NASA TECHNICAL MEMORANDUM

May 1974

NASA TM X-64813

MSFC SKYLAB ORBITAL WORKSHOP
Vol. IV

Skylab Program Office

NASA

George C. Marshall Space Flight Center
Marshall Space Flight Center, Alabama

(NASA-TM-X-64813-Vol-4) MSFC SKYLAB ORBITAL WORKSHOP, VOLUME 4 (NASA) 527 p HC $10.25 CSCL 22B

N74-28331

Unclas

G3/31 42544

PRECEDING PAGE BLANK NOT FILMED

TABLE OF CONTENTS

TABLE OF CONTENTS (Continued)

TABLE OF CONTENTS (Continued)

TABLE OF CONTENTS (Continued)

TABLE OF CONTENTS (Continued)

TABLE OF CONTENTS (Continued)

FIGURES

PRECEDING PAGE BLANK NOT FILMED

TABLES

ABBREVIATIONS AND ACRONYMS

Å	Angstroms
AC	Alternating Current
ACE	Acceptance Checkout Equipment
ACQSS	Acquisition Sun Sensor
ACS	Attitude Control System
ADP	Acceptance Data Package
ALSA	Astronaut Life Support Assembly
AM	Airlock Module
APCS	Attitude & Pointing Control System
ARC	Ames Research Center
ASAP	Auxiliary Storage and Playback
ATM	Apollo Telescope Mount
ATMDC	Apollo Telescope Mount Digital Computer
BTU	British Thermal Units
CBRM	Charger Battery Regulator Module
CCB	Change Control Board
CCOH	Combined Contaminants, Oxygen, Humidity
CCS	Command Communication System
C&D	Control and Display
CEI	Contract End Item
CFE	Contractor Furnished Equipment
CG	Center of Gravity
C_L	Centerline
Cluster	SWS plus CSM (used synonymously with "Orbital Assembly")
CM	Command Module
CMG	Control Moment Gyro
CMGS/TACS	Control Moment Gyros Subsystem/Thruster Attitude Control Subsystem
C/O	Checkout
COAS	Crew Optical Alignment Sight
CO_2	Carbon Dioxide
COFW	Certificate of Flight Worthiness
COQ	Certificate of Qualification
cps	cycles per second
CRS	Cluster Requirements Specification
CSM	Command Service Module
C&W	Caution and Warning
DA	Deployment Assembly
db	Decibel
dc	Direct Current
DCS	Digital Command System
DCSU	Digital Computer Switching Unit
DDA	Drawing Departure Authorization
DDAS	Digital Data Address System
deg.	Degree
DTCS	Digital Test Command System
DTMS	Digital Test Measuring System

ECP	Engineering Change Proposal
ECS	Environmental Control System
EMC	Electromagnetic Compatibility
EMI	Electromagnetic Interference
EPCS	Experiment Pointing Control Subsystem
EPS	Electrical Power System
ERD	Experiment Requirement Document
ESE	Electrical Support Equipment
ESS	Experiment Support System
ETR	Eastern Test Range
EVA	Extravehicular Activity
°F	Degrees Farenheit
FAS	Fixed Airlock Shroud
fc	foot candles
FM	Frequency Modulation
fps	feet per second
FSS	Fine Sun Sensor
ft.	Feet
g	Acceleration due to Earth's Gravity
GFE	Government Furnished Equipment
Grms	G Level, root mean square
GSE	Ground Support Equipment
H_2O	Water
He	Helium
HSS	Habitability Support System
Hz	Hertz
ICD	Interface Control Document
IOP	In Orbit Plane
IU	Instrumentation Unit
IU/TACS	Instrument Unit/Thruster Attitude Control Subsystem
IVA	Intra-Vehicular Activity
JSC	Johnson Spacecraft Center
KHz	Kilohertz
KSC	Kennedy Spaceflight Center
LCC	Launch Control Center
LCG	Liquid Cooled Garment
LH_2	Liquid Hydrogen
LO_2	Liquid Oxygen
LRC	Langley Research Center
LV	Launch Vehicle
LVDC	Launch Vehicle Digital Computer
MDA	Multiple Docking Adapter
MGSE	Maintenance Ground Support Equipment
MHz	Megahertz
MRD	Mission Requirements Document
MS	Margin of Safety
m/sec.	Millisecond
MSFC	Marshall Space Flight Center
MSFN	Manned Space Flight Network
MSOB	Manned Spacecraft Operations Building

N_2	Nitrogen
NASA	National Aeronautics and Space Administration
NHB	NASA Handbook
NiCd	Nickel Cadmium
NM	Nautical Miles
O_2	Oxygen
OA	Orbital Assembly (SWS and CSM - Used synonymously with "Cluster")
OWS	Orbital Workshop
ΔP	Differential Pressure
PCM	Pulse Code Modulation
PCS	Pointing Control System
PMC	Post Manufacturing Checkout
POD	Planning Operational Dose
psi	pounds per square inch
psia	pounds per square inch absolute
psid	pounds per square inch differential
Q	Heat
RCS	Reaction Control System
RF	Radio Frequency
S-IB	First Stage of Saturn I-B Launch Vehicle
S-II	Saturn II
SAL	Scientific Air Lock
SAS	Solar Array System
SCN	Specification Change Notice
SL	Skylab Program
SM	Service Module
SWS	Saturn Workshop (PS/MDA/ATM/AM/OWS/IU/ATM Deployment Assembly)
ΔT	Differential Temperature
TACS	Thruster Attitude Control System
TCRD	Test and Checkout Requirements Document
TCSCD	Test and Checkout Specification and Criteria Document
UV	Ultra Violet
VAB	Vehicle Assembly Building (HI-Bay)
Vdc	Volts direct current
VHF	Very High Frequency
WMS	Waste Management System
WSS	Water Subsystem
Z-LV(E)	Z Axis in Local Vertical (Earth Resources Attitude Mode)
Z-LV(R)	Z axis in Local Vertical (Rendezvous Attitude Mode)

2.2.12 Pressure Garment Conditioning System

2.2.12.1 Pressure Garment Conditioning Station

A. Pressure Suit Conditioning Design Requirements - Design Concept - The 1B87189 PGA Drying Station Assembly is an air circulation pump system that forces air from the OWS cabin through a flexible fiberglass coated hose into the PGA red gas connector and then out the PGA blue gas connector. As the cabin air flows through the air pump, the air temperature is increased above ambient and feeds into the PGA assembly. As the air travels through the PGA, moisture is evaporated and picked up by the air, reducing the air temperature to just a few degrees above ambient. The air is then exhausted into the OWS cabin. The output of the air pump is 18 ACFM (.505m^3/min), therefore resulting in an air volume of 10,800 $ft.^3$ (303m^3) through the PGA during a normal ten-hour drying cycle. After dynamic drying of the PGA, further drying is accomplished by the addition of two desiccant containers approximately 80 in.(203.2cm) in length. Each desiccant container holds 900 gms. of desiccant [at 270°F (132°C)] which is capable of absorbing a minimum of 50 gms. of moisture at a relative humidity of 10 percent and an air temperature of 75°F (23.8°C).

1/ Design Requirements

a. The OWS shall provide a means of circulating unheated cabin atmosphere through a pressure suit, using a blower which is similar to the WMS blower and desiccant bags for moisture removal. Each suit shall be dried sequentially utilizing total blower output for each drying operation. Inflight drying of the desiccant bags shall be provided.

b. The PGA Drying Station Assembly must survive the loads and environments induced during all prelaunch, launch, boost flight, and orbital operations of Skylab. A summary of the design requirements is presented below.

- Circulate OWS Cabin Air through PGA.
- Use power module identical to WMS.
- Maximum air temperature of 120°F (48.8°C) at suit interface.
- Dry three suits in 48 hours (dynamically).
- Minimum air flow to PGA of 10.0 ACFM (.28m^3/min).
- ΔP of 3.5 in. (8.89 cm) water maximum for PGA.
- Minimum moisture removed during dynamic drying to be 400 gms. out of 500 gms. total.

- Provide static desiccant containers (two per PGA) to remove a minimum of 100 gms of moisture at 10 percent RH at 75°F (22.2°C).
- Static desiccant containers to maintain air in suit below 55 percent after 50 hours.
- Minimum number of drying cycles - 23.

B. System Description

1/ Subsystem Configuration - The suit drying equipment consisting of a blower, hoses and desiccant bags is provided to remove moisture from inside the pressure suits after each suited operation. Pressure suits are dried at three (3) suit drying stations located in the OWS forward compartment. Drying is accomplished by installing a suit in the drying station which consists of the PGA portable foot restraints (attached to the forward compartment floor) and a hanger 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, chambers 5 and 6. Figure 2.2.12.1-1 provides an illustration of this suit drying concept.

The PGA Drying Station is composed of a storage ring Container Assembly with the following major components:

1B87189	Suit Drying Station Assembly
1B83241	Power Module

SKYLAB - ORBITAL WORKSHOP
SUIT DRYING STATION

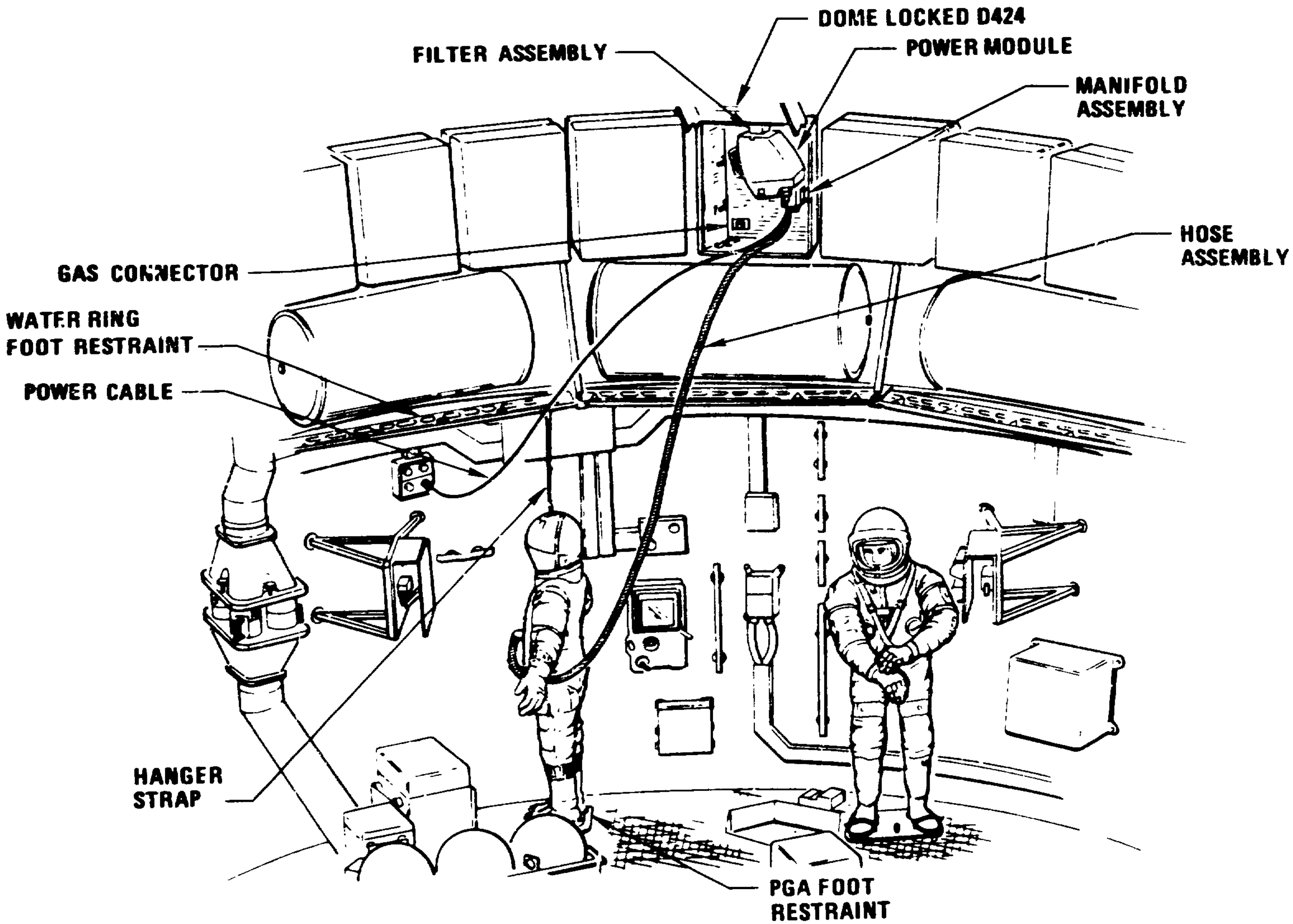


Figure 2.2.12.1-1

1B87188	Filter Assembly
1B87190	Manifold Assembly
1B87196	Hose Assembly
1B87193 & 1B87194	Bracket
1B87197	Gas Connector
1B85811	Power Cable
1B94478	Zitex Desiccant Container

a. Suit Drying Station Assembly (1B87189) - The Suit Drying Station Assembly is the ring container that provides the launch restraint for all the components used during PGA drying. The Container Assembly (1B80510) is normally closed during drying operations.

b. Power Module (1B83241) - The Power Module is the air pump that forces OWS Cabin Air through the PGA assembly. The Module operates normally in a 5 to 6 psia (34.5 to 41.4kN/m^2) environment at 85°F (29.4°C) maximum ambient air temperature. This power module is identical to the one used in the waste management compartment for fecal collection. The module operates on 24 to 30 vdc power supply.

c. Filter Assembly (1B87188) - The Filter Assembly is a gross screen filter that prevents large debris from entering the suction port of the power module. The stainless steel screen is 30X30 mesh wire [.018 in. dia (.045 cm)] supported between a retainer and the filter frame. The filter frame also serves as a support for activating a micro switch located on the power module. The Filter

Assembly is connected to the power module with quick-release fasteners (two provided) and may be removed for cleaning or for power module replacement if necessary.

d. Manifold Assembly (1B87190) - The Manifold Assembly provides the interface connection between the power module exhaust and the flex hose going to the PGA Assembly. The Manifold mounts directly to the base of the container assembly (1B80510). Also, the Manifold contains a fire arrester to prevent propagation of a possible fire source from the power module.

e. Hose Assembly (1B87196) - The Hose Assembly is a fiber-glass coated silicone rubber hose used to interface directly with the PGA Assembly through the red gas connector. The Hose is approximately 16 ft. (4.88m) in length and 1-1/2 in. (3.81 cm) in diameter. A 90° elbow is located at the hose end that mates with the PGA Assembly.

f. Bracket (1B87193 & 1B87194) - These brackets are used to retain the hose and cable assemblies during storage and launch. They mount directly to the Container Assembly (1B80510) at seven places.

g. Gas Connector (1B87197) - The Gas Connector is the flex hose (1B87196) end support for launch and storage when PGA is not being dried. The gas connector is mounted permanently to the base of the container assembly (1B80510-501).

h. Power Cable (1B85811-1 & -501) - The Power Cable is a flex electrical cable that interfaces directly to the

Power Module (1B83241) through a zero "g" connector. The other end of the Power Cable is connected to a utility outlet located near the PGA Drying Station during PGA drying operations. At other times, the Power Cable is coiled inside the Container Assembly (1B80510) and supported by spring clips mounted to the container. A dummy electrical support (1B76238) is provided to restrain the free end of the cable when not in use.

i. Zitex Desiccant Container (1B94478) - The Zitex Desiccant Container is 6-1/2 ft. (1.97m) length of 1-1/4 in. (3.17 cm) diameter flex desiccant [Sorbead "R" Desiccant Type 1, Grade H, Amendment 2, 1/8 in. (5.4 cm) diameter] container. The container has twenty individual compartments containing 45 gms. of dry desiccant. The desiccant is measured and weighed at 280°F (137.7°C).

The Zitex Desiccant Container (two provided per PGA) is placed in the PGA after initial drying of the suit by the PGA Drying Assembly. One end of a container is placed in the right glove, down the right side of the torso, and into the right leg and boot. The other container is in a like manner placed on the left side of the PGA. The containers remain in the PGA until it is used, at which time they are placed in their launch/stowage position in the Container Assembly (1B80510). Prior to PGA drying, the desiccant containers are regenerated by placing in an unused Fecal Processor drawer. In the processor, heat is applied directly to the containers by the pressure plate, and concurrently a vacuum is maintained during a normal ten-hour drying cycle.

A dual set of desiccant containers are provided which allow the regenerating process to begin at any time prior to PGA use if required.

2/ Mechanical Interface (Internal and External) - The PGA Drying Station Assembly interfaces with the ring container support by means of inner supports and four (4) 1/4 in. (.635 cm) diameter bolts. The ring container support interfaces directly with the Skylab tank wall.

The Power Module interfaces with the PGA Drying Station Assembly by two alignment pins and one quick-release fastener.

The Manifold Assembly interfaces with the power module by means of a rubber sponge gasket compressed against the power module housing to form an air tight seal. The Manifold Assembly at the same time is supported on the base of the Container Assembly.

The Hose Assembly interfaces with the Manifold Assembly by means of a hose connection and clamp. The other end of the Hose Assembly interfaces directly to the PGA through the red gas connector.

The Power Cable interfaces with the power module by means of a zero "g" electrical connector and the other end of the power cable interfaces with a utility electrical outlet in a similar manner.

3/ Unique Fabrication Techniques and Important Details - None.

4/ Use of New Technology and Advanced State-of-the-Art Materials Components, Systems, or Techniques. None.

C. Test Program Line Item

1/ Development Tests (CX-5 Report Number G4178) - The test specimen which is essentially identical to the production unit, was subjected to all environments expected through the Skylab mission from launch to on-orbit requirements (Refer to TCD 1T40719 Rev. B).

The following environments were tested:

a. Proof Pressure, Leakage, and Flow vs ΔP.

b. Functional Test of Power Module.

c. Functional Test of Zitex Desiccant Container.

d. Acoustical Measurement Tests.

e. Vibration Test of Zitex Desiccant Containers.

f. Functional Life Cycle Tests.

g. Post Test Inspections.

2/ Qualification Test - Not Applicable

3/ Acceptance Test - Not Applicable

4/ Special Tests - During the first and second week in June, 1972 an actual PGA was loaned to MDAC so that development-type tests could be performed on two desiccant assemblies proposed for use in a semi-closed loop drying system. The following basic procedure was followed:

The PGA drying system, including the PGA, was installed in an environmental chamber that was controlled to the highest air dewpoint expected for Skylab habitation area [60°F (15.3°C)]. The temperature was controlled at 83 $^{+2}_{-0}$°F (28.3 to 29.4°C) to test the thermal characteristics of the Electronic Controller of the power module. The dry weight of the PGA and desiccant assemblies was recorded just prior to the drying test. 500 grms of water were added to the liner of the PGA and PGA closed immediately thereafter. During the drying operation, the continuous decrease in PGA weight was to be recorded but data was lost due to the electronic setup. In one case only was the continuous decrease in PGA weight obtained. A summary of the results of the six ten-hour drying tests is noted in Figure 2.2.12.1-2.

5/ Problems and Corrective Actions

a. Problem - During the initial function air flow test, the power module failed to exhaust a minimum of 5 ACFM (.140m^3/min) to the two PGA. Flow rate as measured was below calibration of the flowmeter.

- Solution - A rubber duct was added to the power module exhaust port and routed to the non-propulsive vent. At the non-propulsive vent a rubber seal was added to prevent air leakage and

ORBITAL WORKSHOP
SUIT DRYING PERFORMANCE
CX-5 TESTING (WT IN GRMS)

TEST RUN	SUIT DRY WEIGHT	WATER ADDED	SUIT WET WEIGHT	SUIT WT AT END OF 10 HOURS	WATER REMAINING AFTER TEST	WATER REMOVED DURING TEST	NOTES
1	21,726.5	498.7	22,225.2	21,893.1	166.6	332.1	1, 2, 3, 5
2	21,737.5	500.0	22,237.5	21,786.6	49.1	450.9	4, 5
3	21,725.0	500.0	22,225.0	21,808.4	83.4	416.6	6, 4
4	21,720.3	501.7	22,222.0	21,771.1	50.9	450.8	5, 7
5	21,712.7	500.0	22,212.7	21,731.1	18.4	481.6	5, 7
6	21,682.4	500.0	22,182.4	21,727.5	45.1	454.9	6, 7

NOTES:
1. WEIGHTS DURING TEST RUN NO. 1 ARE QUESTIONABLE
2. SUIT HANGING VERTICAL WITH ARMS UNSUPPORTED
3. MOISTURE DENSITY NOT CONTROLLED VERY ACCURATELY
4. SUIT HANGING VERTICAL WITH ARMS SUPPORTED TO HORIZONTAL POSITION
5. CLOSED LOOP WITH DESICCANT ASSEMBLIES ATTACHED TO SUIT
6. OPEN LOOP WITHOUT DESICCANT ASSEMBLIES
7. SUIT LAYING HORIZONTAL WITH ARMS SUPPORTED WITH GLOVES UP

Figure 2.2.12.1-2

to channel the air into the manifold assembly.

After this duct addition, the air flow versus ΔP exceeded the design requirement of 5 ACFM (.140m^3/min) to each PGA.

b. Problem - During the initial ten-hour functional test where the test chamber was controlled at 83 $^{+2}_{-0}$°F (28.3 to 29.4°C), the power module electronic controller overheated .

- Solution - A small orifice [$^{.130}_{.134}$ in. dia.($^{.33}_{.335}$cm)] was cut in the rubber duct previously added and air flow channeled across the electronic module. This orifice provided 1.3 ACFM (.0364m^3/min) to the electronic module which reduced the temperature approximately 12°F (-11.1C). To reduce the temperature further, another orifice was cut to increase the air flow but during the test verification run, the new orifice did not reduce the temperature any appreciable amount. Therefore, all remaining tests (life cycle) was run with one orifice only. The resulting temperature was acceptable to the manufacturer of the power module.

c. Problem - During a functional drying test performed at MSC/NASA where approximately 6.85 ACMF (.191m^3/min.), [70% O_2/30% N_2, and 90°F (32.2°C) and 60°dp (15.55°C)], was channeled through the PGA, approximately 75 grams of moisture (water) remained in the suit after 5-1/2 hours of drying using an open loop system. The excessive moisture (75 gms) was considered by MSC/NASA to be not adequate for control of Fungal contamination resulting in degradation of PGA materials.

- Solution - Change concept from drying two PGA's at time to one PGA at a time. Also, after drying PGA with air flow power module, place in the PGA a sufficient amount of desiccant to absorb the remaining moisture. A 6-1/2 ft (1.97m) length of Zitex Desiccant Assembly was added to the drying technique. Test data that uses a PGA simulator (1/10 volume of actual PGA) and a desiccant bag manufactured out of Zitex material and Silica Gel was tested with satisfactory results. Two vacuum drying tests using the wet desiccant bags resulted in the desiccant being dried completely after ten hours.

6/ Subsystem Conclusions

a. Summary of Capabilities Versus Requirements - Based on the test results and the power module performance after life cycles the air flow rate and moisture removal has been demonstrated. Removal of moisture remaining in the PGA after dynamic drying was also demonstrated. It is concluded from test results that the PGA Drying Station will meet all design requirements for use on the OWS.

b. Summary of Open Problems and Plans for Corrective Action - None.

c. Long-Duration Operational Capability - Not applicable.

7/ Subsystem Certification

a. Basis for Certifying Design Maturity and Manned Flight Safety - All functional demonstration tests have been satisfactorily completed to verify that moisture removal from PGA will be accomplished.

b. List of Open Items - None.

c. List of Waivers and Deviations to Specifications - None.

d. Summary of Risk Assessment of Open and Closed Items - None.

e. Summary Assessment of Problem Items Identified on Backup Hardware - No problems.

D. Mission Results

1/ Hardware Anomalies - No anomalies were reported. There was a tendency for the power module located in Ring Container D424 to heat up if the lid was closed. The crew left the lid open during suit drying operations.

2/ Hardware Assessment

a. First Mission Crew Hardware Assessment

The performance of the suit drying station was nominal for the first mission. The crew reported that the suits were dried very well and that there was little or no odor to the suits after the drying process. The initial suit drying was accomplished for the SAS EVA. The suits were always dried adequately and there was no evidence of bacterial growth or odor. The noise level during the long time operation of the blower was unobjectionable.

Hose assembly lengths were acceptable. There were no other changes in procedure or hardware recommended by the flight crew.

The suit dryer power module was too hot to touch. This unit was operated with the ring compartment door closed per procedure. The second mission crew was instructed to leave the door open for additional cooling. There is no explanation for the "hot" blower. It was also recommended that if the blower again gets too hot to touch, the third crew would measure the temperature using the digital thermometer.

The following are questions and answers from the Crew Systems Debriefing:

- How long were individual suits dried after each wearing? 10 hours approximately.

How many desiccants were dried in each chamber? On initial activation we didn't dry. Put in four per suit after SAS EVA - dried two per suit 10 hours - returned the other six to disposal bag and back to locker. Put one in each of two processors. Six are still wet.

The performance of the suit drying equipment was as planned for the second mission. All hardware operated satisfactorily with the exception of the "warm" power module. The suits dried very adequately and no wetness or unpleasant odors were noted.

b. Second Mission Crew Hardware Assessment

Crew comments from the Crew Systems Debriefing are provided as follows:

- How long were individual suits dried after each wearing? We dried all of them about 24 hours, we weren't sure how long was really needed to keep bugs from growing so we put them on (drying) for a long time. The suits really never got very wet.
- Were the extremities (feet, legs, arms, gloves) dry? Yes.
- Was there any evidence of bacterial growth or odor in the PGA's? No.

Comments from the Second Mission Crew Technical Debriefing are provided as follows:

- PLT Moisture in the suits: "I never noticed a whole lot of moisture in the suits, although we always went through the total suit drying procedure. The three little hangers that you hang your LCG's and FCS's on are already installed in the blue water tank ring, right above the suit donning station. You just hook up the suit dryer, and turn it on, and let it blow away; and be sure to keep the come locker door to that suit dryer open so it doesn't overheat. We let our suits dry for 24 hours and then moved them up into the MDA."

Comments from the CDR relative to the problems encountered over drying desiccants in the processor are provided as follows:

- CDR Some of those long thin bologna like desiccants won't allow you to close the fecal drawer. If you don't have anything in the fecal dryer, and you close the door, that little black metal plate that the fecal bag would stand on sort of moves up, pressing near the top vent inside the drawer. Then, when the door closes, you will hear a slight vacuum sound, as the vacuum is pulled on the door, when you move the lever to the vacuum door position. Normally when you put the fecal material in there, the same things happen, except of course, the little tray does not go completely to the top of the enclosure any more because the fecal bag is in the way. So it sort of tends to hold the fecal bag up against the top of the chamber. But when you close the door and move the little lever, you'll hear a kind of vacuum sound and you'll know you're putting a vacuum on the fecal bag. Now when you put in the bottom drawers, those long, white bologna like desiccants, you will push down on the door, that little tray inside the compartment, when you close the door and move the lever, you don't get a vacuum pulled inside the compartment. Now, the only way you realize this is that you don't hear that little characteristic sound, and if you tug on the door, the door will come open a little, showing that there is not a vacuum. Now what occurs in this case is that you don't get a good drying and you also leak atmosphere out. Not fast and not critically, but enough so that it is noticeable. The ones that are on the top of these desiccants are the ones that the next crew should use. And if they put them in there, to be sure that they check, to make sure that the door has a good vacuum seal before they wander off, and set the timer and leave. You put it in, close the door and as you move the lever, listen for a little vacuum sound. Then try the door and see if it can be easily pulled out. If it cannot, you're okay. So set the timer and go on. If it flunks this, the sound, or the fact that the door will open without a lot of effort, then you probably haven't got a good vacuum in there and you need to go back and do it again. We've got a couple of desiccant lengths that won't fit and they're marked with red tape. It's probable that there are others around there, but hopefully the ones that you pick out right at the top of the sacks will be the ones we used and will be acceptable.

c. Third Mission Crew Hardware Assessment

There were no anomalies reported on the pressure suit drying system during the third mission. The only comment, made by the SPT, was that the suits are too close together.

E. Conclusions and Recommendations

Suit Drying - Suit drying was accomplished satisfactorily. The initial suit drying was accomplished for the SAS EVA. Two suits were dried and 2 desiccants per suit were dried in the processor chambers No. 5 and 6. The six spare desiccants were removed to a locker and stowed without drying. The suits were always dried adequately and there was no evidence of bacterial growth or odor. The noise level during operation of the blower was unobjectionable.

Hose lengths were acceptable. There were no other changes in procedures or hardware recommended by the flight crew.

The suit drier power module was too hot to touch. This unit was operated with the ring compartment door closed per procedure. Crews will be instructed to leave the door open for additional cooling. There is no present explanation for the "hot" blower. It was recommended that if the condition recurs, the crew would measure the temperature using the digital thermometer.

F. Development History - During the latter period of the waste management hardware deliveries, the requirement for drying the pressure garment assemblies (PGA) became apparent and an additional power module was added to the Workshop to be used for suit drying. In addition, desiccants used to keep the suit dry were dried in one of the waste processor chambers.

2.2.12.2 Pressure Garment/Equipment Stowage Provisions

A. Design Requirements - Specification Number: CP2080J1C. The Contract End Item (CEI) Detail Specification defined the basic OWS requirement as follows:

Pressure Garment Assembly (PGA) and Related Equipment Stowage (CEI paragraph 3.3.1.11.2): Stowage provisions shall be provided for restraining three extended pressure garment assemblies and three extended Liquid Cooled Garments (LCG's) and associated equipment. A means shall be provided to prevent the pressure suit boots from slipping out of the restraints when the suit is in this extended stowed position.

Additional specific design requirements were as follows (reference ECP W168R2):

1/ Two pressure garment assembly conditioning stations on the upper floor facing Experiment T013, Crew/Vehicle Disturbance and two upper suit restraints which interface with the suit ground clamps and attach to the water bottle ring with a fabric strap.

2/ Foot restraints for attaching the suits to the floor grid (existing foot restraints will be modified to mount in specified locations facing Experiment T013 FMU's).

3/ Strap restraints in the upper compartment for orbit stowage of one pressure garment assembly and three liquid cooled garments.

4/ On orbit restraints for two each helmets and gloves on Experiment T013 mounting brackets.

5/ Three hanger assemblies in the upper compartment for hanging the liquid cooled garments to air dry in the OWS environment.

6/ Armalon stowage bags (2 configurations) will be provided for stowing the Zitex desiccant containers in the ring stowage container.

B. System Description - To locate the PGA's in the OWS for drying purposes and also for on-orbit PGA stowage, two suit drying stations were provided on the OWS forward compartment floor below the suit dryer and adjacent to the T013 structure; each suit drying station accommodated one A7LB spacesuit (reference Figures 2.2.12.2-1 and 2.2.12.2-2). Each drying station was fitted with a portable PGA foot restraint into which the boots of the PGA were inserted, to restrain the suit at the floor level. A PGA hanger strap was used to stretch the PGA into an extended state by tethering the neck area of the PGA to the platform foot restraint. The LCG's were air dried in the OWS atmosphere adjacent to the PGA's. A long strap was used to restrain the legs of the LCG to the OWS forward compartment floor and an LCG hanger was used to restrain the LCG neck area to the T013 structure. A SEVA stowage bag containing a SEVA and a pair of EVA gloves was conveniently located on each T013 structure for on-orbit stowage and ready accessibility. Two complete A7LB spacesuits were located at the suit drying stations during drying operations and when they were not in use. The third A7LB spacesuit was stowed in a designated stowage area in the OWS when not in use.

SKYLAB - ORBITAL WORKSHOP
SUIT DRYING STATION

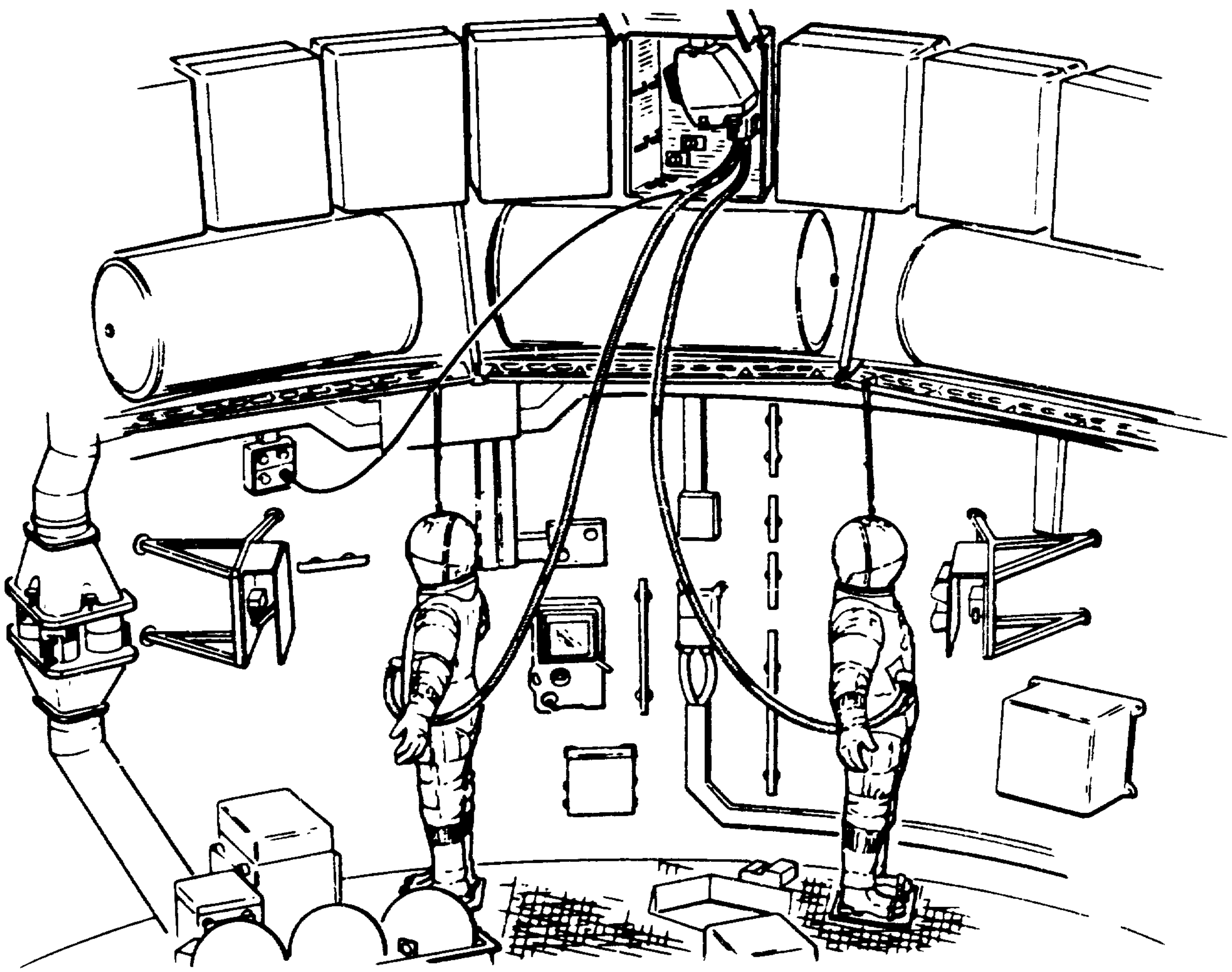


FIGURE 2.2.12.2-1

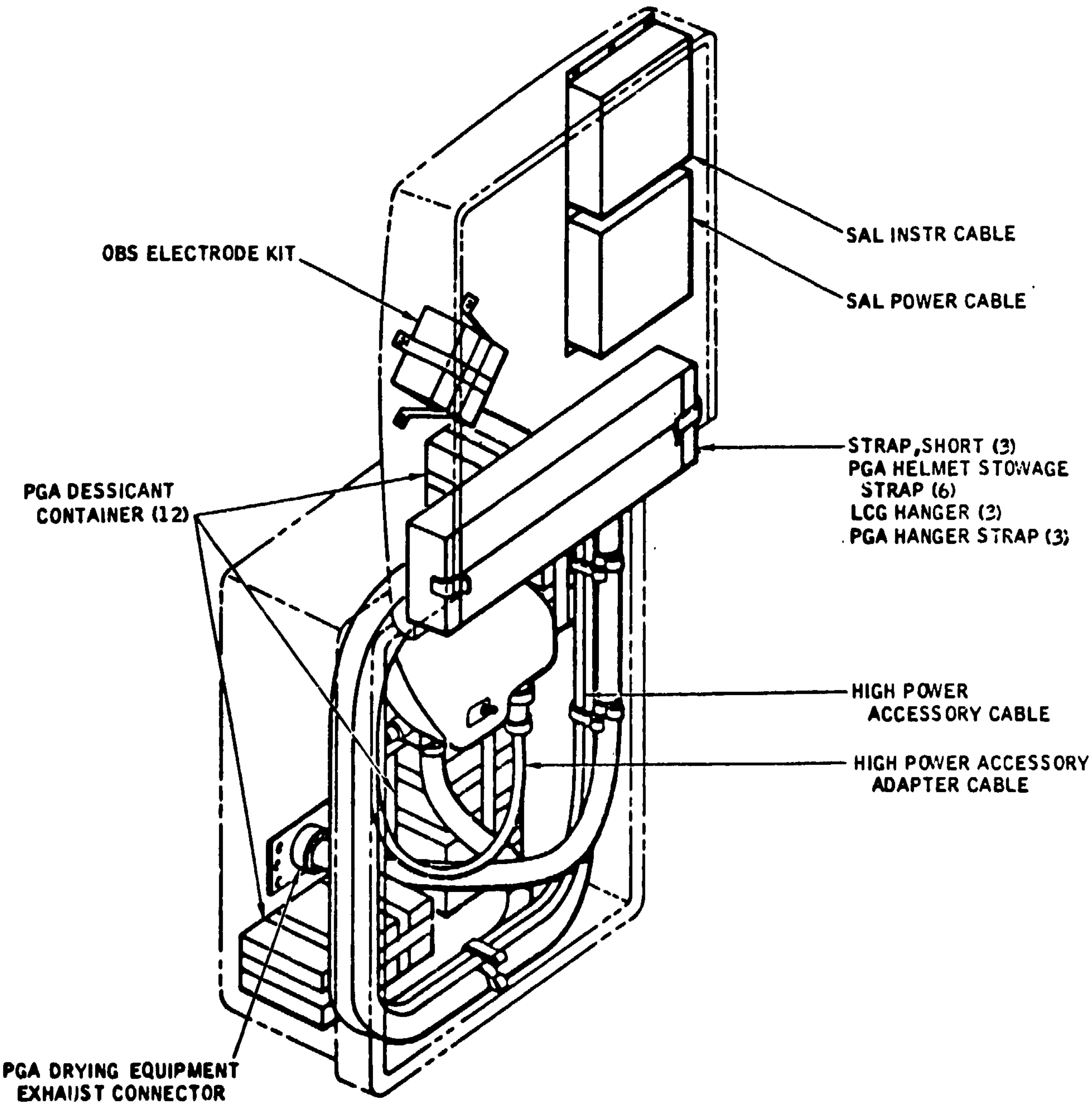


FIGURE 2.2.12.2-2 PGA SUPPORT EQUIPMENT STOWAGE

LCG Hangers: Liquid cooling garment hangers were supplied for use in air drying the LCG's at the suit drying stations in the OWS. The LCG hanger was a rigid, open triangular section that fit into the back and shoulder area of the LCG. A flexible strap fitted with snaps was connected to the triangular section to permit the LCG to be stretched while being air dried. The snaps were provided to secure the LCG hanger to convenient structure. Three LCG hangers were stowed in OWS forward dome stowage compartments until required for use. Each crewman utilized one LCG hanger to dry his LCG in the OWS.

PGA Hanger Strap: Pressure garment assembly hanger straps were supplied for use while the spacesuits were occupying the suit drying stations in the OWS. The PGA hanger strap was a flexible webbed strap, fitted on one end with a coupling and on the other end with snaps. The coupling permitted the strap to be secured to the PGA mounted D-Ring while the snaps permit the strap to be attached to convenient structure. The strap also contained a buckle to allow adjustment of its length to stretch the PGA for suit drying operations. Three PGA hanger straps were stowed with the LCG hanger in OWS forward dome stowage compartment until ready for use. Each crewman utilized one PGA hanger strap to restrain his PGA at the suit drying stations.

Long Straps: The long strap was 26 inches long and 1 inch wide and constructed of a beta fabric webbing with a fluorel covering. Both sides of the strap were fitted with snap studs and snap sockets. These provisions allowed the strap to be secured about a structure or to structure mounted snaps to conform to the envelope of the restrained item.

Portable PGA Foot Restraints: Two portable PGA foot restraints were provided for use on the OWS forward compartment floor grid as a restraining mechanism for spacesuit restraint during suit drying operations. The foot restraint retained the PGA boots through use of a toe-bar and a heel fitting. Heel clips, which were an integral part of the PGA boots, engaged under the foot restraint heel fittings to provide rigid PGA boot restraint. Pip pin retainers were integrated into the restraint to hold the PGA boot in the restraint during the drying operation. A quick-release fastener is located at the rear of the base plate to permit easy installation and removal of the restraint from the grid surface. Two grid clips fitted to the underside of the base plate positively captured the grid surface upon installation to provide rigid engagement of the foot restraint to the grid. The two portable foot restraints were launch secured to the OWS forward compartment floor grid. For use during contingency modes, the foot restraints were carried about the SWS to aid in accomplishing repair/corrective action tasks while the crewman was suited.

C. Testing - Line Item Test CX-5 was performed to establish the capability of the Zitex desiccant containers stowed in Armalon bags to withstand the vibration environment. The test was completed successfully.

Reference Documents:

Test Line Item CX-5	TCD	1T40719
	CTCA	3505
	Test Report	TM-DSV7-SSL-R-7049

D. Mission Results - The pressure garment/equipment stowage provisions functioned as designed.

E. Conclusions and Recommendations - The stowage provisions were satisfactory. The launch restraints provided adequate protection for the hardware used on-orbit, including the Nitex desiccant containers.

F. Developmeht History - The PGA stowage provisions, as initially designed, were flown with no significant modifications.

2.2.13 Stowage System

2.2.13.1 Design Requirements

A. Stowage (CEI CP2080JIC, Paragraph 3.3.1.12)

All items to be stowed within the OWS were identified with their quantity, size, weight, launch location and special stowage requirements in I-SL-008. Stowage capability was to be provided as described in 1B85808.

NOTE: I-SL-008 identified items for stowage on the OWS both initially for launch and subsequently by orbital transfer. 1B85808 OWS Stowage Capability Drawing defined the size, location, stowage, weight limitation, environment, and standard attachment provisions for the stowage locations.

Other specific stowage requirements were:

B. Food Containers and Film Vault (CEI, Paragraph 3.1.2.1.6.2)

The food and film temperature shall be maintained to their ICD requirements so long as the heat generation from the electronic equipment does not exceed the values listed in ICD's 13M13519 and 13M20926.

C. Orbital Maintenance Support (CEI, Paragraph 3.1.4.3)

A tool kit, orbital spares, and Cluster repair kit shall be provided to support the maintenance tasks. The tool design requirements shall be in accordance with SE-014-001-2H. Stowage of these items shall be as specified in I-SL-008.

D. Experiment M487 Habitability/Crew Quarters (CEI, Paragraph 3.3.1.9.1.1)

An M487 experiment module consisting of the following hardware shall be provided:

1/ Stowage container

2/ Portable velometer and air probe

3/ Portable temperature sensors (3 each)

4/ Portable digital thermometers (2 each) and surface probe (1 only)

5/ Portable measuring tape

6/ Portable sound level meter assembly

7/ Portable frequency analyzer and connecting bar

8/ Portable force (push/pull) gauge, extension rod and hook

9/ Spare batteries

10/ Sound meter restraint bag

E. Biomedical Stowage Containers (CEI, Paragraph 3.3.1.9.4)

Mounting accommodations shall be provided for two biomedical stowage containers (GFP).

F. Film Vault (CEI, Paragraph 3.3.1.9.2)

A vault shall be provided for stowage and on-orbit maintenance of film. The relative humidity within the vault shall be maintained at 45 $\pm$ 15 percent for the period from film loading in the Vertical Assembly Building (VAB) to launch, and for orbital storage. The vault shall contain twelve drawers of various sizes and radiation protection as follows:

Drawer Quantity and Dimensions - Inches (mm)		Radiation Protection (2.7 Specific Gravity Aluminum)
2 Drawers, 15x18x6-1/2	(380x457x165)	0.25 in. (6.35 mm)
5 Drawers, 15x18x6-1/2	(380x457x165)	1.90 in. (48.3 mm)
1 Drawer, 15x18x8	(380x457x203)	1.90 in. (48.3 mm)
1 Drawer, 15x18x6-1/2	(380x457x165)	2.90 in. (73.7 mm)
3 Drawers, 15x18x7	(380x457x178)	3.40 in. (86.3 mm)

Three of the 15x18x7 in. (380x457x178 mm) drawers shall be capable of being used as film handling containers.

G. Waste Storage Containers (CEI, Paragraph 3.3.1.10.2.9)

Storage containers for the waste management supplies and for processed samples shall meet the following requirements:

1/ All supplies for sanitary operation of the WMS shall be located in appropriate storage containers, within easy reach of an astronaut while positioned on the fecal collector seat.

2/ Storage containers shall house the tissues and clean waste collection vehicles to be used for fecal, urine, vomitus, and debris collection.

3/ Storage containers shall be provided for used waste collection vehicles and the processed content of each.

4/ The vehicle storage containers for feces, urine, and vomitus shall be removable from the OWS WMC in modular form for transfer to the Apollo CM and subsequent return to Earth.

H. Storage Provisions (Crew Equipment) (CEI, paragraph 3.3.1.10.8.3)

The sleep compartment shall be provided with containers for storing the individual astronaut's equipment, such as clothing, writing materials, log books, personal preference kit, emergency oxygen equipment, emergency hand-held lights, protective head gear, clothing and medical kits. Quantities and unit dimensions of items are specified in I-SI-008.

I. Pressure Garment Assembly and Related Equipment Stowage (CEI, Paragraph 3.3.1.11.2)

Stowage provisions shall be provided for restraining three extended pressure garment assemblies and three extended liquid cooled garments and associated hardware. A means shall be provided to prevent the pressure suit boots from slipping out of the restraints when the suit is in this extended stowed position.

J. Snaps and Velcro Restraints (CEI, Paragraph 3.1.2.1.3.2)

The location of restraints for on-orbit retention of loose equipment shall be as defined in MDC G2439.

NOTE: MDC G2439, Orbital Workshop Snap/Velcro Restraints, established the locations, size, type and spacing requirements for this type of restraint.

K. Urine and Blood Freezer (CEI, Paragraph 3.3.1.10.2.5)

A freezer shall be provided to freeze urine and blood samples. The freezer shall be capable of reducing the temperature of the samples to below + 27°F (270.40K) within 3 hours, to 0°F (255.4°K) within 6 hours, and to below -2.5°F (254°K) within 8 hours after each simultaneous insertion of the samples into the freezer. The freezer wall or sink temperature shall be no more than -2.5°F (254°K).

L. Urine and Blood Return Container (CEI, Paragraph 3.3.1.10.2.6)

A return container shall be provided for transferring the frozen urine and blood samples from the OWS to Earth via the Command Module (CM). The container shall have a thermal control capability to maintain the urine and blood samples after removal from a freezer at temperatures not to exceed 17°F (264.8°K) for 22 hours.

M. Computerized Stowage Management System (ECP041)

The general requirements for a computerized stowage management system are as follows:

1/ The Skylab Stowage List, I-SL-008, will be utilized to prepare a computerized OWS Stowage Master File identified as Computer Program P1213.

2/ The OWS Stowage Master File will identify all of the items that are to be stowed in the OWS - including CFE, GFE, flight spares and maintenance items; the Master File will also identify all OWS restraint hardware.

3/ The OWS Stowage Master File will be computerized and will provide stowage location, quantity, part number, change letter, nomenclature, size, weight, and item number for all OWS stowage items.

4/ Drawings prepared specifically for stowage control will include loose equipment and stowage provisions installation drawings generated from the computerized OWS Stowage Master File. The drawings will be sorted by stowage location.

2.2.13.2 System Description

A. OWS Stowage Hardware

OWS stowage was provided in the forward dome, forward compartment and crew quarters through the use of various sized stowage compartments, dispensers, refrigerated and ambient temperature food storage facilities, refrigerated urine storage, and a film vault (Figure 2.2.13.2-1). All stowage in the OWS was vented to cabin atmosphere by the stowage equipment door or lid joint. The individual stowage locations were assigned subnumbers based on the 400-900 number series assigned to a given area. The letter prefixing the stowage number reference, was used for training purposes only and did not appear with the stowage number on flight hardware. Each stowage provision was fitted with a stowage label that contained the assigned stowage number, the items stowed, and their quantities. A label kit supplied additional labels for use in reidentifying stowage equipment. Marking pens, in the flight data files, permitted the crewman to write on a stowage label or on the stowage equipment surface to track the status of the contents. The stowed equipment within the OWS was arranged to provide a common grouping of like items, e.g., all spares were grouped together, urine collection bags were grouped together, clothing was grouped together. One exception to this was the location of trash bag bundles for resupply. These were located adjacent to trash containers and high use disposal bag areas. OWS stowage also provided on-orbit temporary restraints, through use of various length straps, bungees and fixed and portable utility restraints. Bags were provided for on-orbit stowage of biological inactive trash, such as launch packing, in the plenum area. These bags were called plenum bags.

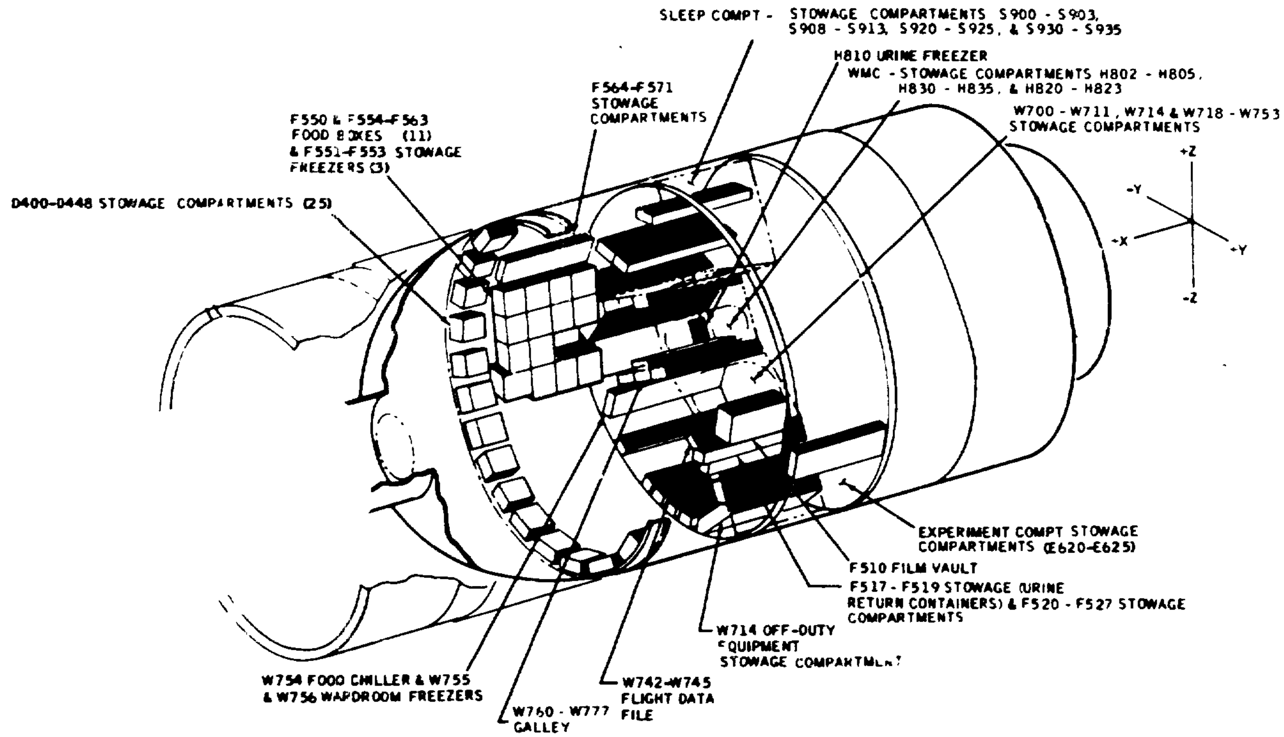


Figure 2.2.13.2-1 SWS Equipment Stowage

Two tool kits and a repair kit provided the on-orbit capability for maintenance and repair.

1/ Stowage Compartments

Stowage compartments in the OWS were of five basic sizes: (1) 6 ft.^{3} (.17 m^3) (stowage compartments of the D400 series); (2) 1.5 ft.^{3} (.04 m^3) (stowage compartments of F523-F527); (3) 3 ft.^{3} (.08 m^3) (stowage compartments of S900-S903); (4) 5 ft.^{3} (.14 m^3) through 6.5 ft.^{3} (.18 m^3) (stowage compartments W714, and H820-823); and (5) 1 ft.^{3} (.028 m^3) (the remaining stowage compartments in the forward compartment and throughout the crew quarters). (Figures 2.2.13.2-2 and 2.2.13.2-3.) These stowage compartment interiors, with the exception of the D400 series stowage compartments, had holes on the top and bottom of the compartment into which adjustable straps were inserted for launch and on-orbit restraint of the stowed items. The latches on the stowage compartments were the lift handle type. The lift handle latches could be forced with a latch release tool if required. All stowage compartments were constructed of sheet metal. The D400 series stowage compartments were removable containers that were designed to provide the capability to be fully packed outside of the vehicle and installed as a complete checked-out unit. The restraints for stowed items within compartments were adjustable straps and custom designed metal bracketry. The packing was provided by armalon/sponge bags and non-flammable fiberboard.

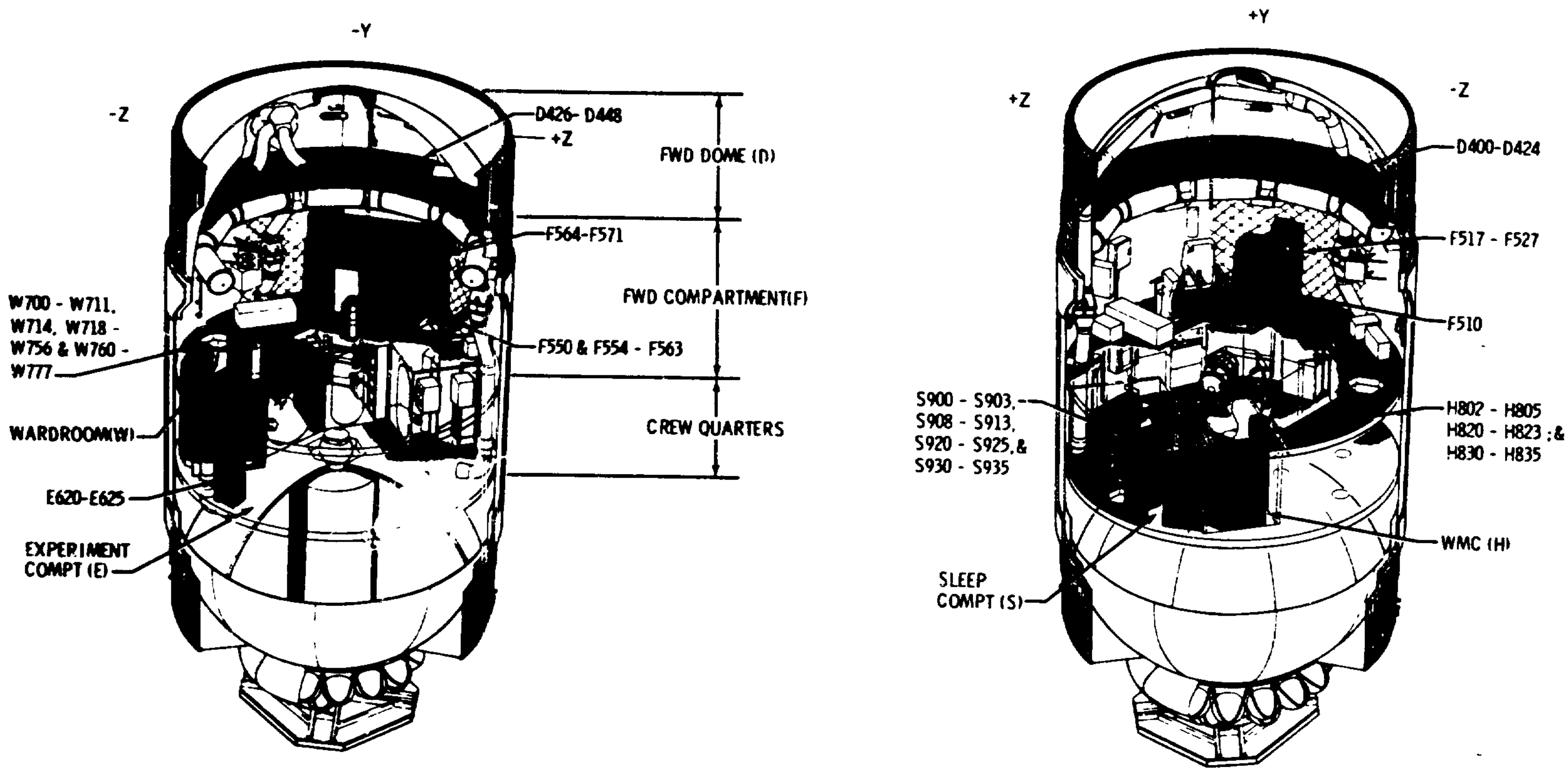


Figure 2.2.13.2-2. OWS Storage

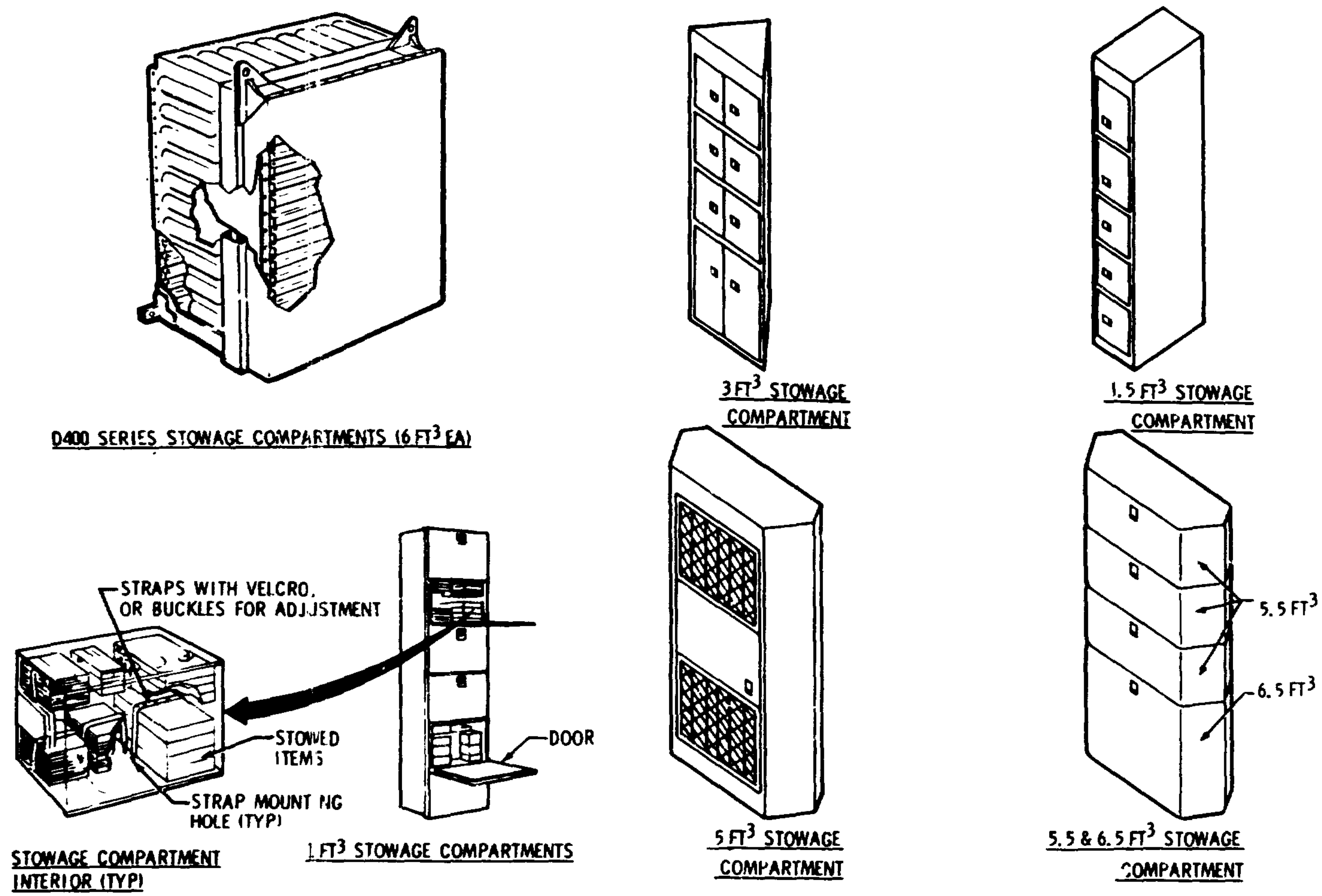


Figure 2.2.13.2-3. OWS Stowage Compartments

2/ Dispensers

Various dispenser mechanisms were provided for high use items that accommodated rapid accessibility as well as stowage.

a. Tissue and Wipe Dispeners

Certain stowage compartments in the OWS crew quarters had tissue dispensers for tissues, wipes and disinfectant moistened pads. (Figure 2.2.13.2-4.) Each dispenser accommodated three cartridges, which were individually dispensed in their own segment of the dispenser. Four dispensers were located in the wardroom, one in the WMC and one in each of the sleep areas. Normally, one dispenser segment contained a cartridge of tissue while the remaining two segments each contained a cartridge of wipes. However, in one of the wardroom isntallations, three cartridges of disinfectant moistened pads were used instead of the dry tissues and wipes. Each dispener contained three spring-feed devices, a cartridge retainer with cartridge retention cams, a compartment door with three tissue access openings, and three hinged dispension lids. The spring-feed mechanisms advanced the tissue in the cartridge from the rear as each tissue was removed.

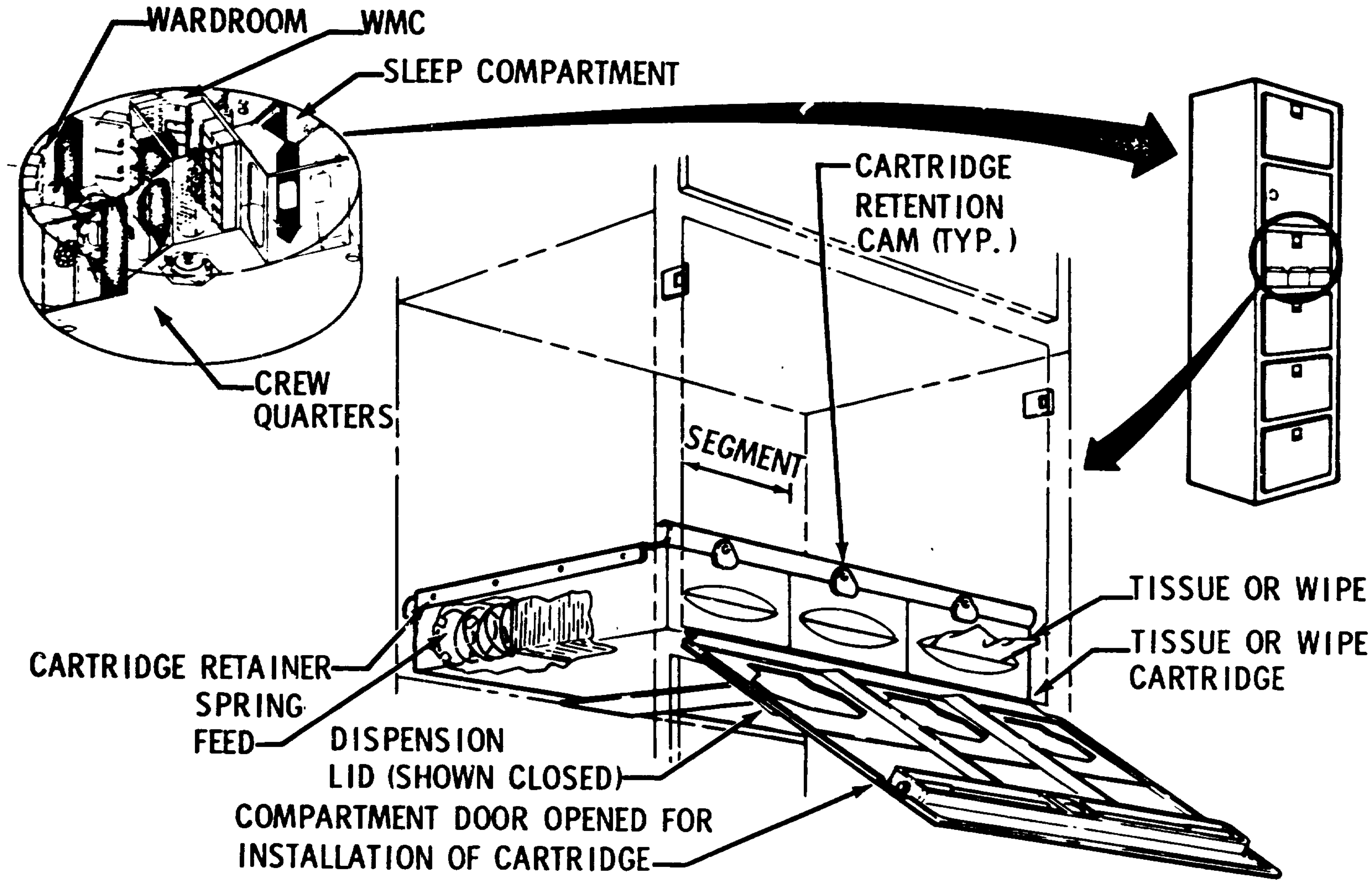


Figure 2.2.13.2-4. Tissue Dispenser — — Installation

The hinged compartment door provided access to the cartridges to facilitate removal and loading operations while also providing access openings on its face through which tissues may be obtained. A spring-loaded dispenser lid covered each access opening on the compartment door to provide flammability control of the combustible tissue. The cartridge retainer and cartridge retention cams restrained each cartridge within the dispenser. The cams permitted easy removal and replacement of a cartridge. When the dispensers were in use, the cartridges occupied only about one-third of the stowage compartment interior, permitting additional stowage of other items. Additional stowage in this area does not hinder removal and replacement of a cartridge.

b. Fecal Bag Dispenser

Fecal bags were readily available to the crew in the WMC through a dispenser. The fecal bag dispenser occupied the H833 stowage compartment adjacent to the handwasher (Figure 2.2.13.2-5). The permanently mounted dispenser contained a spring-feed device, a resupply lid and a dispension lid. As each fecal bag was removed from the dispenser, the spring-feed mechanism

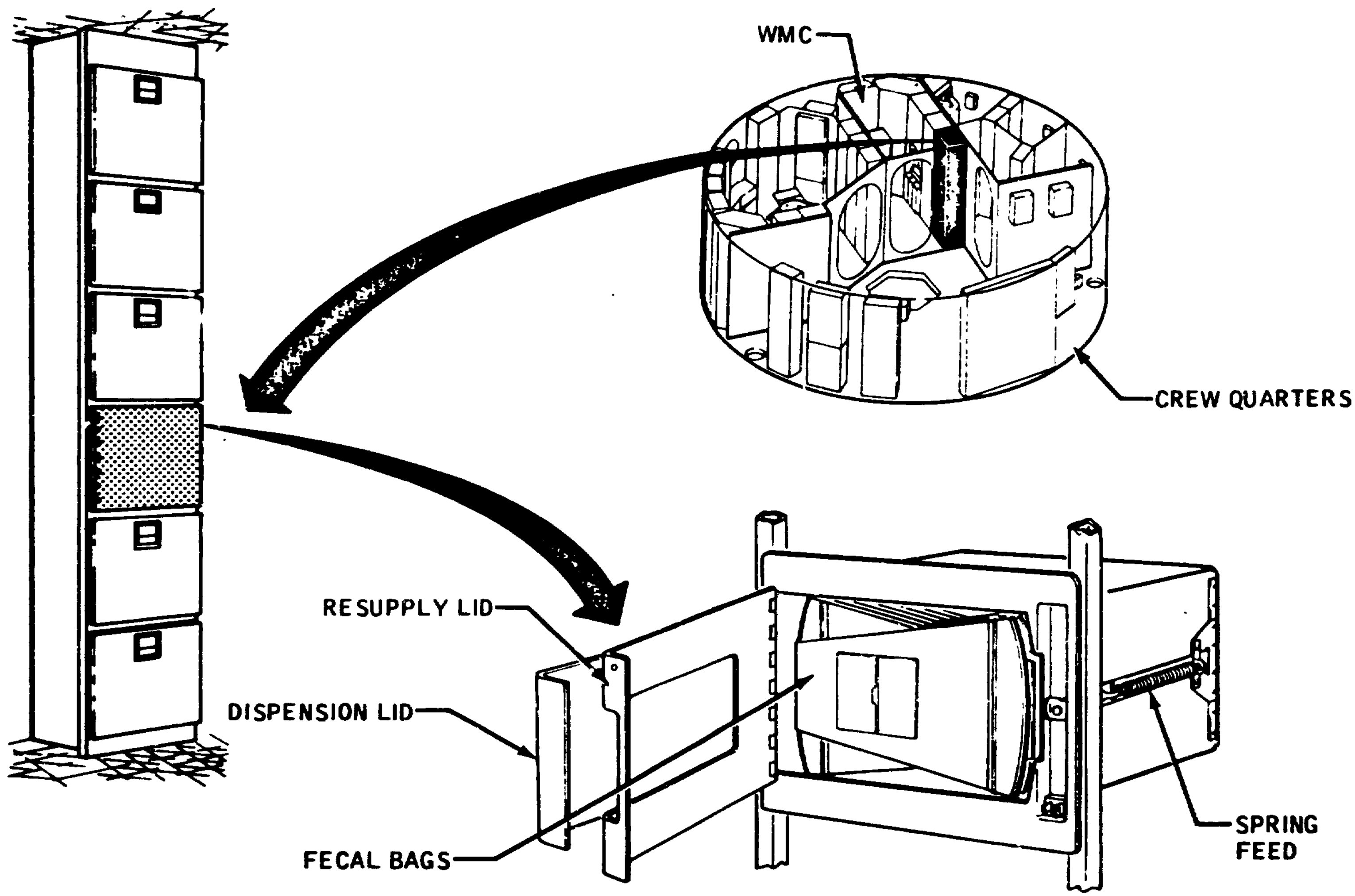
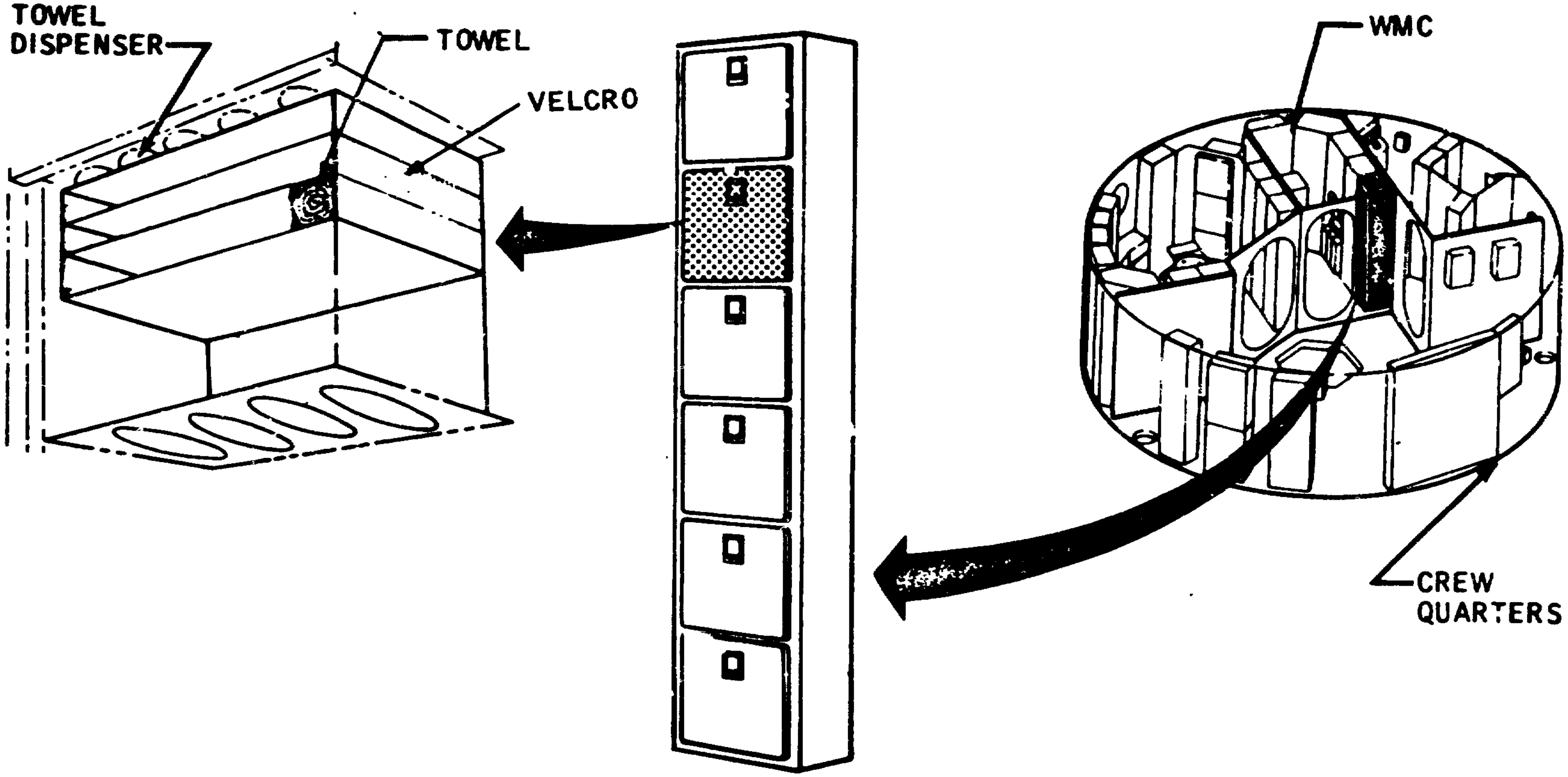


Figure 2.2.13.2-5. Fecal Bag Dispenser

at the rear of the dispenser advanced the remaining fecal bags into an accessible position, replacing the withdrawn item. The resupply lid served to restrain the stored contents while providing an opening through which fecal bags may be obtained. This lid was maintained in the closed position through a latch. The resupply lid was used to replenish the dispenser with a resupply of fecal bags. The dispension lid was spring-loaded closed and must be opened to obtain individual fecal bags.

c. Towel Dispenser

New towels were readily available to the crew through five removable towel dispensers. One towel dispenser was launched in a WMC stowage compartment for immediate use; the remaining dispensers were located in wardroom stowage compartments. The outside surface of the towel dispenser was lined with velcro to mate with velcro located in the stowage compartments (Figure 2.2.13.2-6). Each towel dispenser was launched with a supply of 18 towels. Each towel dispenser was partitioned into three equally sized tiers; the tiers are open at the front and accommodated six rolled towels per day. The towels were restrained in place through friction fit. The stowage compartment door provided flammability control of the combustible towels.



F ·· 2.2.13.2-6. Towel Dispenser

3/ Trash Containers

Certain stowage compartments in the OWS were allocated for use as trash containers for the stowage of trash (Figure 2.2.13.2-7). The trash container was a stowage compartment with a modified door that accepted the installation of a trash bag onto an opening on the backside of the door. Trash was inserted directly into the bag through the opening in the trash container door. A friction-hinged trash lid covered the opening on the trash container door when the container was not in use. Velcro patches were used to maintain the trash lid in the closed position. A tape patch restrained the trash lid during launch and was removed upon SL-2 activation without the use of tools.

4/ Food Boxes

Eleven food boxes provided launch and on-orbit stowage of ambient temperature foods for the SL-2, SL-3, and SL-4 missions (Figure 2.2.13.2-8). Five of the eleven boxes were permanently mounted in the OWS forward compartment on the grid above the wardroom. The remaining six food boxes were dispensed on the forward compartment floor grid around the experiment compartment access opening to ensure structural integrity during launch. Upon SL-2 activation, the six dispersed food boxes were unbolted from their launch stowed locations and bolted adjacent to the five permanently positioned boxes. Each food box door was also

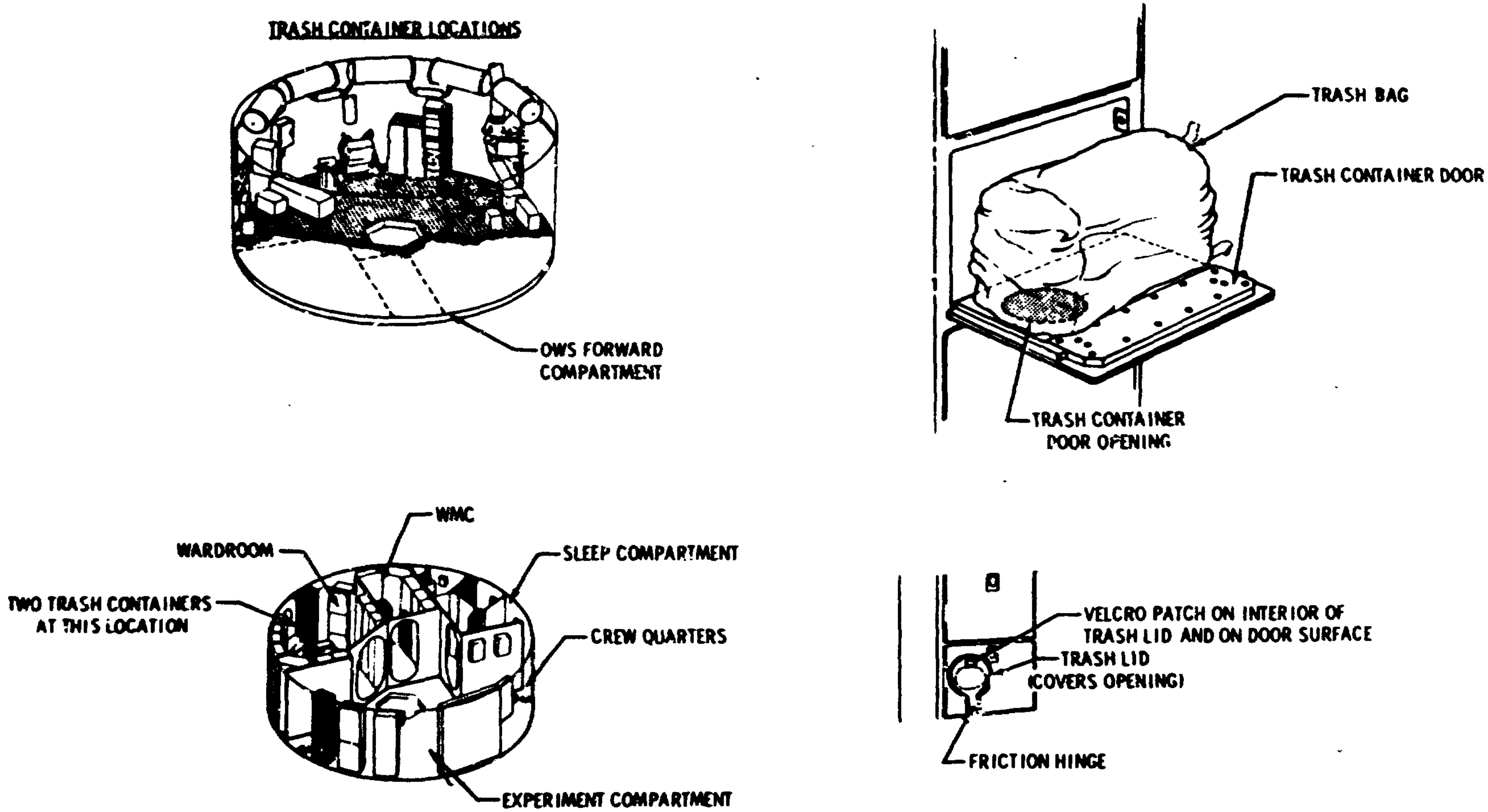


Figure 2.2.13.2-7. Trash Container

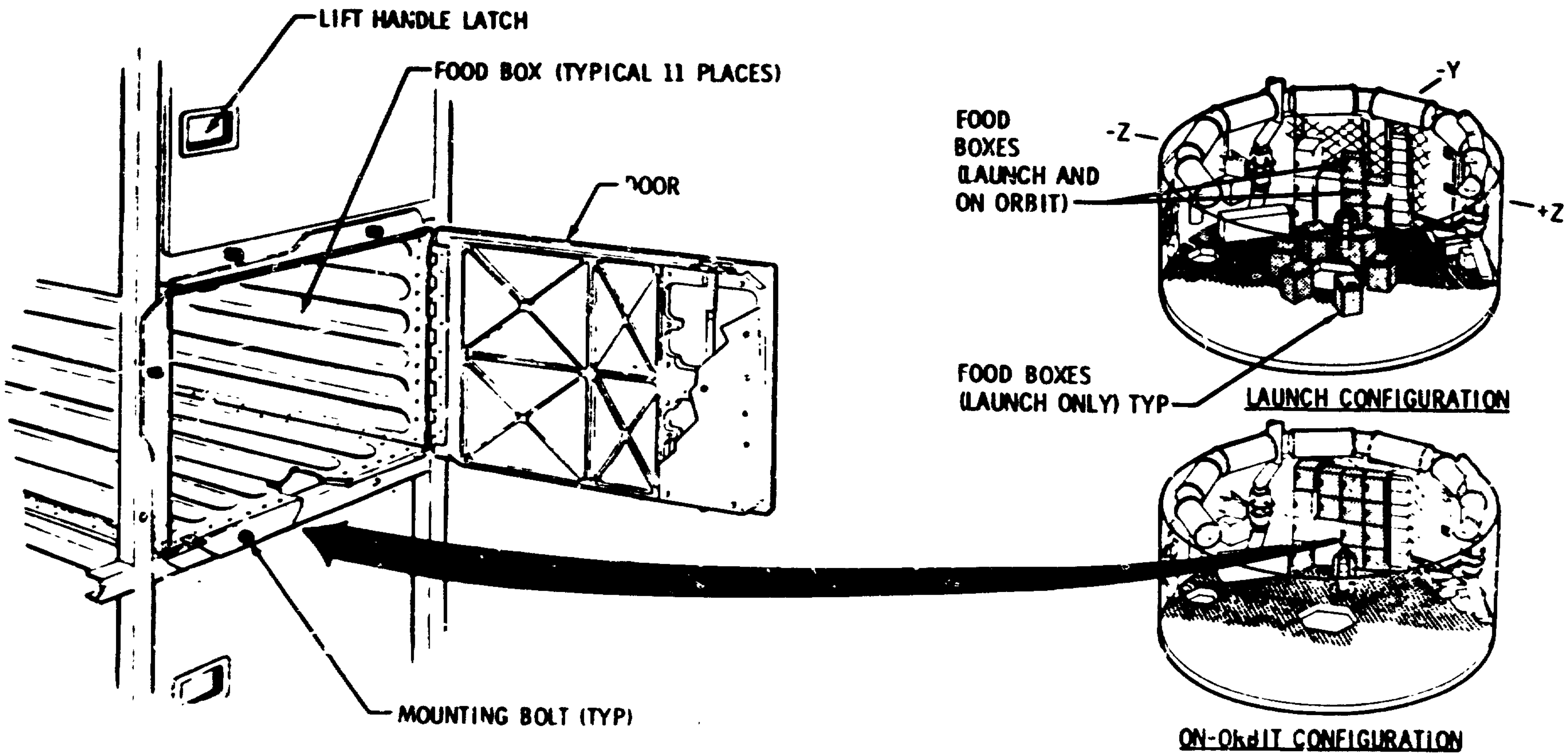


Figure 2.2.13.2-8. Food Boxes

secured closed during launch with bolts. Upon SWS activation all food box launch bolts were removed by the SL-2 crew with the aid of tools. Each food box was a sheet metal rectangular container of 8 $ft.^3$ (.23 m^3). The food box doors were friction-hinged and were opened through the use of a lift handle latch. If the latch fails to unlatch, a latch release tool could be used for forced entry.

5/ Food Freezers and Food Chiller

A three chambered refrigerated unit in the OWS forward compartment and one in the wardroom stored and preserved the entire mission supply of refrigerated foods in a controlled thermal environment vented to the cabin. The three-chambered unit in the OWS forward compartment was the Stowage Freezer with each chamber storing a 28-day supply of frozen food (Figure 2.2.13.2-9). The unit was a foam-filled shell with the primary and secondary loops of the refrigeration subsystem maintaining the frozen food at -10°F (249.8°K). Each freezer was accessible through a foam-filled outer door, fitted with a vented gasket and a trigger latch. A hinged inner door constructed of sheet metal was attached to the outer door by a short length of beta fabric strap. The sheet metal acted as a heat sink to conduct the heat contained around the door area to the cooling coils. Each outer door was

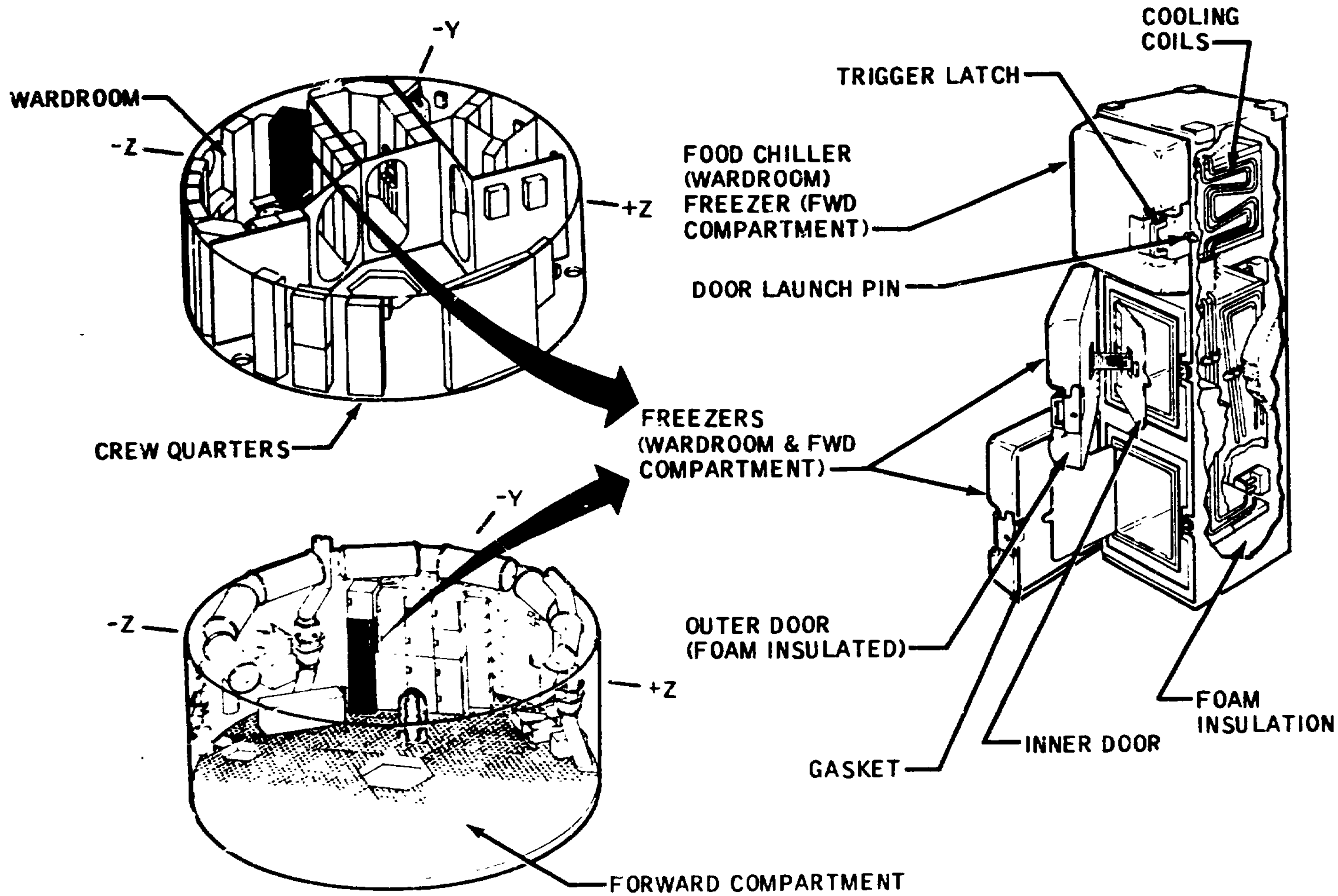


Figure 2.2.13.2-9. Food Freezers and Food Chiller

secured for launch with a launch pin inserted into the side of the door. The trigger latches on each door contained launch pins to prevent damage of launch loads. These launch pins were removed by the SL-2 crew upon SWS activation without the use of tools. A readout of each freezer's thermal environment was available on an indicator through selection of the proper freezer on RS DISPLAY SELECT 1 selector located on Panel 616 and on telemetry. The three chambered unit in the wardroom was the Wardroom Freezer/Food Chiller which allots the lower two chambers to food freezing and the top chamber to food chilling. The two freezers provided a 28-day supply of frozen food each. The food chiller was launched full of ambient food which was removed on activation. The chiller was also used to chill and temporarily preserve unconsumed food. In addition, medical supplies are periodically stored in the chiller. The Wardroom Freezer/Food Chiller is an identical unit to the stowage freezer; however, the coolant loops are modified to permit food chiller operation at 45°F (280.4°K). Temperature readouts are available on Panel 616 and on telemetry.

6/ Urine Freezer

A urine freezer, installed in the WMC, stored and preserved up to a 56-day accumulation of urine samples from three crew members. The urine freezer was a foam-filled shell utilizing the primary and secondary loops of the refrigeration subsystem to maintain the stored urine samples below 0°F (255.4°K) (Figure 2.2.13.2-10). The front of the freezer featured a hinged, foam-filled door that had a vented gasket and a trigger latch. The freezer stowed the urine samples in portable mounted support pad that maintained the urine trays in an accessible position at the top of the freezer through spring action. To prevent the trays from sticking to the freezer, only two urine trays were stowed in the urine freezer at any given time; a foam spacer was employed to transfer the spring force from the support pad to the two urine trays. The freezer door permitted only the top urine tray to slide out. The urine freezer was launched with a spacer and two empty urine trays. The trigger latch on the freezer door contained a launch pin to protect the latch mechanism from damage due to launch loads. This pin was removed by the SL-2 crew upon SWS activation without the use of tools. A readout of the thermal environment of the urine freezer was available on Panel 616 and on telemetry.

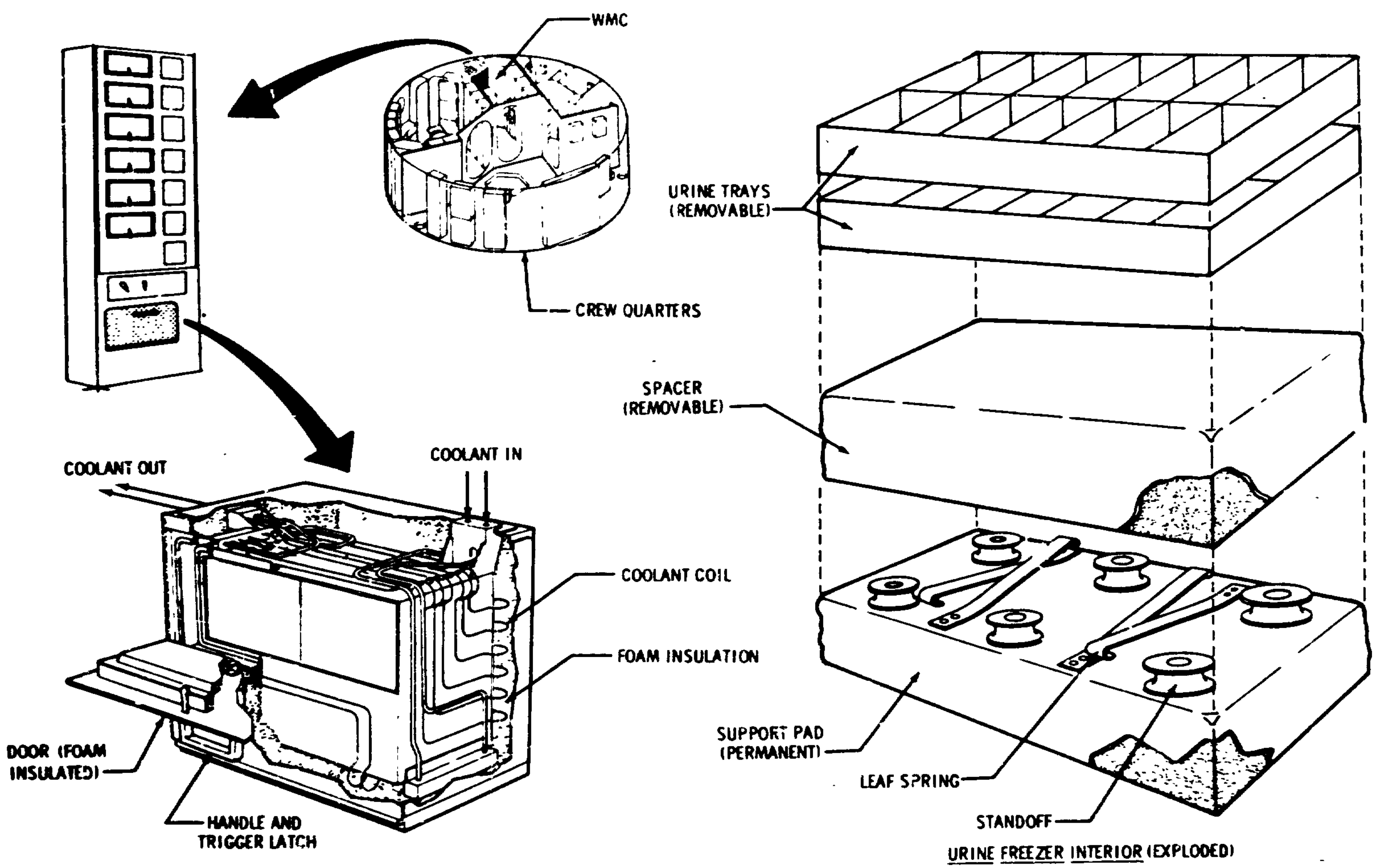


Figure 2.2.13.2-10. Urine Freezer

7/ OWS Film Vault

The Film Vault was a cast aluminum structure, with machined aluminum doors, to protect the stored unexposed film from radiation for its stored interval (Figure 2.2.13.2-11). The vault doors, hinged at the center of the vault provided access to the drawers which contained packaged film cassettes. The doors were secured closed during launch by bolts which were removed by the SL-2 crew during SWS activation with the aid of tools. On-orbit, the doors were secured closed with two dial latches. Each side of the vault contained a strip of velcro which was utilized to temporarily restrain the cassettes as they were removed from the vault. When opened, the vault doors exposed removable drawers which were deployed through the use of strap handles. Salt pads, used for vault humidity control, were stowed in the film vault drawers in sealed containers. During uninhabited periods of the SWS, the salt pads were vented to the relative humidity of the vault at approximately 45 percent to protect the unexpected film from deterioration. The stowed film cassettes were restrained by on-orbit restraints, normally of machined teflon, which provided the ability to extract a single film container without handling other containers. All restraints within the drawers were designed for tooless removal and reconfiguration if necessary on-orbit.

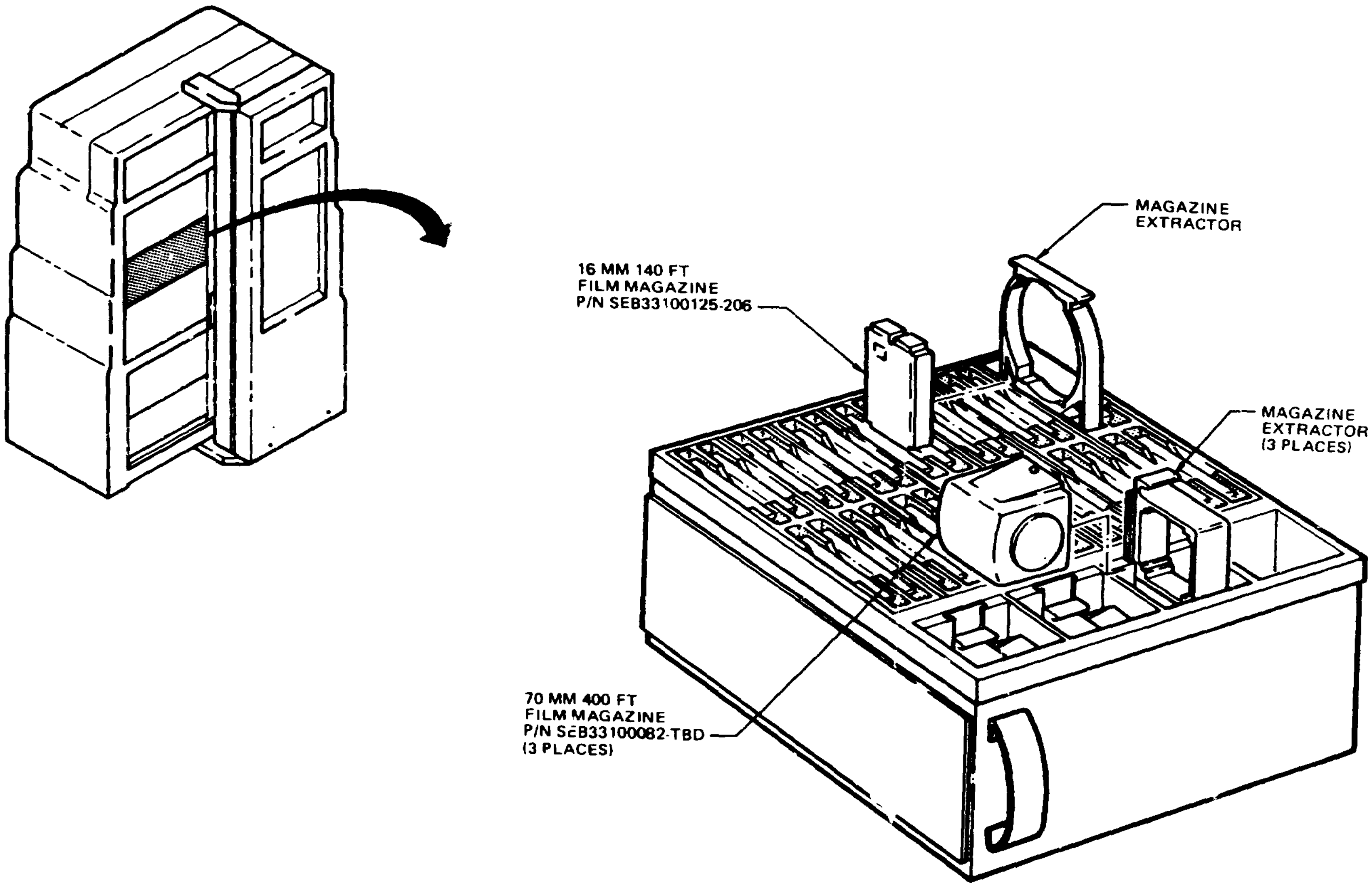


Figure 2.2.13.2-11. Film Vault

The contents of each drawer was packed with corrugated cardboard to minimize vibration during boost. Each restraint had a label that coded the contained film which corresponded to the photo log book.

8/ Temporary On-Orbit Restraints

Fixed and movable restraints were provided for temporary stowage of equipment for convenient restraint and access while performing work tasks and for general on-orbit stowage of daily use items.

a. Short Straps

Sixty-four short straps were launched in OWS stowage compartments. Some of these short straps were wrapped around the long power cables and communication cables stowed in the OWS, as the crewmen required the use of the short strap to restrain the cable when it was in use. The short straps were constructed of a fluorel coated beta fabric webbing which was 12 in. (305 mm) long and one in. (25.4 mm) wide (Figure 2.2.13.2-12). The webbing was faced on one side with velcro pile while each end contained velcro hook. Both sides of the strap were fitted with four snap studs and four snap sockets. These provisions allowed the strap to be secured about a structure or to structure-mounted snaps and velcro to conform to the envelope of the restrained item. The short straps were to be used to temporarily restrain such as cables, tools, books and replacement parts.

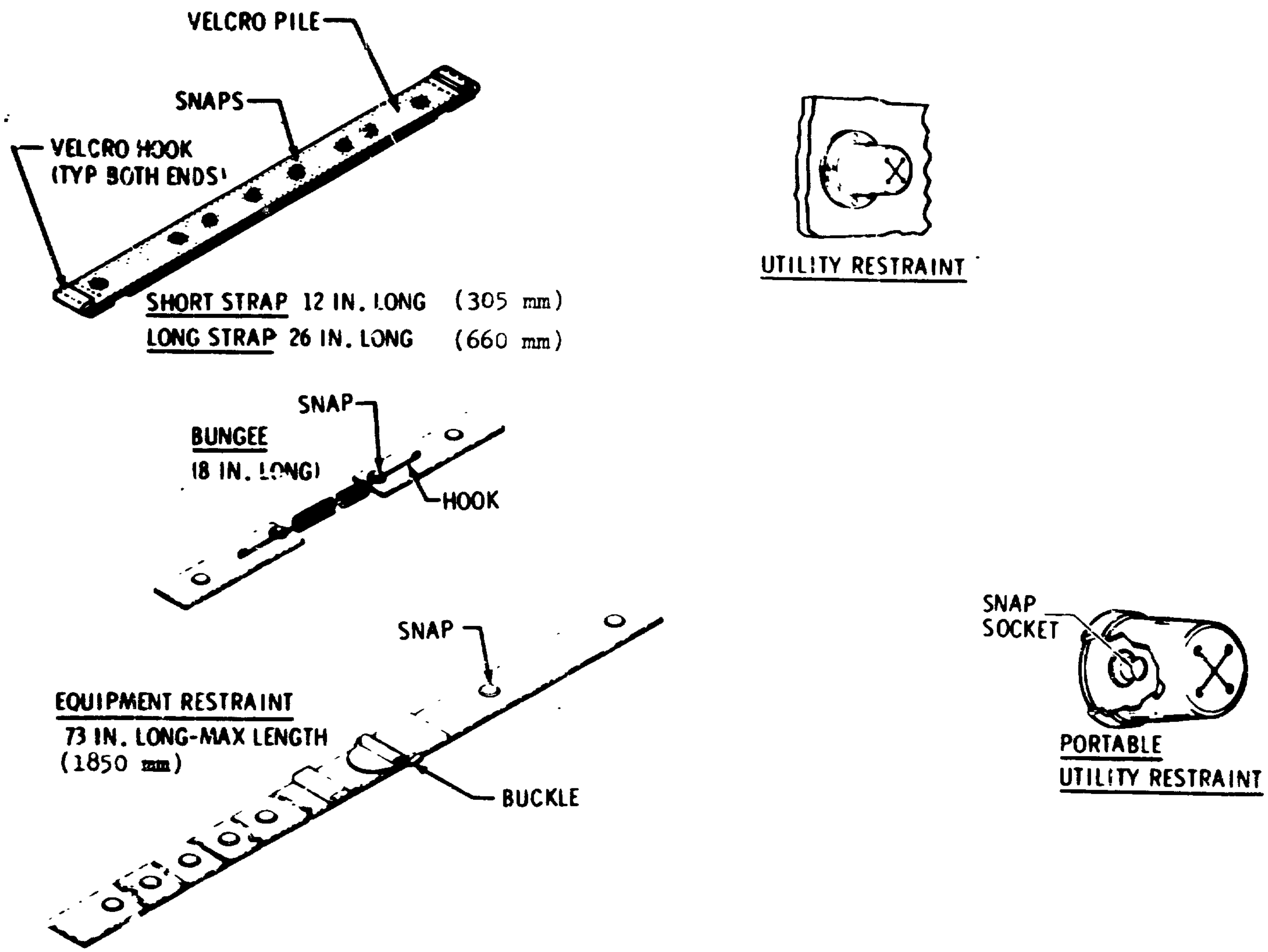


Figure 2.2.13.2-12. Equipment Restraints – Internal

b. Long Straps

Twenty long straps were launched in an experiment compartment for ready accessibility. The long strap was 26 in. (66 mm) long and 1 in. (25 mm) wide and was constructed similar to the short strap but contained four additional snap studs (Figure 2.2.13.2-12). The long straps were to be used to temporarily restrain moderately sized equipment such as the vacuum cleaner, food trays, and replacement parts.

c. Equipment Restraints

Eighteen equipment restraints were launched in an experiment compartment stowage compartment for ready accessibility. The equipment restraint was a fluorel coated beta fabric webbing strap, 73 in. (1850 mm) long and 1 in. (25 mm) wide (Figure 2.2.13.2-12). The end of the restraint to be securely looped and fastened about a handrail, handhold or open grid. The length of the webbed strap was adjustable to a length of 73 in. (1850 mm) through use of a buckle to permit adjustment to the envelope of the restrained item. The equipment restraint was to be used to temporarily restrain large pieces of equipment such as urine return containers and replacement parts.

d. Bungees

Twenty portable bungees were launched in an experiment compartment stowage compartment and were used to restrain reference material such as books or papers. The bungee was 8 in. (203 mm) long and was constructed of a coil spring fitted on both ends with a hook (Figure 2.2.13.2-12). The hook could be attached to holes or joints on SWS stowage compartment doors to permit retention of the reference material or small items against a surface for convenient temporary stowage while performing work tasks. Maximum extension of the bungee was 12 in. (305 mm). Bungees were also installed in the flight data file and in the galley.

e. Utility Restraints

The utility restraint was a fluorocarbon rubber cap, supplied in two forms; fixed to structure and portable (Figure 2.2.13.2-12). The cup contained a cruciform slit into which small flexible items could be inserted for temporary restraint. The interior of the cup was rounded to facilitate cleaning to prevent microbiological growth.

1. Fixed Utility Restraints - Utility restraints were provided throughout the OWS permanently fixed to structure near food preparation areas, in the WMC, in the sleep areas, and near articles of operational equipment.

The utility restraints were used to retain towels, washcloths, tissues, and clothing while they were being temporarily stowed for drying or for ready access.

2. Portable Utility Restraints - Six portable utility restraints were stowed in an experiment compartment stowage compartment. The portable utility restraint was backed with an aluminum disc, fitted with a snap socket (Figure 2.2.13.2-12). The snap socket mated with the snap studs located throughout the SWS for retention of the portable utility restraint in a convenient location. The restraints would be used to temporarily restain tissues, towels, and washcloths near the using area for ready access.

f. Plenum Bags

28 plenum bags were launched on the forward compartment floor. The bags were made of armalon fabric with a drawstring closure. Hooks and "D" rings were provided to facilitate stowage of full bags in plenum areas (Figure 2.2.13.2-13).

PLENUM BAG

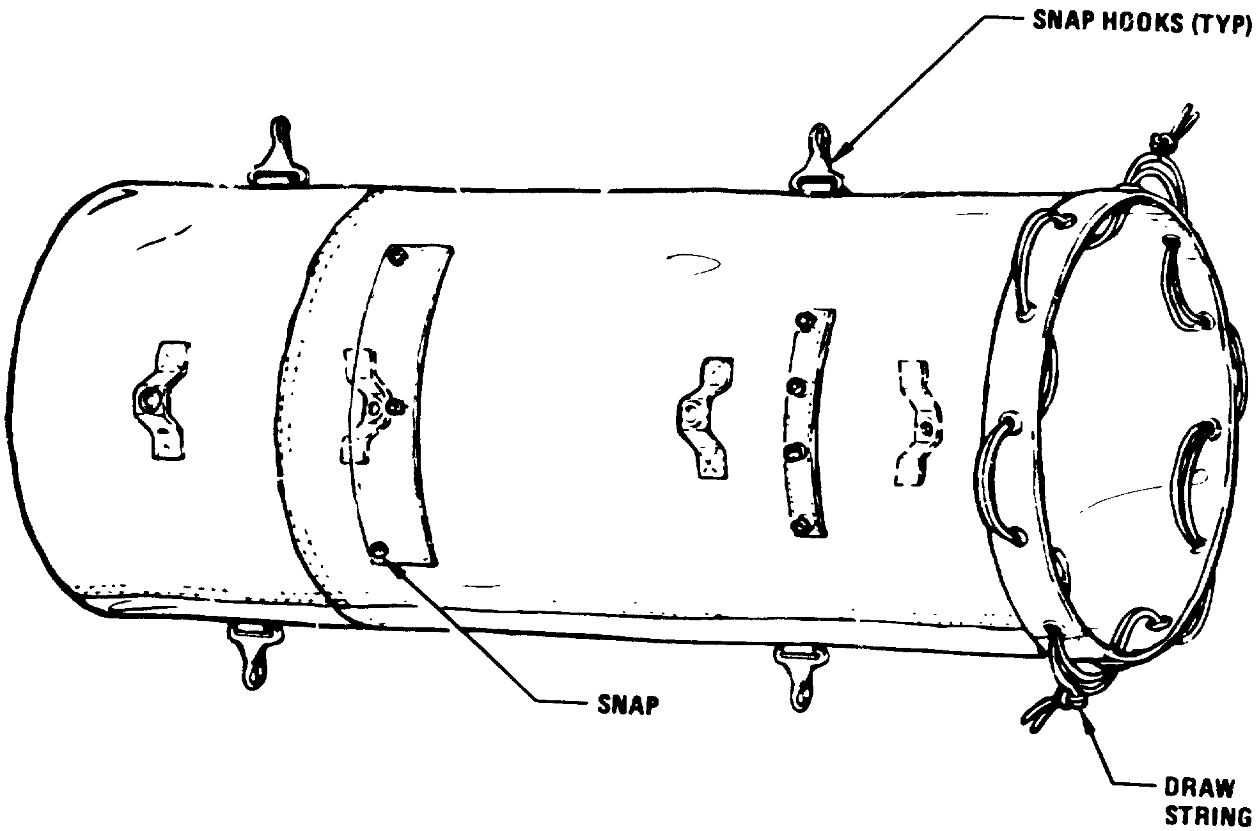


Figure [illegible]

9/ Snaps and Velcro

Velcro pile was provided in "patch" form and was permanently installed on handrails, stowage compartments, structure, etc. throughout the SWS where work tasks were conducted (see MDC G2439). They provided a restraining surface to which velcro-hook lined disposal bags, restraint straps, books, tools, etc. were conveniently restrained for temporary stowage and/or use. In addition, a supply of velcro hook and pile in "patch" form with adhesive backing was provided in Tool Kit 2 for installation in those light-workload areas where capability did not exist. Snap studs were located throughout the SWS on stowage compartment doors, partitions, structure, handrails, etc. and were configured in a standard snap pattern which accommodated all SWS and CSM provisions that contain snap sockets (see MDC G2439). Snaps with adhesive covered mounting plates were provided to give the crew on-orbit capability for locating snaps. In addition, snap studs that could be mounted in any grid node hole were provided.

10/ Tool and Repair Kits

The repair kit contained equipment to repair pressure shell penetrations, ventilation duct damage, and leaking threaded connections. Ni flat patches consisting of 3 by 3 in. (76 by 76 mm) aluminum sheet covered with polybutene sealant, nine aluminum blister patches [5-3/4 in (146 mm), 7-1/4 in. (184 mm), and 8-1/2 in. (216 mm) in diameter] with polybutene sealant around the edges, two 1 lb. (.454 kg) rolls, 3/4 in.

(19 mm) wide polybutene sealant, one roll of aluminumized duct tape, one roll of teflon plumber's tape and a pair of scissors make up the repair kit (Figure 2.2.13.2-14). The tool kits consisted almost entirely of standard off-the-shelf tools (Figure 2.2.13.2-14). Only tools with identified maintenance or operational requirements were flown. The tool kits contained various sizes of the following:

a. Pliers

b. Phillips screwdrivers

c. Blade screwdrivers

d. Sockets and handles

e. Extensions

f. Open end/box wrenches

g. Screwdriver bits, blade and Phillips

h. Allen wrenches

i. Crowfoot wrenches

j. Torque wrenches

as well as a vise, clamps, pinch bar, adjustable wrench, hammer, punch, mechanical fingers, retrieval hook, mirror, Swiss Army knives, tweezers, tape, lubricant, wire, and twine. Each tool, where feasible, had velcro hook bonded to it to interface with velcro pile on tool carrier belts. The contianers for the repair kit and the two tool kits were a common design. The containers consisted of a closed metal box with a spring detented handle. The containers had multiple drawers, each being capable of being removed and attaching to the universal mount for ease of operation.

TOOL AND REPAIR KITS

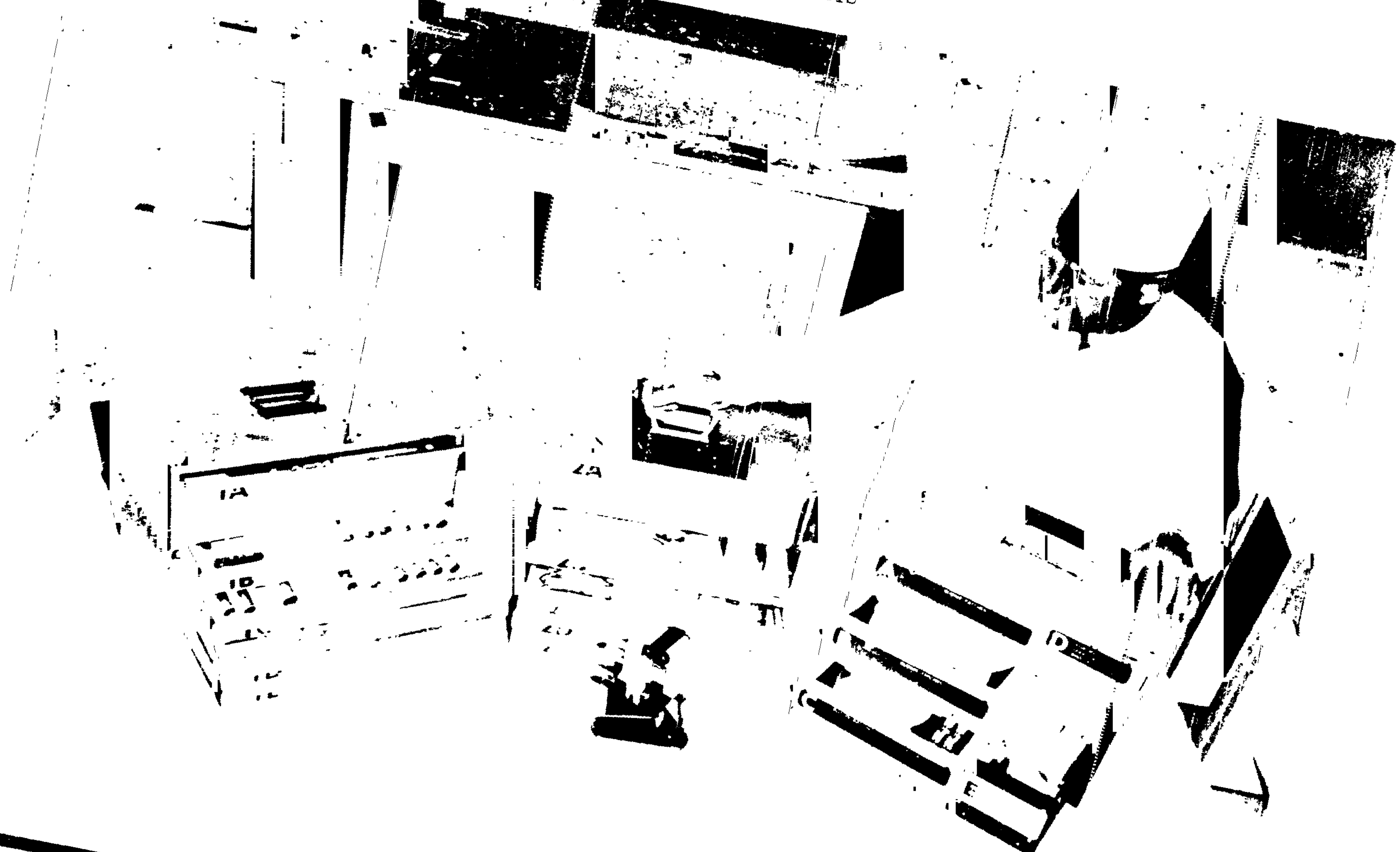


Figure 2.2.13.2-14

There was a spring clip on the drawer slides which afforded a two-position plus removal capability. The cabinets were retained in standard locker compartments by a small drawbolt which engaged the locker, but still allowed the removal of each individual drawer. The restraints used within the drawers were made of molded sponge to form press fits with the loose equipment. The Skylab repair kit was anodized red and the tool kits gray with a detailed label of the contents on each drawer. Each item within the kit, along with the box was marked with part number and serial number. Each item in the kits was identified by a marking in an appropriate spot near the item on the restraint.

B. OWS Stowage Software

1/ The P1213 Computer Program was developed to provide basic storage information describing the loose equipment items aboard the Orbital Workshop vehicle. The program presents this information by means of numerous report formats utilizing, to a large extent, the Mark IV File Management System as a means by which the required reports were generated. A summary of the information contained in the data base is as follows:

a. Item Number

An identification number assigned by NASA for each stowage item with a unique part number. The item number is the key field upon which all the data are based.

b. Category Code

A one or two character code use to describe each item. The current category coes are as follows:

Category Code A - General stowage item within ambient containers, cabinets and lockers.

Category Code B - Stowage items requiring special environmental protection.

Category Code C - Stowage items stowed individually - not in an identified container.

Cateogry Code E - Stowage items stowed in GFE furnished stowage container or other provisions.

Category Code F - Items installed in the vehicle by installation drawing other than the top stowage drawing.

Category Code G - Items installed in the 1G trainer, only.

Category Code H - Items installed in the backup vehicle, only.

Category Code D - Tiedowns, restraints, packing material, hardware, etc., used to install stowage items.

Category Code DX - Stowage Instructions.

Category Code DL - Stowage labels, and label placement drawings.

Category Code J - Tiedowns, restraints, hardware, etc., used to install non-stowage items in the OWS. All items with a "J" category code must be disposed of after OWS activation.

Category Code TT - Items transferred into the OWS or out of the OWS from another part of the cluster. A TT category code indicates that the total quantity of items is transferred - none is launched in the OWS.

Category Code AT, BT, CT, ET - Only a portion of the items are transferred into or out of the vehicle from another part of the cluster. The remaining items are launched in the vehicle with A, B, C, or E category code stowage, as described above. In other words, the item is both a transfer item and an A, B, C or E item.

Category Code P - Indicates a description of the stowage location.

Category Code V - Indicates a volume summary for each stowage location (total volume and available stowage volume).

c. Part Number

d. Engineering Change Letter

e. Serialization Requirements

f. Total Quantity

g. Unit Weight

h. Dimensions

i. Item Nomenclature

j. Label Nomenclature

k. Supplier

l. Agency Responsible for Stowage Provisions

m. Trash Codes, as follows:

A - Trash items which are biologically active or potentially dangerous to the crew. Mandatory disposal in the Trash Airlock.

B - Trash items which are dry and inactive. They may be returned to on-orbit stowage.

C - Trash items which may be processed to render them safe for on-orbit stowage.

NONE - Assumed to have a trash code of "B" if any disposal of item occurs at all.

n. General Notes

o Contractual Authority for Making a Change.

p. Planning Parts Code

q. Special Notes

r. Stowage Locations - 6 digit MDAC location identifier.

s. Location Identification - 5 digit NASA location identifier.

t. Delete Flag - Allows an item to be delted from a particular location.

u. Quantity/Location - Provides the quantity of an item at each stowage location during launch, orbit and return of the three Skylab Missions.

2/ All stowage reports are generated from the File Management System data base. A brief description of each report follows:

a. Master File Report

This report lists all the data in the data base. It is used to maintain and update the information contained therein; it is not a released document.

b. Stowage List Report

This report provides the same basic information as the Master File Report but is much more flexible in that the user has the capability of selecting the categories of items he wishes to be printed. Additionally special features are available which provide a sort on parts code giving all the CFE, or GFE, or whatever, listed together; a sort on Supplier which gives the various codes such as MDACW, MR&O, or whatever, grouped together; also the conventional sort by item number.

c. Stowage Location List

As the name implies, this report provides a listing by location of all the items in the vehicle. However, the user has the flexibility of choosing just those categories of items he wishes to see printed. The option also exists which allows the user to sort these locations by either the McDonnell Douglas location identification or the NASA/Crew identification. A special feature for this report is the ability to sort out those items which have label nomenclature and group them together per location.

It should also be noted here that for almost all the reports described, the capability exists to sort/select on just about any field the user desires.

d. Orbital Workshop Stowage Location Usage Report

This report is in sort by NASA stowage location in alphanumeric order. The header information for each stowage location consists of the MDAC stowage location number, the corresponding NASA stowage location number and the location description. The first entry for each stowage location is a volume summary consisting of the total stowage volume of that location, and the available stowage volume for each of the seven mission time periods - SL-1/2 launch, SL-1/2 orbit, SL-1/2 return, SL-1/3 orbit, SL-1/3 return, SL-1/4 orbit and SL-1/4 return. The volume summary also contains general notes which indicate space reservations, volumes available for launch only, and other data pertinent to each stowage location. Subsequent entries for each location define all items (i.e., stowage items launched in OWS, stowage installation items and transfer items) stowed at that location at any time during the three missions. Items are listed in numerical order by item number, preceeded by the category codes described above.

Those items requiring a trash code are identified by an A, B, or C, as described above.

e. Loose Equipment and Stowage Provisions Installation (1B80701)

This report, which is sorted by NASA location number, lists all stowage items, restraint hardware and labels launched at that location. Reference drawings, such as stowage instructions and label placement, are also listed. Each item stowed at that location is identified in terms of item number, part number, nomenclature and quantity.

f. Loose Equipment and Stowage Provisions Installation - E.O. Change Report

This report, which is also sorted by NASA location number, lists only those changes to part number, nomenclature and quantity since the most recent previous release of the report. If no changes occurred in a particular lcoation, that location is excluded from the E.O. Change Report.

g. Parts List

This report provides a listing of the items stowed in the OWS, sorted by part number. In addition to part number, the report lists item number, nomenclature, total quantity and parts code.

h. Parts List - E.O. Change Report

This report, which is sorted by part number, lists only those changes to part number, nomenclature, quantity and supplier codes since the most recent previous release of the report. It should be noted that reports e., f., g., and h. were provided for the Backup Vehicle and the 1-G Trainer as well as for the Flight Vehicle.

i. Assembly Outlines (AO's)

The computer program generates first sheet AO's for each stowage location which changed since the most recent previous release of AO's. These AO's provide manufacturing authority to install stowage items and restraint hardware at each stowage location. Three different types of AO's are provided:

1. Loose Equipment Stowage Installation
2. Loose Equipment Stowage Kit
3. Locker Mod Restraint

2.2.13.3 Testing

A. CX7 - Film Vault Humidity Control

TCD 1T41307
CTCA 3323
Test Report TM-DSV7-SSL-R6904

This test established the humidity diffusion rate for the OWS film vault and compared the theoretical diffusion rate that was used for designing the humidity control assembly and an actual expected rate demonstrated by the CX7 test fixture. In this test, the humidity diffusion opening with tolerances, i.e., the crack between the two doors, was simulated and the resultant diffusion rates for the various tolerance conditions established. The results of this test showed excellent correlation between the theoretical calculation and the demonstrated diffusion rates and thereby confirms the design of the humidity control assemblies.

B. WSTM-17

TCD 1T42110
CTCA 9029

This test used the CX7 film vault humidity control test specimen to demonstrate that sealing the salt pads in Zitex did not adversely affect their ability to control humidity. The Zitex encased salt pads controlled humidity and therefore allowed MDAC to seal the salt pads and to control the potentially poisonous aqueous solution of potassium-thiocyanate.

C. CX8 - Film Vault Material Compatibility Test

TCD 1T41310

CTCA 3324

Test Report - TM-DSV7-SSL-R-6930

This test investigated the compatibility of the five most sensitive types of film to be stored in the film vault with the interior materials of the vault. The test involves setting up the reduced pressure on-orbit environment to accentuate potential outgassing problems. Four test durations of 1 week, 2 weeks, and 8 weeks were concurrently started and five film clips from each of three specimen containers were taken out of the specified test durations. The film, originally obtained from MSC, was returned to Houston for batch development, densitometry readings and plotting of Hurter Durfield curves for each film clip. Careful examination of the resulting 191 Hurter Durfield curves indicated that the material tested with the five most sensitive films were compatible for up to two months in on-orbit environment. This duration was sufficient to assure that the film vault materials should not adversely affect any of the film stored in the film vault. As a result of design reviews and potential material selection problems, it became necessary to run a second test.

D. CX11 - Film Vault Material Compatibility Development Test

TCD 1T43358

CTCA 3416

Test Report TM-DSV7-SSL-R7051

This is the second material compatibility test. The five most sensitive films were enclosed in the on-orbit OWS environment for 60 days to demonstrate material compatibility. The films were not affected by the material which support the conclusion that the material used in the Film Vault are compatible with the films to be stored therein.

E. ST-23 - Film Equipment, GFE

TCD 1T43488

CTCA 3507

Test Report TM-DSV7-ENR-R-7098

The thrust, radial and tangential, both random and sinusoidal vibration tests were performed on a four drawer test fixture to simulate the vibration profiles to the NASA supplied test specimens. After the tests the specimens were turned over to the NASA representatives. There were no MDAC objectives in this test. Sinusoidal and random vibration tests were performed on the following:

Specimen No. 1 (1) 16 MM Transport Mechanism, SEB 33100278-301

Specimen No. 2 (2) 16 MM Film Magazine, SEB 33100125-206

Specimen No. 3 (2) 16 MM Film Cassette 400 Ft., SEB 33100279-301

Specimen No. 4 (2) 70 MM Magazine Frame, SEB 33100082-301

After test they were turned over to NASA representatives for inspection and checkout.

F. HS-1 - Crew Restraints. Development Test

TCD 1T16801

CTCA 3345

Test Report TM-DSV7-SSL-R-6901

The Crew Restraints Development Test which included equipment restraints, was conducted to evaluate various design concepts of restraints as an aid in determining which specific design in each category should be adopted for manufacturing. The test results obtained provided subjective recommendations of specific design concepts of equipment restraints. Results indicated that the equipment restraints provided adequate restraint and the trash bag presented no problem during removal from stowage in a 5 psi (34.5 kN/m^2) environment and vented trapped gas without structural damage to the bag or seal during decompression.

G. CA-16 - Spare Equipment Stowage Containers. Qualification Test

TCD 1T18431

CTCA 3483

Test Report - TM-DSV7-ENV-R7048

The Spare Equipment Stowage Containers Test was conducted to demonstrate that the loose equipment stowage containers and the equipment mounted within them can withstand the launch and boost dynamic load environments. Several problems were experienced during the test which required corrective action. All corrective actions were retested and incorporated in the flight vehicle following successful test completion.

H. ST-11 - M487 Stowage Container Development Test

TCD 1T42091

CTCA 3313

Test Report - TM-DSV7-ENV-R7033

Sinusoidal sweep tests, random vibration tests and functional tests were performed for development testing of the Orbital Workshop M487 Stowage Container. The tests were performed at the McDonnell Douglas Astronautics Test Laboratories, Santa Monica, California, from 23 February through 25 February 1972. The development testing of the test speciment was satisfactorily performed. The only incident of malfunction or damage that occurred was in the thermistor thermometer which failed to function after the last axis of vibration (tangential). The instrument was cancelled from the kit and replaced with a digital thermometer (SCI Electronics Corporation). All instruments satisfactorily passed all phases of testing except the thermistor thermometer which failed to function after the last axis of vibration (tangential). The instrument was cancelled from the kit and replaced with a digital thermometer (SCI Electronics Corporation).

2.2.13.4 Mission Results

A. Stowage Compartments - The stowage compartments functioned generally as planned. The door latches were apparently easy to operate. However, several latches failed to operate properly during the third mission. The door openings provided adequate access to stored items. The doors remained closed during the launch phase and none of the latches jammed as a result of launch loads. The standard doors and standard hole patterns proved very versatile. The armalon/sponge bags performed as intended. All items packed in them survived the launch environment and were used during orbit. The cardboard packing held up well and did not pose any problems in accessing and removing items of loose equipment. The pelnum bags performed their function of providing containment for biologically inactive trash. The original concern of generating condensation in the plenum area by installing too many plenum bags was proved academic. At the end of the second crew visitation, nine bags were in the plenum area and no condensation was observed.

B. Dispensers - All dispensers functioned as designed except some of the spring loaded doors failed to stay closed during the third mission.

C. Trash Containers - All trash containers functioned as planned. The locations of trash containers were moved in orbit by the first crew to place them at more convenient locations. This was accomplished by changing standard compartment doors. The only difference between the standard compartment and the trash container is the door which is interchangeable and removable by pulling the hinge pin. The resupply trash bags were located in compartments below the trash containers at launch. This differed from the normal location of resupply items in that all other resupply items are grouped together in a specific location. This multi-locationing of resupply bags caused some confusion for as the bags were depleted it was difficult to locate the replacing bags. The original plan was to obtain trash bags for the trash container from the resupply compartment immediately adjacent to the trash container being resupplied. The crew elected to supply all trash containers from a single resupply compartment until it was depleted. As the mission duration increased, the crew had to hunt for a resupply compartment that still had trash bags.

D. Food Boxes - All food boxes functioned as designed.

E. Food Freezers and Food Chiller - The food freezer and food chiller functioned as designed. No problems were encountered in removing food and food racks. The crew recommended that the chiller have some general restraints for holding miscellaneous food items.

F. Urine Freezer - The urine freezer functioned as designed.

G. OWS Film Vault - The film vault generally functioned as designed. A few teflon restraints internal to the vault came loose and floated within the vault drawers. On later missions, more equipment than originally planned was put in the film vaults which caused considerable inconvenience (i.e., unrestrained items interferring with the closing of the drawer above). The dial latch on the vault door was difficult to operate.

H. Temporary On-Orbit Restraints - In general, the temporary restraints performed as intended. Some were found to be more useful than others. The relative results are discussed in the following paragraphs.

1/ Short Straps - The short straps were not used very much. The crew considered them too short for most applications.

2/ Long Straps - The long straps performed very well and were considered "extremely useful."

3/ Equipment Restraints - The equipment restraints also were considered "extremely useful." These restraints were difficult to adjust because of the strap material but the concept was feasible and the flight articles were usable.

4/ Bungees - The bungees were found to be very useful. The crew desired more of them and the capability to locate them in more places. The method of attachment was considered marginal. New bungees with flat metal hooks to catch the edge of locker doors were developed and flown on mission 3. The new bungees were rated "good."

5/ Utility Restraints - The utility restraints were well received and performed their intended function. The crew did comment that the towels would float into the work areas if all four corners were not restrained, but this was not directly attributable to the utility restraints. No use of the portable utility restraints was reported.

6/ Plenum Bags - The plenum bags were used and performed as designed.

7/ Snaps and Velcro - The snaps and velcro placed around the vehicle were used as intended and were considered desirable and necessary. The primary complaint was that there was not enough locations that had velcro.

I. Tool and Repair Kits - The tool and repair kits functioned as designed. The restraints were adequate. Some complaints were made regarding the number of pieces required to build up to a usable tool but this is inherent in "socket" and "handle" type tools. Also, the arrangement of tools in the tool kits, was considered somewhat inadequate.

2.2.13.5 Conclusions and Recommendations

A. Stowage Compartments

In general, the stowage compartments performed their intended functions very well. They were versatile, provided ease of access, had smooth surfaces and blended well with the general interior arrangement. On future vehicles, which will have much more severe weight limitations, several modifications could be made. The standard compartment doors could have been lighter. Several standard lockers could have been designed for supporting lighter loads. Standards could have been established for compartments programmed to carry a certain range of loads. Based on known equipment weights and volumes of various categories of "space type" hardware, a set of standard design parameters could be established that would indicate that for a certain volume, the load carrying design capability should be a maximum of so much. This could tend to reduce flexibility in hardware arrangement, but with proper integration, a rational balance between flexibility, standardization and optimum hardware could be achieved.

The ability to stow ring containers (and the ambient food containers) outside the vehicle minimized the impact of stowage operations including stowage modifications on vehicle time. This feature should be strongly considered when designing stowage provisions for future vehicles.

The restraint straps in the compartments, even though adequate, could have been more flexible, stronger and easier to adjust. Flammability requirements severely limited the choice of strap material.

The armalon/sponge bags and the non-flammable fiberboard proved very effective as a packing material and vibration dampening device. These had the added advantage of being lighter than other materials available that would have satisfied the flammability requirements.

B. Dispensers

All dispensers performed satisfactorily. The towl dispenser did not require the versatility it had. Five dispensers having the capability of being located in any standard compartment were not necessary.

Considering there is only one dispensing location, five dispensers containing 18 towels and a total of 450 towels launched, it becomes evident that one towel dispenser would have been adequate. It must be understood that at the time the towel dispenser was designed, they contained the total quantity of towels to be flown.

C. Trash Containers

The trash containers performed very well. The concept of standard compartments with standard door attachments lent itself to interchanging trash containers as desired. The bag/door interface provided easy replacement of trash bags.

D. Food Boxes

The food box concept was satisfactory. No problems were encountered in relocating the boxes on-orbit. Putting round cans in rectangular boxes is not the most efficient use of space and is an area for improvement. As in the case of the ring containers, the food boxes were stowed before being installed in the vehicle. This approach should be utilized in future vehicles to reduce vehicle time impact due to stowage and stowage changes.

E. Food Freezers and Food Chiller

The food freezers and food chiller performed as designed. They maintained the food at the required temperatures. The problem of round cans in rectangular boxes still existed. Chillers and freezers on future vehicles should have a general restraint capaability such as standard snap or velcro patch patterns to provide the flexibility to handle preflight and flight requirement changes.

F. OWS Film Vault

The film vault performed as designed. For meeting the program requirements, the OWS film vault was quite satisfactory. The large amount of unplanned equipment stowed in the vault drawers suggests a system of universal restraints should have been incorporated.

G. Temporary On-Orbit Restraints

1/ Short Straps - The short straps were designed to fit snug around electrical cables to avoid slipping. This feature made the straps somewhat difficult to attach and probably accounts for the flight crews remark that they were too short. The stiffness of the fluorel material amplified this problem. Future strap designs should not compromise usability to meet a functional requirement. The fluorel material should be replaced by a flexible material such as PBI webbing. The increased usability would outweight the slight increase in flammability especially in the anticipated normal atmospheres.

2/ Long Straps - The long straps performed satisfactorily.

3/ Equipment Restraints - The equipment restraints performed satisfactorily. Again, the strap material itself made the use of these items somewhat difficult. Future designs should utilize other material such as PBI webbing.

4/ Bungees - The bungees appeared to be the best concept for on-orbit temporary restraints. A better attaching method could have been developed. Permanent attachment or snap attachment would have been desirable but would have added weight to the vehicle.

5/ Utility Restraints - The utility restraints performed satisfactorily.

6/ Plenum Bags - The plenum bags performed satisfactorily.

H. Snaps and Velcro

The snaps and velcro performed satisfactorily. A higher shear strength and longer life velcro would have performed better but none were available that would meet the flammability requirements.

I. Tool and Repair Kits

The tool and repair kits performed satisfactorily. The utilization of standard tools proved to be effective and should be continued on future vehicles. The contents of the tool kit should have been arranged according to type but the addition of one tool at a time throughout the design phase made this impractical. There is always a tradeoff to be made between hardware design progression and hardware requirement progression a to whether redesign is required or desired.

On future vehicles a basic comprehensive tool kit should be established early in the design phase. Specific tools would have to be added where the design dictated but the change in the basic kit would be minimized.

J. OWS Stowage Software

The computer program was an excellent vehicle for performing the function of tracking the various stowage items, restraint hardware and required drawings. No previous program of this magnitude and numbers of stowage items exists from which a comparison can be made between manual and computerized management of numerous stowage aspects, but intuition leads to the conclusion that manual preparation would have produced a much higher magnitude of errors. Future programs with their multiple missions and fast turnaround times will find this type of approach to stowage control indispensable.

2.2.13.6 Development History - The closed container stowage capability of the OWS, following wet to dry conversion, was 155 ft^3 (4.4 m^3). At that time 90 ft^3 (2.6 m^3) was allocated with the remainder being growth capability. In late 1970, ECP's 041 and 069 increased the stowage capability to 580 ft^3 (16.4 m^3). This was accomplished by the addition of the ring containers, the film vault, more standard lockers in the forward compartment, several non-standard lockers to make use of existing space.

As the amount of loose equipment steadily increased, it became necessary to relocate some equipment from closed containers to open floor or wall locations, to avoid incorporation of additional stowage containers. At launch, 560 ft^3 (15.8 m^3) of the 580 ft^3 (16.4 m^3) was allocated for specific loose equipment.

To provide a non-flammable packing material without excessive weight penalty, non-flammable fiberboard was fabricated like corregated cardboard. Stowage bags consisting of armalon fabric covered mosite sponge were also developed to stow mainly optical equipment.

2.2.14 Ground Support Equipment System

A major premise of the requirements for OWS GSE was to utilize as much existing equipment from the DSV-4B and DSV-4 programs and to design as little new equipment as possible. Accordingly, a number of items of GSE were utilized in their existing configuration and a number of others were used with varying degrees of modification. New items of equipment were designed for multiple usage as much as possible in order to minimize costs.

Low carbon steel material was used as much as possible, consistent with design requirements, to minimize costs. Higher grade steels, such as 4130 or stainless steels, were utilized where strength requirements dictated their use and where low carbon steels were not satisfactory. In cases where the GSE was to be used inside the OWS and/or where weight was a factor, aluminum materials were used. GSE made of aluminum was anodized or alodine finished and designed so as to prevent entrapment of dirt and dust. The equipment was designed to be made of weldments and/or bolted attachments to permit breakdown of the GSE for storage and shipment.

2.2.14.1 Orbital Workshop (OWS) Spacecraft Handling and Transportation Equipment

A. Design Requirements:

This family of kits was designed to factors of safety shown in Table 2.2.14.1-1.

TABLE 2.2.14.1-1

SPACECRAFT HANDLING AND TRANSPORTATION EQUIPMENT SAFETY FACTORS

OWS DSV7 KIT MODEL NUMBERS	ULTIMATE FACTOR OF SAFETY	YIELD FACTOR OF SAFETY	LIMIT LOAD FACTORS(*): HOISTING/GROUND TRANSPORT LONG.	LAT.	VERT.	LIMIT LOAD FACTORS: SUDDEN MANLOADS LONG.	LAT.	VERT.	ULTIMATE HOIST LOAD	ULTIMATE MANLOAD [MAN WEIGHT = 250 LBS (113.4 kg)]
-321	1.5	1.0	0.0	0.0	-2.0				Wt. OWS x 2.0 L.F. x 1.5 U.F.S. = 3.0 x weight	
-322	1.5	1.0	0.0	0.0	-3.00				Wt. OWS x 3.00 L.F. Ult. F.S. = 4.5 x weight	
-323	1.5	1.0	Condition (1) ±0.75	±0.5	-2.0					
			Condition (2) 0.0	±0.5	-2.0					
			Condition (3) ±1.0	±0.5	-2.0					
-324	1.5	1.0	Condition same as for -323 (1) ±0.75	±0.5	-2.0					
			(2) 0.0	±0.5	-2.0					
			(3) ±1.0	±0.5	-2.0					
-325	1.5	1.0	0	0	-3.0				Wt. OWS x 3.00 L.F. x 1.5 Ult. F.S. = 4.5 x weight	
-335	1.5	1.0	0.0	0.0	-3.00				Wt. DTA x 3.00 L.F. x 1.5 Ult. F.S. = 4.5 x weight	
DSV-IVB -368	1.5	1.0	0.0	0.0	-3.00				Wt. Cover x 3.00 L.F. x 1.5 Ult. F.S. = 4.5 x weight	
DSV-IVB -392	Waiver from NASA with judicial use.									
DSV-IVB -345										

Condition (1): Road Bumps and Irregularities)
Condition (2): Turning) Includes 45 knot wind
Condition (3): Quick Stops and Starts) in any direction.

*(+) Sign indicates aft, port and up
(-) Sign indicates forward, starboard and down.

1/ OWS Weight and Balance Kit (DSV7-321):

The function of the OWS Weight and Balance Kit (Drawing No. 1B88982), when used in conjunction with the DSV-4B-345 Weight and Balance Kit (Drawing No. 1A57907), was to measure the weight and determine the longitudinal center of gravity of the OWS.

The Kit consisted of adapting devices to be used in conjunction with the DSV4B Weight and Balance Kit electrical readout equipment, the DSV7-322 Forward and Aft Hoist Kit and an Overhead Hoisting System. (Figure 2.2.14.1-1)

2/ Forward and Aft Hoist Kit (DSV7-322):

This Kit (Drawing No. 1B81488) was designed to lift the OWS either vertically and horizontally.

The Kit consisted of forward and aft spreader bar assemblies, a hoist beam, spare cable assemblies, and hoisting spacers, adapters and shafts.

The following lifting conditions were required: (1) 2-point horizontal lifting; (2) 2-point vertical to horizontal lifting and (3) single-point horizontal lifting. (Figure 2.2.14.1-2)

3/ Ground Transporter - Stage Dolly (DSV7-325):

The Ground Transporter - Stage Dolly (Drawing No. 1A57853-501) provided support, mobility at 5 miles per hour (8.045 km/hr) maximum

SKYLAB - ORBITAL WORKSHOP

MODEL DSV7-321 WEIGH AND BALANCE KIT

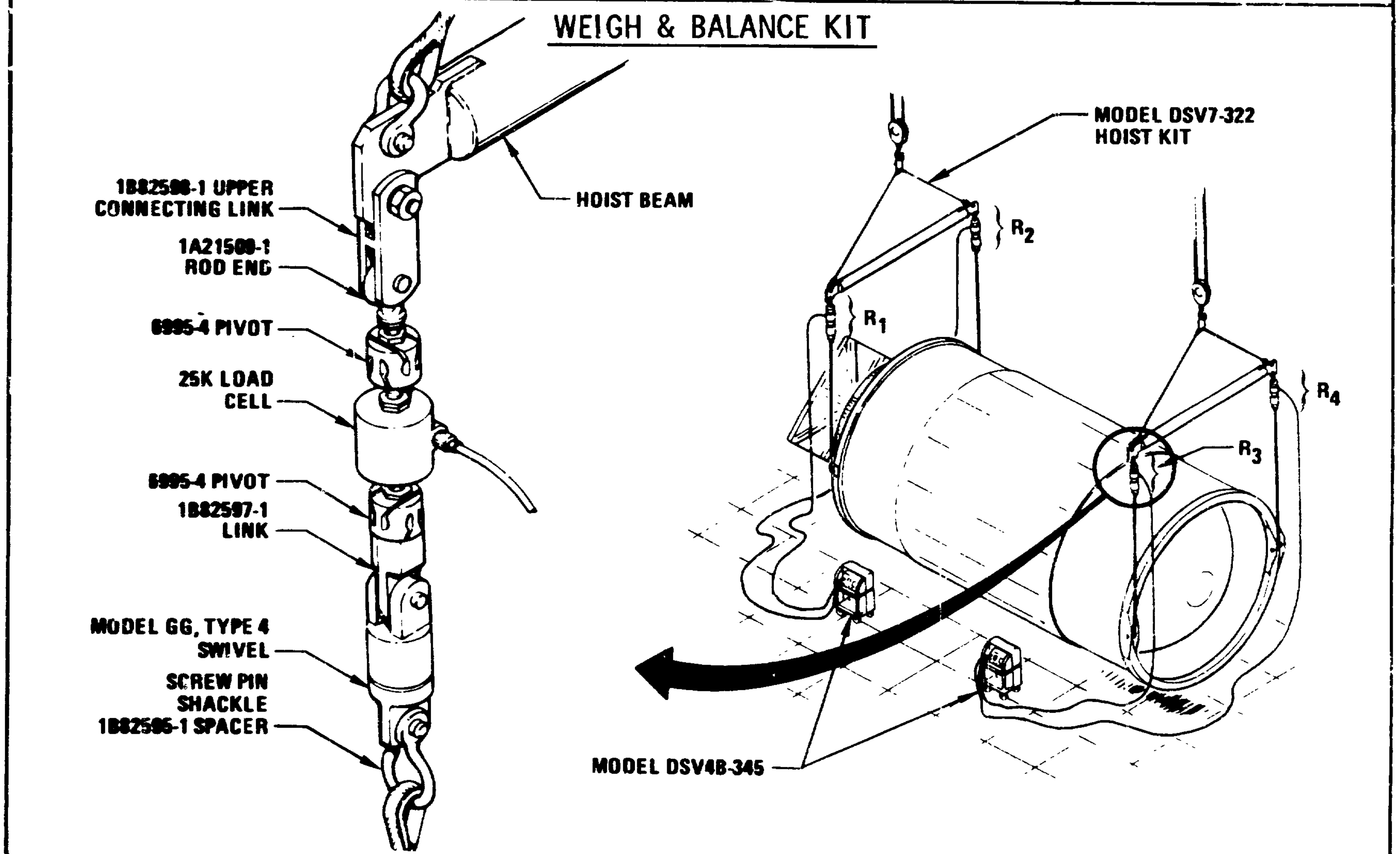


Figure 2.2.14.1-1

MODEL DSV7-322

FORWARD AND AFT HOIST KIT

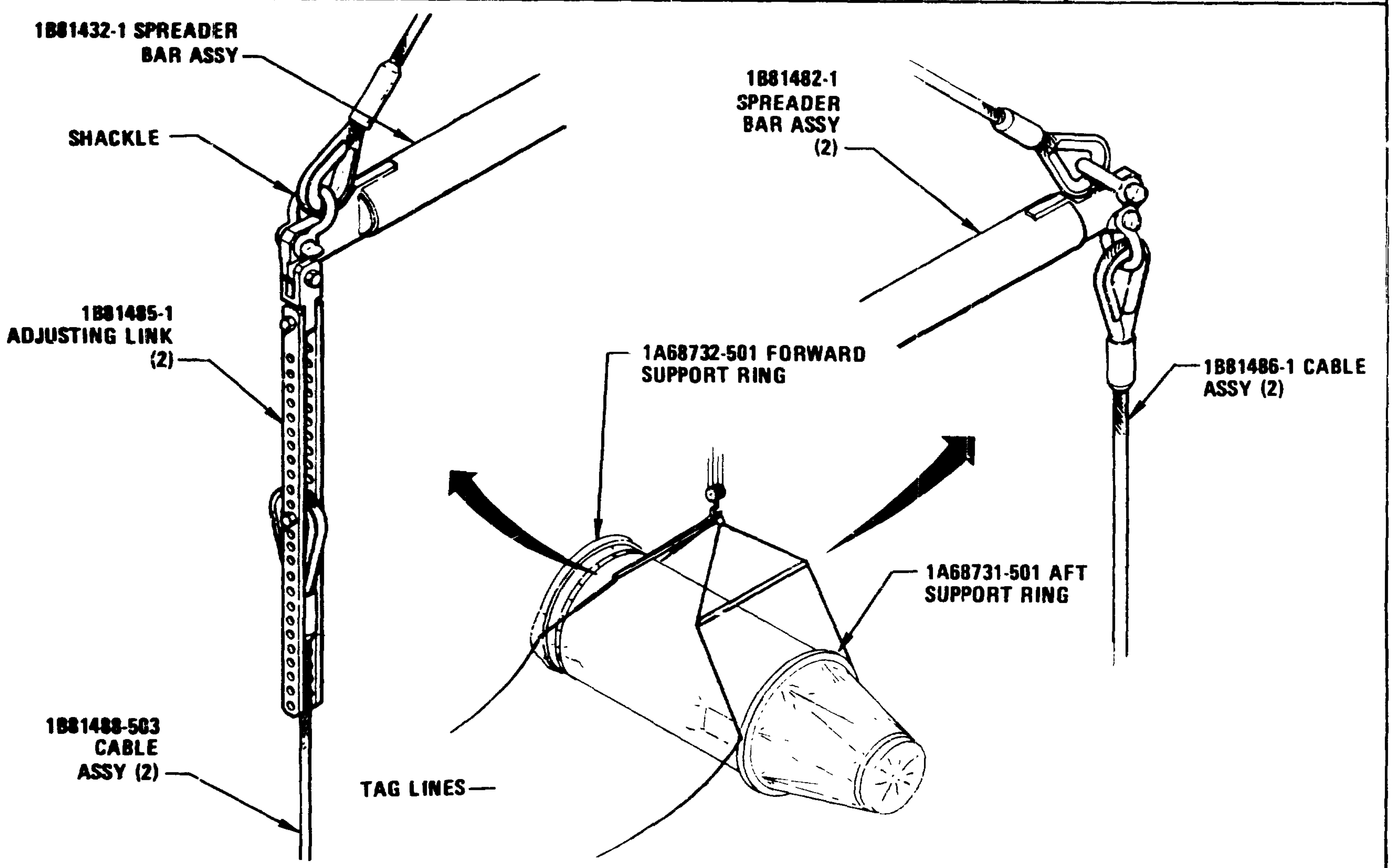


Figure 2.2.14.1-2

over paved roads, and shock isolation by means of a three-point suspension system mounted on two eight-wheeler dual axle and wheel assemblies at the rear, for transporting the OWS and necessary OWS ancillary GSE. The transporter was also capable of towing instrumentation equipment. It incorporated air brakes and was capable of forward and backward movement. There was no turning radius requirement. (Figure 2.2.14.1-3)

4/ OWS Cradles Kit (DSV7-324):

The OWS Cradles Kit (Drawing No. 1B82245) provided support for the OWS during horizontal weighing, during all phases of transportation and during storage of the OWS. The Kit attached to the OWS fore and aft rings and directly to the transporter. It consisted of DSV-4B-301 model modified GSE. (Figure 2.2.14.1-4)

5/ Saturn V Workshop Handling Kit (DSV7-325):

The Saturn V OWS Handling Kit (Drawing No. 1B78733) hoisted and mounted the OWS so that the induced handling loads were safely transmitted into the OWS structure. The kit consisted of segmented metal rings bolted to the forward and aft skirts. The kit consists of modified model DSV-4-302 GSE. (Figure 2.2.14.1-5)

6/ OWS Handling Kit (DSV7-335)

The OWS Handling Kit (Drawing No. 1B86478) provided a means for lifting both the Dynamic Test Article and the OWS flight article. It consisted of an I-beam, a yoke assembly and hoist cables and links. (Figure 2.2.14.1-6)

SKYLAB - ORBITAL WORKSHOP
MODEL DSV7-323
STAGE TRANSPORTER

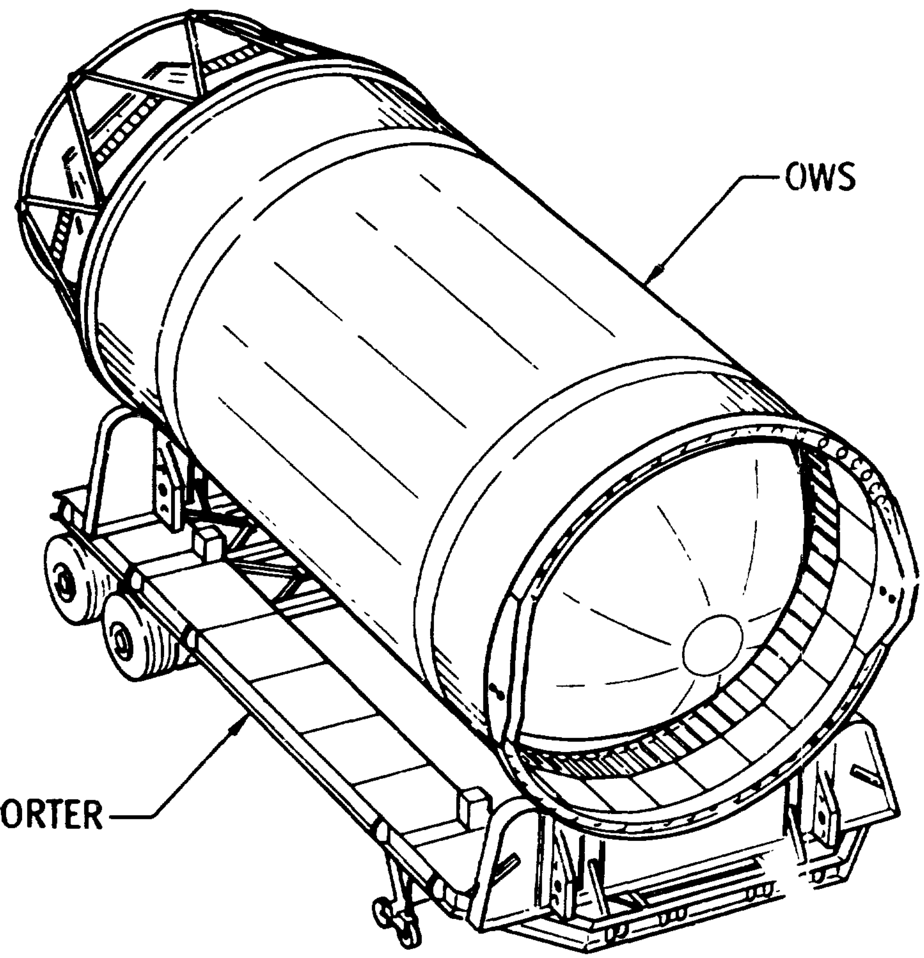


Figure 2.2.14.1-3

SKYLAB - ORBITAL WORKSHOP

MODEL DSV7-324 STAGE-CRADLES KIT

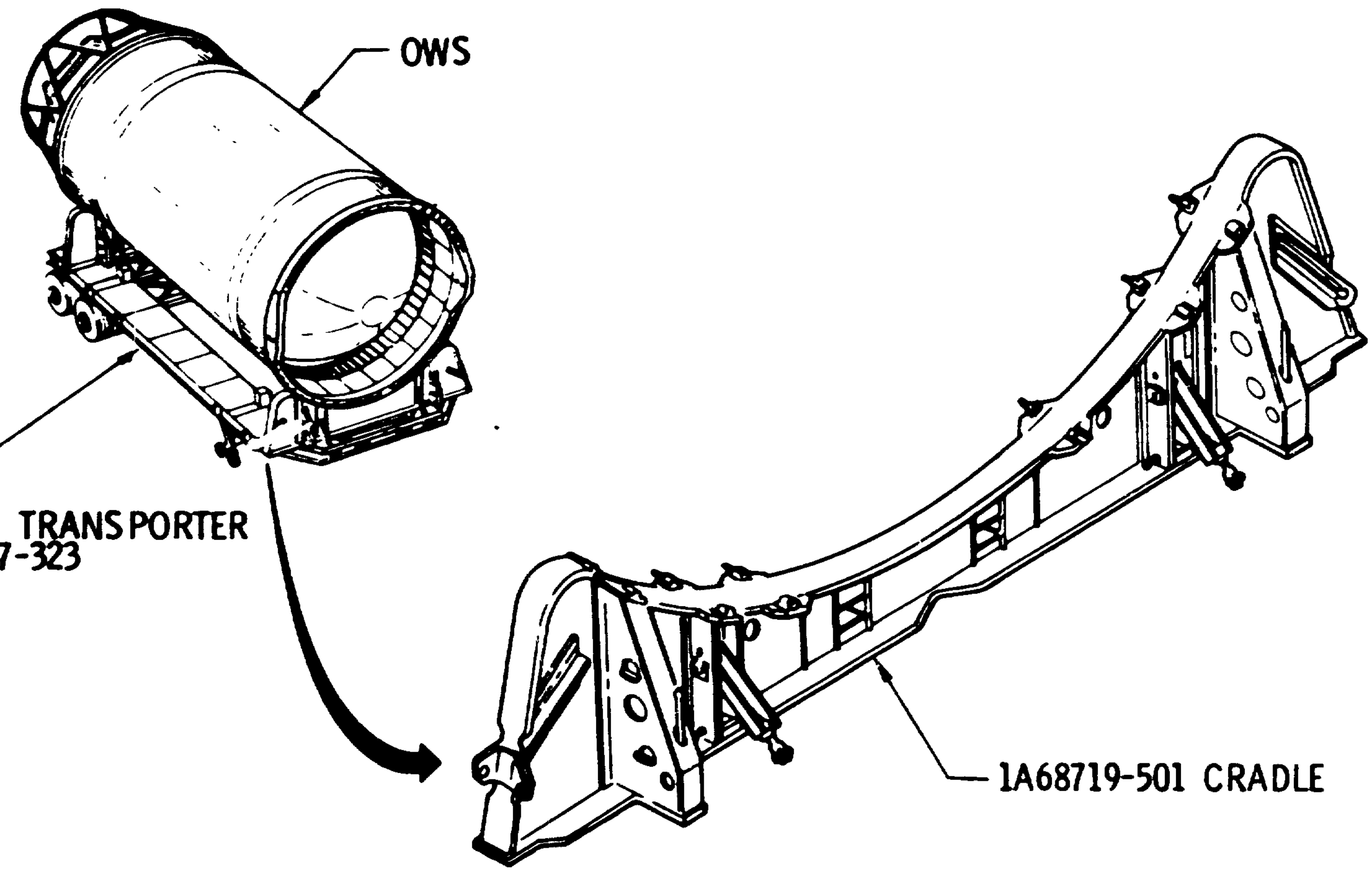


Figure 2.2.14.1-4

SKYLAB - ORBITAL WORKSHOP
MODEL DSV7-325
STAGE HANDLING KIT

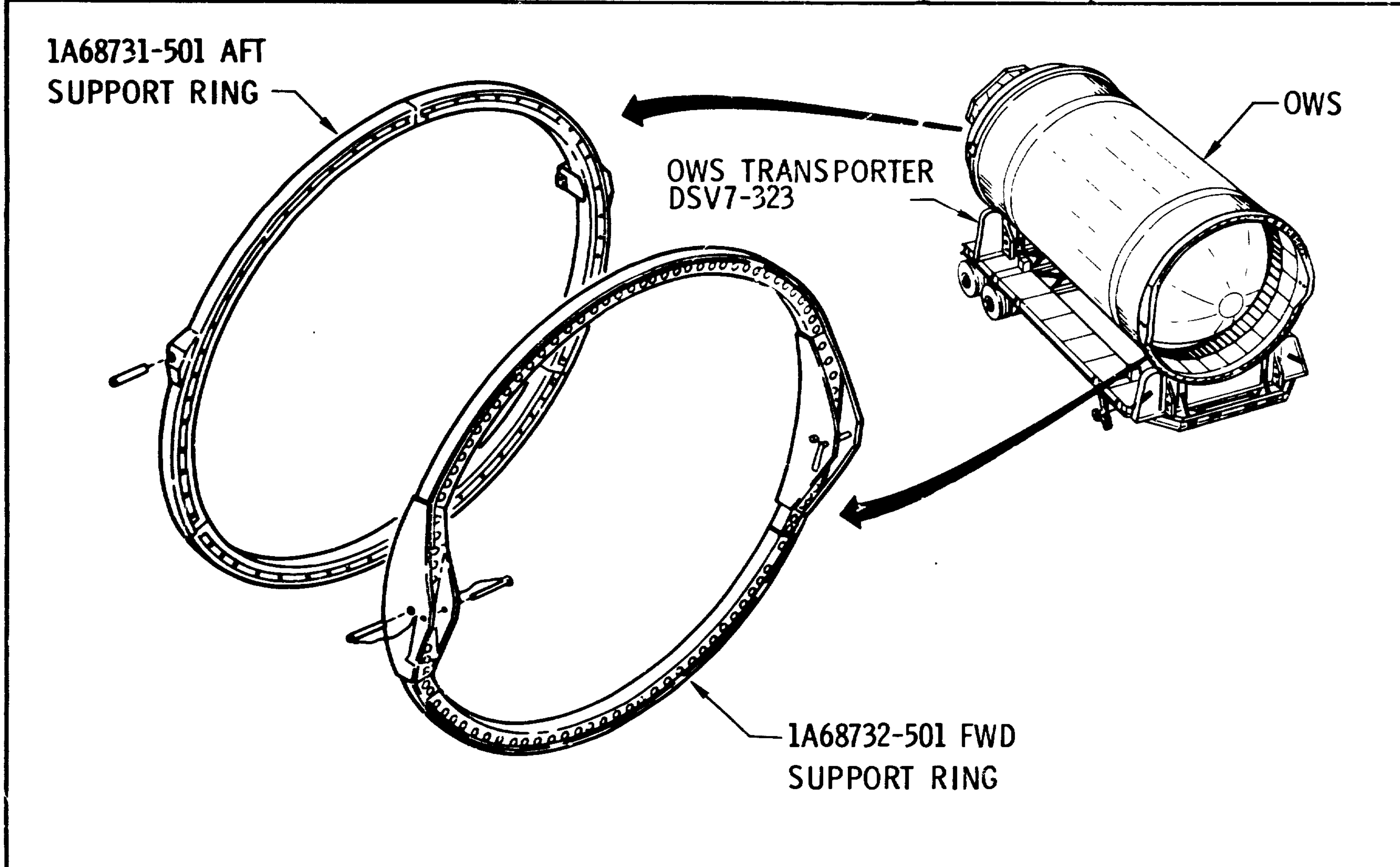


Figure 2.2.14.1-5

SKYLAB - ORBITAL WORKSHOP
MODEL DSV7-335 HANDLING KIT

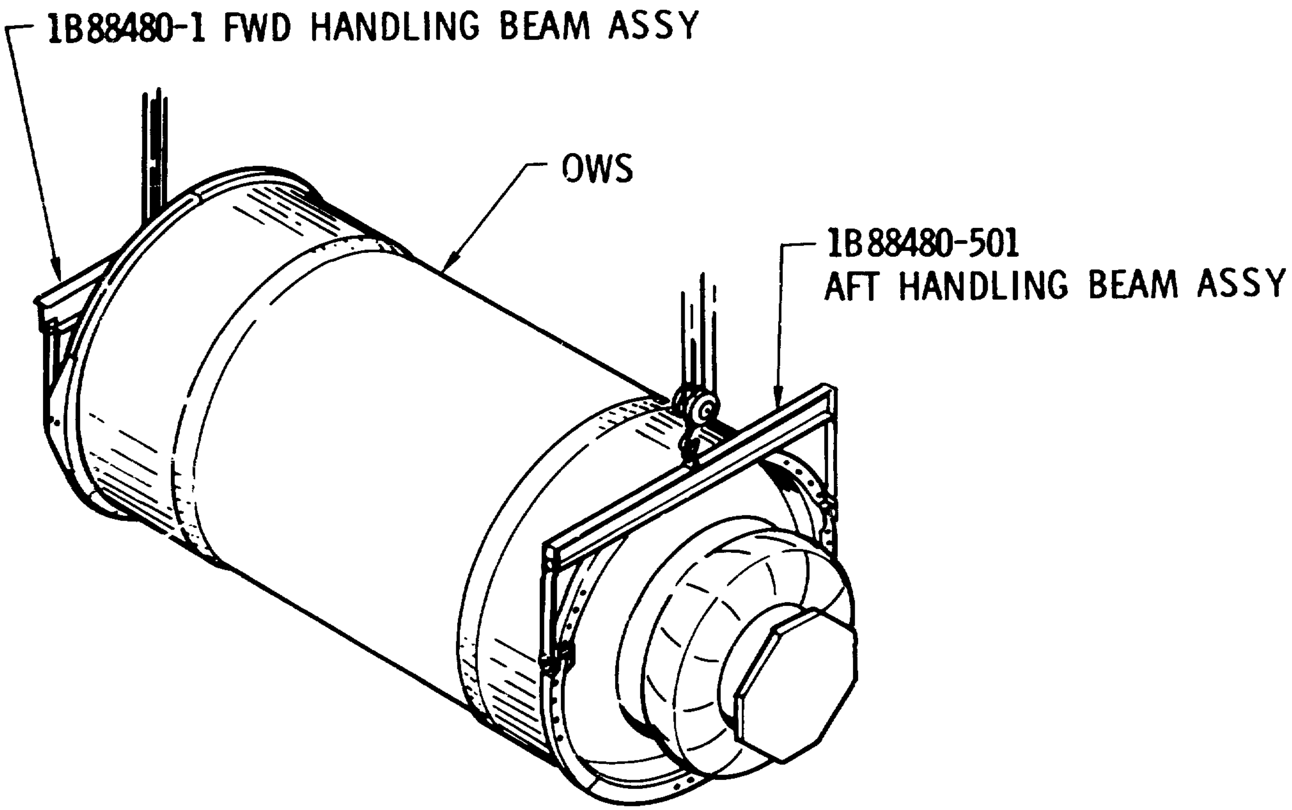


Figure 2.2.14.1-6

7/ Special Tool Kit (DSV-4B-305):

The tool kit (Drawing No. 1A57863) furnished all tools required during handling of the OWS and was mounted on the transporter. (Figure 2.2.14.1-7)

8/ Saturn S-IVB Secondary Desiccant Kit (DSV-4B-365):

The desiccant Kit (Drawing No. 1B56998) permitted free breathing of the habitation area and waste tank checkout and provided desiccant caps to seal the umbilical ends of the original LOX and LH_2 fill and drain lines and the H_2 vent lines. The kit was connected in series with the static Desiccant Kit Model DSV-4B-450 during transportation and while unpressurized in the test stands. It consisted of containers for the silica gel and indicators to check gas relative humidity, hoses, fittings, brackets and desiccant caps. (Figure 2.2.14.1-8)

9/ Saturn S-IVB Stage Cover Hoist Beam Kit (DSV-4B-368):

The beam kit (Drawing No. 1B57200) was required to hoist, position, install and remove the protective pad and environmental cover center section for the OWS. The kit consisted of a two channel mechanism, strap rollers and strap extensions and rollers. (Figure 2.2.14.1-9)

10/ Dummy Interstage and Engine Protective Support Kit (DSV-4B-392):

The support kit (Drawing No. 1B57202) was required to shield the aft end of the OWS from structural damage. The kit supported the aft cover and the OWS in a vertical attitude for removal of the aft handling ring. The design consisted of large and small rings with a tubular structure between with eight platform sections and connecting links. (Figure 2.2.14.1-10)

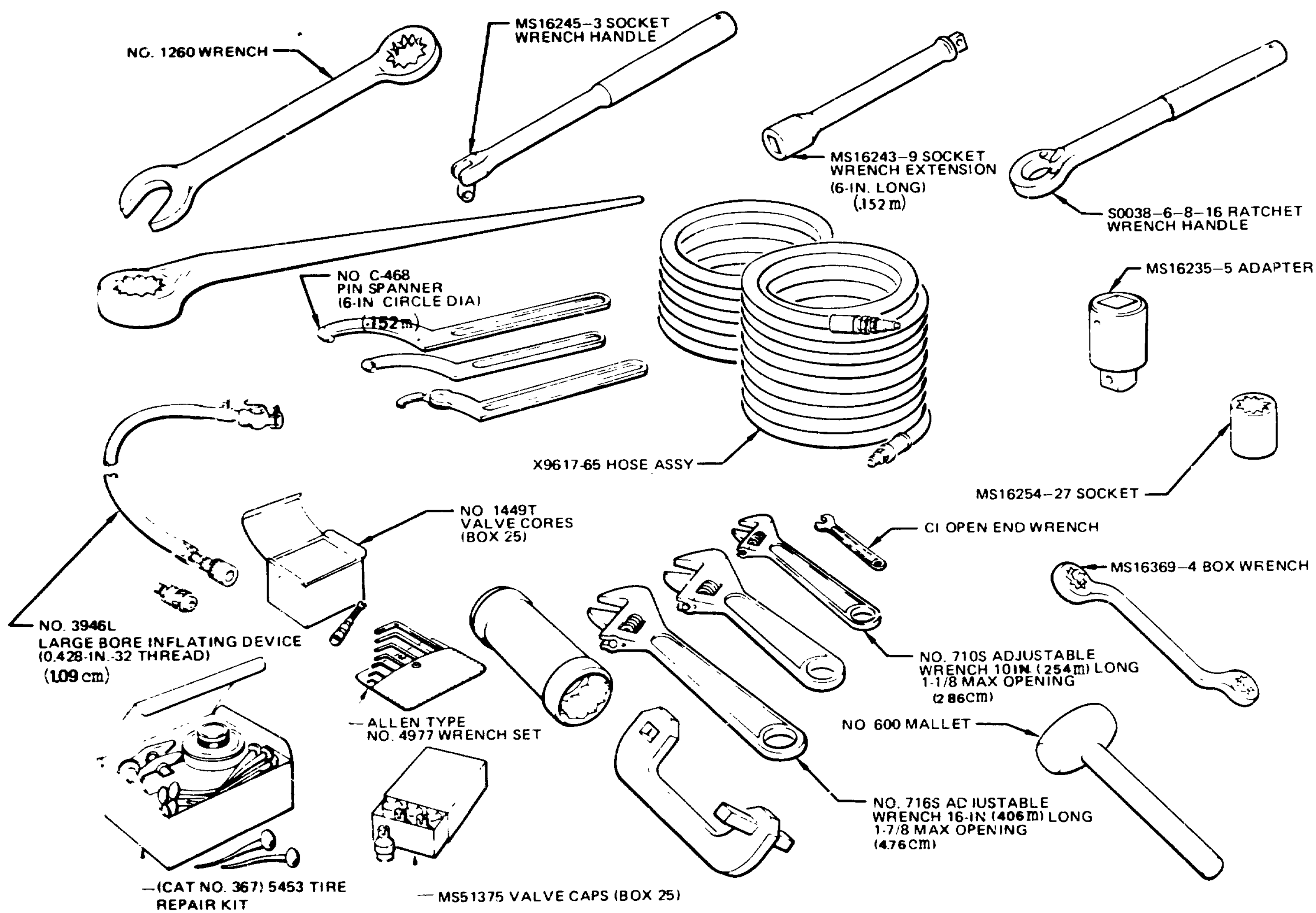


Figure 2.2.14.1-7. Special Tool Kit (DSV–4B–305)

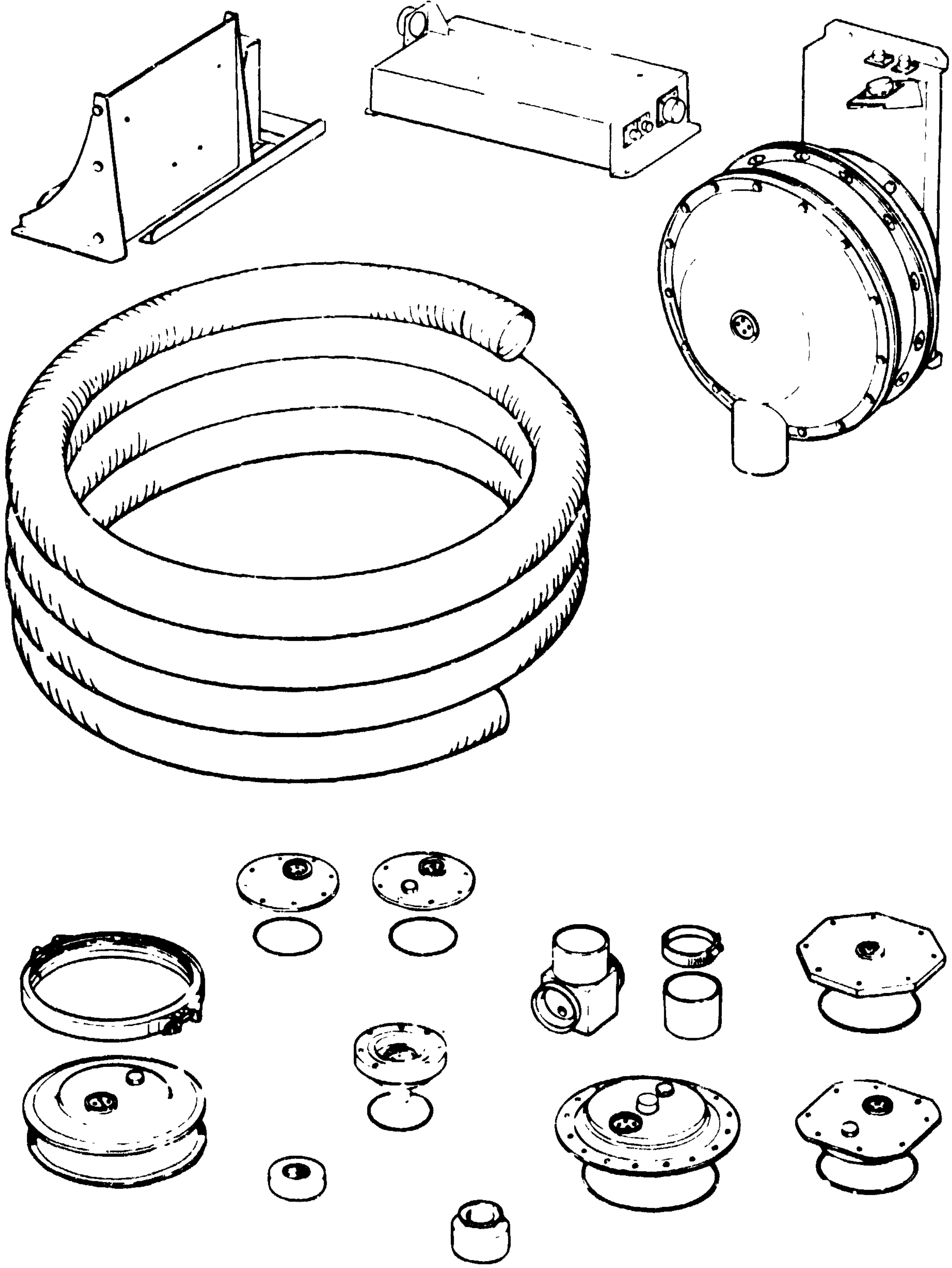


Figure 2.2.14.1-8. Desiccant Kit, Secondary, Saturn S-IVB (DSV—4B—365)

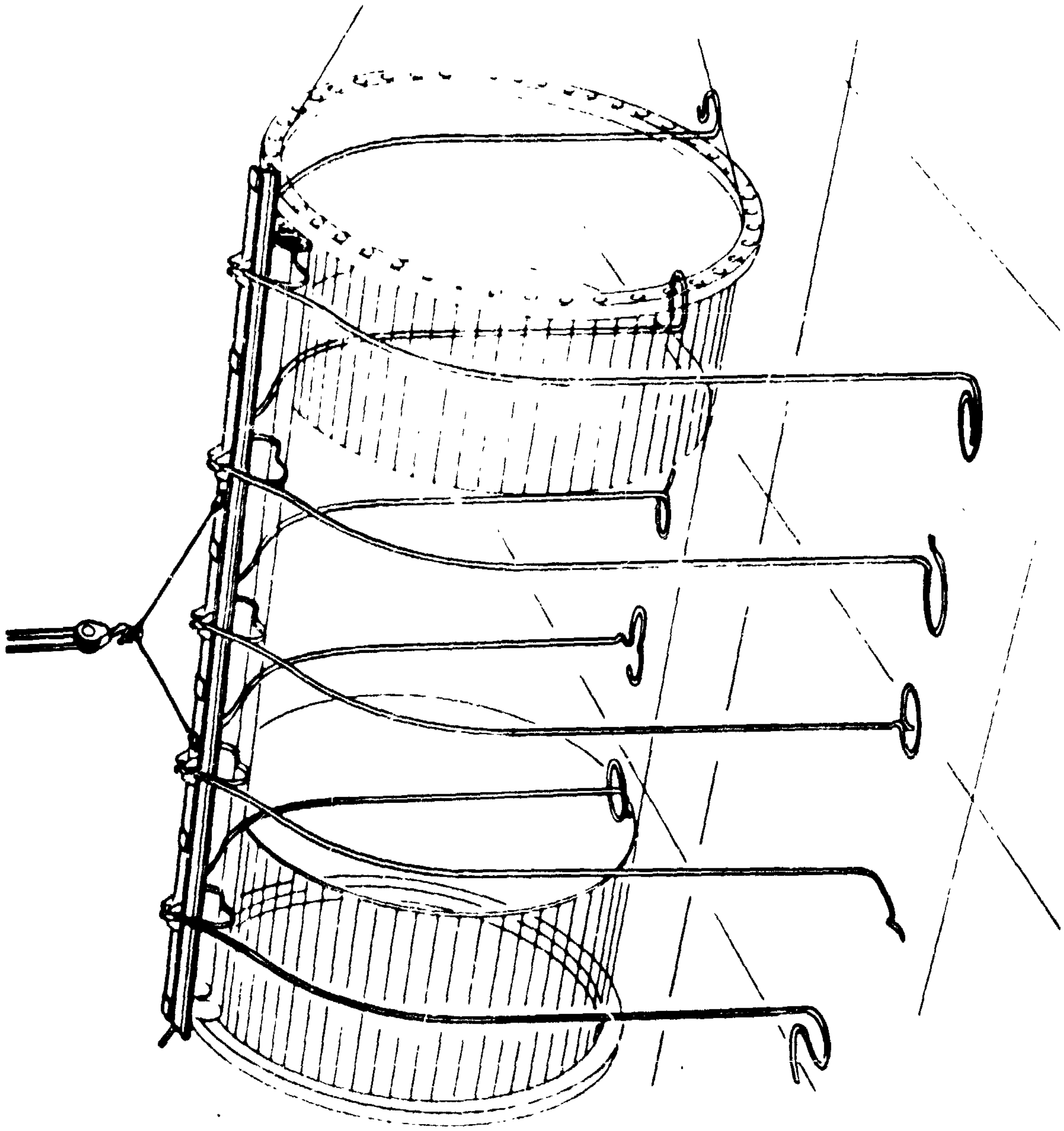


Figure 2.2.14.1-9. Beam Kit, Cover Hoist, Saturn S-IVB Stage (DSV-4B-368)

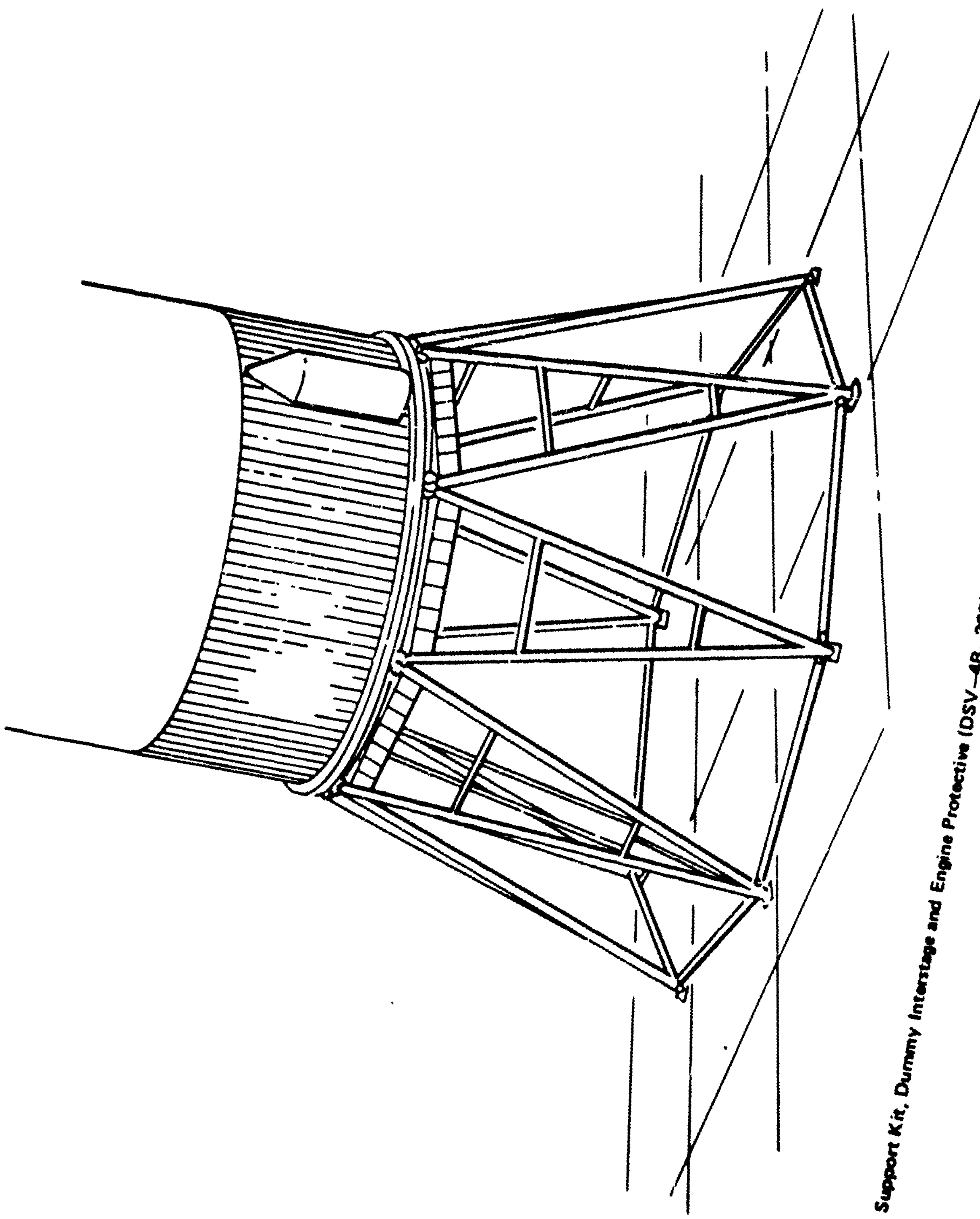


Figure 2.2.14.1-10. Support Kit, Dummy Interstage and Engine Protective (DSV-4B-392)

11/ S-IVB Stage Static Desiccant Kit (DSV-4B-450)

The desiccant Kit (Drawing No. 1B57000) was required to provide a humidity controlled atmosphere for the OWS in the protective cover kit by flowing ingested air through three desiccant beds, one breather each for the cover, the habitation tank and the waste tank, each with a relative humidity indicator. A differential pressure gage permitted monitoring ambient and pressure differences. (Figure 2.2.14.1-11)

12/ Dynamic Desiccant Kit (DSV-4-324):

This Kit (Drawing No. 1B56772) was required to supply a humidity controlled atmosphere for the covered OWS while being transported by sea. The kit consisted of a gasoline engine driving generators to furnish 220 DC power converted to AC power to drive pumps flowing air over desiccant beds and then under the stage cover. The system was mounted on a trailer and was independently self sufficient but capable of using shipboard power. (Figure 2.2.14.1-12)

13/ Stage Weigh and Balance Kit (DSV-4B-345):

The electrical readout equipment only of the Weigh and Balance Kit (Drawing 1A57907) was required, in conjunction with DSV7-322, to determine the weight and center of gravity of the OWS. The readout equipment consisted mostly of purchased parts. (Figure 2.2.14.1-13)

B. System Description:

The OWS Spacecraft Handling and Transportation System provided equipment for (1) weighing and determining the center of gravity of the OWS, (2) supporting the OWS during weighing, transporting and storing,

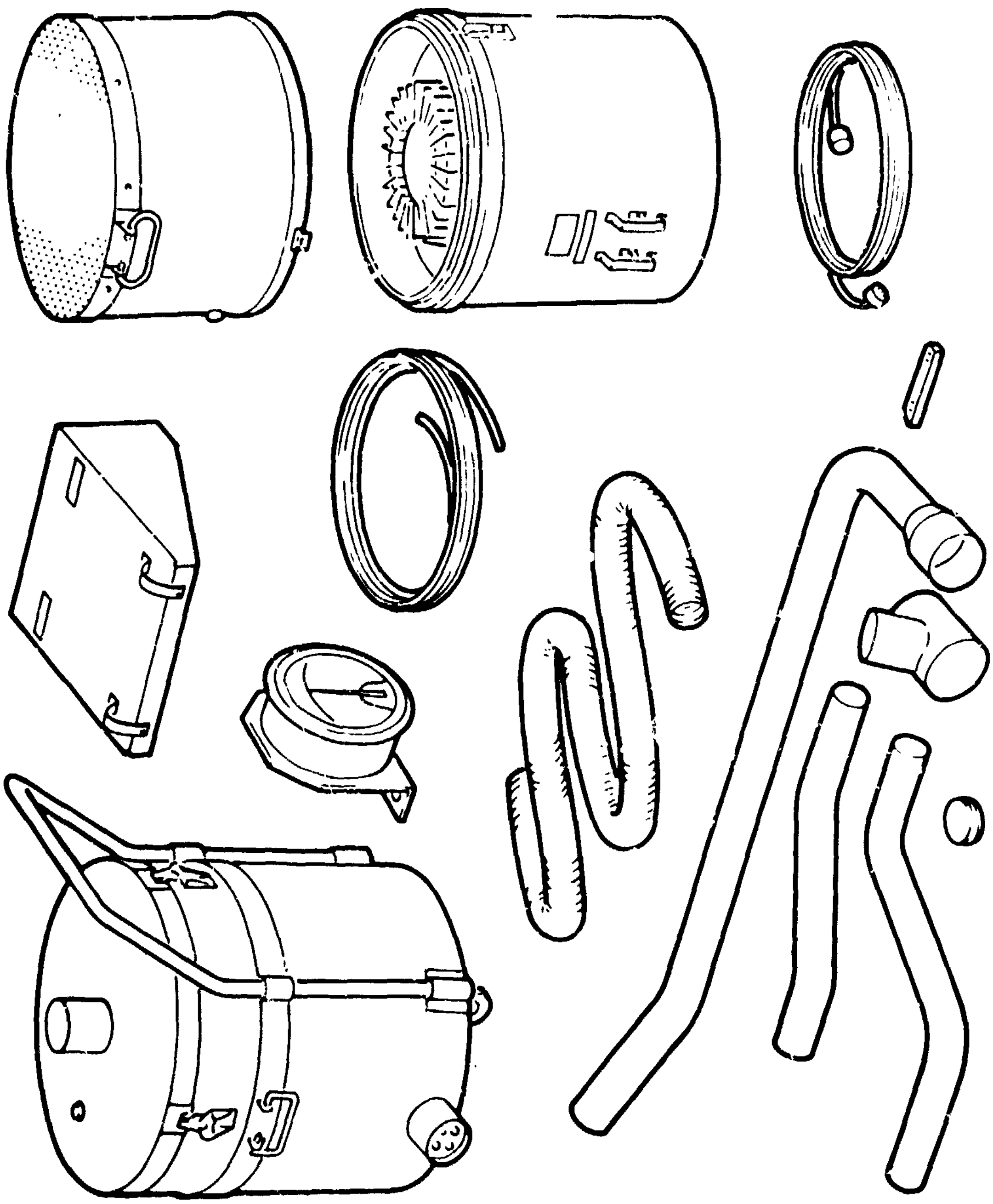


Figure 2.2.14.1-11. Desiccant Kit, Static, S-IVB Stage (DSV–4B–450)

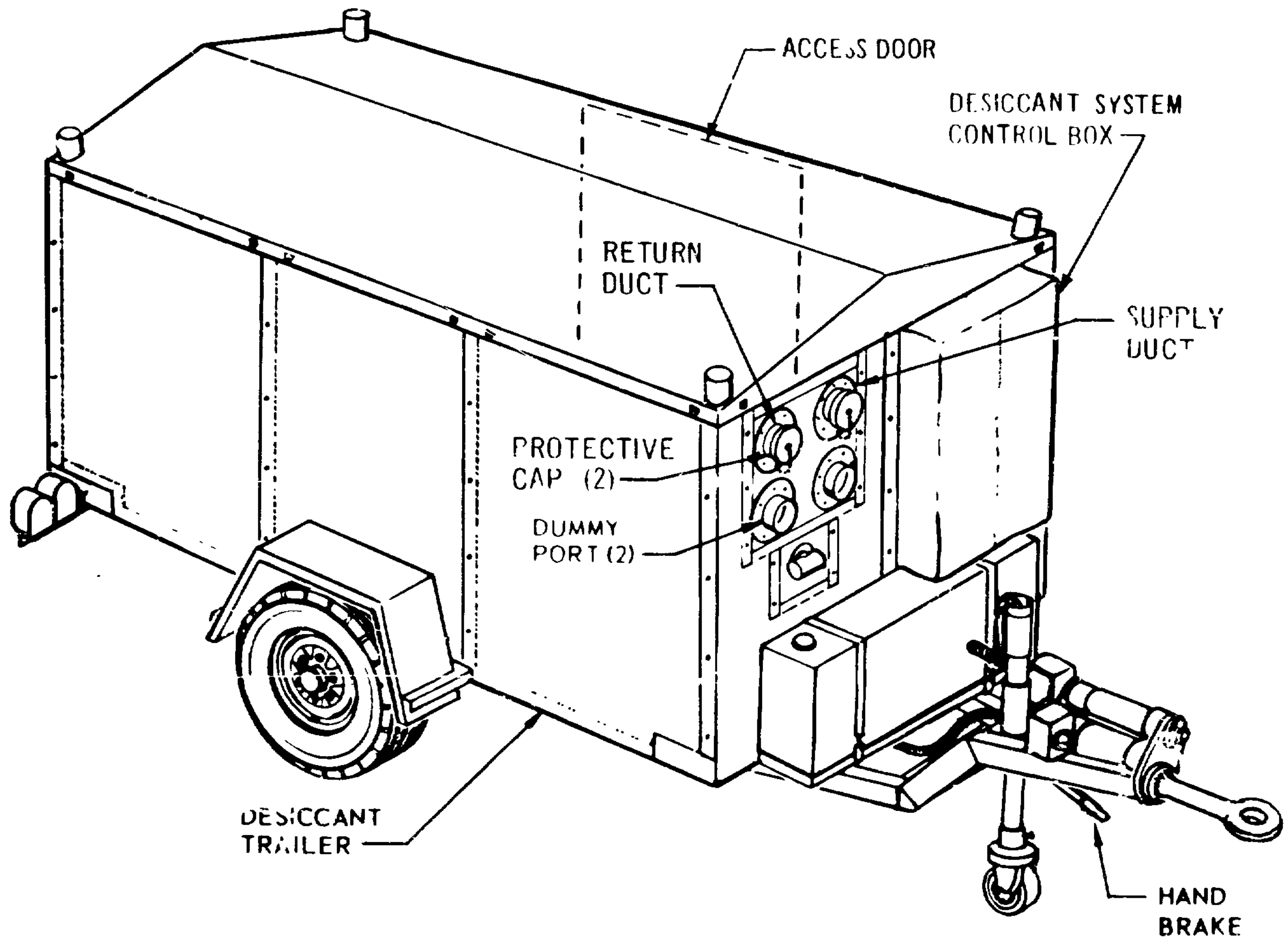


Figure 2.2.14.1-12. Dynamic Desiccant Trailer

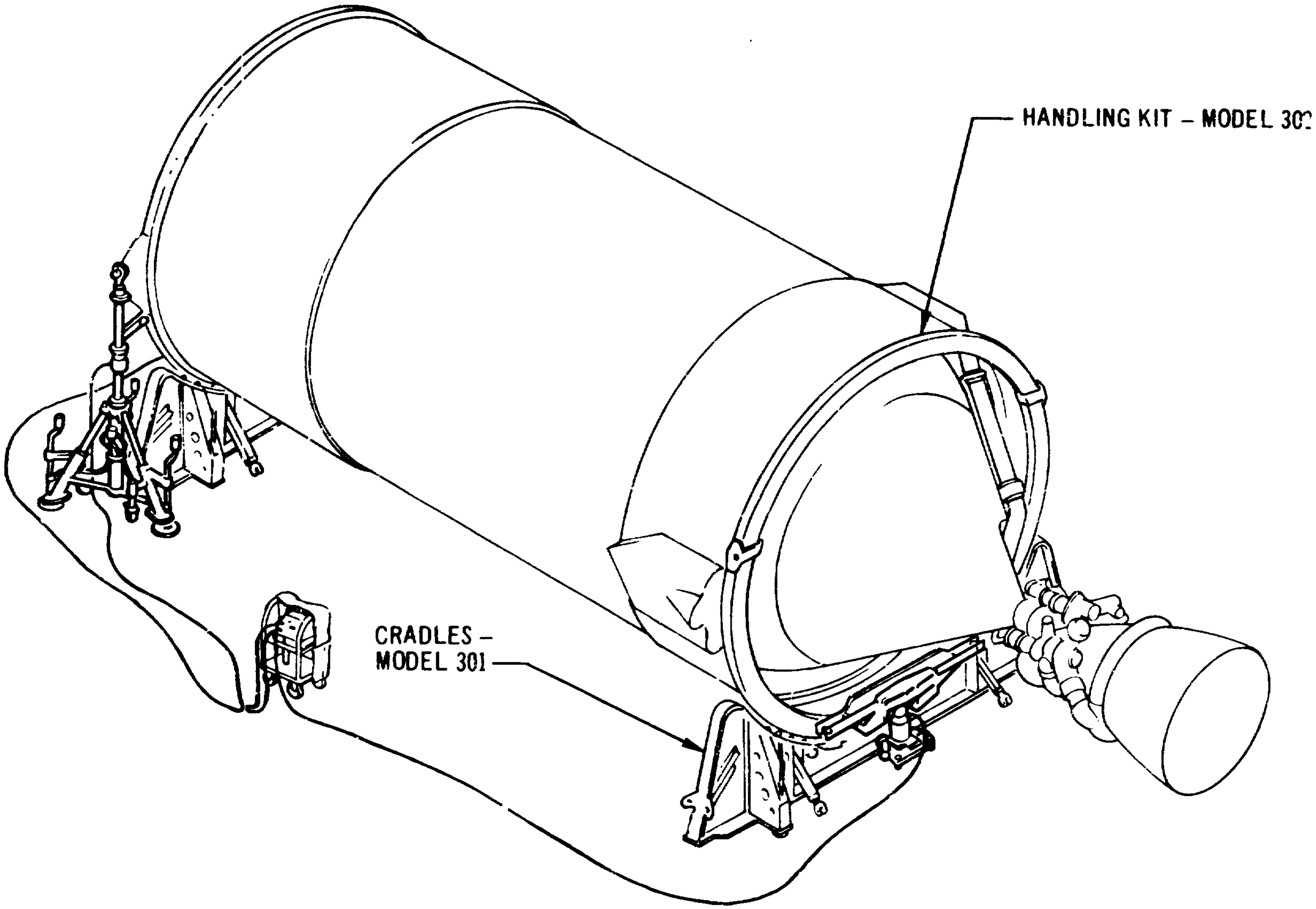


Figure 2.2.14.1-13. Weigh and Balance Kit, Stage (DSV–4B–345)

(3) lifting the Dynamic Test Article, the OWS Cover and the OWS horizontally or vertically during the various steps in the procedures of weighing, transporting and storing the OWS, (4) transmitting induced loads into the OWS stage structure, (5) transporting and supporting the OWS during ground transport, (6) protecting the aft end of the OWS during handling, (7) providing a humidity controlled atmosphere for the covered OWS during transport by land or sea and for providing free breathing for the habitation and waste tanks during checkout and sealing caps for the original LOX and LH_2 fill and drain lines and H_2 vent lines. This entire system handled the OWS from the completion of manufacture through final delivery for flight usage or storage. Consideration was given to any emergency handling situations that might arise due to minute shifts of the OWS when setting it on the transporter, the ground, and for small alignment adjustments and changes in the center of gravity. Some unique features incorporated into this system were air bags for gentle support of the stage and the use of box extrusion shapes for the large handling rings.

C. Testing:

Testing of the Spacecraft Handling and Transportation System consisted primarily of a transportability and load tests of the Ground Transporter-Stage Dolly, calibraiton of the weight and balance kits and proof loading of the Saturn V Workshop Handling Kit rings, the hoist beams and the Weigh and Balance Kit. The cradles were upgraded from the DSV-4B System and strengthened. The Workshop Handling Kit rings were upgrades, the hoist beams were redesigned and the basic S-IVB covers were accepted as satisfactory. The Dummy Interstage and Engine Protective Support Kit for the DSV-4B did not meet OWS design requirements. However, it was agreed with MSFC that by using a Hydra-set, or its equivalent, and care during hoisting, that the dynamic loading could be avoided and the Support Kit could be used without structural change.

The objective of the Ground Transporter-Stage Dolly Production Acceptance Test (1B85219) was to demonstrate the ability of the modified Saturn S-IVB Stage Transporter to transport the DSV-7 OWS Stage in the land transportation mode. The test was conducted over improved roadway surfaces simulating actual operating conditions to demonstrate transporter mobility and stability characteristics. The tests conducted were as follows:

1/ Minimum Turning Radius Test

2/ Braking Test

3/ Backing Test

4/ Road Obstruction Test

5/ Simulated Curb Test

The transporter was instrumented with accelerometers to determine the response of the modified transporter under operational conditions for comparison with previously designed data on Model DSV-4B-300. The data was recorded on magnetic tape over a frequency range of 0 to 50 Hz, and oscillograph time histories were made of all data recorded.

D. Conclusions and Recommendations

The OWS Spacecraft Handling and Transportation System functioned as planned. There were no breakdowns or failures and all equipment functioned as designed. Safety factors were adequate. These designs were the results of years of experience and proved to be of good quality that should not be compromised in future programs. The use of state-of-the-art resulted in a time saving practical system.

It is recommended that a weight growth factor be utilized for design of these GSE systems, when practical.

2.2.14.2 SAS Handling and Transportation Equipment

A. Design Requirements:

This family of kits was designed to factors of safety shown in Table 2.2.14.2-1.

1/ Solar Array Hoisting and Handling Kit (DSV7-304)

The Solar Array Hoisting and Handling Kit (Drawing No. 1B78739) provided:

(a) Rigidity and support for the OWS solar array during its handling, transportation, checkout, and installation onto the OWS,

(b) A means by which the SAS can be hoisted from a horizontal positioned and rotated vertically, and

(c) Support for the solar array during checkout and ordnance installation at KSC.

These design requirements are enumerated by Specification Control Drawing 1B79083, Solar Array System.

2/ Solar Array Shipping and Storage Dolly Assembly (DSV7 305)

The Solar Array Shipping and Storage Dolly Assembly (Drawing No. 1B78741) provided a method for shipping and storing the solar array when used in conjunction with the Model DSV7-304 Solar Array Hoisting and Handling Kit and provided a shipping and storage container with provisions for environmental control when used in conjunction with Model DSV7-306 Solar Array Preservation Kit. The dolly was to have limited towing capability. The cover was to withstand a differential pressure of 0.25 psi (1724 N/m^2). The towing speed was limited to 5 mph (8.045 km/hr) maximum.

TABLE 2.2.14.2-1

SAS HANDLING AND TRANSPORTATION EQUIPMENT SAFETY FACTORS

OWS DSV7 KIT MODEL NUMBERS	ULTIMATE FACTOR OF SAFETY	YIELD FACTOR OF SAFETY	LIMIT LOAD FACTORS (*): HOISTING LONG.	LAT.	VERT.	LIMIT LOAD FACTORS: SUDDEN MANLOADS LONG.	LAT.	VERT.	ULTIMATE HOIST LOAD	ULTIMATE MANLOAD [MAN WEIGHT = 250 LBS (113.4 kg)]
-304	1.5	1.0	(a) Hoisting							
			0.0	0.0	-3.00					
			(b) Ground Transportation							
			Condition (1)							
			±0.75	±0.5	-2.00					
			Condition (2)							
			0.0	±0.5	-2.0					
			Condition (3)							
			±1.0	±0.5	-2.0					
-305	1.5	1.0	Same as for Model -304.							

Condition (1): Road bumps and irregularities) Includes 4.5 knot wind
Condition (2): Turning) in any direction.
Condition (3): Quick stops and starts)

*(+) Sign indicates aft, port and up
(-) Sign indicates forward, starboard and down

For air transport, a 1/4 psi (1724 N/m^2) crushing pressure was imposed and the ultimate hoist load was the weight x 3.0 L.F. x 1.5 ult. F.S. = 4.5 x weight.

3/ Solar Array Preservation Kit (DSV7-306)

The Solar Array Preservation Kit (Drawing No. 1A82059) was to be capable of maintaining sufficiently low humidity within the environmental cover so as to preclude possible corrosive damage to the solar array. Equilibrium with ambient pressure was to be maintained inside the cover through the desiccant containers.

B. System Description:

The SAS Handling and Transportation System consisted of (1) a rigid support frame with structural adapter fittings for mounting to the solar array with two slings of beam-and cable designs which attached to the adapter fittings. (Figures 2.2.14.2-1, -2, and -3); (2) a dolly which consisted of a support frame mounted on castered wheels with swivel locks and manually applied brakes with hoising and fork-lift provisions and a frame and sheet construction protective environmental cover which attached to the dolly and which provided for dessicant containers at the ends of the dolly with a means of accepting umbilicals from the desiccant containers (Figures 2.2.14.2-4 and -5) and (3) to free-breathing desiccant containers similar to the Saturn S-IVB Secondary Desiccant Kit (DSV-4B-365) with necessary ducting, clamps and mounting hardware (Figure 2.2.14.2-4). The SAS Handling and Transportation System included the attachment of two accelerometers and recording equipment to the dolly and keeping a record of accelerations encountered during the round trip from McDonnell

SKYLAB - ORBITAL WORKSHOP
SOLAR ARRAY HOISTING AND HANDLING KIT
MODEL DSV7-304

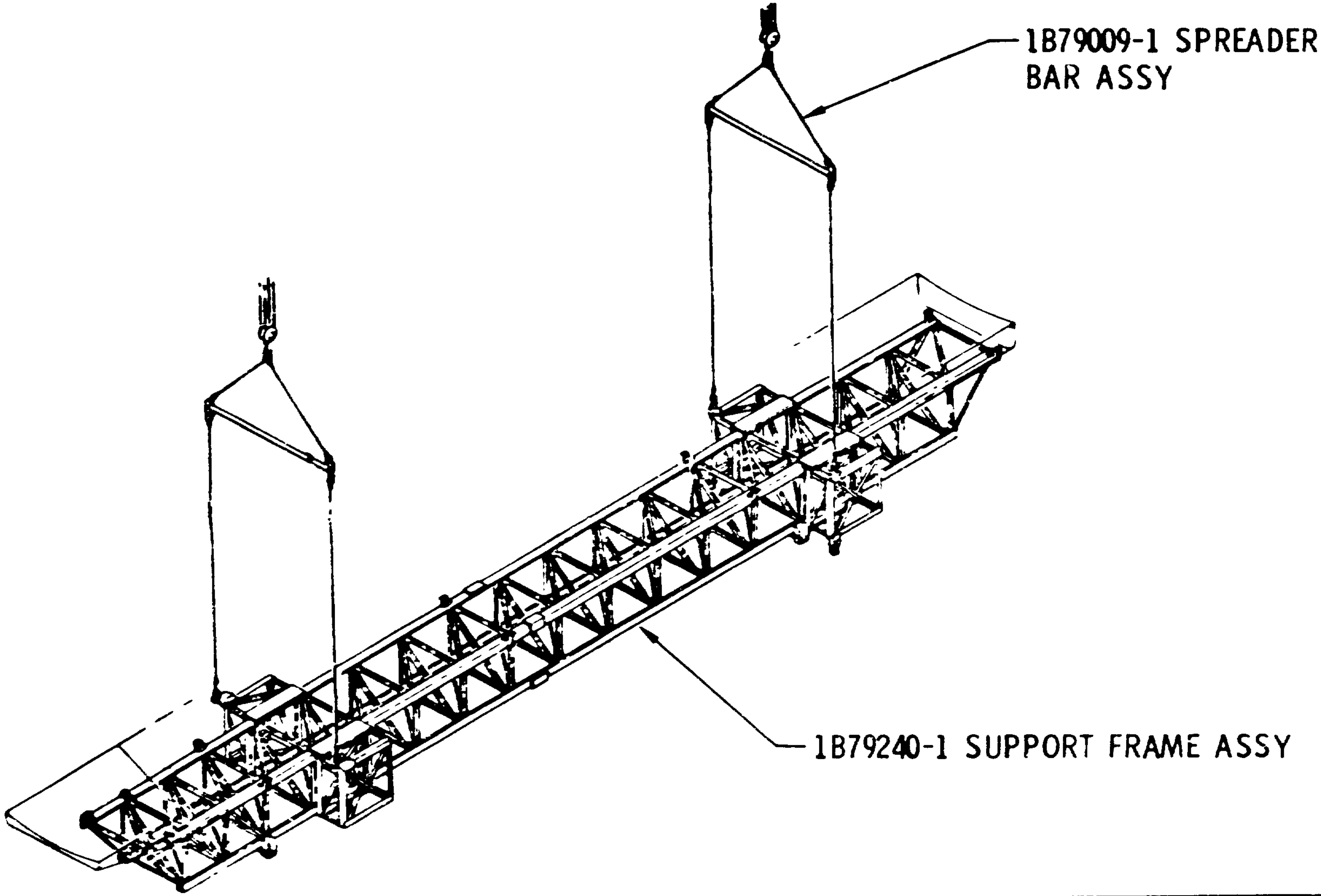


Figure 2.2.14.2-1

SOLAR ARRAY HOISTING AND HANDLING KIT
MODEL DSV7-304

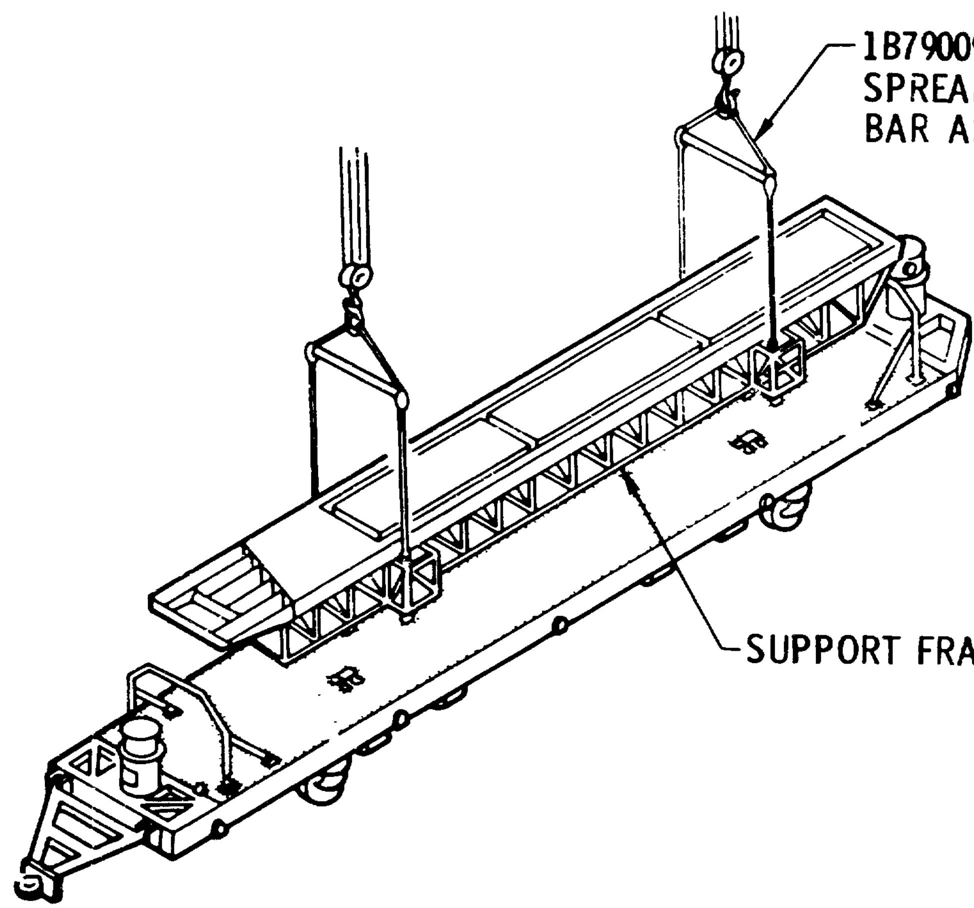


Figure 2.2.14.2-2

SKYLAB - ORBITAL WORKSHOP
HOISTING OPERATIONS

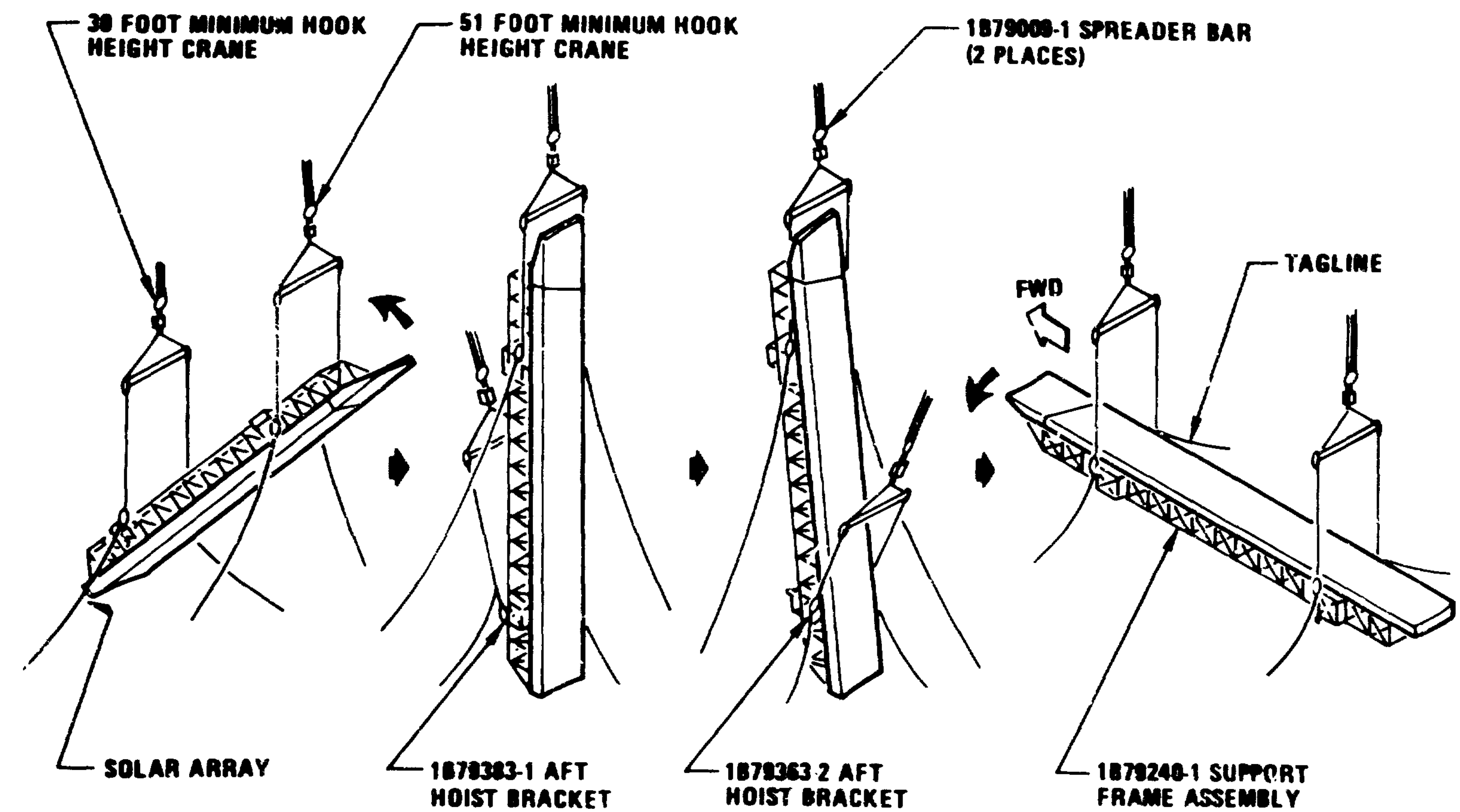


Figure 2.2.14.2-3

SKYLAB - ORBITAL WORKSHOP
MODEL DSV7-305

SOLAR ARRAY SHIPPING AND STORAGE DOLLY KIT

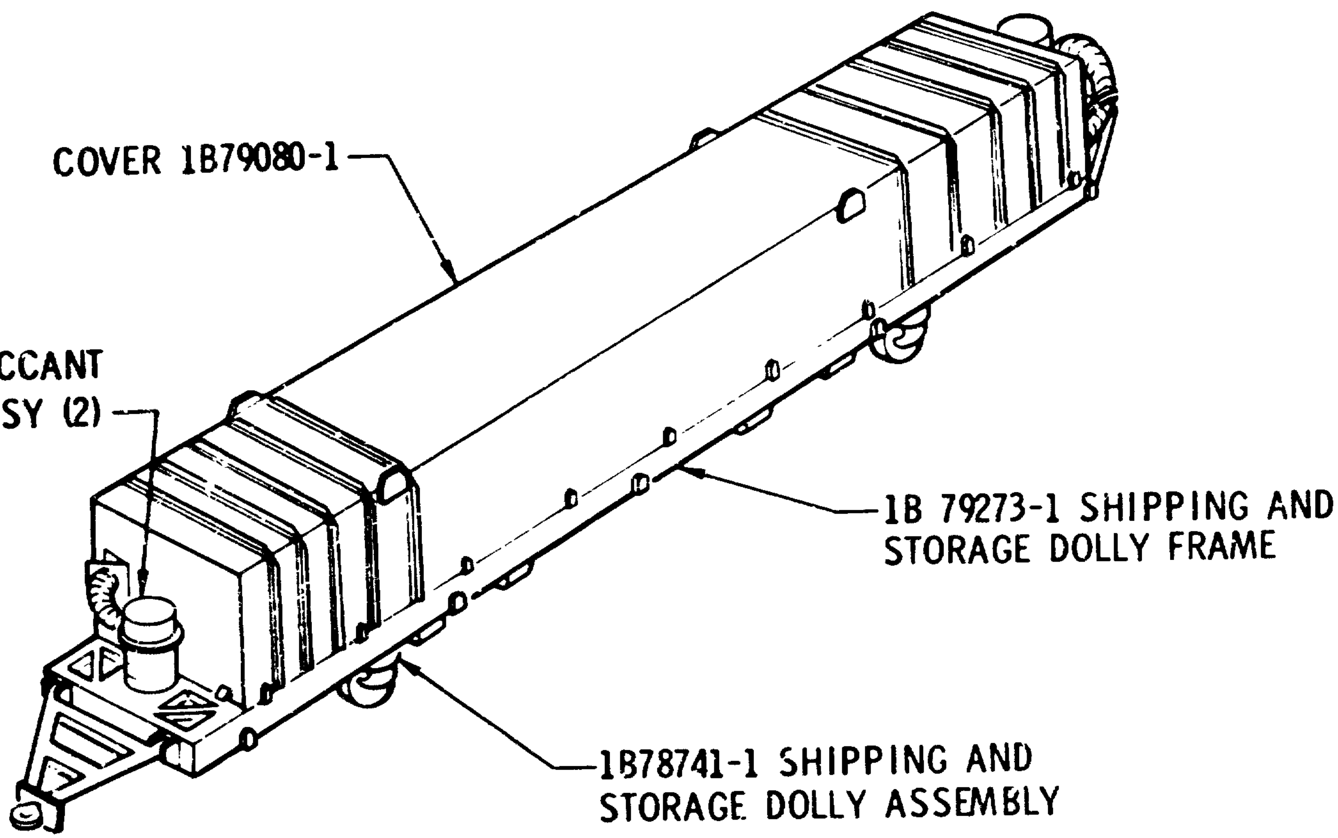


Figure 2.2.14.2-4

SKYLAB - ORBITAL WORKSHOP
SOLAR ARRAY HOISTING AND HANDLING KIT
MODEL DSV7-305

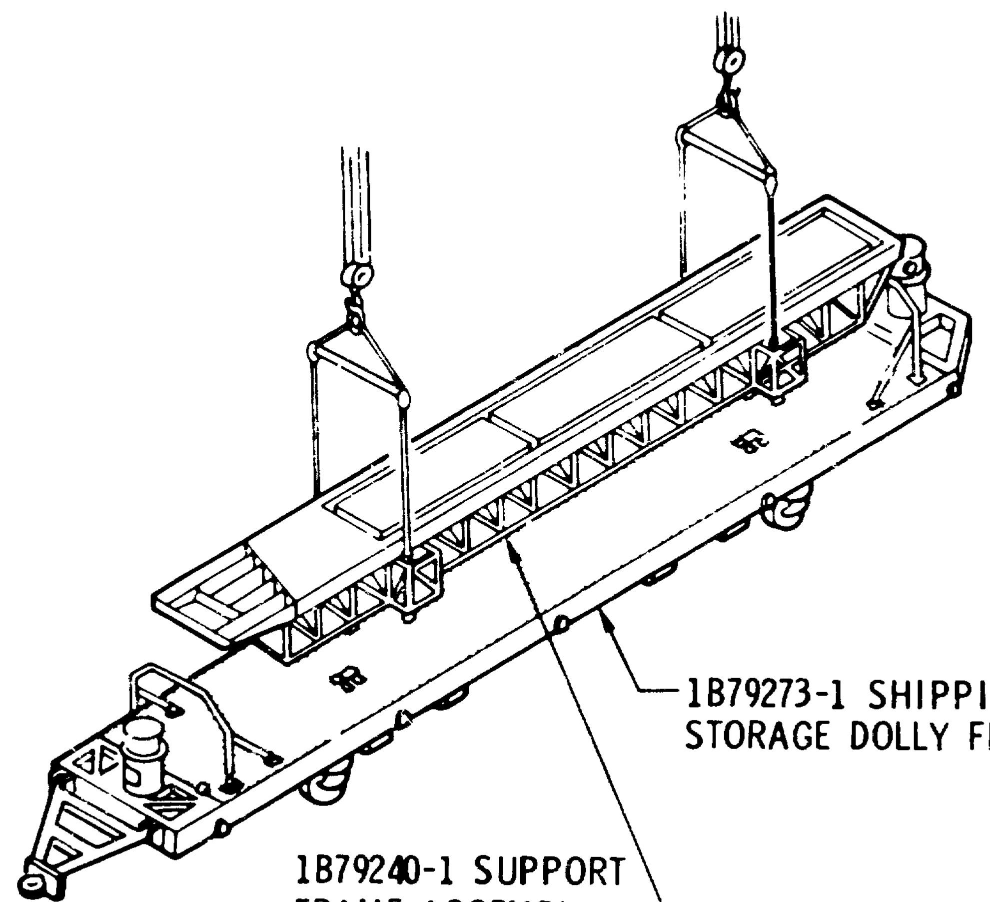


Figure 2.2.14.2-5

Douglas Astronautics Company at Huntington Leach to Cape Kennedy and return. The recorded data indicated that no excessive accelerations were experienced.

C. Testing

Fit and Functional tests only, were performed.

D. Conclusions and Recommendations

The SAS handling and transportation system operated satisfactorily. Safety factors were adequate. The use of existing state-of-the-art and proven techniques resulted in a time saving practical system.

Due to the speed of travel on highways, the desiccant container orifices were subjected to a high level of moisture from the air being delivered into the desiccant bed, therefore, lessening the capability of the desiccant to remove moisture from additional incoming air. This resulted in a reduction of the effectiveness of the desiccant bed.

It is recommended that a variable type orifice be used instead of a large fixed opening in future applications. The inflowing volume of air could be controlled, thus, adding to the effectiveness of the desiccant system.

2.2.14.3 Interstage Handling and Transportation Equipment

A. Design Requirements

This family of kits was designed to Factors of Safety shown in Table 2.2.14.3-1.

1/ Vertical Flared Aft Interstage Access Kit (DSV7-326)

The Vertical Flared Aft Interstage Access Kit (Drawing No. 1B78735) was to provide access for personnel to the interior of the aft section of the OWS and the flared aft interstage while the OWS is in a vertical position, to enable accomplishment of vehicle and equipment checkout, inspections and maintenance.

2/ Flared Aft Interstage Handling Kit (DSV-4B-307)

The function of this handling kit (Drawing No. 1A57867) was to provide a means of transporting for short distances and handling the aft interstage.

B. System Description

The Interstage Handling and Transportation System consisted of a modification of the ModelDSV-4B-311 Vertical Flared Aft Interstage Access Kit which in turn consisted of modular lightweight access platforms with extension platforms and upper level platforms (Figures 2.2.14.3-1, -2 and -3) and the Model DSV-4B-307 Flared Aft Interstage Handling Kit which consisted of a rigid base dolly assembly to which the aft interstage was attached, a hoist beam structure which was attached to the forward end of the aft interstage section on the dolly for lifting purposes and a neoprene coated nylon weather protection cover (Figure 2.2.14.3-4).

C. Testing

This system had been in use many years on the Saturn program and required no further testing.

TABLE 2.2.14.3-1

INTERSTAGE HANDLING AND TRANSPORTATION EQUIPMENT SAFETY FACTORS

OWS DSV7 KIT MODEL NUMBERS	ULTIMATE FACTOR OF SAFETY	YIELD FACTOR OF SAFETY	LIMIT LOAD FACTORS(*): HOISTING/GROUND TRANSPORT LONG.	LAT.	VERT.	LIMIT LOAD FACTORS: SUDDEN MANLOADS LONG.	LAT.	VERT.	ULTIMATE HOIST LOAD	ULTIMATE MANLOAD [MAN WEIGHT = 250 LBS (113.4 kg)]
-326	1.5	1.0				0	0	-2.0		Man wt. x 2.0 L.F. x 1.5 U.F.S. = Man weight x 3.0
DSV-IVB -307	1.5	1.0	(a) Hoisting							
			0.0	0.0	-3.0					
			(b) Ground Transportation Condition (1)							
			±0.75	± .05	-2.0					
			Condition (2)							
			0.0	±0.5	-2.0					
			Condition (3)							
			±1.0	±0.5	-2.0					

Condition (1): Road bumps and irregularities)
Condition (2): Turning) Includes 45 knot wind
Condition (3): Quick stops and starts) in any direction.

*(+) Sign indicates aft, port and up
(-) Sign indicates forward, starboard and down

SKYLAB - ORBITAL WORKSHOP
PLAN VIEW OF FLARED AFT
INTERSTAGE ACCESS KIT MODEL DSV-7-326

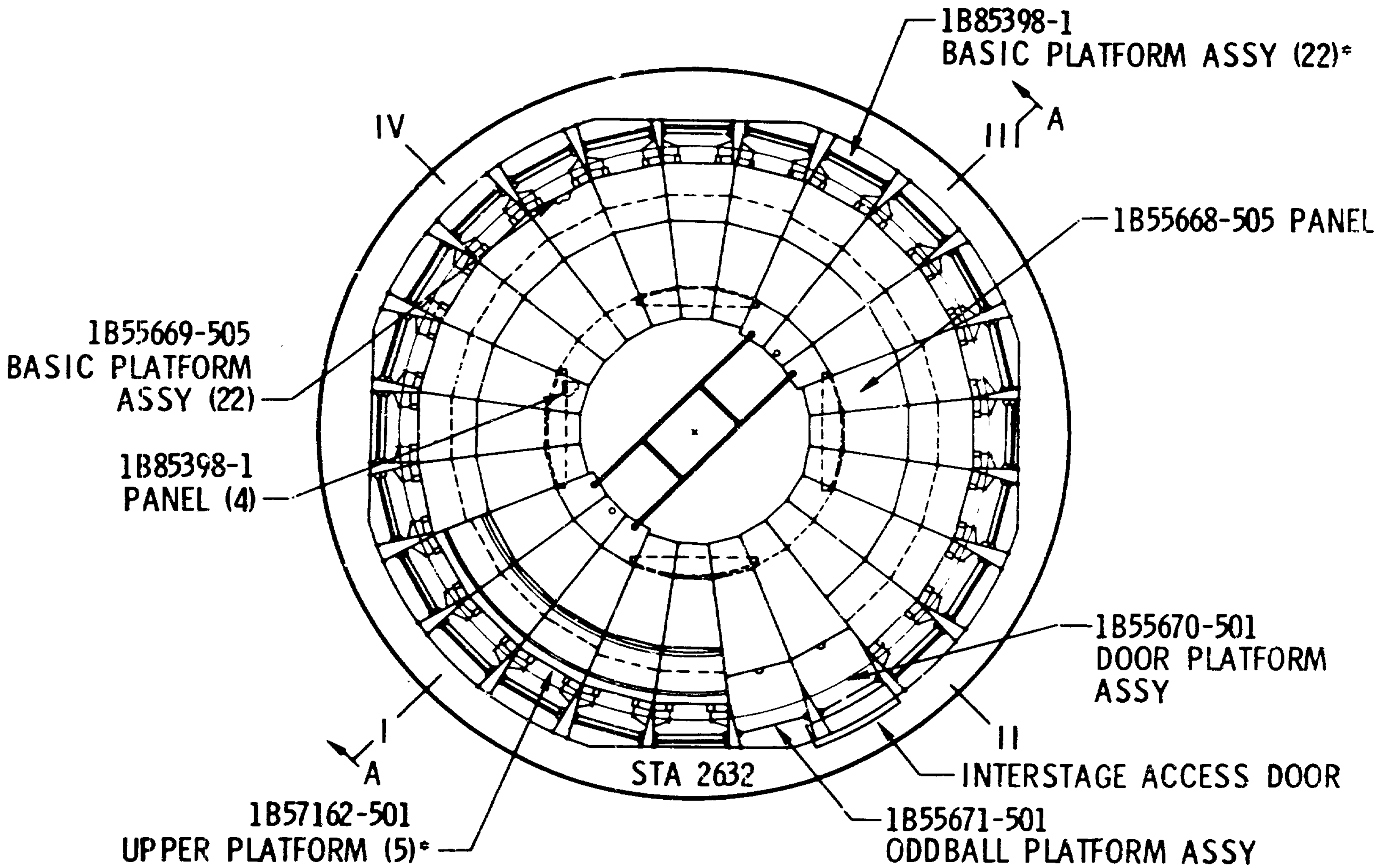


Figure 2.2.14.3-1

SKYLAB - ORBITAL WORKSHOP
MODEL DSV-7-326
FLARED AFT INTERSTAGE ACCESS KIT

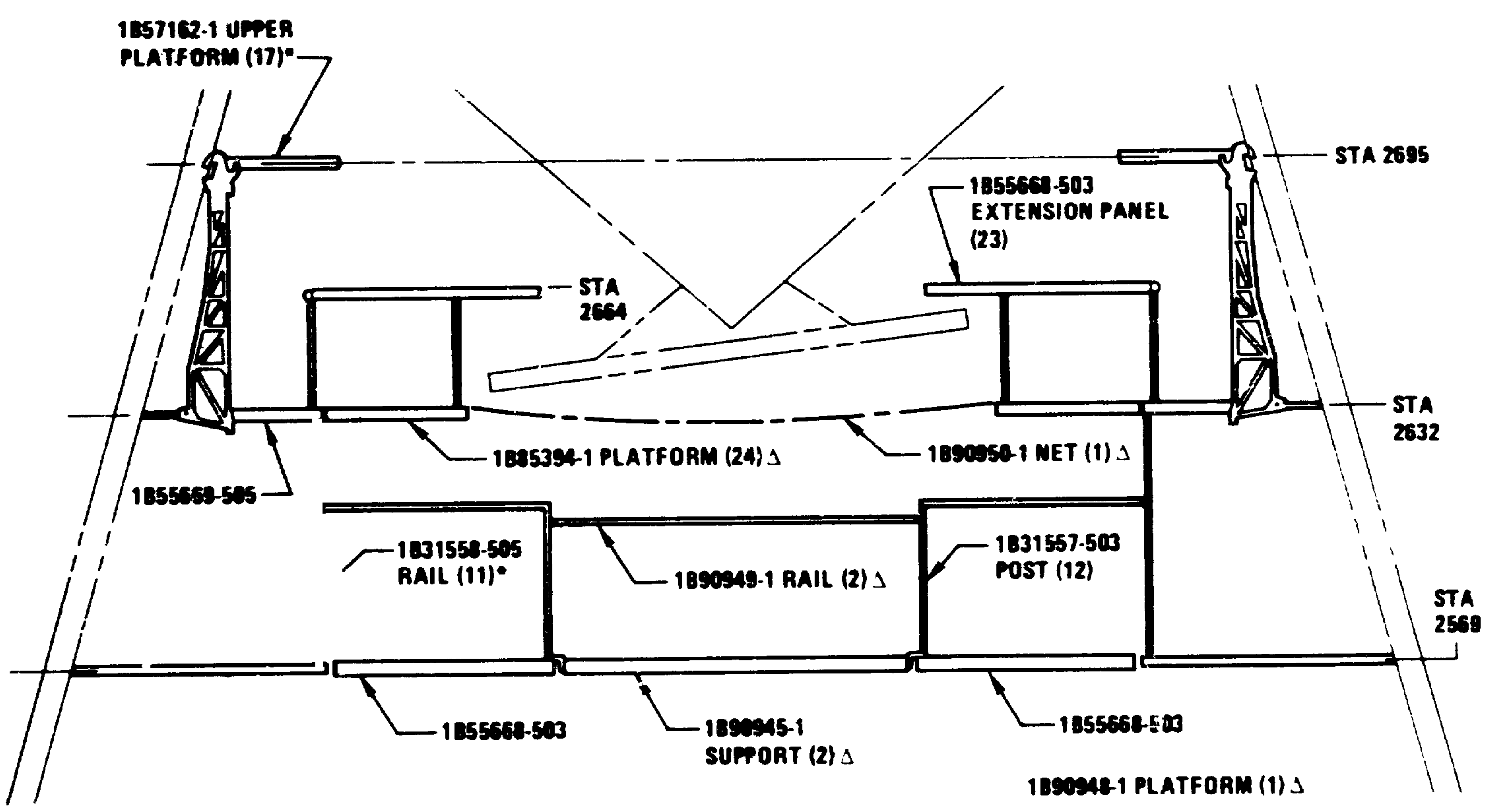


Figure 2.2.14.3-2

SKYLAB - ORBITAL WORKSHOP
MODEL DSV-7-326
BASIC PLATFORM ASSEMBLY

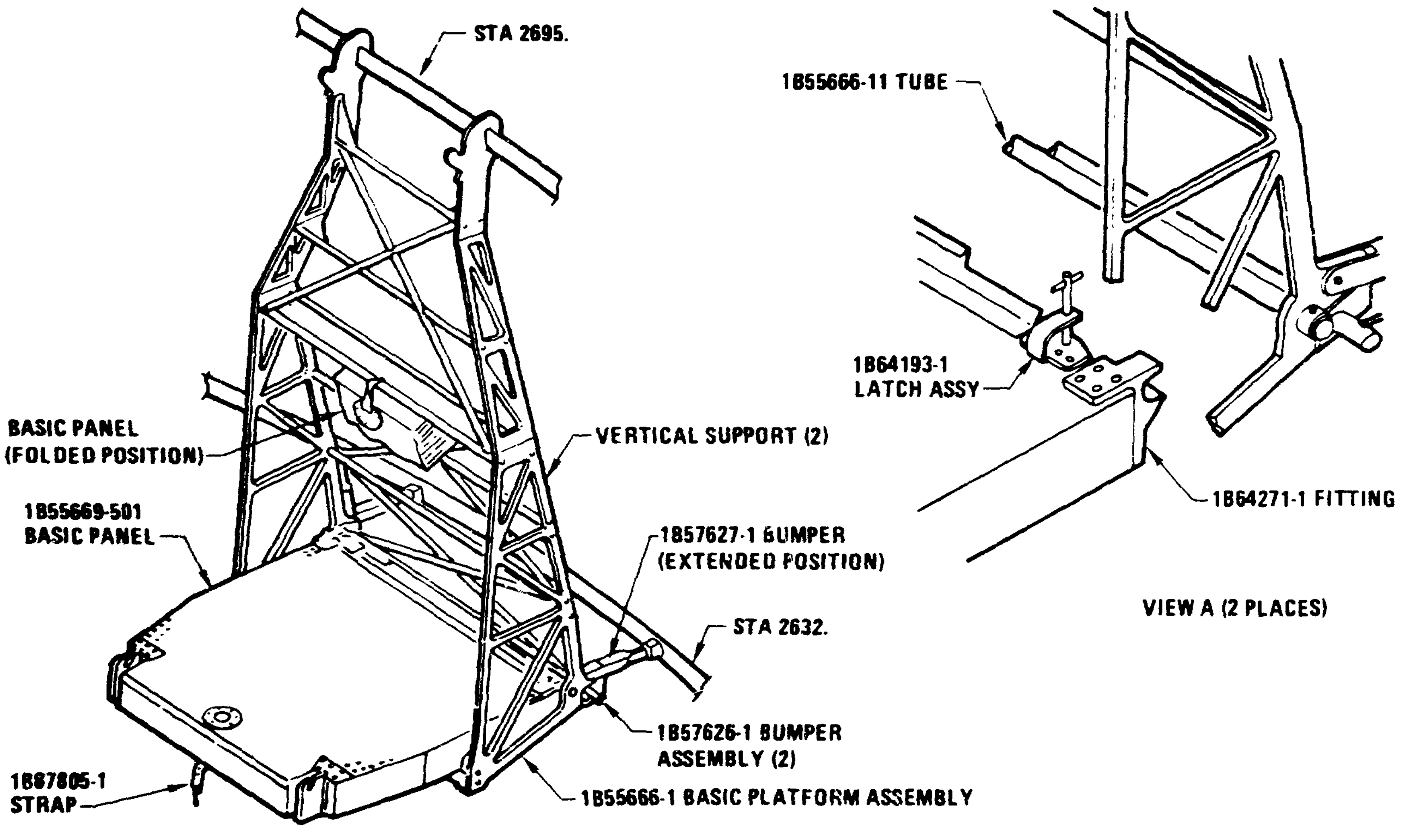


Figure 2.2.14.3-3

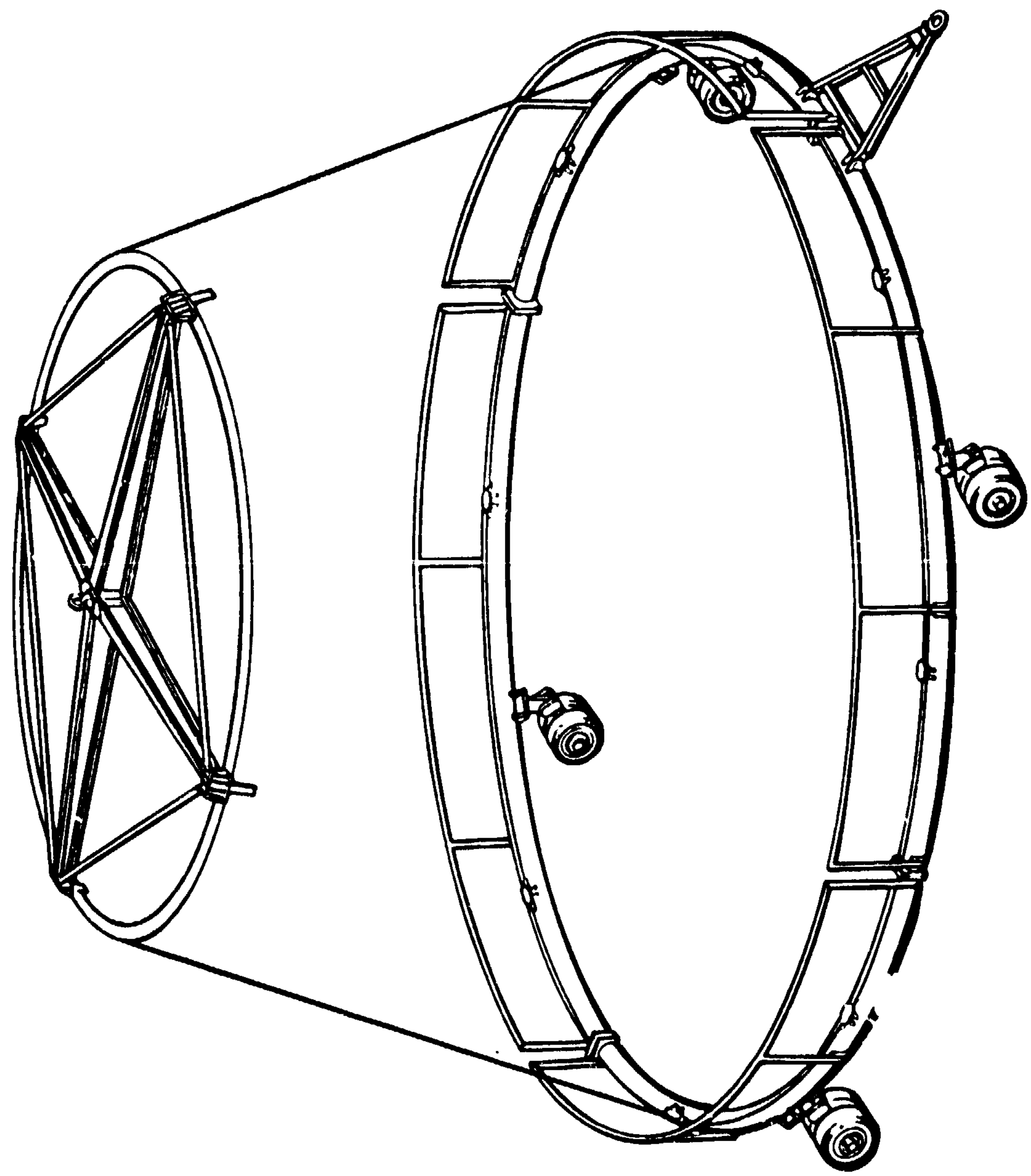


Figure 2.2.14.3-4. Handling Kit Flared Aft Interstage (DSV-4B-307)

D. Conclusions and Recommendations

The OWS Interstage Handling and Transportation System functioned as planned. There were no breakdowns or failures. Safety factors were adequate. The use of existing state-of-the-art designs resulted in a time saving practical system.

The actual load of the flared aft interstage on the dolly was large enough that the tire size was somewhat marginal. Tire size could not be increased due to overhead clearance restrictions on the AKS PT. Barrow. This resulted in a grooving of the tires under the load. It would be recommended that if a new dolly was designed for the OWS or future systems, in lieu of utilizing existing equipment, larger tires be used along with low slung axles to provide proper load carrying capability and minimum overall height.

2.2.14.4 Experiment Handling Equipment

A. Design Requirements

This family of kits was designed to factors of safety shown in Table 2.2.14.4-1.

The general philosophy of designing experiment handling euqipment was to minimize the danger of damage to expensive one-of-a-kind experiments by reducing the degree of human error inherent in the individual experiments from the receiving-inspection point to final installation in the OWS. Because of the extensive checkout and inspection requirements for these critical items, their relatively high weights (in excess of 40 lbs (18.14 kg)) and their fragile nature demanded handling by mechanical means rather than by hand. Psychologically, the use of mechanical handling equipment helped to impress the technicians with the fragility of the experiments.

The design requirements of the individual experiment handling equipment is as follows:

1/ Experiment M074 Specimen Mass Measurement Handling and Installation Kit (DSV7-345).

This kit was to provide a means to manually lift, position, install and remove the specimen Mass Measurement Experiment M074 in its OWS location and also was to provide a means of securing the experiment to the Model DSV7-311 handling dolly.

2/ Experiment M092 Inflight Lower Body Negative Pressure Handling and Installation Kit (DSV7-346).

This kit was to provide a means of mechanically lifting, positioning, installing and removing the lower body negative pressure device.

TABLE 2.2.14.4-1

EXPERIMENT HANDLING EQUIPMENT

OWS DSV7 KIT MODEL NUMBERS	ULTIMATE FACTOR OF SAFETY	YIELD FACTOR OF SAFETY	LIMIT LOAD FACTORS (*): HOISTING/GROUND TRANSPORT LONG.	LAT.	VERT.	LIMIT LOAD FACTORS SUDDEN MANLOADS LONG.	LAT.	VERT.	ULTIMATE HOIST LOAD	ULTIMATE MANLOAD [MAN WEIGHT =250 LBS (113.4kg)]
-345	1.5	1.0	0.0	0.0	-3.0				Wt. of Exp.M074 x 3.0 x 1.5 = 31 x 3.0 x 1.5 = 139.5 lbs.	
-346	1.5	1.0	(a) Hoisting 0	 0	 -3.00				Wt. of Exp.M092 x 3.00 L.F. x 1.5 ult. F.S. = 4.5 x weight	
			(b) Dolly Transport ±2.00	 ±1.00	 -3.00					
-347	1.5	1.0	0	0	-3.00				Wt. of Exp.M093 x 3.00 L.F. x 1.5 Ult. F.S. = 4.5 x Weight	
-348	1.5	1.0	0	0	-3.0				Wt. of Exp.M131 x 3.00 L.F. x 1.5 Ult. F.S. = 4.5 x Weight	
-349	1.5	1.0	0	0	-3.0				Wt. of Exp.M171 x 3.00 L.F. x 1.5 Ult. F.S. = 4.5 x Weight	
-351	1.5	1.0	0	0	-3.00				Wt. of Exp.M172 x 3.00 L.F. x 1.5 Ult. F.S. = 4.5 x Weight	
-352	1.5	1.0	0	0	-3.00				Wt. of Exp.M509 x 3.00 L.F. x 1.5 Ult. F.S. = 4.5 Weight	
-353	1.5	1.0	0	0	-3.00				Wt. of Exp.S019 UV x 3.00 L.F. x 1.5 Ult. F.S. = 4.5 x Weight	
-355	1.5	1.0	0	0	-3.00				Wt. of Exp.S063 x 3.00 L.F. x 1.5 Ult. F.S. = 4.5 x Weight	
-357	1.5	1.0	0	0	-3.0				Wt. of Exp.S183 x 3.00 L.F. x 1.5 L.F. = 4.5 x Weight	
-359	1.5	1.0	0	0	-3.00				Wt. of Exp.T020 x 3.00 L.F. x 1.5 Ult. F.S. = 4.5 x Weight	

TABLE 2.2.14.4-1 (Continued)

EXPERIMENT HANDLING EQUIPMENT

OWS DSV7 KIT MODEL NUMBERS	ULTIMATE FACTOR OF SAFETY	YIELD FACTOR OF SAFETY	LIMIT LOAD FACTORS (*): HOISTING/GROUND TRANSPORT			LIMIT LOAD FACTORS SUDDEN MANLOADS			ULTIMATE HOIST LOAD	ULTIMATE MANLOAD [MAN WEIGHT = 250 LBS (113.4 kg)]
			LONG.	LAT.	VERT.	LONG.	LAT.	VERT.		
-360	1.5	1.0	0	0	-3.00				Wt. of Exp.T025 x 3.CO L.F. x 1.5 Ult. S.F. = 4.5 x Weight	
-361	1.5	1.0	0	0	-3.00				Wt. of Exp.T027 x 3.C L.F. x 1.5 Ult. F.S. = 4.5 x Weight	
-367	1.5	1.C	0	0	-3.0				Wt. of Exp. ETC x 3.C L.F. x 1.5 Ult. F.S. = 4.5 x Weight	
-372	1.5	1.0	0	0	-3.0				Wt. of Locker A9 x 3.0 L.F. x 1.5 Ult. F.S. = 4.5 x Weight	

*(+) Sign indicates aft, port and up
(-) Sign indicates forward, starboard and down

3/ Experiment M093 Bio-Med Containers Handling and Installation Kit (DSV7-347)

This kit was required to provide a means of mechanically lifting, positioning, installing, removing the two Bio-Med Containers Experiment M093 to their OWS locations and securing the containers to the DSV-311 Handling Kit.

4/ Experiment M131 Human Vestibular Function Handling and Installation Kit (DSV7-348)

This kit was designed to provide a means of mechanically lifting, positioning, installing and removing the rotating litter chair motor base, the control console and the equipment storage container components of Experiment M131.

5/ Experiment M171 Metabolic Activity Handling and Installation Kit (DSV7-349)

This kit was required to provide a means of mechanically lifting, positioning, installing and removing the Metabolic Analyzer and Ergometer of Experiment M171 and the ESS Console in its OWS location and also provided a means of securing them individually to the DSV7-311 handling dolly.

6/ Experiment M172 Body Mass Measurement Handling and Installation Kit (DSV7-351)

This kit was designed to provide a means of mechanically lifting, positioning, installing and removing Experiment M172 on the OWS and securing it to the DSV7-311 handling dolly and the vertical hoist.

7/ Experiment M509 Astronaut Maneuvering Unit Handling and Installation Kit (DSV7-352)

This kit was designed to provide a means of mechanically lifting, positioning, installing and removing the Flight Support Equipment, the Astronaut Maneuvering Unit (ASMU), the GN_2 bottle and regulator and the GN_2 bottle pallet components of Experiment M509. The kit was to be capable of lifting and positioning the ASMU on the GFP auxiliary support stand and of protecting the GN_2 bottles when they are secured to their pallet on the OWS floor.

8/ Experiment S019UV Stellar Astronomy Handling and Installation Kit (DSV7-353)

This kit was required to provide a means of mechanically lifting, positioning, installing and removing the Articulated Mirror System Container and Optics Stowage Container, the S020 Experiment Container and the S149 Experiment Container when they are mounted on their storage pallets in their OWS locations, and on the DSV7-311 handling dolly. It was also to provide a method of supporting the experiment components from the OWS floor attached to the Scientific Airlock (SAL) during one-g checkout and was to negate adverse loading of the SAL during checkout.

9/ Experiment S063 UV Airglow Horizon Photography Handling and Installation Kit (DSV7-355)

This kit was designed to provide a means of mechanically lifting, positioning, installing and removing the UV Airglow Horizon Photography Experiment S063 in its launch storage container in the OWS, securing the container to the DSV7-311 handling dolly and aligning the experiment in its proper position.

10/ Experiment S183 Ultraviolet Panorama Handling and Installation Kit (DSV7-357)

This kit was required to provide a means of mechanically lifting, positioning, installing and removing the spectograph assembly and Experiment S183 equipment from the launch storage pallet to its OWS location and to secure it to the DSV7-311 handling dolly. The kit also was to provide a means of supporting the spectograph assembly and film carousel from the floor when attached to the S019 mirror system.

11/ Experiment T020 Foot Control Maneuvering Device Handling and Installation Kit (DSV7-359)

This kit was designed to provide a means of mechanically lifting, positioning, installing and removing the Foot Control Maneuvering Device in the OWS and securing the experiment to the DSV7-311 vertical hoist and handling dolly.

12/ Experiment T025 Coronograph Contamination Measurements Handling and Installation Kit (DSV7-360)

This kit was required to provide a means of mechanically lifting, positioning, installing and removing the coronograph contamination measurements Experiment T025 in its launch storage container to its OWS location and securing the container to the DSV7-311 handling dolly.

13/ Experiment T027 ATM Contamination Measurement Handling and Installation Kit (DSV7-361)

This kit was designed to provide a means of mechanically lifting, positioning, installing and removing the Photometer and the

Sample Array System in their launch storage containers and securing the storage containers to the DSV7-311 handling dolly. The kit was also to provide support for the photometer head and sample array during one-g deployment testing and was to provide support for the photometer head during checkout when it was deployed on top of its container.

14/ Experiment S190B Earth Terrain Camera (ETC) Handling and Installation Kit (DSV7-367)

This kit was required to provide a means of mechanically lifting, positioning, installing and removing the ETC stowage container and the inverter in the OWS and supporting the ETC during 1-g checkout in the OWS.

15/ A9 Container Handling and Installation Kit (DSV7-372)

This kit was designed to provide a means of mechanically lifting, positioning, installing and removing the A9 container to and from its location in the OWS.

P. System Description

This system consisted of a family of handling and installation kits composed of aluminum and steel handles, fittings, adaptor frames, supports, pins, slings, cables, plates, wheels, spreader bars, stands, protective cages and cases, targets, plastic protective covers, extension mechanism support fixtures, deployment rails, counter weights, lens caps, beams, clamps, and attaching bolts, screws, nuts and washers. There was an existing requirement to remove the experiments from the OWS individually if any failed during checkout testing. Brief descriptions of the family of kits are as follows:

1/ Experiment M074 Specimen Mass Measurement Handling and Installation Kit (DSV7-345)

This kit (Drawing No. 1B88982) consisted of a removable aluminum frame which attached to the experiment base plate. Aluminum bronze guide pins for OWS positioning of the experiment were provided (Figures 2.2.14.4-1 and -2).

2/ Experiment M092 Inflight Lower Body Negative Pressure Handling and Installation Kit (DSV7-346)

This kit (Drawing No. 1B88984) consisted of aluminum adaptor fittings and stainless steel support cables to utilize the Installation Support Fixture from the DSV7-349 Handling and Installation Kit, tie-down fittings to attach to the DSV7-311 handling dolly and a semi-circular aluminum upper torso support structure for use during the one-g checkout (Figures 2.2.14.4-3, -4, and -5).

3/ Experiment MO[illegible] [illegible]o-Med Containers Handling and Installation Kit (DSV7-347)

This kit (Drawing No. 1B88986) consisted of aluminum adapter frames to utilize the DSV7-349 Installation/Support fixture from the DSV7-349 H[illegible]ing and Installation Kit and quick release pins to secure the frames to the DSV7-311 handling dolly (Figures to 2.2.14.4-6 and -7).

SKYLAB - ORBITAL WORKSHOP
SMMD HANDLING FIXTURE
MODEL DSV 7-345

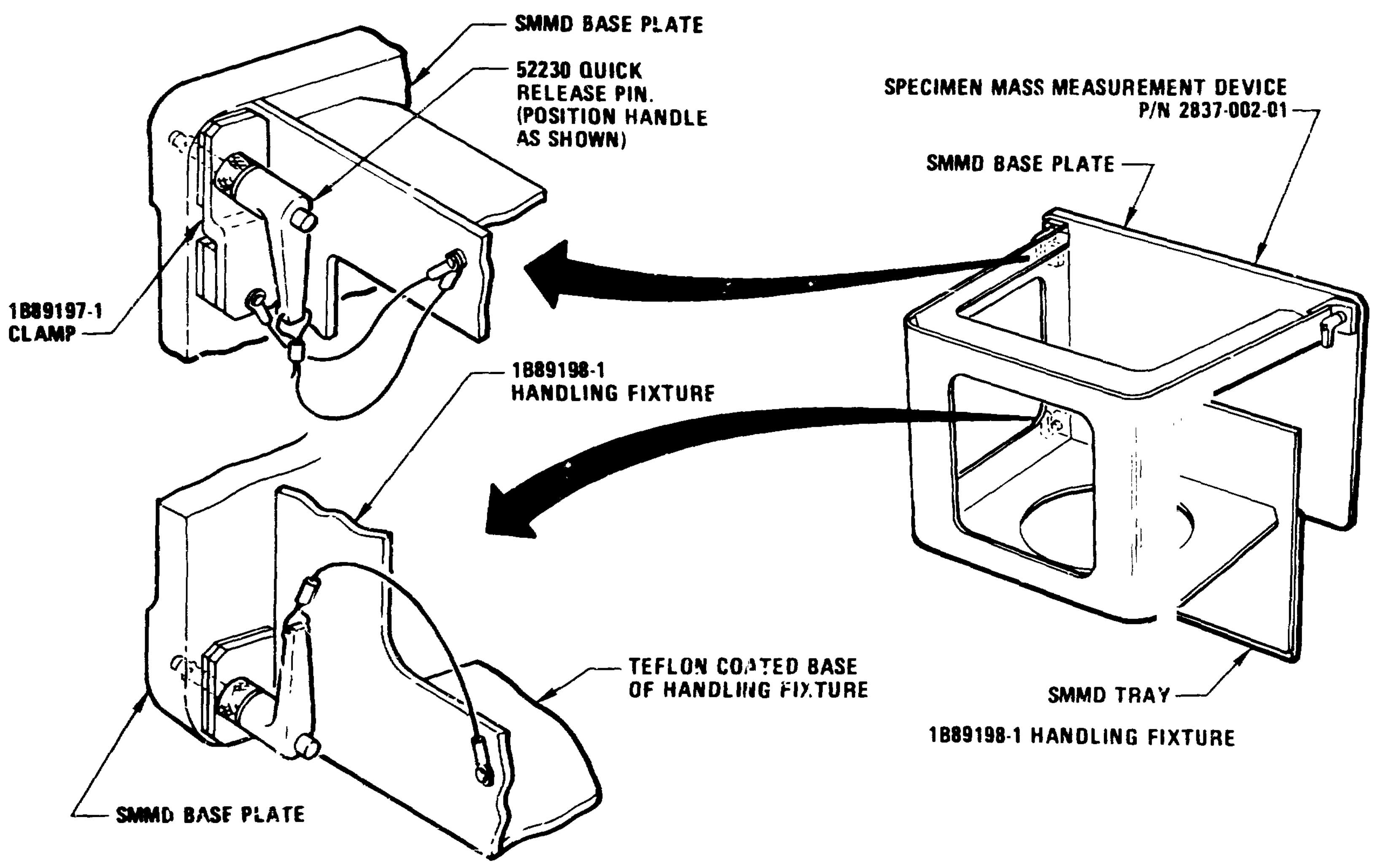


Figure 2.2.14.4-1

SKYLAB - ORBITAL WORKSHOP
MODEL DSV 7-345

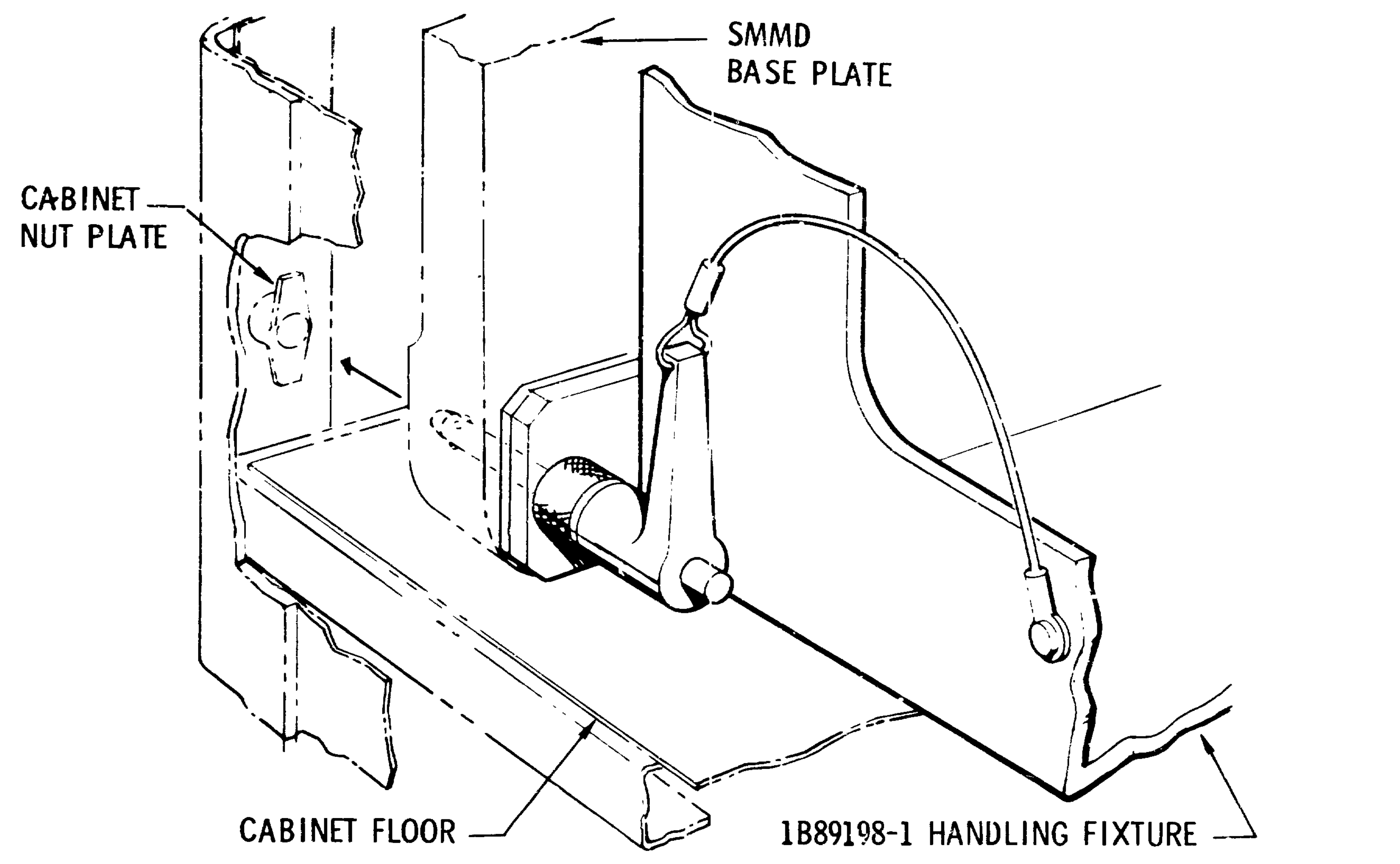


Figure 2.2.14.4-2

SKYLAB - ORBITAL WORKSHOP
MODEL DSV7-346
LBNPD IN SHIPPING CONTAINER

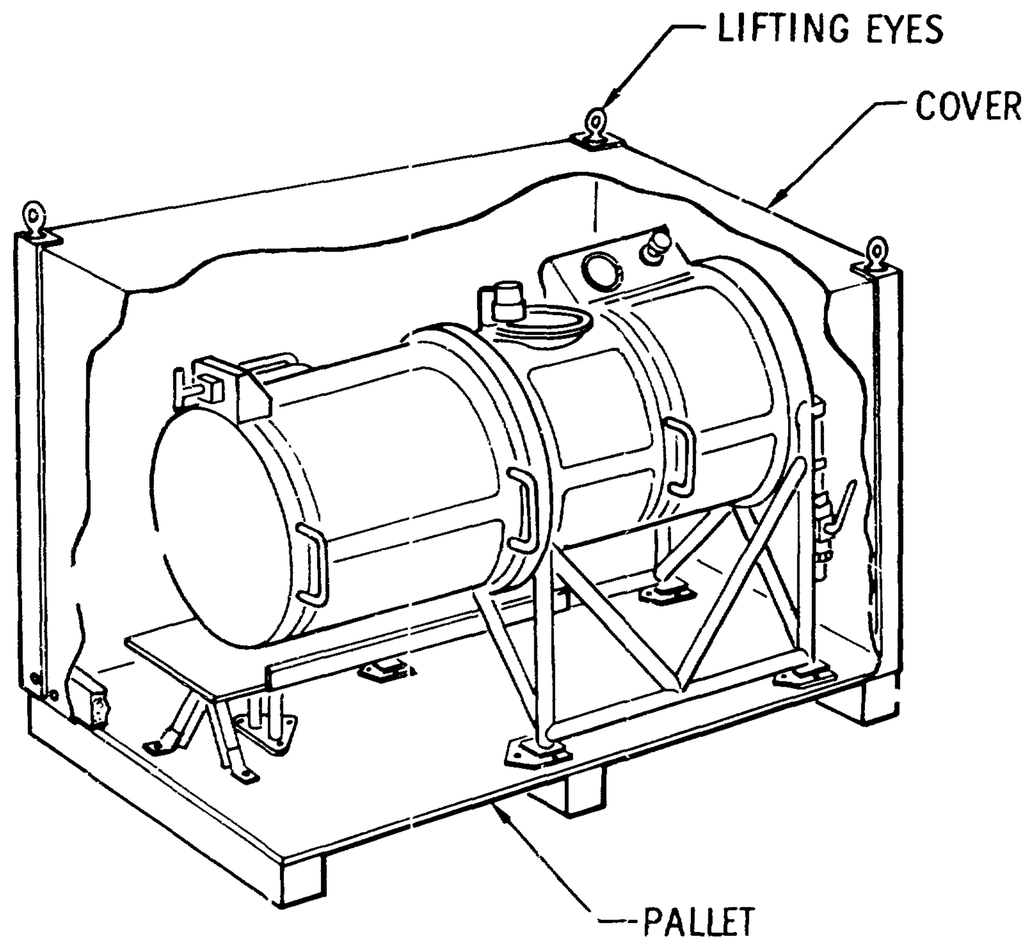


Figure 2.2.14.4-3

SKYLAB - ORBITAL WORKSHOP
LBNPD WITH HOISTING ADAPTER INSTALLED
MODEL DSV7-346

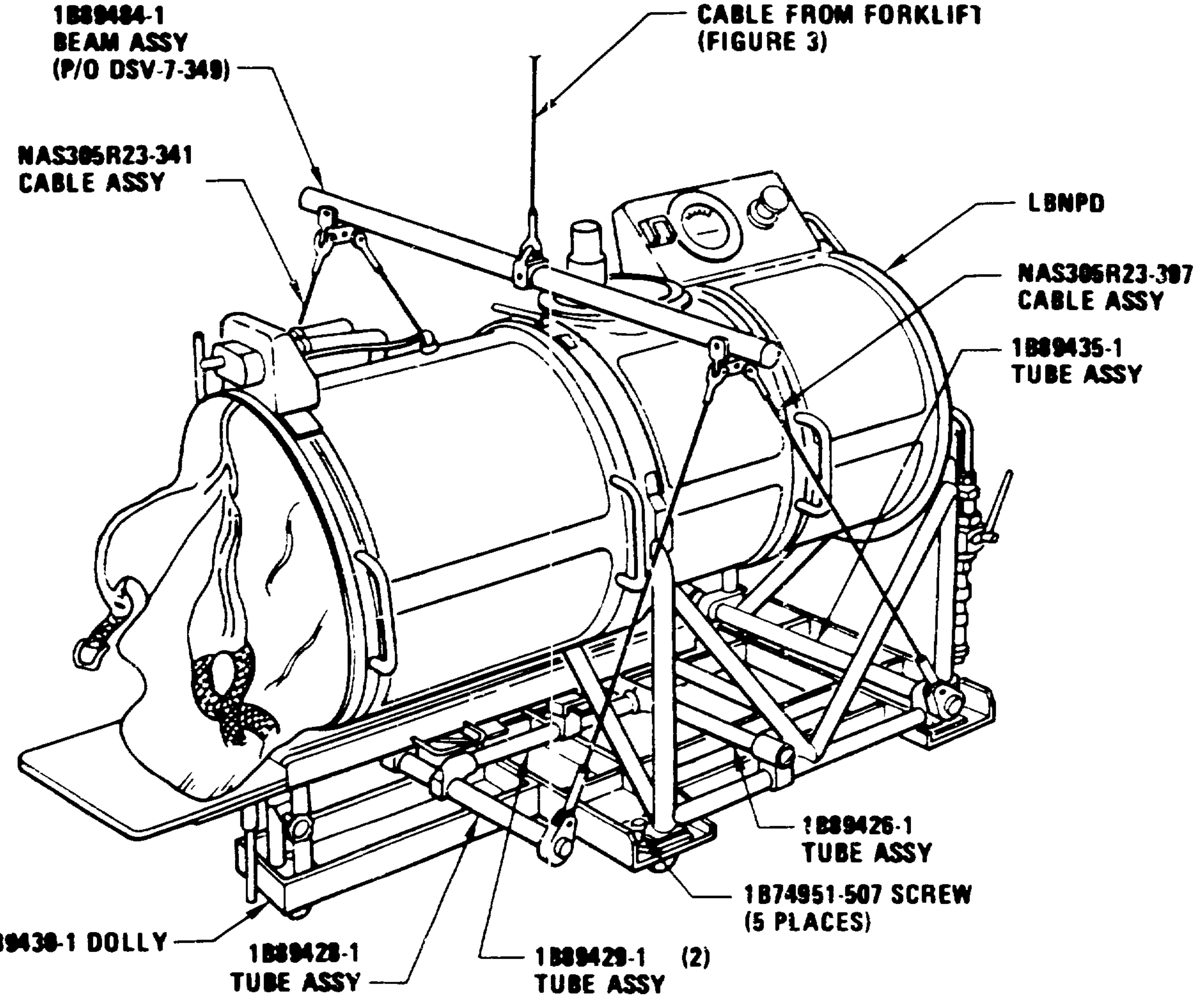


Figure 2.2.14.4-4

SKYLAB - ORBITAL WORKSHOP
FORK LIFT (P/O MODEL DSV-7-349)

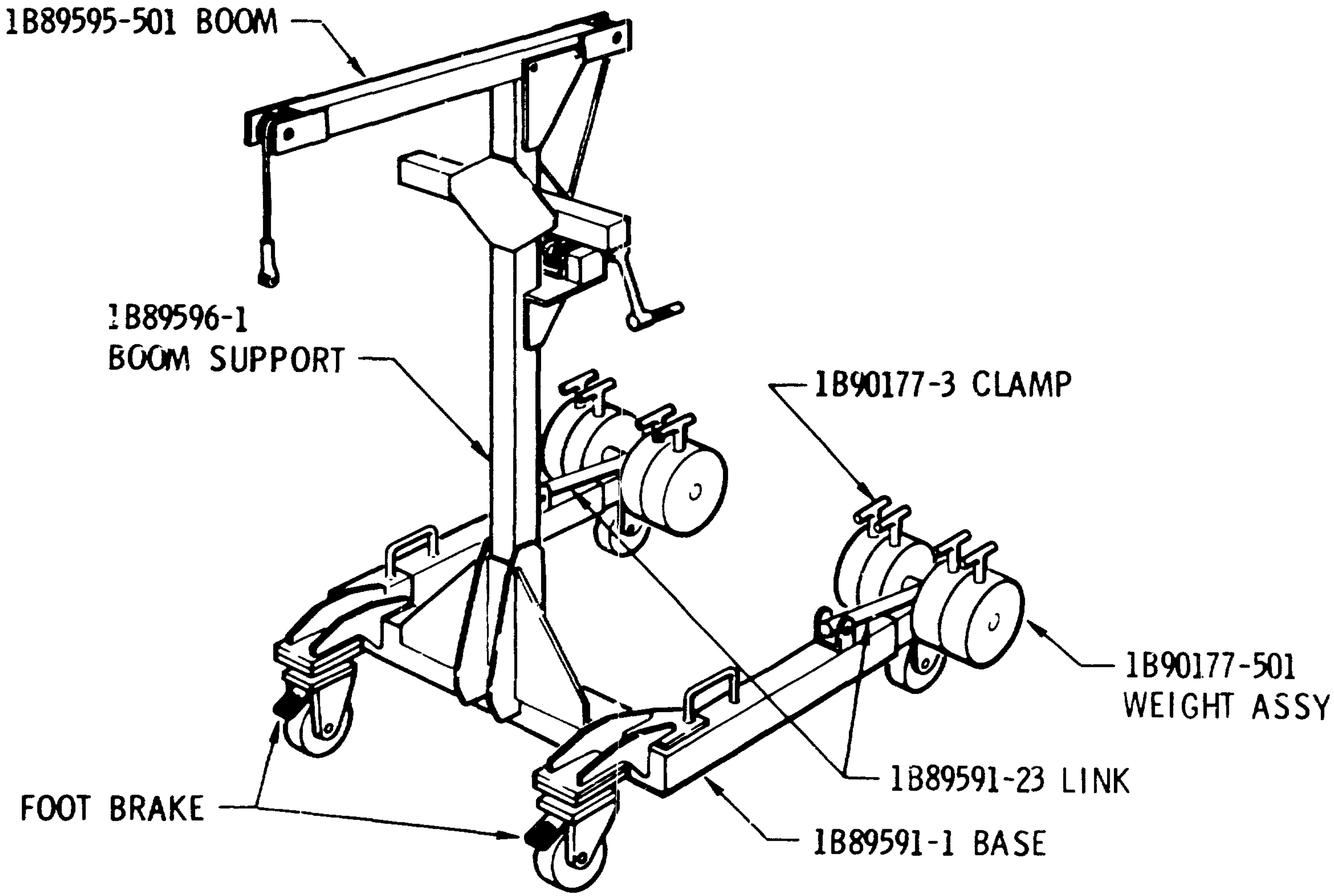


Figure 2.2.14.4-5

SKYLAB - ORBITAL WORKSHOP
MODEL DSV-7-347
HANDLING AND INSTALLATION KIT

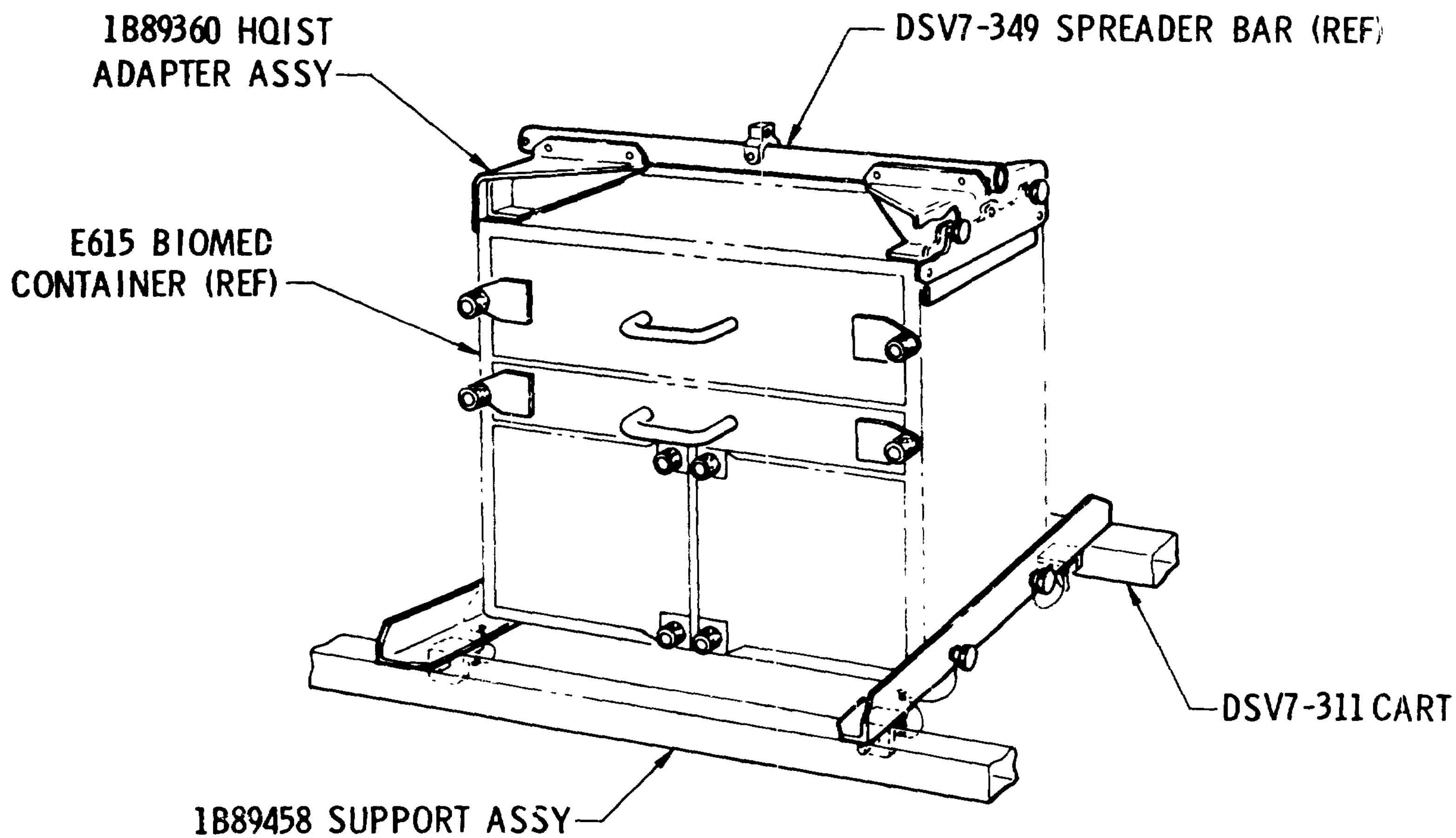


Figure 2.2.14.4-6

SKYLAB - ORBITAL WORKSHOP
MODEL DSV-7-347
HANDLING AND INSTALLATION KIT

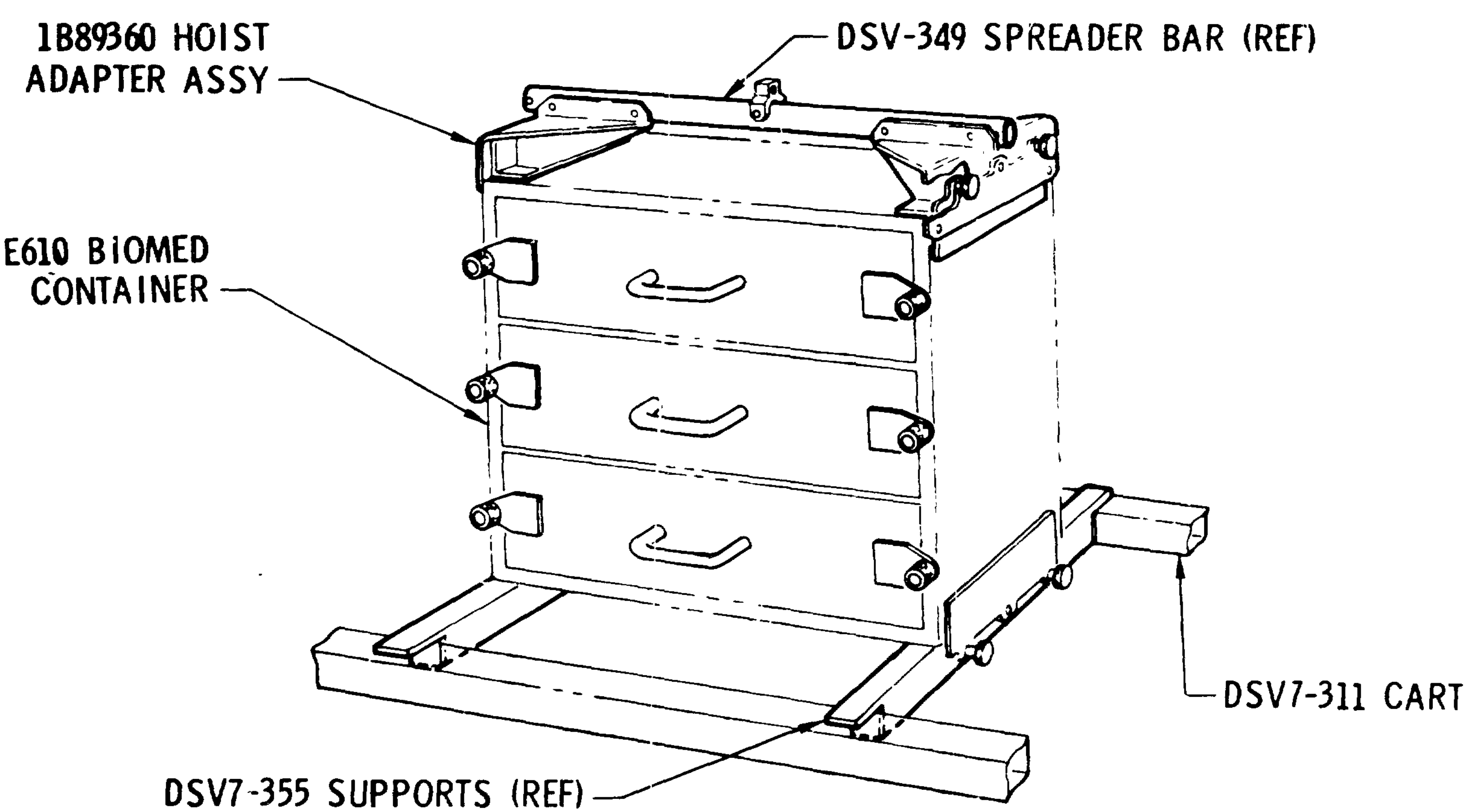


Figure 2.2.14.4-7

4/ Experiment M131 Human Vestibular Function Handling and Installation Kit (DSV7-348)

This kit (Drawing No. 1B88988) consisted of aluminum adapter fittings used in conjunction with the Installation/Support fixture of the DSV7-349 Handling and Installation Kit, aluminum tie-down fittings to attach the experiment components to the DSV7-311 handling dolly and the DSV7-362 Kit padded hoist sling (Figures 2.2.14.4-8, -9, -10 and -11).

5/ Experiment M171 Metabolic Activity Handling and Installation Kit (DSV7-349)

This kit (Drawing No. 1B88990) consisted of an aluminum and steel fixture with full castering lockable wheels with aluminum hold-down fittings, stainless steel cables, an aluminum spreader bar and adapter fittings, floor plates and hoist adapter frames (Figures 2.2.14.4-12, -13, -14 and -15).

6/ Experiment M172 Body Mass Measurement, Handling and Installation Kit (DSV7-351)

This kit (Drawing No. 1B88992) consisted of an aluminum base plate, steel hoist cables, an aluminum spreader bar and aluminum adapter fittings (Figures 2.2.14.4-16 and -17).

7/ Experiment M509 Astronaut Maneuvering Unit (ASMU) Handling and Installation Kit (DSV7-352)

This kit (Drawing No. 1B88994) consisted of an aluminum ASMU adapter, handling fixtures, GN_2 bottle protective case and cage, adapter fittings, spreader bar and donning station supports and support assembly. Hoist cables were of stainless steel. (Figures 2.2.14.4-18, -19, -20, -21, -22, -23 and -24).

SKYLAB - ORBITAL WORKSHOP
CONTROL CONSOLE IN HANDLING FIXTURE
MODEL DSV7-348

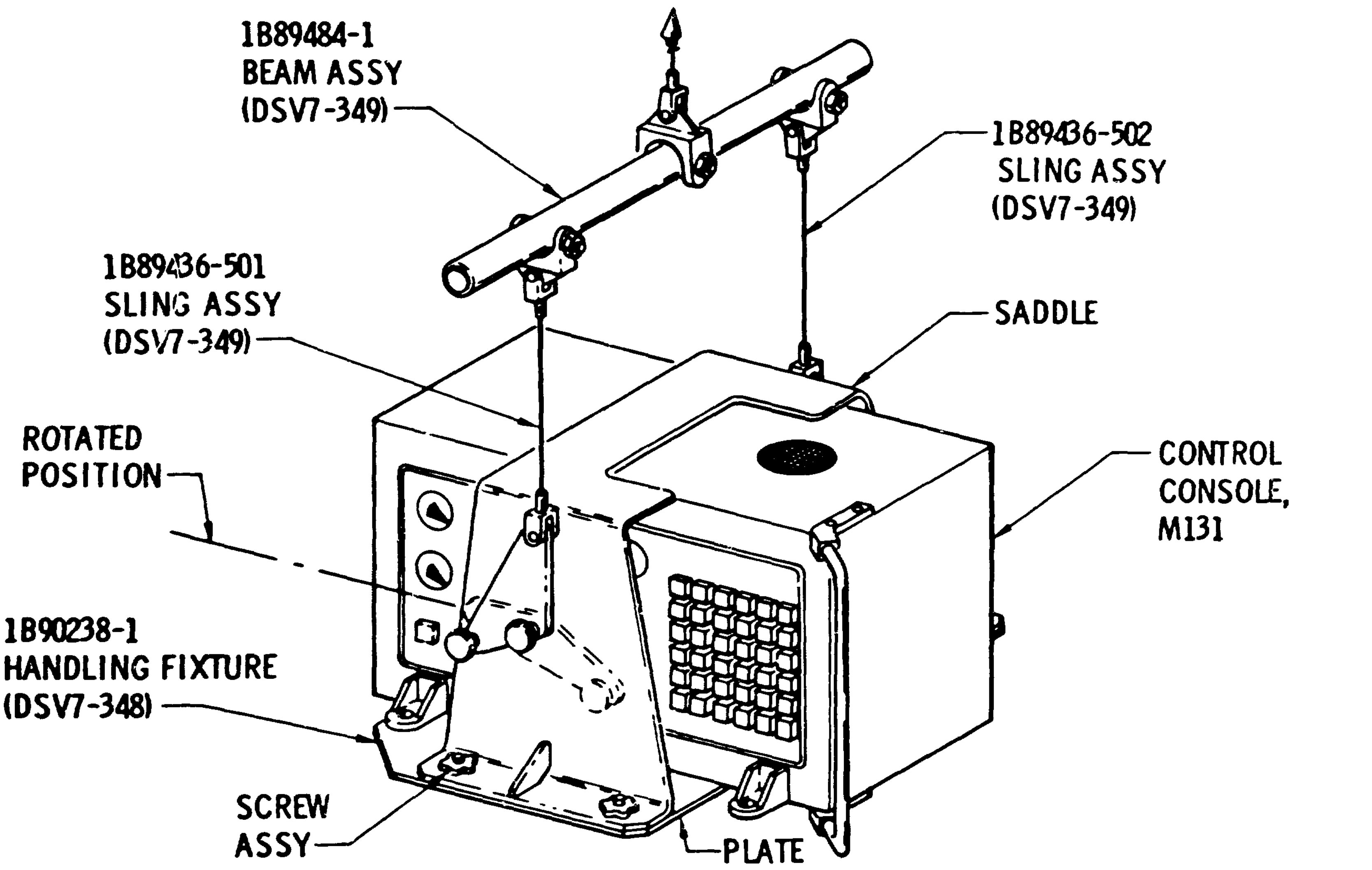


Figure 2.2.14.4-8

SKYLAB - ORBITAL WORKSHOP
CONTROL CONSOLE ON EQUIPMENT HANDLING CART
MODEL DSV7-348

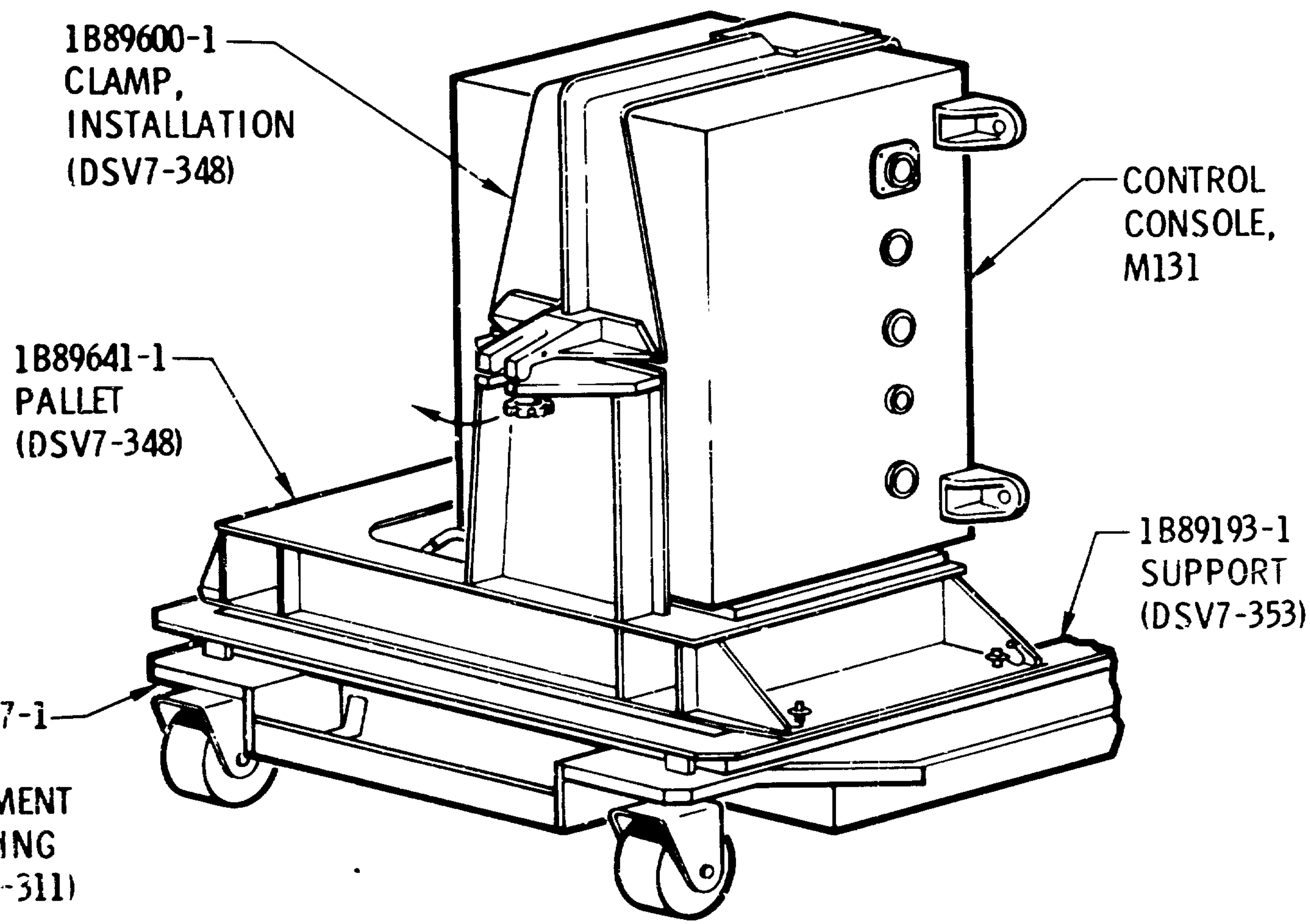


Figure 2.2.14.4-9

SKYLAB - ORBITAL WORKSHOP
INSTALLATION OF CONTROL CONSOLE M131
MODEL DSV7-348

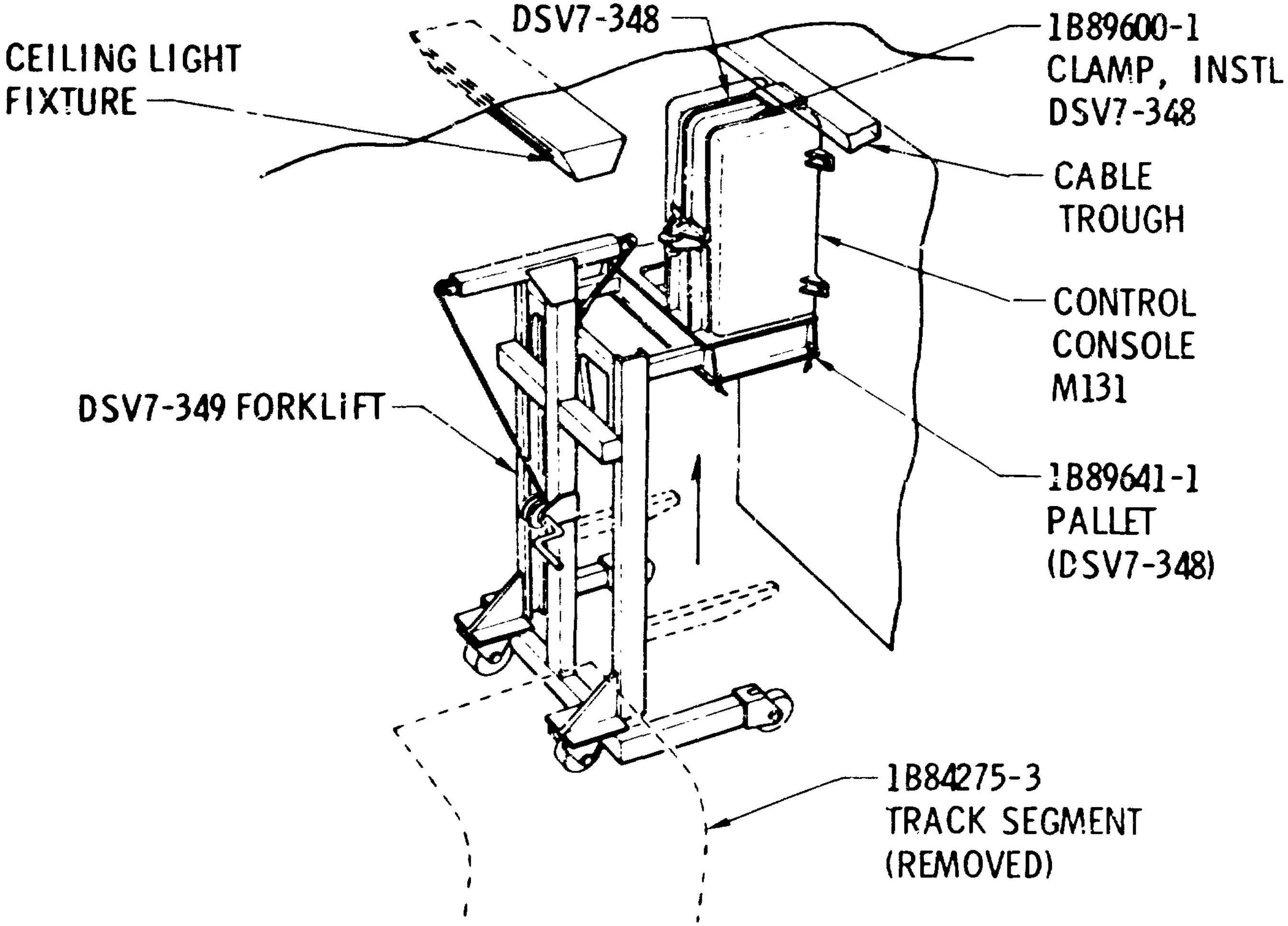


Figure 2.2.14.4-10

SKYLAB - ORBITAL WORKSHOP
MOTOR BASE HANDLING GSE
MODEL DSV7-348

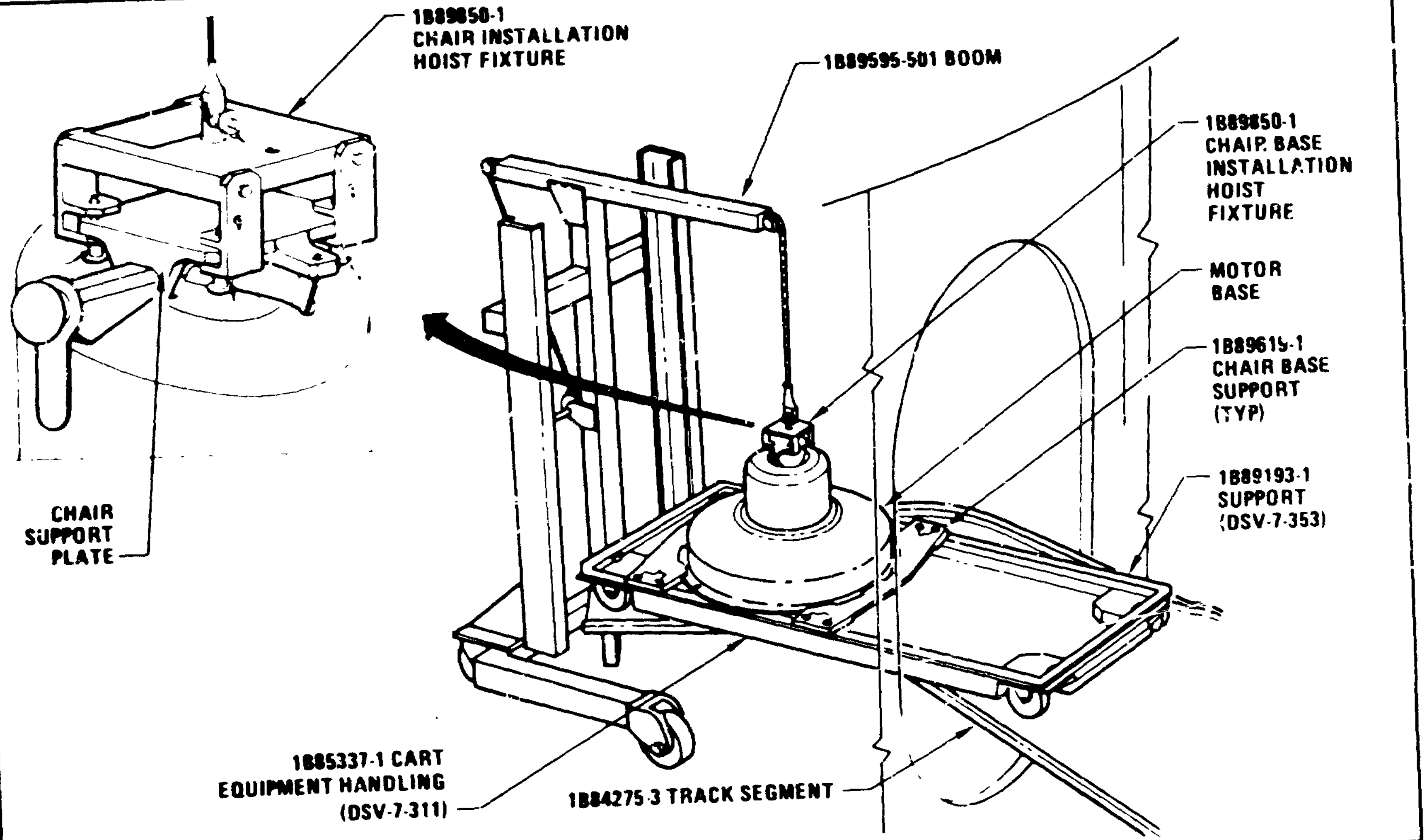


Figure 2.2.14.4-11

SKYLAB - ORBITAL WORKSHOP

MODEL DSV7-349 FORK LIFT - CONFIGURATION A

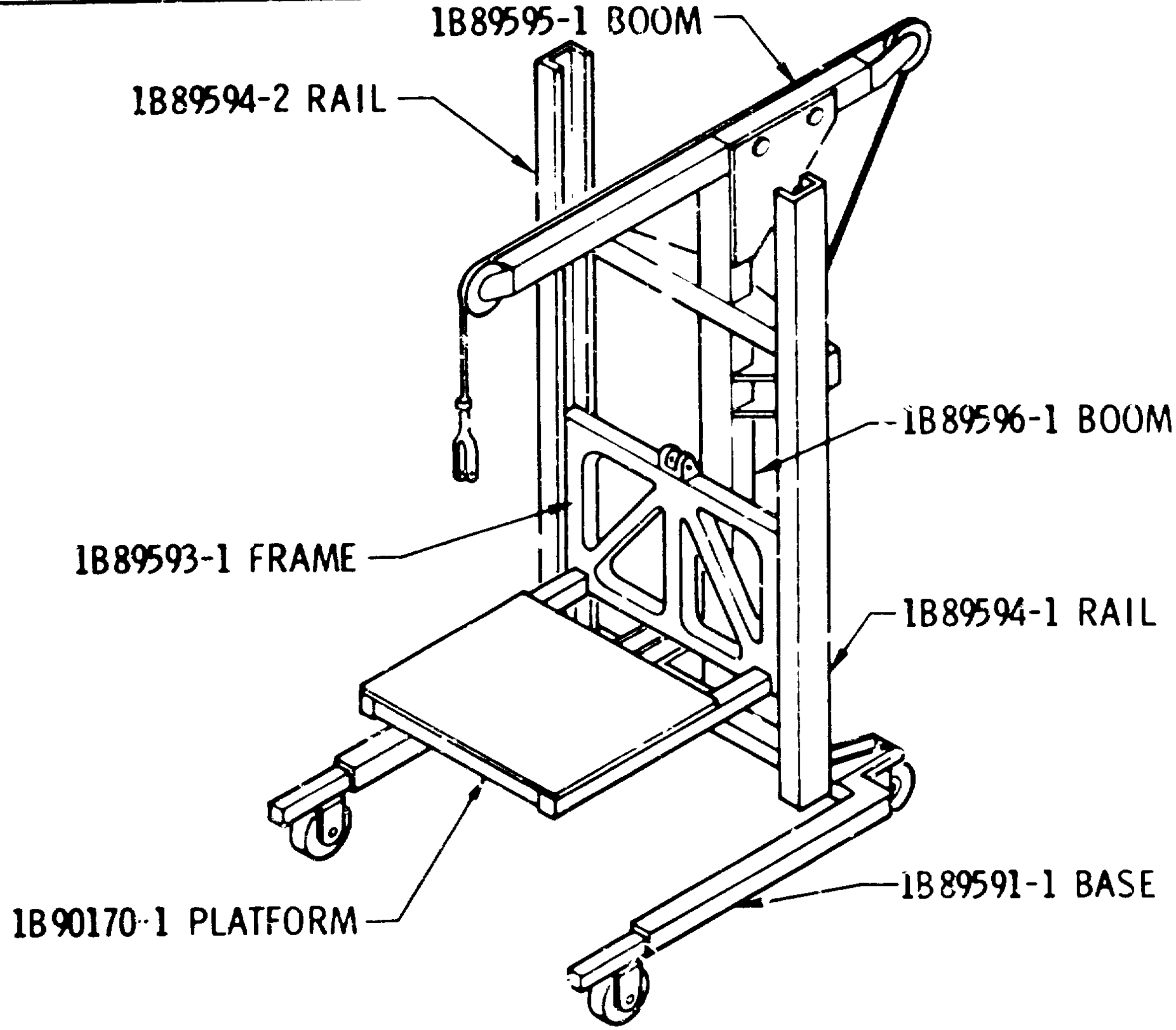


Figure 2.2.14.4-12

SKYLAB - ORBITAL WORKSHOP
MODEL DSV7-349 FORK LIFT - CONFIGURATION B

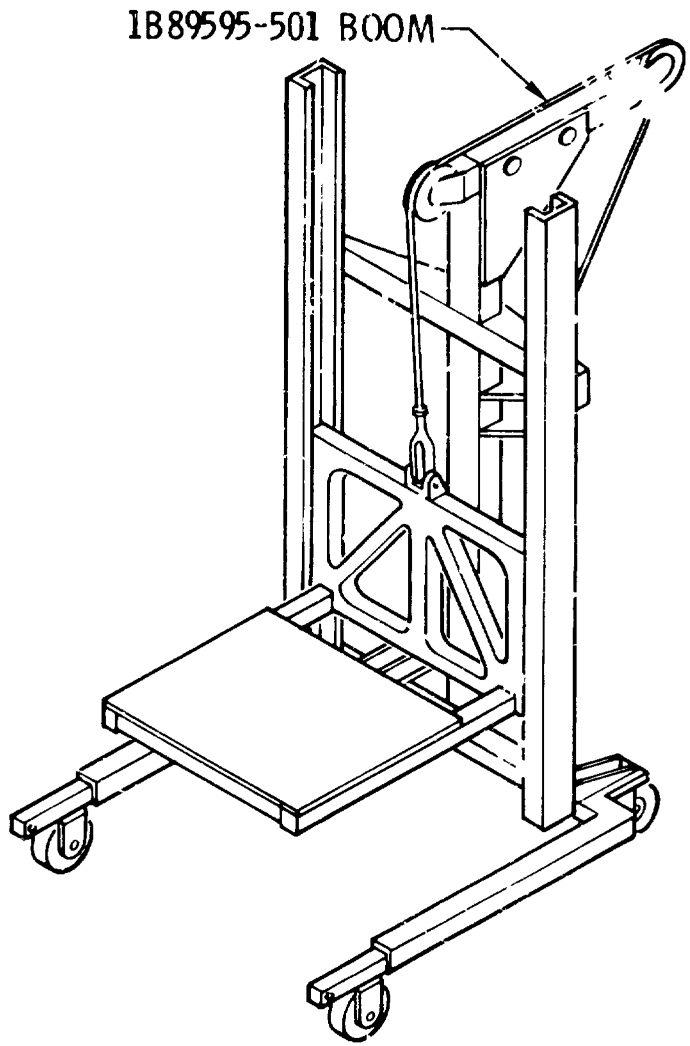


Figure 2.2.14.4-13

SKYLAB - ORBITAL WORKSHOP
MODEL DSV7-349 HOISTING GSE FOR ESS CONSOLE AND METABOLIC ANALYZER

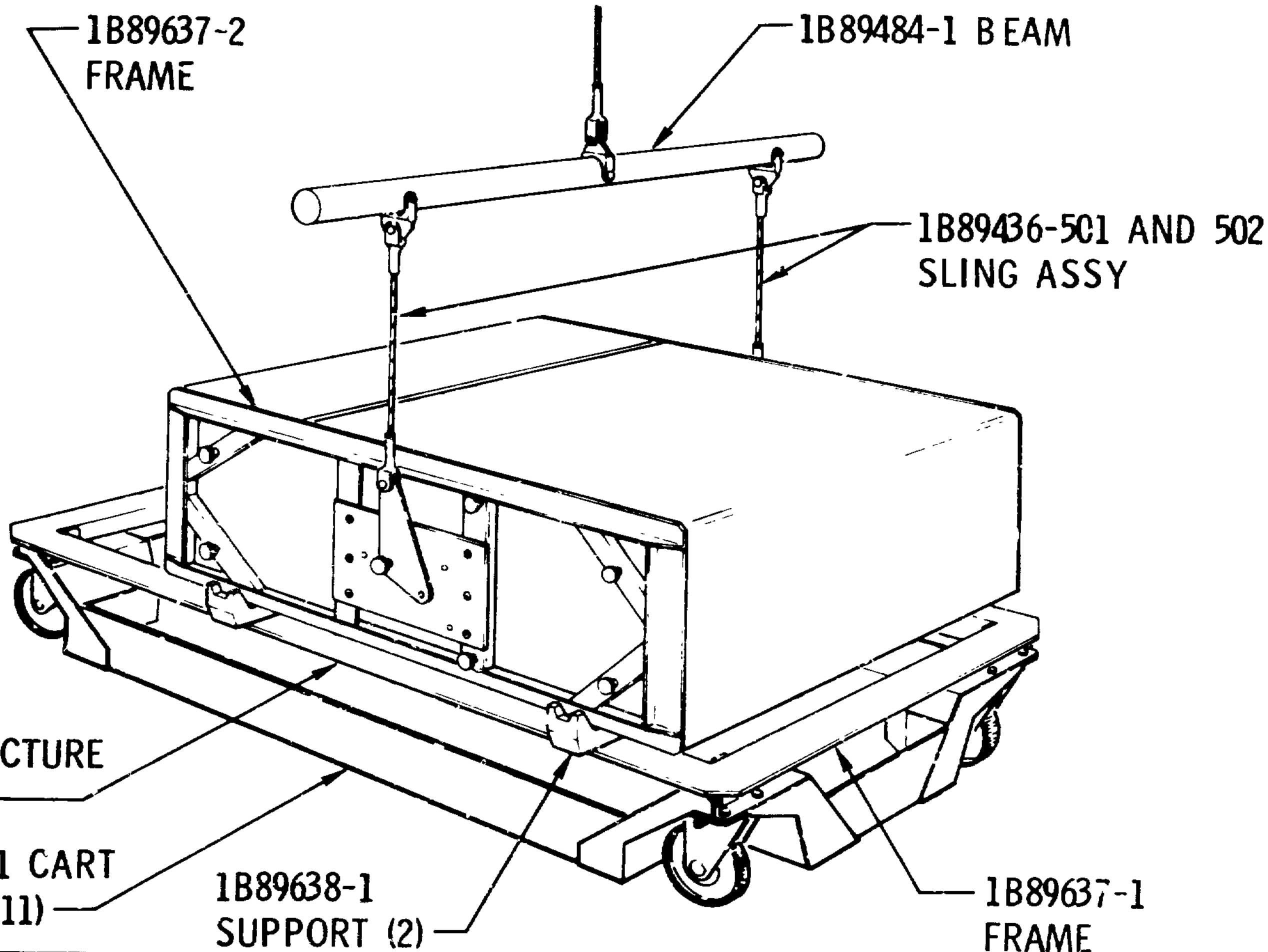


Figure 2.2.14.4-14

SKYLAB - ORBITAL WORKSHOP

MODEL DSV7-349 M171 ERGOMETER HANDLING GSE

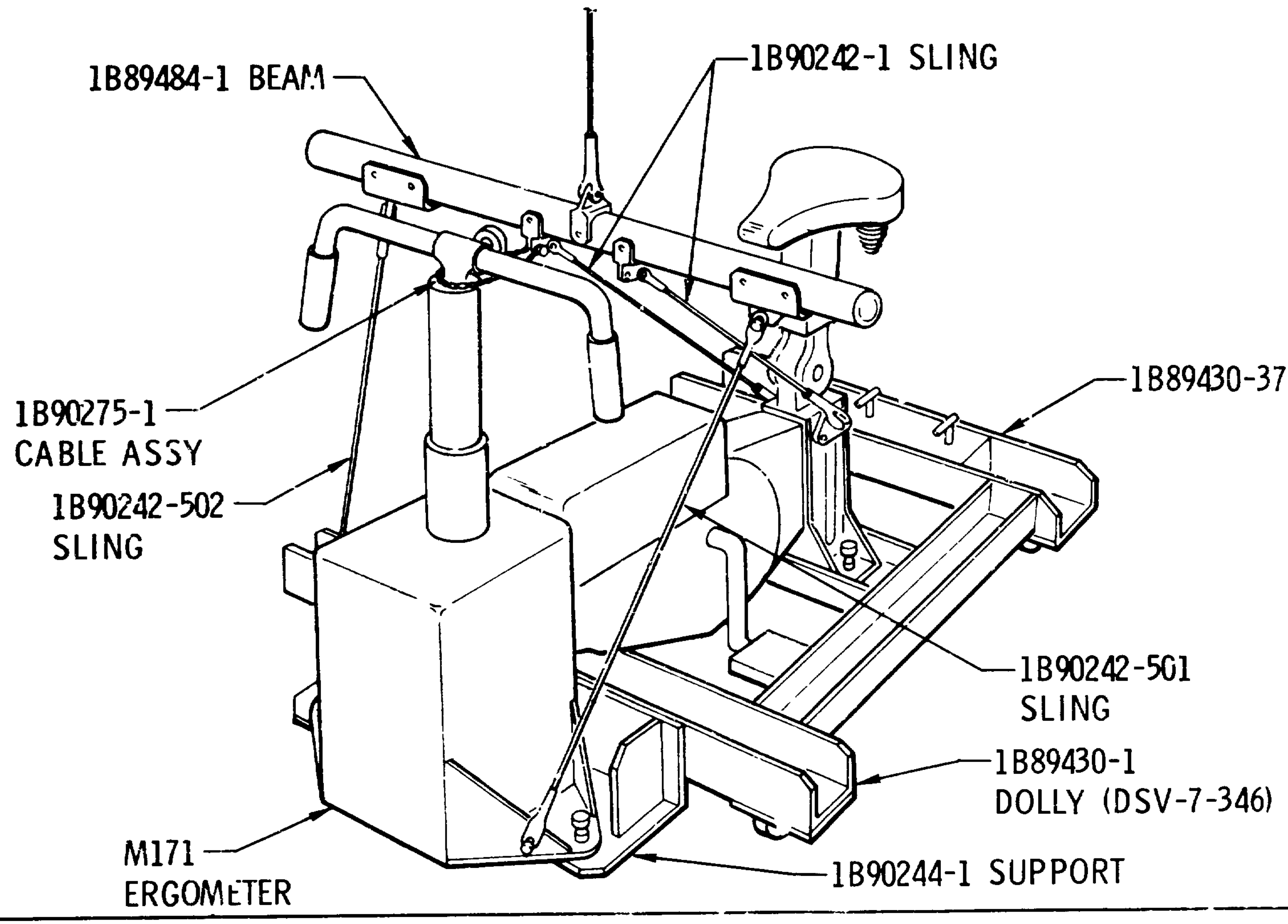


Figure 2.2.14.4-15

SKYLAB - ORBITAL WORKSHOP
MODEL DSV7-351
BMMD HANDLING GSE

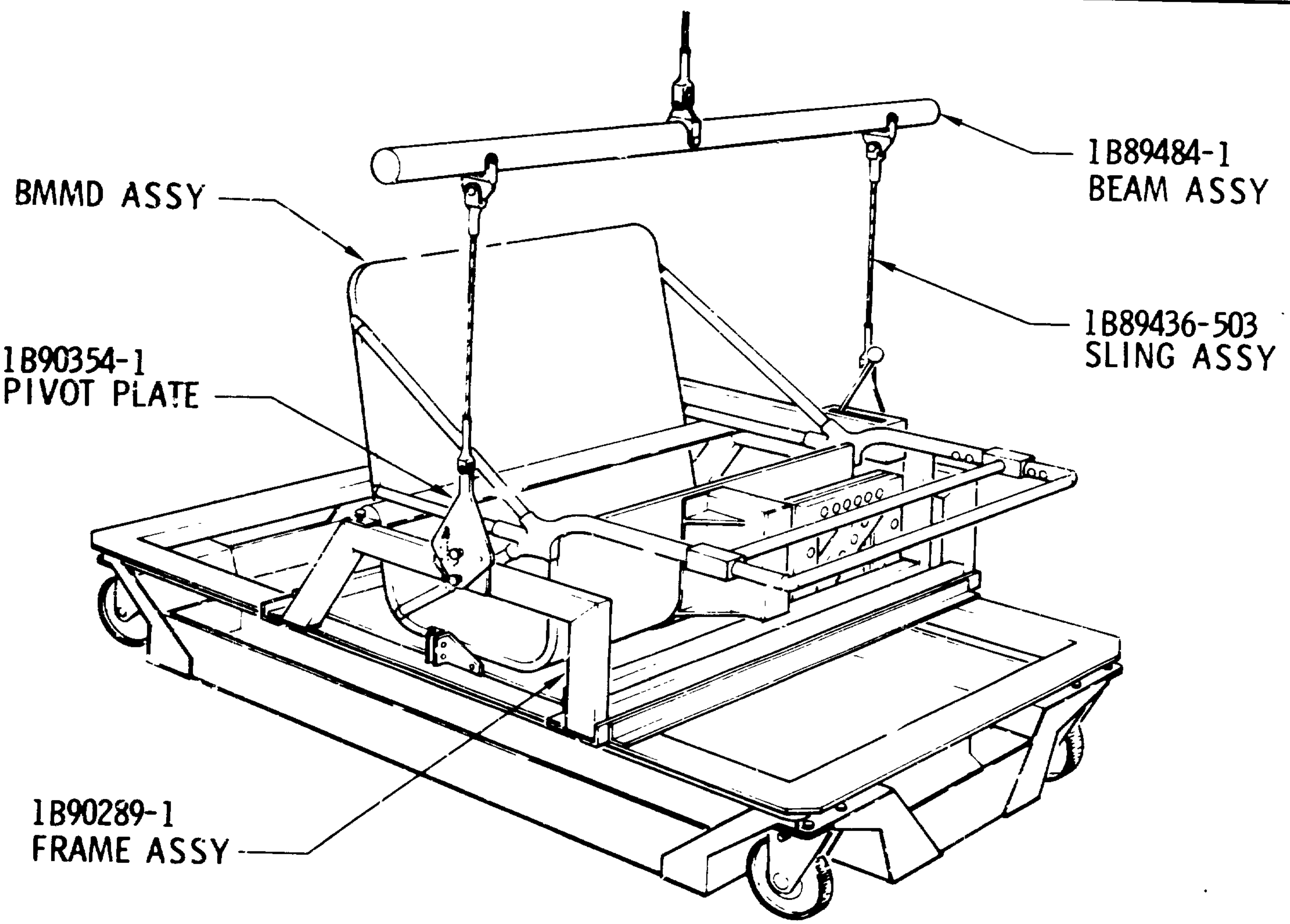


Figure 2.2.14.4-16

SKYLAB - ORBITAL WORKSHOP
BMMD HANDLING GSE
MODEL DSV7-351

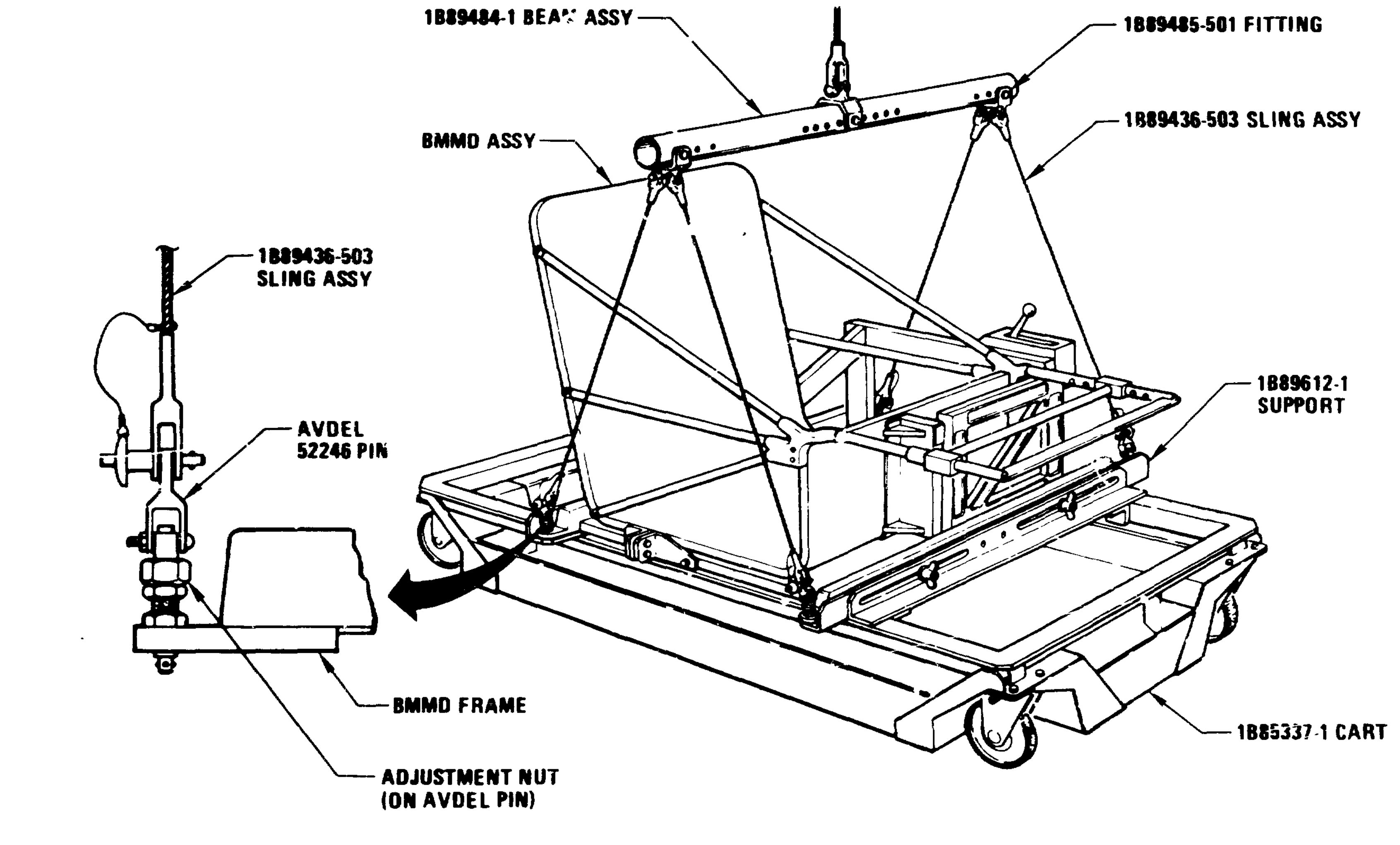


Figure 2.2.14.4-17

SKYLAB - ORBITAL WORKSHOP

RIGHT SIDE VIEW OF ASMU ON DONNING STATION

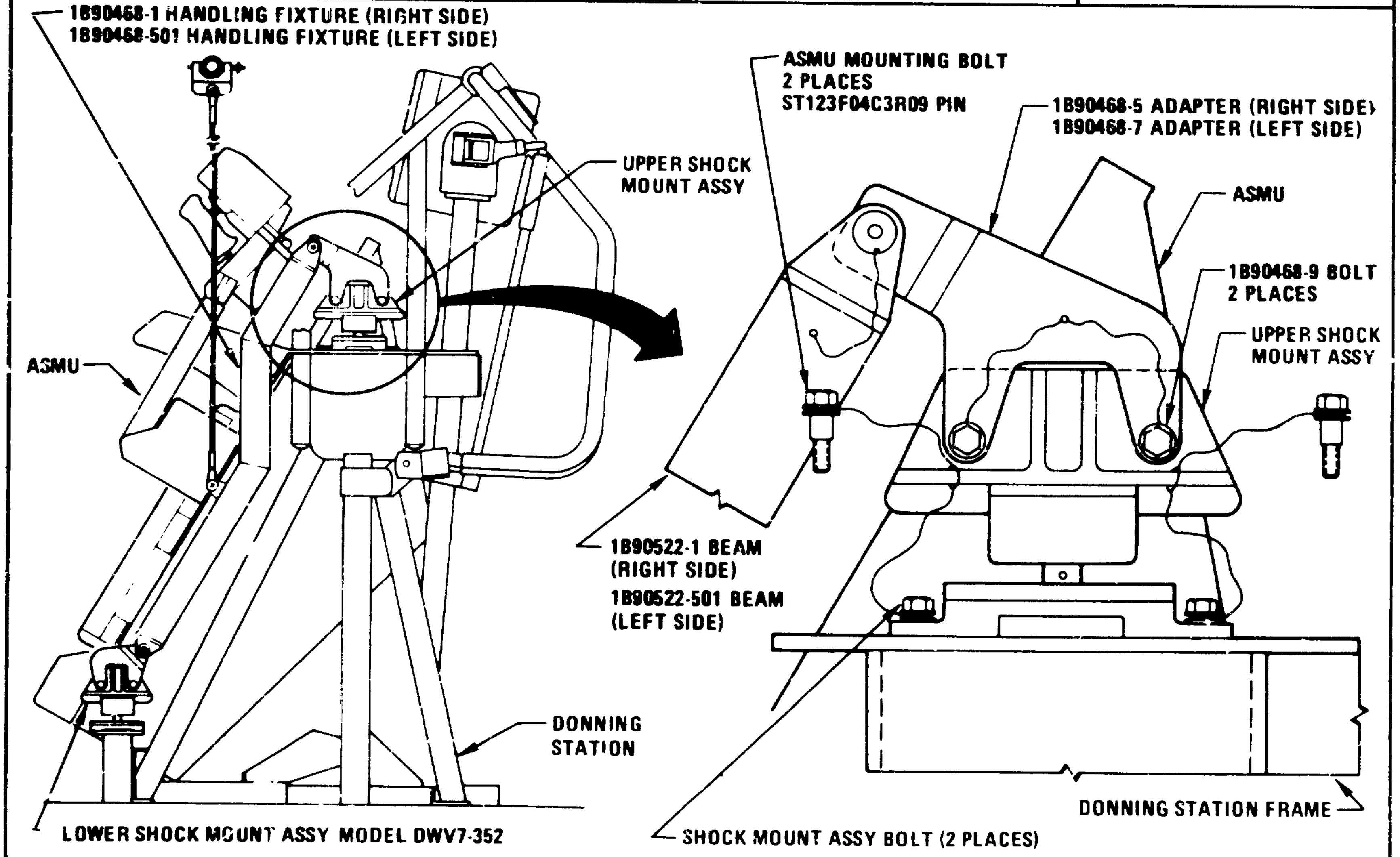


Figure 2.2.14.4-18

SKYLAB - ORBITAL WORKSHOP
MODEL DSV7-352 ASMU ADAPTER

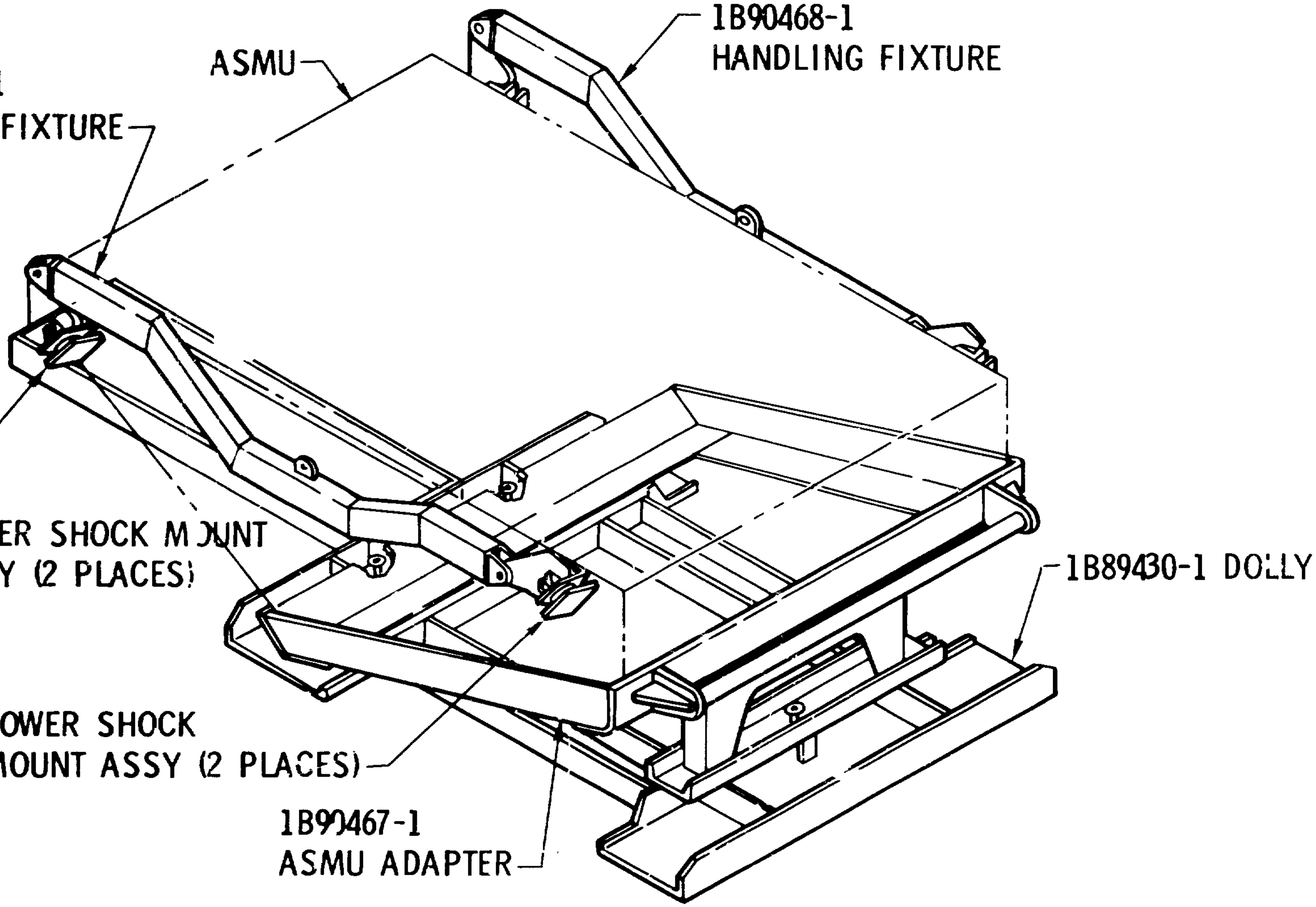


Figure 2.2.14.4-19

SKYLAB - ORBITAL WORKSHOP
RIGHT SIDE DONNING STATION ON 1B85337-1 CART
MODEL DSV7-352

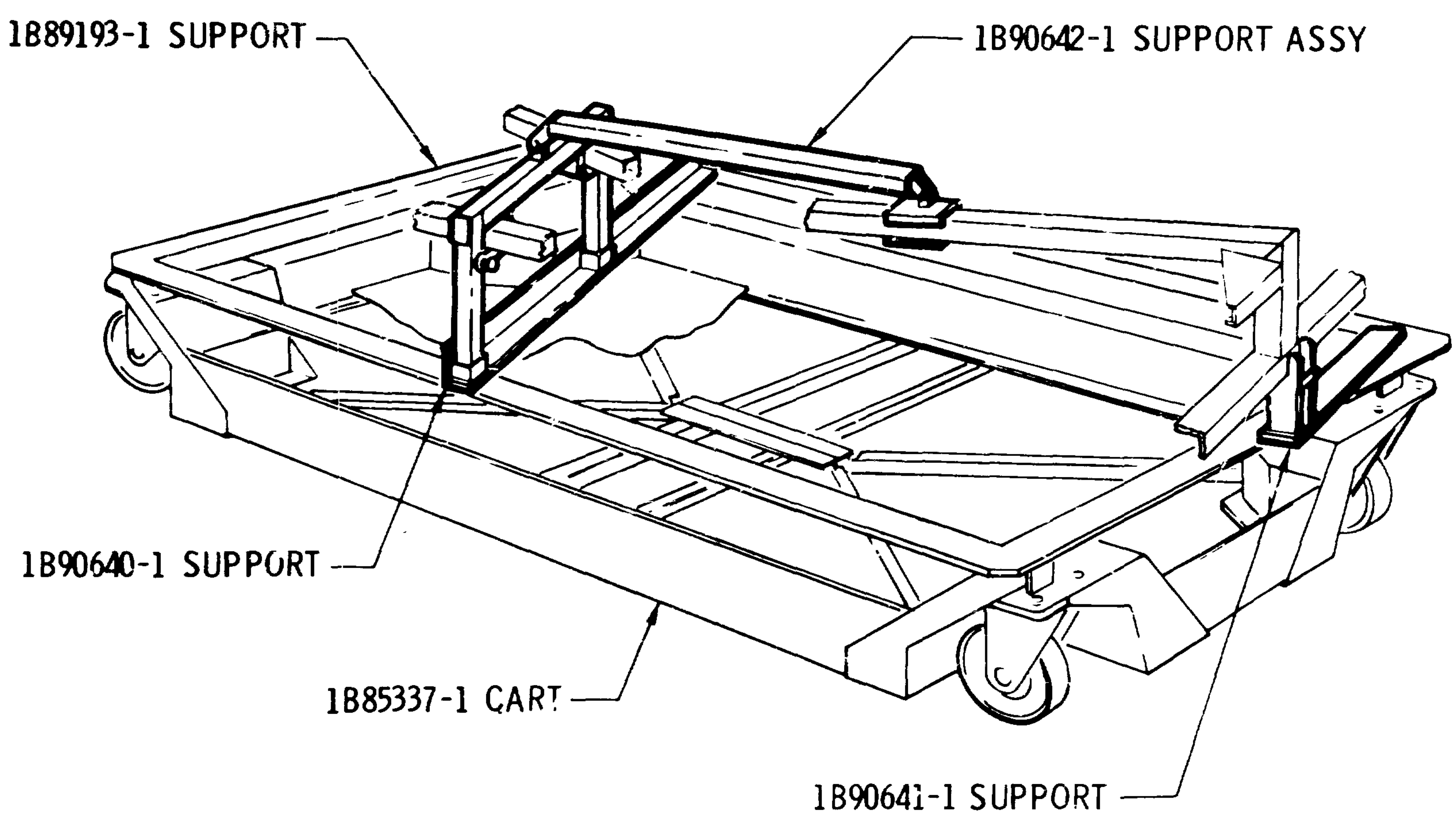


Figure 2.2.14.4-20

SKYLAB - ORBITAL WORKSHOP
MODEL DSV7-352
POSITIONING ASMU ON DONNING STATION

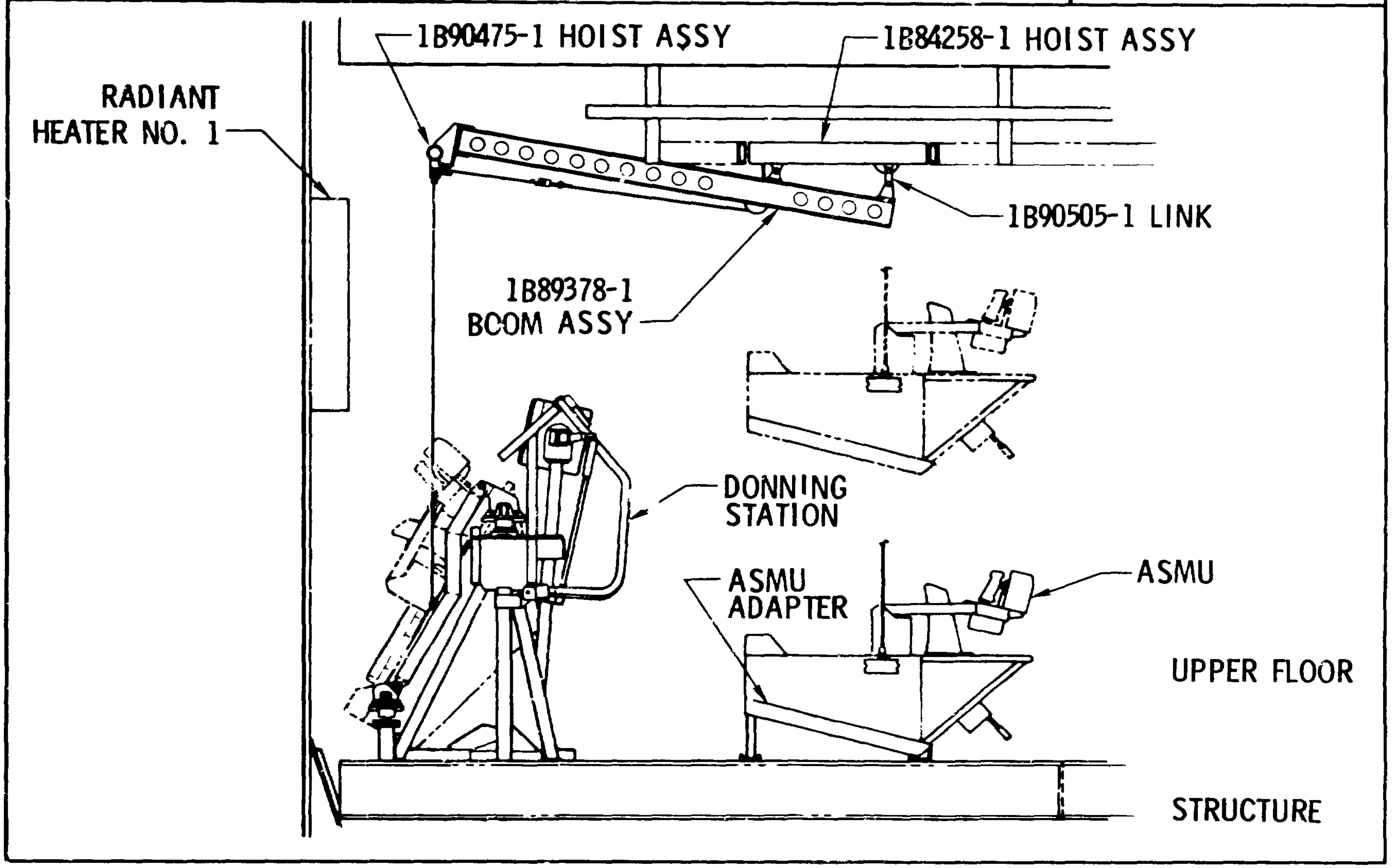


Figure 2.2.14.4-21

SKYLAB - ORBITAL WORKSHOP
MODEL DSV7-352
INSTALLATION OF PROTECTIVE CAGE

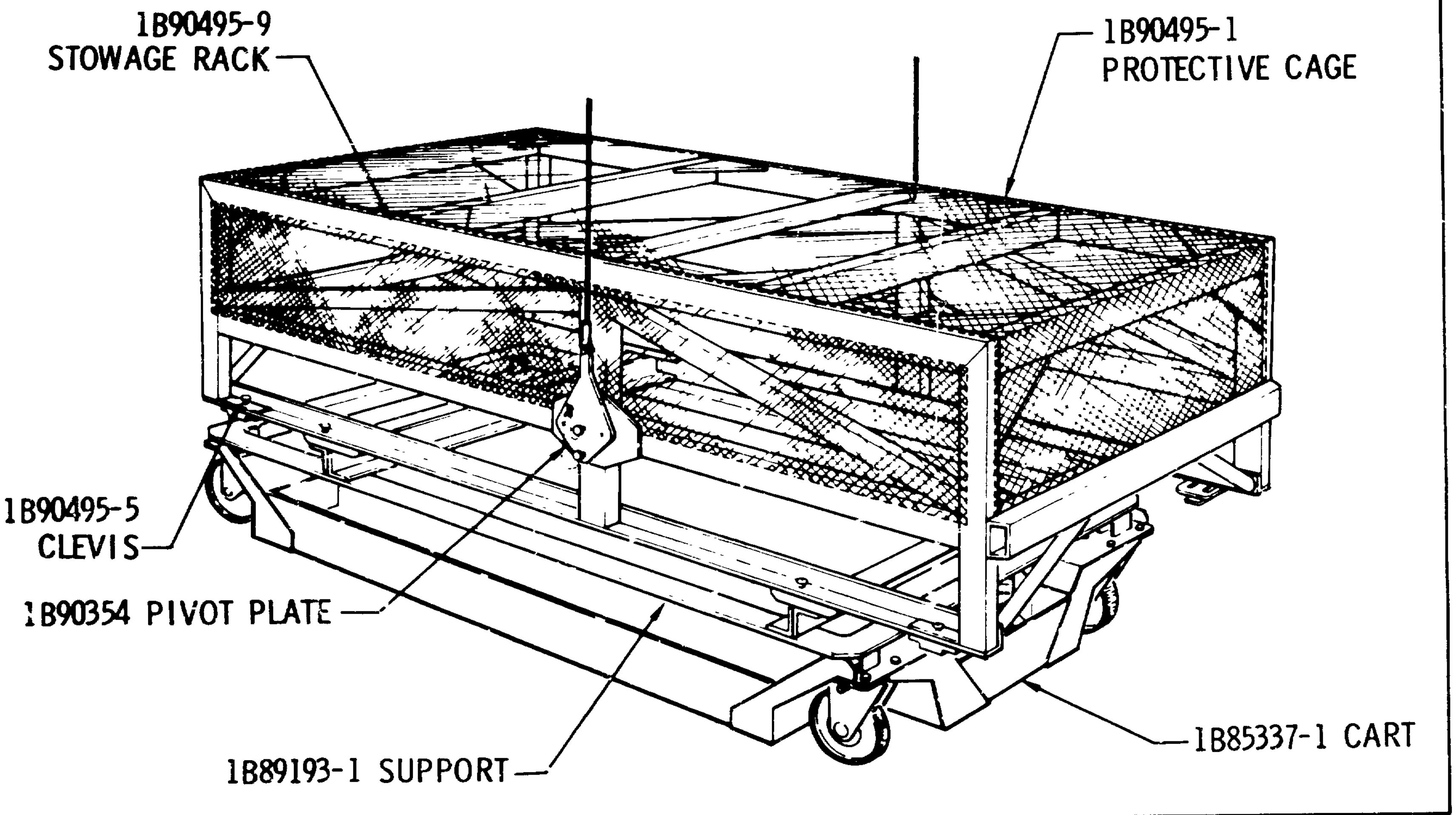


Figure 2.2.14.4-22

SKYLAB - ORBITAL WORKSHOP
PSS BOTTLE HANDLING HOOK
MODEL DSV7-352

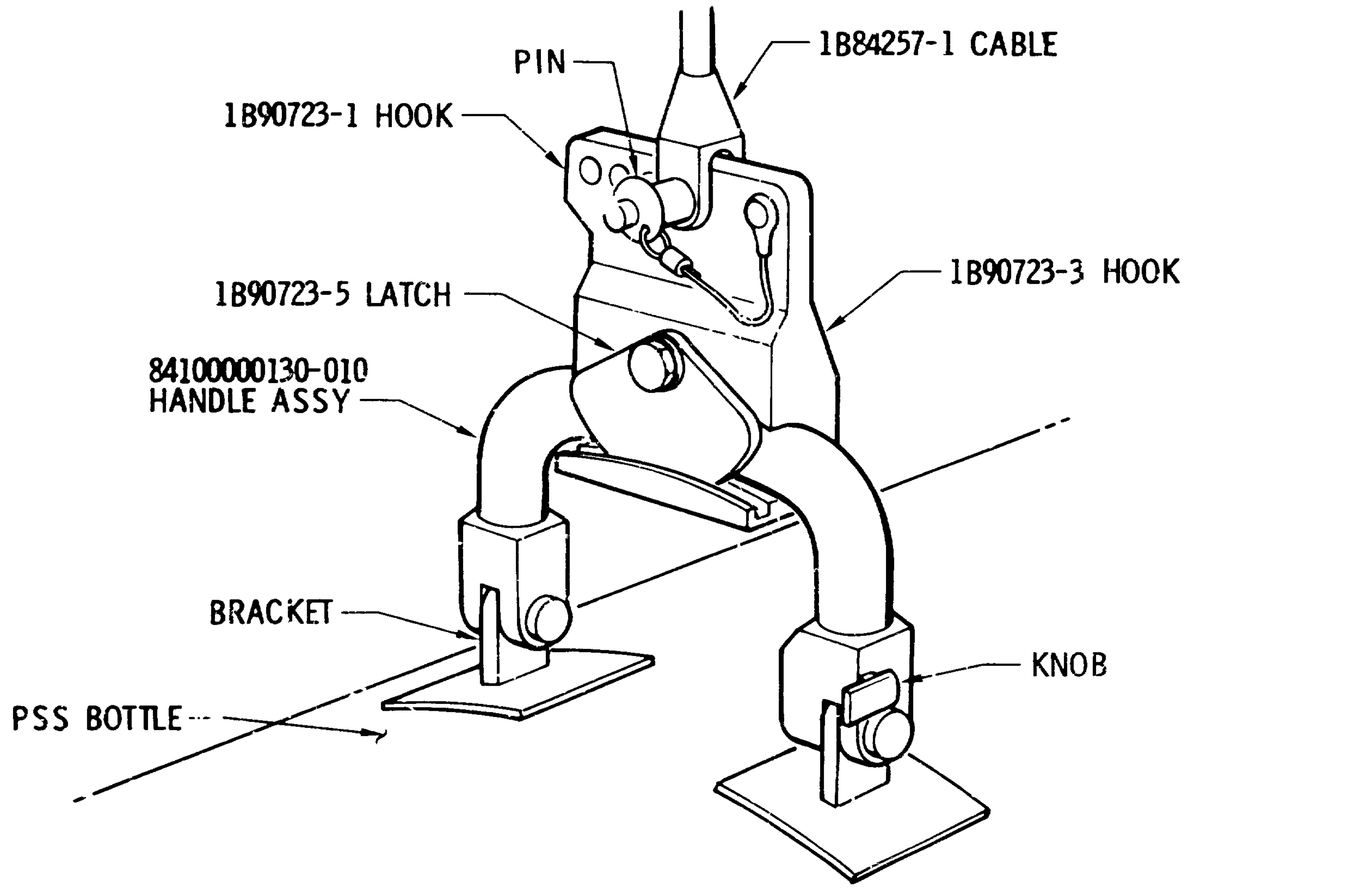


Figure 2.2.14.4-2?

SKYLAB - ORBITAL WORKSHOP
MODEL DSV7-352
PSS BOTTLE HANDLING FIXTURE

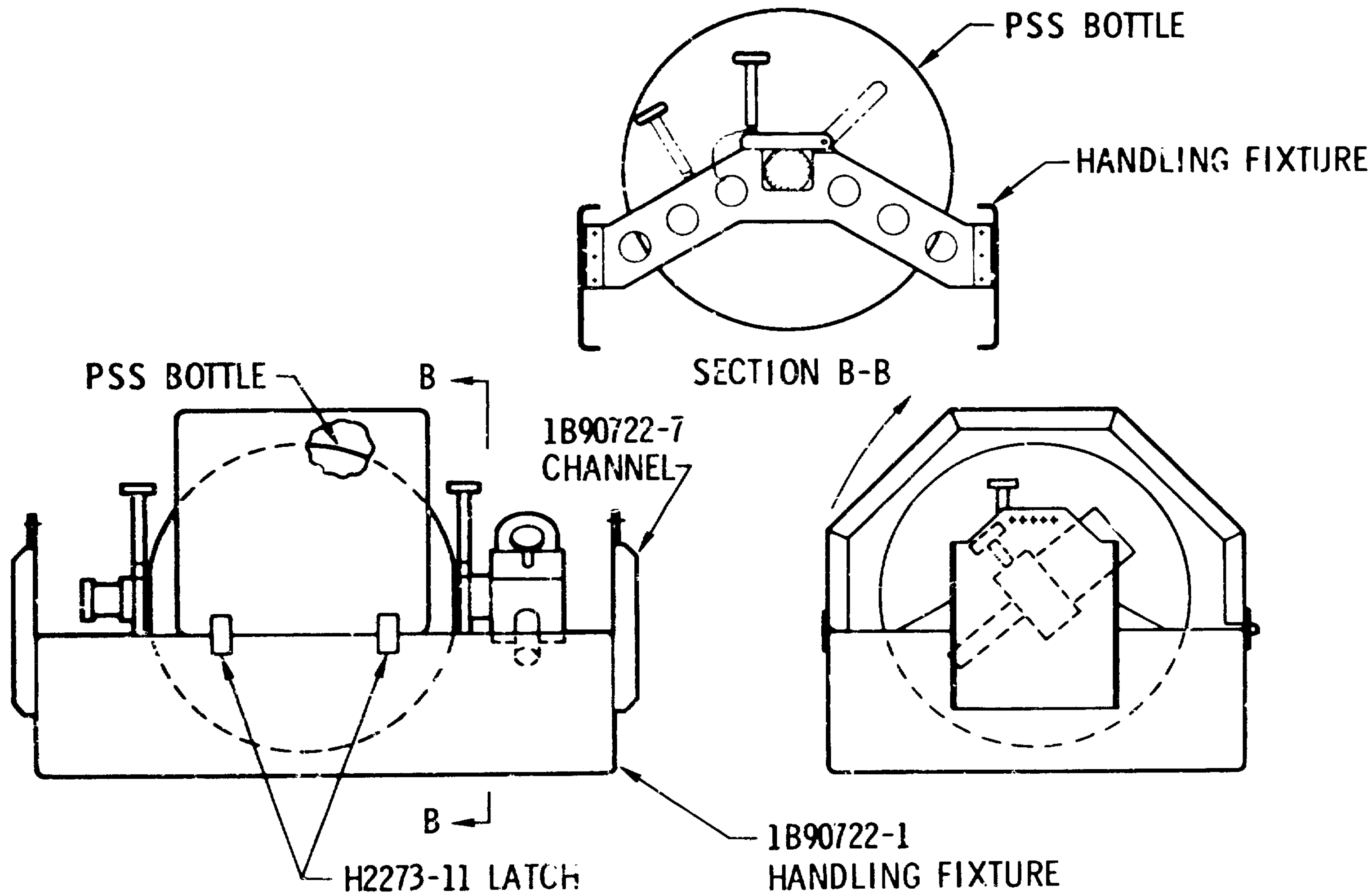


Figure 2.2.14.4-24

8/ Experiment S019 UV Stellar Astronomy Handling and Installation Kit (DSV7-353)

This kit (Drawing No. 1B88996) consisted of an aluminum and steel hoist assembly, an aluminum adjustable support structure for securing the stowage container to the DSV7-311 handling dolly, clamps and supports, an aluminum adjustable support structure to permit one-g checkout and a padded hoist sling (Figures 2.2.14.4-25, -26 and -27).

9/ Experiment S063 UV Airglow Horizon Photography Handling and Installation Kit (DSV7-355)

This kit (Drawing No. 1B89000) consisted of an aluminum fixture assembly for hoisting the stowage container, an aluminum container support assembly to secure the experiment to the DSV7-311 handling cart, an optical alignment support fixture and a mirror carrier tube (Figures 2.2.14.4-28 and -29).

10/ Experiment S183 Ultraviolet Panorama Handling and Installation Kit (DSV7-357)

This kit (Drawing No. 1B89004) consisted of an aluminum camera handling frame assembly, a camera clamp assembly and a camera support assembly (Figure 2.2.14.4-30).

11/ Experiment T020 Foot Control Maneuvering Device Handling and Installation Kit (DSV7-359)

This kit (Drawing No. 1B89008) consisted of an aluminum clamp assembly and yoke and support for securing the experiment to the Model DSV7-311 Handling Cart (Figure 2.2.14.4-31).

SKYLAB - ORBITAL WORKSHOP
MODEL DSV7-353 COMMON FLIGHT
STOWAGE CONTAINERS HANDLING GSE

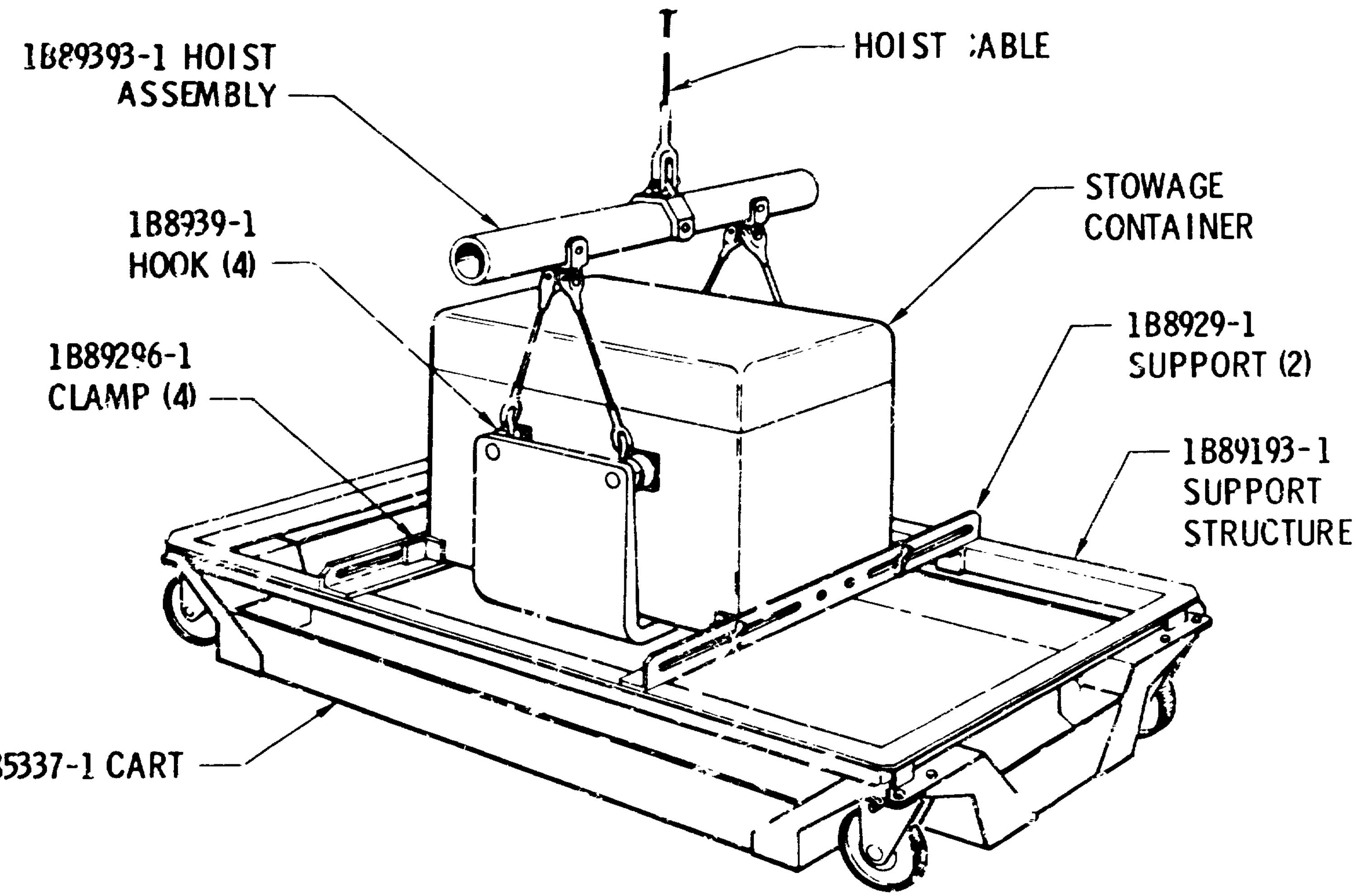


Figure 2.2.14.4-25

C-3

SKYLAB - ORBITAL WORKSHOP
MODEL DSV7-353 AMS SUPPORT

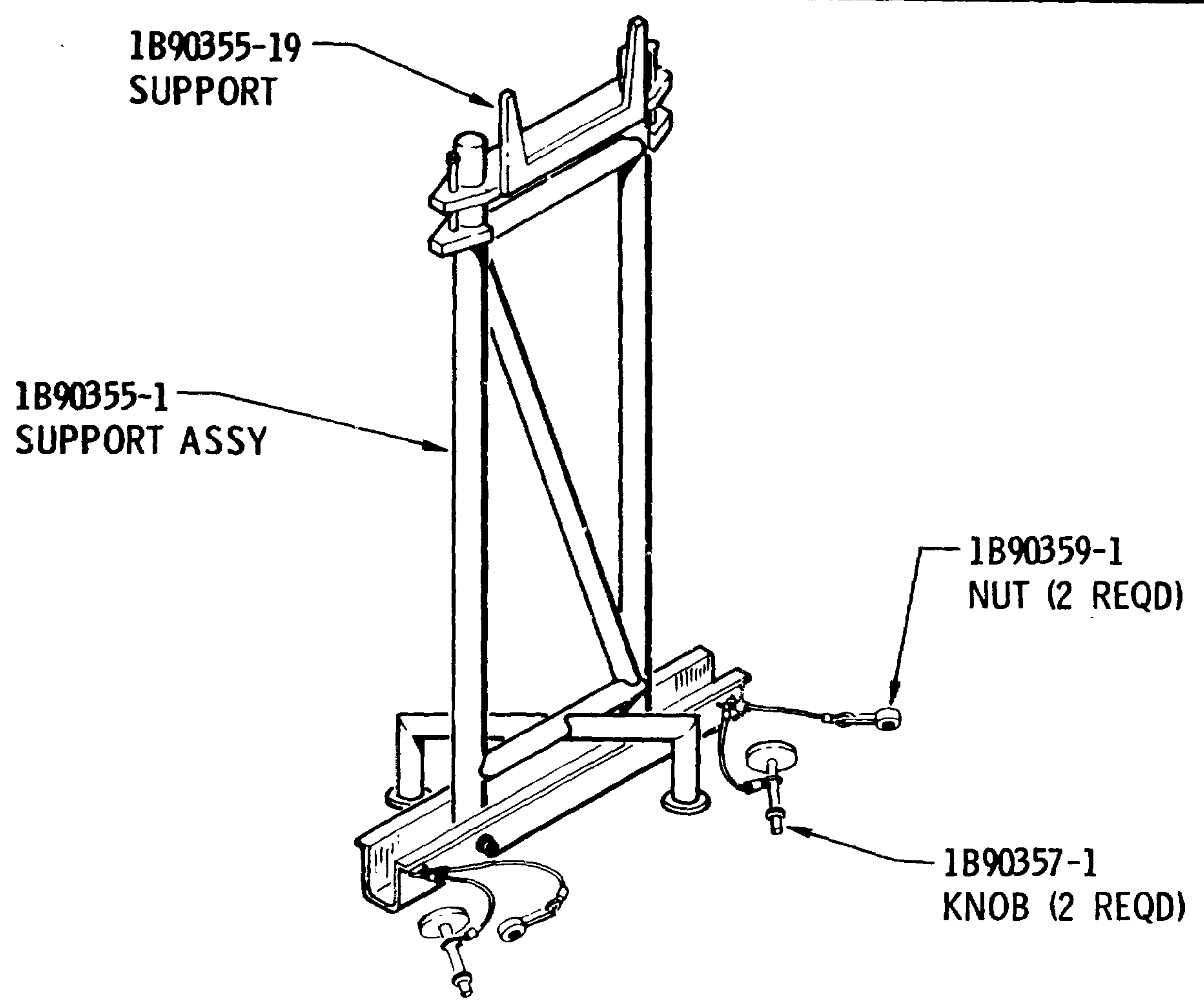


Figure 2.2.14.4-26

SKYLAB - ORBITAL WORKSHOP
MODEL DSV7-353 AMS HANDLING ADAPTER ASSY

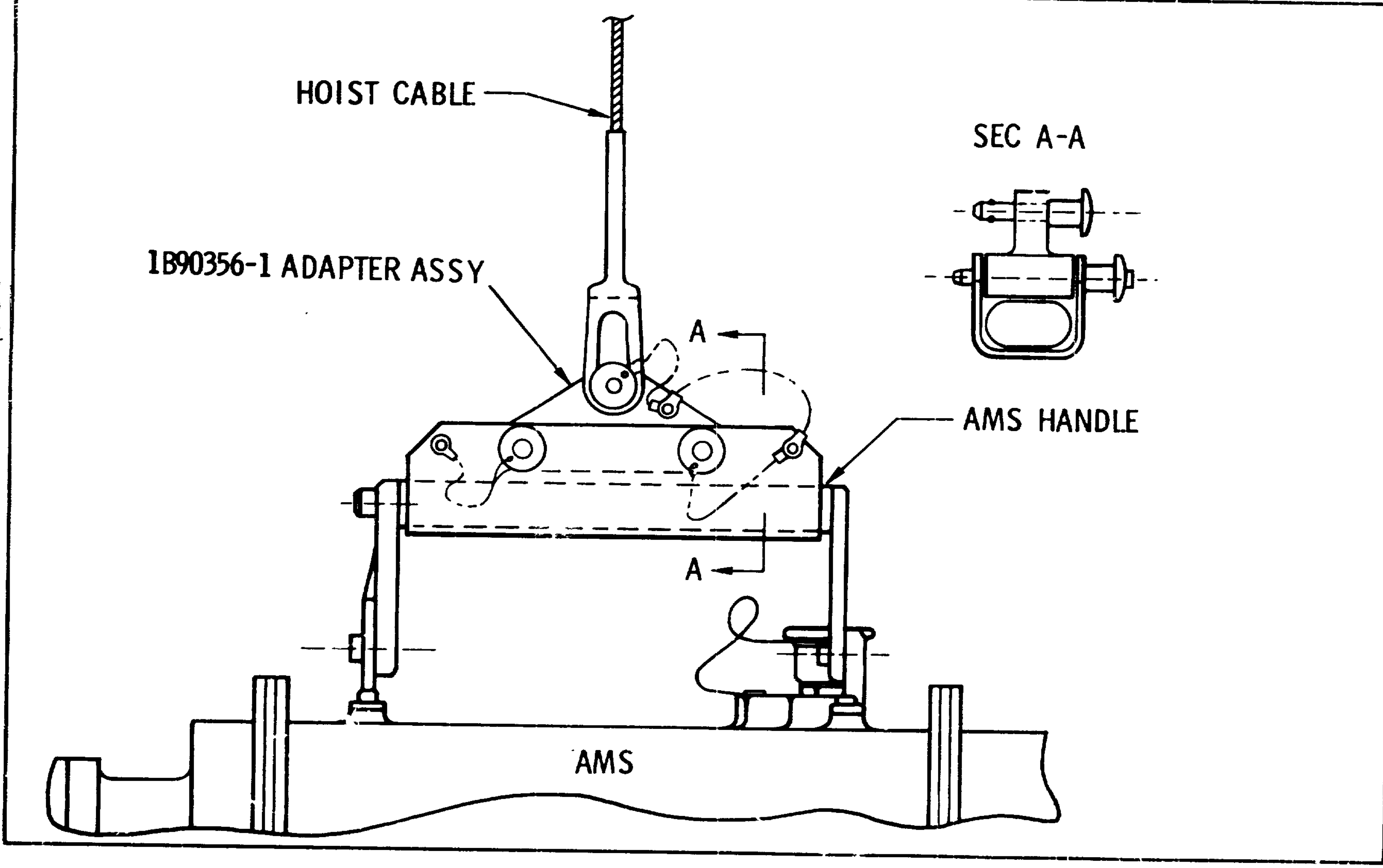


Figure 2.2.14.4-27

SKYLAB - ORBITAL WORKSHOP
MODEL DSV7-355 EXP S063 HANDLING KIT

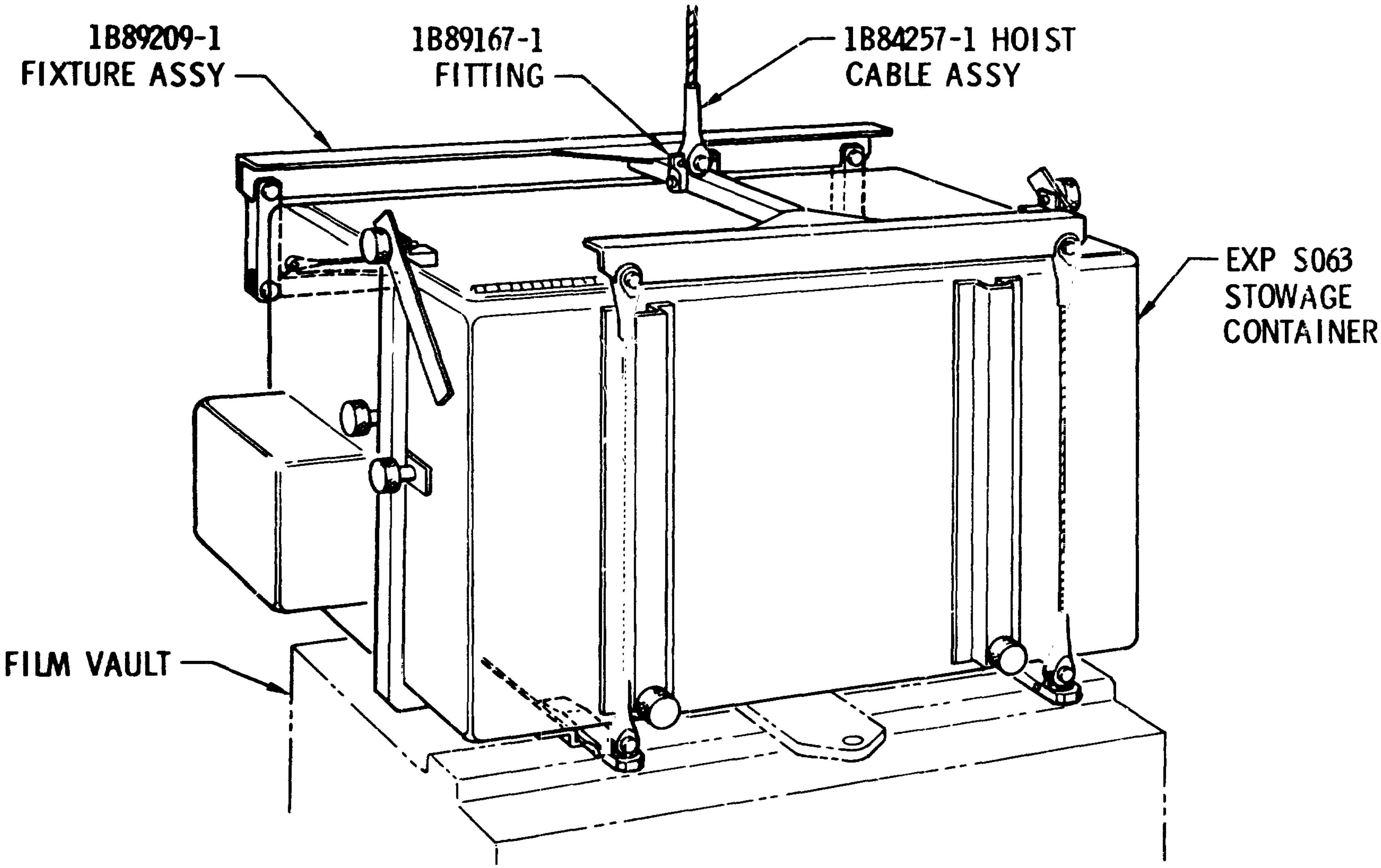


Figure 2.2.14.4-28

SKYLAB - ORBITAL WORKSHOP
MODEL DSV 7-355 ALIGNMENT FIXTURE

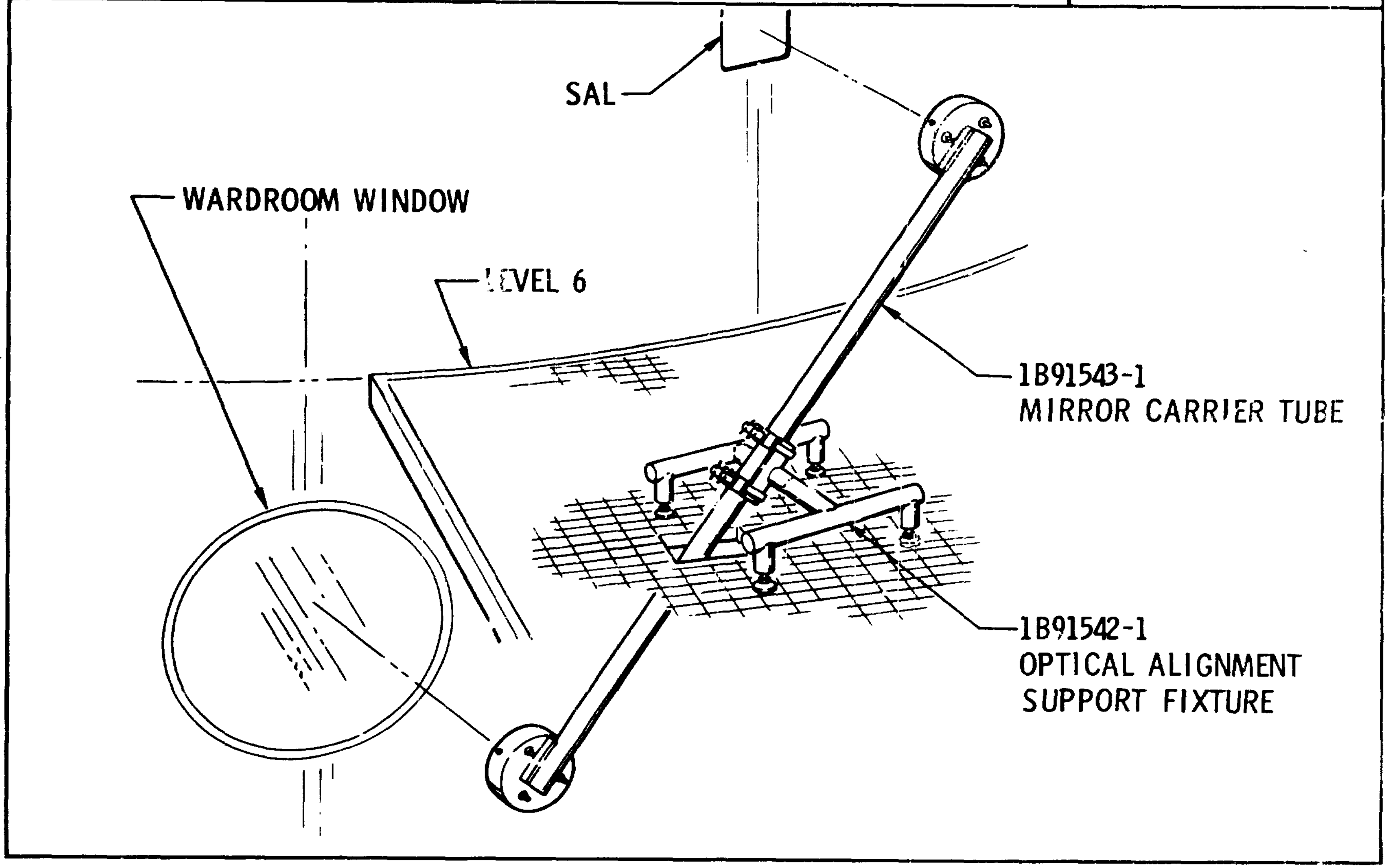


Figure 2.2.14.4-29

SKYLAB - ORBITAL WORKSHOP
MODEL DSV7-357 EXP S183 VV
PANORAMA HANDLING & INSTL KIT

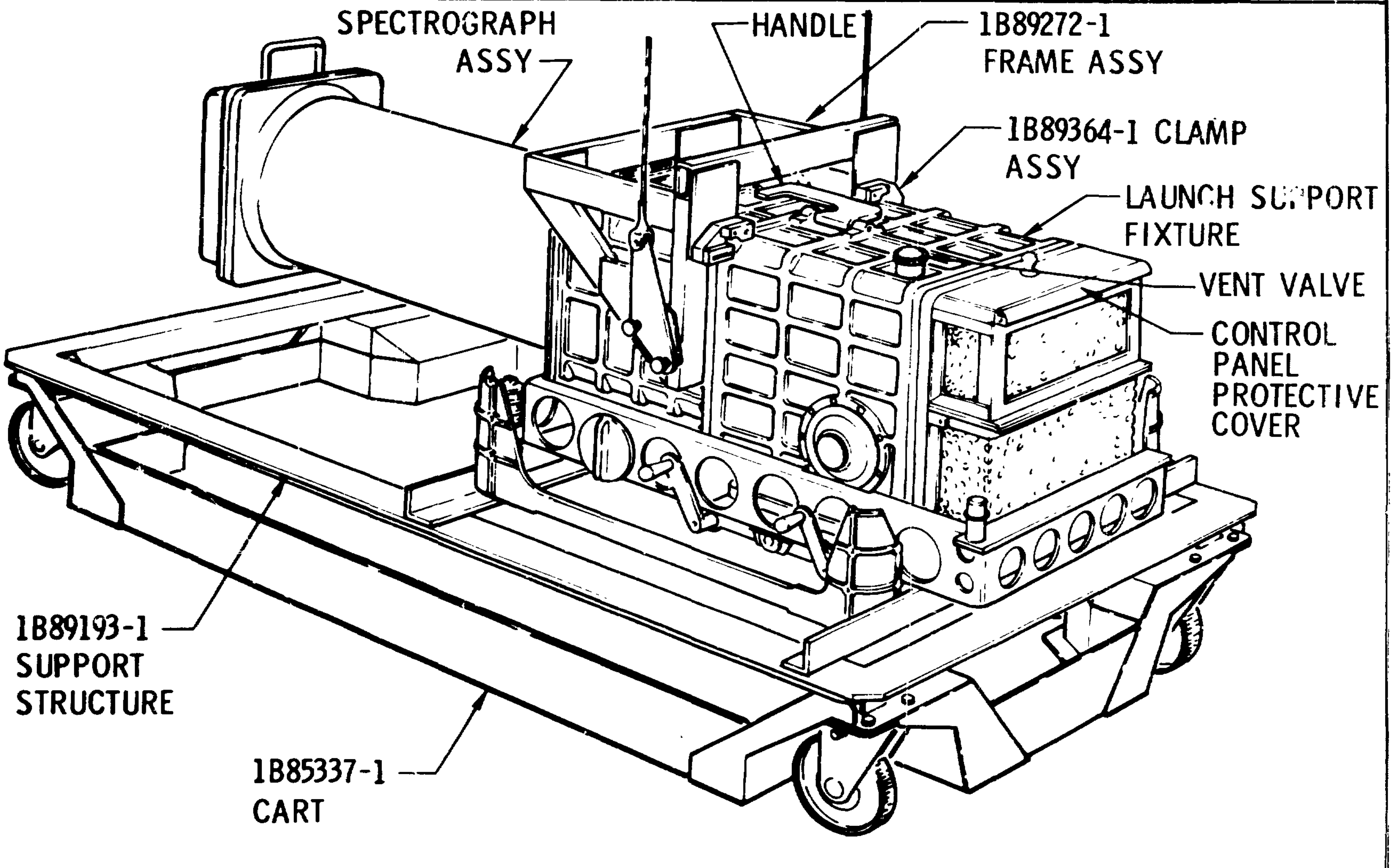


Figure 2.2.14.4-30

SKYLAB - ORBITAL WORKSHOP
EXP T020 FCMU HANDLING AND INSTL KIT
DSV7-359

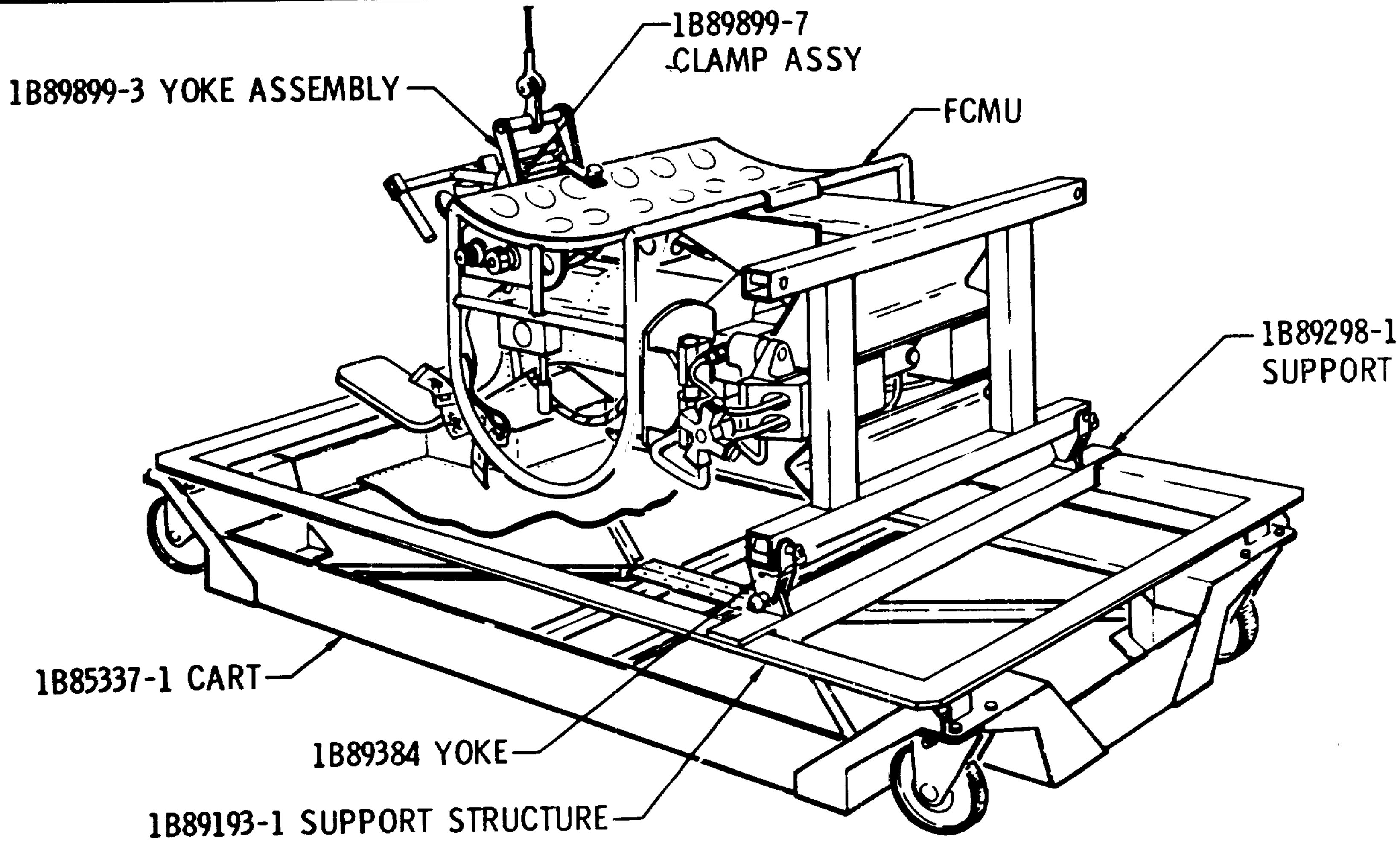


Figure 2.2.14.4-31

12/ Experiment T025 Coronograph Contamination Measurements Handling and Installation Kit (DSV7-360)

This kit (Drawing No. 1B89010) consisted of an aluminum adapter frame to attach the stowage container to the DSV7-311 vertical hoist to lift and position it within the workshop. The adapter frame will have the capability of being secured to the DSV7-311 handling dolly by means of quick release pins.

13/ Experiment T027 ATM Contamination Measurement Handling and Installation Kit (DSV7-361)

This kit (Drawing No. 1B89012) consisted of aluminum hoist adapter fittings, hold down fittings, a photometer head internal support fixture, a sample array extension mechanism external support fixture, a photometer extension mechanism external support fixture, a spreader bar, hoist cables, a sling, GFP photometer head deployment rails, GFP sample array deployment rails, GFP photometer head counter weights and a GFP protective lens cap (Figures 2.2.14.4-32, -33 and -34).

14/ Experiment S190B Earth Terrain Camera (ETC) Handling and Installation Kit (DSV7-367)

This kit (Drawing No. 1B91121) consisted of an inverter handling fixture assembly, an ETC stowage container handling fixture assembly, a support adapter to secure the inverter to the DSV7-311 handling cart, an ETC hoist adapter, a one-g suport adapter for the ETC, an ETC vertical support, clamps and hoist cable adapters (Figures 2.2.14.4-35, -36, -37 and -38).

SKYLAB - ORBITAL WORKSHOP
PHOTOMETER CONTAINER HANDLING GSE
MODEL DSV7-361

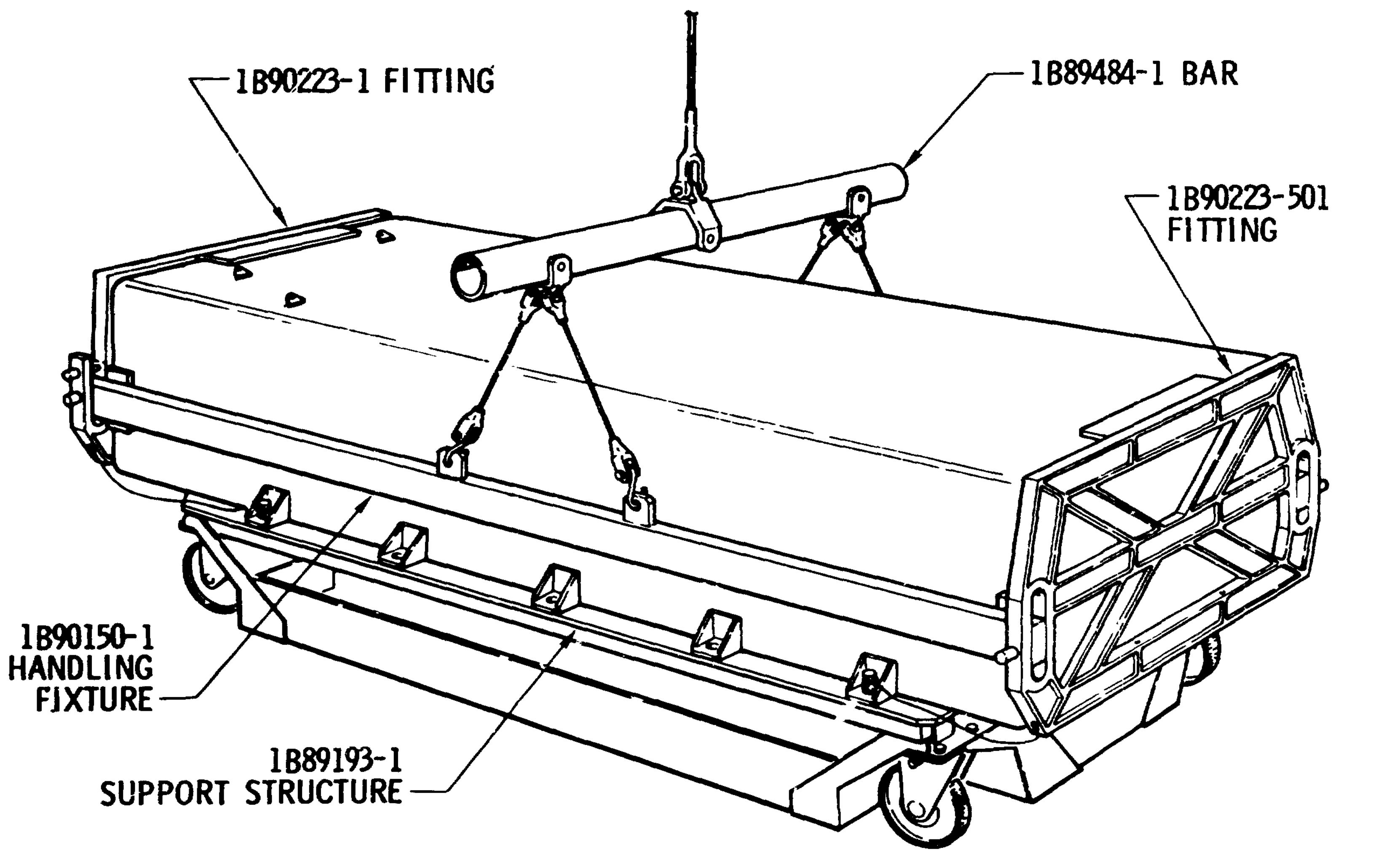


Figure 2.2.14.4-32

SKYLAB - ORBITAL WORKSHOP
MODEL DSV7-361
PHOTOMETER HANDLING GSE

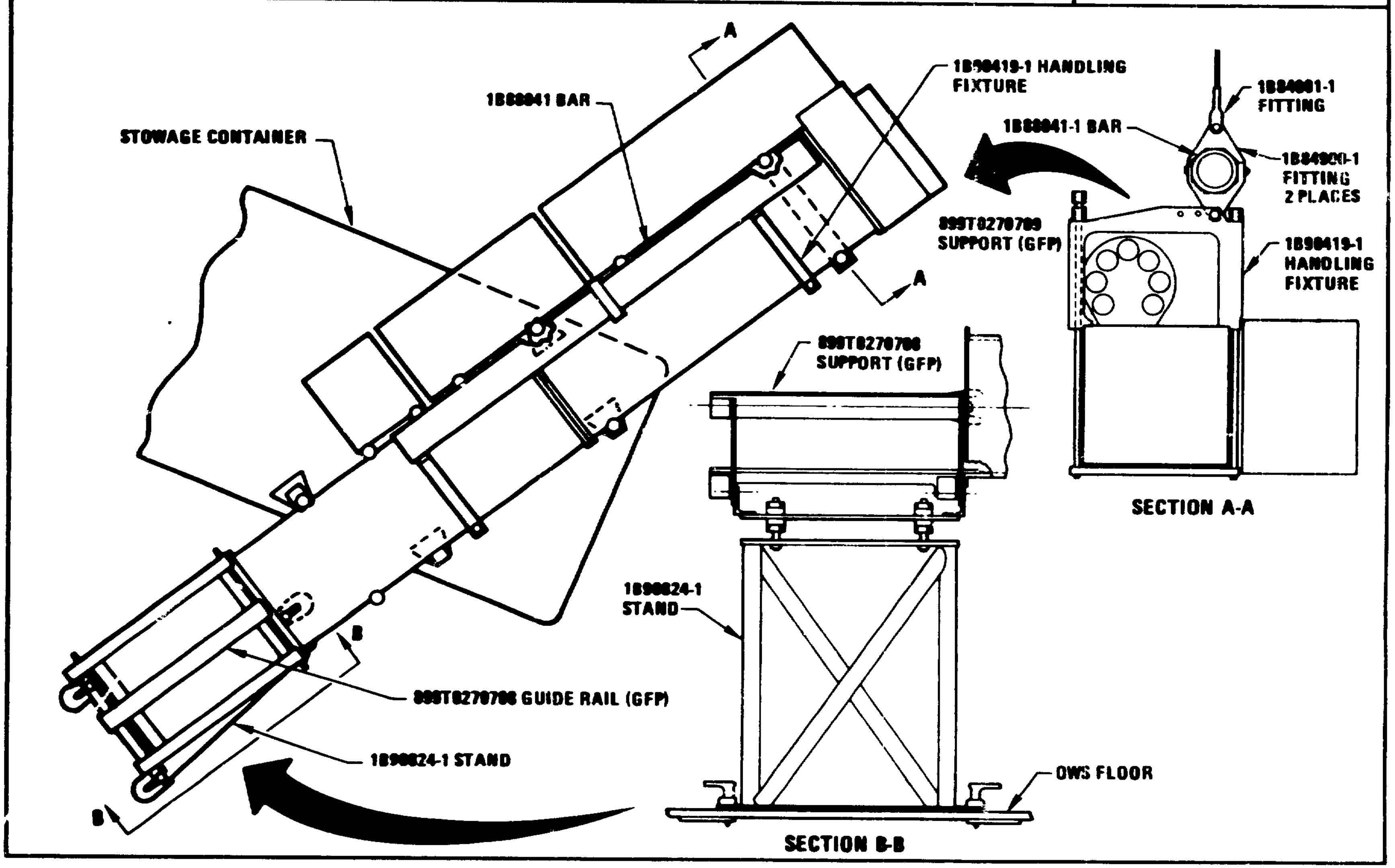


Figure 2.2.14.4-33

SKYLAB - ORBITAL WORKSHOP
MODEL DSV7-361
SAMPLE ARRAY CONTAINER HANDLING GSE

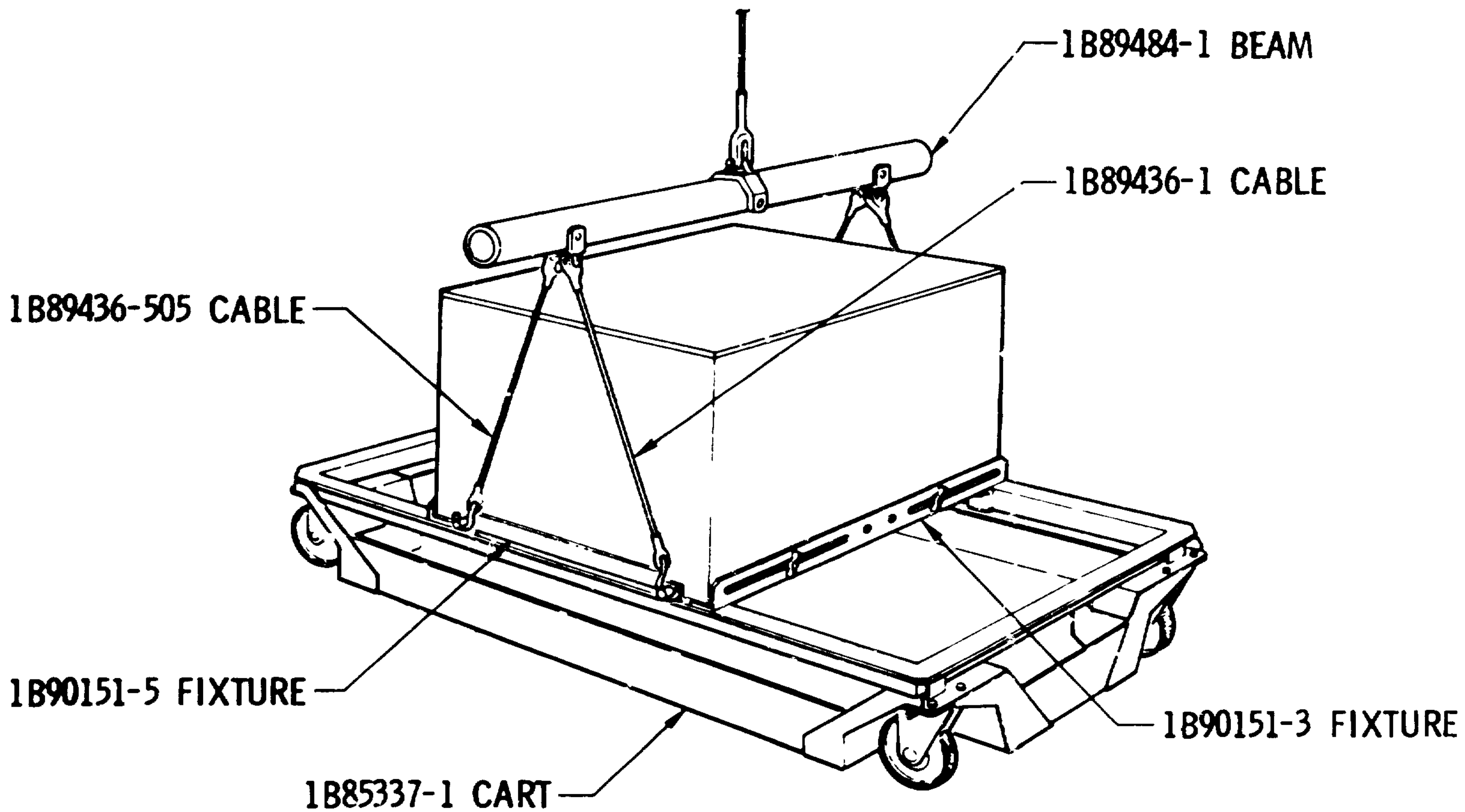


Figure 2.2.14.4-34

SKYLAB - ORBITAL WORKSHOP

INVERTER HANDLING GSE DSV7-367

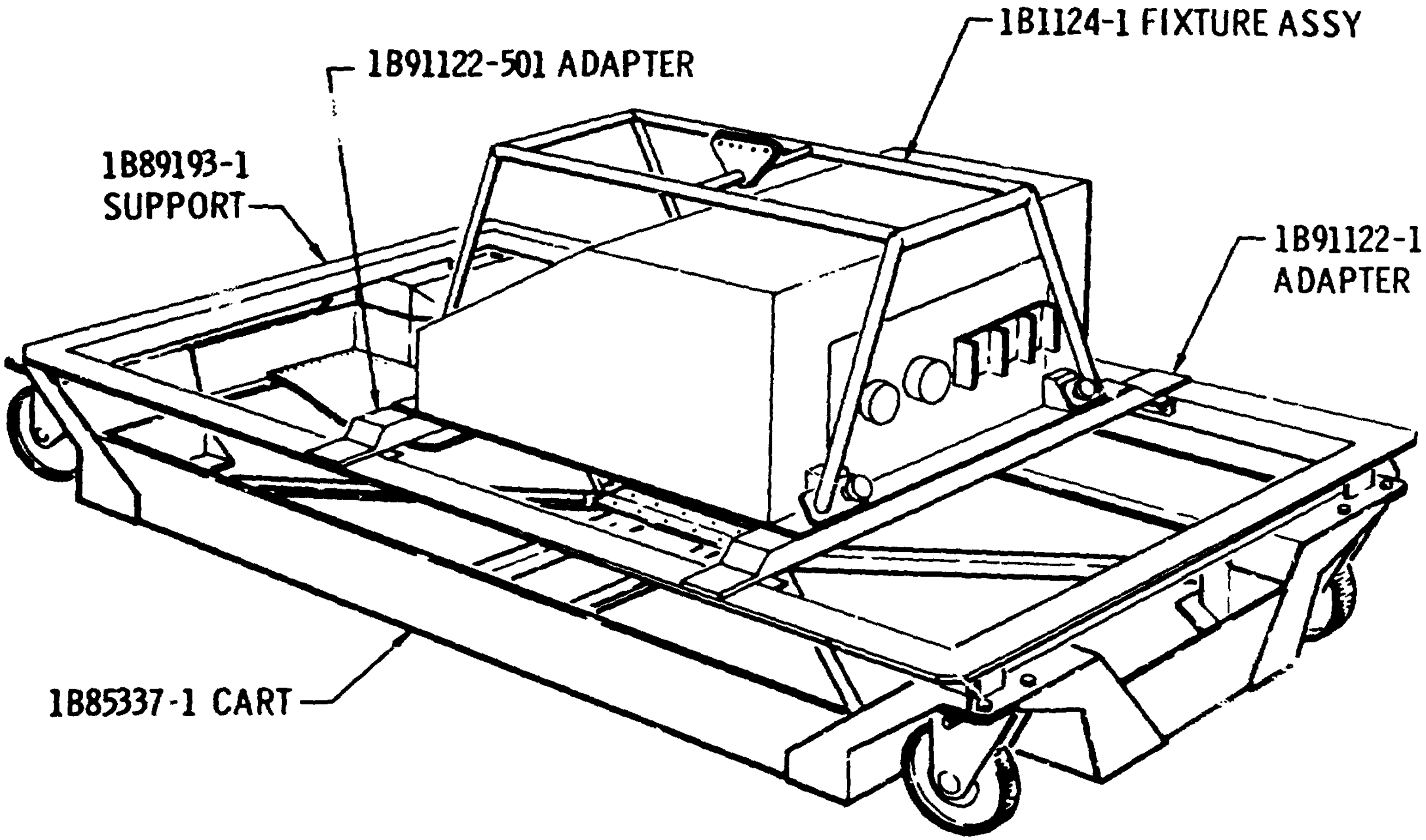


Figure 2.2.14.4-35

SKYLAB - ORBITAL WORKSHOP

ETC STOWAGE CONTAINER HANDLING GSE DSV7-367

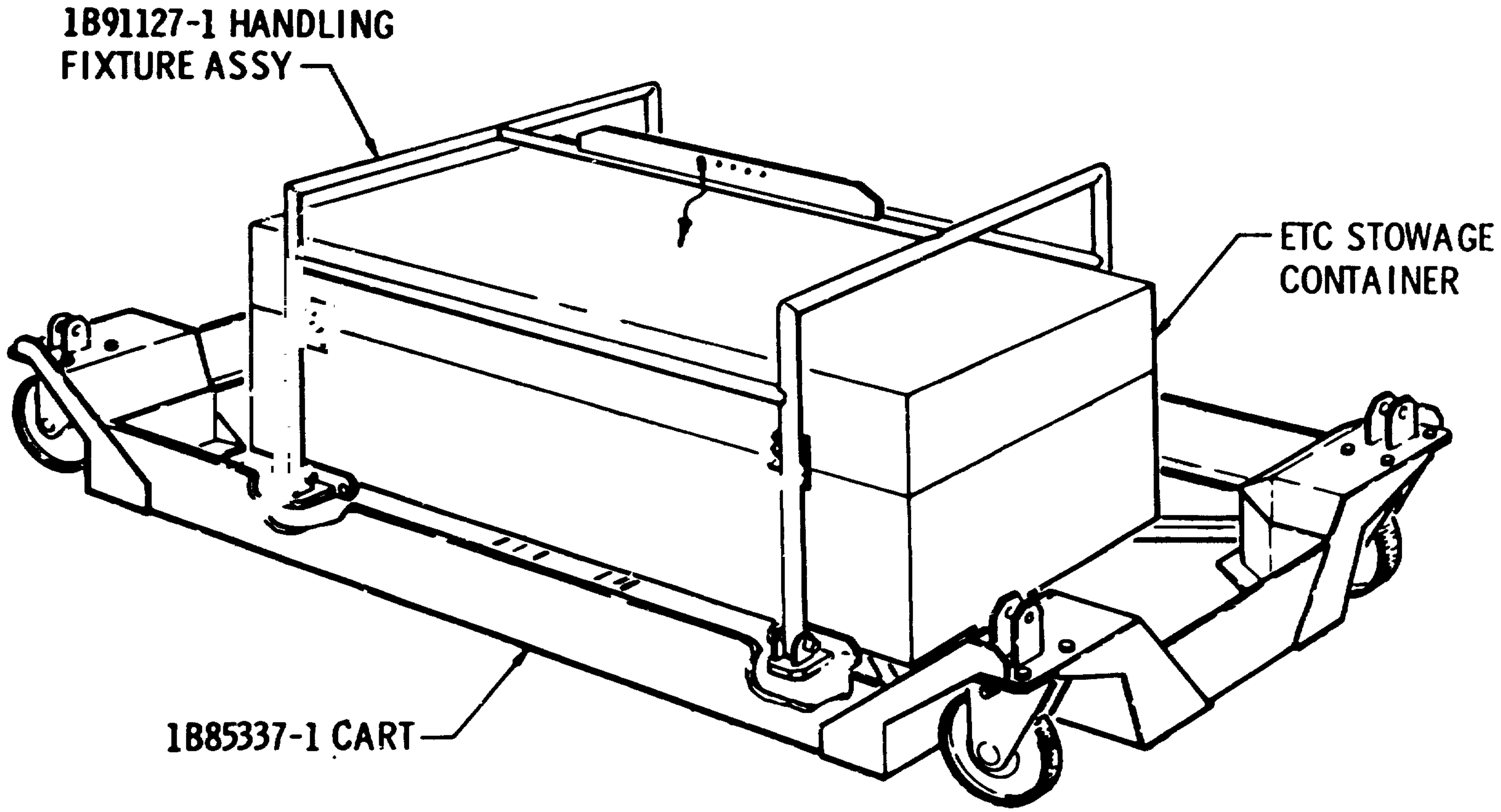


Figure 2.2.14.4-36

SKYLAB - ORBITAL WORKSHOP
MODEL DSV 7-367
ETC HANDLING GSE

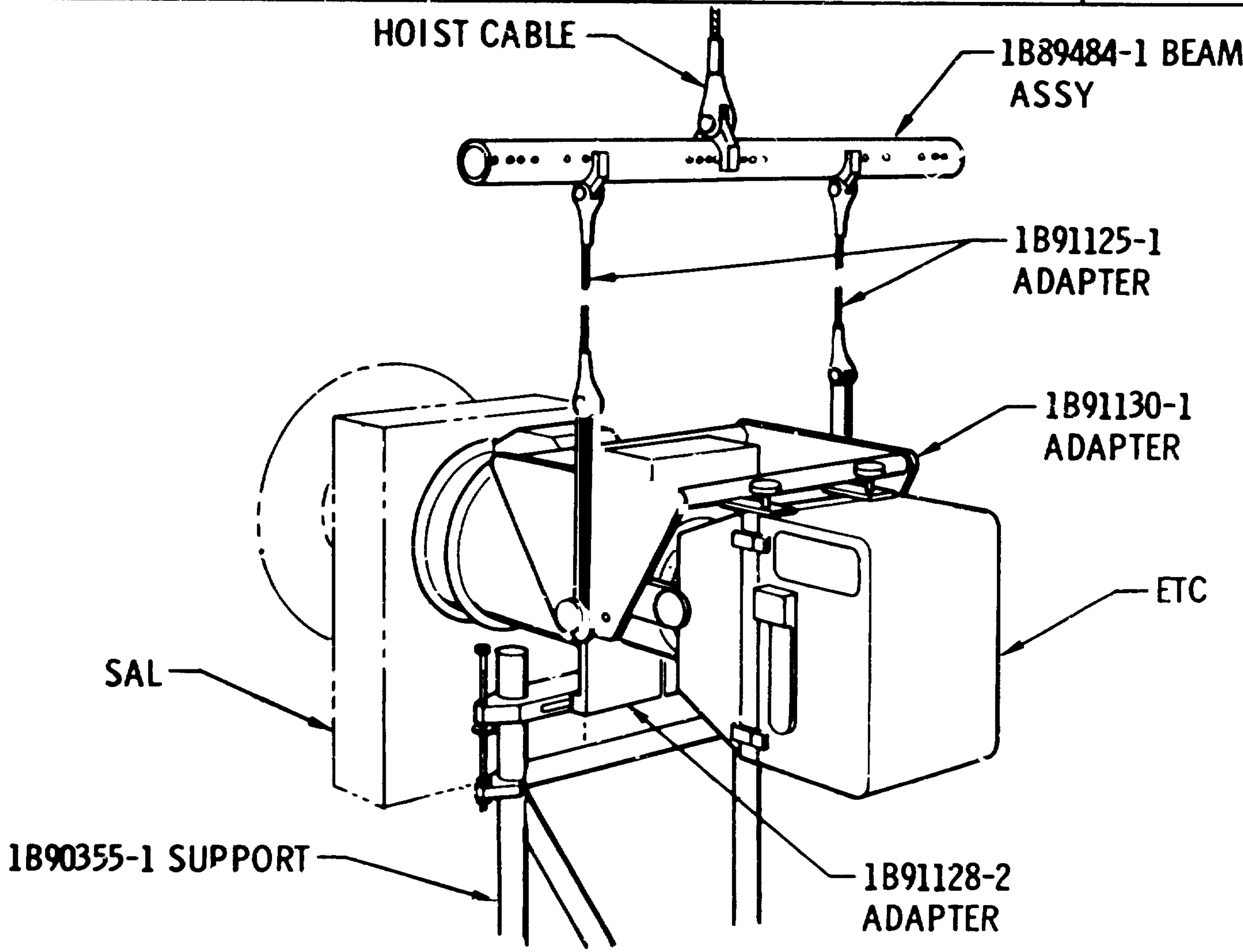


Figure 2.2.14.4-37

SKYLAB - ORBITAL WORKSHOP

MODEL DSV7-367 ETC SUPPORT STAND

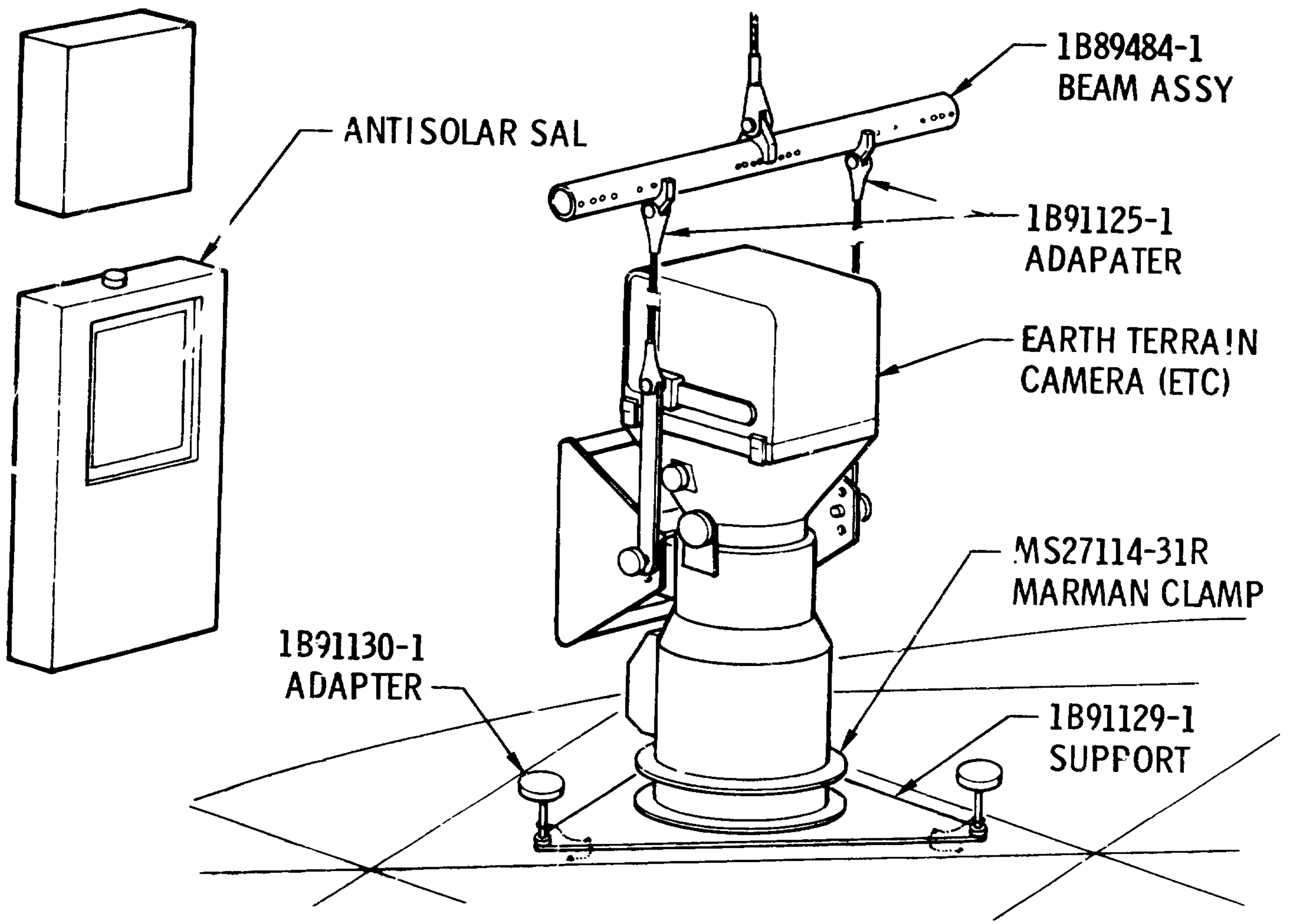


Figure 2.2.14.4-38

15/ A9 Container Handling and Installation Kit (DSV7-372)

This kit (Drawing No. 1B91214) consisted of a forward support adapter, an aft support adapter, an A9 locker hoist, safety cable assembly, an A9 locker hoist beam assembly, and a support assembly to secure the container to the Model DSV7-311 Handling Cart (Figure 2.2.14.4-39).

C. Testing

There was no testing program on this system due to the fact that tight schedules and geographic dispersion of the principal experiments required that the equipment in this system work properly the first time used. Configuration and fabrication were relatively simple so that fit and function became the prime requirements.

D. Conclusions and Recommendations

The creation of a handling system and the integration of requirements for handling the experiments, resulted in the design of a family of equipment. A wide variety of onboard equipment utilizing multiple use of cables, spreader bars and handling carts with adapters, minimized the cost of the system and resulted in a record of 100-percent safe handling of the experiments. It is recommended that future programs employing experiments and/or removable components supplied by a variety of suppliers delegate the installing contractor with the responsibility of handling and installation in order to ensure continuity of design and minimum cost.

SKYLAB - ORBITAL WORKSHOP
MODEL DSV7-372
A9 CONTAINER HANDLING GSE

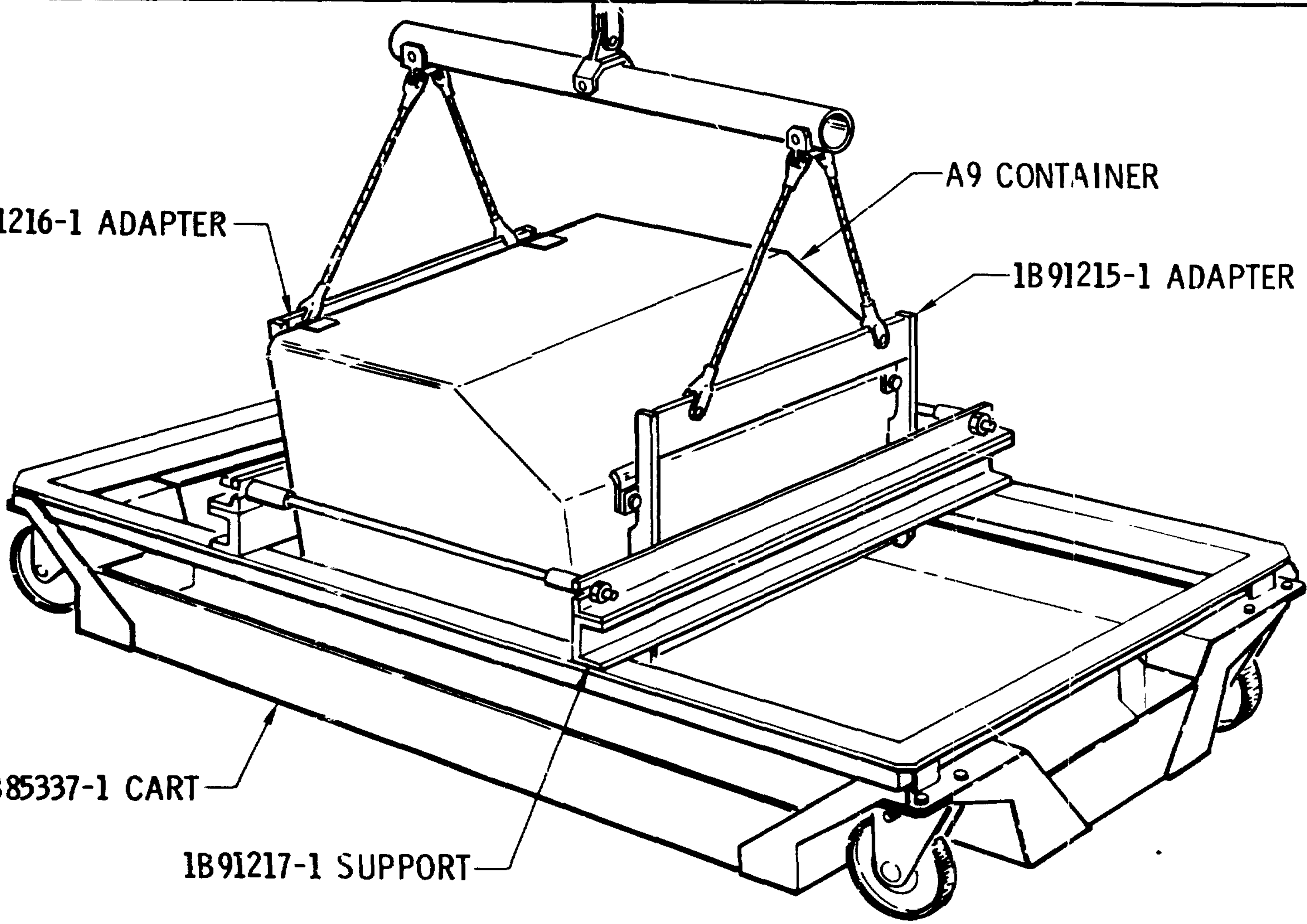


Figure 2.2.14.4-39

2.2.14.5 Meteoroid Shield Handling and Installation Equipment

A. Design Requirements

This family of kits was designed to Factors of Safety shown in Table 2.2.14.5-1.

1/ Meteoroid Shield Handling Kit (DSV7-302)

This kit was required to prevent buckling of the meteoroid shield panels during general handling and during vertical installation and to safely hold the panels in position for final alignment and adjustments. The kit also had to have the capability of mechanically deploying the shield for installation and deployment verification.

2/ Meteoroid Shield Deployment Counterbalance Kit (DSV7-371)

This kit was designed to possess the capability of preloading the meteoroid shield in the vertical direction in order to simulate a zero gravity during deployment testing.

B. System Description

1/ Meteoroid Shield Handling Kit (DSV7-302)

This kit (Drawing No. 1B68231) consisted of an aluminum welded support fixture with machined fittings to handle the meteoroid shield panels, two hoist slings, special vertical support links used for support during final alignment and installation of the shield, a rigging tool fixture assembly to aid in final rigging of the shield, a pin release system to unlatch the mechanical panel for mechanical deployment, spacers and support blocks (Figures 2.2.14.5-1, -2, -3, -4 and -5).

2/ Meteoroid Shield Deployment Counterbalance Kit (DSV7-371)

This kit (Drawing No. 1B91194) consisted of aluminum shield adapters to attach to the meteoroid shield and support the lower

TABLE 2.2.14.5-1

METEOROID SHIELD HANDLING AND INSTALLATION EQUIPMENT FACTORS OF SAFETY

OWS DSV7 KIT MODEL NUMBERS	ULTIMATE FACTOR OF SAFETY	YIELD FACTOR OF SAFETY	LIMIT LOAD FACTORS: HOISTING/GROUND TRANSPORT LONG.	LAT.	VERT.	LIMIT LOAD FACTORS: SUDDEN MANLOADS LONG.	LAT.	VERT.	ULTIMATE HOIST LOAD	ULTIMATE MANLOAD [MAN WEIGHT = 250 LBS (113.4 kg)]
-302	1.5	1.0			-3.0 G's (Down)				Wt. of Kit x 3.0 L.F. x 1.5 ult. F.S. = 4.5 x Ult. weight	
-371	1.5	1.0	(a) Springs in cable assembly						Meteoroid Panel Weight x 2.0 L.F. x 1.5 Ult. F.S.= 3.0 x weight	
			0	0	-1.0 (Down)					
			0	0	-2.00 (Down)					

SKYLAB - ORBITAL WORKSHOP

METEOROID SHIELD HANDLING KIT - DSV7-302

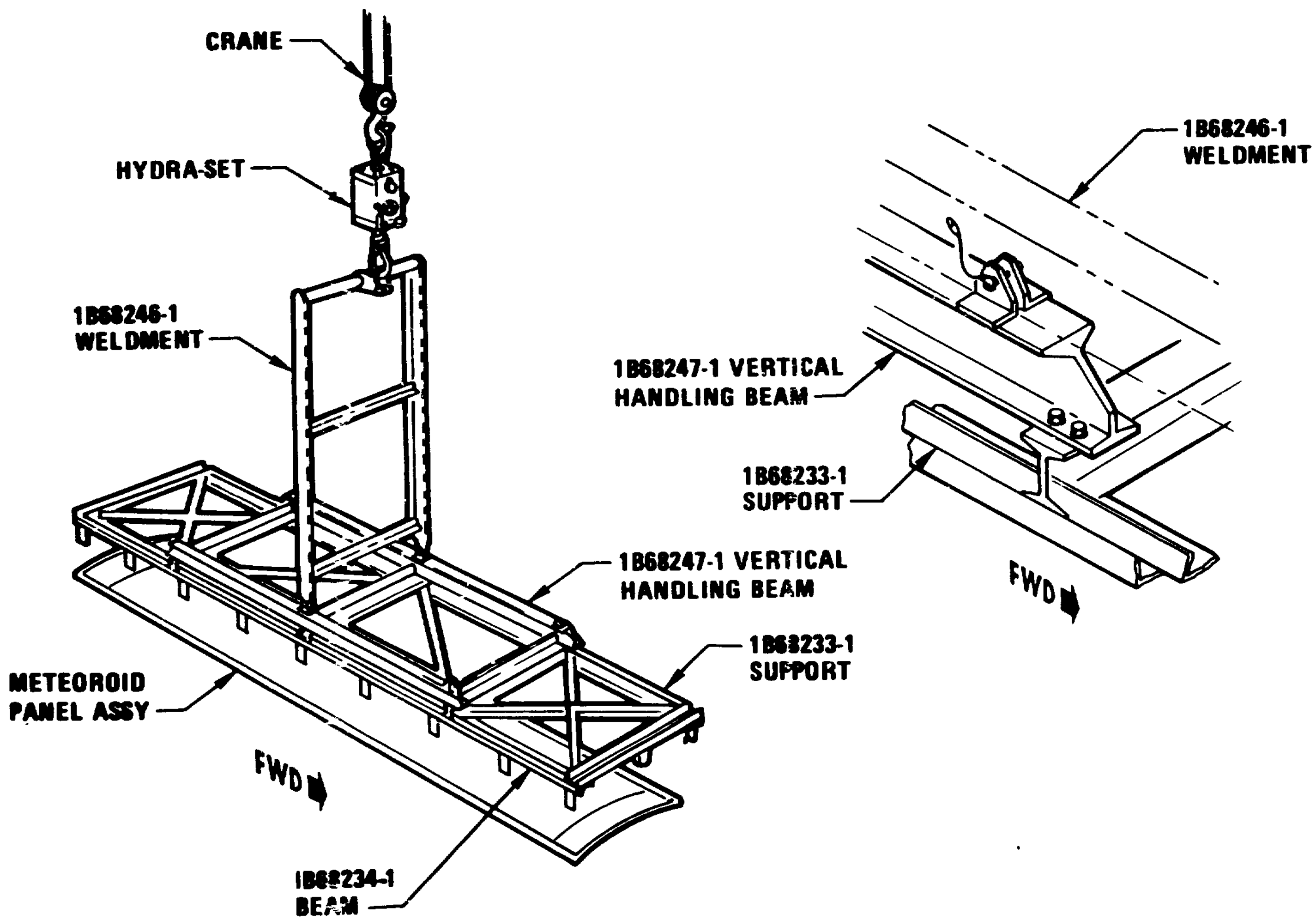


Figure 2.2.14.5-1

SKYLAB - ORBITAL WORKSHOP
METEOROID SHIELD HANDLING KIT
DSV7-302

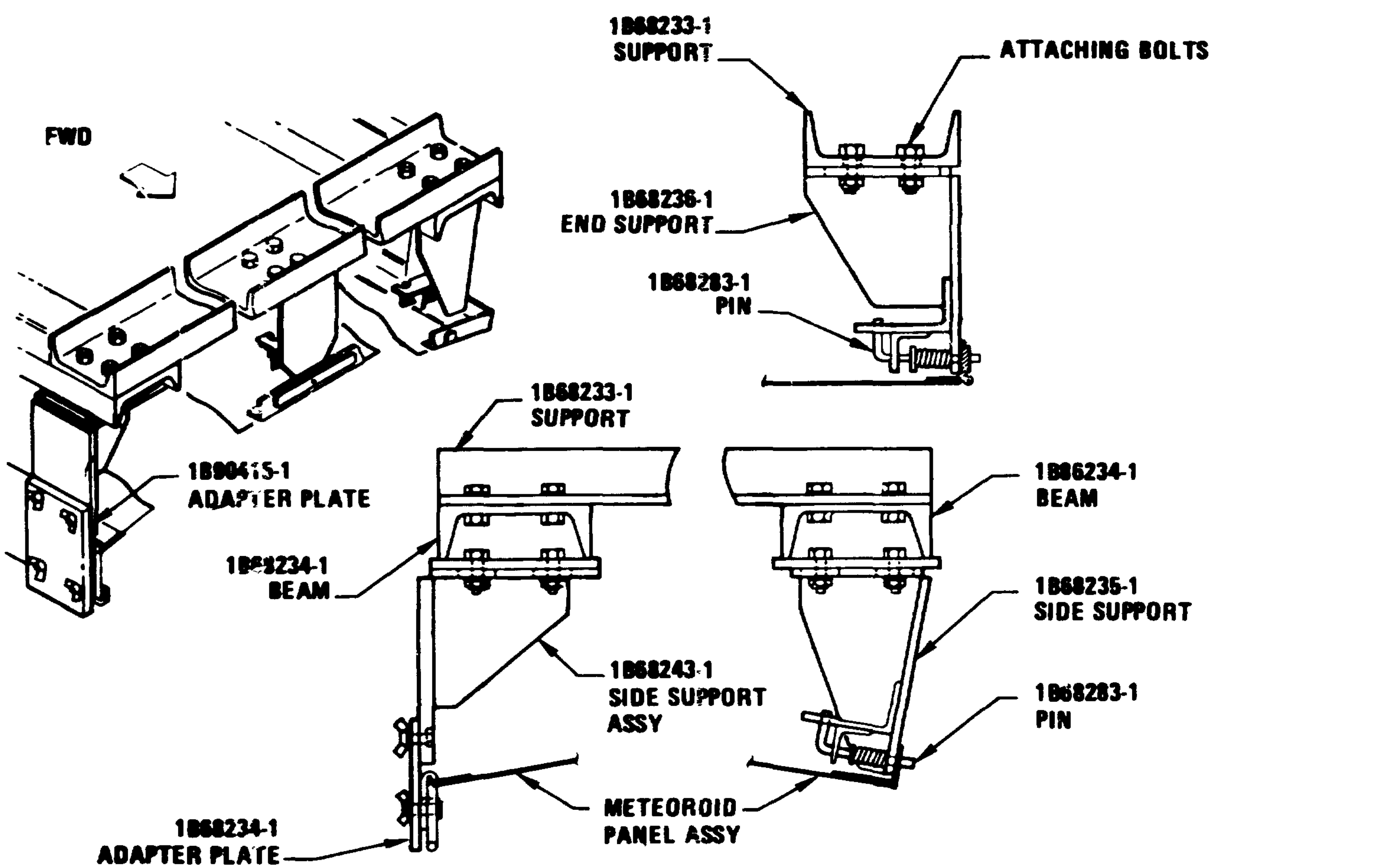


Figure 2.2.14.5-2

SKYLAB - ORBITAL WORKSHOP
METEOROID SHIELD HANDLING FIXTURE

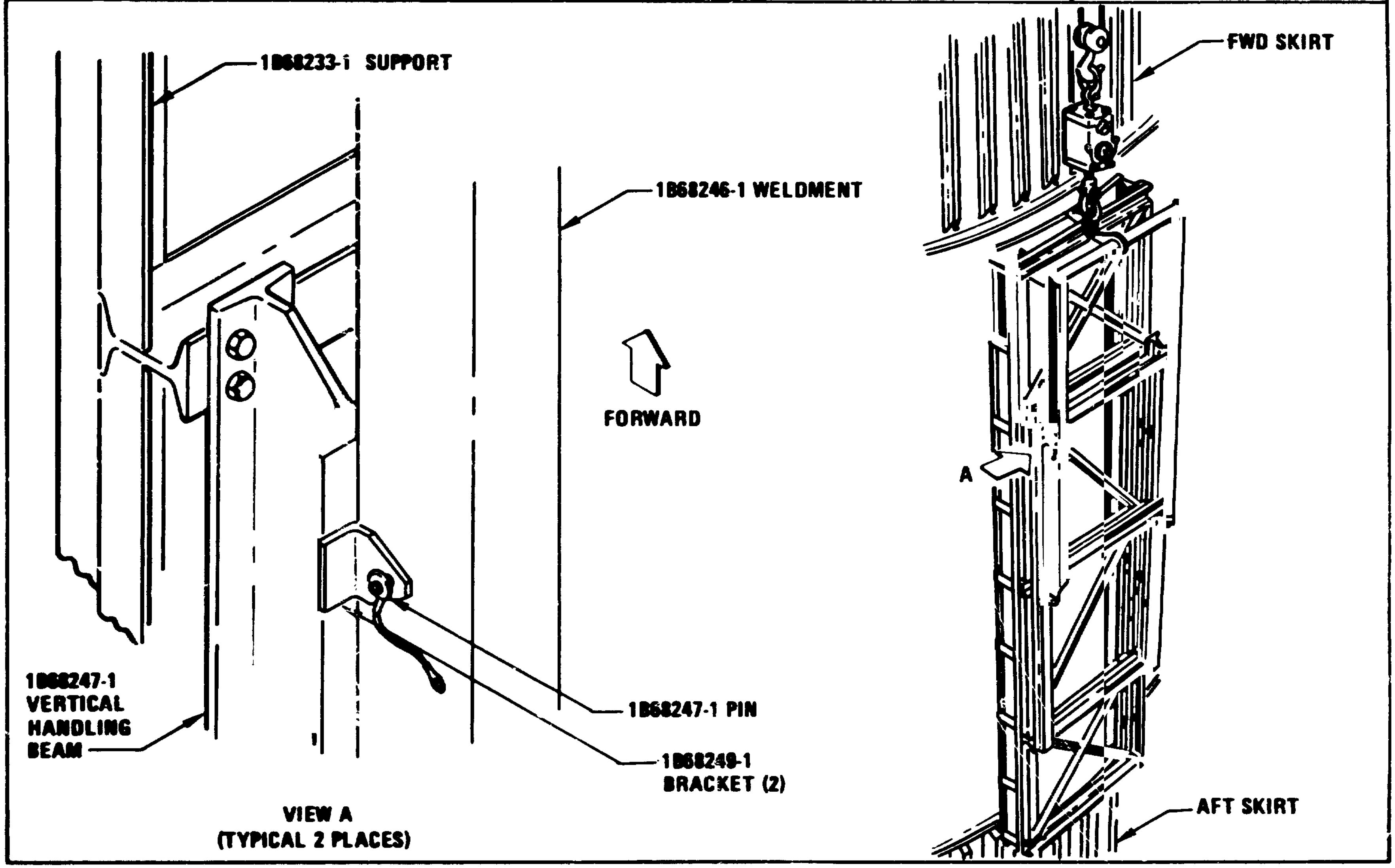


Figure 2.2.14.5-3

SKYLAB - ORBITAL WORKSHOP
METEOROID SHIELD GSE HARDWARE FOR INSTL

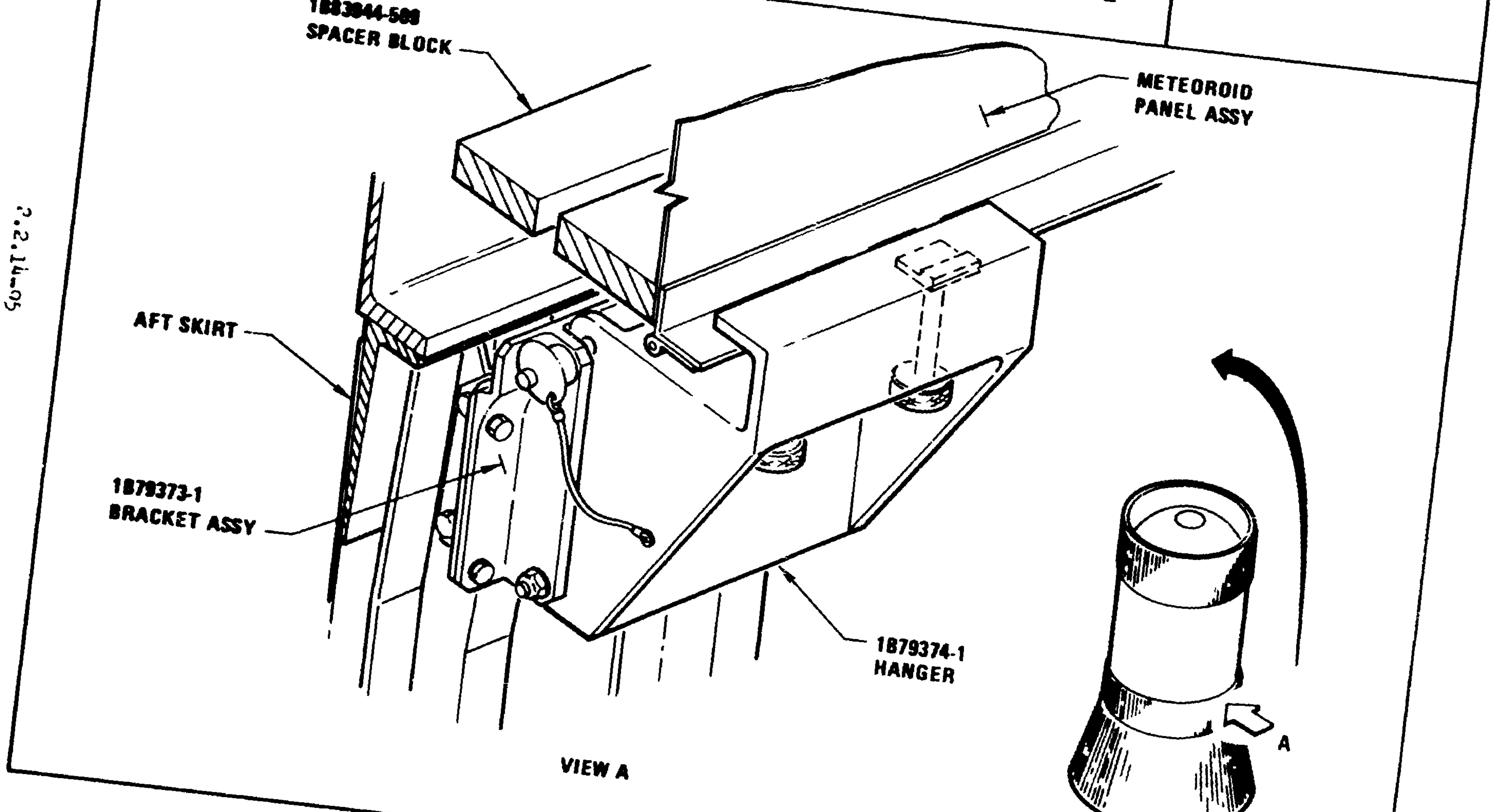


Figure 2.2.14.5-4

SKYLAB - ORBITAL WORKSHOP

HOIST AND RIGGING FIXTURE ASSEMBLY

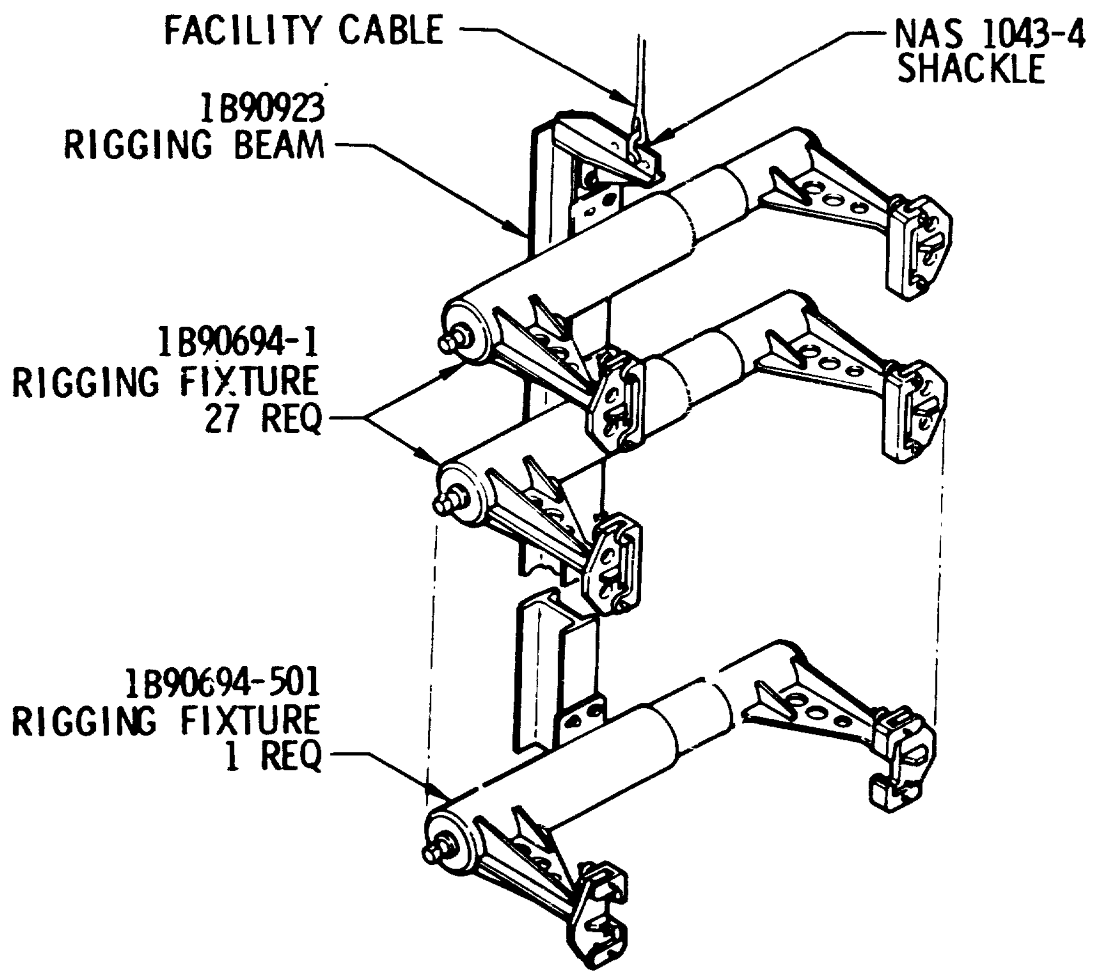


Figure 2.2.14.5-5

ends of the cable assemblies, machined aluminum adapter clamps to attach to the forward support ring to support the upper ends of the cable assemblies, steel cable assemblies with springs and turnbuckles to carry the weight of the meteoroid shield, machined steel arm assemblies for use during shield deployment and machined aluminum fittings with ball bearings to provide support for the idler arms. (Figure 2.2.14.5-6).

C. Testing

There was no testing program on this system.

D. Conclusions and Recommendations

The OWS Meteoroid Shield Handling and Installation System performed per the requirements. The early designed Model DSV-302 Meteoroid Shield Handling Kit and the later designed Model DSV7-371 Meteoroid Shield Deployment Counterbalance Kit had to be used in conjunction with each other in actual practice.

SKYLAB - ORBITAL WORKSHOP
MODEL DSV7-371
METEOROID SHIELD COUNTER BALANCE KIT

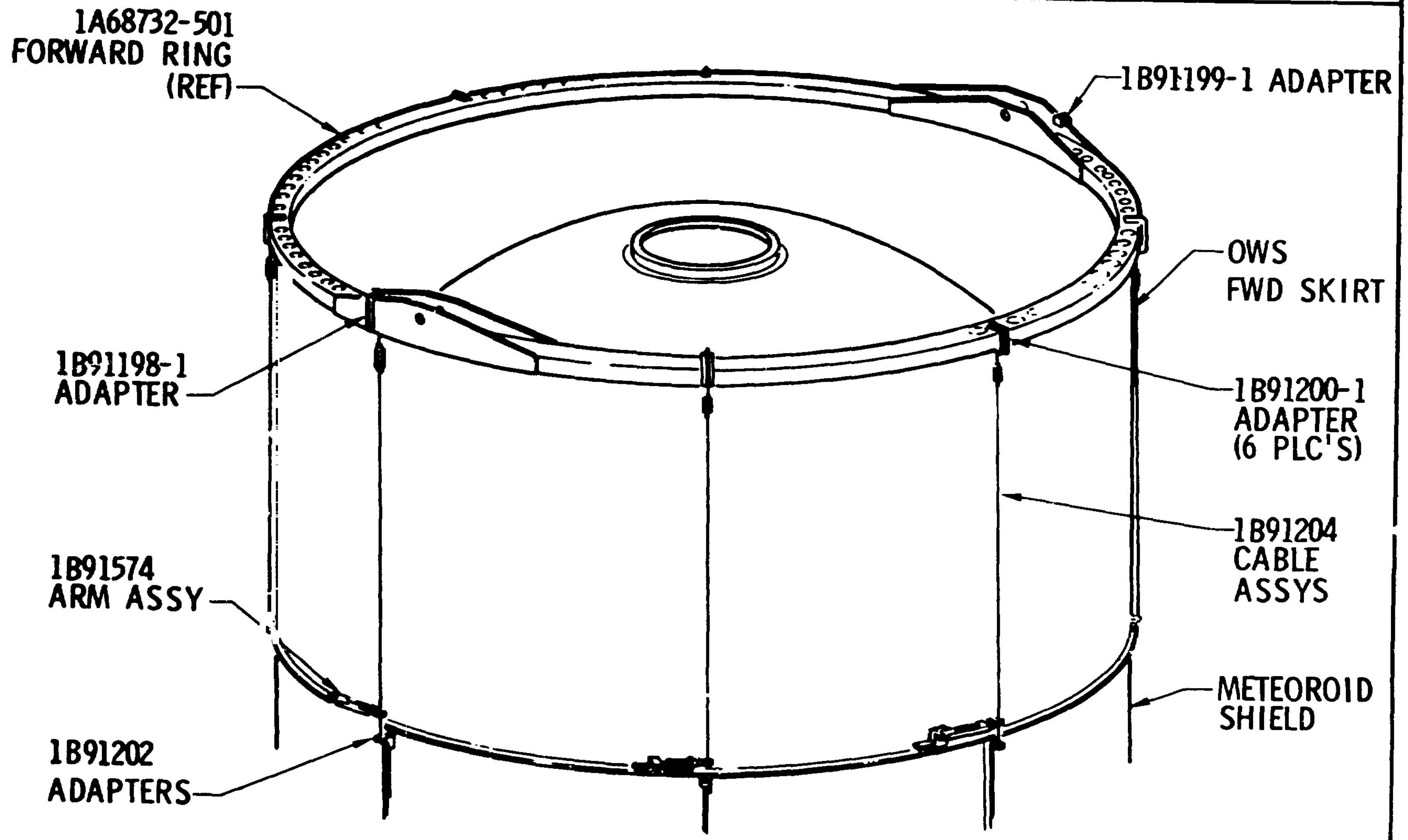


FIGURE 2.2.14.5-6

2.2.14.6 OWS Access Equipment

A. Design Requirements

This family of kits was designed to Factors of Safety shown in Table 2.2.14.6-1.

1/ OWS Crew Quarters Vertical Access Kit (DSV7-303)

This kit was required to provide personnel access to areas within the forward compartment, the crew quarters and the aft compartment while the OWS is in the vertical position. The kit was used in conjunction with the Habitability Support System (HSS) Equipment Handling Kit (DSV7-311) for removal and installation of equipment within these OWS compartments. The kit also provided a means for emergency egress from the forward compartment when the Airlock Module was not joined to the OWS. The access platform assembly was required to be capable of 360° of rotation in order to install equipment in all quadrants of the vehicle. The capacity of the platform was to be 1350 lbs (612 kg) with a maximum limit of three persons permitted at any one time. Kit components were to meet MSFC-STD-101 flammability requirements and 100,000 class clean room requirements. The kit components had to be small enough to be carried through the side access opening. Access was to be provided into the plenum area and to provide secondary emergency egress through the reusable forward hatch when this kit was in use.

2/ LH_2 Tank Dome Protective Cover and Access Kit (DSV7-307)

This kit was designed to be used in conjunction with the Forward Skirt Vertical Access Kit (DSV7-328) to provide a means of protecting the OWS habitation area forward dome and to provide limited access to those components on the dome that are not accessible from the vertical access kit.

TABLE 2.2.14.6-1

ACCESS KITS FACTORS OF SAFETY

OWS DSV7 KIT MODEL NUMBERS	ULTIMATE FACTOR OF SAFETY	YIELD FACTOR OF SAFETY	LIMIT LOAD FACTORS: HOISTING			LIMIT LOAD FACTORS MEN SUDDEN			ULTIMATE HOIST LOAD	ULTIMATE MANLOAD [MAN WEIGHT - 250 LBS (113.4 kg)]
			LONG.	LAT.	VERT.	LONG.	LAT.	VERT.		
-303	1.5	1.0	0.0	0.0	-3.00	0.0	0.0	-2.0	Weight x 3.0 L.F. x 1.5 ult. F.S. = 4.5 x weight	Man Wt. x 2.0 L.F. x 1.5 ult. F.S. = 3.0 x Man Weight [250 lbs (113.4 kg)]
-307	1.5	1.0	0.0	0.0	-3.33					Man Wt. x 3.33 x 1.5 = 250 x 3.33 x 1.5 = 1250 lbs
-311	1.5	1.0	0.0	0.0	-3.0				Wt. x 3.0 L.F. x 1.5 ult. F.S. = 4.5 x Weight	(576 kg)
-317	1.5	1.0	2.0	2.0	2.0				Wt. x 2.0 L.F. x 1.5 ult. F.S. 3.0 x Weight.	
-326	1.5	1.0	0	0	-2.0					Man Wt. x 2.0 L.F. x 1.5 U.F.S. = Man Wt. x 3.0
-328	1.5	1.0				0.0	0.0	-2.0		Man Wt. x 2.0 L.F. x 1.5 Ult. F.S. = 3.0 x Man Wt.

*(+) Sign indicates aft, port and up.
(-) Sign indicates forward, starboard and down.

3/ Habitability Support System (HSS) Equipment Handling Kit (DSV7-311)

This kit was required in conjunction with the Vertical (OWS) Crew Quarters Access Kit (DSV7-303), to provide a means for handling the HSS equipment during installation in the OWS vertical position. This kit was also required for handling the HSS equipment for shipment and during system test. Items of HSS equipment required to be installed in the OWS by this kit were the food containers, urine container, storage containers, water containers, portable water container and film vault drawer. GFR OWS experiments were also to be handled. All kit components were to be capable of being hand carried into the OWS through the side access opening and through the forward compartment floor access opening Trackage of this design was to interface with the dolly track threshold of Model DSV7-317.

4/ Transportation Hatch Kit (DSV7-317)

This kit was designed to provide a means of covering the opening in the side of the habitation area during transportation, handling and checkout of the OWS, to provide a means of attaching the Clean Room (DSV7-309) to the side of the OWS and retain the structural integrity of the habitation area wall when the flight hatch is not in place and to provide an electrical feed-through for activating the Metabolic Analyzer when the side access hatch is installed.

5/ Vertical Flared Aft Interstage Kit (DSV7-326)

This kit was required to provide personnel access to the interior of the aft section of the OWS and flared aft interstage while in an upright position to accomplish the tasks of checkout, inspection and maintenance.

6/ Forward Skirt Vertical Access Kit (DSV7-328)

This kit was designed to provide access to the interior of the forward skirt and the instrument unit (I.U.) to accomplish checkout, inspection and maintenance, and to provide a suitable tracking rail for IBM's I.U. dolly. This kit was also to be used in conjunction with Model DSV7-307 OWS Upper Dome Protective Cover/Access Kit.

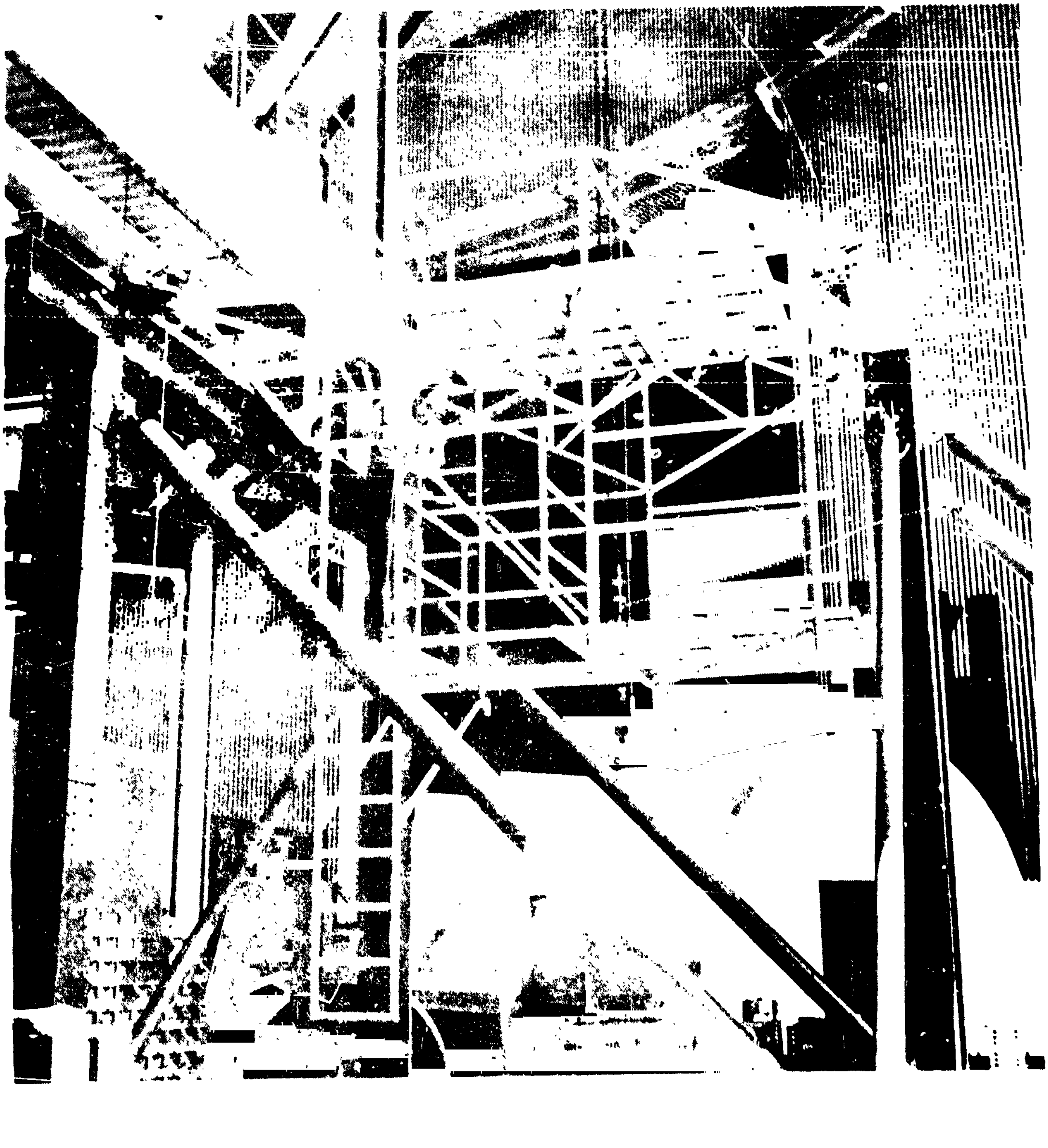
B. System Description

1/ OWS Crew Quarters Vertical Access Kit (DSV7-303)

This kit (Drawing No. 1B73900) consists of an aluminum tubular access platform assembly with removable aluminum platform segments installed such that the rollers on the supporting framework rest on the stowage container support rail with all subassemblies fastened together with tethered quick release pins, three aluminum tubular portable access stands used to install and/or remove the access platform assembly inside the OWS, aluminum protective floor plates with polyurethane pads on the bottom surfaces, aluminum tubular guard rails and ladders, crotch access platforms covered with glass fiber cloth with a polyurethane foam core to be used in the plenum area and sling assemblies (Figures 2.2.14.6-1, -2, -3, -4, -5, -6, -7, -8, and -9).

2/ LH_2 Tank Dome Protective Cover and Access Kit (DSV7-307)

This kit (Drawing No. 1B78743) consisted of eighteen aluminum sheet and tubing platform assemblies serving as a work platform for men working on the forward dome as well as a protective cover from dropped objects and ten aluminum protective covers to protect feed-through receptacles, the electrical panel and the reusable forward hatch area (Figures 2.2.14.6-10, -11, -12, -13, -14 &-15)



SKYLAB - ORBITAL WORKSHOP
VERTICAL CREW QUARTERS
ACCESS KIT MODEL DSV7-303

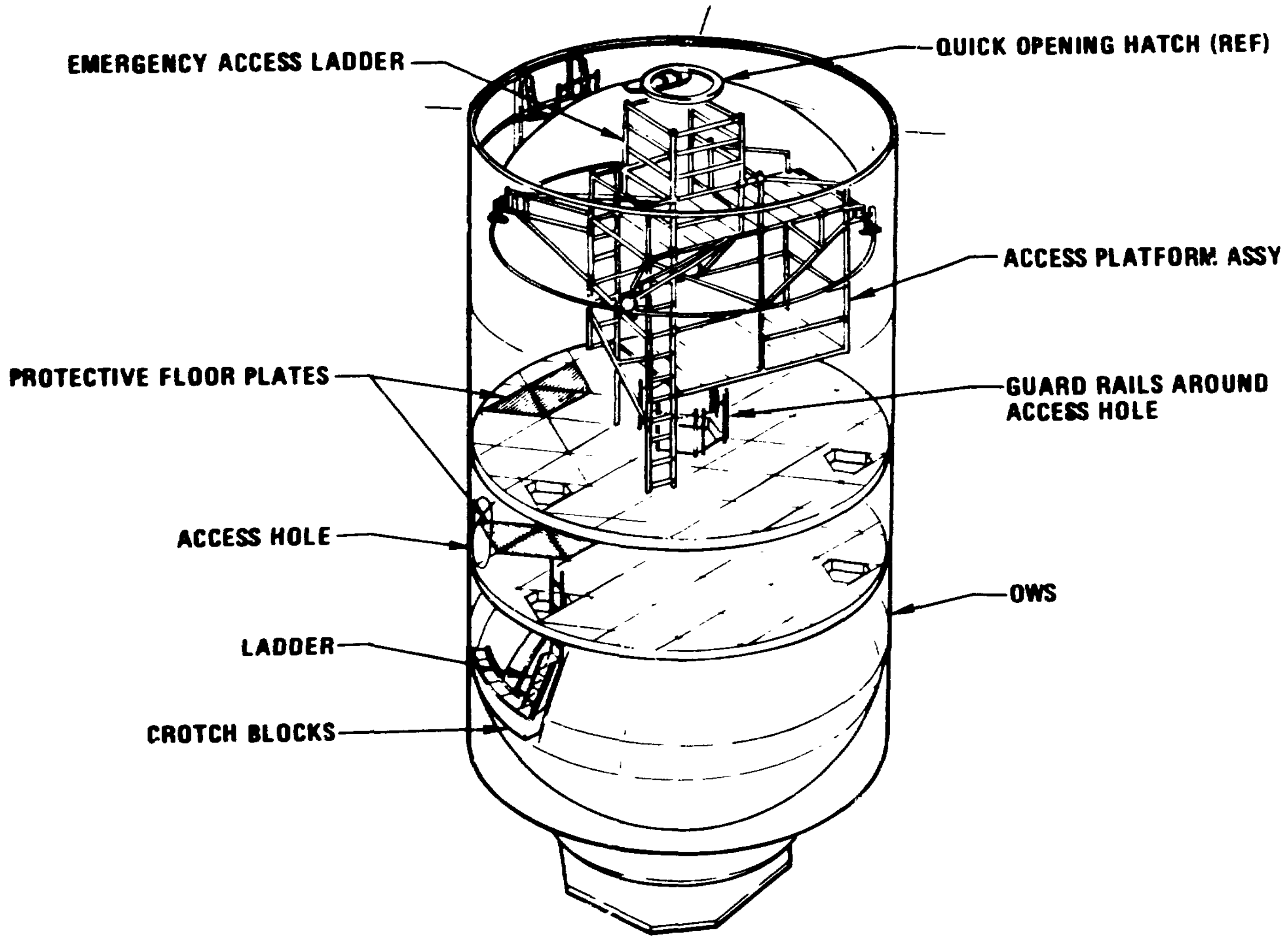


Figure 2.2.14.6-2

SKYLAB - ORBITAL WORKSHOP
ACCESS PLATFORM ASSEMBLY

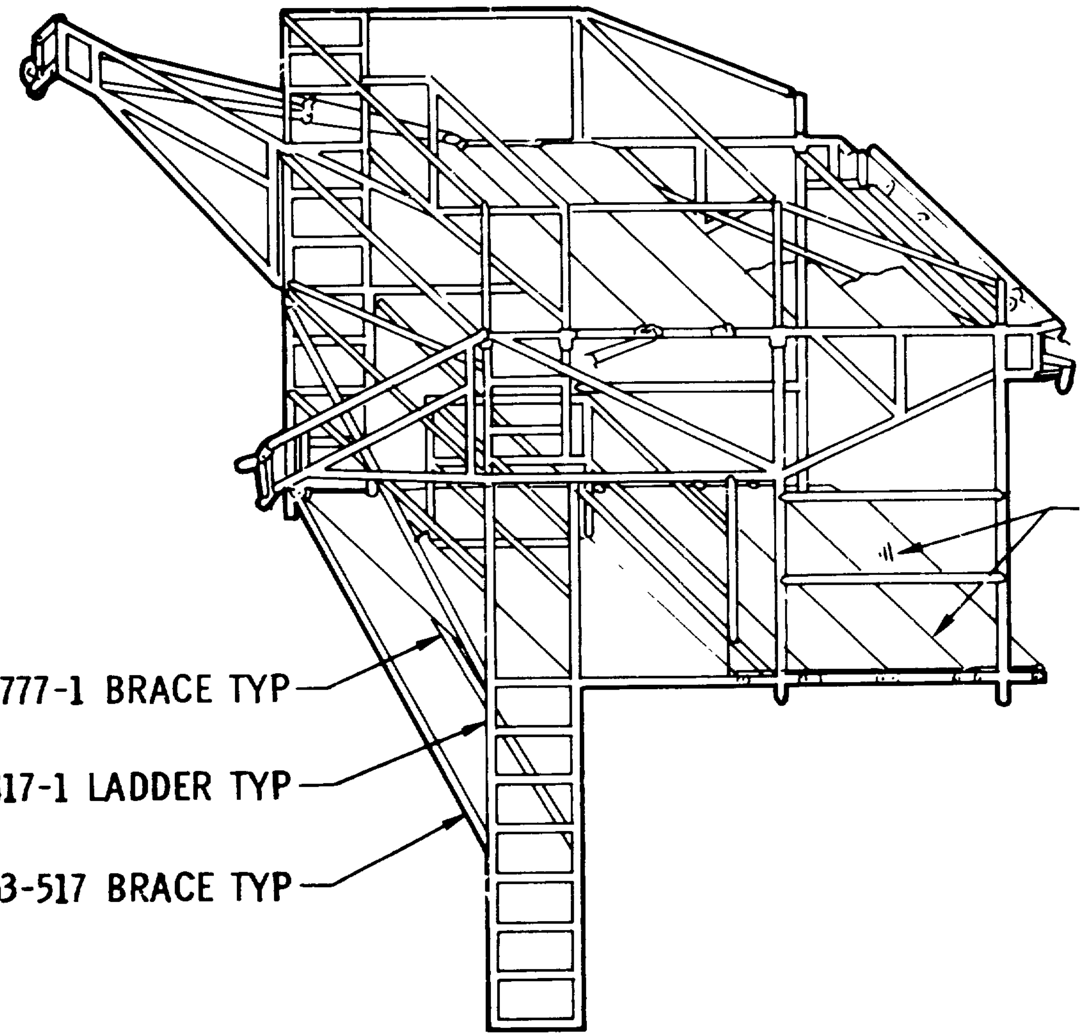


Figure 2.2.14.6-3

SKYLAB - ORBITAL WORKSHOP ACCESS PLATFORM TO SUPPORT RAIL (ROLLING POSITION)

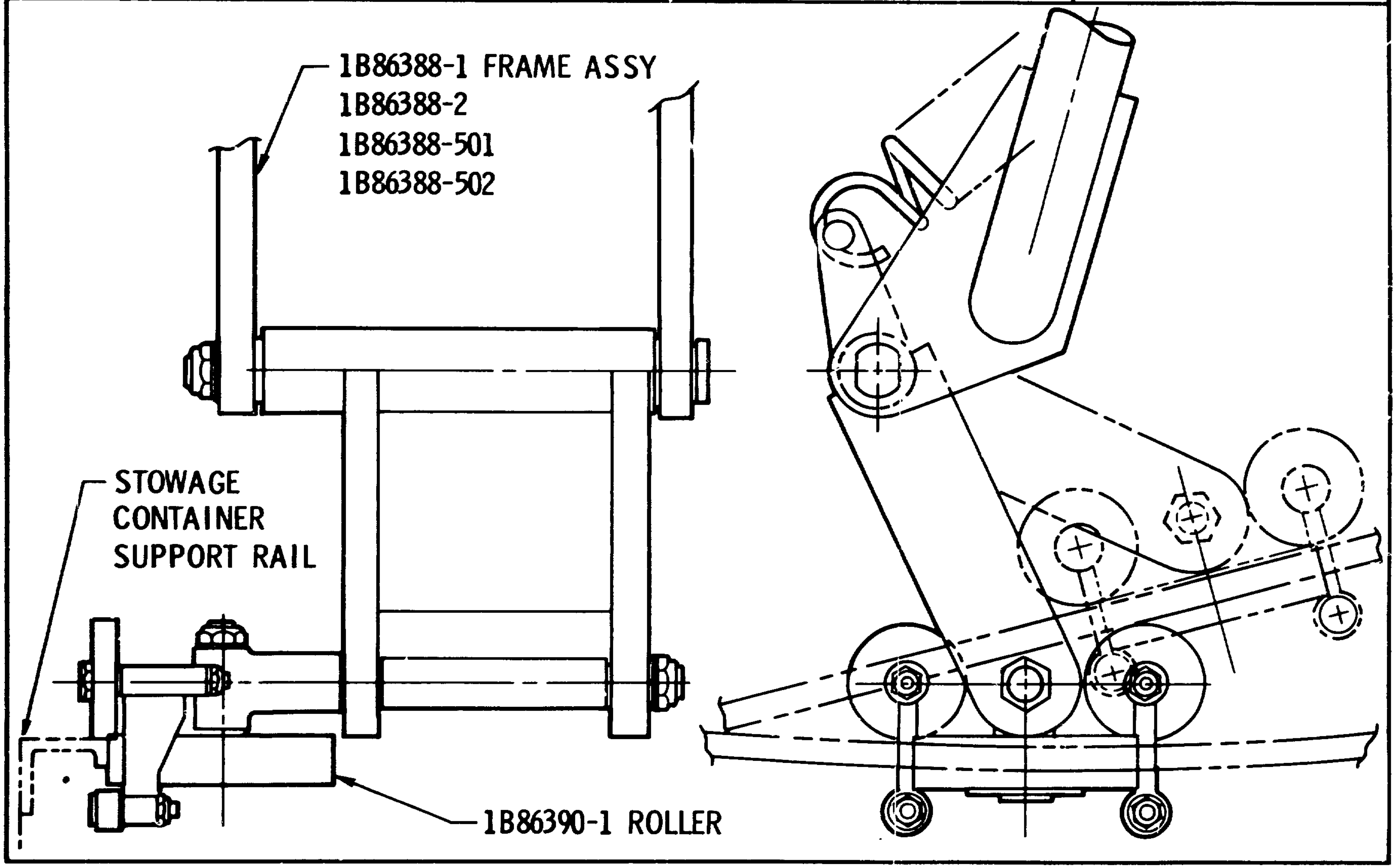


Figure 2.2.14.6-4

SKYLAB - ORBITAL WORKSHOP
ACCESS PLATFORM TO SUPPORT RAIL
(LOCKED/UNLOCKED POSITION)

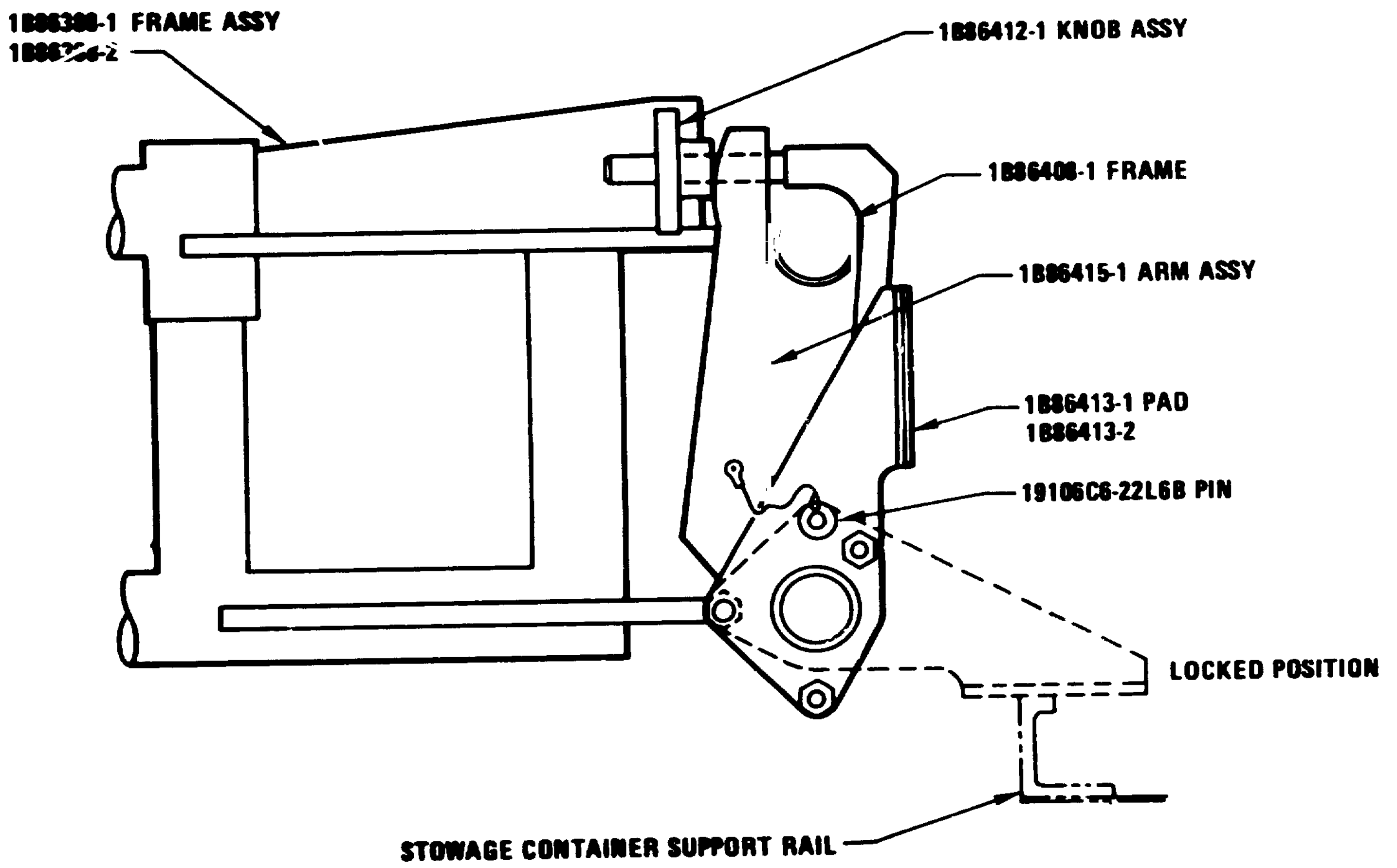


Figure 2.2.14.6-5

SKYLAB - ORBITAL WORKSHOP
ACCESS STANDS FOR INSTALLATION OF KIT

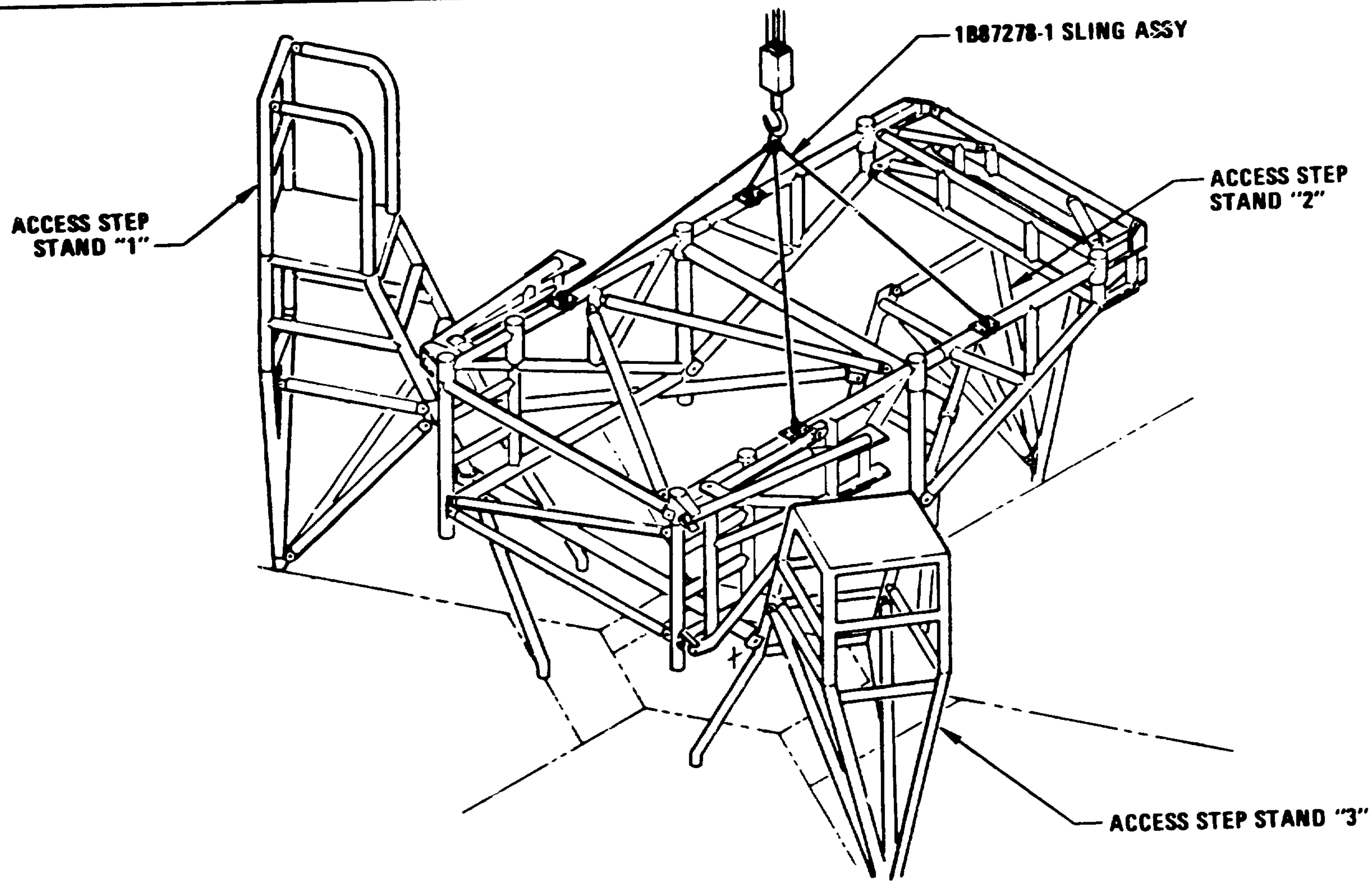


Figure 2.2.14.6-6

SKYLAB - ORBITAL WORKSHOP
CREW QUARTERS ACCESS KIT
MODEL DSV7-303

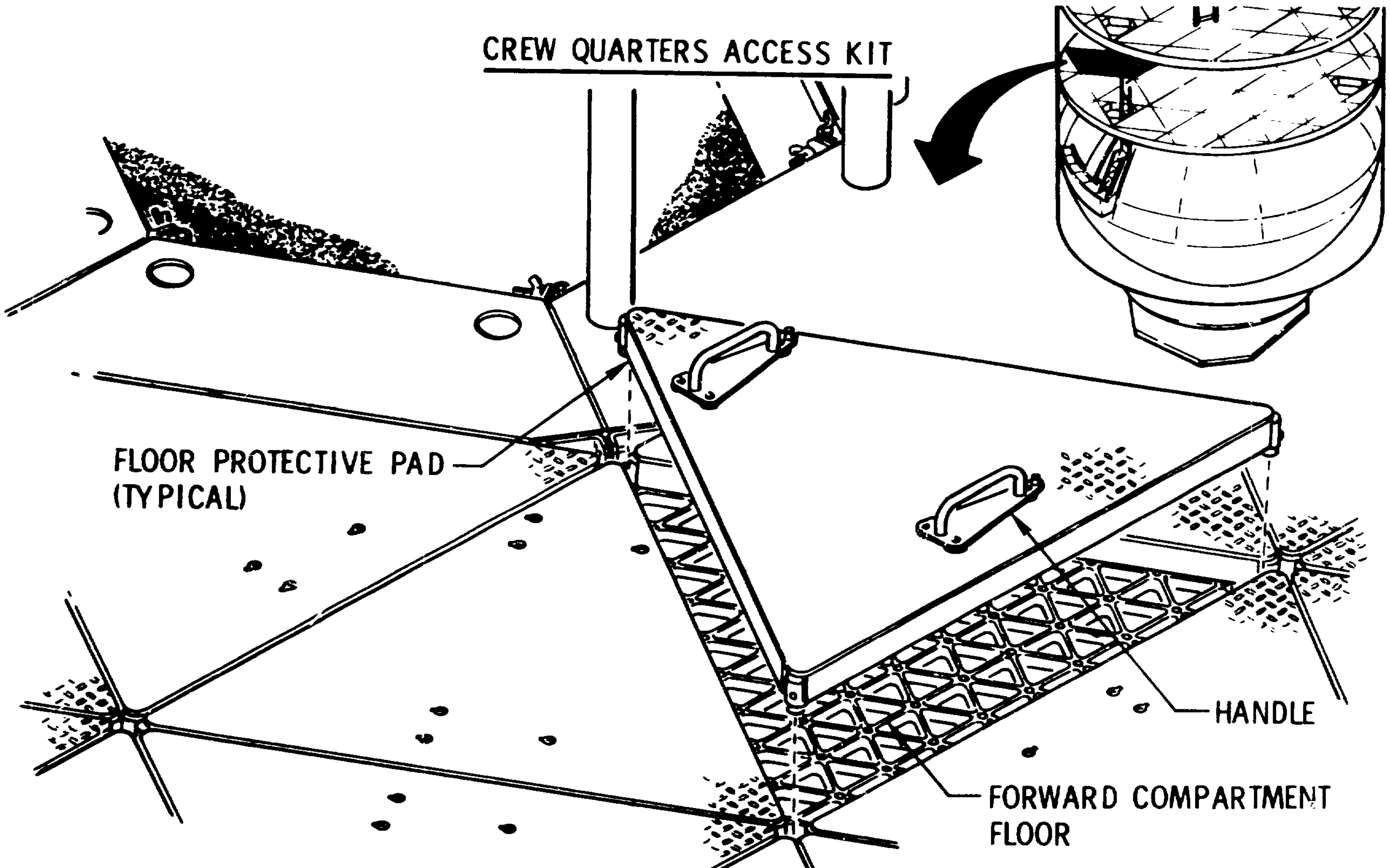


Figure 2.2.14.6-7

SKYLAB - ORBITAL WORKSHOP
CREW QUARTERS FLOOR PLATES
DSV7-303 INSTALLED

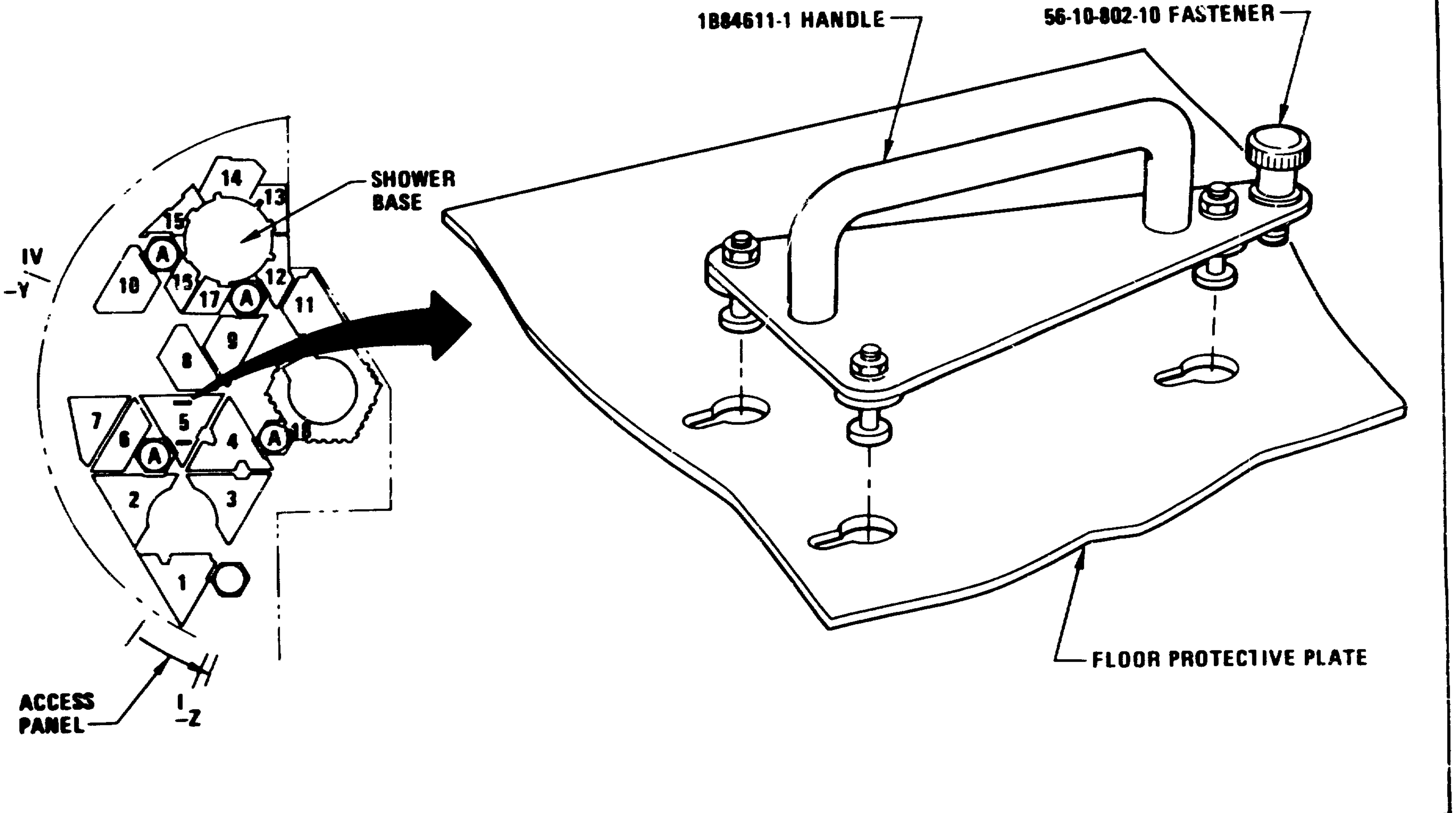


Figure 2.2.14.6-8

SKYLAB - ORBITAL WORKSHOP
PLENUM AREA ACCESS EQUIPMENT

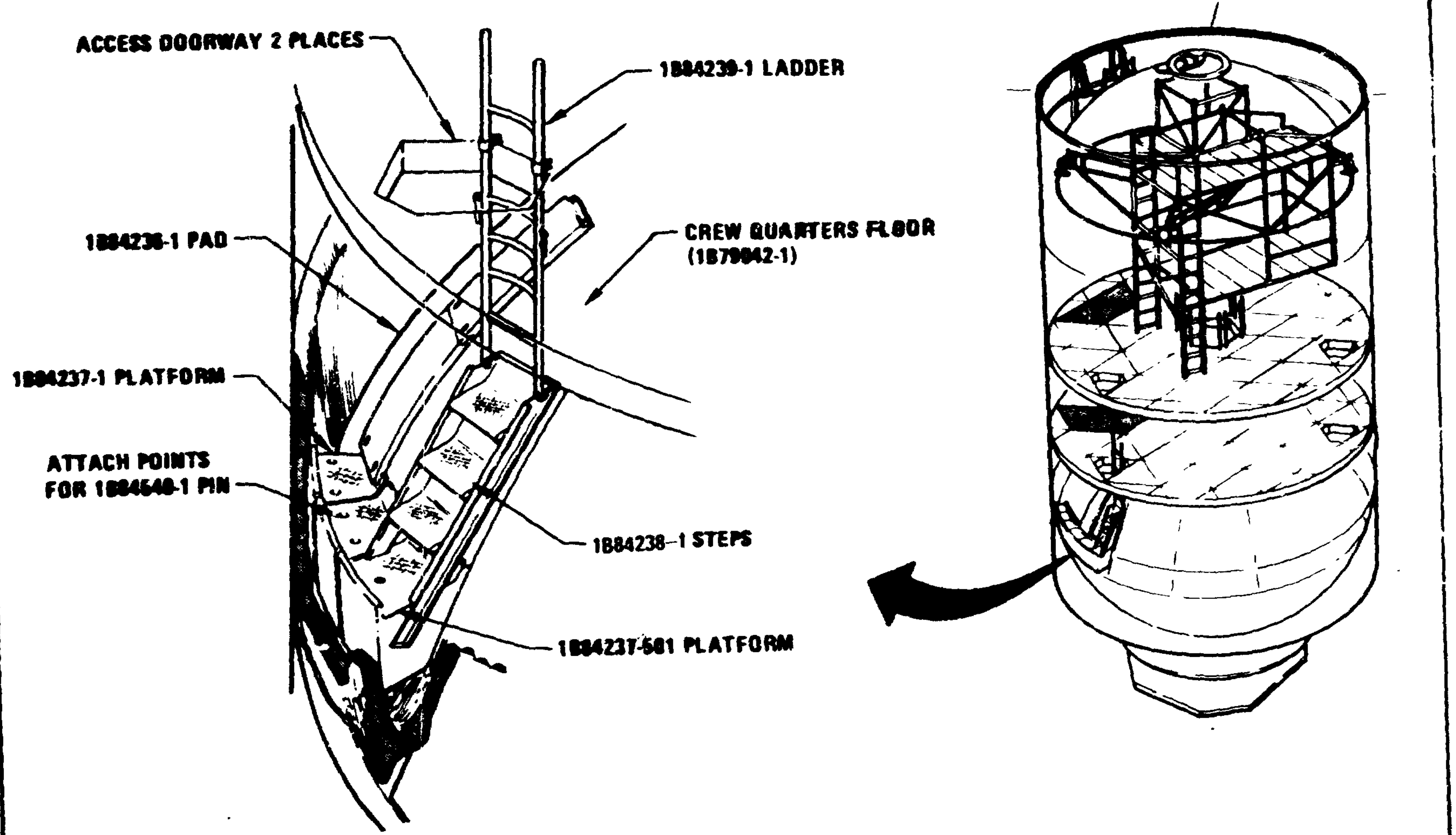


Figure 2.2.14.6-9

SKYLAB - ORBITAL WORKSHOP
MODEL DSV7-307 UPPER DOME PROTECTIVE COVER/ACCESS KIT

KEY:

1	1B84644-1 PLATFORM ASSY
2	1B84644-501 PLATFORM ASSY
3	1B84644-503 PLATFORM ASSY
4	1B84644-505 PLATFORM ASSY
5	1B84644-507 PLATFORM ASSY
6	1B84644-509 PLATFORM ASSY
7	1B84644-511 PLATFORM ASSY
8	1B85504-1 COVER
9	1B85505-1 COVER
10	1B85505-501 COVER
11	1B85506-1 COVER
12	1B85507-1 COVER
13	1B85508-1 COVER
14	1B85508-501 COVER
15	1B85509-1 COVER
16	1B85383-1 COVER
17	1B85244-1 COVER

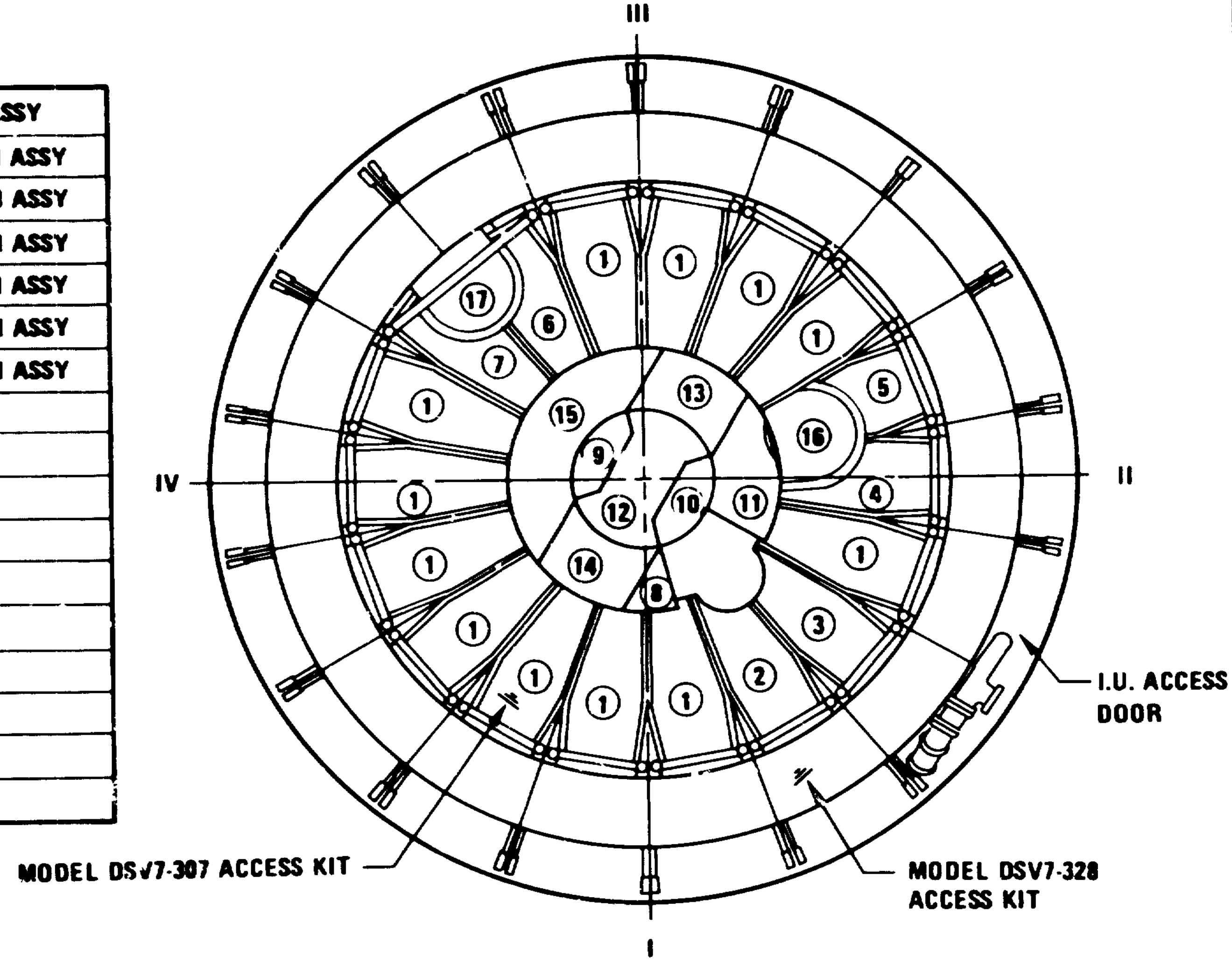


Figure 2.2.14.6-10

SKYLAB - ORBITAL WORKSHOP
DOME PROTECTIVE COVER/ACCESS KIT
& FWD SKIRT ACCESS KIT

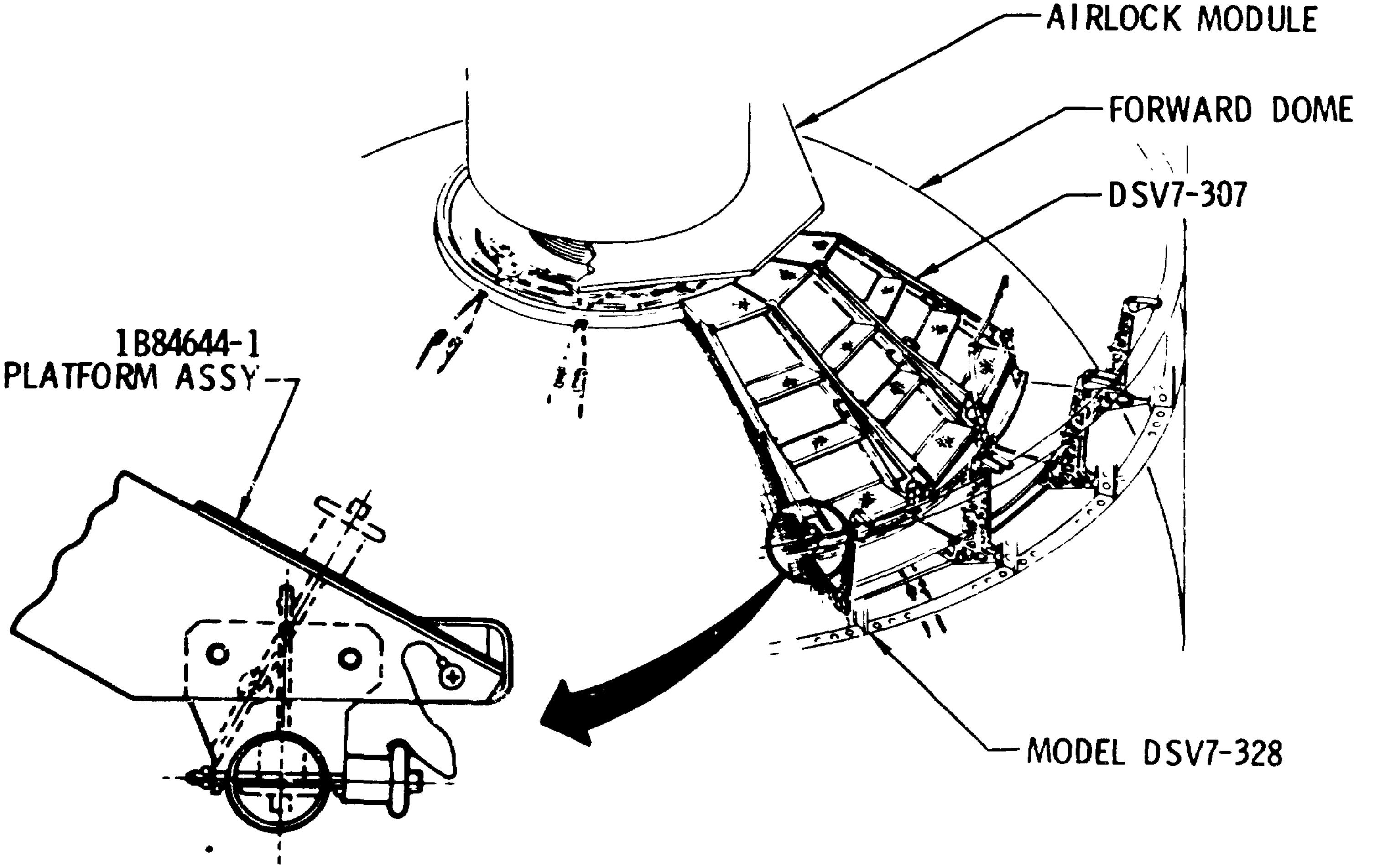


Figure 2.2.14.6-11

SKYLAB - ORBITAL WORKSHOP
LH_2 TANK DOME PROTECTIVE COVER/ACCESS
& FWD SKIRT ACCESS KIT

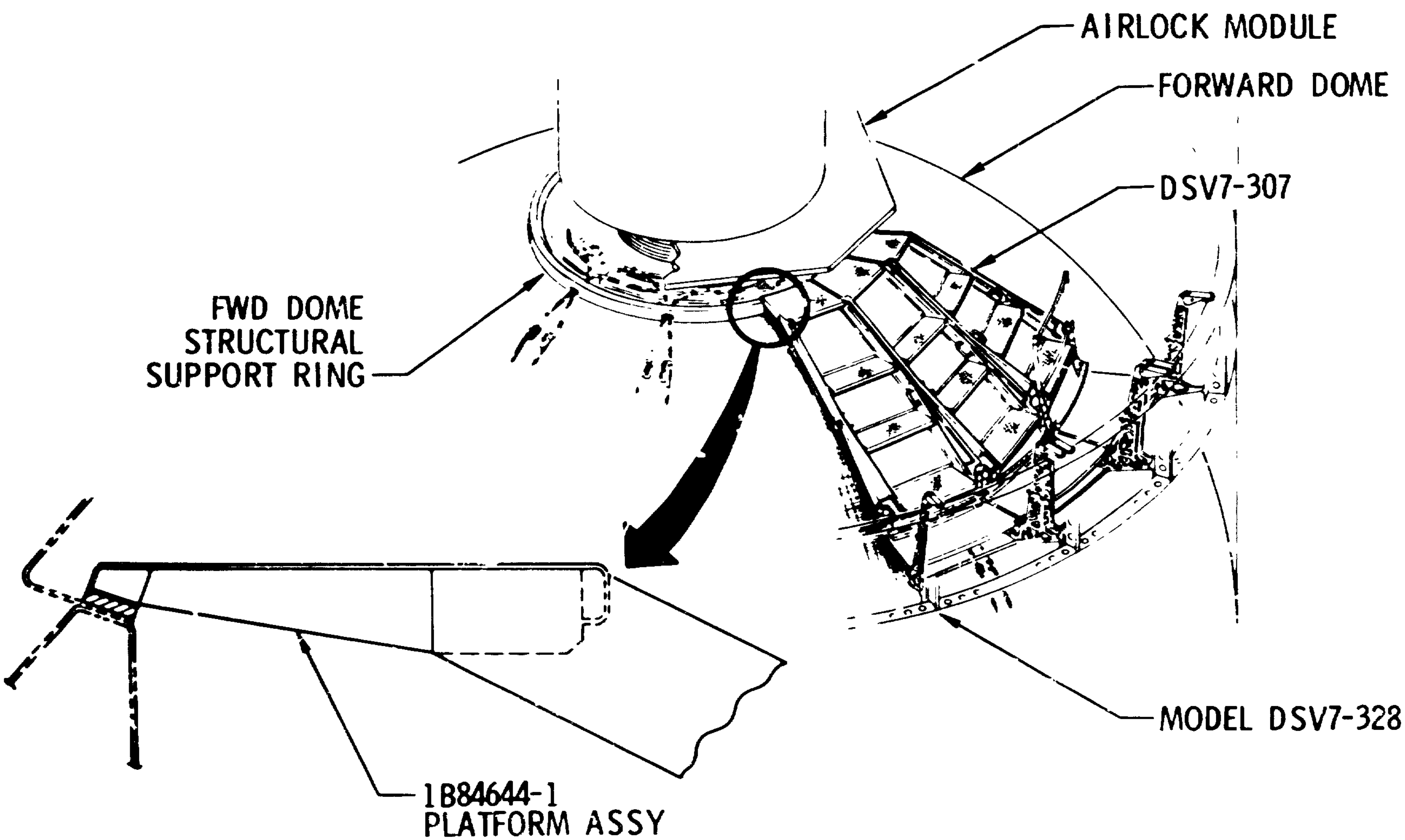


Figure 2.2.14.6-12

SKYLAB - ORBITAL WORKSHOP

LH_2 TANK DOME PROTECTIVE COVER AND ACCESS KIT

MODEL DSV7-307

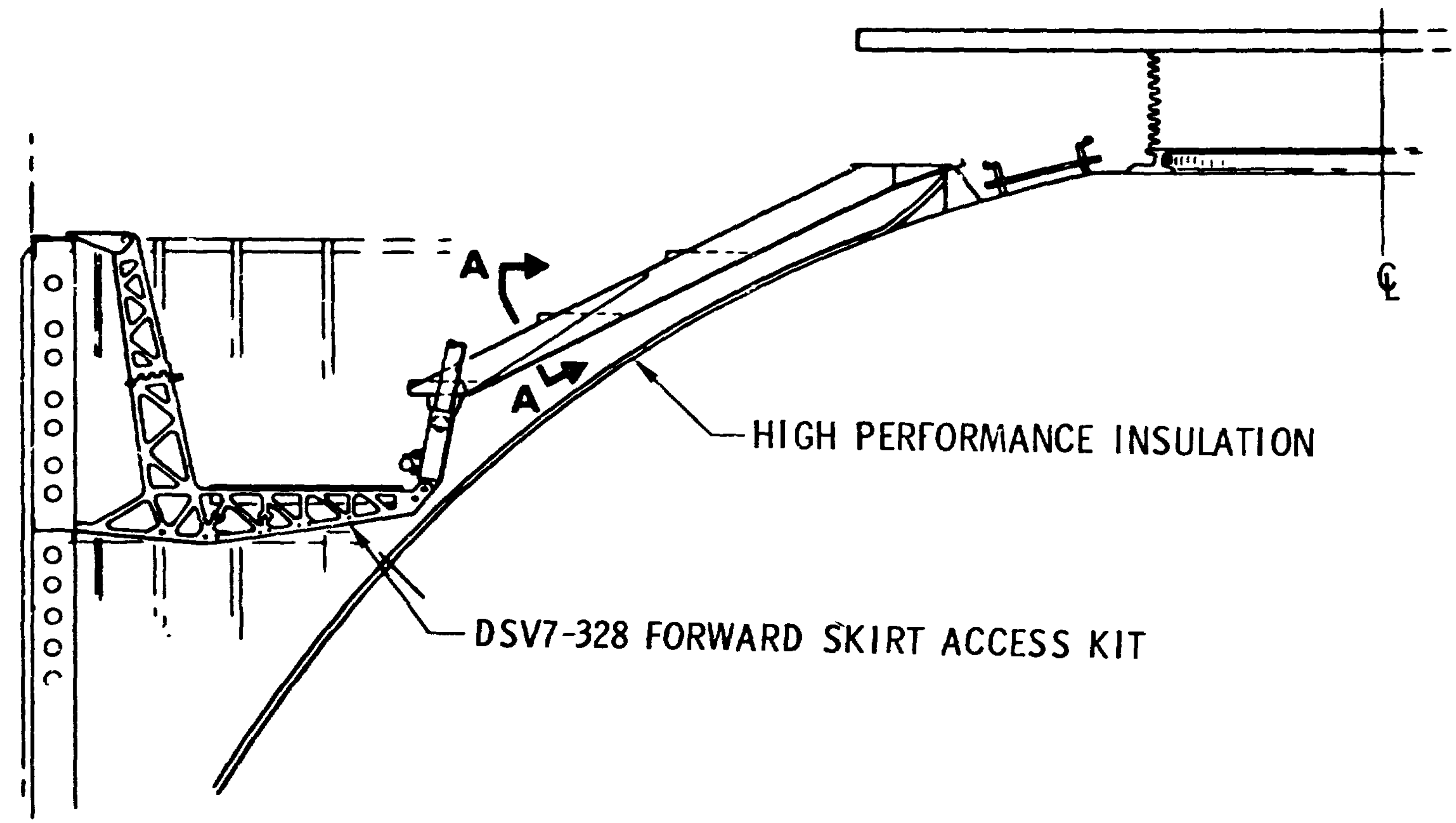


Figure 2.2.14.6-13

SKYLAB - ORBITAL WORKSHOP
LH_2 TANK DOME PROTECTIVE COVER & ACCESS KIT
MODEL DSV7-307

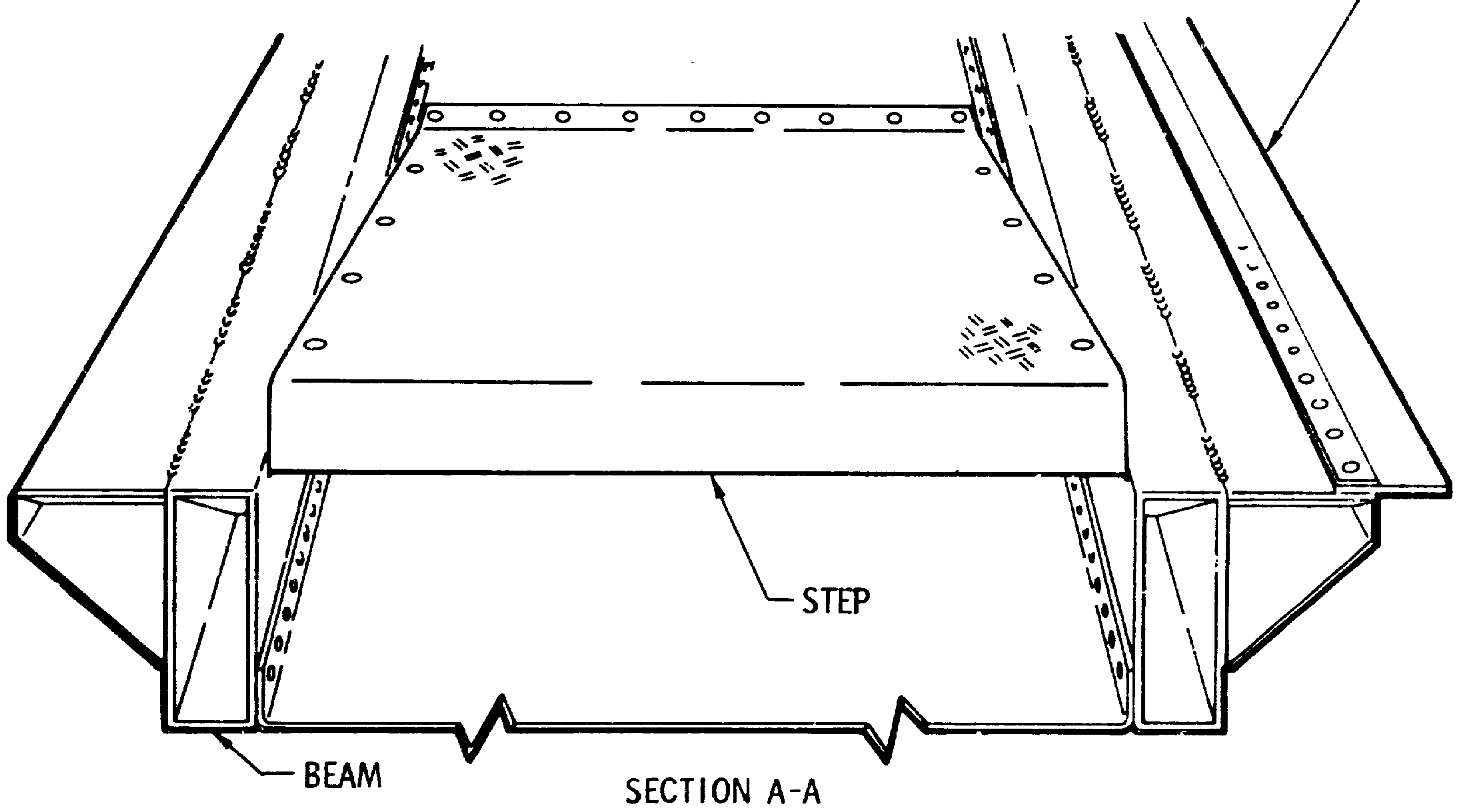


Figure 2.2.14.6-14

SKYLAB - ORBITAL WORKSHOP
PROTECTIVE COVERS

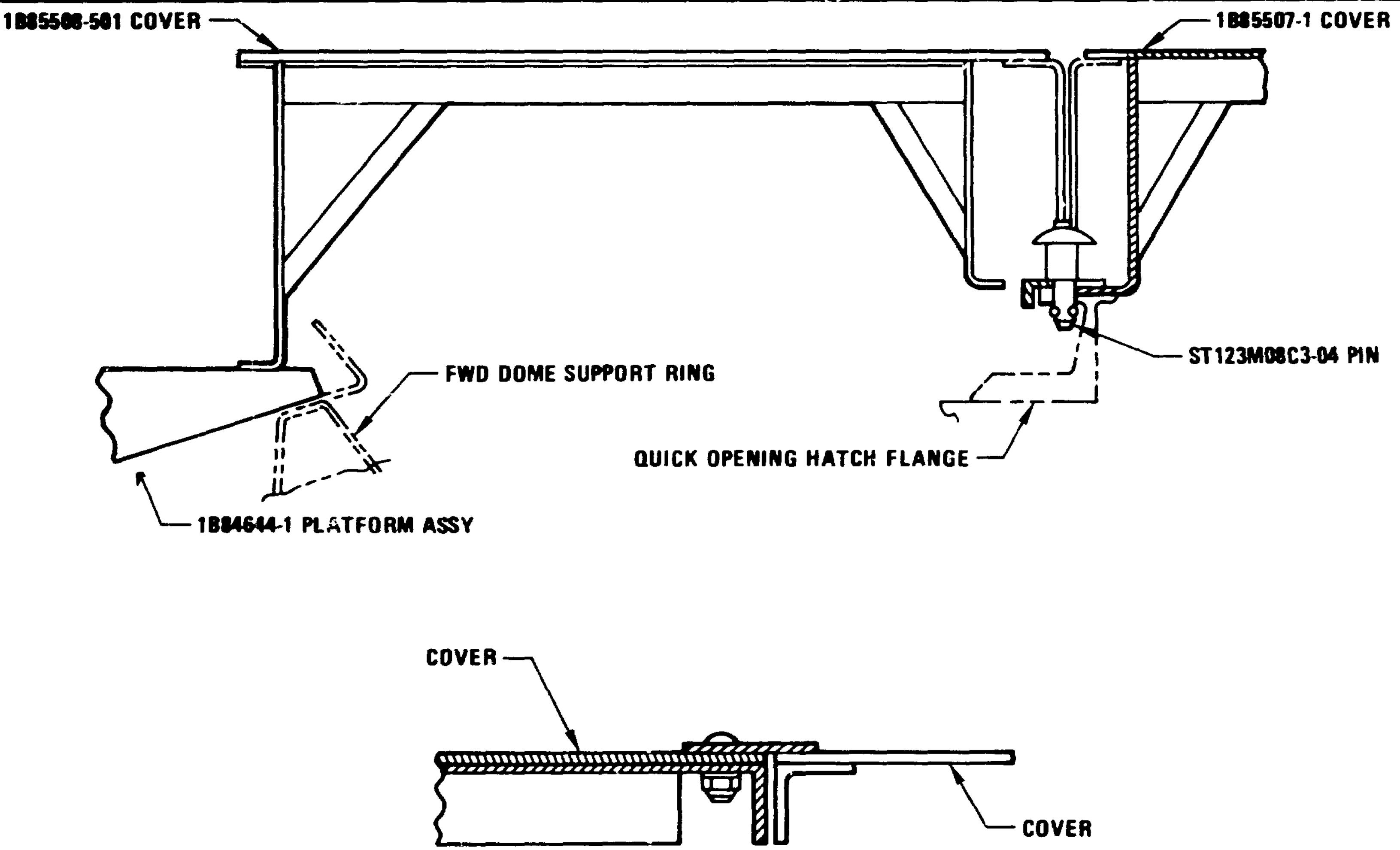


Figure 2.2.14.6-15

3/ Habitability Support System (HSS) Equipment Handling Kit (DSV7-311)

This kit (Drawing No. 1B78749) consisted of a hoist assembly and hoist carrier supported by the hoist rail and guide rail assemblies of the Model DSV7-303 vertical access kit, a dolly track which consisted of elevated track segments which were interconnected from the center of the OWS to the side access opening where it interfaces with the track threshold of Model DSV7-317, a light-weight aluminum dolly or cart which was used for moving equipment on the dolly track, a food container handling fixture, a urine return container handling fixture, a storage container handling fixture, a water container handling fixture, a film vault drawer handling fixture, a portable water tank checkout handling fixture and hoist cables and adapter fillings (Figures 2.2.14.6-16, -17, -18, -19, -20, -21, -22, -23, -24, -25, and -26).

4/ Transportation Hatch Kit (KSV7-317)

This kit (Drawing No. 1B78751) consisted of a GSE access panel which replaced the OWS flight access panel during transportation and which was modified from a rejected OWS flight access panel, two aluminum hatch handles with captive fasteners which were used to handle both the GSE transportation and flight access panels, a welded aluminum structure door-jamb protective ring that fastened to the door jamb to prevent damage to the jamb when the access door was removed, a welded aluminum elevated track dolly truck threshold with tubular guide rails on the side which permitted loaded dollies to be safely maneuvered into the OWS and a welded aluminum tubular panel segment handling frame with special fasteners to handle the meteoroid shield panel assembly (Figure 2.2.14.6-27, -28 and -29).

SKYLAB - ORBITAL WORKSHOP
MODEL DSV7-311 HOIST ASSY

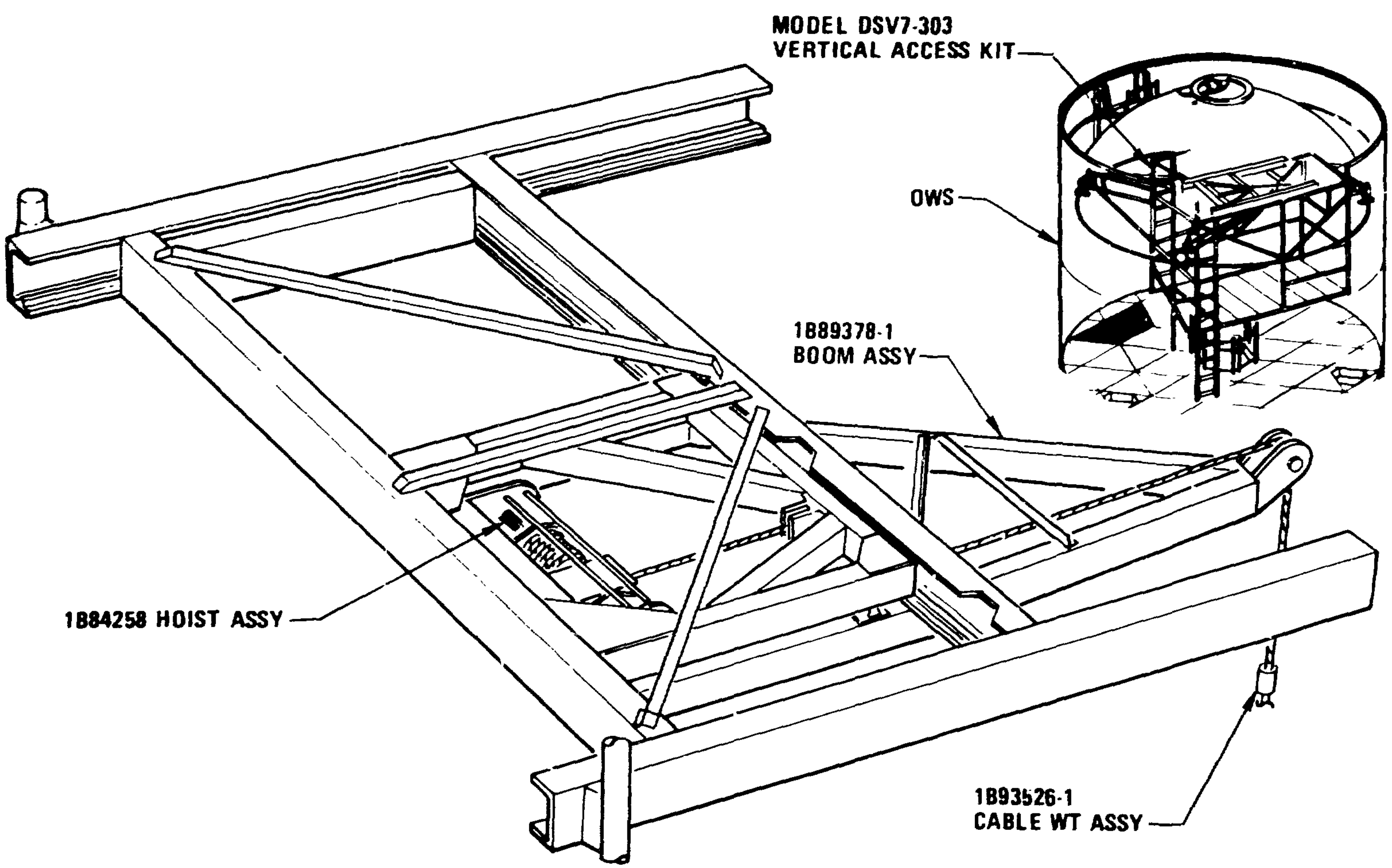


Figure 2.2.14.6-16

SKYLAB - ORBITAL WORKSHOP
MODEL DSV 7-311 DOLLY TRACK

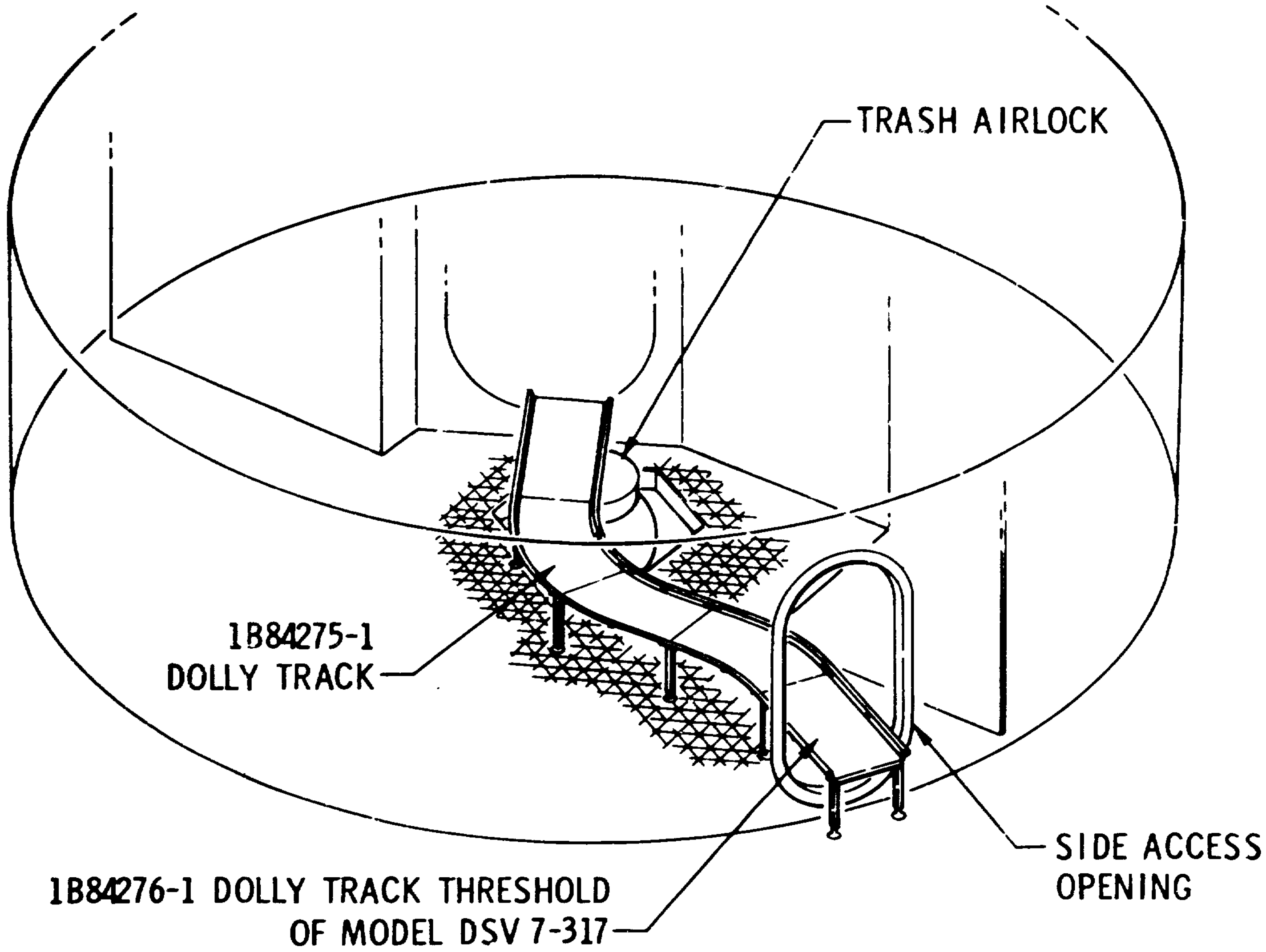


Figure 2.2.14.6-17

SKYLAB - ORBITAL WORKSHOP
MODEL DSV7-311
FOOD CONTAINER HANDLING GSE

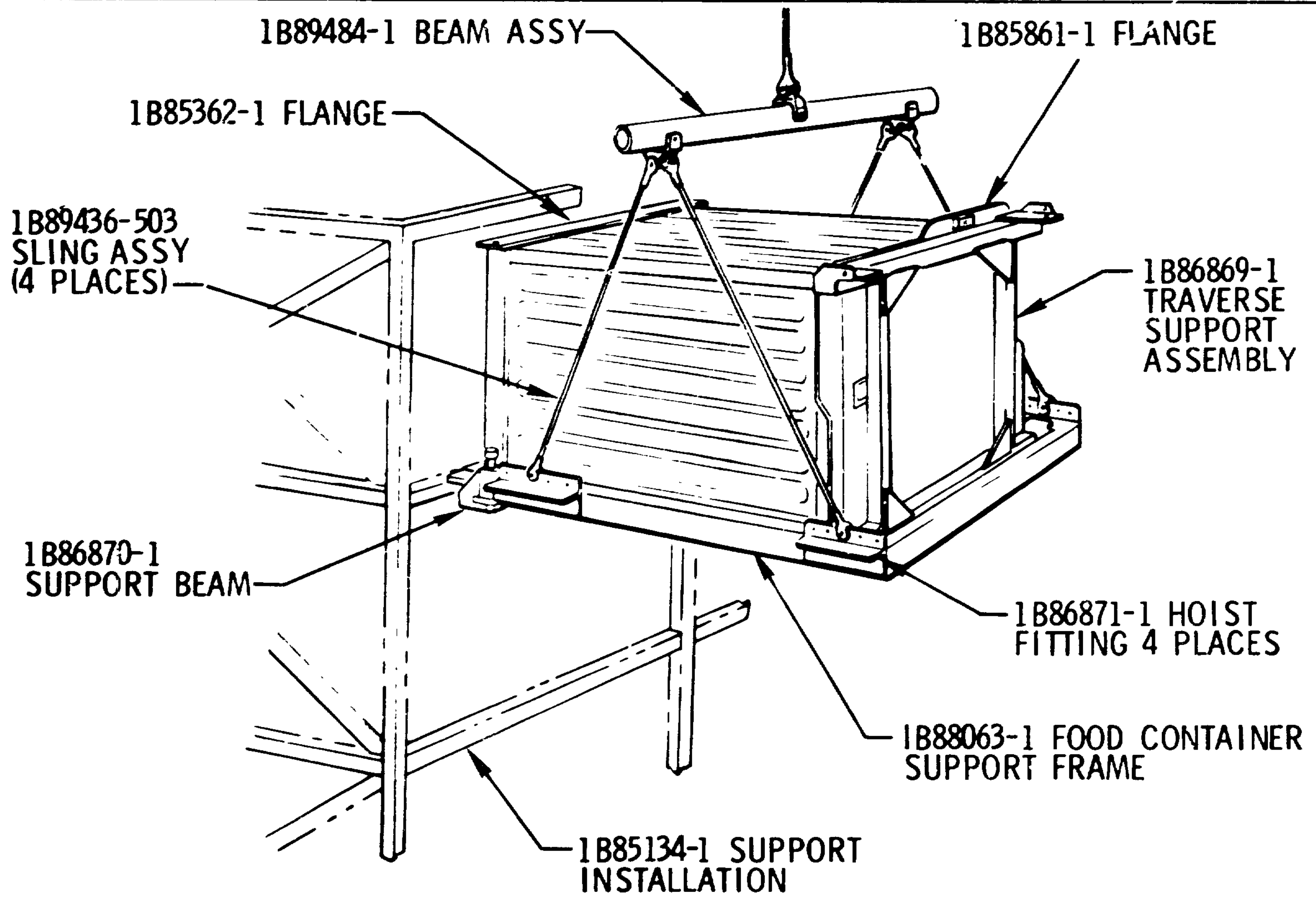


Figure 2.2.14.6 18

SKYLAB - ORBITAL WORKSHOP
MODEL DSV7-311
URINE RETURN CONTAINER HANDLING GSE

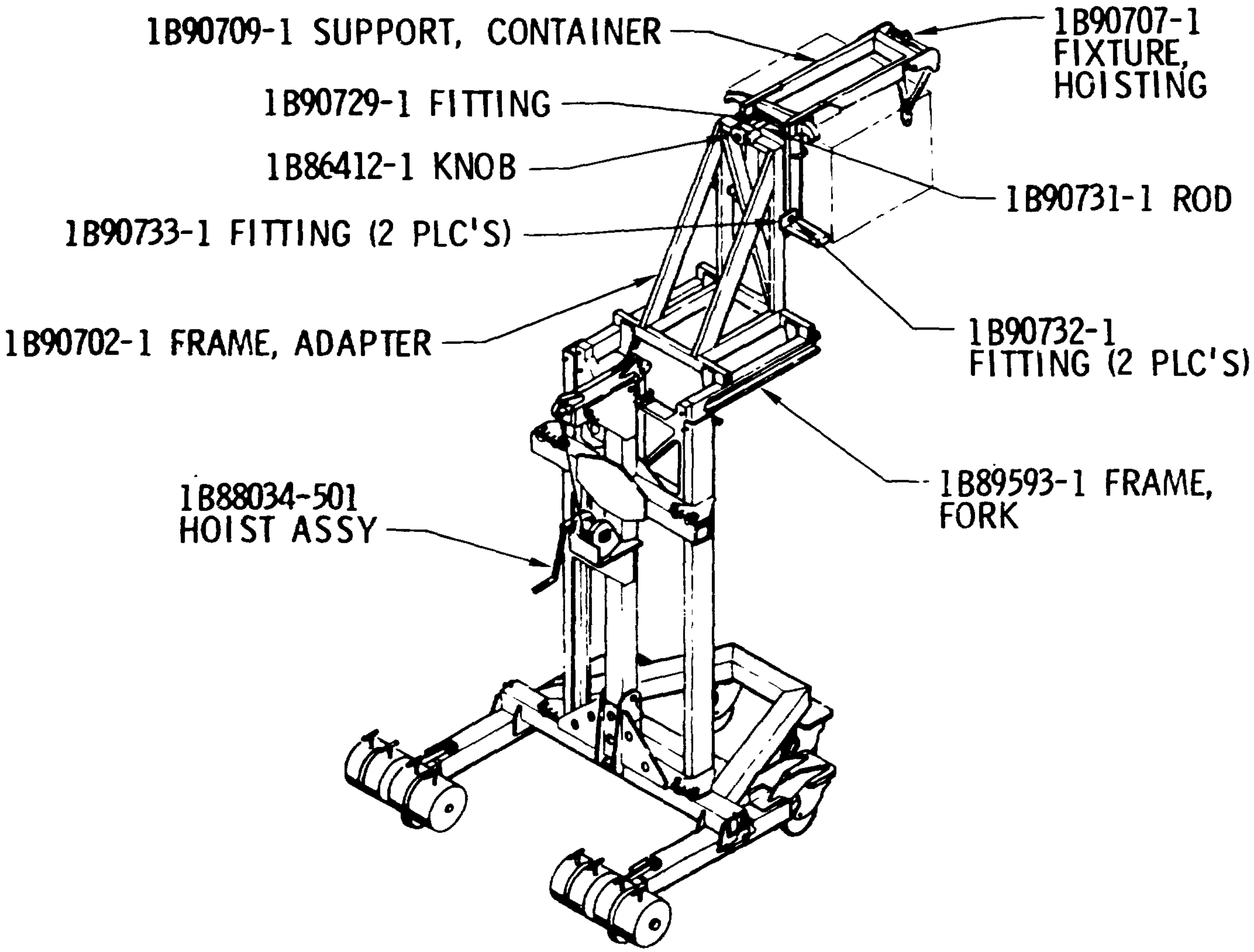


Figure 2.2.14.6-19

SKYLAB - ORBITAL WORKSHOP
MODEL DSV7-311
STORAGE CONTAINER HANDLING GSE

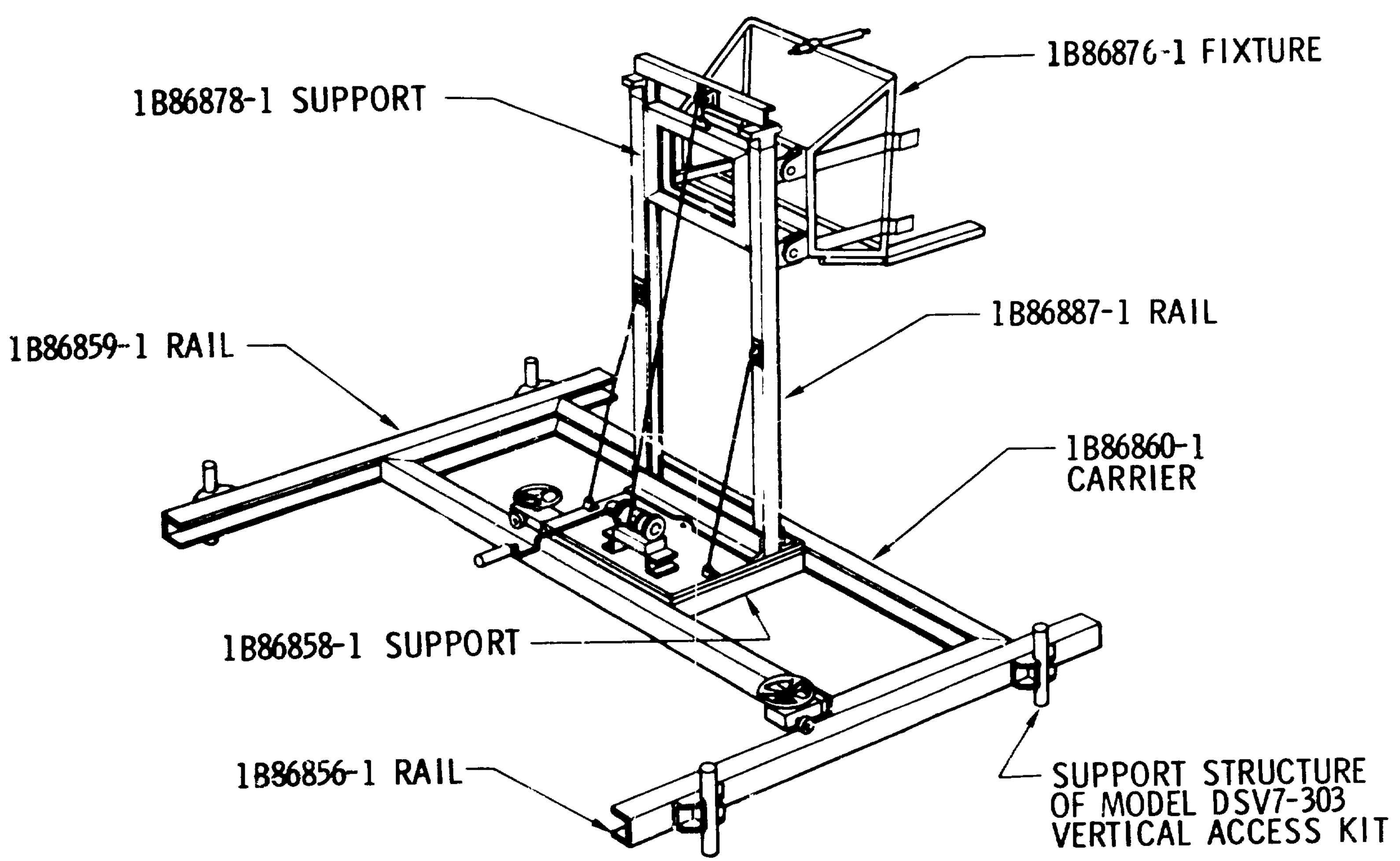


Figure 2.2.14.6-20

SKYLAB - ORBITAL WORKSHOP
MODEL DSV7-311
WATER CONTAINER HANDLING GSE

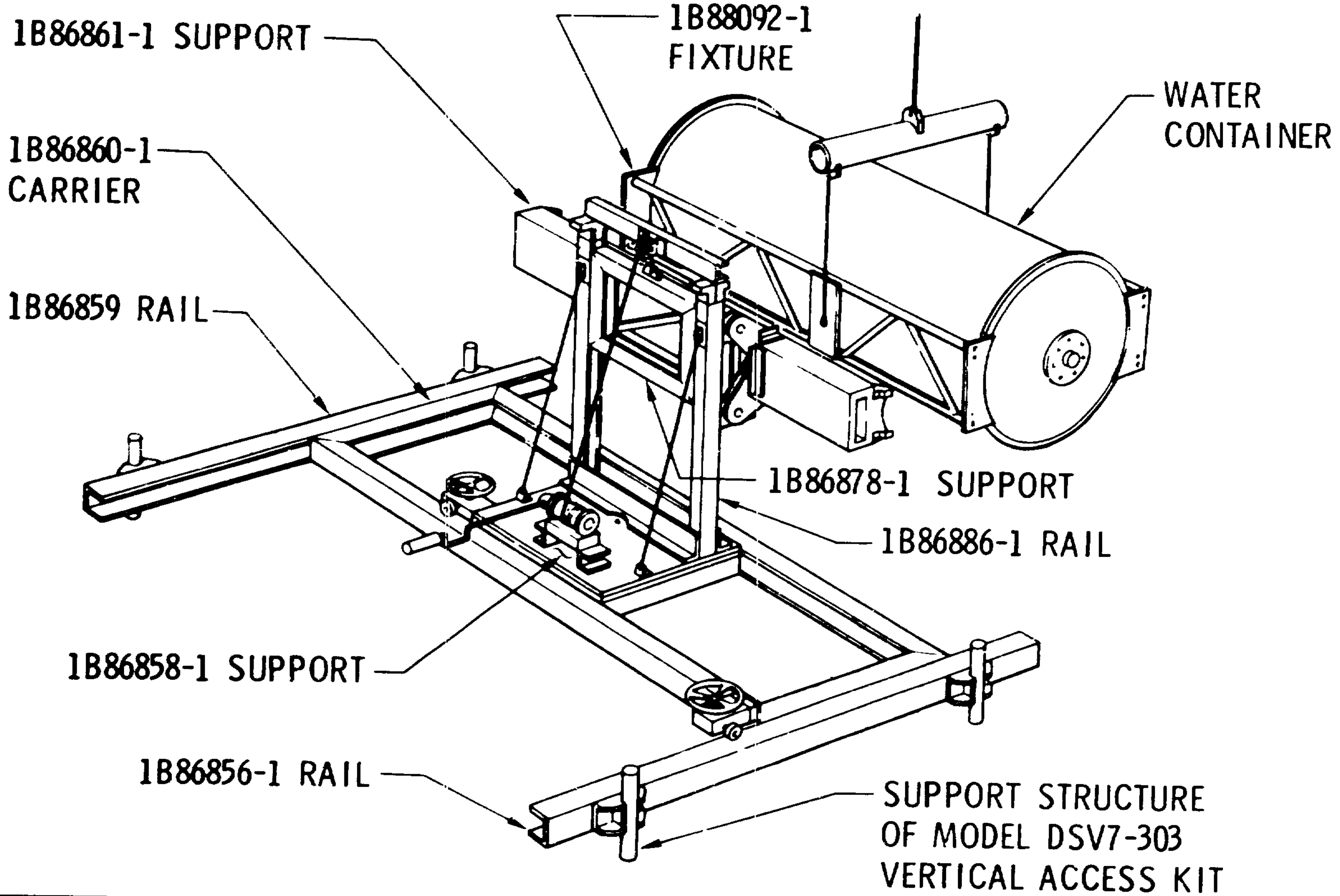


Figure 2.2.14.6-21

SKYLAB -ORBITAL WORKSHOP

MODEL DSV7-311

PORTABLE WATER TANK HANDLING GSE

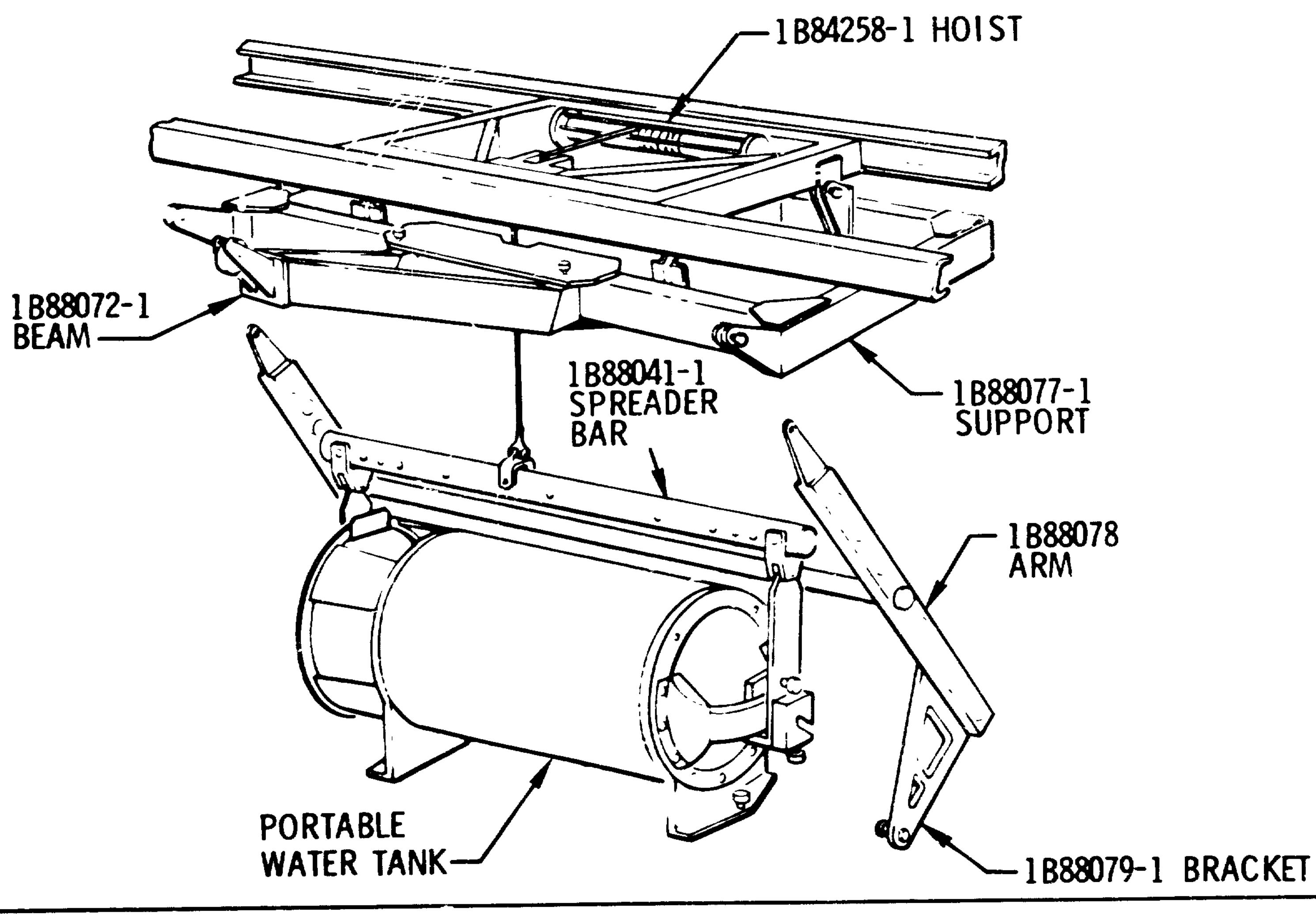


Figure 2.2.14.6-22

SKYLAB - ORBITAL WORKSHOP
FILM VAULT DRAWER HANDLING GSE
MODEL DSV7-311

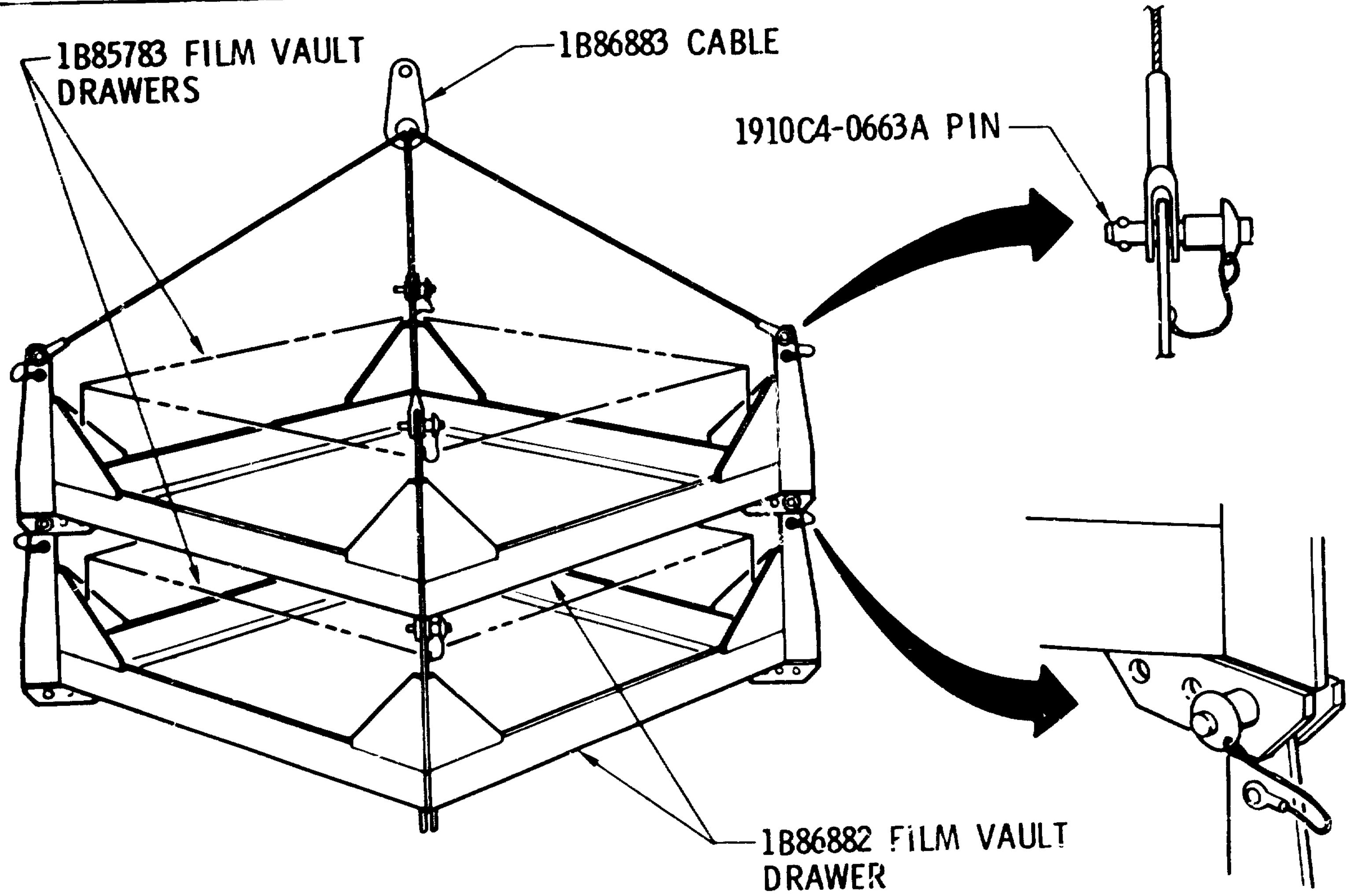


Figure 2.2.14.6-23

SKYLAB - ORBITAL WORKSHOP
MODEL DSV7-311 PORTABLE WATER TANK
CHECKOUT HANDLING GSE

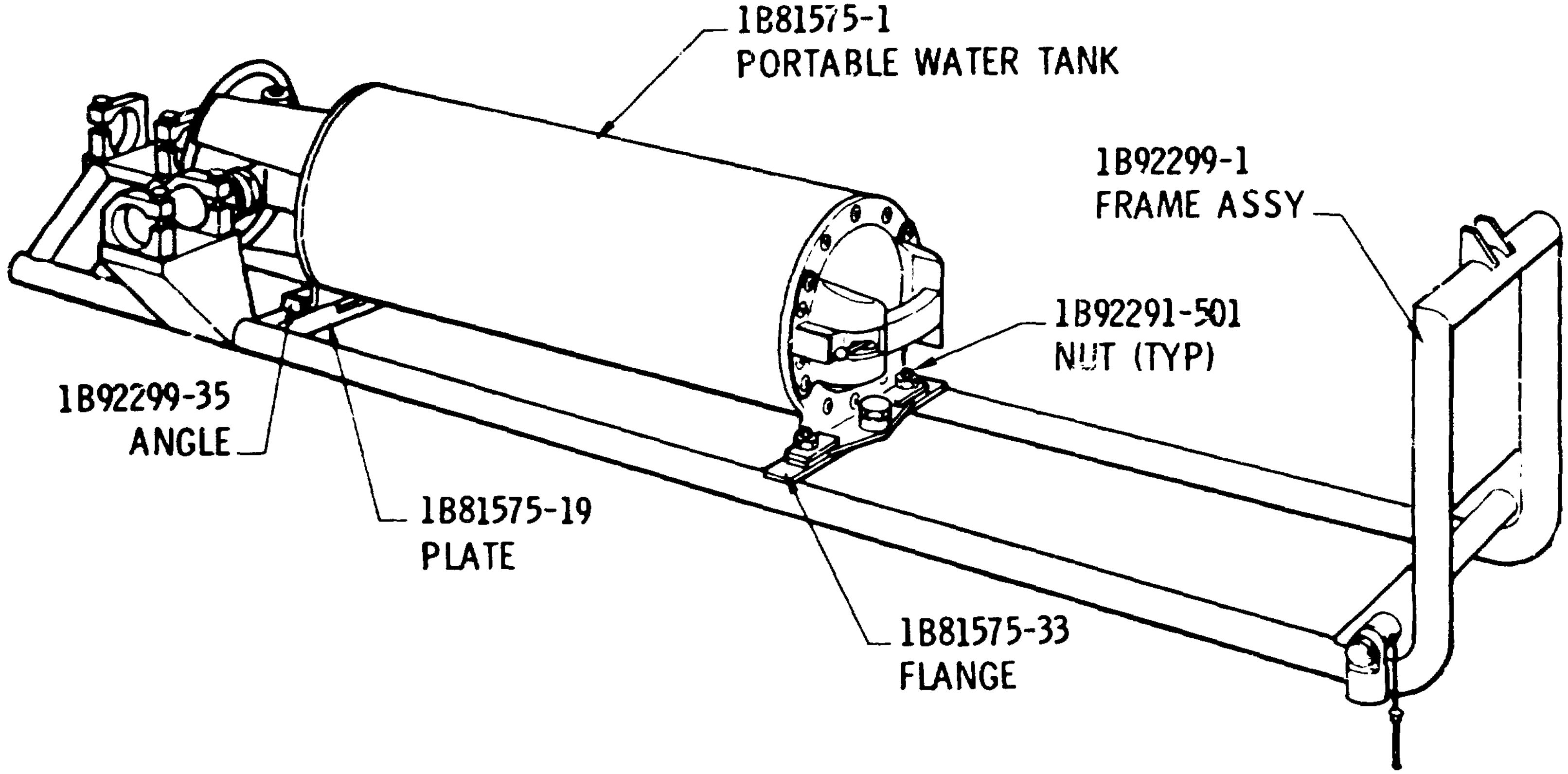


Figure 2.2.14.6-24

SKYLAB - ORBITAL WORKSHOP
MODEL DSV7-311 HSS CART

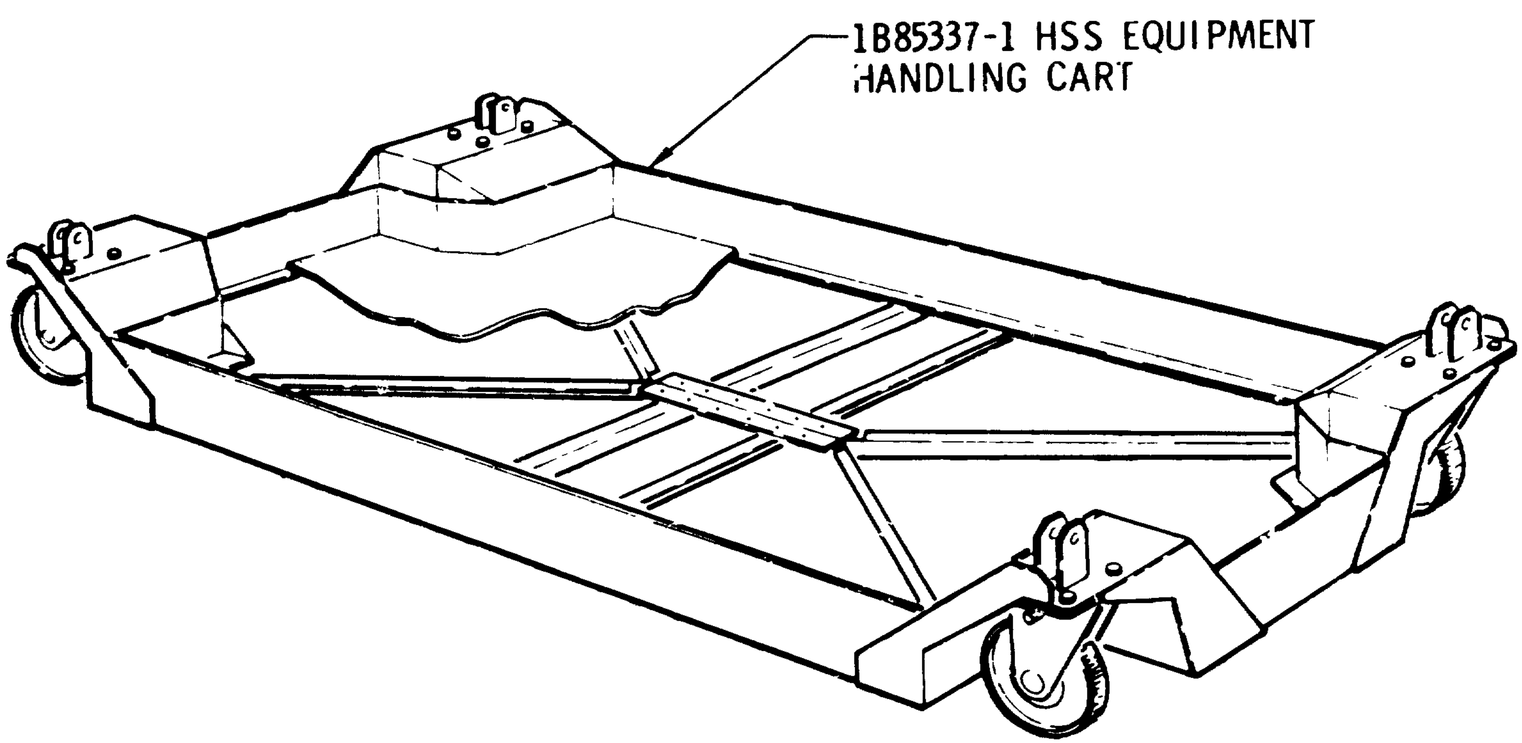


Figure 2.2.14.6-25

SKYLAB - ORBITAL WORKSHOP
CABLE WEIGHT ASSEMBLY INSTALLATION
MODEL DSV7-311

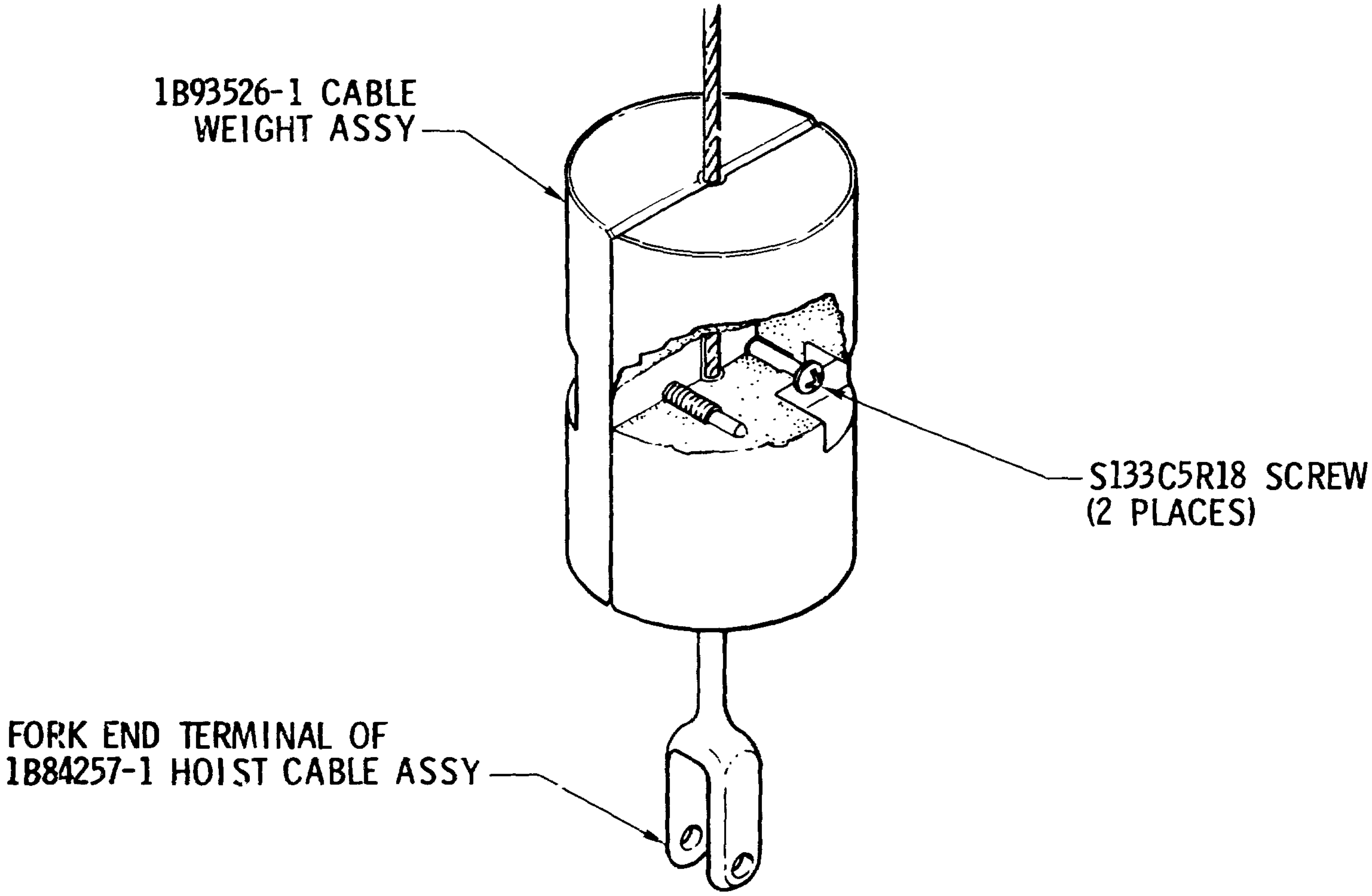


Figure 2.2.14.6-26

SKYLAB - ORBITAL WORKSHOP
HATCH TRANSPORTATION KIT
MODEL DSV7-317

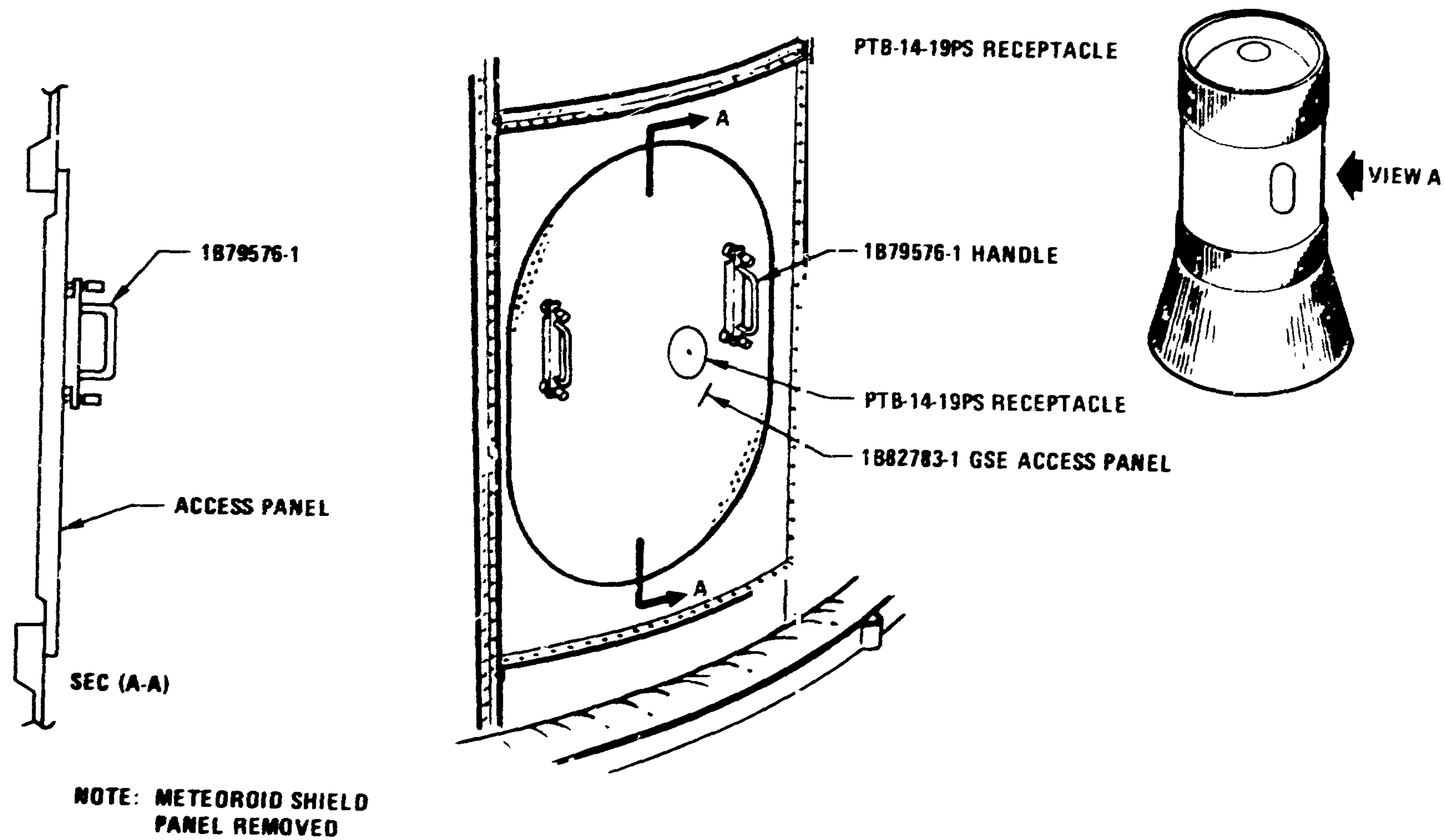


Figure 2.2.14.6-27

SKYLAB - ORBITAL WORKSHOP
HATCH TRANSPORTATION KIT
MODEL DSV7-317

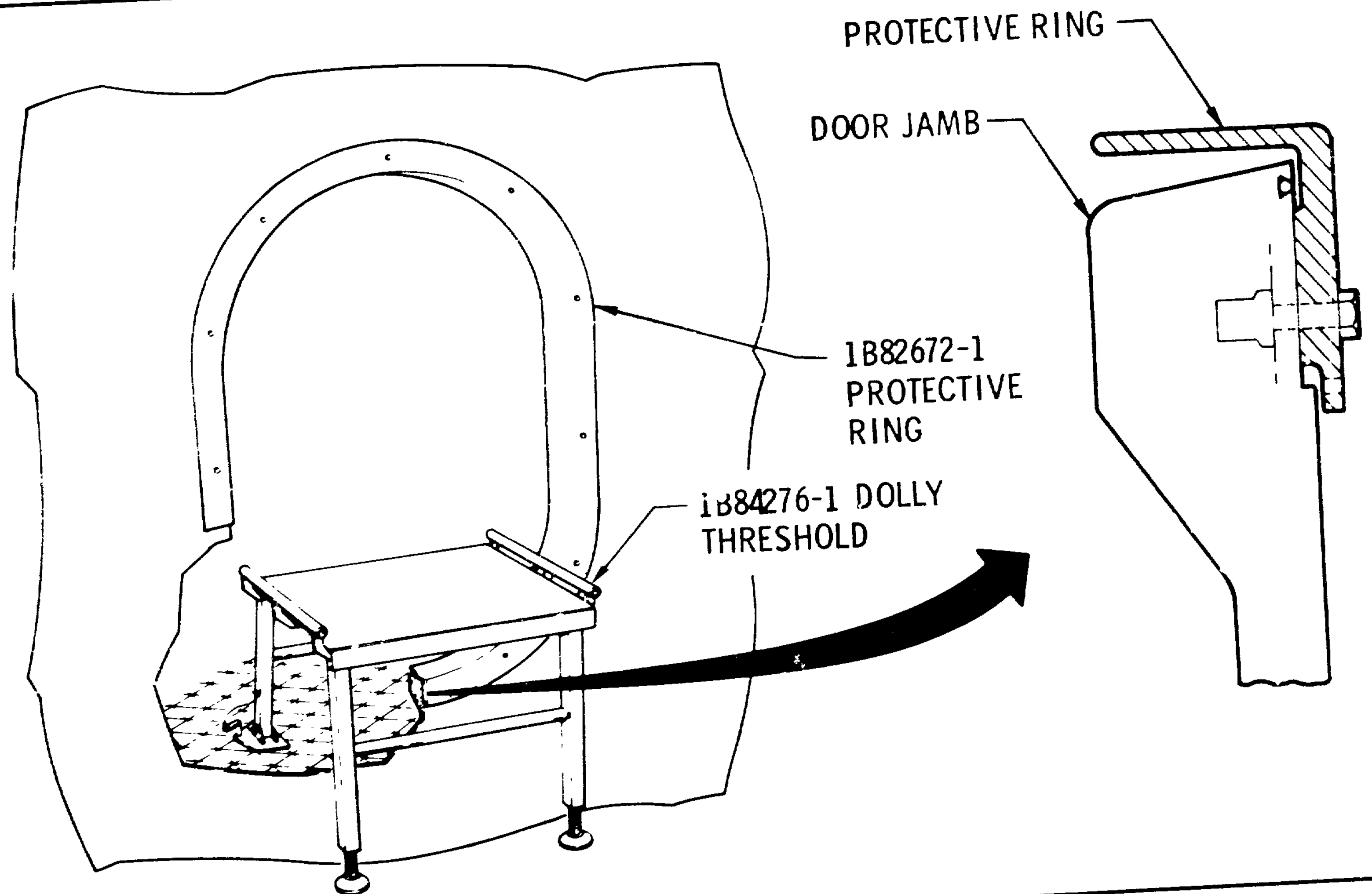


Figure 2.2.14.6-28

SKYLAB - ORBITAL WORKSHOP
HANDLING FIXTURE FOR ACCESS PANEL
METEOROID SHIELD SEGMENT

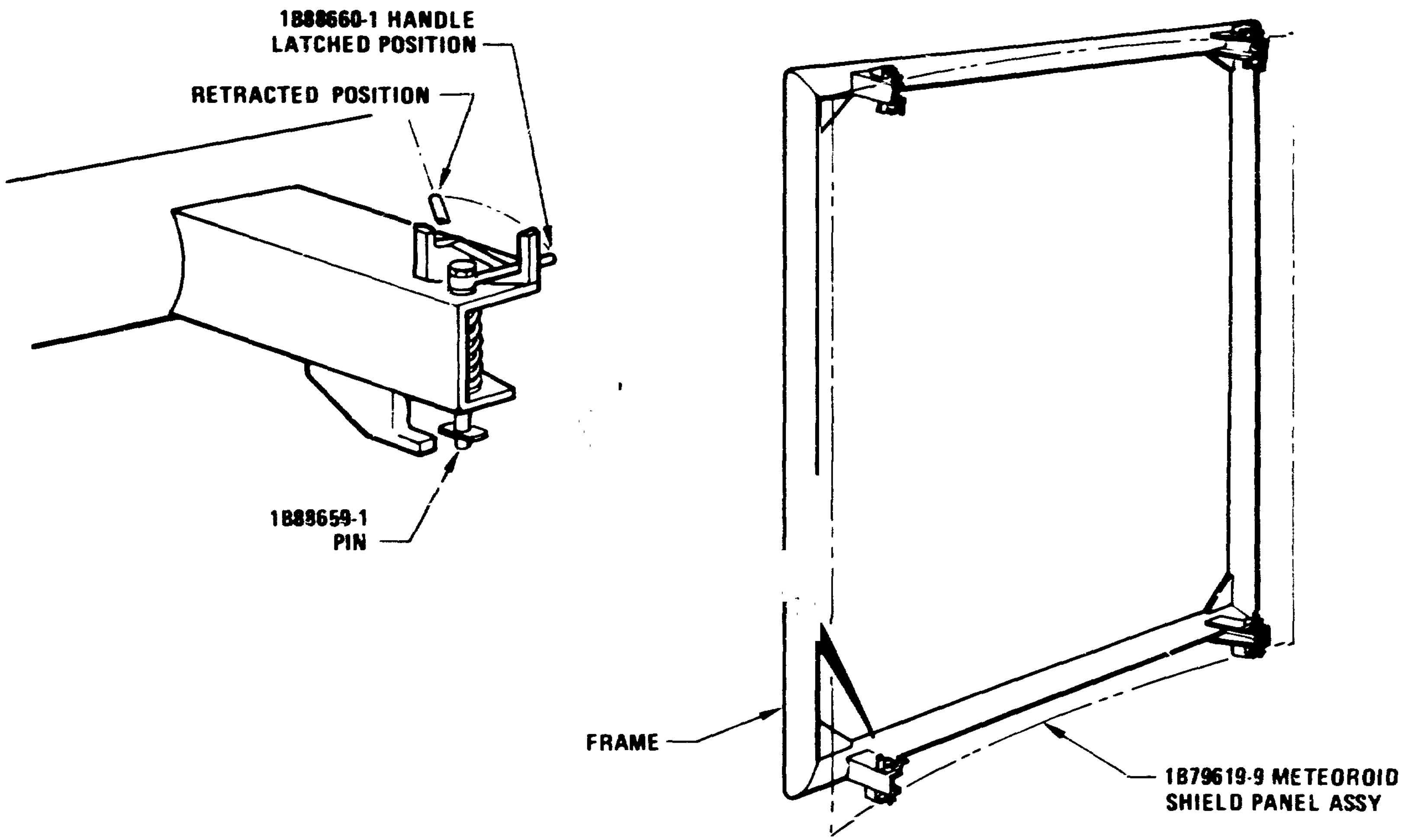


Figure 2.2.14.6-29

5/ Vertical Flared Aft Interstage Kit (DSV7-326)

This kit (Drawing No. 1878735) consisted of a modified Model DSV-4B-311 Vertical Flared Aft Interstage Access Kit. The modifications were to rework the primary platforms to clear the refrigeration radiator, to provide auxiliary platforms to give access to the Thruster Attitude Control System (TACS) bottles and to modify the handrails. The design consisted of modular lightweight platforms with extension platforms and upper level platforms (Figures 2.2.14.6-30, -31, -32 and -33).

6/ Forward Skirt Vertical Access Kit (DSV7-328)

This kit (Drawing No. 1B78737) consisted of a modified Model DSV-4B-402 Forward Interstage Vertical Access Kit. The modifications were to provide pivotal supports for the outboard end of the Model DSV7-307 Access Platforms, to rework the lower end of the handrails and to rework the inboard end of two access platforms to clear the High Performance Insulation (HPI) cover of the electrical feed-through receptacle. Sixteen of the eighteen basic platform assemblies which made up the basic lower level remained unchanged (Figures 2.2.14.6-34, -35, -36, -37 and -38).

C. Testing

All access kits were proof tested to limit load successfully. The DSV7-307 Tank Dome Protective Cover and Access Kit and the DSV7-328 Forward Skirt Vertical Access Kit were checked for fit on the Dynamic Test Article (DTA) at Houston and with the OWS at Huntington Beach. The DSV7-303 Crew Quarters Vertical Access Kit was checked for fit on the Hi Fi at Huntington Beach. The DSV7-326 Vertical Flared Aft Interstage Kit was not tested for fit because previous usage on the DSV-4B gave confidence that the kit would work on the DSV7 OWS.

SKYLAB - ORBITAL WORKSHOP
FLARED AFT INTERSTAGE ACCESS KIT
MODEL DSV7-326

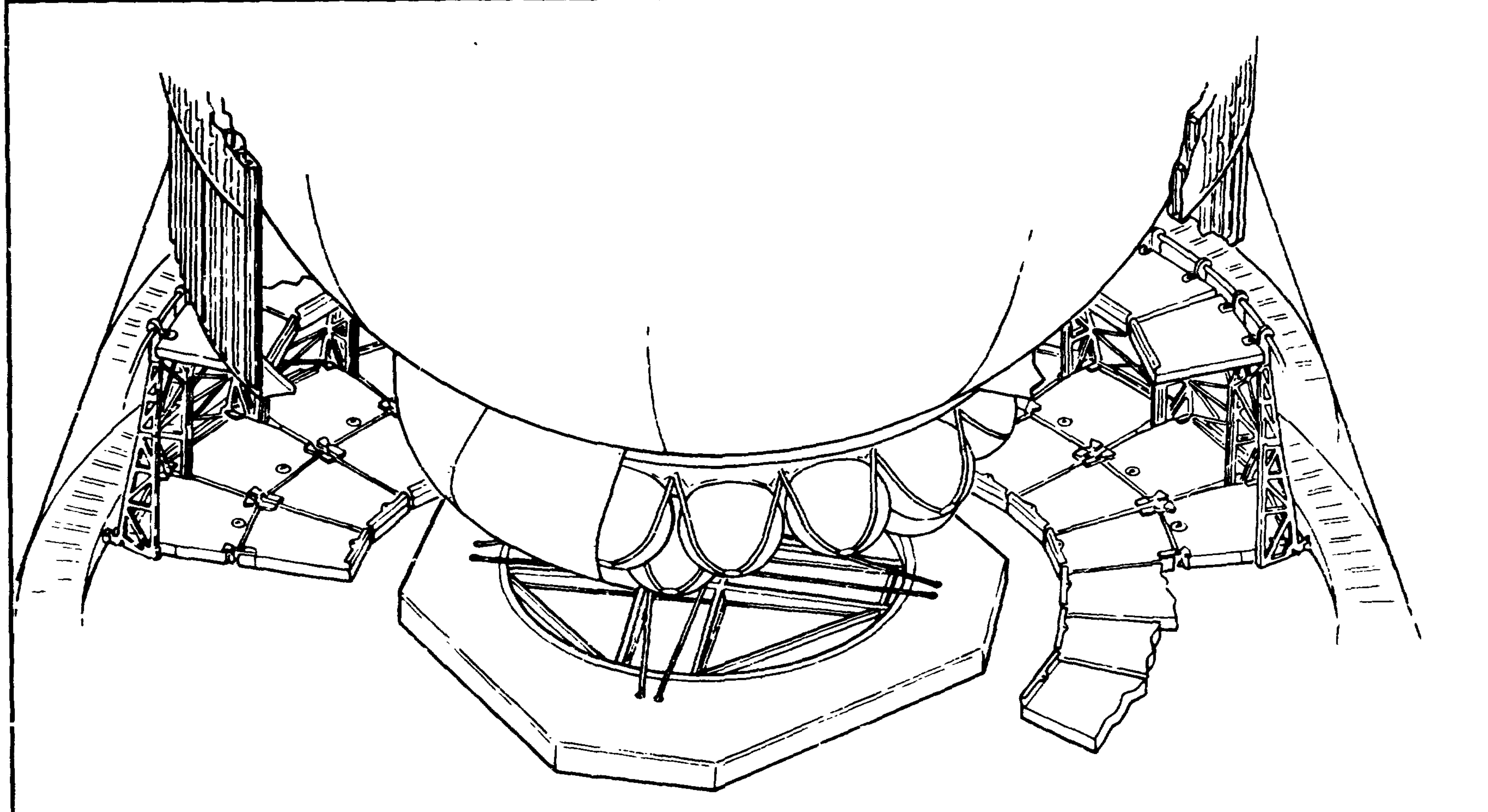
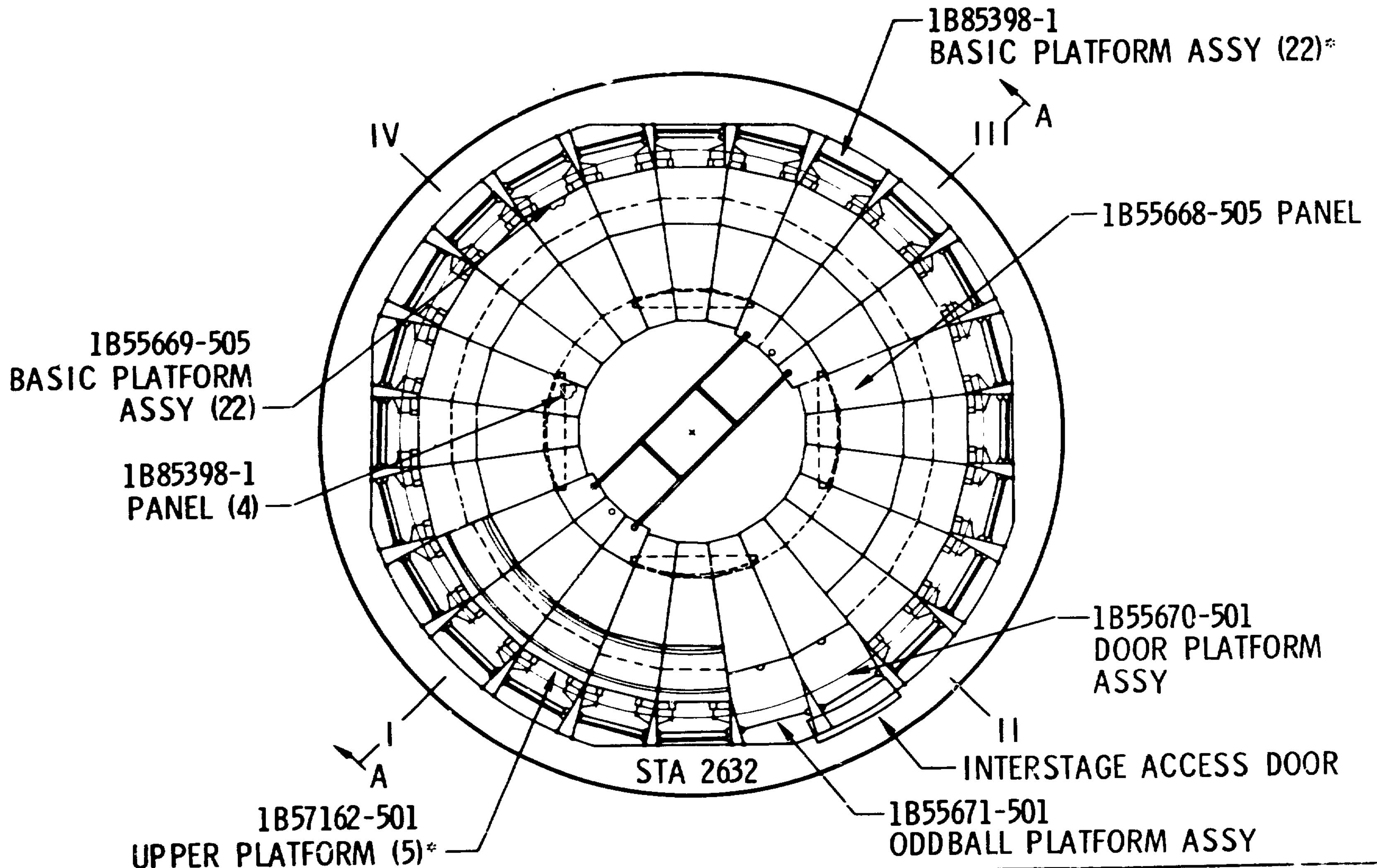


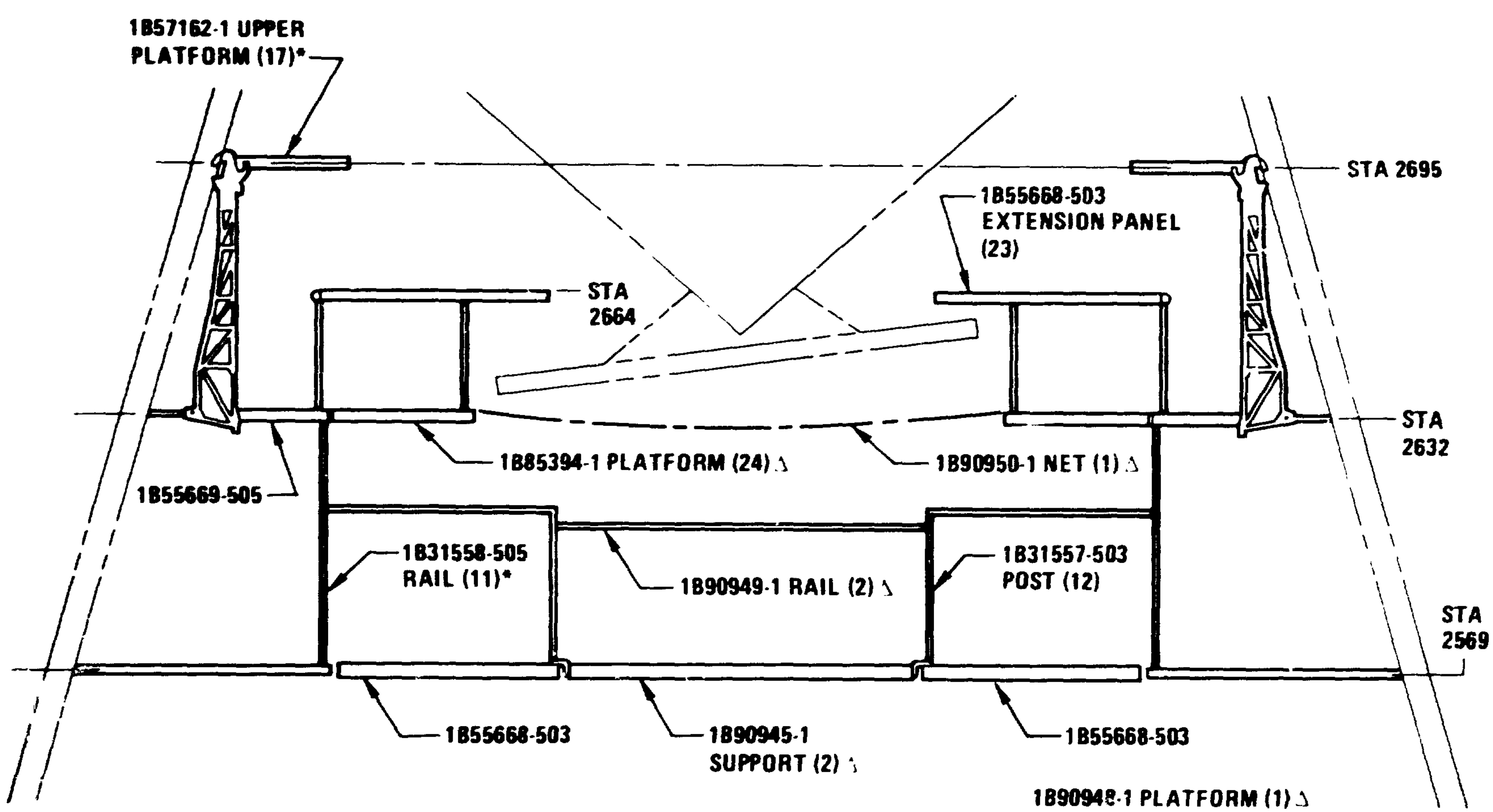
Figure 2.2.14.6-30

SKYLAB - ORBITAL WORKSHOP
PLAN VIEW OF FLARED AFT
INTERSTAGE ACCESS KIT MODEL DSV-7-326



Figure

SKYLAB - ORBITAL WORKSHOP
MODEL DSV-7-326
FLARED AFT INTERSTAGE ACCESS KIT



* DENOTES NO CHANGE FROM MODEL DSV-4B-311 PART
△ DENOTES NEW PART FOR MODEL DSV-4B-326
OTHERS ARE CONFIGURATIONS OF DSV-4B-311 PARTS

SKYLAB - ORBITAL WORKSHOP
MODEL DSV-7-326
BASIC PLATFORM ASSEMBLY

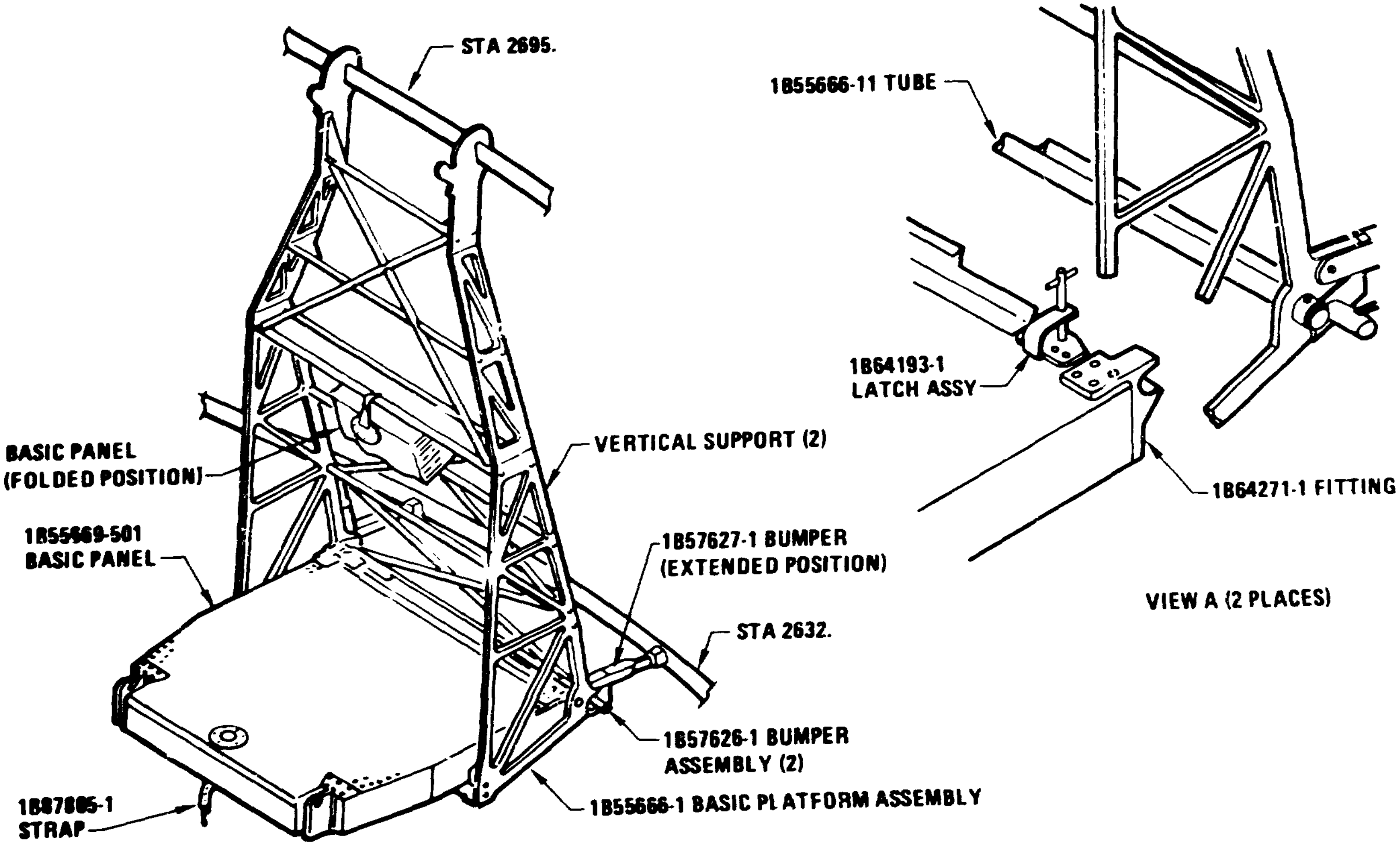


Figure 2.2.14.6-3

SKYLAB - ORBITAL WORKSHOP
FORWARD SKIRT ACCESS KIT
MODEL DSV7-328

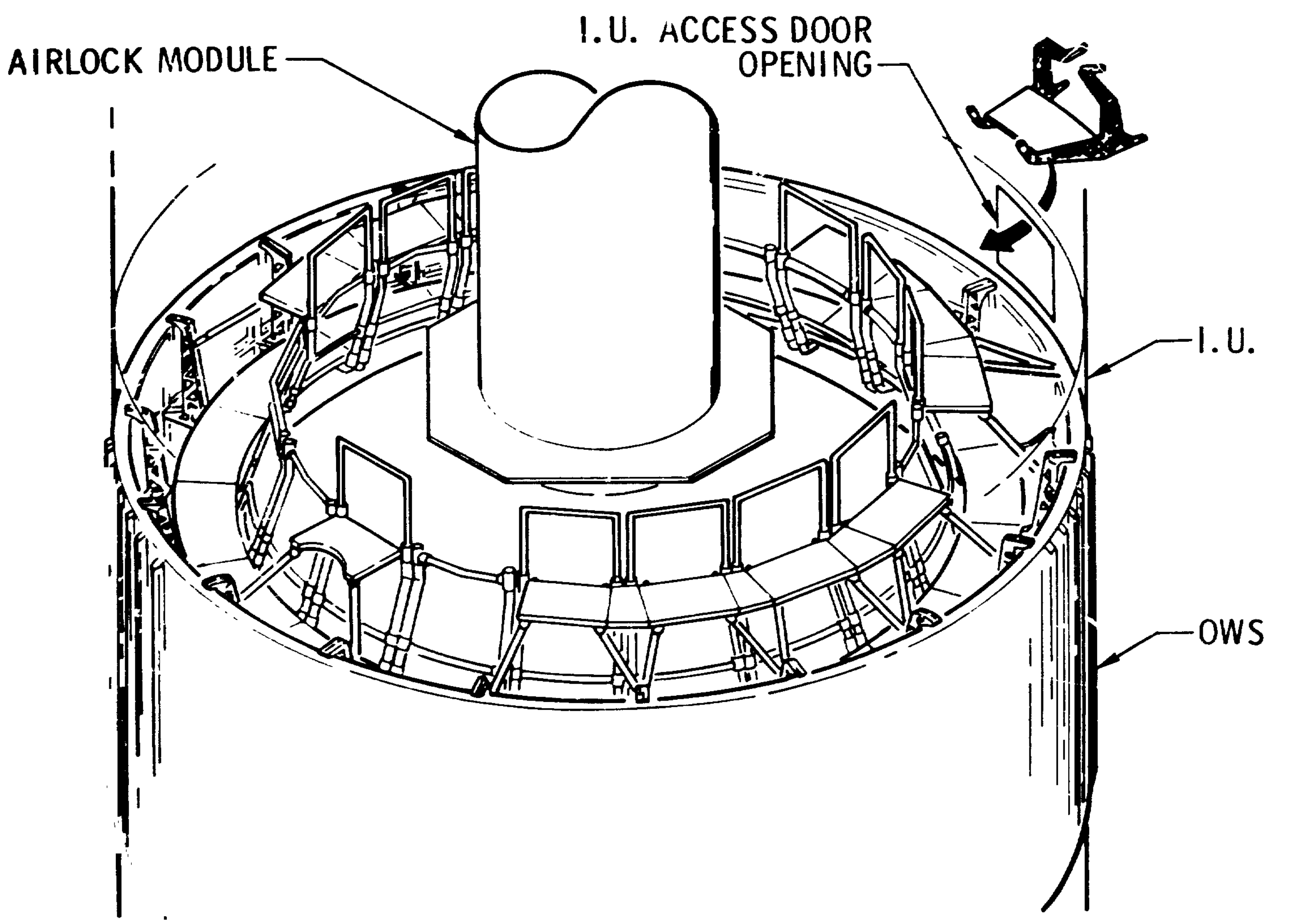


Figure 2.2.14.6-34

SKYLAB - ORBITAL WORKSHOP
DOME PROTECTIVE COVER/ACCESS KIT
& FWD SKIRT ACCESS KIT

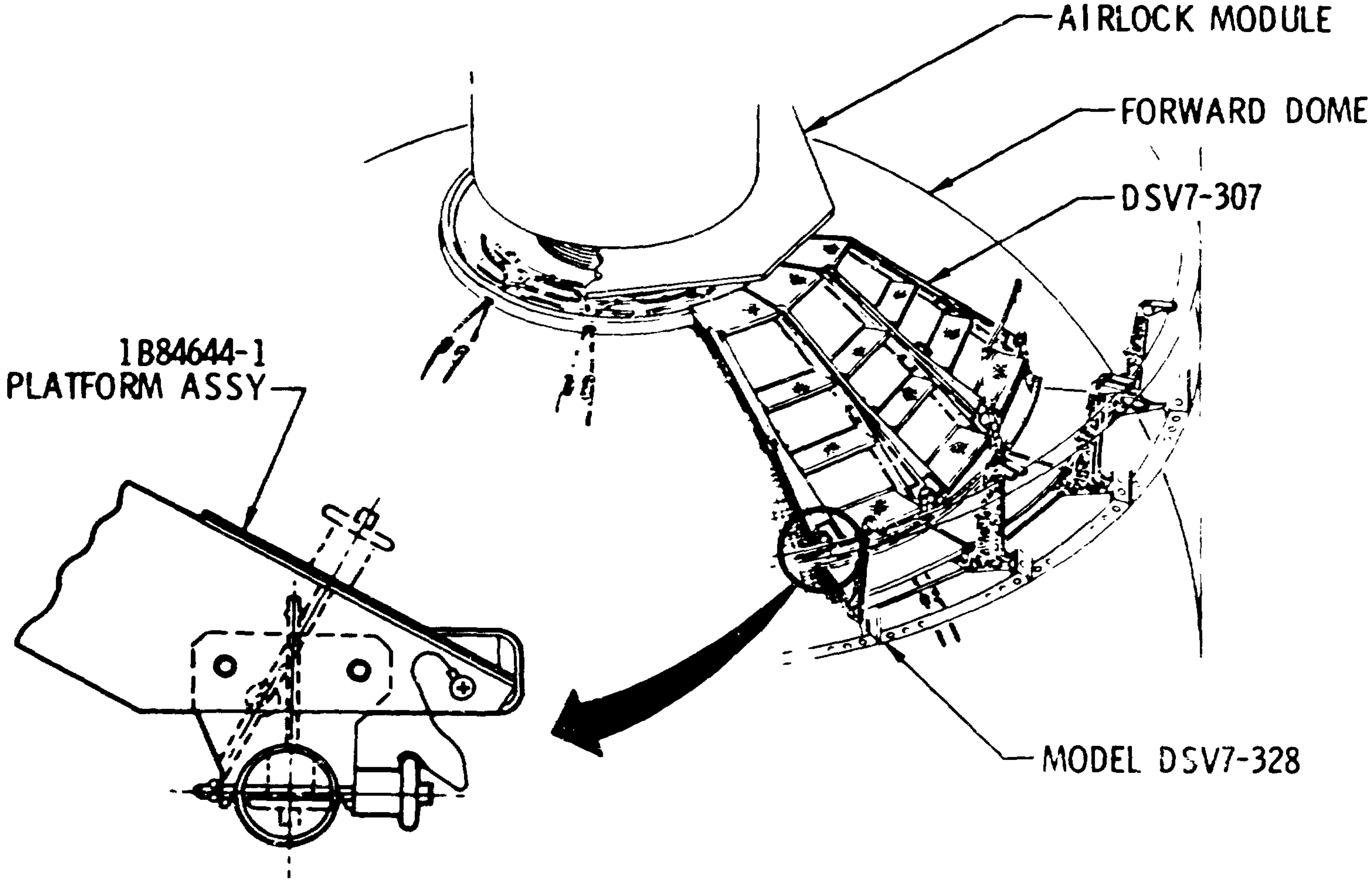


Figure 2.2.14.6-35

SKYLAB - ORBITAL WORKSHOP

BASIC PLATFORM ASSEMBLY

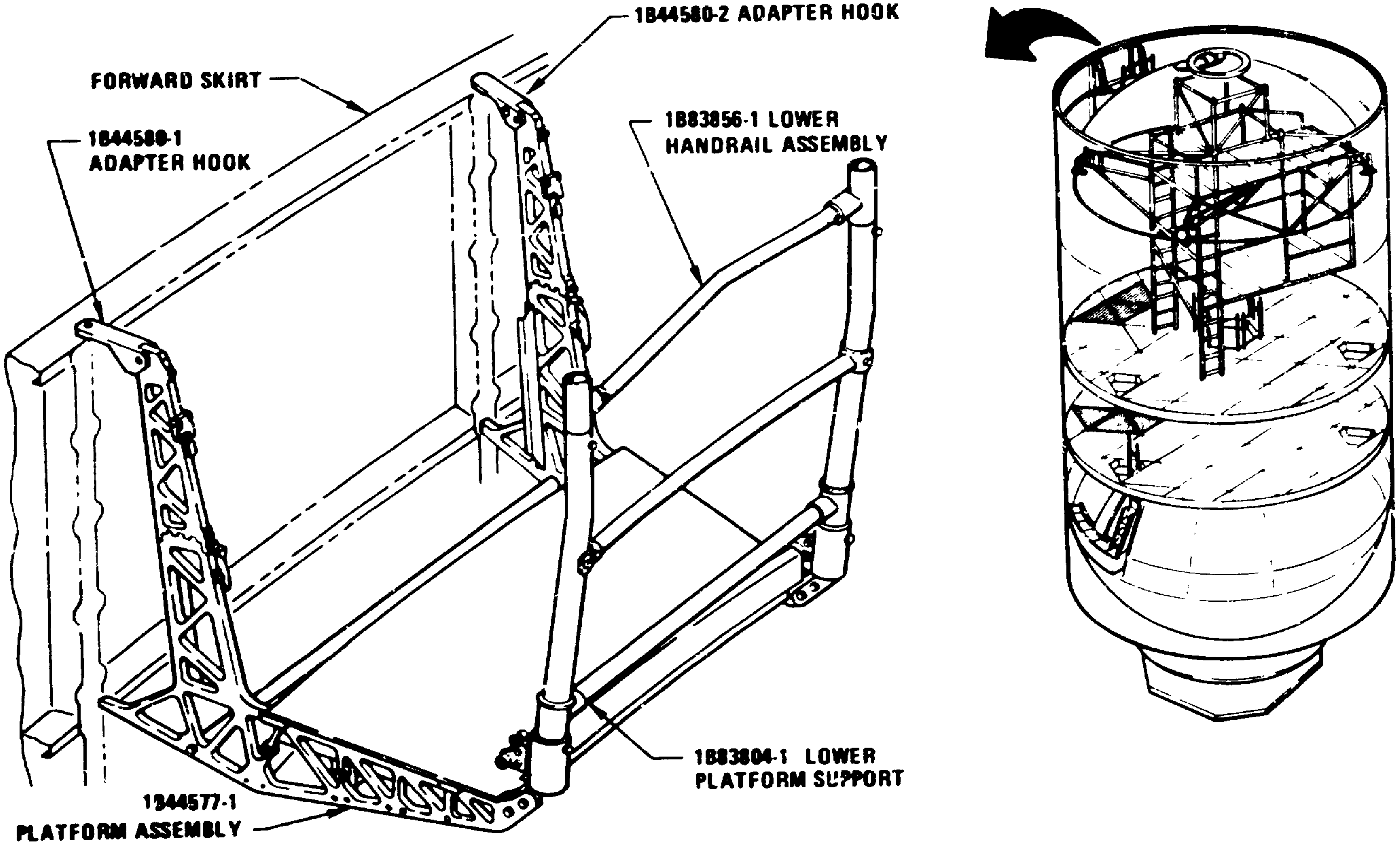


Figure 2.2.14.6-36

SKYLAB-- ORBITAL WORKSHOP
BASIC PLATFORM ASSEMBLY
WITH UPPER LEVEL PLATFORM

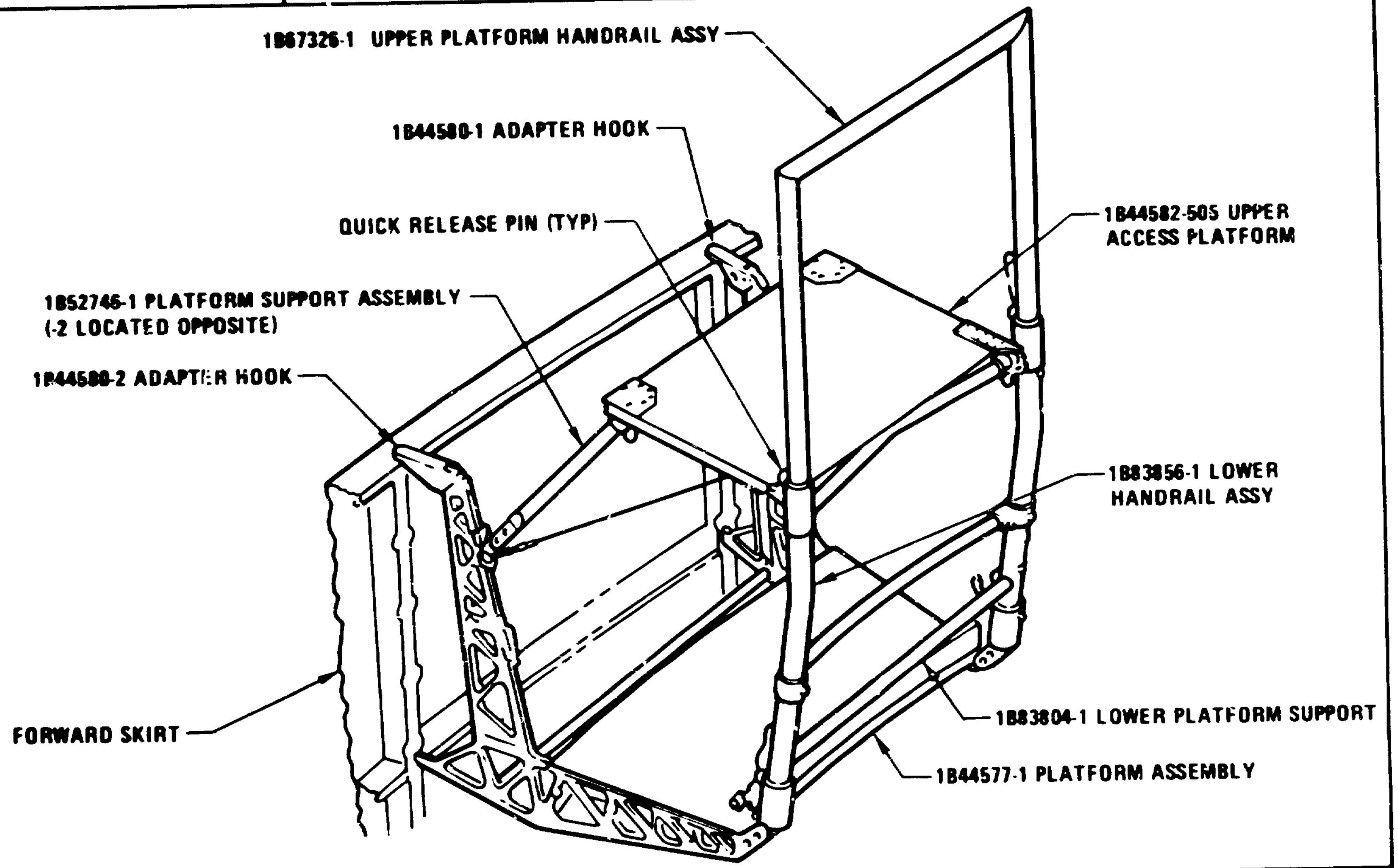


Figure 2.2.14.6-37

SKYLAB - ORBITAL WORKSHOP
FORWARD SKIRT ACCESS KIT
ACCESS KIT MODIFICATION

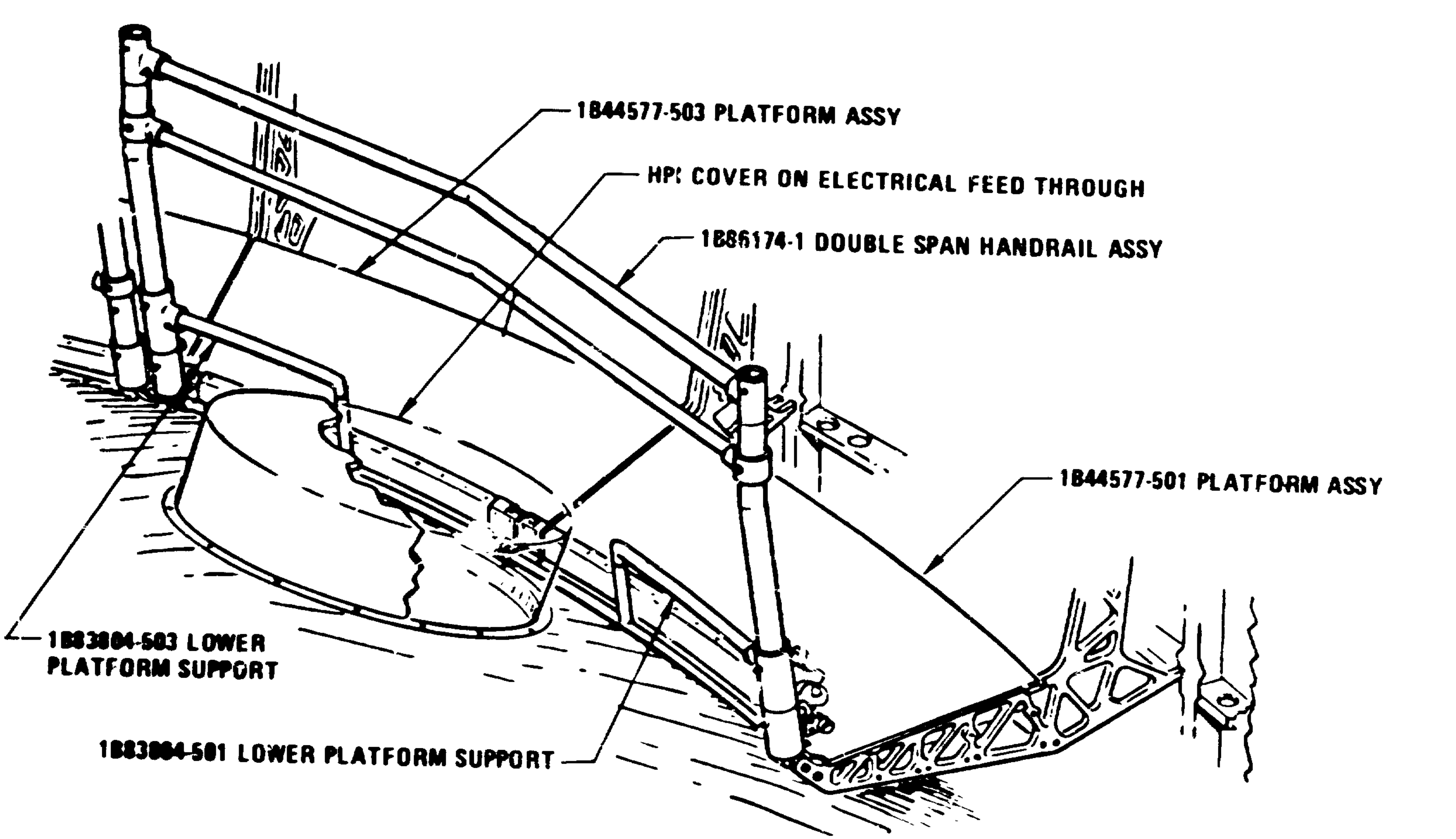


Figure 2.2.14.6-38

D. Conclusions and Recommendations

The access kits fulfilled their design requirements. Any GSE which had functions inside the OWS and which rested on and applied loads to the OWS interior had to be carefully designed and their weight minimized. There could be no marring, denting, or excessive straining of the flight structure. The GSE had to have the capability for rapid assembly/disassembly for entry/exit to the OWS and still provide adequate safety for personnel.

The single recommendation for change is that something other than ball-lock pins be used in certain assemblies. This is due to the tendency of the ball-lock pins to gall in their holes when used many times.

If the internal access GSE is to be used for servicing of liquid lines or attaching test pressure lines, the GSE should have permanent attach points for checkout and servicing equipment. Liquid spillage containers should have permanent attachments in relation to line outlets to assure no spillage internal to the spacecraft.

During the processing of the spacecraft from assembly to launch the internal GSE was removed and replaced frequently. This created storage problems, recleaning in some cases and generally work stopped during the process of removal and reinstallation. The GSE design considerations should be made as the spacecraft configuration is developed to assure maximum ease and safety of removal and installation. Consideration should be given relative to leaving the GSE installed until launch, and therefore the GSE must withstand spacecraft pressure tests, transportation and similar activities.

2.2.14.7 Umbilicals Handling Equipment

A. Design Requirements

This family of kits was designed to Factors of Safety in Table 2.2.14.7-1.

1/ Aft Launcher Umbilical Kit (DSV7-327)

This kit was modified from the DSV-4B-315 Kit and was required to provide electrical cables, an air conditioning unit, refrigerant lines, pneumatic transfer lines and a SAS purge line. The umbilical carrier assembly was required to maintain an inert atmosphere around the electrical connectors and quick disconnects at low temperatures and was required to incorporate a switch to signal carrier withdrawal and retraction after disconnect. Pneumatic and mechanical disconnect of the quick-release pins was required when pressure was applied. The pneumatic and SAS quick-disconnects was required to be activated by carrier disconnect motion. Covers were required to prevent excessive leakage of GN_2 purge gas.

2/ Aft Umbilical Kit, Checkout Stand (DSV7-368)

This kit was modified from the DSV-4B-346 Kit and was designed to provide and support the eletrical cables, pneumatic lines and the air conditioning adapter duct to the OWS. An umbilical carrier was required for attachment to the OWS, electrical grounding was required as well as an eject mechanism to provide electrical cable disconnect from the stage for test purposes.

3/ Forward Launcher Umbilical Kit (DSV7-375)

This kit was modified from the DSV-4B-316 Kit and was designed to support the electrical cables and to provide attachment to the OWS electrical ground and an eject mechanism to provide electrical cable disconnect from the OWS for test purposes.

TABLE 2.2.14.7-1

UMBILICALS HANDLING EQUIPMENT FACTORS OF SAFETY

OWS DSV7 KIT MODEL NUMBERS	ULTIMATE FACTOR OF SAFETY	YIELD FACTOR OF SAFETY	LIMIT LOAD FACTORS: HOISTING/GROUND TRANSPORT			LIMIT LOAD FACTORS SUDDEN MANLOADS			ULTIMATE HOIST LOAD	ULTIMATE MANLOAD [MAN WEIGHT = 250 LBS (113.4 kg)]
			LONG.	LAT.	VERT.	LONG.	LAT.	VERT.		
-327	1.5	1.0								
-368	1.5	1.0								
-375	1.5	1.0								

*(+) Sign indicates aft, port and up.

B. System Description

1/ Aft Launcher Umbilical Kit (DSV7-327)

This kit consisted of an umbilical carrier, a refrigerant coupling (ground half only, including shutoff valves), pneumatic quick-disconnects, an eject mechanism, electrical withdrawal switches, a grounding system and an SAS purge quick-disconnect (ground-half). Modifications to Model DSV-4B-315 were as follows:

a. Removed unnecessary purge plumbing and cap openings.

b. Rerouted purge lines and resized orifices.

c. Designed new seals and plugs to contain purge.

d. Revised installation to reflect new or replaced electrical, pneumatic and propellant lines. (Figure 2.2.14.7-1)

2/ Aft Umbilical Kit, Checkout Stand (DSV7-368)

This kit (Drawing No. 1A57917) consisted of electrical calbes and plugs to connect the J-boxes to the OWS, pneumatic lines to connect the pneumatic consoles to the OWS and an air conditioning adapter duct. The carrier will house the ground halves of the quick disconnects and will support the electrical plugs and maintain their attachment to the OWS. Two quick-release pins attached the carrier to the OWS. The eject mechanism operated pneumatically to disconnect the electrical plugs from their receptacles to simulate lift-off. A grounding system was also provided (Figure 2.2.14.7-2).

3/ Forward Launcher Umbilical Kit (DSV7-375)

This kit (Drawing No. 1A57884) consisted of attachments for electrical plugs and the GH_2 MSFC ball-and-cone type vent coupling locked to the stage by the carrier, an umbilical carrier assembly to support the line couplings and maintain an inert atmosphere around the electrical receptacles and completely disconnect from the

SATURN WORKSHOP
ORBITAL WORKSHOP
MODEL DSV7-327
AFT UMBILICAL CARRIER

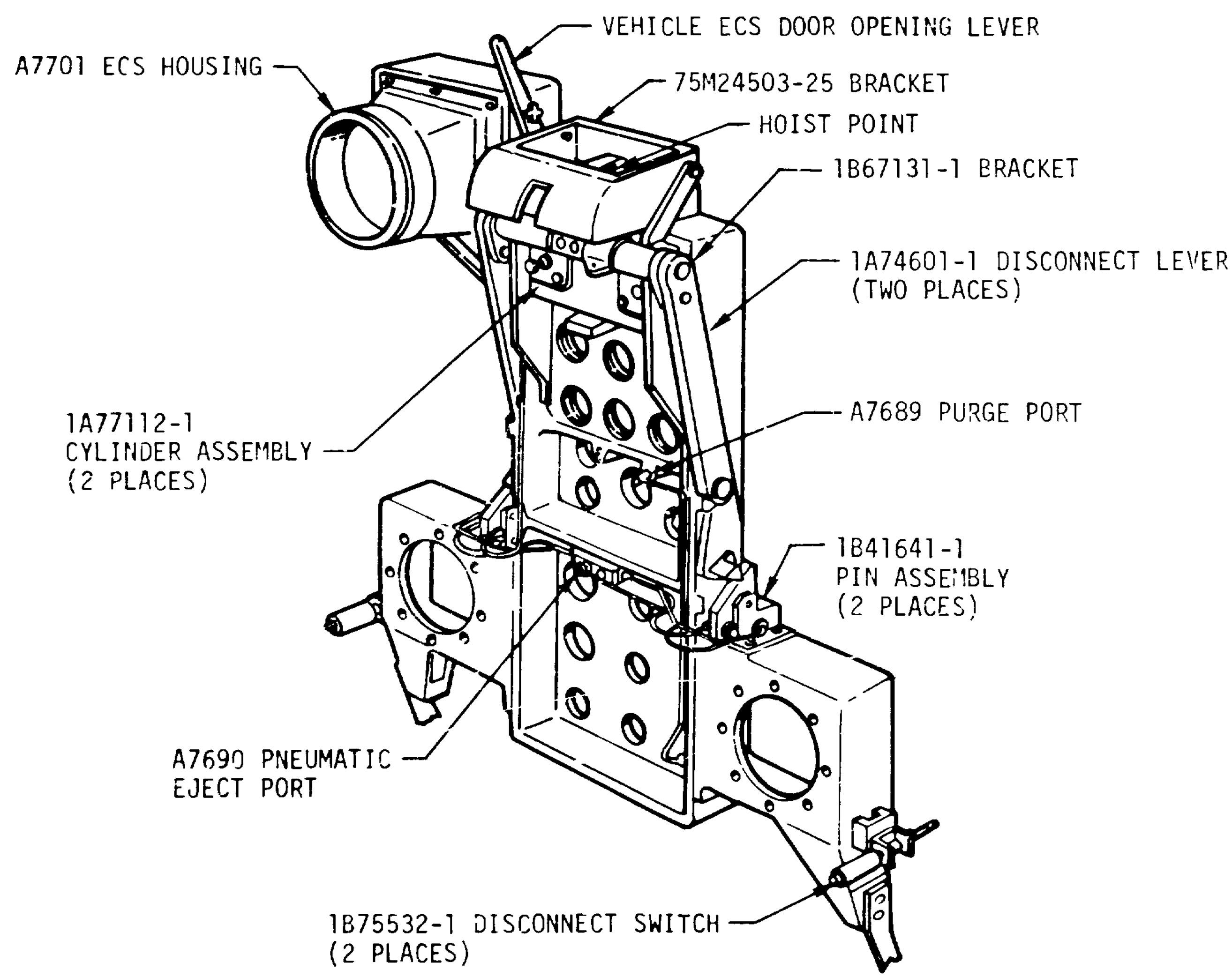


Figure 2.2.14.7-1

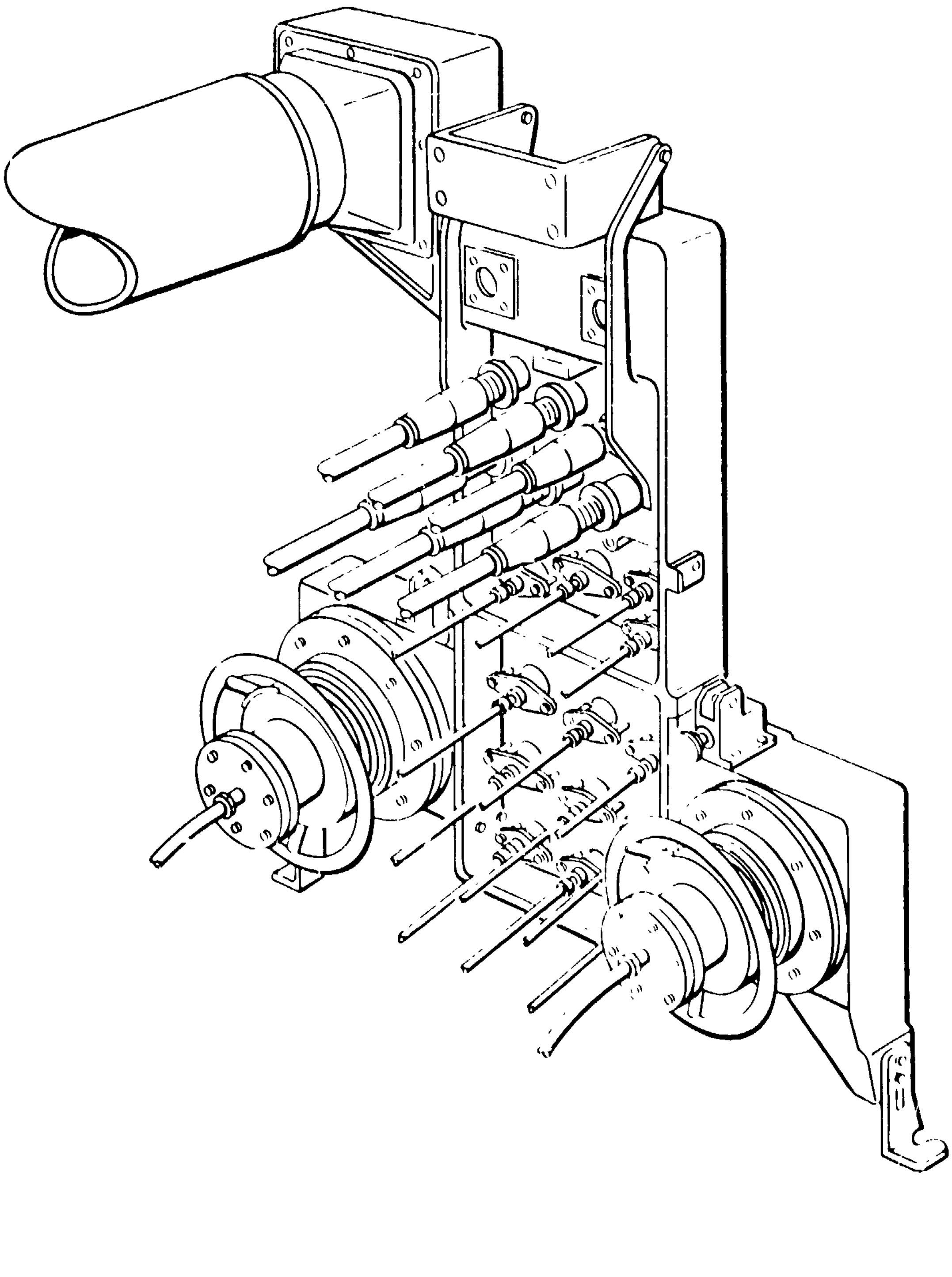


Figure 2.2.14.7-2. Aft Umbilical Kit, Checkout Stand (DSV-4B-346)

OWS within 11 degrees of carrier rotation, a pneumatically operated eject mechanism to disconnect electrical plugs to simulate liftoff and an electrical grounding sys em (Figure 2.2.14.7-3).

C. Testing

Tests were not required because of previous extensive tests on the S-IVB from which this system was derived and because there was no change to the eject system.

D. Conclusions and Recommendations

The OWS umbilicals handling system consisted of a modified model DSV-IVB umbilical handling system with the eject system being used without change. As a result, this system operated as planned as it has for all S-IVB missions.

Umbilical carriers must be designed to assure minimum side loading on disconnects and must have provisions to contain any liquid spillage c used by disconnect leakage or rupture. Umbilicals should also provide against any potential spillage from other sources above the umbilicals.

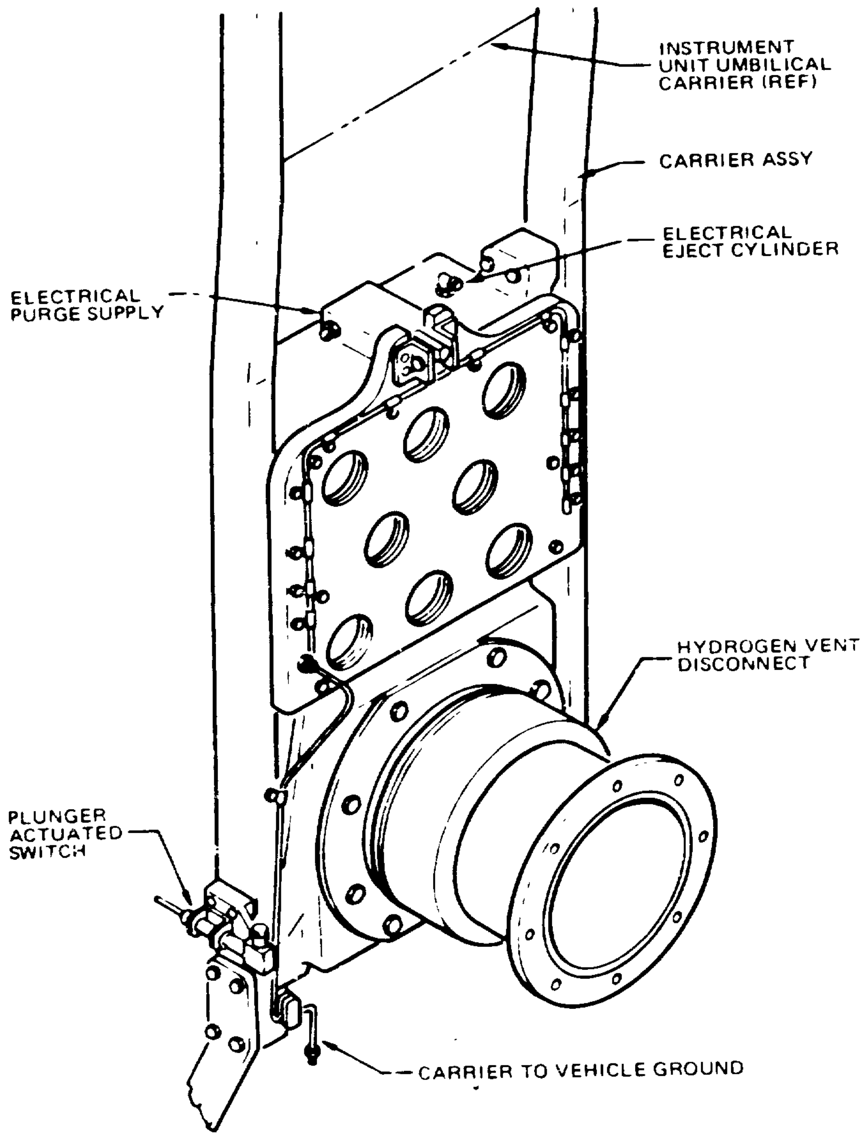


Figure 2.2.14.7-3. Umbilical Kit, Forward Launcher (DSV-4B-316)(DSV-7-375)

2.2.14.8 Refrigeration System Service and Checkout Equipment

A. Design Requirements

1/ Evacuate the Orbital Workshop (OWS) Refrigeration System (RS) to less than 5 mm Hg (666.5 N/m^2) to remove moisture and air prior to filling.

2/ Pressurize the OWS-RS with GN_2 or GH_e for pressure decay leak checks or for purge or drain.

3/ Fill, circulate, demoisturize, and filter the coolanol-15 in the OWS-RS.

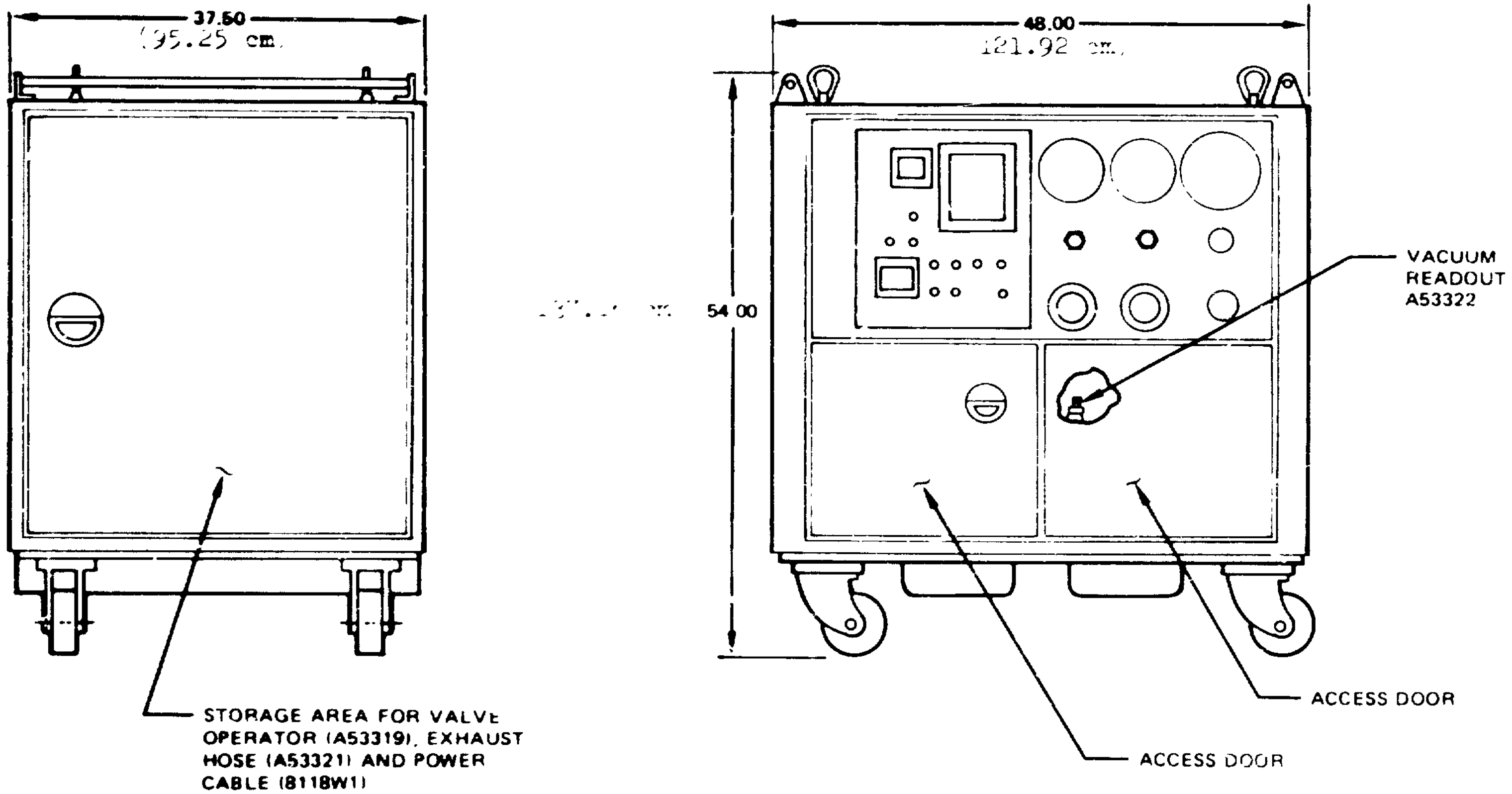
4/ Provide local, manual control, and monitoring.

5/ Items of Ground Support Equipment (GSE) are to be explosion-proof, Electro Magnetic Inteference (EMI) compatible, and capable of being used on the launch pad.

6/ Protect the OWS-RS from overpressurization during servicing and shipping.

B. System Description - To meet the above requirements, several items of GSE were designed to be used in conjunction with each other.

1/ DSV-7-314 Vacuum Pumping Unit - The vacuum pumping unit is a portable, caster-mounted console that is approximately 48 in. (121.92 cm) wide, 37.5 in. (95.25 cm) deep, and 54 in. (137.16 cm) high (Figure 2.2.14.8-1). The unit has mounted panel gages, valves, regulators, switches and indicators, and weighs approximately 1300 lbs. (589.7 kg). The major components of the vacuum pumping unit are the vacuum pump, foreline



ure 14.8-1. Vacuum Pumping Unit Installation (DSV-7-314)

trap, vacuum valves, solenoid valve, hand valves, pressure regulator, relief valves, pressure switch, pressure gage, vacuum gage, oil heater, temperature gage and controller, heaters, filters, quick disconnects, nitrogen gas dryer, flex hoses, electrical power cable, switches, motor controls, time meters, and indicator lights. The electrical portion of Model DSV-7-314 is composed of two GN_2-purged units containing electrical components and controls (Figure 2.2.14.8-2).

2/ DSV-7-315 Refrigeration Service Unit - The service unit is shown in Figures 2.2.14.8-3 and -4; it consists of a completely enclosed, self-contained, caster-mounted console with panel-mounted gages, valves, meters, regulator, switches and indicator lights. The power cable, hoses, and adapters are stored within the cabinet. The service unit systems incorporate safety features that protect the vehicle system from overpressurization. The quick disconnects on the ends of the hoses are keyed to assure proper connection to the vehicle. The gaseous nitrogen system and the coolant system are completely segregated to prevent GN_2 from inadvertently being introduced into the vehicle system when filled with coolant. The electrical portion of the Model DSV-7-315 is composed of two purged units containing electrical components and controls.

The service unit is 84 in. (213.4 cm) high, [illegible] in. (110.[illegible] cm) wide, and 36 in. (91.4 cm) deep. The approximate weight of the system is 1300 lbs. ([illegible] kg) (dry) and 1500 lbs. (680.[illegible] kg) (wet).

SKYLAB - ORBITAL WORKSHOP

FLUID SYSTEM SCHEMATIC (DSV7-314)

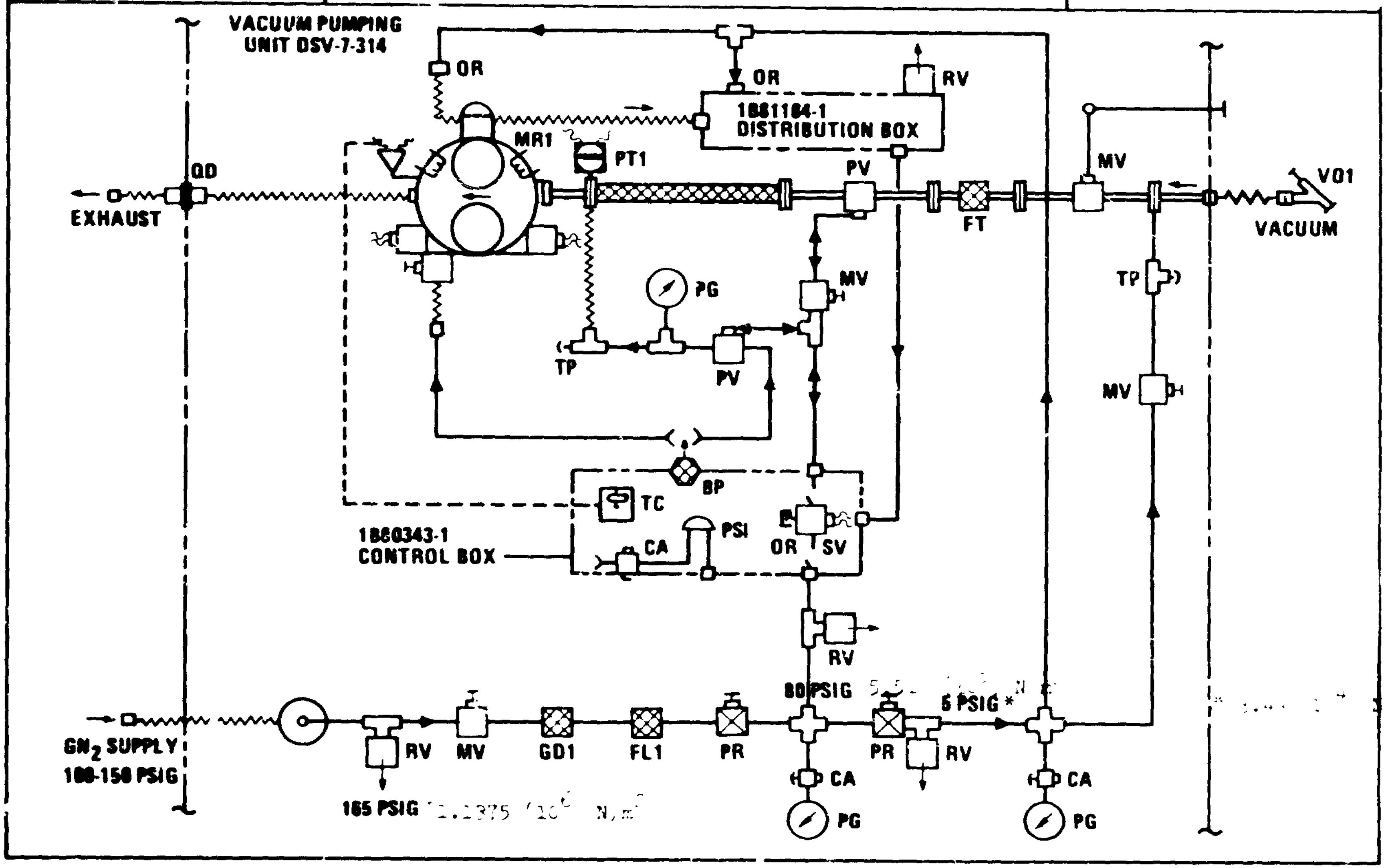


Figure 2.2.14.8-2

SKYLAB - ORBITAL WORKSHOP
REFRIGERATION SUBSYSTEM SERVICE UNIT DSV7-315
FRONT VIEW (DOOR REMOVED)

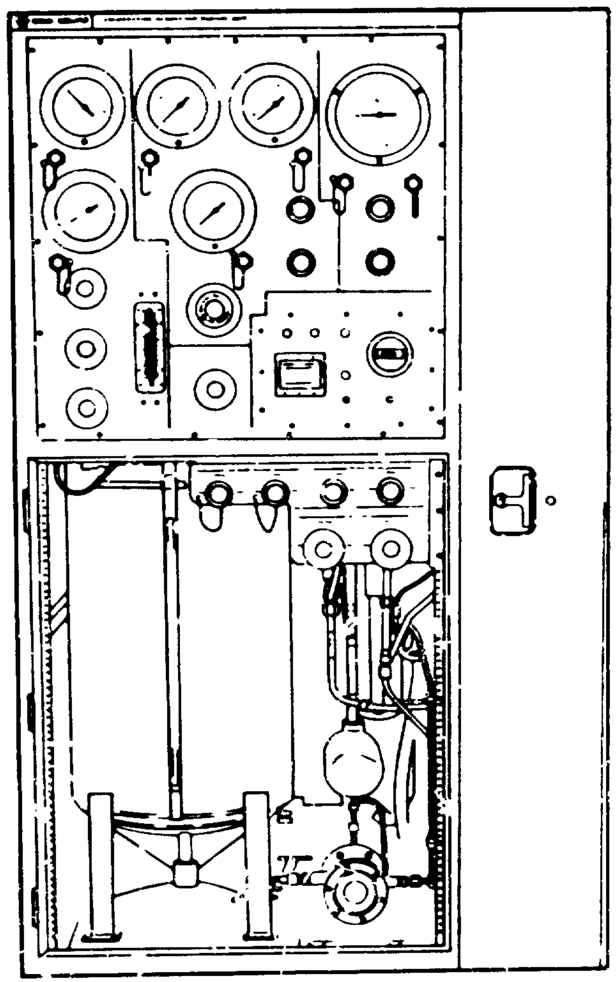


Figure 2.2.14.8-3

SKYLAB - ORBITAL WORKSHOP
REFRIGERATION SUBSYSTEM, SERV··CE UNIT

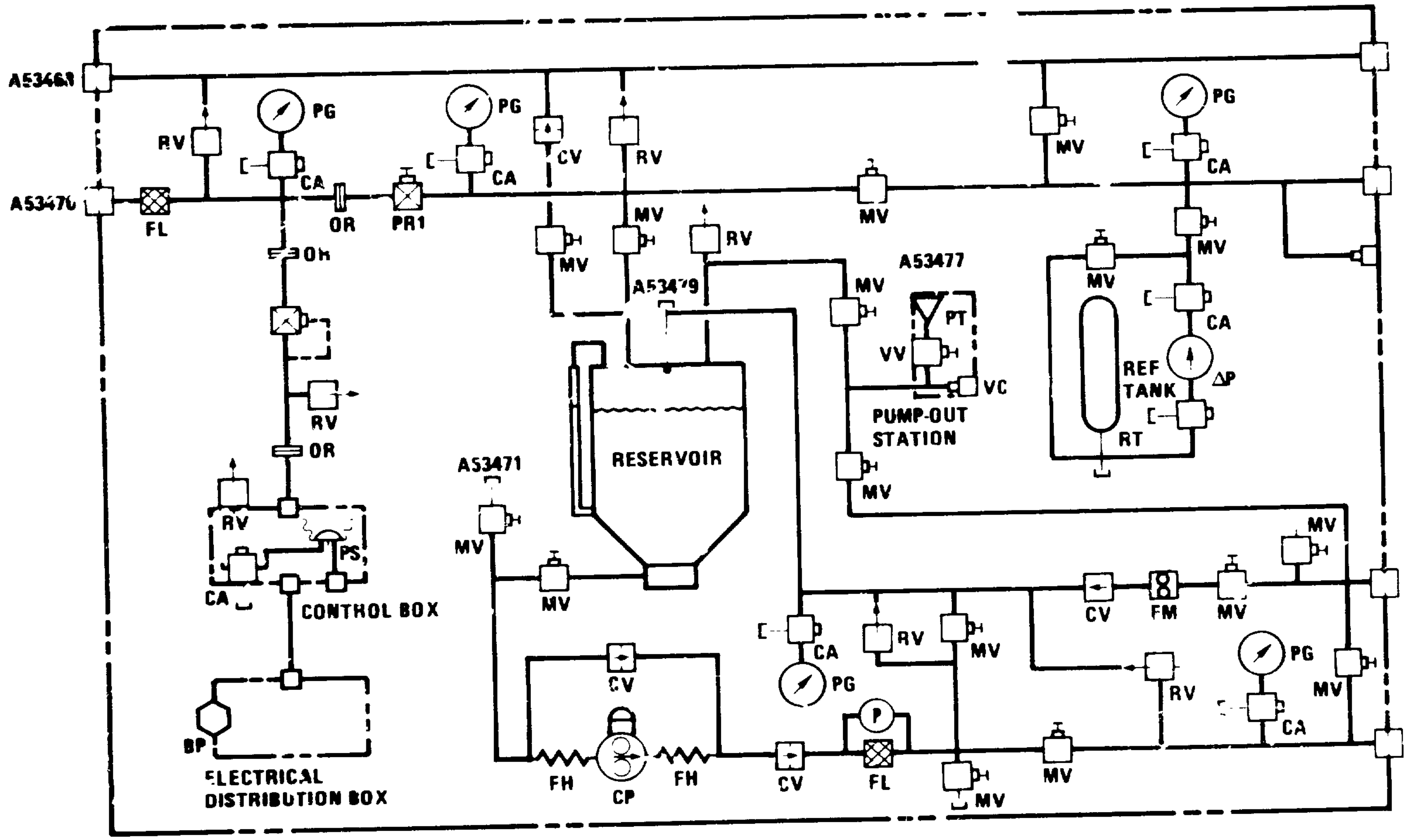


Figure 2.2.14.8-4

The coolant subsystem consists of a 31-gal. (0.117 m^3) reservoir [22-gal. (0.083 m^3) usable], a pump, control valves, monitoring gages, and meters. There is a manifold circuit that ties the system to Model DSV-7-314 so the vehicle system may be evacuated through the coolant hoses. Vacuum gage tubes, which mate with Model DSV-7-316, are provided at the DSV-7-314 interface and the vehicle interface. Coolant is circulated through the system at up to 135 psig (9.306 x 10^5 N/m^2) at 1 to 2 gpm [3.78 (10^3) to 7.57 (10^3) m^3/min] to remove entrapped air bubbles and particles greater than 10 microns (1 x 10^5 m).

The gaseous nitrogen subsystem will accept GN_2 or GH_e at between 400 [2.757 (10^6)] and 500 [3.447 (10^6) N/m^2] psig. The gas can be regulated from 0 to 150 [1.034 (10^6) N/m^2] psig, which is the relief valve cracking pressure. The gas is used for purging the vehicle, purging the electrical components for explosion-proofing, pressurizing the vehicle for leak tests, pressurizing the coolant reservoir, and purging the coolant hoses.

3/ DSV-7-316 Mechanical Test Accessory Kit - This kit accommodates many individual items that are required for protecting checking, and servicing the OWS subsystems. Each of the items can be used independently of the others, on different subsystems and at different times. Only those items of significant importance in relation to the OWS-RS are described here.

a. Pressure Decay Leak Detector - The pressure decay leak detector (1B86835) is shown in Figures 2.2.14.8-5 and -6.

SKYLAB - ORBITAL WORKSHOP
ACCESSORY KIT MECHANICAL TEST
(DSV-7-316)

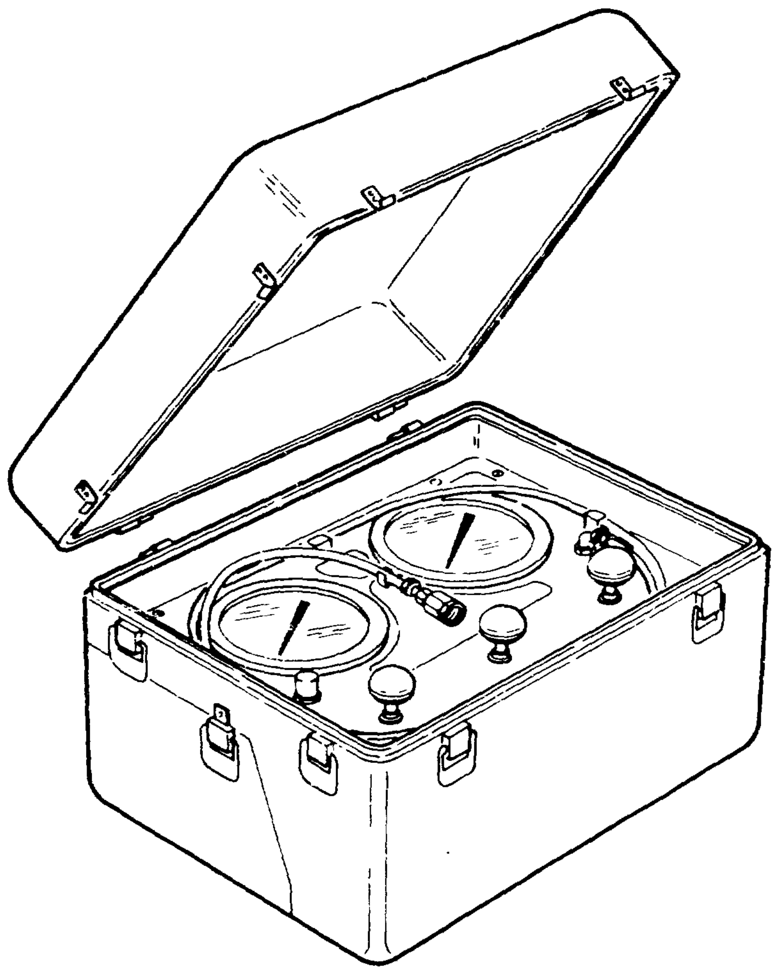


Figure 2.2.14.8-5

SKYLAB - ORBITAL WORKSHOP
ACCESSORY KIT - MECHANICAL TEST (DSV-7-316)
PRESSURE DECAY LEAK DETECTOR SCHEMATIC

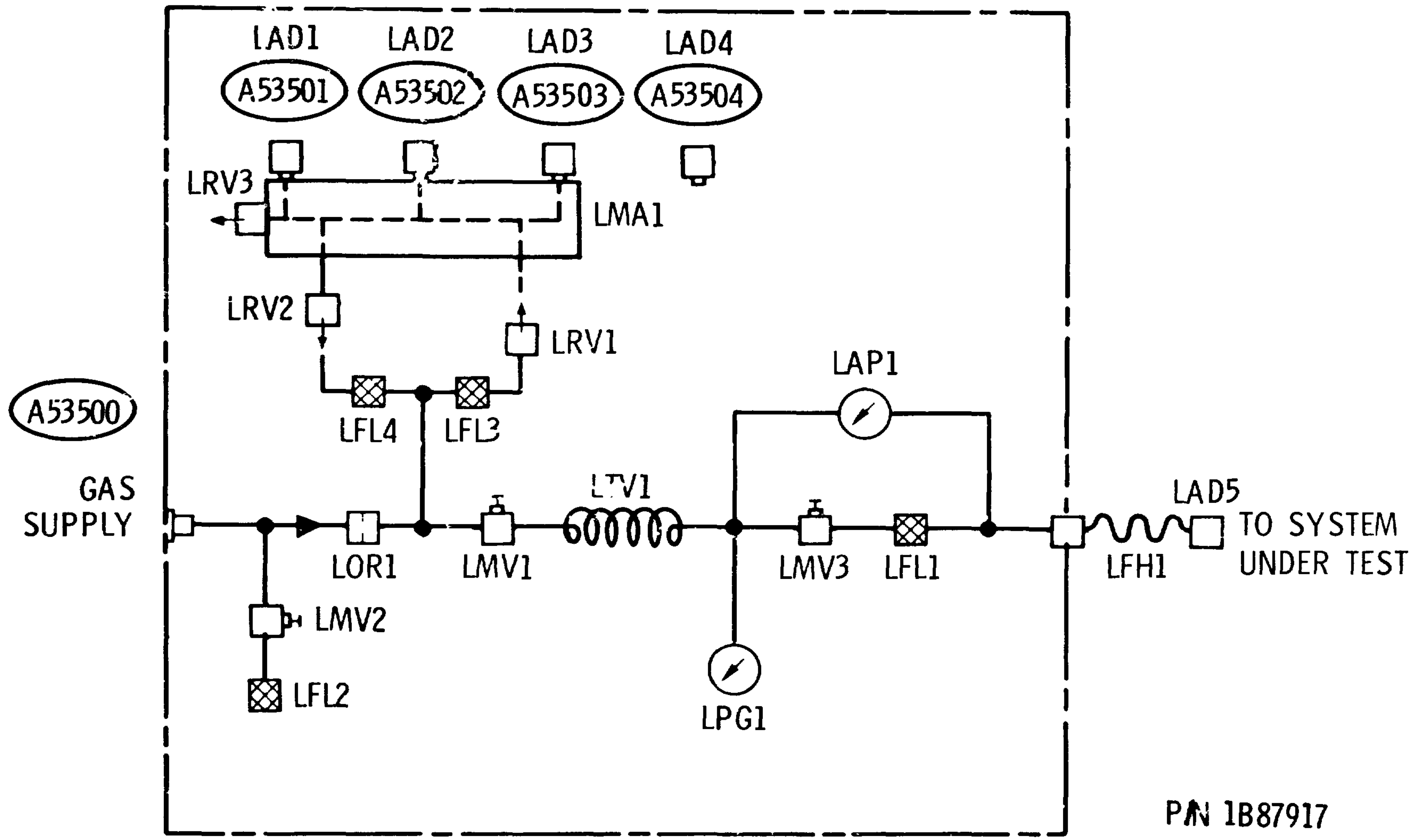


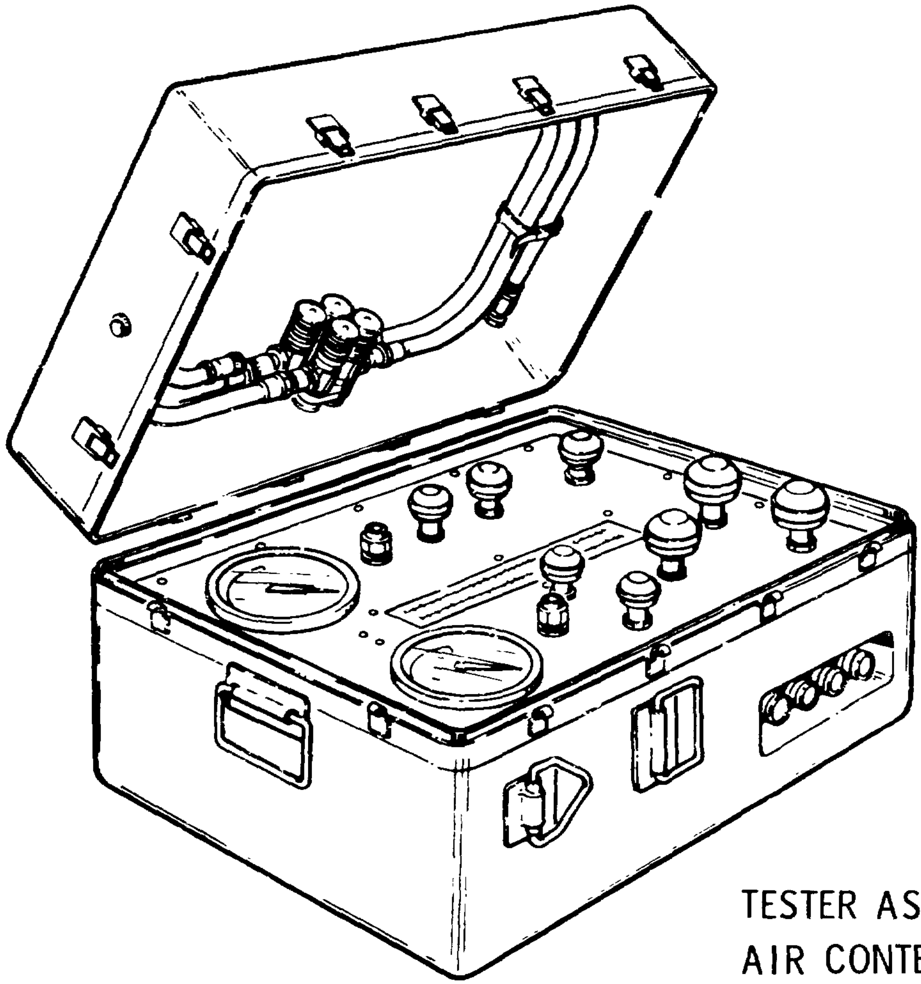
Figure 2.2.14.8-6

The leak detector consists of a suitcase containing a differential pressure gage with a reference volume attached to one side and a flex hose that connects to the vehicle system under test on the other side. It also includes pressure gages, relief valves, shutoff valves, adapters and associated plumbing. It is a portable, self-contained unit and can be used within the OWS to measure the leak decay rate of the RS, the trash airlock, the Environmental Control System (ECS) ground heat exchanger, the portable water bottle, and the waste processor.

b. Air Content Tester - The air content tester assembly (1B85669) is shown in Figures 2.2 14.8-7 and -8. The unit consists of a carrying case that contains a calibrated sight glass, a bottle used for filling accumulators, pressure gages, valves, and associated tubing. It also includes flexible hoses that connect to both primary and secondary circuits of the RS for simultaneous servicing. This device allows concurrent filling of both vehicle circuits, testing them for air content, and assures a quantitative accumulator filling. It is portable, self-contained, and can be used inside the OWS. During servicing and checkout, it will interface with DSV-7-315 and the RS of the vehicle.

c. Shipping Adapter Plate - The RS shipping adapter plate (1B83883) is shown in Figure 2.2.14.8-9 and is used when shipping the OWS from Huntington Beach to Cape Kennedy.

SKYLAB - ORBITAL WORKSHOP
ACCESSORY KIT MECHANICAL TEST (DSV-7-316)



TESTER ASSEMBLY
AIR CONTENT P/N 1B85669

Figure 2.2.14.8-7

ORBITAL WORKSHOP
AIR CONTENT TESTER ASSEMBLY
PN 1B87918-1 (DSV7-316)

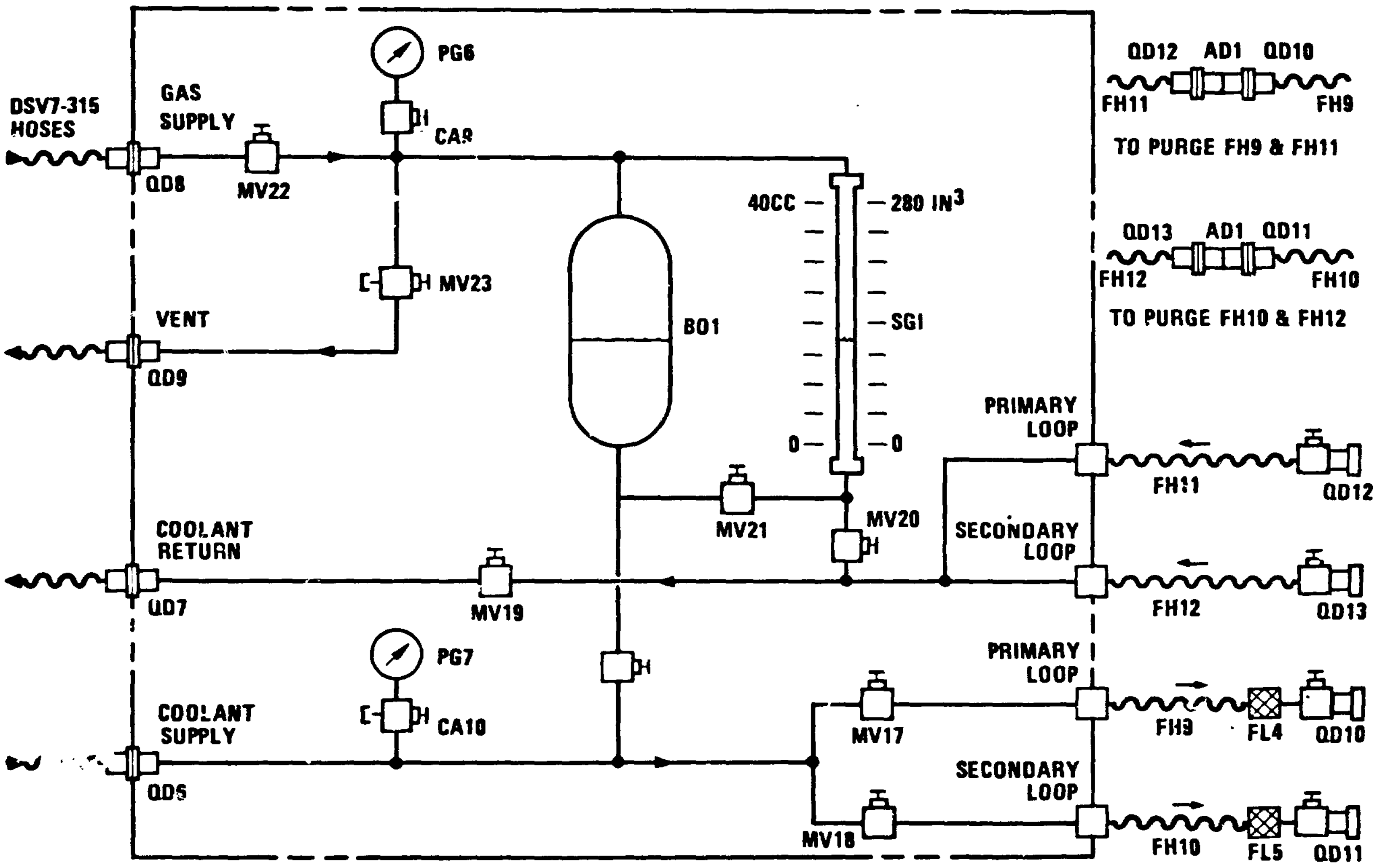
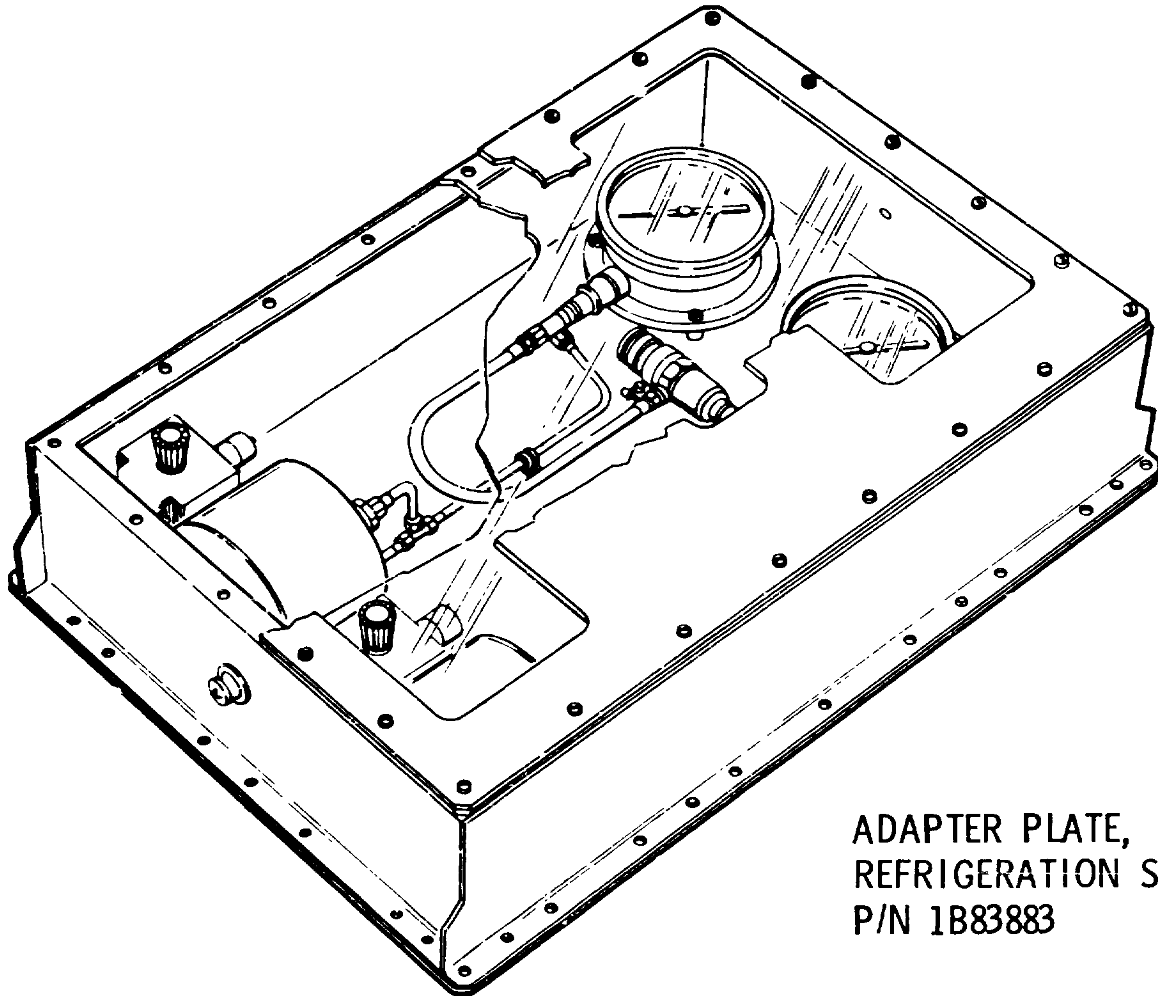


Figure 2.2.14.8-8

SKYLAB - ORBITAL WORKSHOP
ACCESSORY KIT MECHANICAL TEST (DSV-7-316)



ADAPTER PLATE, SHIPPING
REFRIGERATION SUBSYSTEM
P/N 1B83883

Figure 2.2.14.8-9

It provides the ability to indicate the RS primary and secondary loop pressure variations from leakage or temperature changes. It also provides additional accumulator capacity to accommodate system volume changes during shipment. The adapter plate consists of a plate on which is mounted two separate and identical circuits, each of which contains a pressure gage, accumulator, shutoff valve, flex hose, and quick disconnects. The circuits are enclosed with a protective cover that has a clear polycarbonate (Lexan) front panel. The range of the gages is from 0 to 60 psig (0 to 4.136×10^5 N/m^2) with increments of 0.2 psi (1.378×10^3 N/m^2).

C. Test Program of GSE - The performance and design maturity of Model DSV-7-314 have been proven through various tests prior to actual use at KSC. Specifically, this model has performed properly in its production acceptance test (1B82687-PATP1), the handling and checkout procedure (1B89311) and by its use in the refrigeration servicing test and checkout procedure (1B84781).

The performance capability and design maturity of Model DSV-7-315 have been proven through various tests. Specifically, this model had demonstrated design performance in its production acceptance test (1B84050-PATP1), the handling and checkout tests (1B89311) and by its use in the refrigeration servicing TCP 1B84781 conducted at Huntington Beach Vehicle Checkout Laboratory (VCL) prior to shipment to KSC. These tests prove the proper functioning and interface compatibility of this model

The performance capability and design maturity of Model DSV-7-316 have been proven through various tests. Specifically, this model has demonstrated design performance in its production acceptance tests, handling and checkout tests, and the OWS test control procedures.

D. Mission Results - Performance During Service and Checkout - The items of GSE design to service and checkout the OWS-RS performed satisfactorily and met the design requirements imposed upon them. There were no cases of major redesign or resultant schedule impact on the vehicle. Some of the more significant problems encountered and their solutions are as follows:

1/ DSV-7-315 Moisture Content of Coolanol-15 - Qualification tests of RS flight components revealed that at low temperatures, water in the Coolanol-15 had precipitated out of solution, frozen, and blocked an RS filter. Further tests determined that the water content of the Coolanol-15 should be 0.006% by volume maximum (Karl Fisher method) to preclude water freezing at the lowest temperature to be experienced by the RS.

Previous to this the Skylab RS had been filled with Coolanol-15 from Model DSV-7-315. Available data indicated this coolant had a moisture content of 0.016% which was considered too high to be acceptable.

The following action was taken to rectify this problem:

a. The water content of the coolant in DSV-7-315 was reduced to 0.006% maximum by circulating the coolant within the unit while maintaining a dry GN_2 purge through the evacuated ullage of the reservoir.

b. The coolant in the OWS/RS was flushed through the DSV-7-315 utilizing the same procedure.

c. The maintenance procedure for the DSV-7-315 was changed to require filtration of all coolant through a 0.45 micron (4.5×10^{-7} meter) black filter before adding it to the servicer.

2/ DSV-7-315 Heat Buildup of Coolanol-15 - Model DSV-7-315 uses a centrifugal type pump which uses a combined rotor and impeller assembly driven by the magnetic field of an induction motor. A small portion of the pumped fluid circulates through the rotor cavity to cool the motor and lubricate the bearings.

During the initial design of this unit, no provision was made for cooling the Coolanol-15. It was estimated that the steady-state temperature within the unit may average approximately 100°F (310.9°K), but this was not considered high enough to warrent the additional complexity of a heat exchanger. There was no tight temperature requirement at the time and there was concern that a possible leak in a coolanol heat exchanger would contaminate the flight coolant.

During the production acceptance tests of the DSV-7-315, temperatures within the reservoir reached 107°F (314.8°K) but there was still no cause for concern since it was felt that with the addition of the other items of GSE used between the OWS and DSV-7-315 the temperature would be less than 100°F (310.9°K) at the vehicle interface.

When the servicer was actually used in circulating coolant through the OWS-RS, the temperature at the GSE vehicle interface was in the range of 90 to 100°F (305.4 to 310.9°K). Temperature in the GSE servicer reservoir was in the range of 110 to 120°F (316.5 to 322°K) due to the fact that much of the coolant was being bypassed within the GSE and most of the pump heat was going into the reservoir. Also the reservoir was low - having already been used to fill both vehicle loops.

At this time, the maximum allowable temperature of coolanol within the OWS was established at 80°F (299.8°K) as measured by transducers within the pump enclosure and the maximum allowable temperature at the quick disconnect GSE-OWS interface was established at 120°F (322°K).

To ensure meeting the above requirements within the vehicle, it was necessary to pack dry ice around the lower portion of the GSE reservoir and around the pump itself.

If this procedure had not worked, it was recommended that the heat could be removed from the OWS through the ground thermal conditioning system heat exchanger. However, this was not done since the dry ice kept the temperature low enough.

3/ DSV-7-316 Malfunctioning Fill and Vent Quick Disconnects on Coolanol-15 Hose - Two GSE jumper hoses were used within the OWS-RS pump package to bypass coolanol around the vehicle pumps during various servicing and checkout operations. Each end of each hose terminated in a special fill and vent quick disconnect which incorporated a manual valve to allow closing of the vehicle poppet half of the disconnect prior to disconnecting the GSE half.

During removal of these hoses after checkout at KSC, one of the vehicle poppet halfs failed to close completely when the manual valve was activated. When the GSE female half was disconnected the flight poppet sealed properly indicating a malfunctioned GSE half. It was later discovered that the GSE half was not fabricated correctly.

4/ DSV-7-510 Leaking End Fittings of Coolanol-15 Hoses - The flexible fluid hoses used on the GSE servicing the OWS-RS were made from Poly Vinyl Chloride (PVC) sometimes referred to as Tygon. A steel helical wire was molded into the PVC for strength and the hose was then covered with a steel wire braid and a scuff guard heat shrunk over the entire assembly. The ends of the hose were forced into fittings that consisted of three stainless steel parts. (See Figure 2.2.14.8-10.) A nipple fitting with serrations on its OD screwed into a socket which was swaged down to hold the hose and squeeze it over the nipple fitting. The pressing of the serrations on the nipple into the softer PVC was the main sealing surface. The nipple also retained the B-nut used to fasten the hose to its mating fitting.

This particular hose was chosen for OWS use for several reasons. PVC is not only compatible with coolanol, but it is impervious to helium so it could be used for helium leak checks. It is also an excellent material for low vacuum application. Its

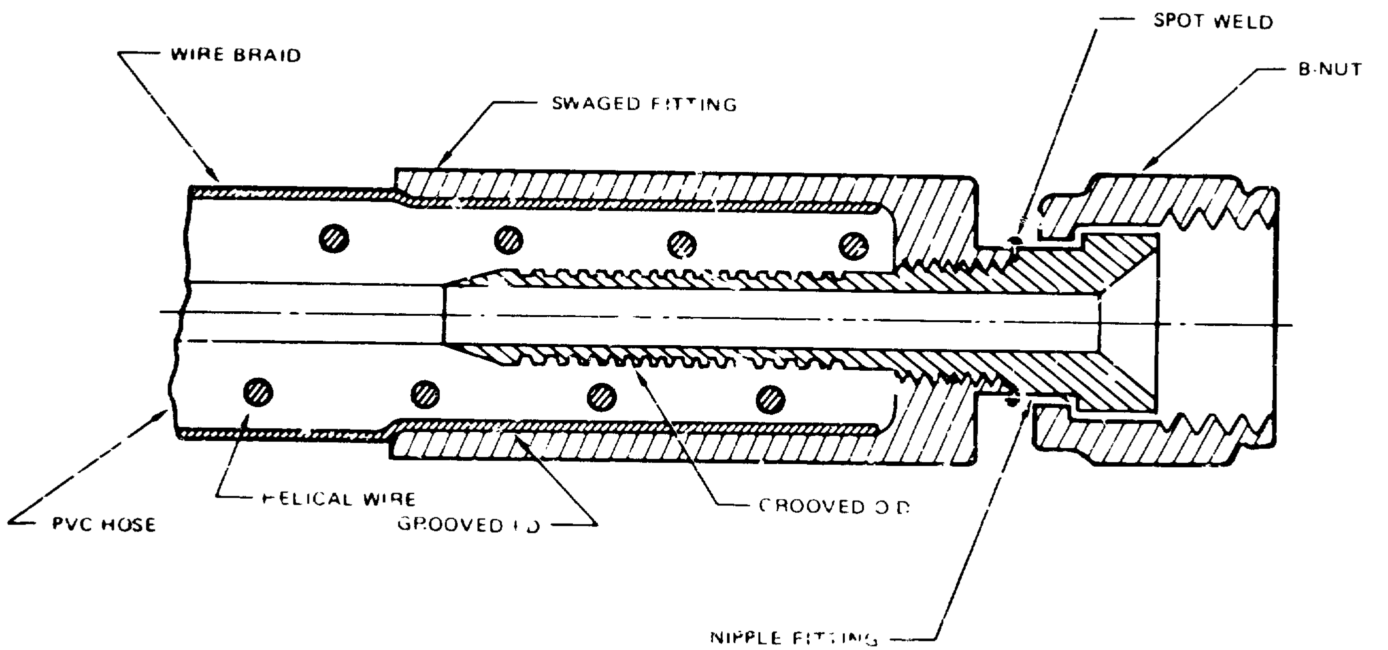


Figure 2.2.14.8-10 Skylab - Orbital Workshop Flexible Hose End Fitting GSE — RS Coolanol-15

smooth inner bore gives it good flow characteristics and allows for easy flush cleaning when used in precision cleaned systems. It could be pressurized to 200 psig (1.38×10^6 N/m^2) operating pressure yet be flexible enough to allow reasonable bends.

This hose (MDAC Part No. 1B80480) experienced a history of leakage problems from the very beginning of the program. Excessive failures and subsequent failure analysis revealed a series of shortcomings in the design which lead to a succession f design changes.

a. It was determined that the 1/4-in. (.635 cm) I.D. hose did not have sufficiently thick walls to properly contain the molded-in helical wire. With bending and use, the wire would work its way through the PVC and cause a leak. The 1/4-in. (.635 cm) size was discontinued and 3/8-in. (.955 cm) I.D. hoses with 1/4-in. (.635 cm) end fittings were instead.

b. It was evident that the internal nipple fitting was rotating within the PVC hose, losing its seal and resulting in leakage. This was caused by a combination of bending, twisting, and axial loading of the hose near the end fittings. The design changes resulting from this were:

   - The nipple fitting was spot welded to the outer swaged fitting so no independent rotation could take place.
   - The smooth I.D. of the swage fitting was replaced with a grooved I.D. for better grip.
   - The saw tooth serrations on the OD of the nipple fitting were replaced by a more square shaped groove pattern.

- The swage configuration on the OD of the swage fitting was changed from a hex shape to a round shape. This not only improved the squeeze but prevented inexperienced operators from applying a wrench to its surface.

- A recommendation was made by NASA/KSC to trim back some of the metal outer braid on the PVC hose before inserting it into the end fitting for swaging. This would allow the swaged fitting to grip the hose material directly. This was never implemented.

c. It was determined that some rejected hoses were really due to air that was trapped between the hose braid and the scuff guard. This air bubbled out of the ends when the hose was immersed in water. To eliminate this problem, the scuff guard was perforated and one-half hour under water was allowed before testing.

d. In addition to hardware design changes, handling and checkout drawings were changed to incorporate detailed instructions for proper handling techniques to avoid twisting or pulling of hoses and to lubricate the B-nut shoulder to minimize friction during torquing.

2.2.14.9 Refrigeration System Ground Thermal Conditioning Equipment

A. Design Requirements - The purpose of the ground thermal conditioning system is to provide refrigerated water-glycol coolant to the OWS ground cooling heat exchanger (CGHX), in support of the vehicle habitability support system (HSS) RS. Model DSV-7-301 is required when the frozen foods are installed in the OWS freezers up to the time of launch. This model also provides the capability to purge the coolant from the HSS/RSS ground cooling heat exchanger prior to liftoff. A summary of the requirements follows:

1/ Provide water glycol to the OWS-RS ground heat exchanger at temperatures low enough and flow high enough to maintain frozen food temperatures within the OWS until launch.

2/ Provide a ground purge capability to flush out the water glycol from the OWS-RS heat exchanger prior to launch.

3/ Provide the instrumentation to monitor the temperature, pressure and flow of the water glycol to and from the ground heat exchanger.

4/ The model must be explosion-proof and EMI compatible.

5/ Original design parameters were as follows:

- Max Vehicle Load — 5000 Btu/Hr (5.271×10^6 J/hr)
- Max Supply Temp — -21°F (243.7°K)
- Min Supply Flow — 3.2 GPM (.012 m^3/min)
- Max Supply Press — 200 psig (1.38×10^6 N/m^2)

Subsequent events led to a relaxation of the flow requirement in order to obtain a colder temperature of -27°F (240.4°K) maximum.

B. System Description - DSV-7-301 Ground Thermal Conditioning System

See Figures 2.2.14.9-1 through -4. The ground thermal conditioning system consists of two thermal conditioning units (TCU) and the coolant control unit (CCU). Interconnecting lines and hoses were KSC-provided.

The TCU (NASA Model S14-121) is a government-furnished part (GFP), modified to satisfy the low temperature requirements. The GFP TCU's were manufactured by Rockwell International Corporation No. 614-854025-141, Serial Number 013, and No. 614-854025-301, Serial Number 008. The major TCU components are a two-stage, 25-hp ($1.864\ 10^4$ watt) reciprocating refrigeration compressor, an air-cooled condenser with two fans, two liquid-to-vapor heat exchangers, an evaporator-chiller, two 3-hp (2237 watt) water-glycol coolant pumps in parallel, solenoid and thermostatic expansion valves, and suitable controls for local and remote operation. It is explosion-proof and EMI compatible. The electrical components include motors for the compressor, pumps and condensor fans, solenoid valves, relays, temperature controller, instrumentation, switches, and indicator light.

The TCU provides the means of removing excess heat from the OWS HSS, RS during the vehicle ground checkout and prelaunch phase. This function is required continuously in support of the vehicle system after the frozen foods are installed in the vehicle freezers until the time of launch (approximately 45 days). The unit is a cabinet-enclosed, self-contained system that refrigerates and circulates water-glycol coolant. Two TCU's are used; one is redundant. The coolant fluid is purged from the CGHX prior to liftoff. The TCU is

ORBITAL WORKSHOP
GROUND THERMAL CONDITIONING SYSTEM
DSV-7-301

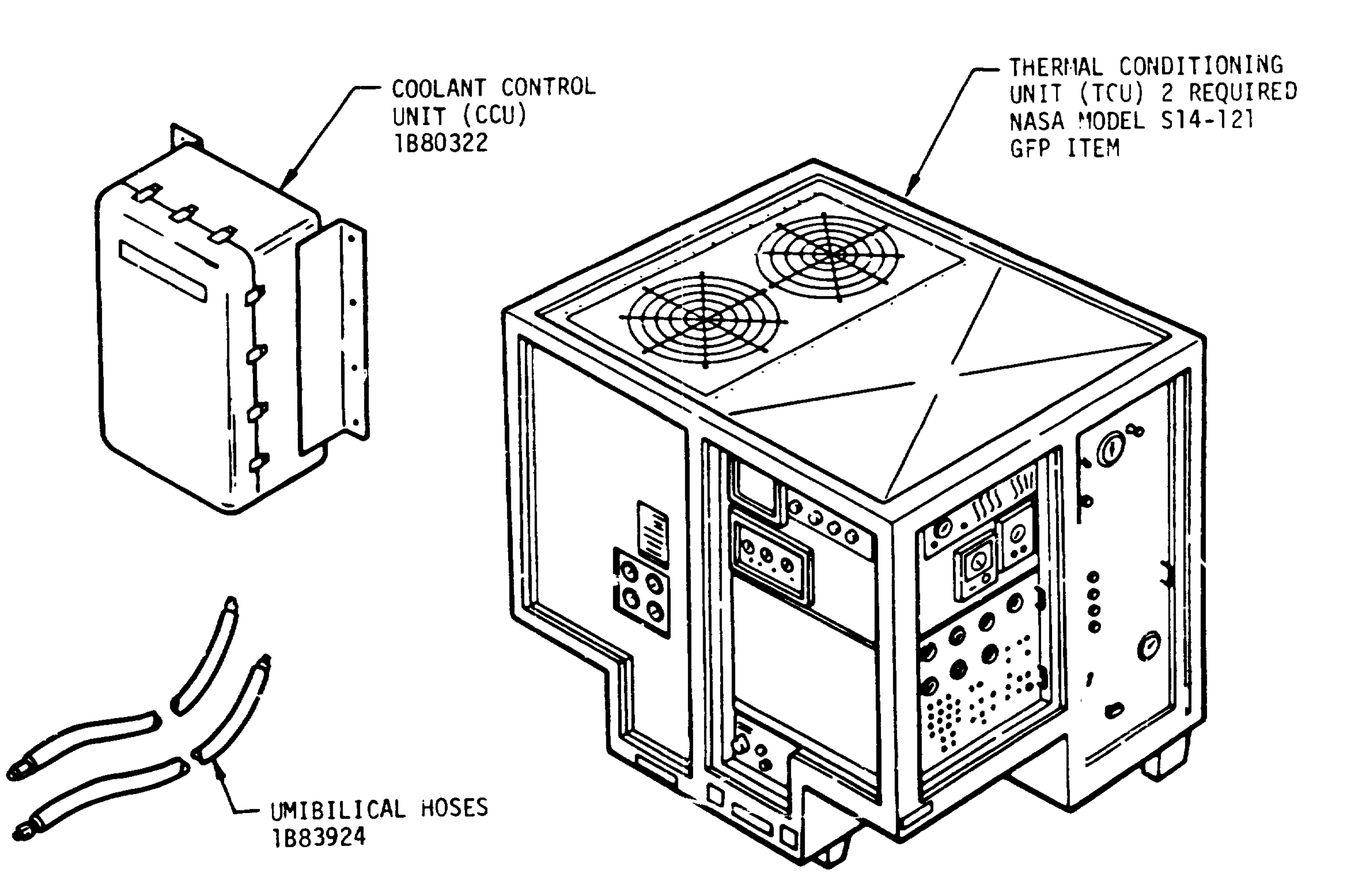


Figure 2.2.14.9-1

SKYLAB - ORBITAL WORKSHOP
GROUND THERMAL CONDITIONING SYSTEM
SYSTEM CONFIGURATION DSV7-301

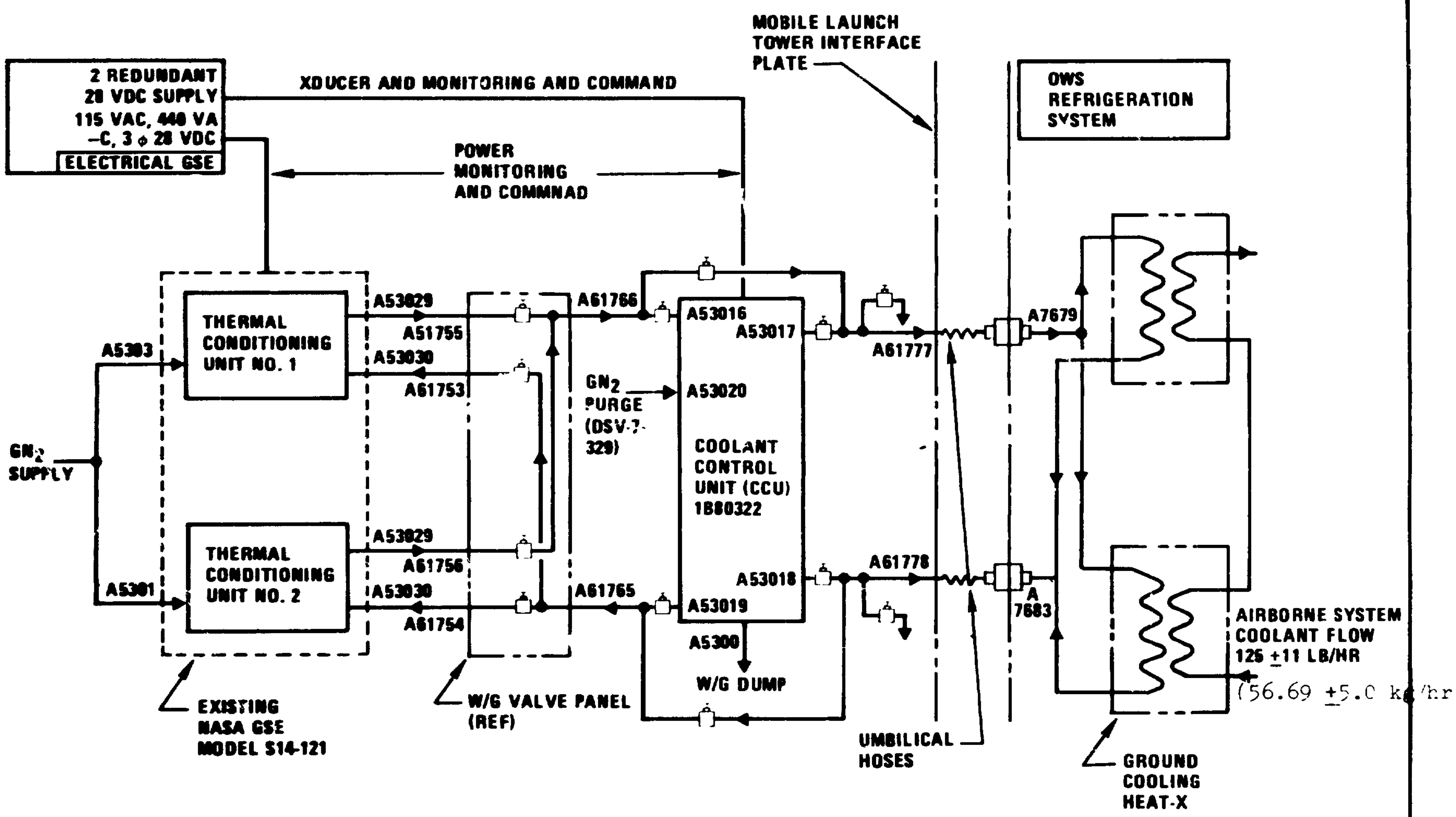


Figure 2.2.14.9-2

SKYLAB - ORBITAL WORKSHOP
GROUND THERMAL CONDITIONING SYSTEM
DSV-7-301
KSC OPERATIONAL CONFIGURATION

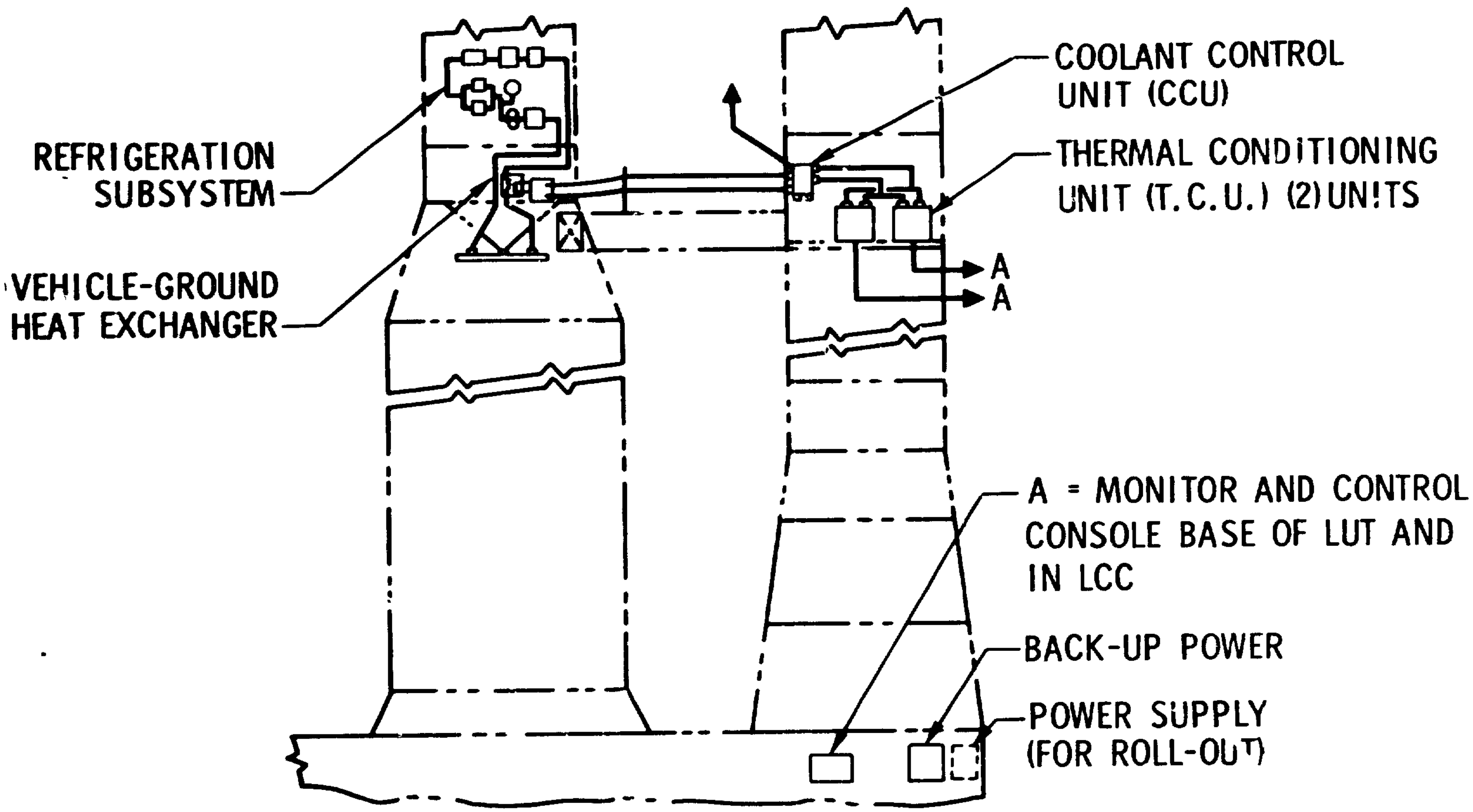


Figure 2.2.14.9-3

SKYLAB - ORBITAL WORKSHOP
GROUND THERMAL CONDITIONING SYSTEM
DSV7-301 CCU MECHANICAL SCHEMATIC

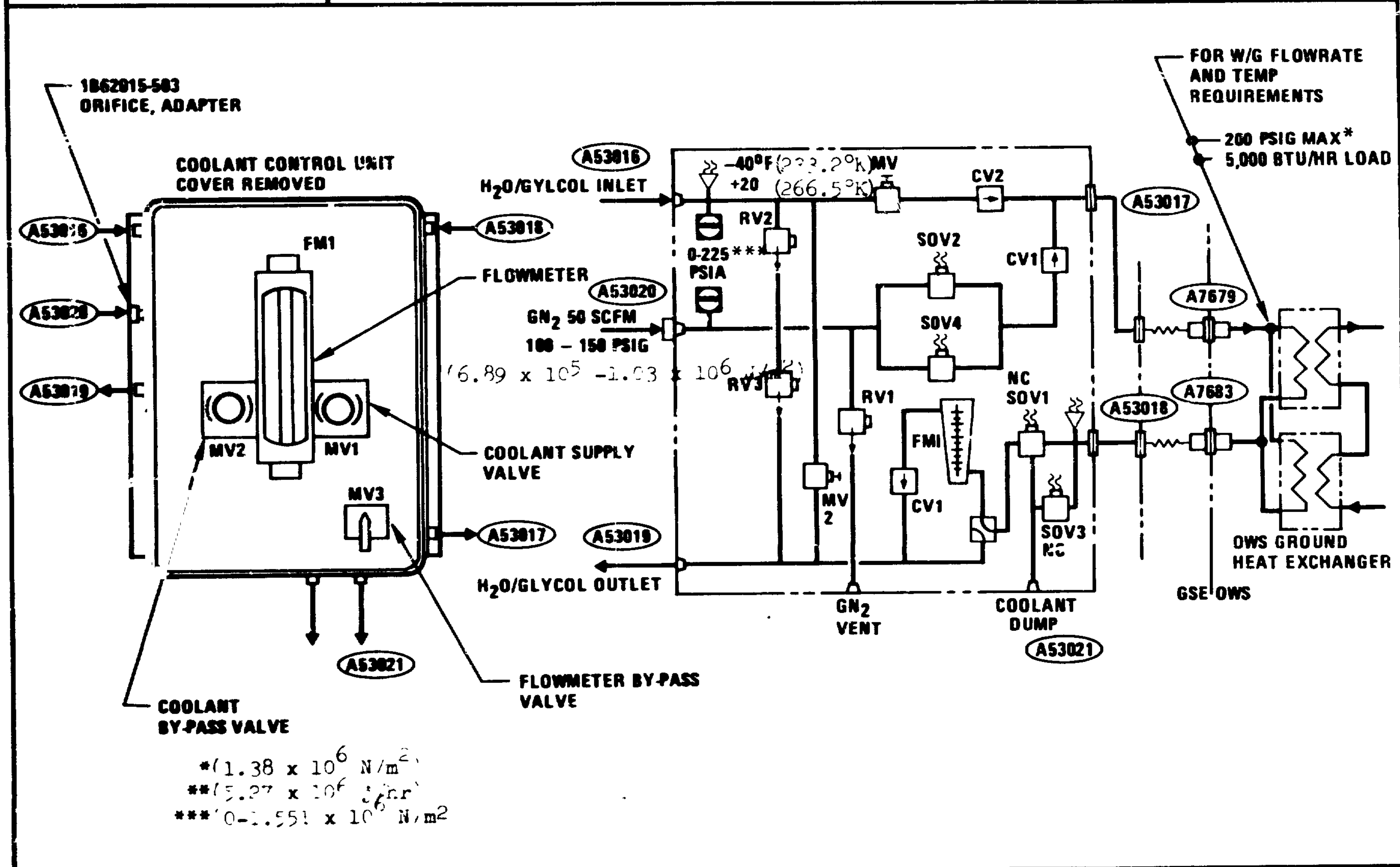


Figure 2.2.14.9-4

capable of being restarted to supply coolant after completion of the purge operation.

The CCU is a wall-mounted, cabinet-enclosed assembly. The CCU contains a roto-meter type flowmeter (frost-free), manual flow control adjusting valves, solenoid valves with talkback, relief valves to protect the vehicle system from overpressurization, and pressure and temperature transducers to indicate temperature and pressure of water-glycol before entry into the vehicle GCHX.

The CCU is designed to control and monitor the coolant supplied to the vehicle GCHX. The functional capabilities of this unit are (1) control coolant flow, (2) remote monitoring of the coolant pressure and temperature, (3) remote monitoring of the GN_2 purge pressure, and (4) purge of the GCHX with GN_2. Redundant valves are incorporated in the GN_2 supply and return lines.

C. Test Program of GSE - The TCU was tested to determine what modifications were required to obtain lower temperatures.

The CCU was production acceptance tested for leakage, solenoid operation and transducer integrity.

The two items were tested together as an operating system in accordance with a handling and checkout drawing prior to vehicle checkout.

D. Performance During Checkout and Prelaunch - From an overall standpoint the Model DSV-7-301 performed in a satisfactory manner. Vehicle requirements were met and schedule was not affected.

Proper temperatures were maintained within the OWS-RS and the purge prior to liftoff was accomplished.

Significant problems encountered and their solutions are as follows:

1/ Inability to consistently operate at temperatures appreciably below the original design requirement.

As previously stated, the original design requirement for flow and temperature at the OWS-RS ground heat exchanger interface were 3.2 GMP (0.012 m^3/min) of water glycol at -21°F (243.7°K) maximum. To provide this temperature, calculations showed the government furnished TCU had to supply approximately -29°F (239.3°K) maximum. Its rated maximum supply temperature as received was -5°F (252.6°K).

After the TCU (Serial No. 013) was modified for lower temperature operation it became evident that reaching the lower temperature was no problem but the flow dropped off considerably due to change of viscosity.

The TCU evaluation test data established a curve which showed the flow vs. temperature relationship. (See Figure 2.2.14.9-5.) The coldest the unit was run was -35°F (235.9°K). At this condition the flow was 1.3 GPM (0.005 m^3/min) and the calculated heat exchanger interface temperature was approximately -27°F (240.4°K). This was not a serious development since the reduced flow was sufficient for the OWS ground heat exchanger performance while the colder temperature achieved was highly desirable.

During actual vehicle tests, Serial No. 013 TCU was called upon to operate appreciably below the -29°F maximum (239.3°K) supply temperature requirement and although the TCU was only

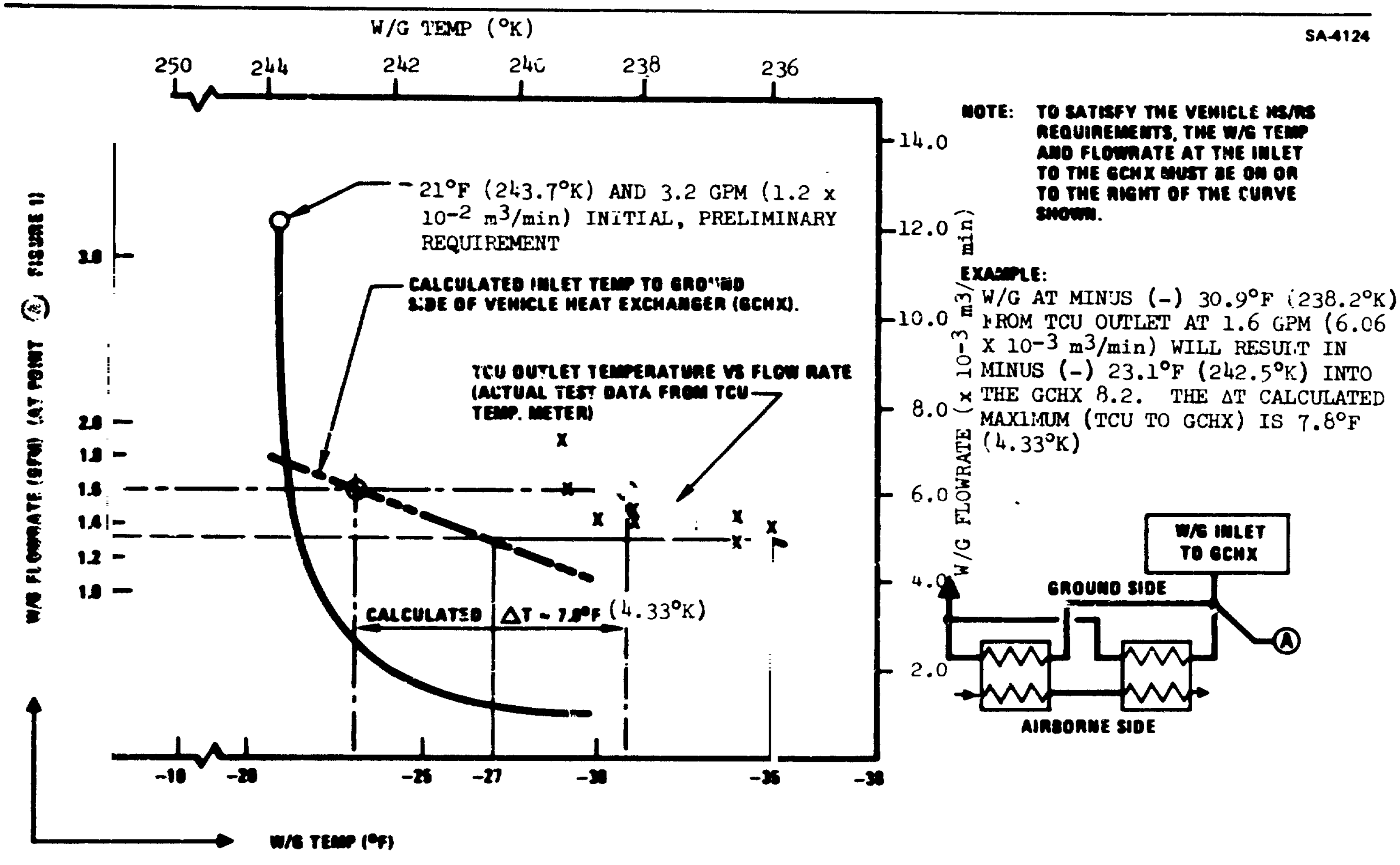


Figure 2.2.14.9-5. Skylab – Orbital Workshop TCU Temperature vs Flowrate

tested to temperatures as low as -35° (235.9°K) it consistently and satisfactorily supported OWS-RS tests by delivering temperatures colder than -40°F (233.2°K). It continued to perform satisfactorily throughout the program.

The other two TCU's modified for cold temperature, however, exhibited anomalies as follows:

a. Serial No. 008 was modified by MDAC-W and used to support qualification test HS-19 of the refrigeration system. This unit exhibited intermittent random temperature irregularities so that it occassionally lost temperature control. At KSC, a malfunctioning hot gas bypass valve was replaced in the refrigeration unit. Retests of this unit showed satisfactory operation while delivering -38°F (234.3°K) water glycol with a simulated vehicle heat load.

b. Serial No. 014 was modified by Rockwell International at KSC to MDAC specifications for low temperature operation. This unit performed satisfactorily and delivered -36°F (235.4°K) until food was loaded on-board and the OWS was closed up. At this time it "warmed" up to -32°F (237.6°K) until Model DSV-7-334 ground thermal conditioning system was activated to cool the interior of the OWS. It then cooled back down to -35°F (235.9°K).

   One explanation for this marginal behavior is that during this time period, the interior temperature of the Workshop was not being continually controlled by a ground system. The internal duct system which controlled the environment during Vehicle Assembly Building (VAB) operations had been removed, last minute closeout functions were performed, the door was secured and the interior of the OWS was purged with GN_2. All of these operations could have had a considerable but temporary additional heat load on the TCU.

2/ Inability to consistently refill the vehicle ground heat exchanger loop after GN_2 purge without activating the low-level light in the ground TCU.

One of the requirements of this item of GSE was to purge the water glycol out of the ground heat exchanger loop just prior to launch. In the case of a "hold" after this function it was highly desirable to be able to refill the loop from the GSE and start temperature control again.

Tests were conducted at Huntington Beach with simulated KSC line volumes indicated marginal capacity in the TCU reservoir to perform this function, but with proper filling of the reservoir a satisfactory restart could be obtained.

Tests conducted at KSC showed the line volume to be greater than simulated at Huntington Beach and to avoid a marginal condition a supplementary reservoir with a separate GN_2 pressurization source was added in parallel to each of the reservoirs in the TCU's.

Subsequently, a leak developed at the connection of the supplementary reservoir to one of the TCU's. Before this leak was discovered there was concern that a leak had developed within the ground heat exchanger of the OWS thermal conditioning system.

3/ Overpressurization of the Vehicle Ground Heat Exchanger Loop - During checkout of the RS in the VAB at KSC, an anomaly occurred which resulted in a pressure of 300 psig (2.06 x 10^6 N/m^2) in the RS ground heat exchanger water glycol loop.

Although this ground system is proofed to 400 psig (2.76 x 10^6 N/m^2) and the heat exchanger to 420 psig (2.89 x 10^6 N/m^2) as a component, normal leak check and operating pressures should not exceed 200 psig (1.38 x 10^6 N/m^2).

The higher than normal pressure was caused by a procedural error which closed a manual shutoff valve in the water glycol return (reservoir) circuit of a TCU while the pump was still running. This action dead-ended the pump and incapacitated the prime GSE relief valves in the CCU. The pressure built up until the backup relief valve in the reservoir of the redundant ground TCU relieved at approximately 250 psig (1.72 x 10^6 N/m^2). By design intent the prime relief valves in the CCU relieve from the supply (pressure) side to the return (reservoir) side of the TCU's. This was done to prevent possible leakage through the relief valves from depleting vital chilled fluid during prolonged remote operation. The relief valves are balanced and will relieve at 190 psig (1.31 x 10^6 N/m^2) regardless of back pressure under flow conditions. In case of a procedural error causing a dead-ended relief valve condition, it was felt that one of the backup relief valves within the TCU would protect the vehicle, which it did.

Since it was not desirable to exceed the normal working pressure of the vehicle system in any case, the following steps were taken to insure the primary GSE relief valves could not be dead-ended:

a. The two manual shutoff valves in each TCU were wired open with warning placards stating their valves must remain open whenever the unit is operating in conjunction with the vehicle.

b. Caution notes were added to procedures to insure that the pump circuit breakers are open when troubleshooting. This insured the pump to be inoperative during these periods.

4/ Water Glycol Leakage of Umbilical Quick Disconnects - During the checkout of the RS in the VAB at KSC, water glycol leakage was observed at the ground heat exchanger return quick disconnect (QD) in the aft umbilical carrier. A failure analysis of the QD indicated leakage was due to excessive usage - (wornout o-ring seals). In addition, there was evidence of possible abuse due to side loads on the QD's which could have resulted from the weight of the GSE hoses, bumping or pulling on the hoses or even stepping on the hoses. The following successful action was taken:

a. All vehicle and GSE QD's were replaced by new parts.

b. These new QD's were mated by serial numbers, leak tested with gaseous helium under varying pressures, temperatures and side loads.

c. A support frame was installed on the aft umbilical carrier to provide clamp supports for the hoses to eliminate side pull.

d. Plastic bagging of mated QD's and periodic visual monitoring of same was implemented.

e. A recommendation was made to lubricate all seals with Krytox each time the QD's are connected.

This effort was done in conjunction with a similar problem on the ground thermal conditioning system QD's. See Figure 2.2.14.10-2.

2.2.14.10 OWS Ground Thermal Conditioning Equipment

A. Design Requirements

1/ Maintain temperatures within the OWS habitation area by supplying conditioned water glycol to a ground heat exchanger within the vehicle. This capability had to continue from time of loading food and film on board until liftoff.

2/ Provide a GN_2 purge of the OWS heat exchanger loop prior to liftoff.

3/ Provide local and remote monitoring of temperatures, pressures and flowrates.

4/ Model had to be explosion-proof and EMI compatible.

5/ Design Parameters - GSE

° Supply Temp	$-3^{o}F$ ($253.7^{o}K$) Maximum Cooling
° Heating, Basic	12000 Btu/Hr, Ambient (1.26×10^{7} j/hr)
° Heating, Additional	14000 Btu/Hr, Venting (1.47×10^{7} j/hr)
° Pressure	200 psig (1.379×10^{6} N/m^{2}) Maximum
° Cooling Load	41000 Btu/Hr (4.32×10^{7} j/hr)
° Flowrate	3 gpm Min (1.135×10^{2} m^{3}/min)

6/ Vehicle Temp Requirements

- 40 to 80°F (277.6 to 299.8°K) General
- 40 to 50°F (277.6 to 283.2°K) Film Vault
- 42 to 65°F (278.7 to 291.5°K) Wall Temp

B. System Description - DSV-7-334 Ground Thermal Conditioning System (See Figures 2.2.14.10-1 through -4) - The OWS interior ground thermal conditioning system kit consists of: two thermal conditioning units; the fluid reheat unit; the fluid control unit; the manual control console; and the power switching unit.

The TCU chills the water glycol, as required, so that the OWS internal atmosphere will be maintained at 40 to 80°F (277.6 to 299.8°K). Heat is removed by using a refrigerant compressor and two condenser fans. The desired temperature is selected on a temperature controller. The temperature range is selectable from approximately -5 to +50 °F (252.6 to 283.2°K). The temperature selected will be monitored by the temperature controller. The water glycol temperature (return and supply), water glycol pressure, and the water glycol flow are all monitored in the TCU.

Two circulating pumps are used in each TCU to circulate the water glycol at the required pressure. One pump is used at a time. Manual control provisions may be used to switch from one pump to the other.

The fluid reheat unit (FRU) heats the water glycol to the GCHX, as required, so that the OWS internal atmosphere will be maintained at 40 to 80 °F (277.6 to 299.8°K). The FRU uses two 9-KW heaters and on overtemperature controller to provide heat to the water glycol. The FRU requires 440-VAC, 3-phase, 60-Hz power for

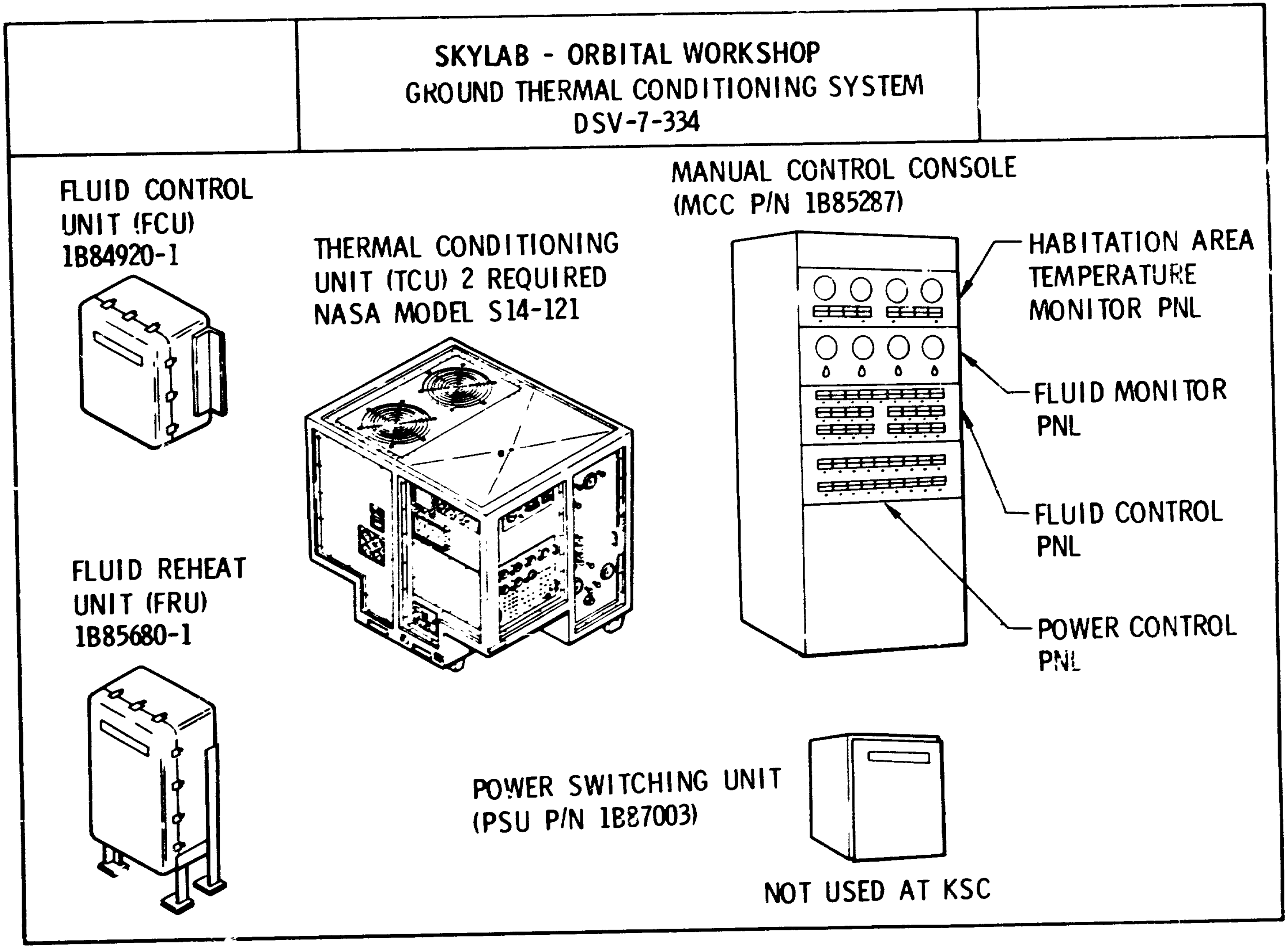


Figure 2.2.14.10-1

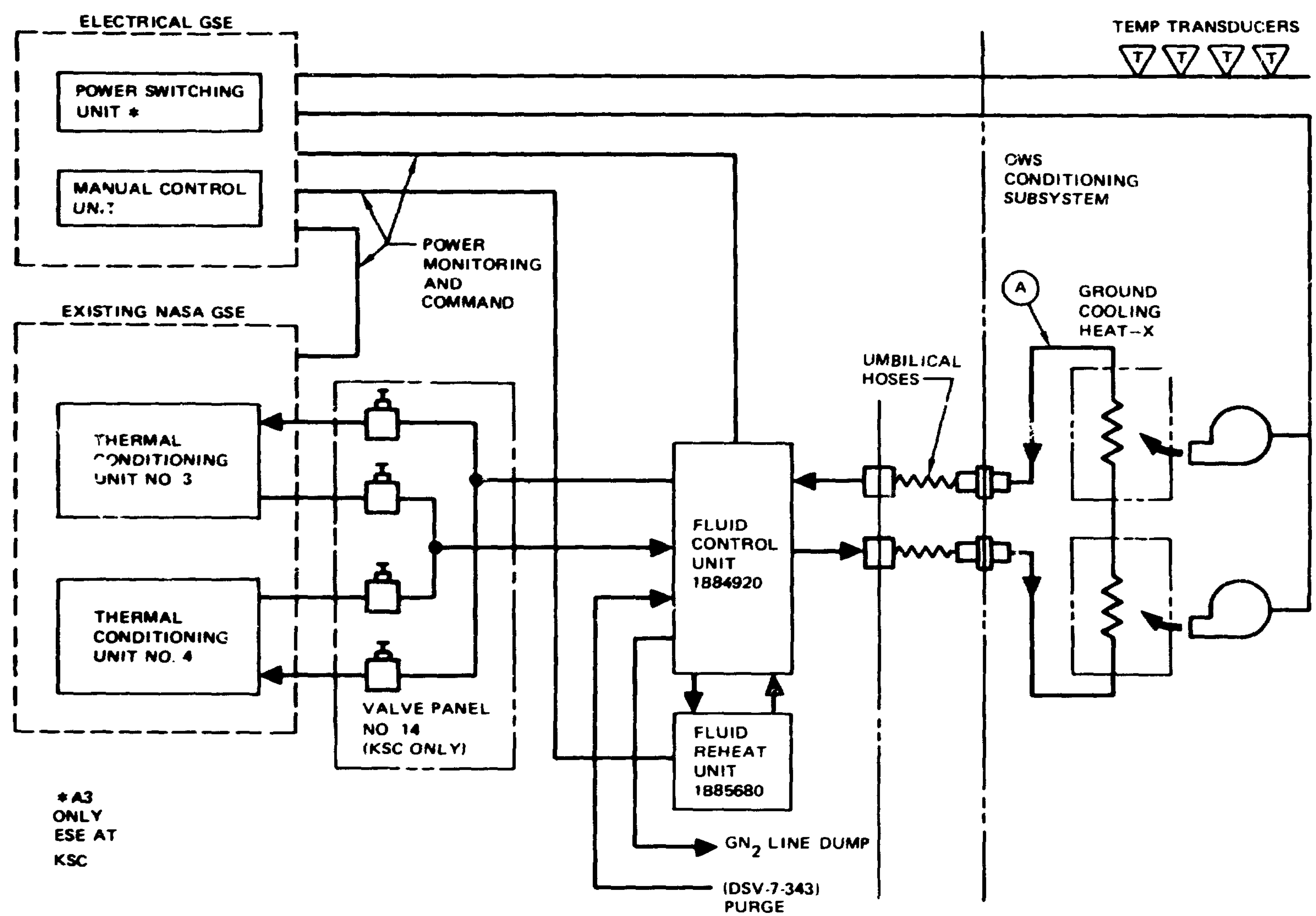


Figure 2.2.14.10-2. Ground Thermal Conditioning System DSV7-334

SKYLAB - ORBITAL WORKSHOP
GROUND THERMAL CONDITIONING SYSTEM
DSV-7-334

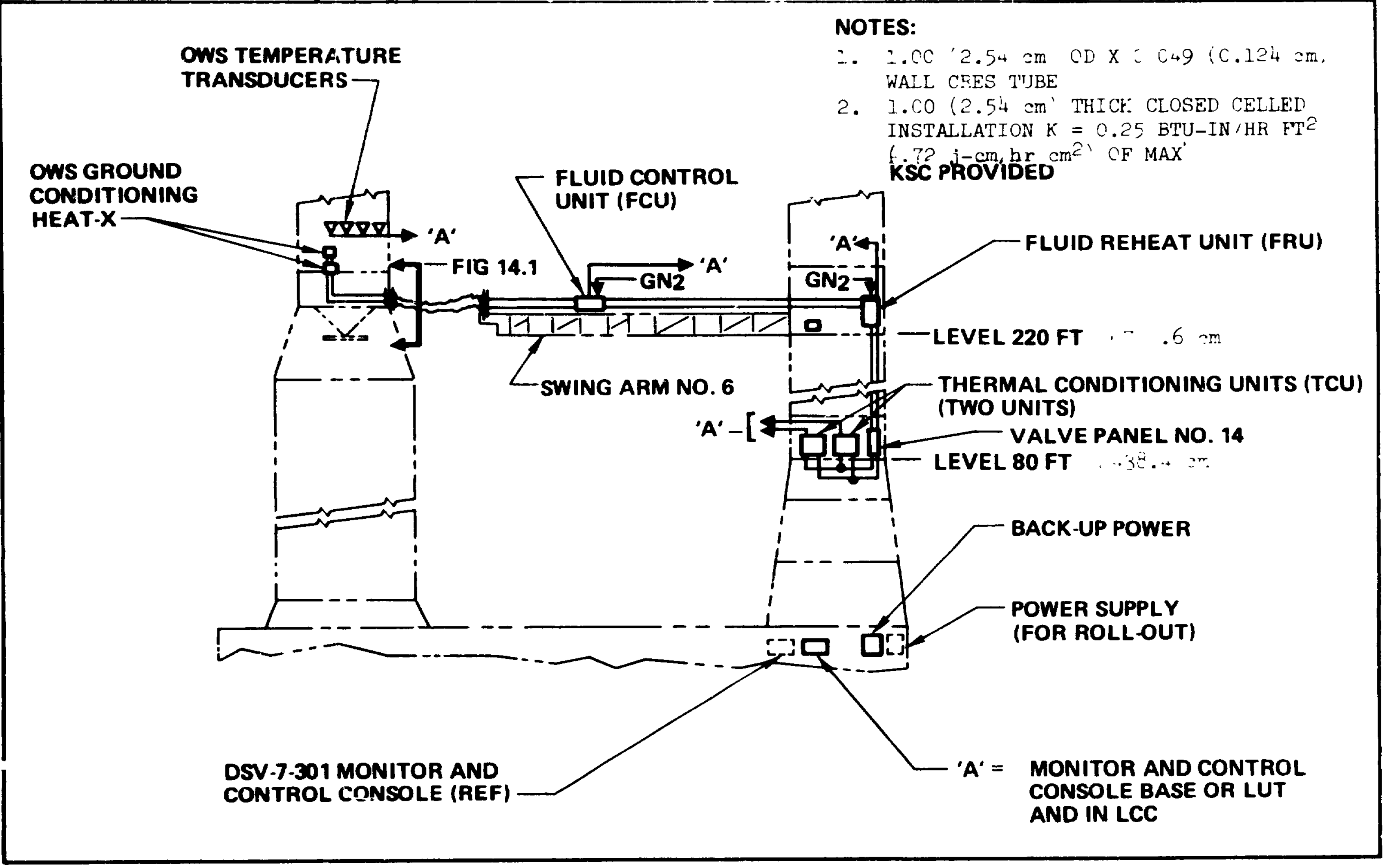


Figure 2.2.14.10-3

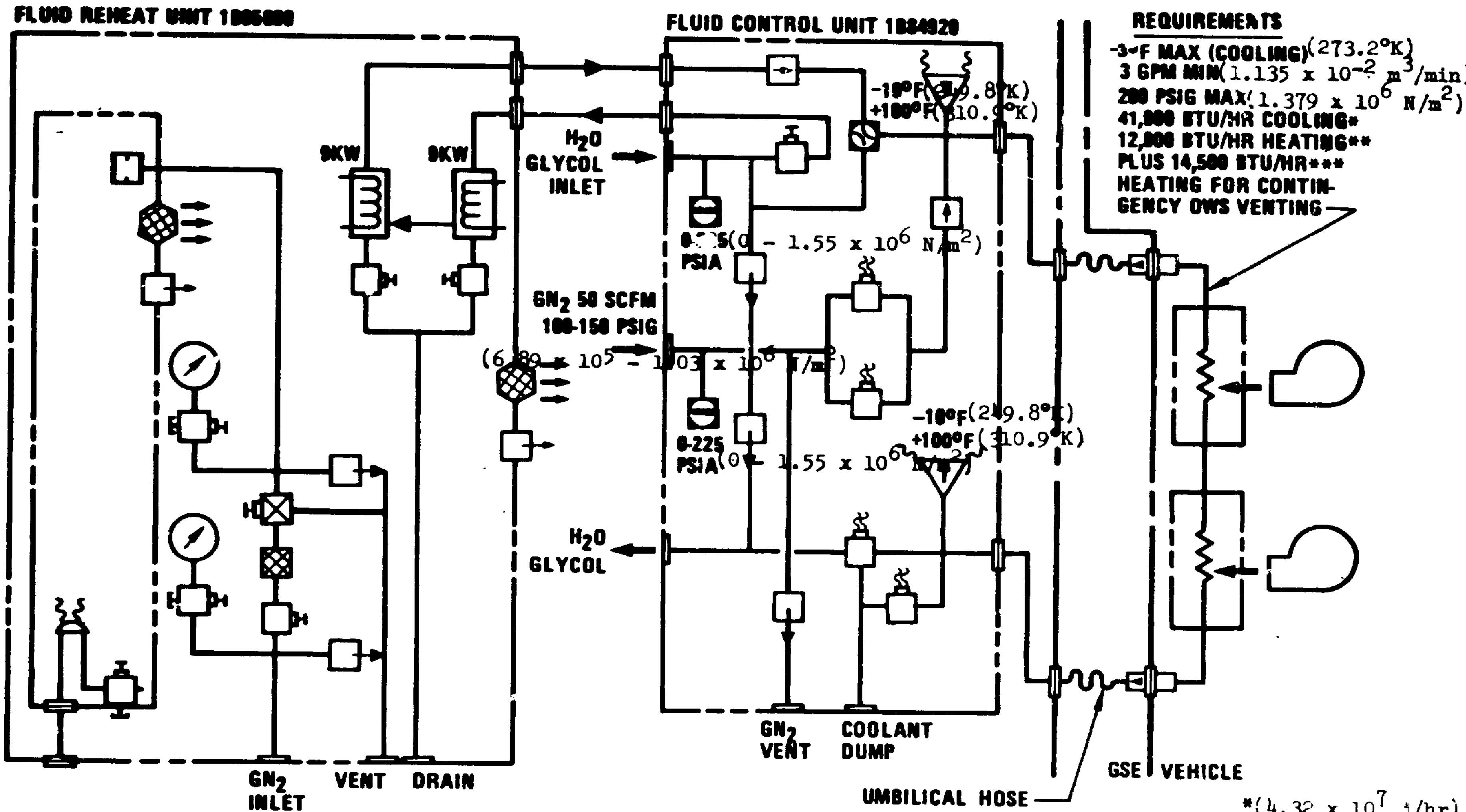


Figure No. 2.2.14..0-4 Ground Thermal Conditioning System OWS Interior DSV7-334 the heaters and uses 28 vdc for commands and indications.

The fluid control unit (FCU), through a pressure transducer, monitors the pressure of the water glycol. Solenoid valves in the FCU can redirect the flow of the water glycol from the GCHX to a coolant dump in ground equipment. The FCU maintains GN_2 pressure supplied to purge the GCHX, and there is a pressure transducer to monitor the GN_2 pressure. The solenoid valve is controlled by external GSE. Power and monitoring of the transducers are also controlled by external GSE. The FCU requires 28 vdc for control and instrumentation.

The manual control console (MCC) provides the system controls and monitors performance. It furnishes control and monitoring for the OWS GTCS fans. The MCC contains manual switches and indicators to control the motor starters and to indicate the normal flow or low flow. The fan failure circuits are in the PSU and cut off the fans in the event of low flow from the fan. The circuits also send signals to the MCC for visual display. The MCC furnishes monitoring of the OWS atmosphere temperature. It contains meters necessary to convert 0 to 5 vdc output from OWS temperature transducers to the temperature of the OWS atmosphere. The MCC has a meter that converts a 0-5 vdc output from the FCU GN_2 pressure transducer to pressure. The MCC requires 28 vdc power.

The power switching unit (PSU) routes power to the various components of model and to the vehicle fans. The PSU was not used at KSC.

C. Test Program of GSE - The performance capability and design of Model DSV-7-334 have been proven through various tests at the Huntington Beach VCL and TICO using one TCU S14-121, Serial No. 013. Specifically, this model performed properly when subjected to the following tests: At TICO, PATP 1B87012 tested electrical portion of FRU (1B87000), the PSU (1B87003), and the MCC (1B85287). At the Huntington Beach VCL, the model was subjected to PATP 1B84920 (FCU), PATP 1B85780 (FRU), H&CO 1B85677 and TCP 1B84783. The TCU used to operate this model at Huntington Beach was not one of the TCU's to be used at KSC with this model. The same TCU that supported DSV-7-301 testing was used since it could provide the same functions.

D. Performance During Checkout and Prelaunch - From an overall standpoint the DSV-7-334 performed satisfactorily and met the design requirements imposed upon it. Temperatures within the OWS habitation area were properly maintained, the ground purge was accomplished prior to launch and the schedule was not affected.

Some significant problems encountered and their solutions are as follows:

1/ Thermal Conditioning Unit Failures - The (TCU) used in DSV-7-334 was an unmodified government furnished item. None of the TCU's were ever tested in Huntington Beach since the TCU from Model DSV-7-301 could adequately meet the performance requirements. The first time any TCU was used for model DSV-7-334 was at KSC and the units selected were from previous Apollo, KSC usage.

The units had no difficulty in meeting the temperature and flow requirements but two minor and one major problem occurred.

a. Serial No. 009 experienced the only serious problem. One of the two large condenser fans failed while the unit was on level 80 of the launch tower. Repair was not possible on the tower so that the entire TCU had to be removed from the tower and replaced. Compounding this problem was the fact that when the fan failed it opened the main facility circuit breaker which controlled both TCU's making it impossible to operate the redundant TCU until the circuit breaker was reset. The condition was in violation of the electrical interface drawing which required separate main facility circuit breakers for each TCU.

b. Serial No. 003 replaced No. 009 on the tower and had a "loose" power cable when initially installed. After that was fixed there were no subsequent problems.

c. Serial No. 005 experienced a leak in the refrigeration system oil separation. After that was fixed there were no subsequent problems.

2/ Water Gl ol Leakage in the Umbilical Quick Disconnects - During the checkout of the ground thermal conditioning system in the VAB at KSC, water glycol leakage was observed at the ground heat exchanger supply quick disconnect (QD) in the aft umbilical carrier. A failure analysis of the QD indicated leakage was due to excessive usage - (wornout V-shaped teflon chevron seals).

In addition, there was evidence of possible abuse due to side loads on the QD's which could have resulted from the weight of the GSE hoses, bumping or pulling on the hoses or even stepping on the hoses. The following successful action was taken:

a. All vehicle and GSE QD's were replaced by new parts.

b. These new QD's were mated by serial numbers, leak tested with gaseous helium under varying pressures, temperatures and side loads.

c. A support frame was installed on the aft umbilical carrier to provide clamp supports for the hoses to eliminate side pull.

d. Plastic bagging of mated QD's and periodic visual monitoring of same was implemented.

e. A recommendation was made to lubricate all seals with Krytox each time the QD's are connected.

This effort was done in conjunction with a similar problem on the refrigeration system QD's. See 2.2.14.9.D.4/.

E. Conclusions and Recommendations - (See 2.2.14.15).

2.2.14.11 OWS Ground Environmental Control Distribution System

A. Design Requirements - The environmental control kit distribution system had to be capable of distributing conditioned ground air to the inside of the OWS to maintain a controlled environment at KSC during checkout and prior to transporting the OWS to the launch pad. The design requirements for Model DSV-7-344 are described in CEI Specification DAC 56692A and schematic number 1B91791.

B. System Description - The Model DSV-7-344 provided an air distribution system that, when installed within the OWS, provided comfort to the personnel during OWS checkout and launch preparations. The air supplied to the system was furnished by ground facilities. The kit was used during OWS launch preparations and checkout at KSC in the VAB. It was installed and adjusted at Huntington Beach prior to shipment. The kit was removed prior to transfer of the OWS to the pad. None of the kit parts were flight items.

The environmental control kit distribution system is shown in Figure 2.2.14.11-1 and schematically shown in Figure 2.2.14.11-2, and consists of parts that make up a readily installed and removable ducting system. The ducting system is primarily composed of flexible fabric ducts, metal fittings, and support hardware. Also included in the kit are covers for the flight OWS air outlet diffusers. The covers prevent the ground distribution system air from entering the flight OWS air duct system.

The flexible fabric ducting is made from a flame self-extinguishing polyethylene coated nylon cloth (Hypalon). Sizes vary from 6.30 (16.0 cm) to 10.30 in. (26.2 cm) inside diameter and 7 to 240 in. (17.8 to 609.6 cm) in length. A conductive path (stainless steel stitch) is provided to alleviate static electricity buildup in the duct material. The metal fittings consist of tees, elbows, connectors, reducers and a damper device. The fittings are made from 0.030-in. (.076 cm) stainless steel sheet. The straps are used to support and tie down the fittings to the OWS structure.

SKYLAB - ORBITAL WORKSHOP
DISTRIBUTION SYSTEM
ENVIRONMENTAL CONTROL KIT (DSV-7-344)

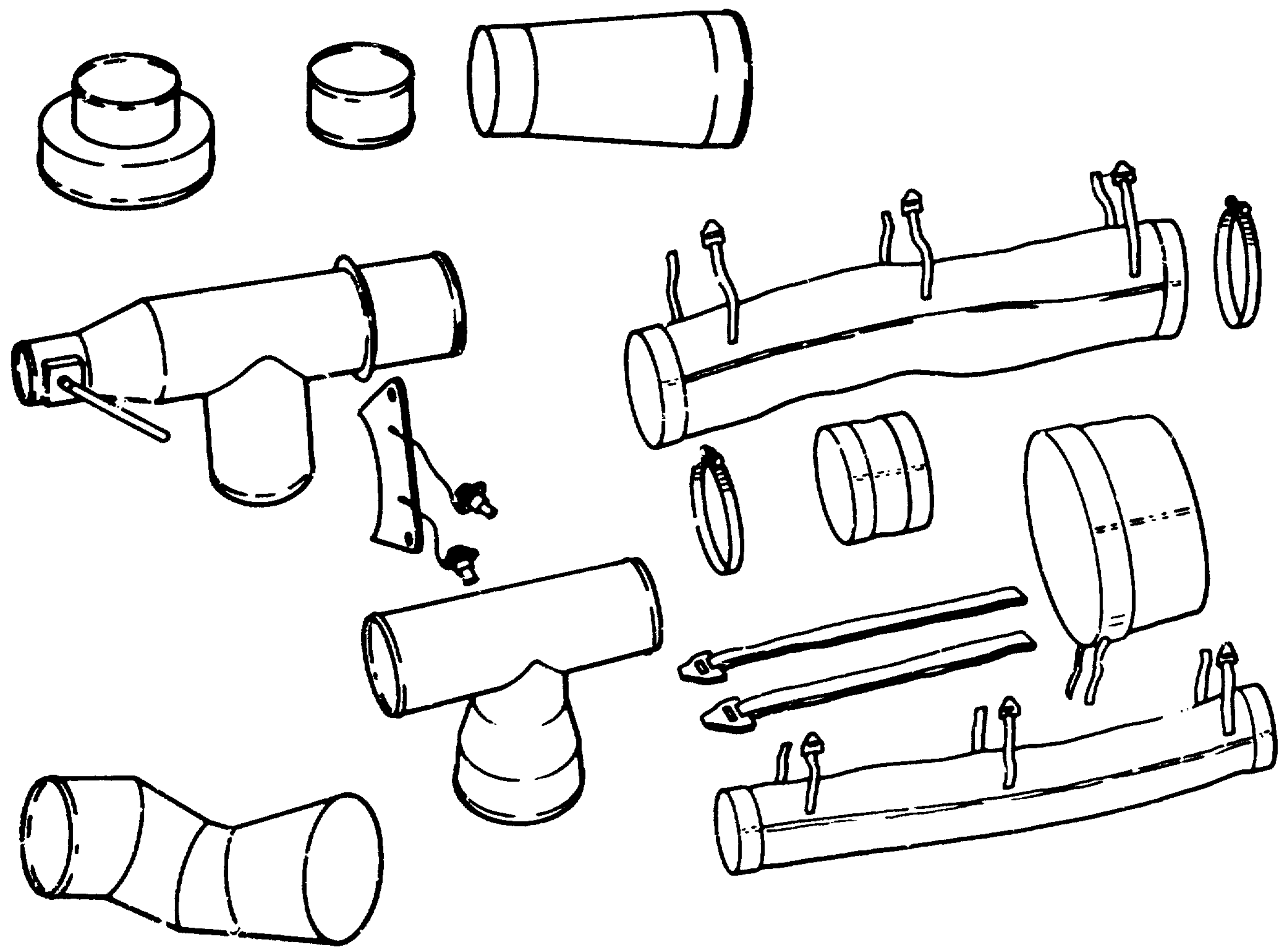


Figure 2.2.14.11-1

SKYLAB - ORBITAL WORKSHOP
NORMAL OPERATIONAL SYSTEM
VAB (& PAD CONTINGENCY)
DSV-7-344

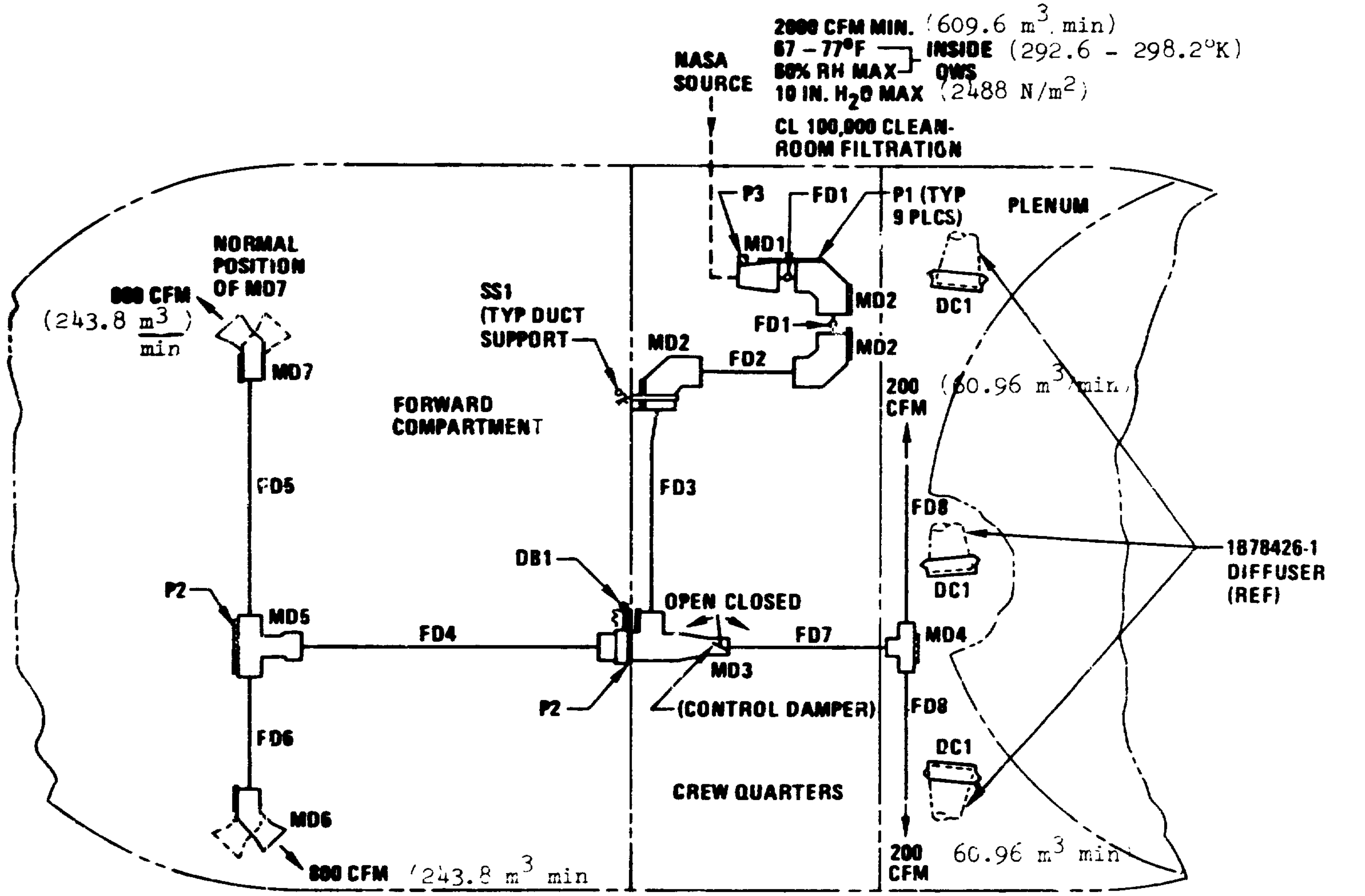


Figure 2.2.14.11-2

The straps have a slip buckle feature and conform to OWS self-extinguishing fire specifications. The protective pads are used to protect the interior surfaces of the OWS from being marred by the metal fittings. The pads are made from a polyurethane rubber sheet material. The diffuser covers are used to cover the flight OWS air outlet diffusers. They are made from flame-retardant coated nylon cloth and measure 18 inches (45.7 cm) in diameter by 6 inches (15.2 cm) long.

C. Test Program - There was no testing of the kit or any of its components prior to its installation at Huntington Beach. However, it was checked at Huntington Beach after installation, and was found to be quite adequate for distributing conditioned air through the interior of the OWS.

D. Performance During Checkout - The GSE (Model DSV-7-344) designed to distribute air through the interior of the OWS performed up to its design requirements. There were no cases of major redesign or problems causing an impact to the vehicle schedule. No significant checkout problems arose.

E. Conclusions and Recommendations - (See 2.2.14.15).

2.2.14.12 Scientific Airlock Ground Checkout Equipment

A. Design Requirements

1/ Leak check Scientific Airlock (SAL) enclosure, SAL outer door and pressurization valve, SAL window, vacuum hose, and associated experiments under simulated orbital pressure differentials of 5 psid ($3.447\ 10^4\ N/m^2$). Acceptable total leak rate: 2.6×10^{-3} sccs.

2/ Fit and functional check of items listed above under 5 psi (3.447×10^4 N/m^2) differential.

a. Vent and pressurization time checks.

b. Check of handle and latch forces.

c. Fit check of all items interfacing with SAL.

B. System Description - To meet the above checkout requirements, a SAL leak test kit was developed. It was made part of the Mechanical Test and Accessories Kit, DSV-7-316. The SAL leak test kit (1B88603) is shown in Figure 2.2.14.12-1 and schematically shown in Figure 2.2.14.12-2. The unit consists of a carrying case containing the necessary plumbing (relief valves, absolute pressure gage, and hand valves) required to transmit GN_2, CH_e, and vacuum from regulated pressure and vacuum sources to the SAL's. The commodities flow through hoses that connect to an adapter plate matched to the SAL opening on the outside of the OWS. A pressure gage, vacuum breaker (relief) valve, manual valve, and calibrated leak will be mounted on the plate. The plate will seal against the surface of the OWS. The kit also contains polyethylene bags to enclose the SAL and experiments inside the OWS and a means of purging the bags with helium during the leak check. This equipment will be used in conjunction with a mass spectrometer to leak check each SAL with its experiments under orbital differential pressure conditions [5 psi (3.447×10^4 N/m^2) differential].

C. Test Program of GSE - The performance capability and design maturity of the SAL leak test kit has been proven through its

SKYLAB - ORBITAL WORKSHOP ACCESSORY KIT MECHANICAL TEST (DSV-7-316)

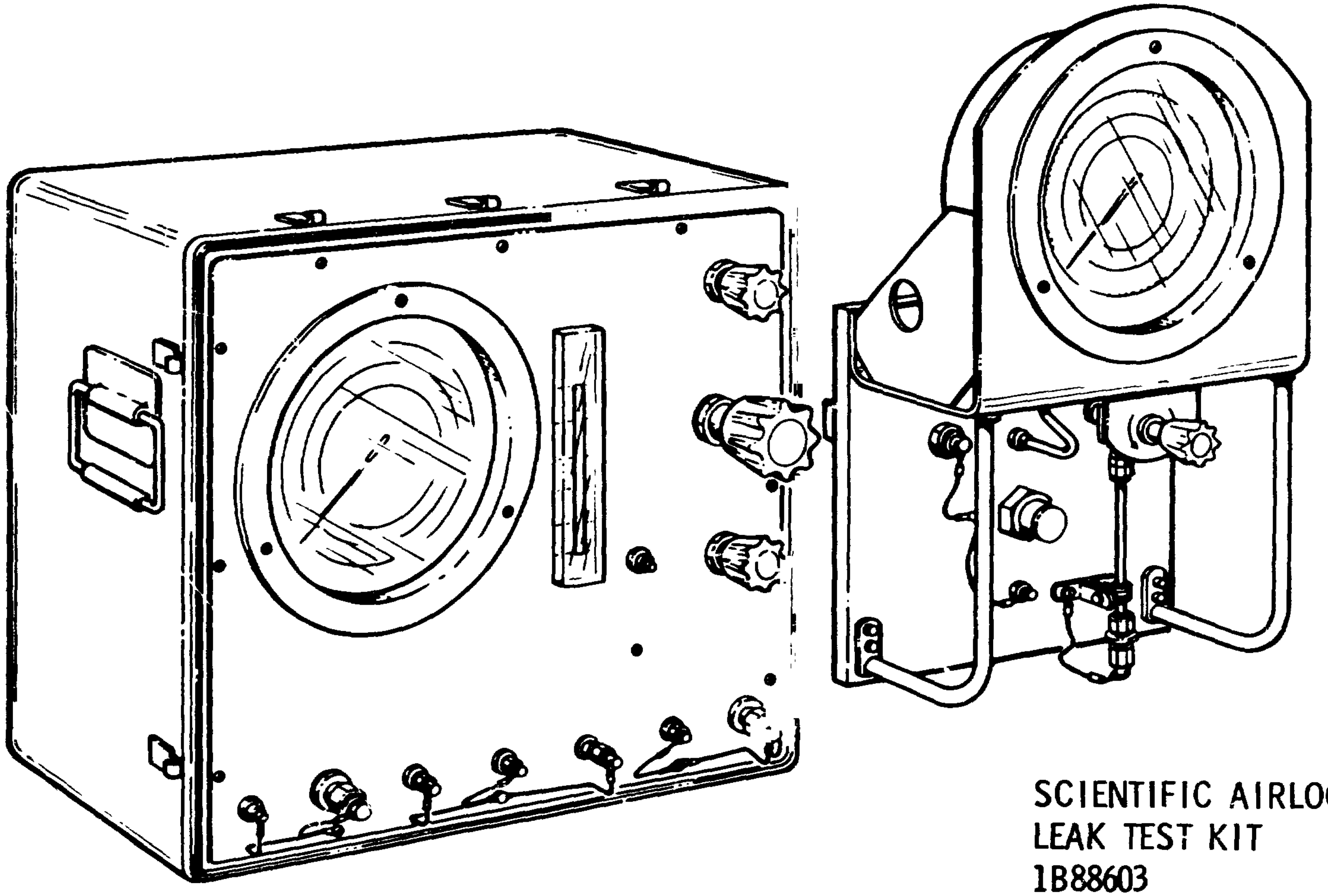


Figure 2.2.14.12-1

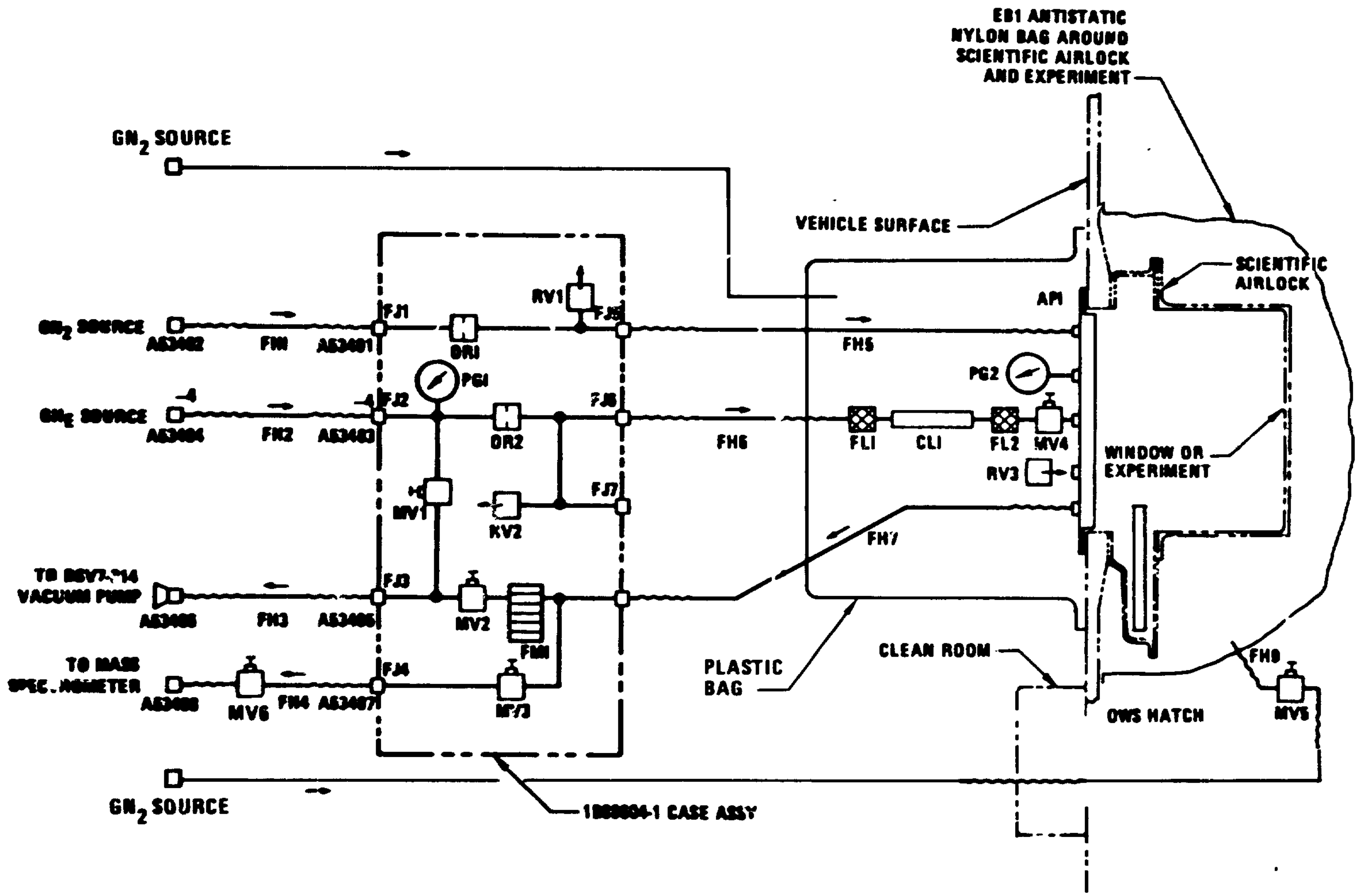


Figure 2.2.14.12-2. Accessory Kit – Mechanical Test (DSV-7-316) Scientific Airlock Leak Test Kit Schematic

production acceptance test and an H&CO which provided optimum system operating parameters as well as a demonstration of system readiness.

D. Performance During Service and Checkout - The GSE designed to checkout the SAL performed up to its design requirements. There were no cases of major redesign or problems causing an impact to the vehicle schedule. However, the significant problems that did arise are as follows:

1/ Leakage of helium into GSE causing contamination of the mass spectrometer.

The nature of this leak test system is as follows:

A purge carrier gas (GN_2) flows at a low rate through the SAL at a pressure 5 psi (3.447×10^4 N/m^2) below atmospheric. The SAL is surrounded by helium. Thus any helium leaking into the SAL is carried away by the purge gas. A very low flow sample of the purge has it diverted to a mass spectrometer, which counts the molecules of helium that are present. Because the maximum allowable leak rate being tested on the SAL was 2.6×10^{-3} sccs., small amounts of extraneous helium leaking through the GSE made the system unworkable by contaminating the mass spec.

Keeping helium from leaking into the system was a problem. The GSE was a kit which was assembled by the TCP during checkout. Hoses and fittings were connected. It was found necessary to perform extensive leak tests of these connections by spraying with helium and sensing with the mass spec (a leak of 1 x 10^{-6} sccs., in the right place made the system unworkable).

Part of the GSE was fitted over the SAL openings on the outside of the spacecraft. This was found to be the major leak path, and was finally enclosed with a PVC bag (which was sealed to the outside of the spacecraft) and purged with GN_2. This solution proved satisfactory.

In addition, it was found that certain valves, because of their location in the system, had to be continually checked for stem leakage. Bellows valves would have served the purpose better than the valves that were used ("O" ring stem seals). Also, on two separate occasions it was found that helium had leaked into the nitrogen supply at the tank farm through a common vent system between the GH_e and GN_2 supplies.

In addition, a PVC (Tygon) line was originally used to connect the mass spec to the system. It was felt that contaminents (plasticizers primarily) outgassed from the PVC and "fooled" the mass spec, as it showed up as a leakage indication. A 20-foot (609.6 cm) clean 1/4-in. (.0635 cm) I.D. copper tube was used in place of the PVC line. It proved to be an excellent solution. Although the tube was long and the diameter small, the response time of the mass spec was not affected. It was tested and found to be about one second.

2/ Fine flow control of gas to the mass spec and control of the flow of GN_2 purge carrier through the SAL.

It was found during checkout that control of the flow of gas to the mass spec required a good quality needle valve. The original valve that was tried was not a needle valve, and was totally unacceptable. The flow into a mass spec is approximately 1 x 10^{-3} sccs. It is controlled by noting the inlet pressure which must be held constant at slightly below 0.2 microns (2.66 x 10^2 N/m^2) of mercury. Several needle valves were tried before an acceptable valve was found, which could hold the flow constant so that the inlet pressure did not drift from its pre-set value.

In addition, the nitrogen purge was to be held at 10 $\pm$2 scfh, (0.283 m^3/hr) and at 502 $\pm$1 mm Hg (6.676 x 10^4 N/m^2). It was found that it was quite difficult (although possible) to maintain the pressure to within $\pm$1 mm Hg (133.3 N/m^2) using the valves which were in the gage regulator assemblies. They did not afford enough control. Again, needle valves would have served the purpose better.

E. Conclusions and Recommendations - (See 2.2.14.15).

2.2.14.13 Water Subsystem Service and Checkout Equipment

A. Design Requirements

1/ Water loaded aboard OWS will meet potable water MSC SPEC-PF-1, Revision D, dated July, 1971.

2/ Total of approximately 6650 lb (3015.8 kg) of water loaded into 10 individual vehicle water tanks.

3/ Able to service and load two water tanks simultaneously.

4/ Incorporate steam generator into model for sterilizing vehicle systems and GSE.

5/ Model is explosion-proof and EMI compatible.

6/ Incorporate iodine injector for biocide treatment of water.

7/ Provide GN_2 or GH_e for system leak checks or purge.

B. System Description - DSV-7-312 water subsystem sterilization and checkout kit. See Figure 2.2.14.13-1 through -4.

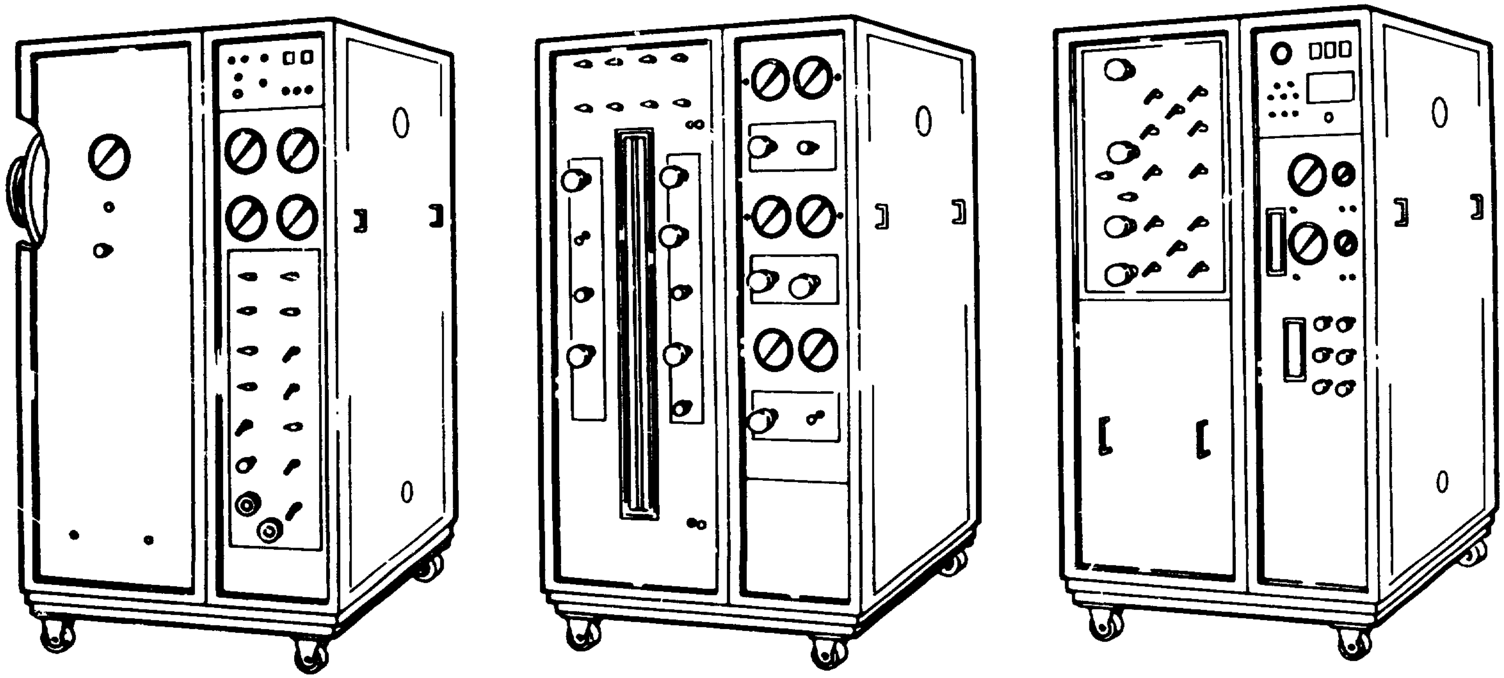
The water subsystem sterilization checkout kits HSS consists of three major consoles and accessories for the checkout and support of the OWS water system. They are the pump and deionization cabinet assembly, the reservoir cabinet assembly, and sterilizer cabinet assembly. Hoses, adaptors, quick disconnects, and other fittings required to support the major consoles are stored in separate containers. Each cabinet uses temperature, pressure and flow devices for controlling and indicating necessary parameters during system servicing, test, and checkout. The electrical components, controls, and instruments of this model are housed in the sterilizer assembly and the pump and deionization assembly. The consoles are explosion-proof and EMI compatible. Monitor and control are local only.

The sterilizer cabinet contains the steam generator and autoclave plus all valves and gages for operation. An SCR power controller is provided to maintain an equal load across each side of the 12-kw delta-connected heater. Two resetable elapsed-time meters are provided - 0 to 999 minutes and 0 to 1000 hours. These meters indicate running time on the steam generator.

The reservoir cabinet contains the water reservoir, the biocide tank and injector, and the nitrogen ejector for degassing the

SKYLAB - ORBITAL WORKSHOP
HSS WATER SUBSYSTEM CHECKOUT AND
STERILIZATION CONSOLE DSV-7-312

P/N 1B79755



CABINET ASSY
STERILIZER
P/N 1B79756

CABINET ASSY
RESERVOIR
P/N 1B79758

CABINET ASSY
PUMP & DEIONIZATION
P/N 1B79757

Figure 2.2.14.13-1

SKYLAB - ORBITAL WORKSHOP
OWS CHECKOUT AND STERILIZATION
WATER SUBSYSTEM, HSS (DSV-7-312)

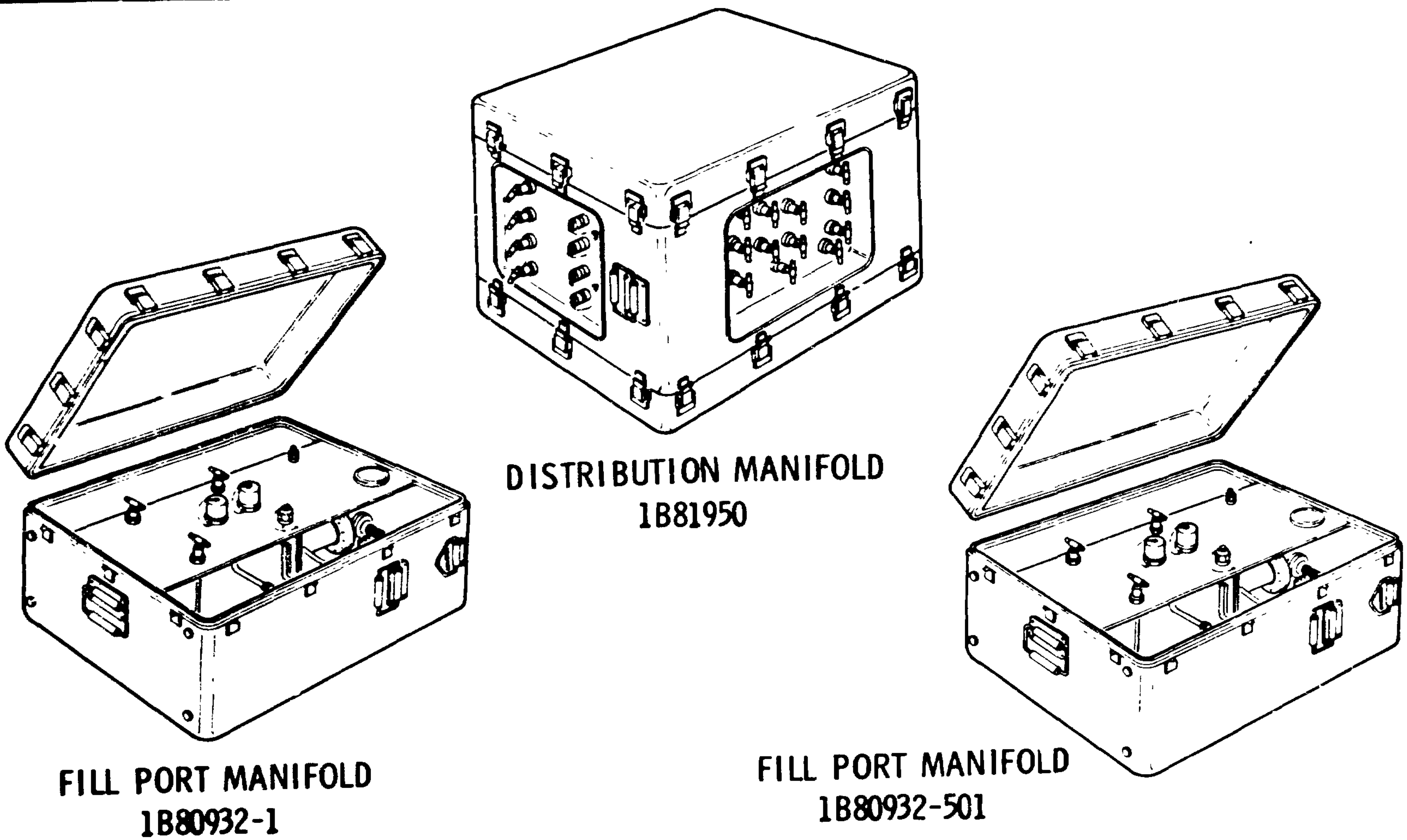


Figure 2.2.14.13-2

SKYLAB - ORBITAL WORKSHOP
OWS CHECKOUT AND STERILIZATION
WATER SUBSYSTEM, HSS (DSV-7-312)

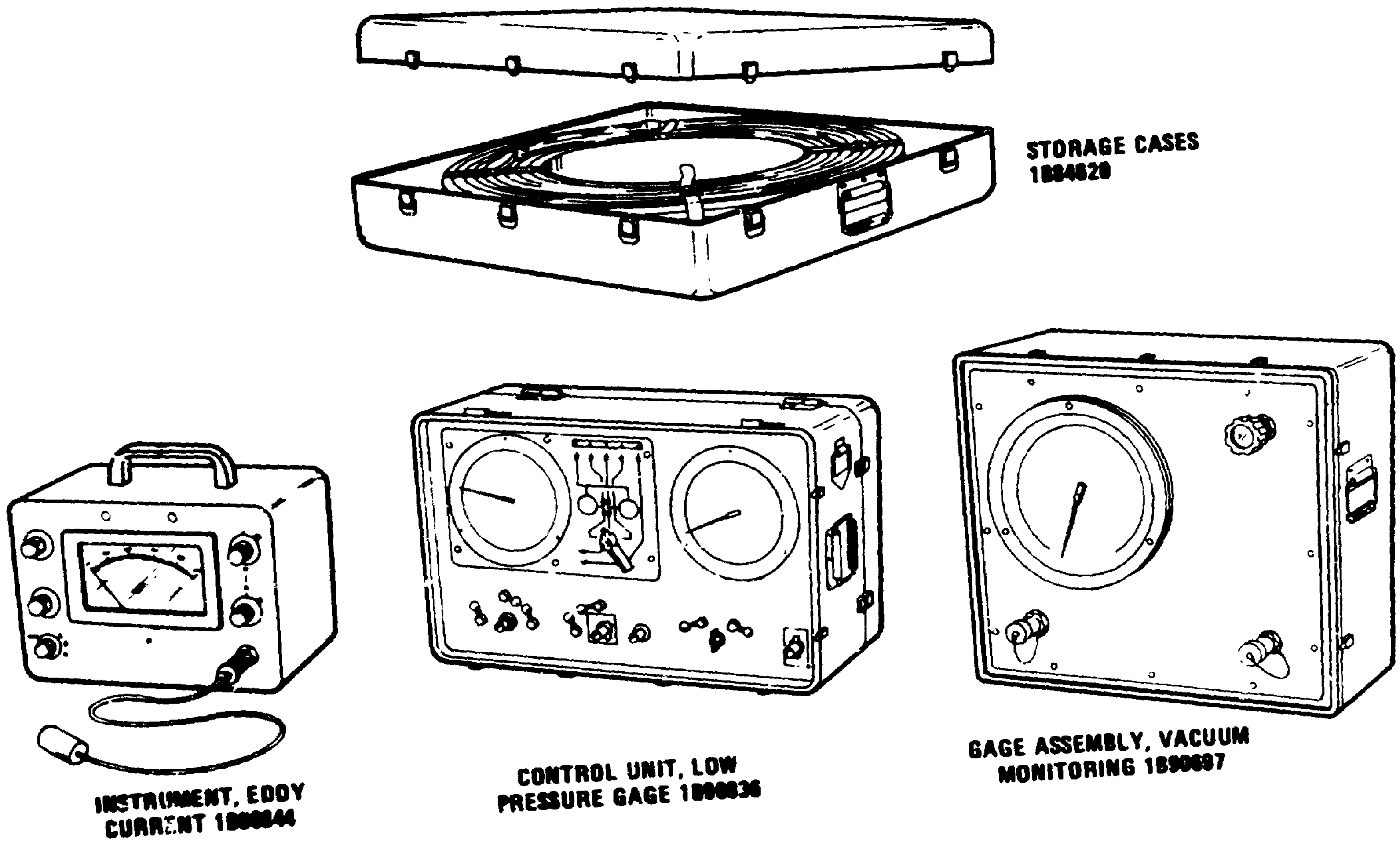


Figure 2.2.14.13-3

ORBITAL WORKSHOP
WATER SUBSYSTEM GSE-DSV7-312

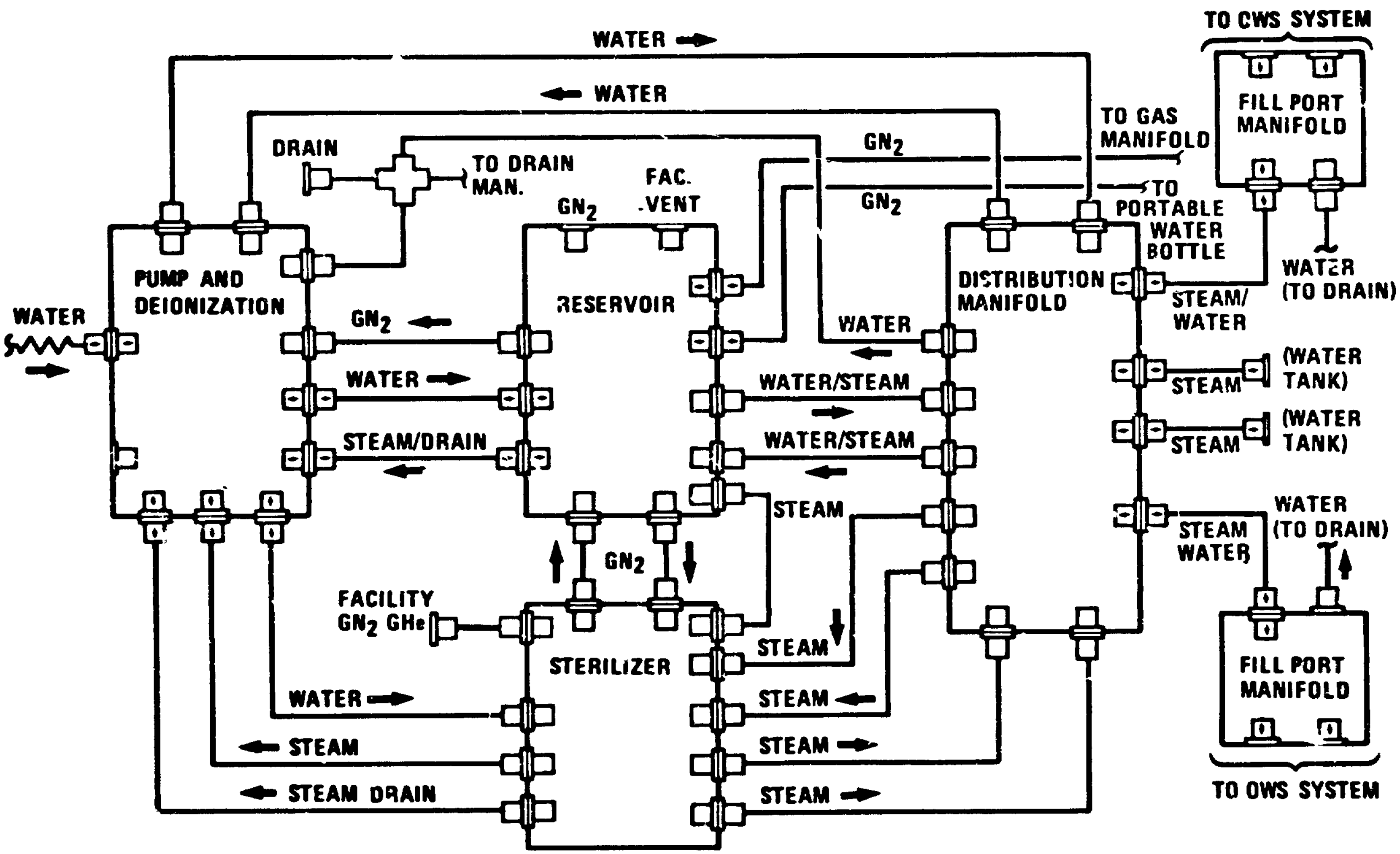


Figure 2.2.14.13-4

the water in the tank. It contains all valves, gages, and plumbing for operation.

The pump and deionization cabinet contains a pump; four filter banks each consisting of a prefilter ion stage, an organic absorption stage, a deionization stage, and a 22-micron (2.2×10^{-5} m) filteration stage; a conductivity meter to measure the conductivity of the water; electrical switch gear; phase sequence relays to ensure proper phase rotation of the motor; and two elapsed time meters. The range of the conductivity meter is 10,000 ohms/cm to 18 megohms/cm.

The lines from the three major cabinets are brought together in a distribution manifold. This manifold distributes the water, steam or gas to either or both of the two fill port manifolds within the vehicle.

Each fill port manifold services one vehicle water tank independently of the other so that concurrent but different servicing of two tanks can take place at once.

In addition to the items discussed above, the kit contains a variety of individual components and adapters for servicing and checkout of the various subsystems of the flight articles.

C. Test Program of GSE - The performance capability and design maturity of Model DSV-7-312 has been proved through various tests. Specifically, this model has demonstrated design performance in its production acceptance test procedures (1B79756-PATP1, 1B79757-PATP1, and 1B84196-PATP1), the maintenance operating procedure 1B81993, and the handling and checkout procedure 1B90956.

Drawing 1B84779 controlled the testing of Model DSV-7-312 with vehicle type water tanks.

D. Performance During Service and Checkout - The GSE (Model DSV-7-312) performed satisfactorily and met its design requirements without any major redesign or schedule impact. Some of the significant problems encountered and their solutions are as follows:

1/ Maintaining Low Vacuum Levels in the Vacuum-Jacketed Steam Lines - Sterilization of the OWS water tanks and other components was accomplished by maintaining steam heat at 250°F (394.3°K) minimum for at least 30 minutes. Since the steam generation in the GSE was so far from the vehicle tanks it was necessary to utilize flexible vacuum-jacketed steam supply lines to reduce heat losses. Surface touch temperatures were also reduced to avoid operator burns without excessive bulky insulation.

The hose itself was a stainless steel convolution within a larger convolution. The annulus in between was filled with high performance insulation and the inner core separated from the outer core by standoffs. Some of these hoses were 35 feet (1066.8 cm) long.

Design requirements for the vacuum annulus of these hoses required evacuation to a level of 100 microns of mercury (13.33 N/m^2) or lower. Leakage was then checked by a predetermined vacuum rise rate or by using a helium mass spectrometer.

It was planned that once evacuated, the hoses would maintain a vacuum level low enough that servicing of the OWS could be accomplished without re-evacuation. As it turned out, this was not possible. The very low leakage rate required to meet this requirement was not realistic in the long lengths of hoses used. Consequently, the hoses had to be constantly under evacuation during steam sterilization operations. This was accomplished by manifolding the evacuation ports of the hoses together and having a vacuum pump evacuating all of them continuously.

E. Conclusions and Recommendations - (See 2.2.14.15).

2.2.14.14 Waste Management System Checkout Equipment

A. Design Requirements - The waste management checkout kit is designed to perform the following:

1/ A vacuum decay leak test on the OWS waste processor.

2/ Verification of operation of the vacuum provision pressure transducer on the OWS waste processor.

3/ A check of the chamber interaction valve and the shutoff valve and check valve of the OWS waste processor.

4/ A functional test of the filter saver valve and pressure plate of the OWS waste processor.

5/ A functional test of the urine collector pressure plate of the OWS urine/fecal collector.

6/ A urine volume determinator calibration on the OWS urine/fecal collector.

7/ An airflow distribution test of the OWS urine/fecal collector.

8/ An airflow versus pressure drop test on the power module of the OWS urine/fecal collector.

B. System Description - The waste management system checkout kit consists of the following major items:

1/ Flowmeter and gage assembly.

2/ Pressure gage.

3/ Checkout cover, fecal seat.

4/ Checkout seal, fecal seat.

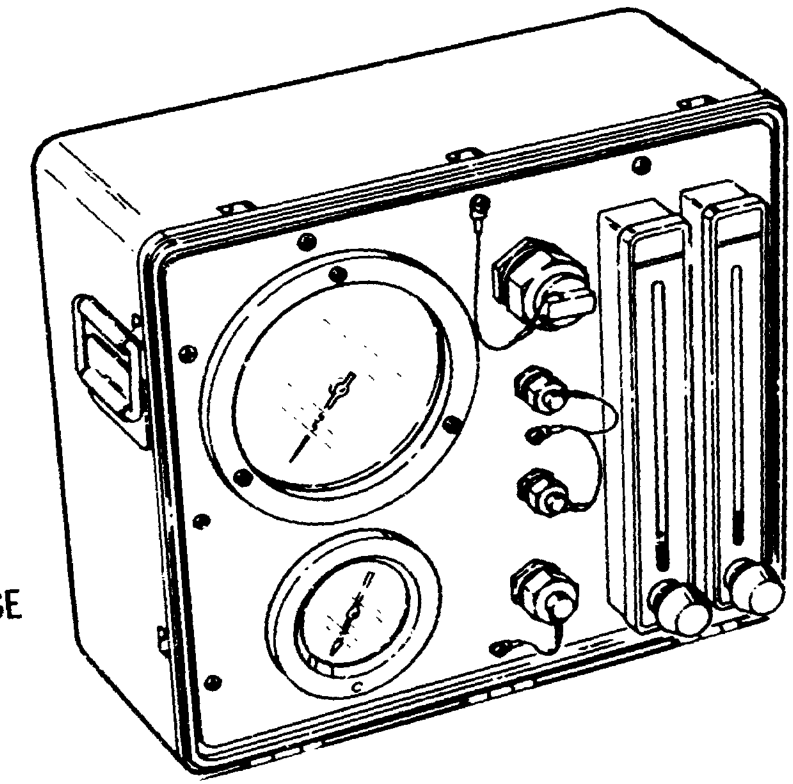
5/ Various miscellaneous accessories including components such as adapters, bags, couplings, hose assemblies, shims, tubing, clamps, and quick-disconnects.

The gas flowmeter and gage assembly consist of a system vacuum gage, a GN_2 source, pressure gage, one high and one low flowrate flowmeter, filters, fittings, plumbing for operation and a carrying case. The gas flowmeter and gage assembly are shown in Figure 2.2.14.14-1 and schematically shown in Figure 2.2.14.14-2. The checkout kit is 22 in. (55.9 cm) high, 13-3/4 in. (34.9 cm) wide, and 19 in. (48.3 cm) deep. The pressure gage is used to measure the differential pressure of GN_2. The instrument scale is -0.5 to +0.5 in. (-124.4 to +124.4 N/m^2) of water with increments of 0.02 (4.97 N/m^2).

The cover fecal seat and seal are used in the functional testing of the OWS urine/fecal collector.

C. Test Program of GSE - The performance capability and design maturity of the SAL leak test kit have been proven through production acceptance tests at both component and assembly levels.

GAS FLOWMETER & GAGE
ASSEMBLY 1B91442



COVER REMOVED

Figure 2.2.14.14-1

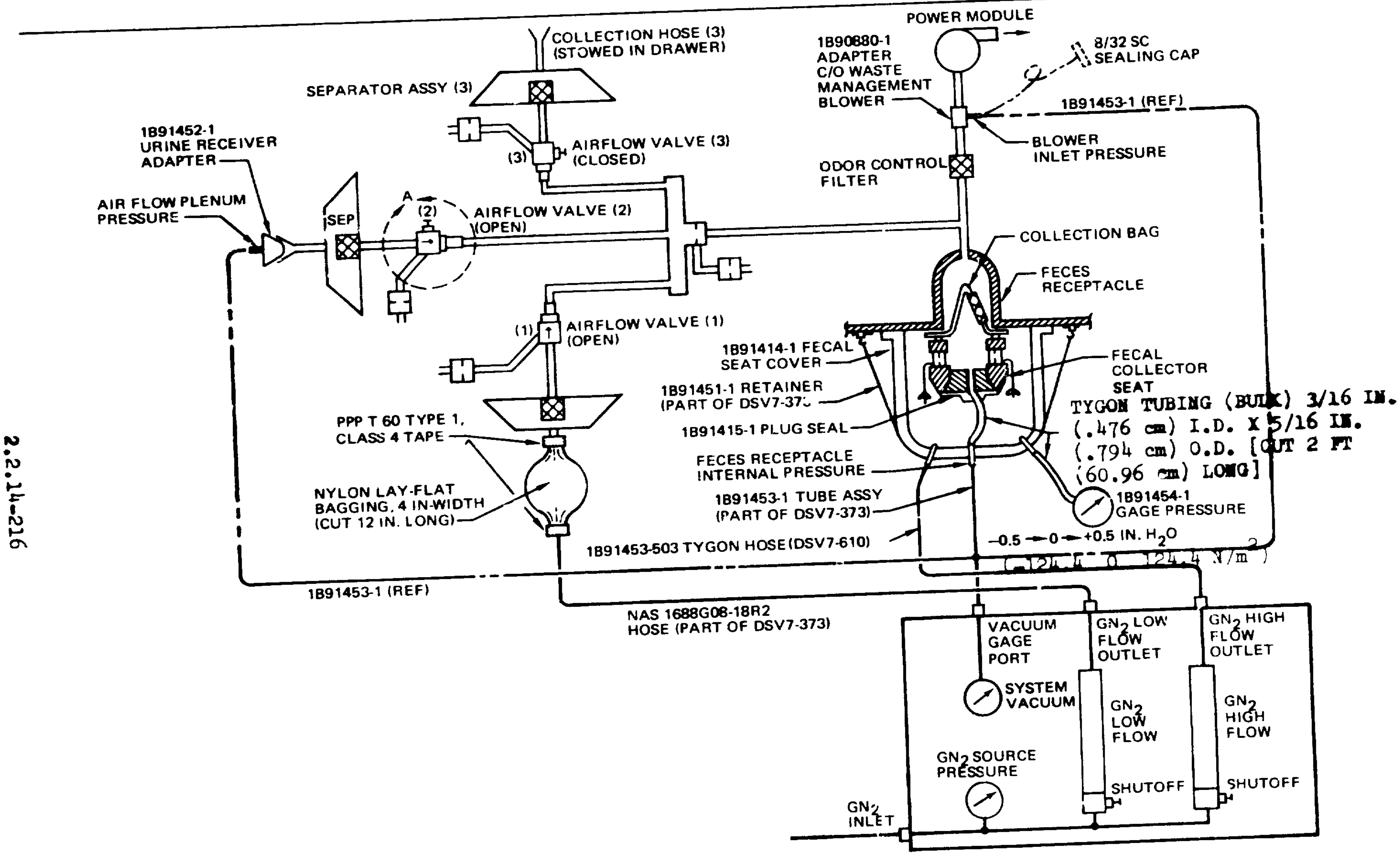


Figure 2.2.14.14-2. Ground Support Equipment Waste Management – Fecal/Urine Collector Air Distribution Test

D. Performance During Checkout - The GSE (Model DSV-7-373) designed to check out the waste management system performed up to its design requirements. There were no cases of major redesign of the equipment due to problems, and no significant checkout problems arose.

E. Conclusions and Recommendations - (See 2.2.14.15).

2.2.14.15 Mechanical GSE Recommendations - Establish clear, firm, and complete definition of responsibilities for the GFP experiment controlled hardware GSE. A delay in establishing the supplier of these GSE items can result in the installing agency resorting to potentially unsafe man-handling of equipment, or rapidly producing a less than optimum piece of handling equipment, at added cost, until the GSE becomes available.

2.2.14.16 Pressurization and Leak Test GSE - The function of the pressurization and leak test GSE was to provide the necessary hardware to leak check and pressurize the habitation area, waste tank, TACS, pneumatic control system, and vacuum outlet system. GSE models in this group included DSV7-300 Leak Test and C/O Accessories Kit (1B76556), DSV7-329 Pneumatic Pressurization Console (1B81183), DSV7-332 Habitation Area and Waste Tank Pressurization Console (1B85301), DSV7-333 Automatic Stage Checkout Console (1B83513), DSV7-343 Pneumatic Stage Console (1B87765), DSV7-350 Vacuum Pumping System Accessory Kit (1B88675), DSV7-363 M509 Sphere Pressurization Supply Kit (1B88812), DSV7-364 Gaseous Nitrogen Purge Panel Assembly (1B88673), DSV4-238 Propulsion System Display Unit (7865700), DSV-4B-329C Checkout Accessories Kit (1B57788), DSV-4B-493A APS C/O Accessory Kit (1B64550), DSV-4B-775 Safety Head (1B70778), and G3104 Rocketdyne Pneumatic Flow Tester.

A. Design Requirements

1/ DSV7-300 - This kit contained the accessories necessary to leak check the OWS orbital configuration including the sealing devices, the habitability support systems, the lower body negative pressure experiment and additional experiments as required. The kit also provided the capability to leak check all vehicle pressurization and vent systems, and the thruster attitude control systems. Also the kit provided the capability to restrict purge gas flow to the high performance insulation during personnel presence and to perform a SAS purge gas leak check. Components of this kit were required to support the following functions:

- Pressurization and leak check of the habitation area.
- Pressurization and leak check of the waste tank.
- Leak check of the orbital configuration sealing devices.
- Checkout of habitation area pressure transducers.

- Checkout of waste tank pressure transducers.
- Leak check of OWS vehicle piping systems by applying vacuum to the LBNP experiment, wardroom water system dump, waste management water system dump, urine dump, waste processor, and refrigeration system pump box vent.
- Leak check of forward entry hatch check valves.
- Leak and functional check of the habitation area pneumatically operated vent system.
- Monitoring pressures in both the habitation area and waste tank.
- Providing warning of low or high pressures in the habitation area, and providing warning if pressure limits were exceeded.
- Controlling the gas vented to the vent stack from the OWS.
- Continuous purge of the MPI with nitrogen (limited to 1 lb/min (.45 kg/min.) during personnel presence in the OWS forward skirt).
- Continuous purge of the SAS with nitrogen. Gages to monitor the SAS purge pressure during ground operations were provided in this kit.
- Purge of the habitation area with nitrogen and sampling of the moisture within the habitation area.
- Providing a positive means of preventing excessive pressure in the habitation area.
- Pressurizing the pneumatic control system sphere.
- Filtering the gas used to pressurize the TACS spheres.
- Preventing injury to personnel in event of failure of a hand-operated TACS fill disconnect when disconnecting under pressure.

- Leak test of the flight half of the TACS manual disconnect.
- Providing a gas-tight connection to each TACS nozzle for leak detection and for applying proof pressure.
- Providing for safety of personnel and equipment during TACS valve leak checks and functional checkout.

2/ DSV7-329 - The requirements of this console were to receive gaseous helium and nitrogen and to regulate and control the distribution of these gases to meet OWS system requirements for leak and functional checkout operations at KSC Launch Complex. More specifically, this console was required to:

- Supply 3200 psig (2.2×10^7 N/m^2) gaseous nitrogen for TACS system pressurization.
- Supply 500 psig (3.4×10^6 N/m^2) gaseous nitrogen for control bottle pressurization.
- Supply 500 psig (3.4×10^6 N/m^2) gaseous nitrogen to purge the DSV7-332 console.
- Supply 150 psig (1.0×10^6 N/m^2) gasious nitrogen to purge the ground thermal conditioning system.
- Provide for venting the TACS bottles to atmosphere.
- Operate remotely from 28 vdc signals controlling solenoid operated valves.
- Provide remote indication of solenoid operated valves positions.
- Provide for remote indication of critical pressures and temperatures within the console.

3/ DSV7-332 - The requirements of this console were to receive ambient nitrogen from pneumatic console DSV7-329 and to provide ambient nitrogen to pneumatic console DSV7-343 for pressurizing the OWS habitation area. More specifically this console was required to:

- o Receive 500 psig (3.4×10^6 N/m^2) gaseous nitrogen from the DSV7-329 console.
- o Provide 500 psig (3.4×10^6 N/m^2) gaseous nitrogen to a restrictor to pressurize the habitation area at a limited flow rate.
- o Provide 500 psig (3.4×10^6 N/m^2) gaseous nitrogen to the DSV7-343 console.
- o Operate remotely from 28 vdc signals controlling solenoid operated valves.
- o Provide remote indication of solenoid operated valves positions.
- o Provide for remote indication of critical pressures and temperatures within the console.

4/ DSV7-333 - This console was required to receive, regulate, and control the distribution of helium and nitrogen gas to meet the leak and functional checkout requirements of OWS. Used at A3 only, this console was required to supply GN_2 or GH_e for leak and functional checkout of TACS, H/A, W/T and PCS systems.

5/ DSV7-343 - The function of this console was to regulate and control OWS peculiar pneumatic servicing and checkout functions during prelaunch operations. This console more specifically was required to:

- o Provide 500 psig (3.4×10^6 N/m^2) to a restrictor to pressurize the waste tank.
- o Provide 750 psig (5.2×10^6 N/m^2) to control valves in the DSV7-332 console.
- o Provide 150 psig (1.0×10^6 N/m^2) GN_2 to purge the DSV7-334 console.
- o Provide GN_2 as required to purge the DSV7-329 console.

- Operate remotely from 28 vdc signals controlling solenoid operated valves.
- Provide remote indication of the solenoid operated valves positions.
- Provide for remote indication of critical pressures and temperatures within the console.

6/ DSV7-350 - The requirements for this kit were to provide a 1×10^{-5} Torr (1.3×10^{-3} N/m^2) vacuum of 0.5 liters/second ($.5 \times 10^{-3}$ m^3/sec) at the experiment M171 metabolic analyzer and lower levels of vacuum for experiments M092, S019, S020, S063, S073, S183, T025 and T027. This kit was also required to keep the DSV7-350 Vacuum Pump cold trap full of LN_2 automatically.

7/ DSV7-363 - The sphere pressurization supply kit was required to provide the necessary lines and fittings to permit use of MDAC facility GN_2 by experiments M509 and T020. The design parameters for the DSV7-363 were:

- MDAC GN_2 supply was at 3200 psig (2.2×10^7 N/m^2), and the required sphere pressure was 500 psig (3.4×10^6 N/m^2).
- A relief valve in the system was required to crack at 600 psig (4.1×10^6 N/m^2) and reseat at 500 psig (3.4×10^6 N/m^2).

8/ DSV7-364 - The gaseous nitrogen purge panel assembly was required to provide low pressure GN_2 to back-fill various experiments.

The panel assembly was to provide for the attachment of a vacuum pump to the experiment interface and to regulate and filter GN_2 from a K-bottle. The DSV7-364 was required to:

- o Regulate facility GN_2 ($<$ 1000 psig [6.9×10^6 N/m^2]) to a pressure level slightly above atmospheric ($<$ 20 psia [1.4×10^4 N/m^2]).
- o Attach to a vacuum system without subjecting the regulator outlet to a vacuum.
- o Display the pressure existing at the outlet of the panel on a gage.
- o Equalize the outlet pressure with atmospheric pressure when required.

9/ DSV4-238 - The requirement for this unit was to provide a means of regulating the facility GN_2 at a desired pressure and to provide a readout of the regulated pressure adjacent to the regulator. The design parameters applicable to the DSV-4B-238 were:

- o Inlet pressure: 200-4500 psig (1.4×10^6 - 3.1×10^7 N/m^2)
- o Outlet pressure: 0-60 psig (0 - 4.1×10^5 N/m^2)
- o Gage pressure range: 0-60 psig (0 - 4.1×10^5 N/m^2)
- o Regulator accuracy: $\pm$ 2%
- o Gage accuracy: $\pm$ 2.5 psig ($\pm$ 17,000 N/m^2)

10/ DSV-4B-329C - This unit was required to provide portable test gages used in checkout of the OWS. These gages had the same design requirements as the DSV4-238 units above. Miscellaneous hardware in this kit differed from the hardware in the DSV4-238 kit.

11/ DSV-4B-493A - This kit was required to provide a means of leak checking various points of the OWS by means of a positive displacement method. These points included:

- o Orbital configuration vent sealing devices.

- o Solenoid vent valve module.
- o TACS flight half disconnect.
- o TACS valves (nozzle outlet).

12/ DSV-4B-775 - This model was required to supply the burst disc used to protect the OWS habitation area NPV duct from being over pressurized. This disc was required to rupture if the pressure within the duct reached 15 psig (1.0×10^5 N/m^2).

13/ G3104 Rocketdyne Pneumatic Flowmeter - This flowmeter was required to measure the flow of gas from the habitation area NPV purge and the gas flow through the access hatch check valves.

B. System Description

1/ DSV7-300 - The leak test accessory kit consisted of the hardware necessary to support leak and functional checks of the H/A, W/T, pressurization control system, and TACS. The kit also consisted of hardware required for purging the H/A. See figures 2.2.14.16-1, -2, -3, -4 and -5.

The hardware consisted of miscellaneous hoses, fittings, caps, filter disconnects, etc.

2/ DSV7-329 - The pneumatic pressurization console was a modification of the DSV-4B-432A console which received gaseous nitrogen and helium and regulated and controlled these gases to meet OWS leak and functional checkout requirements at KSC. The console contained valves, filters, regulators, orifices, etc., for control of gas flow. The flow control valves and vent valves were solenoid operated and remotely actuated. These valves had position talkback switches for remote position indication. Tranducers provided for remote readout of critical pressures and temperatures. See Figure 2.2.14.16-6.

3/ DSV7-332 - The H/A and W/T pressurization console was a modified DSV-4B-438 console which supplied pressurization,

SKYLAB - ORBITAL WORKSHOP
LEAK TEST AND CHECKOUT ACCESSORIES KIT
DSV-7-300

ORBITAL CONFIGURATION LEAK CHECK EQUIPMENT

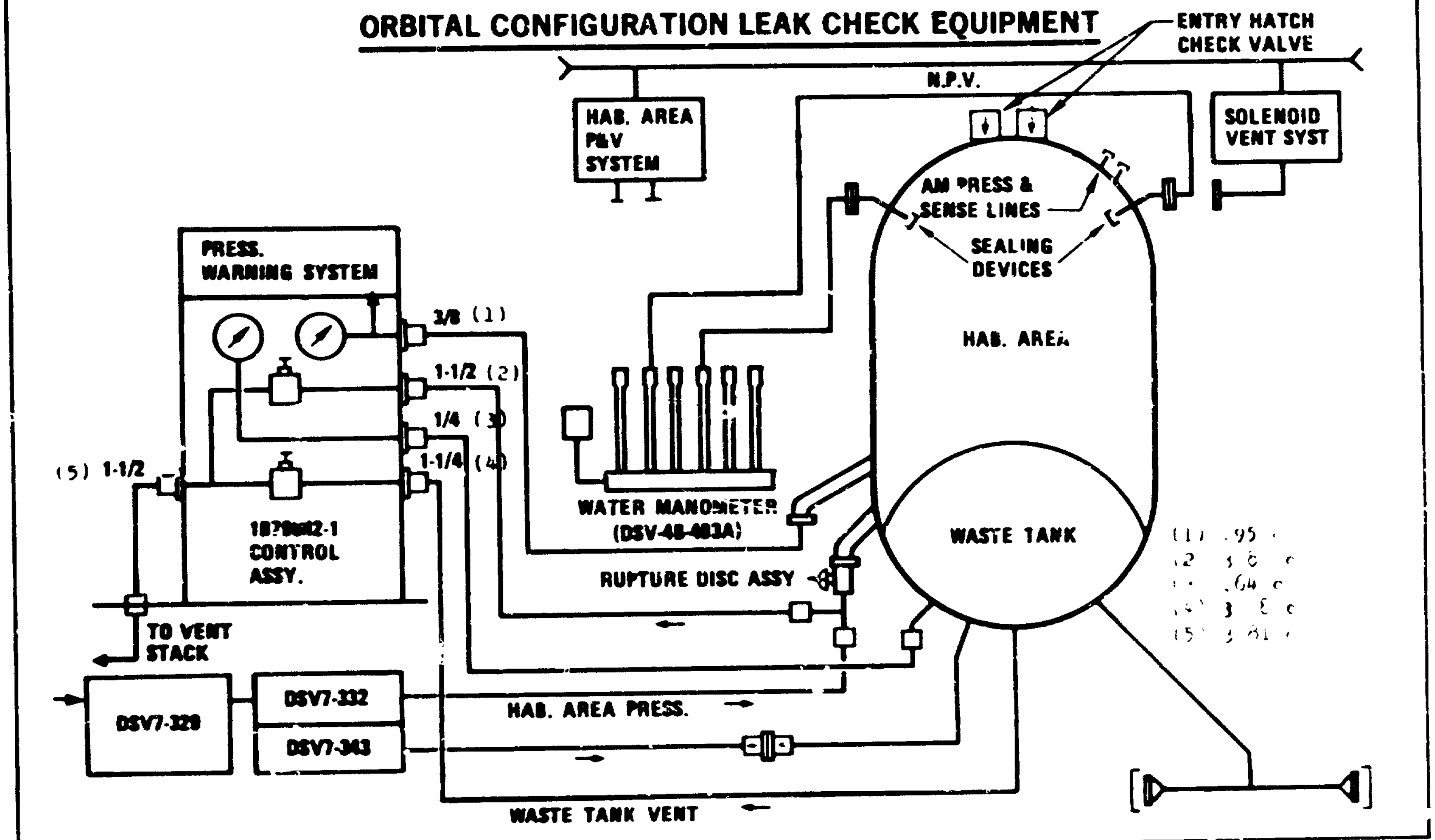


Figure 2.2.14.16-1

SKYLAB - ORBITAL WORKSHOP
LEAK TEST AND CHECKOUT ACCESSORIES KIT
DSV-7-300

LAUNCH CONFIGURATION PRESS AND VENT SYSTEMS LEAK CHECK EQUIPMENT

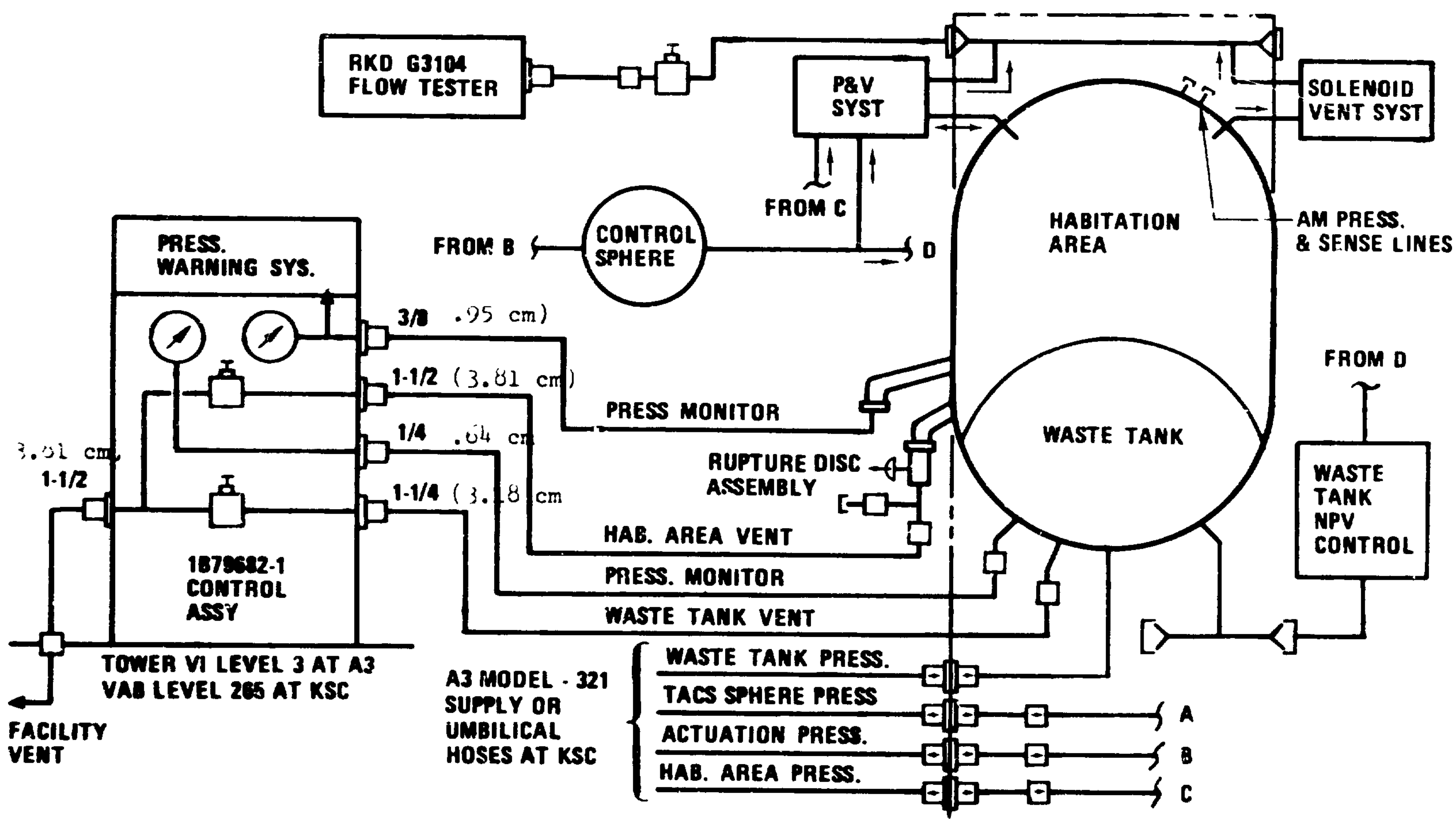


Figure 2.2.14.16-2

SKYLAB - ORBITAL WORKSHOP
LEAK TEST AND CHECKOUT ACCESSORIES KIT
DSV7-300

LAUNCH CONFIGURATION LEAK TEST

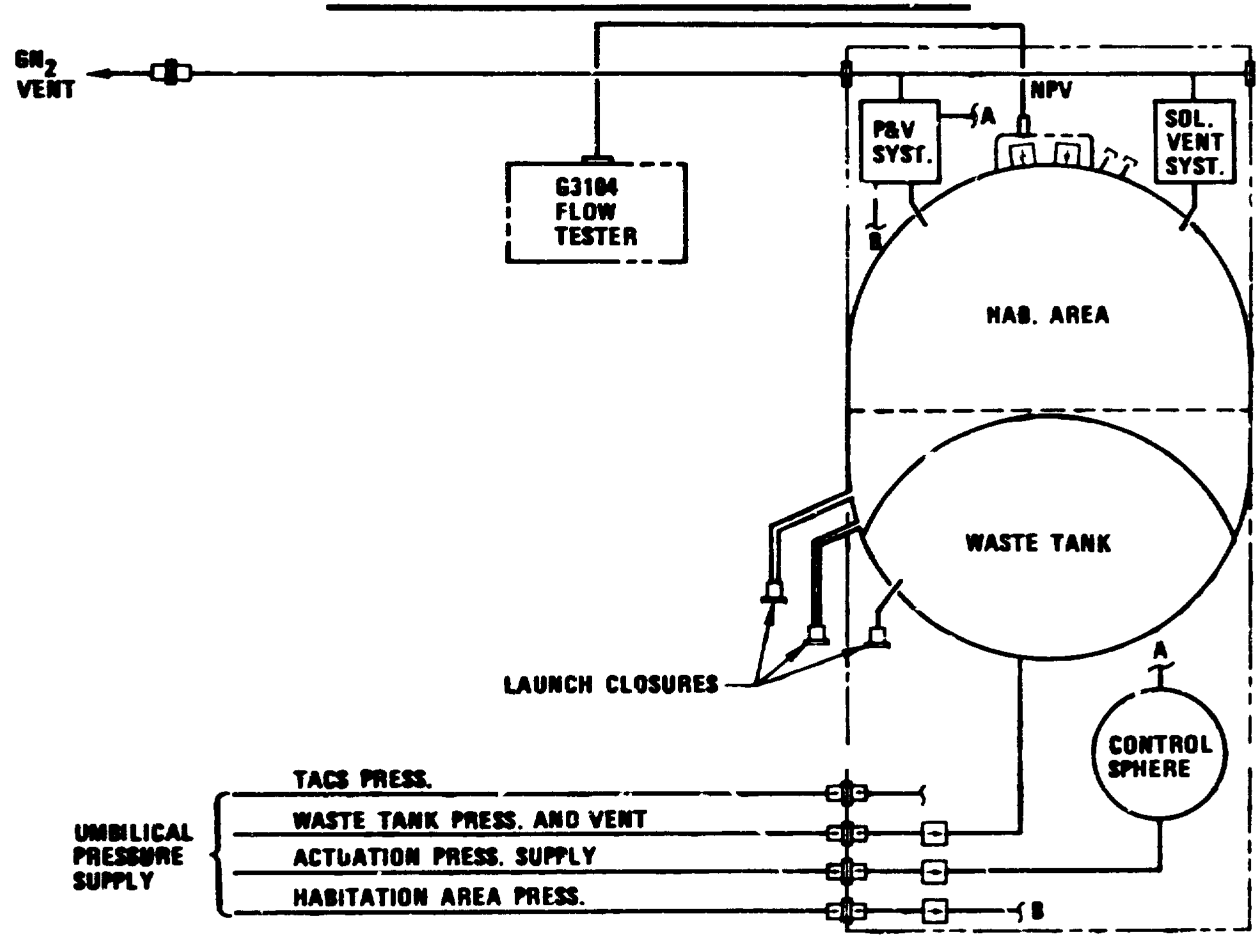


Figure 2.2.14.16-3

SKYLAB - ORBITAL WORKSHOP
LEAK TEST AND CHECKOUT ACCESSORIES KIT
DSV7-300

VACUUM LEAK TESTS - HABITATION SUPPORT SYSTEMS AND LBNP EXPERIMENT

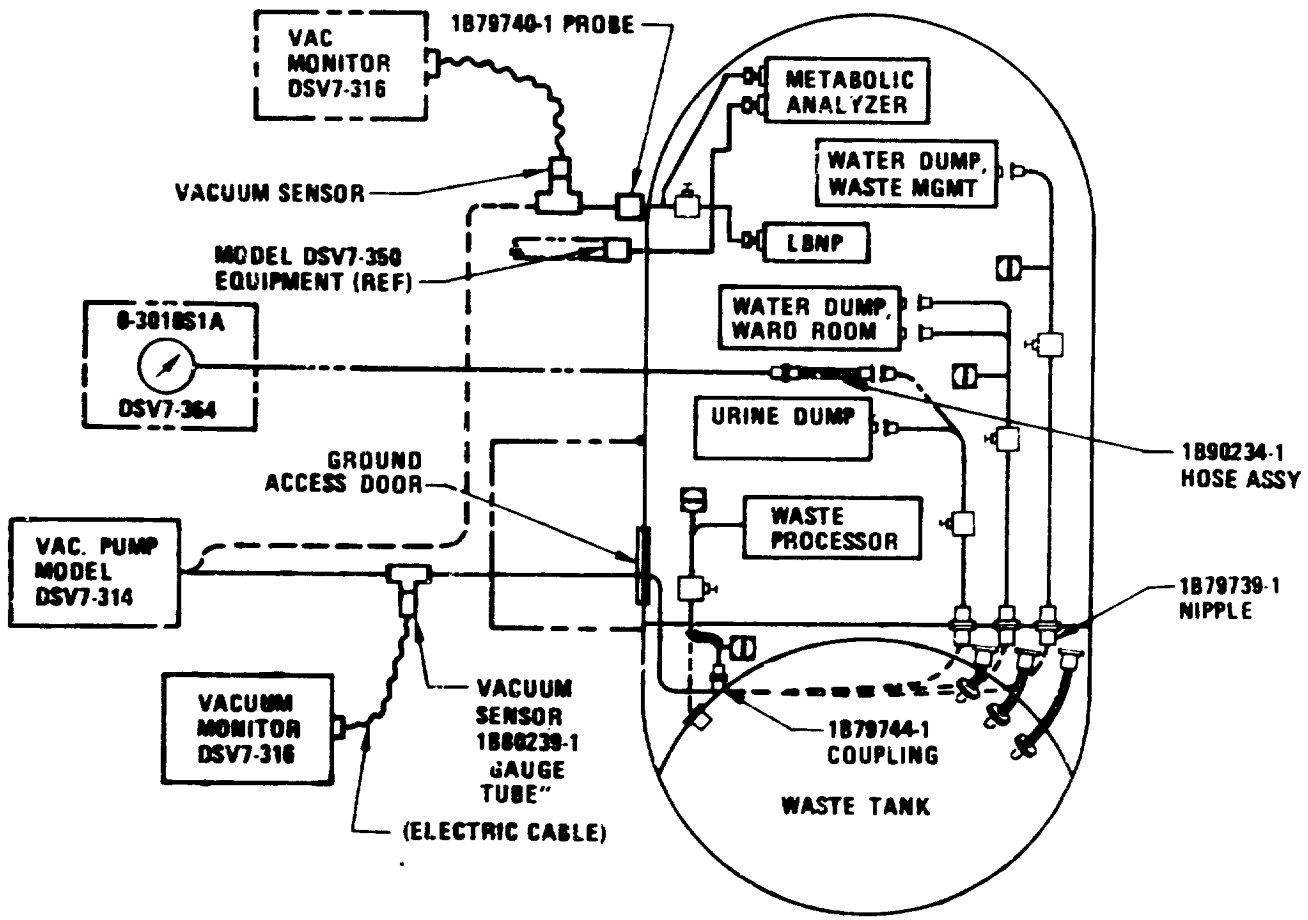


Figure 2.2.14.16-4

SKYLAB - ORBITAL WORKSHOP
LEAK TEST AND CHECKOUT ACCESSORIES KIT
DSV7-300

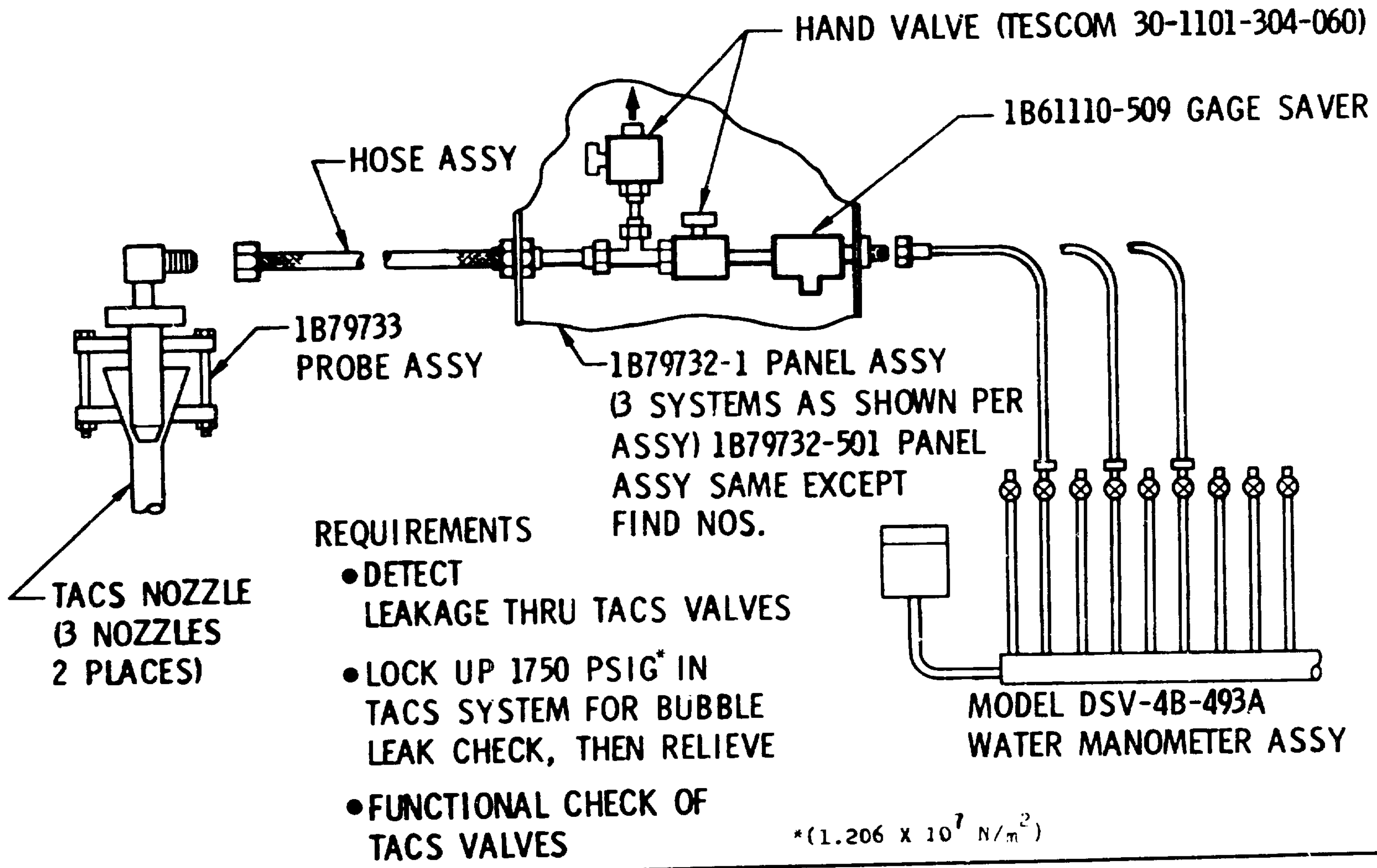


Figure 2.2.14.16-5

SKYLAB - ORBITAL WORKSHOP
PNEUMATIC PRESSURIZATION CONSOLE

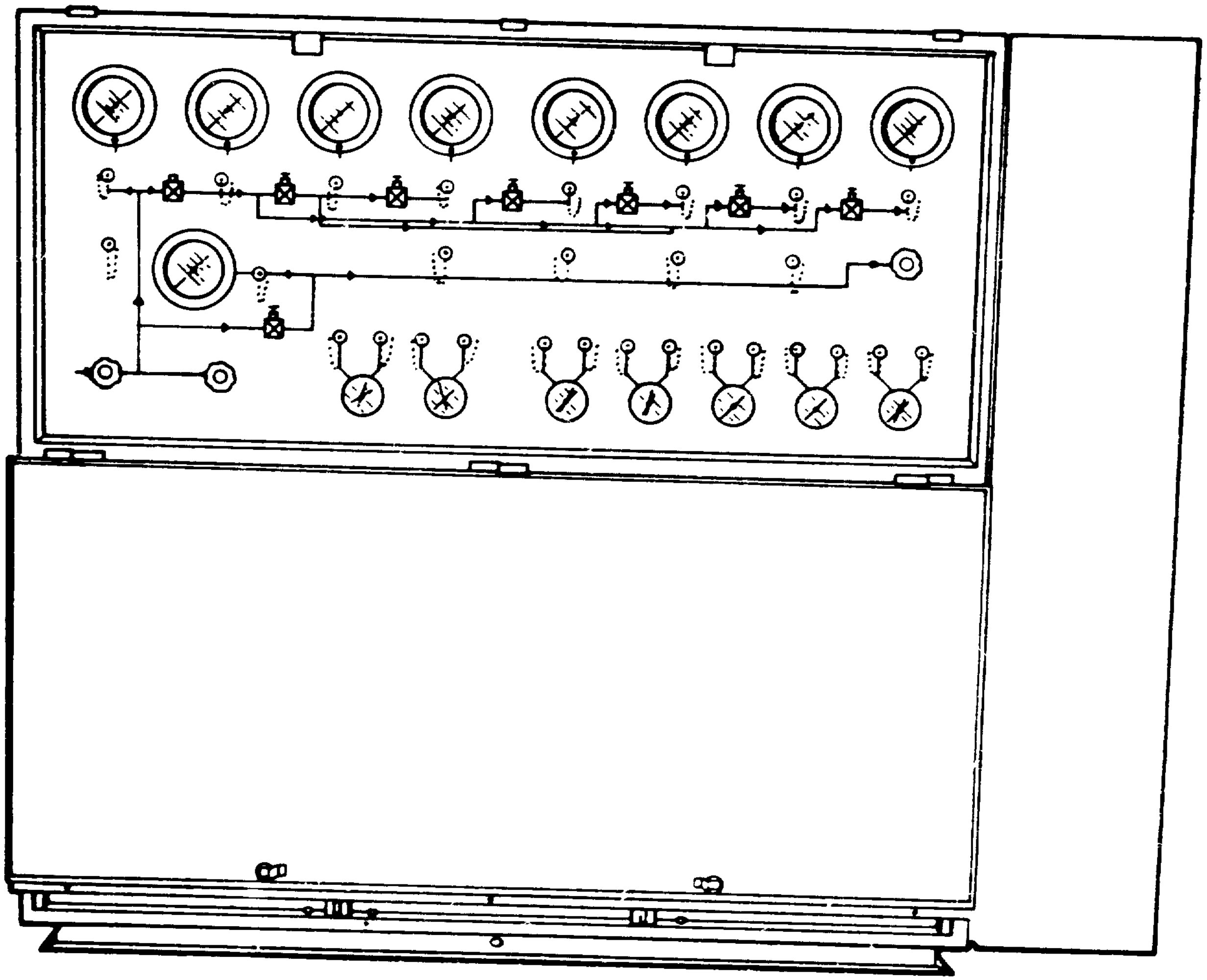


Figure 2.2.14.16-6

checkout and purge gas to the vehicle interface (DSV7-327) and pneumatic console DSV7-343.

The console contained valves, filters, regulators, orifices and piping for the required internal and external connections. Solenoid valves were used for flow control and were remotely actuated. These valves had position talkback switches which provided for remote valve position indication. Transducers provided for remote readout of critical pressures and temperatures. See Figure 2.2.14.10-7.

4/ DSV7-333 - This console was used for checkout of OWS at Huntington Beach. The console was a modified DSV-4B-[illegible] which controlled the GH_e and GN_2 used in checkout of OWS.

The console contained filters, valves, regulators, etc., which controlled the checkout gases. Solenoid valves were used for flow control and were remotely operated. These valves had position talkback switches which provided for remote valve position indication. Transducers provided for remote readout of critical pressures and temperatures within the console.

5/ DSV7-343 - The stage pneumatic servicing console was a modification of a DSV-4B-432A pneumatic console. This console supplied pressurization, checkout and purge gas to the vehicle interface (DSV7-327) and to pneumatic consoles DSV7-329 and DSV7-332.

The console contained valves, regulators, filters, orifices, etc., which controlled the gas flow. Solenoid valves provided for remote flow control. These valves had position talkback switches which gave remote indication of valve position. Transducers provided for remote readout of the critical temperatures and pressures within the system.

SKYLAB - ORBITAL WORKSHOP
GAS HEAT EXCHANGER, MODEL 332 (DSV-7-332)

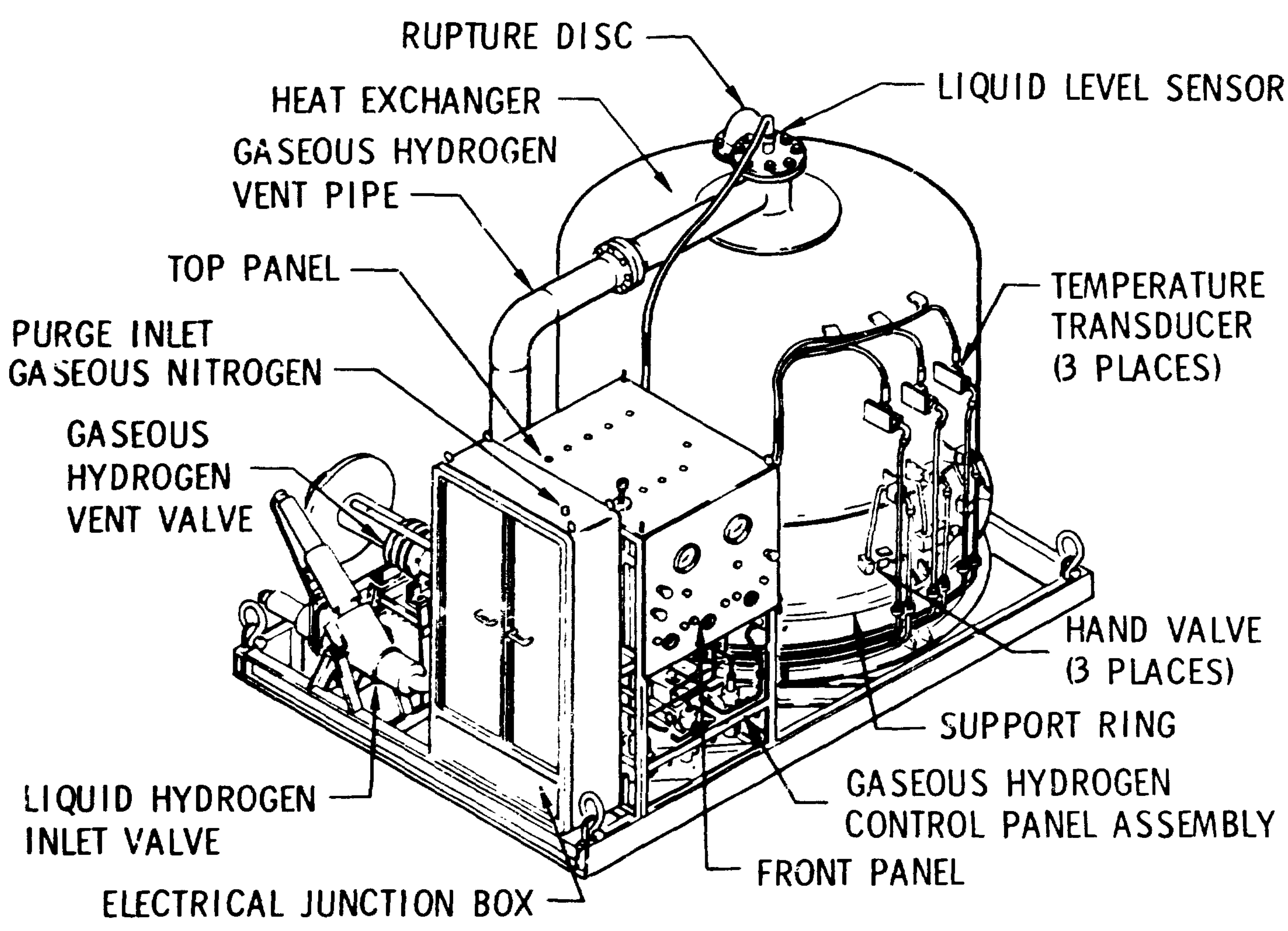


Figure 2.2.14.16-7

6/ DSV7-350 - The vacuum pumping kit contained a Veeco vacuum pumping unit and included necessary controls, instrumentation, ducts, hoses, adapters, and fittings required to create the desired vacuum on OWS experiments. A LN_2 liquid level controlling system kept the cold trap of this vacuum pump full at all times. See Figure 2.2.14.16-8.

7/ DSV7-363 - The M509 pressurization supply kit contained three hose assemblies, a relief valve, a sphere connecting fitting and the necessary interconnecting fittings, packings and seals to fulfill the design requirements of pressurizing the M509 sphere. See Figure 2.2.14.16-9.

8/ DSV7-364 - The nitrogen purge panel assembly was a portable panel containing hand valves, a filter, a regulator and a gage. It connected into the experiment vacuum system and was used to purge and back-fill evacuated experiments with nitrogen. See Figure 2.2.14.16-10.

9/ DSV-4B-238 - The only item of the propulsion system display kit used for OWS checkout was the 1A37850 portable test gage assembly which contained a check valve, hand valves, a regulator, a gage and a filter. This gage assembly was used to pressurize transducers in the H/A and W/T for calibration and to pressurize the H/A NPV system for leak check during checkout.

10/ DSV-4B-329C - This kit was similar to the DSV-4B-238 kit described above and the gage assemblies in both of these kits were used interchangeably in checkout of OWS.

11/ DSV-4B-493A - The only item of the accessory kit used for OWS checkout was the 1B56759 panel assembly. This panel had 24 glass manometer tubes mounted on a panel which gave a measurement of gas leakage through the use of a displacement of water in the tubes.

When connected to a source to be leak-tested, the water

SKYLAB - ORBITAL WORKSHOP
DSV-7-350 VACUUM PUMP EXTERNAL VIEW

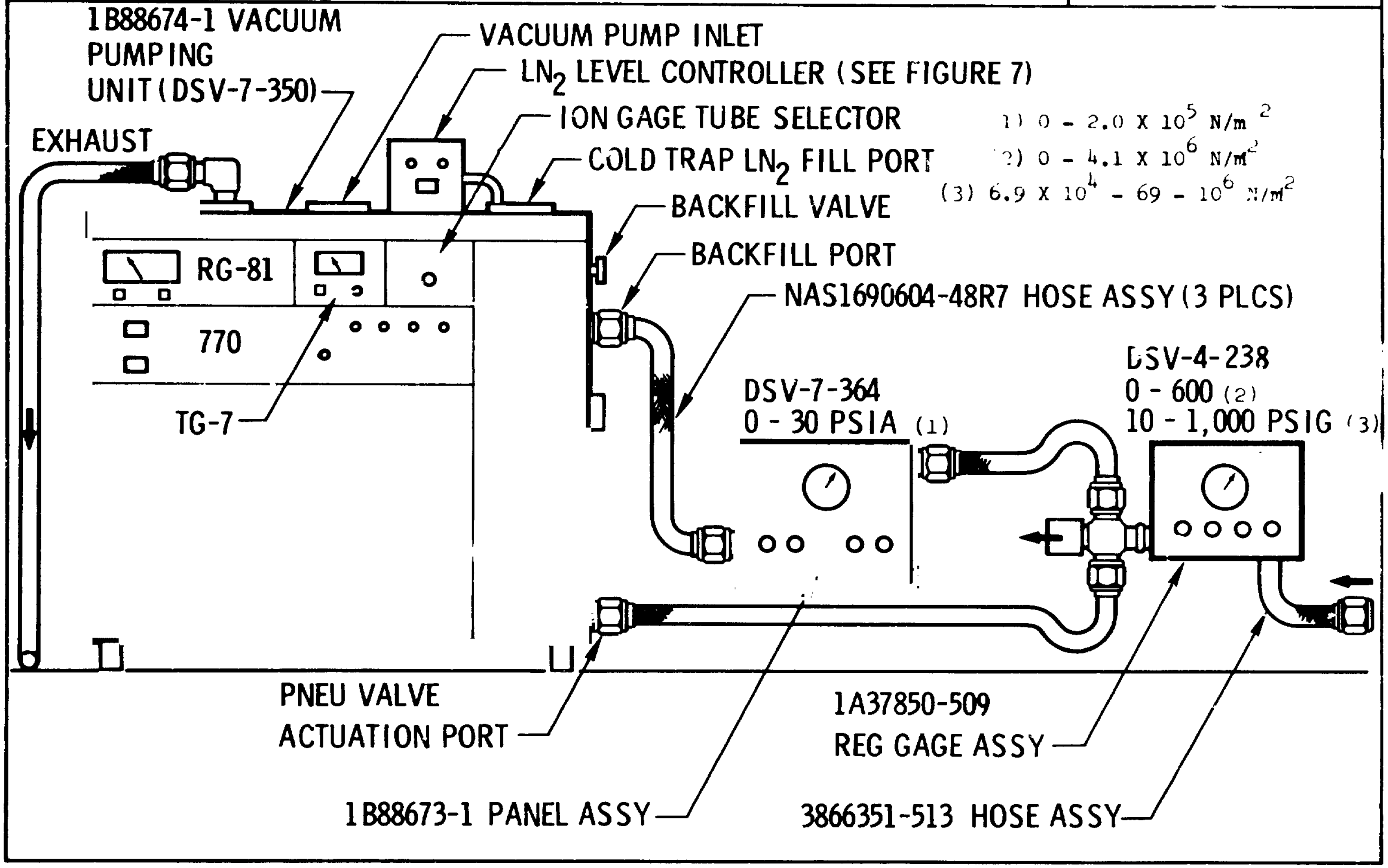


Figure 2.2.14.16-8

SKYLAB - ORBITAL WORKSHOP
MODEL DSV-7-363
M509 SPHERE PRESSURIZATION SCHEMATIC

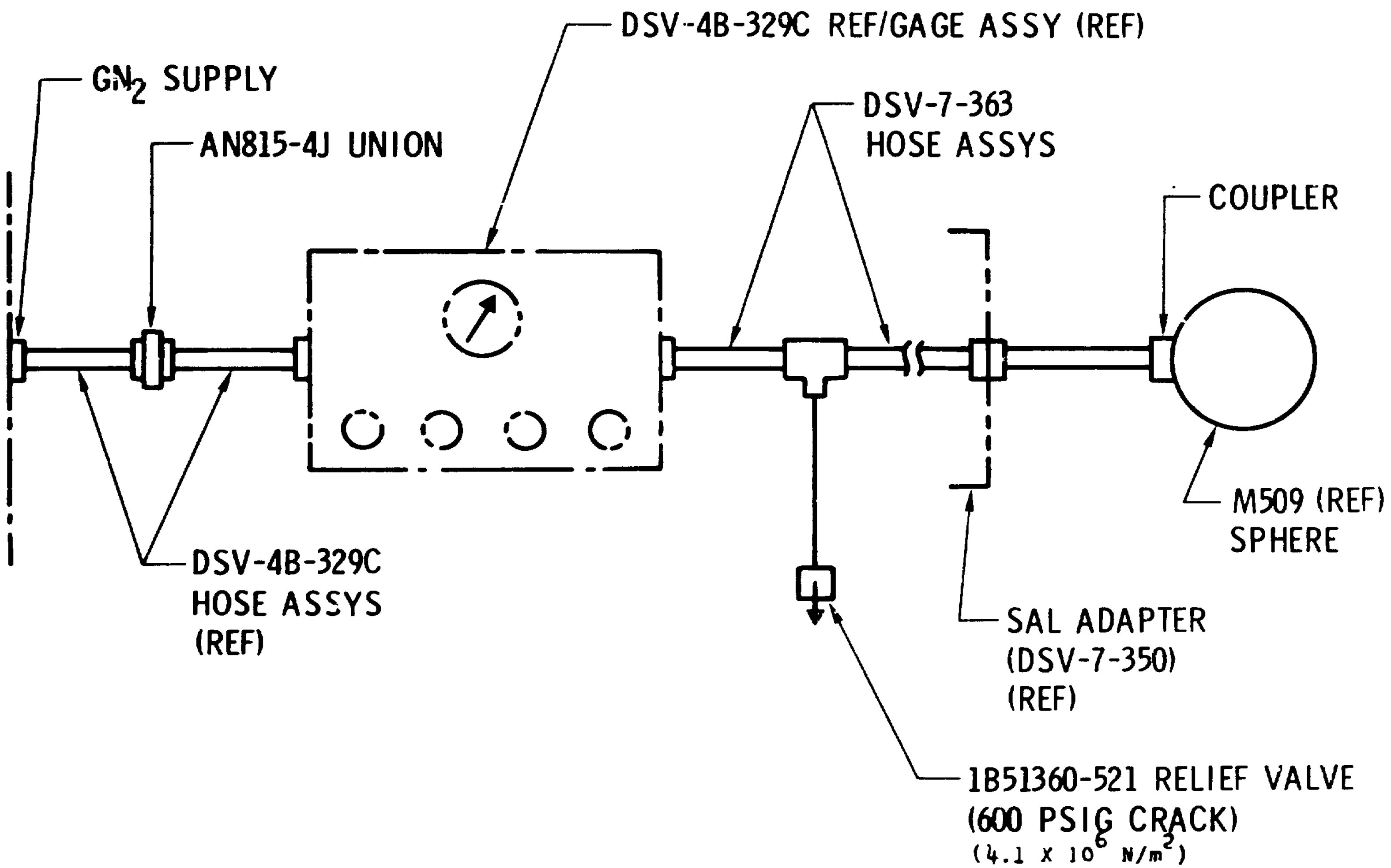


Figure 2.?.14.16-9

SKYLAB - ORBITAL WORKSHOP

DSV7-364 SYSTEM SCHEMATIC

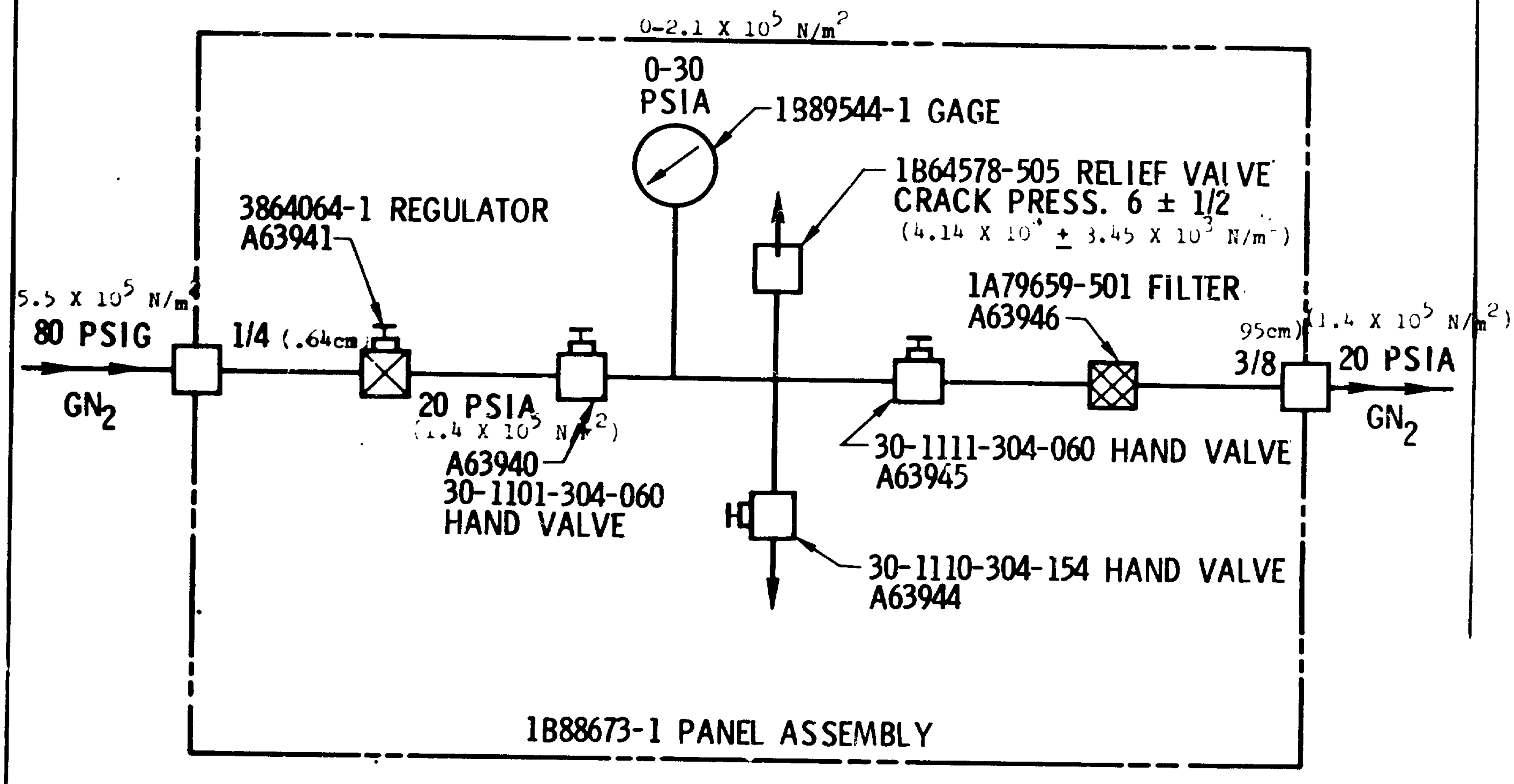


Figure 2.2.14.16-10

displaced in the tubes per unit time was measured. Hoses and fittings from other kits were used to connect this kit to the leak source. See Figure 2.2.14.16-11.

12/ LSV-4F-775 - This model contained a Fike burst disc which was designed to relieve the pressure within the H/A NPV if it reached 15 psig (1.0×10^5 N/m^2). The burst disc would have exposed an opening equivalent to a 2-inch (.05 m) diameter hole had the burst pressure been reached.

13/ G3104 Rocketdyne Pneumatic Flowtester - This device measured leakage of the H/A NPV system and access hatch check valves. The device was simply a flowmeter which was connected to a leak source and leakage was determined by the level that a ball reached within a graduated tube.

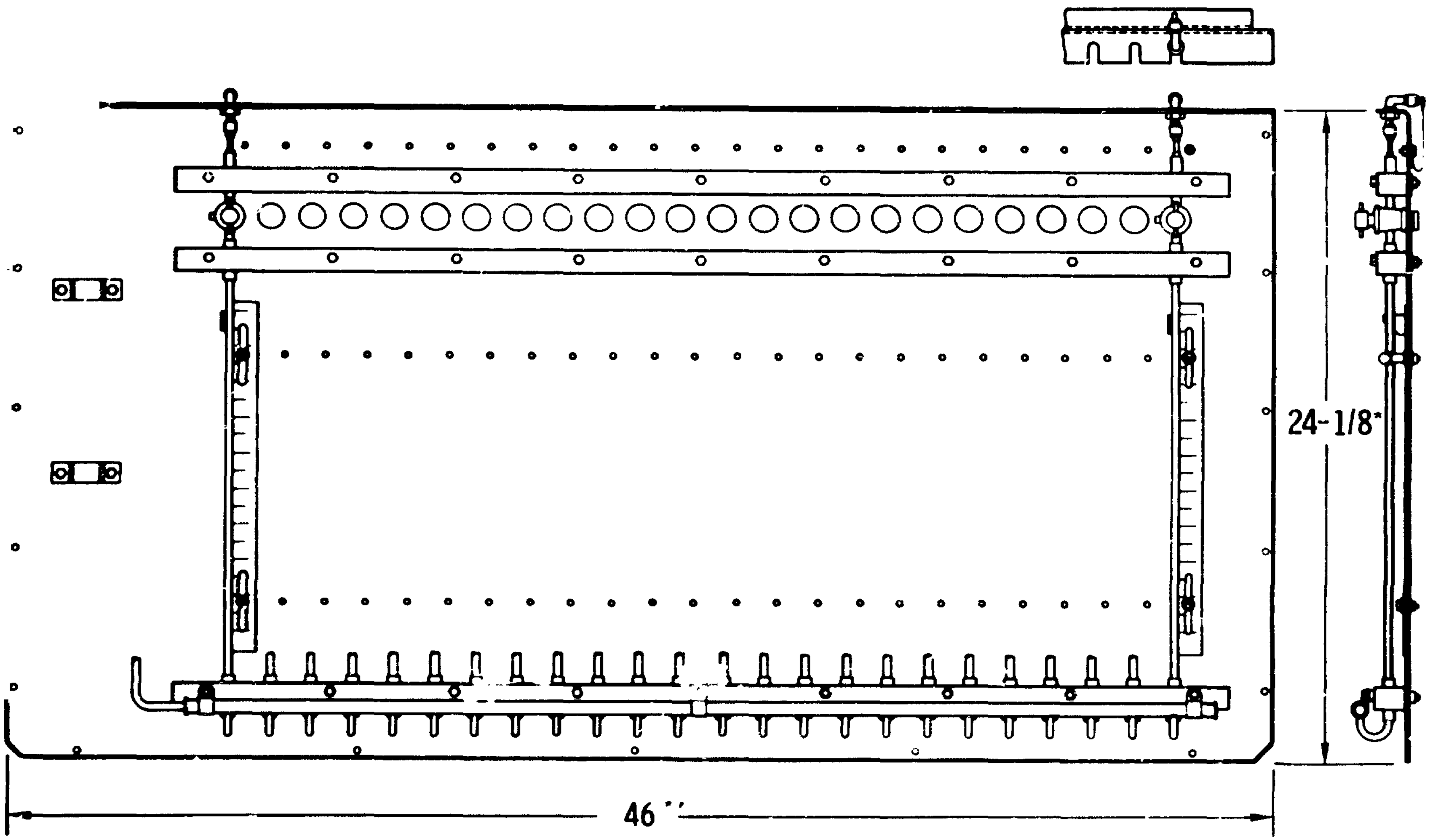
C. GSE Testing - Propulsion GSE used on OWS did not require a testing program. There was no testing program because a portion of the equipment was a modification of a proven model or a new use of a model having previous successful usage elsewhere. New parts were in general informally tested or an analysis conducted to assure that they would perform their function satisfactorily. PAV testing was conducted on pressurization and leak test GSE following manufacture to assure that the components would perform their function correctly. No major problems with this equipment were uncovered.

D. Mission Results - No mission results as such are applicable to this GSE since it is all non-flight hardware. The pressurization and leak test GSE performed its intended mission of pressurizing and checking out the OWS vehicle satisfactorily and with no major problems.

E. Conclusions and Recommendations - The pressurization and leak test GSE performed its function of supporting checkout of the OWS as intended. There were no major problems with the equipment.

Early consideration should be given in establishing the need to carry into a spacecraft, operating pieces of GSE such as a mass spectrometer, or vacuum pumps. These needs are created due to the inability to obtain proper test results with longer test lines. A tradeoff should be made of potential contamination problems and cleaning requirements of these pieces of GSE versus providing a

SKYLAB - ORBITAL WORKSHOP
1B56759-1 PANEL ASSEMBLY
FROM DSV-4B-493A KIT



* (61.23cm) ** 116.8cm)

Figure 2.2.14.16-11

a testing access plate in the spacecraft to route shorter test lines from externally mounted GSE.

2.2.14.17 DSV7-370 Handling and Checkout Kit (1B90528)

A. Design Requirements - The requirements for this kit were to provide non-flight hardware that was installed on OWS during its manufacture, checkout and transportation but which had to be removed prior to launch. All items in this kit were required to be identified in appropriate procedures and by special tags or other means to indicate that they were not to be flown.

B. System Description - The function of this kit was to provide and collect miscellaneous non-flight hardware that was not handled elsewhere. The items included in this kit were:

- Alignment fittings used to align the IU to OWS and OWS to the SII stage.
- Separation keeper used in separation groove during manufacture and transportation to exclude dirt, etc.
- SAS spring retaining nut assembly used to keep SAS plunger in compressed position until SAS was installed on vehicle.
- Coupons attached to vehicle to determine emissivity and absorptivity characteristics of OWS surfaces.
- TACS nozzle covers used to prevent contamination of TACS.
- Pulse sensors used to verify EBW circuits prior to ordnance installation.
- Charcoal cannister protective covers used to seal both inlet and outlet quick disconnects on eight charcoal cannisters.
- Caps on SAS purge pressure sensing system and SAS purge exit ports which prevented contamination during manufacture and transportation.
- Caps for fittings in base of habitation area main electrical outlet used to seal habitation area for pressurizations

required prior to installation of tube assemblies at KSC.

C. Testing - There was no formal testing program of the components of this kit. Where applicable components were PAT tested following manufacture. The majority of these components performed a very basic function and did not require testing.

D. Mission Results - There are no real mission results as such since the kit was made up of non-flight hardware. The hardware performed its function prior to launch of OWS with no major problems encountered.

E. Conclusions and Recommendations - There are no recommendations as the function of this kit is very basic and it performed its function quite satisfactorily.

2.2.14.18 DSV7-511 Partial Checkout Accessories Kit (1B95727)

A. Design Requirements - The partial checkout accessories kit's function was to provide hardware used for OWS backup checkout prior to the launch of OWS-1. Components of this kit were required because they had been expended in the checkout of OWS.

B. System Description - This kit consists of tees, elbows, hoses, seals, washers, etc., and a TACS checkout panel assembly which was used in performing a partial checkout of OWS B/U while OWS-1 was awaiting launch at KSC.

C. Test Program - There was no test program for this kit as the kit was only a collection of hardware needed to continue checkout of OWS B/U. Parts requiring PAT were tested successfully to assure that they would perform their function correctly.

D. Mission Results - Since this equipment was GSE, there are no mission results as such. The equipment performed its function of partial checkout of the OWS B/U.

E. Conclusions and Recommendations - The partial checkout kit performed its function satisfactorily. There are no recommendations concerning this kit since it is very basic and performed its function satisfactorily.

2.2.14.19 Electrical GSE System - General

A. Design Requirements - The basic design requirements for the Electrical Ground Support System were to minimize the manufacturing of GSE and SE required to support OWS checkout. To accomplish this task, the existing S-IVB Automatic Checkout System (ACS) was utilized in conjunction with a minimum number of new electrical end items for Huntington Beach checkout.

MDAC did not provide the electrical checkout system at the Kennedy Space Center used for launch and pre-launch checkout; however, individual end items were provided for subsystem checkout in the VAB.

Table 1-1 of the Orbital Workshop Ground Support Equipment Model Specification, DAC-56692, lists the models of GSE furnished new or made by modifying existing Government Furnished GSE.

Table 1-2 of DAC-56692 lists the models of S-IVB GSE and SE which were used for system checkout of the OWS at HB.

B. System Description - The Automatic Checkout System is a digital computer controlled checkout system. A computer interface unit controls the transmission of data between the computer and control consoles and display units. The checkout system is capable, under computer control or manual control, of operating the OWS subsystems to determine acceptable performance and record and document results of all tests performed. The checkout system provides fault isolation to a replaceable module or component within the Workshop, provides required manual control for human intervention to ensure reliability and safety. New electrical modules were manufactured to compliment the existing S-IVB ACS for special OWS systems.

The following list shows the new electrical GSE that was manufactured for testing at HB and KSC.

Model No.	Title	HB C/O	KSC C/O
DSV7-100	Airlock Module Simulator	X	
DSV7-102	SAS Instrumentation Simulator	X	X
DSV7-104	Ground Elect. Test Kit	X	
DSV7-105	Internal Test Lighting Kit	X	X
DSV7-106	TACS Elec. Checkout Kit	X	X
DSV7-109	SAS Component Test Set		X
DSV7-122	HSS Refrigeration Test Set	X	X
DSV7-129	Experiments Cable & Connector Kit	X	X
DSV7-503	Habitation Area Mass Decay Leak Test Kit	X	X
DSV7-504	TV Subsystem Elec. Checkout Kits	X	X
DSV7-506	Special Test Devices		X
DSV7-507	KSC Elec. Accessory Kit		X
DSV7-509	TACS Elec. Test Kit	X	

C. Testing - The checkout system was tested as a complete integrated unit at HB before the ACS was connected to the OWS. The individual end items that were designed to be used independently of the ACS were checked out by means of an Acceptance Test Procedure.

The models used for subsystem checkout at KSC were functionally tested by an end item Acceptance Test Procedure prior to use on the OWS.

No major problems were encountered during GSE checkout at HB or KSC.

D. Mission Results - The Automatic Checkout Systems mission is to verify the design integrity and operational capability of the

OWS. The GSE at MDB and KSC performed this mission properly.

E. Conclusions and Recommendations - The ACS and subsystem end items performed well and accomplished its task to verify the OWS electrical systems.

2.2.14.20 Airlock Module Simulator (DSV7-100)

A. Design Requirements - The purpose of the Airlock Module Simulator (AMS) was to provide an electrical interface, to the OWS, representing the AM. Power, control and monitoring functions of the AM were to be provided by the AMS both manually and automatically under control of the Automatic Checkout System (ACS).

In order to provide all the necessary functions, the AMS had to simulate the following Airlock Module Systems:

- Power Distribution
- Instrumentation
- Attitude Control System
- SAS and Meteoroid Shield Control
- Communications
- Caution and Warning
- Thermal Control
- Illumination Power and Con[illegible]
- Experiment Accommodations
- Pressure Control
- Apollo Telescope Mount (ATM) and Multiple Docking Adapter (MDA) Control
- Refrigeration System Control

In addition, test points and circuit protection was specified.

B. System Description

1/ Physical - The AMS consists of seven bays of equipment, separated into three consoles. A four-bay console was located in the Test Control Center. The other two consoles, a bay unit and a two-bay junction box, were located on the eighth level of tower 6 at A3-VCL.

2/ Functional

a. Power Distribution - The AMS was capable of distributing 28 VDC GSE power to the OWS either manually or automatically. Manual control and monitoring was provided through the use of a power and control panel. Automatic control was effected under computer control.

b. Instrumentation - The heart of the AM data system was simulated by the AMS in order to provide a means of processing OWS TM data. A control panel, a decommutation unit and an interface with the ACS provide the capability to do a complete checkout of the OWS instrumentation system.

c. Attitude Control, Pressure Control, ATM and MDA, RS - An electrical interface is provided by the AMS to allow automatic checkout of the OWS TACS, PCS, ATM and MDA functions and RS.

d. SAS and Meteoroid Control - AM control of the deployment systems for the SAS and the meteoroid shield are simulated on an appropriate panel built into the AMS. In addition, the capability to send simulated AM Digital Command System (DCS) commands automatically is provided.

e. Communications and Biomed - A front panel is provided for power and controls to test the OWS Intercomm and Biomed Systems. In addition, a capability to interconnect the OWS Intercom System to GSE Communications System was included.

f. Caution and Warning System (CWS) - Two panels are provided for the CWS. One panel contains the controls and indicators necessary to simulate functions between the AM CWS and the OWS. A second panel supplies power for the Fire Detection System in the OWS. In addition, indications of "FIRE" from the OWS are displayed on the "Fire Detection" panel.

g. Thermal Control System (TCS) - A panel is provided which allows controls and indications for the application of power to the radiant heaters. Displays of heat exchanger commands are also provided.

h. Illumination - A control and display panel provides controls and indications for emergency and initial/entry lights. In addition, indications of bus voltage status are displayed.

i. Experiment Accommodations - A panel is provided to control the activation of scientific airlock experiments. In addition, various displays are provided.

C. Testing - The model DSV7-100 had a continuity test performed on the wiring after manufacturing. Then, an Acceptance Test Procedure was accomplished against the unit at HB, and finally the unit was used during the GETS test before being used to checkout the OWS.

D. Mission Results - The model performed as required.

E. Conclusions and Recommendations - The AMS was the most important element of the OWS GSE. It was utilized in every test either in a manual mode or in an automatic mode and, in many cases, in both modes.

However, it should have simulated the AM more precisely. An audio center should be included because, during A3 checkout, the Intercomm System Gain was substantially different than that in the flight system.

2.2.14.21 Solar Array Instrumentation Simulator (DSV7-102)

A. Design Requirements - The purpose of the SAS simulator is to provide portable GSE to support instrumentation testing for SAS functions when the SAS wings are not installed on the OWS.

The unit is therefore designed to provide the capability to simulate wing section deployment, as well as wing fairing deployment. In addition, each temperature probe installed on the SAS wings is simulated. Identical units are utilized to simulate each of the two SAS wings. Since circuit protection is provided on the OWS, it is not required in the simulator.

B. System Description - The SAS simulator consists of two junction boxes and sixteen cable assemblies. Within each J-box, ten 200 ohm, 1/4 watt resistors simulate the SAS temperature probes. Six 1000 ohm, 1/4 watt resistors are provided to simulate wing section deployment position. In addition, two single pole toggle switches are utilized to provide indications of simulated wing fairing deployment. Eight cables are utilized to connect each junction box to the OWS. Three cables route all temperature probe simulator outputs to various temperature bridge modules on the OWS. The second group of three cables connects the wing section deployment position simulators to the multiplexers on the OWS. The OWS provides 5 vdc to the simulator which is then returned, through the 1000 ohm resistors, to the OWS. Two cables are utilized to provide 28 vdc to the switches in the simulator to allow control of deployment indications to the OWS.

C. Testing - The unit had a Product Acceptance Test performed on each J-box prior to use on the OWS. No problems were encountered during any of these tests.

D. Mission Results - No fit problems were encountered when the flight SAS was installed at KSC. In addition, the data returning from the Skylab before and after the deployment problems proved that the simulator performed as expected during its usage at HB and KSC.

E. Conclusions and Recommendations - The SAS instrumentation simulator performed as expected in all respects. However, as a result of the mission support test (TI003), a recommended improvement would be to replace the fixed resistors in the wing section position indications should be replaced with potentiometers.

2.2.14.22 Ground Electrical Test Kit (DSV7-104)

A. Design Requirements - The purpose of the Ground Electrical Test Kit was to provide a collection of hardware necessary to perform electrical checkout of the OWS at A3-VCL. The kit was required to provide cables, cable trays and/or supports and feedthroughs, transient and 6 db detectors with associated cables and junction boxes, test box assemblies and load simulators.

B. System Description

1/ Installed Cables - Thirty-seven interconnecting cables between the Airlock Module Simulator (AMS), DSV7-100, and the OWS provided the necessary simulated power, commands and responses. Since the AMS was located in two different areas within the VCL, 26 interconnecting cables were required. Various interconnections among many of the permanently located OWS GSE in A3-VCL required the use of 13 cables. In addition, 30 cables connected the permanently installed OWS GSE to the existing GSE utilized to check S-IVB stages. Eight cables provided facility power to the OWS GSE permanently installed at A3-VCL.

2/ Loose Cables - A number of cables to provide interface between OWS components and the existing DSV-4B-726 breakout box were utilized during various tests and troubleshooting.

All necessary cabling for interconnection of EMC equipment was also considered a part of the DSV7-104.

3/ Test Box Assemblies - A number of test box assemblies were utilized to checkout the OWS DAS, TV and Power Distribution Systems.

4/ Resistive Load Simulators utilized in measuring voltage drops during power distribution system testing were a part of the Model DSV7-104.

5/ All of the transient detectors and junction boxes utilized during EMC testing of OWS 1 are a part of the DSV-7-104.

C. Testing - Product Acceptance Testing and Receiving Inspection was performed with no significant problems resulting.

D. Mission Results - The model met its design requirements.

E. Conclusions and Recommendations - Most of the items listed were utilized many times, either during checkout of OWS 1 or the backup OWS. The following recommendations are made as a result of some problems encountered during checkout:

1/ Spare EMC detectors should be made available.

2/ The load simulators should be capable of being attached to the OWS grid work in the ceiling.

3/ The adjustable load simulators should have an "adjustment locking" capability.

2.2.14.23 Internal Test Lighting Kit (DSV7-105)

A. Design Requirements - The purpose of the Lighting Kit is to illuminate the interior of the OWS in support of test and checkout activities.

Twelve portable lights were to be furnished to provide a minimum of 25 foot-candles (269 lumen/m^2) at a distance of 4 ft. (1.2 m) from each light source. Each light was to provide on/off control and be capable of directing light at various angles. The lights had to produce a negligible amount of EMI. In addition, each light housing was required to be explosion-proof.

Control of the lights was to be effected from a box located outside the OWS. Special cleaning and packaging requirements were also specified.

B. System Description - The unit consists of one explosive-proof and two non-explosive proof junction boxes, twelve lights and a number of cables. The non-explosive proof J-boxes provided individual on/off control of 6 lights through a 7.5 ampere circuit breaker. The explosive proof J-box provides on/off control for each of 4 lights through individual switches. Two 10 ampere circuit breakers service the 4 lighting circuits. Twelve 35 ft. (10.7 m) cables are utilized to provide power and control to the lights. A 25 ft. (7.6 m) cable routes power to the non-explosive proof J-boxes. However, the explosive proof J-box receives facility power through a 75 ft. (22.9 m) cable with an explosive proof plug.

C. Testing - There were no problems encountered during the product acceptance tests. In addition, during testing accomplished in the circuit study lab at A3, 55 foot-candles (592 lumen/m^2) were measured at a distance of 4 ft. (1.2 m) from the lamp under test.

D. Mission Results - The model met its design parameters.

E. Conclusions and Recommendations - The unit was used during testing in the "High Fidelity Mockup" at Huntington Beach (HB). It was not used during checkout in the VCL at HB nor was it used to support KSC checkout. Functionally, the unit met all design requirements. However, the lights were cumbersome to utilize, relocate, etc. Therefore, it is recommended that the model DSV7-105 not be utilized in case of future OWS checkout.

2.2.14.24 TACS Electrical Checkout Kit (DSV7-106)

A. Design Requirements - The TACS Electrical Checkout Kit provides a means of obtaining valve voltage and current traces, bilevel indications of valve actuation, thruster inlet pressure measurements, relay contact malfunction indications, and TACS system IU/ATMDC timing information which will provide data for analysis in the checkout of the OWS Thruster Attitude Control System.

The model provides the control and selection capability of a module and thruster in addition to individual or any combination of valve selection on any thruster. Operation of the selected valves in either momentary or continuous and an indication status of the valve selection is provided on the TACS electrical checkout kit control panel.

B. System Description - The TACS Electrical Checkout Kit (8106) contains three portable boxes, six pressure transducers and a set of drag-on cables.

The Electrical Checkout Kit Control Unit (8106A1) is a portable unit that interfaces, via drag-on cables, with the OWS Thruster Relay Control Unit. Also connected to the 8106A1 unit is an oscillograph; not part of model DSV7-106. In addition to the switches and lights utilized for various combinations of thruster valve indications and control, the unit contains shunts and valve command pick-off points distributed to the external oscillograph for recording voltage and current valve traces. Each control line contains a 5-amp fuse to protect the OWS in case of a short within the box.

The TACS Electrical Checkout Kit Instrumentation Unit (8106A2) is a portable unit used to condition the TACS pressure measurements provided by the model DSV7-106 six pressure trandurcers. The six pressure transducers monitor thruster pressure. Drag-on cables are used to interface the transducers and the Instrumentation Unit.

The TACS Electrical Checkout Kit J-Box (8106A3) distributes the thruster pressure measurements from the 8106A2 instrumentation unit to an external oscillograph; again not part of model [illegible] The J-box also interfaces the TACS relay control module., distributing data to the external oscillograph for TACS system IU/ATMDC timing tests at KSC.

C. Testing - A PATP was performed on the Model DSV7-106. Also, the model was checked with the ACS at HB as part of the electrical preparations prior to connection to the OWS.

D. Mission Results - The unit verified the electrical validity of the TACS subsystem.

E. Conclusions and Recommendations - The model performed satisfactorily during TACS checkout at HB and KSC. No major problems were encountered.

2.2.14.25 SAS Component Test Set (DSV7-109)

A. Design Requirements - The SAS Component Test Set provides the capability for the generation of Dark Current-Voltage (I-V) data for OWS solar modules. The test set will be used by the SAS manufacturer for product acceptance testing and derivation of initial dark I-V data. It will also be used at KSC. The unit provides the capability of applying 5 to 10 known voltages to each of 120 solar-cell modules in a wing, one at a time. The applied voltage is time limited to a range of 1 to 2 seconds. While applying a known voltage to each solar-cell module, the applied voltage, current drawn and resistance of the RTB's are monitored and recorded. The measurement system has an accuracy of within 0.1 percent. Additional requirements provide 120 VDC (120 ma) power for back biasing diodes in the SAS power unit; also, the unit is portable, mobile and requires only AC power to operate.

B. System Description - The solar array system component test set is composed of two bays of electrical equipment mounted on a dolly with wheels and forklift provisions. These two bays contain logic, control, DVM's, line printer, power supplies, circuit breakers, and a drawer (to hold loose equipment supplied with the test set). The DSV7-109 also has a J-box, cables, and adapters to provide the interface for various dark IV test modes.

The operation is based on the sequencing of three counters - the temperature counter, the power supply counter and the module counter. The sequencing of the counters and the decoded output of the counters can be controlled by front panel switches. The temperature counter function is to automatically sequence a matrix that switches resistance temperature bulbs (TRB's) on the SAS wing to the input of a digital voltmeter. The power supply to the proper voltage values (as determined by front panel switches). The number of voltages applied is determined by front panel switches. The module counter's function is to sequentially activate matrices that apply the programmable power supply output to the appropriate module under test and to monitor on the DVM, through a redundant pair of wires from the modules, the voltages applied to the module. All data is output on a line printer for a permanent record.

C. Testing - The performance capability of the model has been satisfactory in both its PATP and H&CO. No major problems were encountered.

D. Mission Results - The model met its designed objectives.

E. Conclusion and Recommendations - The unit performed satisfactorily at both the supplier and KSC.

2.2.14.26 HSS Refrigeration Test Set (DSV7-122)

A. Design Requirements - The HSS Refrigeration Test Set provides the capability of simulating failure or normal operating modes of the refrigeration electrical system and monitoring their effect in an ambient condition. In addition, the unit provides a monitoring capability when the refrigeration system is operational.

The model verifies OWS HSS refrigeration electrical system logic operation in the following systems:

- o Coolant Pump Inverters

- Regenerative Heater Controllers
- Radiator Bypass Valve Controllers
- Control Logic Units

The unit is also transportable and self-contained, requiring only AC power to operate.

B. System Description - The HSS Refrigeration Test Set is composed of two bays of electrical equipment mounted on a dolly with wheels and forklift provisions. These two bays contain (1) a relay plane with relays and lamp drivers, (2) panels that contain switches and lamps, (3) voltmeter and counter, (4) power supplies, and (5) test point panels. The DSV7-122 also has a J-box and cables to provide the interface to support refrigeration electrical testing.

Within the model switching is provided to simulate normal or low delta-P, liquid level, or flow. Resistors are provided to simulate high or low temperatures for all temperature control sensors and majority voting logic verification. Variable resistance is provided to verify switching points of temperature comparator logic and lights are provided to indicate the state of comparator circuits, valves and logic. A volt-ohmmeter is provided to measure AC, DC, MV and ohms. A frequency counter is provided to measure frequency, phasing and time delays. Test points are provided to access selected vehicle functions.

C. Testing - The performance capability and design maturity of model DSV7-122 has been proven by satisfactory completion of PATP and H&CO procedures.

D. Mission Results - The unit verified the electrical portion of the refrigeration subsystem.

E. Conclusion and Recommendations - No major problems were encountered during the use of model DSV7-122 at HB or KSC. A minor problem of some consequence was discovered at HB during refrigeration electrical preparations. The counter would not count properly because of excessive noise on the input of the Digital Isolator Card. The problem was eliminated by reducing the value of the isolation resistor in Model DSV7-122, which in turn raised the voltage input to the digital isolation card above the noise level.

In conclusion, the unit performed well at both HB and KSC, encountering no major problems at either test site.

2.2.14.27 Experiments Cable and Connector Kit (DSV7-129)

A. Design Requirements - The purpose of the Experiments Cable and Connector Kit was to provide a kit of loose hardware to interface with OWS experiments for use during checkout. The kit was required to provide connectors, adapters contacts and cables which are compatible with an existing breakout box as well as various experiments. The kit was to be stored in a portable container.

B. System Description - The DSV7-129 consists of 19 cable assemblies, 5 loose connectors and an adapter. The components within the kit are utilized as follows:

1/ Cable assemblies with breakout or external power requirements are mated with experiments.

2/ Loose connectors are mated with all other known experiment connectors as required.

3/ An adapter cable to mate cables to the DSV7-726 breakout box.

4/ A power cable for experiment T013.

5/ A coaxial cable for Standing Wave Ratio (SWR) measurements for experiment M509.

6/ An SWR adapter.

Each of the components indicated were utilized during checkout of the OWS experiments, while installed in the OWS at HB and again at KSC.

C. Testing - During receiving inspection tests and product acceptance testing, no problems were indicated.

D. Mission Results - The model met its designed objectives.

E. Conclusions and Recommendations - The kit proved to be extremely useful. It was used in more situations than originally anticipated. As a result, there is no question that it would be utilized again in the future.

2.2.14.28 Habitation Area Mass Decay Leak Test Kit (DSV7-503)

A. Design Requirements - Provide a unit to perform a gross leakage rate (mass decay) test of the OWS habitation area to verify that the overall leakage rate is within allowable limits.

B. System Description - The model consists of equipment located inside the habitation area and consoles located in the testing area. Inside the habitation area, there are twenty themister transducers, five quartz thermometers, five fan assemblies, and two distribution boxes distributed throughout the OWS to provide a reliable measurement of the inside temperature. The equipment is connected through an electrical feedthrough to the Dymec Data Acquisition System and a Control J-Box. After the equipment is connected, the OWS hatch was closed and the habitation area pressurized to 5.0 ± 0.5 psig (34.5 ± 3.45 kn/m^2) with gaseous helium. Then the gross leakage rate test is conducted until stabilized test data is obtained over a length of time, approximately 48-hours, sufficient to determine the leakage rate.

C. Testing - The transducers, thermometers, pressure standards, and the Dymec System were calibrated prior to installation for the leak test. Then, the total electrical system was verified by an acceptance test before the mass decay test was performed.

D. Mission Results - The unit worked well at HB and KSC.

E. Conclusions and Recommendations - The model accomplished the task, as expected. However, a portable air conditioner for the Dymec enclosure would provide the needed temperature stability that was not obtained when a remote unit was used at KSC.

2.2.14.29 TV Subsystem Electrical Checkout Kit (DSV7-504)

A. Design Requirements - Provide the necessary equipment to perform the following tests on the TV subsystem.

1/ Time Domain Reflectometry of individual segments and the total subsystem

2/ Isolation tests

3/ Fault current verification

4/ Voltage magnitude and polarity power outlet tests

5/ Gain verification tests

6/ Frequency response

7/ DC response

8/ Linearity

9/ Signal-to-noise

10/ Converter noise

11/ Camera operation

B. System Description - The model consists of cables, connectors, load terminations signal generators, and a video amplifier which were connected in various configurations as identified in the TV subsystem ATP 1B91066 and KS0045 to accomplish the tasks listed above.

C. Testing - The individual items of the model had receiving test performed prior to its use.

D. Mission Results - The model completed the verification of the OWS TV subsystem.

E. Conclusions and Recommendations - The model performed satisfactorily.

2.2.14.30 Special Test Devices Index List (DSV7-506)

A. Design Requirements - Provide special test devices needed for test and checkout of the OWS/AM/MDA.

B. System Description - The model consists of four groups of special test devices assigned to the following drawings: 1B93005, 1B93006, 1B93007 and 1B93008. These special devices are connected in various ways as defined in KSC Acceptance Test Procedures.

C. Testing - An acceptance test was accomplished on each test device prior to use.

D. Mission Results - The devices performed properly in the tests in which they were used.

E. Conclusions and Recommendations - The model performed as expected, however, to prevent delays in testing time, the following recommendations are applicable:

1/ Add smaller alligator adaptors.

2/ Increase the quantity of test leads and test lead adaptors.

3/ Create load simulator for use on the 400 Hz fan circuits.

4/ Create load simulators for 4D111 and 4D119 bus loading.

2.2.14.31 KSC Electrical Accessory Kit (DSV7-507)

A. Design Requirements - Provide special electrical equipment to support the following checkout and prelaunch activities at KSC:

1/ Monitor the pre-load setting on the Solar Array System.

2/ Verify DC power characteristics during maximum power transfer from the AM/MDA to the OWS.

3/ Actuation of the Solar Array magnetic proximity switches.

B. System Description - To monitor the pre-load setting on the SAS load sensors, this model has a strain indicator, a balance unit, load sensor harnesses, extension cables, and patch cords. The hardware is hooked up to the SAS sensors and the OWS cinch bars are torqued until the proper reading is obtained on the indicator gauge.

To verify the DC power characteristics, this model contains load simulators and cables that are connected to the busses to monitor voltage during power transfer.

To actuate the solar array proximity switches, this model contains a magnetic actuator which is placed near the SAS switches during SAS testing.

C. Testing - The individual items had receiving tests performed prior to use on the OWS.

D. Mission Results - The model performed properly during the

E. Conclusions and Recommendations - The model is acceptable for the tasks it has to perform.

2.2.14.32 TACS Electrical Kit (DSV7-509)

A. Design Requirements - The TACS Electrical Checkout Kit provides a means of obtaining valve voltage and current traces, bilevel indications of valve actuation, thruster inlet pressure measurements, relay contact malfunction indications, and TACS system IU/ATMDC timing information which will provide data for analysis in the checkout of the OWS thruster attitude control system.

The model provides the control and selection capability of a module and thruster in addition to individual or any combination of valve selection on any thruster. Operation of the selected valves is either momentary or continuous and an indication status of the valve selection is provided on the TACS electrical checkout kit control panel.

B. System Description - The TACS Electrical Checkout Kit (8509) contains two portable boxes, six pressure transducers and a set of drag-on cables.

The TACS Electrical Checkout Kit Control Unit (8509A1) is a portable unit that interfaces, via drag-on cables, with the OWS thruster relay control unit. Also connected to the 8509A1 unit is an oscillograph, not part of model DSV7-106. In addition to the switches and lights utilized for various combinations of thruster valve indications and control, the unit contains shunts and valve command pick-off points distributed to the external oscillograph for recording voltage and current valve traces. Each control line contains a 5-amp fuse to protect the OWS in case of a short within the box.

The TACS Electrical Checkout Kit Instrumentation Unit (8509A2) is a portable unit used to condition the TACS pressure measurements provided by the model DSV7-106 six pressure transducers. The six pressure transducers monitor thruster pressure. Drag-on cables are used to interface the transducers and the Instrumentation Unit.

C. Testing - A PATP was performed on model DSV7-509. Also, the model was checked with the ACS at HB as part of the electrical preparations prior to connection to the OWS.

D. Mission Results - The unit verified the electrical validity of the TACS subsystem.

E. Conclusions and Recommendations - The model performed satisfactorily during TACS checkout at HB and KSC. No major problems were encountered.

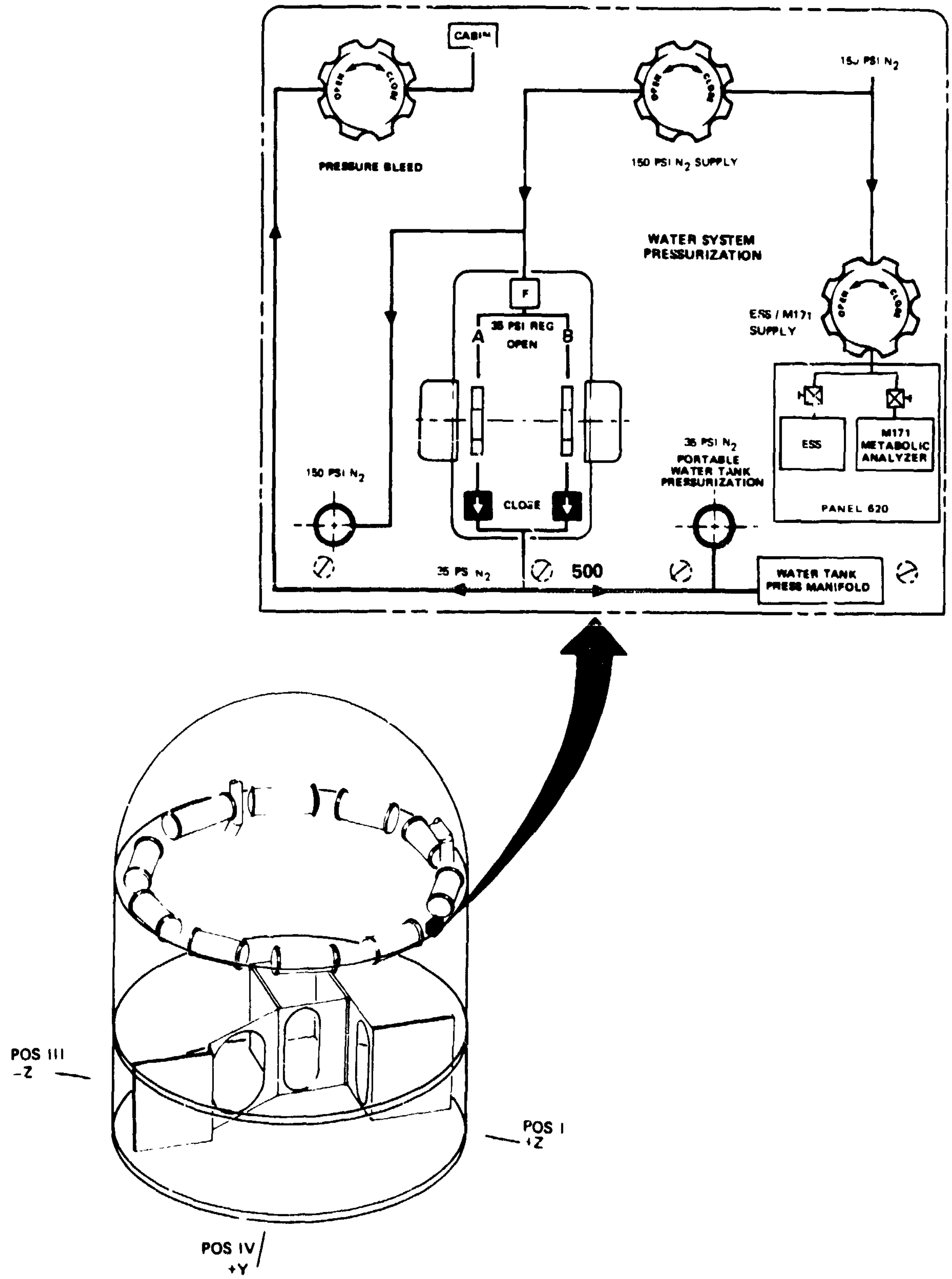
2.2.15 Marking System

2.2.15.1 Design Requirements - CEI Section 3.3.10: "Equipment inside the habitation area shall be marked or labled, as required, to enhance crew performance and to promote crew safety."

The Orbital Workshop Operational Nomenclature Document (MDC G0837C), dated April 16, 1973, contains illustrations reflecting the actual nomenclature as placarded on or near operational equipment.

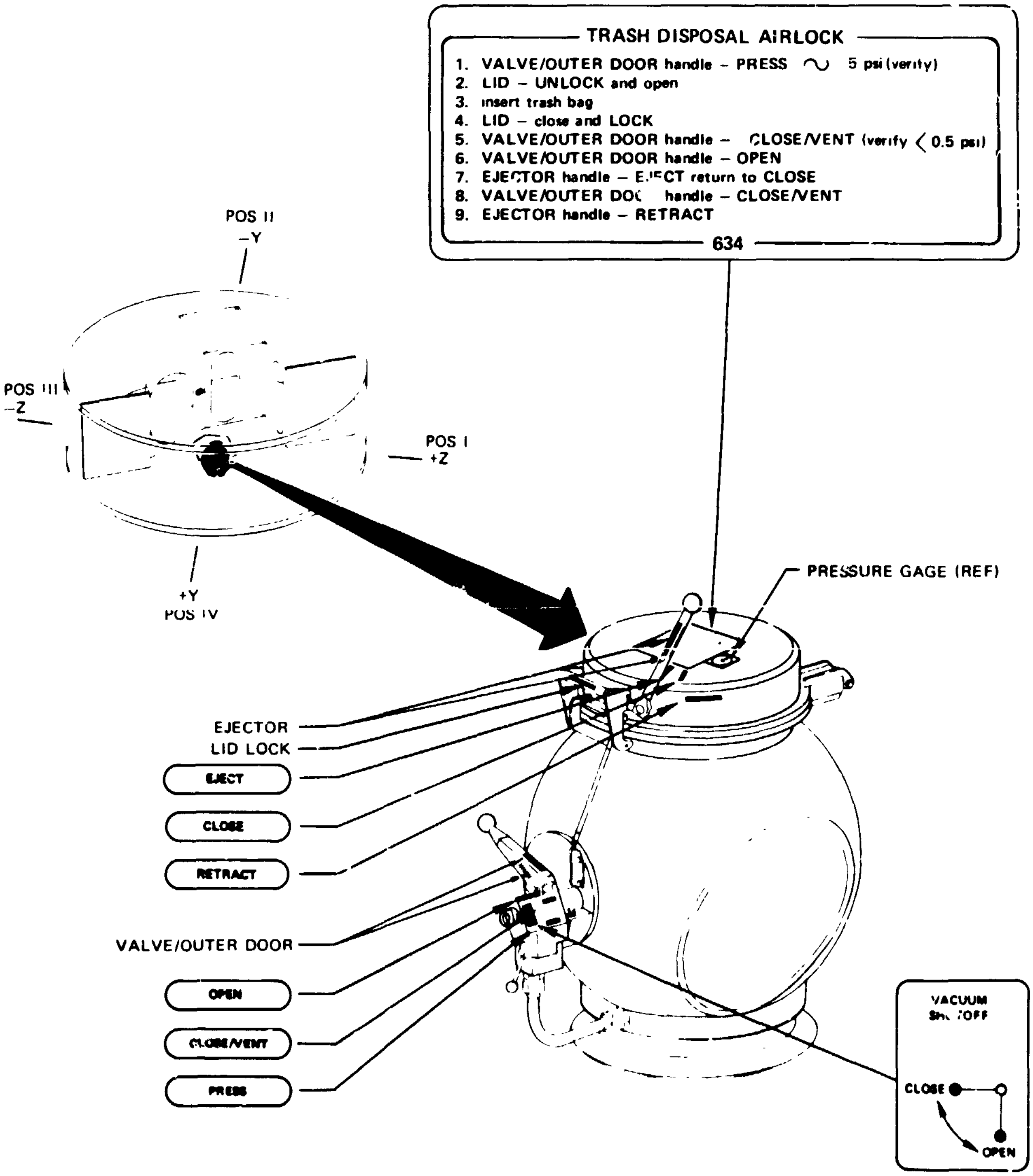
2.2.15.2 System Description - The MDAC-W design approach to markings was presented to the Crew Systems Support Working Group at the Skylab Orbital Workshop Critical Design Review. The marking systems are broken into three major areas: operational, procedural and numerical.

The operational markings consist of control and display (C/D) panels and other operational equipment such as scientific airlock controls, electrical outlets, vent valves, trash airlock, tool kits, water tank controls, waste management equipment, etc. The operational markings on this equipment included the identification of functional control positions and the marking of the mode of operation, e.g., directions of rotation, "lift to turn", "squeeze to release," etc. Most operational markings were accomplished by silkscreening. An example of an operational panel using silkscreen markings is the water pressurization panel 500 (Figure 2.2.15.2-1). Some equipment, however, utilized labels as a means of identifying functional positions. Examples of operational equipment using labels are the trash airlock (figure 2.2.15.2-2) one of the scientific airlocks. water tanks and the portable water tank (Figure 2.2.15.2-3). For equipment that was expected



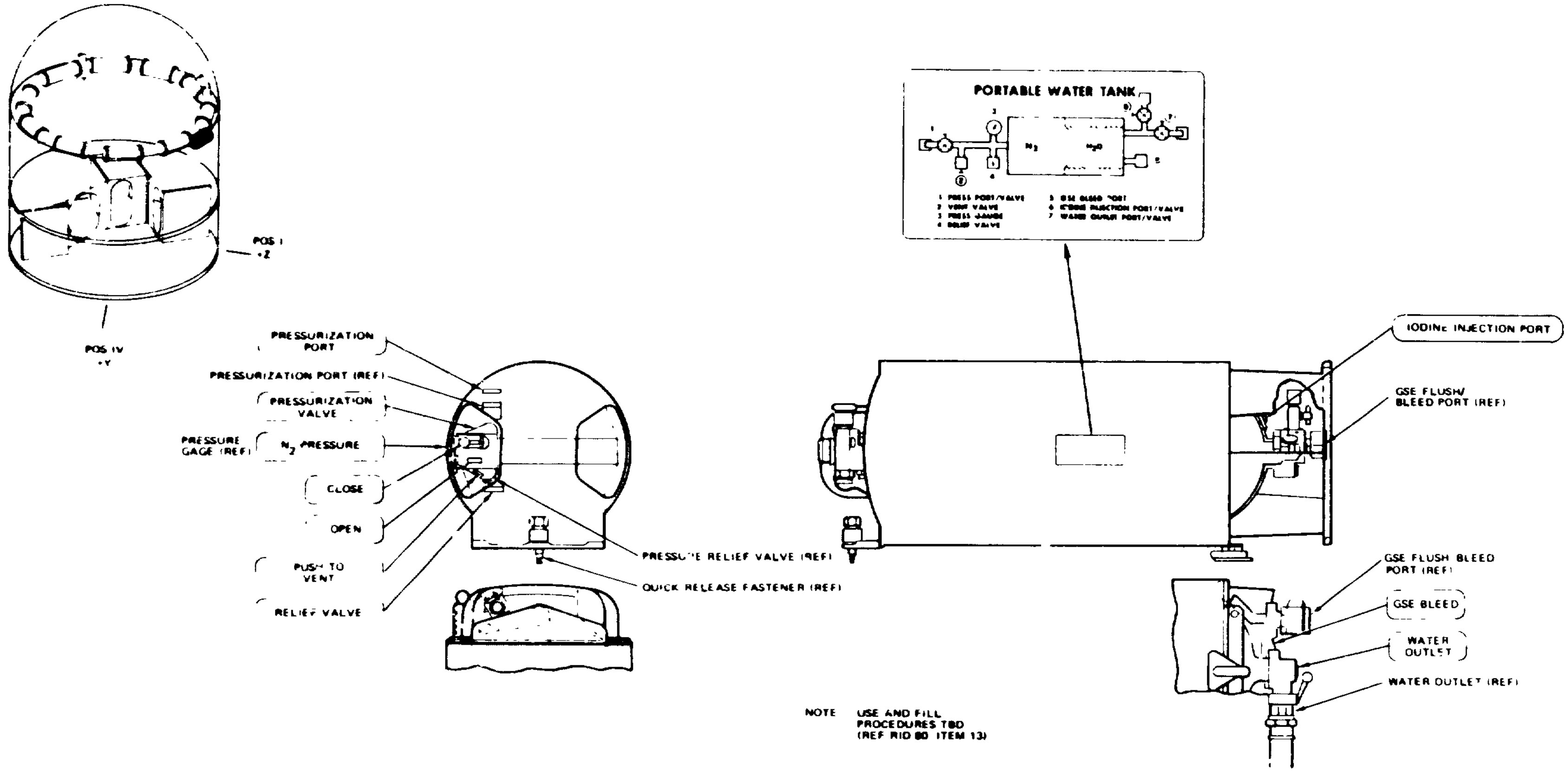
Water Pressurization Panel – 500

Figure 2.2.15.2-1



Trash Disposal Airlock – 634

Figure 2.2.15.2-2



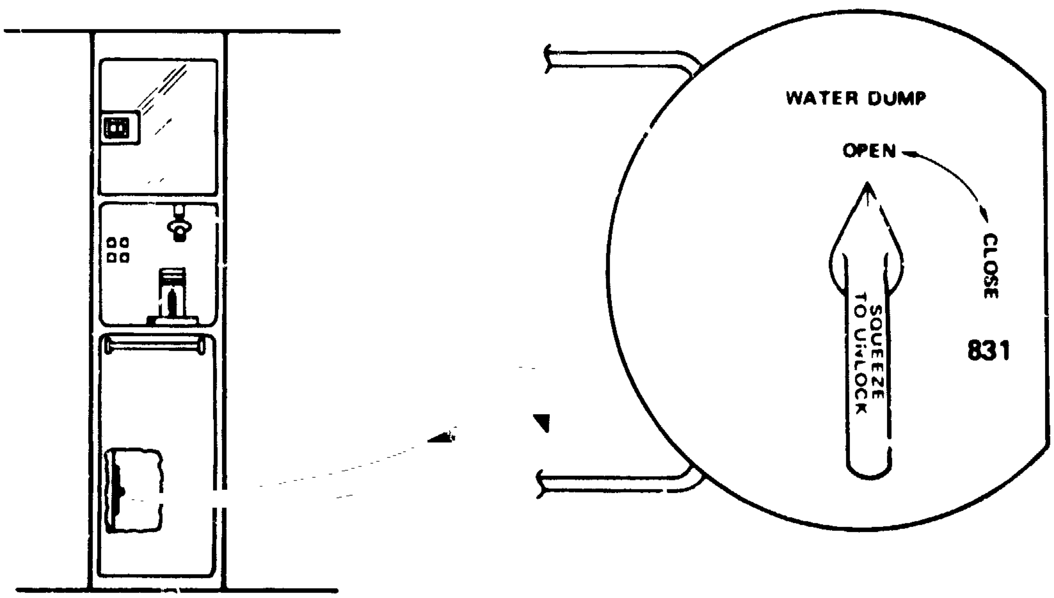
Portable Water Tank

to see much repeated usage or handled in such a way that could possibly obliterate the nomenclature, the technique of engraving the equipment and filling the recess with ink was specified. This method protected the marking from rubbing by placing it beneath the surface of the part that would normally receive the wear. Examples of equipment marked in this manner are the dump valves and their identification (backing) plates (Figure 2.2.15.2-4) fecal processor doors (Figure 2.2.15.2-5), and the trash airlock control levers (Figure 2.2.15.2-2).

Procedural markings consist of labels and placards that are installed on or near various pieces of operational hardware that require more than a simple operating procedure. The procedural labels contained abbreviated operating instructions for their related equipment. They were intended to supplement, but not replace, the use of procedural handbooks or checklists. An example of a typical procedural label is the SMMD operation/calibration label located in the WMC (Figure 2.2.15.2-6). In most cases the procedural labels were installed on an intermediate backing plate which in turn was either screwed into place or held in place by velcro hook and pile.

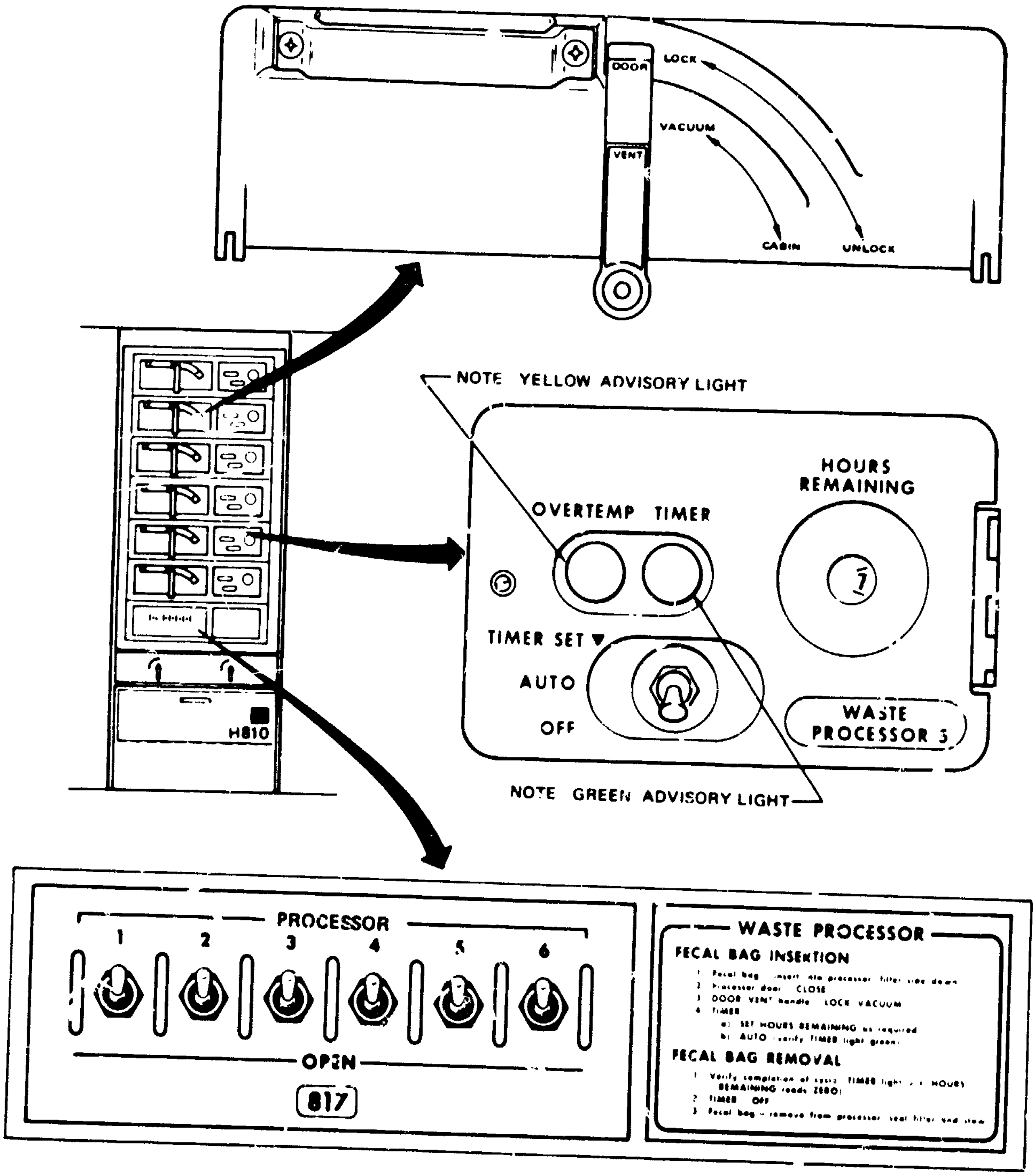
The third category of markings is numerical. Contained within this category is:

- The OWS numbering system.
- The cluster reference system.
- The stowage numbering system.



Waste Management Compartment Water Dump V' – 831

Figure 2.2.15.2-4



CLUSTER REF NUMBER 817 DECAL
TO BE APPLIED BY MDAC-W

Waste Processor Door
Waste Processor Control & Display Panel
Waste Processor Circuit Breaker Panel – 817

Figure 2.2.15.2-5

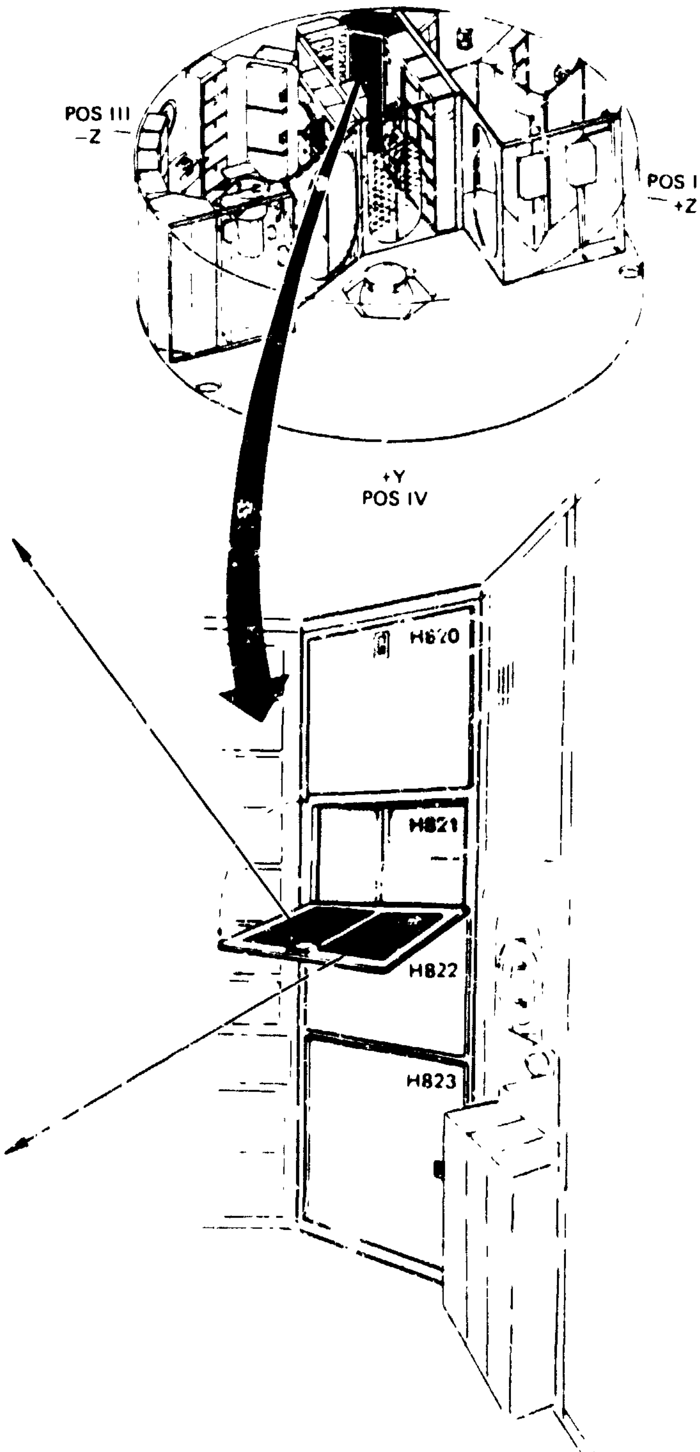
SMMD

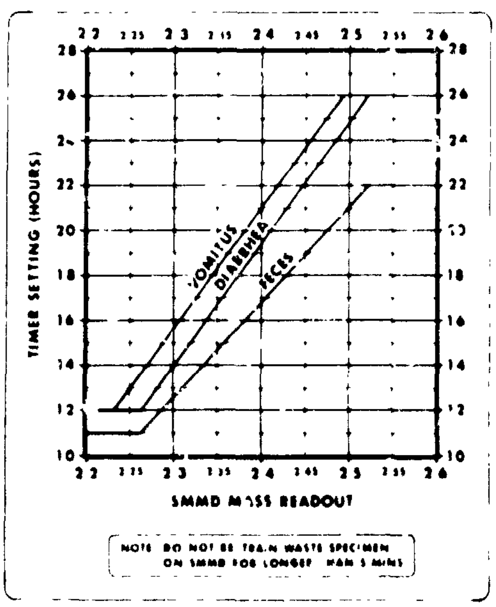
OPERATION

1. Obtain note pad
2. Place specimen on tray
3. MASS/OFF/TEMP – MASS
4. RESET – press
5. Control lever – RELEASE (hold until counter stops)
6. Control lever – LOCK
7. Log reading on note pad
8. Repeat measurement for total of 3
9. MASS/OFF/TEMP – OFF
10. Control level – LOCK (verify)
11. Remove specimen and log SMMD readouts on tag
12. Process specimen
13. If necessary clean tray and tie-down

CALIBRATION

1. Obtain SPT Food Log
2. Measure tray temp (M487 ... al Thermometer)
3. Log reading
4. MASS/OFF/TEMP – MASS
5. RESET – press
6. Control lever – RELEASE (hold until counter stops)
7. Control lever – LOCK
8. Log reading in Food Log
9. Repeat for a total of 5
10. Calib points 0, 50, 100, 1[illegible], 250, 350, 500, 750, 900, 0
11. MASS/OFF/TEMP – OFF
12. Voice record data at any convenient time





SMMD Operation/Calibration
SMMD Reading Versus Processing Time

Figure 2.2.15.2-6

The OWS numbering system assigns a number to a piece of equipment and enables that piece of equipment to be correlated to its related control/display panel, e.g., light fixtures correlated their C/D panel, water tank heaters to their C/D panel heater controls, urine drawers to their related C/D panel circuit breakers, etc. The numbers are assigned to the euuipment in a sequential manner starting at the +Z axis (VCS duct 1) and progresses clockwise, in other words, left to right around the compartment when viewing from the center.

The cluster reference system was developed in order to identify the different control/display devices throughout the Skylab cluster. The breakdown of the cluster reference numbers used only in the OWS is as follows:

o	Dome	400-499
o	Upper Wall	500-599
o	Experiment Compartment	600-699
o	Wardroom	700-799
o	Waste Management Compartment	800-899
o	Sleep Compartment	900-999
o	Plenum Area	1000-1099

Labels and silkscreening methods were used for applying cluster reference numbers. Silkscreening was used for permanently installed equipment, i.e., vent valves, control/display panels, and electrical outlets. Labels were used on equipment that was GFP or on similar equipment that was used in several places in the OWS.

6
C'

Examples of these would be TV control panels, fire detection control panels and scientific airlocks.

The stowage numbering system consists of three digit numbers that are assigned in the same sequence as the OWS numbers and cluster reference numbers, i.e., by compartment, left to right, using the same breakdown of numbers as the cluster reference system. The number correlates stowage locations with stowage lockers and a label carrying this number is applied to the outside of the appropriate cabinet door. On this label is also printed the approved stowage nomenclature acronyms for the items that are stowed in the locker, including the quantity if more than one.

Another category of stowage related labels is the miscellaneous stowage lagel. This label is used primarily inside stowage (ring) containers and are intended to:

- Identify the hard mounted stowage items.
- Identify the tools, if any, required to remove the item from stowage.
- The procedure involved, if not obvious, to remove the item from stowage.

While most items were identified by a label, there were some instances where the stowage item was packaged in a fabric pouch. The method used to identify these pouches was hand lettering, using a black "magic marker" felt tip pen. The stowage nomenclature was hand lettered on a separate fabric "nameplate" and sewn onto the pouch.

In addition to the stowage labels that were applied to stowage lockers, there was a requirement to provide the flight crew with the capability of updating the stowage labels on-orbit. The method chosen was blank labels with a felt tip marking pen. Two sizes of blank labels were provided. Also, a moderate number of crew identification "Snoopy" labels were provided.

In order to accomplish the design approach of the above marking systems, several marking methods were specified. A description of those methods follow:

A. The prime methods of permanently marking OWS equipment was the silkscreen process and hand lettering with Magic Marker felt tip pen. The silkscreening followed normal silkscreen procedures. The ink used, however, was Uniglaze C1336 black ink. This ink was approved for use on the OWS from an offgassing standpoint and is, in fact, the only silkscreen ink meeting the limits specified by the MSFC Spec. 101A, Flammability, Odor and Toxicity Requirements document. There were problems with this method in that the silkscreened markings were vulnerable to normal wear. Very few markings in the OWS escaped some form of chipping or flaking.

B. The fabric pouches were identified with hand lettered fabric "name-plates" sewn to them. The method of marking the nameplate was to use the sharp edge of a black "magic marker" felt tip pen. The lettering was specified on the hardware drawing to be approximately .25 in. (6.3mm) high with a .06 in. (1.5mm) stroke width and the lettering style was to be similar to futura. The .25 in.

(6.3mm) high lettering was considered close to a minimum size in order to achieve a clear and concise character. This method of marking fabric proved to be very successful and was superior to other, more sophisticated methods that were tried.

C. All labels used in the OWS were of the anodized "metal foil" type. The label background color is gold with black lettering. The gold color is defined by MDAC-W color chip STP 0302-020305. The black lettering matches Fed-Std-595-37038 (flat finish).

D. The type face of the OWS labels was futura demi-bold. This type face being preferred over futura medium because of its heavier stroke. When using a photo-etching process on metal foil labels this heavier stroke is necessary in order to allow for a certain amount of "shrinking" of the type face during the process.

E. The overall dimensions of labels and their basic format was established during several flight crew reviews of OWS mockups (Crew Station Review and Crew Compartment Stowage Review). Also, MDAC-W was requested through CCSR RID's to follow as a guideline NASA SC-D-001, General Specification for Metal Foil Decals where it was compatible with MDAC-W marking approaches.

F. The minimum label thickness was .003 in. (.076mm). This thickness was reserved for only those locations that required wrapping a label over a curved surface. It was not desirable to use the .003-inch thick label on a flat surface as the label was so thin that it tended to deform and pick up any surface irregularities when installed. In addition, handling the label without damaging it proved most difficult. All procedural labels, stowage labels, and most operational labels are .008-in. (203mm) thick although some operational labels are .005-in. (.127mm) thick. As the requirements for label content changed it became a rule that the label thickness would be increased to .008-in (.127mm). Those labels whose thicknesses remained at .005-in (.127mm) are simply labels whose content did not require changing.

G. The adhesive used on all permanently installed OWS labels was Scotchweld No. 583 solvent activated adhesive. This adhesive is a permanent type adhesive that requires activation with M.E.K. prior to application. When applied properly, this adhesive provided a good bond between the label and its mating surface.

H. For the special on-orbit blank labels and "Snoopy" labels, a pressure sensitive adhesive was used (Scotch Brand No. 468). Also, these special labels used an oversize teflon backing which served two purposes. First, the oversized backing allowed crewmembers to remove the backing with their fingers, without the need of special tools or aids. Second, the teflon was used in lieu of paper in order to meet flammability requirements.

2.2.15.3 Testing - No formal testing program was carried out on the marking system of labels.

During several mockup reviews, problems with the label adhesive was discovered. The OWS labels, when first manufactured included a pressure sensitive adhesive identified as Scotch Brand No. 465, manufactured by the 3M Company. While this adhesive was recommended by the label manufacturer as being a common adhesive and used by them on most of the labels they manufactured, the adhesive proved to be inadequate to firmly adhere the label to its mating surface. Considerable discussion on adhesives took place until finally the adhesive was revised to a more permanent solvent activated adhesive. The adhesive selected was Scotch Weld No. 583 solvent activated adhesive. This adhesive proved to be satisfactory for use in the OWS environment.

The original on-orbit blank labels also used Scotch Brand No. 465 adhesive. Since these labels were intended for on-orbit use, the adhesive had to be a pressure sensitive type. The replacement adhesive selected was Scotch Brand No. 468 which is chemically similar to the previously used No. 465, but is thicker. This increased thickness provided a better bond to a mating surface and was considered to be adequate for the on-orbit environment.

2.2.15.4 Mission Results - No comments were received from the Missions 1 and 2 Flight Crews regarding the adequacy and durability of OWS markings. The Mission 3 crew noted that some of the character sizes on some labels, such as on the air distribution ducts and ring containers, were too small to be easily read at a distance.

The crew also noted that in some cases the nomenclature on equipment did not match the procedure nomenclature which resulted in some confusion.

2.2.15.5 Conclusions and Recommendations - In general, the OWS marking systems were adequate and contributed to a successful mission.

Although no significant problems were encountered in flight, experience gained during the silkscreening of the various OWS panels suggests certain recommendations than can be made for future application. As described in Paragraph 2.2.15.2, the panels silkscreened with uniglaze ink were not able to witnstand normal wear. For future applications it is strongly recommended that an ink more suitable for silkscreening, e.g., MDAC STM 0248 catalyzed silkscreen ink, be used. This ink has proved to be easily applied using normal practices and stands up very well to normal wear.

The metal-foil labels proved to be an excellent method of identifying stowage content and for procedural labels. For future applications it is recommended that the .008 inch (.203mm) thickness be used for all labels applied to a flat surface. In general, the application of labels on a curved surface is not recommended. However, if this cannot be avoided, the .003 inch (.076 mm) thickness should be specified.

2.2.15.6 Development History - The only significant problem in the development of markings and labels was the selection of an adequate adhesive for labels. This is discussed in paragraph 2.2.15.3.

2.3 MATERIAL USAGE AND CONTROL

2.3.1 Introduction

This section covers the materials, significant processes, and material verification tests used to manufacture and verify the Skylab Orbital Workshop (OWS) hardware. Included within this section are the material and process selection criteria and assessment rationale that were applied in the design application to maintain materials control to assure safety of the OWS and the astronauts.

The compatibility and acceptability of material selections and usages included consideration of all material characteristics and disciplines described in the technical and design requirements documentation of MDAC and NASA/MSFC.

The materials and processes used are in compliance with the design and material requirements as stated in the Contract End-Item Detail Specification, Orbital Workshop Performance/Design and Qualification Requirements, CP2080J1C. MDAC has complied with the design requirements for material and process application and their verification test, quality assurance test requirements, test procedures, and data collection and reporting procedures as required by Contract NAS9-6555, Schedule II. The complete list of all materials and processes used in the OWS fabricated hardware has been provided the NASA and can be found in the computer tabulation runs, P1775 Program, OWS System Process and Material Specifications.

The material and process discussions are subdivided into the following category headings of Flammability, Odor and Offgassing; Materials

Compatibility; Metallics; and Non-Metallics. Each selected subject within the category follows a general discussion presentation consisting of subparagraphs of requirements, alternative solutions, tests, discussions (as needed), and conclusions.

2.3.2 Flammability, Odor, and Offgassing

A. Requirements

1/ The controlling document for selecting materials is MSFC-SPEC-101A with modifications as noted in the CEI Detail Specification. MDAC Document 1B78110, Flammability, Offgassing and Odor Requirements, Materials, was prepared to provide the engineering definition for contractual compliance, implementation, and control of MDAC internal designs and supplier designs. MDAC drawing 1B86198, Flammability Batch/Lot Test Requirements, is a list of materials that have been batch or lot tested to maintain control per MSFC-SPEC-101A over certain materials prior to their use on the OWS.

It is emphasized that the basic ground rule applied to the OWS design was fire prevention. Therefore, the use of all flammable materials was reviewed, documented, and reported on P0327 usage forms (Figure 2.3.2-1). The use of materials classified as Type II (self-extinguishing), and Type III (flammable) and components classified as Type III (classifications are per MSFC-SPEC-101A) were reported along with the appropriate rationale for approval by NASA/MSFC. Flammable materials were used only in the absence of a suitable nonflammable material. Each submittal item (Type II or III) was also

MCDONNELL DOUGLAS CORPORATION

PO327
MATERIAL/COMPONENT USAGE
ORBITAL WORKSHOP

DATE ____________

CARD	RECORD IDENT	DETAIL DRAWING	NEXT ASSEMBLY DRAWING	INSTALLATION DRAWING	SUBJECT	OUT GASSING	METALLIC / NON-METALLIC	TYPE 1 2 3	REQUEST NUMBER	DWG LTR
1										

CARD	RECORD IDEN	SKIP	MATERIAL/COMPONENT LOCATION X Y Z	OFF GASSING RATES MICROGRAMS PER GRAM FOR 72 HRS: CARBON MONOXIDE	TOTAL ORGANIC	WEIGHT LBS. (NEAREST 100th)	SKIP	ODOR RATE	AREA (NEAREST SQ. INCH)	SKIP	VOLUME (NEAREST CUBIC INCH)	SKIP
2												

CARD	RECORD IDENT	MATERIAL NAME (GENERIC)	MANUFACTURER'S NAME	DESIGNATION OR TRADE NAME
3				

CARD	RECORD IDENT	NOTES:
4		
5		

KEYPUNCH: PUNCH THE ABOVE AS WRITTEN

MATERIAL SPECIFICATION:	MATERIAL/COMPONENT USAGE SAMPLE 1877017:
RATIONALE FOR USE (INCLUDE PERTINENT INFORMATION & SPECIFICATIONS) WITH DESIGN PARAMETERS	

ORIGINATOR:	APPROVALS	PREPARED BY	PAGE ___ OF ___

6G-2461-6 (11 JAN 1972) MDC G0136 SUPPLEMENT

PO327 Material/Component Usage Orbital Workshop

Figure 2.3.2-1

included as part of the materials use map (MDAC drawing 1B77015). The map depicts the location of each item and aids in determining the distribution of material throughout the habitable interior and its proximity to other items.

2/ The authorizing references, documentation, and reporting responsibilities that are applicable to MDAC and suppliers who furnished equipment for installation in the OWS are shown in Tables 2.3.2-1 and 2.3.2-2. In addition to the reports listed, MDAC has submitted a tabulated report on the offgassing characteristics of materials used in the interior. This report, identified as Computer Program P0327, tracked the cumulative sum of the organic content and carbon monoxide offgassing rates.

B. P0327 Usage Report Form

1/ A P0327 form (MDAC Form 60-2461-4 or the revised Form 60-2461-5, dated January 11, 1972, Material/Component Usage) was provided for all drawing releases. P0327 forms initiated for design elements using flammable material were assigned an identifying number. Rationale developed to support the material usage was put on the form for approval by the OWS Program Manager and was then submitted to NASA/MSFC for review and approval.

2/ The rationale or installation information supplied with each reported use indicated, for example, the provisions for isolation and a fire hazard analysis to ensure that adequate safety (isolation) provisions or test data were available

Table 2.3.2-1

MDAC CONTRACTUAL REFERENCES, RESPONSIBILITIES, AND REPORTING TASKS

Reference Authorization	Reporting Document or Item	Comments
Contract NAS9-6555, Schedule II, Exhibit A, Statement of Work, dated February 1, 1970, Paragraph 6.0, Potentially Flammable Materials	1B77015; Map of materials and components usage	A map depicting the nature and location of all materials which were defined as other than Type I per MSFC-SPEC-101A has been submitted
Orbital Workshop CEI Detail Specification, CP2080J1C, dated November 26, 1969, Paragraph 3.3.3, Materials, Parts, and Processes	MDAC Letters A3-250-AFA80L-1666, A3-250-AFA8-L-2053, and A3-250-AFA8-L-2432 identify and list materials which did not require batch or lot testing Each material subject to an offgassing test requires the submittal of a mass spectrometer spectrogram of that material	Material and component selections for interior OWS equipment are in compliance with MSFC-SPEC-101A for flammability, odor, and outgassing requirements as modified by the exceptions and understandings noted in the CEI Specification. The materials list is a computer printout of all materials used on the OWS
MSFC-DRL-171A, Orbital Workshop and Ground Support Equipment Contract Data Requirements List, dated December 1, 1969, Line Item J22, TM 554B (basic contract as modified by C0660)	Report MDC G0126, Orbital Workshop Material/Component Usage	The report consists of the P0327 form, Material/Component Usage, which are inclusive of each discipline (material)

Table 2.3.2-2

SUPPLIER CONTRACTUAL REFERENCES, RESPONSIBILITIES, AND REPORTING TASKS

Reference Authorities	Reporting Item	Comments
Procurement work statement and specifications control drawings, as applicable	P0327 forms	The authorizing document (1B78110) for flammability, odor, and offgassing
Specification Drawing 1B78110-1, Flammability, Outgassing and Odor Requirements, Materials	Identifies and reports all materials which do not require batch or lot testing The 1B78110 requires the identification and rationale for use of Type II and III materials and items identified as Type III components	The engineering definition for contractual compliance: it implements the odor, flammability, and toxicity controls for internal and supplier designs. The drawing was prepared in order to reflect the contractual requirements as defined in CEI Detail Specification, CP2080J1C
Supplier Data Articles A.5.2, Material Usage Data; and A.5.3, Components Usage Data, both dated January 12, 1969	Lists containing flammable materials usage with flammability and outgassing characteristic provided. Samples of materials are required if they have not been previously used.	Requires reporting of use of all nonmetallics, certain metallics, and processing or shop materials (solvents, processing solutions, etc.)

to substantiate the intended design application. Each design technology initiated the materials and components usage form where a report was required in accordance with the established contractual data requirements for reporting to NASA. The form was provided with all drawing releases and routed for approvals of specific material disciplines through various technologies before final approval by the Fire Marshal and Program Manager.

3/ Three hundred forty (340) usage agreements and two hundred thirty (230) amendments were submitted to NASA/MSFC. A listing of the non-metallic materials used within the OWS and the weight of each is shown in Table 2.3.2-3.

C. Significant Flammable Materials

1/ Following is the general information on the identification of significant flammable materials and the present quantity and location or distribution of these items in the OWS. The stowage or installation approach used and testing conducted to assure that safety provisions were satisfied for these items is also presented.

2/ The majority of the flammable materials reported were used on detail parts (O-ring seals, ink markings, thread locking inserts, etc.). Table 2.3.2-4 gives the pertinent characteristics of the significant flammable materials used in the OWS. The items included in Table 2.3.2-4 were selected because of the relatively large mass or quantity of material used.

Table 2.3.2-3

MATERIALS USED

NO.	TITLE	WEIGHT-LBS. (kg)	
1	Nylon	3.23	(1.46)
2	Teflon	1793.58	(813.39)
3	Fluorocarbon Rubber Sheet/Moldings	95.70	(43.40)
4	Ink, Warnow, Black	0.04	(0.02)
5	Rubber Sponge, Mosites 1062	84.54	(38.34)
6	Activated Charcoal	68.07	(30.87)
7	Micatex Paint	25.00	(11.34)
8	Balsa Wood	2.30	(1.04)
9	Polyurethane Foam, 1P20011	1531.06	(694.33)
10	Urea Resin, MMM-A-188	1.50	(0.68)
11	Plastic Terminal Board	53.15	(24.10)
12	Kynar	0.79	(0.36)
13	Ink, Marker	0.03	(0.01)
14	Filled Epoxy Insulator	37.12	(16.83)
15	Silicone Rubber	127.90	(58.00)
16	Fluorocarbon Rubber Clamps	6.53	(2.96)
17	Stycast 2651	23.39	(10.60)
18	Stycast 2850	97.68	(44.30)
19	Diallyl Phthalate	12.39	(5.62)
20	Delrin 500	1.38	(0.63)
21	Primer, 1P20073	0.10	(0.05)
22	Adhesive, 1P20085	14.15	(6.42)
23	Potting, 1P20074	0.10	(0.05)
24	Epoxy Potting, MSFC-SPEC-222	0.20	(0.10)
25	Paper	29.00	(13.15)
26	PBI (T-Treated)	116.14	(52.67)
27	Nomex Thread	3.36	(1.52)
28	Coolanol-15	53.80	(24.40)
29	Rayon Terrycloth	378.00	(171.42)
30	Aluminum/Cardboard	6.00	(2.72)
31	Kapton	0.27	(0.12)
32	DC-4 Lubricant	0.05	(0.02)
33	NBG Tubing	0.08	(0.04)
34	Food Grade Viton	11.61	(5.27)
35	Matte Varnish No. 17-358	0.01	0.004)
36	Mylar	0.07	(0.03)
37	Potting, PR 1933	2.34	(1.06)
38	Polybutene	0.27	(0.12)
39	Adhesive, 1P20075	23.83	(10.80)
40	Sealant, 1P20057	3.32	(1.51)
41	Adhesive, 1P20001	93.09	(42.22)
42	Adhesive, STM0480	0.01	(0.004)
43	Primer, STM0481	0.01	(0.004)
44	Polyester Paint	0.04	(0.02)
45	Borosilicate Insulation	1.72	(0.78)
46	Fiberglass (Glass Tape, MIL-I-19166)	11.84	(5.37)
47	Lubricant, DC-340	0.52	(0.24)

Table 2.3.2-3 (Continued)

MATERIALS USED

NO.	TITLE	WEIGHT-LBS.	(kg
48	Silicone, RTV 154	0.16	(0.07)
49	Adhesive, EC1663	0.60	(0.27)
50	Adhesive, Epon 828	3.82	(1.73)
51	Silicone, RTV102	0.04	(0.02)
52	KEL-F	0.86	(0.39)
53	Neutrogena Soap	12.50	(5.67)
54	Adhesive, 1P20025 Class I	2.25	(1.02)
55	Adhesive, 1P20014	3.81	(1.73)
56	Stycast 2262	0.09	(0.04)
57	Cetyl Alcohol	0.01	(0.004)
58	Butyl Rubber	0.22	(0.01)
59	Silicone Grease	0.01	(0.004)
60	Gold Tape	0.51	(0.23)
61	Sealant RTV 560	0.01	(0.004)
62	Polyurethane Coated Nylon	0.84	(0.38)
63	Polyethylene	0.86	(0.39)
64	Ethylene-Propylene Rubber	0.01	(0.004)
65	Epoxy Sealant, MSFC 2021529	0.02	(0.008)
66	Ink, Uniglaze	0.01	(0.004)
67	Vespel SP-1	5.19	(2.35)
68	Freon 22	14.35	(6.51)
69	Indium Foil	0.01	(0.004)
70	Shrink Tubing, MSFC-SPEC-276	0.30	(0.14)
71	Velcro	35.37	(16.04)
72	Tape, Scotch No. 425 (Y-9050)	2.57	(1.17)
73	Stycast 109D	3.00	(1.36)
74	MIL-E-5556 Paint	0.01	(0.004)
75	Tape, Mystik 636D	2.02	(0.92)
76	Rubber, Buna-N	0.01	(0.004)
77	Adhesive, RTV 118	0.02	(0.008)
78	Sylgard 184	2.16	(0.98)
79	Scotchcast XR5038 Potting	0.12	(0.05)
80	Glass Tape Mystik 7001	0.38	(0.17)
81	Nomex/Kapton/Nomex	0.06	(0.03)
82	Polyamide Tape MIL-T-43435	0.10	(0.05)
83	Polyester Glass	0.11	(0.05)
84	Epoxy Resin	0.82	(0.37)
85	Lubricant DC 3400	0.01	(0.004)
86	Tape Scotch 583	0.01	(0.004)
87	Polymide Varnish	0.16	(0.07)
88	Dodecane	38.74	(17.57)
89	Lubricant, Tallow/Wax	0.02	(0.01)
90	Polyester Foam	1.47	(0.67)
91	Epoxy Adhesive, S-17094	0.01	(0.004)
92	Potting EC2273	8.80	(3.99)
93	Permacel Insulator	0.57	(0.26)
94	Poly Vinyl Butyral	1.00	(0.45)

Table 2.3.2-3 (Continued)

MATERIALS USED

NO.	TITLE	WEIGHT-LBS.	(kg)
95	Salt Pads (Ambivalent Desiccant)	0.53	(0.24)
96	Zitex	3.06	(1.39)
97	Zinc Chromate Primer	0.03	(0.01)
98	Cation Exchange Resin (Styrene/ Divinyl Benzine)	6.80	(3.08)
99	Natural Latex	5.98	(2.71)
100	Adhesive, HT424	1.23	(0.58)
101	Loctite	0.01	(0.004)
102	Crepe Towel Paper	2.10	(0.95)
103	Conolan 6000 (Plastic Foil)	2.11	(0.96)
104	Adhesive, SR 529	0.31	(0.14)
105	Sealant, Epoxy 801	0.04	(0.06)
106	Tape, Scotch 465	1.83	(0.83)
107	Tape, Mystik 7453	0.07	(0.03)
108	Quick Sol-U	1.41	(0.64)
109	Adhesive, RTV 112	0.06	(0.03)
110	Adhesive, RTV 106	0.01	(0.004)
111	Ink, Black Magic Marker	0.01	(0.004)
112	Ink, Green Magic Marker	0.01	(0.004)
113	Potting RTV 156	0.30	(0.14)
114	Potting EC1663	0.45	(0.20)
115	Petroleum Grease	0.06	(0.03)
116	Polyolefin Plastic	0.30	(0.14)
117	Ink, 73X Black	0.01	(0.004)
118	Adhesive, 1P20031	0.05	(0.02)
119	Ink, Ball Point Pen	0.01	(0.004)
120	Polystyrene	0.08	(0.04)
121	R2 Retort Stock	0.05	(0.02)
122	Polypropylene Foam	5.42	(2.46)
123	Aclar Film	0.04	(0.02)
124	Adhesive, Scotchweld 583	0.05	(0.02)
125	Adhesive, Intercel 1C1001-91	433.83	(196.74)
126	Paper Label and Adhesive	0.01	(0.004)
127	Adhesive, 3M No. 63	0.01	(0.004)
128	Ink, Epoxy, White Warnow	0.02	(0.008)
129	Polyolefin Shrink Tubing, STM069-01	0.13	(0.06)
130	Tape, Red Vinyl, Scotch No. 471	0.45	(0.20)
131	Lubricant, Kendall Oil, SRG-40	0.01	(0.004)
132	Adhesive, Polysulfide, 1P20098	0.01	(0.004)
133	Low Friction Coating, STM0536-01	0.14	(0.006)
	Total	5336.41	(2420.06)

Table 2.3.2-4

TABULATION OF SIGNIFICANT FLAMMABLE MATERIALS

Item	Reported on Suppl No.	Quantity No. of Items or Weight in Pounds* (kg)	Stowage or Installation Location	Sample Supplied For Flammability Testing
Fixed Items				
Polyurethane Foam	10005	1,010.0 (458.03)	Tank Walls and common bulkhead	Ref: A3-860-KBBA-TM-172 dated December 1966 DAC Report DAC-60609 dated March 1967; TM X-53732 dated April 1968**
	10049	0.1 (0.05)	Tank wall small plug at weld seam	
	10069	245.3 (111.24)	Refrigeration system lines and freezer walls	
	10073	1.9 (0.86)	Tank wall at access door jamb	
	10134	1.9 (0.86)	Tank wall at access door jamb	
	10192	8.9 (4.04)	Ground thermal conditioning system lines	
	10209	30.7 (13.92)	Electrical cabinet cold plate wall	
	10218	0.7 (0.32)	Urine chiller drawer walls	
	10227	4.0 (1.81)	Radiant heater walls	
	10256	1.4 (0.06)	Helium port cover on tank wall	
	10262	16.8 (7.62)	Debris bag (see stowed items)	

*Weight given is for the flammable material only.
**Successfully passed flammability testing.

Table 2.3.2-4

TABULATION OF SIGNIFICANT FLAMMABLE MATERIALS (Continued)

Item	Reported on Suppl No.	Quantity No. of Items or weight in Pounds*(kg)	Stowage or Installation Location	Sample Supplied For Flammability Testing
	10280	88.4 (40.09)	Fecal bag (see stowed items)	
	10282	28.7 (13.02)	Contingency fecal bag (see stowed items)	
Refrigerant (Coolanol-15)	10026	20.0 (9.07)	Throughout OWS, contained in steel lines	Ref: MDC-G2784 dated November 1970**
General Illumination Light Assembly	10016	42 items	8 on forward dome 10 around water bottles 4 in wardroom 3 in waste management compartment 3 in sleep compartment 14 in aft experiment compartment	Supplied per CO 293, dated February, 1971 (Ref test Request MD-31)**
Wire Harnesses (insulated wire)	10008	1,400.0 (634.90)	Throughout OWS contained in enclosures	Ref: MSC2035B MD16, dated May 21, 1971 MSC2035B MD10, dated April 15, 1971 MDAC SP/N NTR-215 MSC2035B MD9, dated April 15, 1971 A3-250-AES1-L-1380 dated May 5, 1971**

*Weight given is for the flammable material only.
**Successfully passed flammability testing.

Table 2.3.2-4

TABULATION OF SIGNIFICANT FLAMMABLE MATERIALS (Continued)

Item	Reported on Suppl No.	Quantity No. of Items or Weight in Pounds* (kg)	Stowage or Installation Location	Sample Supplied For Flammability Testing
Stowed Items				
Sleep Restraints	10202	30 items, each at 6.7 lb (3.04)	One in each sleep compartment 27 stowed in lockers, 3 in 13A121 12 in 13C121 12 in 13D121	Supplied per CO 407, dated June 24, 1971
Towels	10027	420 items, each at 0.5 lb (0.23), 210.0 lb (95.24) total	Stowed in lockers Bulk Stowage 189 in 10A456 126 in 13F121 3 in 15A235 6 in 15B235 6 in 15C235 In dispensers 18 in 15C245 18 in 15D245 18 in 1-E245 18 in 15F245 18 in 16E390	Supplied per CO 293, dated February 10, 1971 (Ref. Test Request MD-29)**
Washcloths	10027	840 items, each at 0.2 lb (0.09), 168.0 lb (76.19) total	Stowed in lockers In dispensers 84 in 15A235 112 in 15B235 112 in 15C235 112 in 15D235 84 in 15C245 84 in 15D245 84 in 15E245 84 in 15F245 84 in 16E390	Supplied per CO 293, dated February 10, 1971 (Ref. Test Request MD-29)**

*Weight given is for the flammable material only.
**Successfully passed flammability testing.

Table 2.3.2-4

TABULATION OF SIGNIFICANT FLAMMABLE MATERIALS (Continued)

Item	Reported on Suppl No.	Quantity No. of Items or Weight in Pounds* (kg)	Stowage or Installation Location	Sample Supplied For Flammability Testing
Charcoal	10002	61.3 (27.80) (in 6 items)	In canister within ventilation unit over WMC. Spare units stowed in lockers 2 in 10A201 1 in 10A184 2 in 10A168	None required
	10277	8.1 (36.73) (in 6 items)	Odor filter in waste management compartment in Processor Module 5 spares in 10A216	
Water Bottle Heaters	10015	15.8 (71.66) (in 10 items)	One on each water bottle in forward compartment	Supplied per CO 293, dated February 10, 1971 (Ref Test Request MD-30)**
Water Heater	10C61	12.6 (5.71) (in 2 items)	One in food table in wardroom - One in WMC in cabinet above sink	Supplied per CO 419, dated July 2, 1971 (Ref Test Request MD-32)**
Adhesives	Reported in 53 supplements Majority included in 10055 and 10209	72.6(32.92) (10055) 10.5(4.76) (10209) 27.9(12.65) (in 51 supplements)	Bonds foam to walls Bonds foam in cabinet Throughout the OWS	None required

*Weight given is for the flammable material only.
**Successfully passed flammability testing.

Table 2.3.2-4

TABULATION OF SIGNIFICANT FLAMMABLE MATERIALS (Continued)

Item	Reported on Suppl No.	Quantity No. of Items or Weight in Pounds* (kg)	Stowage or Installation Location	Sample Supplied For Flammability Testing
General-Purpose Tissues	10022	4,312 items, contained in 11 dispensers Weight established at 1.0 lb (0.45) per dispenser 11.0 lb (4.99) total	Stowed in lockers in dispensers 1 in 16D130 2 in 13E182 2 in 13E242 2 in 13E312 1 in 15F125 1 in 15F285 1 in 15F355 1 in 15F385	Supplied per CO 293, dated February 10, 1971 (Ref Test Request MD-29)**
Utility Wipes	10022	4,116 items, contained in 18 dispensers Weight established at 1.0 lb (0.45) per dispenser, 18 lb (8.10) total	Stowed in lockers In dispensers 1 in 16D130 1 in 13E182 1 in 13E242 1 in 13E312 2 in 15F125 3 in 15D235 3 in 15C235 1 in 15B235 2 in 15F285 1 in 15D355 2 in 15F385	Supplied per CO 293, dated February 10, 1971 (Ref Test Request MD-24)**
Debris Bag	10262	140 items, each at 0.19 lb (0.09), 26.3 lb (11.93) total	Stowed in lockers (single bag used in vacuum cleaner) 14 in 12A268 14 in 12F268 14 in 12G268 14 in 12H268 70 in 12C450 14 in 15D285	Similar to fecal bags supplied per CO 293, dated February 10, 1971 Sample bag has been supplied for test in conjunction with vacuum cleaner supplied per CO 510. (Ref. Test Request FH-45)**

*Weight given is for the flammable material only.
**Successfully passed flammability testing.

Table 2.3.2-4

TABULATION OF SIGNIFICANT FLAMMABLE MATERIALS (Continued)

Item	Reported on Suppl No.	Quantity No. of Items or Weight in Pounds* (kg)	Stowage or Installation Location	Sample Supplied For Flammability Testing
Fecal Bags	10280	465 items, each at 0.39 lb (0.18), 179.2 lb (81.27) total	Stowed in lockers 84 in 12A268 84 in 12B268 84 in 12F268 84 in 12G268 84 in 12H268 45 in 16C390	Supplied per CO 293, dated February 10, 1971 (Ref Test Request MD-29)**
Contingency Fecal Bags	10282	191 items, each at 0.22 lb (0.01), 42.4 lb (19.22) total	Stowed in lockers 6 in 16A130 11 in 16D130 11 in 12A268 11 in 12B268 11 in 12F268 11 in 12G268 11 in 12H268 119 in 12C450	Supplied per CO 293, dated February 10, 1971 (Ref Test Request MD-29)**
Urine Bladder	10263	441 items, each at 0.13 lb (0.06), 59.6 lb (27.03) total	Stowed in lockers 9 in 10A308 96 in 10A324 96 in 10A340 96 in 10A356 96 in 10A372 24 in 10A388 24 in 16A300	Inlet hose portion Supplied per MD-67, dated April 4, 1972 **
Waste Water Bag	10114	5 items, each at 1.1 lb (0.50), 5.5 lb (2.49) total	Stowed in lockers 5 in 16F300	Supplied per CO 551, dated October 30, 1971 (Ref. Test Request MD-78)**

*Weight given is for the flammable material only.
**Successfully passed flammability testing.

Table 2.3.2-4

TABULATION OF SIGNIFICANT FLAMMABLE MATERIALS (Continued)

Item	Reported on Suppl No.	Quantity No. of Items or Weight in Pounds*	Stowage or Installation Location	Sample Supplied For Flammability Testing
Trash Bag (small)	10182	424 items, each at 0.07 lb (0.03), 29.7 lb (13.47) total	Stowed and used in lockers Stowed items 53 in 16A390 53 in 15D385 53 in 15A235 53 in 11A288 53 in 11B288 53 in 11C288 53 in 11F288 53 in 12B460 Usage locations 1 in 16B130 1 in 15C385 1 in 13D312 1 in 13D182 1 in 13D242 1 in 11D288 1 in 12D460	Supplied per CO 293, dated February 10, 1971 (Ref Test Request MD-29)**

*Weight given is for the flammable material only.
**Successfully passed flammability testing.

The stowage or installation approach used to ensure adequate safety for each of the tabulated items is as follows:

a. Installation of Fixed Items - The majority of the permanently installed flammable materials were small in size, separate items, or easily isolated component parts. These include:

   1. The charcoal filters that were enclosed in metal canisters and stowed or installed for use in metal enclosures.

   2. The water tank heaters that were installed on metal water tanks were enclosed in nonflammable fluorocarbon rubber-impregnated fiberglass.

   3. The personal hygiene water heaters in the waste management system and wardroom food table were enclosed in a metal outer can and installed in a metal locker on the metal food table structure.

   4. The adhesives used were sandwiched between layers of nonflammable material or were used to bond significantly larger masses of flammable material in place (such as polyurethane foam to the OWS tank wall).

   The remaining fixed items include the foam insulation, refrigerant, light assemblies, and wire harnesses. The general design approach followed is to contain or isolate the flammable material. The commonly used approaches were enclosure with metal (provides a large heat sink), wire troughs with fire breaks, or isolation by separation from other flammable materials. Each use and its installation and protection or isolation provisions was documented and submitted on a material usage form, as discussed previously.

Special precautions and design provisions have been imposed and incorporated with respect to the above uses of fixed flammable materials. These include the following:

5. Polyurethane foam insulation installations were covered by a minimum of 0.003 in. (.076mm) thick aluminum foil. The tank wall insulation also included a fiberglass liner covered by the aluminum foil. All penetrations through the foam incorporated fiberglass and aluminum foil protective covers to isolate the foam from exposure to the OWS atmosphere. Polyurethane foam used within freezer walls was sandwiched between metal walls of 0.030 in. (.76mm) minimum thickness. Extensive flammability testing was conducted to determine the minimum foil thickness that would provide the desired flammability protection.

6. The refrigeration subsystems installation incorporates the following design provisions to eliminate potential leak paths for the refrigerant:
   a) All tubing joints within the OWS pressurized interior were brazed.

b) O-ring sealed boss fittings replaced MC flared fittings. This provides the interface seal between the CRES tubing and aluminum active components.

c) All active components were enclosed in a sealed vacuum vented container.

d) Damage protection was provided by foam insulation jackets around the refrigerant lines (thermal requirement), which in turn were covered by aluminum shrouds of 0.050 in. (1.27mm) minimum wall thickness.

In addition, extensive flammability testing was conducted using typical segments of refrigerant-soaked insulated lines to substantiate the adequacy of the design approach.

7. Electrical components and wiring installations incorporated the following special system design features, in addition to normal circuit protection devices:

a) All encapsulated electronic modules were coated with a layer of plasma-arc sprayed aluminum (Metco No. 54) to preclude flame propagation.

b) All wiring inside the OWS was routed through a system of closed metal troughs containing fire barriers or non-flammable convoluted tubing.

c) The power control console was compartmentalized to preve... flame propagation.

d) The light assembly was made up of a composite arrangement consisting of a tempered glass tube over the basic Lexan lamp for flammability protection and a 0.020 in. (.508mm) Teflon exterior coating over the glass tube to shatterproof the glass. This arrangement was assembled into the lamp end fittings and potted. The lamp was in turn installed in a metal housing for additional protection during use.

b. Installation of Stowed Items - Flammability protection for stowed items was provided by the metal stowage cabinets and, in certain instances, by nonflammable glass fabric bags enclosing the item when removed from a metal locker. Installation of stowed items did not include any specific requirement to fireproof the item before placing it in the cabinet. The stowage interface was concerned only with size, weight, vibration, shock, and flotation (zero-g) constraints. The locker itself provided the flammability protection required.

Stowage restraints or packaging provided was nonflammable, where possible (Armalon bags for small items or nonflammable strap-type restraints for larger installations).

Specific stowage concepts applied to the stowed flammable materials noted in Table 2.3.2-4 are given in Table 2.3.2-5.

Table 2.3.2-5

STOWAGE CONCEPTS

Item	Concept
Sleep restraints	Restrained in cabinet by straps except for the three in use.
Towels	Rolled individually and stored in bundles. Used from a dispenser which holds 24 towels in a metal container closed on five sides. The dispenser was installed in a metal cabinet. Only the rolled end of the towel cylinder was exposed to the atmosphere of the cabinet. Bulk stowage of replacement towels for the dispensers was in a cabinet restrained by straps.
Washcloths	Stowed in bundles of 28 cloths in a metal container closed on five sides. The container was installed in a metal cabinet. Cloths were extracted through a spring-loaded metal door in the sixth side of the metal container.
Tissue/wipes	Stowed in closed aluminum foil coated box. Used in a tissue/wipe dispenser, with the ends of the box punched out. The dispenser installation used a spring-loaded metal door which had to be opened to remove a tissue/wipe. The dispensers were installed in a metal cabinet.
Bags (trash, urine, etc.)	Stowed in bundles in metal cabinets and strap-restrained. Exposure was limited to the time of usage only. Installation for the specific bags was as follows: Debris bags: inside the metal vacuum cleaner housing. Fecal and contingency fecal bag: installed in the collection module housing, short-duration exposure under direct surveillance by the crew member. Urine bladder assembly: installed in metal centrifugal separator housing. Waste water bag: in metal locker. Trash bag: in metal locker, accessible by means of a metal door

D. Special Flammability Protection Cases

1/ Special precautions were taken and design provisions incorporated for the design and installation of major flammable materials. The following paragraphs present the design features incorporated and the testing performed to support the design approach for polyurethane foam insulation, electrical wiring, general illumination light assembly, and the refrigerant (Coolanol-15).

a. Polyurethane Foam - The selection of the liquid hydrogen fuel tank of the Saturn S-IVB stage as the habitable volume for the OWS required a significant modification in material to eliminate a potential fire hazard. The hazard was due to the use of polyurethane foam insulation bonded to the internal walls of the tank. The insulation was a glass fiber-reinforced polyurethane foam sealed with a glass fabric impregnated with a polyurethane resin. The existing insulation was retained, necessitating a design modification to provide a flame-retardant coating on the internal insulation.

1. A study and test program was initiated in which three phases of tests were conducted, as follows:

a) The first phase consisted of the preliminary screening of flame-retardant materials. Specimens of Dyna-Therm D-65, aluminum foil, and other materials bonded to the insulation were tested for thermal shock, tensile strength at cryogenic temperature, and thermal contraction rate. The most promising materials were then considered for structural testing in a 3 ft. (91.4cm) dome specimen.

b) The second phase consisted of testing to determine flame-resistance, the offgassing characteristics, and the products of combustion of various coatings considered. The materials were tested under the simulated atmospheric conditions that would be encountered in the OWS.

c) The third phase consisted of a 3 t. (91.4cm) dome panel test. This test was performed to prove the structural integrity of the flame-resistant coated insulation system. The material was tested in liquid hydrogen, pressurized, and the external skin heated to duplicate the conditions imposed on the S-IVB stage.

As a result of this program, it was concluded that aluminum foil was the best flame-retardant system evaluated in this program. Test results demonstrate that aluminum foil provides maximum retardation of foam burning rate and is the only system evaluated that prevents surface flame propagation. Offgassing products and rates with aluminum foil were sufficiently low to be handled adequately by the activated charcoal absorber of the atmospheric control system. The 3 ft. (91.4cm) dome test demonstrated that the liner with aluminum foil will withstand exposure to cryogenic and pressure environment. The coating weight is approximately half that of Dyna-Therm D-65, either with or without the glass fabric reinforcement.

Details on the materials considered and the specific tests conducted are included in Technical Memorandum No. 117, A3-860-KBBA-TK-172, dated December 1966.

This program was followed by a test program conducted to determine the structural integrity of a flame-resistant coating on the internal insulation. The test evaluated two candidate materials, aluminum foil and Dyna-Therm D-65, in an 8 ft (2.4m) diameter scale tank.

The tests indicated that either material was feasible for use as a flame-resistant coating with the aluminum foil structurally more adequate than the Dyna-Therm D-65 coating.

Details on this test program are included in Technical Memorandum No. 178, A3-860-KBBA-TM-178, dated march 1967.

In conjunction with the structural testing programs conducted, an additional testing effort was made to determine the effectiveness of the flame-retardant materials.

The offgassing and aging properties of these materials as well as the insulation material were were also studied.

The early phases of testing identified only one configuration that completely prevented the spread of a fire on the surface of the insulation. This was 0.002 in. (.052mm) thick aluminum foil bonded to the surface. This configuration also was found to almost completely prevent the offgassing of hydrocarbons from the insulation material.

The aluminum foil was found to prevent surface burning and limit subsurface decomposition to approximately a 10 in. (25.4cm) diameter cavity. These tests were conducted with a 1/2 in. (1.27cm) diameter penetration hole through the sample, 5-psia (34.5 kN/m^2) oxygen above the sample, and approximately 0.25 psi (1.7 kN/m^2) maintained below. No effect of exposure to the mission profile, including time spent in 5-psia (34.5 kN/m^2) oxygen up to 28 days, was observed in the burning properties. Offgassing of the samples extrapolated to 30 days indicated a buildup of less than 5-ppm total organics in an S-IVB hydrogen tank.

Details on these tests are included in Douglas Report DAC-60609, dated March 1967.

2. In addition to the MDAC testing efforts described above, testing and evaluation of the proposed foil covering were conducted by the Materials Division of MSFC (Ref: Technical Memorandum X-53732, dated April 30, 1968). These studies were made to verify that the foam protection scheme of using an aluminum foil liner was adequate to prevent fire and fire propagation in the insulation due to internal sources.

From the results of this activity, it was concluded that the three-dimensional insulation material can be made nonflammable by covering it with an aluminum foil liner. To be completely compatible with the OWS and to accommodate damage to the liner without jeopardizing the OWS, it has been shown that a liner thickness of 0.003 in. (.076mm) is required. With this liner thickness, even damage to the liner will not result in catastrophic combustion, but rather, the insulation will be self-extinguishing in less than 1 ft^2 (.093m^2) of area. The addition of the 0.003 in. (.076mm) thick liner makes the three-dimensional insulation exceed the most stringent requirements placed on material flammability for manned space flight.

The design approach used in the OWS was the application of a minimum thickness of 0.003 in. (.076mm) aluminum foil. A typical example of this insulation is shown in Figure 2.3.2-2.

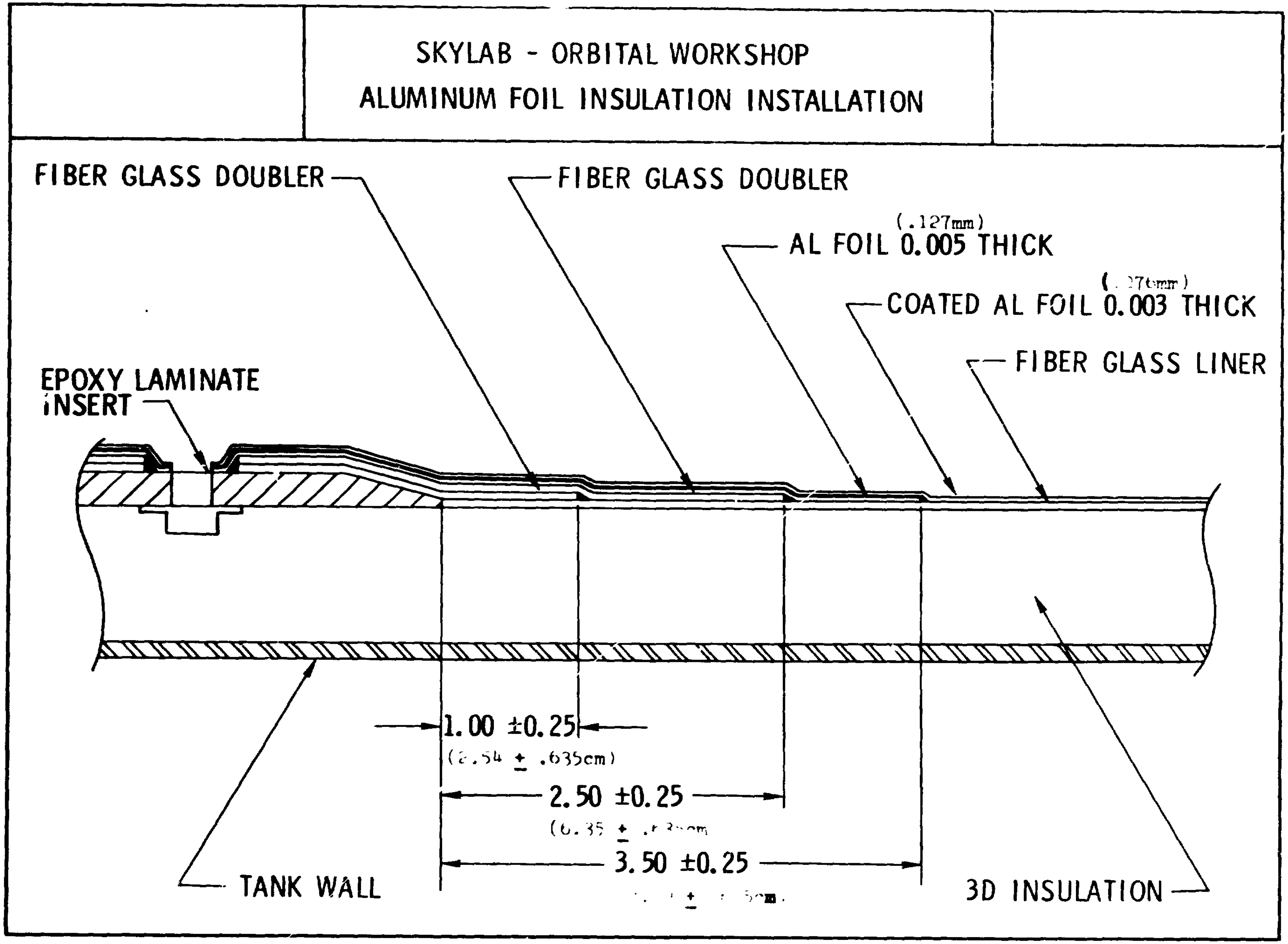

SKYLAB - ORBITAL WORKSHOP
ALUMINUM FOIL INSULATION INSTALLATION
FIBER GLASS DOUBLER
FIBER GLASS DOUBLER
(.127mm)
AL FOIL 0.005 THICK
COATED AL FOIL 0.003 THICK
FIBER GLASS LINER
EPOXY LAMINATE INSERT
1.00 ±0.25
(2.54 ± .635cm)
2.50 ±0.25
3.50 ±0.25
TANK WALL
3D INSULATION

Figure 2.3.?-2

Where epoxy laminate inserts were installed or when foam thicker than one inch was used, a minimum of 0.005 in. (.127mm) thick foil was bonded over these materials to provide adequate flammability protection.

b. Electrical Wiring - The initial internal tank wire cover concept was for all wiring to be installed in a way that permitted visual inspection and provided protection from physical damage by the crew.

1. The configuration baselines consisted of open wire bundles with protective covers at selected locations. Since physical damage was likely to occur only in high-traffic areas, adequate protection could be achieved if the wires were covered. Consequently, the wire harnesses were structurally protected from normal astronaut contact in high-traffic areas. This was done by routing wires in channels of the structural members immediately adjacent to mechanical and electrical equipment or structures, covering the wires with a metallic shield, or by covering wire breakouts to equipment with Teflon corrugated tubing.

   When the crew quarters were inverted with a soft (fabric) ceiling located immediately above the LO_2 dome, the hat section ceiling frame members were used for wire protection. Visibility was obtained by flat perforated covers.

Subsequently, when CO 15 (ECP W027) was received in November 1969 to invert the crew quarters, the floor orientation was revised to the present configuration and the soft ceiling disappeared. However, the channel cover design was carried over.

2. In January 1970, the requirement stating that all wires needed tight segmented compartments for fire protection was received (Letter PM-AA-SW-286-69). The present closed conduit concept defined in the following was developed to meet this new criterion.

   Visibility was deleted as a requirement (Supplemental Agreement 94); however, complete prelaunch access remained a requirement. The new design provided for all internal tank wiring to be routed in closed conduit on convoluted tubing.

   A trade study was conducted to evaluate various design concepts, hardware, manufacturing techniques, installation techniques, rework techniques, and accessibility for inspection. This evaluation covered the following concepts:

   a) Tubular metal conduit and junction boxes using fittings such as y's, tee's, crosses and straight fittings, at specified intervals for wire harness support within the tubing.

b) Wire harnesses in a braided fiberglass cover with Teflon tubing installed during the weaving process.

c) Wire harness with fiberglass and Teflon tubing slipped over it and terminated in special fittings at each branch.

d) Wrapping wire harnesses with aluminum foil.

e) Convoluted tubing (Thermofit NBG) was evaluated for replacement of fiberglass or Teflon tubing for ease of manufacturing and to reduce contamination of the OWS atmosphere. Samples were tested and approved by MSFC.

The study resulted in an overall design concept that enclosed major wire harness runs in a closed-conduit (metal channels with covers). This allowed manufacturing to use standard wire harness fabrication procedures on all main wire runs. Wire harness branches that extend away from the main wire run in the closed conduit, required fiberglass and Teflon tubing to be terminated in fittings at the closed conduit and at the connector back shell.

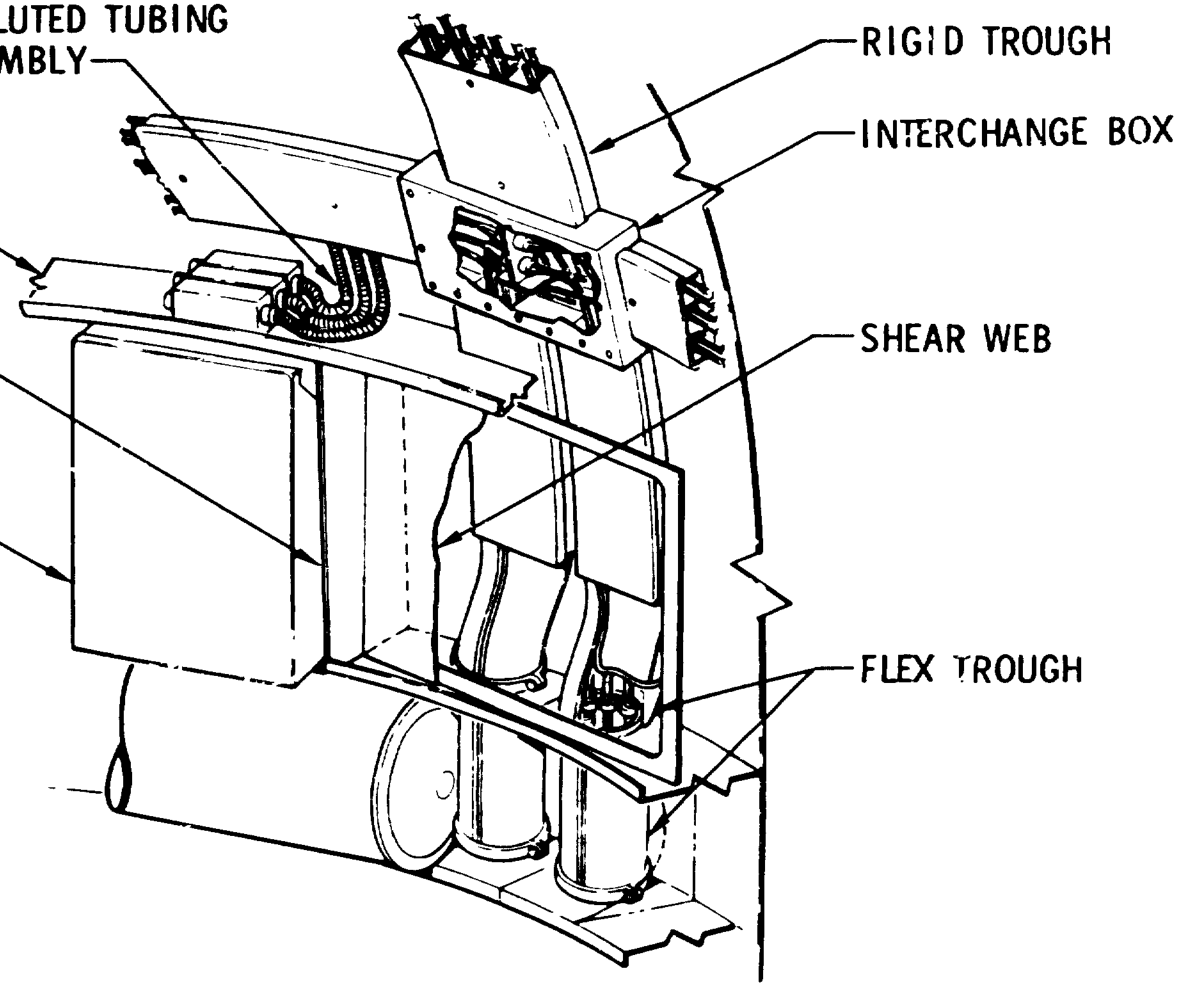
As a result of these study efforts, the wiring installation were changed from the baseline OWS internal wiring cover system to a more sophisticated system. The baseline called for standard wire harness runs protected in high-traffic areas by various materials, covers, hat-section ceiling frames, and metal guards, and interconnected by standard interface connectors supported by standard brackets. The more sophisticated system provided for routing all wiring inside the OWS through a closed conduit (trough) system for increased protection against flame and physical damage (Figures 2.3.2-3 through -6).

Basically, the new closed container system consisted of rigid conduit, flexible conduit, interchange boxes, convoluted tubing, and barrier boots. (See Figures 2.3.2-7 through -10). Barriers are included in these devices to inhibit flame propagation (see Fig. 2.3.2-11).

3. Specific design details on these concepts are given below.

   a) Troughs - Rigid (see Figure 2.3.2-8) - The rigid aluminum troughs with the fire barriers form the basic enclosure unit for interconnecting wire routing. The Teflon insulated wire inside the trough is not covered with any additional flame-protective materials. Fire barriers are installed periodically throughout the length of the trough runs. They are comprised of aluminum doublers [minimum 0.060 in. (.152cm)], NBG grommets

ORBITAL WORKSHOP CLOSED INSTALLATION SYSTEM (OVERALL CONCEPT)



NOTE:
COMPARTMENTIZED
CONSOLE/CABINETS NOT
SHOWN

Figure 2.3.2-3

SKYLAB - ORBITAL WORKSHOP
WIRE TROUGH INSTALLATION
TANK SIDEWALL 1B74713

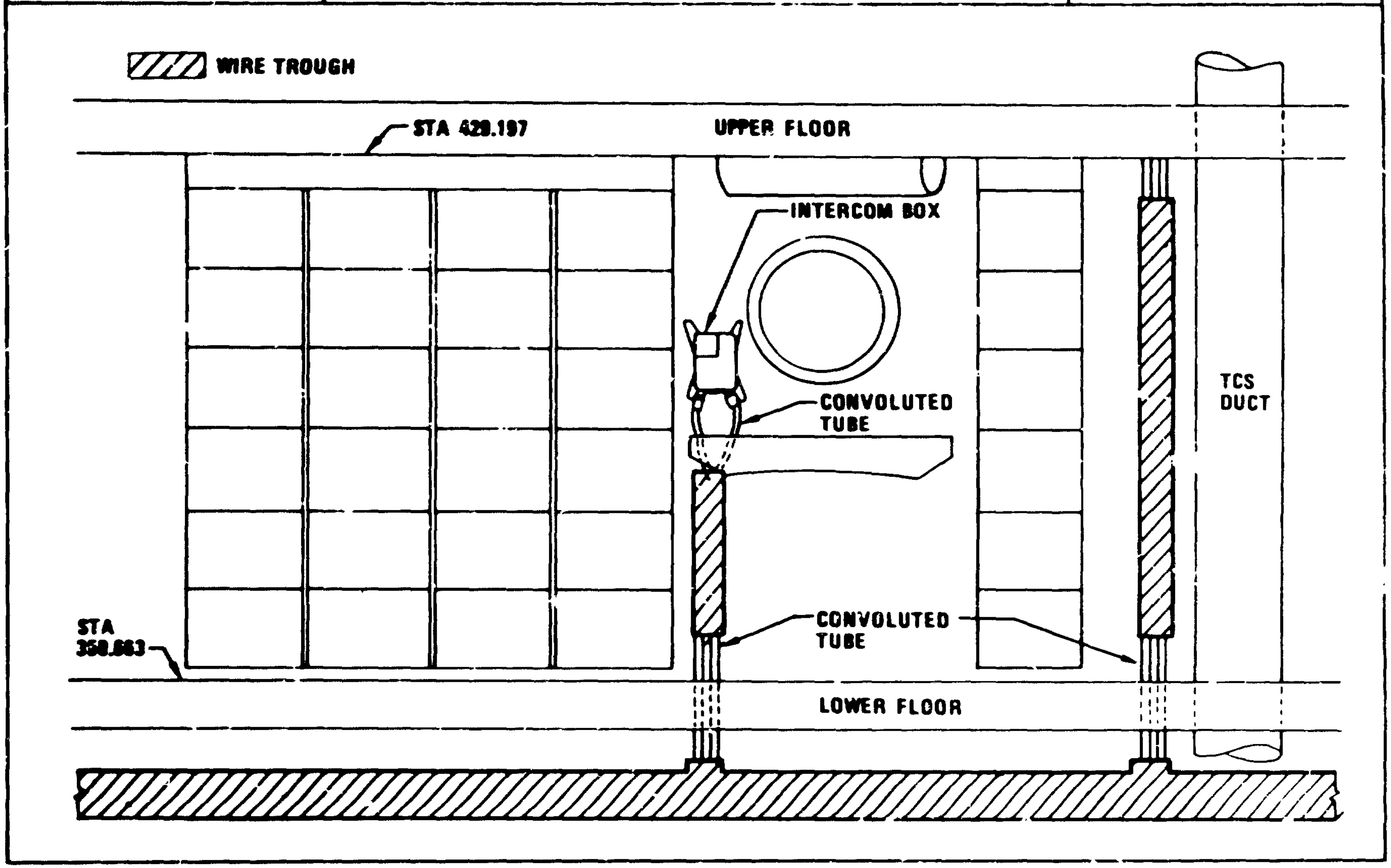


Figure 2.3.2-4

SKYLAB - ORBITAL WORKSHOP
WIRE TROUGH INSTALLATION
CREW QUARTERS CEILING - 1B74714

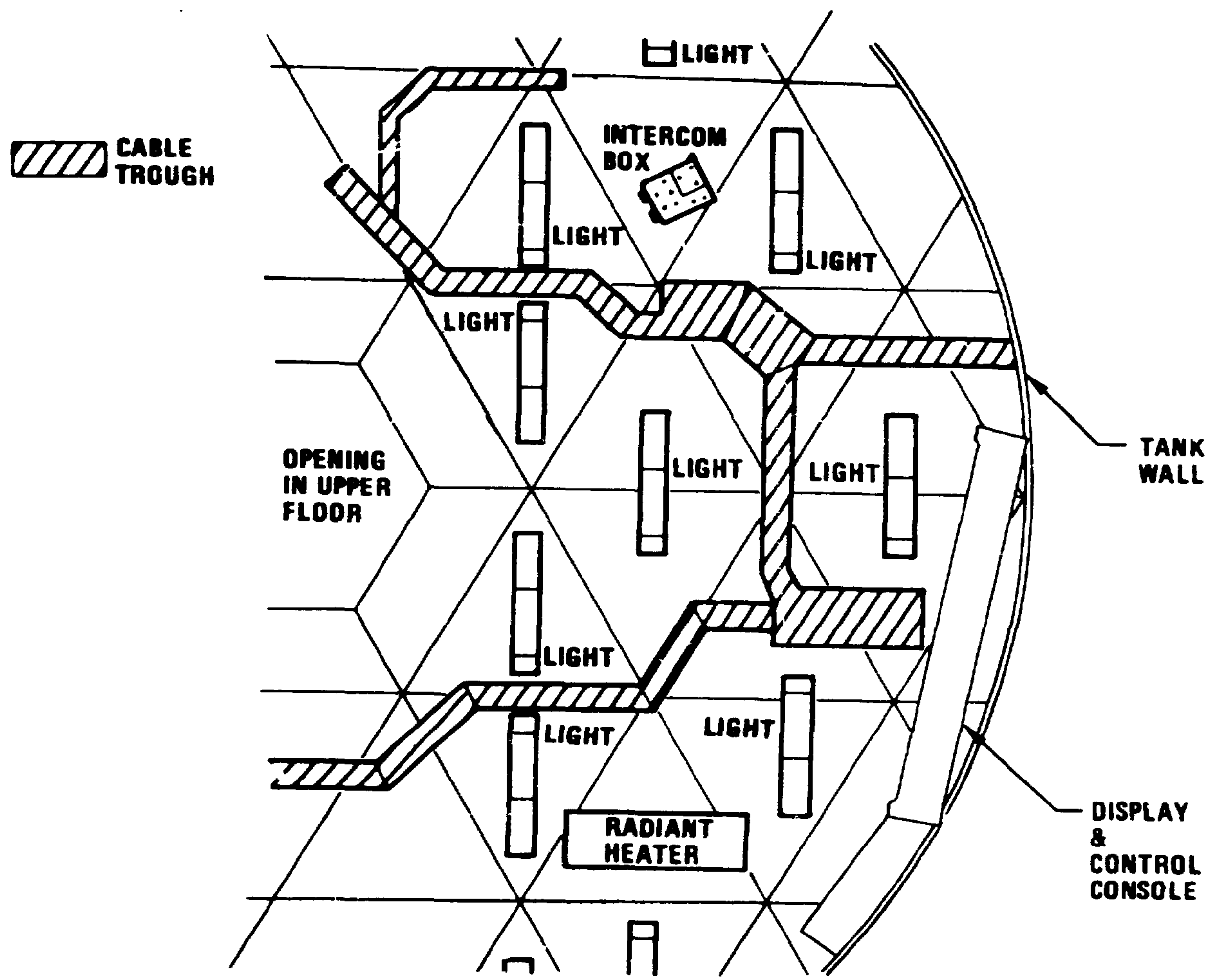


Figure 2.3.2-5

ORBITAL WORKSHOP
WIRE TROUGH INSTALLATION TANK SIDEWALL
1B74713

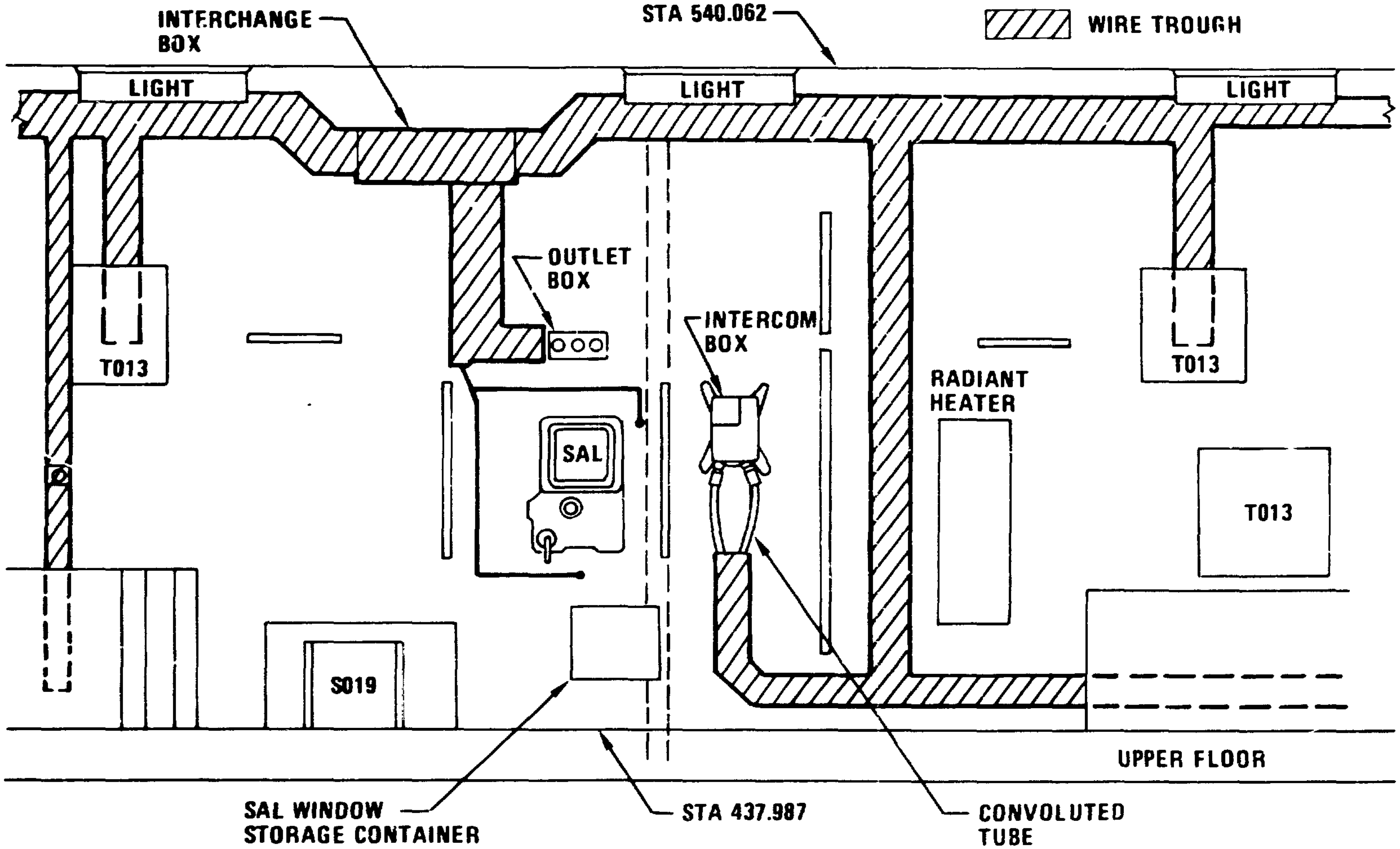


Figure 2.3.2-6

ORBITAL WORKSHOP FLEX TROUGH USAGE (GENERAL CONCEPT)

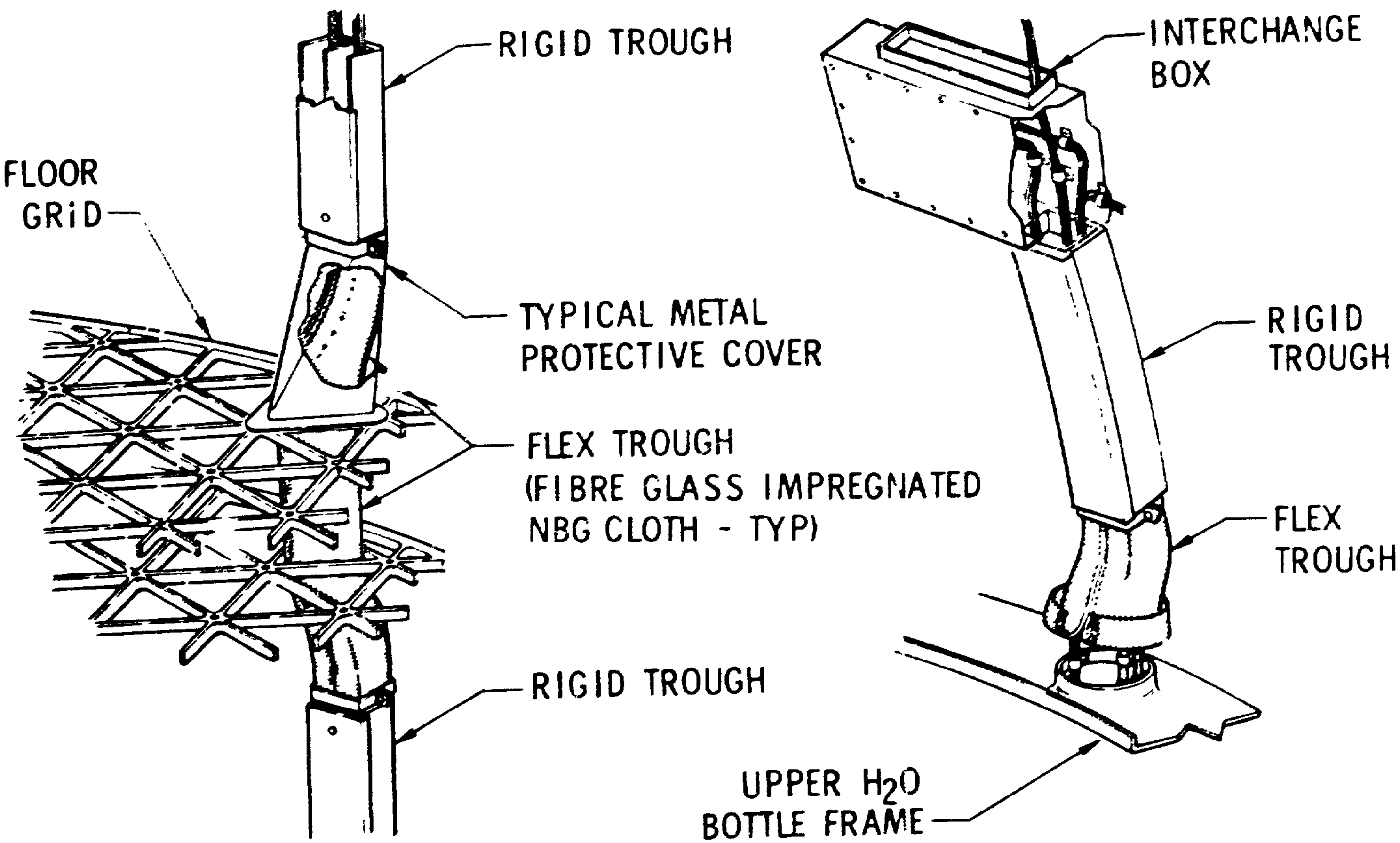
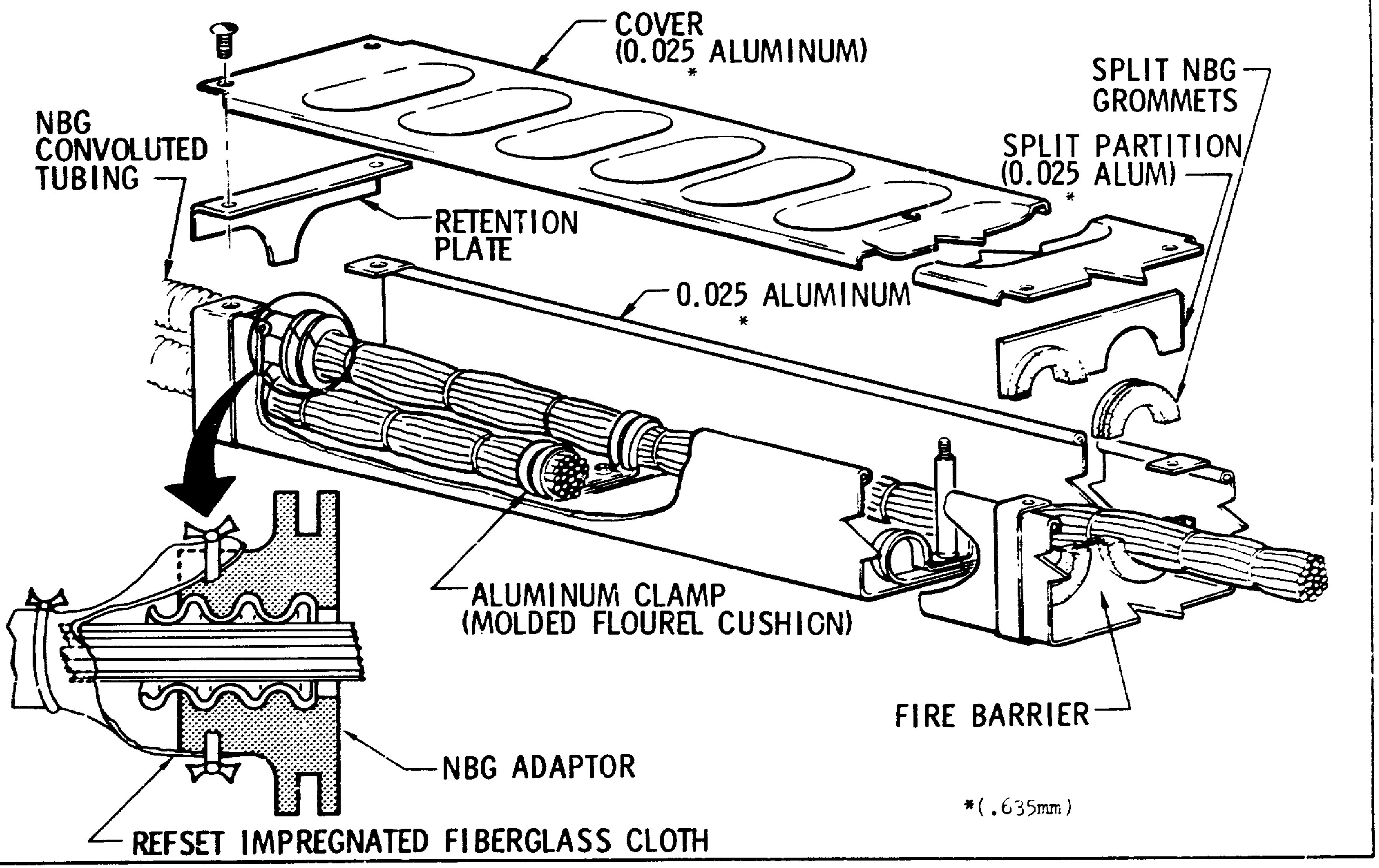


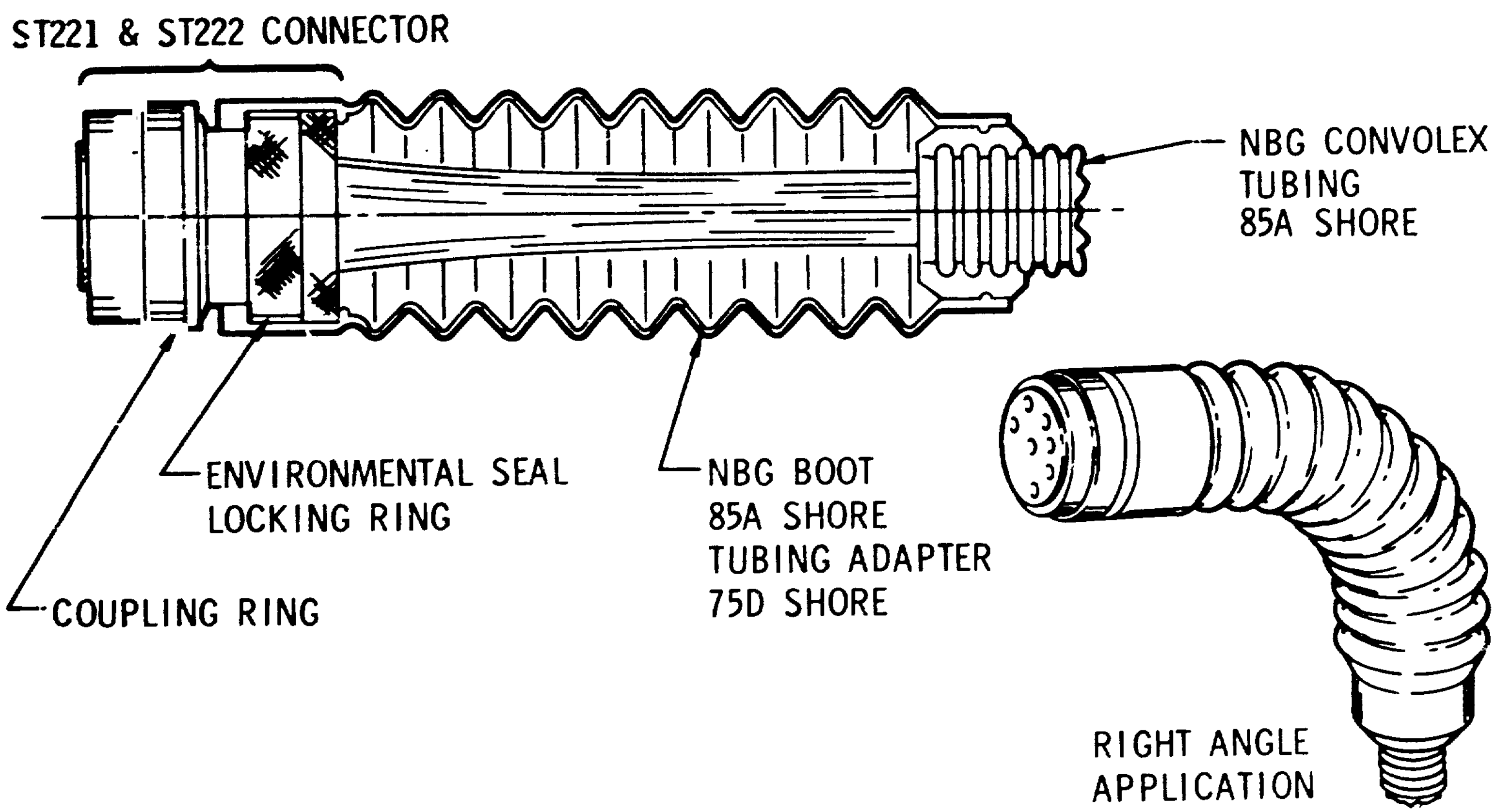
Figure 2.3.2-7

SKYLAB - ORBITAL WORKSHOP

RIGID TROUGH



SKYLAB - ORBITAL WORKSHOP
APPLICATION OF
CONNECTOR BOOT ASSEMBLY TO TUBING



SKYLAB - ORBITAL WORKSHOP

WIRE TROUGH TYPICAL SECTION AT WIRE CLAMP

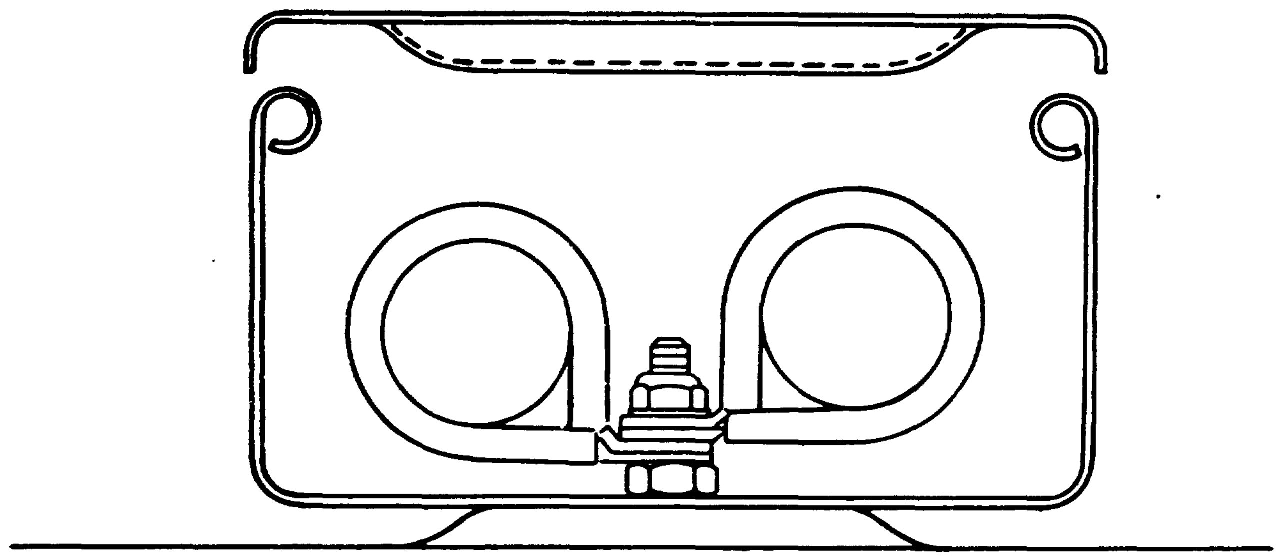


Figure 2.3.2-10

SKYLAB - ORBITAL WORKSHOP
WIRE TROUGH FIRE BREAK AND END FITTING

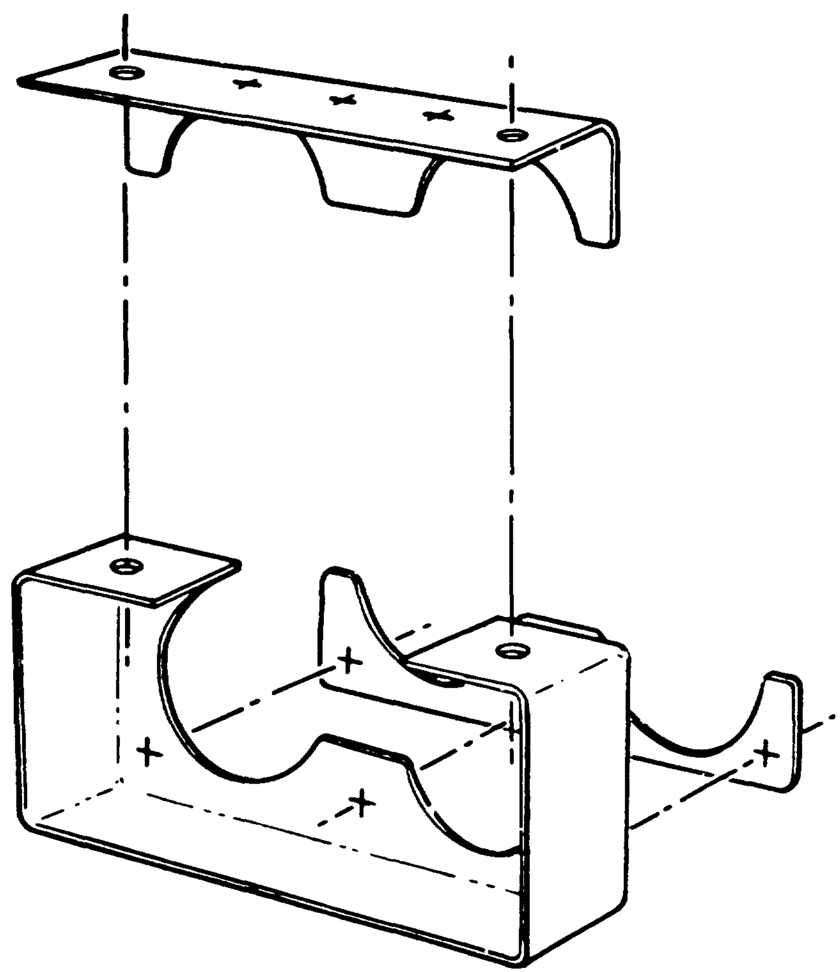


Figure 2.3.2-11

(201C012 through 042), and Refset impregnated fiberglass cloth served or tied with tying tape. The following materials are used for the fiberglass cloth:

- o Refset, L3203-6
- o E glass cloth (1528 or equivalent), STM0619 [minimum 0.010 in. (.254mm)].
- o Teflon-coated glass tying cord, STM0344A01C213.

b) Troughs - Flexible (see Figure 2.3.2-7) - The flexible troughs are used as extensions of the rigid troughs at points where the wire is routed to adjacent structure, which has a different acoustic or vibration level. It consists of Refset impregnated STM0619 cloth with glass tying tape for serving. The flexible troughs are fastened to the structure or the rigid troughs by the same STM0344A01C213 tying cord and fire barrier grommet that is used with the rigid troughs.

c) Interchange Boxes (see Figure 2.3.2-7 - The aluminum interchange boxes are required for complex crossover and interchanges of wire harnesses. The maximum size [with a minimum thickness of 0.050 in. (1.27mm)] is 12 in. (30.48 cm) by 24 in. (6.096cm) by 6 in. (15.2cm). The boxes consist of a cover, housing, and support brackets of aluminum with fire barriers identical to those used in the rigid troughs.

d) <u>Compartmentalized Housing</u> (Console or Cabinet) - Large metal housings [minimum 0.032 in. (.813mm) thick] for electrical equipment like the display control console and the refrigeration electronics cabinet have been compartmentalized with metal partitions. A fire barrier was provided at all wire penetration points similar to those used in the rigid troughs. It is comprised of the same Refset impregnated cloth used in the rigid troughs but of different size. In most cases, a metal portion fitting is used rather than the NBG grommet to secure the cloth.

e) <u>NBG Flexible Tubular System</u> - The various parts of the NBG system (except as indicated below by an asterisk) are made by a proprietary process with a proprietary material. The NBG flexible tubular system consists of the following components:

- o Convoluted tubing [minimum 0.030 in. (.762mm)] STM 0519
- o Convoluted connector boots [minimum 0.050 in. (1.27mm)], 201B3 Series

o Boot-to-tubing adapter [minimum 0.095 in. (2.4mm)] 201B4 Series

o Tubing-to-trough adapter [minimum 0.075 in. (1.9mm)] 201 E Series

o *Glenair zero-g connector adapter (aluminum), G2518 and G2519

o *Cloth boots Refset impregnated STM0619 cloth with glass tying tape for serving.

Any combination of the components is assembled on the wiring harness to make an enclosure-type installation.

4. The following data are supplied to document the testing that justifies the design and material use. It should be noted that some of the tests or test units covered more than the OWS habitable area interconnecting wire harnesses and accessories. Also, some were tested on a system level rather than as an individual component or part configuration. This was done for convenience and practicability, but more significantly because it required a number of assembled parts to provide a testable item. A good example would be the boot-to-tubing or tubing-to-trough adapters. They were too small for use in a current overload test. In addition, they were not intended to function alone, but were to be used as

one of several parts to create an enclosed tubular system.

Table 2.3.2-6 lists the various tests conducted and the status of the results.

c. General Illumination Light Assembly

1. The initial OWS general illumination light consisted of a fluorescent lamp contained in a Lexan tube to provide the protection against lamp breakage and mercury contamination. The Lexan material did not meet flammability requirements and a study was initiated to provide a suitable lens material for the light assembly.

2. This study was conducted by Sylvania Electronics Systems and the results (published July 8, 1969) pointed out the following materials as having the most potential for fulfilling the optical, flammability, and nonbreakable requirements:

   a) Polycarbonates (Lexan)

   b) Chemically tempered glass (Herculite II)

   d) Fluorocarbons.

   The materials were evaluated individually and in combinations. The results indicated that there was no one material capable of satisfying all physical and optical requirements. Polycarbonate materials met all but the flammability requirement; however a Teflon sleeve improved this characteristic. A

Table 2.3.2-6

COMPONENT AND SYSTEM TESTS

Description Item/Part/System	Reference	When Tested, DAC Engineer	Where Tested, Test Documentation	Result Documentation
Identification lable 0.020 inch thick NBG tied to harness/ convoluted tubing, system test	MSC2035B MD16, dated May 21, 1971	May 20, 1971 Gonzales	NASA, Huntsville MSFC-SPEC-101A Test No. 4	Trip Report A3-250-MM-RE/AFF2-71081, dated June 1, 1971. Meets Type I of Test No. 4-films - No A3 copy
NBG boot, convoluted tubing, boot and adapter, system test	MSC2035B MD10, dated April 15, 1971	February 1, 1971 Okada	NASA, Huntsville MSFC-SPEC-101A Test No. 4	Trip Report A3-250-MM-RE/AFF8-71065, dated February 10, 1971. Meets Type 1 of Test requirements - films - No A3 copy
NBG boot, convoluted tubing, and adapter with potting compound on connector, MDAC-East Test Requirement	MDAC SP/N NTR 215	February 23-24, 1971 W. Wicks (MDAC-East)	NASA, Huntsville MSFC-SPEC-101A Test No. 4	Meets Type 1 of Test 1 Requirements Interoffice NASA Memo E-454-3770, dated March 2, 1971
1B75091-501-DF139 Power console distribution area	MSC 2035B MD9, dated April 15, 1971	February 16-17, 1971 Gonzales	NASA, Huntsville MSFC-SPEC-101A Test No. 7	Trip Report A3-250-MM-RE/AFF2-71029 films - No A3 copy

Table 2.3.2-6

COMPONENT AND SYSTEM TESTS (Continued)

Description Item/Part/System	Reference	When Tested, DAC Engineer	Where Tested, Test Documentation	Result Documentation
Wire trough power console circuit breaker assembly 16 wire harnesses (mostly covered by fiberglass sleeves, etc.) System test	A3-250-AES1-L-1380 dated May 5, 1971	April 5 10, 1970 Holden	NASA, Huntsville MSFC-SPEC-101A Test No. 4, Test No. 6, Test No. 7	Trip Report A3-250-MM-RE/AFF2-70099, dated June 26, 1970 MSFC Memo S&E-ASTN-MX-70-135. Meets Type 1 Test No. 4. Films at A3 MP.51, 782, dated June 22, 1970
NBG boot NBG convoluted tubing NBG tubing, smooth NBG adapters, boot NBG adapters, trough	Batch No. 1699-35-7	C. F. Wissman	MDAC-West MSFC-SPEC-101 Test No. 1	LWS 85 045 LWS 85 046 LWS 85 047
Cable clamp liner RL 3771		April 7, 1970 E. J. O'Neill	MDAC "A" MSFC-SPEC-101 Test No. 1	Type 2 as a material per Test No. 1 Lab Report MP 51, 754, dated April 7, 1970
Sealing plugs, connectors	ST264	March 23, 1970	MDAC-West 1B78110	LWS 88249, dated March 23, 1970 RED = Type 2 (20 ga) BL = Type 1 YLO = Type 1

combination of chemically tempered glass, polycarbonate, and Teflon was used to bring about a complete solution to the flammability requirement.

As a result of this study and in response to the requirements received January 9, 1969 (Letter PM-AA-SW-286-69), the lamp assembly was redesigned.

3. The materials for the light were a Sylvania F8T5 lamp covered with Sylgard 182 and ytrrium oxide fill inside a Lexan tube. A chemically tempered glass tube with a 0.020 in. (.508mm) Teflon exterior coating was placed over the Lexan tube. This arrangement was assembled into the lamp end fittings and potted.

The rationale for this design was to provide a light configuration that (1) sealed the mercury vapor to prevent toxicity, (2) met flammability requirements, (3) prevented shattered glass in the OWS atmosphere, and (4) met illumination requirements. In meeting the requirements in items 1 to 3, the light illumination was degraded. This new configuration required five additional lights and 62.5 watts of additional electrical power for the OWS illumination system.

A general illumination light (MDAC P/N 1B69364) was supplied to MSFC by CO 293, dated February 10, 1971 for flammability testing. As a result of these tests the light was approved for use in OWS.

4. Lights were provided to illuminate the habitable areas (forward compartment and crew quarters). Refer to Drawing No. 1B76406 for exact locations and designations.

The forward compartment included the volume between the forward dome and the crew quarters. Eight lights were located on the dome approximately 45 degrees apart near the handrails and 45 degrees up from the tangent point of the cylindrical section; 10 lights were in the forward compartment approximately 36 degrees apart and located near the tangent point of the cylindrical section and the dome below the water bottles.

The crew quarters included the waste management compartment, wardroom, sleep compartment, and experiment compartment. The lights were installed as follows:

a) Four lights in the wardroom.

b) Three lights in the waste management compartment.

c) Three lights in the sleep compartment.

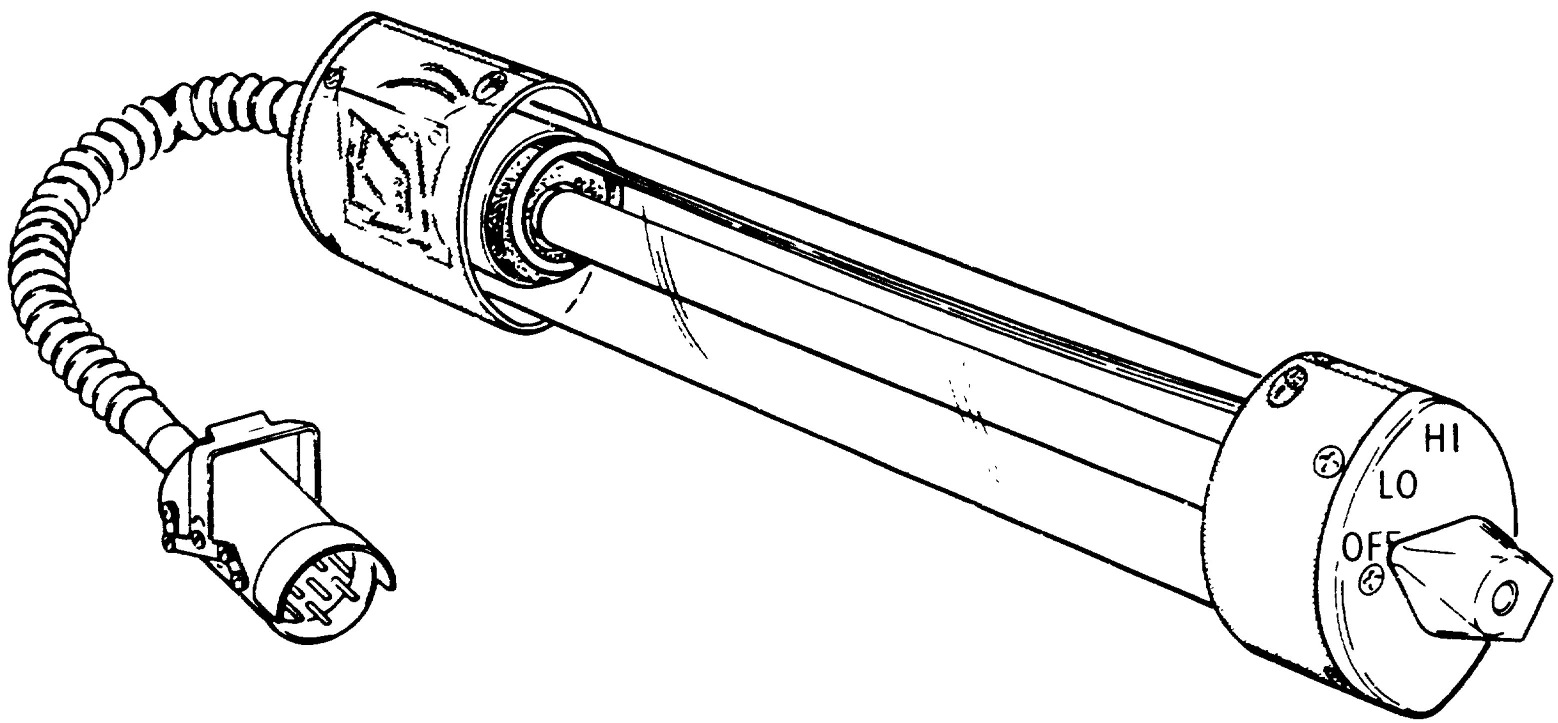
d) Fourteen lights in the experiment compartment.

e) Twenty-four in the forward compartment.

The light housings (Figure 2.3.2-12) were permanently installed and lights were designed for crew replacement with spare lamps. The lights could be controlled from either the light assembly or the control panel. In addition, two airlock-controlled lights were installed above the power distribution console and two lights at the exit. These lights were included among the initial-entry lights used

SKYLAB - ORBITAL WORKSHOP

GENERAL ILLUMINATION FLUORESCENT BULB



REF 1B69364

Figure 2.3.2-12

during initial operations-entry and emergency-lighting conditions. A switch was provided on each lamp assembly for off-low-high control of each light, independently. The end of the preinstalled light housing assembly was indexed to the switch on the light bulb. The bulb has an attached pigtail with a zero-g connector that allows one-handed replacement. A hinged cover on the housing assembly protected the pigtail after installation and supported the lamp.

Design and construction details on the light bulb are shown in Figures 2.3.2-12 and -13. The bulb installed in the protective metal cover is shown in Figure 2.3.2-14.

d. Refrigerant (Coolanol-15)

1. The OWS refrigeration system provided a closely controlled temperature environment for food freezing, food refrigeration, potable water chilling, urine chilling, and urine sample freezing.

   The refrigeration system supplied coolant fluid temperatures for refrigeration at -14°F to +41°F (247° to 278°K).

   The refrigeration system used a single-phase liquid refrigerant, Coolanol-15 circulated through the temperature-controlled storage units absorbing excess heat. The absorbed heat was in turn transferred to the space radiator, the thermal capacitor,

SKYLAB - ORBITAL WORKSHOP
CROSS SECTION OF LENS ASSEMBLY

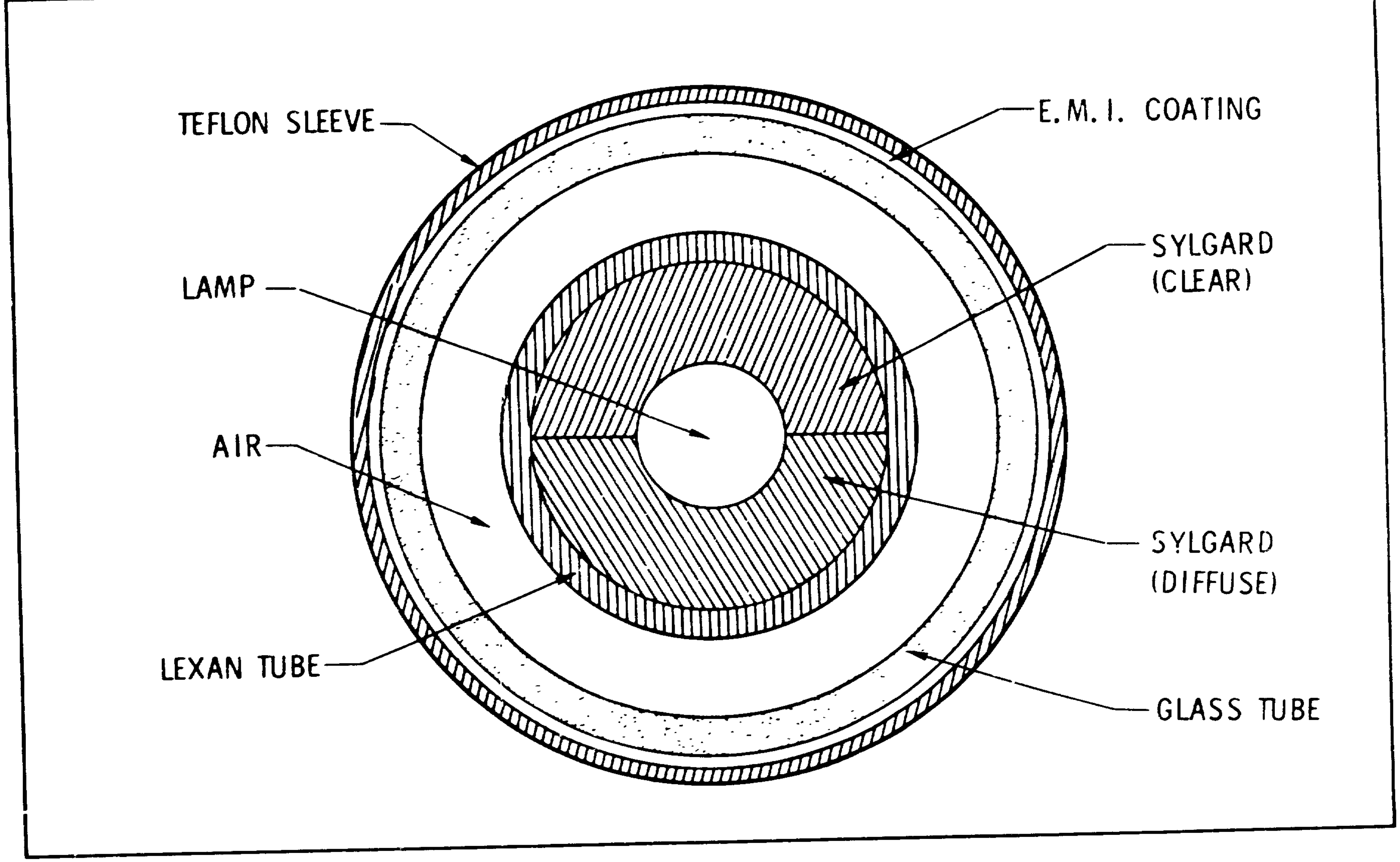
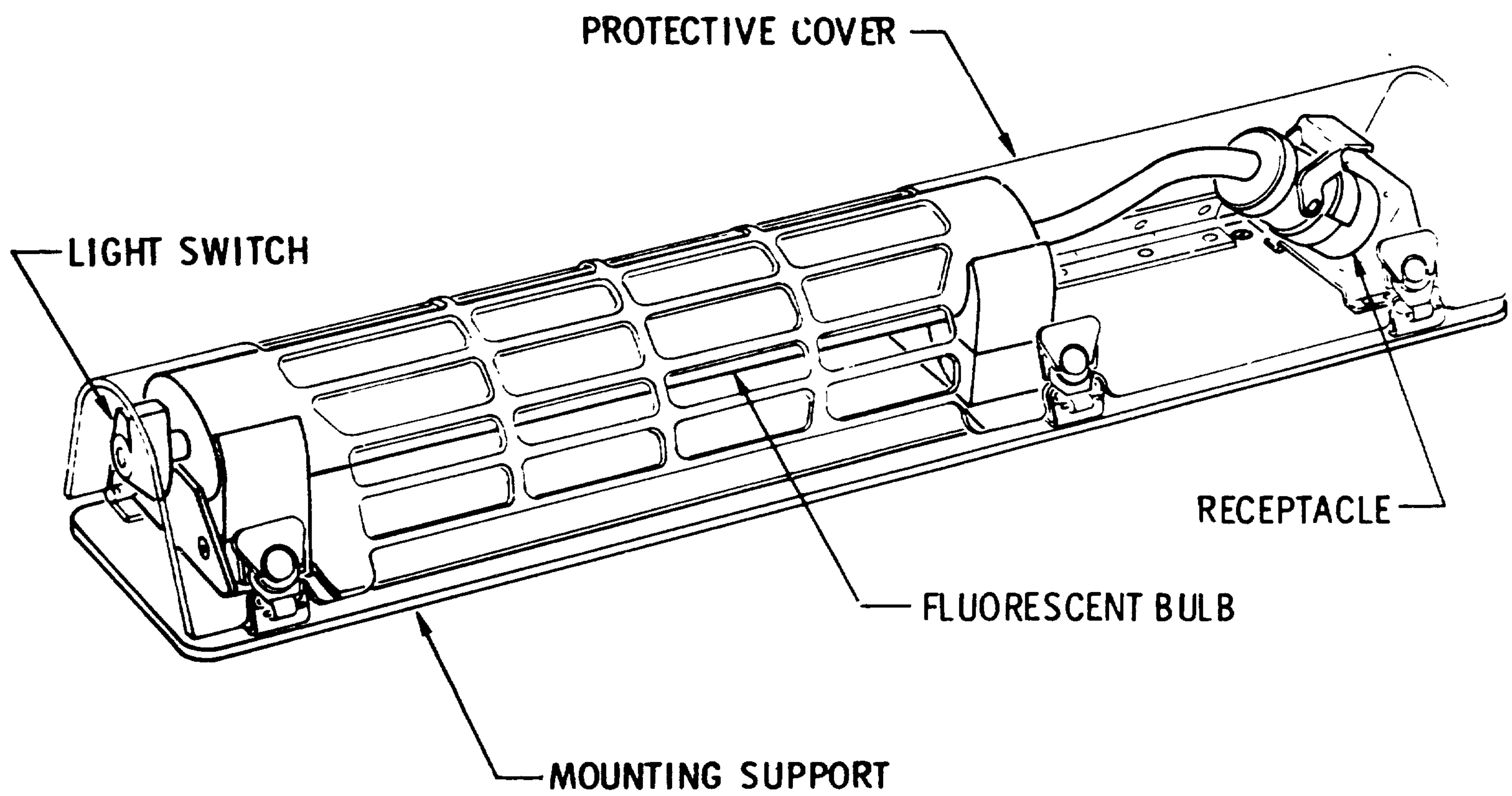


Figure 2.3.2-13

SKYLAB - ORBITAL WORKSHOP
GENERAL ILLUMINATION FLOODLIGHT



REF 1B75186

Figure 2.3.2-14

or the ground cooling heat exchanger.

2. Coolanol-15 required special design because of its hazardous nature. The refrigeration system installation incorporated the following design provisions to eliminate potential leak paths for the refrigerant.

   One of the key features in the design to prevent Coolanol-15 leaking into the habitable area was locating the pump package in an evacuated enslosure. Any leaks from equipment in this enclosure would result in the free Coolanol being vented to the waste tank.

   Other important features were the use of off-the-shelf-qualified, proven components and hardware, the use of brazed Aeroquip union connections where possible, use of MC-type connectors, use of AND-STD ports with Viton O-rings, or Teflon-coated metallic-K-seals where lines connected to components. Figure 2.3.2-15 presents a typical connection for tran tion from CRES tube to the freezer aluminum boss, which incorporated the AND-STD ports. Figure 2.3.2-16 depicts the typical component-to-boss fluid connection. This connection used an O-ring seal or K-seal for pressure integrity.

SKYLAB - ORBITAL WORKSHOP
REFRIGERATION SUBSYSTEM BRAZE FITTING FOR TRANSITION FROM ALUM TO CRES TUBING

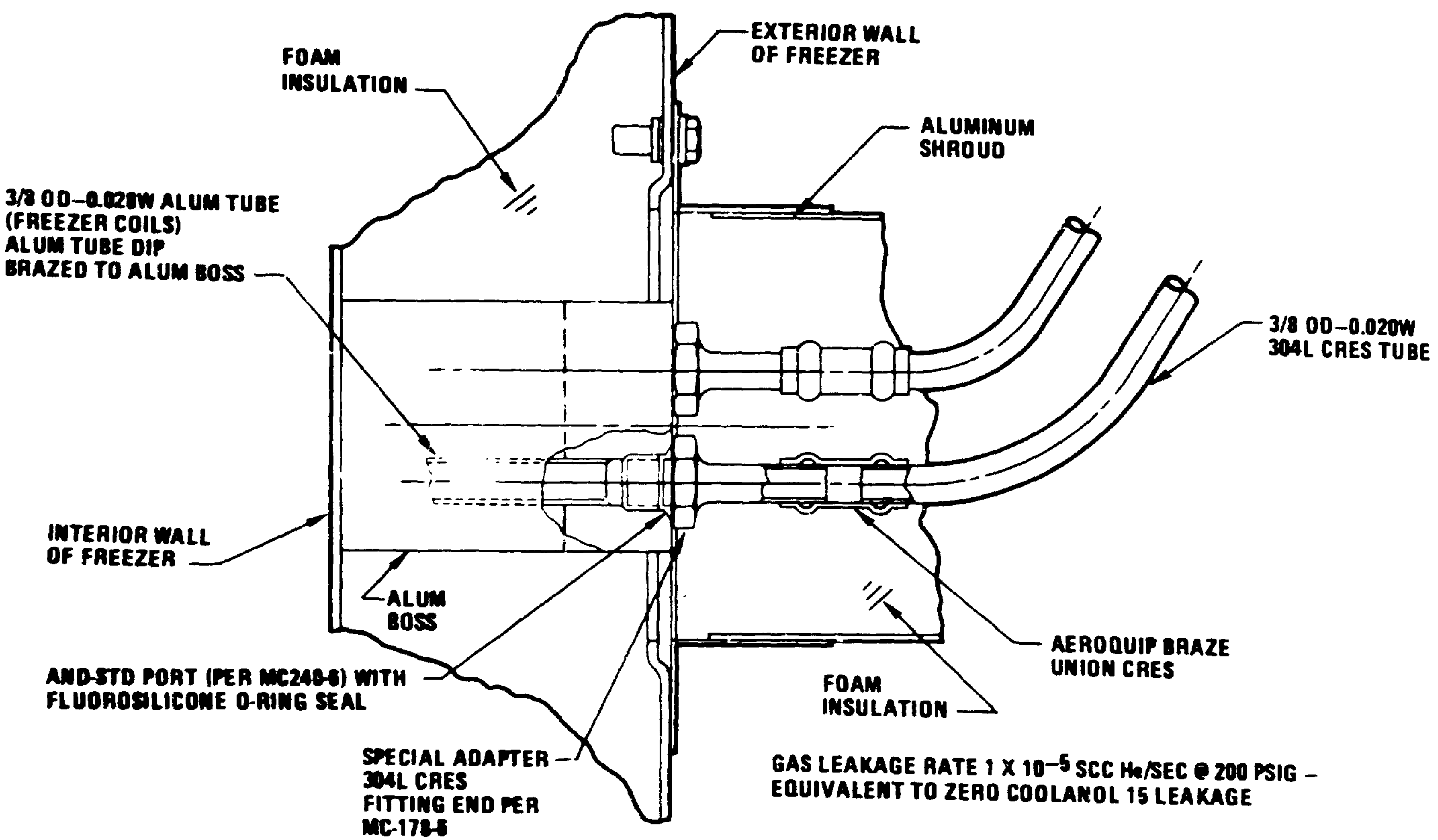
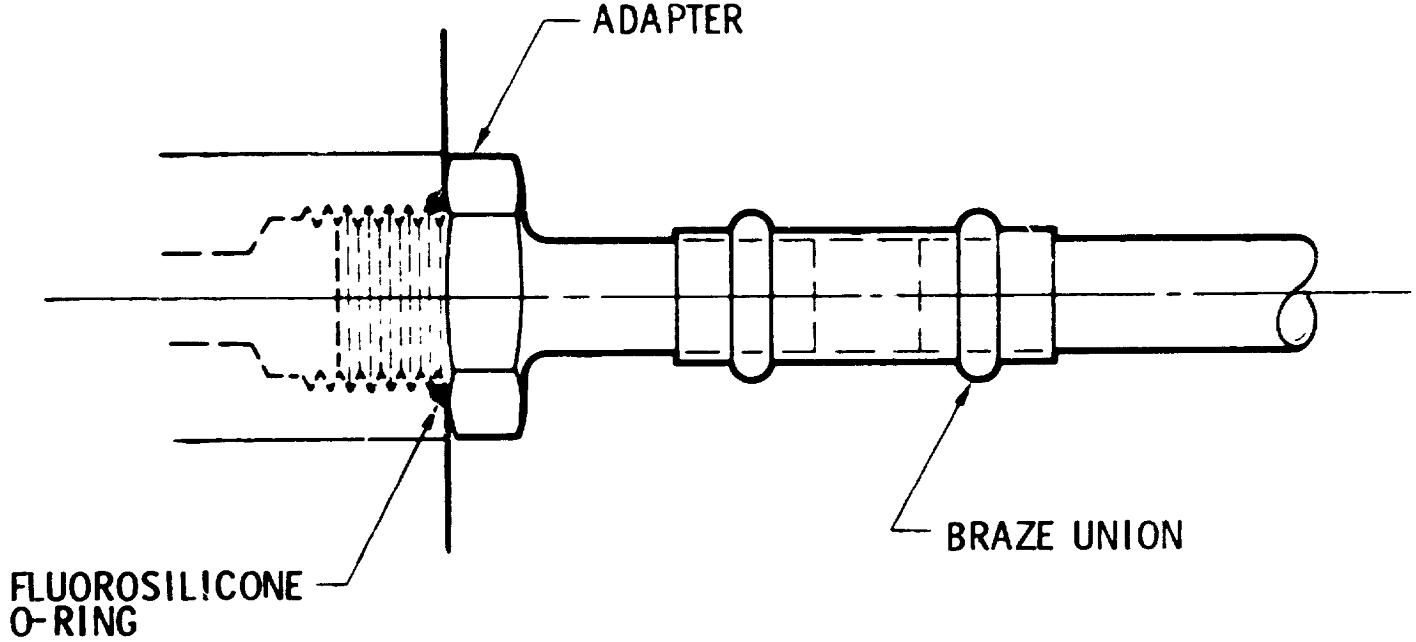


Figure 2.3.2-15

SKYLAB - ORBITAL WORKSHOP
REFRIGERATION SYSTEM
COMPONENT-TO-BOSS FLUID CONNECTION



A typical flare tube fitting, used only inside the pump package enclosure, is shown in Figure 2.3.2-17. The use of MSFC-developed MC fittings increased the reliability of the connection.

3. The size of the pump accumulators was important. The maximum amount of Coolanol-15 contained in the two pump accumulators was 104 in^3 (2.94m^3) per loop. If a major leak were to deplete the accumulator of fluid and pressure, a safety switch would shut down the active coolant pump. The maximum amount of Coolanol-15 that would leak from the system was that contained in the accumulators, or 104 in^3 (2.94m^3). The lines, pumps, etc., would still be full of fluid but no force would remain in the system to expel this remaining Coolanol once the accumulator bellows bottomed out.

   Protective insulated covers were used around the Coolanol lines. There were two types of insulation used - a flexible, open-cell foam directly around the tube, and a closed-cell rigid polyurethane foam jacket around the flexible core. The insulation was then covered with 0.050 in. (1.27mm) aluminum shrouds. The line construction is shown in Figure 2.3.2-18.

4. An evaluation of alternative coolant fluids was also conducted in which the impact of changing to Freon

SKYLAB - ORBITAL WORKSHOP
REFRIGERATION SYSTEM
FLARE TUBE CONNECTOR (MC)

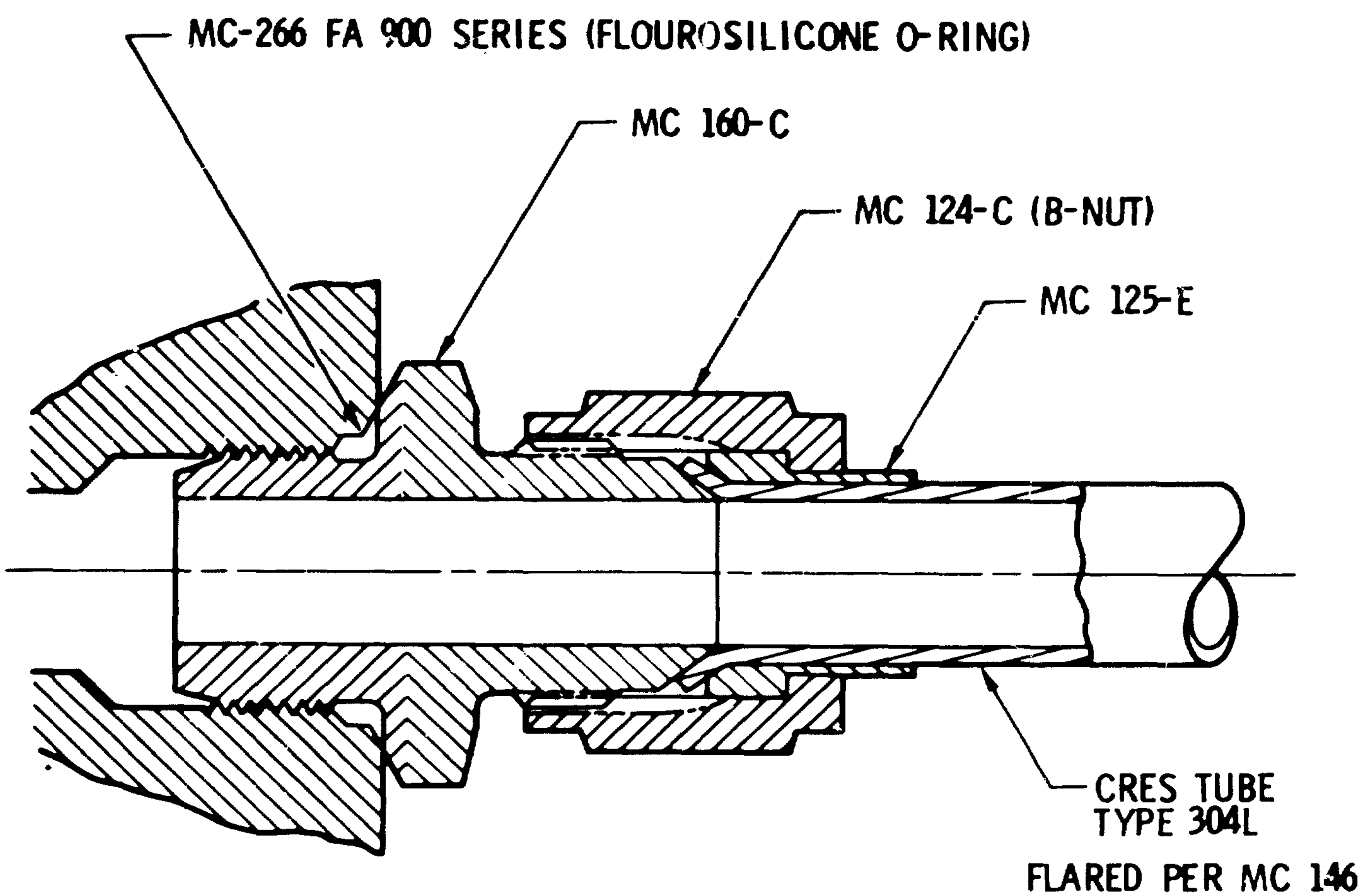


Figure 2.3.2-17

SKYLAB - ORBITAL WORKSHOP
REFRIGERATION SUBSYSTEM
REFRIGERATION PUMPING UNIT ENCLOSURE

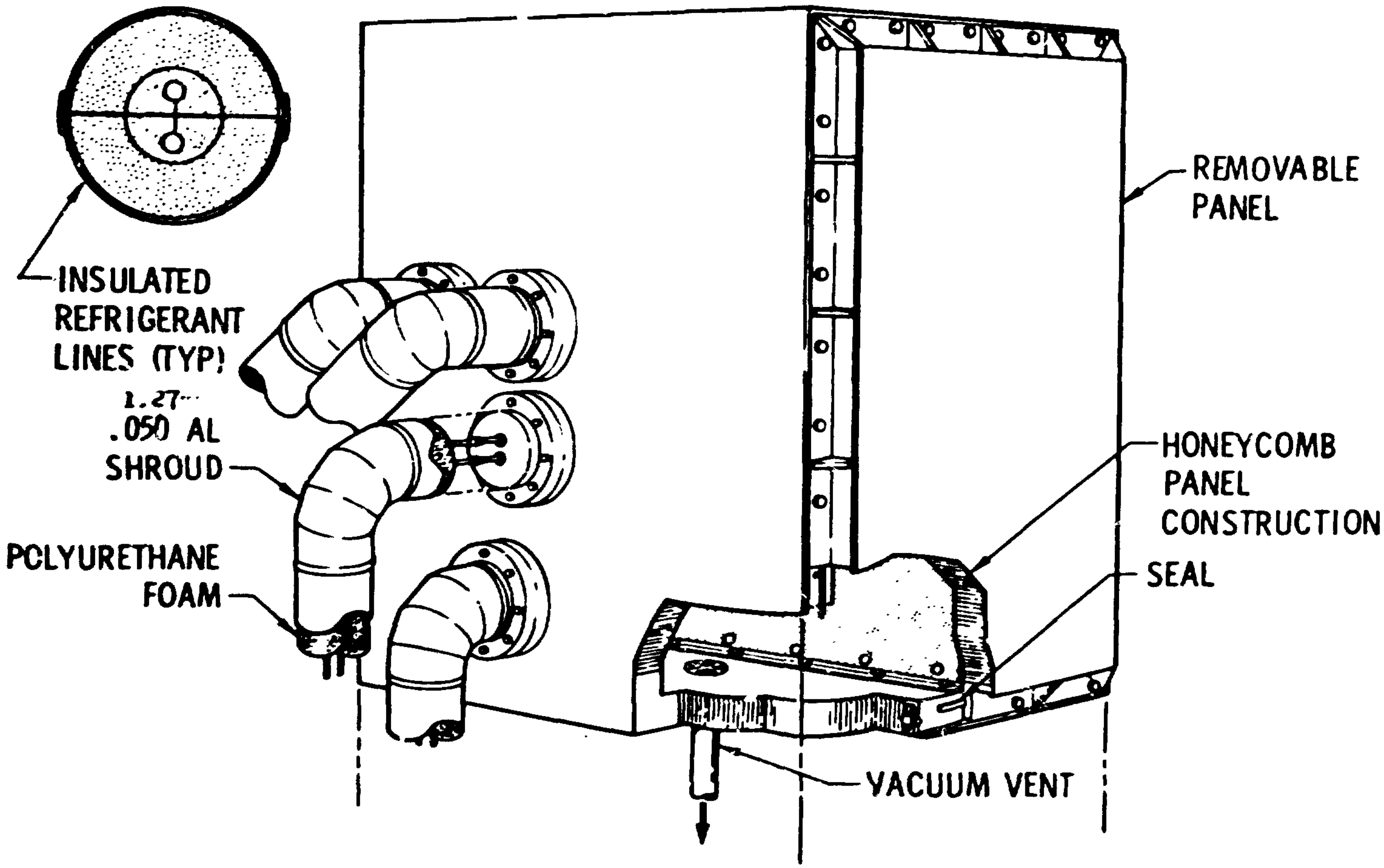


Figure [illegible] -18

E-1 and FI-75 was assessed (see Report No. MDC G2784, dated November 10, 1970). The conclusion of this study was to retain the existing coolant.

In support of this study, several flammability test samples of polyurethane foam-covered, aluminum-jacketed lines were prepared and tested at MSFC. These test samples were saturated with Coolanol-15 and subjected to flammability tests in a 100 percent oxygen atmosphere at 6.0 psia (41.4 kN/m^2). Igniters were placed both internal and external to the aluminum jacket over the foam insulation. In addition, the aluminum tape used to cover the joint where the two half-shells come together was removed and the tests were repeated again with both internal and external ignition sources.

The test results indicated that minor charring and discoloration occurred, but no significant, sustained combustion could be initiated. The samples used for these tests are shown in Figures 2.3.2-19 through 22 in the closed condition and as they appeared when opened after the tests were completed.

SKYLAB - ORBITAL WORKSHOP
SHROUDED COOLANT COMBUSTIBILITY TEST
AL TAPE INTACT

(41.4 kN/m²)
6.0 PSIA, 100% O_2 - COOLANOL 15 SATURATED
EXTERNAL AND INTERNAL IGNITERS

Figure 2.3.2-19

SKYLAB - ORBITAL WORKSHOP
SHROUDED COOLANT LINE
COMBUSTIBILITY TEST SAMPLE - AL TAPE REMOVED

6.0 PSIA, 100% O_2 - COOLANOL 15 SATURATED
EXTERNAL & INTERNAL IGNITERS

Figure [illegible]

SKYLAB - ORBITAL WORKSHOP
SHROUDED COOLANT LINE
COMBUSTIBILITY TEST SAMPLE - AL TAPE REMOVED

(41.4 kN/m^2)
6.0 PSIA, 100% O_2 - COOLANOL 15 SATURATED
EXTERNAL & INTERNAL IGNITERS

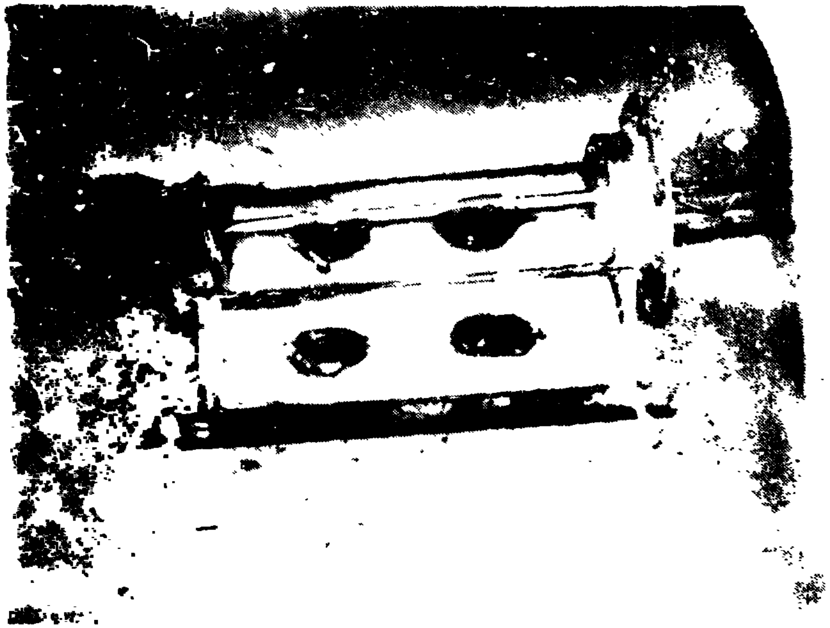


Figure 2.3.2-21

SKYLAB - ORBITAL WORKSHOP
SHROUDED COOLANT COMBUSTIBILITY TEST
AL TAPE INTACT

($41.4\ kN/m^2$)
6.0 PSIA, 100% O_2 - COOLANOL 15 SATURATED
EXTERNAL AND INTERNAL IGNITERS

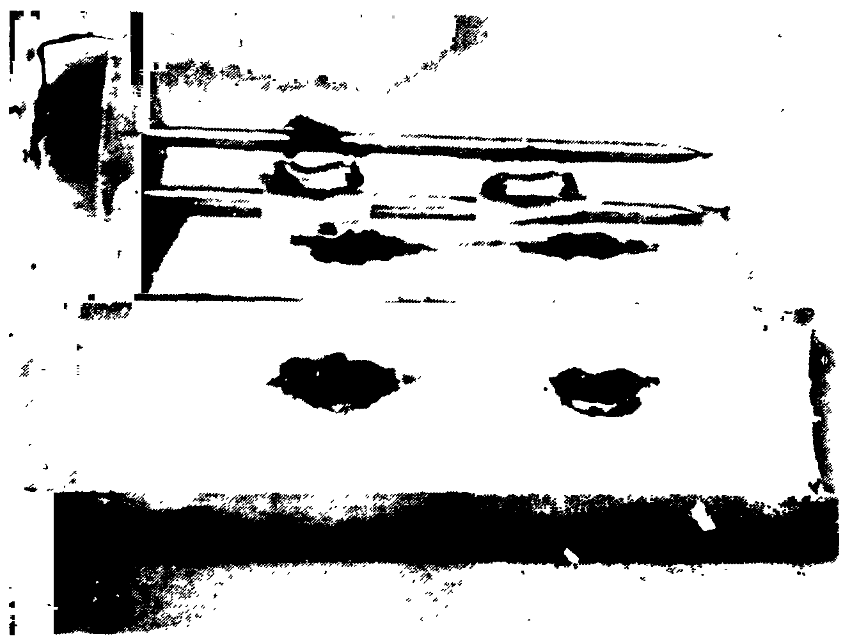


Figure 2.3.2-22

2.3.3 Material Compatibility

This subsection describes the method of control and assessment for materials used in flight hardware designs. The contractor has applied documented controls to govern the selection of materials and components for the purpose of minimizing or eliminating potential hazards and to ensure compatibility of materials and components with mission environments. The demonstration of the materials application compatibility is documented in this section. Material uses that do not meet the guidelines and criteria for acceptability, are incompatible, or have flammable characteristics have been reported along with the appropriate rationale to substantiate the material use in the particular design to NASA/MSFC. To comply with the basic contract NAS9-6555, Schedule II, for material control, MDAC initiated reporting form P0327, Material/Component Usage (see Figure 2.3.2-1) to obtain approval from NASA/MSFC for uses of certain materials for OWS hardware.

The material disciplines and reporting tasks for compliance with material compatibility requirements were imposed on all major subcontractors supplying equipment so that MDAC could meet its contractual responsibilities. All data generated by MDAC subcontractors has been transmitted to NASA/MSFC.

A. General Guidelines

1/ As authorized by Change Order 660, the P0327 form was expanded to include other material disciplines already under contract for reporting an incompatibility or material not meeting the acceptance criteria but which can be substantiated in the design application. These other material disciplines already under contract are outgassing, hardware contamination, and age control of synthetic rubber.

2/ Also, as authorized, MDAC initiated a survey of all detailed part and assembly drawings to ascertain material compatibility in the design application and with operational environments. Disciplines to be covered by this in-depth reassessment were corrosion prevention, creep, fatigue, cold flow, lubricity, stress corrosion, fungus resistance, and hydrogen embrittlement. The review provided NASA/MSFC with a documented reassessment of materials used in OWS designs; however, the survey was terminated prior to completion. The survey results are reported following the disciplines and control program paragraphs.

B. Material Guidelines and Criteria

The following guidelines and acceptance criteria for each discipline or material characterization noted below were used to determine compatibility and acceptability of materials on using drawings.

1/ Age Control (Synthetic Rubber Age control of synthetic rubber materials and components as per MSFC-STD-105A, as modified in CEI CP2080J1C. The age control of synthetic rubber was limited to those items noted in the Mission/Safety Critical Items (MCI) List, per MDAC drawing 1B75304. MDAC has prepared and maintained drawing 1B88809, List, Age Sensitive Items Control Orbital Workshop, for reporting the age-sensitive synthetic rubber items to MSFC.

2/ Cold Flow - The selection evaluation of components for analysis consisted of a review of the designs to determine if the applied steady state of installation loads are sufficient to cause cold flow. Where applicable, the effect of elevated operating temperatures was considered. All designs were reassessed for possible evidence of cold flow. Since there were no controlling specifications for cold flow, it was not possible to provide a quantitative evaluation. Therefore, only a qualitative evaluation, based on experience and good engineering judgment, was performed.

3/ Contamination Control - The requirements appear in CEI CP2080J1C, and in the Contamination Control Plan, MDC-G0384A. Contamination control and cleanliness requirements related to OWS hardware were applied throughout manufacturing, test, and checkout of the OWS module. Mercury contamination control was in accordance with MSC Standard 120, Breathing Systems, Requirement to Test for Mercury Contamination, and implemented by the MDAC document, Orbital Workshop Mercury Control Plan.

4/ Corrosion Prevention - Each detail part was reassessed with respect to the need for protection from corrosion. The MDAC drafting manual contains general rules for determining the protection necessary to prevent corrosion of metallic parts and the prevention of bimetallic corrosion because of dissimilar metals contacting. Applications using metallic materials were reassessed and evaluated. MDAC Finish

Specification F-297 was the controlling document for all finishes and coatings for MDAC internal designed flight hardware. All MDAC supplied designs and standard parts installed in the OWS were reviewed, evaluated, and documented for corrosion protection adequacy.

5/ Creep - Since there were no controlling specifications for creep, it was not possible to provide a quantitative evaluation. Therefore, only a qualitative evaluation, based on experience and good engineering judgment was performed. (Creep data published in MIL-HBD-5 were used for applicable designs.)

6/ Fatigue - The controlling document for fatigue is MSFC Report S&E-ASTN-ADV. (71-73), dated April 1971, entitled "Vibration, Shock, and Acoustical Test Specification for the S-IVB Orbital Workshop Components and Assemblies." Vibration and acoustic test results were acceptable for evaluation of structural adequacy. Typical fatigue analysis methods were used to evaluate components which are subjected to vibration loads. A conservative design approach was taken to minimize potential fatigue problems by using a design ultimate factor of safety of 1.40 times limit equivalent static load, wherever practical. The limit equivalent static load was defined as the maximum vibration load (3 sigma) developed from the random vibration environment. For fatigue analysis purposes a (2 sigma) maximum vibration load was used along with the specific life cycle requirement, and no factor of safety was employed.

7/ Flammability - The controlling criteria appears in Subsection 2.3.2.

8/ Fungus Resistance - Fungus-resistant materials were preferred. Materials that act as fungus nutrients had to be covered with a suitable protective coating in all designs. Fungus nutrient materials were considered to be excluded from identification and reporting requirements if they were encapsulated or in hermetically sealed components. Hardware applications were evaluated according to their fungus resistance; depending on materials that support or are damaged by fungi. The evaluation was limited to areas of the OWS that were exposed to moisture.

9/ Hydrogen Embrittlement - Certain applications of metals were reviewed to determine their susceptibility to embrittlement in the presence of hydrogen. Released drawings were reviewed with the following metal applications:

a. Low-alloy steels (e.g., 4130, 4140, 4340, 52100 and 6150) heat treated to 180 or 200 ksi (1.24×10^8 N/m^2 or 1.37×10^8 N/m^2) or higher [above 160 ksi (1.10×10^8 N/m^2) yield strength].

b. Corrosion-resistant steels.

c. 18 nickel maraging steels (e.g., 250 maraging).

d. Titanium alloys (e.g., 6 Al-4V).

10/ Lubricity - Each lubricant use or lubricity application (i.e., electroplating to prevent galling) on all drawing configurations was assessed for design adequacy to meet mission requirements. Since there was no controlling specification for lubricity, a qualitative evaluation was performed, based on experience and good engineering judgement. The design parameters (i.e., load, rpm, speed, operating temperature, life requirements, operating environment, etc.) were identified and compiled to enable each lubricant design application to be assessed for meeting mission objective.

11/ Offgassing (Toxicity) - The controlling criteria appears in Subsection 2.3.2. The P0327 Computer Program calculates material offgassing rates and computes the total cumulative offgassing rate for materials used. The total offgassing rates (toxicity) are the calculated total offgassing products of the carbon monoxide (CO) and total organic (TO) emissions from each exposed material or from nonhermetically sealed components that permit backwash of offgassing products into the habitation area atmosphere.

12/ Odor - The controlling criteria appears in Subsection 2.3.2.

13/ Outgassing - The controlling criteria appears in Subsection 2.3.5.1.

14/ Stress-Corrosion Susceptibility - The definition and acceptance criteria for assessment of metal alloy use appears in MSFC drawing 10M33107, Design Guidelines for Controlling Stress-Corrosion Cracking. The use of all metal alloys is reviewed and those listed in 10M33107 are assessed and evaluated for design adequacy regarding the possibility of crack initiation and propagation.

C. Management (Control Program)

1/ The material control program is administered by the Program Manager through the Fire Marshall's office. Six basic management tools were implemented to aid in administration of the materials control program: Material and Component Usage Report (P0327 Form), Fire Marshall's office, Toxic Hazard Control, Documented Material Compatibility Review, Materials Computer Program (P0327), and Materials Data Bank.

a. P0327 Usage Report Form - Controls were established for the selection and use of materials to ensure consistency with design and program objectives.

The control feature within the engineering organization was the assessment by the technologies of materials used on detail, assembly, and installation drawings. A P0327 form was provided with all drawing releases to note the applicable subject discipline for which the drawing was reviewed. P0327 forms generated because of an incompatibility were approved by the OWS Program Manager and were submitted to NASA/MSFC for review and approval.

b. Fire Marshall - The office of Fire Marshall was created within the Chief Design Engineer's Office to provide direction and to serve as the focal point for P0327 MDAC approvals.

The basic philosophy to ensure a fire-free habitable area in the OWS was carried out by indoctrinating the designer to use nonflammable materials. The use of flammable materials was approved only on the basis that no suitable nonflammable material was available.

c. Toxic Hazard Control

1. To protect the flight crew from toxic physiological effect from the use of any hazardous material, each such material used in the OWS was subject to approval of the Design Office, Materials and Process, Engineering, and Crew Systems.

2. A computer program was developed to provide accountability for bulk materials and materials used in components. This accountability extended to all materials classified as potentially hazardous that were not located in a sealed container and not in encapsulated modules. Information recorded includes complete identity of the materials and components and their location within the habitable area, the amount and exposed area of the material, and cumulative information on the total offgassing products. The purpose of this accounting aided astronaut safety by providing an evaluation involving the aspects of toxicity thresholds.

d. Material Compatibility Assessment Review - The material compatibility survey covered released drawings on flight hardware (detail, assembly, installation, vendor, standard parts, and material substitutions in fabricated hardware) for the OWS to assess material compatibility in using designs. Goverment-furnished properties were excluded from this review.

A matrix worksheet of drawing information (including identification numbers, nomenclature, and criteria with example as shown in Figure 2.3.3-1) and the material discipline parameters as defined were compiled to demonstrate material compatibilities in OWS drawings released as of 31 March 1972.

e. Material Usage Computer Program, P0327 - The computer program is used to calculate the total offgassing rates for carbon monoxide and total organics for each material and the sum of all material offgassing products.

f. Material Data Bank - A comprehensive set of data on flammability and offgassing was available to aid the materials and design engineer to select materials for the crew areas. These data included outside sources such as MSC-06281, Nonmetallic Materials Design Outlines and Test Data Handbook (more commonly known as the COMAT list). With respect to internal sources, MDAC has prepared a data bank computer program to aid in the maintenance and retrieval of information on nonmetallic materials considered for use on various space programs. This program updates a master file, which is maintained on magnetic tape, and provides a complete up-to-date reference of nonmetallic materials. The file contains the generic name, the trade name or number, the vendor name, and test results. The test results include flammability category, combustion rate, flash point, fire point, carbon monoxide and total organics offgassing data, and odor rating. Nearly 2,000 materials are listed.

D. Materials Compatibility Assessment Review Summary

1/ Major subcontractors completed the Materials Compatibility Assessment Review (MCAR) and their results and data were transmitted to NASA/MSFC.

2/ The MDAC results of the MCAR showing percentage of completion is presented in Table 2.3.3-1. The evaluation of the draw-part numbers consisted of an examination of the pertinent detail and assembly drawings and a review of the applicable mission requirement including the environment and load conditions. Table 2.3.3-1 contains the summary of MDAC drawing part numbers that were to be evaluated and a summary of drawing part numbers that were not evaluated because of termination of the effort prior to completion. After the MCAR effort NASA/MSFC authorized (CO 026) the stress corrosion survey of 153 drawings which are included in the percentage completion figure in Table 2.3.3-1. No work or evaluation by MDAC was done on any worksheets provided by major subcontract parts prior to termination of the MCAR.

E. Recommendations

1/ The Contractor must apply adequate control methods at the start of the project to govern the selection of materials and components to ensure compatibility of materials with mission environments.

2/ The material application for a particular characteristic must be shown in a documented record which demonstrates material compatibility in the using design.

MCAR SURVEY SUMMARY*

(MDAC HARDWARE)

Table 2.3.3-1

MATERIALS CHARACTERISTIC	TOTAL NUMBER OF PARTS	PARTS NOT EVALUATED	COMPLETION PERCENTAGE
Coldflow	917	611	67
Corrosion Prevention	1577	473	30
Creep	192	86	45
Fatigue	1728	344	20
Fungus Resistance	110	33	30
Hydrogen Embrittlement	157	135	99
Lubricity	901	376	42
Outgassing	20	0	100
Stress Corrosion	1799	344	47

*Flammability, Odor and Offgassing summaries are presented in Subsection 2.3.2. Age Control and Contamination (hardware) were each 99 percent complete.

3) The survey of hardware drawings to determine compatibility of materials should be initiated at the start of any new program. This would lessen costs and the impact of design changes resulting from a retroactive assessment review downstream in the program.

2.3.4 METALLICS

2.3.4.1 Selection Criteria and Characteristics

A. General

1/ The metallic materials selected for the OWS for MDAC designed hardware were restricted to corrosion and heat resistant steels and alloys and aluminum alloys, with a few exceptions, i.e. bearings, cams, etc.

Extensive use was made of 17-4 PH heat treated to H1025, A286, 7-7 PH heat treated to CH900 and the 300 series stainless.

Although many different aluminum alloys were selected, considerable use was made of alloy 6061 because of its resistance to stress corrosion and good joint efficiency when welded.

B. Requirements

1/ The requirements for the selection of metallic materials was governed by the MDAC Drafting Manual. The selection criteria was similar to that used during the design of the Saturn SIVB. When MSFC Document 10M33107, "Guidelines for Controlling Stress Corrosion Cracking was issued, this document was used to select materials in regard to stress corrosion resistance. Previous to that time, the experience gained on the Saturn SIVB was used as a guide to selecting material with good resistance to stress corrosion.

C. Tests

1/ Little metallic material testing was conducted to determine mechanical properties since most materials used were fully documented in MIL-HDBK-5 "Metallic Materials and Elements for Aerospace Vehicle Structures." Some tests were conducted to determine material characteristics to reflect specific design requirements. These included creep testing, and evaluation of compatibility of metals with different environments. The specific details of many of these tests are mentioned elsewhere in this document

2.3.4.2 TACS Bi-Metal Joint

A. Requirements

1/ It was necessary to effect a joint between the Titanium 6AL-4V TACS nitrogen storage spheres and the 304L stainless steel tubing used in the TACS plumbing system. This joint had to have a very low leak rate and had to have high reliability. After a review of various joining techniques a bi-metal joint (titanium 6AL-4V to 304L stainless steel) manufactured by Nuclear Metals was selected.

B. Alternate Solutions

1/ In selecting the type of joint, a review of mechanical joints (flared fittings and conoseal type joints) were evaluated. This evaluation disclosed that the mechanical joints could not consistently meet the leak rate requirements or reliability of the bi-metal joints.

C. Discussion

1/ During the fabrication and production acceptance testing of the bi-metal joint, MDAC worked with Nuclear Metals and developed processing specifications that controlled each step in the manufacture of the joints. Through the use of these specifications, the reliability of the joints was assured.

2/ MDAC also worked with Nuclear Metals in developing a non-destructive test of the diffusion bonded transition joint between the titanium and the stainless steel. Techniques were developed so that a defect 2/64 in (.794 mm) in diameter could be detected using ultrasonic inspection. This achievement was considered significant because of the difficulties involved in the ultrasonic inspection due to the different acoustic impedence of the two materials.

3/ The metallurgical characteristics of the bi-metal joints were carefully analyzed, and the results of this analysis incorporated into the manufacturing specification. The width of the transition joint was controlled to minimize the formation of intermetallic compounds. This was controlled by limiting times and temperatures during joint fabrication.

D. Conclusions and Recommendations

The bi-metal joint selected successfully passed all development and qualification testing and has been used for ten months on the TACS system. During testing and operation no joints leaked or failed to meet all design objectives. The use of this joint is highly recommended for future applications where dissimilar metals must be joined in high pressure systems.

2.3.4.3 Electron Beam Welding

A. Requirements

1/ Several designs required joining techniques that could be used for thin materials, could be made without contamination of the parts, or would not damage (through heat) adjacent areas. It was determined that electron beam welding was the most attractive joining technique.

B. Alternate Approaches

1/ Methods of mechanically joining the joints in question were evaluated. This method was not considered acceptable because (1) there wasn't enough room for mechanical fasteners, or (2) the joint would not be leak tight.

C. Discussion

1/ Urine Probe Assembly

It was necessary to effect a narrow weld with a minimum heat input to join two parts of this assembly. Too large a weld would result in damage to the electric wiring immediately adjacent to the joint. A vacuum was also required on the inside of the probe. This was provided by EB welding the inner portion closed. The resulting atmosphere inside the probe was that of the vacuum chamber [1×10^{-4} torr (1.33×10^{-2} N/m^2)]. Since the weld was effected in a vacuum, the cleanliness of the probe was maintained during welding.

2/ Fittings for Coolanol System

a. Due to design modification of the Coolanol system fittings for induction brazing were required that had unique geometries. Many of these incorporated a brazed joint with a mechanical joint. If these unusual configurations had been ordered from the induction braze fitting supplier, Aeroquip, the lead time would have been prohibitive. The fittings were fabricated instead by EB welding half of a standard, in stock, braze fitting to a machined part.

b. EB welding permitted the joining of the thin wall [0.028 in (.711 mm)] stainless steel parts while maintaining the cleanliness required for subsequent induction brazing.

3/ Potable Water Deionizer

a. The design called for the installation of seven 10 micron stainless steel filters into each end of the deionizer cartridge. In order to reduce the possibility of corrosion, little or no faying surfaces were desired. This requirement eliminated the use of a support ring and mechanical fasteners.

b. The final design incorporated the use of EB welding. The filters, composed of a number of layers of screen, were EB welded directly into the cartridge head. Only through the use of EB welding could the thin filters be joined to the much more massive cartridge. The smooth fillets produced by EB welding eliminated any faying surface. During welding the filter cleanliness was also maintained.

D. Conclusions & Recommendations

1/ Electron beam welding proved to be an indispensable joining method for the OWS hardware. It was particularly useful in joining cleaned parts where cleaning after assembly was impractical and for joining materials with wide variations in thickness. In many cases the added cost of EB welding was offset by savings derived from the elimination of other procedures.

2.3.4.4 Urine Chiller

A. Requirements

1/ In order to reduce weight and to increase the thermal response of the urine chiller, the use of aluminum was considered necessary. The chiller used coolanol as the cooling medium and the coolanol plumbing was fabricated from stainless steel so that induction brazing could be used to join the tubes. A joint was required between the aluminum and the stainless steel. Since the chiller was located in an inaccessible area, a leak free joint was a requirement.

B. Discussion

1/ A survey was conducted of the different types of aluminum to stainless steel joints available. Based on past history and testing conducted for the Apollo Program, a joint fabricated by Bi-Braze Corp. was selected. This joint consisted of an aluminum coated 304L stainless steel tubing that was aluminum dip brazed into an aluminum 6061-T6 boss.

2/ During the design of this joint, care was taken so that unexpected loading of the bi-braze joint could not happen. A support was added near the joint so that any handling loads would be picked up by the support and would not adversely affect the bi-brazed joint.

3/ Careful control of the materials used and the process procedures was exercised. All tubing was metallurgically examined to determine freedom from grain boundry carbide precipitation.

C. Conclusion

1/ No joint failures were experienced during testing or operation. This type of joint can be recommended for future useage.

2.3.4.5 Induction Brazing

A. Requirements

1/ It was necessary to effect "leak-free" joints in the 304L stainless steel plumbing on the TACS, Refrigeration Subsystem, Vacuum Outlet System, and Water Pressurization System. The maximum leak rate that could be tolerated was 1×10^{-6} sccs per joint. After a review of various joining methods, induction brazing using automatic temperature control brazing equipment manufactured by Aeroquip Corp. was selected.

B. Alternate Solutions

1/ In selecting this type of joint, a review of mechanized joints (flared fittings and swage-lock) were evaluated. This evaluation disclosed that these mechanical joints could not consistently meet the leak rate requirements or reliability of a brazed joint.

C. Discussion

1/ The brazed joints utilized unions and fittings of 304L stainless steel containing preplaced 82% gold - 18% nickel braze alloy. The sleeves and fittings were obtained precleaned and packaged from Aeroquip. The induction brazing process used an inert gas (Argon) shield on the inside and outside of the tube joint to prevent oxidation or contamination during brazing.

D. Conclusions and Recommendations

1/ Induction brazing resulted in joints with leak rates less than 1 X 10^{-10} sccs (less than the lower limit of the leak detecting equipment). Brazed joints are readily inspectable by visable and by x-ray techniques. There was no instance of a braze joint leaking after passing visual, x-ray, leak and proof testing. Induction brazing is relatively simple and quick to perform. The joints are 100% reliable.

2.3.4.6 Aluminum Tube Welding

A. Requirements

1/ It was necessary to make reliable, leak free, joints in the aluminum tubing of the radiator. The radiator tubing was 6063-T5 while the tubing leading from the radiator manifold was 6061-T6. It was required to weld joints between 6063-T5 and 6061-T6 and between 6061-T6 and 6061-T6. These welds had to be made in-place on the radiator assembly.

B. Alternate Solutions

1/ In selecting this type of joint, a review of mechanical joints (flared fittings was conducted. It was determined that mechanical joints could not consistently meet the leak rate requirements.

C. Discussion

1/ The welding process used an insert ring of 4043 aluminum alloy between the two tubes for filler material. An Astro Arc weld head specially modified by MDAC to weld 1/4 in (.635 cm) OD aluminum tubing was used with a pulsating current power supply. The welding required the use of flux on the I.D. of the weld joint to promote proper wetting of the molten filler material. This also required flushing of the tubing after welding to remove the flux.

D. Conclusions and Recommendations

1/ This was the first use of in-place tube welding for joining small diameter aluminum tubing. Consideration should be given in the future to eliminate the use of the filler insert and flux through the development of high frequency pulsating current.

2.3.4.7 Potable Water Tank

A. Requirements

1/ A metal potable water tank was required that would contain the drinking water for the duration of the mission without leaking.

B. Discussion

The most suitable material was determined to be 320 Stainless Steel (ref. 2.3.5.14).

1/ During the biocide depletion tests it was noted that faying surfaces promoted an increase in metal ions due to crevice corrosion. The design of the tank took this into consideration and all welded joints were developed to eliminate or minimize faying surface.

Metallurgical examination of full sized tanks after development and qualification testing revealed no corrosion of the stainless steel.

C. Conclusion

1/ The water tank fabricated from 321 Stainless Steel performed satisfactorily.

2.3.4.6 Biocide Tank

A. Requirements

1/ A container was needed for the biocide solution (30,000 PPM iodine). A material had to be selected that would not adversely affect the iodine nor be attacked by it.

B. Discussion

1/ Based on the general corrosion resistance, three materials were selected for testing. These were pure titanium, 316L stainless steel and nickel base alloy Hastelloy C-276. Tests indicated that either titanium or Hastelloy C-276 were acceptable materials (ref. 2.3.5.15).

Since the container was a welded structure and contained a bellows, Hastelloy C-276 was selected due to its weldability and formability. Both of these characteristics were important since the bellows is fabricated from formed convolutions that are joined by a burn-down weld.

C. Conclusion

1/ Three iodine containers fabricated from Hastelloy C-276 performed satisfactorily.

2.3.5 Non-Metallics

2.3.5.1 Outgassing

A. Requirements

1/ Table 2.3.5.1-1 summarizes the outgassing requirements and the design criteria for the OWS. The OWS contract (CEI CP2080J1C) requires that high-vapor-pressure materials used on OWS ext rior surfaces in line of sight of optically critical surfaces conform to or be overcoated with materials designated acceptable in NASA/MSFC Dwg. 50M02442 if the surface area of the material exceeds the values given in Table 2.3.5.1-1 and Figure 2.3.5.1-1, as a function of the distance to the optically critical surface. Optically critical surfaces are defined as orbital attitude control sensors, experiment windows or experiment optics.

2/ MDAC established outgassing design criteria for the OWS exterior (MDAC Dwg. 1B79102), which are based on the requirements defined in CEI CP2080J1C. Dwg. 1B79102 limits the outgassing during the first hour in a vacuum to 0.20 percent of the material weight, and decreases this limit to 0.04 percent during the 21st hour in a vacuum. Requirements to protect optically critical surfaces from outgassing were met by (1) employing acceptable materi ls, (2) obeying the required distance versus projected area relationship given in Table 2.3.5.1-1, or (3) meeting the maximum outgassing rate design criteria (0.2 percent/hr of material weight during first hour in vacuum, 0.04 percent/hr during 21st hour). Exceptions to the third requirement (rate versus time) were shown from test data to occur prior

Table 2.3.5.1-1

MATERIALS OUTGASSING REQUIREMENTS, DESIGN CRITERIA, AND DEFINITIONS

SPECIFICATION	REQUIRES	DEFINES
CEI - CP2080J1C - OWS PERFORMANCE/DESIGN AND QUALIFICATION REQUIREMENTS	o COMPLIANCE WITH REQUIREMENTS OF DWG. 50M02442 ----- OR o DISTANCE FROM OUTGASSING SURFACE TO OPTICALLY CRITICAL SURFACE ≤ DEFINED ALLOWABLE	o ALLOWABLE DISTANCE ≥ L L, FT(m) for A, IN^2 (mm^2) 4 (1.22) — 1 (.645) 9 (2.74) — 5 (3.22) 20 (6.10) — 25 (16.1) 40 (12.19) — 100 (64.5) WHERE A IS PROJECTED AREA OF OUTGASSING MATERIAL
DWG. 50M02442 ATM MATERIAL CONTROL FOR CONTAMINATION DUE TO OUTGASSING	o MWL* RATE ≤ 0.2%/HOUR DURING TEMPERATURE CYCLING o STEADY-STATE MWL RATE ≤ 0.04% o DOES NOT STATE MAXIMUM TIME ALLOWED TO REACH STEADY-STATE	o STEADY-STATE MWL AS CONSTANT FOR 8 HOURS o TEST PRESSURE ≤ 1 X 10^{-6} TORR (≤1.33 x 10^{-4} N/m^2) o TEST HEATING RATE = 2°C/MINUTE/MINUTE
DWG. 1B79102 OUTGASSING REQUIREMENTS - ORBITAL WORKSHOP EXTERIOR	o MWL ≤ 0.20% DURING THE TIME 1.4 THROUGH 2.4 HOURS OF TEST o MWL ≤ 0.04% DURING THE TIME 20.4 THROUGH 21.4 HOURS OF TEST o TEST TEMPERATURE ≤ MAXIMUM ORBITAL TEMPERATURE OF OUTGASSING MATERIAL	o TEST PRESSURE REDUCED TO 5 X 10^{-6} TORR (6.66 x 10^{-4} N/m^2) DURING FIRST TEST HOUR o OUTGASSING MATERIAL HEATING RATE = 8°F (259.8°K) MINUTE AT START OF SECOND TEST HOUR UNTIL TEST TEMPERATURE IS REACHED
*MWL = MATERIAL WEIGHT LOSS		

SKYLAB - ORBITAL WORKSHOP
ALLOWABLE SURFACE AREA OF HIGH VAPOR PRESSURE MATERIALS

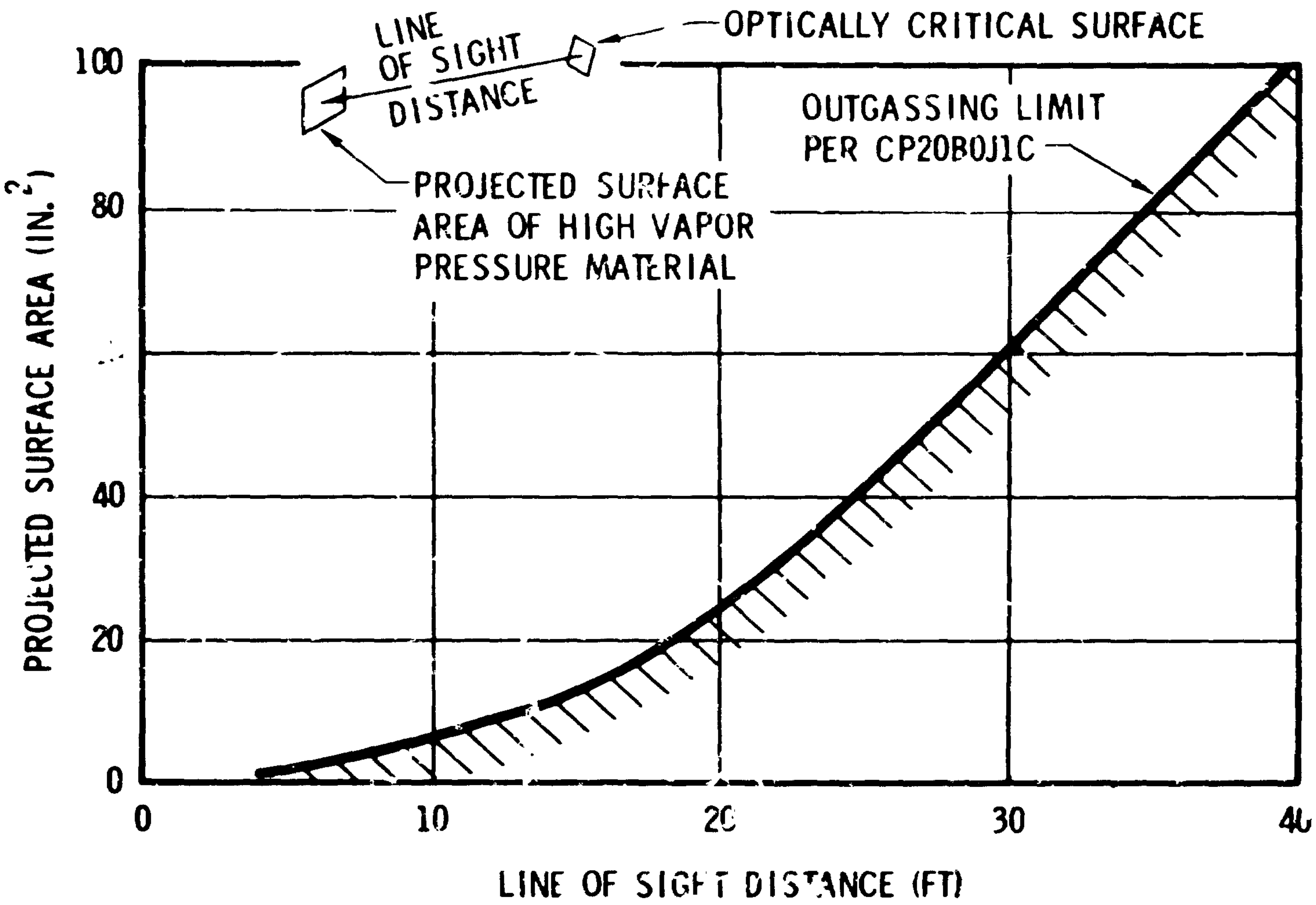


FIGURE 2.3.5.1-1

to deployment of optically critical surfaces. However, by the time optically critical surfaces are deployed, the outgassing rate is below the allowable maximum.

B. Outgassing Tests

MDAC has measured the outgassing rate of several materials used on the OWS exterior surfaces in simulated orbital conditions (Reference MDAC Report MP 51,704 (PDL 1D4397), June 3, 1970). The outgassing rate of S-13G thermal control coating, shown in Figure 2.3.5.1-2 is typical of the coatings considered. Figure 2.3.5.1-3, which is an interpretation of Figure 2.3.5.1-2, shows that the coating outgassing rate will exceed the specification required limit of 0.20%/hour during the first hour, but it will drop to below the steady-state required rate (0.04%/hour) after a few hours in orbit, many hours before any optically-critical equipment was deployed. The tests demonstrated that OWS outgassing would not contribute significantly to external contamination of the Skylab.

Outgassing of high vapor pressure materials; such as thermal control paints, silastic rubber seals, cadmium plating, and bearing grease; will occur on the exterior of Skylab. All of the outgassing contributes to external contamination. Some of the generated vapor and gas will escape, and the remainder will remain near the Skylab either in a cloud or will be absorbed on exterior surfaces. The principal surface coatings on the OWS exterior are identified in Figure 2.3.5.1-4. A tabulation of all external materials used on the OWS exterior is shown in Tables 2.3.5.1-2, -3, and -4. Amount of exposed area and rationale for use of each material is indicated.

C-6

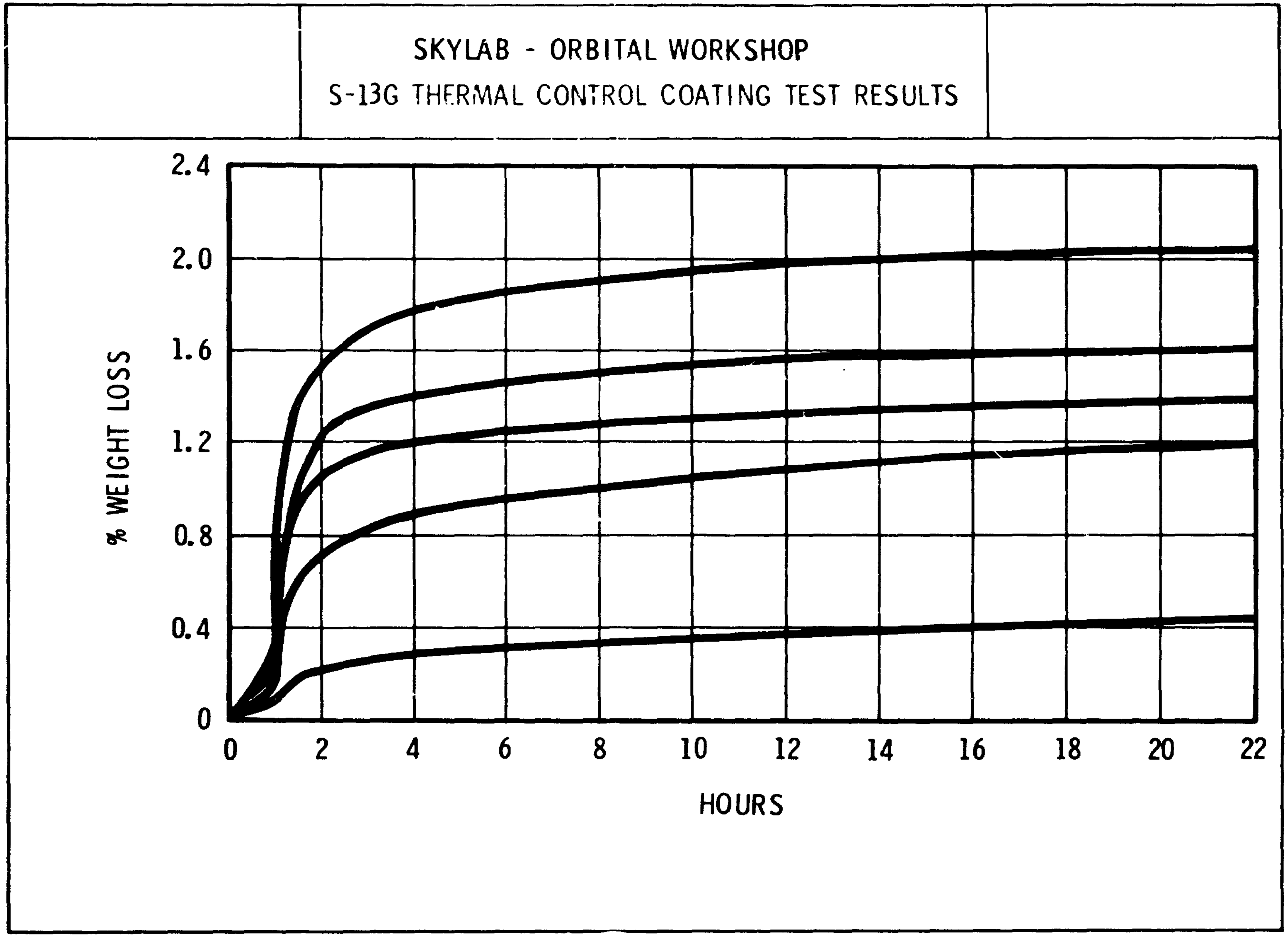


FIGURE 2.3.5.1-2

SKYLAB - ORBITAL WORKSHOP
S13G PAINT PREDICTED OUTGASSING RATE AS A FUNCTION OF TIME IN ORBIT

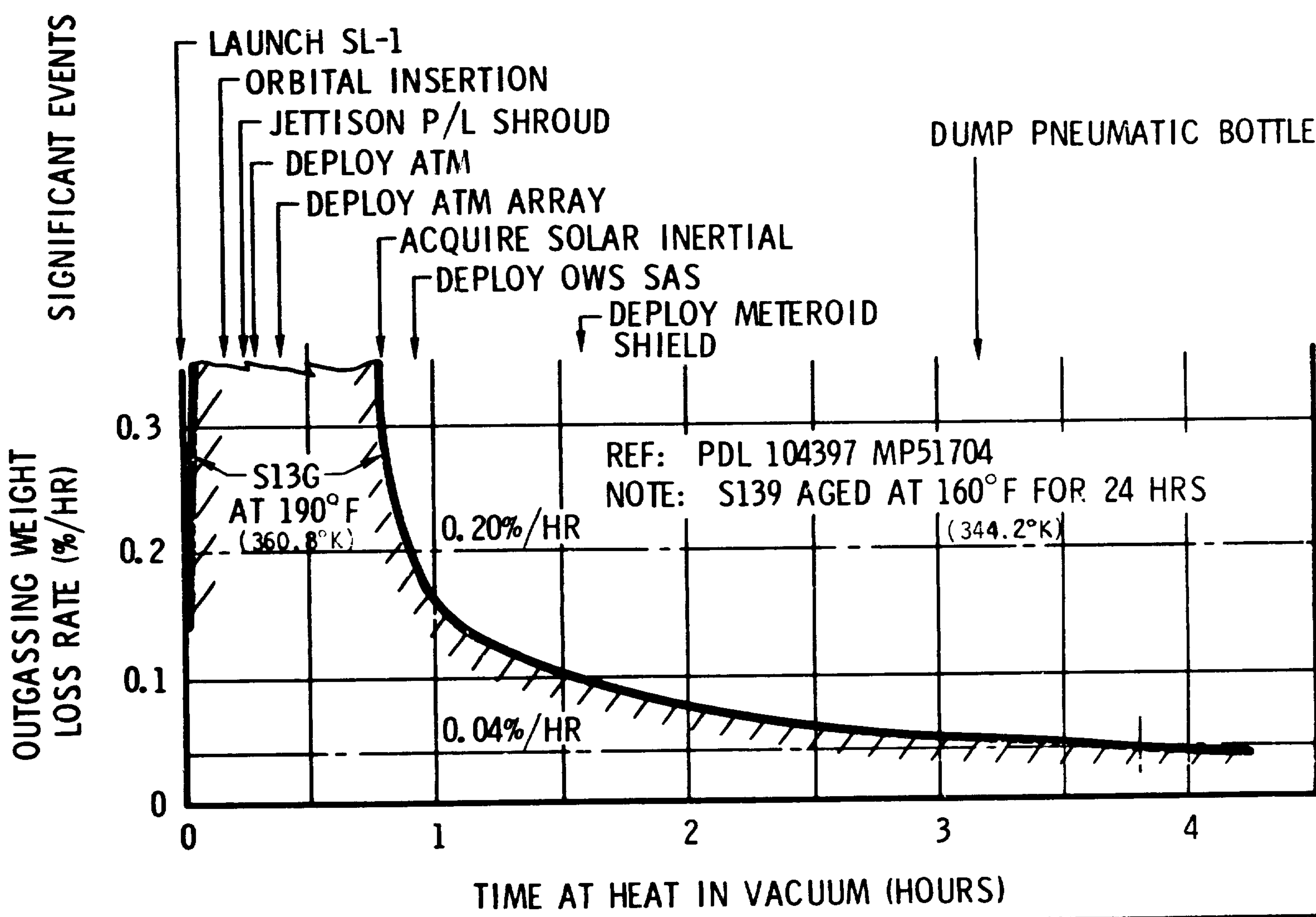
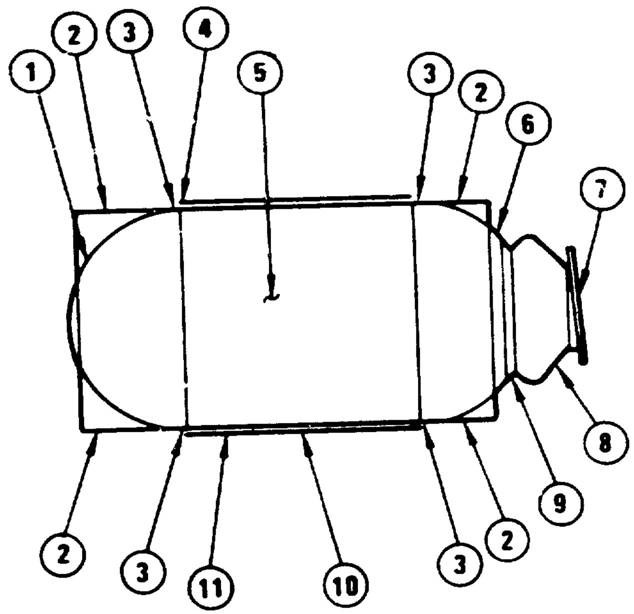


FIGURE 2.3.5.1-3

SKYLAB - ORBITAL WORKSHOP
OWS EXTERNAL COATINGS

1. FWD DOME – COVERED WITH HIGH PERFORMANCE INSULATION
2. FWD AND AFT SKIRTS:
   - INNER SURFACES – PRIMED WITH EPOXY FR PRIMER
   - EXTERIOR SURFACES – COATED WITH EPOXY CAT-A-LAC BLACK AND S-13G WHITE OVER EPOXY FR PRIMER
3. THERMAL SHIELDS – BOTH SURFACES PRIMED WITH EPOXY FR PRIMER
   - INNER SURFACE – FINISHED WITH GOLD PLATED POLYIMIDE FILM (KAPTON)
   - EXTERIOR SURFACE – FINISHED WITH EPOXY CAT-A-LAC BLACK
4. METEOROID SHIELD BOOTS –
   - INNER SURFACE – COATED WITH GREEN TEFLON S954-101 EXTERIOR SURFACE - PAINTED WITH EPOXY CAT-A-LAC BLACK
   - OVER EPOXY FR PRIMER
5. TUNNEL COVERS – BOTH SURFACES PRIMED WITH EPOXY FR PRIMER
   - INNER SURFACE – FINISHED WITH GOLD PLATED POLYIMIDE FILM (KAPTON)
   - EXTERIOR SURFACE – FINISHED WITH EPOXY CAT-A-LAC BLACK AND S-13G WHITE



6. AFT DOME – PRIMED WITH ZINC CHROMATE. FINISHED WITH GOLD PLATED POLYIMIDE FILM (KAPTON)
7. RADIATOR – EXTERIOR SURFACES COATED WITH S-13G WHITE OVER EPOXY FR PRIMER
8. TACS METEOROID SHIELD – BOTH SURFACES PRIMED WITH EPOXY FR PRIMER. EXTERIOR SURFACE FINISHED WITH EPOXY CAT-A-LAC BLACK AND S-13G WHITE
9. THRUST STRUCTURE – BOTH SURFACES PRIMED WITH ZINC CHROMATE. EXTERIOR SURFACE (NOT COVERED BY TACS METEOROID SHIELD) OVERCOATED WITH EPOXY FR PRIMER AND CAT-A-LAC BLACK
10. METEOROID SHIELD – BOTH SURFACES PRIMED WITH EPOXY FR PRIMER
    - INNER SURFACE – FINISHED WITH GREEN TEFLON S954-101
    - EXTERIOR SURFACE – FINISHED WITH EPOXY CAT-A-LAC BLACK AND S-13G
11. TANK SURFACE – FINISHED WITH GOLD PLATED POLYIMIDE TAPE (KAPTON), EPOXY CAT-A-LAC BLACK AND S-13G WHITE

2.3 54

	SKYLAB - ORBITAL WORKSHOP EXTERNAL MATERIALS REVIEW ACCEPTABLE PER 50M02442 "V"		
MATERIAL	**SPECIFICATION**	**AREA EXPOSED** in^2 (m^2)	**REFERENCE**
FR PRIMER	9708926	NONE, COVERED BY PAINT	PAGE 93
BLACK EPOXY PAINT	STM0537-01 CAT-A-LAC 463-3-8	281,500 (181.6)	PAGE 32
WARNOW INK, BLACK	STM0248	1/8 IN. (3.18 mm) HIGH LETTERS	PAGE 91
SILICONE ADHESIVE	STM0598/RTV 118	390 (.251)	PAGE 70
WHITE PAINT	STM0538 CAT-A-LAC 463-3-100	214 (.138)	PAGE 92
FLUOROGOLD	6521004	0.15 (9.68×10^{-5})	PAGE 132
NYLON GROMMETS	MS21266	10.6 (6.84×10^{-3})	PAGE 169
ADHESIVE	1P20001, LEFKOWELD 109	10.6 (6.84×10^{-3})	PAGE 70
LUBRICANT	APIEZON GREASE L	TRACE	PAGE 128
TEFLON	AMS3651	2.3 (1.48×10^{-3})	PAGE 132

TABLE 2.3.5.1-2

SKYLAB - ORBITAL WORKSHOP
EXTERNAL MATERIALS REVIEW
ACCEPTABLE PER CEI SPECIFICATION

DWG NO.	TITLE	MATERIAL [AREA EXPOSED – IN.^{2} (m^2)]						
		CADMIUM	S13G	RTV 1016	MIL-E-5556 PAINT	1P20067 73X INK	MIL-R-5847 SILICONE	Black Paint
1B68047	PANEL ASSY TUNNEL		2400 (1.54)					
1B68400	MET. SHIELD INSTL	2.9 (.0019)	5000 (3.23)					
1B79619	PANEL ASSY		12000 (7.74)					
1B68046	PANEL ASSY		8000 (5.16)					
1B68051	PANEL ASSY		3200 (2.06)					
1B68052	PANEL ASSY		1700 (1.09)					
1B80684	PANEL ASSY		22400 (14.45)					
1B76625	SENSOR INSTL			1320 (0.85)				1320 (0.85)
1B83531	TRANSDUCER INSTL			470 (0.30)				470 (0.30)
1B76857	PAINTING & MARKING		48100 (31.03)		85 (0.055)			
1B69669	SKIRT ASSY FWD					1/4" LETTERS (6.34 mm)	1.8 (0.0012)	
TOTAL EXPOSED AREA – IN.^{2} (m^2)		2.9 (0019)	102800 (66.32)	1790 (1.15)	85 (0.055)	1/4" LETTERS (6.34 mm)	1.8 (0.0012)	1790 (1.15)

Table 2.3.5.1-3

SKYLAB - ORBITAL WORKSHOP
EXTERNAL MATERIALS REVIEW
ACCEPTABLE PER CEI SPECIFICATION

DWG NO.	TITLE	MATERIAL [AREA EXPOSED – IN.^{2} (m^2)]					
		LUBRICANT EVERLUBE 812	PAINT TT-E-529	SILICONE SEAL	PAINTED LABELS	1P20014 SILICONE PRIMER	Red Torque Stripes
1B68047	PANEL ASSY		1/2" LETTERS *				
1B68408	MET. SHIELD INSTL	2.9 (0.0019)		590 (0.38)			156 (0.10)
1B79619	PANEL ASSY		1/2" LETTERS *				
1B68046	PANEL ASSY		1/2" LETTERS *				
1B68048	PANEL ASSY		1/2" LETTERS *				
1B68051	PANEL ASSY		1/2" LETTERS *				
1B68052	PANEL ASSY		1/2" LETTERS *				
1B80604	PANEL ASSY		1/2" LETTERS *				
1B78825	SENSOR INSTL				7.5 (0.005)	NONE	
1B83531	TRANSDUCER INSTL				17.5 (0.012)	NONE	
1B80660	SKIRT ASSY FWD					NONE	
TOTAL EXPOSED AREA – IN.^{2} (m^2)		2.9 (0.0019)	1/2" LETTERS *(1.25 cm)	590 (0.38)	25 (0.016)	NONE	156 (0.10)

Table 2.3.5.1-3 (Continued)

SKYLAB - ORBITAL WORKSHOP
EXTERNAL MATERIALS REVIEW
ACCEPTABLE PER CEI SPECIFICATION

DWG NO.	TITLE	MATERIAL [AREA-IN.^{2} (m^2)]		
		PAINT MIL-P-8793	NEOPRENE GROMMET MIL-STD-417	SILICONE GROMMET STM0396
1B76857	PAINTING & MARKING	1/4" LETTERS *		
1B77164	SKIRT ASSY FWD		2.4 (0.0015)	0.6 (0.0004)
1B78353	SKIRT ASSY AFT		1.6 (0.0010)	1.6 (0.0010)
	TOTAL EXPOSED AREA IN.^{2}	1/4" LETTERS *(.634 cm)	4.0	2.2 (0.0014)

TABLE 2.3.5.1-3 (CONTINUED)

TABLE 2.3.5.1-4

SKYLAB - ORBITAL WORKSHOP

EXTERNAL MATERIALS REVIEW

RATIONALE FOR USE

MATERIAL	USAGE	RATIONALE FOR USE
Lubricant, Everlube 812	Lubricates Met. Shield Hinge Pins	No Optical Surfaces are in Line-of-Sight.
Paint, TT-E-529	Serialization Numbers	Typical Marking is Approx. one in.^{2} (.0006m^2). All markings meet area/distance requirements of CEI.
Silicone Rubber	Circum Seal at Top and Bottom of Met. Shield	Material is postcured at 300°F (422°K) and 10^{-3} torr (.013 N/m^2) for three hours. Meets area distance requirements of CEI Spec.
Painted Labels	Transducer and Sensor Identification	Ten labels at 2.5 in.^{2} (.0016m^2) each. All labels meet area/distance requirements.
Silicone Primer	Prime Coat for Silicone Sealant	None exposed.
Paint, MIL-P-8793	Instruction Decal Lettering	Twenty decals. Lettering on typical decal is less than five in.^{2} (.0032m^2). All decals meet area/distance requirements.
Neoprene MIL-STD-417	Grommets at Penetrations	Five grommets at 0.8 in.^{2} (.0005m^2) ea. All grommets meet area/distance requirements.
Silicone Rubber STM0396	Grommets at Penetrations	Three grommets at less than one in.^{2} (.0006m^2) ea. All grommets meet area/distance requirements.

TABLE 2.3.5.1-4 (Continued)

SKYLAB - ORBITAL WORKSHOP

EXTERNAL MATERIALS REVIEW

RATIONALE FOR USE

MATERIAL	USAGE	RATIONALE FOR USE
Red Lacquer Torque Stripes DPM 3029	Torque Stripes at Bolted Connections	Rates are within limits at time of deployment of optical surfaces. Ref. Attachment I.
Cadmium	Plating on Met. Shield Hinge Pins	Temperature is less than 250°F (394°K). Ref. PM-SL-SW-669-71, 6-11-71. Ref. A3-250-AAAA-M-141, 8-4-71.
S13G Paint	Thermal Control Coating	Rates are within limits at time of deployment of optical surfaces. Ref. P0327 Supp No. 10501.
Silicone Sealant RTV 1016	Covers Wiring Installations	Rates are within limits at time of deployment of optical surfaces. Ref. Test Data Sheet No. 95804, Sept. 1970.
Paint, MIL-E-5556	Index Marks for Alignment of Interstages with OWS	Six index marts are exposed. Three fwd at 12 in.^{2} (.0062m^2) ea, three aft at 16 in.^{2} (.010m^2) ea. All index marks meet area/distance requirements of CEI Spec.
Warnow 73X Ink	1/4" (634 cm) Letters for Identification Marking	Typical marking is less than one in.^{2} (.0006m^2). All markings meet area/distance requirements of CEI Spec.
Silicone Rubber MIL-R-5847	Circum Seal on Recessed Cover	Edge only is exposed. No optical surfaces are in line-of-sight.
Black Paint Cat-A-Lac 463-3-100 No Heat Cure	Covers Wiring Installations (Over RTV 1016)	Rates are within limits at time of deployment of optical surfaces. Ref. Attachment II.

Attachment I to:
Table 2.3.5.1-4

ORBITAL OUTGASSING RATE OF MARKING LACQUER (DPM 3029)

This attachment provides data that confirms that the outgassing rate of marking lacquer on the antisolar and solar sides of the OWS meets the specification requirements before optically-critical equipment is deployed in orbit. The antisolar side is in the shade when the Skylab is in the SI attitude, but has limited exposure to sunlight during two other Skylab attitudes; rendezvous and earth resources experiment package (EREP). Outgassing on the "hot" (solar) side surface is not as critical as the antisolar side since the continuous heating on the "hot" side results in the outgassing rate decreasing to a value below the specified limit prior to deployment of optically-critical items.

Outgassing is most critical adjacent to the two scientific airlocks (SAL) through which optically-critical equipment is deployed. One SAL is located on the OWS solar side at fin plane 1 (-Z axis), and the other SAL is at fin plane III (+Z axis).

Thermal analyses were made to determine the temperature history of the OWS surfaces adjacent to the SALs during boost and in orbit through the first EREP maneuver. Tests to simulate orbital outgassing rates were then conducted in a vacuum chamber using the analytically defined heating schedules. The predicted orbital outgassing rate of marking lacquer is shown in Figure 1 for the -Z axis, and in Figure 2 for the +Z axis. Both of these figures show that the outgassing rate of marking lacquer decreases below the maximum allowable rate ($0.2\%/cm^2$-hr) in less than one hour after launch, long before the deployment of the first optically-critical equipment that is in line-of-sight of the outgassing surfaces.

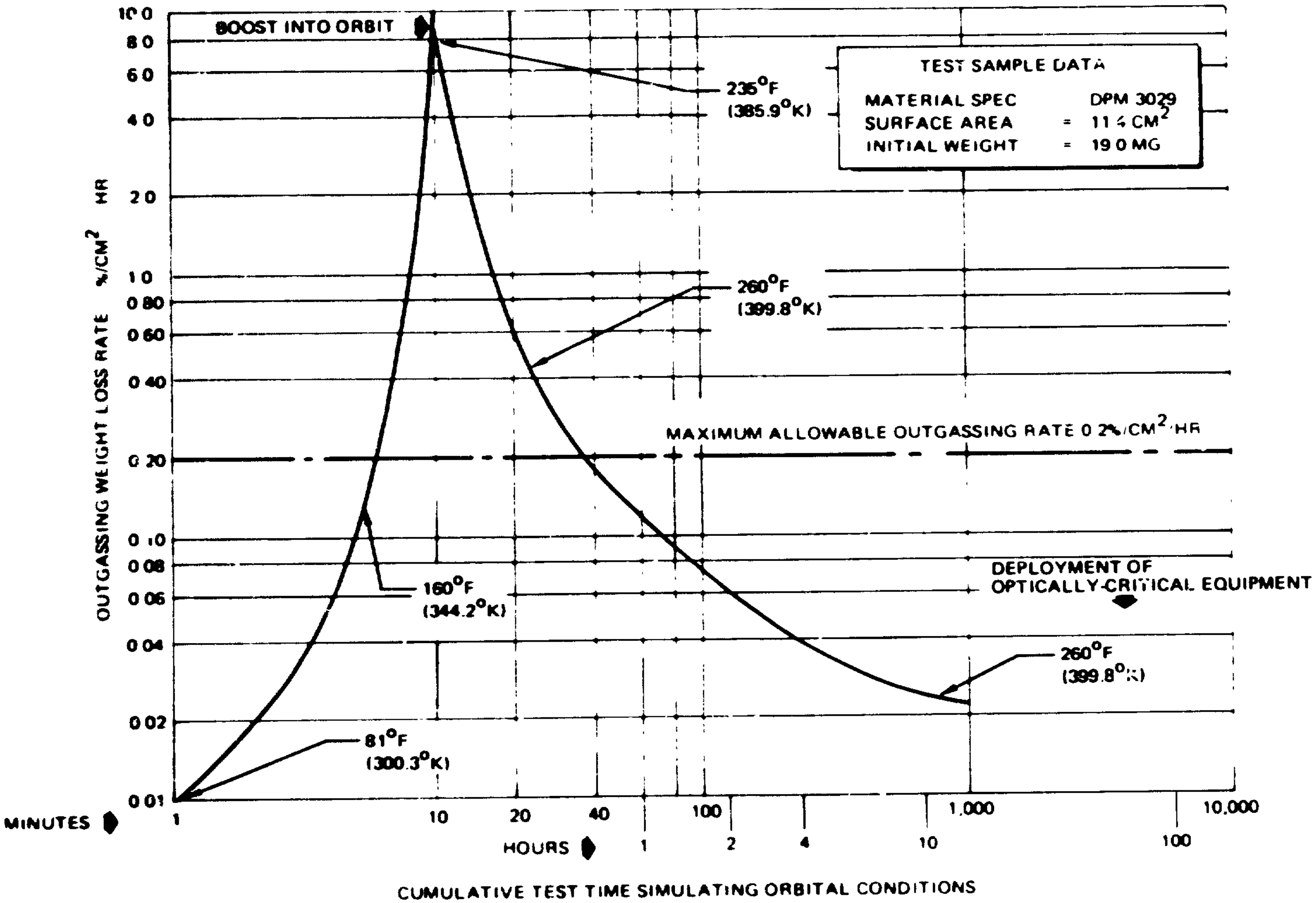


Figure 1. Marking Lacquer Outgassing Test Simulation of OWS Exterior Orbital Conditions Adjacent to the Solar SAL (-Z Axis)

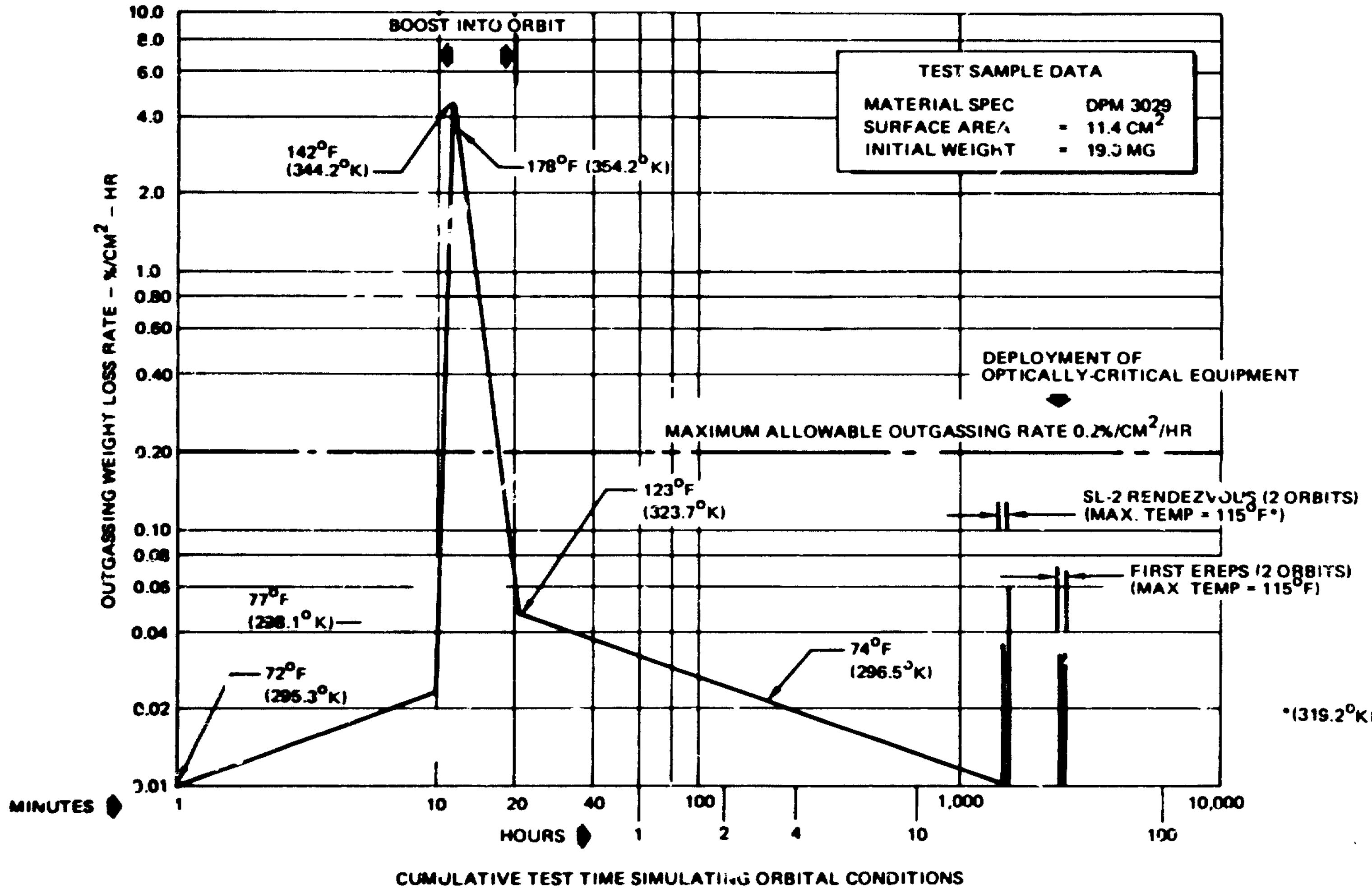


Figure 2. Marking Lacquer Outgassing Test Simulation of OWS Exterior Orbital Conditions Adjacent to the Antisolar SAL (+Z Axis)

Attachment II to:
Table 2.3.5.1-4

ORBITAL OUTGASSING RATE OF BLACK EPOXY PAINT (DPM 4272)

This attachment documents justification for the use of black epoxy (Cat-a-lac) paint, that has not been heat-aged, on the exterior surfaces of the Orbital Workshop.

CEI Specification, CP2080J1C, requires that the material weight loss rate of each outgassing surface shall be less than 0.2%/[illegible]-cm^2, or that the distance from the outgassing surface to the nearest optically critical surface shall comply with the area-distance rule shown in Figure 1.

The outgassing characteristics of OWS surfaces adjacent to the solar SAL (+Z axis) and the antisolar SAL (-Z axis) were evaluated because they are close to optically-critically-critical equipment and they represent the extreme temperature conditions for the normal Skylab orbital attitude (solar inertial). All other OWS exterior surfaces have temperature histories that lie between these extremes. Demonstration that the outgassing of black epoxy, without heat aging, is acceptable at the extreme conditions also demonstrates acceptability at all other OWS exterior surface locations.

The +Z axis surface is hottest and outgasses at the highest rate initially, decreasing rapidly as the volatile constituents are driven off. The -Z axis surface is coldest and outgasses at the lowest rate, retaining volatile constituents for the longest time. When the Skylab attitude is changed for rendezvous or earth resources experiments, the -Z axis surface temperature increases to an intermediate value with a corresponding increase in its outgassing rate.

Tests of black epoxy painted surfaces were conducted to determine their outgassing rates in an environment simulating these operating conditions. The simulation test data for the solar SAL and the antisolar SAL are plottted in Figure 2. For each of these tests, the specimens were maintained at room temperature during the first hour while the test chamber pressure was reduced to less than 6 x 10^{-6} torr (7.99 x 10^{-4} N/m^2) (mm Hg). Then, in each test, the sample temperature was raised rapidly to the maximum test temperature and maintain at this temperature for the remainder of the test.

Figure 3 shows the maximum vacuum outgassing rate of black epoxy (not previously heat-aged), as a function of the maximum surface temperature. The data points on this curve represent the peaks on the curves in Figure 2. This curve indicates that the outgassing rate will never exceed the maximum allowable, if the peak surface temperature does not exceed 180°F (355.3°K). At any given maximum temperature, the outgassing rate decreases rapidly from the maximum value, as shown on Figure 2.

The test results indicate that, adjacent to the solar SAL, outgassing will decrease to below the maximum allowable (0.2%/hr-cm^2) in about 25 minutes. Since no optically-critical equipment in line-of-sight of these surfaces is deployed until many hours later in orbit, the use of black epoxy paint in this location meets the requirements specified.

The test simulating outgassing adjacent to the antisolar SAL showed that the maximum outgassing rate of black epoxy will not exceed the maximum allowable during boost [178°F (354.2°K), Figure 3], or in orbit [120°F (322°K), Figure 2]. Therefore, the use of black epoxy paint in the vicinity of the antisolar SAL meets the requirements specified.

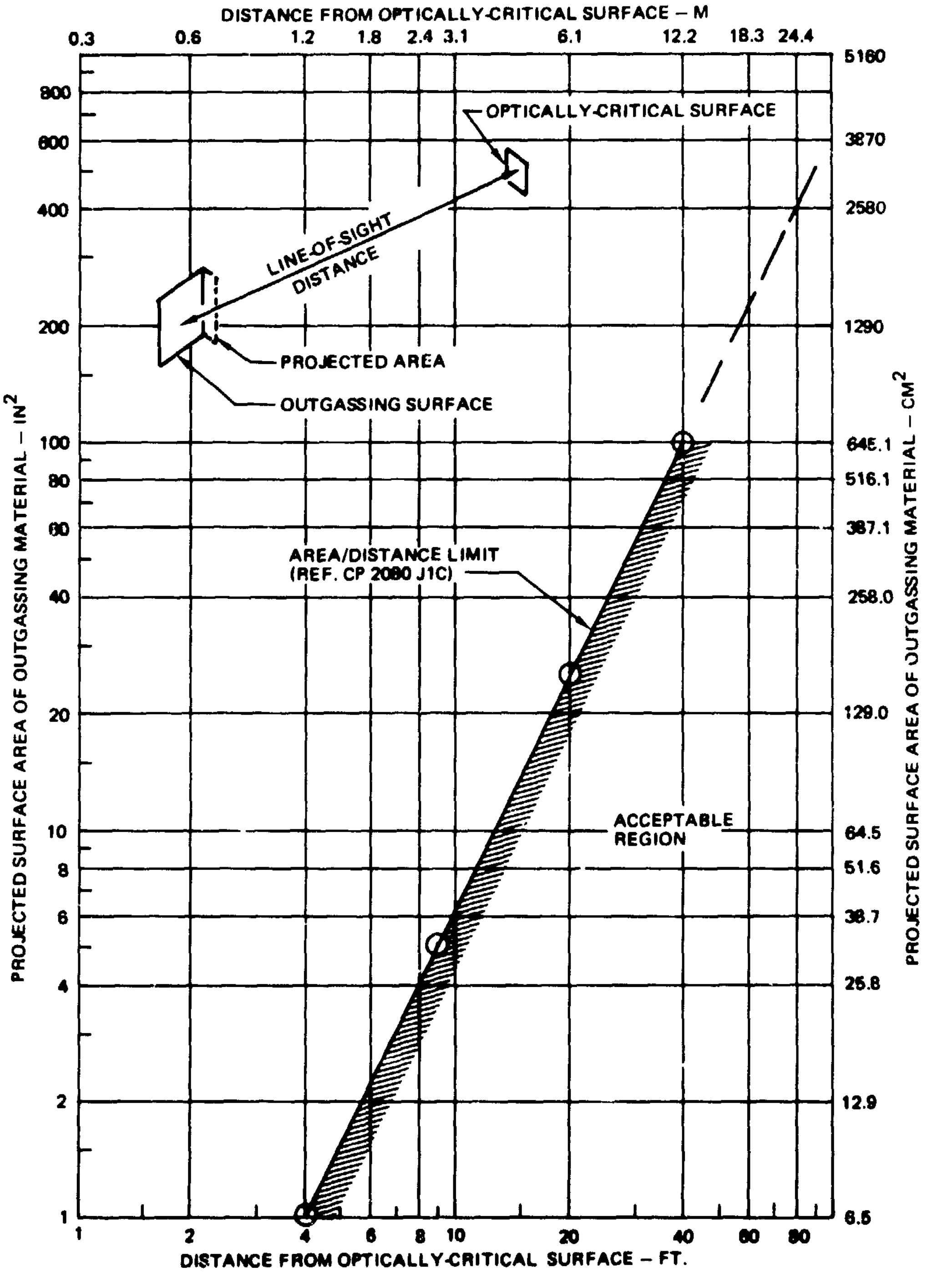


Figure 1. Allowable Area of Outgassing Surface Versus the Line-of-Sight to an Optically Critical Surface

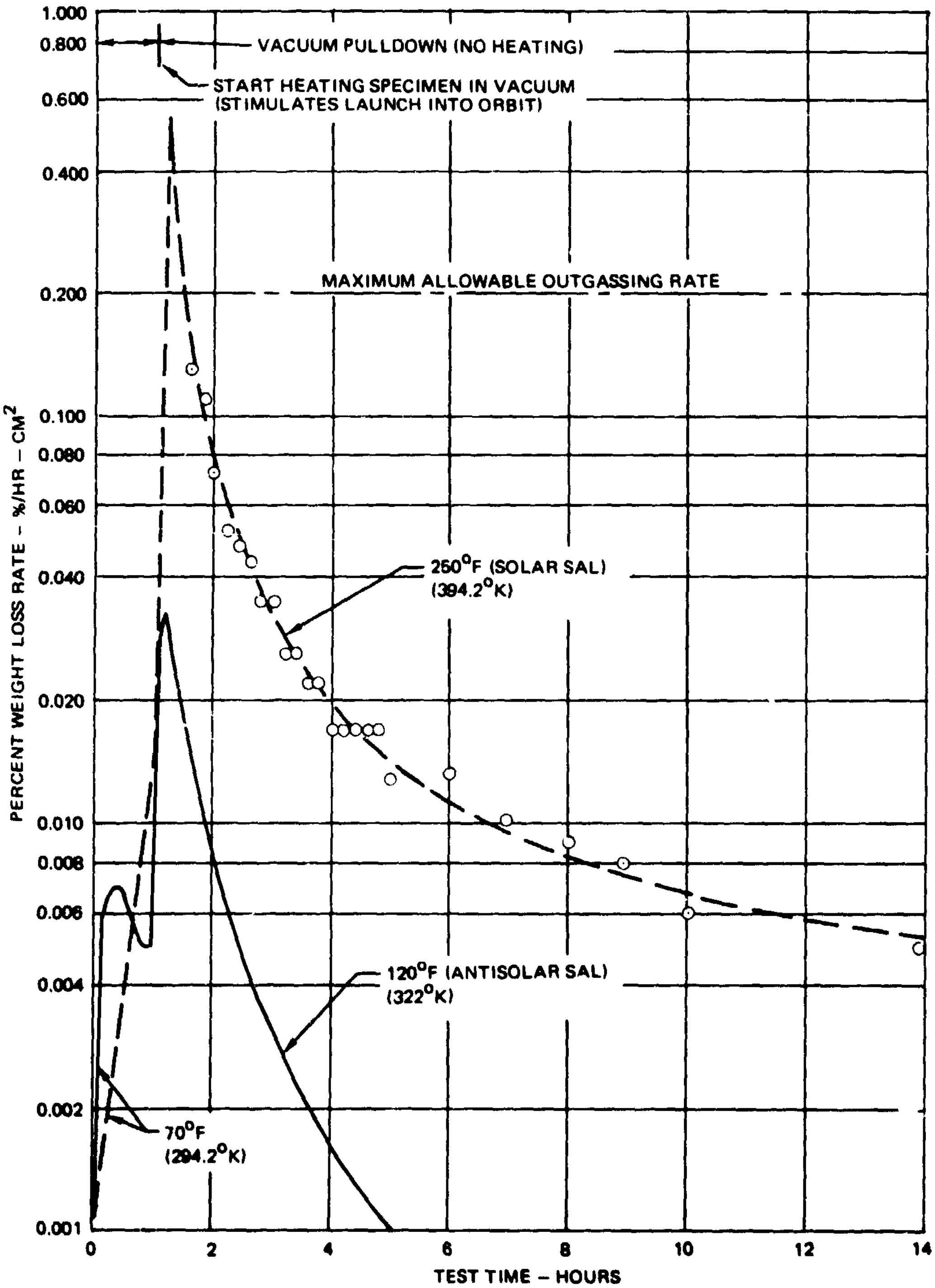


Figure 2. Black Epoxy (Cat-A-Lac) Outgassing Weight Loss Rate Data

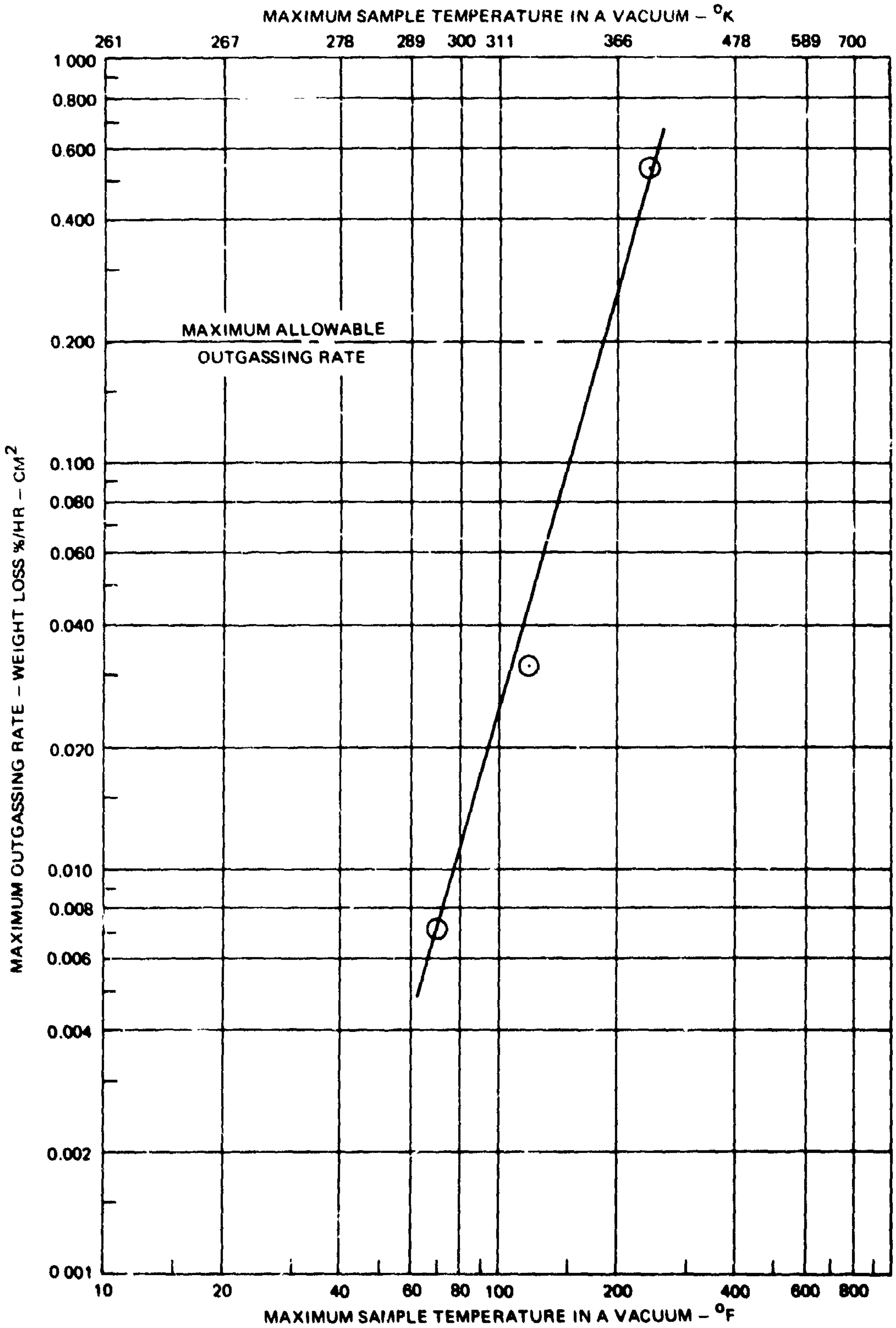


Figure 3. Maximum Outgassing Rate of Black Epoxy Coating as a Function of Maximum Surface Temperature

2.3.5.2 Teflon coating on Interior Fire Retardant Liner - The aluminum foil fire retardant liner used on the interior of the OWS was coated to meet contract requirements (CEI CP2080J1C).

A. Design Requirements

1/ Provide high emittance

2/ Have a color acceptable to crew systems

3/ Have abrasion resistance

4/ Be non-flaking

5/ Be easily cleaned in orbit

6/ Be non-toxic

7/ Meet flammability and offgassing requirements of MSFC-SPEC-101A

8/ Be compatible with LH_2 (liquid hydrogen)

NOTE: This was a requirement for the "wet" Workshop only.

B. Other Materials Considered

1/ The following coatings were considered and discarded for the reasons noted:

a. A MDAC developed silicate base inorganic paint with zinc oxide pigment was not acceptable because of excessive flaking when exposed to LH_2.

b. Alodine 407-47, a green chemical conversion coating was not used because the color not acceptable to crew systems and because it reduced the light level.

C. Tests - A low temperature contraction test proved that the Teflon coating did not affect the physical properties of aluminum foil when it was immersed in LH_2.

2.3.5.3 Color Anodizing - The majority of the interior aluminum structures (floors, walls, cabinets, etc.) were color anodized.

A. Design Requirements

1/ Provide high emittance

2/ Provide colors acceptable to crew systems

3/ Be abrasion resistant - non-flaking

4/ Be non-toxic

5/ Meet offgassing and flammability requirements of MSFC-SPEC-101A

6/ Be compatible with liquid hydrogen

B. Finishes considered before anodizing was selected - The following coatings were considered and discarded for the reasons noted:

1/ Inorganic paints (Micatex) were found to generate particles when bumped by other equipment

2/ Epoxy paints did not meet offgassing and flammability requirements of MSFC-SPEC-101A

NOTE: Laminar X-500 polyurethane coating was used on the upper ring locker doors to replace Micatex after it was found that the doors chipped around the edges during usage. This material was selected because it had previously been approved for use in the Airlock.

C. Conclusions and Recommendations - The anodic coating met all the major requirements; however, the colors could have been more uniform. One of the problems associated with anodic colors is the lack of uniformity between the same color on different alloys, and in some cases, between different panels of the same alloy. In general, the larger the quantity of alloying constituents, the more difficult it is to get uniform colors. Since color anodizing is more of an art than a science, it should be accomplished in shops which have experience in the successful application of colors. The selection of colors which have been successfully applied throughout the aluminum industry should also be considered. Continued use of colored anodic coatings for future habitated spacecraft is recommended for basic structures which require impact and wear resistance; however, the use of low offgassing, flame resistant coatings for accent colors should be considered.

2.3.5.4 Bonding Snaps - There was a need to bond numerous snaps to surfaces inside the Workshop.

A. Requirements - Adhesive strength requirements were interpreted as being the ability to hold the snap in place while being subjected to numerous cycles of snapping and unsnapping.

B. Initial Selections

1/ The initial adhesive selected was Mystik G360 double-faced tape. This material worked satisfactorily so long as all snapping and unsnapping was performed using nominal care; however, when the unsnapping was done in a particularly jerky manner, the snap would fall off.

2/ The next adhesive selected was Hysol's EA911F epoxy. This material was acceptable except when the snap was being bonded to a relatively flexible surface, where the bonded snap would just peel away.

3/ A total of nine adhesives were evaluated for this application using three sizes of bond area for the snap with optimum performance found in 1P20075 polyurethane adhesive. The 1P20075 polyurethane adhesive was used for this application.

C. Recommendations - For future applications it is suggested that wherever possible the snaps be riveted in place instead of adhesive bonded.

2.3.5.5 Bonding Foil Labels - Initially 3M's Scotch 465 acrylic based adhesive transfer tape was used to attach aluminum foil labels.

A. Problem

1/ Two problems were encountered with the Scotch 465; on removing the paper backing from the back of the label, the adhesive at the starting edge of the label was destroyed, and the foil itself at the starting edge was stretched or deformed causing a peeling edge effect in the installed label.

B. Resolution

1/ To resolve this problem the paper backing was split across the middle of the label so that the backing could be peeled away from the center of the label toward the edge. This solution resolved the destruction of the adhesive at the edge of the label but did not eliminate the peeling edge effect. The problem was finally resolved by changing to Scotch 583 solvent activated adhesive. The high adhesion of the Scotch 583 overcame the tendency of the label edge to peel away.

2.3.5.6 Low Emittance Surface on Tank Wall Exterior - The exterior wall of the OWS was coated with goldized Kapton.

A. Design Requirements

1/ Provide low emittance surface in space vacuum

2/ Have essentially zero outgassing rate in space vacuum

3/ Be unaffected by contact with interior of the meteoroid shield

4/ Be resistant to atmospheric corrosion

B. Alternate Finishes Considered - The following coatings were considered and eliminated for the reasons stated:

1/ Lock-Spray Gold, a two component system which deposited a gold film on metal or non-metal substrates. This did not coat aluminum foil easily nor uniformily. It also used hydrazine as a reducing agent, thus presenting a safety hazard, especially when used to cover large areas.

2/ Gold coated ceramic coating was applied to aluminum foil. The corrosion resistance of the foil was very low as shown by complete failure of the foil in less than two (2) hours in a salt spray cabinet.

3/ Stainless steel and nickel foil were both used as substrates for gold plating. Although both plated satisfactorily, the emittance was marginal, and these coated foils were very difficult to bond to the tank wall because they were quite stiff.

4/ The concept of applying a gold coated pressure sensitive tape was investigated next. Several manufacturers of pressure sensitive tapes were consulted on the availability of a gold coated pressure sensitive tape capable of meeting the temperatures, environment, emittance, and low outgassing requirements of the

Workshop exterior. The two resulting candidate materials were 3M's Y9184 Goldized Kapton pressure sensitive (P/S) tape and Mystik 4017 (also known as PD550) gold coated Kapton P/S tape. Initial evaluations of the two tapes eliminated the Y9184 tape because of the extremely poor adhesion of the gold coating. The Mystik 4017 was tested in the as-received condition and met all functional requirements. It was subsequently subjected to long term outdoor exposure, hi-temperature exposure, hi-vacuum exposure, and hi-humidity exposure to determine any degradation in required properties. Mystic 4017 passed all tests successfully.

2.3.5.7 Exterior Paints - S-13G, White and Black Cat-a-Lac - S-13G, white and black Cat-a-Lac were used on the exterior of the OWS.

A. Design Requirements

1/ Meet the absorbtance and emittance requirements established by Aerothermo group to maintain acceptable temperature range within the Workshop

2/ Meet the outgassing requirements of MSFC Drawing 50M02442

3/ Meet the and requirements after long exposure to space environments.

4/ Protect stage from corrosion prior to launch.

5/ Low enough cure temperature to prevent damage to stage components.

B. Other Materials Considered

1/ Z-93 silicate coating was not acceptable because it was difficult to apply uniformly over uneven surfaces, and it required a cure temperature above 300°F. The cured coating could be easily damaged and was very difficult to repair. It was easily contaminated, and difficult to clean. It could be damaged by water exposure.

The finishes used on the exterior of the OWS were selected because of their thermal properties and low outgassing. All these materials had been successfully used on other space flights, and all were listed in 50M02442. In addition, extensive evaluation of the potential contamination by offgassing of the S-13G was submitted to NASA on P0327 Form, Supplement No. 10501.

2.3.5.8 Elastomeric Seals

The elastomeric seals within the workshop can be divided into two general categories.

1. Those seals used to seal the workhop interior from the evironment of space, and
2. Seals within internal systems in the workshop.

A. Requirements

For seals used to seal off the space environment, the primary requirements were:

1/ Low permeability to gases

2/ Good vacuum stability

3/ Ability to withstand service conditions

4/ Ability to meet the flammability and offgassing requirements for workshop interior

5/ Ability to meet the outgassing requirements for workshop exterior when in direct line-of-site of optical surfaces.

B. Seals Discussion

Fluorocarbon rubber seals were used for all subject seals. For the hatch and the access door seals a 75 shore A durometer flame resistant fluorocarbon elastomer per STM 0564-010302 was used. The O-rings used for the primary seal of the window was made from a 75 shore A durometer fluorocarbon elastomer meeting the outgassing requirements of 1B79102. This material was per STM 0601-010101. The window seals were also subjected to a thermovacuum bake of 48 hours at 400°F (477.6°K) and 10^{-3} torr further improve its outgassing characteristics.

C. Sealing Systems

The three basic systems within the workshop that required sealing were:

a. The water system

b. The refrigeration system

c. The waste management system

1/ A primary requirement for any elastometers used in contact with drinking water was that they meet the FDA requirements of "Food Grade Rubber." Initially all these seals were made from food grade Viton per STM 0592-010304. This material does not meet the flammability requirements of 1B70110, but since it is totally enclosed and in water this was not significant. During qualification testing it was found that in several applications the compression set of the food grade Viton was too high and caused minor leaks. The affected seals were replace with food grade silicone O-rings per STM 0592-010204 and the system worked very satisfactorily. Wherever O-rings were used in this system and were not in contact with the water, low compression set Viton per MIL-R-83248 was used.

2/ In the refrigeration system, Coolanol-15 compatibility was of primary significance. For this application fluoro-silicone seals per MIL-R-25988 were satisfactorily used.

3/ In the waste management system, since the seals would be effected and disengaged very often it was decided that it was essential to use an elastomer which possessed optimum compression set characteristics, addition to the other functional requirements. Low compression set Viton per MIL-R-83248 was successfully used in all applications except for the outboard hatch of the trash airlock. In this application it was necessary to use a very soft elastomer, 30-40 shore A, to allow a seal to be effected with the available compressive load. A silicone elastomer seal was successfully used in this application.

2.3.5.9 Velcro

Velcro fasteners were used in numerous applications throughout the workshop.

A. Requirements

1/ On the exterior of the workshop Velcro Corp.'s HAQ12-1 hook (Nomex Tape with nylon hook) and HAQ12-2 pile (Nomex tape with Nomex pile) were used successfully and met the flammability requirements of being non-flammable in air.

2/ For the interior of the workshop, the only Velcro products to meet the flammability and outgassing requirements of 1B78110 were P537 pile (Fluorel coated beta glass tape with etched TFE pile) and H5T2 hook (Fluorel coated Beta glass tape with PBI hooks).

B. Usages

1/ After May 1971 the H572 hook [.006 in. (.152 mm) diameter PBI fiber] was replaced by H616 PBI hook [.008 in (.203 mm) diameter PBI fiber], by the suppliers own volition.

2/ Toward the end of the OWS program a shorage of PBI fiber occurred and the H616 hook tape had to be replaced with H549 polyester hook tape.

2.3.5.10 Foam Insulation on the Common Bulkhead

A. Tests

An unreinforced polyurethane foam panel with aluminum foil outer liner representing a candidate insulation system for the common bulkhead was fabricated and submitted to NASA MSFC for flammability testing. During the pressure reduction cycle for the flammability test, the test panel foam disintegrated. A test program was then initiated to test various designs of foam reinforcement which would withstand the OWS pressure reduction without structure failure of the polyurethane foam. Three basic configurations of foam (unreinforced, 3-D reinforced and 1-D reinforced) with 181 glass cloth liner on the foam and .005" aluminum foil forming the outer skin, were tested under a simulated OWS pressure blow down cycle. Both the 3-D and the 1-D reinforced foam successfully withstood the test. The 1-D reinforced system was selected and used on the OWS. The results of the evaluation tests were reported in MDAC Technical Memorandum No. TM 138, dated January 15, 1971.

2.3.5.11 Shatterproof Gauge Glass

A. Requirements

It was required to have a shatter-proof cover-glass for the gauges in the workshop. The use of shatterproof transparent plastic materials such as acrylics and polycarbonates was disregarded because none of these met the flammability requirements of 1B78110.

B. Discussion

A clear, pressure sensitive FEP Teflon film [.0035 in (.088 mm) total thickness] was found which, when applied on the glass, met the flammability and functional requirements of the application. The selected material was RV-CT-91 "Tuf-Gard" fabricated by Arvey Corp., Lamcet Div. MDAC Material Specification STM 0606-01 was written around this material.

2.3.5.12 Webbings

Webbings were required for use in numerous restraint applications throughout the OWS.

A. Requirements

1/ The initial candidate webbing materials investigated were polybenzimidazole (PBI), Teflon coated beta glass and Fluorel coated beta glass. The PBI webbings (Fabrics Research Labs No's. S101, S103, S141 and S143) did not meet the flammability and outgassing requirements of 1B78110.

2/ The Teflon coated beta glass webbing (Haver Industries No. 99-00075) would not function properly when used with buckles and did not meet flammability requirements. The Fluorel coated beta glass webbing (Raybestos Manhattan RL 3003) met all requirements but was rejected by the crew due to excessive shedding of the Fluorel coating.

B. Selection

1/ The webbing finally selected was Raybestos Manhattan's RL 4480 which consisted of a .010 in (.254 mm) thick layer of urette fabric (Monsanto's flame retardant treated aromatic nylon) sandwiched between two .012 in (.305 mm) thick layers of Raybestos Manhattan's Fluorel L3203-6. All cut ends were covered with tips molded of L3203-6 for ease of insertion into buckles as well as to meet the flammability requirements. This webbing met all flammability, outgassing and functional requirements.

2.3.5.13 Coolanol 15 Precipitate - Coolanol 15 was selected as the heat exchange fluid in the OWS refrigeration system.

A. System Test

1/ During a cold test run of a simulated refrigeration system, a significant pressure drop across the filter was noted. Disassembly showed that the filter was clogged with material that was principally water.

2/ To establish the maximum amount of water that could be tolerated by the system, a series of tests were run using Coolanol 15 with various percentages of water. As a result of these tests 0.006% by volume of water was established as the maximum allowable amount.

B. Test Results

1/ In working with various batches of Coolanol 15, it was found that some batches contained a gelatinous precipitate which was identified as silicic acid, a product resulting from the reaction of water with the silicate ester, the principal ingredient of Coolanol 15.

2/ Laboratory tests were conducted to establish the amount of water which could be tolerated without causing the hydrolysis reaction. It was established that Coolanol 15, which met the water content limit required to prevent ice blockage of the filter, would not form silicic acid under any of the conditions used in the tests.

3/ It was found that excess water could be removed by circulating the Coolanol 15 within the servicer while maintaining a dry nitrogen purge through the evacuated ullage of the reservoir. All coolant used for the OWS was dried before it was introduced into the refrigeration system.

2.3.5.14 Water and Biocide Storage Tanks

A. Requirements

1/ The water storage tank was required to contain an aqueous solution of iodine in the concentration range of 2-12 parts per million (ppm). If the iodine content dropped below 2 ppm, it was to be replenished with an injection of 30,000 ppm iodine from the biocide storage tank. Potassium iodide was also present to facilitate the preparation of concentrated iodine solutions. Both tanks had to have a very slow reaction rate with their contents and be resistant to any localized attack such as pitting corrosion that could cause leakage. Furthermore, materials had to be selected that would generate only minimal amounts of iron, nickel, and chromium ions during the expected corrosion reaction.

B. Water Tank Testing

The testing can be divided into materials screening and tank qualification.

1/ Screening - Two types of screening tests were performed: Coupon tests, using high concentrations of iodine, small specimens, and elevated temperatures; and subscale tank tests using tanks made of the most promising materials (304, 316, 321 and 347 stainless) and having a volume of approximately 12 liters.

2/ Tank qualification - Based on the tests listed above, as well as weldability and strength considerations, 321 stainless steel was chosen for the tanks. A series of tests were carried out in full-sized tanks to measure iodine depletion and corrosion rate, and to characterize the corrosion products.

C. Test Results

1/ The above tests showed that the average rate of reaction of the internal tank surfaces is less than one microinch per year.

2/ This rate of reaction results in iron, chromium, and nickel corrosion products exceeding the specification limits within a few months.

3/ The rate of depletion of iodine in the tank is such that replenishment is required before completion of the mission.

4/ The reaction rate of the tank surfaces and the iodine depletion are approximately linear, indicating that the characteristics of the passive layer on the metal surface do not change significantly.

5/ No corrosion was visible on the metal surfaces after 8 months.

2.3.5.15 Biocide Tank

A. Testing

1/ Small volume (400 cc) bellows tank storage containers and accelerated coupon tests were run on candidate materials, including 316 L stainless steel, Hastelloy C-276 alloy, and titanium. The 30,000 ppm iodine concentration depleted to zero in the 316L containers in a 57 day test. Hastelloy C-276 and titanium showed low depletion rates.

B. Selection

1/ Hastelloy was selected for the biocide container since bellows made of this material could be easily fabricated. Also, the use of titanium was prohibited by MSFC-Spec 101A.

2.3.5.16 Water Purification by Ion Exchange

A. Requirements

1/ Due to a slight reaction between the water and the metal storage tanks and the downstream lines, the allowable metallic ion concentrations would be exceeded within a few months after the tanks were filled. The maximum allowable ionic concentrations in parts per million (ppm) were (per

MSC-SPEC PF-1): iron, 0.3; chromium, 0.05; and nickel, 0.05. A method to purify the water was required.

B. Discussion

1/ The installation of an ion exchange bed was the only feasible way of purifying the water. The main problem was the selection of a cation exchange bed that would remove the unwanted metallic ions but not the biocide (iodine).

C. Cation Exchange Resin Selection and Tests

1/ Several different types of cation exchange resins were tested to determine the most suitable type for the Skylab ion bed. Resins tested were:

a. Rexyn AG 53 cation exchange gel; weak acid, synthetic inorganic ion exchanger.

b. Amberlite IRC-50 cation exchange resin; weak acid ion exchange resin.

c. Amberlite IR-120 cation exchange resin; strong acid sulfonated polystyrene resin.

d. Bio-Rad AG 50W-X8 cation exchange resin; stong acid sulfonated polystrene resin.

e. Chelex 100 cation exchange resin; weak acid resin

Tests were performed on the above resins to:

a. Determine what depletion of the iodine biocide resulted when the water containing it was passed through the resin.

b. Determine the efficiency of the resins for removing iron, chromium and nickel ions.

c. Determine the change in pH of the water when passed through the resin.

D. Test Results and Usage

1/ Test results showed that the most satisfactory cation exchange resins were strong acid types such as Amberlite IR-120 and Bio-Rad AG50W-X12. (Reference MP Report 51,940 [PDL 104859]).

2/ Further testing, and conversations with personnel in Dow Chemical Company and other companies producing cation exchange resins, indicated that a rigid (highly cross-linked) form of strong acid resin, synthesized using styrene and 12% divinylbenzine, was best for the Skylab water system. A specially purified form of a suitable resin, designated Bio-Rad AG50W-X12, obtained from Bio-Rad Company, 32nd and Griffin Ave., Richmond, Calif. 94804, was chosen. This resin is Dowex 50W-X12 resin, synthesized by Dow Chemical Company, Midland, Michigan, which has been extensively treated by Bio-Rad to reduce contaminants to low levels, and has been converted to the potassium form.

3/ For maximum metallic ion removal with minimum pressure drop, a size range for the ion exchange resin of 20 to 50 mesh was chosen. The size of the cartridge was chosen to give the greatest possible depth for passage of the water, since conversations with experts at Dow had indicated that poor efficiency of metallic ion removal might otherwise occur.

4/ Preliminary testing of the ion exchange resins indicated that they would all remove iodine biocide from the water. Since the specifications for water system performance require that iodine biocide be present at the outlet from the water system, an iodine pretreatment step was added to decrease the tendency of the resin to remove iodine. This step involves flowing an iodine solution of 100 ppm concentration through the filled cartridge for several days, and then flowing a low concentration iodine solution through until the effluent iodine concentration has dropped to an acceptable level.

5/ Long-term tests were performed on the ion exchange cartridge filled with resin, and it was found that even after extended pretreatment of the resin with iodine it was not possible to maintain a suitably high concentration of iodine in the effluent water under water usage conditions simulating those expected on Skylab. Because of this, smaller volumes of resin were used in the final configuration flight unit to reduce the quantity of iodine removed.

..5.5.17 Multilayer Insulation

A. Requirements

1/ Multilayer insulation was installed on the external surface of the forward dome to provide proper thermal management of the OWS habitation areas. The insulation consisted of multiple layers of metallized plastic film isolated from each other by separator sheets. The separator was a key material parameter.

B. Alternative Solutions

1/ A polyurethane foam was considered initially but was rejected on the basis of particle generation. A net material was subsequently identified as the most attractive type of separator. The first netting considered was a nylon material. However, the material was found to outgas excessively in a vacuum environment. Net outgassing was reduced by replacing the Nylon material with a Dacron counterpart which could be stiffened without use of any volatile compounds and which, inherently, absorbed less moisture.

C. Material Selection

1/ The specific net utilized was a configuration developed under NASA CRAD Contract NAS8-21400, "Investigation of High Performance Insulation Application Problems," 1-69 to 6-73. Additional developments on the same CRAD program, particularly in the area of fabrication technology, were utilized in the OWS Program. Details of the CRAD development are presented in Contract reports.

D. Recommendations

1/ Future uses of multilayer insulation (MLI) for thermal control could realize increased system performance and lower system weight by incorporating results of an MDAC MLI development study which has subsequently identified an improved net configuration.

2.3.5.18 Polyimide Laminates

A. Requirements

1/ Within the workshop a need existed for relatively rigid, thermally insulative, sheet material which could be formed. This was the type of application a plastic laminate would satisfy. Polyimide/glass laminates were found to be the only system which would meet the stringent flammability and offgassing requirements.

B. Material Processing and Application

1/ At that time the state-of-the-art of polyimide resin-glass fabric laminating was almost non-existent and therefore the processing methods for epoxy/glass, polyester/glass, and phenolic/glass laminating were followed.

It was found that the extreme tackiness of the prepreg made it extremely difficult to lay up sharp corners, and the step-up temperature cure and large quantity of outgassing products during cure resulted in porosity and bridging at sharp radius corners and angles.

The problems in laminating Dupont's Pyralin 35-513 polyimide/181 glass prepreg were resolved by designing around the material limitations.

APPROVAL

MSFC SKYLAB ORBITAL WORKSHOP

FINAL TECHNICAL REPORT

Orbital Workshop Project

The information in this report has been reviewed for security classification. Review of any information concerning Department of Defense or Atomic Energy Commission programs has been made by the MSFC Security Classification Officer. This report, in its entirety, has been determined to be unclassified.

This document has also been reviewed and approved for technical accuracy.

William K. Simmons, Jr.
Manager, Orbital Workshop Project

Rein Ise
Manager, Skylab Program