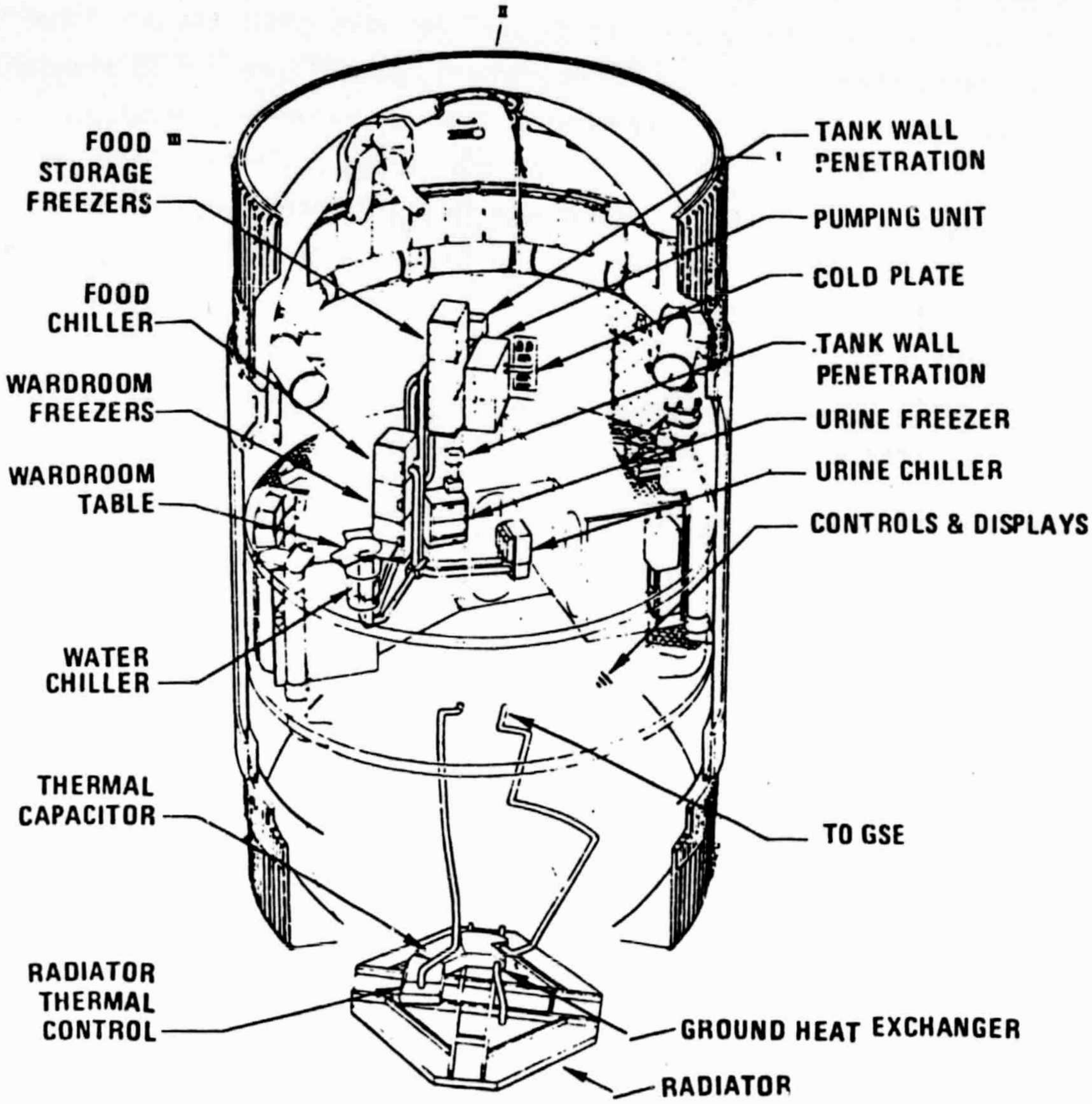


Figure E-17 Refrigeration System

Stowage Facilities, Figure E-18

Stowage capability for provisions is included throughout the OWS. Twenty-five standardized stowage containers in the forward dome and 16 standard stowage lockers located in the various areas accommodate general provisions such as clothing, sleeping restraints, urine collection bags, etc. For ambient food storage, 11 containers in the forward compartment and two galley cabinets are provided. Five food freezers, three in the forward compartment and two in the wardroom are installed. A refrigerator for perishable food is located in the wardroom and a urine freezer is included in the waste management compartment. The total stowage capability of the 210 containers on board is 580 ft^3 (16.4 m^3).

Experiment Accommodations

For OWS experiments, hardware accommodations necessary to integrate experiment equipment and perform the experiments are provided. These consist of structural attachments, electrical cabling, pressurization and vacuum plumbing, and stowage restraints. A pair of scientific airlocks, anti-solar and solar, are installed in the cylindrical tank walls of the habitation area in the forward compartment to provide visual and physical access outside for experiments requiring it. Figure E-19 shows the vacuum provisions for the waste management system; the vacuum access is through the waste tank to utilize the nonpropulsive venting system of the waste tank. Figure E-20 shows the vacuum provisions to accommodate the metabolic activity and lower body negative pressure experiments.

Mission Performance

The Orbital Workshop was designed to have a meteoroid shield. The shield, a cylindrical structural skin .025 in. thick, was to be deployed 5 inches off the habitation tankage after OWS orbital insertion. Two functions were to be performed by the shield. First, as implied, was to provide protection against a meteoroid penetration of the habitation area to an acceptable level of risk, but more importantly it was to provide passive thermal protection against solar radiation for the habitable compartment.

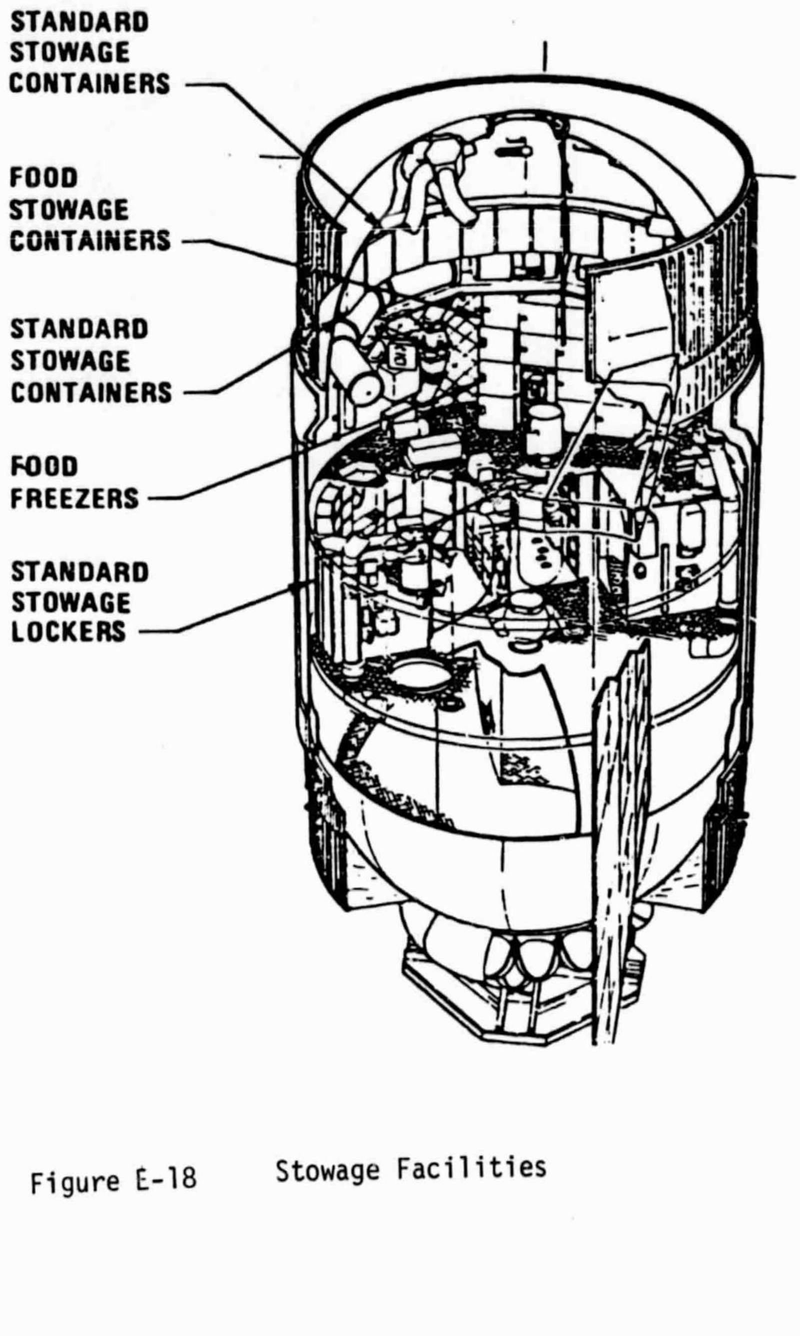


Figure E-18 Stowage Facilities

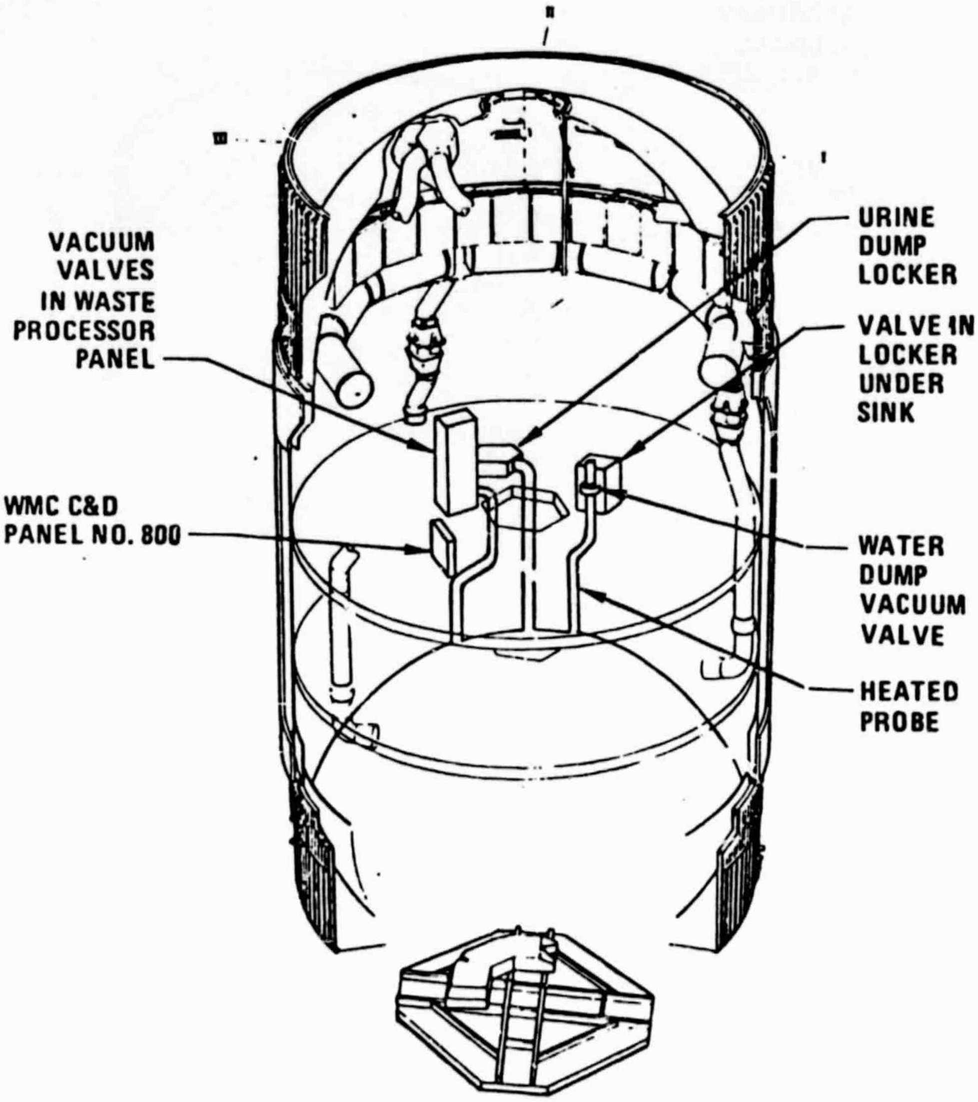


Figure E-19 Waste Management Vacuum Provisions

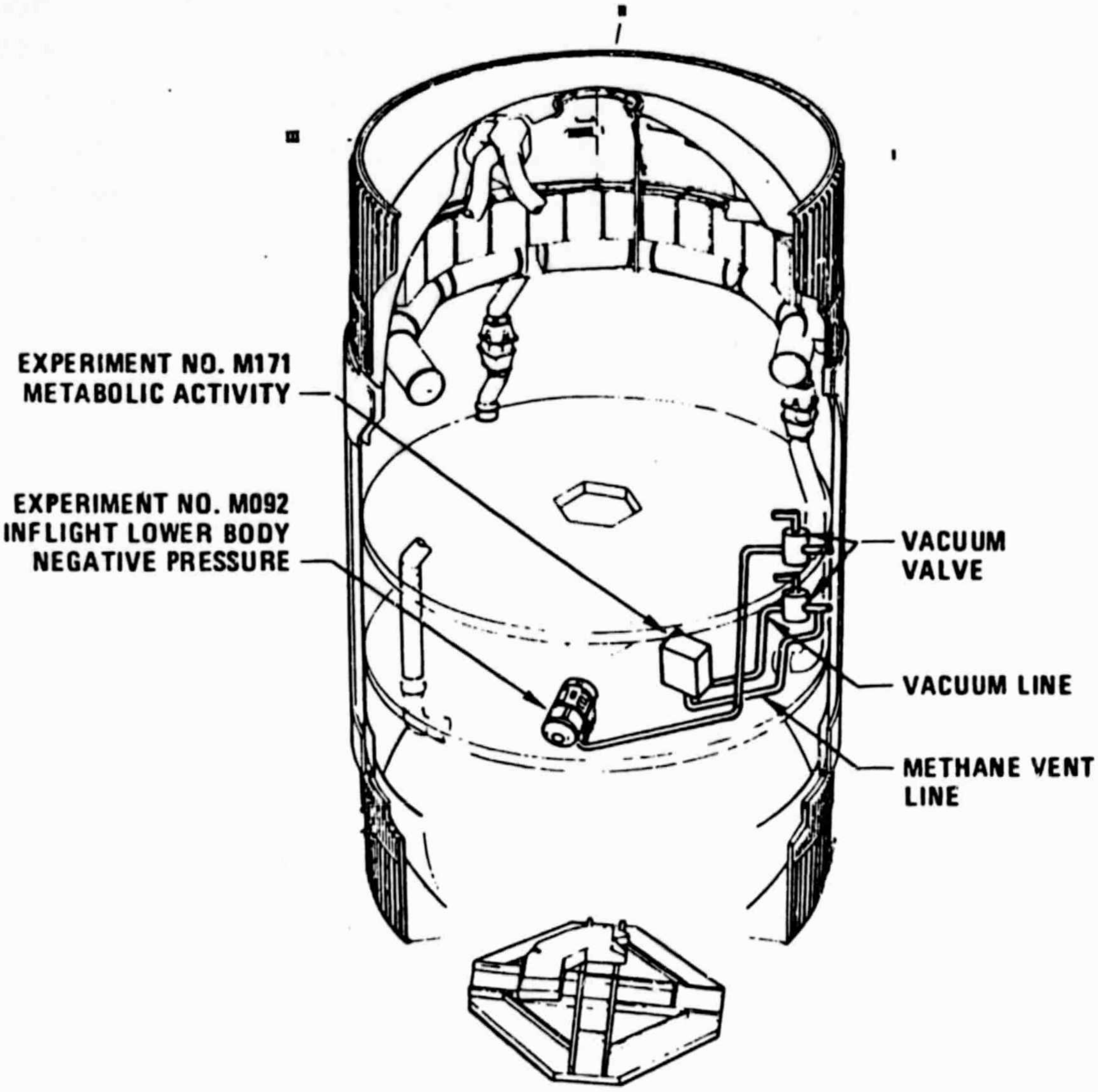


Figure E-20 Experiments Vacuum Provisions

The launch of SL-1 occurred on 14 May 1973. Pressure in the auxiliary tunnel portion of the meteoroid shield caused the shield to be torn away from OWS during early ascent. As the shield was ripped away, the structural tie-downs for Solar Array System (SAS) beam fairing 2 were severed. The unsecured SAS wing was separated from OWS by impingement forces from the retrorocket plumes at payload staging. Further, remnants of the torn shield remaining the vicinity of SAS beam fairing 1 prevented the normal programmed orbital deployment of the array. This array, however, was successfully deployed when the SL-2 crew, through Extravehicular Activity (EVA), broke away the deployment restraints.

The loss of the meteoroid shield caused a reduction in the probability of no pressure loss from the OWS habitation area from 0.995 during a minimum period of eight consecutive months to 0.985 during a minimum period of 56 consecutive days. The passive thermal protection afforded OWS by the shield was lost.

SL-2 launch scheduled for 15 May 1973, was delayed 10 days during which time contingency actions to rectify the anomalous condition of SL-1 were planned and tested. Over this 10-day period, the goldized OWS exterior was exposed to direct solar input. Internal OWS temperature and temperatures of the ambiently stored food and photographic film increased. The internal temperature rise was rapid for approximately 1-1/2 days after orbit insertion. The change rate decreased consistent with the orbital attitude of the spacecraft which was generally Solar Inertial (S.I.)/50° pitch effected to provide temperature control.

Also due to the loss of the meteoroid shield, OWS external and internal surface temperatures approached 300 and 200°F (148°C and 93°C), respectively. These elevated temperatures caused the internal insulation to be subject to outgassing of hydrocarbon products. For this reason, the OWS atmosphere was vented five times prior to habitation. Also, there was the possibility that some portion of the insulation had become debonded; however, inspection by the SL-2 crew determined the degree to be negligible. The loss of the meteoroid shield impaired the passive thermal control system; however, after the deployment of the JSC thermal parasol, the OWS insulation system; i.e., aluminized mylar high performance insulation (HPI), external on the forward dome and the polyurethane foam internally, provided a habitable structure for the duration of the Skylab missions.

OWS systems performed in accordance with design expectations. For SL-1/SL-2, they functioned in the primary mode of operation; no backup capability was utilized.

The high temperature encountered early in the SL-1/SL-2 mission, prior to deployment of the thermal parasol, which provided a shade for the sun side of the OWS Habitation area, did generate some unique difficulties which were not unexpected. The five sensors in sleep compartment 2 gave three false alarms due to increased sensitivity resulting from high temperatures. Water tank 1 iodine content was low after iodine inspection. This was expected based on test data. Ventilation duct 1 flow meter failed, perhaps as a result of high temperatures. These were minor problems and did not degrade the mission.

Several operational problems developed that were solved without mission degradation by using modified procedures; e.g., disposal of large quantities of items through the trash airlock, leakage of habitation atmosphere through the trash airlock due to the operating handle being in a wrong position and fogging of the wardroom window. The more significant problems encountered are identified below by OWS subsystem.

A. Refrigeration - On day of year (DOY) 173, following SL-1/SL-2 deactivation, data indicated simultaneous refrigerant flow through the radiator and by-pass leg of the system primary loop. The by-pass valve was cycled by flight controllers which improved the loop performance. Notwithstanding the split-flow degraded mode of operation, adequate temperature control throughout the system was proviced by the primary loop.

   The coldest food freezer temperature dropped below the Contract End Item (CEI) specification limit of -20°F (-28°C) on DOY 271 and did so several times during the storage period between SL-3 splashdown and SL-4 launch. This is attributed to cabin temperatures dipping to the low 60°F's (15°C's). The freezer specification limit was for system design, the food being

C-3

capable of withstanding much colder temperature. The food, in fact, was stored onboard OWS at -40°F (-40°C) at KSC. Therefore, the freezer low temperatures between -20°F and -25°F (-28°C and -31°C) had no deleterious effect on the food.

B. Electrical - Thermal analyses indicated that due to a worst case beta angle during the SL-1 mission, mounting bases for some components experienced temperatures as much as 20°F (11.1°C) higher than design maximum. However, laboratory examination of the components involved revealed that no problems would be encountered.

C. Instrumentation and Communications - The low level "B" multiplexer commenced intermittent operations on DOY 215. Mission data was not impacted, however, since we provided alternate sources for all data measurements. Thus, onboard troubleshooting of the malfunction by the Skylab crews was never recommended.

The SL-1 launch anomaly which caused the loss of SAS beam fairing 2 destroyed 50 percent of the OWS electrical power generation capability. This in no way jeopardized Skylab power systems and though some experiment activity was curtailed due to contingency power management early in SL-2, the total planned exper ent activity for the program was exceeded. Due to design margin and reasonable conservatism, SAS wing 1 provided 58 percent of the total SAS power requirements and showed little detectable degradation in power output throughout the Skylab missions.

OWS TACS successfully fulfilled all vehicle control demands imposed on it throughout the SL-1/SL-2 mission. It was the primary attitude control system for the SL-1 payload following S-II separation until the Control Moment Gyros (CMG's) were sufficiently spun up to permit transfer to Apollo Telescope Mount (ATM)/CMG control. Following transfer to CMG control, the TACS continued to function as a supplemental system to correct large attitude error rates and provide momentum relief to the CMGs. Further, TACS impulse consumption significantly exceeded the predictions for a nominal profile. The excessive usage is attributed to SL-1/SL-2 mission anomalies delineated as follows:

- "ATM/CMG" switchcover occurred 10 hours later than scheduled due to CMG anomalies.
- Unplanned attitude maneuvers for Skylab thermal conditioning.
- Excessive CMG "reset firings" were performed while maintaining unusual vehicle attitude.
- Large vehicle perturbations were associated with Stand-up Extravehicular Activity (SEVA) and EVA to deploy SAS wing 1.
- Several unsuccessful "hard dockings" were attempted by the SL-2 CSM.

The TACS total usable impulse at liftoff was approximately 80,000 lb/sec (200,000 N-sec), compared to the maximum predicted usage of about 16,000 lb/sec (71,000 N-sec). This extensive use of TACS impulse presented no concern for the completion of the Skylab missions since, after arresting the anomalous condition of SL-1/SL-2, the impulse usage was nominal. No detectable system leakage was observed from a series of periodic mass calculations throughout the completion of the mission profile.

SL-3 was launched 28 July 1973. After CSM docking, Skylab was activated; the activation of OWS was normal. The MSFC twin-pole sunshade was EVA deployed by the crew on DOY 219 as a backup for the JSC parasol. OWS systems continued to perform in the primary mode. SL-3 splashdown occurred on September 25, 1973, completing the 59-day mission.

SL-4 launch occurred 16 November 1973. The mission staytime was increased from the planned 56-day mission to 84 days. The CSM was docked to the Orbiting Assembly on the third docking attempt and SWS was activated. OWS activation was normal. All OWS systems performed as required for SL-4 plus meeting the increased demands of the longer mission notably well at the end of the mission. SL-4 splashdown was on 8 February 1974, completing the Skylab program missions.

Table E-1 summarizes the OWS Experiment Activity for the three manned missions.

Table E-1

OWS EXPERIMENT ACTIVITY

EXPERIMENT	SL-2 PLANNED	SL-2 ACTUAL	SL-2 PERCENT	SL-3 PLANNED	SL-3 ACTUAL	SL-3 PERCENT	SL-4 PLANNED	SL-4 ACTUAL	SL-4 PERCENT
M092 Inflight Lower Body Negative Pressure	24	22	91	51	50	98	78	67	86
M093 Inflight Vectorcardiogram	24	18	75	51	49	96	78	63	81
M131 Human Vestibular Function	19	13	68	21	24	114	30	27	90
M133 Sleep Monitoring	15	13	87	21	20	95	8	18	225
M171 Metabolic Activity	15	15	100	24	28	117	36	36	100
M487 Habitability Crew Quarters	11	11	100	18	18	100	21	21	100
M509 Astronaut Maneuvering Unit	-	-	-	4	6	150	8	5	63
M516 Crew Activities/Maintenance	-	-	-	7	5	71	7	3	43
S019 UV Stellar Astronomy	8	4	50	12	27	225	14	13	93
S020 UV/X-Ray Solar Photography	-	-	-	-	-	-	1	3	300
S063 UV Airglow Horizon Photography	-	-	-	12	12	100	7	7	100
S073 Gegenschein/Zodiacal Light	11	11	100	30	6	20	36	15	42
S149 Particle Collection	1	1	100	2	2	100	1	1	100
S183 UV Panorama	9	3	33	12	14	117	23	18	78
S190B Earth Terrain Camera	9	6	67	22	29	132	50	38	76
S201 Extreme UV Electronographic Camera	-	-	-	-	-	-	12	10	83
S228 Trans-Uranic Cosmic Rays	1	1	100	1	1	100	3	3	100
S019K UV Stellar Astronomy - Kohoutek	-	-	-	-	-	-	20	13	65
S063K UV Airglow Horizon Photography - Kohoutek	-	-	-	-	-	-	22	14	64
S073K Gegenschein/Zodiacal Light - Kohoutek	-	-	-	-	-	-	0	1	-
S183K UV Panorama - Kohoutek	-	-	-	-	-	-	13	6	46
S201K Comet Kohoutek Photometric Photography	-	-	-	-	-	-	15	14	93
T025K Coronograph Contamination Measurements - Kohoutek	-	-	-	-	-	-	2	2	100
T002 Manual Navigation Sightings	-	-	-	34	31	91	34	16	47
Kohoutek	-	-	-	-	-	-	20	13	65

FOLDOUT FRAME

	Kohoutek	-	-	-	-	-	-	20	13	65
S063K	UV Airglow Horizon Photography - Kohoutek	-	-	-	-	-	-	22	14	64
S073K	Gegenschein/Zodiacal Light - Kohoutek	-	-	-	-	-	-	0	1	-
S183K	UV Panorama - Kohoutek	-	-	-	-	-	-	13	6	46
S201K	Comet Kohoutek Photometric Photography	-	-	-	-	-	-	15	14	93
T025K	Coronograph Contamination Measurements - Kohoutek	-	-	-	-	-	-	2	2	100
T002	Manual Navigation Sightings	-	-	-	34	31	91	34	16	47
T003	Aerosol Analysis	10	7	70	20	19	95	26	30	115
T013	Crew Vehicle Disturbances	-	-	-	1	1	100	-	-	-
T020	Foot Controlled Maneuvering Unit	-	-	-	3	3	100	3	2	67
T025	Coronograph Contamination Measurement	-	-	-	-	-		1	1	100
T053	Earth Laser Beacon Assessment	-	-	-	-	-		46	20	44
ED31	Bacteria and spores	2	2	100	-	-	-	2	2	100
ED32	In Vitro Immunology	-	-	-	1	1	100	-	-	-
ED41	Motor Sensory Performance	-	-	-	-	-	-	3	3	100
ED52	Web Formation	-	-	-	3	3	100	-	-	-
ED61/62	Plant Growth/Plant Phototropism	-	-	-	-	-	-	2	2	100
ED63	Cytoplastic Streaming	-	-	-	3	1	33	3	2	67
ED72	Capillary Studies	-	-	-	-	-	-	3	1	33
ED74	Mass Measurement	-	-	-	4	4	100	-	-	-
ED76	Neutron Analysis	2	2	100	-	-	-	2	2	100
ED78	Liquid Motion	-	-	-	1	0	0	-	-	-

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