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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)

2.2.11 <u>Habitability Support Systems</u>

2.2.11.1 Waste Management Subsystem

A. Design Requirements - The Waste Management Subsystem (WMS) shall provide for the collection, processing, storage, and/or disposal of the feces, urine, and vomitus as well as debris, particulate matter, and free water from the atmosphere, and shall provide support for experiments M071 (Mineral Balance), and M074 and M073 (Bi-Assay of Body Fluids). It shall also provide a Waste Disposal System utilizing the LOX tank as a waste tank for disposing of all wet and dry materials and refuge collected in the habitable areas internal to the orbital assembly.

1/ General Requirements - The WMS shall be capable of collecting urine, feces, and vomit simultaneously; shall be designed to preclude mixing and cross contamination of urine, feces, vomit, and debris between crew members; and shall prevent cross contamination in excess of one percent between the samples from the same crew member obtained on different days. The WMS shall provide the capability for transferring processed and identified samples of the collected urine, feces, and vomit to the Command Module (CM) for subsequent return to earth for analysis. All atmosphere used in the collection process of the WMS equipment (except for intentionally dumped atmosphere) shall be passed through a replaceable odor control filter. Odor removal assemblies, with filter replacements as required, shall maintain the level of malodorous constituents of flatus within the compartment as specified in paragraph 3.3.1.2.1.7 of CP2080J1C. It shall also provide for the collection, temporary storage and disposal into the waste tank of refuse collected in the habitable areas of the workshop. The functions, equipment, items and general requirements for the WMS are listed below:

- Fecal collection: vacuum drying and storage
- Urine collection: sampling, volume determination, disposal and/or freezing, and storage of samples
- Vomitus collection: vacuum drying and storage
- Debris collection: deactivation and storage
- Removal of free water from the atmosphere
- Storage of new and used tissues, empty and filled collection vehicles
- Sample processing and storage techniques, which are compatible with mission operations, from launch through recovery.
- Collection, temporary storage and disposal of refuse

Equipment Items:

- Fecal collector
- Urine collector
- Vomitus containers
- Vacuum cleaner
- Waste processor
- Urine freezer
- Collection bags
- Storage containers
- Toilet tissues and dispenser
- Urine return container

- Disposal bags
- Trash Airlock

General Requirements:

- All subsystems shall be designed to support a crew of three for each mission
- All equipment provided for personal use of the crew shall be identified for each crew member.
- Aids and restraints shall be provided as necessary for the operation of each of the subsystems. One-handed operation shall be a design goal
- All materials used in the subsystem shall be selected to minimize particulate contamination.
- The subsystem shall be designed to provide the capability of being cleaned for collections of accumulated debris or spilled debris
- The subsystems shall be designed to minimize equipment handling and operations
- All systems necessary for life support are to be supplemented by contingency methods in the event of failure. These backup efforts need not support the experiment requirements
- The subsystem shall provide for sanitary disposal of waste which is not to be returned for analysis, such as soiled rags, towels clothing, waste water and refuse.

a. Fecal Collector Requirements - The fecal collector shall provide the capability to collect and contain all consistencies of fecal matter. The requirements for the collector are:

1. The fecal collector shall provide a positive means to ensure separation, collection, and containment of the feces and wiping material.
2. Capability shall be provided to clean the fecal collector seat and associated equipment after use.
3. A fixed receptacle shall be provided to support the fecal collector bags during use.
4. The fecal collector seat and the related restraint equipment shall be arranged in such a manner that the crewman may assume the squat position during defecation and be able to perform the wiping without escape of the feces from the collection container.
5. The opening of the fecal collector seat shall be designed to minimize the possibility of smearing the seat with residual fecal material by relative motion between the buttocks and the fecal collector seat.
6. All equipment, controls, and displays of the WMS shall be visible and accessible to the astronaut while positioned on the fecal collector seat.
7. The fecal collection process shall not alter the constituents of the fecal material (including water)

until a mass measurement has been performed and its results recorded. After the mass measurement, the fecal collection shall be vacuum dried.

8. The maximum duration of each complete defecation cycle (excluding defecation) shall not exceed 15 minutes. The cycle shall include system preparation, initiation of processing, and preparation of the WMS for the next cycle. The WMS shall be designed to limit initial preparation time to no more than 30 seconds.

9. The clear depth measured from the top of the fecal collector seat to the bottom of the fecal collection bags shall be a minimum of thirteen inches.

10. Accommodations shall be provided for an articulating GFP mirror near the fecal collector.

b. Urine Collector Requirements - The urine collector shall provide the capability to collect, contain, determine volume, sample urine, and to dispose of excess urine. The requirements for the urine collector are:

1. The urine receiver shall completely enclose the urine stream during the collection process. The tailoff or dripping portion of the normal urination process shall be accommodated by the urine collector.

2. The urine receiver and the urine collection unit shall be operable while the astronaut is restrained in the seated or standing position.

3. The urine collection unit shall be designed to collect and contain the urine for the following conditions:

   - Average output of 2000 ml/man/24 hours
   - Maximum output of 4000 ml/man/24 hours
   - Minimum output of 600 ml/man/24 hours
   - Maximum delivery rate shall correspond to the curve shown in Figure 2.2.11.1-1.
   - Average of 10 micturitions/man/24 hours
   - Minimum single void of 35 ml

4. A means shall be provided to control bacteria growth, odors and contamination.

5. The urine collector shall provide the capability to extract representative samples of 122 ml (minimum), from a homogenous pool for freezing. The samples shall be frozen below -2.5°F (-19.2°C) within 8 hours of each 24 hour pool period.

6. Urine remaining after sample extraction shall be disposed of into the LOX tank. The system shall provide the capability to dispose of the urine at scheduled intervals.

7. The urine collection unit shall determine the volume of each 24 hour void to an accuracy of ± 15 percent.

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MAXIMUM URINE DELIVERY RATE

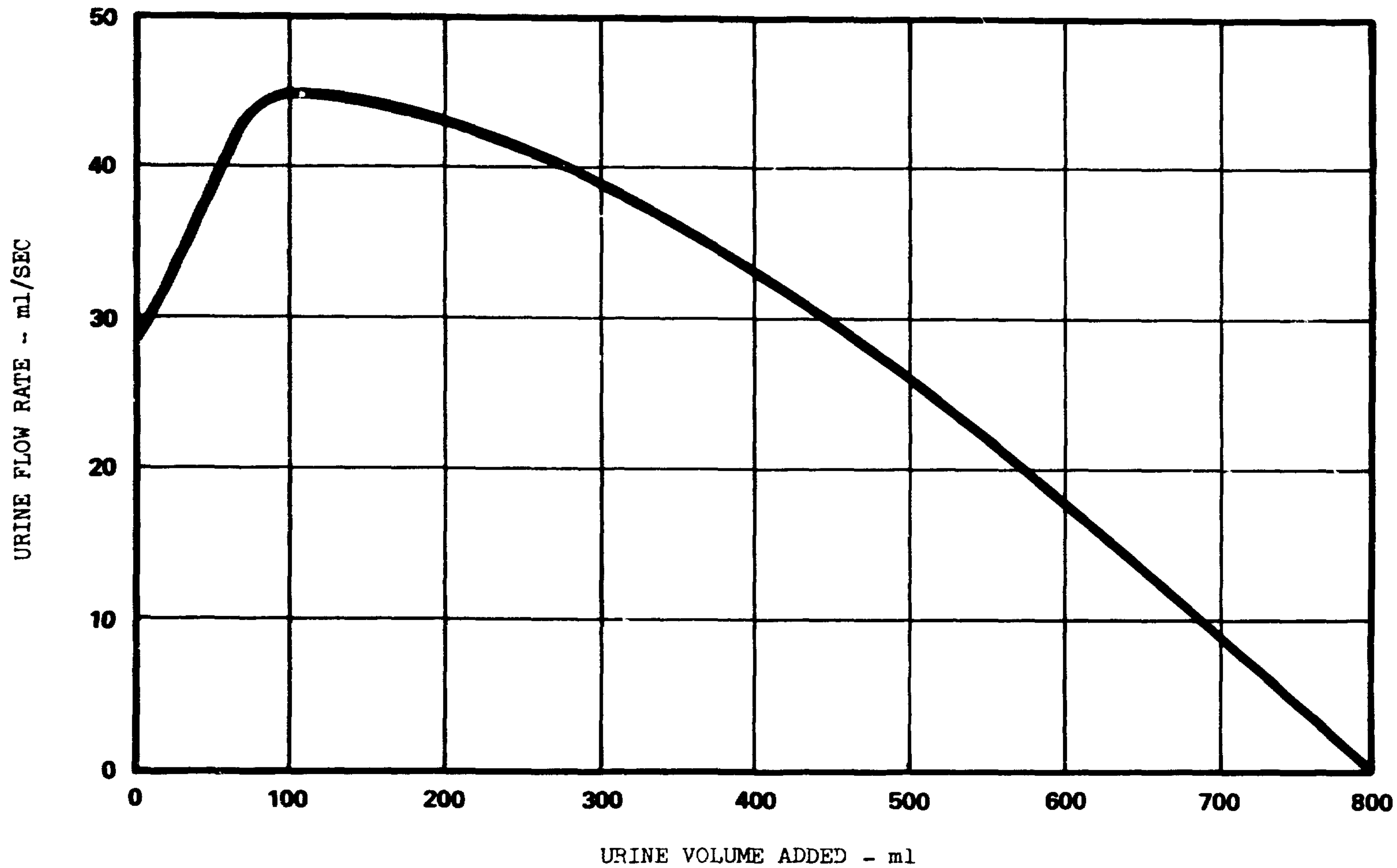

Figure 2.2.11.1-1

8. The urine collector shall be designed to prevent cross-contamination between the users. A flushing capability shall be provided as a means of controlling cross-contamination between the 24 hour pooled urine collections for each user. The flushing system shall be capable of dispensing water from a pre-installed water container in four increments of 50 ± 5 ml per crewman per 24 hour pooling period. Use of the flushing system shall limit the day to day cross-contamination between urine samples to less than one percent of the volume collected each day. The total urine/flush residual carry-over from day to day shall not exceed 10 ml.

9. The 24 hour urine pool shall be maintained at a temperature below 59°F (15°C). The temperature of the pool shall not exceed 59°F (15°C) for more than an accumulated time of 3 hours during the 24 hour period.

10. The maximum time for each urination cycle (excluding urination) shall not exceed one (1) minute. The cycle includes system preparation and preparation of the WMS for the next urination cycle. The WMS shall be designed to limit initial preparation time to no more than 30 seconds.

11. Volume measurement, sampling, sample stowage, and system preparation for the next 24 hour cycle

(excluding the actual dumping time required to dispose the excess urine at scheduled intervals) shall not exceed 20 minutes total time for three crewmen.

12. The urine collection system shall interface with the CM for transferring, collecting, measuring and sampling, and the dumping of the urine collected during CM operations prior to OWS activation.

13. A lithium chloride tracer shall be incorporated as the prime method to determine the volume of urine collected in each 24 hour urine pooling period. Lithium shall be added in the amount of 30 $\pm$ 0.3 mg into each pooling bag prior to flight.

14. An alternate urine collection system shall utilize Apollo type roll-on cuffs and adapters to accommodate urine collection directly into urine collection bags without the use of air entrainment. Provision shall be made on each adapter to prevent backflow. After each void, the urine collection bags will be stowed employing the chilling provisions of the urine collector. Primary volume measurement shall be accomplished by using a lithium chloride tracer. The on board mechanical volume measurement system shall be used. The contingency urine collection system shall also provide the capability for extracting urine samples.

c. Vomitus Collection - Contingency fecal bags shall be provided to collect and contain vomitus material from the crewmen. Specific requirements for collecting and containing vomit are:

1. Vomitus shall not be collected in the same container with other wastes.
2. The bags shall have the capability of being carried by the crewmen without interfering with their mobility and performance.
3. The bags shall be capable of operation without the aid of a vacuum source or atmosphere circulation equipment and shall be portable.
4. Each bag shall be designed to contain a minimum of 100 ml of vomitus.
5. The bags shall interface with the waste processor for processing and shall interface with the GFP Specimen Mass Measuring Device (SMMD).
6. The bags shall be provided as specified in I-SL-008.

d. Waste Processor Requirements - The waste processor shall provide for vacuum-drying the fecal and vomitus collections and debris collections (if necessary) so that the waste products therein are deactivated and bacterial contamination is prevented. Requirements for waste processing are:

1. All fecal and vomitus collections shall be vacuum dried.

2. Each processor shall have the capability of being individually controlled and shall include a display to indicate to the Astronaut when each specimen has been deactivated and is ready for storage.

3. The atmosphere overboard-leakage rate of the processor shall be apportioned from the five pound mass/day total OWS leakage rate.

4. All control parameters necessary to monitor operation of the processor shall be apparent to the operator.

5. Six processors shall be provided.

6. Temperature sensors shall provide direct power interrupt to the heaters in the event of an over-temperature processing condition.

e. Thermal Conditioning Requirements - Provision shall be made to freeze the urine samples to below +27°F (-2.8°C) within 3 hours, to 0°F (-17.8°C) within 6 hours and to below -2.5°F (-19.2°C) within 8 hours.

f. Urine Return Requirements - Provisions shall be provided for transferring the frozen urine samples from the OWS to Earth via the Command Module (CM). The provisions shall have a thermal control capability to maintain the urine samples after removal from the urine freezer at temperatures not to exceed 17°F (-8.3°C) for 22 hours.

g. Collection Bags - Collection bags shall be provided for the daily collection of urine, sampling of urine, and collection of feces. The requirements for the fecal and urine collection bags are:

1. The fecal bags shall be fabricated from an impermeable outer material and shall be designed for compatible operation with the fecal collector and the waste processor. The fecal bags shall interface with the SMMD (GFP).
2. The urine collection bags shall be compatible with the urine collector for 24 hour urine pooling, urine chilling, volume measurement of the urine, and transfer of the urine to the urine sample bags. The urine collection bags shall also be compatible with urine dumping into the waste tank or with disposal of full urine bags into the trash airlock.
3. The urine sample bags shall be compatible with freezing a minimum of 122 ml of urine and shall be designed for minimum stowage volume.
4. Modified fecal bags shall be provided for use in the CM. These bags shall be compatible with the waste processor and shall interface with the SMMD.
5. The collection bags shall be designed to prevent splashing during waste collection. The bags shall be configured so that no contact with the interior surface is required in order to seal, process, and store the bags for return.

6. A means shall be provided to pass gas from the collection bags but not solids and liquids. The bags shall be impervious to liquids, gases, and solids when sealed.

7. All collection bags which are placed on the SMMD shall be marked with the empty bag weight to within ±3.0 grams.

8. Each urine sample bag and the fecal and vomitus collection bags shall provide for recording:

   - Designation of the Astronaut providing the sample
   - Time at initiation of processing or freezing
   - Volume or mass of the sample

9. The collection bags shall be designed to require minimum stowage volume. Refer to the Stowage List for the quantities of bags required.

10. The OWS waste collection bags shall interface with the CM stowage facilities.

11. The fecal bag shall be designed to eliminate fecal matter from contacting the seal lip during defecation.

12. Urine half sample bags having a minimum volume of 50 ml, shall be provided and shall be compatible with the blood sample collection system.

h. Waste Storage Requirements - Provisions for the storage of the waste management supplies and 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 contents of each.

4. The vehicle storage containers for feces, urine, and vomitus shall be removable from the OWS Waste Management Compartment (WMC) in modular form for transfer to the Apollo CM and subsequent return to earth.

i. Toilet Tissue Requirements

1. Toilet tissues and a dispenser shall be provided for use in the WMC.

2. A dispenser for the toilet tissue shall be easily accessible to an astronaut positioned on the fecal collector seat.

3. The chemical composition of the toilet tissues shall not alter the collected sample constituents.

j. Vacuum Cleaner - A portable vacuum cleaner system shall be provided to collect and contain particulate material from any location within the OWS. The requirements for debris collection and containment are:

1. The portable vacuum cleaner system shall be capable of collecting debris (including free water) and particulate matter from the atmosphere from all accessible areas of the OWS. After being filtered, the atmosphere shall be returned to the OWS.
2. The vacuum cleaner shall be capable of being operated throughout the OWS.
3. Removable collection vehicles shall be utilized.
4. The portable vacuum cleaner system shall be electrically powered utilizing a universal electrical cable and preinstalled electrical junction boxes.
5. Capability shall be provided for cleaning in restricted areas.
6. Means shall be provided to deactivage collected debris such as food wastes.
7. Vacuum cleaner bags shall be supplied as specified in I-SL-008.
8. The vacuum cleaner shall have an interlock to prevent operation unless a bag is installed.
9. The vacuum cleaner shall provide the capability to contain collected waste when the blower is not operating. The vacuum cleaner shall incorporate provisions to permit one-handed carrying of the vacuum cleaner and attachments and include a capability to be attached to the grid floor.

10. The vacuum cleaner shall have opposing, non-propulsive, exhaust vents and shall have a three-position switch for on, off, and momentary.

k. Trash Collection Bags

1. Large Trash Bag

- Shall have capability of closing and reopening during loading and unloading of trash items.
- Shall have capability of being restrained to OWS wall locations and crewman's utility belt by means of snaps.
- Opening shall be sized and designed to accommodate all trash items defined by Logistics.
- Large bag shall restrain moist and dry solids.
- Shall not open or rupture when exposed to trash airlock depressurization and waste tank pressures.
- Venting shall be done through the bag material and seams stitching.
- Restraint tabs shall be provided to restrain and position bag in trash airlock.

2. General Purpose (GP) Trash Bags

- Loading of trash items in GP bag shall be done by crewman using one hand.
- Removing and replacing GP bag from locker door shall be done with minimum effort to crewman, and requiring no tools.

- Trash items shall remain in GP bag when trash lid is open, by some means of restraint.
- Opening shall be sized and designed to accommodate all trash items defined by Logistics, except for urine and 16-inch (0.406 meters) food containers.
- Shall restrain moist and dry solids.

  Opening of filled bag shall have the capability of being closed prior to storage in waste tank.
- Shall not open or rupture when exposed to trash airlock depressurization, and waste tank pressures.
- Venting shall be done through the bag material and seams stitching.
- Restraint tabs shall be provided to restrain and position bag in trash airlock.

1. Trash Airlock - The trash airlock shall be designed to perform normally in the 5 psi (34.5 kN/m^2) environment provided in the OWS. Its life shall be based on five operations per day for 140 days at OWS interior ambient temperatures. Its proof pressure shall be approximately 10 psi (68.9 kN/m^2) differential and shall be capable of withstanding an orbital malfunction differential pressure of 26 psid (179.3 kN/m^2) without damage (see Figure 2.2.11.1-2).

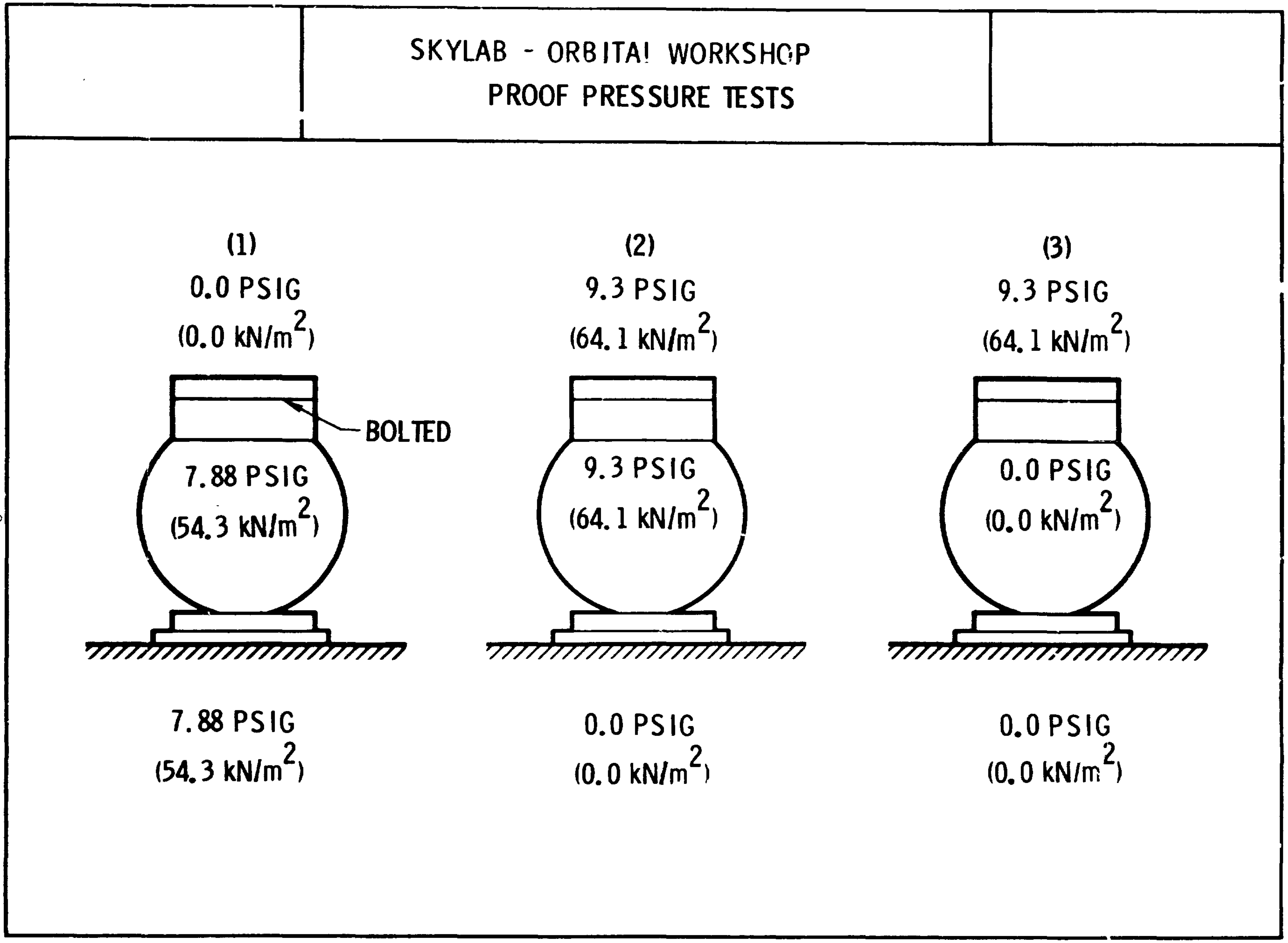

Figure 2.2.11.1-2

2/ Design Parameters - The design parameters for each major component of the subsystem are shown in the following specifications:

a.	Fecal/Urine Collection Module	SCD 1B79135
b.	Centrifugal Separator	SCD 1B87234
c.	Fecal Collection Bag	SCD 1B79138
d.	Contingency Fecal Collection Bag	SCD 1B79450
e.	Urine Collection Bag	DWG 1B95300
f.	Urine Sample Bag	DWG 1B95357
g.	Vacuum Cleaner Bag	SCD 1B79142
h.	Portable Vacuum Cleaner Assembly	SCD 1B79137
i.	Power Module - Blower	SCD 1B83241
j.	Waste Processor Module	SCD 1B79136
k.	Trash Airlock	DWG 1B81491
l.	Trash Bags	DWG 1B82542
m.	Disposal Bag	DWG 1B85790

B. Subsystem Description - The Waste Management Subsystem (WMC) is composed of five groups of equipment: The collection module equipment group which makes possible the gathering and positive containment of biological wastes from the crewmen, urine-air separation, urine measurement and urine sampling; the vacuum cleaner module (debris collection) equipment group which makes possible the gathering and positive containment of loose waste from throughout the OWS; the collection bag and handling equipment group which receives and contains the wastes, and provides for handling while those wastes are moved between the various equipment and when the wastes are processed; the waste processor equipment group which makes possible the vacuum drying and inactivation of the solid biological wastes contained in collection bags; and the waste disposal equipment which makes possible the temporary storage of refuse in trash bags and the disposal of the trash bags into the waste tank via the trash airlock.

The five equipment groups are selectively utilized in such a manner as to accomplish six unique and completely controlled functions:

- Debris collection
- Urine collection
- Contingency urine collection
- Fecal and/or diarrhetic collection
- Vomitus collection and/or contingency fecal collection
- Refuse collection and disposal

In debris collection the crewman removes a debris bag from its stowage container and installs the bag in the vacuum cleaner cannister. The debris is then collected and contained in the bag in a normal vacuum cleaning manner. The crewman then removes the debris bag from the vacuum cleaner, seals the bag and places it in a trash bag for eventual disposal in the waste tank by way of the trash airlock.

In urine collection the individual crewman removes the urine receiver from the drawer and installs it on the collection module. The crewman then micturates into the inlet line of the collection module. Entrained air flow carries the urine to the centrifugal separator; where air and urine are separated and the urine pumped into the urine bag. The urine is collected in this manner for a 24-hour period, and the urine bag is replaced at 24-hour intervals. After that period the total volume is determined and a sample extracted in a sample bag. The sample (bag) is frozen and stowed in a container for return to earth in the Command Module (CM). The urine bag containing the residual urine is removed from the collection module, placed in a trash bag for eventual disposal in the LOX tank by way of the trash airlock.

In contingency urine collection the crewman micturates directly into the urine bag by way of an elastomer cuff. The bag is stowed in the collection module for a 24-hour period. Again urine is collected for a 24-hour period, volume determined, sampled, and disposed of as above.

In fecal/diarrhetic collection a fecal bag is removed from its stowage container and installed in the collection module. The crewman defecates into the fecal bag using entrained air flow to assist moving the bolus from the crewman into the bag. The used bag is sealed, removed from the collection module and placed in the Specimen Mass Measurement Device (SMMD) where the the mass is determined. The sealed bag is then placed in the waste processor for a given time (the time is a function of the mass) during which the solid wastes are processed (dryed) by the combined effects of vacuum and heat. The processed material is then stowed for return to earth via the command module.

In vomitus collection and in contingency fecal collection the crewman obtains a contingency fecal bag from its stowage container and defecates/vomits directly into the bag. The bag is then sealed, mass determined, processed, stowed and returned to earth as above.

In wet and dry material and refuse collection the crewman obtains trash bags from stowage containers and mounts them in the following locations:

- Waste management compartment
- Wardroom
- Sleep compartment
- Experiment compartment
- Forward compartment

Periodically as required filled bags are sealed and disposed of into the waste tank by way of the trash airlock.

Design Concept-Trash Airlock - The 1B81491 trash disposal airlock assembly is basically a pass-through chamber built into the waste tank common bulkhead and extending through the floor into the habitation area. Each side of the chamber is equipped with a hatch, forming an airlock (Figures 2.2.11.1-3 through -6). The hatch on the habitation area side is subject to the habitation area pressures and temperatures. In orbit, the waste tank is vented to space vacuum, and the hatch on that side of the airlock is exposed to the waste tank temperature. The airlock is equipped with a pressurization valve that allows its pressure to be equalized with that of either the habitation area or the waste tank, as required. The valve body contains the habitation area vent in the form of a threaded female port which is also used as a pressurization test port. In orbit, the trash disposal airlock is normally vented to the waste tank. The airlock body is spherical, approximately 24-inches (0.61 meters) in diameter, and has a pressure gage for crew observation. It is equipped with a mechanical ejector to accomplish the transfer of the waste material to the waste tank. The functional steps of the operation cycle of trash disposal from the habitation area are as follows:

- Valve/outer door handle - press 5 psi (34.5 kN/m^2) (verify)
- Lid - unlock and open
- Insert trash bag
- Lid - close and lock
- Valve/outer door handle - close/vent [verify 0.5 psi (34.5 kN/m^2)]
- Valve/outer door handle - open
- Ejector handle - eject return to close
- Valve/outer door handle - close/vent
- Ejector handle - retract

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TRASH DISPOSAL SUBSYSTEM
TRASH BAG LOCATIONS

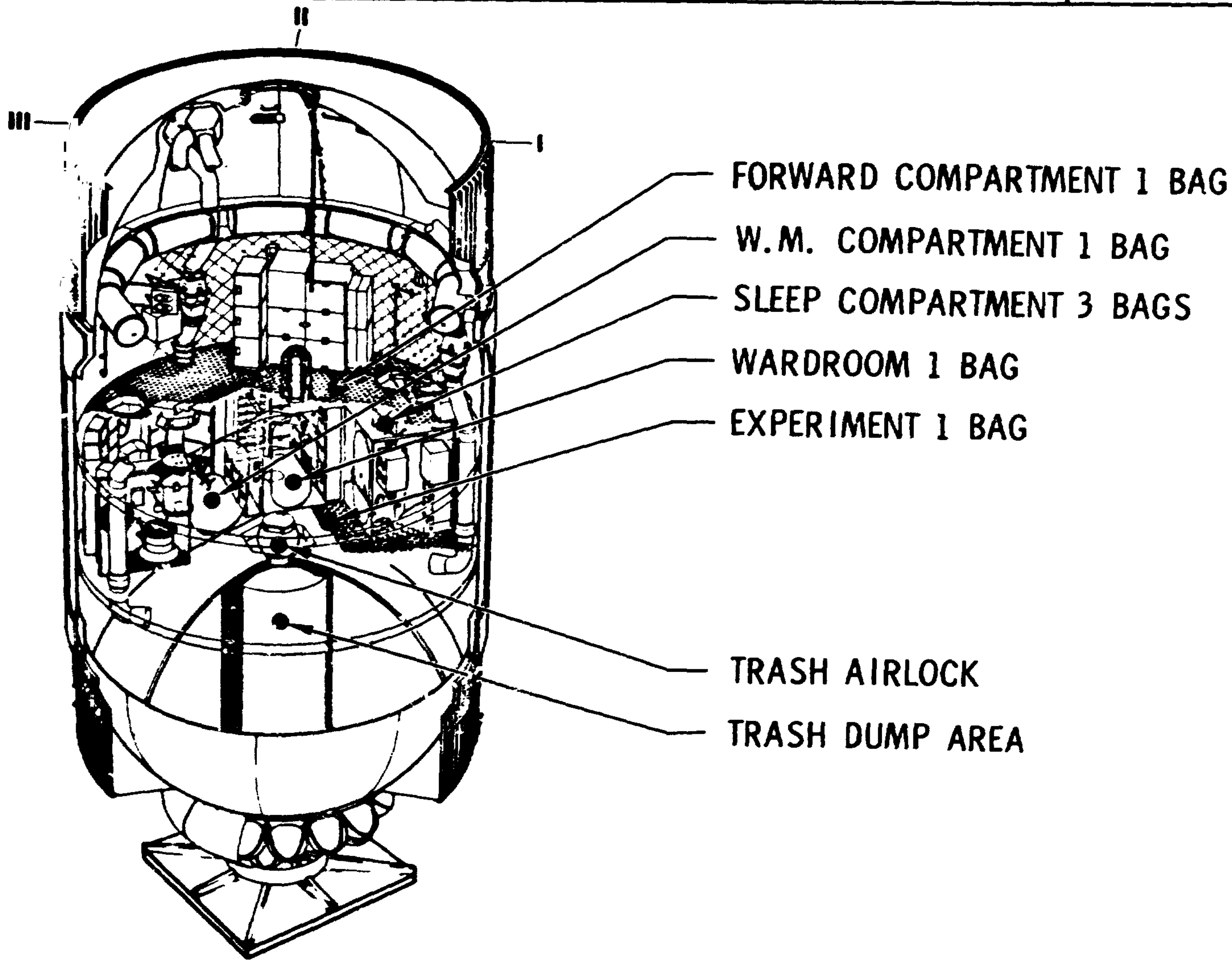

Figure 2.2.11.1-3

SKYLAB - ORBITAL WORKSHOP
TRASH DISPOSAL AIRLOCK
SEQUENTIAL OPERATION

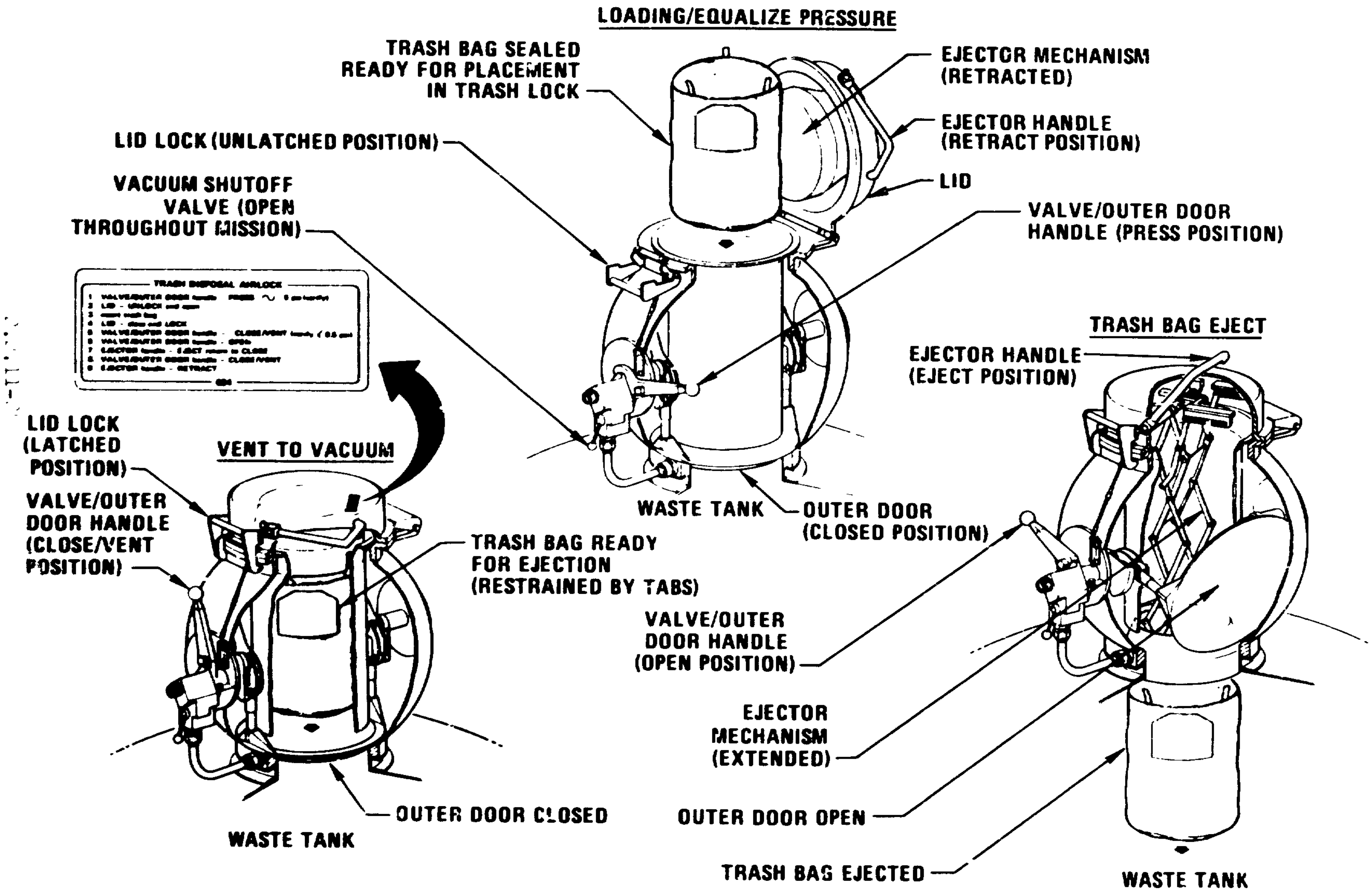

Figure 2.2.11.1 &

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TRASH LOCK LOADING EQUALIZE PRESSURE

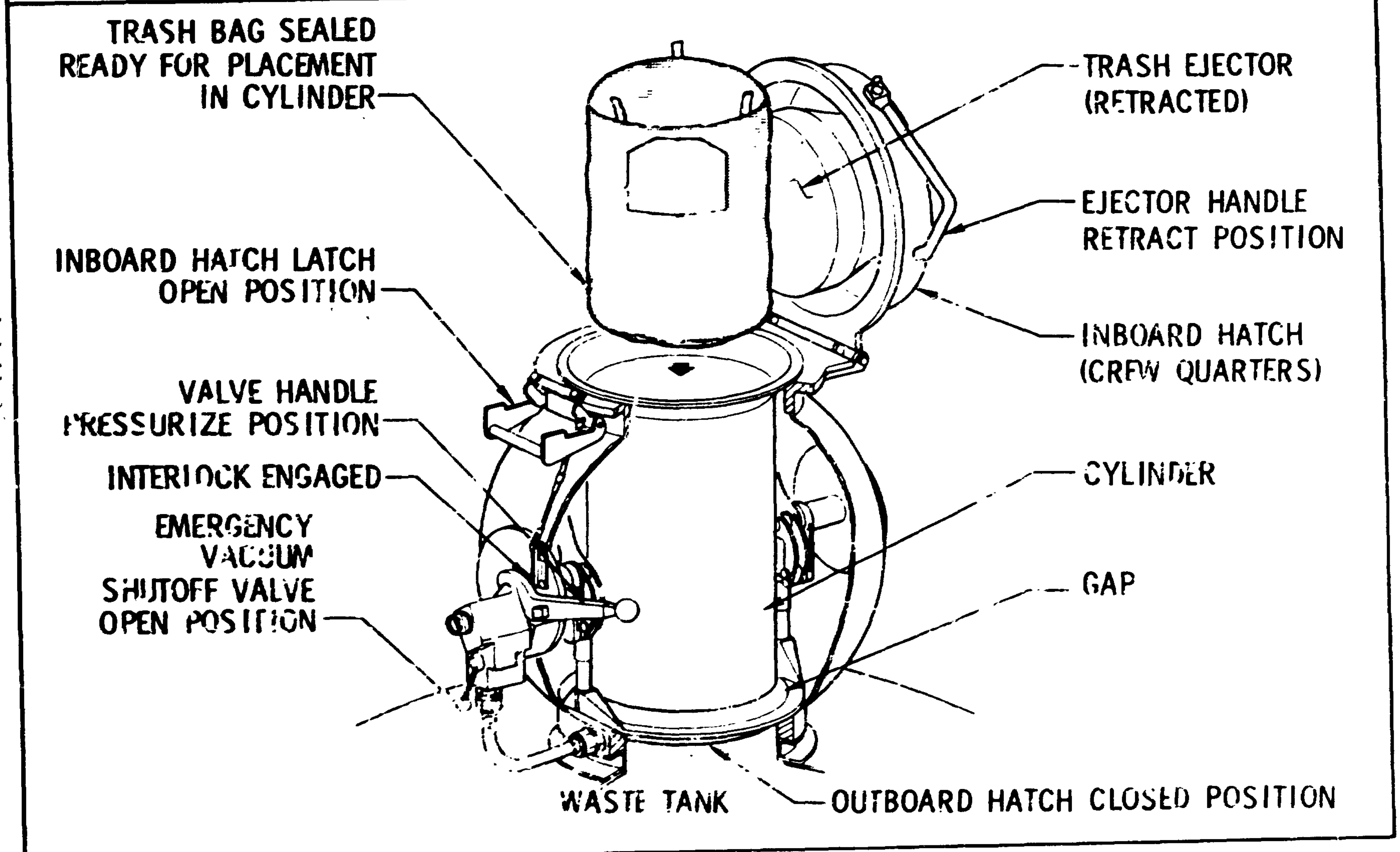


Figure 2.2.11.1-5

SKYLAB-- ORBITAL WORKSHOP
TRASH LOCK TRASH BAG EJECT

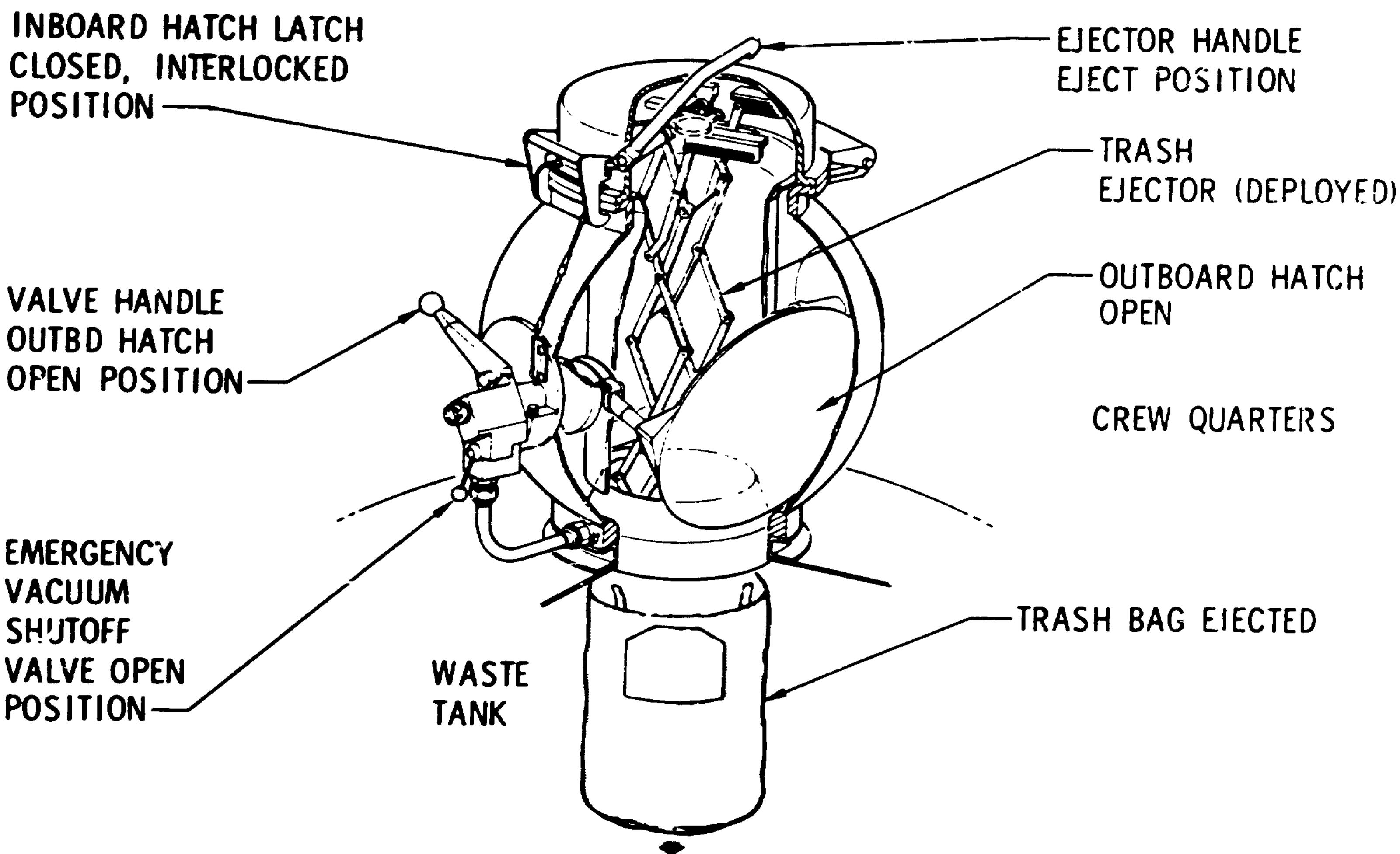


Figure 2.2.11.1-6

A flow diagram of the six functions is presented in Figure 2.2.11.1-7. Functional descriptions are presented in Figure 2.2.11.1-8 through 2.2.11.1-11.

1/ Waste Management Supplies - Waste management supplies for collection of waste material consist of fecal bags, contingency fecal bags, urine collection provisions and contingency urine cuffs to collect and to retain a crewman's body wastes. Collection bags are provided to support waste management activities for normal operational usage, for contingency collection modes, and to facilitate hygienic waste collection, waste processing and on-orbit storage and/or disposal. Vacuum cleaner bags are also supplied to collect and to retain cabin debris, and trash bags are supplied to the collect refuse in habitable compartments.

Collection bags are constructed of an impermeable outer material with an opening of sufficient size to allow waste material and air to enter (Figure 2.2.11.1-12). A vapor port on each collection bag (except the urine bag) allows air and vapors to pass through and exit the bag The vapor port contains a millipore filter with a hydrophobic surface; water and solid material cannot exit through this vapor port. Liquid waste material in the bag is repelled from the vapor port by the hydrophobic surface and is attracted to the side of the bag opposite the vapor port by a hydrophilic surface. Collection bags also include a sealable closure to permit positive retention of the collected wastes during storage or

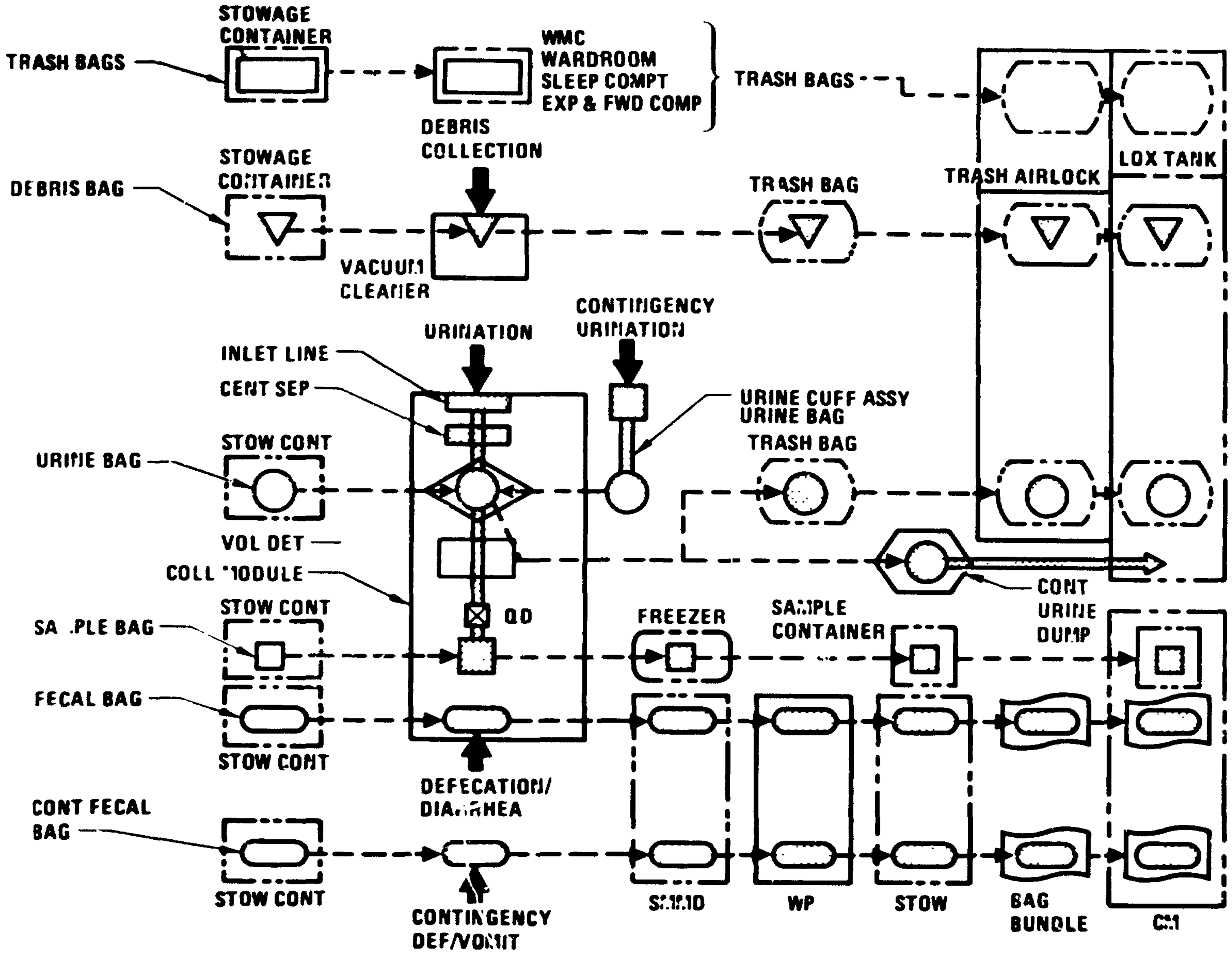


Figure 2.2.11.1-7. Waste Management Schematic

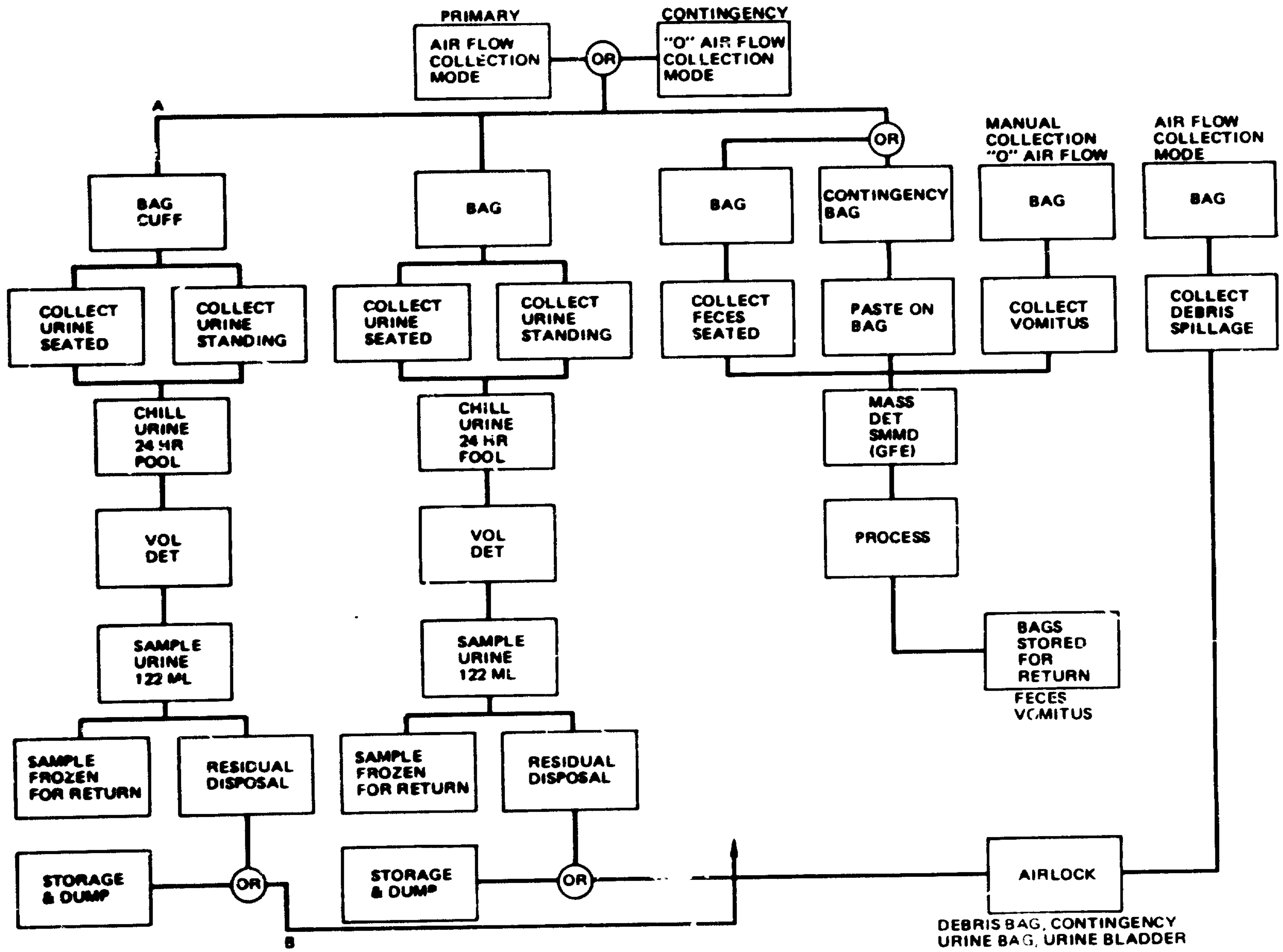


Figure 2.2.11.1-8. Skylab - Orbital Workshop DCR HSS Waste Management Subsystem

WASTE MANAGEMENT SUBSYSTEM

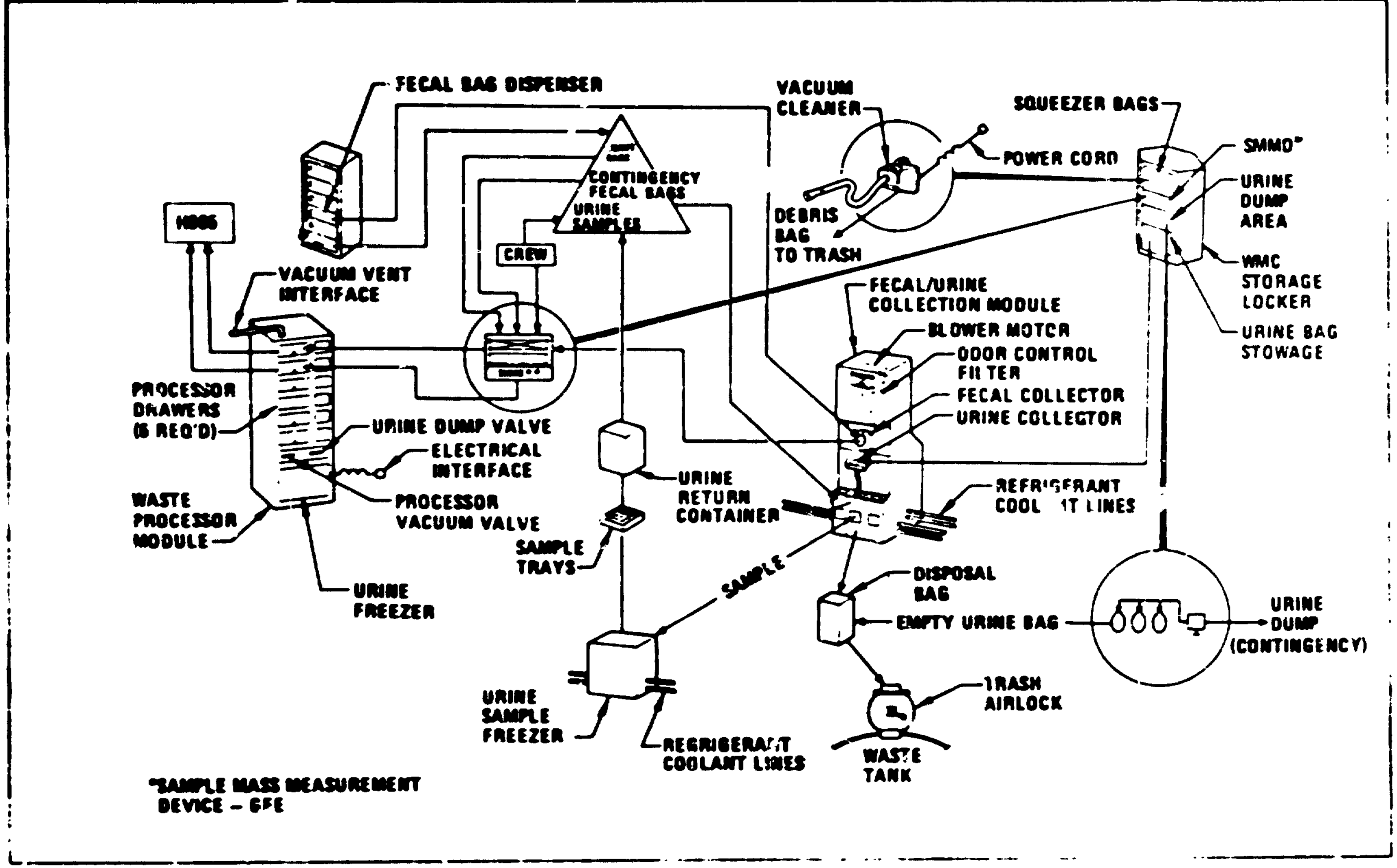


Figure 2.. .11.1-9

ORBITAL WORKSHOP

4000 ML - URINE SYSTEM

VOLUME DETERMINATOR STOWAGE

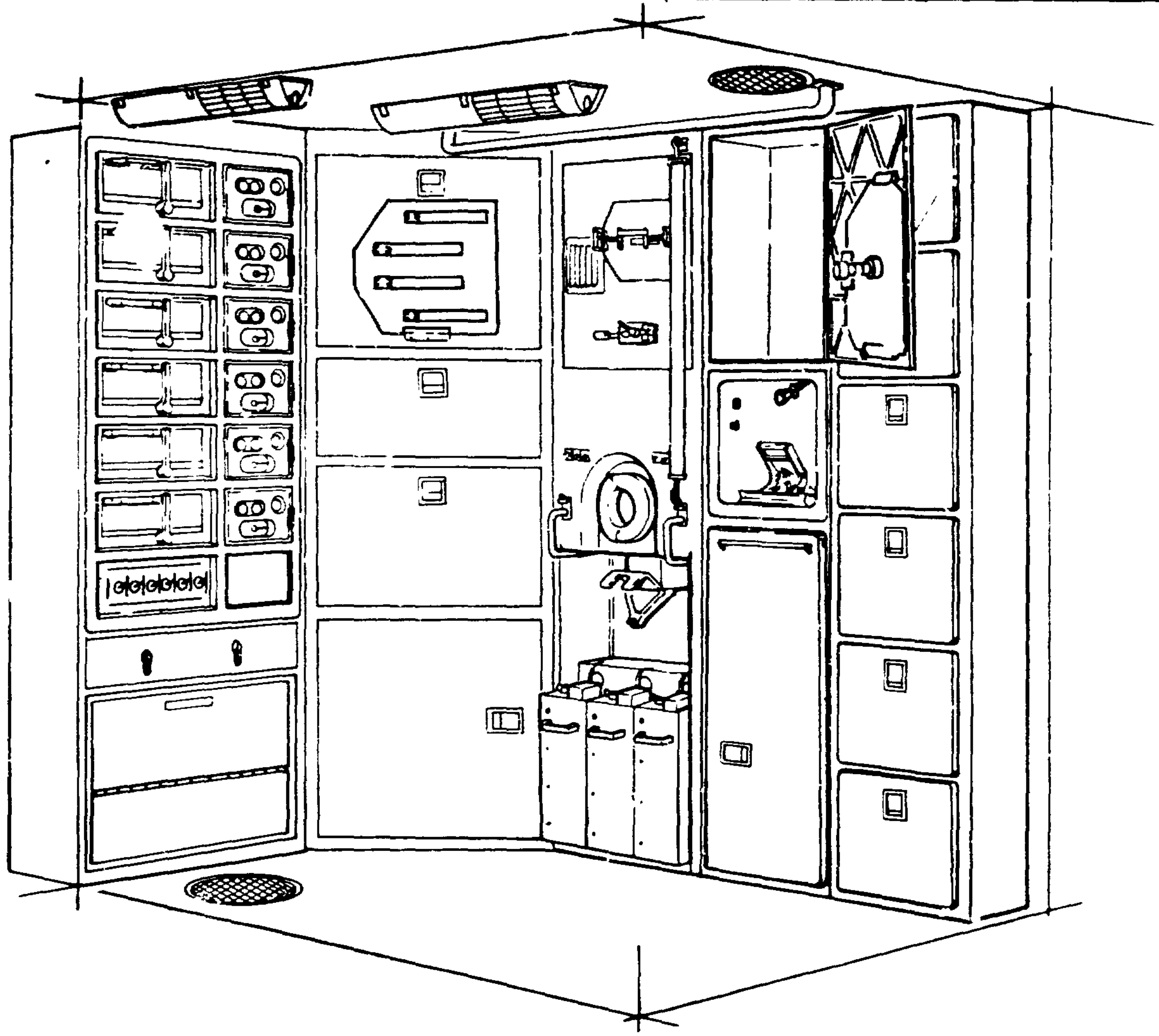


Figure 2.2.11.1-10

SKYLAB - ORBITAL WORKSHOP
WASTE MANAGEMENT SUBSYSTEM

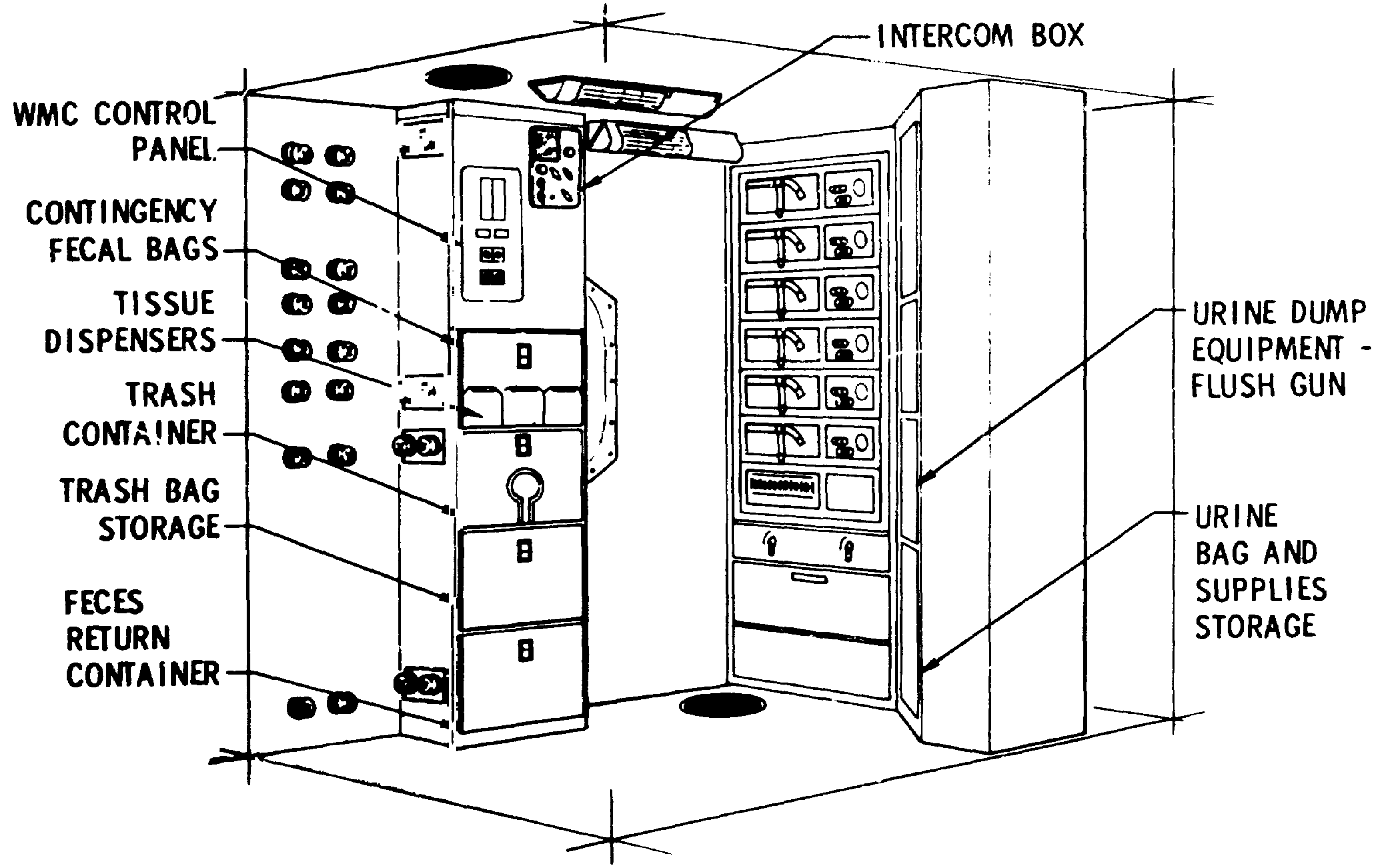


Figure 2.2.11.1-11

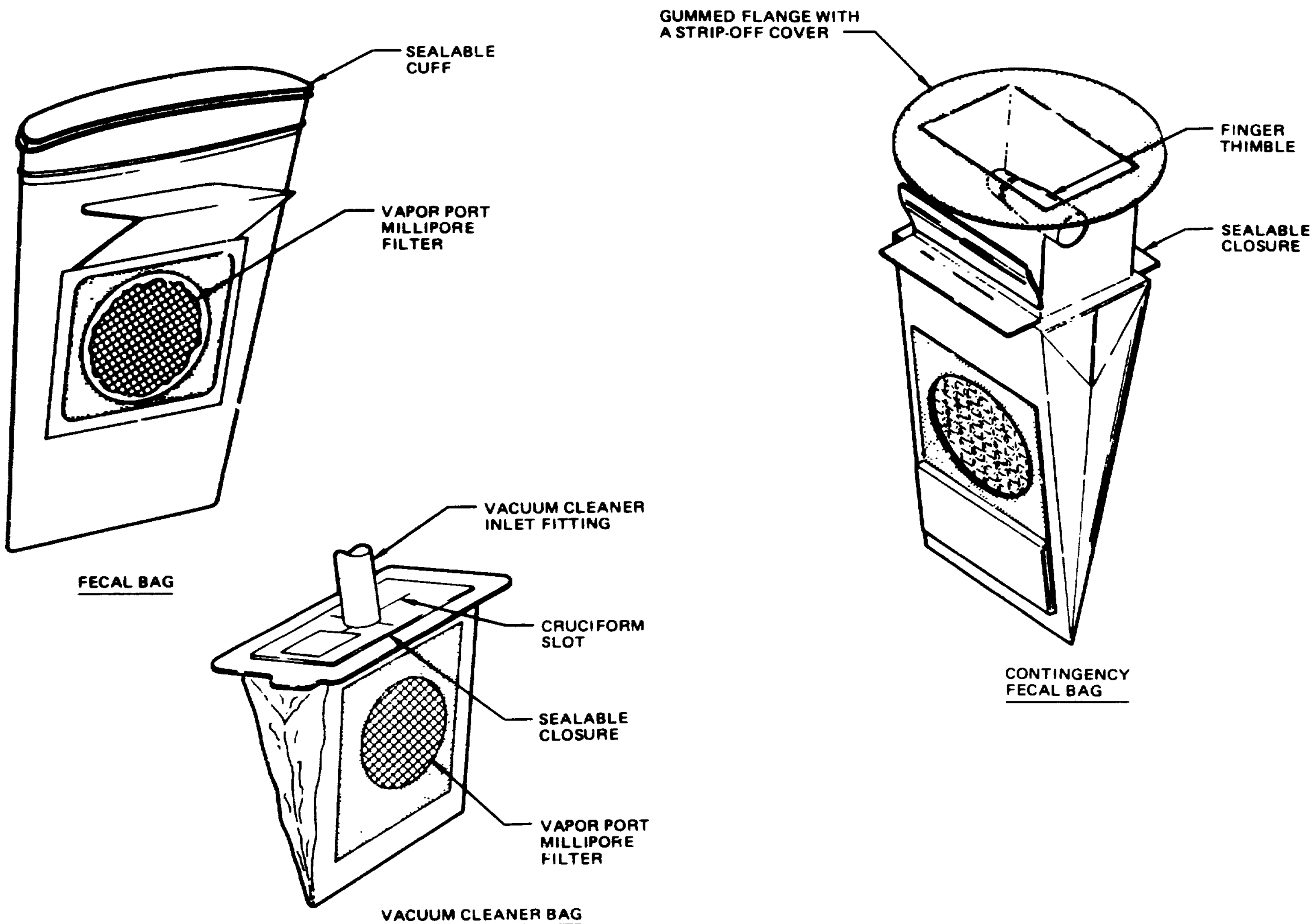


Figure 2.2.11.1-12. Waste Management Collection

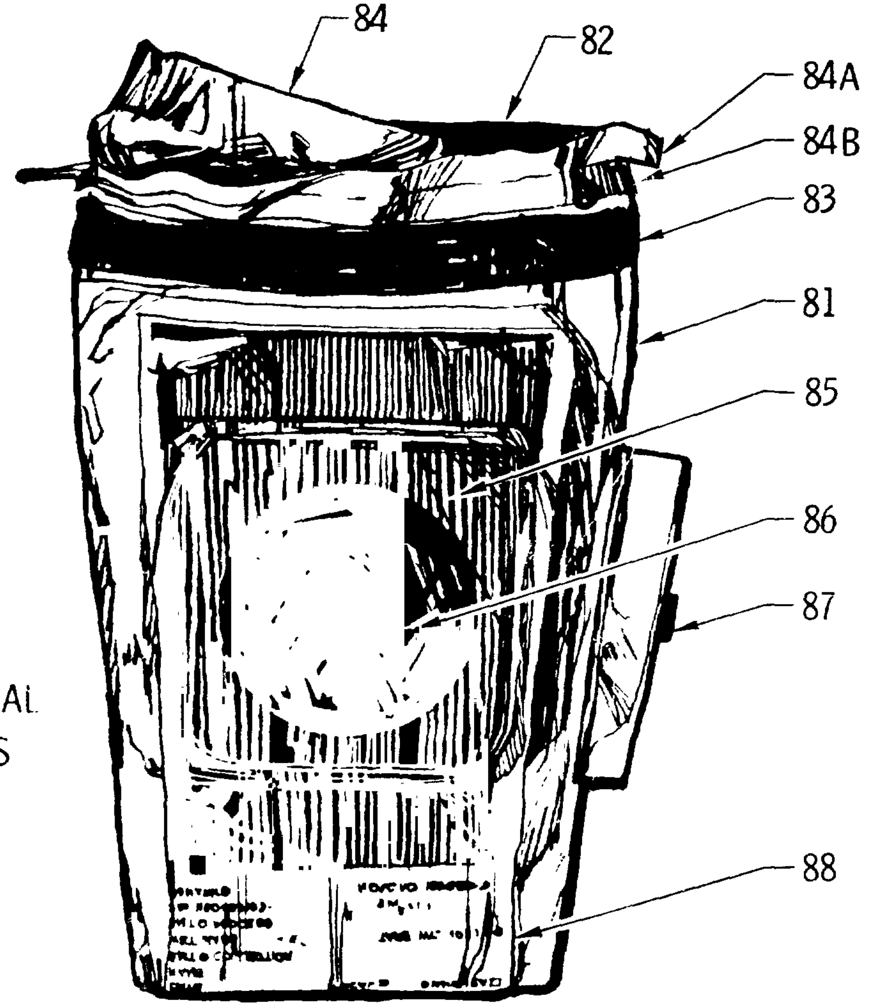
disposal. A data entry tag is provided as an integral part of the fecal bags, contingency fecal bags and sample containers to permit each crewman to record pertinent data for use during post-flight analysis.

a. Fecal Bags - Fecal bags (Figure (Figure 2.2.11.1-13) are utilized to collect fecal matter in the fecal collector (Figure 2.2.11.1-14). The fecal bag permits collection of feces while installed in the fecal collector utilizing a gravity substitute entrained airflow technique. Cabin air and the fecal matter are drawn into the collection bag utilizing a blower. Air' is then allowed to escape from the bag while the fecal material is retained in the bottom of the bag through the suction effect.

   Fecal bags are obtained from a fecal bag dispenser in the WMC. A single bag is removed and inserted into the fecal collector. With the gravity substitute airflow blower operating, fecal matter is retained in the bag during the waste collection function. A vapor port provided on the bag passes only vapors from the bag. Solids and liquids are retained in the bag by the millipore filter on the vapor port in conjunction with the action of the hydrophobic and hydrophilic surfaces.

   The wiping function is accomplished using wipes; the wipes are disposed of in the fecal bag. Adhesive sealing features on the bag opening insure waste isolation from

SKYLAB - ORBITAL WORKSHOP
WASTE MANAGEMENT SUBSYSTEM
FECAL COLLECTION BAG



81. BAG ENVELOPE
82. INER CUFF
83. OUTER CUFF
84. PRIMARY SEAL
84A. SECONDARY SEAL
84B. ADHESIVE TABS
85. FILTER
86. VENT
87. VENT SEAL
88. DATA TAG

Figure [illegible].11.1-13

SKYLAB - ORBITAL WORKSHOP
FECAL COLLECTOR -- FUNCTIONAL DIAGRAM

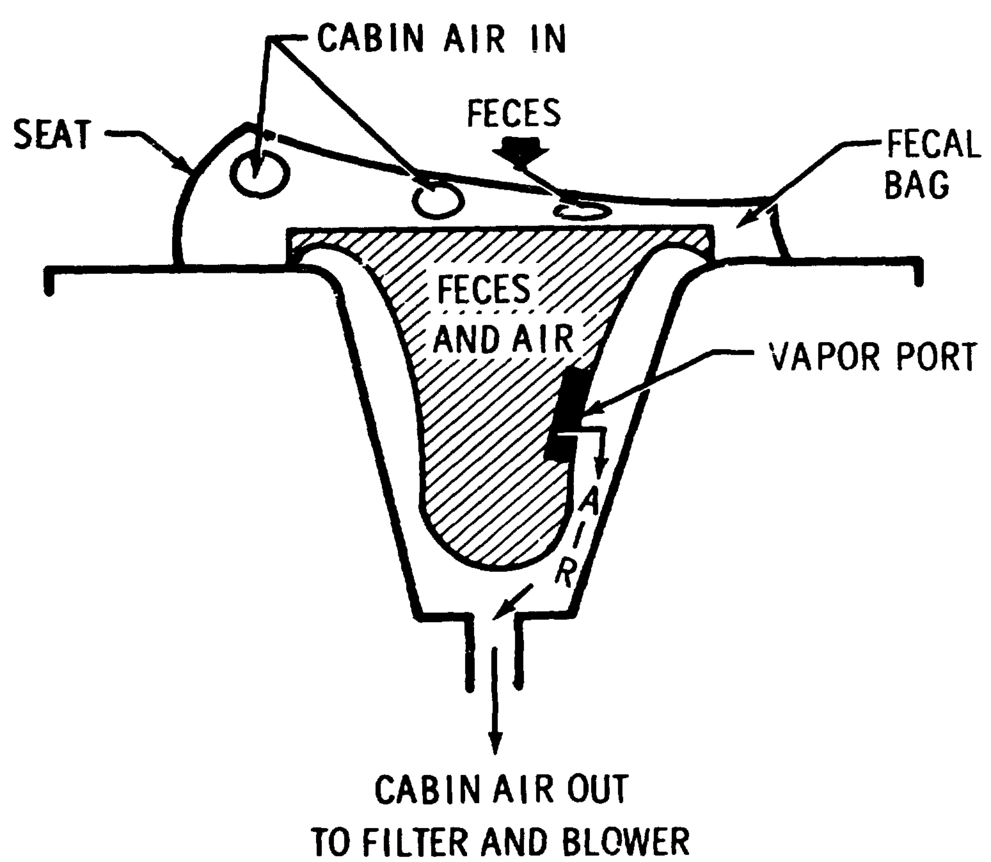


Figure 2.2.11-1-14

the external environment. After the bag is sealed and removed from the fecal collector, the bag and its contents are weighed on the specimen mass measuring device (SMMD) in the Waste Management Compartment (WMC). Pertinent data is recorded on the bag's data entry tag. The bag and its contents then undergo waste processing to a solid form to facilitate on-orbit storage and preservation (Figure 2.2.11.1-15). During waste processing, all trapped air and water is removed from the waste material through the application of mechanical pressure, heat and exposure to vacuum pressure. When waste processing is complete, the filter port on the bag is sealed and the bag is transferred to a stowage compartment in the WMC for eventual return to earth in a fecal return bundle.

b. Contingency Fecal Bags - Contingency fecal bags are provided for the contingency collection of fecal matter and for normal collection of vomitus. The bags collect feces or vomitus without the aid of gravity substitute airflow or a collection facility. The bag utilizes a gummed flanged which facilitates a positive adhesion to the buttocks during defecation (Figure 2.2.11.1-16). A finger thimble is provided integral to the bag to perform the bolus separation function. The secondary wiping function is accomplished using wipes; the wipes are disposed of in the bag. An adhesive closure seals the bag for containment of waste material.

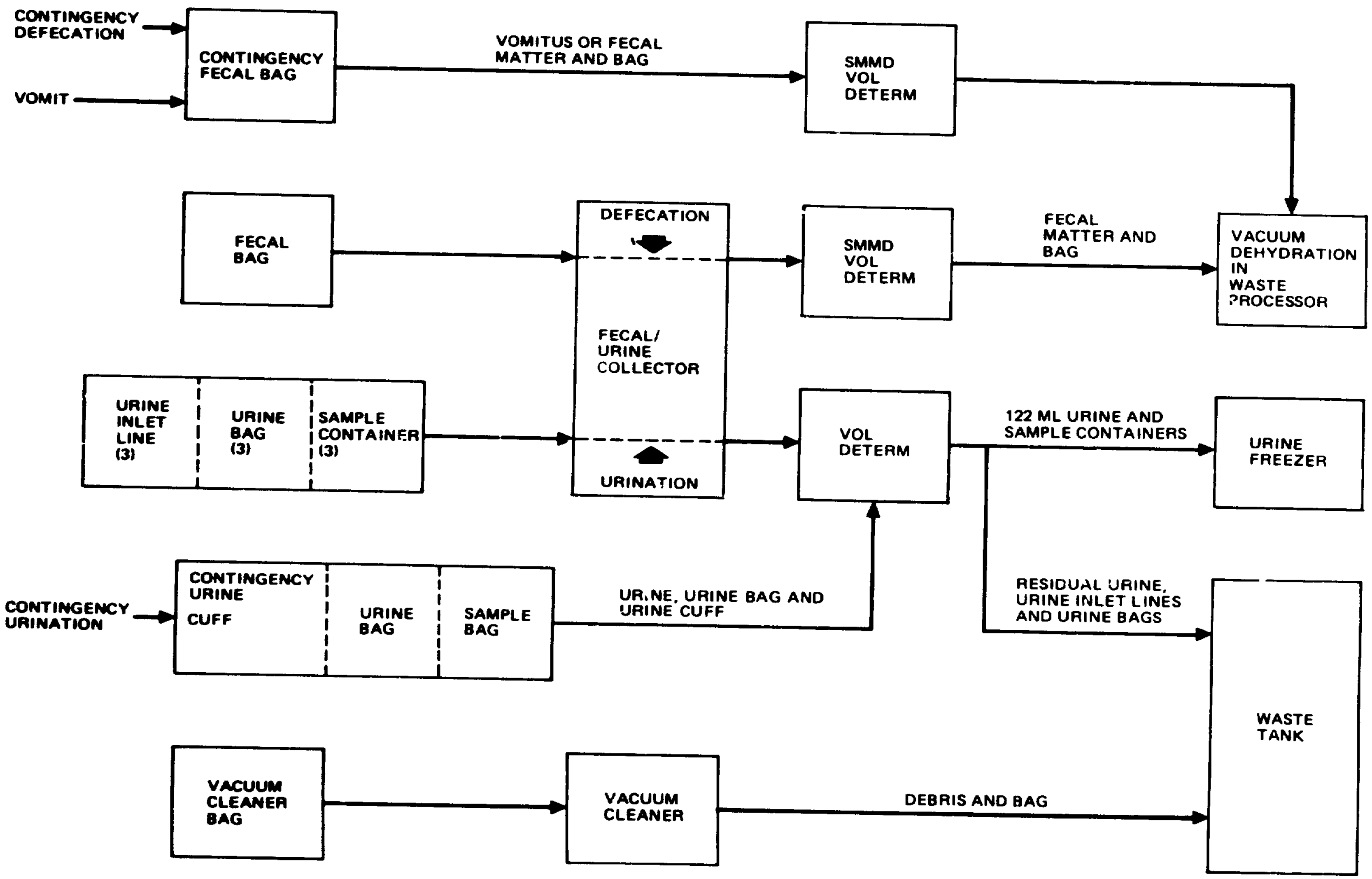
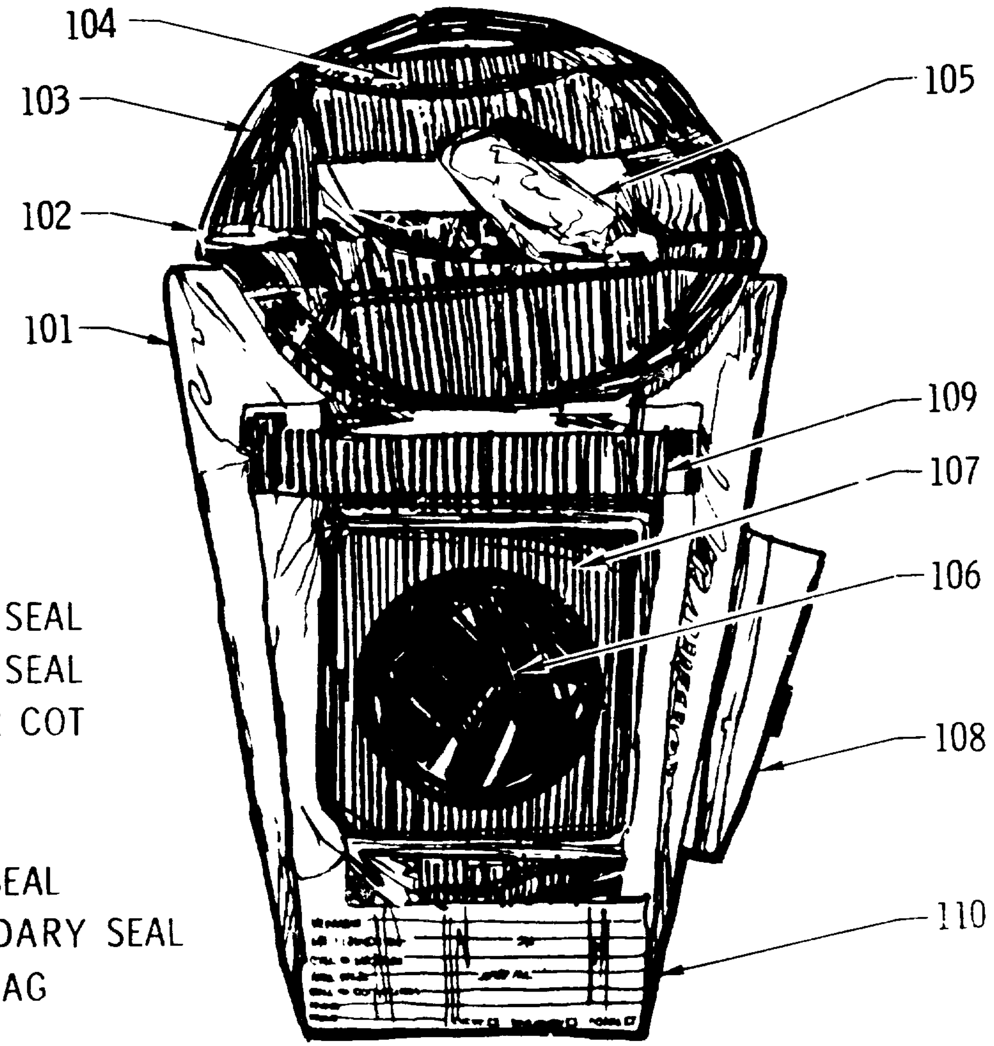


Figure 2.2.11.1-15. Skylab - Orbital Workshop Collection Bag Usage Scheme

SKYLAB - ORBITAL WORKSHOP
WASTE MANAGEMENT SUBSYSTEM
FECAL CONTINGENCY BAG



101. BAG
102. FLANGE
103. OUTER SEAL
104. INNER SEAL
105. FINGER COT
106. VENT
107. FILTER
108. VENT SEAL
109. SECONDARY SEAL
110. DATA TAG

For use as a vomitus bag, the crewman does not remove the strip-off cover, but presses the bag firmly to the mouth area when vomit collection is desired.

The bag features are similar to those of the fecal bag to permit mass determination, data entry, waste processing, and on-orbit storage for eventual return to earth in a fecal return bundle.

c. Urine Collection Provisions - The urine collection provisions of urine inlet lines, urine bags, and sample containers are used to collect urine in urine drawers (fecal/urine collector) in conjunction with a gravity substitute airflow. Each of the three urine drawers (one per crewman) contains a urine inlet line, a urine bag and box assembly and a centrifugal separator to collect and store each days urine collections from each crewman The collection cycle ends after the morning urination.

- Urine Inlet Lines - The urine inlet line connects to a urine separator in the urine drawer and routes urine from the crewman to the urine separator in the drawer. The crewman urinates into a hand conical-type urine receiver on the inlet line. A mount (urine receptacle) is provided on the fecal urine collector which positions the receiver for either standing or sitting urination. Three urine inlet lines are used, one per crewman, and are disposed of in a disposal bag after eight days of urine collection cycles are completed (Figure 2.2.11.1-17). Replacement urine inlet lines are made readily available from a limited supply in a WMC stowage compartment. The WMC supplies are replenished periodically from packages of urine inlet lines stowed in OWS forward dome stowage compartments.

- Urine Bags - Urine bags attach to the urine separators in the urine drawers and provide urine storage during the 24-hour collection cycle period for sample withdrawal. One urine bag is used in each urine drawer and connects to the drawer's urine separator with a urine inlet boot (Figure 2.2.11.1-17). This boot routes urine from the urine separator into the urine bag. A check valve inside the boot retains the collected urine in the bag. A urine dump quick-disconnect is provided on the urine bag for use in disposing of the urine in the backup mode using urine dump equipment. Each urine collection bag contains a precise quantity of Lithium Chloride which is used for post-flight volume determination.

  Each crewman uses one urine bag per day and disposes of his urine bag and the urine into a disposal bag at the end of the daily urine collection cycle after

URINE COLLECTION AND SAMPLING EQUIPMENT

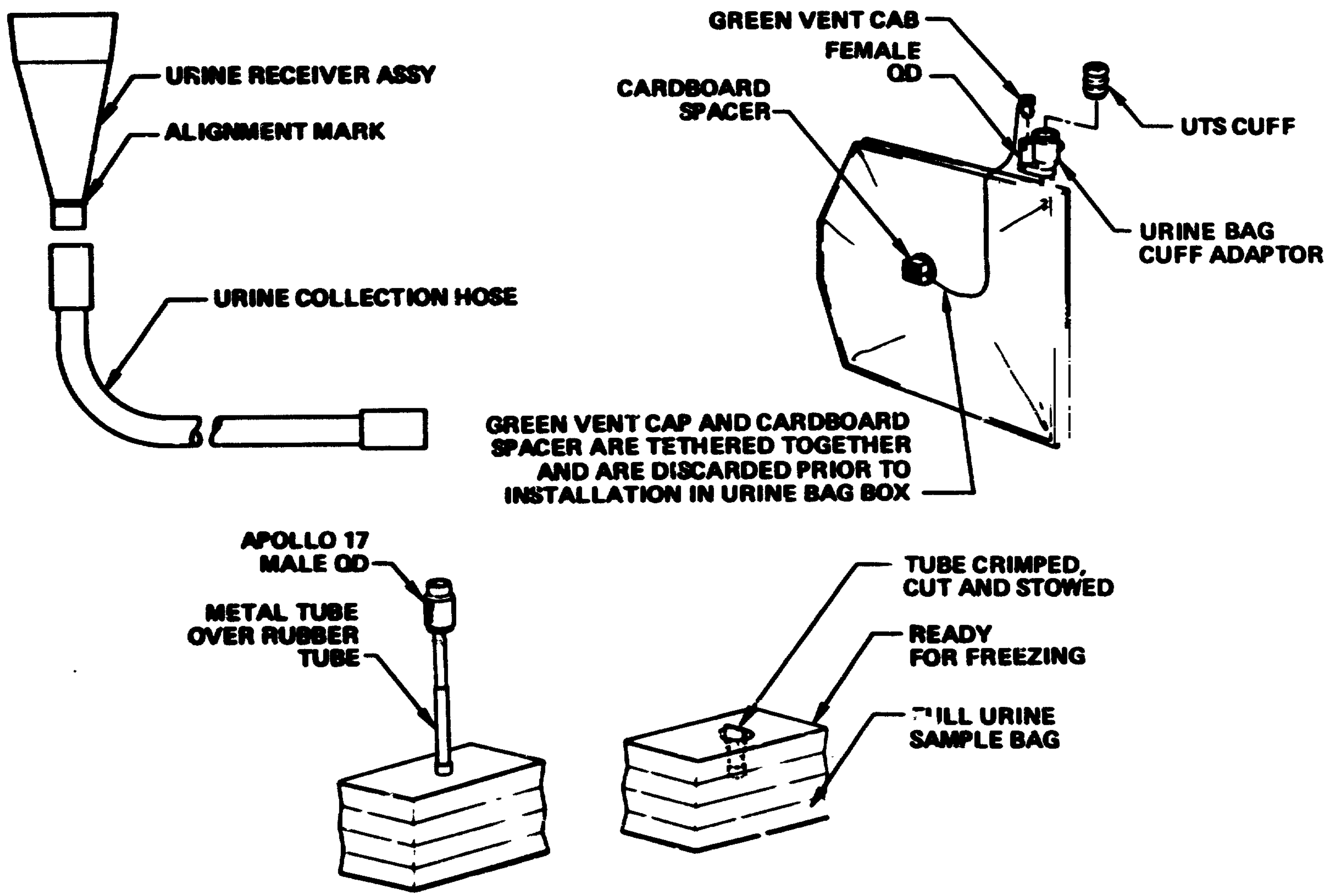


Figure 2.2.11-1-17

sample withdrawal (Figure 2.2.11.1-15). Replacement urine bags are made readily available from a limited supply in a WMC storage compartment. The WMC supplies are replenished periodically from packages of urine bags stowed in OWS forward dome stowage compartments.

- Urine Bag Box Assembly - The urine bag box assembly (one per crewman) contains the urine collection bag. This box serves as a handling fixture for the urine bag, during manual mixing (shaking) of the 24-hour urine pool with the Lithium Chloride and contains the bag during the sampling operation which takes place on the upper panel of the fecal/urine collector. When in the urine drawer the bag box which contains a spring loaded pressure plate maintains back pressure on the urine in the urine bag and maintains thermal contact with the cold plate to assure urine chilling.
- Sample Containers - At the end of the daily urine collection cycle, the urine which has been accumulating in the urine bag over a 24-hour period will be sampled using a sample container. Three sample containers are used daily (one per crewman) and are individually contained in the crimper/cutter on the upper panel of the collection module. The sample container will expand to a volume of

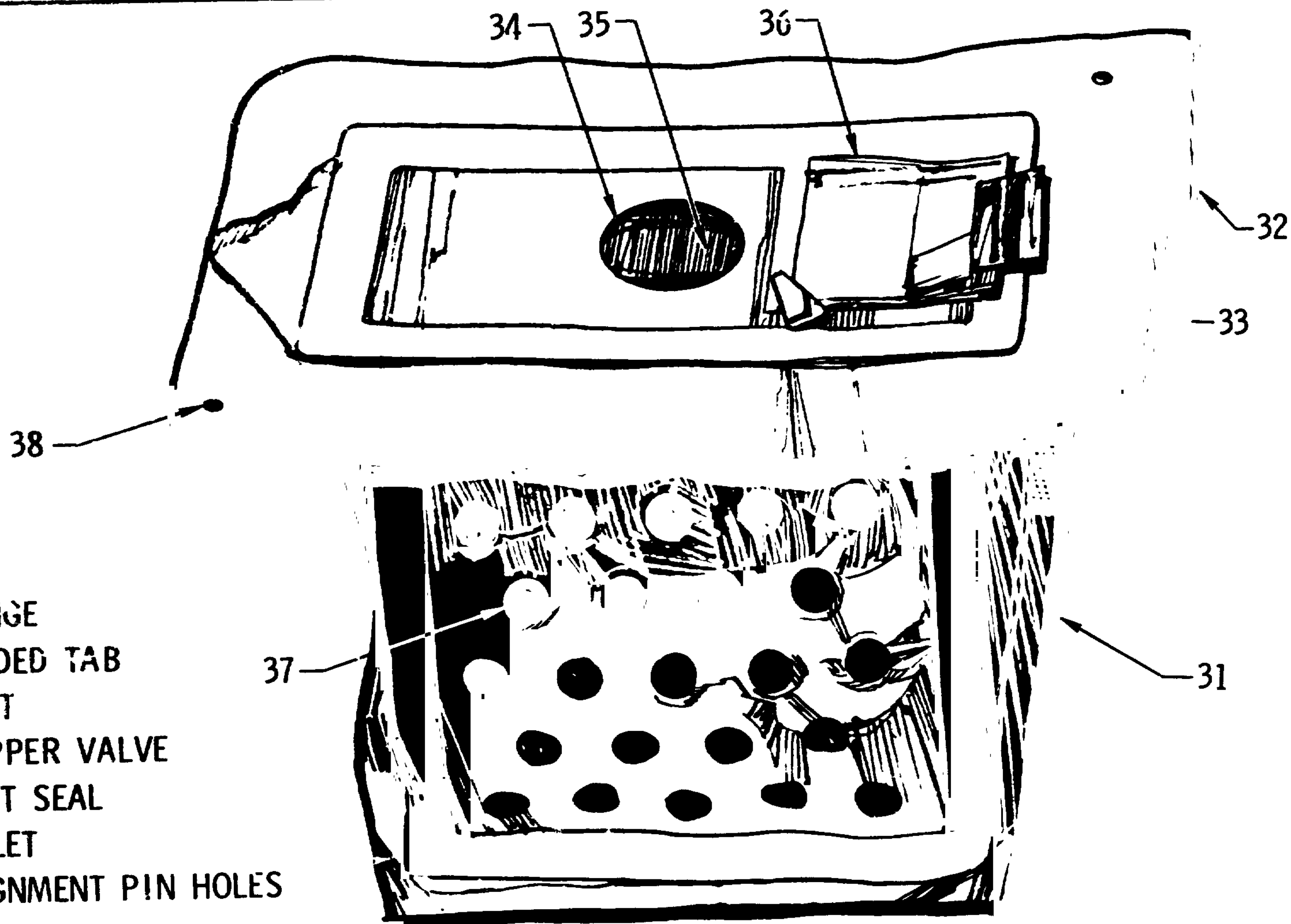
approximately 122 ml during urine sample withdrawal. The sample containers are stowed in the collapsed state and evacuated of all air. The sample container is connected to the urine bag quick disconnect (QD) through a mating QD on the sample bag. The sample container then expands to the sampled volume while being restrained by the crimper/cutter door. The crimper/cutter handle is actuated which seals and cuts the sample bag and seals the hose remaining with the urine bag. The three sample containers (one from each crewman) are then transferred to the urine freezer for on-orbit preservation for eventual return to earth in a urine return container (Figure 2.2.11.1-17). Replacement sample containers are made readily available from a limited supply in a WMC stowage compartment. The WMC supplies are replenished periodically from packages of sample containers stowed in OWS forward dome stowage compartments.

- Contingency Urine Mode (Cuffs) - Contingency urine cuffs are used as a backup mode or an alternate mode of collecting urine. This mode of urine collection may be used at the crewman's discretion or if the blower and/or separator is inoperative. The cuff connects to the cuff adaptor and valve assembly located on a corner of the urine bag. Use of the cuff permits the crewman to use the urine collection system without the use of the gravity simulating airflow system. 24-hour collection is maintained as in the normal airflow mode. The bag box assembly, urine drawer, chilling and sampling are used in the normal manner except that during urination the bag box and/or bag is removed from the urine drawer for use.

d. Vacuum Cleaner Bags - Vacuum cleaner bags (Figure 2.2.11.1-18) are provided for use in the vacuum cleaner to collect and retain particulate matter and water utilizing gravity substitute airflow from the vacuum cleaner blower. Upon installation in the vacuum cleaner, the vacuum cleaner inlet fitting inserts itself into the opening on the debris bag when the bag's access door is closed to permit air and debris to be directed into the bag (Figure 2.2.11.1-12). The air then exits the debris bag through the vapor port while solids and liquids are retained in the bag. When sufficiently full, or at 7-day intervals, the debris bag is sealed, removed, and disposed of in the trash disposal airlock (Figure 2.2.11.1-15).

e. Trash Collection Bags - Biologically active trash is disposed of into the waste tank in trash collection bags which provide for controlled off-gassing of liquids contained in the trash. Controlled venting via the trash bags prevents excessive waste tank pressures. In

SKYLAB - ORBITAL WORKSHOP
WASTE MANAGEMENT SUBSYSTEM
DEBRIS COLLECTION BAG



31. BAG
32. FLANGE
33. MOLDED TAB
34. INLET
35. FLAPPER VALVE
36. INLET SEAL
37. OUTLET
38. ALIGNMENT PIN HOLES

Figure 2.2.11-1-18

addition, bagged trash minimizes the formation of large ice crystals, which may have collected on and clogged the screens in the waste tank. Two types of trash collection bags were provided: trash bags that served as trash receiving stations within the OWS; and disposal bags used for bagging large items.

- General Purpose Trash Bags - Certain stowage compartments in the OWS are allotted to the collection of trash in a trash container. Eight trash containers are located in the OWS; one in the experiment compartment, two in the wardroom, one in the WMC, three in the sleep compartment (one in each sleep area), and one in the OWS forward compartment (Figure 2.2.11.1-19). Each trash container accommodates a trash bag which accepts and retains all trash inserted into the bag (Figure 2.2.11.1-20). Four hundred and twenty trash bags are grouped in packages of 7, 8, and 45 trash bags per package. These packages are stowed in stowage compartments throughout the OWS and are used as resupply provisions. The filled trash bags are then disposed of into the waste tank through the trash disposal airlock.

  Small trash from throughout the Orbital Assembly (OA) is brought to one of the eight trash containers for disposal. The trash is inserted through the hole in

ORBITAL WORKSHOP
TRASH DISPOSAL SUBSYSTEM
TRASH BAG LOCATIONS

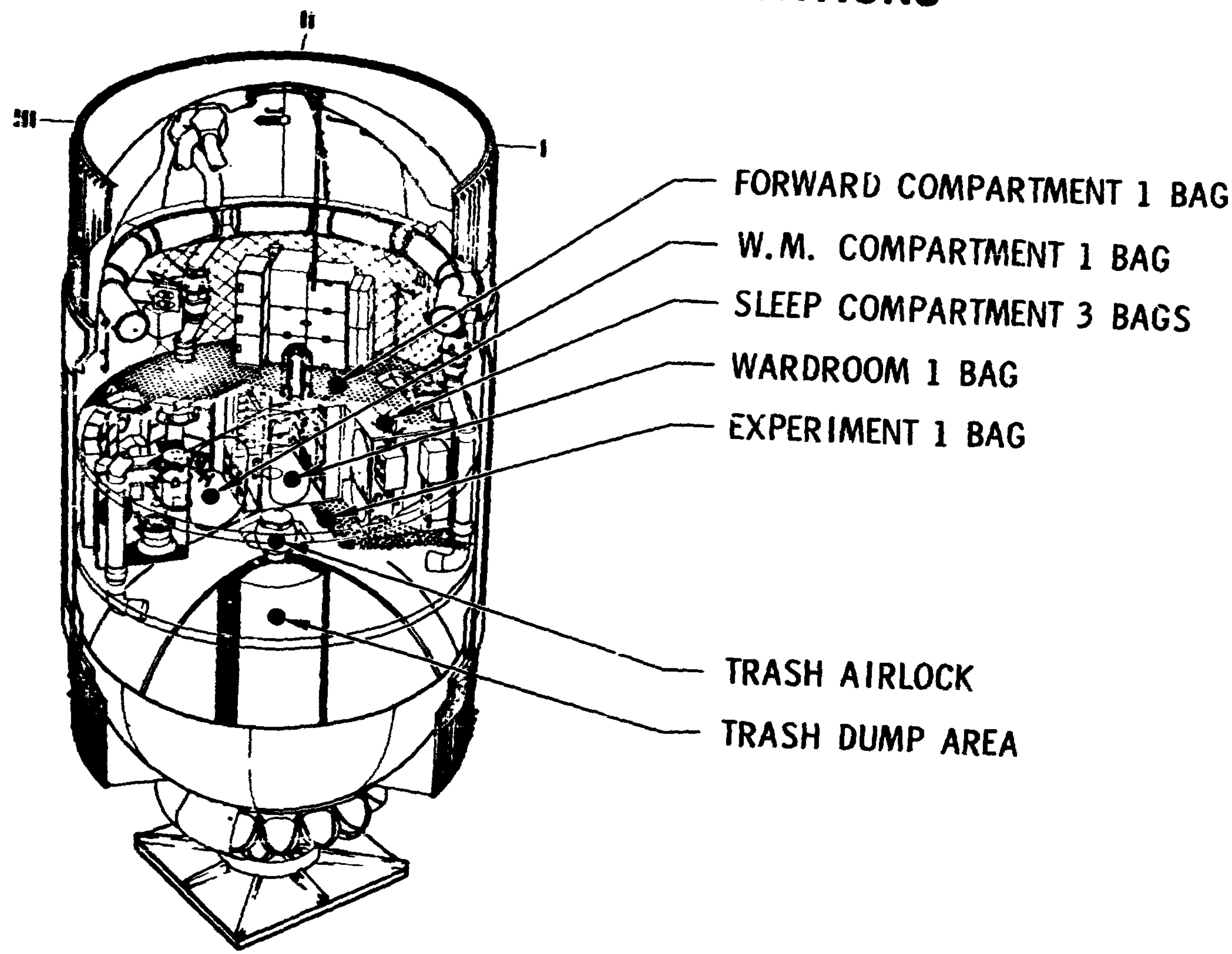


Figure 2.2.11.1-19

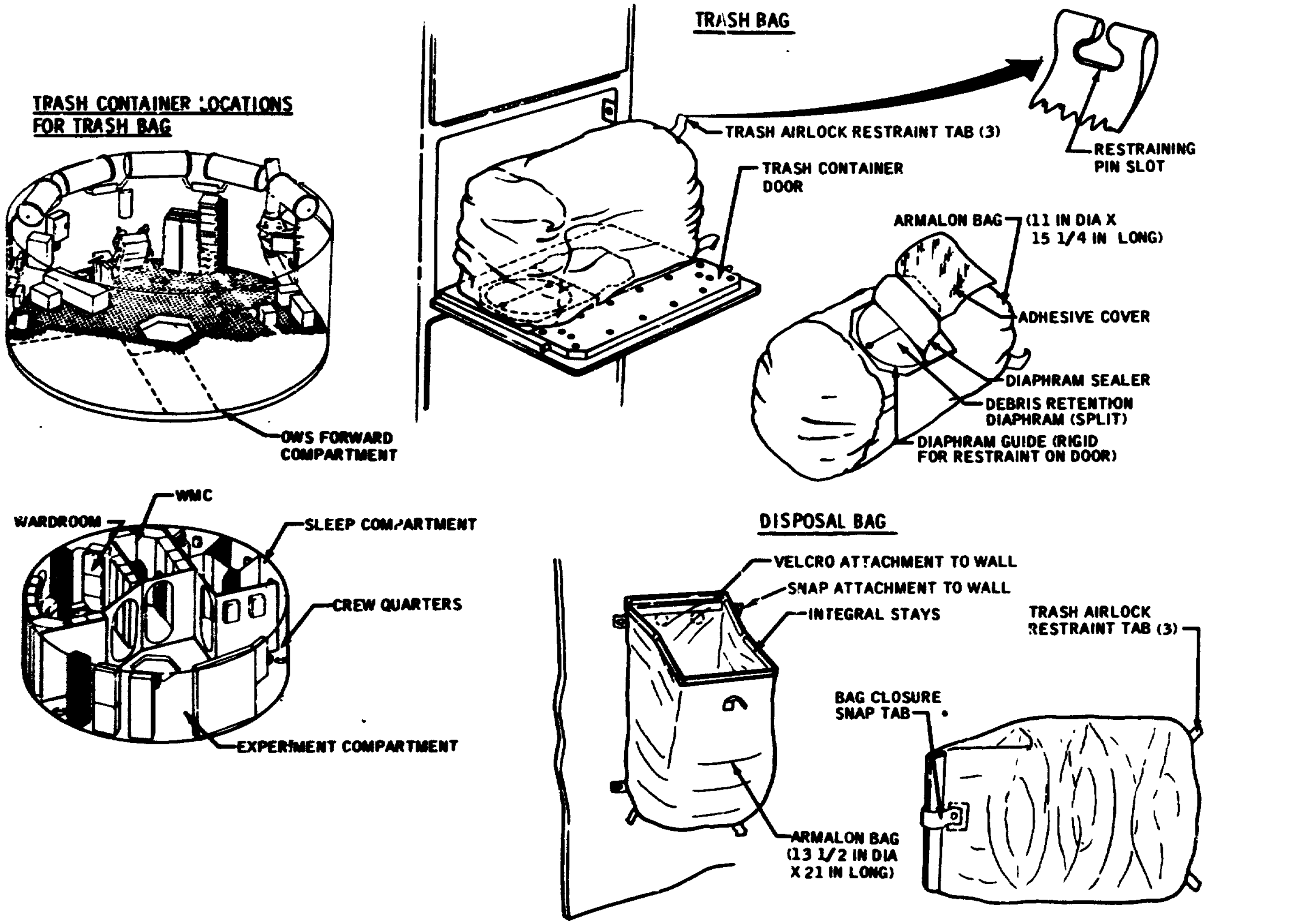


Figure 2.2.11.1-20. Trash Collection Bags

the trash container door, directly into the trash bag mounted onto the backside of the door. The trash bag contains a split, flexible diaphragm through which the trash is inserted into the bag. The 6-1/2-inch (0.17 meters) diameter of the diaphragm constrains the use of the bag to small items such as tissues, towels, washcloths, etc. The trash bag is 11-inches (0.28 meters) in diameter by 15-1/4-inches (0.39 meters) long and is constructed of armalon. The bag is impermeable in the orbital assembly (OA) habitable atmosphere, but will vent vapors when exposed to the vacuum of the waste tank. The trash bags in the wardroom and the WMC are replaced daily, other trash bags are replaced weekly. When a trash bag is removed from the trash container, a bag-mounted adhesive-backed cover is sealed into place over the diaphragm to seal off the opening. The bag is then placed in the trash disposal airlock for disposal into the waste tank. The trash bag is restrained in the airlock by three bag-mounted restraint tabs, which fit over three restraining pins in the airlock. One side of the tab is open to permit rapid bag release from the pin during the trash ejection cycle.

- Large Trash Bags - Disposal bags are used for large items (urine bags, sleep restraints, food overcans, charcoal filters, etc.) which do not fit into the trash bags. Three hundred and fifty-two disposal bags, grouped in packages of 35 and 37 disposal bags per package, are stowed in stowage compartments throughout the OWS. When a large item is to be disposed of, a disposal bag is obtained from one of the stowage compartments and transferred to the work area. The disposal bag is secured near the work area by the bag's velcro lining or its snaps (Figure 2.2.11.1-20). The snaps mated with the SWS snap pattern. "Stays" in the bag opening maintained the bag open or shut.

After use, the bag is sealed shut by a snap tab on the bag and disposed of into the waste tank through the trash disposal airlock. The disposal bag is restrained in the trash disposal airlock by the same type of restraining tabs used for the trash bags.

The disposal bags are 13 1/2-inches (0.34 meters) in diameter by 21-inches (0.53 meters) long. The roll-over sealing featu of the bag reduces the useful volume of the bag by 20 percent and the length by about 4-inches (10.2 centimeters). Each bag is constructed of armalone and is impermeable in the OA habitable atmosphere; however, the bag will vent vapors when exposed to the vacuum of the waste tank.

2/ Waste Management Equipment - Waste management equipment associated with the collection, processing, storage and return or disposal of waste material is provided through use of a fecal/urine collector, waste processors, urine freezer, urine dump equipment, fecal return bundles, urine return containers, and vacuum cleaner and trash airlock.

a. Fecal/Urine Collector - The fecal/urine collector (Figure 2.2.11.1-21) is a rigid, vertical-mounted unit which provides the hardware items necessary to collect feces and urine from each crewman. The unit contains one fecal collector for collection of a single defecation and three urine drawers, one per crewman, to collect each urination and to store the urine in a chilled state for a 24-hour period. A fecal/urine collector blower unit provides a gravity substitute airflow to draw and retain the waste material into the fecal collector and into the urine drawer centrifugal separator and storage bag during waste collection (Figure 2.2.11.1-22). The gravity substitute airflow is filtered through a fecal collector filter to remove noxious odors prior to its recirculation back into the cabin by the blower unit.

The fecal/urine collector permits one crewman to accomplish defecation and urination simultaneously while seated on the collector. Body stabilization is attained through use of collector-mounted crewman restrains consisting of a lap belt and two handholds. The urine

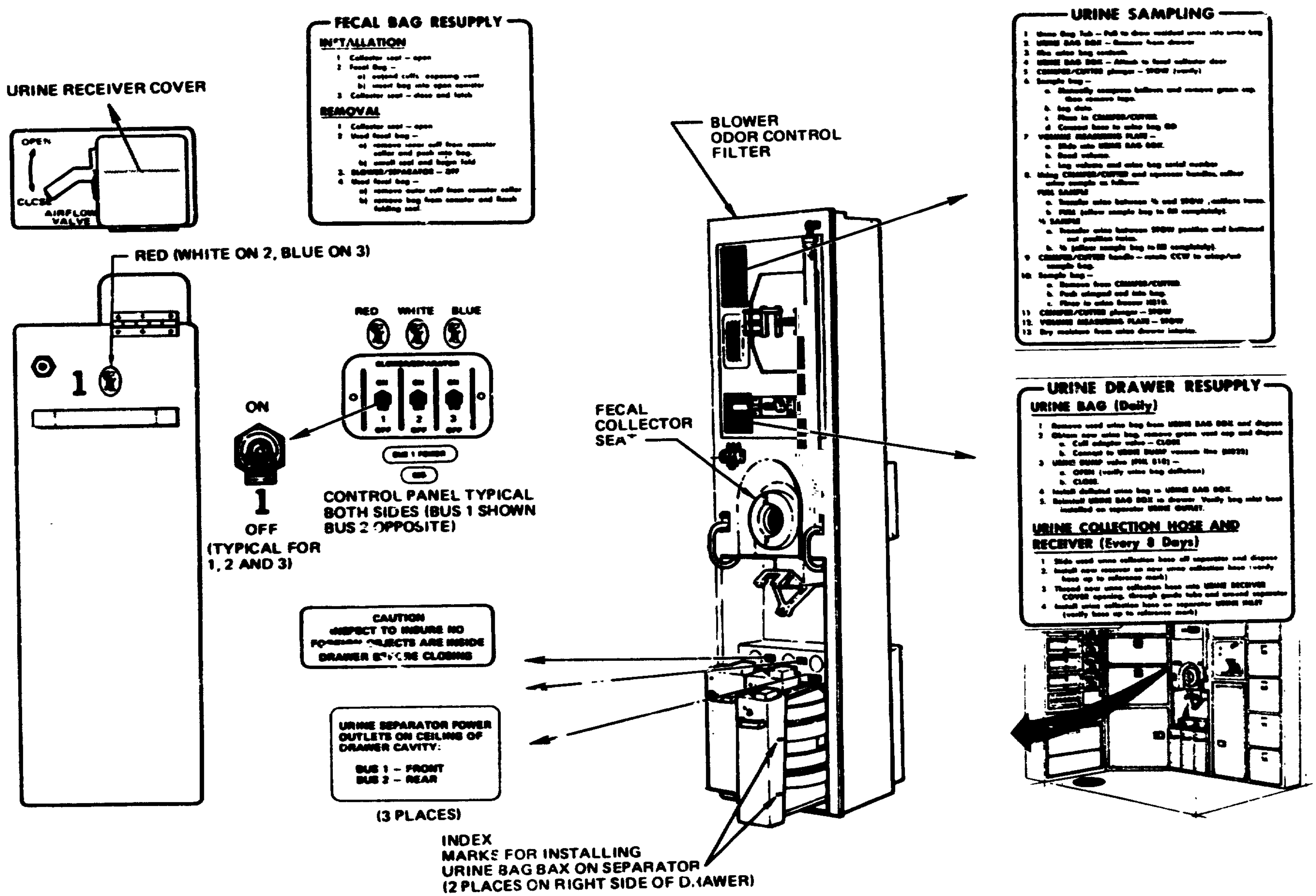


Figure 2.2.11.1-21. Fecal/Urine Collector

SKYLAB - ORBITAL WORKSHOP
FECAL/URINE COLLECTOR -- BLOCK DIAGRAM

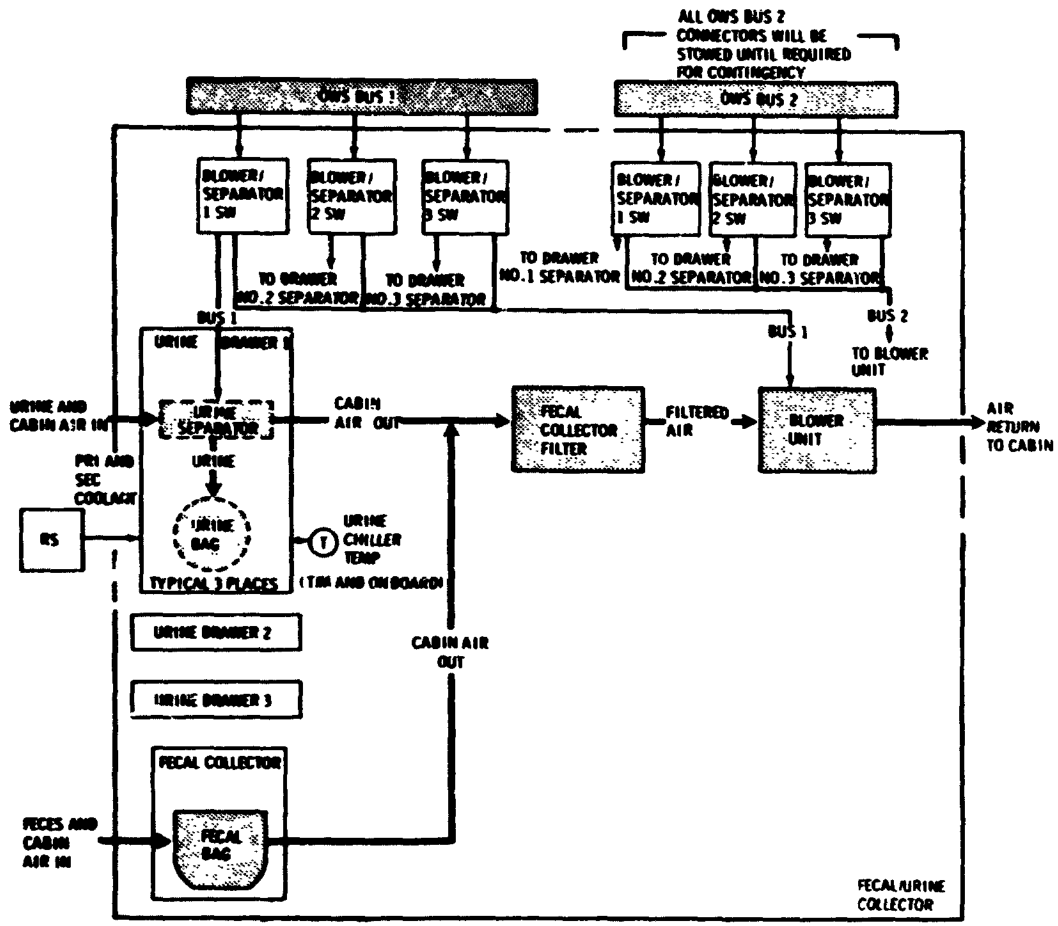


Figure 2.2.11.1-22

receptacle, utilized for attaching the urine receiver assembly of the urine bag is located at a convenient height to facilitate standing urination. The urine receptacle is movable into two different positions to accommodate comfortable body positioning during seated or standing urination. A pair of light-duty foot restraints is located in front of the fecal/urine collector to permit standing urination and to allow the crewman to conduct maintenance on the fecal/urine collector.

- Fecal Collector - The fecal collector is an integral part of the fecal/urine collector and consists of a fecal collection receptacle, a mesh liner and a hinged seat (Figure 2.2.11.1-23). The hinged seat provides access to the mesh liner to permit installation of a fecal bag. The seat is contoured and contains airflow holes to allow cabin air to be drawn into the fecal bag as a gravity substitute airflow. The seat upon closure, provides an integral seal between the fecal bag and the fecal collection receptacle and between the seat and the bottocks of the crewman. Gravity substitute airflow through the seat airflow holes, draws the feces into the fecal bag where it is retained. Air drawn from the cabin into the fecal bag is exhausted through the collection bag's vapor port, through the mesh

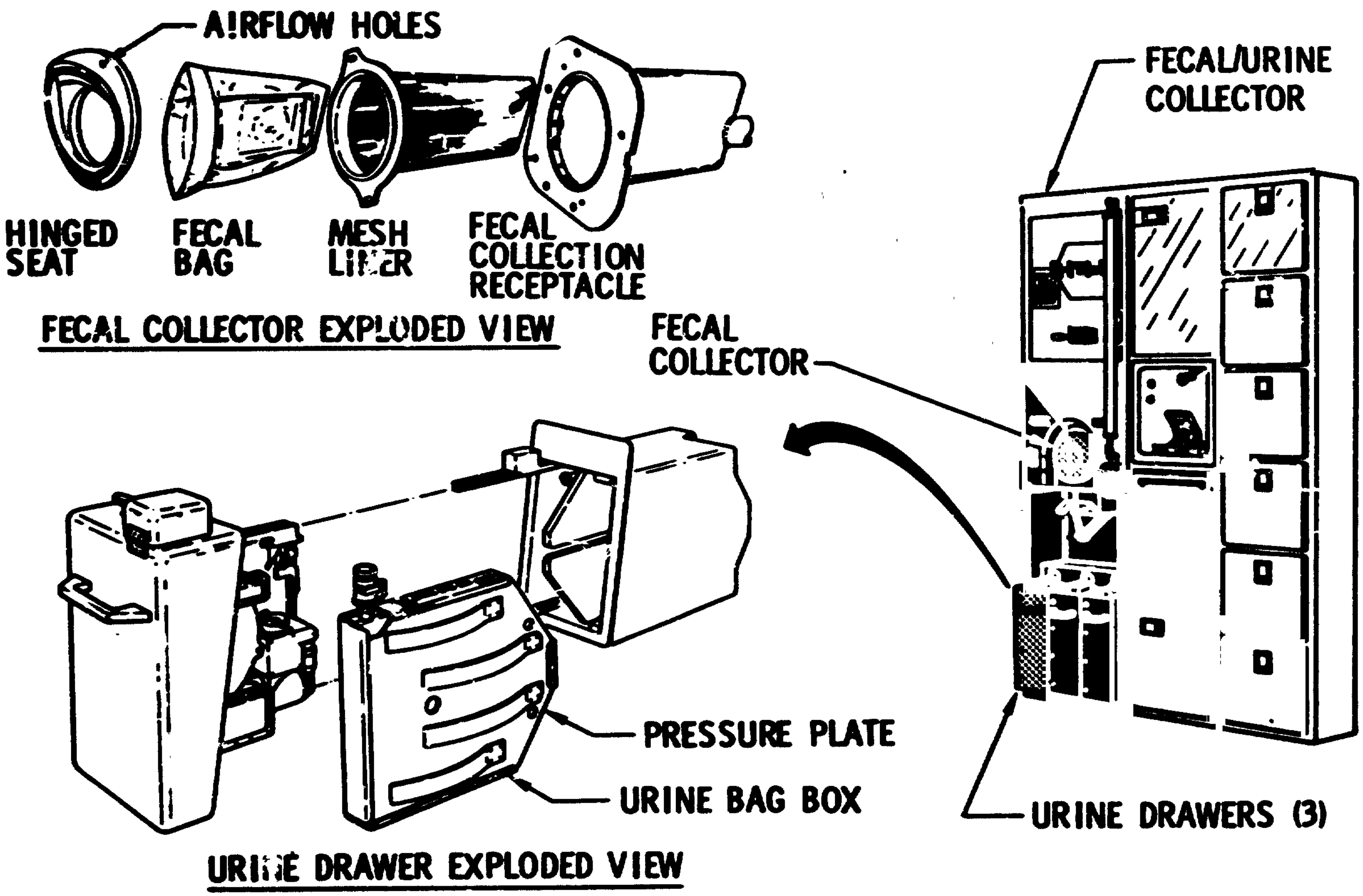


Figure 2.2.11.1-23. Fecal and Urine Collection Facilities

liner and into the fecal collection receptacle. The cabin air is then passed on to the fecal collector filter and the blower unit. The fecal bag is removed from the fecal collector after each defecation and replaced immediately with a new bag. The fecal bag with its contents is then vacuum dried in a waste processor to facilitate on-orbit storage.

- Urine Drawers - Three urine drawers are located at the base of the fecal/urine collector, one assigned to each crewman through the use of "Snoopy" decals. The urine drawers provide a facility to collect, temporarily store for 24-hours, the urine from three crewmen. Each drawer contains the facilities to accept the urine (urine inlet line), to separate the air from the urine (urine separator), to collect and store the urine (urine bag). Each urine drawer is also serviced with Refrigeration System (RS) coolant to refrigerate the urine bag, to cool the urine separator and is provided with a gravity substitute airflow from the collector's blower unit. Two banks of switches, Blower/Separator Bus 1 Power and Bus 2 Power switches, are located on the fecal/urine collector cabinet adjacent to the fecal collector. The switches are used to simultaneously power the collector's blower unit and the drawer's urine separator.

In use, the crewman will select his drawer using the urine inlet receiver and Airflow Valve which permits gravity substitute airflow to draw the air into the urine separator. The appropriate blower/separator switch on the fecal/urine collector is then turned on to start the drawer's urine separator and to start the collector's blower unit (Figure 2.2.11.1-24 and -25). The crewman then places the urine receiver on the urine receptacle to receive urine. The cabin air and the crewman's urine are drawn through the urine inlet line and into the urine separator (Figure 2.2.11.1-26). Here the urine and air are separated by centrifugal action with the urine being passed into the urine bag and the cabin air being routed to the filter and blower. Upon completion of urination the crewman restows the urine receiver, the Airflow Valve is closed and the blower-separator switch is turned off; however, an interlock circuit permits the urine separator to continue operating for five minutes to empty the separator of all urine. This operation is repeated over the 24-hour urine collection cycle with the urine being pooled each time in the urine bag. This accumulation of urine is refrigerated by a cold plate type urine chiller which is supplied RS primary and secondary coolant to preserve the

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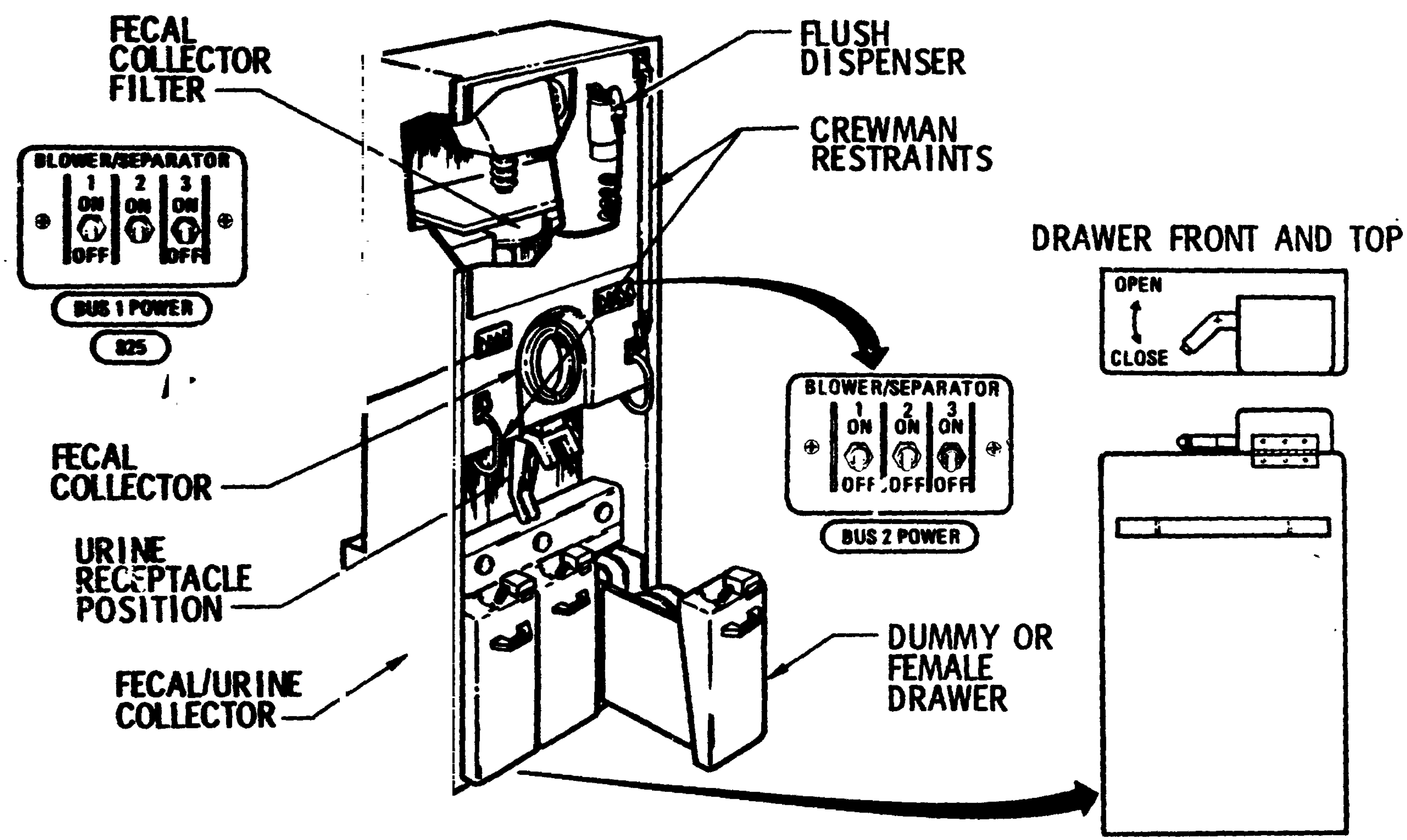


Figure 2.2.11.1-24. Fecal/Urine Collector

SKYLAB - ORBITAL WORKSHOP
FECAL/URINE COLLECTOR -- SCHEMATIC

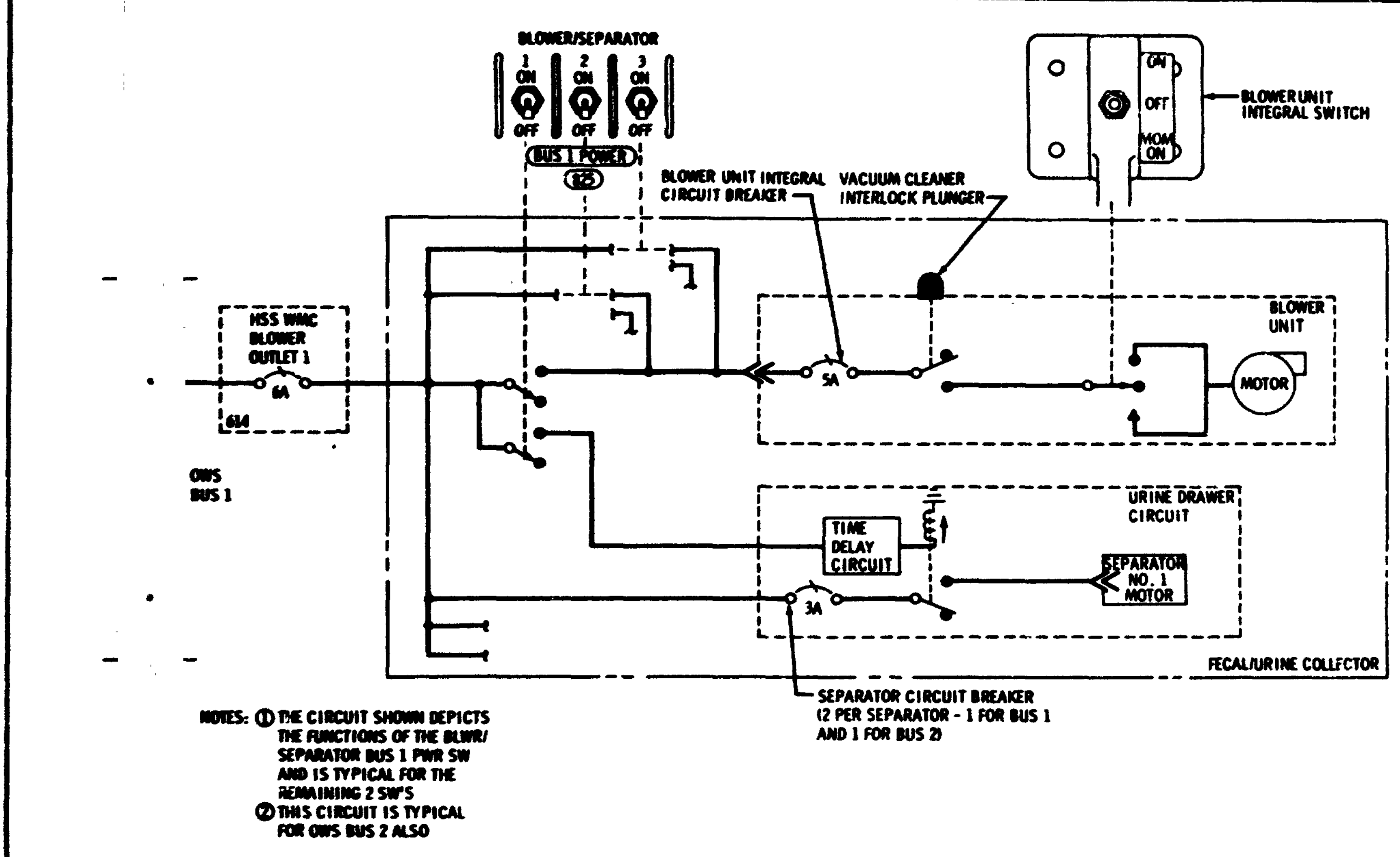


Figure 2.2.11.1-25

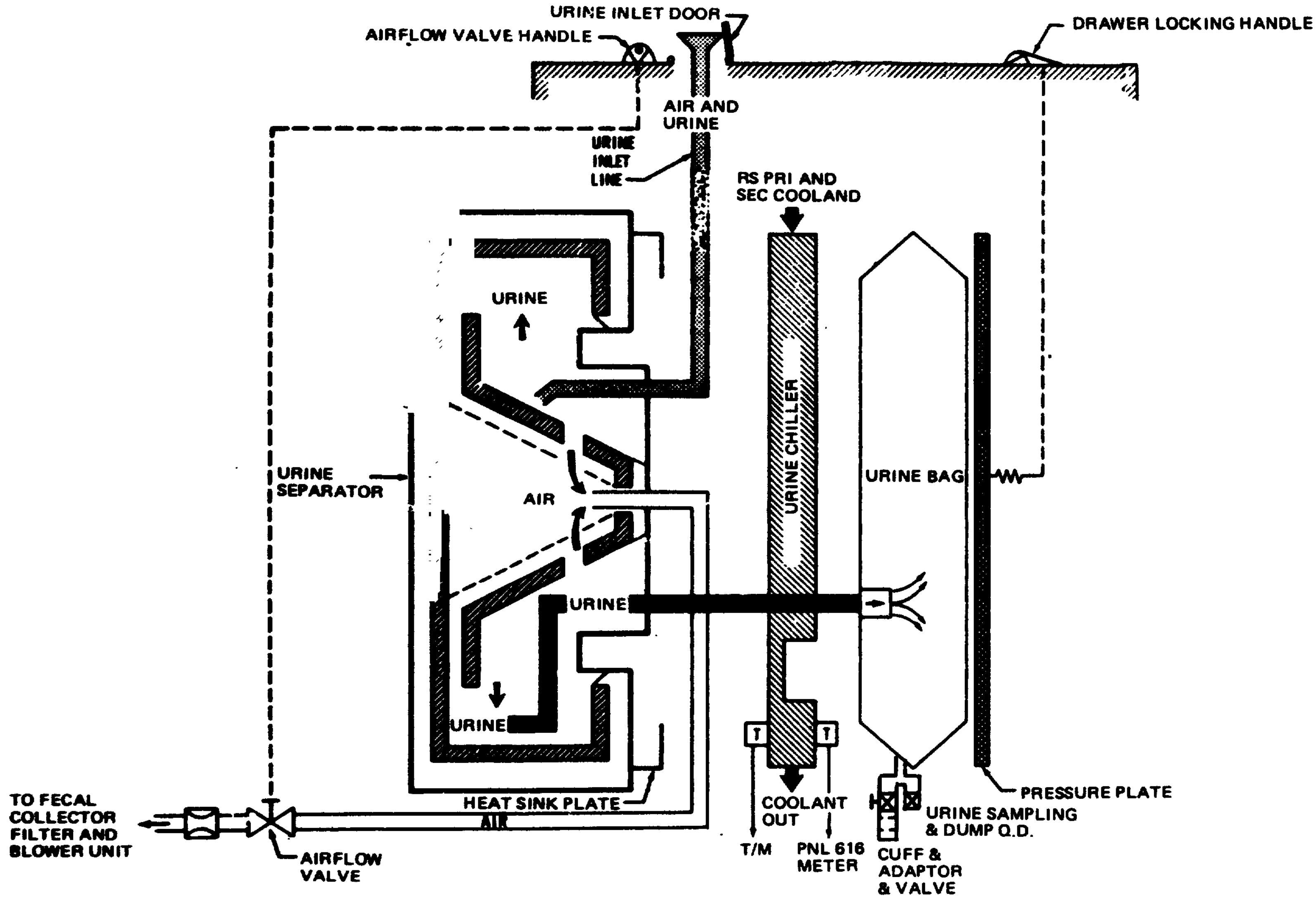


Figure 2.2.11.1-26. Typical Urine Drawer - Schematic

urine at approximately 59°F (15°C). The urine separator also contacts the urine chiller with two heat sink plates to cool the separator prior to urine collection. The urine chiller in each drawer contains two temperature readouts, one for on-board display on panel 616 and one on telemetry (Figure 2.2.11.1-27).

At the end of the 24-hour urine collection cycle, the urine drawer is opened, the urine bag is disconnected from the separator. The urine bag and bag box assembly are removed and the urine bag is then manually mixed to insure a homogeneous mixture. The bag and box assembly are mounted on the face of the collector in the urine bag squeezer mechanism. The volume measurement plate is installed in the box assembly and the volume is determined and recorded. A sample bag is obtained and installed in the crimper/cutter assembly, the QD of the sample bag is connected to the QD of the urine bag, the urine bag squeezer is actuated which transfers urine from the urine bag into the sample bag, the crimper/cutter is actuated which seals and cuts the sample bag and seals the mating half of the sample bag hose which remains with the urine bag. The sample bag is removed from the cutter assembly and stowed in the urine freezer. The urine bag with the remaining

SKYLAB - ORBITAL WORKSHOP
URINE CHILLER -- FUNCTIONAL DIAGRAM

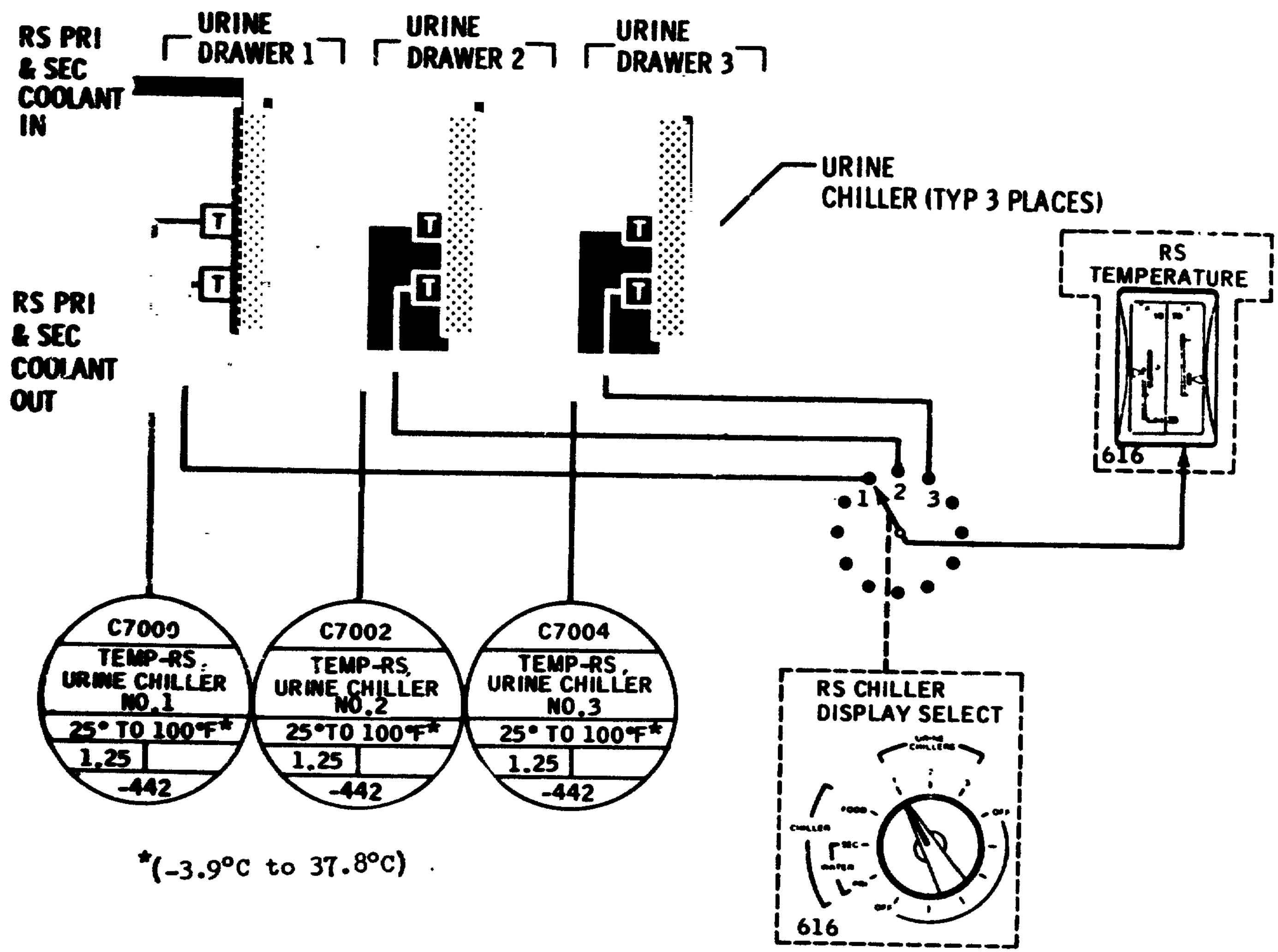


Figure 2.2.11.1-27

urine is removed from the box assembly and stowed in the trash disposal bag. A fresh urine bag is obtained and connected to the urine dump line to remove trapped air and check for leakage through the urine bag QD. The bag is then installed in the box assembly and placed in the urine drawer. The bag is connected to the centrifugal separator. The urine receiver and inlet hose assembly are removed and a fresh urine receiver hose assembly is installed to the separator and stowed in the receiver compartment of the drawer every eight days. The drawer is closed and locked, ready for the next days collections. This procedure is repeated for the other two drawers. The trash bag with the three filled urine bags and used urine receiver assemblies is sealed and disposed of through the trash airlock into the waste tank.

- Urine Separators - One removable urine separator is located in each urine drawer (Figures 2.2.11.1-26 and -28) and is used to separate the cabin air from the crewman's urine during the collection process. The urine separator is powered by a removable motor which is supplied OWS bus power from panel 825 blower/separator switches on the fecal/urine collector cabinet (Figure 2.2.11.1-24). A time delay circuit is provided to allow the separator

SKYLAB - ORBITAL WORKSHOP
URINE SEPARATOR - EXPLODED VIEW

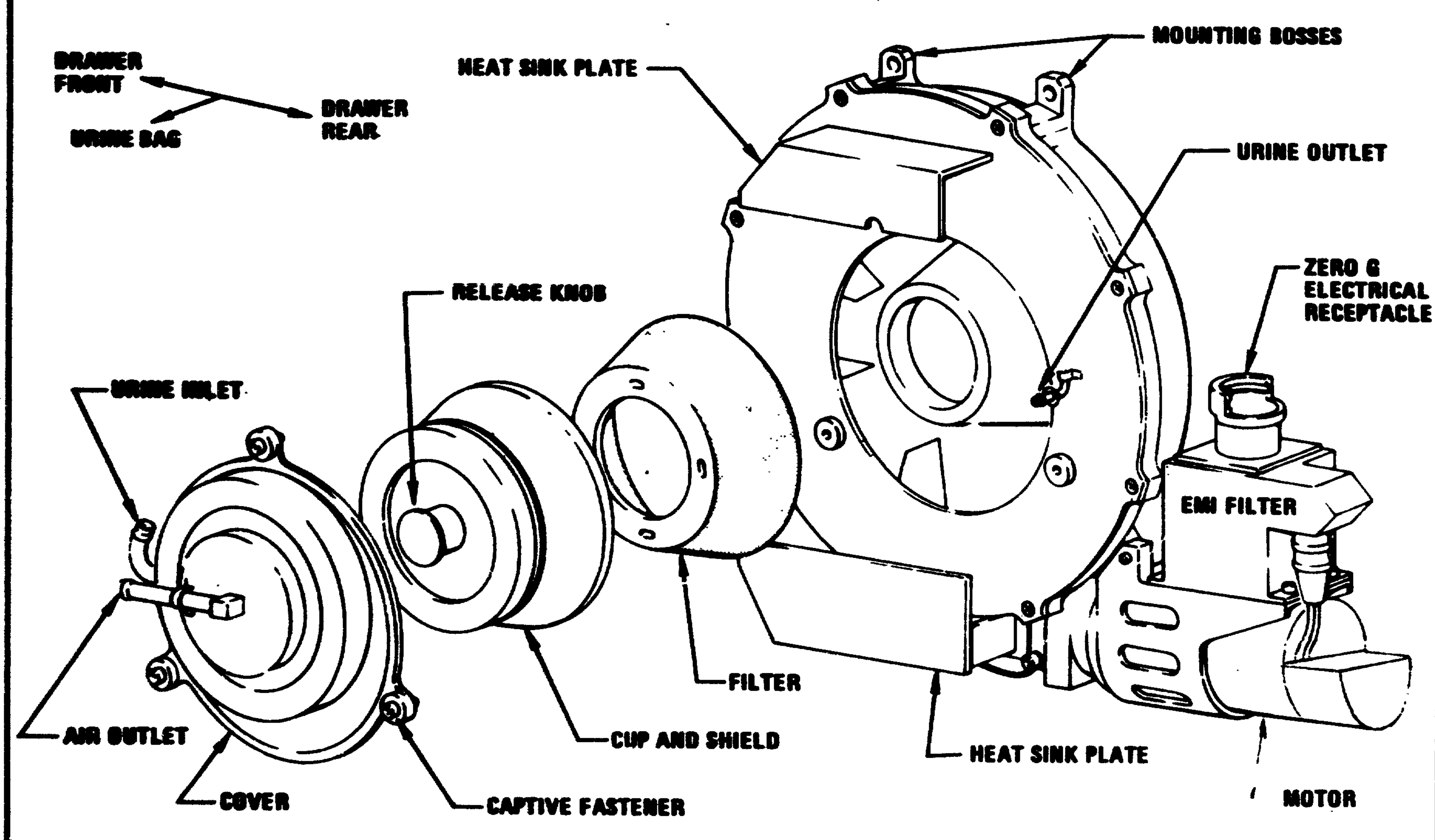


Figure 2.2.11.1-28

to run for additional 5 minutes after the blower/separator switch is positioned off to empty the separator of residual urine. A separate circuit breaker for each separator is provided within the fecal/urine collector cabinet.

Each urine separator contains a urine inlet which attaches to the drawer's urine inlet line. The urine inlet routes the cabin air and the crewman's urine into the vaned separator. The spinning action of the vanes acts on the urine/air mixture and propels the urine to the periphery of the separator through centrifugal action. The cabin air exhausts through the center of the separator through a replaceable filter to the air outlet for routing to the filter and blower. A urine outlet on the separator housing picks up the urine at the separator's periphery and routes it to the urine inlet boot of the urine bag. A heat sink plate, mounted on the top and bottom of the separator housing, is used to contact the urine chiller for thermal conditioning of the urine separator. The separator is chilled to prevent it from increasing the temperature of the urine during the separation process. One urine separator is provided for the personal use of each crewman. The additional separators are stowed in OWS forward dome stowage compartments along with one spare. The urine separators and their motors for the SL-2 mission are launched in position in the secured urine drawers in the fecal/urine collector module. Upon activation the SL-2 crew will unsecure the urine drawers and remove two launch restraints (one bolt each) from each separator. Each subsequent mission's crewmen will then install their urine separators using the original three motors. The used separators are tape sealed at their openings, five are stowed in the T027 locker and one in the food freezer. The SL-4 separators will be flushed and remain installed in the urine drawers. Two spare motors, one spare separator, three spare urine separator power cables, and six spare separator filters are stowed in the spare parts stowage compartments in the OWS forward dome (locker D428).

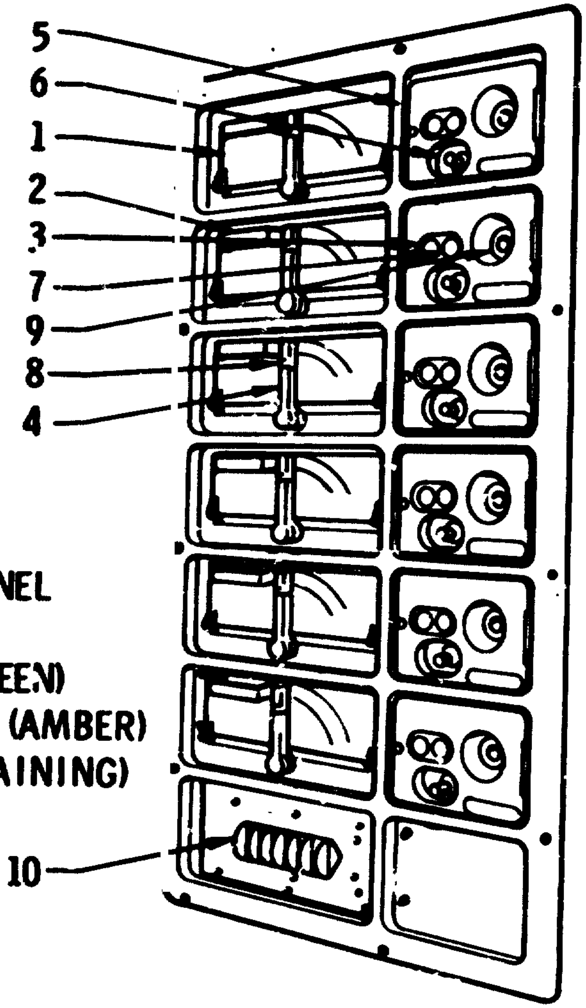
- Collector Odor Control Filter - The fecal collector filter is located within the fecal/urine collector cabinet behind a hinged door and removes odors resulting from defecation and urination. The filter processes all the air used during waste collection prior to its entering the blower. The filter removes the odors by passing the air through an annular bed of activated charcoal. The filter is replaced every 28 days and the replacements are stowed in OWS spare parts stowage compartments in the OWS forward dome.

- Blower Unit - The fecal/urine collector blower unit is located within the fecal/urine collector cabinet behind a hinged door and provides a gravity substitute air flow for the hygienic collection of feces and urine. The blower unit exhausts cabin air back into the WMC which is drawn through the fecal collector and the urine drawers and passed through the fecal collector filter. The blower unit is replaceable, should it fail, with a spare provided in a spare parts stowage compartment in the OWS forward dome. The blower unit is also interchangeable with the suit dryer blower unit and the vacuum cleaner blower unit which may also be utilized as replacement parts. Quick release mounting techniques are employed on each of the three blower units to facilitate interchangeability. The collector's blower unit is normally powered from OWS bus 1 through the BLOWER/SEPARATOR BUS 1 POWER switches located adjacent to the fecal collector. A short power cord with a zero-g connector then routes power to the blower unit. In the event that OWS bus 1 power is unavailable, OWS bus 2 power may be utilized through the BLOWER/SEPARATOR BUS 2 POWER switches located opposite to the bus 1 switches. To accomplish this, the bus 1 power cord is removed from the blower unit and the short power cord from the bus 2 circuit is connected to the blower unit. The blower unit contains an integral circuit breaker, readily accessible in a recess on the blower unit's housing. A vacuum cleaner interlock, for use when the blower unit is utilized in the vacuum cleaner is over-ridden when used in the fecal/urine collector. The plunger-type interlock on the blower unit's housing is actuated continuously while installed in the fecal/urine collector utilizing an override stub permanently located on the blower unit's mount in the collector cabinet. Once the blower unit is mounted in the fecal/urine collector, the override stub depresses the interlock plunger and retains the relay on the power supply contact. Integral switch control is provided on the handle of the blower unit to supply power to the blower motor continuously (ON position) or momentarily (MOM ON position-for use in the vacuum cleaner). Prior to the installation of the blower unit in the fecal/urine collector, the blower unit's integral power switch is actuated to the ON position. This configuration enables the blower/separator bus power switches on the fecal/urine collector to accomplish master control.

b. Waste Processors - The waste processors preserve those organic and inorganic constituents of vomit and feces required to support the medical experiments. The waste processors vacuum-dry the vomit and feces specimens in their collection bags so that the residue may be safely stored on-orbit until return to earth. The processor also dries the desiccants used for suit drying.

Six independent waste processors are wall-mounted in the WMC (Figure 2.2.11.1-29). Each processor utilizes mechanical pressure, an electric heating element and waste tank vacuum pressure to accomplish the drying of waste material. Each processor will accommodate one fecal bag or one contingency fecal bag or a suit desiccant and is controlled by individual control and display panels which include a timer, manually set by the crewman to automatically initiate and terminate the drying cycle. The drying time is selected as a function of the waste material's mass. The waste processor control and display panels are replaceable with one spare provided in a spare parts stowage compartment in the OWS forward dome. Each waste processor contains a hand-operated vacuum/cabin vent valve which is interlocked to the door lock/unlock handle (Figure 2.2.11.1-30). This interlock prevents inadvertent opening of the processor door while the unit is processing. The vacuum/cabin vent valve handle protrudes over the chamber door and must be rotated to the horizontal position to permit door actuation; however, the interlock is removable to permit separate handle action. Upon rotation

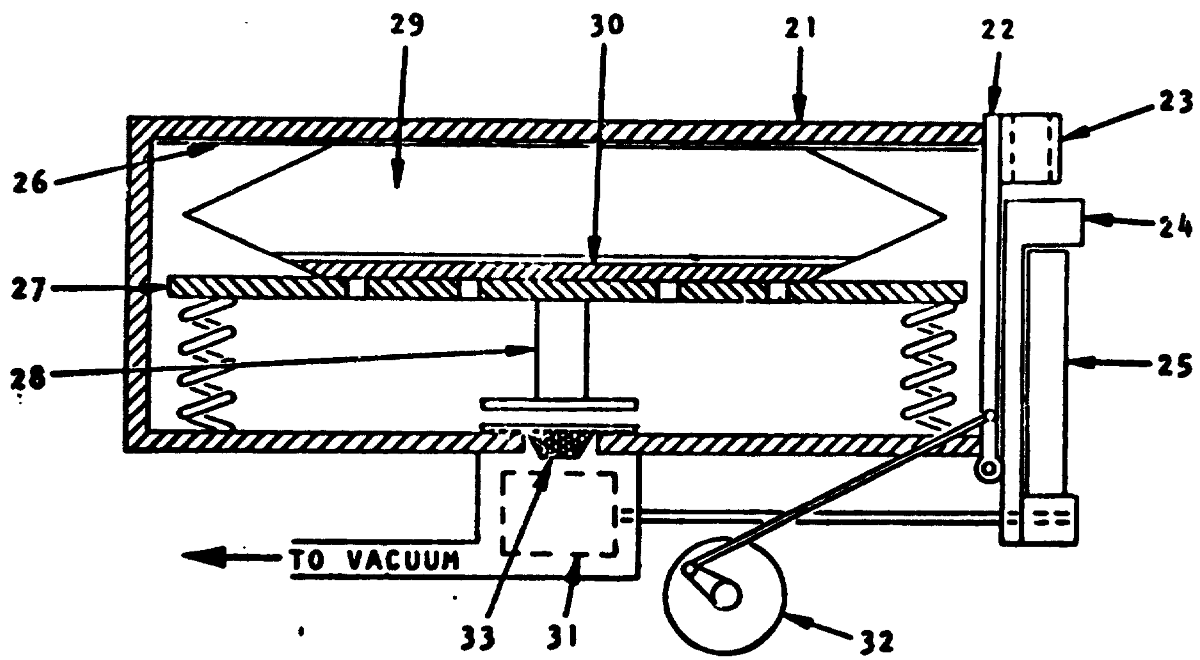
SKYLAB-- ORBITAL WORKSHOP
WASTE MANAGEMENT SUBSYSTEM



1. PROCESSOR DOOR
2. DOOR HANDLE
3. DOOR LOCK HANDLE
4. VENT VALVE HANDLE
5. PROCESSOR CONTROL PANEL
6. POWER SWITCH
7. TIMER STATUS LIGHT (GREEN)
8. OVERTEMP STATUS LIGHT (AMBER)
9. TIMER DIAL (HOURS REMAINING)
10. CIRCUIT BREAKERS

Figure 2.2.11.1-29

WASTE PROCESSOR CHAMBER



21. PROCESSOR CHAMBER
22. CHAMBER DOOR
23. DOOR HANDLE
24. DOOR LOCK
25. VENT VALVE HANDLE
26. HEATED SURFACE
27. PERFORATED PRESSURE PLATE
28. FILTER SAVER VALVE
29. COLLECTOR BAG
30. BAG FILTER
31. VENT VALVE
32. DAMPER
33. SCREEN

Figure 2.2.11.1-30

of the vacuum/cabin vent valve to the cabin position, the vacuum outlet to the waste tank is sealed off and the cabin air is bled into the processor. When the processor pressure is equalized with the cabin, the door can be opened. The collection bag containing the waste material is then placed in the open processor and the door is closed. The vacuum/cabin vent valve is rotated to the vacuum position to lock the door shut and to open the processor chamber to the vacuum of the waste tank. A processor pressure plate is actuated upon door closure which applies a slight force to the collection bag, aiding in the expulsion of the vapors through the bag's vapor port and maintaining the bag in contact with the heater surface. The crewman then selects the desired drying interval for the particular mass of waste material in the bag. Automatic waste processing has now been initiated as a 15-minute delay timer begins counting down to permit sufficient collection bag deflation prior to the application of heat. Upon expiration of the 15-minute delay timer, the green timer light is illuminated and the temperature control circuit is activated with the processor heater being thermostatically controlled to 105°F (40.6°C). This temperature will be sufficient, with the reduced pressure in the chamber, to cause the water in the waste material to evaporate and to be exhausted through the vacuum/cabin vent valve into the waste tank utilizing the waste processor vacuum vent line. Upon expiration of the hours remaining timer, the heater element is turned off automatically, completing the waste processing.

The collection bags are then removed and transferred to a storage area in the WMC for eventual return to earth in fecal return bundles. (See Figure 2.2.11.1-31). In the event that the processor temperature exceeds 165°F (73.9°C), an overtemp cut-off circuit will activate, illuminating the amber overtemp light, removing timer and heater power.

A LAMP TEST switch is provided on panel 600 in the WMC to checkout the waste processor status lights. Activating the switch to the bus 1 or bus 2 position will illuminate all the TIMER lights and the OVERTEMP lights on all six waste processors simultaneously (see Figure 2.2.11.1-32).

The waste processor door seals, filter saver valve seals and vapor port are replaceable with a spare stowed in a spare parts stowage compartment in the OWS forward dome.

SKYLAB -ORBITAL WORKSHOP WASTE PROCESSING AND URINE MANAGEMENT FACILITIES

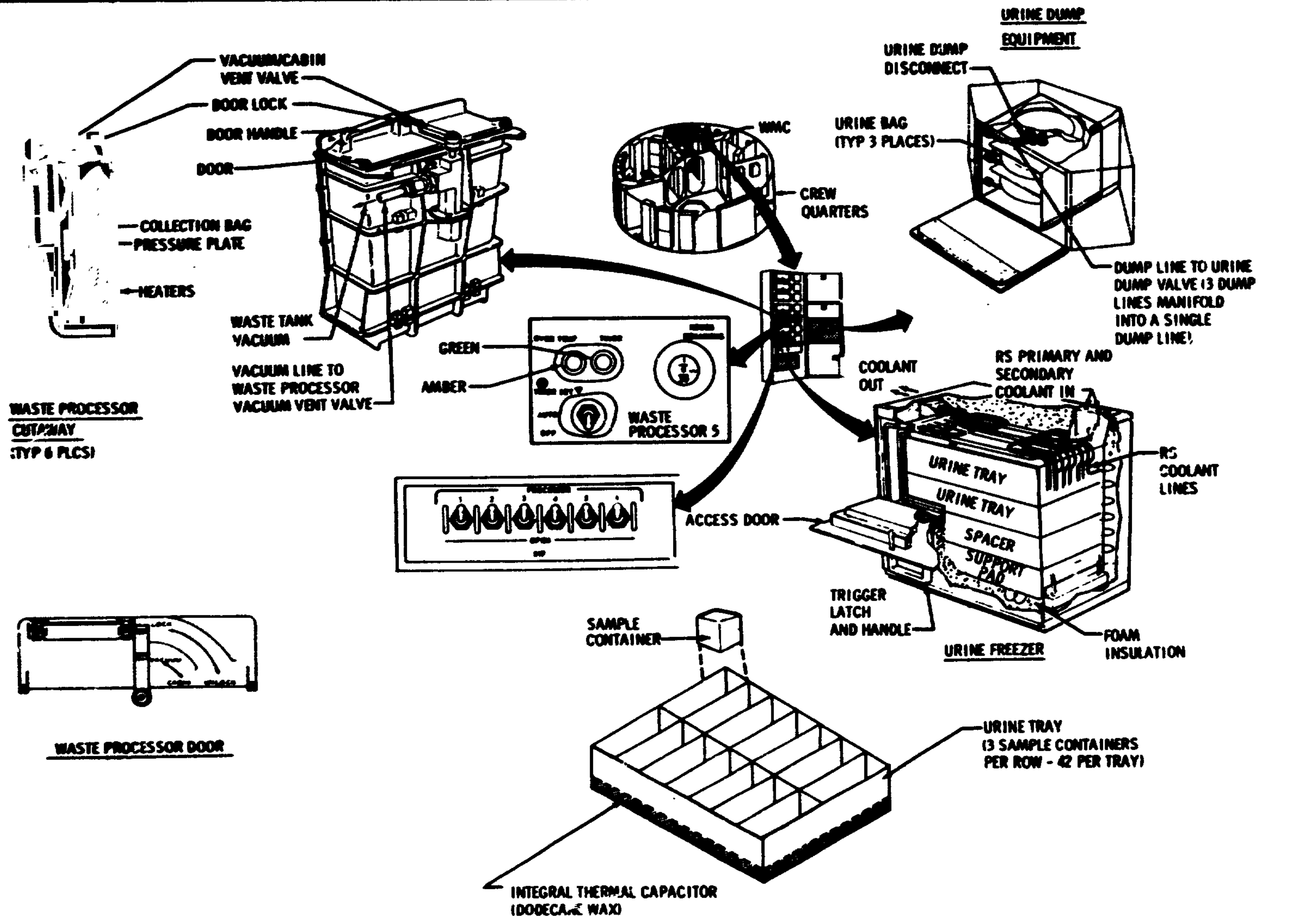


Figure 2.2.11-1-31

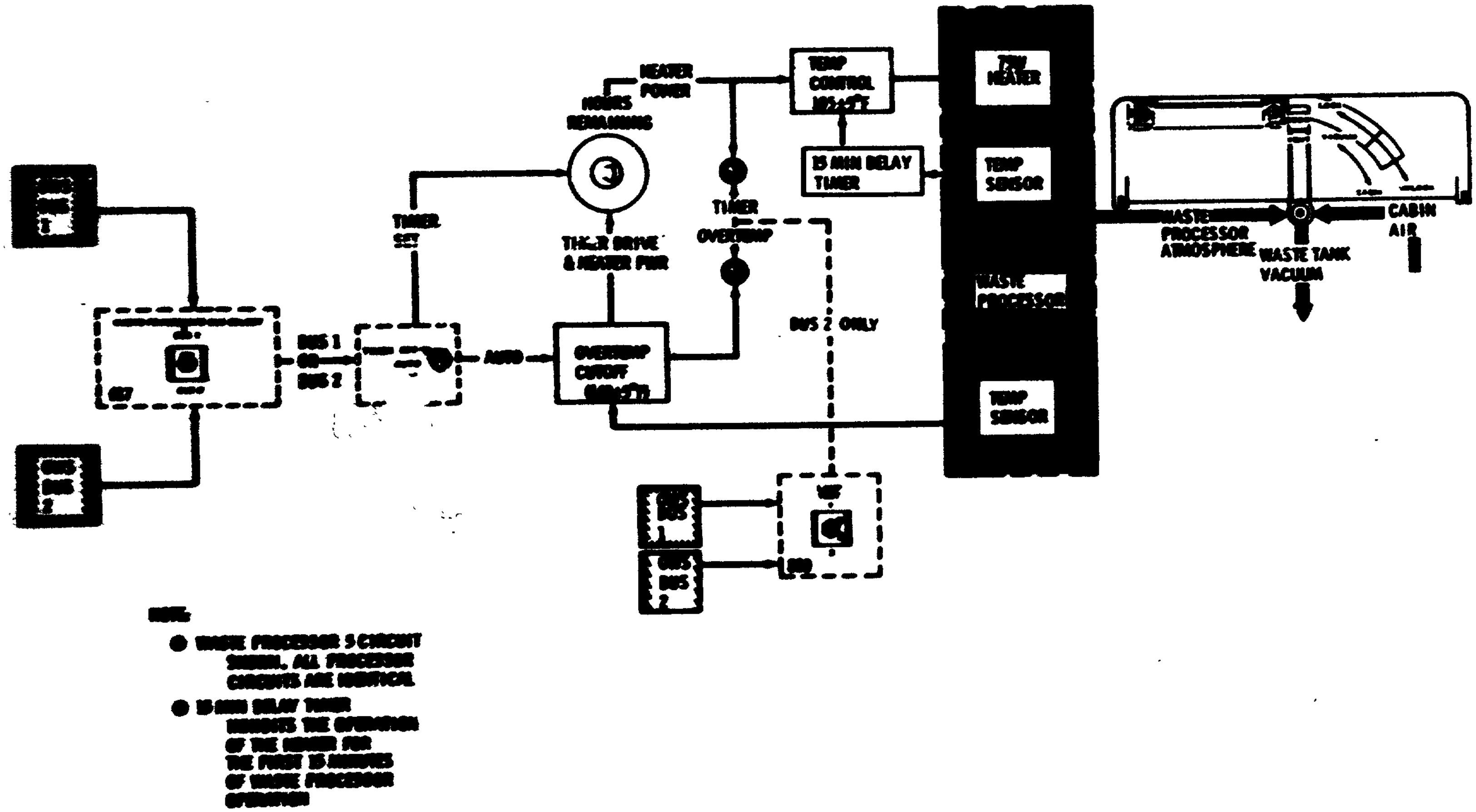


Figure 2.2.11.1-32. Waste Processor - Functional Diagram

c. Urine Freezer (part of refrigeration subsystem) - The urine freezer is located in the WMC immediately below the waste processors and provides interim low-temperature storage of urine samples for eventual return to earth at the end of the mission. The 122 ml urine samples, which are contained in sample containers, are retained in urine trays which hold 42 sample containers (2 weeks accumulation) in partitioned segments (Figure 2.2.11.1-31). Two urine trays are stacked in the freezer at all times together with either three tanks of thermal capacitor (SL-2 mission) or with a spacer (SL-3 and SL-4 missions).

An integral thermal capacitor composed of dodecane is contained in a sealed bottom compartment of each urine tray. The dodecane, after being thermally conditioned in the freezer, maintains the sample containers below 17°F (-13°C) during the return to earth portion of the mission in a urine return container.

For the SL-2 mission, the urine freezer is launched with two urine trays and with three removable tanks of thermal capacitor (dodecane) to assure thermal stabilization of the trays prior to the installation of the initial urine samples from the SL-2 crew. The tanks will accompany the SL-2 urine trays in the urine return container during the return-to-earth portion of the SL-2 mission to provide an additional heat sink and filler material in the SL-2 urine return container. At the end of the SL-2 mission when the urine freezer is emptied, a spacer, which remains in the freezer thereafter, is inserted into the urine freezer together with two empty urine trays. The remaining two urine trays for the next mission are stowed in wardroom freezer 1 (food depleted during SL-2 mission) for thermal conditioning. After the first 28 days of the SL-3 mission, the urine freezer will be filled with frozen samples. These sample containers in their urine trays will be transferred to wardroom freezer 1 for storage during the remainder of the mission. The two empty urine trays which occupied the wardroom freezer since the previous SWS deactivation, will be transferred to the urine freezer. At the end of the SL-3 and SL-4 missions, four filled urine trays used on each of these missions will be returned to earth in a urine return container. The SL-3 and SL-4 mission supply of urine trays and the urine freezer spacer are stowed in the urine return containers until ready for use.

Two temperature measurements are located in the urine freezer for on-board display on panel 616 and on telemetry.

d. Urine Dump Equipment - The urine dump equipment is utilized as a backup means to dispose of a days accumulation of urine in urine bags using a liquid dump method to the waste tank. The urine dump equipment is located in the WMC stowage compartment H822 adjacent to the fecal/urine collector (Figure 2.2.11.1-31). The compartment contains the facilities to store, for a 24-hour period, three urine bags containing the urine, remaining after sample withdrawal. Upon completion of the 24 hour holding period, or when desired during this time period, the crew may drop the urine into the waste tank through the urine dump. This procedure will be utilized in the event of the failure of the primary disposal method (the trash disposal airlock).

The urine dump equipment stowage compartment is subcompartmentalized into a three-tiered area, one tier for each urine bag. Each tier (Figure 2.2.11.1-33) is fitted with a dump line containing a quick-disconnect which mates with the urine dump quick-disconnect on the urine bag. Each dump line manifolds into a single urine dump line and urine dump valve on panel 818. Opening of the urine dump valve provides waste

SKYLAB - ORBITAL WORKSHOP DCR
URINE SYSTEM DUMP COMPARTMENT

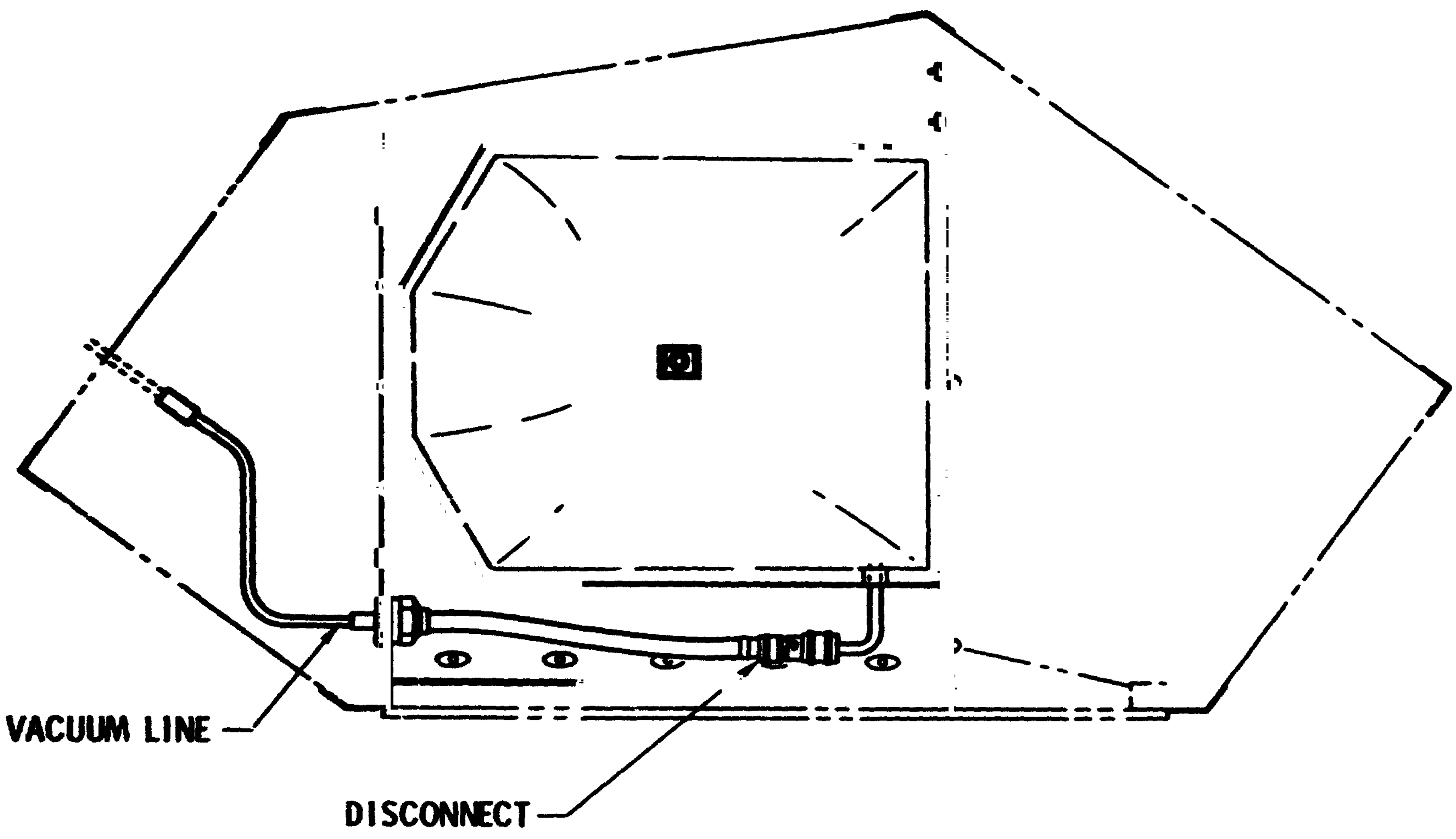


Figure 2.2.11.1-33

tank vacuum pressure to the urine dump equipment dump lines to permit urine to flow from the urine bags into the waste tank.

Prior to use, the urine bags are connected through the dump QD to the urine system to evacuate the gas and check the bag for leakage. Full urine bags will be transferred to the urine dump equipment immediately after volume determination and sampling when this backup method of disposal is desired. Normally, the three urine bags containing the residual urine will be immediately disposed of into the waste tank through the trash disposal airlock.

e. Fecal Return Bundles - Twenty-five fecal return bundles are provided for use by the SL-2, SL-3 and SL-4 crews to return the mission accumulation of fecal matter and vomitus deposits contained in processed collection bags to earth.

The fecal return bundles (Figure 2.2.11.1-34) are beta fabric bags which are provided with separate fecal return bundle straps to secure the return bundle to adjacent equipment in the CM during deorbit and recovery operations. Processed fecal bags and contingency fecal bags are stowed on-orbit in a stowage compartment in the WMC. At the end of each mission these collection bags are gathered up and placed in fecal return bundles in varying quantities, so as to limit the volume of the return container to its particular stowage envelope in the CM. The fecal return bundles are then transferred to the CM and secured at predetermined locations using the fecal return bundle straps.

SKYLAB - ORBITAL WORKSHOP
WASTE MANAGEMENT SYSTEM
FECAL & URINE RETURN CONTAINERS

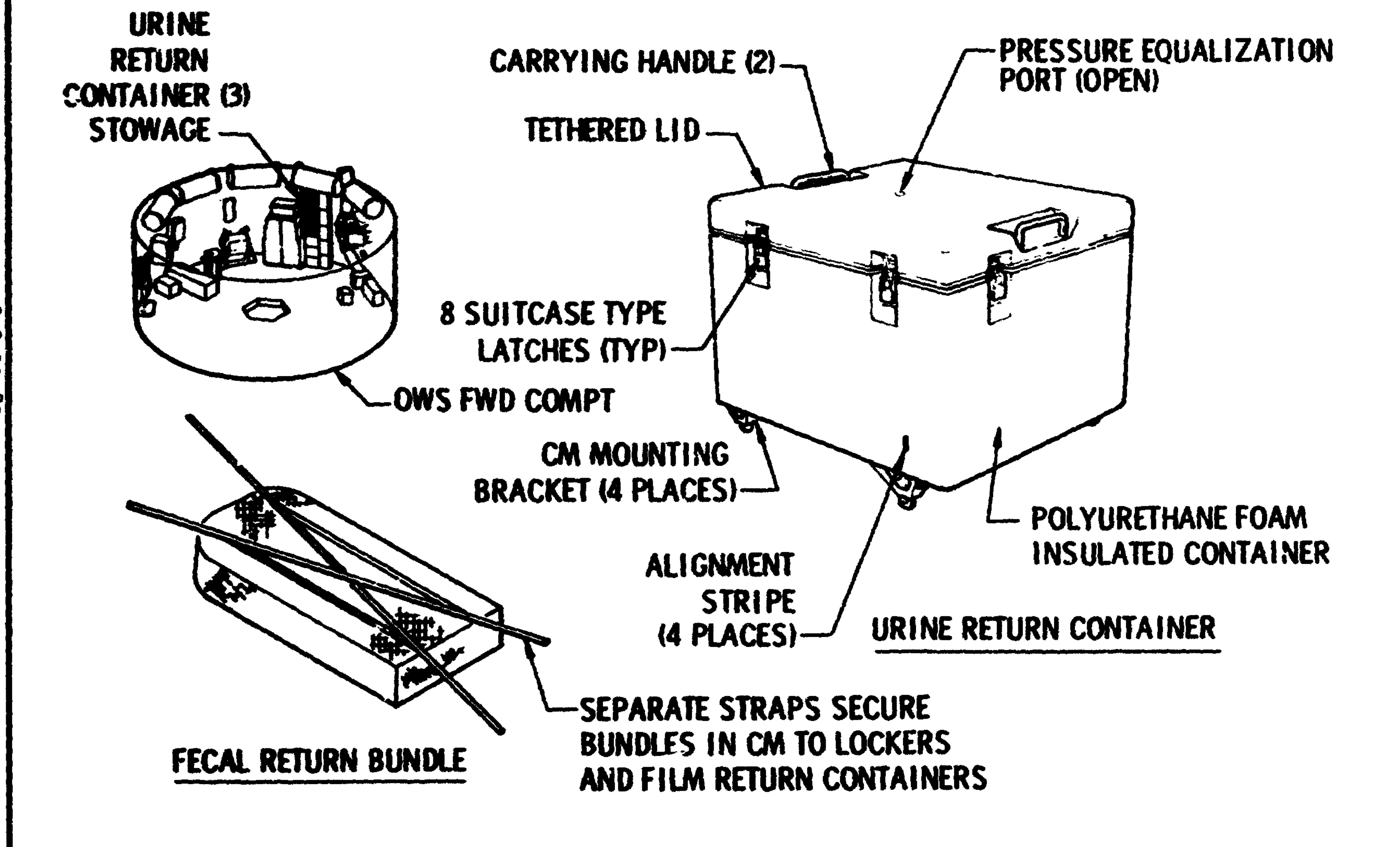


Figure 2.2.11.1-34

f. Urine Return Containers (part of transfer stowage subsystem) - Three urine return containers (Figure 2.2.11.1-34) are stowed in the OWS forward compartment and are utilized to preserve up to a 56-day accumulation of urine samples during the return to earth in the CM.

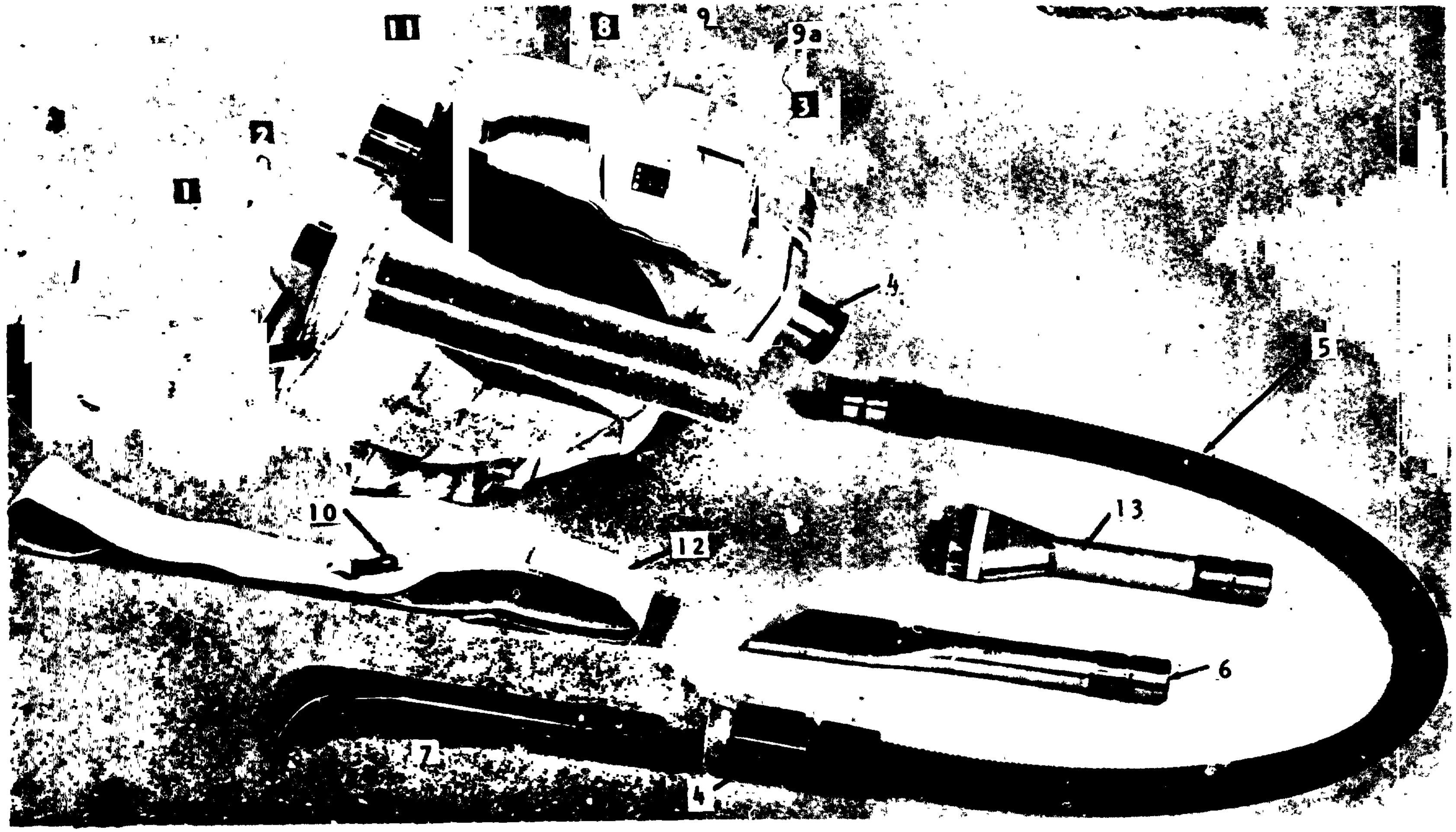
Each urine return container features top loading, utilizing a removable lid retained by eight latches and is attached to the return container with a short tether. An open pressure equalization port is located in the lid to maintain the internal pressure of the return container equivalent to the cabin pressure. The return containers utilize an "ice chest" design, that is, a container shell filled with foam insulation. Four CM type bulkhead mounting brackets are located on the underside of each return container to permit positive restraint in the CM or restraint in its stowed location in the OWS. Alignment strips are provided on the container to aid the crewman in the installation of the return container on its mounts. An identical mounting technique is employed in both the OWS and in the CM. While stowed in the OWS, two of the three urine return containers provide on-orbit stowage of eight urine trays (four per return container), urine return container filler material, and a urine freezer spacer. The remaining two urine trays are launched in the urine freezer.

Upon completion of each mission, the urine samples in their urine trays are transferred from the urine freezer to the mission's urine return container. The four empty urine trays stowed in the return container are then removed. Two are placed in the urine freezer and two are placed in wardroom freezer 1. The SL-2 crew will insert the urine freezer spacer in the urine freezer upon SL-2 deactivation and transfer the three deodecane tanks in the freezer to the SL-2 urine return container. The urine return container lid is secured into place and the return container and its contents are then transported to the CM. The urine samples are maintained in the frozen state through the phase change of the thermal capacitor in the urine trays in conjunction with the thermally insulated return container. In this manner, the urine is maintained below 17°F (-13°C) during CM deorbit and recovery operations.

g. Vacuum Cleaner - The vacuum cleaner (Figure 2.2.11.1-35 and 36) is used to collect and retain particulate matter, water and debris utilizing a gravity substitute airflow provided by a blower unit. The vacuum cleaner is a portable, self-contained unit powered from convenient hi-power accessory outlet. The vacuum cleaner utilizes a debris bag which retains the debris for eventual disposal.

The vacuum cleaner is stowed for ready accessibility in OWS forward compartment locker compartment F522 together with its attachments, hose and caddy. A beta fabric caddy completely encloses the VC unit and provides pouch-type stowage and convenient access of vacuum cleaner accessories (Figure 2.2.11.1-35). A waist tether stows around the caddy when not in use. A short strap provides caddy stowage of the

VACUUM CLEANER ASSEMBLY



1. CANISTER COVER	4. HOSE CONNECTIONS	7. SURFACE TOOL	10. SNAP HOOK
2. COVER LATCH	5. FLEX HOSE	8. UNIT HANDLE	11. STOWAGE MOUNTING BRACKET
3. TOOL CADDY	6. CREVICE TOOL	9. SWITCH	12. BODY BELT
		9A. SWITCH GUARD	13. BRUSH ATTACHMENT

Figure 2.2.11.1-35

SKYLAB - ORBITAL WORKSHOP
VACUUM CLEANER AND ACCESSORIES

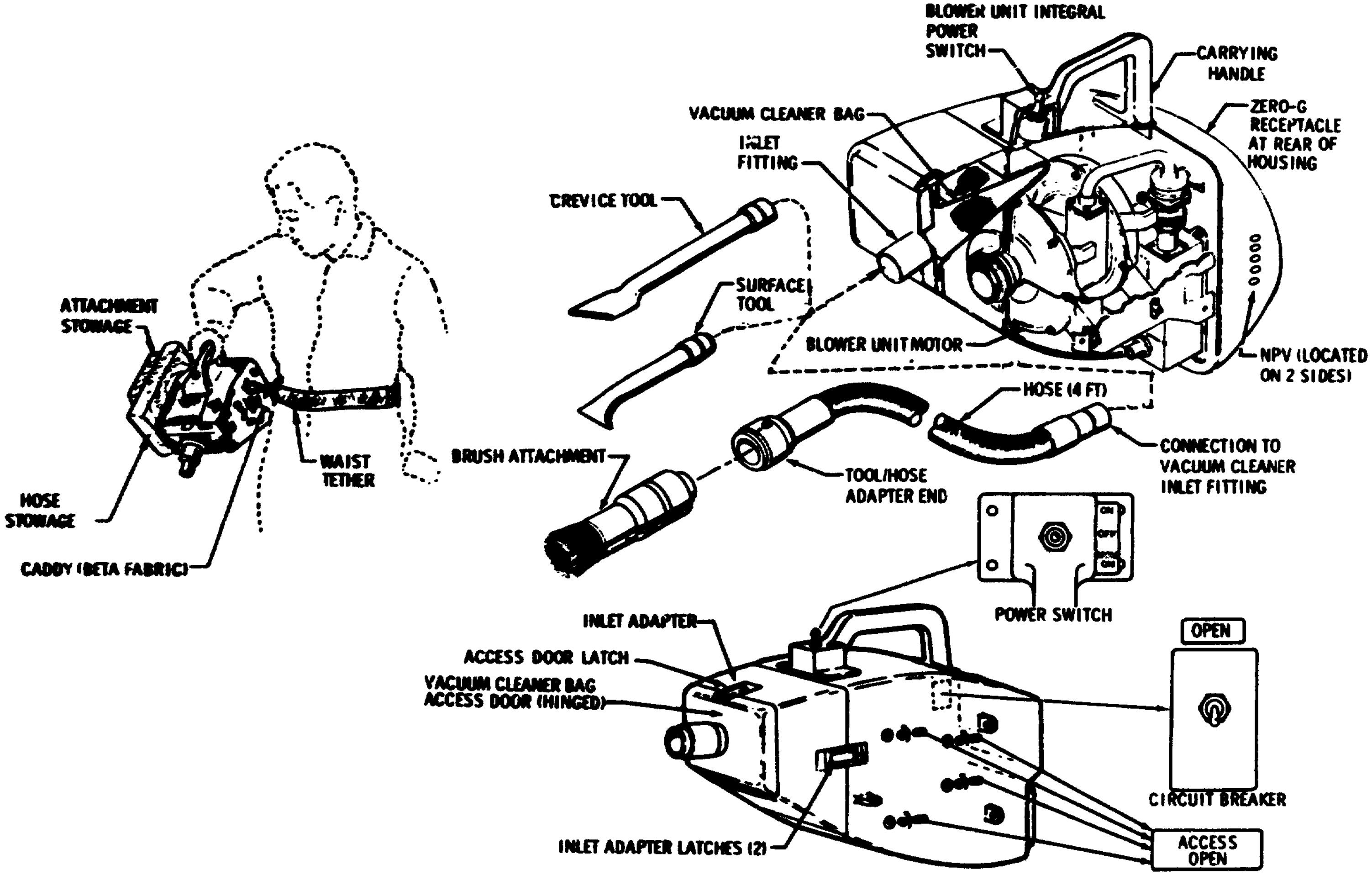


Figure 2.2.11.1-36

15-foot (4.6 meters) hi-power accessory cable when the cable is not in use. The short strap is also used to secure the cable to convenient structure to restraint the cable when it is deployed for use. Three attachments are provided:

- A surface tool for screen cleaning and for collection of loose and free floating debris.
- A crevice tool to facilitate the cleaning of confined areas.
- A brush attachment for removal of dirt and debris adhering to surfaces.

A 4-foot (1.2 meters) long flexible hose is supplied which connects to the vacuum cleaner inlet fitting and provides a tool/hose adapter with a locking feature for the attachments. The hose together with the vacuum cleaner and 15-foot (4.6 meters) power cable provides a radius of operation of approximately 20-feet (6.1 meters) from the hi-power accessory outlet.

A vacuum cleaner bag access door is hinged to the blower unit through the use of one latch. The access door is used to install and remove the debris bag when full or at weekly intervals. Blower unit airflow and debris enters the vacuum cleaner through the inlet fitting on the access door and passes into the bag. The entrained airflow retains the debris into the bag while the air exits the bag through the bag's vapor port. Air is then exhausted through NPV's located on both sides of the blower unit to negate any vacuum cleaner motion produced by the exhausting airflow. The blower unit is controlled by a blower unit integral

3 position lever lock power switch located on the carrying handle. The blower unit integral power switch features a MOM ON position and an ON position for short term usage or for extended usage. The blower unit's circuit is as described for the fecal/urine collector blower unit. The vacuum cleaner interlock plunger is operative when the blower unit is utilized as a vacuum cleaner. The plunger is depressed when a debris bag is installed (enabling the circuit) and extended when the bag is removed (disabling the circuit) insuring against inadvertent operation of the vacuum cleaner when the debris bag is not in place.

The inlet adapter of the vacuum cleaner is completely removable to allow the blower unit to be interchanged with other blower units. The vacuum cleaner blower unit is identical to the fecal/urine collector blower unit and to the suit dryer blower unit and may be interchanged with each other in the event of a malfunction.

h. Trash airlock - The trash airlock (Figure 2.2.11.1-37) is composed of welded segments forming a spherical shell with machined aluminum fittings to accommodate the various mechanism components. Basic components include:

- 1B82638 Inboard Hatch Assembly - Al Plate 7075-T651
- 1B82848 Outboard Hatch - Al Plate 6061-T651
  Outboard Hatch Seal - Fluorosilicone Rubber MIL-R-25988 Type II Class 1 - Grade 60

CLUSTER
OWS
TRASH AIRLOCK

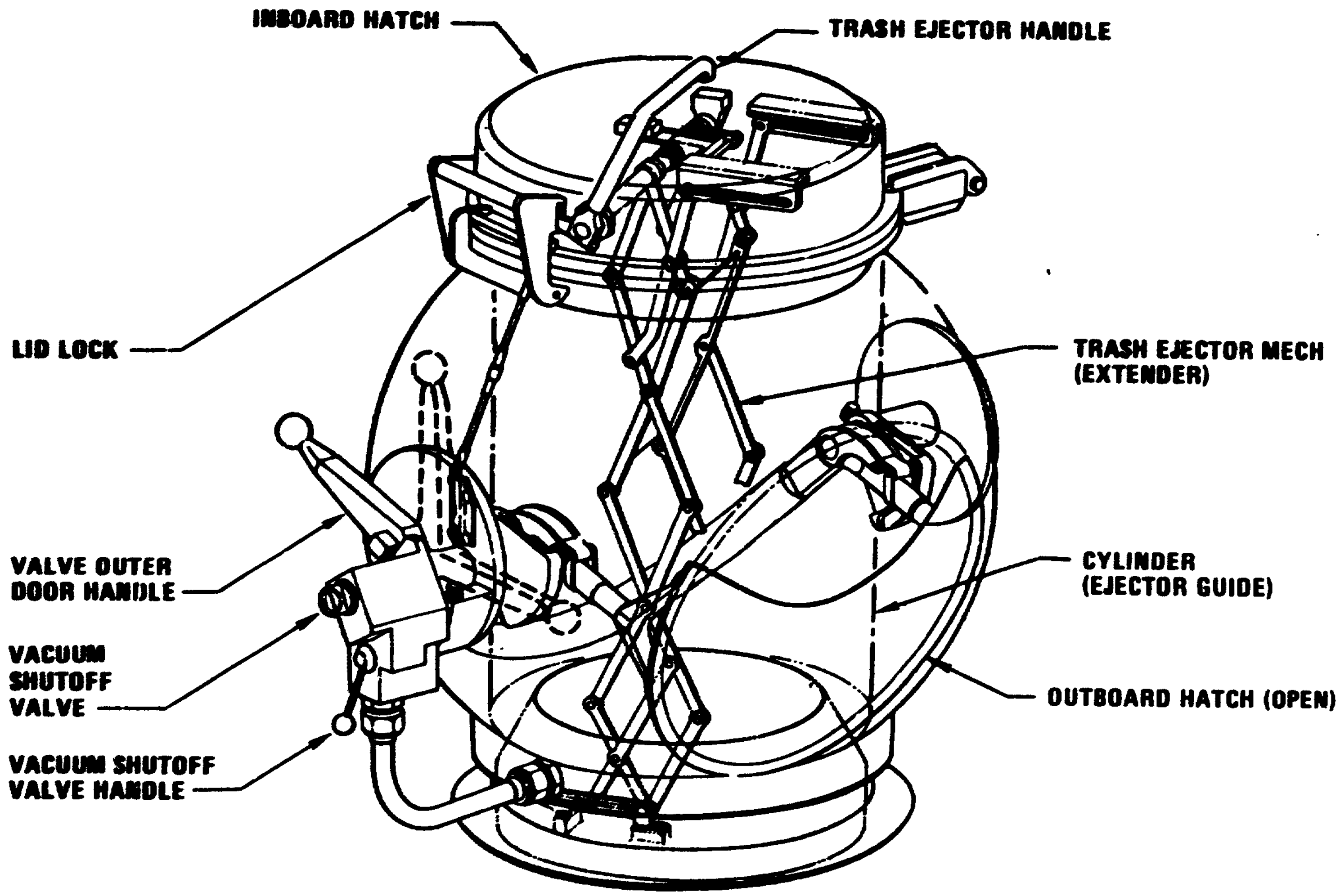


Figure 2.2.11.1-37

- 1B8267(Sphere Shell Weldment - Al Plate 6061-T651
- 1B82618 Cylinder Assembly - Al Plate 6061-T651
- 1B82636 Trash Ejector Mechanism - Al Plate 7075-T651
- 1B82646 Pressurization Valve Assy CRES - A-286

  CRES - 316
- 1B90672 Absolute Pressure Gage
- 1B82853 Inboard Hatch Latch - CRES Bar 3055e

1. Inboard Hatch Assembly (1B82638) - The hatch subassembly is the lid covering the trash container cylinder. It contains a gasket-type seal which is removable on-orbit and may be replaced with an on-orbit spare if necessary. The hatch subassembly houses the ejector mechanism in a circular cavity approximately 4-inches (10.2 centimeters) deep and 13.8 inches (35.1 centimeters) in diameter.

2. Outboard Hatch Assembly (1B82848) - The outboard hatch or "eyelid" forms the seal between the vehicle environment and the waste tank vacuum when trash is being inserted into the airlock cylinder. Its seal is molded into the eyelid and cannot be replaced on-orbit. After the trash bag has been inserted into the cylinder and the inboard hatch is closed and latched, the eyelid is operated by means of the valve/outer door handle. Operation of this handle causes the eyelid to lift inward 0.4-inch (1.02 centimeters) to prevent scuffing of the seal. It rotates inside the sphere to clear the opening through which the trash bag is ejected into the waste tank.

3. Sphere Assembly, Weldment (1B82676) - The sphere assembly is a weldment shell which serves as the basic mounting structure for the mechanical system which makes up the trash disposal operating system. The sphere itself is composed of six welded segments. The segments are -3, -5, -7, -9, -11, -13. The welds are performed on an automatically programmed welding machine. The material thickness of the matching welding surfaces are 0.145 ± 0.005-inch (0.368 ± 0.013 centimeters), with a mismatch of 0.005-inch (0.013 centimeters) permitted. This mismatch assures that the proper weld penetration is achieved, assuming that the other welding constants are maintained.

4. Cylinder Assembly (1B82618) - The cylinder assembly serves as the compartment into which the trash bag is inserted before ejection into the waste tank. It provides a smooth-walled cylinder 13.81 inches (35.1 centimeters) in diameter and approximately 22-inches (55.9 centimeters) long. Three steel pegs are provided at the inboard circumference of the cylinder at 120 degrees to support and position the trash bags before ejection.

5. Trash Ejector Mechanism (1B82636) - The trash ejector mechanism is based on the lazy tongs principle with several elements in series. The mechanism is equipped with an ejection plate which contacts the trash bag and ejects it into the waste tank when the ejection handle is raised to the eject position.

6. Pressurization Valve Assembly (1B82646) - The pressurization valve assembly is actuated by the valve/outer door handle. It has a three-fold purpose (Figure 2.2.11.1-37). The handle is normally stowed in the depressurized position when in orbit. In this position, the airlock is vented to the waste tank vacuum. Moving the handle clockwise from this position causes the valve to expose the airlock to the 5 psi (34.5 kN/m^2) vehicle environment which pressurizes the airlock and permits the inboard hatch to be opened. After insertion of the trash, the handle is rotated to depressurize, which exposes the airlock to the waste tank vacuum. When the airlock pressure has been lowered to approximately 0.2 psi (1.38 kN/m^2), the handle is in the full counter-clockwise position which opens the outboard hatch to permit trash ejection.

7. Absolute Pressure Gage (1B90672) - The absolute pressure gage permits the crewmen to read pressure from approximately zero to 15 psia (103.4 kN/m^2). Knowing the pressure in the airlock enables the crewmen to decide when it is time to open the eyelid and eject the trash.

8. Inboard Hatch Latch (1B82853) - The inboard hatch latch functions to:

   - Unlatch the inboard hatch, making it possible to raise the lid for trash insertion.

- Provides an over-center latch to hold the lid in a preloaded condition to ensure an adequate seal between the vehicle and the waste tank when the airlock is exposed to the waste tank vacuum.

  NOTE: The pressure in the vehicle causes sealing of the airlock by forcing the inboard hatch against its seal.

9. Mechanical Interface (Internal and External) - The trash airlock interfaces with the common bulkhead by means of an aluminum alloy flanged ring. The airlock attaches to one ring flange with 24 1/4-inch (61.6 centimeters) diameter bolts. The opposite flange is then bolted to the common bulkhead.

3/ Waste Management Design and Development Reviews - The Preliminary Design Review (PDR) of the Waste Management Subsystem was presented at MSFC August 27-28, 1969. The same methods for basic fecal collection and processing, contingency fecal collection and processing, and vomit collection and processing presented at the PDR exist in the final design. There is one exception: vomit was to be collected in a separate bag; presently, contingency fecal collection and vomit collection utilize the same bag.

The urine collection and preservation system presented at the PDR utilized a bag for each collection. Each bag, after collection, was placed in the processor where the urine was vacuum dried; then stored, and returned via the command module for analysis.

Subsequent to the PDR, the preservation scheme for urine was changed from vacuum drying to chilling during collection and sampling; and freezing of the sample obtained after each 24 hour collection period. The system utilized a single collection bag. After each collection the gas in the bag was expelled thru a zitex filter membrane, and the bag containing the urine was held against a chill plate to maintain the urine below 59°F (15°C).

Just prior to the Critical Design Review (CDR) in September 1970 a failure of this urine collection method occurred. The filter in the collection bag clogged, and would not permit air flow after being in contact with the urine for a period of time during chilling.

The CDR of the Waste Management Subsystem, except for urine collection and preservation, was presented at MDAC September 14-17, 1970. The same basic system was presented that was presented at the PDR. The only significant difference was tne utilization of a 6 drawer processor instead of a nine processor due to the elimination of vacuum drying urine.

At that time 3 methods of collecting urine were under design and test: (1) A one-bag collection system which used a modified collection bag with a larger filter which allowed holding the bag open during the 24 hour collection period to limit filter expcsure, (2) A two-bag collection system where the urine was collected in one bag; then transferred to a holding bag that did not have a filter, for chilling the urine, and (3) centrifugal separator system that separate the urine from the air and pumped the urine iato a holding bag for chilling the urine.

The CDR of the urine collection and preservation system was presented at Fairchild Industries March 31, April 1, 1971. All three systems were presented at the CDR.

Subsequent to the CDR, the one- and two-bag schemes were cancelled and the separator system implemented.

At this time the modifications to the urine system to include the separator were as follows:

- Addition of a new 24 hour urine pool holding bag which incorporated 2000 ml capacity, a recirculation line to mix urine with the lithium chloride secondary volume determination agent contained in the bag, a urine receiver capable of receiving urine and of connection to the recirculation line, and through use of a screw on adaptor is also capable of cuff contingency mode collection.

- Urine Separtors.
- Folding Teflon urine receiver and inlet hose and valve assembly.
- A rectractable pressure plate capable of exerting a pressure equivalent to 6 inches (1.49 kN/m^2) of water on the urine holding bag. It also kept the bag in initimate contact with the cold plate in order to chill the urine pool. The pressure plate was actuated through the airflow valve handle on the urine drawer front panel. This plate connected mechanically to the volume measurement indicator dial gage.
- The drawers were modified to accommodate the urine separators, urine collection bag, and pressure plate, etc.
- Additional equipment like hose rollers, urine collection transfer assembly (UCTA) adaptors, new urine sample bags, etc.

During the Skylab Medical Experiment Altitude Test (SMEAT) conducted at MSC, Houston, during July and August 1972 it was determined that the 2000 ml capacity of the urine system was not adequate. As a result, the final design parameters of the urine system were established during a meeting on September 26, 1972 at MSC.

The final iteration is as follows:

- Preliminary volume determination chemically using the lithium chloride tracer.
- Elimination of recirculation by use of manually shaking of the urine pool.
- Design of a 4000 ml urine holding bag capable of alternate cuff mode operation.
- Modification of the urine sample bag.
- Design of a urine bag container box and spring actuated pressure plate
- Elimination of the mechanical dial gage volume measurement system by a micrometer gage plate system used in conjunction with the urine bag box assembly and the manual squeezer handle assembly used to take samples.
- Design of a hard-metal cone-receiver in place of the old teflon folded cone construction, and associated inlet hose.

- Design of a combination urine sample bag holder and crimper/cutter assembly for use in sampling and sealing the sample.

- Design of a urine bag box support mechanism capable through use of squeezer handles of applying additional pressure on the urine collection bag to assure adequate filling of the urine sample bags. This device is also used in conjunction with the micrometer volumetric plate for mechanical volume measuring.

- Modification and simplification of the urine drawer to accommodate the new hardware.

- Design of new adapters for use with interface equipment such as the UCTA's and the urine dump system.

There are no open action items from the Preliminary and Critical Design Reviews.

C. Testing

1/ Application of OWS Test Program Results - The performance capability of the Waste Management System has been substantiated through a test program that has verified conformance with Waste Management Subsystem Requirements. Tables 2.2.11.1-1, -2, and -3 are a listing of Line Item and Component tests and components included in the Test Assessment Document, G0474C.

Table 2.2.11.1-1

WASTE MANAGEMENT SUBSYSTEM DEVELOPMENT TESTS

LINE ITEM	TITLE	REPORT NUMBER
HS-3	Zero G Fecal Collection	TM-192
	Fecal Collector	TM-20
HS-4	Processor	TM-201
	Vacuum Cleaner	TM-198
HS-5	Urine Collection & Processing	TM-191
HS-14	Microbic Equipment	G4156
HS-24	TAL	G3364
HS-34	W.M. Odor Control	TM-203
HS-39	UCMSS Preliminary Spec Test	TM-193
HS-51	UCMSS Two Bag System	TM-196
HS-55	Urine Centrifugal Separator Assembly	TM-204
HS-56	Flush Gun	R6989A
HS-60	Centrifugal Separator Plexiglas	TM-206
HS-61	Two Bag Tracer Variation	TM-205
HS-62	Centrifugal Separator Collect Subsystem	G4132
HS-67	Trash Bags	G4094
HS-75	Press Gage TAL	G3377
HS-89	Urine Subsystem - Redesigned	G4198
ST-34	Moiste and Polyfoam Odor	G4159
ST-35	TAL Compatibility	G4228
W-ST-M-30	Mosite and NOPKO Foam Vacuum	A3-250-AGWO-72101
W-ST-S-5	Vibration Isolation Test	A3-290-ABFS-M-31

Table 2.2.11.1-2

WASTE MANAGEMENT SUBSYSTEM QUALIFICATION TESTS

LINE ITEM	TITLE	REPORT NUMBER
HS-2	WMS Support	G4176
HS-90	Urine Subsystem Redesigned	G4199
HS-91	Urine Bag Assembly	G4196
HS-41	Urine Freezer	R7038
HS-42	Urine Sample Ret Cost	G3973
HS-74	Biocide Wipes	R7067
HS-85	Urine Freezer (Blood)	G4150

Table 2.2.11.1-3

WASTE MANAGEMENT SYSTEM

TEST ASSESSMENT DOCUMENT INDEX

Table 2.2.11.1-3 (Continued)

2/ Problem Summary - All problems encountered in the Design and Development of Waste Management Subsystem components have been satisfactorily resolved. A summary of the problems, their resolution, and their status is presented in Tables 2.2.11.1-4 through 2.2.11.1-8.

Table 2.2.11.1-4

WASTE MANAGEMENT SUBSYSTEM
PROBLEM SUMMARY
COLLECTION MODULE

ITEM	PROBLEM	SOLUTION	STATUS	
			CLOSED	OPEN
1	ODOR CONTROL FILTER MOUNTING PIN FAILURE IN VIBRATION TESTING	PROVIDE A LAUNCH RESTRAINT	X	
2	EXCESSIVE LEAKAGE IN S/N 3 HEAT EXCHANGER	EXPOXY REPAIR AND RESTRICTED USE TO QUALIFICATION TEST UNIT	X	
3	TIME DELAY RELAY FAILURE TO TIME OUT DUE TO SHORT IN CONNECTOR	IMPLEMENT STRINGENT CLEANING AND INSPECTION PROCEDURES	X	
4	MICROCRACKS IN HEAT EXCHANGER TUBING	RESTRICTED USE TO NON-FLIGHT HARDWARE ONLY	X	
5	CRIMPER/CUTTER BINDING AND GENERATING PARTICLES OF HOSE AND ALUMINUM CHIPS	REDESIGNED CUTTERS AND ANVIL TO PROVIDE CUTTING ACTION IN LIEU OF SHEARING ACTION	X	
6	URINE SAMPLE BAG LEAKAGE AT SLEEVE/FERRULE HEAT SEAL.	REDESIGN MATERIAL, IMPROVE TOOLING AND MANUFACTURING PROCEDURES	X	
7	URINE COLLECTION BLADDER CHECK VALVE LEAKAGE	DESIGN NEW VALVE	X	
8	VOLUME DETERMINATION USING LITHIUM CHLORIDE TRACER	REDESIGN BLADDER AND POSITION LITHIUM CHLORIDE IN PERIFERY	X	

Table 2.2.11.1-5 - PROBLEM SUMMARY

CENTRIFUGAL URINE SEPARATOR ASSEMBLY (CUSA)
SUBSYSTEM: HABITABILITY SUPPORT SUBSYSTEM, WASTE MANAGEMENT SUBSYSTEM

ITEM	PROBLEM	SOLUTION	STATUS CLOSED	STATUS OPEN *
CUSA	MOTOR MOUNTING BOLT LOOSENING (VIBRATION)	THE BOLT TORQUE REQUIREMENTS WERE INCREASED TO 25-28 IN-LB. (2.82 - 3.16 N·m) TO PROVIDE A FORCE SUFFICIENT TO PREVENT THE BOLT BACKING OUT DURING VIBRATION.	X	
	PITOT TUBE ROTATION (VIBRATION)	THE PITOT MOUNTING WAS REDESIGNED TO INCORPORATE A LARGER OD BOLT TO LOCK THE PITOT IN PLACE.	X	
	SMALL DYNAMIC SEAL LEAKAGE	THE SEAL BACK-UP SPRING WAS REPLACED WITH A STIFFER SPRING WHICH ELIMINATED SEAL FLATTENING AND LEAKAGE.	X	
	LARGE DYNAMIC SEAL LEAKAGE	A BACK-UP SPRING WAS INCORPORATED TO MINIMIZE SEAL LIQUID LEAKAGE. TEST PROCEDURES HAVE BEEN REVISED TO ELIMINATE LEAKAGE.	X	

*SHOW ESTIMATED COMPLETION DATE

Table 2.2.11.1-6
WASTE MANAGEMENT SUBSYSTEM
PROBLEM SUMMARY
VACUUM CLEANER AND POWER MODULE

ITEM	PROBLEM	SOLUTION	STATUS CLOSED	STATUS OPEN
1	VACUUM CLEANER CANISTER WELD CRACKS RESULTING FROM VIBRATION TESTING	ADDED COMBINATION OF RIVETING AND WELDING TO ACCOMPLISH JOINING IN LIEU OF ONLY WELDING: IMPROVED WELDING TECHNIQUE TO INSURE FULL ROOT PENETRATION	X	
2	BLOWER BEARING FAILURES (1ST AND 2ND)	TIGHTENED CRITICAL TOLERANCES AND CONTROLS OF MANUFACTURING PROCEDURES AND INSPECTION ON THE ROTATING ASSEMBLY: ADDED REQUIREMENT FOR ALLOWABLE IMPELLER RUNOUT TO BLOWER ACCEPTANCE TEST	X	
3	BLOWER, SHORTING OF PIN 1 TO PIN 5 WITHIN THE ELECTRONIC CONTROL MODULE WHILE UNDERGOING VACUUM CLEANER SUPPLIER PROTOTYPE TESTING. FOUND EVIDENCE OF COLD FLOW OF WIRES WITH ONE SHORTING TO AN EXIT PIN.	INSTITUTED MORE RIGID MANUFACTURING AND INSPECTION PROCEDURES FOR WIRING AND POTTING OPERATIONS	X	
4	BLOWER, BROKEN WIRE AT PIN OF INPUT CONNECTOR DURING PREQUALIFICATION TESTING.	FUTURE INSTRUMENTATION-POWER SUPPLY GROUND FAULT PRECLUDED BY MODIFIED TEST PROCECURES: IMPROVED DESIGN, MANUFACTURING AND INSPECTION PROCEDURES RELATING TO CONNECTOR FABRICATION OPERATIONS	X	

Table 2.2.11.1-7

WASTE MANAGEMENT SUBSYSTEM
PROBLEM SUMMARY
WASTE PROCESSOR

ITEM	PROBLEM	SOLUTION	STATUS CLOSED	STATUS OPEN
1	SESCO DAMPER PERFORMANCE	BREAKAWAY FRICTION PROBLEM SOLVED BY PROPER SEATING OF BEARING: HIGH DAMPING COEFFICIENT PROBLEM SOLVED BY ELIMINATING TEMPERATURE COMPENSATING DEVICE	X	
2	HEATER PLATE CAUSING CHAMBER LEAKAGE	SEALING MADE EFFECTIVE BY USING VITON GROMMET REDUNDANT SEAL	X	
3	TEMPERATURE CONTROL UNIT OUTPUT TRANSISTOR SHORTED, WHILE BEING TESTED	SHORTING DUE TO TEST SET-UP; TEST FIXTURE IMPROVED TO PREVENT ACCIDENTAL SHORTING OF TRANSISTOR OUTPUT	X	
4	TEMPERATURE CONTROL UNIT OUTPUT TRANSISTOR FAILED "OPEN". FOUND ALUMINUM WIRE WELD CRACKED ON ONE TRANSISTOR	TIGHTENED CONTROL ON MATERIALS, MANUFACTURING PROCEDURES, AND INSPECTION	X	
5	INTERVAL TIMER SOLDER SPLASH FAILURE	REDESIGN OF HERMETIC SEAL CAN	X	
6	INTERVAL TIMER LEDEX ROTARY SOLENOID OVERSTRESS	AVOID CONTINUOUS STEPPING OPERATION (TAKES > ONE HOUR ON TO PRODUCE - FAILURE). NORMAL OPERATION IS A 10 SECOND PERIOD.	X	
7	INTERVAL TIMER ACCEPTANCE TEST FAILURE	IMPROVED ASSEMBLY, SOLDERING, AND INSPECTION PROCEDURES	X	
8	INTERVAL TIMERS RUNNING FAST ON THE SUPPLIER PROTOTYPE	REDUCED INERTIA OF GEARS, CHANGED FROM STAINLESS STEEL TO ALUMINUM	X	

Table 2.2.11.1-7 (Continued)

WASTE MANAGEMENT SUBSYSTEM
PROBLEM SUMMARY
WASTE PROCESSOR

ITEM	PROBLEM	SOLUTION	STATUS	
			CLOSED	OPEN
9	FILAMENT LAMP FAILURE, SUPPLIER PROTOTYPE POST VIBRATION	FAILURE DUE TO EXCESSIVE VIBRATION LEVELS. NO CHANGE MADE IN LAMPS	X	
10	EMI FILTER POTTING CRACKS, SUPPLIER PROTOTYPE POST VIBRATION FINDINGS	VIBRATIONAL OVERSTRESS CAUSED CRACKS. NBG SUPPORTING SLEEVE WAS NOT USED; ON PRODUCTION UNITS NBG SLEEVE WILL REDUCE WIRE VIBRATION.	X	
11	PROCESSING WASTE QUANTITIES GREATER THAN SPEC REQUIREMENTS	DOUBLE BAG TECHNIQUE (ONE BAG INSIDE ANOTHER) HANDLES > 500 ml.	X	
12	PROCESSOR DOOR SEAL LEAKAGE	IMPOSED FLATNESS TOLERANCE ON DOOR, UPGRADED FINISH IS SEAL GROOVE	X	
13	TIME DELAY RELAY FAILURE	OVERSTRESS DURING EXCESS VIBRATION LEVELS (OUT OF SPECIFICATION) CAUSED LEAK IN CAPACITOR SEAL. CHANGED TO HI REL CAPACITOR	X	
14	EMI FILTER FAILURE - LIFE TEST	28 VOLT POWER SUPPLY FAILED; 84 VOLTS REACHED EMI FILTERS RATED FOR 80V. SOLUTION: IMPROVED TEST SET-UP. FAILED EMI FILTER WAS NOT HI REL PART AS USED IN FLIGHT UNIT	X	

Table 2.2.11.1-8

WASTE TANK - TRASH DISPOSAL AIRLOCK

PROBLEM SUMMARY

ITEM	PROBLEM	SOLUTION	STATUS	
			CLOSED	OPEN
1.	Absolute pressure gage - failed in first phases of vibration testing.	Made more rugged. Retested successfully.	X	
2.	Outboard hatch - drifted from its exact center after cycling due to brinnelling of alum hub for antirotational bolt.	Tension strut was added. Retested successfully.	X	
3.	Pressurization valve plug - plug land galled, causing valve handle load increase. Bore was also galled.	Land was turned down to give clearance with bore. Handle load reduced to acceptance level, continued testing with no further problem.	X	
4.	Inboard hatch latch - galling between latch eccentric and mating part due to lack of proper lubricant caused excessive latch loads.	Solid film replaced with krytox grease. Testing continued succesfully.	X	

3/ Subsystem Conclusions

a. Waste Processor

- Summary of Capabilities versus Design Requirements

  The processor module has demonstrated its capability of attaining the design requirements. The unit has:

  Demonstrated its ability to process feces, diarrhea, and vomitus to an inactive state in which bacterial growth is prevented.

  Demonstrated that the leakage rate from the cabin atmosphere through the processor is well within the 0.27 lb/day (122.5 grams/day) allowance.

  Demonstrated that it can be operated with a minimum of crew time, effort, and maintenance.

  Successfully completed qualification unit vibration testing (at MDAC).

  Met the touch temperature requirement of 105°F (40.6°C) (except for indicator lamps).

  Successfully met the electrical requirements such as over and undervoltage, input transients, and reversed polarity.

- Summary of Open Problems and Plans for Corrective Actions

  There are no open problems nor plans for corrective action associated with the processor module. All problems generated during the development and design phases have been resolved satisfactorily.

- Long Duration Operational Capability

The unit as a whole has been subjected to life testing of 140 cycles of operation of each of the six processing chambers to simulate one operation per day of a chamber during a 28 day mission and two 56 day missions. A cycle involves opening and closing the chamber door, vent valve, and locking handle; the pressure plate assembly and damper are also operated by virtue of their connection to the chamber door. Some failures of indicator lamp filaments (each lamp has two filaments) and timer skipping of 1/2 hour increments occurred. Voltage surges due to the test set-up are believed responsible for lamp filament failures.

Timers were reworked to the production configuration, employing aluminum rather than stainless gears for reduced inertia. A second 140 cycle operational life test was completed.

In addition to the above test of the complete unit, various components of the processor module have been subjected to qualification tests which include a life test. These components are:

COMPONENT	LIFE TEST	REPORT
Heater	555 hrs. at 40V	D-7268, Cox and Co.
Temperature Control Unit	233 100 cycles/ 1295 hrs.	D-7268, Cox and Co.
Timer	Equivalent 5000 hrs.	QTR-0168, Stelma, Inc.
Time Delay Relay	300 Cycles	ER-419-9, Tempo, Inc.
Vacuum Valve	3000 Cycles	QTR-548, James, Pond & Clark

b. Collection Module

- Summary of Capabilities Versus Design Requirements

The Fecal/Urine Collection Module has demonstrated to date, its capability of attaining the design requirements. The unit has:

Successfully completed prototype vibration testing.

Been able to supply the necessary airflow.

Been able to accommodate the necessary coolant flows.

Successfully met the electrical requirements.

Attained the necessary accuracies for volume determination.

Demonstrated the ability to collect in a zero G environment.

The capability for efficient man interface.

The ability to prevent bacteria contamination in the airstream introduced by collection.

- Summary of Open Problems and Plans for Corrective Actions

There are no open problems nor plans for corrective action associated with the Fecal/Urine Collection Module. All problems generated during the development and design phases have been resolved satisfactorily.

- Long Duration Operational Capability

The unit as a whole has been subjected to life testing and several of the more critical components have successfully undergone life tests in excess of the requirements. The more important components and their capabilities are as follows:

Blower Assembly

Two endurance tests have been run on the blower, one for 2000 hours and another for 630 hours, successfully, although the requirement is 250 hours.

Odor Control Filter

Development tests have shown that the odor control filter has an operational lifetime in excess of fifty-four days or nearly twice the lifetime required (28 days). These tests were run absolutely dry which makes the results extremely conservative. The odor control filter did demonstrate a greater life expectancy during qualification.

Time Delay Relay

Any one time delay relay will be required to undergo 840 cycles while in orbit. During qualification testing (reference Tempo Report Number ER 419-9) two units were subjected to 3000 cycles each without deleterious effects. This is well in excess of the requirement.

c. Vacuum Cleaner and Power Module

o Summary of Capabilities Versus Design Requirements

The power module and vacuum cleaner have demonstrated to date the capability of attaining their respective design requirements. The units have:

Successfully completed vacuum cleaner qualification testing.

Provided the necessary airflow for zero-G collection with specified power consumption limitations.

Succesfully met all electrical and electromagnetic interference requirements.

Successfully completed prototype vibration testing.

Met the touch temperature limitation of 105°F (40.6°C).

Demonstrated an operational life and cycling capability in excess of specified requirements during prototype testing of the vacuum cleaner and testing of its most critical time dependent item, the blower.

Demonstrated one handed operation with a minimum of crew time, effort and maintenance.

Demonstrated the performance of the blower at the habitation period pressure and atmospheres.

Demonstrated the ability of the blower to sustain orbital storage without subsequent degradation in performance.

Been able to demonstrate acceptable levels of acoustical noise generation during power module operation.

- Summary of Open Problems and Plans for Corrective Action

There are no open problems nor plans for corrective action associated with the power module or vacuum cleaner. All problems generated during the design and development phases have been satisfacatorily resolved.

- Long Duration Operational Capability

The operational life requirement of the power module is 250 hours of running time with a minimum of 7000 cycles; the operational life requirement of the vacuum cleaner is a minimum of 980 cycles for a total running time of 94 hours.

This latter operational life requirement was demonstrated in the vacuum cleaner qualification test. In addition the life cycle test on the supplier prototype vacuum cleaner verified that the unit was capable of meeting the specified operational life requirements. The vacuum cleaner was operated for 1963 cycles of 6 minutes each; the canister was removed and reinstalled on the power module 100 times; the hose from the vacuum cleaner was attached and detached 980 times; the accessory tools were attached and detached at the vacuum cleaner, and at the end of the hose, a total of 980 times at each location (the cycling was divided evenly between the three tool attachment); the debris bag was changed a total of 280 times. These tests are reported in MS115T0105.

Two endurance tests have been run on the blower, the most critical time dependent item in the power module.

In order to validate the solution of premature bearing failures, a test program was undertaken to demonstrate the compressor reliability. A blower was modified to incorporate the recommended changes in Table 2.2.11.1-6, Item 2 and subjected to a pre-qualification test which included vibration, vacuum, acoustic noise, aerodynamic performance, and extended life. The blower was operated successfully for 600 hours without signs of degradation in performance. The results of this testing are documented in AiResearch Report Number 71-7693, dated July 28, 1971. Based on the results of this inspection, 1400 hours of additional endurance testing seemed to be a viable goal. Therefore, this additional testing was undertaken and completely successfully. The results of this additional testing are documented in AiResearch Report Number 71-7962 dated November 12, 1971.

Prior to completion of endurance testing, a blower assembly was subjected to qualification testing successfully. In the course of testing the unit experienced 7,000 starting surges over a period of 630 hours of operation. The results of this testing are documented in AiResearch Report Number 71-7886, dated September 30, 1971.

Based upon the foregoing test results, the capability of the power module and vacuum cleaner to meet and exceed their operational life requirements is deemed to have been clearly demonstrated.

d. Collection Bags

o Summary of Capabilities Versus Design Requirements

The collection bags have demonstrated their capability of attaining the design requirements.

1. The Fecal and Fecal Contingency Bag have demonstrated:

Their ability to collect in a zero-g environment.

Their ability to prevent bacteria contamination from escaping into the atmosphere during collection, mass measurement and processing.

Their capability to collect the maximum required volume of feces, diarrhea and vomitus.

Their compatibility with the operational requirements of the 1B79136-1 Waste Processor Module.

Their capability to provide sanitary conditions for the collection, retention and sealing of feces, diarrhea and vomitus.

Their ability to prevent mixing of and cross-contamination of collected feces, diarrhea and vomitus.

Their capability to be disposed of through the trash airlock and withstand the airlock depressurization.

2. The Debris Collection Bag has:

The ability to contain waste matter particles and liquid while installed in the Vacuum Cleaner with the power module shut-off.

Provided sanitary conditions for the collection, retention and sealing of debris by the crewman.

Demonstrated its ability to prevent bacteria contamination from escaping into the atmosphere.

Demonstrated its ability to interface with the vacuum cleaner interlock to prevent operation unless a bag is installed.

The capability to collect 350 ml and contain liquids at 20 inches (4.98 kN/m^2) of water pressure with no leakage.

The capability to be disposed of through the trash airlock and withstand the airlock depressurization.

- Summary of Open Problems and Plans of Corrective Actions

There are no open problems nor plans for corrective action associated with the Collection Bags. All problems generated during the development and design phase have been resolved satisfactorily.

- Long Duration Operational Capability

The collection bags have completed the shelf life test as recorded in MS115T0047 ("Test Plan and Procedure for Shelf Life Tests of Collection Bag Adhesive Materials", dated January 15, 1971).

3. Trash Collection Bags

Two line item tests were performed to establish the adequacy of the trash bags.

Line Item HS-67 Trash Bag Deployment Test

Line Item ST-35 Trash Airlock Functional Capability Test

The Trash Bag Development Test consisted of tests to evaluate concepts of trash bag materials and designs and to verify proper operation of the final selected configuration under simulated on-orbit conditions. Part I of the test included leakage, burst and stowage tests on materials and bag designs. Part II verified the operational interface of the trash disposal airlock/ trash bag concepts and included life cycle tests of parts of the Trash Disposal Airlock Assembly.

Based on the design requirements established for the Waste Management, Trash Collection Subsystem, it was concluded that the materials and design configurations selected will meet the above requirements.

The interface of the Trash Disposal/Trash Bag concepts was verified and the life cycle tests of the ejector detent and inboard hatch latch assembly were successfully completed.

The objectives of the ST-35 test were to evaluate the compatibility of the airlock's internal trash cylinder and its ejection system when subjected to various contingency anomolous configurations of filled trash, urine and disposal bags. This test consisted of airlock depressurization and ejection cycling of armalon bags containing combinations of stowed items that may have presented a ejection problem during habitation. The ejected equipment items were compiled from the OWS Stowage Location Usage Report.

All testing was completed successfully. None of the bagged specimens became lodged within the airlock cylinder, no problems were experienced with bag breakaway tabs and rejection forces were low to moderate.

No problems were encountered with bag tape and snap fastener even during degraded bag modes, therefore all specimens ejected through trash airlock within the limitations of the test objectives were thereby qualified for use in the Orbital Workshop.

e. Centrifugal Urine Separator

- Summary of Capabilities Versus Design Requirements

  Based on the successful completion of all special feasibility testing, Design Verification Testing, and Production Acceptance Testing of each unit, it is concluded that the centrifugal urine separator is compliant with all of the applicable specification control drawing design requirements.

- Open Problems and Resolution Summary

  None.

- Time/Life Cycle Limitations

  The SV748753-1 Support and Filter is a time/life cycle limited component. Based upon the Design Verification Testing and resultant data obtained, Hamilton Standard recommends the Support and Filter be replaced after 28 days of use. (Reference: Centrifugal Urine Separator Design Verification Test Report SVHSER 5965).

f. Trash Airlock

- Summary of Capabilities Versus Requirements

  Based on analytical results shown in Table 2.2.11.1-9, it is seen that actual factors of safety exceed required factors of safety and, therefore, the structural integrity of critical components of the trash disposal airlock is verified analytically.

  It is concluded from the analytical and test results that the trash disposal airlock meets all design requirements for use on the OWS.

  The trash airlock development test (line item HS-24) was completed successfully and verified the design requirements for leakage, proof and burst pressures, vibration, and repeated functional cycles under orbital differential pressure and temperature environments.

4/ Subsystem Certification

a. General

Design maturity of the OWS Waste Management Subsystem (WMS) is predicted on the results of the extensive and methodical testing. The test results demonstrate that:

- The method of achieving waste management in a zero-g environment is valid.
- The functional capability of the WMS system/components is not degraded after exposure to simulated flight level environments.

Table 2.2.11.1-9

TRASH DISPOSAL

STRUCTURAL EVALUATION SUMMARY

DESIGN CONDITION	PART NAME	DESIGN LOAD OR STRESS (LIMIT)	ALLOW LOAD OR STRESS	REQUIRED DESIGN F.S. (OVER LIMIT)	ACTUAL F.S. (OVER LIMIT)	REQUIRED
Astronaut Applied Load	Fitting, Turnbuckle	320 lbs. (1423 N)	524 lbs. (ult) (2331 N)	1.4 (ult)	1.63 (ult)	OWS stress anal RPT Vol. V. Pg. 6.5.1-93
	Bolt NAS1004-34A	76 ksi (338 kN)	140 ksi (ult) (623 kN)	1.40 (ult)	1.85 (ult)	OWS Stress anal RPT Vol. V. Pg. 6.5.1-91a
Boost and Orbital Blowdown Malfunction	Shaft, inner race, bearing	130 ksi (578 kN)	150 ksi (ult) (667 kN)	1.0 (ult)	1.15 (ult)	OWS stress anal RPT Vol. V. Pg. 6.5.1-75
	Bolt, Toggle	130 ksi (578 kN)	155 ksi (ult) (689 kN)	1.0 (ult)	1.19 (ult)	OWS stress and RPT Vol. V. Pg. 6.5.1-106
Mechanical Displacement	Spring Ejector detent	112 ksi (498 kN)	174 ksi (ult) (774 kN)	1.4 (ult)	1.55 (ult)	OWS stress anal RPT Vol. V. Pg. 6.5.1-146
	Spring, latch	134 ksi (596 kN)	194 ksi (ult) (863 kN)	1.4 (ult)	1.45 (ult)	OWS stress anal RPT Vol. V. Pg. 6.5.1-135

- o The system/component endurance capabilities are adequate for the proposed OWS flight program.
- o The materials used in the WMS are compatible with crew safety.
- o The methods used in the WMS are compatible with crew safety.

Specific major component certification is given below.

b. Waste Processor

- o Basic for Certifying Design Maturity and Manned Flight Safety

  Design maturity of the waste management fecal and vomitus processor is based on extensive and methodical development spanning a period of at least six years.

  Initial development established basic design parameters such as temperature, vacuum line sizing and pressure plate force. Further refinements incorporated such features as pressure plate and door damper, temperature controls for operational and over temperature modes, time delays and timers. Hardware incorporating these features was subjected to severe laboratory tests such as vibration and cycling to evaluate its flight worthiness.

  All flight units undergo a comprehensive acceptance test prior to installation. Design safety criteria were emphasized during the design phase. Safety features inherent in the design the processor are:

  A safety interlock prevents opening of the chamber when vented to vacuum.

Burn hazards are eliminated by stringent temperature control and limitations.

Shock hazards are eliminated by use of low voltage.

Electrical fire hazards are eliminated by design and construction under strict Quality Control supervision.

c. Collection Module

o Basis for Certifying Design Maturity and Manned Flight Safety

Design maturity of the waste management fecal and urine collection module is based on an extensive and methodical development period spanning at least six years.

Initial development established basic design parameters such as airflow, orifice size and orientation, and man interface. Further refinement of the system was accomplished by flight testing in a KC-135 aircraft in a zero-G environment using a simulated fecal dispenser. The system was finally man-rated by operating in a zero-G flight test program using human subjects.

The Skylab hardware, beside incorporating all the parameters established during the development program, has been subjected to severe laboratory tests such as vibration and cycling to evaluate its flight worthiness.

All flight units undergo a comprehensive acceptance test before being installed.

Design safety criteria were emphasized and carefully monitored during the design phase. Safety features inherent in the design of the collector module are:

Supports and restraints safety retain the crewman in position during collection in zero-G.

Noxious odors and gases are filtered out of the collection airstream by an odor control filter.

Fecal bacteria are prevented from escaping into the Skylab atmosphere.

All controls are guarded against inadvertent actuation.

Shock hazards are eliminated by the use of low voltage.

Redundancy, spares, and the ease of replacement enhance the safety and reliability of the collector.

d. Vacuum Cleaner and Power Module

o Basis for Certifying Design Maturity and Manned Flight Safety

Design maturity of the waste management vacuum cleaner and power module is based on extensive and methodical development spanning a period of at least six years.

Initial development established basic design parameters such as airflow and orifice size. Early zero-G flight tests were conducted on the Manned Orbital Laboratory (MOL) Program to refine these basic parameters. Further refinements incorporated such features as varied attachments including a surface tool, crevice tool, brush and hose.

Hardware incorporating these features was subjected to severe laboratory tests such as vibration and cycling to evaluate its flight worthiness, safety and performance.

All flight units undergo a comprehensive acceptance test prior to installation. Design safety criteria were emphasized during the design phase. Safety features inherent in the design of the vacuum cleaner are:

A safety interlock prevents operation as a vacuum cleaner if debris bag is not installed, preventing contamination of the power module.

Overload hazards are eliminated by use of a circuit breaker integral with power module.

Shock hazards are eliminated by use of low voltage.

Electrical fire hazards are eliminated by design and construction under strict Quality Control supervision.

e. Collection Bags

o Basis for Certifying Design Maturity and Manned Flight Safety

Design maturity of the waste management collection bags is based on an extensive and methodical development period spanning at least six years.

Initial development established basic design parameters such as bag element arrangement, pressure differential and filter material.

Further refinements resulted in adaptation of the basic parameters to the different bag configurations. Sealing methods were developed and extensively tested. Various filter materials were selected and tested for processing optimization. Time line tests were conducted for substantiating statistical data.

Flight hardware incorporating all these features were subjected to severe laboratory tests to evaluate its flight worthiness from a safety and performance criteria.

Each flight bag undergoes a comprehensive acceptance test before being installed.

o Trash Collection Bags

All testing was completed successfully. None of the bagged specimens became lodged within the airlock cylinder, no problems were experienced with bag breakaway tabs and rejection forces were low to moderate.

No problems were encountered with bag t[illegible] and snap fastener even during degraded bag modes, therefore all specimens ejected through trash airlock within the limitations of the test objectives were thereby qualified for use in the Orbital Workshop.

f. Trash Airlock Subsystem Certification

o Basis for Certifying Design Maturity and Manned Flight Safety

All stress analysis and structural demonstration tests relative to the trash disposal airlock have been satisfactorily completed to verify structural integrity.

o List of Open Items

None.

o List of Waivers and Deviations to Specifications

None.

5/ Test Summaries

Qual HS-2 the fecal/urine collection system successfully passed all Qualification Tests. The specimen demonstrated satisfactorily performance and compliance with design requirements.

Note: Redesign of the urine system from 2000 ml capacity to 4000 ml capacity shortened some of the testing. This testing was picked up later by HS-90.

The portable vacuum cleaner, the waste processor, stowed urine separator, urine dump compartment, fecal bag dispenser bag bundles and collection bag return assembly all successfully passed their individual qualification test requirements with no failures or problems noted. Each specimen tested demonstrated satisfactory performance and compliance with its design requirements.

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D. Mission Results

1/ Fecal Collection

a. Hardware Anomalies

1. Collector Module

No anomalies were reported.

2. Air Flow

No anomalies were reported.

3. Fecal Bags

No significant anomalies were reported relative to the fecal bags. Several of the black rubber outer cuffs did, however, come loose from the fecal bags during the first mission. Those bags were discarded and replaced with new bags. No anomalies were reported from the second or third mission crews.

4. Contingency Fecal Bags

As in Apollo, the cleanup tasks after using the paste-on contingency fecal bags required excessive wiping. There was no mention of the finger cott or the ability of the adhesive to retain the bag in position; however, there were no complaints. There was no mention of contingency bag sealing. It was stated that it took the first mission CDR approximately one hour to perform the contingency fecal collection. The specimen mass measuring device (SMMD) was not used to obtain the mass of the feces collected in the contingency bags. There was also no mention of any difficulties placing the contingency bag into the processor or filter sealing after removal from the processor.

The contingency bags were not damaged n[illegible] did they leak. Although there were no changes to procedure or hardware recommended, it was clear that the crews were not satisfied with the use of the paste-on contingency fecal bags. They were messy and very undesirable to use. Since these bags are used infrequently and there are no obvious substitutes, the crews could only convey their dissatisfaction.

5. Odor Control

Late in the third mission the crew reported a urine (ammonia) odor coming from the collection module. The odor was apparent when the blower was operating and indicated a failure of the odor control filter. They requested the ground's recommendations.

The odor control filter was designed for 28 days of operation and, as a result, the housekeeping procedures required filter replacement halfway through the originally planned 56 day mission for SL-4. When the mission was extended to 85 days, no provision was made for additional filter replacement. Although the filter was designed for 28 days, it was tested for 56 days. The Qualification Test [illegible]ver failed on the 54th day. In SL-4 the second filter had bee[illegible] installed approximately on the 28th day. Therefore, on the day the crew reported the odor (DAY 79) this filter had been operating for approximately 51 days. The conclusion that the SL-4 filter had, in fact, failed about when expected.

It was recommended that the filter and blower (if necessary) be replaced. One more spare filter was on board. No further conversations with the crew on this problem were found and it is not known if these units were replaced.

6. Fecal Bag Management

No anomalies were reported.

b. Hardware Assessment - The fecal collection equipment worked successfully and the crews expressed general satisfaction. Crew assessments of fecal collection equipment operation and usage are provided as follows:

1. First Mission Crew Assessment

The geometry of the fecal urine collector was found to be satisfactory with respect to seat and standing positions except for two comments; the urine receiver was easier to use when not installed in the yoke (holder), and the crews complained of the severe "crouch" position required to be seated properly in order to maintain a good seal on the collector seat.

The air flow system of collecting feces was reported to be a good concept and worked exceptionally well; however, it was felt that higher air flow would provide even more satisfactory results. In order to obtain the proper seal required for good air flow collection, the hand grips were always used. It was reported that excessive pulling force on the grips was required to attain the proper seal. Triangle shoes were removed during collection prior to the feet being placed in the foot wells.

Minor difficulties were encountered installing the bag in the fecal receptacle as the second cuff was occasionally difficult to install on the receptacle. It was also reported that several cuffs debonded and those bags were discarded. There was a report during flight that the velcro lap belt worked loose. However, during the crew debriefing that report was corrected. The crew indicated they were talking about a different belt and that the fecal collector velcro lap belt was satisfactory.

The crew recommended that on longer missions, the seat be fabricated from a softer material and the outside diameter widened. This would make it easier to obtain a good air flow seal. Controls and wipes were readily accessible in all positions. The air flow did not become uncomfortable and bolus separation was obtained in most cases depending partially on the consistency of the feces, which varied. However, it definitely was not like that obtained on Apollo - it was more firm and easier to separate.

There was no difficulty in wiping; however, the articulating mirror was always used. All crewmen used approximately two wipes each, which they placed in the bag, and then used a wet washcloth for final cleaning which was then disposed of in the urine disposal bag.

The collector seat did not become dirty. Bag sealing was accomplished by the method which makes a one-inch fold instead of one-half inch folds. Bag sealing was always done with the blower on, and although there were no seals which leaked, the crew commented several times on the "unforgiving" sticky adhesive on the bag. The time required to accomplish bag sealing, mass measuring, and processor loading was not considered excessive. Odor control was satisfactory and noise level was acceptable except during sleep periods. This is discussed under Urine Collection Hardware Assessment, paragraph 2/b. below. There were 48 fecal collections during the first mission which is an average of one collection every two days per crewman. There were no fecal bags damaged during use and no filter or seal leaks. Torn cuffs, as stated previously, were relatively common but caused no major problem. The only changes to procedure or hardware recommended by the crew were the softer and wider seat plus the use of the urine receiver without the yoke. The crew recommended this fecal collection air flow concept for future space missions.

The following crew comments are provided for fecal collection equipment assessment:

SPT The fecal collection equipment - works, much to our surprise, if one is careful and takes it slow. Fecal collection equipment, the air flow method of collection appears to be practical. A larger air flow, I think is mandatory on future mission designs. The air flow is marginal, however, the method appears feasible, and the urine collection, not only is the method feasible but the flow is probably adequate and very close to it.

CDR Waste management and hygiene equipment turned out to be a fantastically pleasant surprise. I probably was most adamant against the fact that I didn't think the fecal collection equipment would work and we have all discovered pleasantly that it works in an absolutely outstanding manner and I have to rate it as excellent.

The fecal/urine collector lap strap and handholds are an absolute requirement to the fecal collection equipment working correctly in that you do have to pull the cinch down and hold yourself very close - firmly on the seat in order for the air flow to work correctly. If you do that the fecal collection equipment works excellently and therefore straps are necessary. Perhaps they could be designed to do a little bit better job of holding together than it does right now, but we'll work on it.

PLT I as a new boy - hearing horror stories from the old heads - have been deliriously happy and surprised with the operation of the waste things and equipment - the fecal collection and the urine collection both. The air stream on the fecal collection unit works quite well. I have found personally that I use the belt and I must use the handhold and pull myself down on the seat to make sure you get a good seal. The better the seal you got around the lid of the seat, the better the equipment seems to work.

2. Second Mission Crew Assessment

The second mission crew rated the fecal collection equipment as generally good in terms of its operation and effectiveness. The comments made under assessment by the first mission crew were generally applicable for the second mission crew comments. The second mission crew, however, more critical in terms of the amount of "trouble" it was to prepare the collector for collection and general fecal collection management tasks. The second crew also felt that the air flow was low and should be increased for future applications of using air flow as a gravity substitute. The crew stated that the air flow for fecal (and urine) collection was acceptable but low. It was suggested that at least 50 percent increase in air flow would probably be required for satisfactory operation. The crew also did not like the vertical orientation for the fecal collector or the "hunters" position required for usage. The CDR commented that his orientation on the fecal collector versus the lights on the ceiling was such that his body blocked the light, which made it very difficult to read while defecating. The following crew comments from the second mission are provided for fecal collection equipment assessment.

- On DOY 223, the CDR reported, "Fecal collection equipment - I would have to give a good to that. The reason is it takes time to work. It seems to me there must be a better way to get rid of waste material than putting a bag on, taking a bag off, weighing it and all that. I realize that those requirements did not come with the design of this equipment, but came with the M071/M073 experiment. It would appear that maybe some of these could be eliminated rather simply. The flush toilet is the obvious answer. What we're going to do about fecal matter touching the sides of the fecal bag and making it rather poor to look at and esthetically displeasing, I don't know. Perhaps if you have some quick, solid insert you could throw into the seat, use it and then push the insert in afterwards; one that doesn't take near so long. I think we could use a little bit more air flow and also I think the fecal bag could be a little deeper. I've noticed when I expel a rather normal bolus, it winds up touching the bottom of the fecal collector and therefore pushing back on the anus. It then breaks free and starts rubbing around on the cheeks and that makes the messy operation. It would appear to me that if we could just make the bag three, four or five inches longer, this would not then make it so messy plus taking time to clean up."

- On DOY 223 the PLT reported, "Fecal collection equipment - I rate that very good to excellent. The only drawback to the fecal collection business is that it's too much of a nuisance to fill a new bag. There should be a better way of fastening a bag on there - a lot quicker. It takes you about 30 seconds to relief yourself fecal-wise, and about 10 minutes to take care of all the logging, taking the fecal bag in the processor out, securing it in the locker, putting the used bag in the processor, and then putting a new fecal bag in the collector."
- On DOY 229 the CDR reported, "The strap that you use when you're defecating is marginal; it'll hold you down but it really needs to be better. Also when you're on the fecal collector and your head's over, you tend to be close to the ceiling which is troublesome, but mostly, it blocks out all your light. Therefore, if you want to read on the job you are going to have to do it with your book in the dark. It's have been much better if we'd have made that thing set horizontal and not tried to save space and all that stuff. Could have put ot over there in the corner."
- On DOY 246 the PLT reported, "Waste management and cleanup chores, decided that the air systems (blower) that we've got in the fecal collector and urine drawer that waste management is much improved. And so it's that item right there, the air entrappment idea that has taken a lot of the mess and a lot of the work time out of the waste management. So I think that that's a real plus and something we ought to continue to have in future systems. Cleaning up after waste management exercise is no problem, there's essentially no cleanup at all."

- On DOY 222 the PLT reported, "I think another great design is the waste management system. It's essentially a no mess operation. And the only thing that takes a little time - it takes 30 seconds to have a bowel movement and about 10 to 15 more minutes to log all the data and snap the new bag in place. So that installation of the new bag could be designed in a more efficient manner."
- On DOY 251 the CDR reported, "Fecal collector filter. Easy to put in, piece of cake. That's a good one. Just slide a couple of pieces of rubber over and snap them on. That's a winner."

3. Third Mission Crew Assessment

The third mission crew assessed the fecal collection system in a manner similar to the first two mission crews. They felt that the system worked in a very satisfactory man r. The CDR commented on DOY 333 that the first time he used the fecal collector, he was very pleasently surprised. "I found that they (fecal and urine collection systems) worked as advertised."

The crew also made similar comments relative to all of the "trouble" the management tasks made in the collection process. The time required for bag change, mass measurement, processing, etc., was thought to be excessive and annoying.

2/ . Urine Collection

a. Hardware Anomalies

1. Urine Separator (Centrifugal Separator Urine Collection)

- First Mission Hardware Anomalies

The first crew reported initial low air flow in the urine receiver during the first urine collection. This condition was corrected by installing a fecal bag in the fecal receptacle. This was necessary in order to provide the pressure drop needed to balance the air flow between the fecal and urine collection for normal subsystem operation.

During the early morning of DOY 149, a urine chiller temperature of 56°F was noted for Urine Chiller No. 1 for an extended period. The crew reported that the cause was due to inadvertently leaving the collector blower/separator switch on for an extended period. Upon correction of switch position the temperature returned to normal.

During the morning of DOY 157, a low air flow in Urine Drawer No. 3 was reported. The crew changed the separator filter and the air flow became normal. The following questions and answers were sent to the crew relative to this anomaly.

- CDR Question: When your urine separator filter was removed, could you see what was blocking the filter? Did the centrifuge have urine in it?

  Answer: There was no visible blockage of the urine filter by any material that we could see, and no, the centrifuge did not have urine in it when we changed it out.

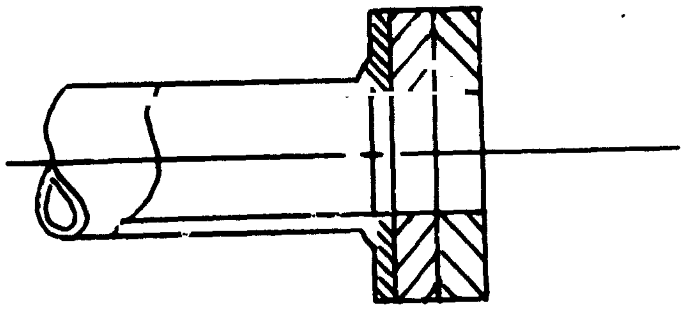
- **Second Mission Hardware Anomalies**

Operation of the collector was normal through the entire mission until DOY 267 (MD-59) when, on deactivating his urine drawer (removing and replacing the centrifugal separator), the SPT found that the suction line seal had debonded and floated away from the suction line. The seal was captured, taped to the collector face, and photographed. Examination of the returned photograph pin-pointed the failure mode and a repair kit was fabricated for the third mission crew to remedy the problem (see Figure 2.2.11.1-38 for an illustration of the problem and its proposed solution).

On DOY 267 it was reported that the urine separator suction line washer debonded. This anomaly was reported by the SPT as follows:

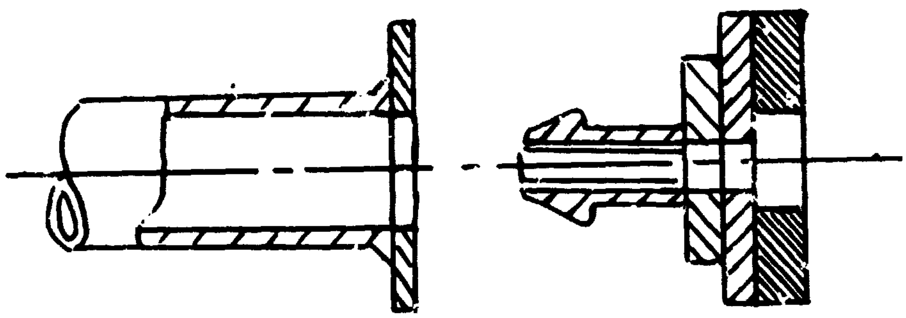
- "There is a gas and supply line that runs up from the backside of the drawer, out through a little flange that then meets with the gas supply line that runs out to the movable portion of the drawer on the slides. Now this mates with the little washer that has both a rubber composition with a metal backing plate on it. The back plate on this metal washer is bonded in some way to the fixed portion of the drawer. However, on the SPT drawer (No. 3) that bonding has come loose. As a matter of fact, the little washer was sticking to the movable portion of the drawer, so tonight it came loose while I had the drawer completely out. Now we're going to use it again, but of course it will be essential for the next mission that the air fitting be tight before any

URINE COLLECTION DRAWER NO. 2



LAUNCH CONDITION

SEALS BONDED TO SUCTION LINE
FLANGE BECAME DEBONDED



REPAIR TECHNIQUE

STAINLESS STELL COLLET INSERTS INTO EXISTING
SUCTION LINE WITH PROVISIONS TO SEAL DRAWER
MOUNTED VALVE BODY

URINE COLLECTION DRAWER SEAL DEBONDING SECOND MISSION

Figure 2.2.11-1-38

of the drawers will function properly. And so some new bonding agent should be brought along so that the little rubber composition washer can be rebonded to the fixed portion of the drawer."

- Third Mission Hardware Anomalies

  During the last week of the mission, it was reported by the CDR, that urine salt crystals had begun to show on all the separators. This formation had also shown up during Qualification Tests and did not impair the performance of the separators.

2. Urine Bag and Receiver/Hose

- First Mission Hardware Anomalies

  A minor problem with the urine receiver hoses catching on the urine drawers is discussed later in this section.

- Second Mission Hardware Anomalies

  A small amount of urine leakage was reported which was associated with bags and receiver hoses. These minor anomalies were described during the Crew Technical Debriefing as follows.

  - CDR "We only had a couple of urine spills towards the end. I had one when my little rubber grommet wasn't fit perfectly on the centrifuge. I noticed the spill. I looked in there and saw that it fit correctly on one side, and on the other side it had bent under. So apparently it had let urine somehow come out that way."

    SPT "You're talking now about the interface between the bag and the separator. I noticed that some of the bags leaked. When you pulled vacuum on it you can hear the air hissing into the little black boot. I noticed that one time when I had a bag that was like that. It did leak around the boot where it fits on the separator and I had some urine spill. If they find a bag that leaks when they pull a vacuum on it, they might just want to throw it away if they have plenty of them. I never did that because I didn't know how deep the supply was."

- Third Mission Hardware Anomalies

  Two leaks were reported in urine collection bags during the third mission. The spills were cleaned up and the bags replaced.

3. Urine Collection - Roll-On Cuff (OWS Bag)

- First Mission Hardware Anomalies

  The most adverse comments pertained to the residual urine remaining in the roll-on cuff causing the crew's fingers to become wet with urine during each use. There were no crew comments on the cuff installation and no physical discomfort due to back pressure when using the roll-on cuff. Handling of the loose bag during collection and installation in the drawer was not mentioned; however, none of the urine bags was damaged or leaked. The samples were obtained from the roll-on cuff collection using the urine collection bag similar to the urine collection transfer assembly (UCTA) samples in that they also contained excessive air. It was not necessary to use the roll-on cuff. Cuff collection was never used as a result of failure of separator collection. No changes in procedure were mentioned which would improve roll-on cuff collection.

- Second Mission Hardware Anomalies

  No anomalies were reported relative to the roll-on cuff (OWS Bag) urine collection system.

- Third Mission Hardware Anomalies

  No anomalies were reported relative to the roll-on cuff urine collection system.

4. Urine Sampling and Measuring Equipment

- First Mission Hardware Anomalies

  No anomalies were reported during the first mission with urine sampling. Post mission analysis revealed that the volume of samples was low (average 90-100 ml rather than 120-130 ml). It appears that the method used by the PLT for sampling was the best; that being, keeping pressure on the urine bag as the sample is being taken.

- Second Mission Hardware Anomalies

  A small amount of leakage was reported on DOY 218 relative to the urine sample bags. This was not a serious problem and did not occur frequently. The CDR reported a leak of about 1/2 of a sample bag of urine. It is estimated that the volume of this leak was about 60 millimeters or 2 ounces. This problem was noticed at the time that a sample bag was being changed. Apparently, the configuration of the sample bag had indicated that it was properly attached, but as it turned out, the CDR said that it had leaked despite the fact that it looked all right. This anomaly was reported on DOY 218 as follows.

- This is the CDR for the Biomed people. I just took a urine sample and the top of the sample bag leaks at the lower right hand corner as viewed from the top, where the little spout is. Since that corner leaked urine, another sample was taken.

- Third Mission Hardware Anomalies

  Two leaks in urine sample bags were reported during the third mission. The bags were replaced with new bags and placed in the freezer.

5. Urine Collection and Transfer Assembly (UCTA) Equipment

- First Mission Hardware Anomalies

  Samples taken from the UCTA's during the first mission appeared to contain excessive air. It was estimated that these samples contained approximately 70 percent air. This was reported by the crew and confirmed by the sample volumes measured post flight. The crew did not recommend any method of reducing air in the sample bag. There were no crew comments regarding the method used to squeeze urine samples from the UCTA; however, during the crew debriefings, no difficulties in obtaining the samples were reported.

- Second Mission Hardware Anomalies

  The second mission crew also experienced problems with excessive air in the UCTA's. Crew comments relative to this problem are provided as follows:

  - SPT On our first mission day, the CDR and PLT each had two UCTA's, but the SPT only had one UCTA, so we only had five samples to make instead of the standard six. The samples were made as per checklist, but as noted before on the earlier mission, there's a lot of air getting into these samples. That's particularly true of PLT sample number 2 because the UCTA didn't have much in it, probably only a couple or 300 ml of urine and that may have contributed to the extra air that got in there. But I have been taking special pains to get or did take special pains to get the sample bag as full as was possible. My guess is they're something like two-thirds to three-quarters full of urine and the remainder is air.

- Third Mission Hardware Anomalies

  The third mission crew reported a leak in one UCTA. There is no reported information as to the nature or cause of the leak.

b. Hardware Assessment

1. Urine Collection

- First Mission Crew Hardware Assessment

  Air flow was considered adequate by the first crew for urine collection. Time for urine collection was not excessive. Noise level of the urine separators was not disturbing during use; however, when the system was used during sleep periods, the sleeping crewmen were, on occasions, awakened by the separator noise. This was attributed to the relatively low noise levels in the spacecraft which made any other noises seem loud and disturbing. This was not considered a problem requiring any further action except for design of future space vehicles.

Only one change in procedure became obvious to the first crew while collecting the urine. The receiver yoke (holder) was not used in the standing position. It was more suitable in zero-g to hold the receiver in their hands and to "float" freely while urinating. This was brought out emphatically by all three crewmen. Also, one foot restraint was enough for stand-up urination.

Urine drawer chillers operated normally throughout the mission period. The crew reported no excessive buildup of moisture on the heat exchanger plate. The crew did, however, wipe the plates daily. On MD-25, the crew relayed the values readout by the onboard display of refrigeration system temperatures:

Urine Chiller 1 - 44°F (6.7°C)
Urine Chiller 2 - 45°F (7.2°C)
Urine Chiller 3 - 44°F (6.7°C)

Examination of all-data digital tape (ADDT) data and real time data for the duration of the mission also indicate an average temperature for three chillers of 45°F (7.2°C).

The following crew comments from the first mission are provided for general urine collection equipment assessment.

- CDR "The urine collection equipment also, I have to say, after all the revoluations works in an outstanding manner. I have to rate it as excellent. The urine collection equipment - once we found out that it didn't work right unless you have a fecal bag in. Otherwise you don't get enough suction to the urine receiver. It works quite well. It stays surprisingly clean and after some 4 days of use, the urine receiver and hose have no odor, which I was concerned about prior to launch."

  PLT "This is for the medical adn M071 people. Apparently the maximum volume that our present urine measuring system will handle is 3800 (ml). I measured my bag this morning and it came out to 3800 (ml). But, I had quite a difficult time getting the volume measurement plate into the bag, where you bring that last flap up over the top. I think just squeezing it into the bag will give you no more than a 3800 (ml) measurement. I have a feeling that there is an additional, but indeterminate, quantity in the bag. If you wanted a number, I'd guess right at 4000 (ml).

Later analysis of the lithium chloride tracer supported the 3800 (ml) maximum volume measurement.

- Second Mission Crew Hardware Assessment

Crew assessment for urine collection hardware during the second mission was somewhat varied and in certain cases conflicting. In general, the crew agreed that the system was adequate and did a good job of collecting. Most objections or criticisms were in regard to the excessive crew time that was required for sampling, bag change out, etc. The following crew comments are provided relative to urine collection hardware assessment.

- On DOY 223 the PLT reported, "Urine collection equipment works very well, haven't had any spills; blowers all work good - it's just a great system. It's no fuss, no muss. If there's some way we could save time in taking samples, changing bags and so forth, that'd be a plus for that system but as it is, it's pretty good."
- Crew Technical Debriefing

  CDR How about waste management?

  PLT Works, great system.

  CDR Works well but if we ever ended up with a new system I think we'd want to improve the flow in both the urine system and the fecal system. One of the things I thought could be improved would be to have some way of not using a tissue after every urination to wipe off the penis. At the end I would wipe it on the cuff and that worked fairly well, but it seems to me they could have directed a slight air flow at a certain point on the lid of that cup that would allow you to eliminate all the urine and you wouldn't have to use a tissue to do the job. Did we change hoses and cups as often as they recommended - once a week, once every 3 days?"

PLT I changed probably once every 2 weeks.

CDR You just did because they told you to, it wasn't because you felt like you needed to.

PLT Just for bugs and you can't tell when you need it on account of bugs. There's a set of three cups and hoses which come with every bag replacement kit. If you remember you can use them, swap them out.

- On DOY 223 the CDR reported, "Urine collection equipment - way too much trouble. It needs more air flow. There are several things that occur. One when you urinate with an additional volume, you can stop up the centrifuge and cause backflow. That tends to scare you a little bit. In addition to that, if when you finish urinating your last little drop, you'd like to wipe it off on something as opposed to always getting a tissue, when you wipe it off on the edge of the cup and it just hangs there in a big blob. When you move the cup...it comes off and becomes a beautiful gold ball quivering through the air and you have to figure out a way to jerk out something and stop it or catch it and that is a lot of trouble. I think more air flow and some sort of paying attention to boundary layer control where the air would tend to flow along the boundary of the cup and some little amount in the middle, I think, would do the job. Maybe some little point where you could rub off the penis and get the last drop where the air flow was especially high would be good.

°Third Mission Crew Hardware Assessment

The urine collection system was reported by the third mission crew to work very good.

On DOY 333 the CDR reported, "I think the equipment in there (Waste Management Compartment) is very good. The pot and the urine collection devices I think are surprisingly easy to use and they're very effective. I don't know how much better you can get these. Of course, I must admit that before I got here I had very grave reservations for the ability of these systems to work well and I must say I was very pleasently surprised...the first time in using both systems I found that they worked as well as advertised.

The complaints of the system are basically the same as the first and second crews.

The compartment lacked a good restraint system.

It took too long to seal fecal bags and obtain samples.

Urine spills were a mess to clean up.

2. Daily Sampling and Bag Change-Out

° First Mission Crew Hardware Assessment

The daily sampling and urine bag change-out task varied from 15 to 30 minutes depending on the crewman and the learning curve. Each crewman normally performed sampling on his own system. In removing the urine bag box from the urine collector drawer, the removal of the urine bag inlet boot from the urine separator outlet tube always resulted in some urine drops. It was standard procedure for the crewmen to wipe off these drops with a tissue. The PLT found it very difficult to use the pull tab on the urine bag to draw the urine from the separator urine outlet. The tab kept falling back in the hole in the urine bag box. As a result, after a few days he no longer used the pull tab. It is not known if the other crewmen used the pull tab or not.

All of the crewmen mixed the urine according to procedure; however, the CDR made it a practice of mixing twice to insure adequate mixing. There was no difficulty in (a) installing the urine bag box in the squeezer deivce, (b) in using the volume determinator plate, (c) installing sample bag into crimper cutter, or (d) connecting the sample bag hose to the urine bag. However, the PLT was unable to measure urine quantity greater than 3800 ml. He had two samples which both measured 3800 ml and felt he had more than 3800 ml in the bags. Later LiCl volume determination indicated approximately 3800 ml in one and 3600 ml in the other bag.

No sample bags leaked; however, one sample bag was either damaged by the CDR during removal from the stowage restraint or damaged prior to removal.

The most significant problem in the urine system was low sample bag volumes. The system was designed to collect samples from 120 to 130 ml. During sample extraction all crewmen noticed air entrapped (small bubbles) in the urine in the sample bag. This was more pronounced on the first mission and different techniques were used on the second mission which reduced this problem.

It is not clear where air was coming from; however, the most obvious source is the centrifugal separator. There is no obvious reason for the excess air to be generated by the separator and zero-g testing is almost impossible. All crewmen reported that sufficient force was applied to the squeezer handle.

The CDR noticed that the urine in the sample bag flowed back in the urine collection bag after releasing the squeezer handle as indicated by bubble flow. Also cycling the sample bag did nothing to decrease air in the sample bag.

In extracting the half sample, the SPT reported he moved the barrel to "Full" position and then back to "Half" hoping to increase half sample size. Procedural changes for the second mission reduced this problem.

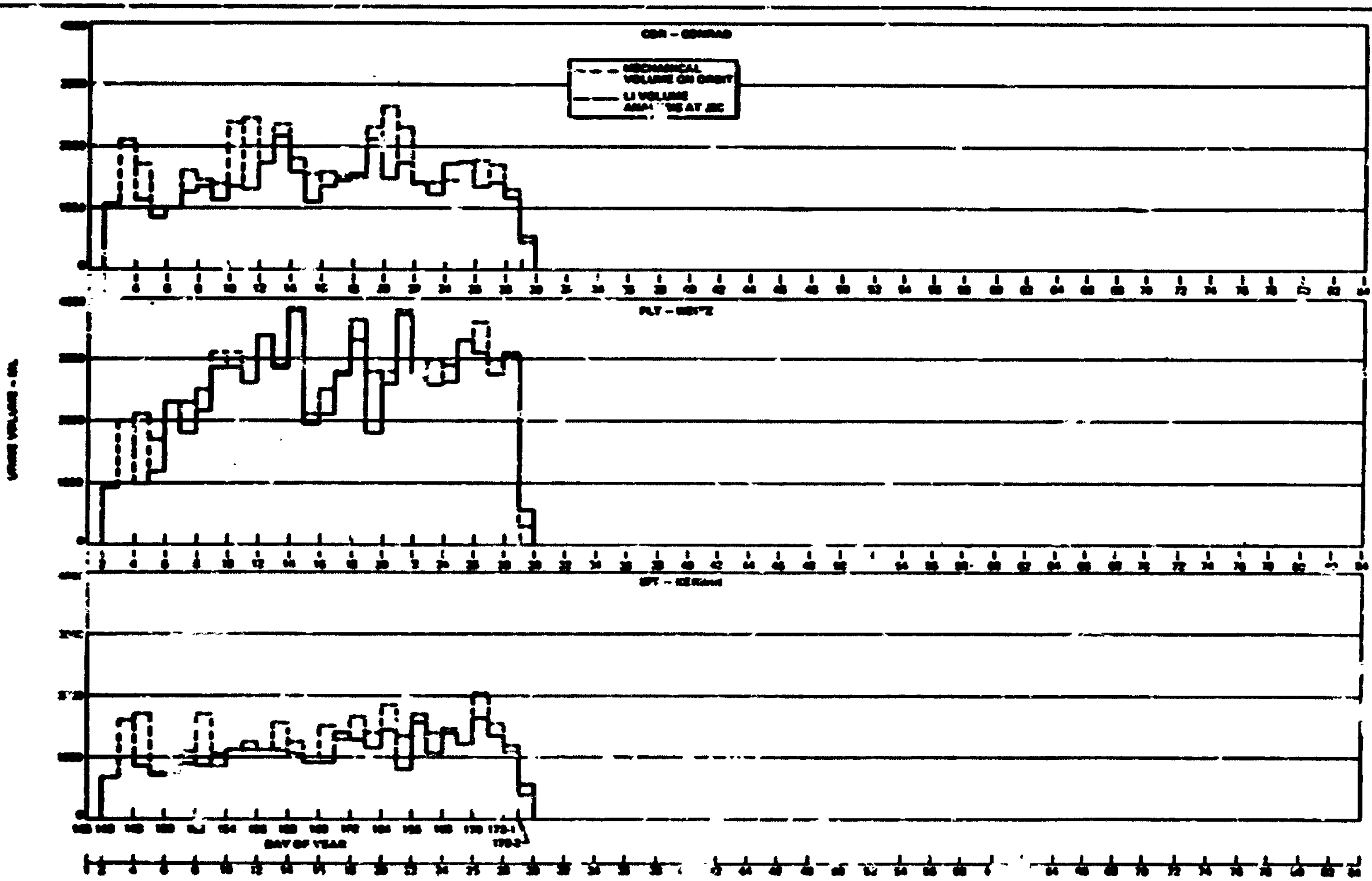
The other tasks required for sampling, i.e., crimp cutting of the sample bag tube, pushing crimped tube into the sample bag, installing bag into freezer tray and handling freezer trays with frozen bags were not difficult.

The urine dump system was not used to dump urine; however, all urine bags were evacuated through the urine dump system prior to the daily installation in the urine drawers. The CDR and SPT also evacuated their sample bags prior to use, although this did not appear to help increase sample volume. During urine bag evacuation, one inlet check valve "squealed" indicating air passing through the check valve. That bag was disposed of and subsequently it was the general practise by the crew to use the inlet boot plug.

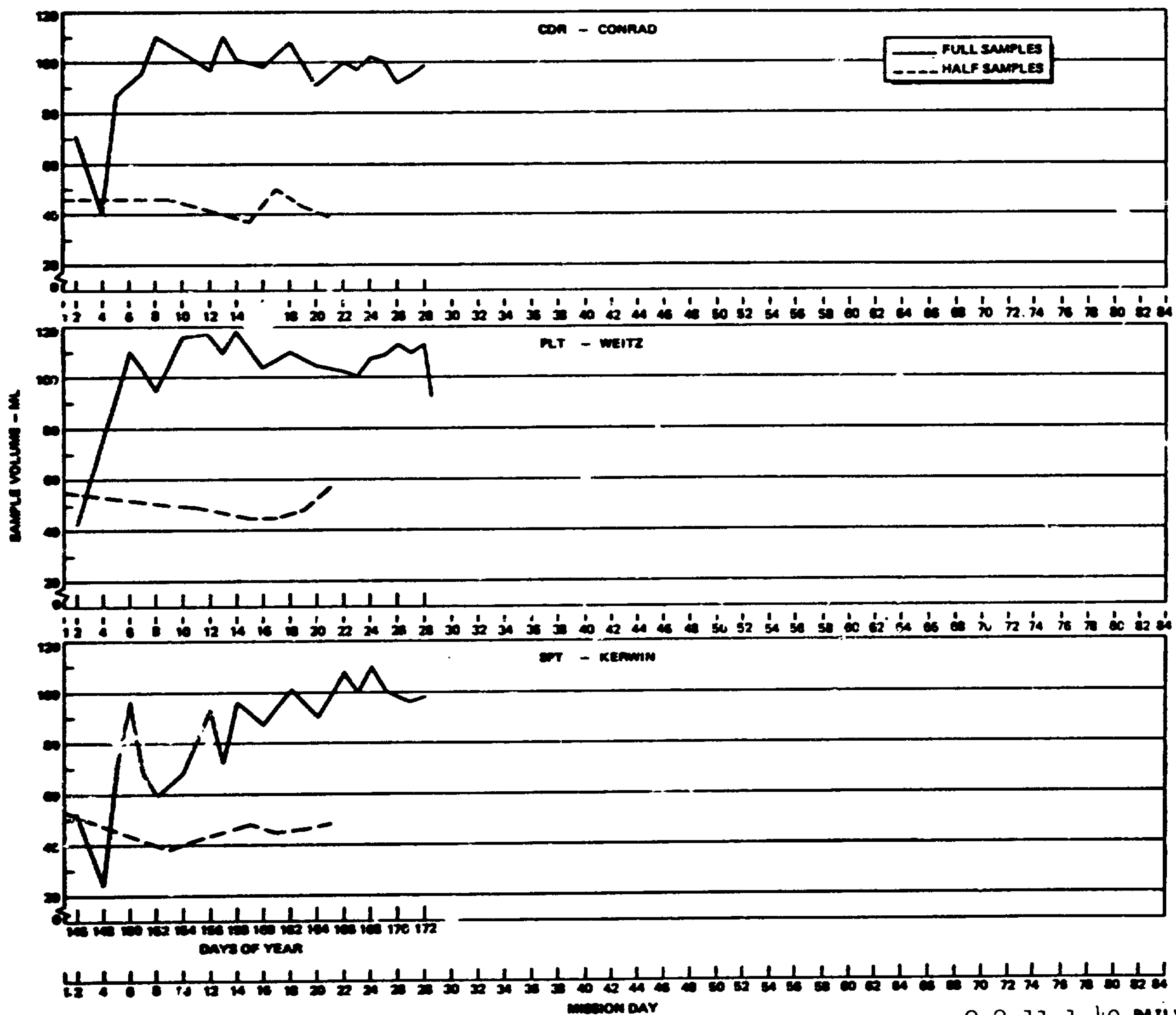
No difficulty was experienced installing a new urine bag in the urine bag box and on the separator. Only the PLT's urine drawer had a tendency to stick while closing - it was difficult to close the last inch of travel. The PLT reported that he was reluctant to slam the drawer and thereafter he applied a force slowly which closed the door adequately. None of the drawer tracks was lubricated. The drawer closing latch worked easily and the drawer opening "stop" always prevented the drawer from coming out entirely.

It was reported at least once that two separators were "on" simultaneously and the resulting current did not open the circuit breaker.

The daily urine volume (mechanical versus Li analysis) for the first crew is included in Figure 2.2.11.1-39. However, in general, the CDR averaged approximately 1400 ml, the PLT 2560 ml, and the SPT 1100 ml. The daily urine sample size is included in Figure 2.2.11.1-40.



2.2.11.1-39 DAILY URINE VOLUME (MECHANICAL VS LI ANALYSIS) - FIRST MISSION



2.2.11.1-40 DAILY URINE SAMPLE SIZE - FIRST MISSION

No changes to hardware became obvious to the crew during the daily urine sampling and daily bag change-out tasks. However, after reviewing the post-flight urine sample volumes of each crewman, it appears the PLT's procedure of pushing with one hand on the squeezer handle during crimper cutting of the sample bag tube may have helped obtain the larger samples. This procedure was recommended for the second mission crew.

° Second Mission Crew Hardware Assessment

General assessment of the daily sampling and urine bag change-out was similar to that of the first mission crew. System management task times were about the same with each crewman normally performing his own tasks.

A minor amount of urine droplets was usually found when removing the urine bag box from the urine collector drawer, the removal of the urine bag inlet boot, etc. Like the first mission, this was usually wiped up with general purpose tissue.

There was no significant difficulty reported relative to any of the sampling and bag change-out tasks.

Crew comments relative to daily urine sampling and urine bag change-out assessment are provided as follows:

° SPT Got a little information for the biomed people. PLT found out that you sent a change up for us to hold down on the urine bag while we take the sample to cut out the number of bubbles and fill the bag better. Well, PLT found out if he sloshed the urine back and forth in the bag, slowly, so it didn't make bubbles, he had better luck. Now, I haven't been able to develop his technique yet. But he seems to be getting very good samples that way. In addition to that he does the squeezing down hard.

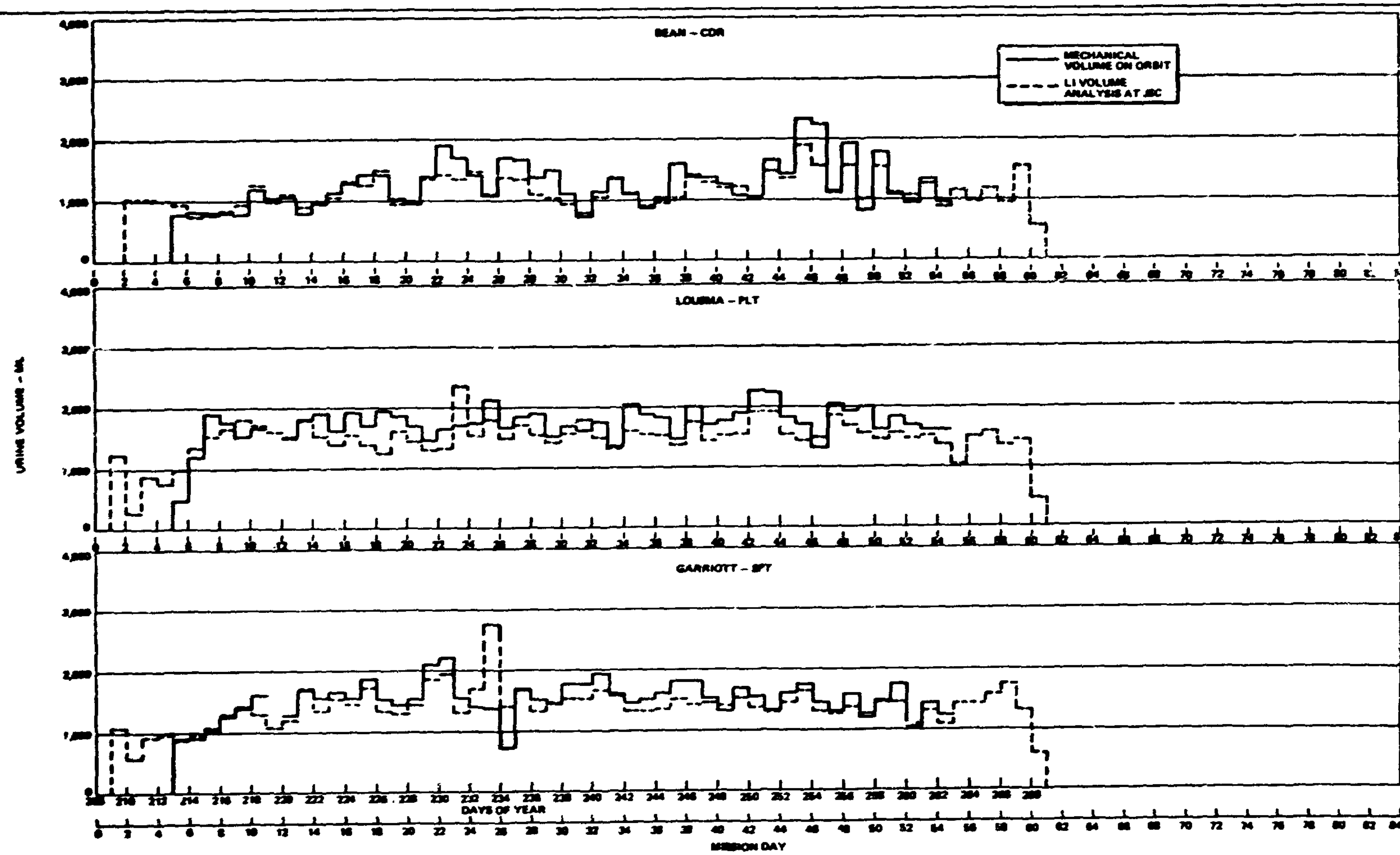
On DOY 239 the CDR reported, "What is the most disconcerting personal hygiene problem you have encountered? I think probably the urine dump...your fingers get dirty as the rubber nozzle has urine in it..."

On DOY 246 the PLT reported, "Waste Management is a very clean system. It works well and is quite a tribute to engineering design and ingenuity. I had one spill and I think a bag broke a little bit, but it didn't let much urine out. I plugged it in one place and I was able just to soak it up with a few wipes, so the waste management chores are no problem."

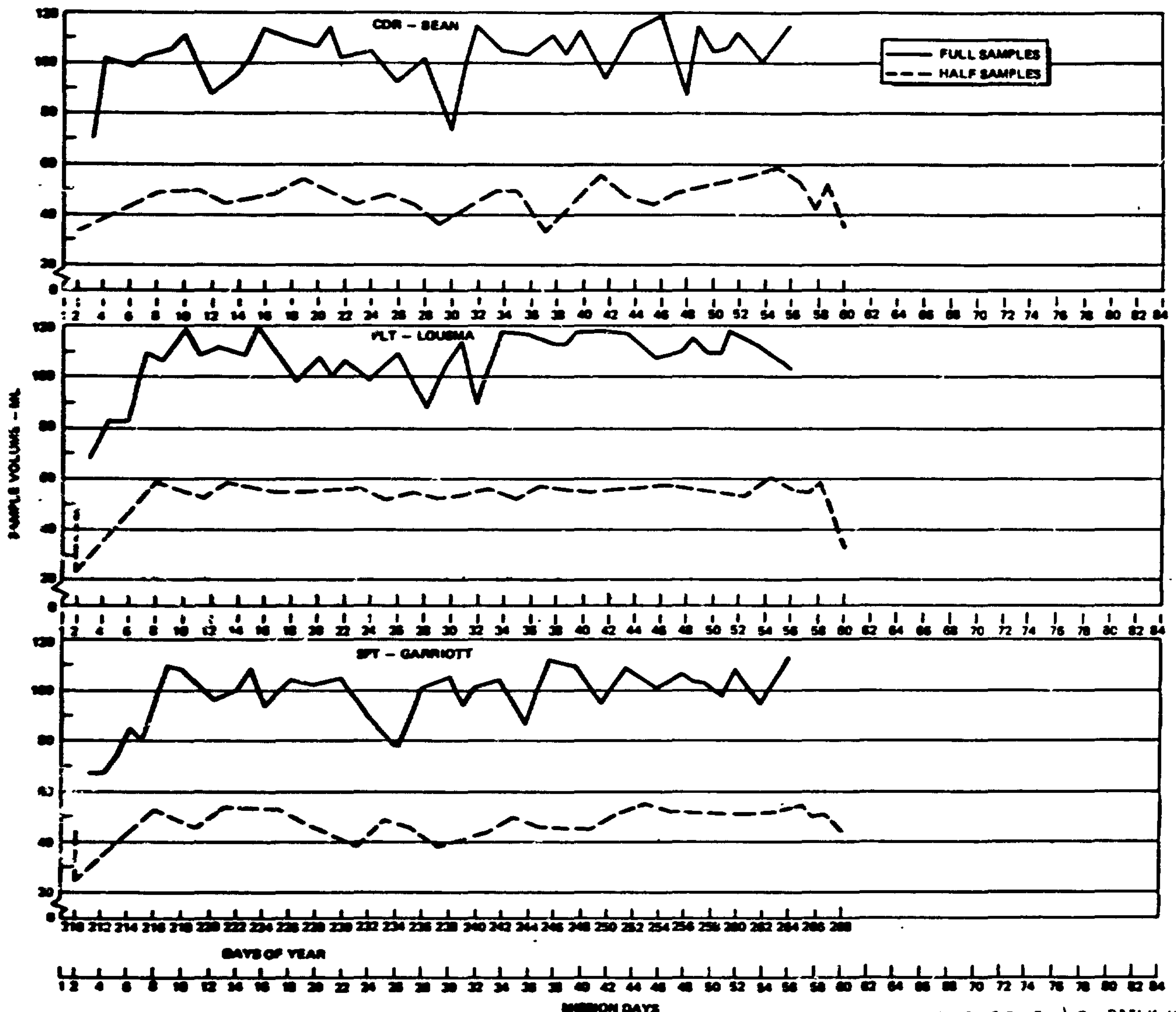
The daily urine volume (mechanical versus Li analysis) for the second crew is included in Figure 2.2.11.1-41. However, in general, the CDR averaged approximately 1140 ml, the PLT 1490 ml and the SPT 1400 ml. The daily urine sample size is included in Figure 2.2.11.1-42.

- Third Mission Crew Hardware Assessment

  There were no specific crew comments on sampling and bag change out except that the operation took too much time, especially with the additional requirement to dump the urine bag and add the boric acid tablets.



2.2.11.1-41 DAILY URINE VOLUME (MECHANICAL VS LI ANALYSIS) - SECOND MISSION



2.2.11.1-42 DAILY URINE SAMPLE SIZE - SECOND MISSION

3 Urine Collection and Sampling System Maintenance

- First Mission Crew Hardware Assessment

There were no urine spills and none of the urine bags leaked or broke during the first mission. The condensation in the urine drawers was minimal and confined to the chiller plate (primarily on the bumpers). This condensation was wiped daily, although the CDR felt that this may not have been necessary. Occassionally, the urine hoses were pinched when caught behind the separator motor. This was corrected during the mission by insuring that the urine hose was not in a position to become pinched prior to closing of the drawer and no further action is required. There was no mention on the frequency of inlet hose and receiver change-out or if they were changed at all. It was a general practice by the crewmen to wipe the excess urine from the receiver with tissue after each usage. The one occurrence of separator filter change-out due to the PLT's filter clogging required about 30 minutes of maintenance time. There was nothing on the filter to indicate the cause of clogging. Several things could have caused the filter clogging - high single void quantity combined with foaming is the most likely. This same separator was reported to be "cruddy" (grey substance) in the motor to separator gear areas. This was found during deactivation when the motors were switched to a new separator and the gear area was subsequently wiped off before the motor was installed on the new separator. There was no evidence of urine odor or bacterial growth noticeable in the urine drawer area.

The urine collection water flush system was not used; in fact, it was not activated.

The crewmen reported no new wear or scratches on the urine chiller plates and the thermal pads were not excessively worn.

It was never necessary to change a separator motor due to failure; however, the separator motors were removed as planned from each of the three separators during deactivation.

There was no indication of urine bag check valve leakage back into the separator.

Crimper/cutter area (on the fecal collection door) did not become contaminated with chips or urine.

- Second Mission Crew Hardware Assessment

There was no major spillage or breakage of urine or sample bags during the second mission. One sample bag was reported to have leaked, but it was not a significant amount. The loose urine was readily cleaned up and created no serious problem. Additional urine droplets were cleaned up as required at the boot interface to the urine separator.

There were no reported urine hose pinchings during drawer opening or closing. Inlet hoses and receivers were reported to have been changed about every 15 days.

The condensation in the urine drawers was minimal and confined to the chiller plates. This condensation was wiped daily as a part of bag change-out. There were no separator filter change-outs required and no clogging reported. There was also no identified problem relative to urine odor or bacterial growth in the urine drawers. The drawers were considered to be in clean condition at activation. The SPT commented on this subject during the Crew Technical Debriefing.

- "The SPT had no spills at all. He also cleaned all the drawers out just before deactivation. I think we got a nice clean system all the way across there for the next crew. The whole thing looks in good shape."

Comments from the CDR relative to drawer cleanliness are provided as follows:

- "Also one of the things we were worried about before we went was that we might come upon a moldy rubber or an open urine drawer and might be a lot of bugs around in there somehow. There never was. Everything was clean and dry and neat. I think it's probably going to be the same for the next crew. We left it real clean and he should be able to step in and put whatever he's got in the drawers or in the coolers. It all should work."

- Third Mission Crew Hardware Assessment

  There were two urine spills in the collection module reported by the third mission crew. Both spills were cleaned up by using used towels and cloths. The compartments were wiped down by biocide wipes. As in the first two missions a minimum amount of condensation in the drawers was reported which was wiped daily.

  Although some odor from the collector and urine salts on the separators was reported in the last week of the mission, no change outs or maintenance were performed.

4. Post-Flight Analysis

- First Mission Crew Hardware Assessment

  The daily urine volume (mechanical versus Li analysis) from each urine collection bag from the first mission is plotted in Figure 2.2.11.1-39. The accuracy of inflight volume measuring as compared to post-flight LiCl analysis varied randomly. However, it was clear that the inflight measuring system was more accurate at the higher collected volumes. There appeared to be a gradual learning curve which improved the inflight measuring slightly during the latter part of the mission. The sample bags arrived frozen as planned in the lab. None of the sample bags leaked after thawing out. The samples appeared to be acceptable for the biomedical experiments except for the low quantities in the urine sample bags mentioned previously.

- Second Mission Crew Hardware Assessment

  The daily urine volume (mechanical versus Li analysis) from each collection bag from the second mission is plotted in Figure 2.2.11.1-41. The sample bags arrived at the lab frozen as planned and appeared to be acceptable for the biomedical experiments. The urine volumes for each of the first mission crewmen as determined by the analysis for lithium concentration in the returned urine samples are provided by Table 2.2.11.1-10.

  The urine volumes for each of the second mission crewmen as determined by the analysis for lithium concentration in the return urine samples are provided by Table 2.2.11.1-11.

- Third Mission Crew Hardware Assessment

  Table 2.2.11.1-12 shows the urine volumes (mechanical) reported by the crew in the daily log. The sample volumes and urine volumes by lithium chloride analysis are to be obtained from JSC.

DOY	MD	CDR	SPT	PLT
145	1	Li Trace Only	Li Trace Only	Li Trace Only
146	2	1057 ml	687 ml	913 ml
147	3	Not Received	Not Received	Not Received
148	4	1125 ml	849 ml	981 ml
149	5	831 ml	702 ml	1185 ml
150	6	1000 ml	725 ml	2309 ml
151	7	1256 ml	894 ml	1800 ml
152	8	1336 ml	884 ml	2166 ml
153	9	1146 ml	858 ml	2869 ml
154	10	1358 ml	1129 ml	2869 ml
155	11	1120 ml	1301 ml	2624 ml
156	12	1734 ml	1120 ml	3374 ml
157	13	2162 ml	1116 ml	2869 ml
158	14	1558 ml	1034 ml	3838 ml
159	15	1104 ml	919 ml	1943 ml
160	16	1358 ml	918 ml	2114 ml
161	17	1452 ml	1400 ml	2739 ml
162	18	1564 ml	1282 ml	3631 ml
163	19	2103 ml	1164 ml	1794 ml
164	20	1480 ml	1439 ml	2607 ml
165	21	1723 ml	809 ml	3720 ml
166	22	1406 ml	1564 ml	2629 ml
167	23	1235 ml	1085 ml	2585 ml
168	24	1733 ml	1406 ml	2629 ml
169	25	1743 ml	1230 ml	3315 ml
170	26	1350 ml	1631 ml	3112 ml
171	27	1412 ml	1356 ml	2773 ml
172-1	28	1168 ml	1101 ml	3081 ml
172-2	28	533 ml	560 ml	565 ml

Table 2.2.11.1-10

DAILY URINE VOLUME (LI ANALYSIS) - FIRST MISSION

DOY	MD	CDR POOL VOL (LiCL)	SPT POOL VOL (LiCL)	PLT POOL VOL (LiCL)
210	1	1041 ml	1082 ml	1237 [illegible]
211	2	1024 ml	924 ml	8[illegible]0 ml
212	3	993 ml	950 ml	748 ml
213	4	924 ml	878 ml	965 ml
214	5	718 ml	950 ml	1341 ml
215	6	789 ml	1094 ml	1515 ml
216	7	840 ml	1267 ml	1652 ml
217	8	908 ml	1421 ml	1778 ml
218	9	1241 ml	1288 ml	1684 ml
219	10	974 ml	1070 ml	1345 ml
220	11	1086 ml	1188 ml	1476 ml
221	12	894 ml	1727 ml	1778 ml
222	13	974 ml	1345 ml	1520 ml
223	14	1034 ml	1543 ml	1388 ml
224	15	1286 ml	1450 ml	1530 ml
225	16	1239 ml	1729 ml	1366 ml
226	17	1493 ml	1330 ml	1239 ml
227	18	936 ml	1278 ml	1594 ml
228	19	944 ml	1437 ml	1437 ml
229	20	1330 ml	1832 ml	1286 ml
230	21	1404 ml	1937 ml	1308 ml
231	22	1330 ml	1308 ml	2318 ml
232	23	1462 ml	1696 ml	1520 ml
233	24	1066 ml	2741 ml	1775 ml
234	25	1352 ml	1408 ml	1476 ml
235	26	1323 ml	1660 ml	1696 ml
236	27	1077 ml	1301 ml	1535 ml
237	28	1010 ml	1146 ml	1408 ml
238	29	903 ml	1530 ml	1546 ml
239	30	757 ml	1530 ml	1769 ml

DAILY URINE VOLUME (LI ANALYSIS) - SECOND MISSION

Table 2.2.11.1-11

DOY	MD	CDR POOL VOL (LiCL)	SPT POOL VOL (LiCL)	PLT POOL VOL (LiCL)
240	31	1117 ml	1654 ml	1471 ml
241	32	1356 ml	1551 ml	1290 ml
242	33	1076 ml	1313 ml	1577 ml
243	34	882 ml	1291 ml	1546 ml
244	35	930 ml	1313 ml	1515 ml
245	36	1023 ml	1493 ml	1342 ml
246	37	1391 ml	1423 ml	1729 ml
247	38	1270 ml	1437 ml	1417 ml
248	39	1164 ml	1417 ml	1507 ml
249	40	1191 ml	1515 ml	1530 ml
250	41	984 ml	1360 ml	1889 ml
251	42	1471 ml	1291 ml	1889 ml
252	43	1335 ml	1455 ml	1520 ml
253	44	1872 ml	1642 ml	1441 ml
254	45	1535 ml	1306 ml	1476 ml
255	46	1096 ml	1253 ml	1838 ml
256	47	1566 ml	1389 ml	1678 ml
257	48	984 ml	1248 ml	1551 ml
258	49	1520 ml	1450 ml	1441 ml
259	50	1081 ml	1476 ml	1551 ml
260	51	1041 ml	1082 ml	1459 ml
261	52	1240 ml	1315 ml	1517 ml
262	53	859 ml	1082 ml	1362 ml
263	54	1117 ml	1439 ml	1045 ml
264	55	947 ml	1439 ml	1488 ml
265	56	1155 ml	1597 ml	1572 ml
266	57	916 ml	1805 ml	1338 ml
267	58	1525 ml	1338 ml	1425 ml
268	59	545 ml	619 ml	465 ml

DAILY URINE VOLUME (LI ANALYSIS) - SECOND MISSION

Table 2.2.11.1-11 (Continued)

MISSION DAY	URINE VOLUME MECHANICAL - ml			URINE VOLUME LI. CL.			SAMPLE VOLUME		
SL-4	CDR	SPT	PLT	CDR	SPT	PLT	CDR	SPT	PLT
1									
2									
3									
4	1200	3500	2400						
5	1200	2750	1500						
6	1400	1500	1600						
7	0800	1200	3000						
8	1800	1700	0900						
9	1800	1600	2400						
10	1200	[illegible]100	2400						
11	1500	1700	2100						
12	2100	1500	3000						
13	1200	1300	1500						
14	1800	1600	2800						
15	1300	1700	1600						
16	1900	2100	1850						
17	2200	1200	2200						
18	2500	2200	3000						
19	1100	2300	2000						
20	1400	2950	2600						
21	2200	1400	2000						
22	1200	1450	1700						
23	1650	1450	1800						
24	1900	2400	2100						
25	2000	1400	1250						
26	1300	1200	2200						
27	2250	1500	1850						
28	1200	1250	1500						
29	1600	1500	1900						
30	2100	1600	2300						
31	1000	1250	1800						
32	1350	1700	2000						
33	1550	1100	1500						
34	0900	1150	1300						
35	1850	2000	1850						
36	2000	1100	2300						
37	1200	1750	2000						
38	1600	1550	2250						
39	2000	2250	1800						
40	1750	2200	1100						
41	0800	1650	2200						
42	2000	0950	1850						
43	0850	1850	1100						
44	1900	2050	1950						
45	1700	1200	1800						
46	1750	1350	1500						
47	1800	2100	1750						
48	2100	2250	2250						
49	0900	0750	1450						
50	2100	2200	25[illegible]						
51	2100	3050	19[illegible]						
52	1750	1750	210[illegible]						

DAILY URINE VOLUME (LI ANALYSIS) - THIRD MISSION

Table 2.2.11.1-12

MISSION DAY	URINE VOLUME MECHANICAL - ml			URINE VOLUME LI. CL.			SAMPLE VOLUME		
SL-4	CDR	SPT	PLT	CDR	SPT	PLT	CDR	SPT	PLT
53	3600	1750	2650						
54	--	--	--						
55	2400	3850	2700						
56	2600	1800	3350						
57									
58	2750	1700	2500						
59	1600	1750	2000						
60	1800	2100	2400						
61	1000	2300	1300						
62									
63									
64	1750	1400	1700						
65									
66									
67	1300	1300	1800						
68	2650	4000	2650						
69									
70	1850	1900	1900						
71	2600	1950	4200						
72									
73	2800	1600	4200						
74	1700	0950	1900						
75	2100	1450	1800						
76	1150	1900	1250						
77	1200	0850	2250						
78	2100	2000	2600						
79	1700	3000	2600						
80									
81									
82	2150	1800	2000						
83	2300	2700	2100						
84									

DAILY URINE VOLUME (LI ANALYSIS) - THIRD MISSION (Cont.)

Table 2.2.11.1-12

3/ Waste Processing

a. Hardware Anomalies - No anomalies reported.

b. Hardware Assessment

1. First Mission Crew Hardware Assessment

The processor valve and door handles, door, damper, and pressure plate mechanisms all operated satisfactorily.

Except for MD 28, all fecal bags for the first mission were processed using vacuum but without power.

Since the SMMD was inoperative (due to being left on for an extensive period) at the beginning of the mission, the crew did not use the maxx/time curves for determining processing time. However, because of the low frequency of collections, i.e., every other day per crewman, the four processor chambers used for vacuum drying the fecal bags were not overtaxed.

The crew developed their own procedure for processing which was considered satisfactory by ground control. The first crewman placed his bag in Chamber 1, the next bag in Chamber 2, and the next bag in Chamber 3. The next collection from any crewman was placed in Chamber 4. The subsequent collections were placed in the chamber which had been processing the longest. This was determined by the data and time as recorded on a piece of tape placed on each chamber door. As a result, most bags were processed from 26 - 48 hours. A few bags were left in the chamber for as long as four days. When removed by the crew, the bags looked dry.

The timer control was only operated on Chambers 1 and 2 on the last day, and operated satisfactorily.

2. Second Mission Crew Hardware Assessment

There were no problems at the bag/processor interface. The four top chambers were used to process feces; the two lower chambers were used to dry desiccants (PGA and film vault). At various times during the mission all chambers were in use; however, since power was not applied except on Mission Day 28, all chambers were not powered up at one time. Processing with heat on the last day also produced satisfactorily dry bags; however, processing time for these bags is not known.

Because of a procedure used by the crew, the SMMD mass/time processing curves were never used. The SMMD was exchanged for the wardroom SMMD sometime in the mission; however, mass data are not yet available. There was no noted difference between the specimens dried with heat and dried without heat.

Only one suit drying desiccant was dried in each of chambers 5 and 6 - taking approximately 10 hours to dry. The processor was not used to dry any other items but feces or desiccants.

Because of the procedure used by the crew there was never a need to store full fecal bags awaiting an empty chamber.

No chambers were cleaned due to bag leakage or odors.

There was never a requirement to replace the pressure plates or vacuum thimble screens. Temperature warning did not occur. There was never a requirement to replace a control panel nor did any circuit breakers open during "power on."

No processor door seals were replaced.

At no time during processing did the vacuum pressure reading on WMC panel 800 pressure gage exceed .2 psia (.138 kN/m^2). Apparently the samples were acceptable for biomedical analysis upon return to earth.

There was no specific crew comment relative to processor hardware assessment. It is assumed that all equipment operated satisfactorily.

The processors operated during the second mission in a normal manner with all components and equipment functioning as anticipated. There were no crew comments received relative to any problems with any of the processing equipment. Four chambers were used for fecal processing and the remaining two for desiccant drying.

There were no reported problems at the bag/processor interface. At various times during the second mission all chambers were in operation.

There was one problem associated with interference between the suit drying desiccants and the processor. This problem is discussed in paragraph 2.2.12.1 Suit Drying.

No repair or maintenance on any of the waste processor equipment was required during the second mission.

The WMC pressure measurement was reported off scale high (high waste processor exhaust line pressure) on DOY 210.

3. Third Mission Crew Hardware Assessment

There were no anomalies or specific crew comments relative to the processor hardware during the third mission. Processor heat was used during the mission per the relative mass measurements/time chart provided. It is assumed that all equipment operated satisfactorily.

4/ Vacuum Cleaner

a. Hardware Anomalies - No anomalies were reported.

b. Hardware Assessment

1. First Mission Crew Hardware Assessment

The first mission crew reported that the vacuum cleaner worked satisfactorily on the debris screens. The crew also reported that the WMC fan screens and mixing chamber screen were picking up trash and dirt. They felt that housekeeping involving cleaning of screens should be done about every 3 days instead of once a week.

The first mission crew also reported that in general all vacuum cleaning tools worked well and 4 to 5 vacuum bags were used throughout the mission. The vacuum cleaner was not used to collect wet debris or for any use other than debris collection. There were no recommended changes to the vacuum cleaner procedures or hardware; however, there was a very strong recommendation that future vacuum cleaners be more powerful. The vacuum cleaner was used about 15 minutes at a time.

2. Second Mission Crew Hardware Assessment

The second mission crew stated the vacuum cleaner needed more suction to vacuum filter screens. The following are comments relative to the vacuum cleaner:

- On DOY 223 the PLT reported, "The vacuum cleaner works very well. We have a lot of vacuuming to do because that screen up there in the dome gets real dirty plus some of the fans in the MDA and the filters in the WMC. The mesh is too big in the mol sieve area to collect anything so there is no sense in worrying about that. Everything gets caught there in the solids trap."

- PLT - "Vacuum cleaner - we use it. We just leave whatever is running - fans and all. And the vacuum cleaner sucks against that very well. Mostly what we've picked up from the screens is paint chips, bread crumbs, small pieces of paper, hair and lint, that kind of stuff. Normally what I do when I vacuum is pick up the big things and throw them in the trash bag and then vacuum. I've been changing the vacuum cleaner bag every time I've used it because there's usually a lot of junk that we pick up and I figure it's getting pretty full."
- On DOY 223 the CDR reported, "Vacuum cleaner - not enough suction. Although it seemed to get in every place we tried to, it just needs more suction. You couldn't sell that to a housewife in 15 minutes - she'd say it do-sn't pick up anything. Let's get a bigger fan and all that."

  "I notice they had estimated housekeeping 3D, which is a vacuum cleaner bag replacing, at 20 minutes. I'd say it's about 5 to 10 minutes.

3. Third Mission Crew Hardware Assessment

The third mission crew reported the vacuum cleaner served the purpose for which it was designed but that it could be improved by providing a simpler method of attachment in its stowage locker and by placing the circuit breaker in a more obvious location. The following are comments relative to the vacuum cleaner:

On DOY 344 the CDR reported:

Vacuum cleaner, they serve the purpose for the low vacuum requirement here and I think the - the circuit breaker location on the vacuum cleaner, - I - find myself turning that thing upside down, sideways and every other direction every time I never can remember where it is. ...is excellent It keeps me from bumping the breaker of course but it just seems to me I don't know why it is, I personally find myself searching for that circuit breaker every time I get ready to use the vacuum cleaner. It ought to be located in the same general area as the switch I'm not saying it ought to be next to it, but that's the only thing that is bothering me about the vacuum cleaner.other than that and its weird shape which is no particular problem. And the - but the one thing about the vacuum cleaner I think was really - is unacceptable is the way that thing stows stores and some of the - the mounts that were designed. All of them are blind pin locations. You have to - it takes you longer to put the doggone thing into stowage, if you bother to put it into stowage, than to use the vacuum cleaner.

5/ Trash Airlock (TAL)

a. Hardware Anomalies - Very little additional risk results from this interlock deactivation.

An assessment was made using the MSFC mission support TAL to determine the cause of the interlock rod damage (bending). It is believed that the bent rod was a result of operating the lid latch while the outer door handle was in the wrong position. This situation would have caused the interlock rod to experience high compression loads and possibly caused a slight bow (permanent set). Video from the OWS on DOY 254 confirmed that the bend is very slight and no loss of interlock function is involved. In addition, it must be realized that the interlock rod can have no effect on the amount of force necessary to operate the lid latch.

A review of checkout data indicates that the on-board spare seals do not exhibit associated closing forces significantly different from the currently installed seal:

- S/N 4 (Installed): 21-25 lb
- S/N 1 (Spare: 21-25 lb
- S/N 6 (Spare): 33-35 lb
- S/N 1001D (Spare): 21-25 lb

Although improvement did not seem likely with a seal changeout, the crew was advised that if they wanted to shop around through the spare seals and choose the one they considered best, this was acceptable. The crew chose to leave the TAL as is.

b. Hardware Assessment - Other than the anomalies discussed above, the operation of the trash airlock was acceptable and did accomplish its intended purpose during the course of the first two missions.

The second mission crew expressed, on several occasions, their feeling of dependence on the trash airlock and their concern about the situation that would result from a permanent malfunction. They also occasionally criticized the amount of time needed for trash disposal and termed the operation a "nuisance."

The third mission crew again reported on the difficulty of operating the lid latch and that it required a second crew member standing on the lid and pushing on the ceiling to assist in closing the latch.

It was also reported by the third mission CDR that there was no good way of restraining oneself while performing the trash airlock functions.

E. Conclusions and Recommendations

All Waste Management systems performed successfully in-flight. The flight crew comments during and after the mission were very complimentary. There were no damaged fecal bags and only minor urine spills. This contributed immensely to the flight crew's attitude toward waste management. Samples of dried feces and frozen urine were returned for post flight analysis.

The contingency systems were not required to be used except as planned before activation and after deactivation. Urine collection was simple and easy. The daily sampling and bag change-out task which the crew disliked prior to the mission because of their complexity and time consuming operations, were found to be acceptable tasks in-flight. The only anomaly was the low volume in the sample bags returned. In stead of 122 ml the samples averaged between 90 and 110 ml. Procedure revisions were recommended to the SL-3 and SL-4 crews which did increase quantities of the returned samples.

Fecal collection was very successful. It was the one area of waste management which could not be adequately tested in 1-G or in the simulated zero-G of the KC 135 aircraft. Prior to the SL-2 mission, the flight crew was very skeptical of its operation. Their past experiences with the Gemini and Apollo paste-on bag were extremely unfavorable; however, crew comments such as: "turned out to be a fantastically pleasant surprise" and "works in an absolutely outstanding manner and I have to rate it as excellent" tell the story. For future spacecraft they felt a higher airflow would provide even better results.

Fecal processing and suit desiccant drying gave the crews no problems. Most of the fecal processing was accomplished successfully without power.

The vacuum cleaner worked well but was never used to pick up wet debris. Again, the flight crews repeated that increased airflow would be required on future spacecraft. Suit drying was acceptable. Because of the revised activation sequence, suit drying and desiccant drying were not accomplished in the preferred sequence; however, this did not degrade the drying of suits.

The waste management subsystem proved that using airflow as a gravity substitute is an adequate means of collecting feces and urine. For future systems, higher quantities of airflow should be provided. A softer seat material should be used to make it easier in obtaining a seal. Some means of monitoring critical system airflows (ΔP gages) should be provided to the crew.

The trash airlock was utilized successfully throughout the three missions. Although there were no malfunctions of the airlock there were several operational difficulties which were successfully resolved.

There were two incidents of near jamming which were attributed to overfilled trash bags. Further problems were avoided by better control of trash combinations during disposal.

It was noted during SL-2 that the valve handle could be inadvertently kicked into or left in an intermediate position between PRESS and VENT which caused a cabin atmosphere leakage of as much as 3.3 lb/hr. This problem was overcome by strapping the handle in the PRESS position in between operations.

During SL-3 an operating characteristic of the airlock was highlighted. The manual force required to squeeze the lid during the initial portion of the latching operation is high. This high force characteristic is more significant in weightless conditions because body restraint is more difficult. It was found that the high force of latching could be overcome by proper technique or use of two crewmen.

Although the trash airlock was utilized to approximately 80 percent of the expected on-orbit operation with no malfunction, there are two improvements recommended for future use. First, a detent device should be added to the valve handle in order to positively maintain the valve handle in the PRESS or VENT positions between operations. Second, the squeeze force during the latching operation should be reduced. This could be done by refining the hinge gap adjustment by shimming and/or changing to a softer rubber for the lid seal.

An additional method of trash disposal should be considered to avoid a possible single point failure of potentially significant magnitude.

F. Development History - The initial waste management system for Skylab used a similar bag for both fecal and urine collection. One bag was to be used for each individual collection. Incorporated in the bag was a Zitex (teflon) filter which would pass air c y, not liquids or solids. Air flowing into the bag, through the filter, and subsequently through an odor control filter and a blower provided a simulated gravity condition. Both the urine and feces collected were then to be vacuum dried in a waste processor so that the residual sample could be returned to Earth for medical analysis. This basic concept for fecal collection and processing was flown in the Skylab mission.

However, the medical experiment was not able to accept vacuum dried urine samples because of insufficient confidence in the quality of urine constituents obtained from vacuum dried sample. Urine stored by freezing was the accepted method for extended storage. As a result, a 24-hour pooling bag was designed with a capacity of 2000 ML from which a 120ML sample was to be taken and placed in the freezer for storage prior to return to earth. This bag also used a Zitex filter in a manner similar to the original urine bag. During the early testing, the filter concept of separating air from the urine could not be adequately proven. Subjecting the filter to 24 hour wetting appeared to degrade the filter. As a result, the subsequent modification used two bags interconnecting, one for collection and one for storage. The collection bag used the filter for collection in the manner similar to the previous design. After each collection the urine was transferred to a storage bag. The collection bag filter was then allowed to dry between collections. Subsequent testing still left some doubt as to the adequacy of the filter for separation of air and urine. As a result, a centrifugal separator was brought into the picture and for a period of time, three concepts were being studied, the single bag, the two bag system, and the centrifugal separator system. After the initial testing, the separator proved to overcome all of the inherent faults of the bag/filter concepts. The centrifugal separator concept was implemented and work on all other systems dropped. All of these urine system changes occurred during a 1-1/2 year period. For the next year, the design was not changed. Testing was completed and flight hardware was delivered.

During the Skylab Medical Experiment Altitude Test (SMEAT) it became apparent that daily collections could be expected to be greater than 2000 ML and a larger bag would be required. In addition, the existing bag was subject to cuts which caused objectionable urine spills during test. A decision was made to provide for collection of 4 liters per day per crewman and since the Workshop had been delivered to KSC and it appeared that there was not sufficient time to complete a new design, NASA/JSC proposed the use of the Apollo bag and cuff collection. Although this appeared to be the most expeditious method of solving the problem, the Apollo bag also had many of its own problems especially in attempting to meet the medical experiment requirements. After a short period of study, a system was designed using the same centrifugal separator and a 4 liter bag which was also resistent to cutting and which met all of the requirements. Within three months, all new hardware was delivered to KSC in time to meet the launch vehicle checkout requirements. This 4 liter system was flown in the Skylab mission.

The vacuum cleaner which contains a blower powered by a brushless DC motor had very little change since the original design, however, a non-propulsive vent was added to the vacuum cleaner, hi-rel electrical components were designed into the electronics and the motor bearings were revised to withstand the longer life. This blower was identical to the one used in the collection module.

The initial design for the Trash Airlock was revised only slightly. Several interlocks were added to prevent hazardous conditions from occurring.

2.2.11.2 Water Management System

A. Design Requirements - The HSS water subsystem was to provide potable water to the waste management subsystem, wardroom, and personal hygiene subsystems in the quantities and under the conditions required by each subsystem. (There was to be no common connection between the waste management/personal hygiene and wardroom water subsystems. Provisions were to be made for draining the water distribution system between missions.)

A minimum of 6,000 pounds (2,722 kilograms) of water was to be contained (in 10 separate tanks) inside the launched OWS as near the center of gravity of the orbital assembly as practical. The 10 tanks were specifically allocated as follows:

- Wardroom water system (potable): Tank Nos. 1, 2, 3, 4, 5, and 10
- Hygiene water system: Tank Nos. 6, 7, and 8
- Airlock module servicing: Tank No. 9

The 6,000 pound (2,722 kilograms) supply was to suffice for the three missions.

The water subsystem was to use iodine as the biocide and was to provide the capability to monitor selected iodine levels between 2.0 mg/l and 12 mg/l. The iodine level was to be maintained between 2.0 mg/l and 12.0 mg/l, except in the water heater; however, the iodine concentration in each water container was to be maintained to ensure a maximum iodine level of 6 mg/l at time of consumption. (In-orbit addition of iodine to the water was to be accomplished in such a manner as to ensure complete dispersal throughout the system.) Positive protection against freezing during all mission phases was to be provided.

If the water contained solutes or suspended chemicals, these chemicals had to be known and predictable. The design was to assume that each crewman ingest 7.5 pounds (3.39 kilograms) of water/day. Objectionable gasses were not to be introduced into the water subsystem.

All components of the water subsystem were to be designed to prevent adverse chemical and physical effects on either the potability of the water or the components in contact with the water. (The quality of the potable water from the use-ports in the wardroom was to meet MSC-PF-SPEC-1.) (In order to ensure biological separation, there was to be no common connection between the waste management/personal giene and wardroom water subsystems.)

The water subsystem was to consist of the following:

- o Water stowage bottles and transfer provisions.
- o Water dispensing equipment for:
  - o Food preparation and drinking water.
  - Personal hygiene water.
- o Portable water tank.
- o Optical iodine comparator.

Provision was to be incorporated to allow the water distribution system to be drained at the end of each mission. (Prior to activating the wardroom water distribution syrtem at the beginning of SL-3 and SL-4, the system was to be disinfected with a water solution containing approximately 100 mg/l free iodine.)

The water dispensing equipment was to control and dispense the water which would be used by the astronauts for food preparations, drinking, and for personal hygiene. No requirement was to exist for specific amounts or accuracies in personal hygiene water dispensing. Design of the food rehydration probe and potable water dispenser was to ensure that water could be easily dispensed. The water dispensing equipment was to have sufficient capacity for three crewmen to be able to eat simultaneously. The system was to provide the capability of determining the amount of water dispensed. Requirements for the water dispensing equipment are described in the following paragraphs.

The OWS was to have the capability of providing, in the wardroom, water for either hot or cold food reconstitution.

Water Dispenser - Food Reconstitution - The wardroom crewmen's table was to provide one hot water and one cold water dispenser for food reconstitution. Sufficient hot and cold water was to be available to prepare meals for three crewmen simultaneously.

1/ Hot Water Dispenser Limitations

Dispense Volume Increment:	1 oz (29.57 cc) with 1/2 oz (14.79 cc) increments to 6 oz (177.42 cc) ± 1 percent
Total Dispense Volume:	6 oz (177.42 cc) max
Operating Pressure:	35 +5, -3.5 psig (241 + 34.5, -24.1 kN/m²)
Dispensed Water Temperature:	150 +9, -5°F (65.6 +5, -2.8°C) at 24 VDC to 30 VDC (Nominal: 150 ±5°F(65.6 ± 2.8°C) at 28 VDC)
Time to Charge:	6 sec max (6 oz) (177.42 cc)
Time to Discharge:	8 sec max (6 oz) (177.42 cc)

2/ Cold Water Dispenser Limitations

Dispense Volume Increment:	1 oz (29.57 cc) with 1/2 oz (14.79 cc) increments to 6 oz (177.42 cc) ± 1 percent
Total Dispense Volume:	6 oz (177.42 cc) max
Operating Pressure:	35 +5, -3.5 psig (241 +34.5, -24.1 kN/m²)
Dispensed Water Temperature:	45 +0, -12°F (7.2 +0, -6.6°C)
Time to Charge:	6 sec max (6 oz) (177.42 cc)
Time to Discharge:	8 sec max (6 oz) (177.42 cc)

3/ Dispenser Physical Envelope

See Figures 2.2.11.2-1 and 2.2.11.2-2

4/ Backup Dispenser Physical Envelope

See Figure 2.2.11.2-3

The requirements for water used for drinking were to be:

- o There were to be three dispensers for drinking water incorporated into the wardroom (each dispenser was to have three interchangeable heads which were to be sterilized and packaged in a clean container).
- o The dispenser was to deliver cold water in discrete increments of 0.44 to 0.50 fluid ounces (13.0 to 14.8 cubic centimeters) repeatable to ± 1 percent. Visual indication of the amount of water used was to be provided.

The requirements for water to be used for personal hygiene activities were:

- o A supply of water was to be provided in the WMC for personal hygiene activities.
- o The water supply was to include a dispenser which would deliver water at a temperature of 125° +9°, -5°F (51.7 +5 -2.8°C) for skin cleansing.
- o The personal hygiene water dispenser was to be designed to prevent cross-contamination between astronauts.

The urine collection and sampling process were to limit day-to-day cross-contamination between urine samples to less than 1 percent by volume of each sample collected. The urine collector was to be designed to prevent cross-contamination between the users. A flushing capability (urine flush network) was to be provided as a means to control cross-contamination between the 24-hour pooled urine

SKYLAB - ORBITAL WORKSHOP
WARDROOM FOOD
RECONSTITUTION WATER DISPENSERS

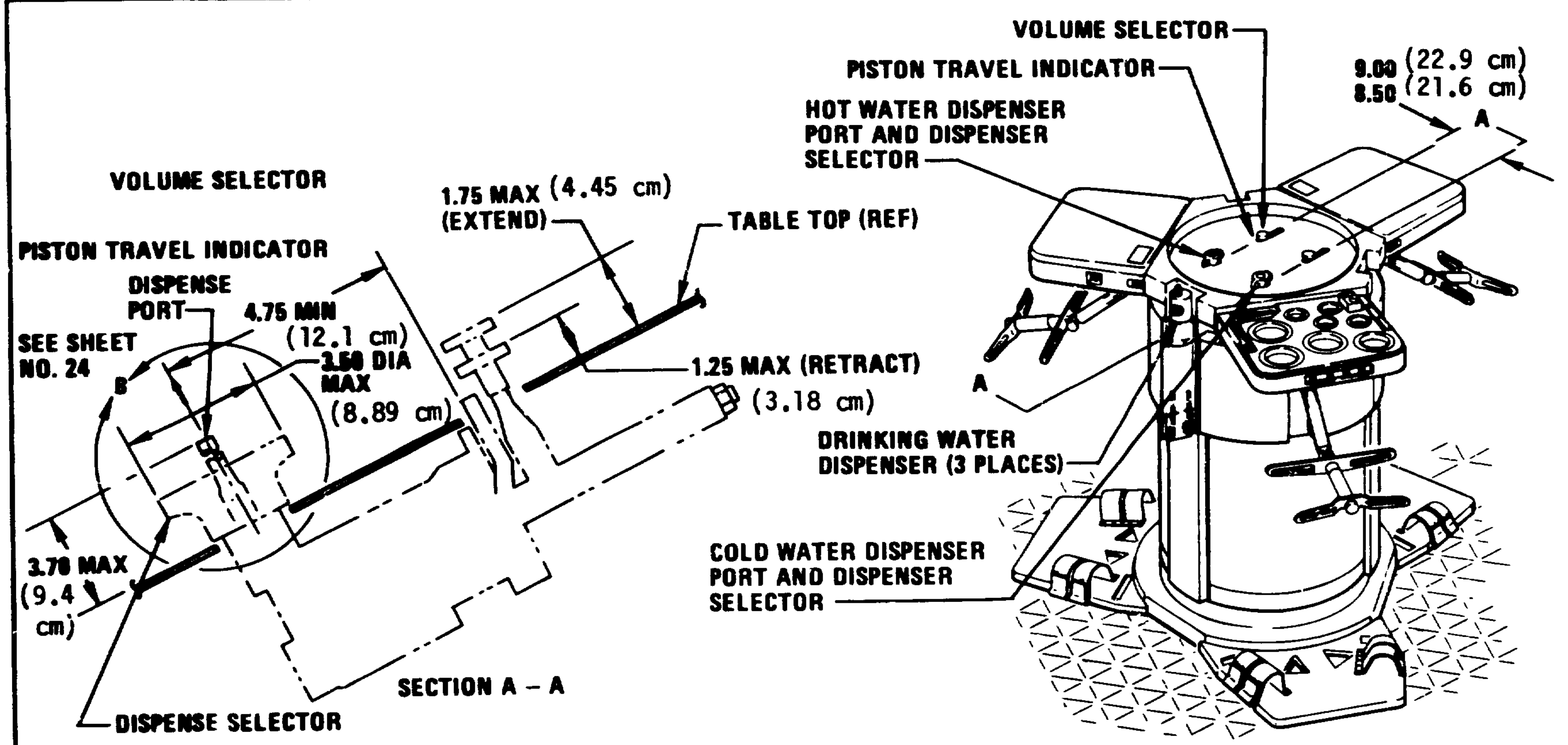
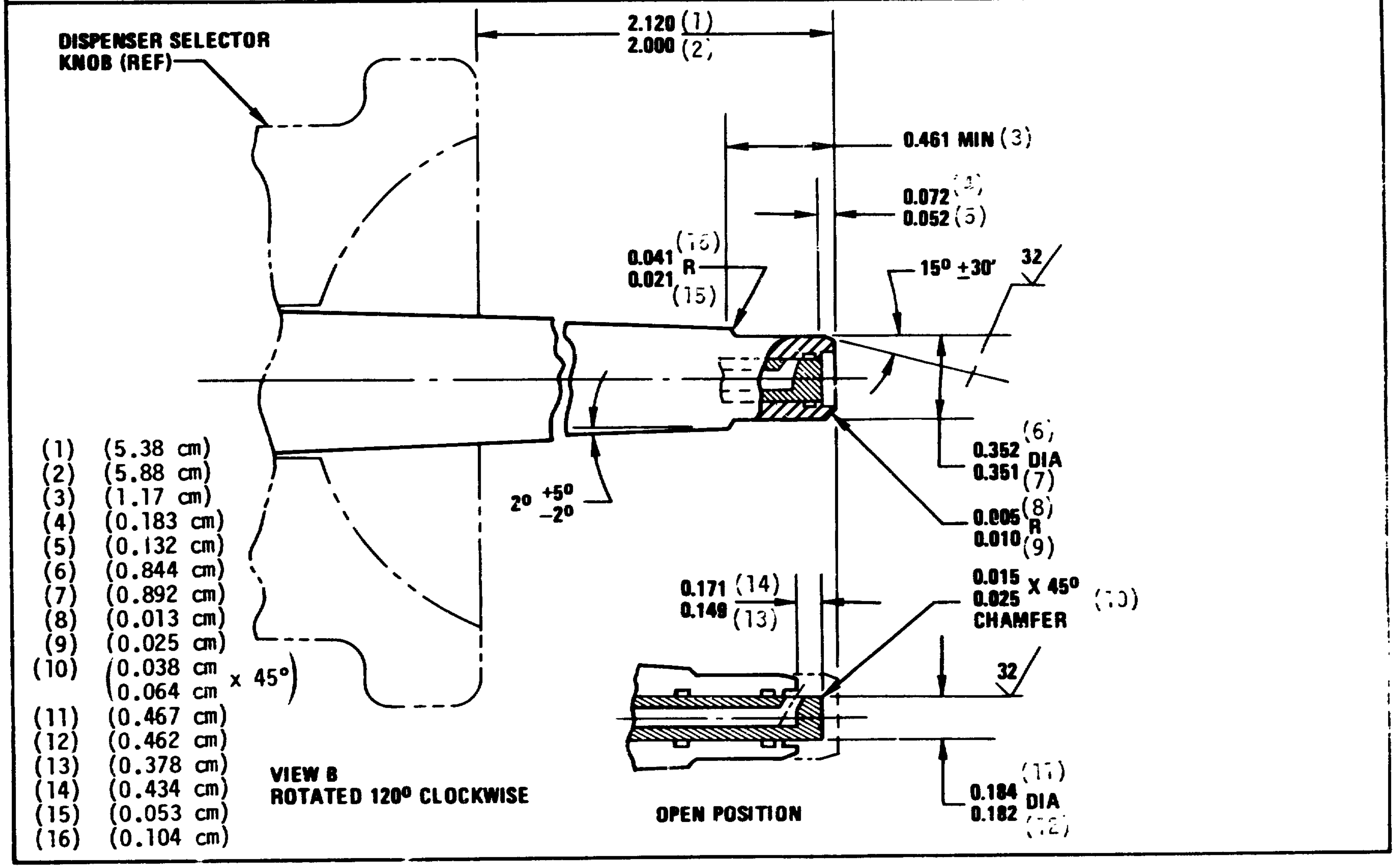


Figure 2.2.11.2-1

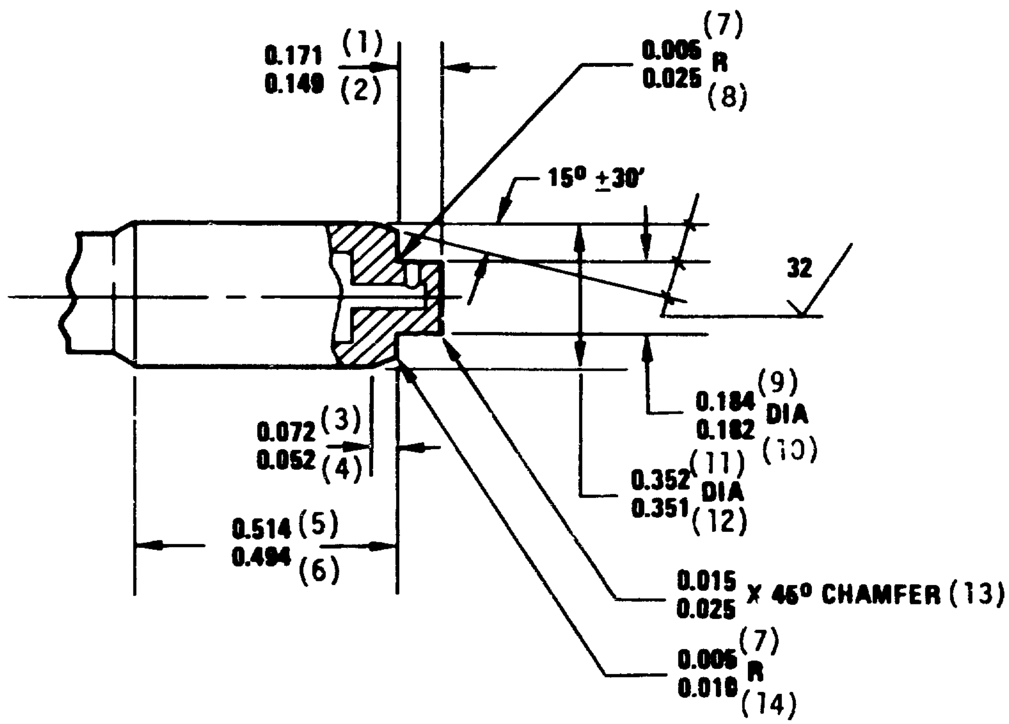
SKYLAB - ORBITAL WORKSHOP
WATER DISPENSER



(1) (5.38 cm)
(2) (5.88 cm)
(3) (1.17 cm)
(4) (0.183 cm)
(5) (0.132 cm)
(6) (0.844 cm)
(7) (0.892 cm)
(8) (0.013 cm)
(9) (0.025 cm)
(10) (0.038 cm / 0.064 cm x 45°)
(11) (0.467 cm)
(12) (0.462 cm)
(13) (0.378 cm)
(14) (0.434 cm)
(15) (0.053 cm)
(16) (0.104 cm)

Figure 2.2.11.2-2

SKYLAB - ORBITAL WORKSHOP
REHYDRATION BACKUP PROVISION
(DRINKING WATER DISPENSER)



(1) (0.434 cm)
(2) (0.378 cm)
(3) (0.183 cm)
(4) (0.132 cm)
(5) (1.31 cm)
(6) (1.25 cm)
(7) (0.013 cm)
(8) (0.064 cm)
(9) (0.467 cm)
(10) (0.462 cm)
(11) (0.894 cm)
(12) (0.892 cm)
(13) (0.038 cm / 0.064 cm x 45°)
(14) (0.025 cm)

Figure 2.2.11.2-3

collections for each user. The flushing system was to be capable of dispensing water from a preinstalled water container in four increments of 50 $\pm$5 ml per crewman per 24-hour pooling period. The flush water was to be the same as used in the personal hygiene water subsystem.

A portable water tank was to be provided that would be filled from taps on the preinstalled OWS water containers. The portable water tank was to hold approximately 28 pounds (12.7 kilograms) of water, and was to be compatible with a water solution containing 100 mg/l of free iodine.

The water subsystem was to provide a crew-operable hand-held optical iodine comparator with the following features:

- o Illumination of both the sample and the standard was to come from behind the comparator.
- o The light source was not to be self-contained and was to be an existing source such as the OWS portable light or cabin lights.
- o The comparator was to utilize a 0 through 12 ppm standard.
- o The comparator was to be secured by means of a hand-operated captive fastener during launch and when not being utilized.

B. **Water System Description** - The water system supplies crew members with potable water for food reconstitution, drinking, personal hygiene, and housekeeping. A network was designed for urine separator flushing, but this feature was not used. Water for these purposes is stored and distributed by networks to water management equipment and water usage facilities. Water purification equipment was provided to maintain microbiological control in the water system. The water subsystem consists of the following hardware items (see Figures 2.2.11.2-4,

ORBITAL WORKSHOP
WATER SYSTEM

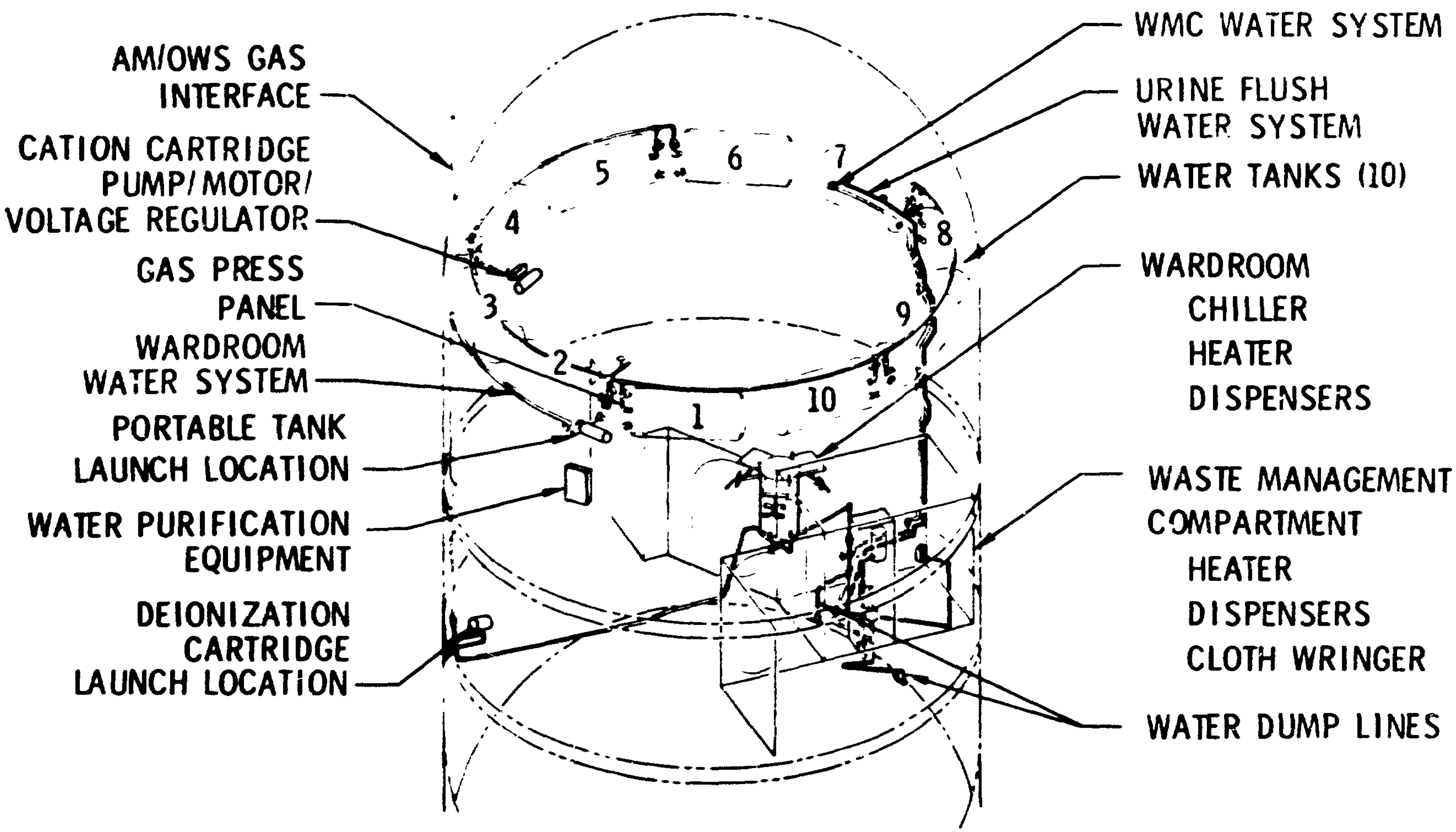


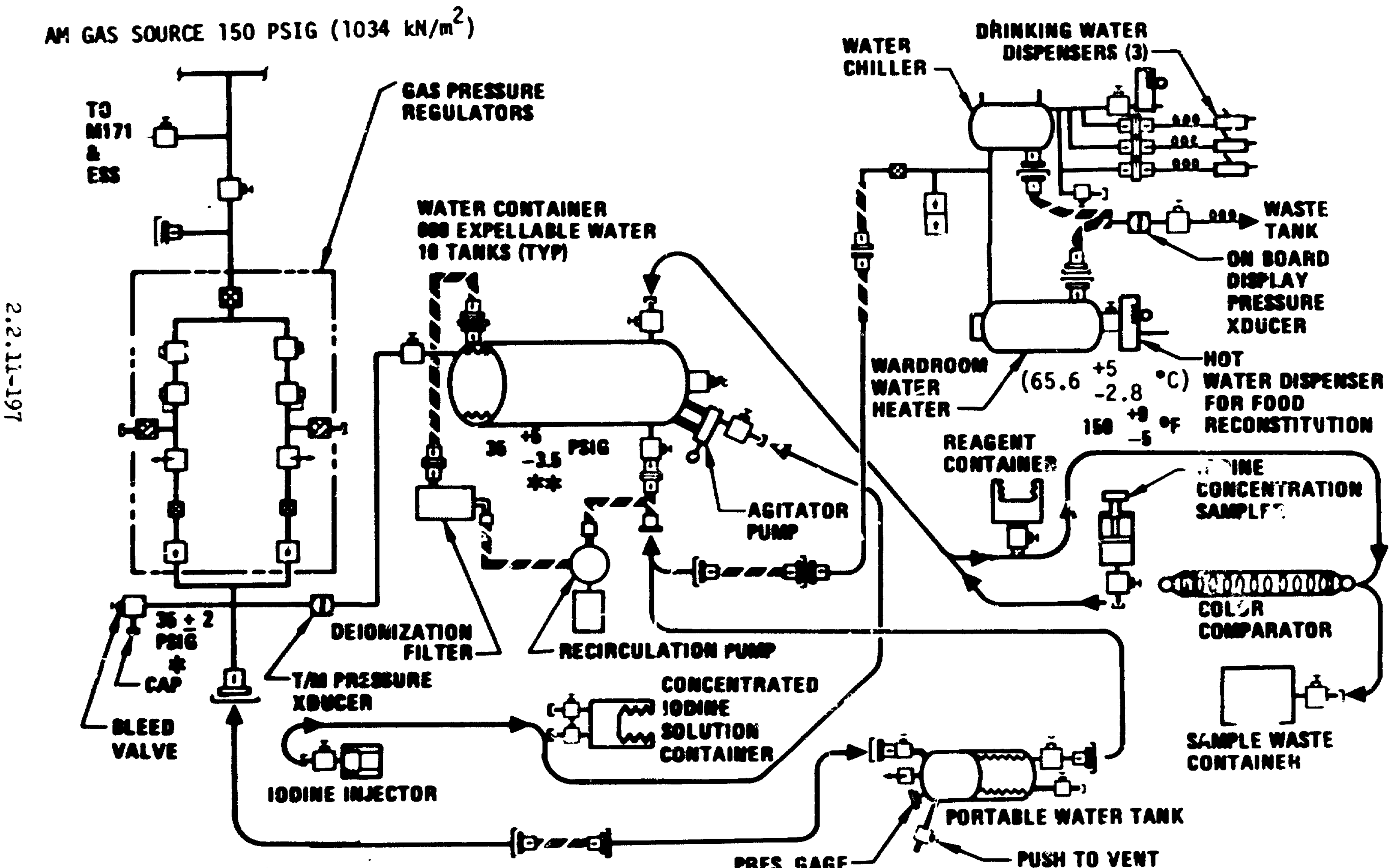
Figure 2.2.11.2-4

2.2.11.2-5, and 2.2.11.2-6):

- Water storage comprised of 10 isolated stainless steel tanks with integral stainless steel expulsion bellows, quick disconnects, fill and drain ports, iodine injection and sample ports, nitrogen isolation hand valves, level indicators, heater blankets, agitator pumps, and hand operated shut-off valves.
- Portable water container which can be filled from the water storage network and pressurized from the pressurization system.

  Water pressurization system which utilizes a nitrogen supply from the airlock module (AM). The system includes pressure regulators, relief valves, check valves, filters, isolation hand valves, a pressure transducer, and related plumbing.
- Wardroom water distribution which includes relief valves, a water heater, a water chiller, hot and cold food and beverage reconstitution dispensers, three individual drinking water dispensers, quick disconnects, flex hoses, and related plumbing.
- Urine system flush water network which includes quick disconnects, a flush water dispenser, flex hoses, a filter, and related plumbing.
- Waste management compartment (personal hygiene) water network which includes quick disconnects, a dispensing valve, flex hoses, relief valves, a water heater, and related plumbing. The hygiene network also includes a manual washcloth squeezer.
- Two vacuum dump/drain systems to evacuate the wardroom network and the waste management water network. The systems consist of quick disconnects, flex hoses, hand shut-off valves, pressure transducers, heated discharge probes, and related plumbing.
- Water purification control equipment.

ORBITAL WORKSHOP
POTABLE WATER SYSTEM SCHEMATIC

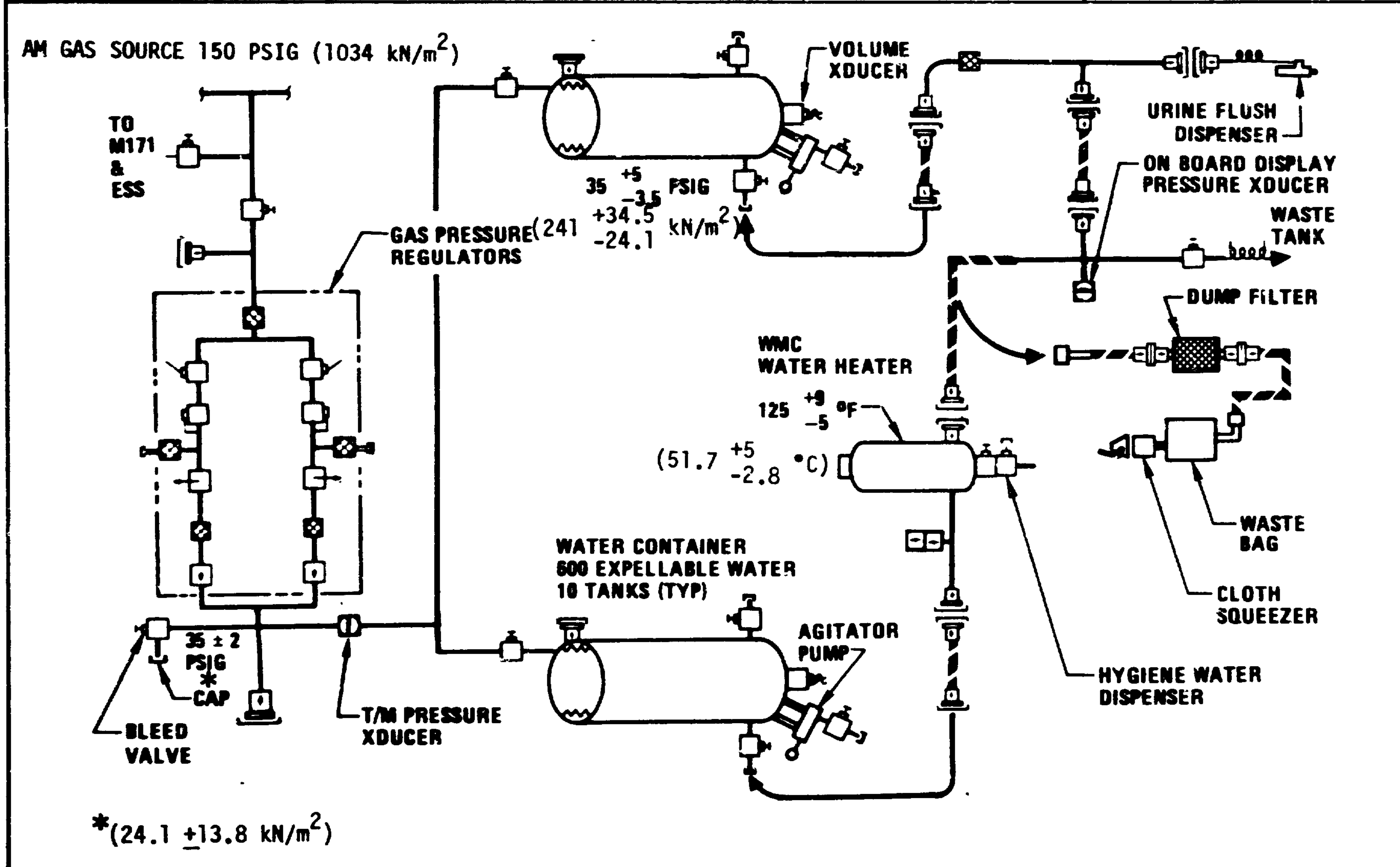


* (241 ±13.8 kN/m²)

** (241 +34.5 −24.1 kN/m²)

Figure 2.2.11.2-5

SKYLAB - ORBITAL WORKSHOP
WMC WATER SYSTEM SCHEMATIC



Water is stored in ten 600 pound (272.2 kilogram) capacity stainless steel storage tanks in the forward compartment area of the OWS (see Figure 2.2.11.2-4). The water tanks (WT) are identified as 1 through 10 and are assigned to particular water networks: WT 1, WT 2, WT 3, WT 4, WT 5, and WT 10 are assigned for wardroom use, i.e., drinking and meal preparation, WT 6 is assigned to the urine system flush water network, i.e., flushing of the urine separation; WT 7 and WT 8 are assigned to the WMC water network, i.e., body cleansing; and WT 9 is provided as a contingency water tank in the event that additional water is required due to excessive water consumption or due to a failure of one of the water tanks. A water outlet quick disconnect is located on each water tank for connecting and disconnecting water distribution lines. In use, only one water tank at a time is connected to its particular water line; the sequence of water tank usage is predetermined (Table 2.2.11.2-1).

Each water tank is basically composed of a stainless steel cylinder with a sealed metal bellows inside. Each water tank is an independent unit supplied with a nitrogen gas pressurant to maintain water supply pressure. The sealed bellows assembly forms an N_2 gas chamber, which is supplied with N_2 pressurant controlled from Panel 500. Water surrounds the N_2 gas chamber and is provided a constant pressure during usage (bellows assembly extends as water is withdrawn from the water tank). (See Figures 2.2.11.2-7 and 2.2.11.2-8.)

A pressure of 35 psig (241kN/m^2) is continuously maintained in the N_2 gas chamber during habitation through N_2 pressure regulation. When the bellows assembly has extended to the end of the water tank,

Table 2.2.11.2-1

WATER BUDGET

FUNCTION	MAXIMUM 3 CREWMEN USE RATE	TOTAL REQUIREMENT, LB (kg)	CONTAINERS REQUIRED	USABLE AVAILABLE * LB (kg)	REMAINING USABLE LB (kg)
METABOLIC TANKS:		3282.9 (1489.1) (total)	[1,10,2,3,4,5]	3549.6 (1610.08)	266.7 (120.97)
CM RETURN	24 LB/MISSION (10.89 kg/ MISSION)	72.0 (32.66)			
METABOLIC	22.5 LB/DAY (10.21 kg/ DAY)	3028.4 (1373.66)			
WR SYSTEM BLEED (END OF MISSION)	15 LB/MISSION (6.8 kg/ MISSION)	45.0 (20.41)			
WR SYSTEM MICROBIOLOGICAL FLUSH	21 LB (9.53 kg) START 1ST MISSION 58 LB (26.3 kg) START 2 & 3 MISSIONS	137.0 (62.14)			
IODINE SAMPLING		0.5 (0.227)			
WMC TANKS:		1336.8 (606.36) (total)	[7,8,9]	1774.8 (805.04)	438.0 (198.67)
WM SYSTEM BLEED (END OF MISSION)	7.5 LB/MISSION (3.4 kg/ MISSION	22.5 (10.21)			
HOUSEKEEPING	4 LB/DAY (1.81 kg/DAY)	544.2 (246.84)			
PERSONAL HYGIENE	3 LB/DAY(1.36 kg/DAY)	409.8 (185.88)			
OWS SHOWER	6 LB SHOWER (2.72 kg/ SHOWER (1 SHOWER/MAN/WEEK)	360.0 (163.29)			
IODINE SAMPLING		0.3 (0.136)			
URINE SEPARATOR TANK:		254.9 (115.62) (total)		591.6 (268.35)	336.7 (152.72
URINE FLUSH	600 ML/DAY	180.3 (81.78)			
URINE SEPARATOR BLEED	3.4 LB/MISSION (1.59 kg/ MISSION	10.5 (4.76)			
LSU RESERVICING		34.8 (15.79)			
ATM C&D PANEL RECHARGE		24.0 (10.89)			
CONDENSING HEAT EX-CHANGERS RESERVICING		3.9 (1.77)			
M479 EXTINGUISHING		1.3 (0.59)			
IODINE SAMPLING		0.1 (0.454)			
				TOTAL REMAINING	1041.4 (472.37)

*BASED ON ACTUAL USABLE QUANTITY OF 591.6 POUNDS (268.35 kg) PER CONTAINER

SKYLAB - ORBITAL WORKSHOP
WATER STORAGE PROVISIONS

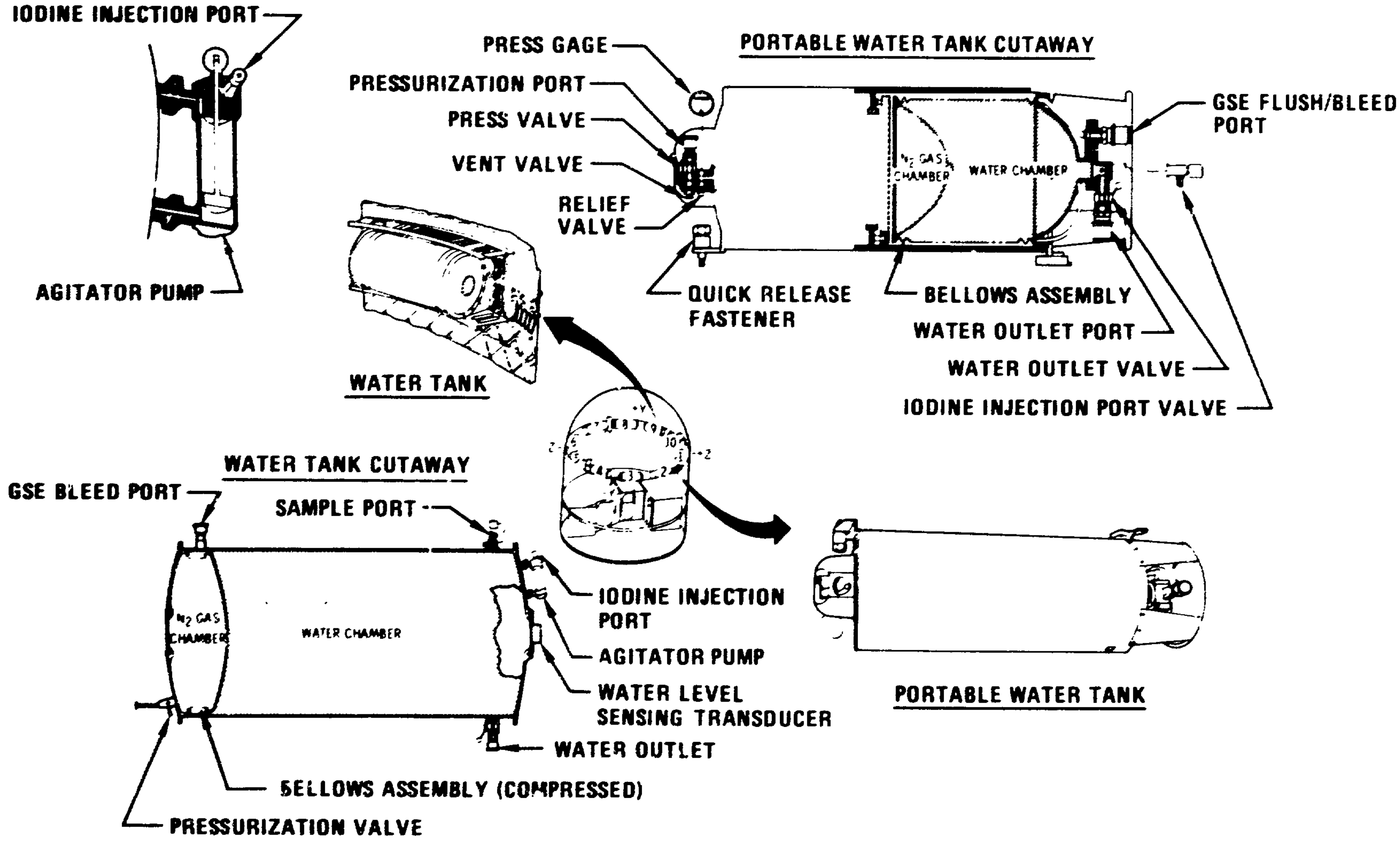
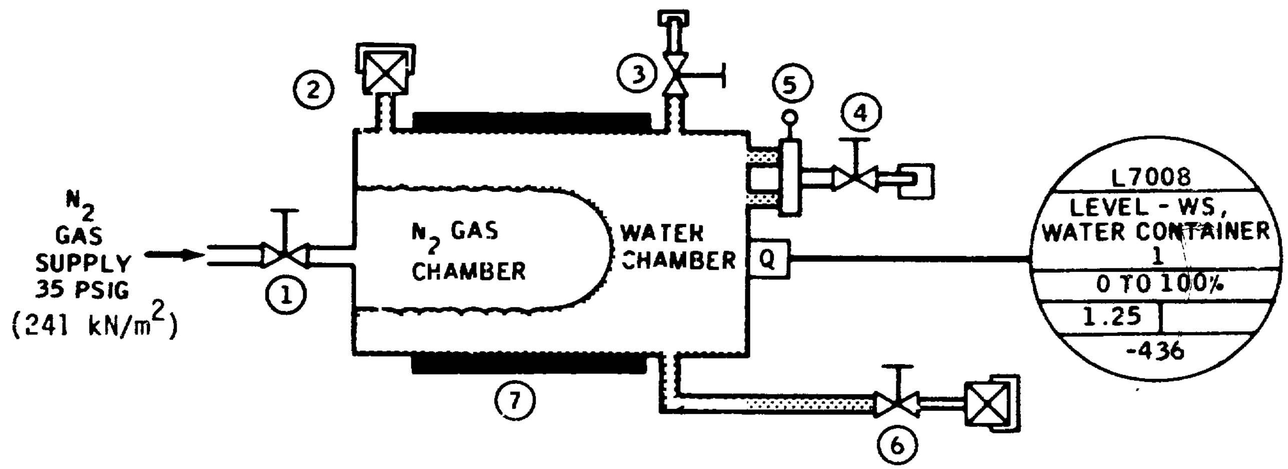


Figure 2.2.11.2-7

SKYLAB - ORBITAL WORKSHOP
WATER TANK - SCHEMATIC (TYP)



WATER TANK SERVICING EQUIPMENT:

1. PRESSURIZATION VALVE
2. GSE BLEED PORT
3. SAMPLE PORT VALVE
4. IODINE INJECTION PORT VALVE
5. AGITATOR PUMP

6. WATER OUTLET VALVE
7. HEATER BLANKET

NOTE: WT 2 THRU WT 10 ARE INSTRUMENTED BY MEASUREMENTS L7009 THRU L7017 RESPECTIVELY

Figure 2.2.11.2-8

depleting that tank, residual water (approx. 73.3 pounds) (33.25 kilograms) remains trapped around the bellows assembly. Hand-operated valves isolate each water tank's water chamber and N_2 gas chamber from the remainder of the system.

In addition to the hand-operated valves used to isolate the water tank's water chamber (water outlet valve) and N_2 gas chamber (pressurization valve), each water tank contains water tank servicing equipment to facilitate ground filling of water (using the GSE bleed port) and to permit water purification (Figures 2.2.11.2-7 and 2.2.11.2-8). Purity of the water is maintained by using iodine as a biocide. The water is periodically sampled on-orbit by use of the sample port valve. If the on-orbit sample analysis reveals a need to purify the water, iodine will be injected into the tank through the iodine injection port, with dissolution obtained through operation of the agitator pump (Figure 2.2.11.2-9).

Two water tank heater blankets are used on each water tank to maintain the water temperature at above 55°F (12.8°C) during all mission phases. Redundancy is provided (Figure 2.2.11.2-10) since both bus 1 and bus 2 heater blankets will be operated simultaneously. The two control sensors on each heater blanket are remotely located on the water tank to ensure proper temperature distribution through the water chamber. An overtemp sensor provides heater blanket control at a slightly higher water temperature in the event of a failure of one of the control sensors.

One of the water tanks will be used as a water servicing tank after it has been partially depleted. This water tank will be

ORBITAL WORKSHOP
PUMP ASSEMBLY WATER AGITATOR

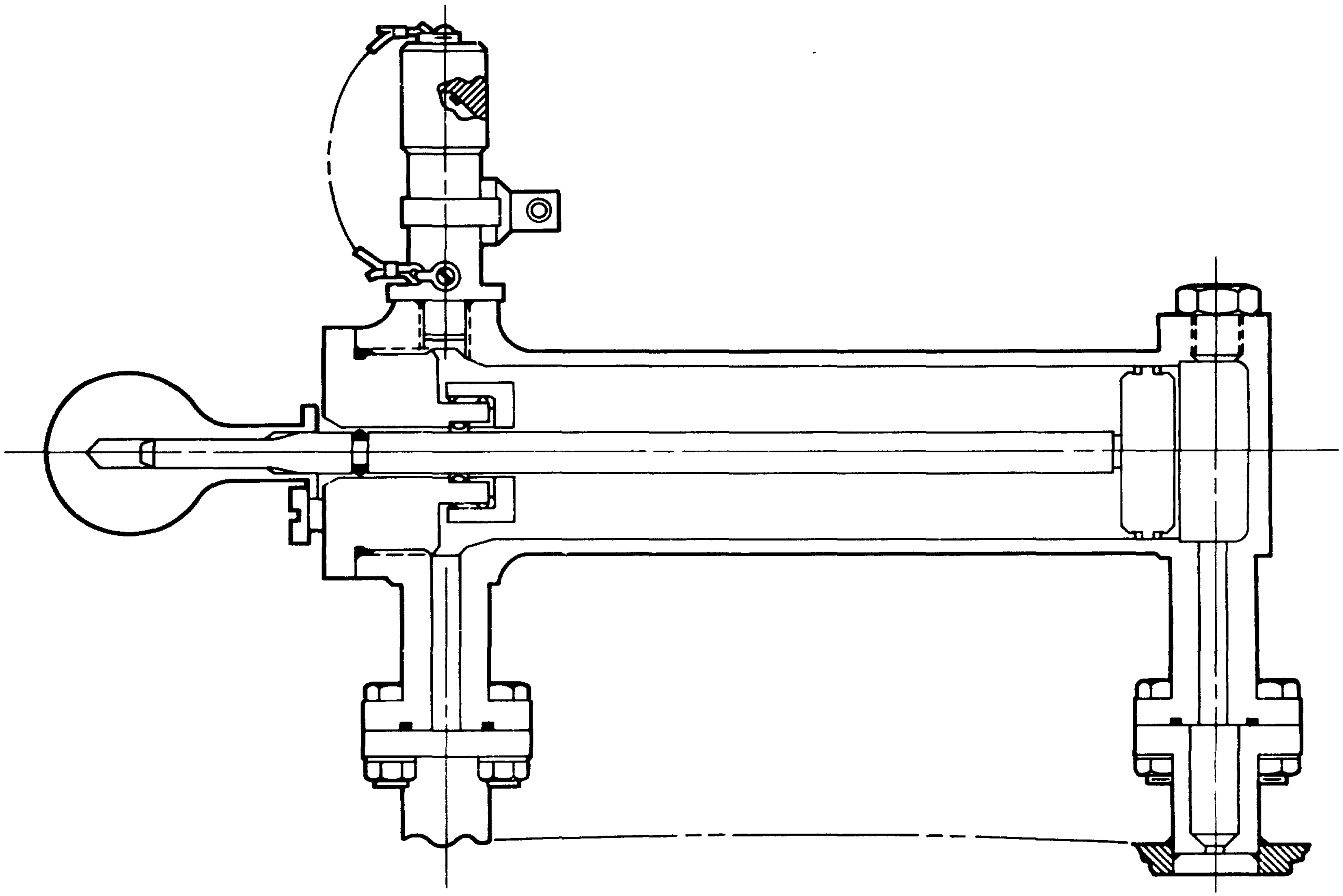
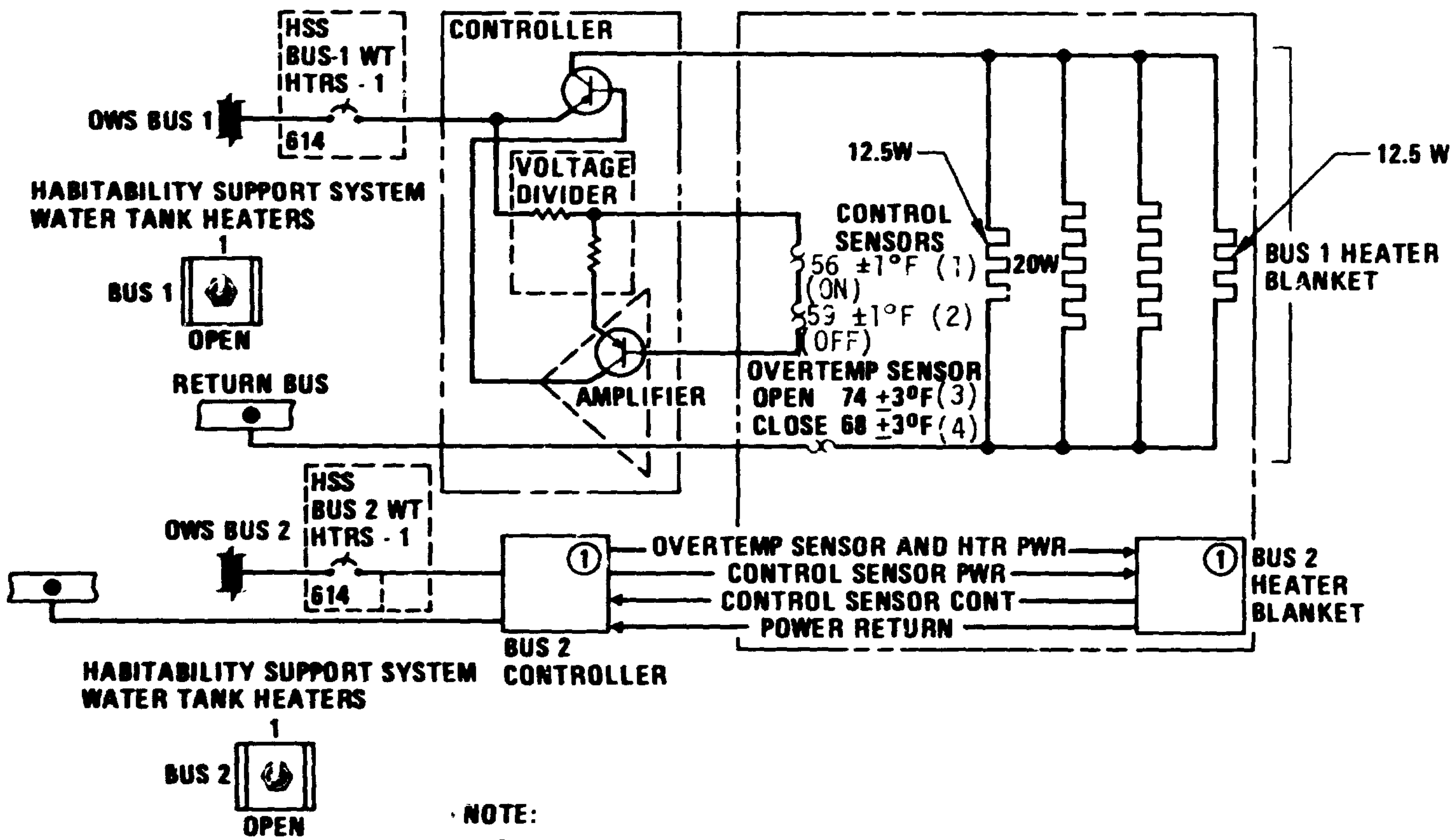


Figure 2.2.11.2-9

SKYLAB - ORBITAL WORKSHOP
WATER TANK HEATER BLANKET -- SCHEMATIC (TYP)



(1) (13.3 ± .56°C)
(2) (15 ± .56 °C)
(3) (23.3 ± 1.67°C)
(4) (20 ± 1.67°C)

NOTE:

① BUS 2 HEATER BLANKETS AND BUS 2 CONTROLLERS ARE IDENTICAL TO THE BUS 1 CIRCUITRY
② THIS SCHEMATIC IS TYPICAL FOR WT 2 THROUGH WT 10

Figure 2.2.11.2-10

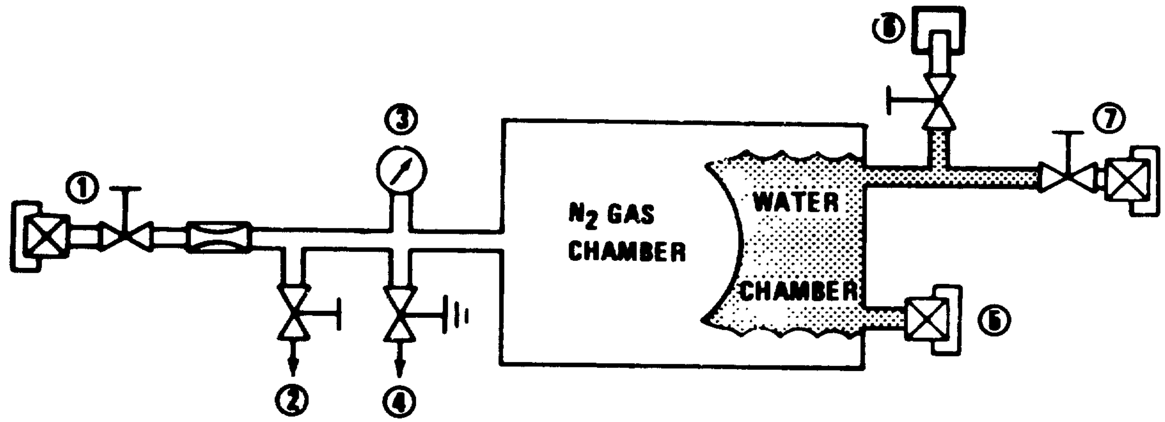
isolated from the water networks and subsequently used to replenish the water in the ATM C&D/EREP cooling system and in the suit cooling systems. In addition, this water tank will be used to charge the LSU's and PCU's.

Water quantity, for each water tank, is available only on telemetry. This information is used not only to track water usage but to perform water purification.

2/ One portable water tank is provided in the OWS for use as a contingency water supply in the event of a water network failure and for the wardroom water network fill, soak, and flush during SL-3 and SL-4 activation. The portable water tank is an independent and completely portable tank that accommodates a self-contained pressurization unit and a 26 pounds (11.79 kg) capacity water supply. The portable water tank is mounted in the OWS forward compartment on a wall bracket below WT 1 and WT 2 (Figure 2.2.11.2-7). The portable water tank is launched and stowed on-orbit in this location and may be removed for use through operation of a single quick-release fastener (after initial removal of four launch bolts).

The portable water tank is a cylinder, housing an N_2 gas chamber that surrounds a sealed bellows assembly accommodating its water supply in a water chamber. The N_2 gas chamber provides self-contained pressurization of the water chamber, utilizing a precharged volume of N_2 pressurant. The N_2 gas chamber pressure is monitored by the crewman on a pressure gage located on the portable water tank (Figure 2.2.11.2-11). The N_2 precharge is conducted prior to launch while the tank is empty. The tank is launched in this configuration and, prior to its first on-orbit use, the N_2

SKYLAB - ORBITAL WORKSHOP
PORTABLE WATER TANK -- SCHEMATIC



1. PRESS PORT VALVE
2. VENT VALVE (PUSH BUTTON)
3. PRESS GAUGE (0-80 PSIG) (0-552 kN/m^2)
4. RELIEF VALVE (CRACK 51 PSIG (352 kN/m^2) - RESEAT 45 PSIG (310 kN/m^2)
5. GSE BLEED PORT
6. IODINE INJECTION PORT VALVE
7. WATER OUTLET PORT VALVE

- LAUNCH EMPTY - GN_2 PRECHARGE 20 TO 25 PSIG (138 TO 172 kN/m^2) FOR LAUNCH
- ON ORBIT GN_2 PRESS EMPTY 18 TO 22 PSIG (124 TO 152 kN/m^2)
- WATER PRESSURE FULL 35 $^{+5}_{-3.5}$ PSIG (241 $^{+34.5}_{-24.1}$ kN/m^2)
- WATER CHAMBER CAPACITY 26 TO 27.5 LBS (11.79 TO 12.47 kg)
- N_2 GAS CHAMBER VOLUME - 2,225 $IN.^3$ (36461 cc) (BELLOWS COLLAPSED)
  - 1,500 $IN.^2$ (24581 cc) (BELLOWS EXTENDED)

Figure 2.2.11.2-11

gas volume will be vented by the crew to a lower precharge pressure, using the push-button vent valve. Overpressure protection for the tank is provided by an integral relief valve. The N_2 gas chamber may be repressurized through the pressurization port using the nitrogen fill hose connected to the 35 psi (241 kN/m^2) N_2 portable water tank pressurization connector on Panel 500. The portable water tank pressurization valve contains an orifice that will permit N_2 gas chamber pressurization from the 150 psi (1034 kN/m^2) N_2 connector on Panel 500, if the 35 psi (241 kN/m^2) port becomes inoperable. Water for the portable water tank is obtained from a water tank through use of one of the water hoses.

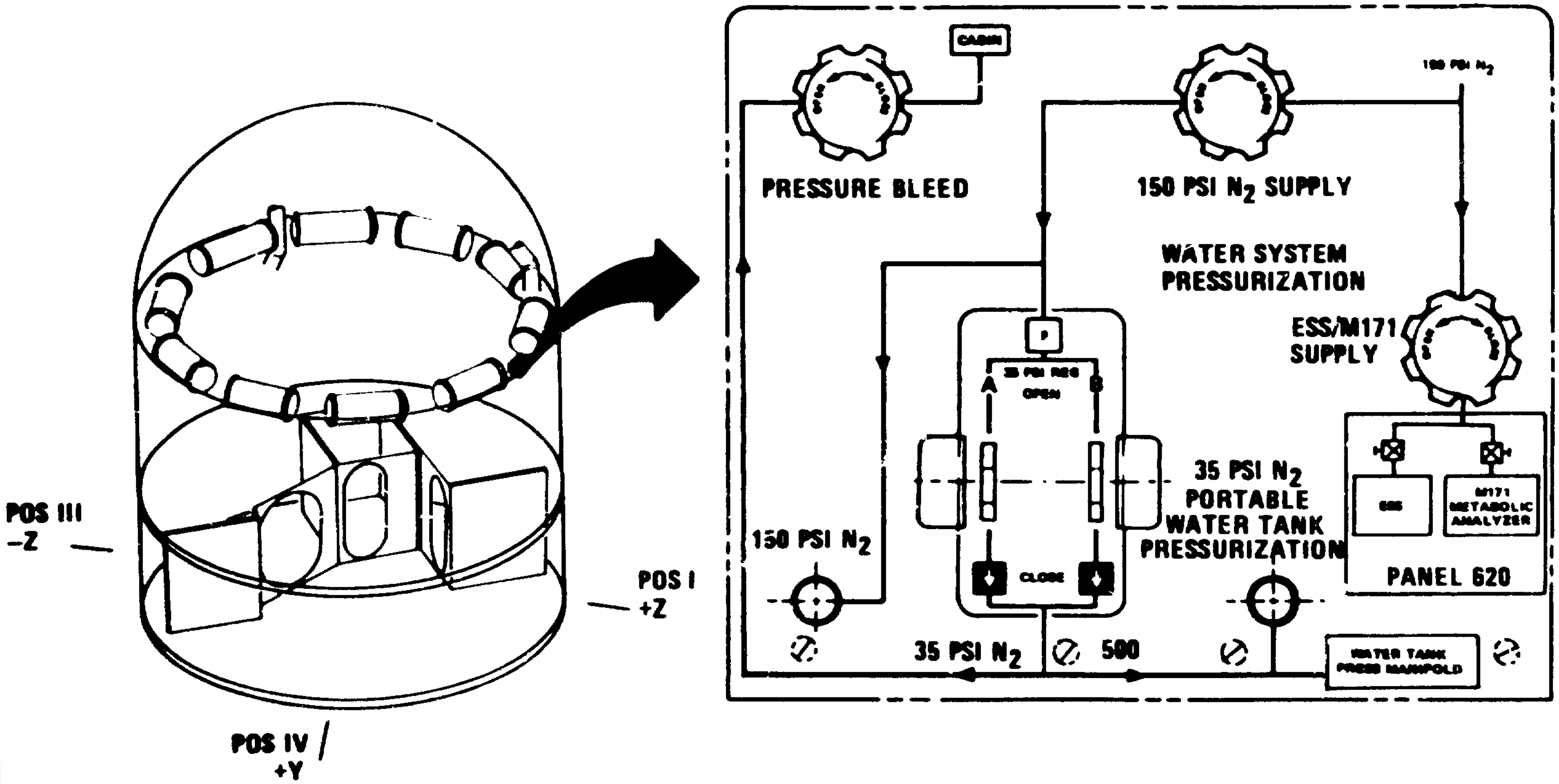
For use as a contingency water supply, the portable water tank may be transported near the area of use if one of the water networks fails. Location in these instances will be on the OWS forward compartment floor above either the wardroom or the WMC. The quick-release fastener on the portable water tank permits retention on any grid surface. A water hose with an appropriate dispenser is then passed through the grid into the using area. For use in the WMC, a quick-disconnect is attached to fitting which protrudes through the ceiling above the WMC water heater. This is required since the WMC ceiling grid is completely enclosed with a liner. A dispenser may then be connected to the ceiling-mounted quick-disconnect.

Also, upon SL-3 and SL-4 activation, the wardroom water network will be filled, soaked, and flushed with a concentrated iodine solution in water to remove microbiological contamination incurred during storage. To accomplish this, the portable water tank is filled with water from a water tank; the portable water tank wardroom network is filled with this concentrated solution and allowed to soak for a one-hour period with the portable water tank connected. At the end of the soak period, the concentrated solution and the water-iodine solution remaining in the portable water tank are flushed into the waste tank.

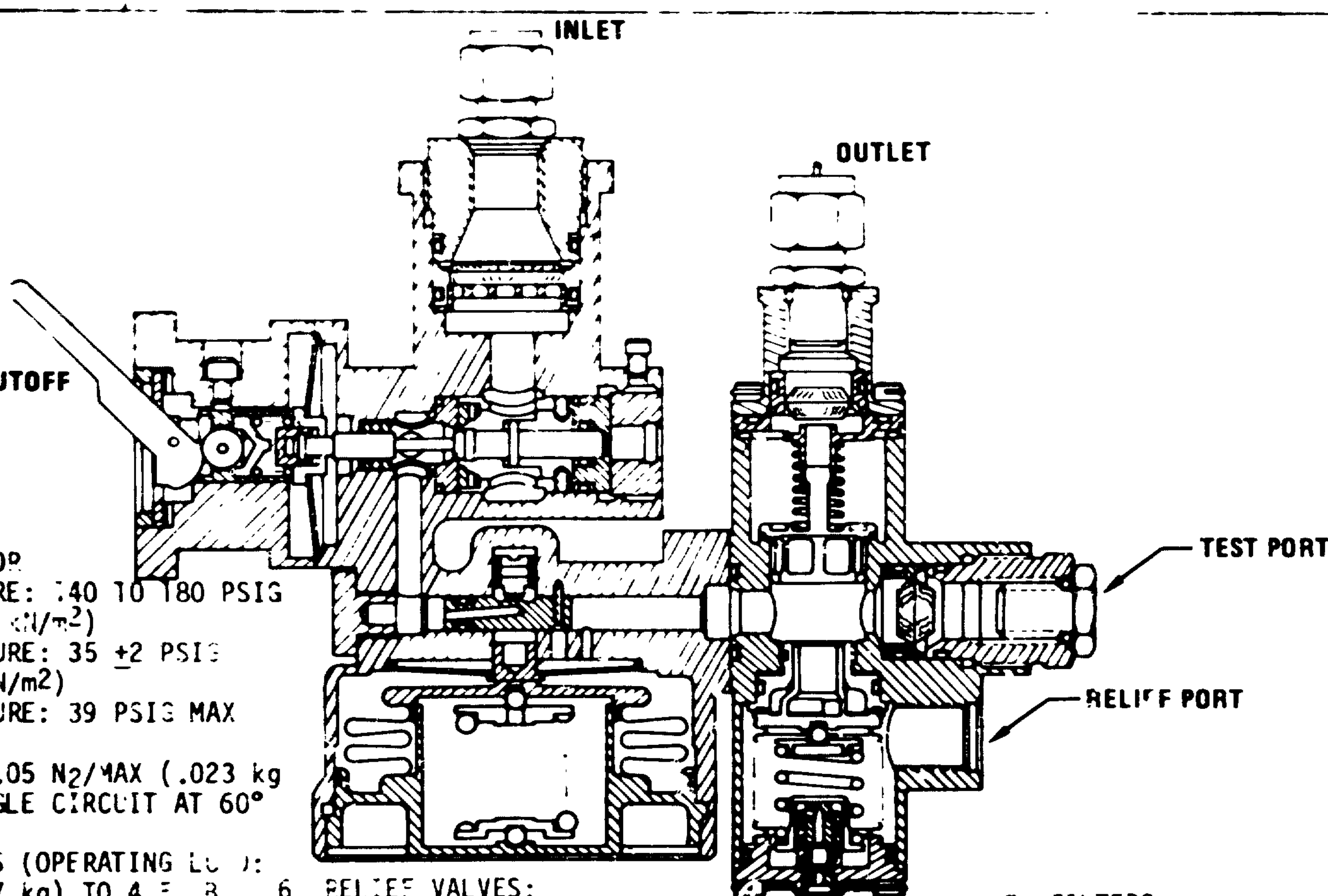
3/ Gaseous nitrogen at 150 psi (1034 kN/m^2) is provided from the airlock module through a manual shut-off valve and orifice to the water system pressurization Panel 500 (Figure 2.2.11.2-12). The gaseous nitrogen is regulated down to 35 psi (241 kN/m^2) by dual redundant pressure regulators (Figure 2.2.11.2-13). The 35 psi (241 kN/m^2) gaseous nitrogen is supplied to the back side of the bellows in each of the 10 water tank assemblies, positively expelling water when the shut-off valve is opened and the quick disconnect engaged. Gaseous nitrogen at 150 psi (1034 kN/m^2) is also provided from Panel 500 to the ESS and M171 experiments.

The water system pressurization line consists of a tubing run from the AM/OWS interface (octagon ring) to Panel 500 (Figure 2.2.11.2-14) and from the panel to each water tank and to ESS and M171 experiments (Figures 2.2.11.2-15 and 2.2.11.2-16). The tubing is routed down the outside of the forward dome, down the auxiliary tunnel, and penetrates the habitation area just below the water tank support structure. The tubing continues along the underside of the water tank support structure to Panel 500. Tubing is routed from Panel 500 again along the underside of the water tank support structure to each water tank. The experiment gaseous nitrogen lines are also routed from Panel 500 along the underside of the water tank support structure, down the habitation area tank wall to

SKYLAB - ORBITAL WORKSHOP
WATER PRESSURIZATION PANEL



SKYLAB - ORBITAL WORKSHOP
PRESSURE REGULATOR



PRESSURE REGULATOR
1. INLET PRESSURE: 140 TO 180 PSIG (965 TO 1241 kN/m^2)
2. OUTLET PRESSURE: 35 ±2 PSIG (241 ±13.8 kN/m^2)
3. LOCKUP PRESSURE: 39 PSIG MAX (269 kN/m^2)
4. FLOW RATE: 0.05 N_2/MAX (.023 kg N_2/MIN) (SINGLE CIRCUIT AT 60° ±10°F INLET)
5. TOGGLE VALVES (OPERATING LOAD): 0.5 LB (0.227 kg) TO 4.5 LB (2.04 kg)
6. RELIEF VALVES:
   CRACK, FULL FLOW AND RESEAT WITHIN 180 (1241 kN/m^2) PSIG BETWEEN 43 AND 47 PSI (296 AND 324 kN/m^2)
   FLOW AT 140 TO 180 PSIG: 0.001 TO 0.02 LBS N_2/MIN (.00045 TO .0091 kg N_2/MIN)
7. FILTERS:
   10 MICRON NOMINAL, 25 MICRON ABSOLUTE

Figure 2.2.11.2-1.

SKYLAB - ORBITAL WORKSHOP
WATER PRESSURIZATION NETWORK

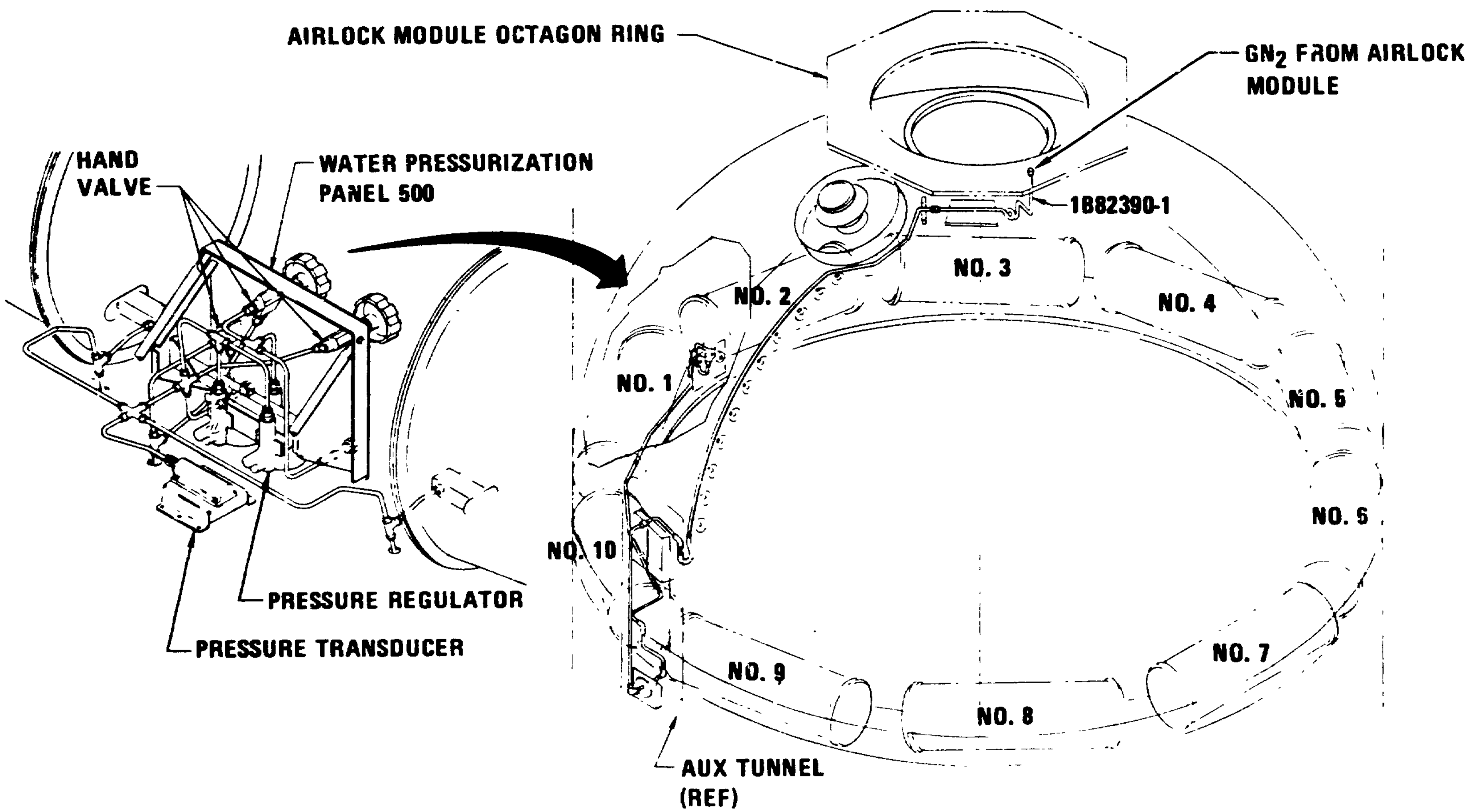


Figure 2.2.11.2-14

SKYLAB - ORBITAL WORKSHOP
WATER PRESSURIZATION NETWORK

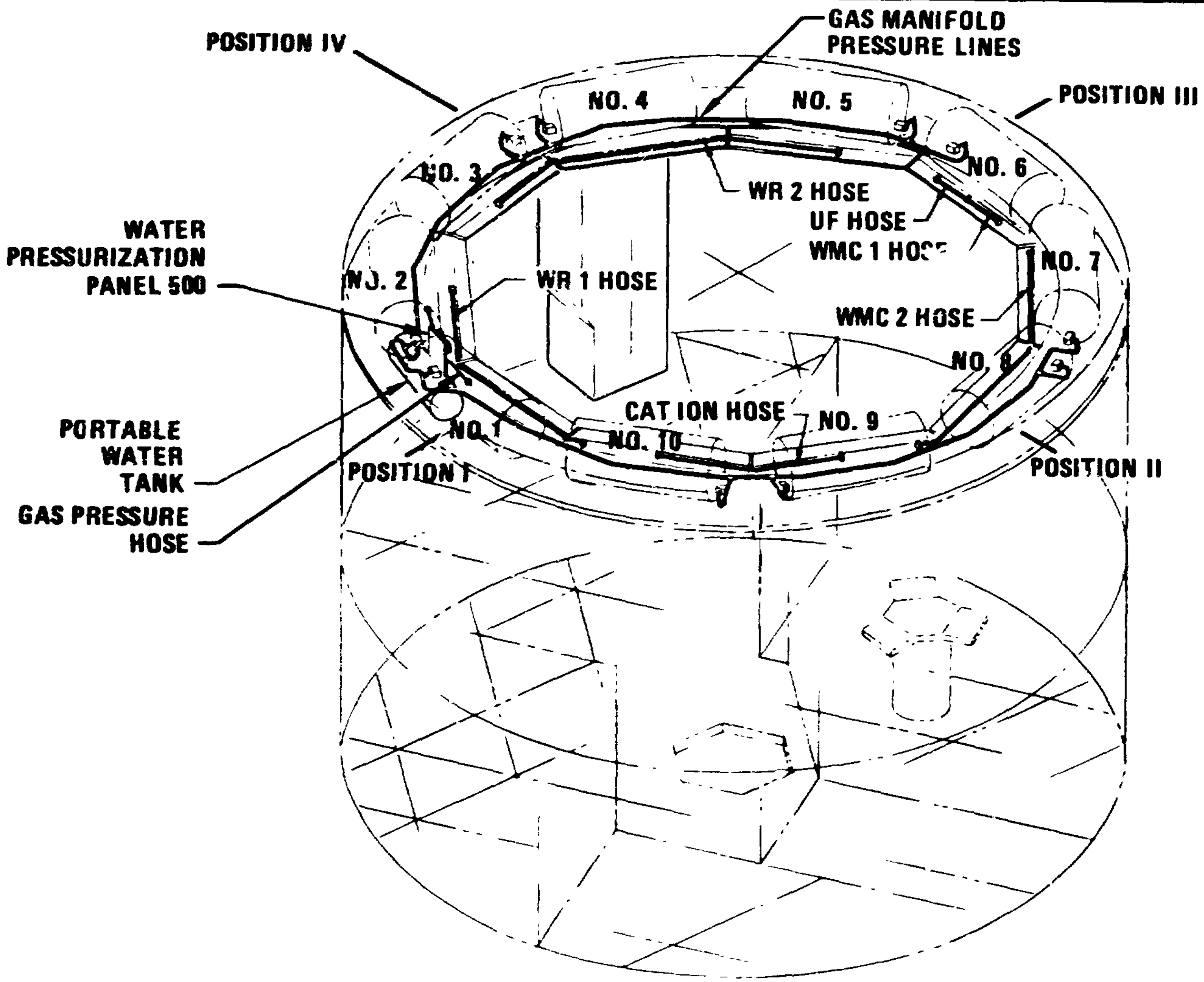


Figure 2.2.11.2-15

SKYLAB - ORBITAL WORKSHOP
WATER PRESSURIZATION NETWORK

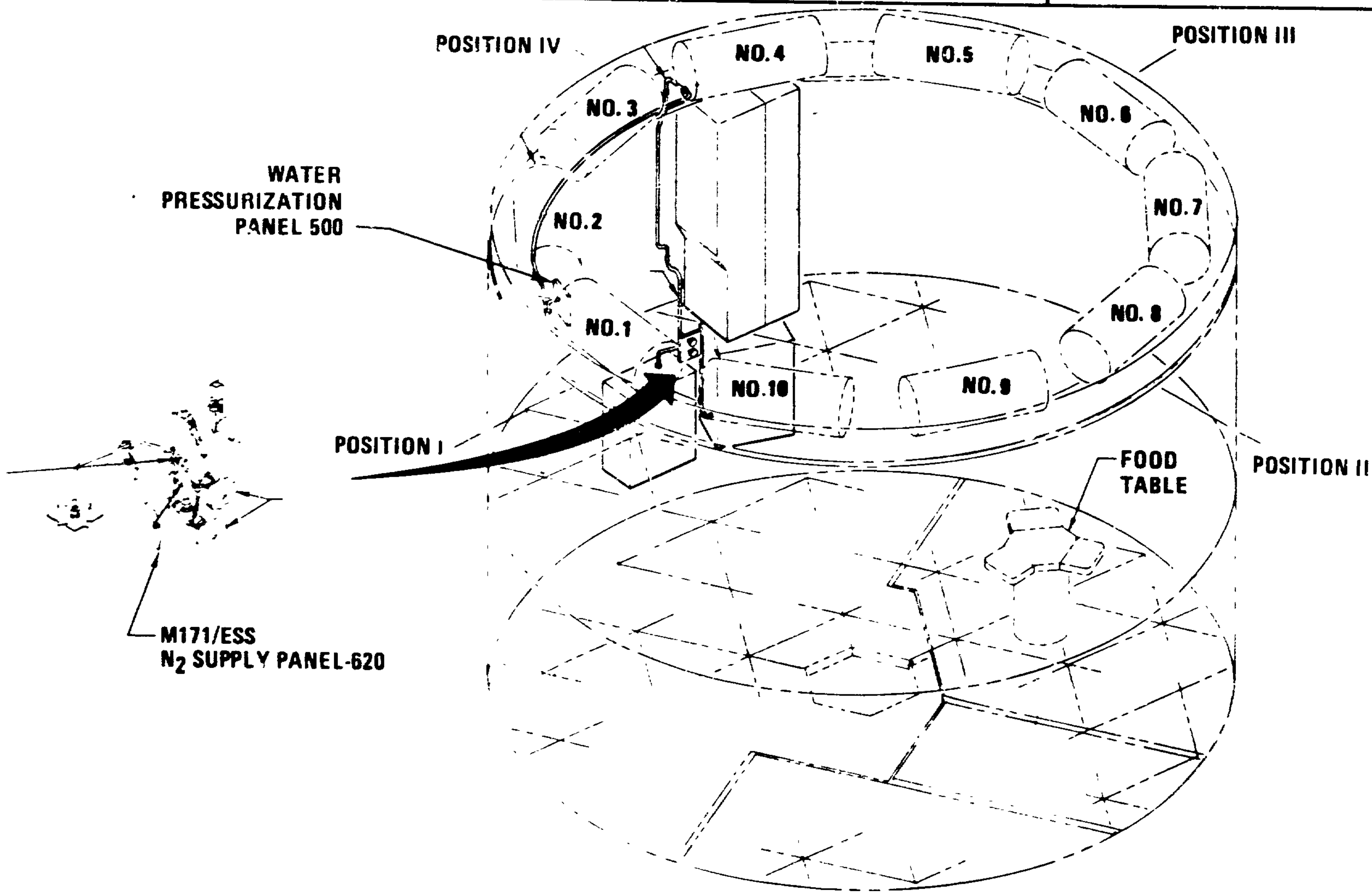


Figure 2.2.11.2-16

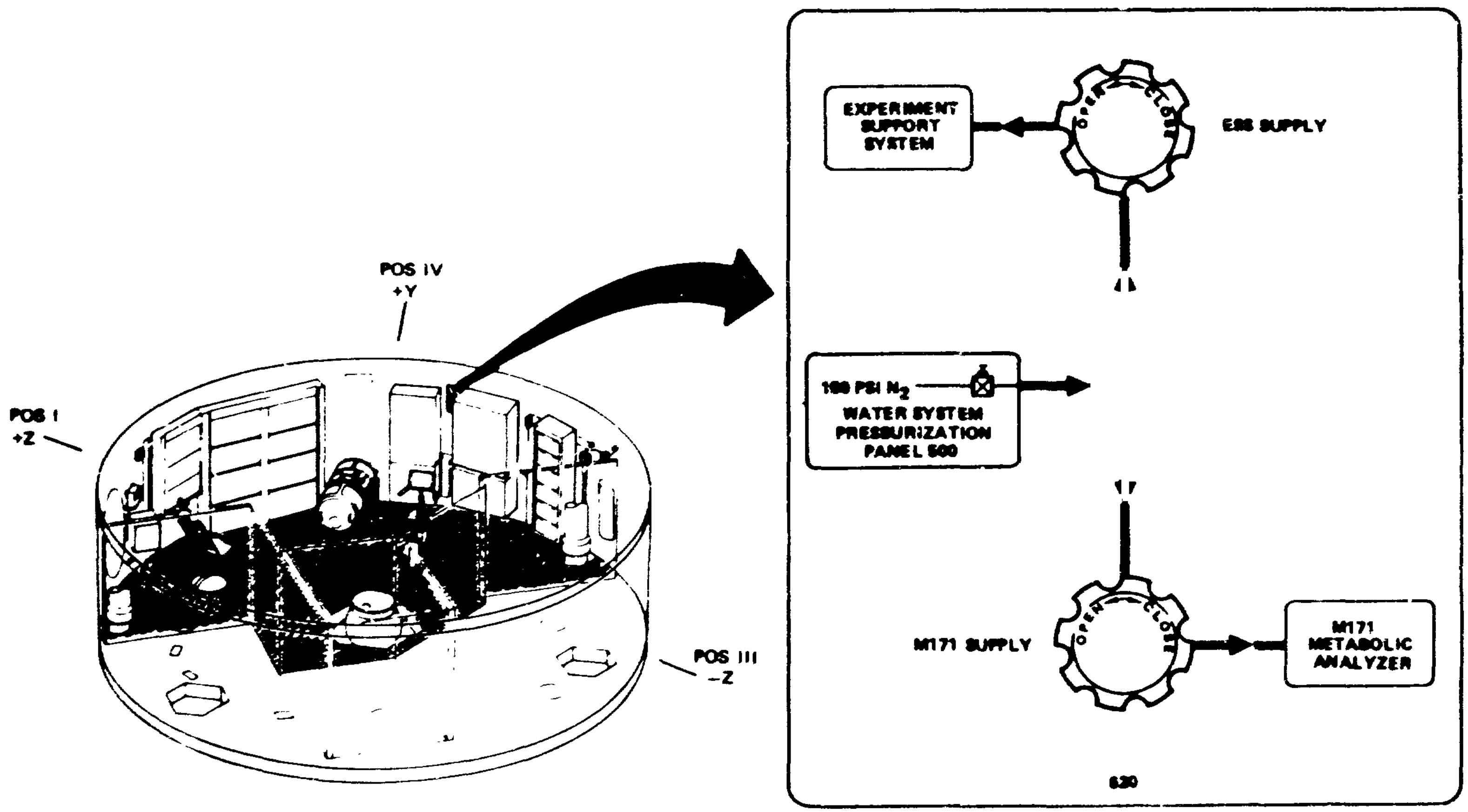
Panel 620 (Figure 2.2.11.2-17) and from Panel 620 to ESS and [illegible] experiments.

4/ The wardroom water network supplies water to the food table in the wardroom, where the water is chilled or heated for food reconstitution and drinking. The wardroom water network is composed of two water hoses, a water supply line, a filter, relief valves, a water heater, and a water chiller (Figure 2.2.11.2-4).

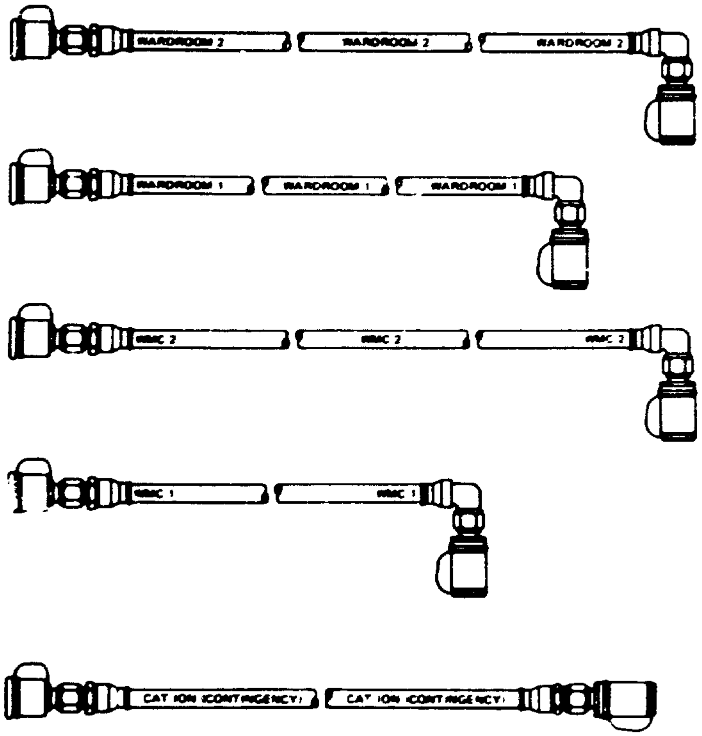
Two flexible water hoses of different lengths (Wardroom 1 and Wardroom 2), with quick-disconnects, are provided (Figure 2.2.11.2-18 and Figure 2.2.11.2-19) to connect the desired water tank to the wardroom water supply line. The Wardroom 1 water hose connects WT 1, WT 2, WT 3, or WT 10 to the water supply line; the Wardroom 2 water hose is used in conjunction with the Wardroom 1 water hose to connect WT 4 and WT 5 to the water supply line. When not in use, the water hoses are stowed on the platform foot restraint, utilizing quick-release clamps. The water hoses are used only during manned phases of the missions. During storage, the wardroom water network is exposed to the OWS atmosphere through a wardroom purge fitting (filter) on the Wardroom 1 or Wardroom 2 water hose quick-disconnect to control microbiological growth in the wardroom water network. The water hose quick-disconnects and their O-rings are replaceable, with spares provided in the water system equipment container. A spare water hose is stowed in a spare parts stowage compartment in the OWS forward dome.

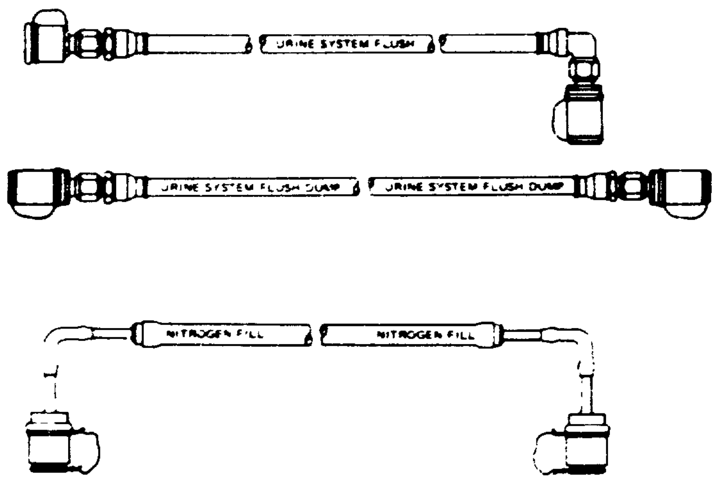
The wardroom water supply line consists of a tubing-run from the wardroom water port quick-disconnect below WT 2 (Figures 2.2.11.2-20 and 2.2.11.2-21), to the wardroom food table.

SKYLAB - ORBITAL WORKSHOP
ESS N_2 SUPPLY PANEL



SKYLAB - ORBITAL WORKSHOP
HOSES

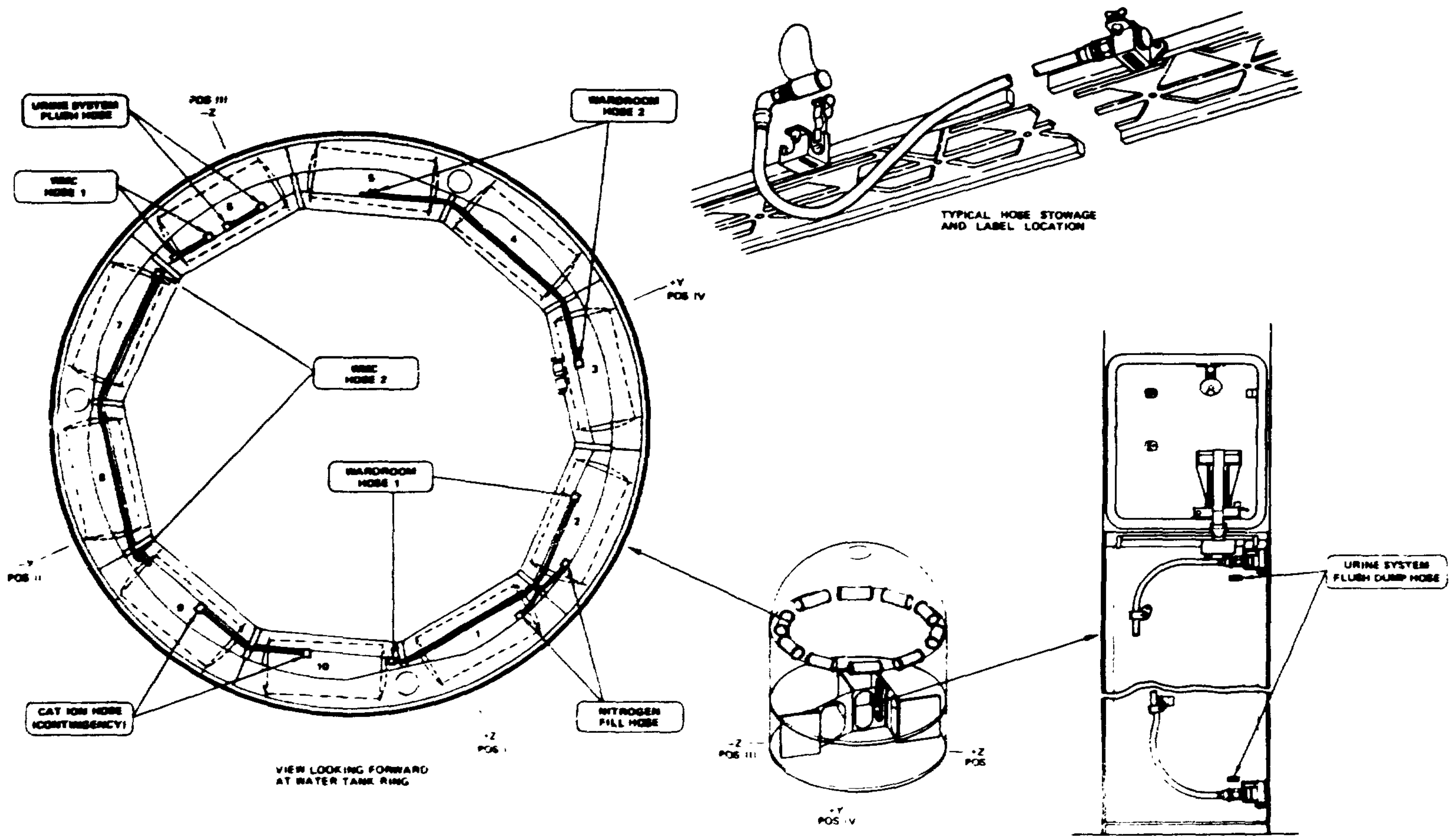




HOSE	LENGTH IN	USE
WARDROOM 2	148	H_2O TANKS 4 & 5 TO WARDROOM OUTLET
WARDROOM 1	118	H_2O TANKS 1 2 3 4 5 & 10 TO WARDROOM OUTLET
WMC 2	148	H_2O TANK 8 TO WMC OUTLET
WMC 1	28	H_2O TANK 7 TO WMC OUTLET
CAT ION (CONTINGENCY)	56	CAT ION CARTRIDGE TO PORTABLE H_2O TANK
URINE SYSTEM FLUSH	28	H_2O TANK 6 TO URINE FLUSH OUTLET
URINE SYSTEM FLUSH DUMP	44	URINE SYSTEM FLUSH DUMP (LOCKER 4872) TO WMC DUMP LINE (BELOW SINK
NITROGEN FILL	30	PANEL 500 (35 PSI N_2 GO) TO PORTABLE WATER TANK

Figure 2.2.11.2-18

SKYLAB - ORBITAL WORKSHOP
HOSE RESTRAINT



SKYLAB - ORBITAL WORKSHOP WARDROOM AND WMC WATER PORT; URINE FLUSH PORT

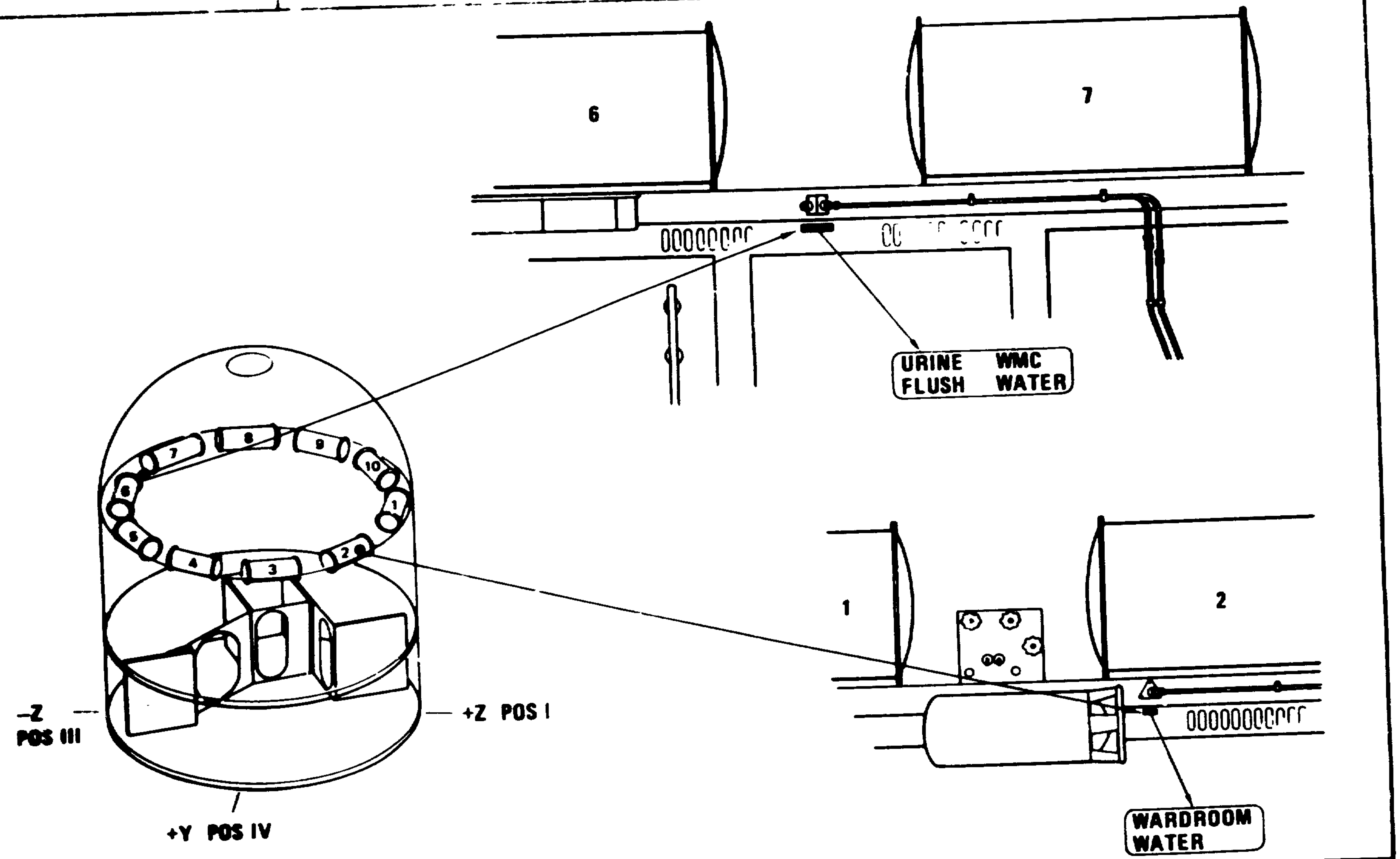
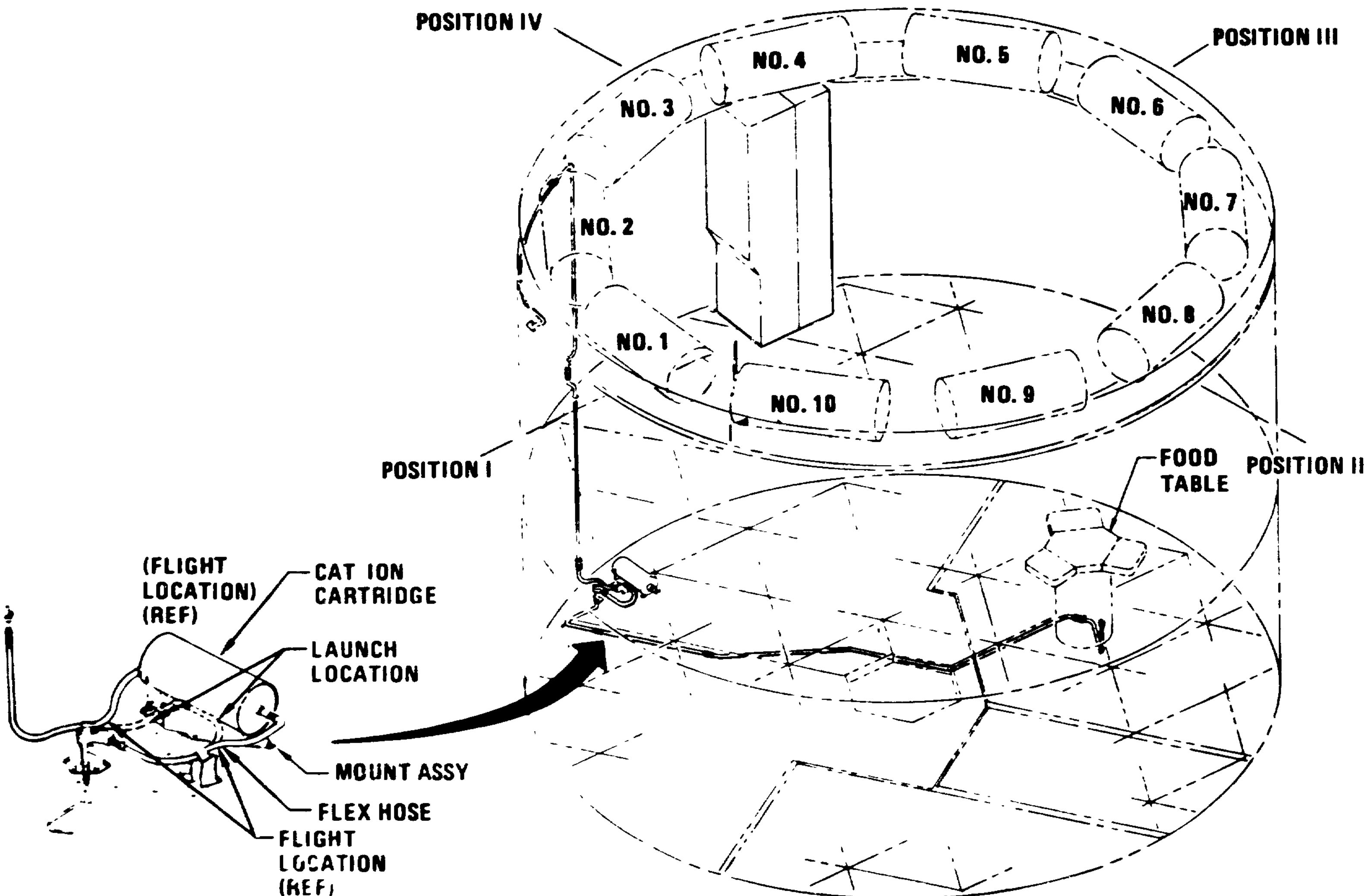


Figure 2.2.11.2-20

SKYLAB - ORBITAL WORKSHOP
WARDROOM WATER NETWORK



The tubing is routed down the habitation area tank wall and under the experiment compartment floor.

The wardroom water network filter is upstream of the water chiller and water heater in the food table (Figure 2.2.11.2-5). The filter screens out small particles, which may clog dispensers.

The wardroom water network relief valves, located in the food table upstream of the water chiller and water heater (Figure 2.2.11.2-5), are installed in series and set at the same pressure. The relief valves will maintain a water supply pressure at a maximum of [illegible] psig (400 kN/m^2) in the event of an overpressurization. The relief valves vent directly into the interior of the food table pedestal. The primary purpose of the relief valves is to prevent overpressurization in the event that the water heater is inadvertently activated prior to connection of the supply hose to a water tank. A small amount of water will be vented.

The wardroom water heater, located in the food table, is made accessible to the crewman by a hinged panel on the food table pedestal. The heater heats and stores water for the hot wardroom water dispenser valve (Figure 2.2.11.2-22). A strip heater located in the reservoir, maintains water in a heated state within the water heater. A control sensor is provided for water temperature control (Figure 2.2.11.2-23). In addition, a water overtemp sensor will maintain the water slightly above the nominal using temperature if a water overtemperature condition occurs. If the water is inadvertently operated while empty, the heater overtemp sensor will detect the overheating of the water heater reservoir and will cycle the strip heater on and off to limit reservoir wall temperatures to 300°F ([illegible]).

SKYLAB - ORBITAL WORKSHOP
WARDROOM AND WMC H_2O HEATERS

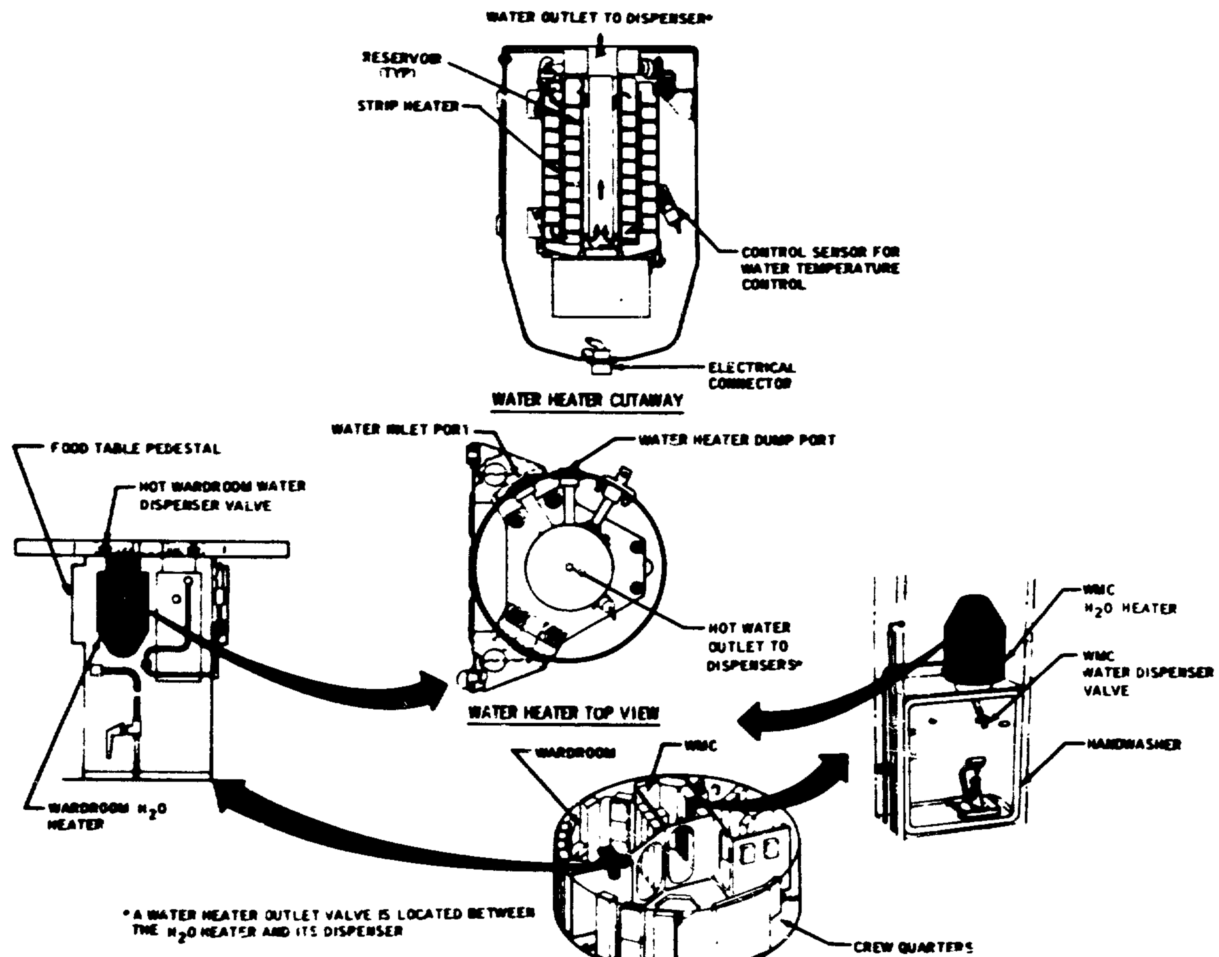
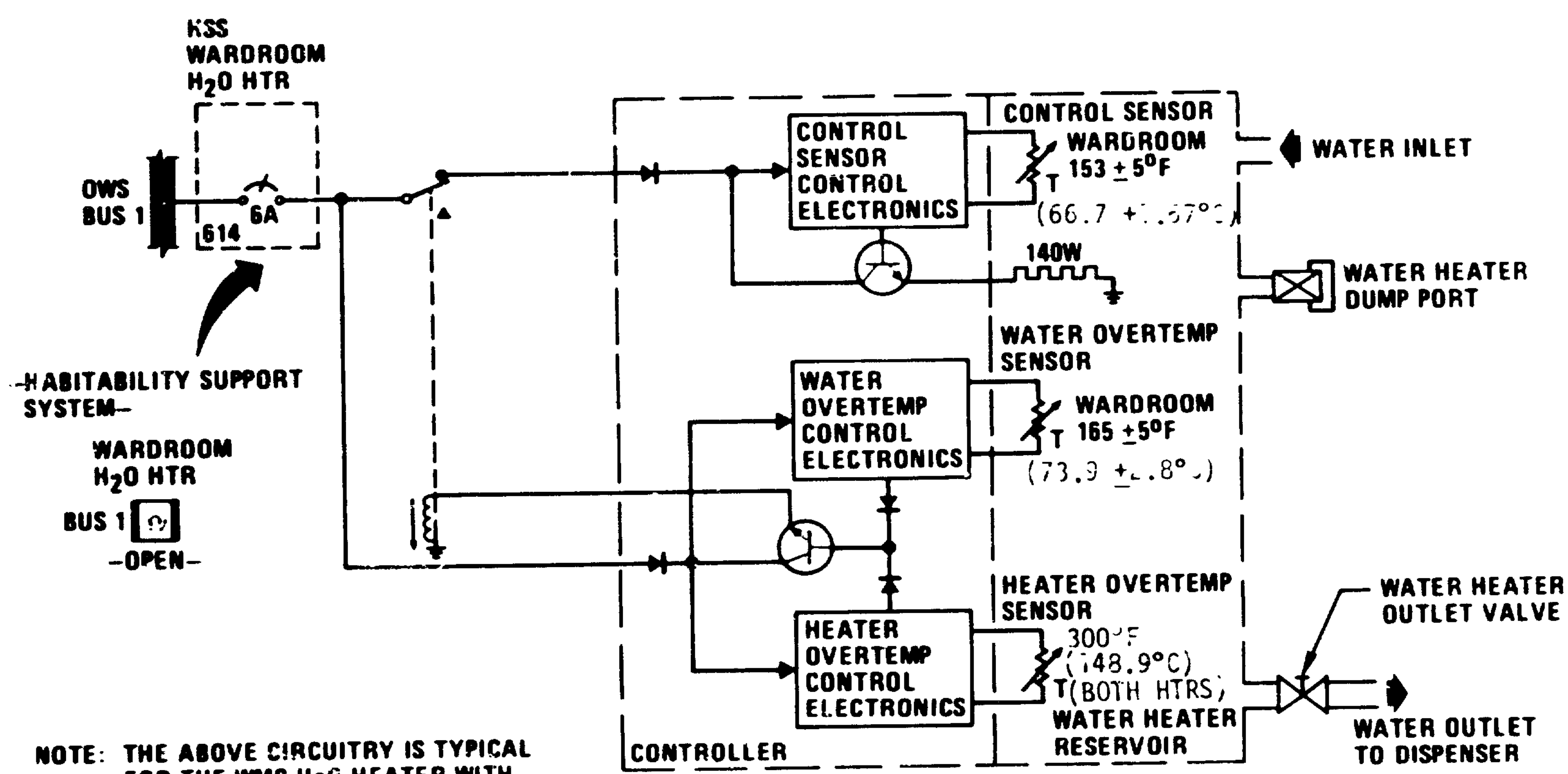


Figure 2.2.11 2-22

SKYLAB - ORBITAL WORKSHOP
WATER HEATER -- FUNCTIONAL DIAGRAM



NOTE: THE ABOVE CIRCUITRY IS TYPICAL FOR THE WMC H_2O HEATER WITH THE NOTED VALUES. THE SINGLE EXCEPTION IS THAT THE WMC H_2O HEATER IS POWERED FROM OWS BUS 2 THROUGH A SEPARATE 6 AMP CIRCUIT BREAKER.

Figure 2.2.11.2-25

The HSS vardroom water heater circuit breaker is closed after water system activation and opened prior to water system deactivation.

A water heater outlet valve, located on the heater's water outlet port, allows the water heater to be isolated from the hot wardroom water dispenser valve. A water heater dump port on the heater, fitted with a quick-disconnect, mates with one of two water dump vacuum lines stowed nearby. The wardroom water heater along with the entire wardroom water network, is filled and drained using the vacuum provision subsystem wardroom water dump during each SWS activation and deactivation.

The water chiller, located in the food table, is made accessible to the crewman by means of a hinged panel on the food table pedestal. The water chiller supplies chilled water to the cold wardroom water dispenser valve and water guns (Figure 2.2.11.2-24). Water entering the water chiller is cooled in a fin-lined reservoir, which uses refrigeration subsystem primary and secondary coolant to refrigerate the water. The water in the reservoir is protected from freezing by the refrigeration subsystem coolant loop logic unit, which monitors water chiller coolant inlet temperature. If the coolant inlet temperature becomes less than 33°F (0.56°C), the logic unit will automatically turn on the active loop's chiller low indicator on Panel 616 while simultaneously switching to the backup coolant loop (Figure 2.2.11.2-25). An RS Display Select 2 selector and RS temperature gage on Panel 616 permit onboard monitoring of the water chiller's coolant inlet temperatures.

SKYLAB - ORBITAL WORKSHOP
HSS WATER SYSTEM
WATER CHILLER

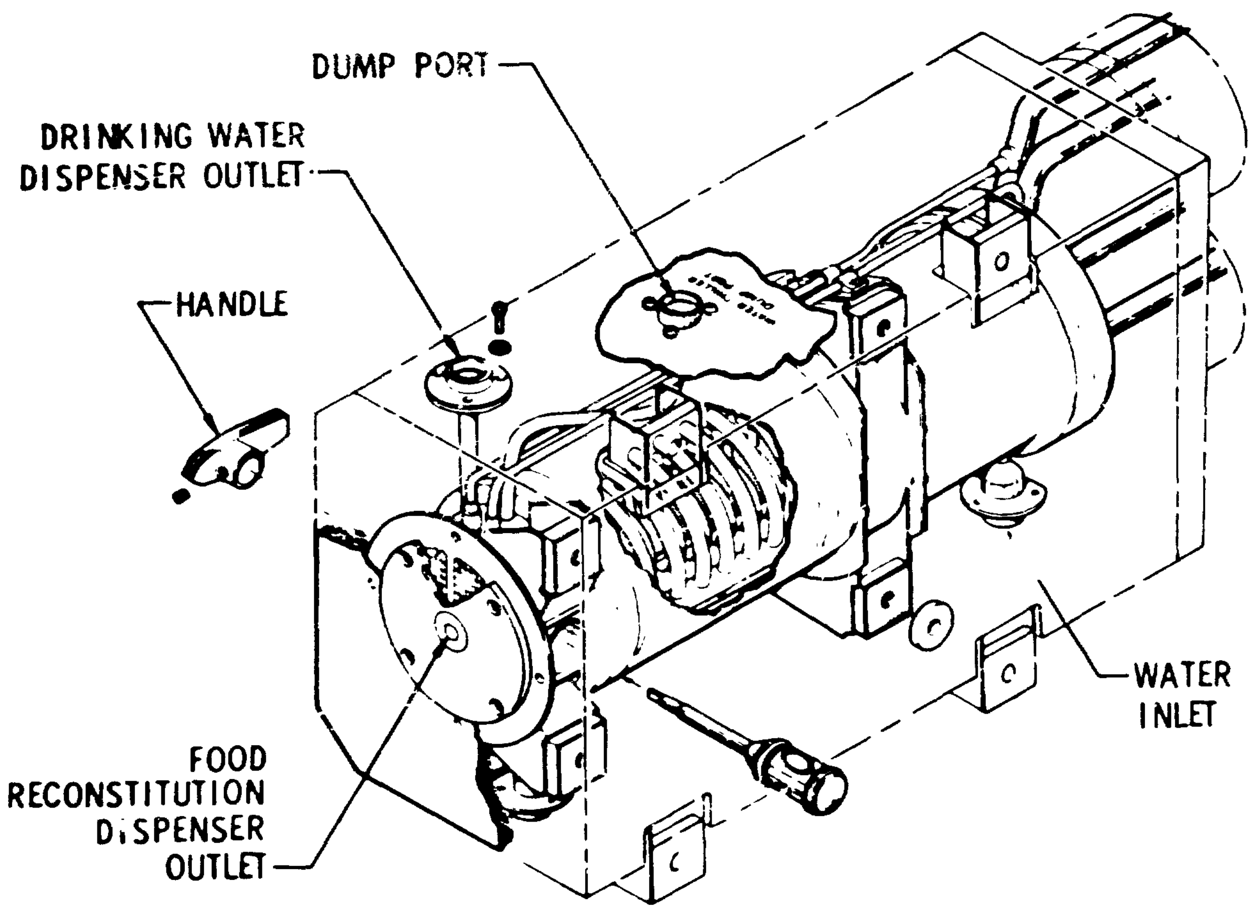


Figure 2.2.11.2-24

SKYLAB - ORBITAL WORKSHOP
WATER CHILLER - FUNCTIONAL DIAGRAM

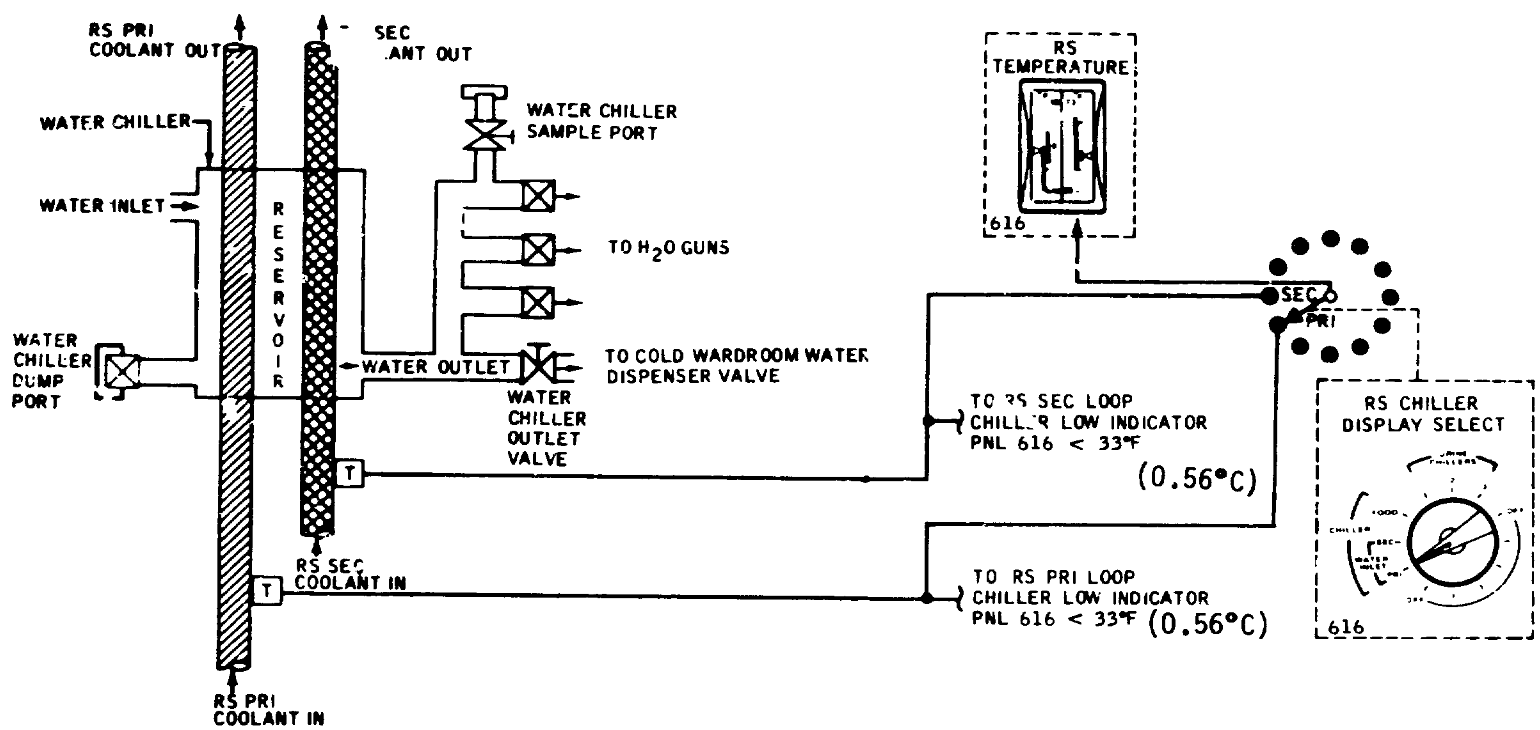


Figure 2.2.11.2-25

The chilled water is routed to a water chiller outlet valve to supply the cold wardroom water dispenser valve (Figure 2.2.11.2-24). The water outlet valve is used to isolate the water chiller from the dispenser, facilitating dispenser removal and replacement. Chilled water is also routed to three quick-disconnects that supply water to the water guns. One of the water gun supply lines contains a water chiller sample port and valve to permit sampling of chiller water in determination of the biocide degradation from the water tank to the water management equipment.

A water chiller dump port, located on the reservoir, is fitted with a quick-disconnect that mates with one of two water dump vacuum lines stowed nearby. The water chiller and the entire wardroom water network are filled and drained, using the vacuum provision subsystem wardroom water dump, during each SWS activation and deactivation.

The wardroom water network supplies water to two wardroom water dispenser valves (Figure 2.2.11.2-26), one cold and one hot, for reconstituting dehydrated foods and beverages. Each is located on the upper surface of the food table within easy reach of each crew member. The water chiller, mounted in the food table pedestal, provides chilled water to the cold wardroom water dispenser valve; the internal table-mounted water heater supplies hot water to the hot wardroom water dispenser valve. Insulated lengths of tubing connect the dispensers to their respective source to provide food and beverage reconstitution at near chiller/heater temperatures. Each dispenser interfaces with a food can or beverage pack at its reconstitution port. Each dispenser provides the amount of water

SKYLAB - ORBITAL WORKSHOP
WATER MANAGEMENT DISPENSERS - INSTALLATION

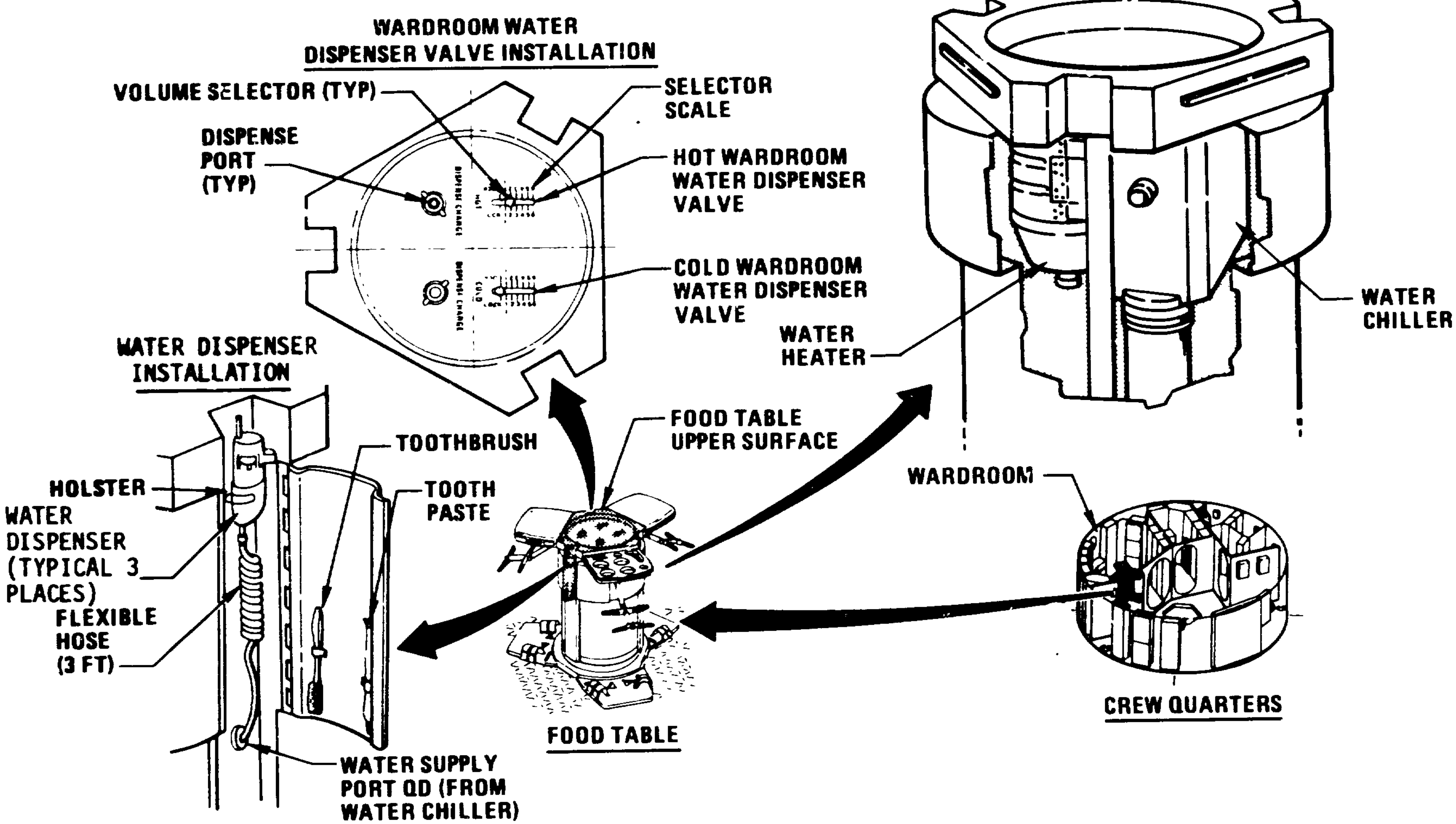


Figure 2.2.11.2-26

designated on the food can or beverage pack.

The wardroom water dispenser valves are charged, using the volume selector to select the desired water quantity on the selector scale displayed on the table's surface (Figure 2.2.11.2-26 and 2.2.11.2-27). The crewman rotates the charge/dispense selector to charge position to fill the dispenser's accumulator with the selected volume of water. The crewman may view the charging process by observing the movement of the piston position indicator on the dispenser. The food can or beverage pack's reconstitution port is then placed over the dispense port. Discharge of the water into the food can or beverage pack is accomplished by setting the charge/dispense selector to dispense and depressing the dispense port inward. The discharge cycle may be verified by the crewman by again observing the movement of the piston position indicator on the dispenser.

The wardroom water dispenser valves are removable to facilitate replacement. One spare is provided in the water system equipment container.

Three water dispensers for drinking pur[illegible]s are supplied water from the wardroom water network. They are loca[illegible]d on the food table pedestal, adjacent to each eating station, to provide a convenient and separate drinking device for each crew member (Figure 2.2.11.2-26). Chilled water is supplied to each dispenser from the water chiller located in the food table pedestal. Each dispenser is stored in a separate holster around the periphery of the food table's pedestal and is connected to the water chiller by a coiled, flexible hose and a

SKYLAB - ORBITAL WORKSHOP

HSS FOOD RECONSTITUTION WATER DISPENSER

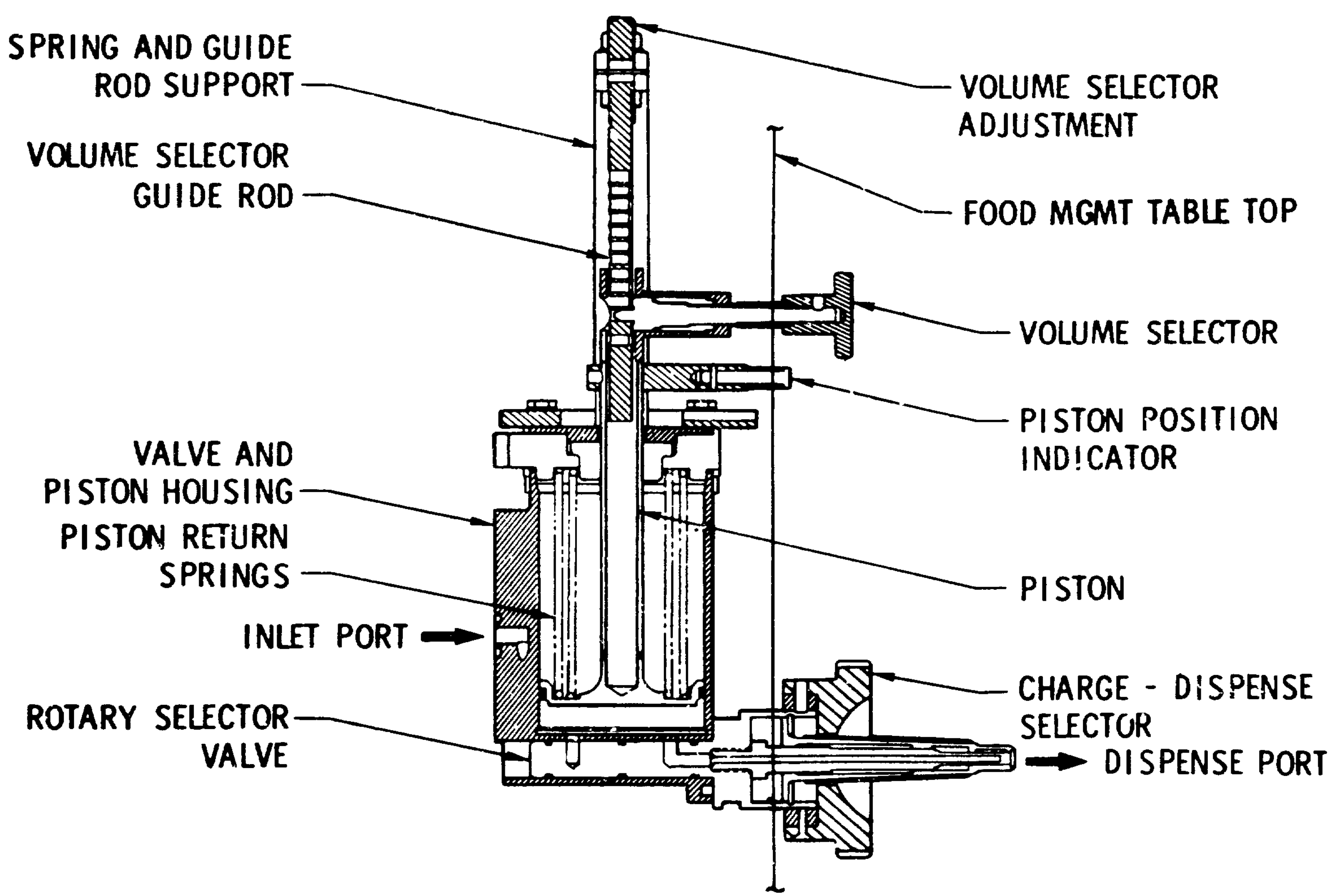


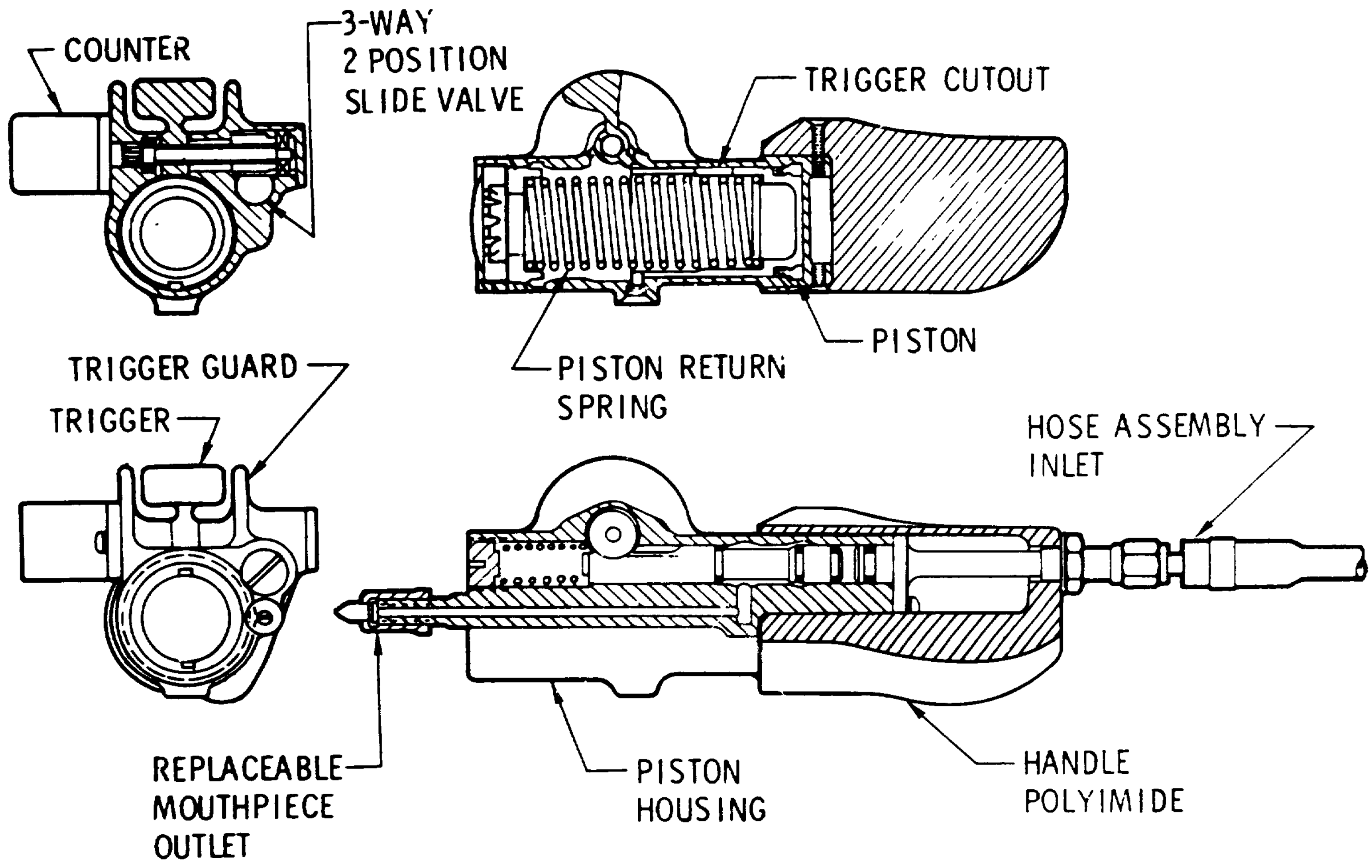
Figure 2.2.11.2-27

quick-disconnect. The water dispensers are fitted with replaceable drinking mouth-pieces, with spares stowed in the water system equipment container and identified as water dispenser resupply provisions. The water dispenser discharges chilled water in small, drinkable quantities through operation of a trigger mounted on the handgrip (Figure 2.2.11.2-28). Actuation of the trigger allows a fixed quantity of chilled water to be charged into the dispenser's accumulator. Immediately following charging, the cycle continues uninterrupted into a discharge mode that expels the accumulator water through the mouthpiece.

Each crew member will use a personal drinking mouthpiece and will use his designated (color-coded) water dispenser to facilitate water management through use of a four-digit counter mounted on the dispenser's handgrip. The counter maintains a continual record of the number of water dispenser actuations. To provide metabolic experimentation data, each crew member will enter in the log book the total number of water dispenser actuations during a 24-hour period. The counter will record up to 9,999 cycles and will automatically restart from zero.

The water dispensers also provide backup capability to the wardroom water dispenser valve. A water gun/food bag adapter, provided in the water system equipment container, will interchange with the drinking mouthpieces on the water dispensers, thus allowing reconstitution of food or beverages with chilled water. The water dispensers are then trigger-operated to obtain reaconstituted water in 1/2-ounce (14.17 grams) increments. The water dispenser/food bag adapter is only used with the food or beverage reconstitution ports; therefore, it will be necessary to reinstall the drinking mouthpiece

SKYLAB - ORBITAL WORKSHOP
HSS WATER SUBSYSTEM
DRINKING WATER DISPENSERS



to permit drinking. Each water dispenser's flexible hose is fitted with a quick-disconnect at the hose/table interface. If a water dispenser fails, one spare and its flexible hose may be obtained from the water system equipment container. A port tank/water dispenser adapter is also provided in the water system equipment container to permit installation of a water dispenser onto the portable water tank.

Each water dispenser is restrained for launch by a clamp with two bolts. The launch restraints will be removed by the SL-2 crew upon SWS activation (Figure 2.2.11.2-29).

During SWS activation and deactivation, the water management equipment dispensers must be bled to remove trapped air or water.

To bleed the wardroom water dispenser valves and the water dispensers, a water dispenser/dispenser squeezer bag adapter is installed on a squeezer bag at the bag's inlet. The adapter fits the dispense port of the wardroom water dispenser valves and the mouthpiece of the water dispensers. Following wardroom water network filling or draining, the squeezer bag with the adapter is placed on the water outlet ports of the wardroom dispensers. The dispensers are cycled until the dispenser is filled (for activation) or until the dispenser is emptied (for deactivation). After the bleeding operations, the squeezer bag is used in the WMC and the water dispenser/dispenser squeezer bag adapter will be returned to stowage. The adapter is towed in the water system equipment container.

5/ The urine system flush water network supplies water from the water tank to the water management (urine system flush) equipment located in the WMC corner stowage compartment. This equipment is used to

ORBITAL WORKSHOP
WATER SUBSYSTEM
DRINKING WATER DISPENSER INSTALLATION

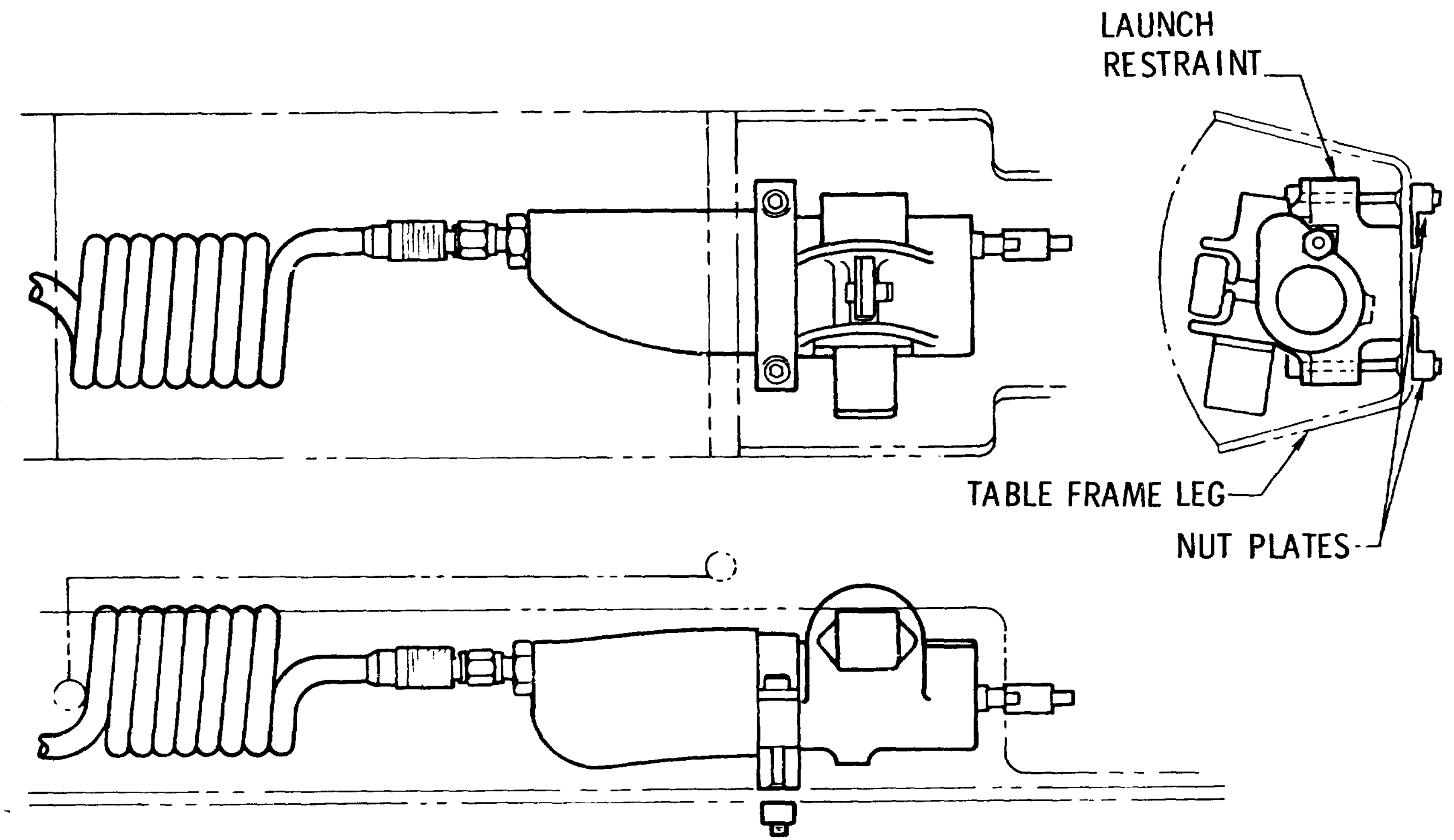


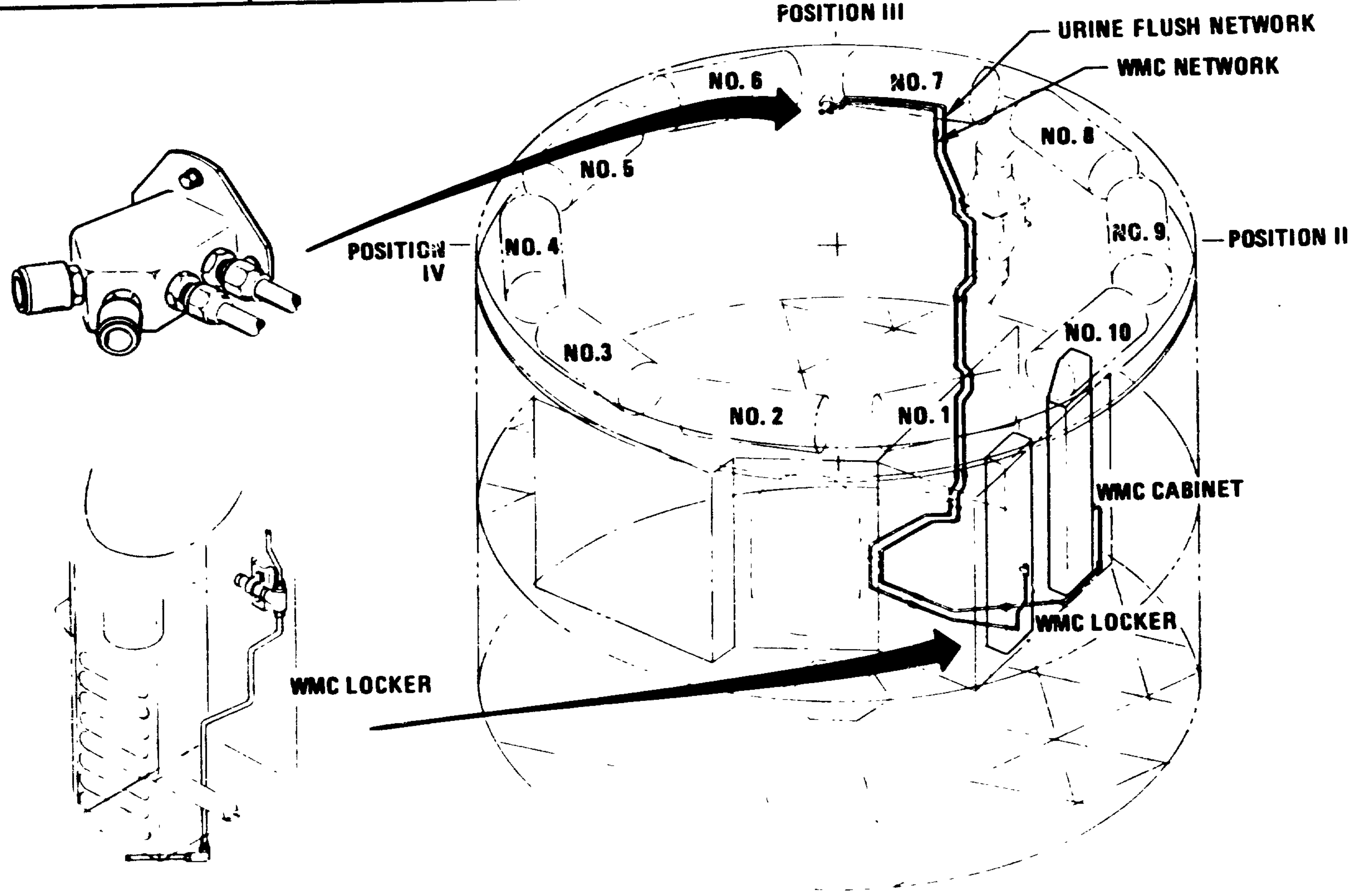
Figure 2.2.11.2-29

flush residual urine from the urine separators in the fecal urine collector, thus minimizing cross-contamination of the crewman's daily urine pool with the previous day's trapped urine. The urine system flush water network is composed of a water hose, a water supply line, and a filter (Figures 2.2.11.2-4 and 2.2.11.2-17). NOTE: Prior to start of the OWS mission a decision was made to eliminate use of the urine flush system.

One flexible urine system flush water hose, with quick-disconnects, connects WT 6 to the urine system flush water supply line (Figures 2.2.11.2-18 and 2.2.11.2-19). When not in use, the water hose is stowed on the platform foot restraint utilizing quick-release clamps. The water hose is connected during each SWS activation and is disconnected during each SWS deactivation. During storage, the urine system flush water network is exposed to the OWS atmosphere through installation of a urine system flush purge fitting (filter) on the water hose quick-disconnect; this controls microbiological growth in the urine system flush water network. The water hose quick-disconnects are replaceable, with spares provided in the water system equipment container. A spare water hose (the longest) is stowed in a spare parts stowage compartment in the OWS forward dome.

The urine system flush water supply line consists of a tubing-run from the urine flush water port quick-disconnect between WT 6 and WT 7 (Figure 2.2.11.2-20) to the WMC corner stowage cabinet (urine dump equipment [Figure 2.2.11.2-30]). The tubing is routed down the habitation area tank wall and under the WMC floor. The urine flush water port quick-disconnect attaches the urine system flush

SKYLAB - ORBITAL WORKSHOP
WMC WATER SUPPLY NETWORK



water hose for water network operation.

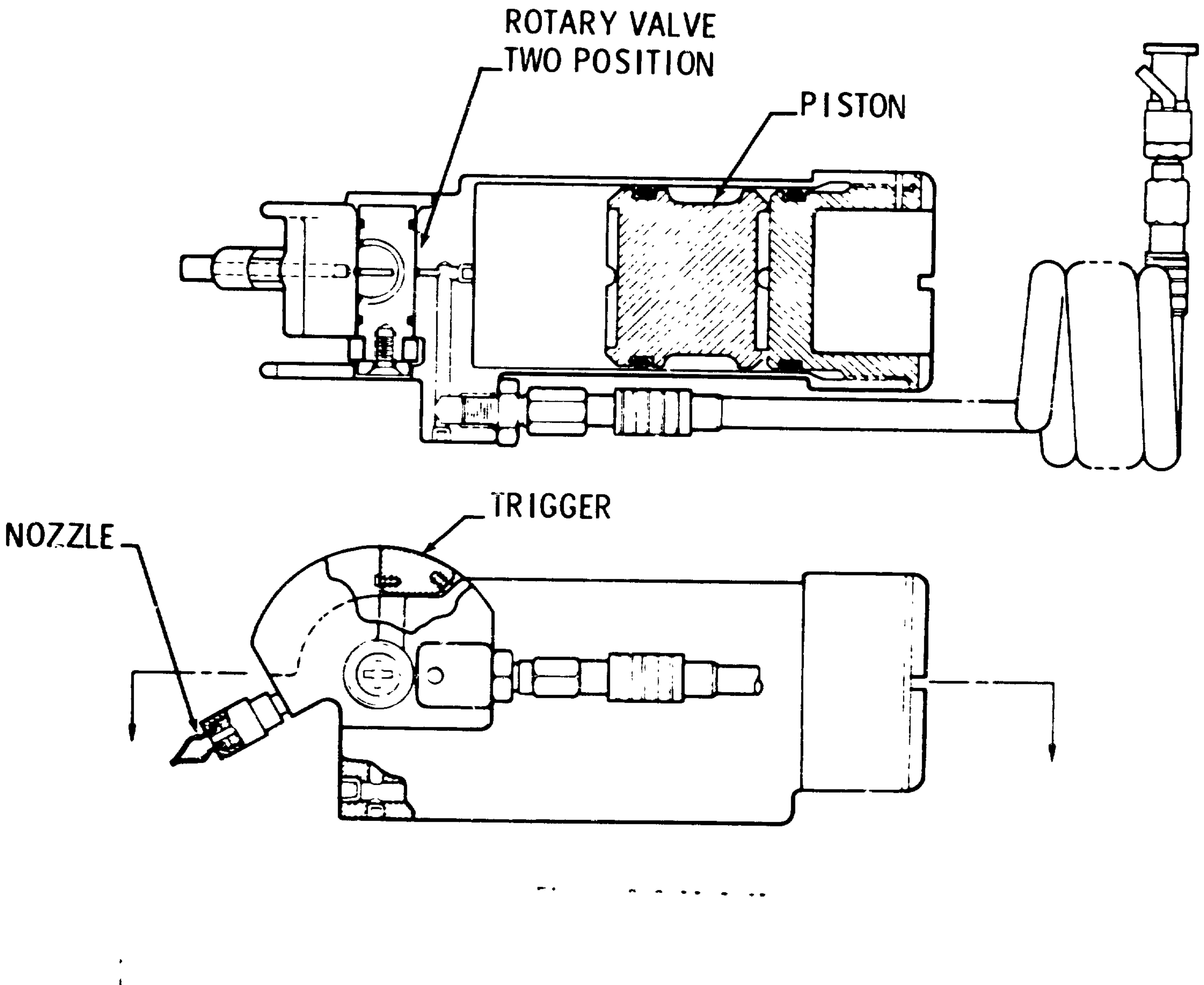
The urine system flush water network filter is located in the WMC corner stowage cabinet upstream of the urine system flush dispenser. The filter screens out small particles that may interfere with the operation of the dispenser. The line between the filter and the dispenser contains a water dump port quick-disconnect that mates with the urine system flush dump hose for filling and draining of the urine system flush water network during each SWS activation and deactivation.

One urine system flush dispenser is used to flush the urine separators in the fecal/urine collector. The dispenser is located in a recess adjacent to the three-tiered urine dump equipment in the WMC (Figure 2.2.11.2-22) for convenient access. The urine separators are water-flushed daily with the dispenser to preclude cross-contamination of the day's urine pool with the previous day's urine pool. Actuation of the urine system flush dispenser trigger ejects a fixed volume of water (Figure 2.2.11.2-31). Four trigger actuations are sufficient to decontaminate each urine separator. A coiled, flexible hose provides efficient stowage and a large radius of operation.

The urine system flush dispenser is restrained for launch by a clamp with two bolts. The launch restraints will be removed by the SL-2 crew upon SWS activation.

During SWS activation and deactivation, the water management equipment dispensers must be bled to remove trapped air or water. The urine system flush dispenser is bled directly into washcloths which are disposed of in a trash bag.

ORBITAL WORKSHOP
URINE FLUSH DISPENSER



6/ The WMC water network supplies water to the water heater in the WMC, where the water is heated and routed to a dispenser for body cleansing and housekeeping purposes. The WMC water network is composed of two hoses, a supply line, relief valves, and a water heater.

Two flexible water hoses of different lengths (WMC 1 and WMC 2) with quick-disconnects connect the desired water tank to the WMC supply line. The WMC 1 water hose connects WT 7 to the WMC water supply line, and the WMC 2 water hose connects WT 8 to the WMC water supply line. When not in use, the water hoses are stowed on the platform foot restraint, utilizing quick-release clamps. A water hose is connected to the desired water tank upon each SWS activation and is removed upon each SWS deactivation. During storage, the WMC water network is exposed to the SWS atmosphere, through installation of a WMC purge fitting (filter) on the water hose quick-disconnect, to control microbiological growth in the WMC water network. The water hose quick-disconnects and their O-rings are replaceable with spares provided in the water system equipment container. A spare water hose is stowed in a spare parts stowage compartment in the OWS forward dome.

The WMC water supply line consists of a tubing-run from the WMC water port quick-disconnect between WT 6 and WT 7 (Figure 2.2.11.2-20) to the water heater in the WMC. The tubing is routed down the habitation area tank wall and under the wardroom and WMC floor. The quick-disconnect between WT 6 and WT 7 is used to attach a WMC water hose for water network operation.

The relief valves in the WMC water network are located below the hand washer in the WMC and upstream of the WMC water heater (Figure 2.2.11.2-6). The two relief valves, installed in series and set at the same pressure, will maintain a water supply pressure at a maximum of 58 psig (400 kN/m^2) in the event of an overpressurization. The relief valves vent directly into the interior of the stowage compartment below the hand washer. The primary purpose of the relief valves is to prevent overpressurization in the event that the water heater is inadvertently activated prior to connection of the supply hose to a water tank. A small amount of water will be vented.

The WMC water heater is located in a stowage compartment above the hand washer in the WMC (Figure 2.2.11.2-22). Access to the heater is gained through a hinged door. The heater supplies hot water for body cleansing and housekeeping purposes through use of the WMC water dispenser valve. The temperature control system described in the wardroom water heater section is depicted in Figure 2.2.11.2-23). The WMC water heater is identical to the wardroom water heater except for the temperature settings on the heater. The HS WMC water heater circuit breaker is closed after water system activation and opened prior to water system deactivation.

A water heater outlet valve is located on the heater's outlet port and permits WMC water network isolation from the WMC water dispenser valve. A water heater dump port on the heater is fitted with a quick-disconnect that mates with a water dump vacuum line stowed nearby. The WMC water heater and its entire network are filled drained utilizing the vacuum provision subsystem WMC water dump during each SWS activation and deactivation.

The WMC water network supplies water to a WMC water dispenser valve located in the hand washer (Figure 2.2.11.2- 6). The dispenser is provided hot water from the WMC heater to allow partial body cleansing and housekeeping. The dispenser contains a plunger which, when depressed, expels three jets of water in a continuous stream into the crewman's hand-held washcloth (Figure 2.2.11.2-32). The water temperature at the hot water jets is maintained at near-heater temperature by a foam-insulating cap at the WMC water heater's base and by foam insulation around the major portion of the dispenser. The dispenser's shaft and plunger protrude through the top of the hand washer into its interior for ready accessibility.

The WMC water dispenser valve is removable, with one spare provided in the water system equipment container.

The water usage facilities allow partial body cleansing and housekeeping for maintenance of crewman personal hygiene, in the form of a hand washer. The hand washer is located in the WMC and is provided with a supply of hot water from the WMC water dispenser.

The hand washer is a metallic box, opening into the WMC to permit access to hand washer-mounted equipment (Figure 2.2.11.2-33). The equipment consits of soap holders, a squeezer, a handrail, and a squeezer bag. The WMC water dispenser valve protrudes through the top of the hand washer to provide a convenient hot water supply. A pair of light-duty foot restraints, located below the hand washer on the WMC floor, restrains the crewman during personal hygiene activities at the hand washer.

Four magnetic soap holders are located in the hand washer to retain the soap, each of which contains a metallic insert.

SKYLAB - ORBITAL WORKSHOP
PERSONAL HYGIENE WATER DISPENSER

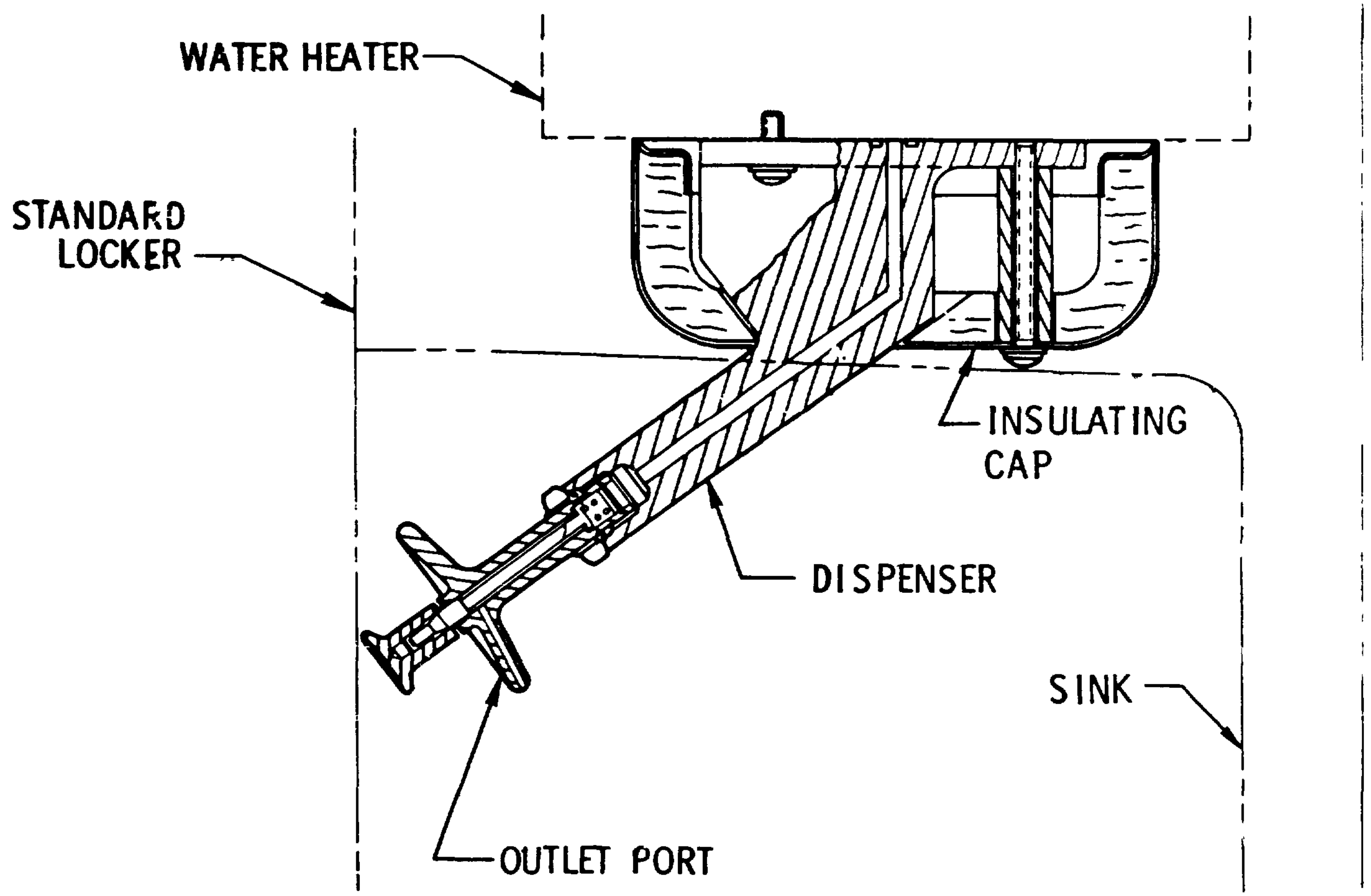


Figure 2.2.11.2-32

PARTIAL BODY CLEANSING FACILITIES - HANDWASHER

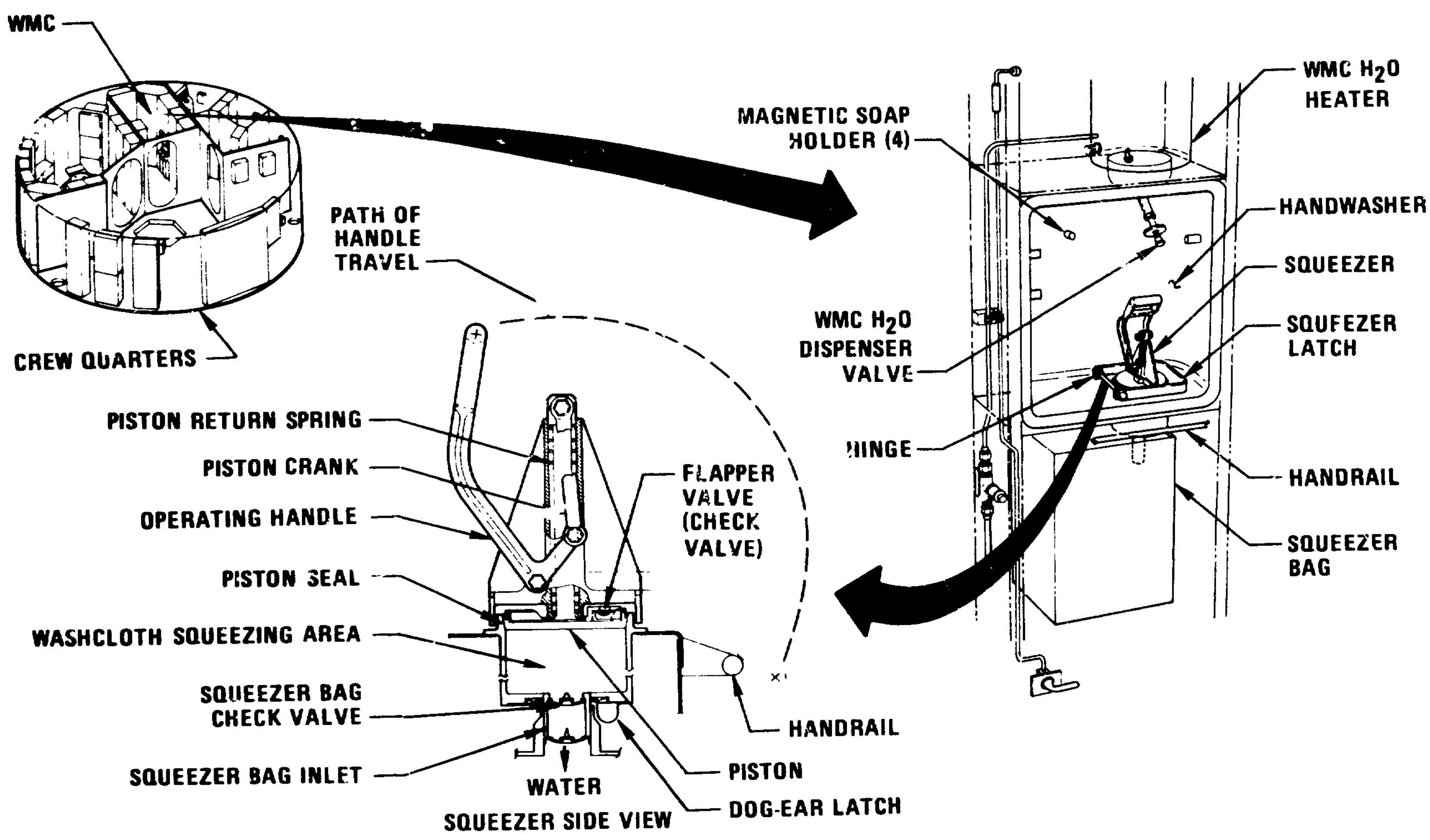


Figure 2.2.11.2-33

The squeezer is a hand-operated unit that permits the crew member to compress a washcloth, thereby removing excess water from the washcloth. The squeezer's operating handle, when rotated toward the crewman, drives a piston down into the washcloth squeezing area, compressing the cloth and removing the water. The squeezer is fitted with a latch and a hinge to permit crewman access to the washcloth squeezing area. The washcloth is inserted into the squeezing area, and the squeezer is latched shut. The crewman then rotates the operating handle while restraining himself with the hand washer-mounted handrail. The water entrained in the washcloth is forced out by piston action, and is directed into a squeezer bag located underneath the squeezer. When the operating handle is released, the flapper valve mounted in the piston opens and allows cabin air to enter the washcloth squeezing area to cause piston return. The flapper valve and the piston seal are replaceable, with spares provided in a stowage compartment in the OWS forward dome.

The squeezer bag (Figure 2.2.11.2-34) is held firmly in place utilizing a squeezer-mounted dog-ear latch, which, when rotated, forms a watertight seal against the bag inlet and permits easy replacement of the bag. The squeezer bag collects all squeezed water in the bag and retains it through the use of a check valve installed on the squeezer bag inlet. The squeezer bag consists of a polyurethane-coated nylon fabric bladder and an outer armalon protective cover. A dump hose with a quick-disconnect is provided as an integral part of the bag. A pocket is provided on the outer cover for the dump filter. The collected water is dumped through the filter into the waste tank periodically. Spare bags are provided to permit replacement for each mission. The used empty squeezer bags are then

WASHCLOTH SQUEEZER BAG

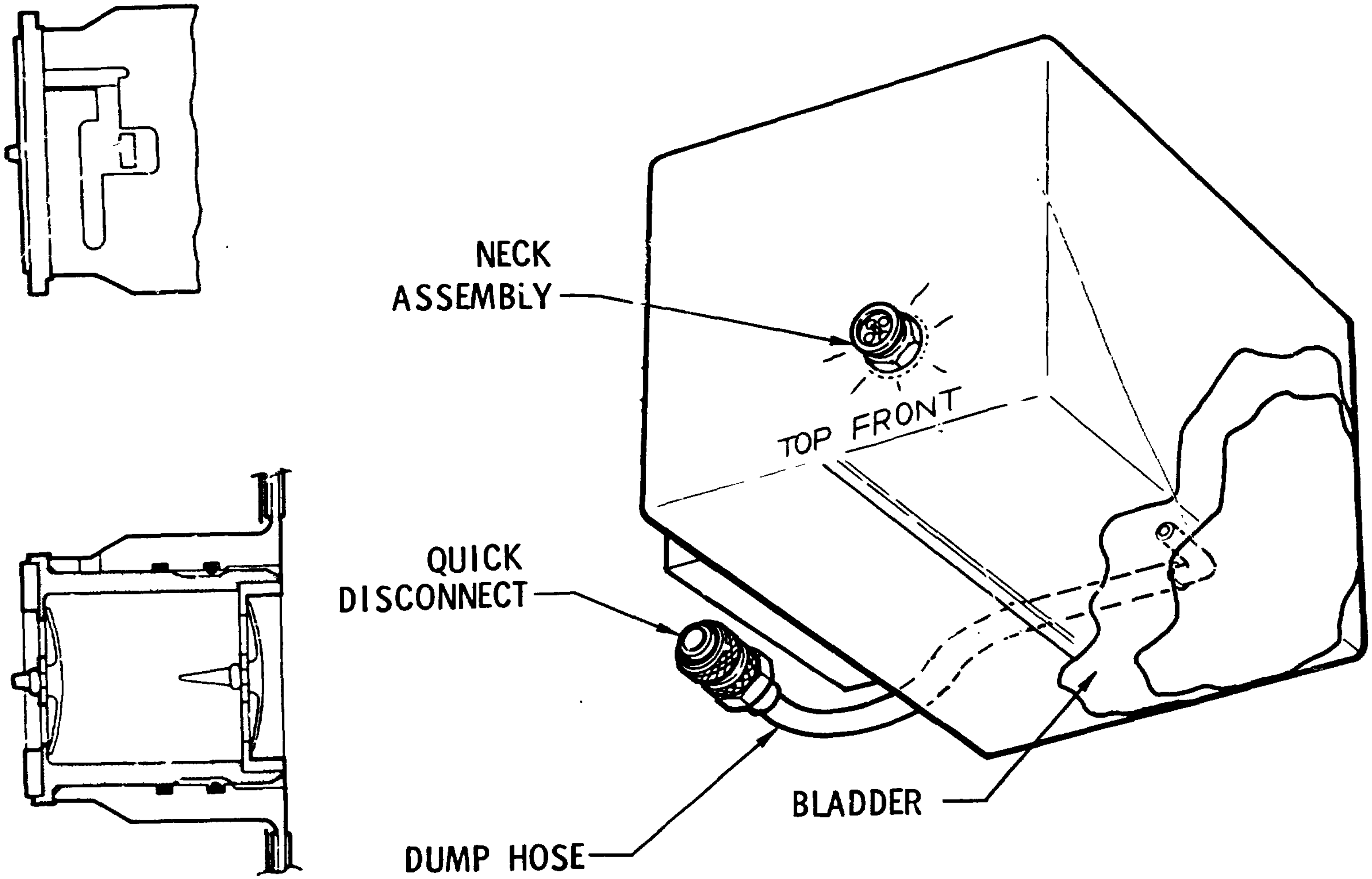


Figure 2.2.11.2-34

disposed of through the trash disposal airlock in a trash bag.

During SWS activation and deactivation, the water management equipment dispensers must be bled to remove trapped air or water. The WMC water dispenser valve is bled directly into washcloths which are disposed of in a trash bag.

7/ The water vacuum provisions consist of two dump lines, connecting OWS crew compartments to a screen-isolated liquid dump area in the waste tank (Figure 2.2.11.2-35). The liquids and gases dumped into the waste tank are non-propulsively vented overboard.

Each dump system includes a hand-operated shut-off valve, stainless steel and flexible tubing, and brazed fittings. Nozzle heaters on the liquid dump probes prevent freezing of the liquid on the nozzle.

The wardroom water dump (Figure 2.2.11.2-36) provides for wardroom water network evacuation into the waste tank. Dumping is accomplished through quick-disconnects, flexible hoses, tubing, a hand valve, and a heated waste tank discharge nozzle (dump heater probe).

The flexible hose is stowed in the food table pedestal and mates with the wardroom water heater or chiller with quick-disconnects. The hose is connected to the water dump hand valve on Panel 706 in the food table, which in turn routes the water to its dump heater probe for disposal into the waste tank. A pressure measurement upstream of the Panel 707 water dump hand valve is displayed on Panel 700 for onboard use during water dump. Water dumps are terminated when the pressure decreases to 0.7 psia (4.83 kN/m^2).

Water is dumped into the waste tank through a replaceable dump

SKYLAB - ORBITAL WORKSHOP
VACUUM DUMP AND VACUUM EXHAUST SYSTEMS

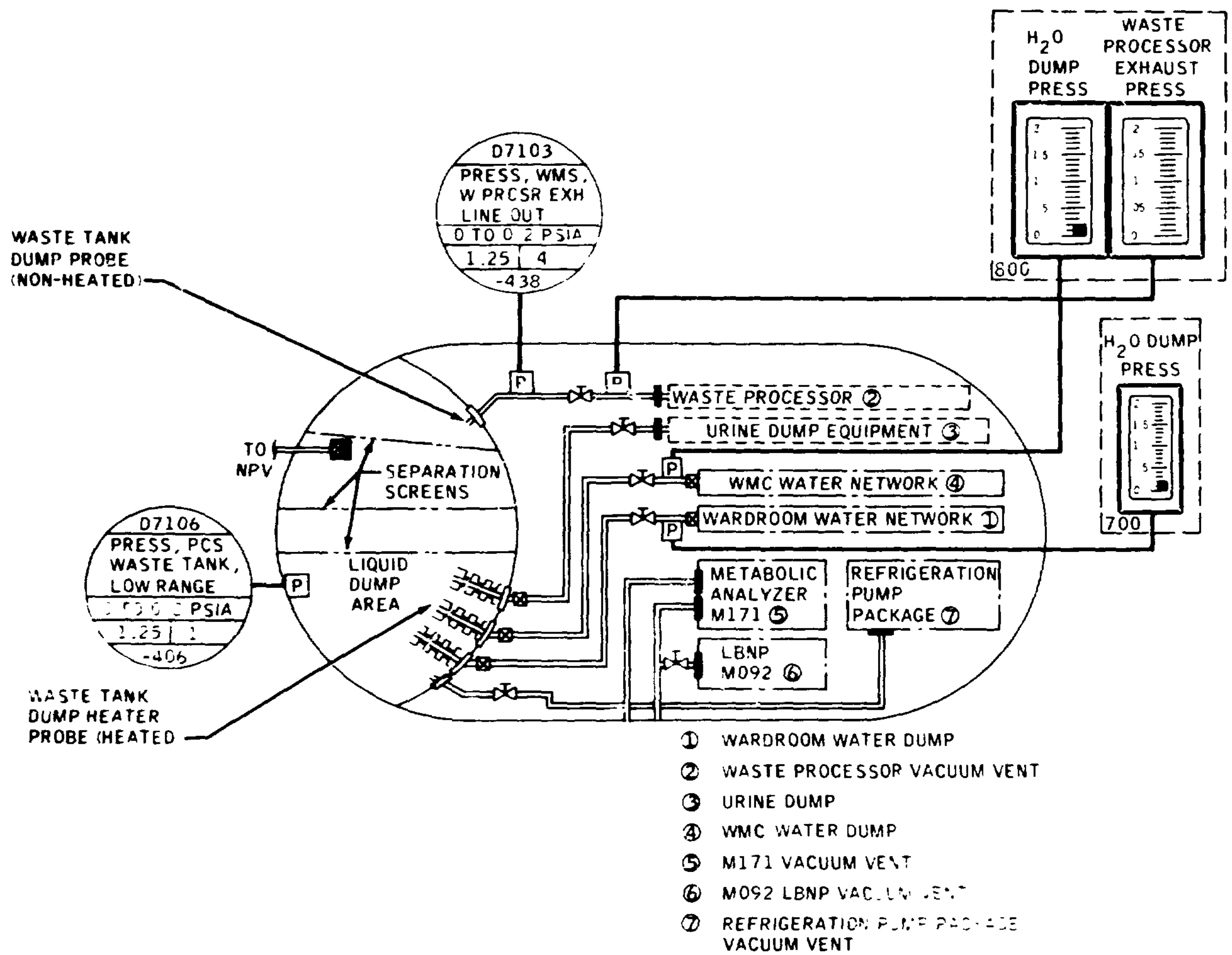


Figure 2.2.11.2-35

SKYLAB - ORBITAL WORKSHOP
WARDROOM
VACUUM OUTLET - WATERDUMP

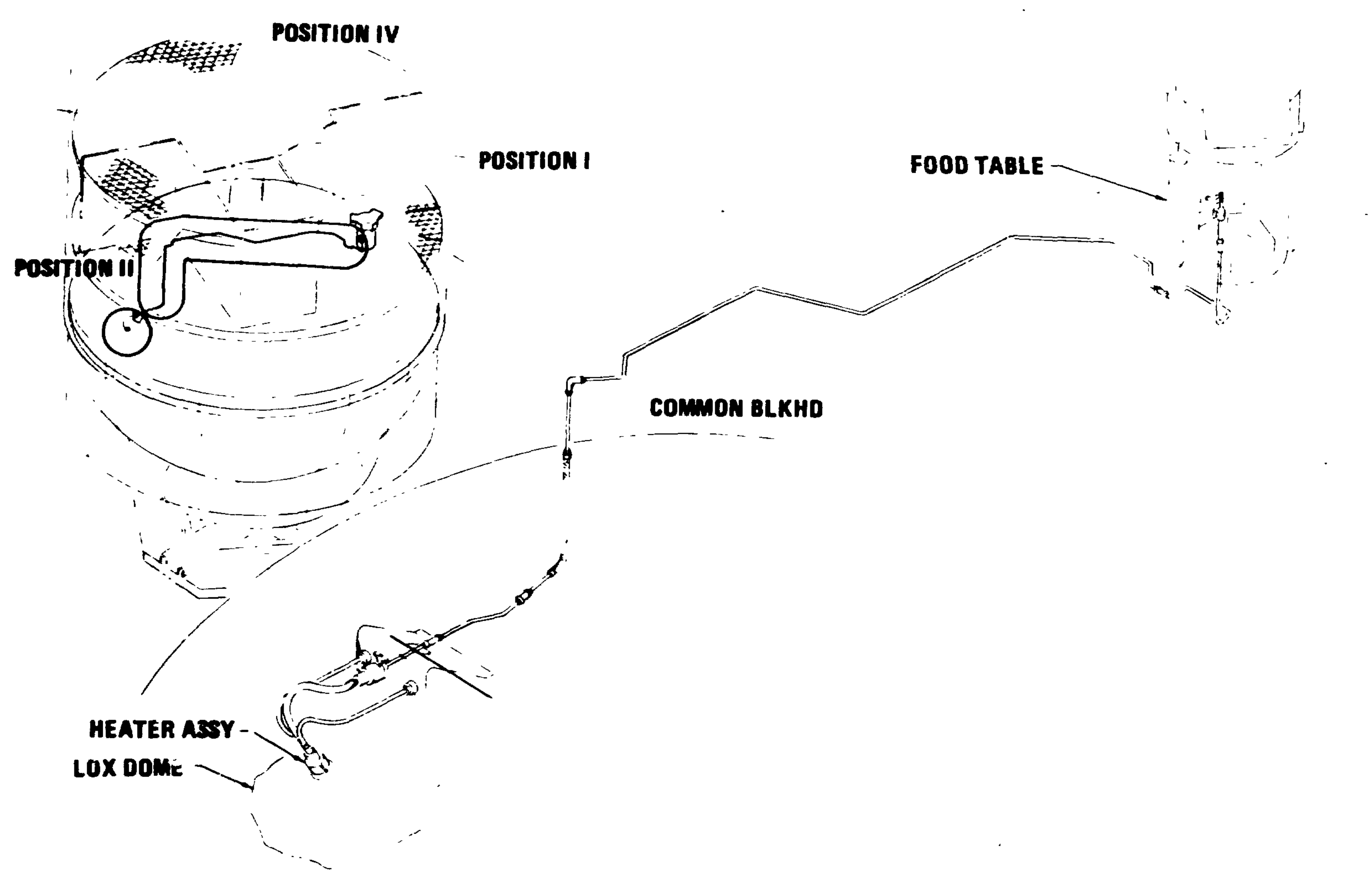


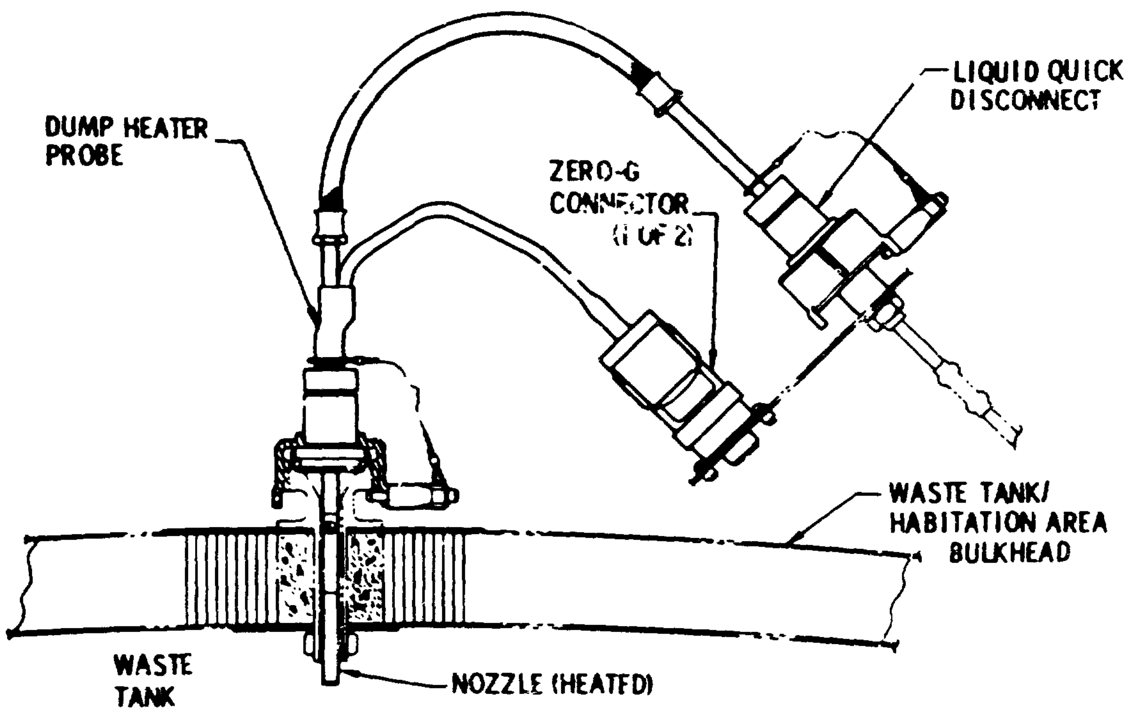
Figure 2.2.11.2-26

heater probe which contains two zero-g connectors (bus 1 and bus 2), a quick-disconnect, and a dual-element nozzle heater (Figure 2.2.11.2-37). The dump heater probe's heated nozzle extends into the waste tank. Separate control of each heater element is with a water dump heater switch on Panel 700 (Figure 2.2.11.2-38). A water dump heater light on Panel 700 is illuminated during heater operation; in addition, a remote dump heater light on Panel 617 illuminates whenever any of the three dump heater probes is powered. The dump heater probe must be powered for 15 minutes preceding any dump to clear the nozzle of any ice blockage. A spare dump heater probe is provided in a stowage compartment in the OWS forward dome.

The wardroom water dump will be used upon SWS activation to evacuate the wardroom water network prior to filling operations. For SL-3 and SL-4 activation, an additional iodine fill and soaking operation is performed on the wardroom water network with the iodine/water solution dumped through the wardroom water dump after the one-hour soak period. Upon SWS deactivation, the wardroom water network is drained of water.

The WMC water dump, located in the WMC, provides for evacuation of the WMC water network, urine system flush water network, washcloth squeezer bag, and the condensate control system into the waste tank (Figures 2.2.11.2-35 and 2.2.11.2-39). The WMC water dump uses quick-disconnects, flexible hoses, tubing, a hand valve, and a heater waste tank discharge nozzle (dump heater probe). A flexible hose with a quick-disconnect stowed below the hand washer mates with the WMC water heater for water network dump, with the urine system flush dump base for urine system flush water network dump,

SKYLAB - ORBITAL WORKSHOP
DUMP HEATER PROBE



SKYLAB - ORBITAL WORKSHOP
VACUUM PROVISION SCHEMATIC (TYP)

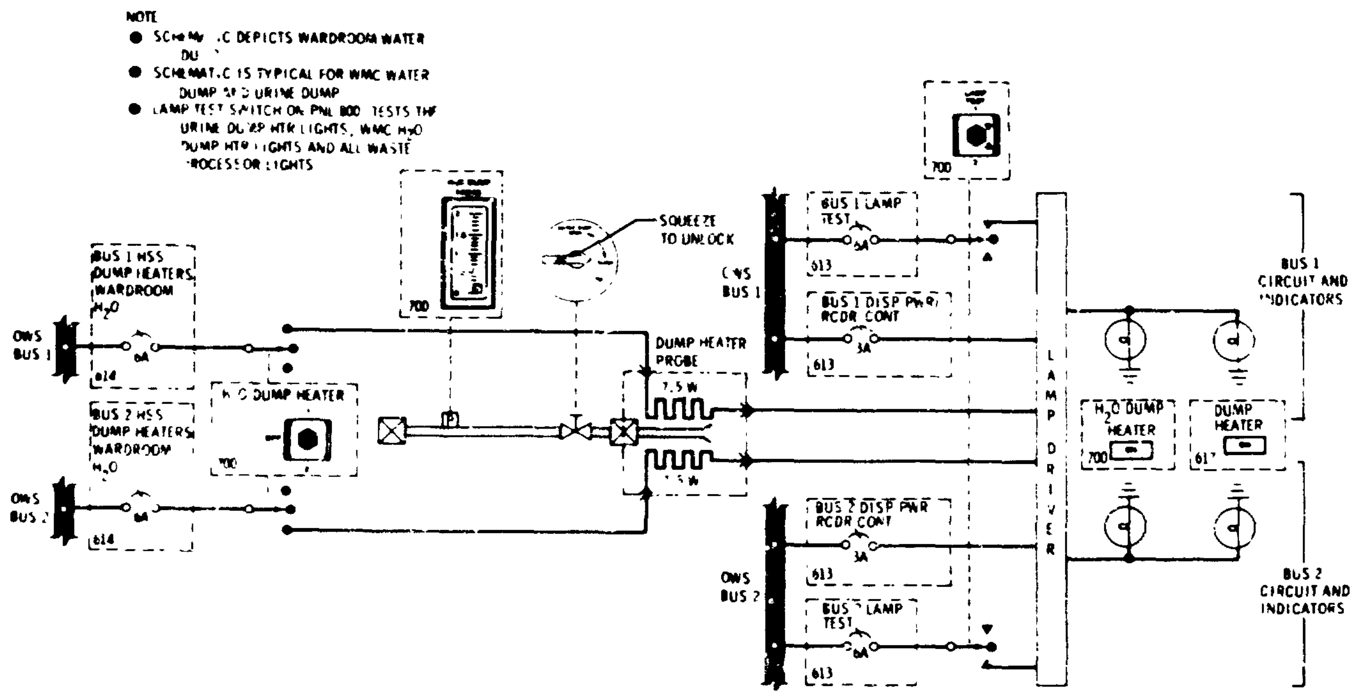
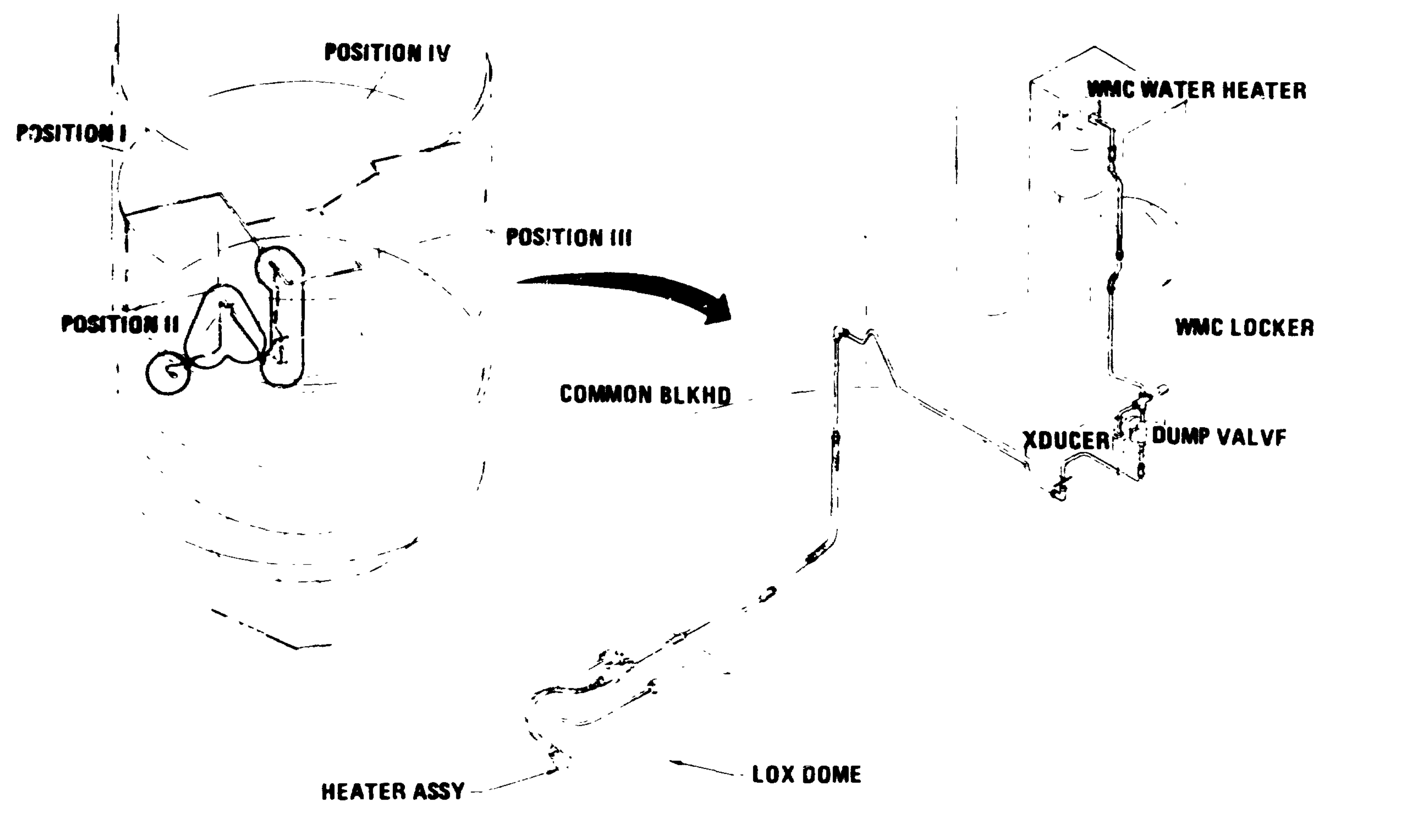


Figure 2.2.11.2-38

SKYLAB - ORBITAL WORKSHOP
WMC VACCUM OUTLET WATER DUMP



and with the condensate control syst[illegible] dump line for condensate tank dump. The flexible hose is connected to a water dump hand valve on Panel 831, which routes the water to its dump heater probe for disposal into the waste tank. The configuration and operation of the dump heater probe are like the wardroom water dump heater probe using a switch and indicator on Panel 600. A pressure measurement upstream of the Panel 831 water dump hand valve is displayed on Panel 800 for onboard use for water dump termination. Water dumps are terminated when the pressure decreases to 0.7 psia ($4.83 kN/m^2$).

The WMC water dump will be used upon SWS activation to evacuate the WMC water network and urine system flush water network prior to water filling operations. During the habitation period, the condensate tank will be periodically dumped through a line that connects the condensate tank with the WMC. Upon SWS deactivation, the WMC water network and the urine system flush water network will be drained of water.

d/ The water system is purified by using water purification equipment, with iodine used as the biocide and water deionization equipment, with an ion exchange resin (MDAC Spec STM 0625) to filter (remove) the metallic ions from the water.

The water tanks are ground-serviced with purified water, using iodine to provide microbiological control within the water tank water until the SL-2 cr[illegible] inhabits the SWS. The crews of each mission will use the water purification equipment to: sample the water tank water periodically and determine its iodine concentration, and add iodine as required to the water tank water to maintain the

the desired iodine concentration. The water purification equipment will also be utilized to: inject iodine into the portable water tank for wardroom water network fill, soak, and flush, and inject a given quantity of iodine into the cat ion cartridge (ion exchange resin container). The water deionization equipment will be used by the crews of each mission to filter metallic ions from each wardroom water tank prior to use and as required.

The water purification equipment is in a container mounted on the habitation area tank wall near the +Z SAI in the OWS forward compartment (Figure 2.2.11.2-40). The container door is hinged and fitted with dial-type latches. The container is also fitted with two pushbutton vent valves on the door, which, when depressed, equalize container pressure with cabin pressure to ensure safe door opening.

The water purification equipment is composed of the following units: two water samplers, two reagent containers, one color comparator, one waste sample container, one iodine addition chart, two iodine containers, and two iodine injectors. Those pieces of purification equipment containing two units are divided into primary and backup units (Figure 2.2.11.2-40).

The water sampler (Figure 2.2.11.2-41) is used to extract a sample of water from a water tank to determine its iodine content. The water sampler is portable and consists of a fitting that mates with the sample port on the water tank, a shut-off valve, an accumulator with a glass sight tube, and a piston. A water sample is taken by operating the piston slide and drawing the piston back until it reaches the end of its travel, thus filling the

SKYLAB - ORBITAL WORKSHOP
WATER PURIFICATION EQUIPMENT

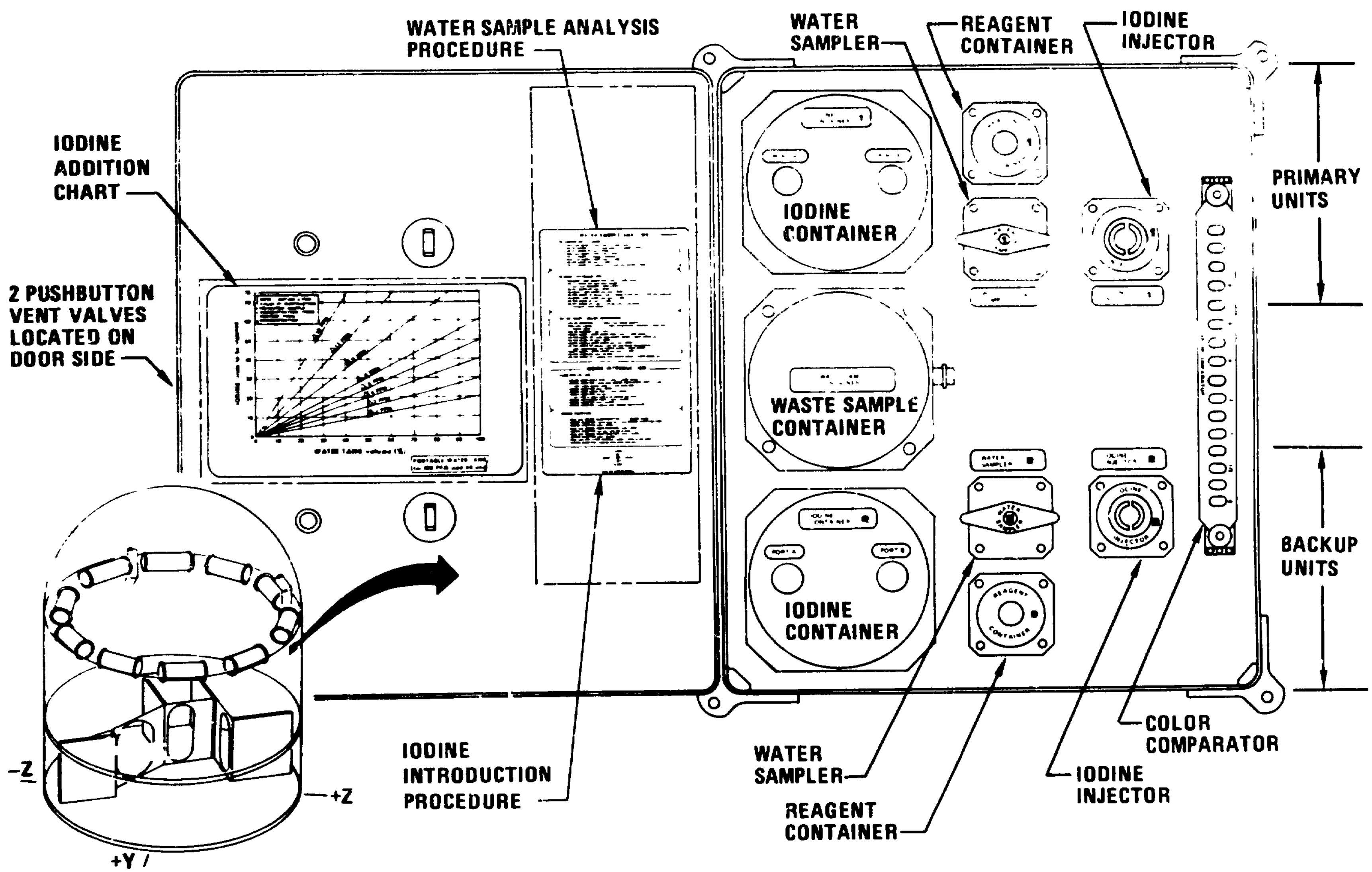
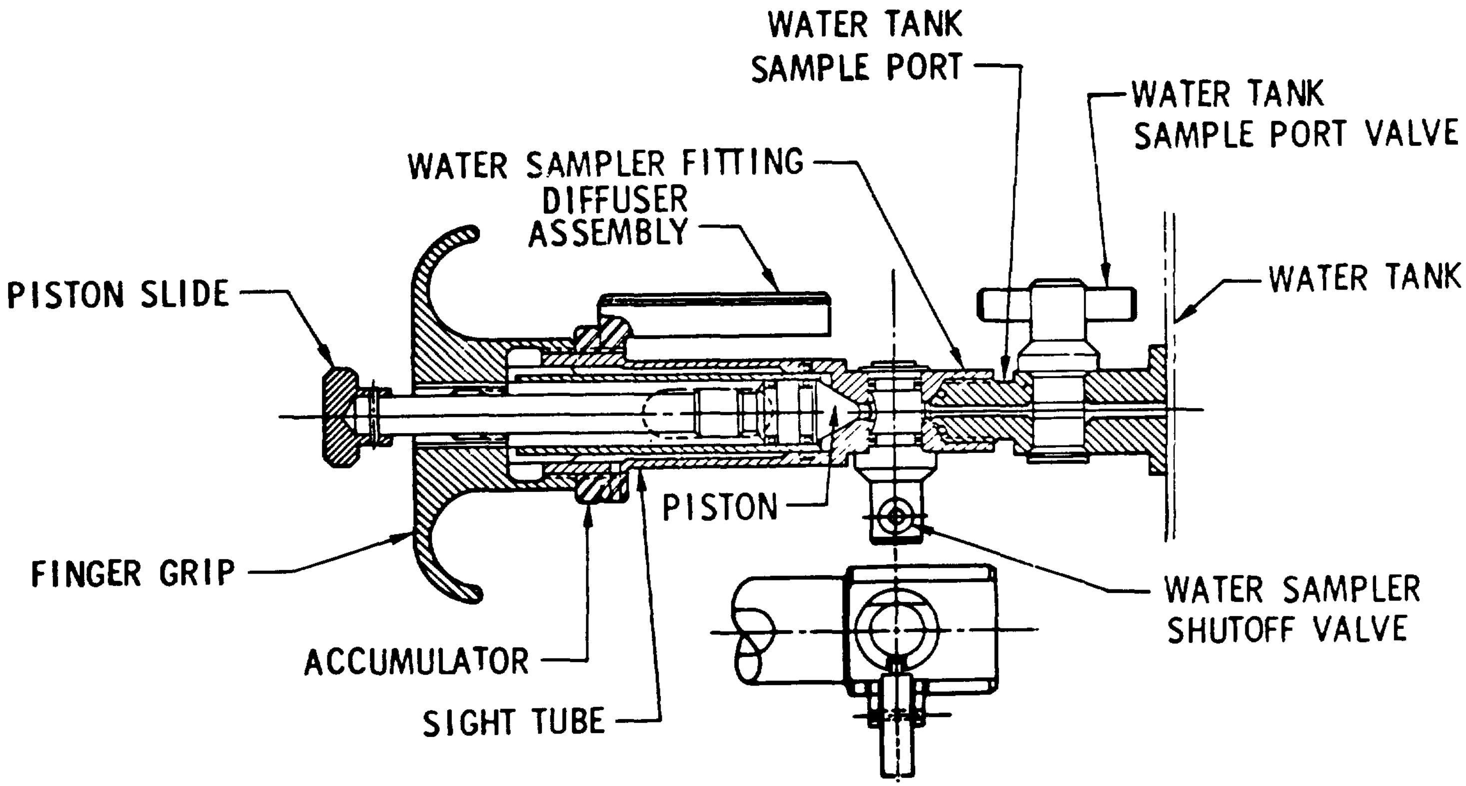


Figure 2.2.11.2-40

SKYLAB - ORBITAL WORKSHOP
WATER SAMPLER



accumulator with a given amount of water.

To permit observation of the water sample, the sample is mixed with a reagent to convert the clear water sample to a blueish hue. The reagent is obtained from a container (Figure 2.2.11.2-42) by installing the water sampler onto container's transfer port. The reagent is withdrawn from the container into the water sampler by engaging the threaded portion of the water sampler's piston slide into the threaded finger grip and rotating the piston slide until it bottoms out. The proper amount of reagent has now been extracted from the reagent container. The water sampler is then agitated by the crewman to completely mix the reagent with the water sample, resulting in a blue solution as viewed through the sight tube.

The reagent container is permanently attached to the water purification equipment container and stores the entire mission supply of amalo starch reagent (Figure 2.2.11.2-42). The amalo starch reagent, when mixed with a water sample, tints the sample blue to aid the crewman in determining the iodine concentration in the water tank. The reagent is stored in its container under the pressure exerted by a positive expulsion bellows to facilitate transfer of the reagent to the water sampler. The reagent container's transfer port contains a shut-off valve and a threaded transfer port to permit reagent withdrawal.

The color comparator is stowed in the water purification equipment container utilizing two calfax fasteners to facilitate quick removal and reinstallation (Figure 2.2.11.2-43). The color comparator contains eight blue-tinted film windows and seven clear viewing ports, which are used to determine the iodine concentration in parts

ORBITAL WORKSHOP
HSS WATER SUBSYSTEM
REAGENT CONTAINER ASSEMBLY

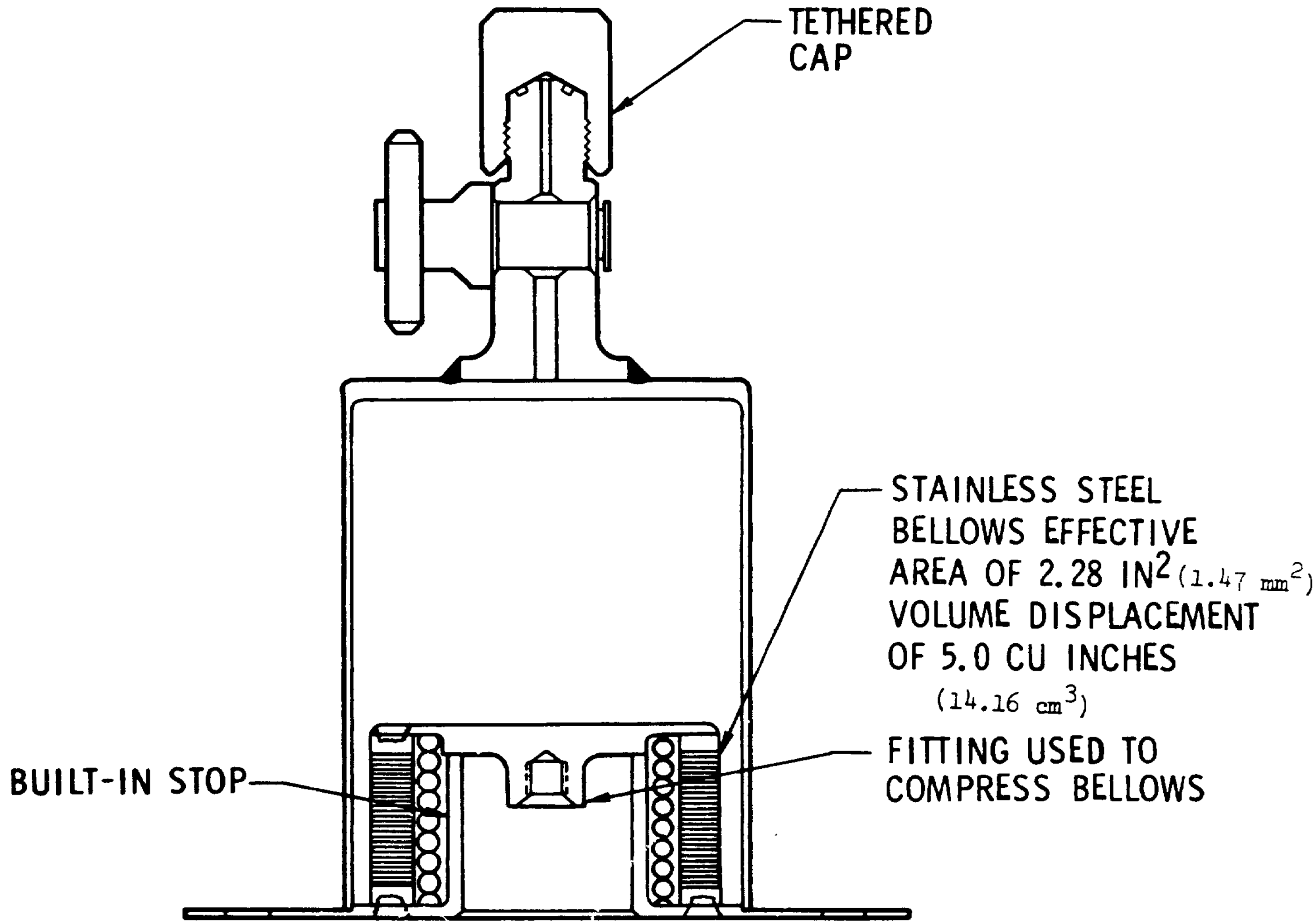


Figure 2.2.11.2-42

SKYLAB - ORBITAL WORKSHOP
COLOR COMPARATOR

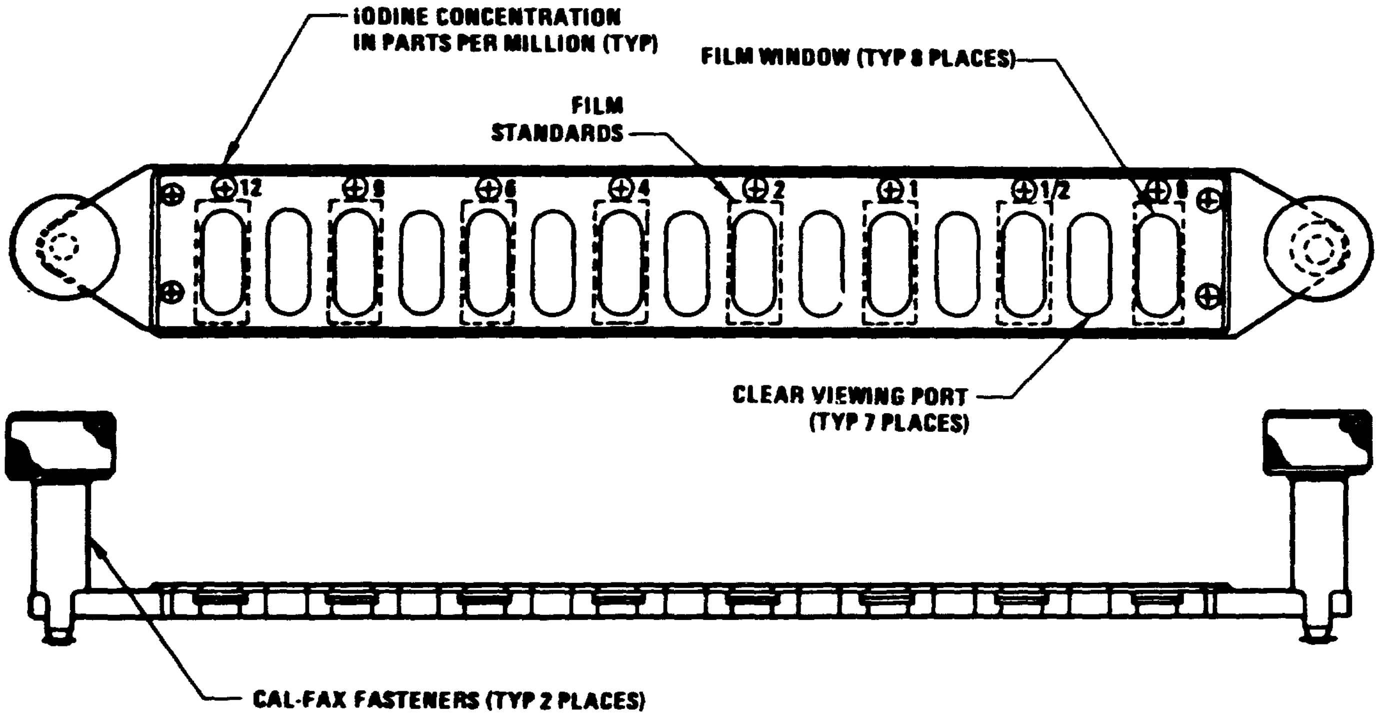


Figure 2.2.11.2-43

per million in a given water sample. The comparator is calibrated from 0 to 12 ppm with the blue color of the film increasing in intensity with the corresponding increase in iodine concentration.

After the water sample and reagent mixture have been agitated in the water sampler, the solution will appear some shade of blue as viewed through the water sampler's sight tube. The color comparator is then passed over the sight tube until the blue tint of the solution matches one of the blue-tinted film windows on the comparator. The solution's tint is visually compared to the film's tint through the clear viewing port located adjacent to each film window. When the proper tint has been determined, the iodine concentration in ppm is read from the comparator above the appropriate film window or extrapolated.

Upon completion of iodine concentration determination, the water sample and reagent solution contained in the water sampler are disposed of in a permanently mounted waste sample container (Figure 2.2.11.2-44). The water sampler is fastened onto the waste sample container's transfer port, and the solution is transferred through operation of the shut-off valves and the water sampler's piston slide.

The waste water sample storage volume permits storage of all water purification waste water for the duration of the missions.

An iodine addition chart is permanently bonded to the water purification equipment container door and is used to determine the amount of iodine to be injected into the water tank to return its iodine concentration to the desired level (approximately 6 ppm).

ORBITAL WORKSHOP
HSS WATER SUBSYSTEM
WATER/IODINE WASTE SAMPLE CONTAINER
P/N 1B80557

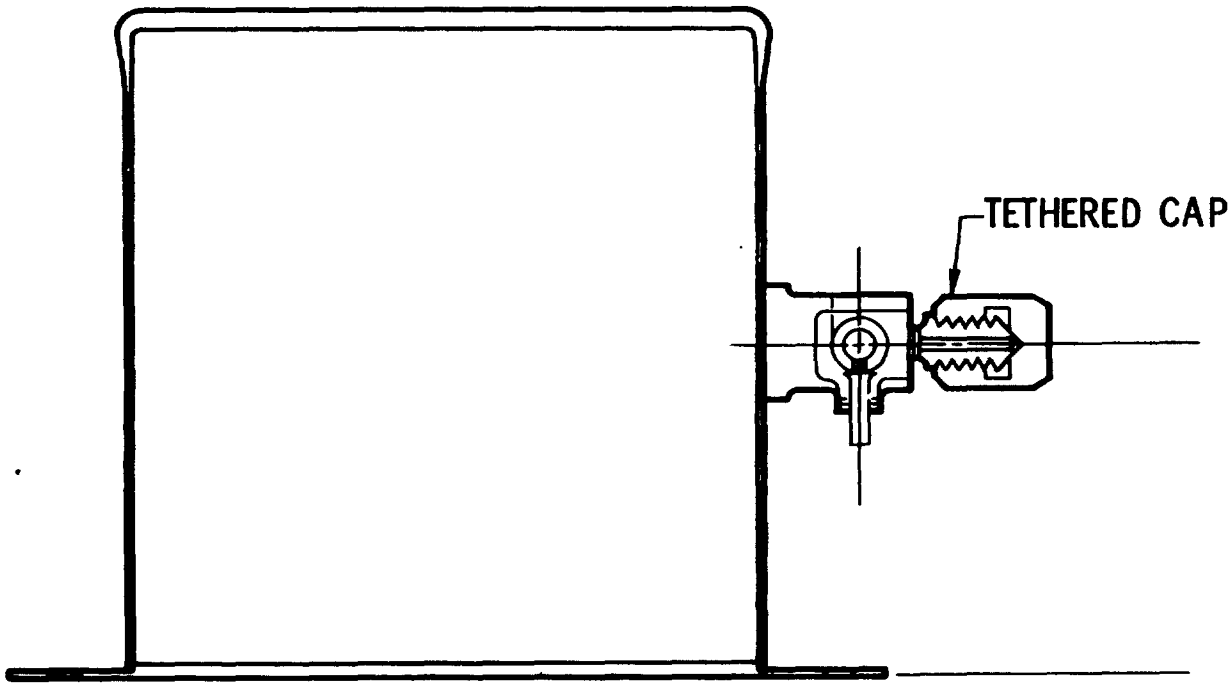


Figure 2.2.11.2-44

Each iodine concentration line on the chart (Figure 2.2.11.2-45) is identified with concentrations noted in ppm. The concentration on a particular line is the iodine concentration as determined on the color comparator. The eight iodine concentration lines depict the delta between the desired iodine concentration level in the water tank (approximately 6 ppm) and the actual concentration as determined on the color comparator. Utilizing this delta ppm and the water volume remaining in the sampled water tank, the units of iodine to be injected into that particular water tank to attain the desired iodine concentration of 6 ppm are readily determined.

If the iodine concentration in a particular water tank must be increased, the additive iodine is obtained from the iodine container (Figure 2.2.11.2-46). The iodine container, permanently mounted in the water purification equipment container, stores a highly concentrated biocide (iodine solution). This concentrated iodine solution is injected directly into the water tank water. The iodine stored in the iodine container permits water purification for the duration of all missions. A positive expulsion bellows aids in the transfer of the stored iodine into an iodine injector.

The iodine injector is a portable unit used to withdraw an appropriate amount of iodine from the iodine container and to inject this amount into a water tank. The injector's inlet fitting screws onto the iodine container's transfer port for iodine transfer (Figure 2.2.11.2-47).

The iodine injector is obtained and installed on the iodine container. The over-cylinder on the injector is drawn back until the desired number of units of iodine appears on the injector's calibrated scale.

IODINE ADDITION CHART

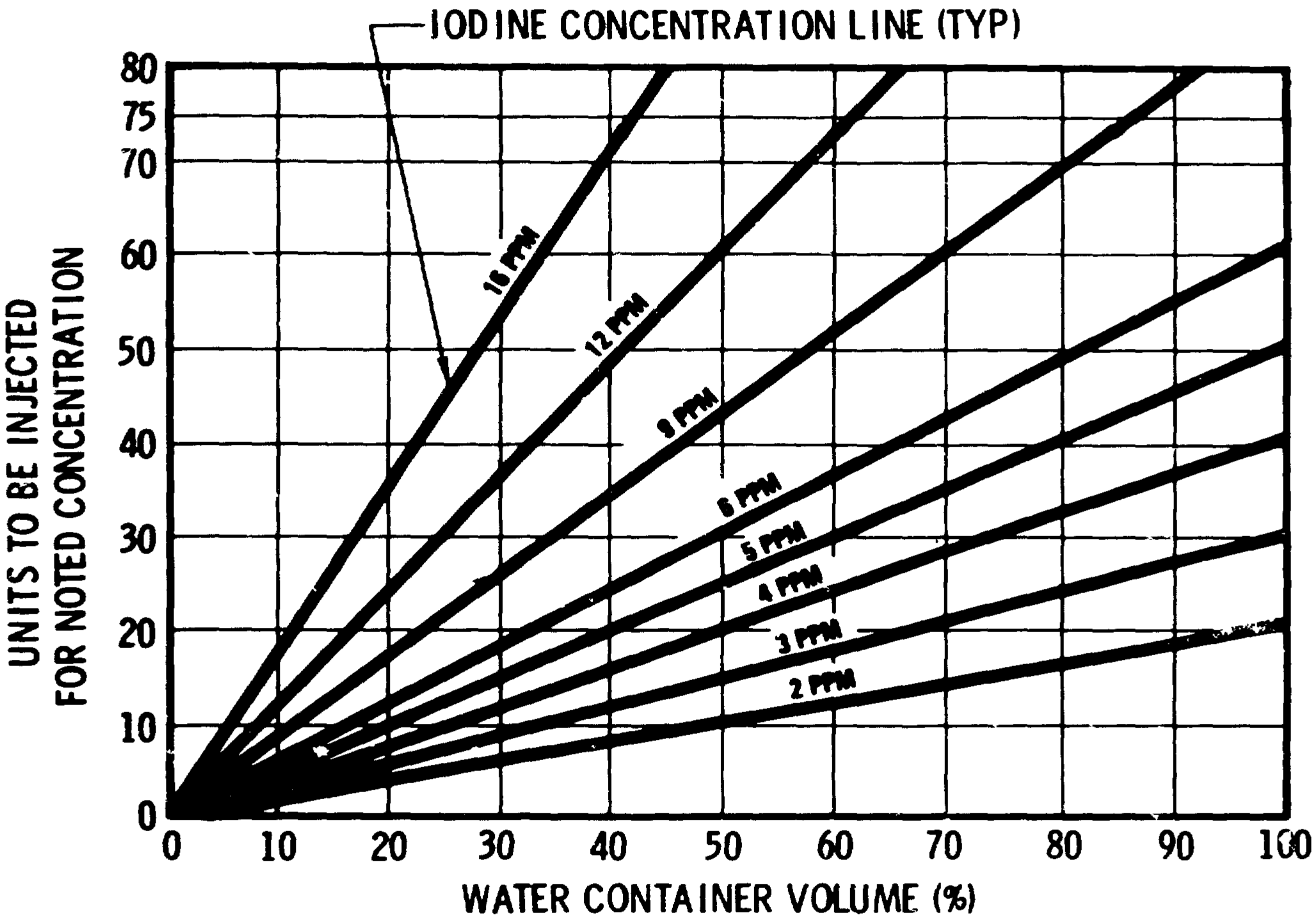


Figure 2.2.11.2-45

SKYLAB - ORBITAL WORKSHOP
IODINE CONTAINER

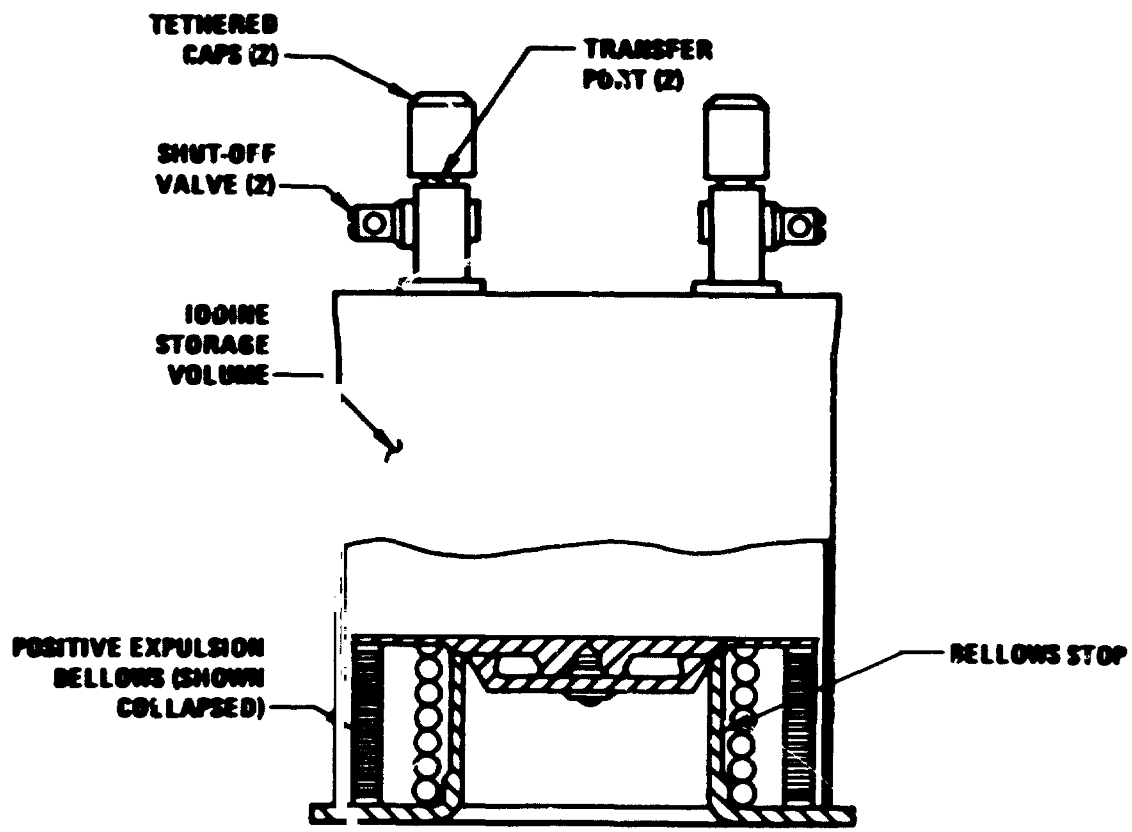
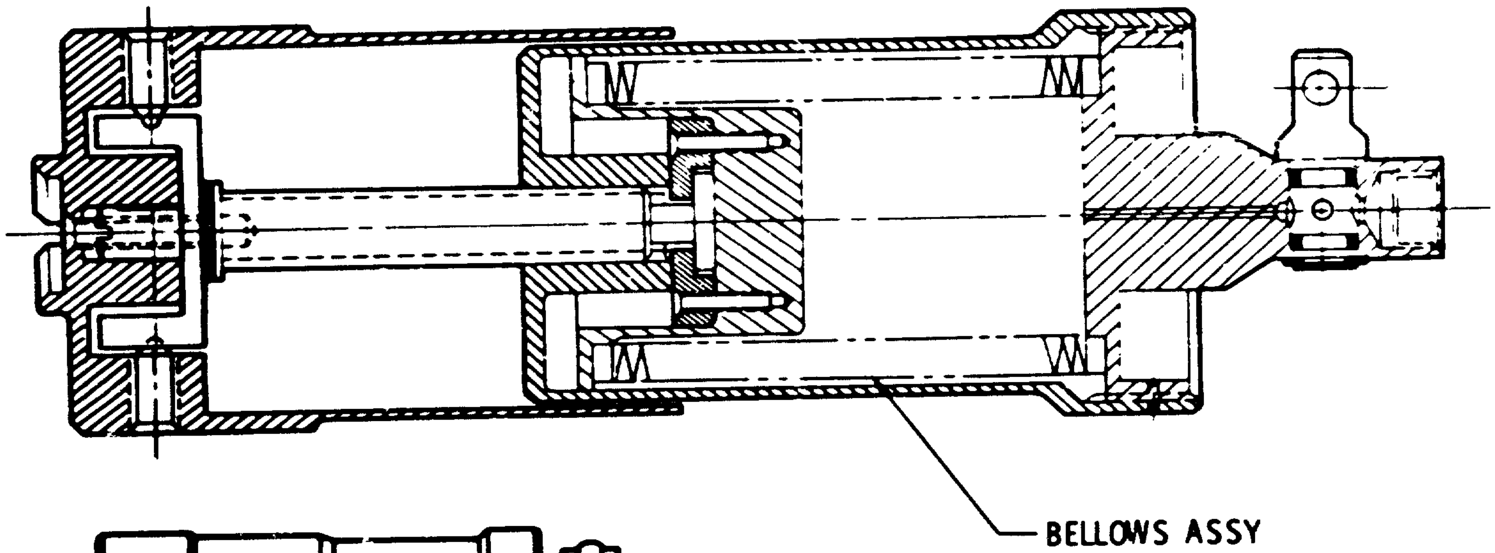
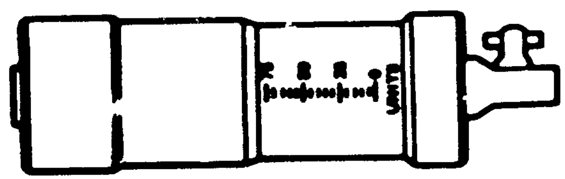


Figure 2.2.11.2-46

SKYLAB - ORBITAL WORKSHOP
HSS WATER SUBSYSTEM
IODINE INJECTOR





IODINE INJECTOR

Figure 2.2.11.2-47

This action withdraws the iodine concentrate from the iodine container and transfers it into the iodine injector. The injector is then removed from the iodine container and installed on the water tank's iodine port; the iodine concentrate is then injected into the water tank water by depressing the over-cylinder.

9/ The water deionization equipment (Figure 2.2.11.2-48) consists primarily of a stainless steel cartridge containing approximately 66 cubic in. (1082 cubic cm) of ion exchange resin. The resin reacts with iron, chromium, and nickel ions, removing them as the water passes through the resin bed. The cartridge has been designed with a thermal expanxion chamber and an iodine injection port.

The removable cation cartridge is in the wardroom water network to remove metallic substances contained in the wardroom water supply which result from the reaction of the water purification biocide (iodine) with the weter tank materials. The cartridge minimizes the crew intake of certain minerals. The cartridge, fitted with quick-disconnects, is located under the LBNP experiment (Figure 2.2.11.2-21) and is installed with a quick-release type mount similar to the waste management system blower unit mounts. The cartridge is connected to the wardroom water supply line during each SWS activation and is removed upon each SWS deactivation. When the cartridge is removed, the wardroom water supply line quick-disconnects are remated to maintain a flow path, allowing water network filling and draining. The cartridge is launch-charged with a water/iodine solution. Upon each SWS deactivation, the biocide concentration is maintained by the injection of iodine through its iodine injection port into the cartridge.

SKYLAB - ORBITAL WORKSHOP
WATER DEIONIZATION FILTER ASSEMBLY

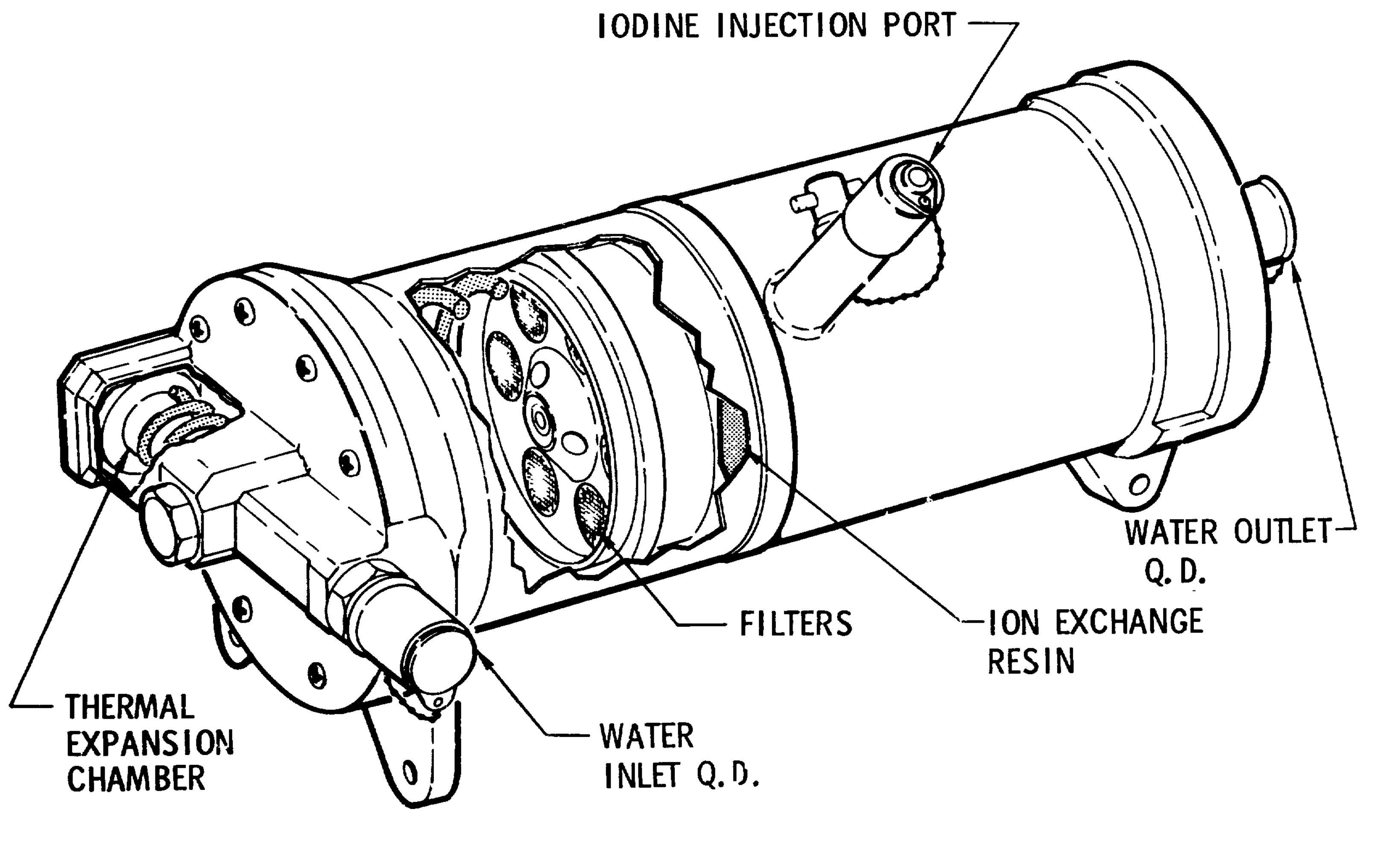


Figure 2.2.11.2-48

If the wardroom water network fails, the cartridge will be used with the portable water tank to continue support of wardroom functions. A quick-release mount, installed under the water tank foot restraint between WT 1 and WT 2, holds the cartridge for contingency use. Using a wardroom water hose, the cartridge is attached to a water tank and connected to the portable water tank with the CATION (CONTINGENCY) water hose. The portable water tank is then filled with water that has been "softened" by the cartridge. The portable water tank is then located above the wardroom for use. The cartridge is used only for wardroom water supply.

10/ The Water Management Subsystem provides water for drinking, food and beverage preparation, body cleansing and for flushing of the urine separator.

It also provides water for the Life Support Umbilical/Pressure Control Unit (LSU/PCU), the AM EVA/IVA cooling loop, the ATM Control and Display (C&D) Panel cooling loop and for the Experiment 512 Water Quench System.

Water is stored in ten, six-hundred pound capacity storage tanks in the forward dome area of the OWS. Six tanks are allocated for wardroom use, i.e., drinking and meal preparation. Two tanks are allocated for Waste Management Compartment (WMC) use, i.e, body cleansing. One tank is allocated for flushing of the urine separator, providing water for the LSU/PCU, the ATM EVA/IVA cooling loop, the ATM C&D Panel cooling loop and for the Experiment M512 Water Quench System. The one remaining tank is allocated for contingency use, in case of excessive water usage or failure in the water supply, in either the wardroom or the WMC. In addition, a portable water tank is provided to allow continuance of the mission in case of a failure in the supply system to the wardroom or the WMC. Total water capacity of the system is such that the capacity of one of the ten water tanks could be lost without decreasing the water supply below mission requirements.

Pressurizing gas at 150 $\pm$ 10 (1034 $\pm$ 69 kN/m^2) psia from the Airlock Module is regulated down to 35 $\pm$ 2 (241 $\pm$ 13.8 kN/m^2) psia by dual redundant regulators. Relief valves set at 45 (310 kN/m^2) psia insure that, in case of regulator failure, the system pressure will never rise beyond the system design limits.

Pressurizing gas at 35 $\pm$ 2 (241 $\pm$ 13.8 kN/m^2) psia is applied to the back side of bellows in each of the ten water container assemblies positively expelling water from a tank when shut-off valve is open and the quick-disconnect is engaged.

In the wardroom, water is supplied to a water chiller, which lowers water temperature to 45°F (7.2°C) maximum, and to a water heater, which heats water to 152 $\pm$ 5°F (66.7 $\pm$ 2.8°C). Hot water is made available to the crew at the hot water food reconstitution dispenser. Cold water is made available to the crew at the cold water food reconstitution dispenser and the individual drinking water dispensers. In preparation for storage, water is drained from the wardroom water lines to prevent microbial growth within the lines (and components) and as a precaution against freezing of the water.

In the Waste Management Compartment, water is supplied to a water heater, which heats water to 127 $\pm$ 5°F (52.8 $\pm$ 2.8°C). Hot water is made available to the crew at the body cleansing water dispenser, which dampens washcloths for crew use. In preparation for storage, water is drained from the wardroom water lines to prevent microbial growth within the lines (and components) and as a precaution against freezing of the water.

In the urine flush water network, water is supplied directly to the urine flush dispenser. The urine separators are water-flushed daily with the dispenser to preclude cross-contamination of the day's urine pool with the previous day's urine pool.

11/ The water subsystem schematics are presented in Figures 2.2.11.2-49 and 2.2.11.2-50. There are no criticality category 1 single failure points (SFP) in the water subsystem. There are two items that are category 2 SFP's, the hose assembly (1B79654-1) of the wardroom and WMC water drain system. The critical failure mode is leakage which will result in loss of cabin atmosphere. The items are noted on the schematic. The criticality evaluation is based on the following directions.

SKYLAB - ORBITAL WORKSHOP
PORTABLE WATER SYSTEM SCHEMATIC

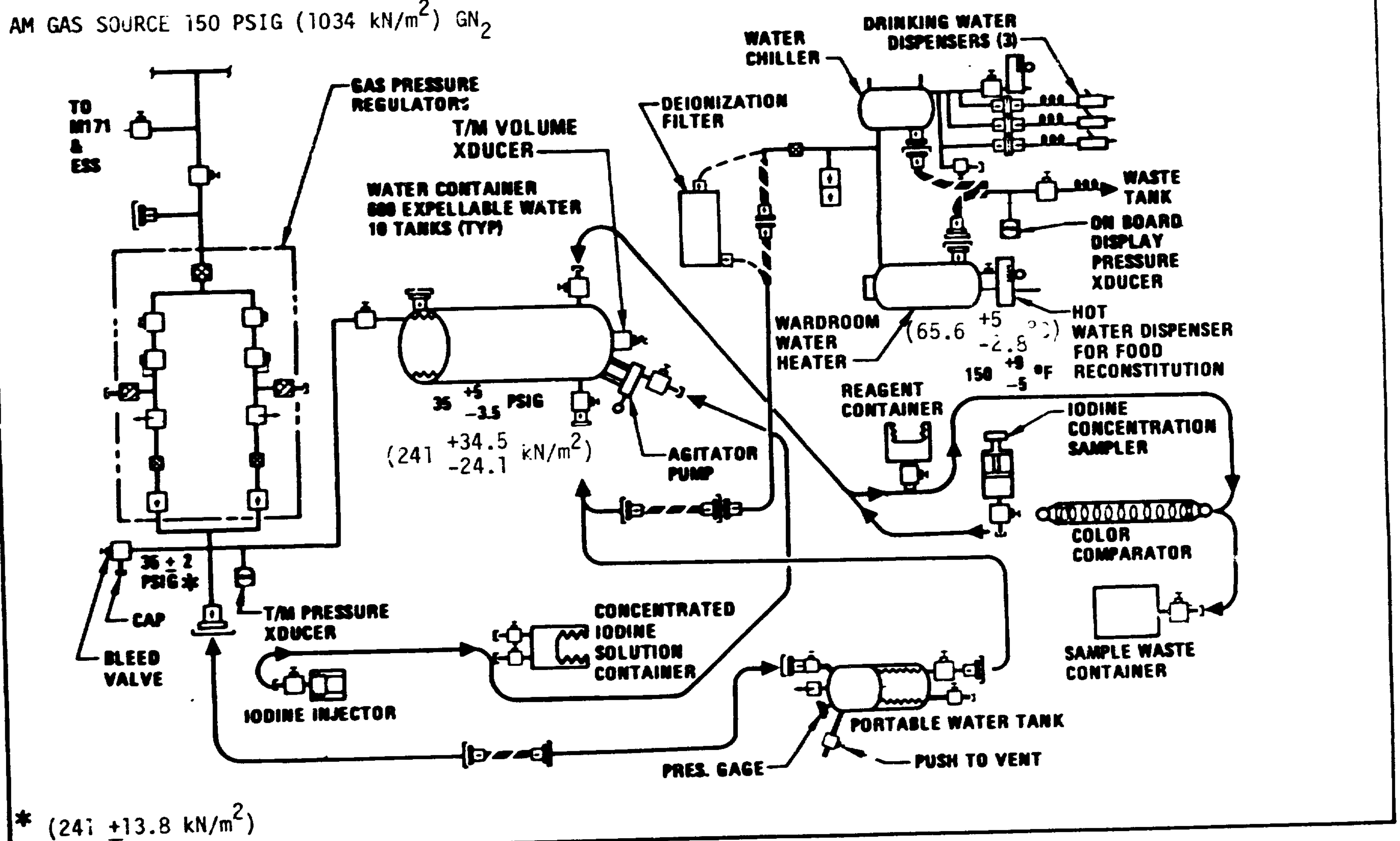
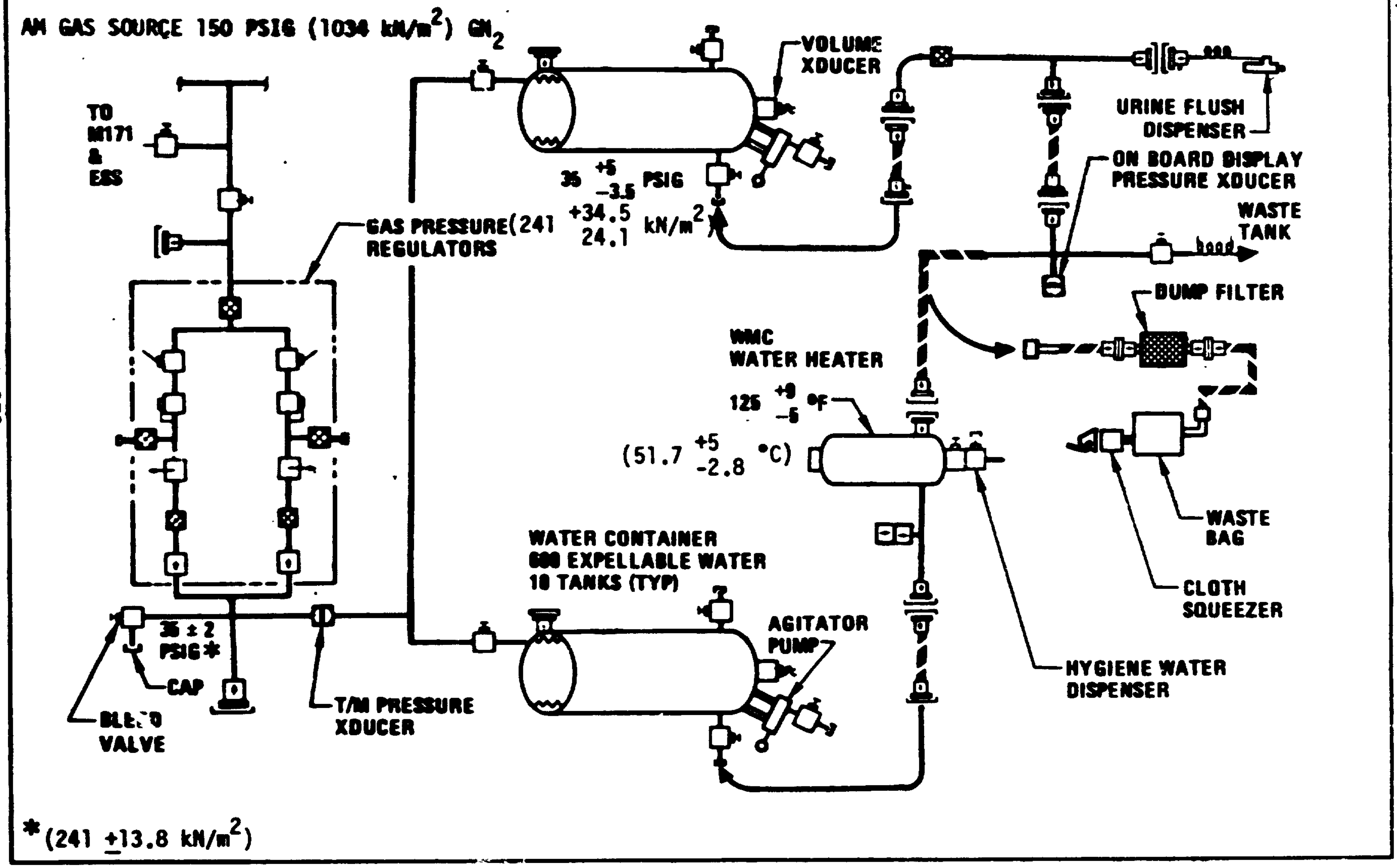


Figure 2.2.11.2-49

SKYLAB - ORBITAL WORKSHOP
WMC WATER SYSTEM SCHEMATIC



C. **Water System Testing**

1/ Development and Qualification Tests - Performance was verified on the component level and system level by qualification and development tests. The test line item numbers, test specimens and test control drawings (requirements) are listed in Table 2.2.11.2-2. Table 2.2.11.2-3 lists those components included in the Test Assessment Document MDC G0474C. This document delineates the rationale for qualification of each item to each environment. Significant problems encountered during testing are summarized on Table 2.2.11.2-4. A test conclusion and a summary of each test are included in Table 2.2.11.2-5.

TABLE 2.2.11.2-2

WATER SYSTEM DEVELOPMENT AND QUALIFICATION TEST LINE ITEMS

Line Item	Test Specimens	TCD
HS-7	Complete water system (less 9 of 10 water tanks and one of each water purification equipment items)	1T17599
HS-8	1. Pressurization system, one storage tank plus simulated network 2. One storage tank 3. Plexiglass tank and associated fittings	1T18145/ 1T16892
HS-10	1. Food reconstitution dispenser 2. Food reconstitution dispenser 3. Plug valve assembly	1T16971
HS-11	1. Drinking water dispenser 2. Drinking water dispenser 3. Plug valve assembly	1T16863
HS-12	1. Water heater assembly 2. Water heater assembly	SVHS5189
HS-14	Water purification equipment	
HS-16	Personal hygiene water dispenser	1T16832
HS-32	Water storage container bellows	1T18117 SC-52448
HS-48	1. Washcloth squeezer assembly and bag assembly 2.-6. Bag assembly 7. Bag assembly 8. Bleed adapter assembly and bag assembly	1T41131
HS-56	1. Urine flush dispenser 2. Hose assembly	1T41840
HS-59	1. Water deionization assembly 2. Three simulated filter assemblies	1T41718

TABLE 2.2.11.2-3

WATER SYSTEM
ITEMS IN TEST AND ASSESSMENT DOCUMENT (TAD) MDC G0474C

ITEM		PAGE
1B78356	HEATER, HSS WATER SYSTEM (WATER HEATER)	9-1
1B78612	DISPENSER ASSY, WATER DRINKING	9-5
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TABLE 2.2.11.2-4

OWS WATER SUBSYSTEM
PROBLEM SUMMARY

NO.	PROBLEM	SOLUTION
1	HS-8 Water Tank Leakage	
	1. Agitator Pump	1. Seal configuration redesigned and successfully passed tests.
	2. Sample Valve	2. Seals changed to silicone and successfully passed tests.
2	HS-8 Water Tank Outlet Valve Leakage	Inspection revealed defective seal.
3	Water Tank Dome Reversal	Bellows pressurized and dome returned to normal position. Testing continued.
4	Support Bolt Failure During HS-8 Water Tank Vibration	Failure occurred because of improper installation. Reworked to production configuration and successfully passed test.
5	Leakage from Gas Valve on HS-7 Water Tank	Inspection revealed that valve bore is oval and oversize 0.007 in. (.0178 cm). Leakage detected after PAT due to long-term compression set of seals. Testing continued using larger seal.
6	Seal Failure in Gas Shutoff Valve on Portable Water Tank	Production change to seal made using harder material. Preliminary tests indicate it eliminates problem.
7	Failure of Water Purification Equipment During Vibration	Redesign and retest accomplished and successfully passed.
8	Washcloth Squeezer Tie-Down Strap Loosened During Vibration	Loose end of strap was taped in place during test. Production drawing changed to incorporate tape.
9	Excessive Leakage From Chiller Dispenser Piston Seal	Test data on gas and water leakage at the end of the test was found acceptable.
10	Relief Valve Failures in Waste Management Water Module	Contamination found embedded in poppet seals; source unknown. Considered isolated case. No additional contamination found (iron materials).
11	Overtemperature Check of Wardroom Water Heater out of Specification	Orientation of heater has an effect on the water temperature due to convection currents, which are not present in zero g. Retest in horizontal position brought temperature within specification.

TABLE 2.2.11.2-4 (CONTINUED)

NO.	PROBLEM	SOLUTION
12	Leakage From Valves in Water Purification Equipment	Seals changed to silicone and successfully passed tests.
13	Reduced Flow From Waste Management Water Dispenser	Seal material changed to viton. Prior material was not compatible with iodine.
14	Leakage From Waste Management Water Heater Shutoff Valve	Valve adjustment was inadvertently disturbed during torque test. Vendor readjusted valve, stopping leak.
15	Water Expulsion From Relief Valve During Operation of Wardroom Food Reconstitution Dispensers	A restrictor was added to selector valve which reduced the pressure spike (water hammer) caused by piston striking stop during dispenser charging.
16	Leakage From Portable Water Tank Water Shutoff Valve	Same as Item 12.
17	Leakage From Water Tanks Agitator Pump	Inspection of pump revealed that teflon coating on end cap had been worn off, and cap had scored shaft, causing leaks. However, pump had been operated over 250 times (life cycle requirement is 100). Due to test requirements excessive operation is felt to be the cause of failure.
18	During development test preliminary checks, the squeezer loads were approximately three times predicted values.	The housing and its attachments were redesigned to carry the increased loads. No yielding occurred during subsequent testing.
19	During squeezer life cycle development test the top assembly latch began to open under load after 50 cycles. The latch tang had yielded.	The latch was redesigned to carry the increased loads. Latch location was redimensioned to better control geometry. The piston rod was shortened, and shims were added, to control maximum squeeze (and load). No further latch malfunction occurred during subsequent life cycling.
20	During development test preliminary checks, the squeezer piston seal leaked water.	The piston had a light-duty ball seal. A medium-duty ball seal was installed. No further water leakage occurred during subsequent testing.

TABLE 2.2.11.2-4 (CONTINUED)

NO.	PROBLEM	SOLUTION
21	During squeezer life cycle development test, the handle began to bind after 5,000 of 13,000 required cycles.	Disassembly showed the bearing surfaces to be galled. The bearing surface finish was improved, from 32√ to 16√, and the pins were electroliz-coated. During retest, the bearings began to squeak at 5,000 cycles. Disassembly showed the bearings had again galled. The bearing surface finish was further improved to 8√, and aluminum-bronze bushings were installed (running against the electrolized surface). The required 13,000 cycles were completed. Disassembly showed the bearing wear to be acceptable.
22	During development tests of the washcloth squeezer and bag, the bag failed leakage tests. Removal of the protective cover revealed that the teflon film bladder had parted at its heat-sealed seams.	After much development work, a bag construction of polyurethane coated nylon fabric was selected. In addition, the bag neck was redesigned to incorporate a venting feature, and a hose was added to the bottom of the bag to allow dumping. A filter and connection to the WMC water dump were also added.
23	HS-14 iodine injector bellows leaked biocide solution.	The 316 stainless steel material used in bellows fabrication was not compatible with 30,000 ppm I2 biocide solution. All material wetted by the biocide solution was changed to Hastelly "C" and test was successfully completed.
24	HS-14 iodine container biocide solution failed to empty completely.	The biocide is forced out by an extending bellows assembly. The bellows assembly cocked and hung up on container wall. The bellows assembly was precision-aligned to the container wall, and the surface roughness of the bellows head and the container wall were reduced. The test was successfully completed.
25	HS-10 food reconstitution dispenser did not meet leakage requirements (Test Specimens 1 and 2)	The leakage problem was discovered to be that the piston sealing spring force was too light for the teflon seals. The design change was to install one heavy spring seal in place of the two light spring seals. This change was performed on Specimen 2. Leakage requirements were met.

TABLE 2.2.11.2-4 (CONTINUED)

NO.	PROBLEM	SOLUTION
26	HS-10 food reconstitution dispenser: during repeat cycle and biocide compatibility test, the rotary valve plug started to bind (Test Specimen 2)	The problem was discovered to be caused by the incompatibility between the dry film lubricant on the plug diameter and the DC4 seal lubricant, which broke down the dry lube film barrier and caused metal-to-metal contact. The dry film lubricant was replaced with Teflon S coating. This resolved the binding problem.
27	HS-10 food reconstitution dispenser: the repeat cycle and biocide compatibility test was continued starting from 0 cycles. A functional check was performed at 2,700 cycles, and the piston seal did not meet design leakage requirements.	At this time, due to the schedule, it was decided to continue the test with this seal. At the completion of the repeat cycle test (10,000 cycles), the piston seal did not meet the design requirements; however, the leak rate was much less at the end of this test. There was no positive indication of why the seal failed to perform, except for some very faint scratches on the cylinder wall. There was no visible evidence of degradation due to biocide. It was decided to teflon-coat the accumulator piston to prevent any possible metal-to-metal contact. The reworked specimen was retested, and the test was successfully completed.
28	HS-11 drink dispenser: Specimen 1 or 2 did not meet leakage requirements.	The leakage problem was discovered to be from several causes: sealing spring force too light for teflon seals, valve spool and accumulator piston were scratching housing in the sealing area, and damage to the middle valve spool seal due to pinching the seal lip during installation. The following design changes were made. The accumulator piston was coated with Teflon S, the valve spool diameter was decreased in the area of the seals and a chamfer was added to the middle seal groove, the sealing spring force was increased, and the load for the accumulator piston and valve spool return springs was increased. A leak test was performed on Specimen 2, and design requirements were met.
29	HS-11 drink dispenser: during repeat cycle tests, between 4,000 and 6,000 cycles, the trigger counter skipped counts (Test Specimen 2)	The problem was discovered to be excessive lost motion between the trigger drive shaft and the counter shaft. The thickness of the counter shaft flat was increased, and the repeat cycle test (20,000 cycles) was successfully completed.

TABLE 2.2.11.2-4 (CONTINUED)

NO.	PROBLEM	SOLUTION
30	HS-11 drink dispenser: Specimen 1 was assembled using new design parts. After completion of repeat cycle test (20,000 cycles), the specimen did not meet leakage requirements.	The problem was discovered to be from several sources: the trigger and accumulator piston mating surfaces, due to wear, were discharging metal particles, causing scratches in the accumulator piston seal area; the valve spool seal near the gear end was worn almost through at the seal contact area; and the seal at the inlet had a broken spring. The redesign consists of hard chrome plating (electrolizing) the trigger and accumulator piston mating surfaces to prevent wear particles from damaging the seal area. A redundant seal was also incorporated. The reworked specimen was retested, and the test was successfully completed.
31	HS-56 urine flush dispenser: The required water volume dispense time was not met.	The orifices in the dispenser were enlarged from 0.051 in. (0.13 cm) diameter to 0.090 in. (0.229 cm). The test was successfully completed.
32	HS-59 during vibration tests, the floor grid failed at the cation cartridge mount assembly attach point.	It was concluded that the vibration loads were not adequately transferred to the floor grid support structure. A new mount assembly was designed which distributes the vibration loads to the support structure. The vibration test was repeated with no failure.
33	HS-59 tests showed that the deionization resin absorbed an excessive amount of iodine from the water, and the required iodine concentration levels could not be maintained.	Study revealed that a reduced resin volume may not deplete the iodine excess ely. The design was revised to reduce resin bed size to 30 percent. Tests showed that the requirements can be met with 30 percent resin bed size.
34	HS-59 cation cartridge: after expansion chamber piston cycling tests (200 cycles), the redundant end face seal unseated.	Seal groove redesigned to increase seal retention capability. Retest was successfully completed.
35	HS-12 during vibration testing of the water heater, the mounting structure developed cracks.	The mounting structure was redesigned. Retest showed redesigned structure to be adequate.

TABLE 2.2.11.2-4 (CONTINUED)

NO.	PROBLEM	SOLUTION
36	HS-12 examination of the heater inner surfaces after the 26-day biocide compatibility test showed corrosion.	The cause of corrosion was thought to be electrical leakage from the heater element. A new heater element was made and installed using improved potting, and a 30-day test was performed. Examination showed only slight staining. A further improvement was made by redesigning the electrical header (feedthru) and potting. After a 6-day retest, no evidence of corrosion was found.
37	HS-12 some production heaters had excessive leakage at the electrical header interface.	The header and potting were redesigned to improve bond area and material. No further leakage has occurred.
38	During HS-7 qualification tests the wash water bag to squeezer seal leaked.	The leakage was found to be caused by force on the bag by the compartment door which caused a moment on the seal. The problem was solved by changing the seal material, hardness and thickness.
39	Metal ion data collected during HS-7 qualification tests showed that iron and chromium were greater than allowed.	Work was started on the development of a mechanical filter. Analysis of the data by JSC Life Sciences Directorate determined that the levels would not be a medical problem. All work was stopped on the filter development.
40	The water heater elements failed at 120 days of operation, in the HS-7 qualification test.	Failure was found to be caused by deterioration of the element due to corrosion type action. The OWS 1 life problem was solved by addition of a spare water heater unit which would be installed by crewman at failure of the first unit. Redesign and retest of the water heater to completely metal-enclose the heater element is in progress for OWS Backup vehicle. Testing on this new (non-OWS-1) will be accomplished in line item HS-94.
41	During HS-8 long duration water storage tests (11 months) it was determined that the ionic species would exceed the specification requirements.	The excess ions were generated by reaction of iodine and water with the tank and bellows. The deionization filter was added to the wardroom network to remove the excess metal ions generated in the water tanks prior to transfer of water to the table for use.

TABLE 2.2.11.2-5

WATER SYSTEM DEVELOPMENT AND QUALIFICATION
TEST COMPLETION STATEMENTS

TEST PLAN ITEM TITLE: WATER SUBSYSTEM, WARDROOM WATER DISTRIBUTION NETWORK QUALIFICATION TEST (HS-7) SPECIMEN NO. 1
TEST PLAN AND ITEM NUMBER: DAC 56697A; HS-7-1
PART NUMBER: 1T17962-5
TECHNICAL MEMORANDUM OR REPORT NUMBER(S): MDC NO. G4194A TM-DSV7-F&M-R-7056-1, REV. A, VOL V

TEST CONCLUSION: Based upon the engineering observation of the qualification test performance and the evaluation of the test results presented in the attached report, it is concluded that the above test satisfied the requirements to demonstrate the performance capability of the wardroom water distribution network.

TEST SUMMARY: Qualification tests were performed for the purpose of verifying that the wardroom water distribution network (HS-7-1) met the design requirements of pre-launch and on-orbit operations. All problems encountered during the testing were successfully resolved except that the iron and chromium ionic concentrations exceeded the CEI specification requirements (per MSC-PF-SPEC-ID). This led to the requirement to perform an additional 56-day simulated mission test. The results of the additional test are reported in TM-DSV7-F/M-R-7056-10.

TEST PLAN ITEM TITLE: WATER SUBSYSTEM, WASTE MANAGEMENT WATER SUPPLY NETWORK
TEST PLAN AND ITEM NUMBER: DAC 56697A; HS-7
PART NUMBER: 1T17962-2
TECHNICAL MEMORANDUM OR REPORT NUMBER(S): MDC G4194 TM-DSV7-F&M-R-7056-2

TEST CONCLUSION: Based on the engineering observation of the qualification test performance and evaluation of the test results presented in the referenced report, it is concluded that the above item is qualified for flight use on the Orbital Workshop.

TEST SUMMARY: All tests were completed successfully. A list of problems encountered and their solutions are as follows:

1. Tape strips were added to the washcloth squeezer launch restraint strap to prevent loosening during vibration. The door lanyard attach bolt nuts were changed to self-locking to prevent loosening during vibration.

2. The source of the corrosion material (iron) in the relief valves was not established. Chemical analysis determined it was primarily iron. Considered to be an isolated case.

3. Water dispenser seal was changed from neoprene to fluorocarbon rubber to prevent swelling when exposed to iodine water solution. A depression in the plunger head sealing surface was reworked to drawing spec and successfully passed leakage retest.

4. Water heater shutoff valve operating torque increased during life cycle. The valve was added to the cycle significant list to monitor any torque increase with use. Actual mission use is only 6 cycles and is not considered to be a problem.

TABLE 2.2.11.2-5 (CONTINUED)

5. Squeezer bag dump line hose assembly leaked and was changed to a heavier wall to eliminate the problem.

6. The material, shore hardness and thickness of the squeezer bag neck seal were changed to eliminate the leakage.

TEST PLAN ITEM TITLE: WATER SUBSYSTEM, WATER CONTAINER
TEST PLAN AND ITEM NUMBER: DAC 56697A; HS-7
PART NUMBER: 1B79098-1
TECHNICAL MEMORANDUM OR REPORT NUMBER(S): MDC G4194; TM-DSV7-F&M-R-7056-3

TEST CONCLUSION: Based on the engineering observation of the qualification test performance and evaluation of test results presented in the attached report, it is concluded that the above item is qualified for flight use on the Orbital Workshop.

TEST SUMMARY: The water tank assembly successfully passed the following tests:

(1) Complete procedure required for filling; (2) Iodine dispersion; (3) Water level transdcuer; and (4) a series of simulated 28-day missions. All tests were successfully passed.

All the seals in the shutoff valves and the seals in the quick-disconnect caps were changed from food grade viton to food grade silicone to reduce the permanent compression set and eliminate leakage problems encountered in the purification equipment tests.

During the pressure decay test it was discovered that the gas shutoff valve leakage was excessive and was caused by an oval, over-sized housing bore. Since the same valve had operated satisfactorily in two specimens in HS-8 after being exposed to the same plus additional environments, the housing was not reworked. Non-production over-sized seals were installed which stopped the leakage.

TEST PLAN ITEM TITLE: WATER SUBSYSTEM PURIFICATION EQUIPMENT
TEST PLAN AND ITEM NUMBER: DAC 56697A; HS-7
PART NUMBER: 1B81201-501
TECHNICAL MEMORANDUM OR REPORT NUMBER(S): MDC G4194; TM-DSV7-F&M-R-7056-4, VOL I

TEST CONCLUSION: The water subsystem purification equipment, which includes an iodine container, reagent container, waste container, iodine injector, water sampler and color comparator, successfully passed the design requirements of function, proof pressure, sterilization, vibration, leakage and repeat cycle.

TEST SUMMARY: All of the equipment successfully passed all the design requirements. However, some problems did occur during the course of testing. The problems and the resolutions are noted below:

The color comparator attaching cal-fax fasteners loosened during vibration. A drawing change was made to increase the fastener torque to 50-55 inch-pounds. (5.65-6.21N•m)

A failure of the water sampler during vibration was traced to a combination of assembly damage and interaction from an injector failure. An assembly caution note was added to the drawing and the launch restraints were redesigned and the sampler was retested under vibration.

An assembly pin in the iodine injector fell out during vibration. A change was made to add an additional pin with positive retention of both pins and the injector was retested under vibration. The injector bellows leakage failure during life cycle testing was traced to overpressurization. A torque limiting device was added to the injector allowing the proof pressure to be reduced to 100 psig. (689 kN/m^2)

The iodine container bellows "hung up" during repeat cycle. A spring adjustment requirement was added which eliminated the problem as verified by retest under vibration.

The high compression set of the food grade viton seals causing leakage was discovered during the testing. The seals were replaced with food grade silicone which has low compression set and is much less affected by the high sterilization temperatures.

TEST PLAN ITEM TITLE: WATER SUBSYSTEM, PORTABLE WATER TANK QUAL TESTS (HS-7) SPECIMEN NO. 5
TEST PLAN AND ITEM NUMBER: DAC 56697A; HS-7-5
PART NUMBER: 1B81575-1
TECHNICAL MEMORANDUM OR REPORT NUMBER(S): MDC G4194, VOL II; TM-DSV7-F&M-R-7056-5

TEST CONCLUSION: Based on the engineering observation of the qualification test performance and evaluation of test results presented in the attached report, it is concluded that the above item is qualified for flight use on the Orbital Workshop.

TEST SUMMARY: The following tests were performed:

Proof, Collapse, Leakage, Function, Ground Flush and Fill, Biocide Soak and Compatibility, Iodine Injection and Mixing Technique Evaluation, Ground Sterilization and Drying, Repeat Cycles and Vibration.

The following test anomalies occurred:

1. During ground flush and fill operations in the O-ring in the gas shutoff valve was found to be damaged (split) causing a gas leak. The hardness of the seal material was increased to 90 shore hardness which eliminated this seal problem.

2. During the iodine injection and mixing technique evaluation the water shutoff O-ring seal was leaking water. The seal material was changed to a low compression set food grade silicone which eliminated any more leakage problems.

TEST PLAN ITEM TITLE: WATER SUBSYSTEM, PRESSURIZATION ASSEMBLY, QUAL TEST (HS-7) SPECIMEN NO. 6
TEST PLAN AND ITEM NUMBER: DAC 56697A; HS-7-6
PART NUMBER: 1T17962-3
TECHNICAL MEMORANDUM OR REPORT NUMBER(S): MDC G4194, VOL II; TM-DSV7-F&MpR-7056-6

TEST CONCLUSION: Based upon the engineering observation of the qualification test performance and evaluation of the test results presented in the referenced report, it is concluded that the above item is qualified for flight use on the Orbital Workshop.

TEST SUMMARY: The following tests were performed: Proof, Leakage and Function. All these tests were completed successfully and fulfilled all specified design requirements.

TEST PLAN ITEM TITLE: WATER SUBSYSTEM, URINE FLUSH SYSTEM NETWORK
TEST PLAN AND ITEM NUMBER: DAC 56697A; HS-7
PART NUMBER: 1T17962-113
TECHNICAL MEMORANDUM OR REPORT NUMBER(S): MDC G4194, VOL V; TM-DSV7-F&M-R7056-7

TEST CONCLUSION: Based on the engineering observation of the qualification test performance and evaluation of test results presented in the referenced report, it is concluded that the above item is qualified for flight use on the Orbital Workshop.

TEST SUMMARY: The urine flush water supply system network was subjected to a series of tests which duplicated or simulated the conditions which the OWS flight vehicle network will experience. The tests included proof, leak, network checkout tests, network activation and deactivation, simulated 28-day mission and life cycle. All tests were completed successfully.

The only problem occurred in the initial leak test when a loose, improperly installed plug (Lee Plug) was found and replaced. No further problems were encountered.

TEST PLAN ITEM TITLE: WATER SUBSYSTEM, WMC CONTINGENCY WATER LINE QUAL TEST (HS-7) SPECIMEN NO. 8
TEST PLAN AND ITEM NUMBER: DAC 56697A; HS-7-8
PART NUMBER: 1T17962-115
TECHNICAL MEMORANDUM OR REPORT NUMBER(S): MDC G4194, VOL III; TM-DSV7-F&MR-7056-8

TEST CONCLUSION: Based on the engineering observation of the qualification test performance and evaluation of test results presented in the referenced report, it is concluded that the above item is qualified for flight use on the Orbital Workshop.

TEST SUMMARY: The following tests were performed: Proof, Leakage, Flush, Biocide Soak/Conditioning, Drain and Dry, and Activation. All these tests were completed successfully and fulfilled all specified design requirements.

TEST PLAN ITEM TITLE: WATER DEIONIZATION GLASS AND SIMULATED METAL CARTRIDGE (30% RESIN VOLUME DEVELOPMENT TEST)
TEST PLAN AND ITEM NUMBER: DAC 56697A; HS-7-9
PART NUMBER: 1T42111
TECHNICAL MEMORANDUM OR REPORT NUMBER(S): MDC G4194, VOL VII, TM-DSV7-F&M-R-7056-9

TEST CONCLUSION: Based on the engineering observation of the pre-qualification test performance and the evaluation of the test results presented in the referenced report, it is concluded that the above test satisfied the requirement to demonstrate the performance capability of the deionization cartridge.

TABLE 2.2.11.2-5 (CONTINUED)

TEST SUMMARY: Pre-qualification tests were performed on simulated deionization cartridges using different resin pre-treatment procedures and different storage and usage times. The influent iodine concentration and the influent ionic species concentration (iron, nickel and chromium) were controlled at specified quantities. The effluent water was monitored and analyzed in order to supply the iodine and ionic species concentration data necessary to evaluate in advance the expected performance of the flight type deionization cartridge.

The results disclosed that all CEI spec requirements (per MSC-PF-SPEC-1D) were met except for the iron and chromium ionic concentrations which were exceeded. MSFC and JSC were informed, resulting in the following direction:

1. Discontinue this Line Item (HS-7-9) per NASA Letter SL-RH-90-73, dated 3-20-73.

2. Continue Line Item HS-7-1 qualification test, per MSFC Change Order No. 995, dated 3-13-73, without any hardware changes to obtain additional ionic species concentration data.

TEST PLAN ITEM TITLE: WATER SUBSYSTEM, WARDROOM WATER DISTRIBUTION NETWORK, SPECIMEN NO. 1
TEST PLAN AND ITEM NUMBER: DAC 56697; HS-7
PART NUMBER: 1T17599-1
TECHNICAL MEMORANDUM OR REPORT NUMBER(S): MDC G4194, VOL VIII; TM-DSV7-P/M-R-7056-1(

TEST CONCLUSION: Based upon the engineering observation of the qualification test performance and the evaluation of the test results in the attached report, it is concluded that the above test satisfied the requirements to demonstrate the performance capability of the wardroom water distribution network with the exceptions as noted below.

TEST SUMMARY: The deionization filter allowed passage of ionic species of iron and chromium exceeding the water specification level. However, refer to NASA letters A&PS-PR-KW(LW-73-73) and SL-SW-84-73-M for acceptance of levels obtained.

Tests on two water heaters were terminated with failures after approximately 120 days each. Analysis showed the failures were due to corrosion attack of the heater element by the iodine in the water. A heater element design was tested under line item HS-94, water heater qualification test.

TEST PLAN ITEM TITLE: WATER STORAGE CONTAINER ASSY
TEST PLAN AND ITEM NUMBER: DAC 56697A; HS-8
PART NUMBER: 1T17737, 1T17745, 1T18174
TECHNICAL MEMORANDUM OR REPORT NUMBER(S): MDC G4175; TM-DSV7-F&M-R-7057, VOLS I AND II

TEST CONCLUSION: Based upon the engineering observation of the development tests and evaluation of the test results presented in the referenced report, it is concluded that the above item satisfies the design and performance requirements for the unit.

TEST SUMMARY: In Phase I, the following tests were performed on the water tank: Proof, Leak, Functional, Repeat Cycle, Vibration (with heater blanket) and Ultimate

Design Pressure. All tests were completed successfully.

In Phase II, the following tests were performed:

1. Gas pressurization panel proof, leak, vibration, functional and repeat cycle.

2. Agitator pump biocide dispersion effectiveness.

3. Heater blanket simulated space storage operation. All components passed all tests successfully.

Phase III tests obtained long term real time data and monitored changes in iodine and ionic species concentrations, gas content, microbiological and particulate levels, bellows pressure changes.

Phase IV testing was performed to establish the effectiveness, completeness and potential problem areas of the following water tank vehicle prelaunch operational procedures: Flush, steam sterilization, purge, leak pressurization, condition (100 ppm soak) and fill.

In addition, a simulated wardroom water system distribution network was used to gain data of iodine depletion times for activation and deactivation operations, and the effectiveness of ground and flight sterilization procedures.

Test results were used to establish prelaunch checkout and astronaut task procedures.

Phase V testing utilized a full scale plexiglass tank to facilitate the observation of flow patterns resulting from the injection of dye through various configurations and oreintations of dispersing ports from the agitator pump. The best configuration was then tested with iodine. The chosen configuration was tested on the actual tank in Phase II to verify the effectiveness of the agitator pump/dispersion port combination to create a homogeneous iodine mixture within the tank.

TEST PLAN ITEM TITLE: FOOD RECONSTITUTION WATER DISPENSER
TEST PLAN AND ITEM NUMBER: DAC 56697A, Line Item HS-10
PART NUMBER: 1T16973-1, -501
TECHNICAL MEMORANDUM OR REPORT NUMBER(S): TM-DSV7-F&M-R-6915

TEST SUMMARY: This development test was performed by MDAC-W, Santa Monica, CA, from March 3, 1970 through May 25, 1970 (Phase I) and September 21 through July 13, 1971 (Phase II). Phase I testing with test specimen 1T16973-1 included valve seal friction, proof pressure, leakage, function, flow pressure drop, and repeat cycles. Phase II testing with test specimen 1T16973-501, serial numbers 01 and 02 included valve and piston seal friction, proof pressure, leakage, function, flow rate and pressure drop, repeat cycles, biocide compatibility, sterilization temperature, and interface compatibility.

TEST CONCLUSION:

1. Phase I testing satisfactorily demonstrated the feasibility of developing Phase II hardware.

2. Piston seal leakage and friction were considered marginal. Further testing

TABLE 2.2.11.2-5 (CONTINUED)

was accomplished per Line Item W-STM-20. This testing demonstrated satisfactory seal performance.

The units satisfactorily passed all other testing.

TEST PLAN ITEM TITLE: DRINKING WATER DISPENSER
TEST PLAN AND ITEM NUMBER: DAC 56697A; Line Item HS-11
PART NUMBER: 1T17904-1, 1T16864-503
TECHNICAL MEMORANDUM OR REPORT NUMBER(S): TM-DSV7-F&M-R6938

TEST SUMMARY: This development test was performed by MDAC-W, Santa Monica, CA, from February 2 through March 6, 1970 (Phase I), and September 30 1970 through August 14, 1971 (Phase II). Phase I testing, on specimen 1T16864-503, included valve seal friction, function, relief pressure, leakage, force requirements, repeat cycles, and flow. Phase II testing on specimen 1T17904-1, S/N 01 and 02 included function, proof and relief pressure, operating torque, operating time, dispensed volume accuracy, leakage, seal friction, and repeat cycles.

TEST CONCLUSION:

1. Phase I testing satisfactorily demonstrated the feasibility of developing Phase II hardware.

2. The units satisfactorily passed all test requirements.

TEST PLAN ITEM TITLE: WATER HEATER
TEST PLAN AND ITEM NUMBER: DAC 56697; Line Item HS-12
PART NUMBER: 1B78356-1, -501
TECHNICAL MEMORANDUM OR REPORT NUMBER(S): Hamilton Standard Report No. SVHSER 5728, VOL I, VOL I SUPPLEMENT NO. 1, VOL II and VOL III (MDC G3945)

TEST SUMMARY: This development test was performed by the Hamilton Standard Division of United Aircraft Corporation, Windsor Locks, Conn, from October 14, 1970 through February 15, 1971, on P/N SV729650-3, Serial Nos. 00001 and 00002. Testing included proof, yield, burst, and collapse pressures, leakage, flow, EMI, biocide compatibility, water temperature, touch temperature, power consumption, vibration, thermal environment, start up and recovery times, and steam sterilization.

TEST CONCLUSION: The units satisfactorily passed all phases of testing.

TEST PLAN ITEM TITLE: WATER PURIFICATION EQUIPMENT
TEST PLAN AND ITEM NUMBER: DAC 56697A, HS-14
PART NUMBER: 1T18302-1
TECHNICAL MEMORANDUM OR REPORT NUMBER(S): MDC G4156; TM-DSV7-F&MpR-7058

TEST CONCLUSION: The water purification equipment, which includes an iodine container, reagent container, waste container, iodine injector, water sampler and color comparator, successfully passed the design requirements of function, proof and design burst pressures, leakage, vibration, repeat cycle, biocide compatibility, bending and impact loads. Further tests will be performed during test line item

TABLE 2.2.11.2-5 (CONTINUED)

HS-7 to qualify the equipment for use on board the OWS flight vehicle.

TEST SUMMARY: Vibration tests caused failures of the following parts requiring the noted rework:

1. Color comparator came loose from its support as a result of low torque on the cal-fax fasteners. The torque was subsequently increased and no further problems occurred.

2. The water sampler loosened in its launch restraint. The restraints were reworked and no further problems were encountered.

3. The iodine container failed as the result of the bellows rubbing on the container wall. A bellows restraint was added and no further problems occurred on subsequent tests.

4. The waste container bellows also leaked as a result of bellows/container wall scrubbing. Analysis revealed that the bellows was unnecessary and therefore was eliminated.

Three failures occurred during testing of the iodine injector. Two of the failures involved the bellows requiring the addition of a bellows sleeve guide and a change from 316 L stainless to hasteloy C material for compatibility with 30,000 ppm iodine. The other failure was the result of screw thread galling which was solved by applying lubricant to threads.

TEST PLAN ITEM TITLE: DISPENSER ASSEMBLY, WATER, PERSONAL HYGIENE
TEST PLAN AND ITEM NUMBER: DAC 56697A; HS-16
PART NUMBER: 1T18127-1
TECHNICAL MEMORANDUM OR REPORT NUMBER(S): TM-DSV7-F&MpR-6760

TEST SUMMARY: Tests were performed to determine:

1. Valve Leakage
2. Valve Proof Pressure
3. Valve Burst Pressure
4. Flow Rate
5. Outlet Velocity Acceptable for Washcloth Wetting
6. Force Required for Operation
7. Life Cycles

TEST CONCLUSION:

1. Leakage was acceptable (no bubbles in two minutes).
2. There was no visible leakage or deformation during proof pressure (80 psig) (552 kN/m^2).
3. There was no visible leakage or deformation during burst pressure (160 psig) (1104 kN/m^2).
4. Flow rate was 1.16 in^3/sec (19 cc/sec) with 35 psig (241 kN/m^2) water applied to valve inlet.
5. Outlet velocity and water spread were acceptable for washcloth wetting.

TABLE 2.2.11.2-5 (CONTINUED)

6. Force required to fully open valve with 35 psig (241 kN/m^2) water pressure was 36 ounces (10 N).

7. There were no signs of wear or abnormal conditions after 20,000 cycles.

TEST PLAN ITEM TITLE: WATER STORAGE CONTAINER BELLOWS
TEST PLAN AND ITEM NUMBER: DAC 56697A; HS-32
PART NUMBER: 1B79099, D52310
TECHNICAL MEMORANDUM OR REPORT NUMBER(S): MDC G3611

TEST SUMMARY: This test specimen consisted of a bellows assembly installed in a cylinder simulating a production water container. The bellows was subjected to proof and ultimate pressure tests, leak, spring rate and cycle testing. It was cycled under various position and loading conditions.

TEST CONCLUSION: The HS-32 test was completed successfully. All of the design requirements were met and the bellows assembly is determined to be satisfactory for production release.

NOTE: Although the vendor recommended that the bellows be proofed and leak checked at 15 psid (103 kN/m^2), MDAC did not concur and maintained $41.0^{+0}_{-.5}$ psid ($283^{+0}_{-3.4}$ kN/m^2) for proof and $5.0^{+0}_{-.5}$ psid ($34.5^{+0}_{-3.4}$ kN/m^2) for leak check. Since a limited number of bellows were made, a high level of confidence could be established only by proofing each bellows to the design requirements.

TEST PLAN ITEM TITLE: WASHCLOTH SQUEEZER
TEST PLAN AND ITEM NUMBER: DAC 56697A; HS-48
PART NUMBER: 1T19863, 1T19816, 141 00023
TECHNICAL MEMORANDUM OR REPORT NUMBER(S): TM-DSV7-SSL-R-7062

TEST SUMMARY: The washcloth squeezer test consisted of tests of the washcloth squeezer, squeezer bags, and dump filter. The squeezer was functionally tested and life cycled. Its capacity for proper function throughout the OWS mission was demonstrated. The squeezer bags maintained their leak tight integrity after exposure to the pressure changes anticipated for OWS. The dump filter functioned properly even after the volume of wash water equivalent to that expected for a 28-day mission had flowed through it.

TEST CONCLUSION: All tests were successfully completed. The only problems occurred during the life cycle testing of the washcloth squeezer. Some of the rotating parts showed evidence of galling after 5000 cycles. Plating and material changes were incorporated and no further problems were encountered.

TEST PLAN ITEM TITLE: URINE SEPARATOR FLUSH DISPENSER ASSY
TEST PLAN AND ITEM NUMBER: DAC 56697A; HS-56
PART NUMBER: 1T41789-1
TECHNICAL MEMORANDUM OR REPORT NUMBER(S): TM-DSV7-F&MpR-6989, REV A

TEST SUMMARY: This development test was performed at MDAC-WD, Fluids and Mechanical Laboratories at Santa Monica, CA. The purpose of the test was to verify that the urine flush dispenser assembly would meet design requirements established for OWS use. The dispenser was subjected to proof, leakage, functional, vibration, flow

TABLE 2.2.11.2-5 (CONTINUED)

differential pressure, repeat cycle and burst pressure. Prior to development testing, Product Acceptance Test (PAT) was performed on the dispenser per 1B[illegible] which resulted in a rework of the dispenser to decrease the dispenser time. After rework, the dispense time was reduced to 3.3 seconds which was below the 4.0 seconds design requirement. During development test all design requirements were met, except that during repeat cycling a particle got lodged between the valve and valve housing resulting in stoppage of trigger mechanism. Upon disassembly and removal of particle, the unit was reassembled and repeat cycling continued. No further problem developed and repeat cycling was completed.

TEST CONCLUSION:

1. The dispenser assembly functioned satisfactorily throughout all testing except for the noted particle lodging in the valve mechanism.

2. The shuttle valve controlling flow quantity functioned satisfactorily and showed very little wear at test completion.

TEST PLAN ITEM TITLE: WATER DEIONIZATION ASSEMBLY DEVELOPMENT TEST HS-59
TEST PLAN AND ITEM NUMBER: DAC 56697A; HS-59
PART NUMBER: 1T42111
TECHNICAL MEMORANDUM OR REPORT NUMBER(S): MDC G4181; TM-DSV7-F&M-A-7063

TEST CONCLUSION: Based on the engineering evaluation of the development test results presented in the referenced report, it is concluded that the above item satisfies the design and performance requirements for the item.

TEST SUMMARY:

1. Vibration tests caused failure of the mount assembly requiring redesign in order to redistribute the loads, primarily to the floor grid support beams rather than the grid itself.

2. The seals in the deionization cartridge were changed from a food grade viton to a food grade silicone material. This change resulted in reduced permanent compression set characteristics for the seals and eliminated the previous seal leakage problem.

3. The seal groove on the thermal expansion chamber was made deeper to increase the retention of the packing in the seal groove.

4. **The resin volume was reduced from 221 in^3 to 66 in^3 (3622 to 1082 cc) (30% original volume) to overcome the excessive iodine depletion rate experienced with the higher resin volume.**

2/ List of Waivers and Deviations to Specifications - A deviation was obtained (SCN 226) to allow touch temperatures of 115°F (46.1°C) on the personal hygiene water heater dump quick-disconnect and 135°F (57.2°C) on the wardroom water heater dump quick-disconnect. The requirement is a maximum touch of 105°F (40.6°C).

Qualification test data showed that iron and chromium would exceed specification limits during the second OWS mission. NASA Letter A&PS-PR-KW (LW-73-73) dated March 13, 1973 indicated that the anticipated iron and chromium levels would not cause a medical problem.

There are no other approved system performance waivers or deviations except those related to materials offgassing and materials flammability.

3/ Factory Checkout - Factory checkout of the water system is covered in Section 5.0.

4/ Launch Preparations at KSC - Launch preparations of the water system are covered in Section 5.0.

D. Mission Results - The results of the water system use during the Skylab (SL) mission were generally as expected. The mission section results include the water loaded, allocation and usage, the water storage and treatment, the water distribution, and the system hardware performance.

1/ Water Management

a. Amount of Water - The following is a detailed accounting of the amount of water aboard the Orbital Workshop (OWS) for utilization during SL-2, SL-3, and SL-4:

Tank No		Loaded H_2O/ Tank Lbs (kg)	Expellable H_2O/ Tank Lbs (kg)
1		661.2 (299.92)	595.2 (269.98)
2		661.1 (299.87)	595.1 (269.93)
3		661.2 (299.92)	595.2 (269.98)
4		655.6 (297.38)	589.6 (267.44)
5		655.6 (297.38)	589.6 (267.44)
6		660.2 (299.46)	594.2 (269.52)
7		662.0 (300.28)	596.0 (270.34)
8		658.8 (298.83)	592.8 (268.89)
9		638.4 (289.57)	572.4 (259.64)
10		661.6 (300.00)	595.6 (270.16)
	Total	6575.7 (2982.71)	5915.7 (2683.32)

b. Water Allocation - The water tanks carried aboard the OWS were allocated for use as follows:

Tank No	Sequential Usage
1	First Wardroom Tank (SL-2
2	Third Wardroom Tank (SL-3 and SL-4)
3	Fourth Wardroom Tank (SL-4)
4	Fifth Wardroom Tank (SL-4)
5	Sixth Wardroom Tank (SL-4)
6	Urine Flush/Contingency Tank/Fire Hose
7	First Waste Management Compartment (WMC) Tank (SL-2 and SL-3)
8	Second WMC Tank (SL-3 and SL-4)
9	Contingency (Wardroom or Waste Management) Extra-vehicular Activity (EVA) Suit Loop
10	Second Wardroom Tank (SL-3)

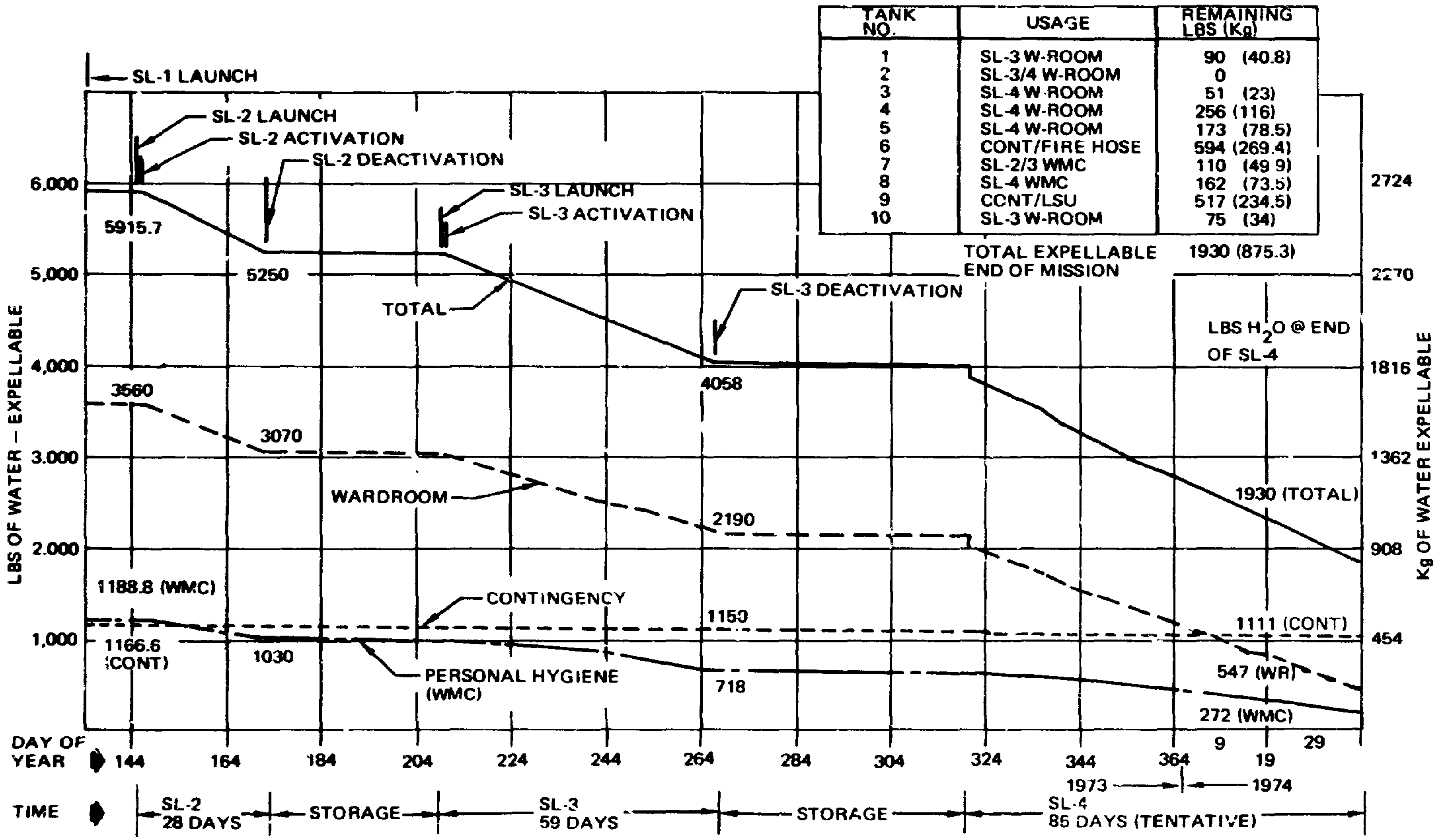
b. Tank Usage - Figure 2.2.11.2-51 shows the total water usage throughout the three missions. Figures 2.2.11.2-52 through -56 show the water total remaining for individual water tanks. Figures 2.2.11.2-57 through -65 show the drinking water (only) consumption history for each crewman. Table 2.2.11.2-1 shows the planned water budget. The budget averages out at 23.2 lbs/day (10.55 kg/day). Based upon total water used as shown on Figure 2.2.11.2-51, the percentage of water used of that allocated was 67 percent for SL-2, 69 percent for SL-3, and 72 percent for SL-4. (SL-4 allocation adjusted for 85-day mission.)

2/ Water Storage and Treatment

a. Water Tanks - The water tanks on the OWS were designed to supply the potable water for use in the Wardroom and the wash water for use in the WMC.

The water tanks loaded with water successfully survived the launch environment and its anomalies with no apparent problems. There was concern about the integrity of the water tanks during the unmanned flight of the Saturn Workshop (SWS) until SL-2 crew arrived, because of the high temperature in the vehicle. The fear was that elevated temperatures would cause the water to expand and damage the gas/water dome or bellows.

After arrival of the SL-2 crew and the deployment of the sun shade, the vehicle and water temperatures began to drop. The crew readily activated Tank Nos. 1 and 7 and no problems or anomalies were reported during the SL-2 mission.



TANK NO.	USAGE	REMAINING LBS (Kg)
1	SL-3 W-ROOM	90 (40.8)
2	SL-3/4 W-ROOM	0
3	SL-4 W-ROOM	51 (23)
4	SL-4 W-ROOM	256 (116)
5	SL-4 W-ROOM	173 (78.5)
6	CONT/FIRE HOSE	594 (269.4)
7	SL-2/3 WMC	110 (49 9)
8	SL-4 WMC	162 (73.5)
9	CONT/LSU	517 (234.5)
10	SL-3 W-ROOM	75 (34)
	TOTAL EXPELLABLE END OF MISSION	1930 (875.3)

Figure 2.2.11.2-51. Water Usage – Skylab Missions

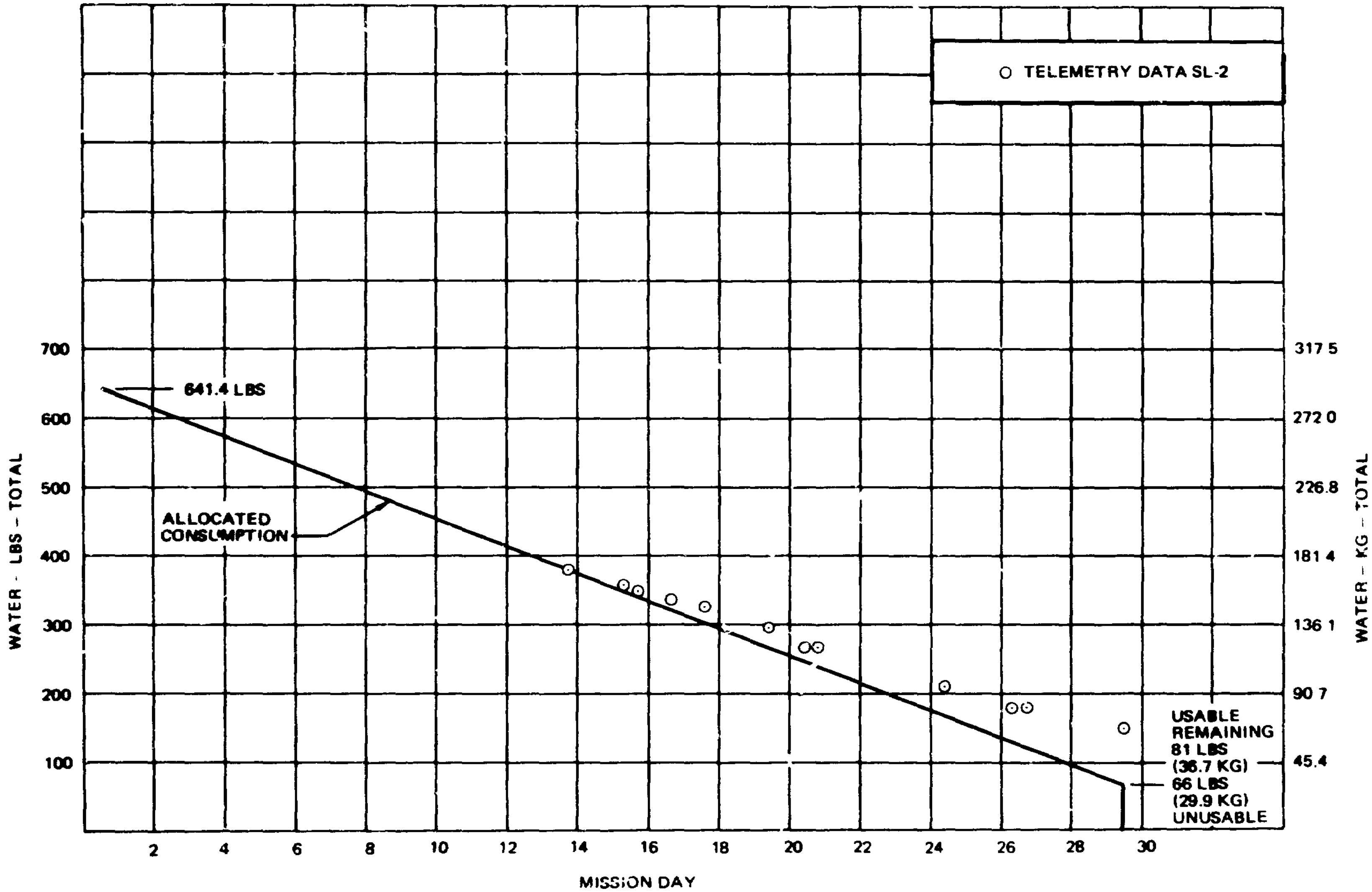


Figure 2.2.11.2-52. Water Consumption Tank 1 SL-2 Wardroom

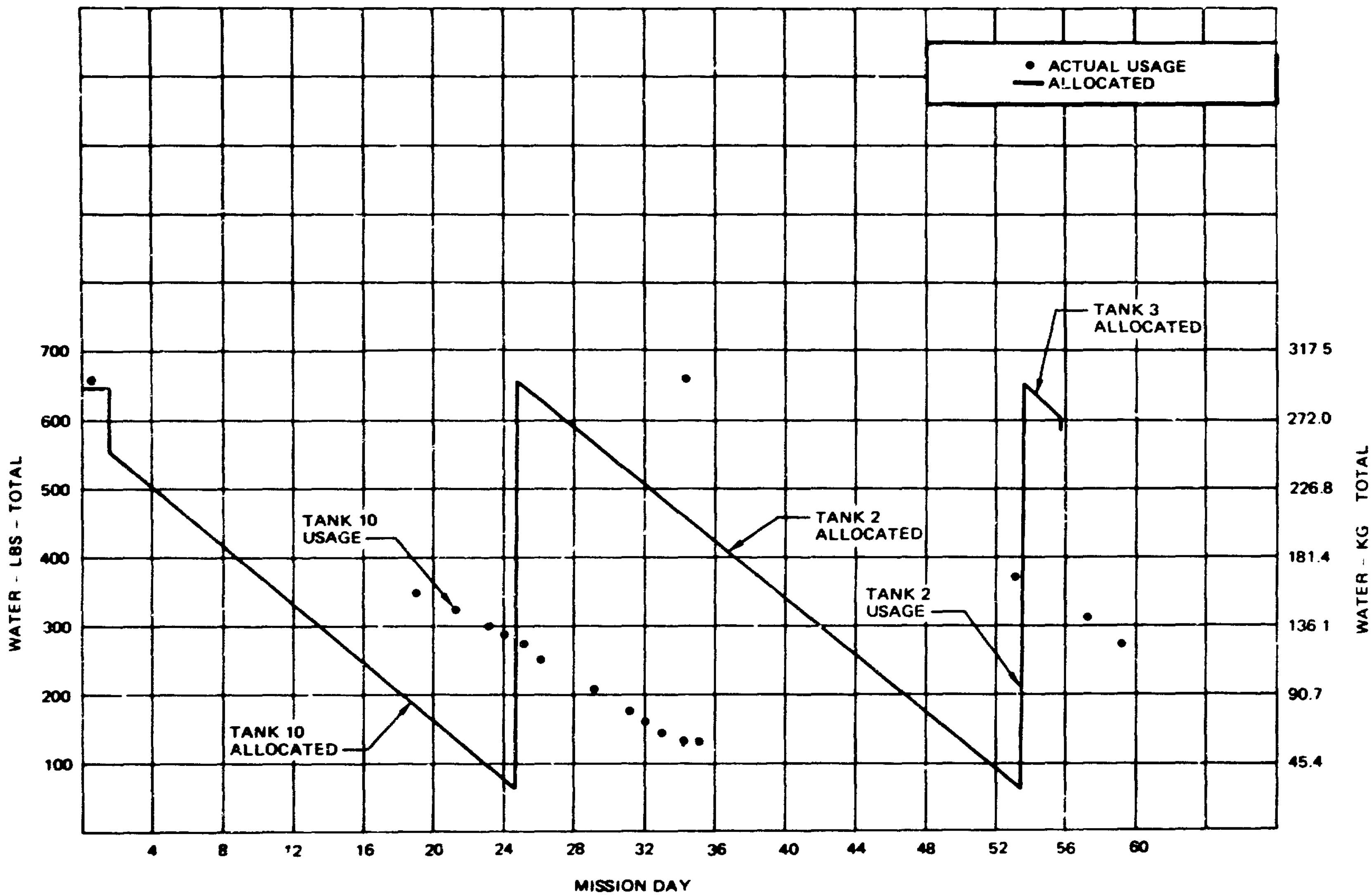


Figure 2.2.11.2-53. Water Consumption Tanks 10 and 2 SL-3 Wardroom

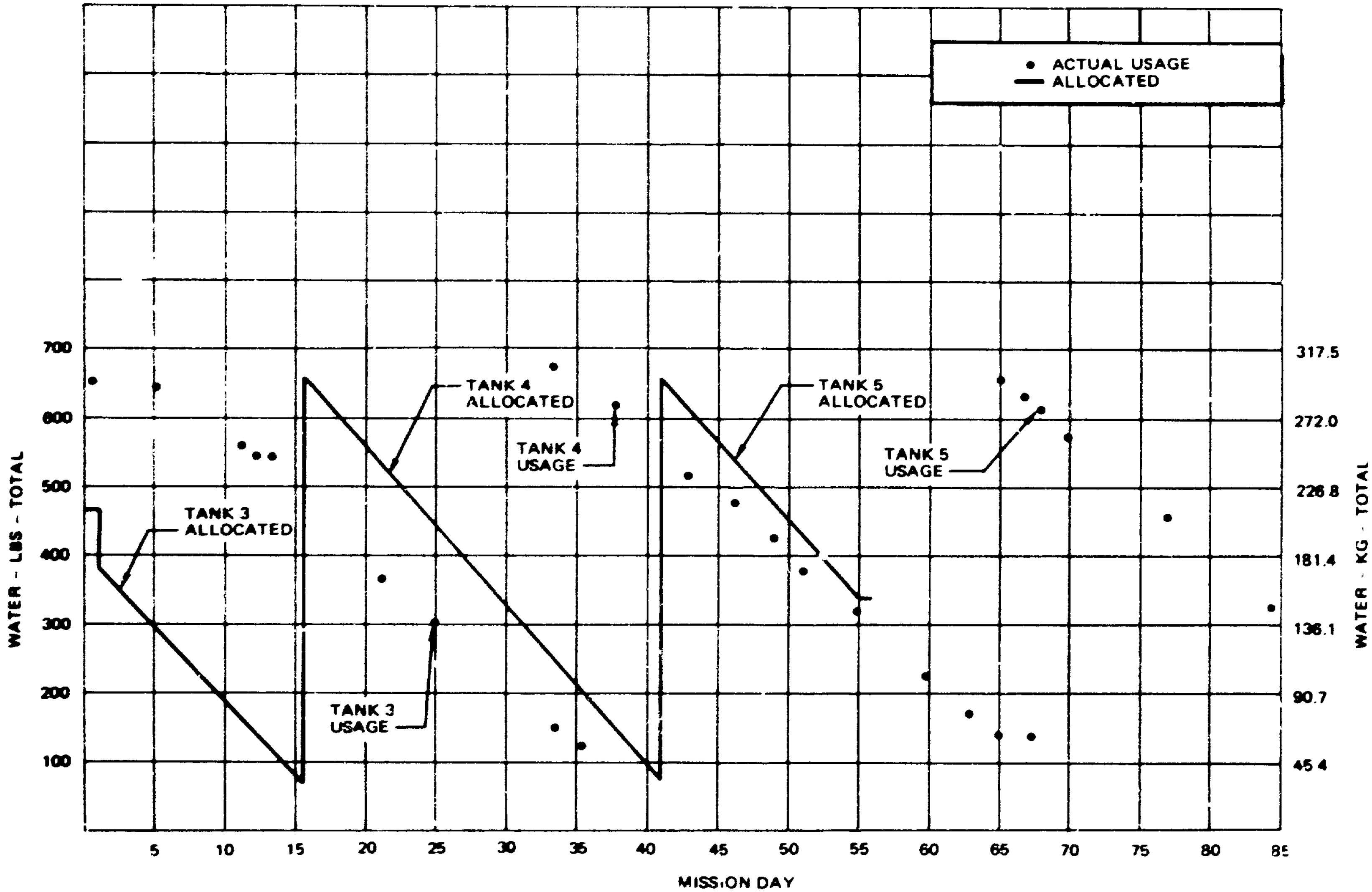


Figure 2.2.11.2-54. Water Consumption Tanks 2, 3, 4 and 5, SL-4

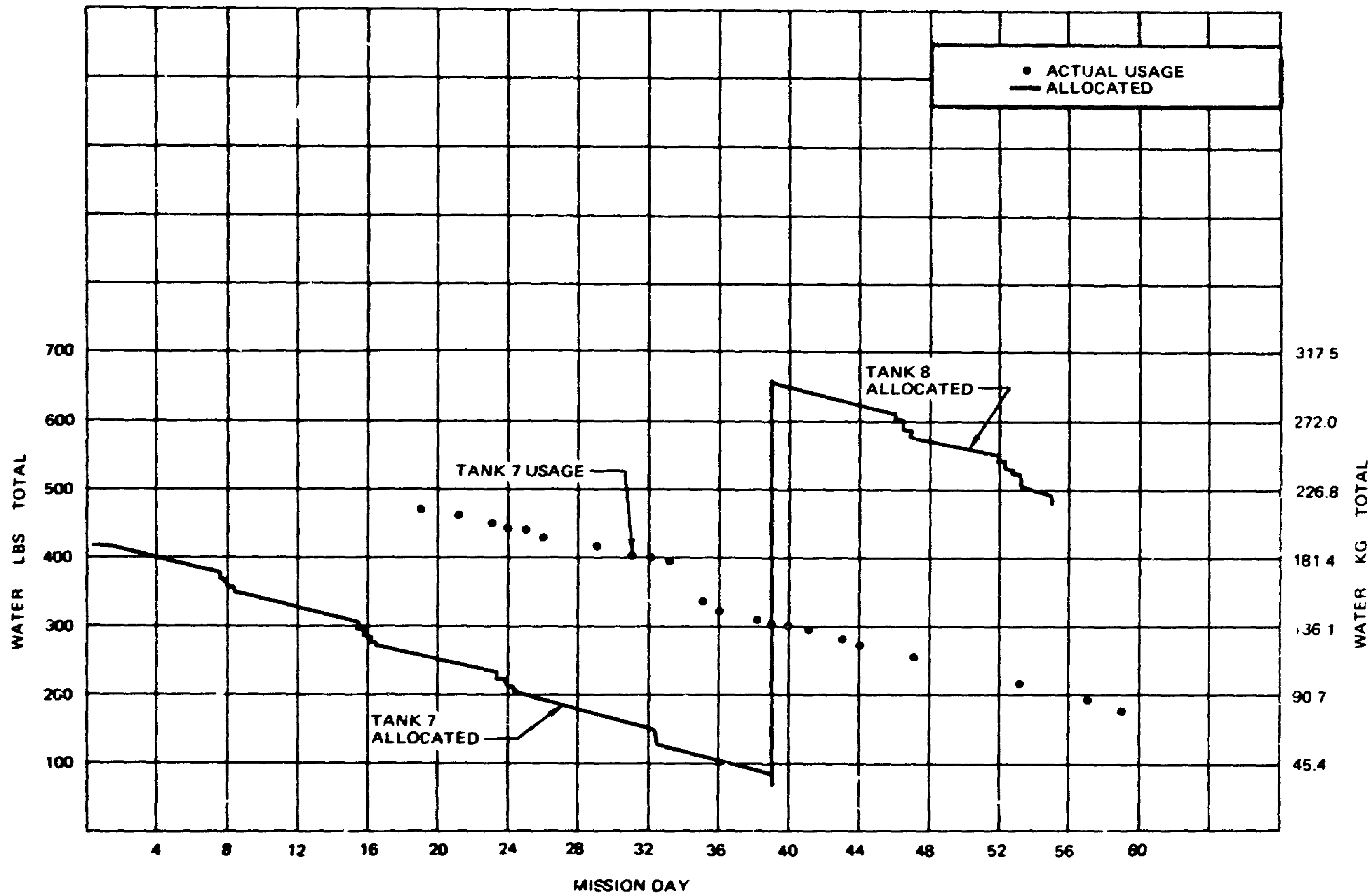


Figure 2.2.11.2-55. Water Usage Tank 7, SL-3 Personal Hygiene

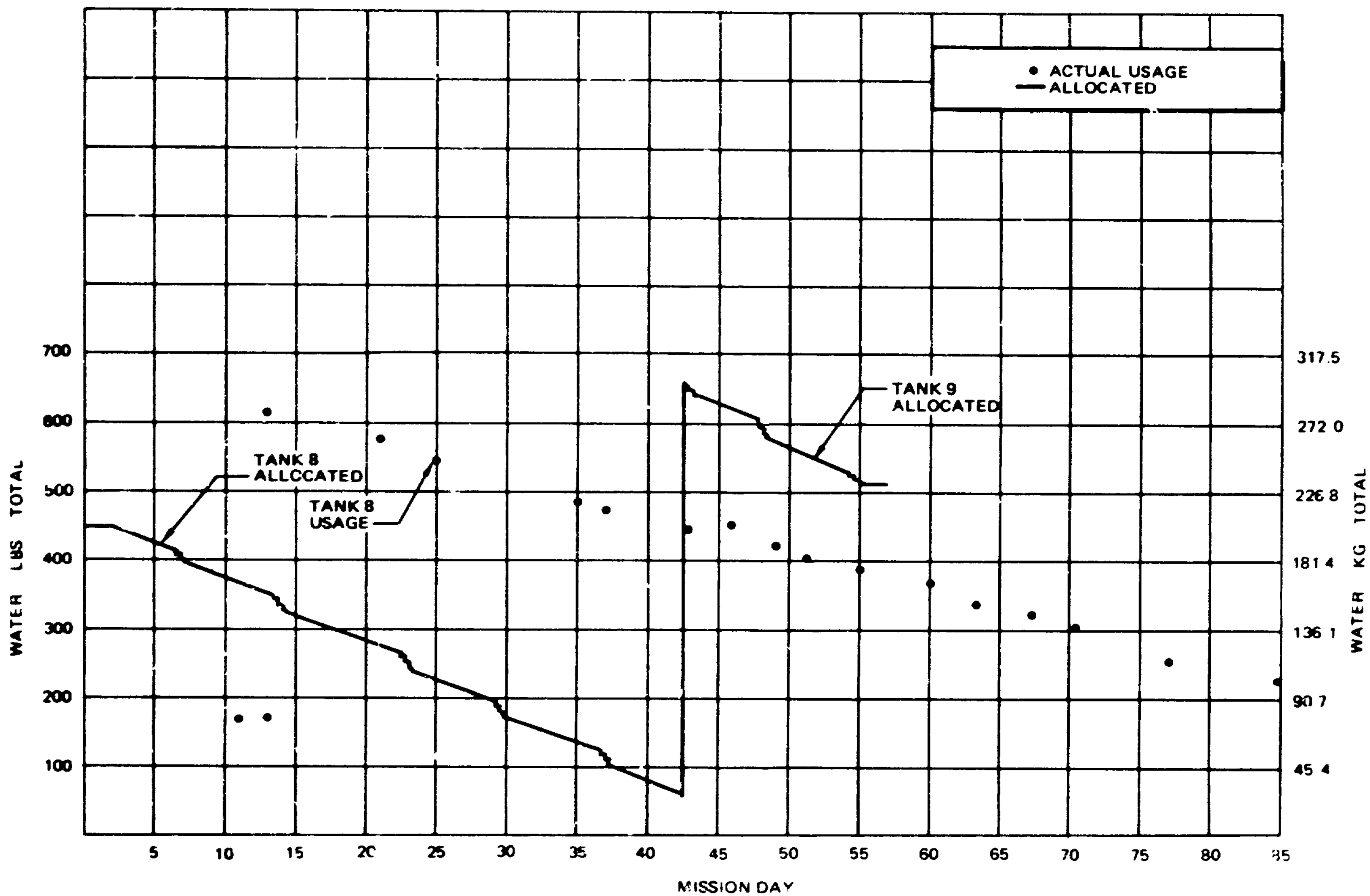


Figure 2.2.11.2-56. Water Usage Tanks 7 and 8, SL-4 Personal Hygiene

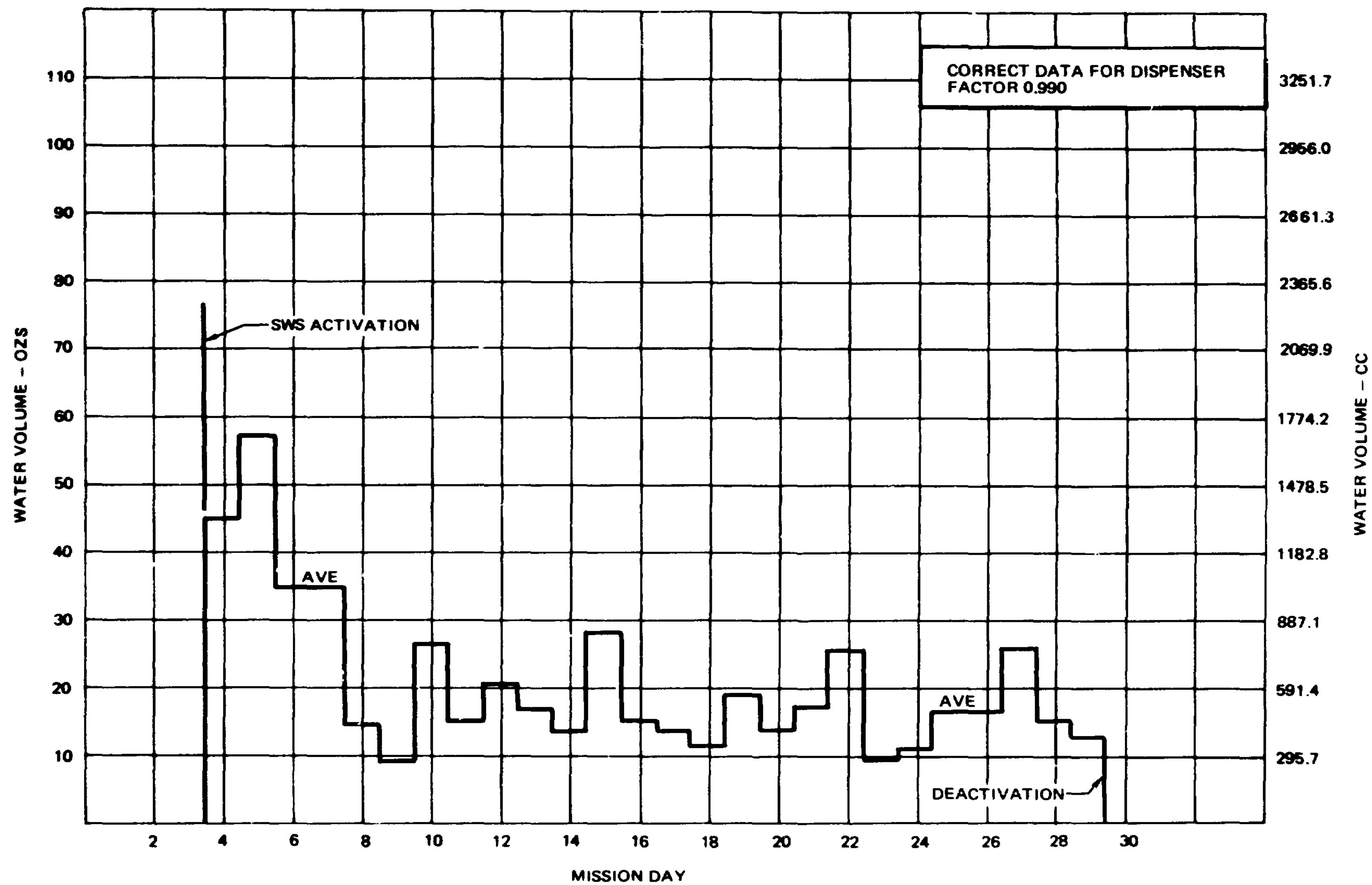


Figure 2.2.11.2-57. Daily Drinking Water Consumption CDR SL-2

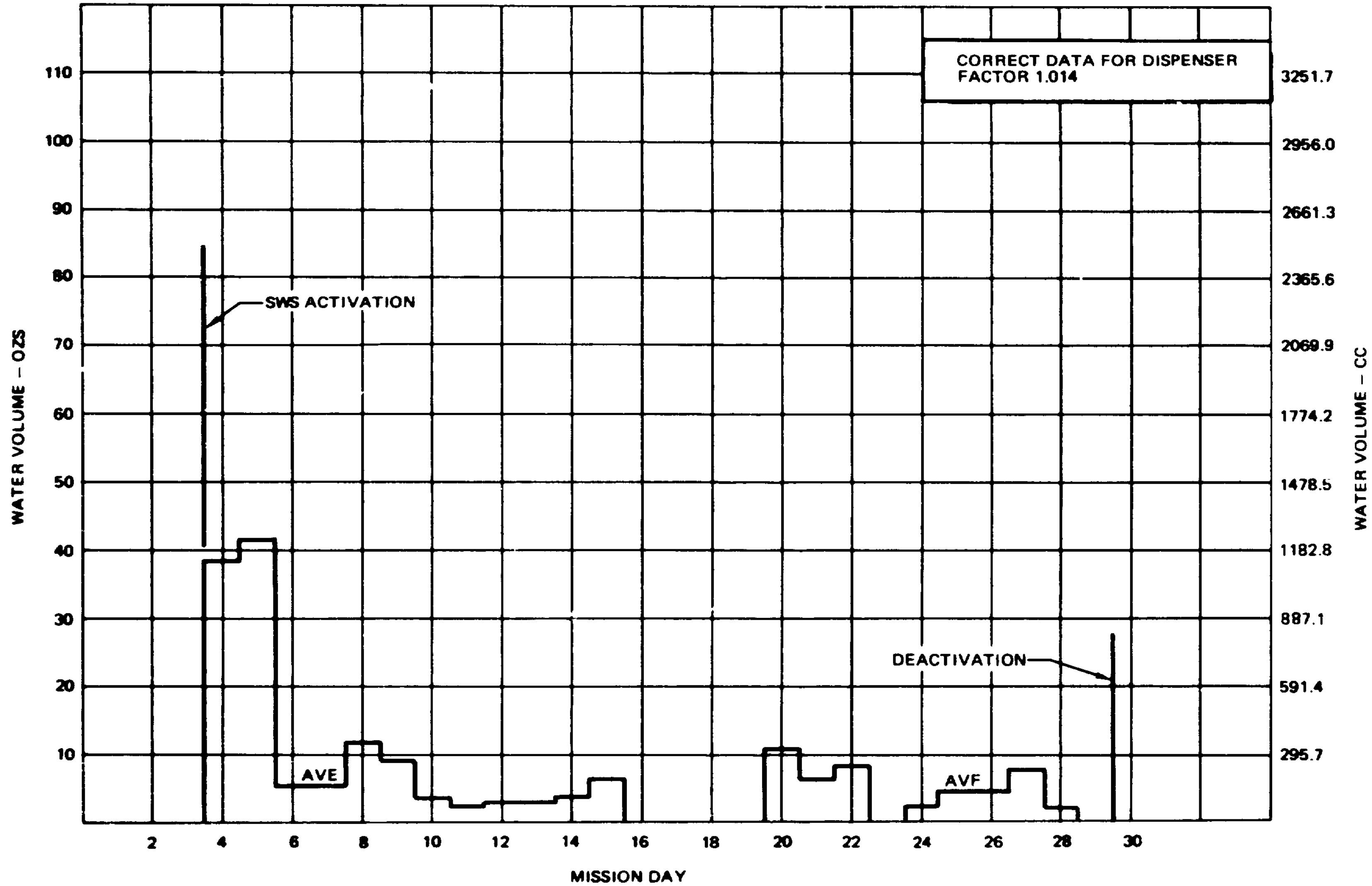


Figure 2.2.11.2-58. Daily Drinking Water Consumption SPT – SL-2

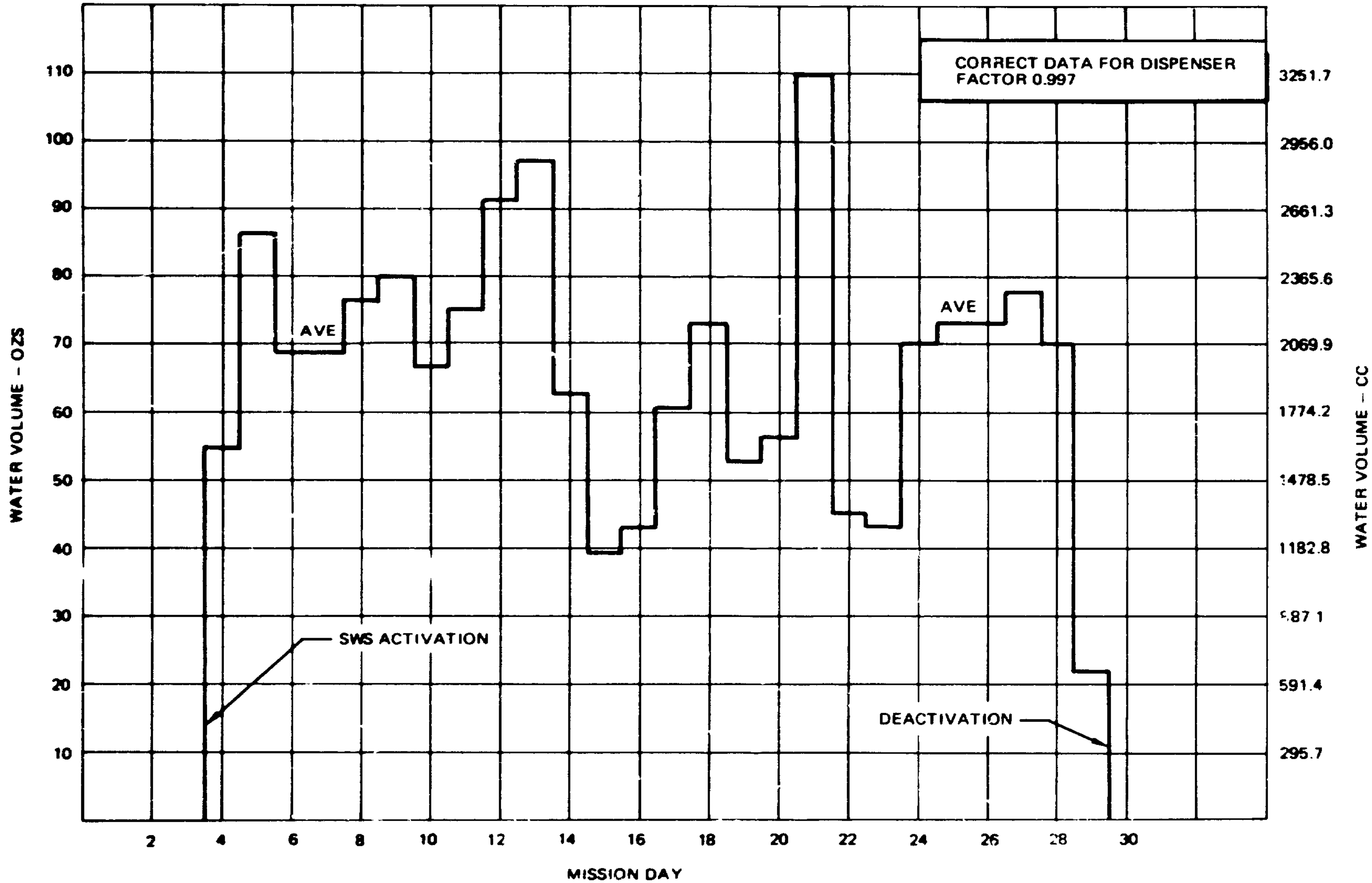


Figure 2.2.11.2-59. Daily Drinking Water Consumption PLT – SL-2

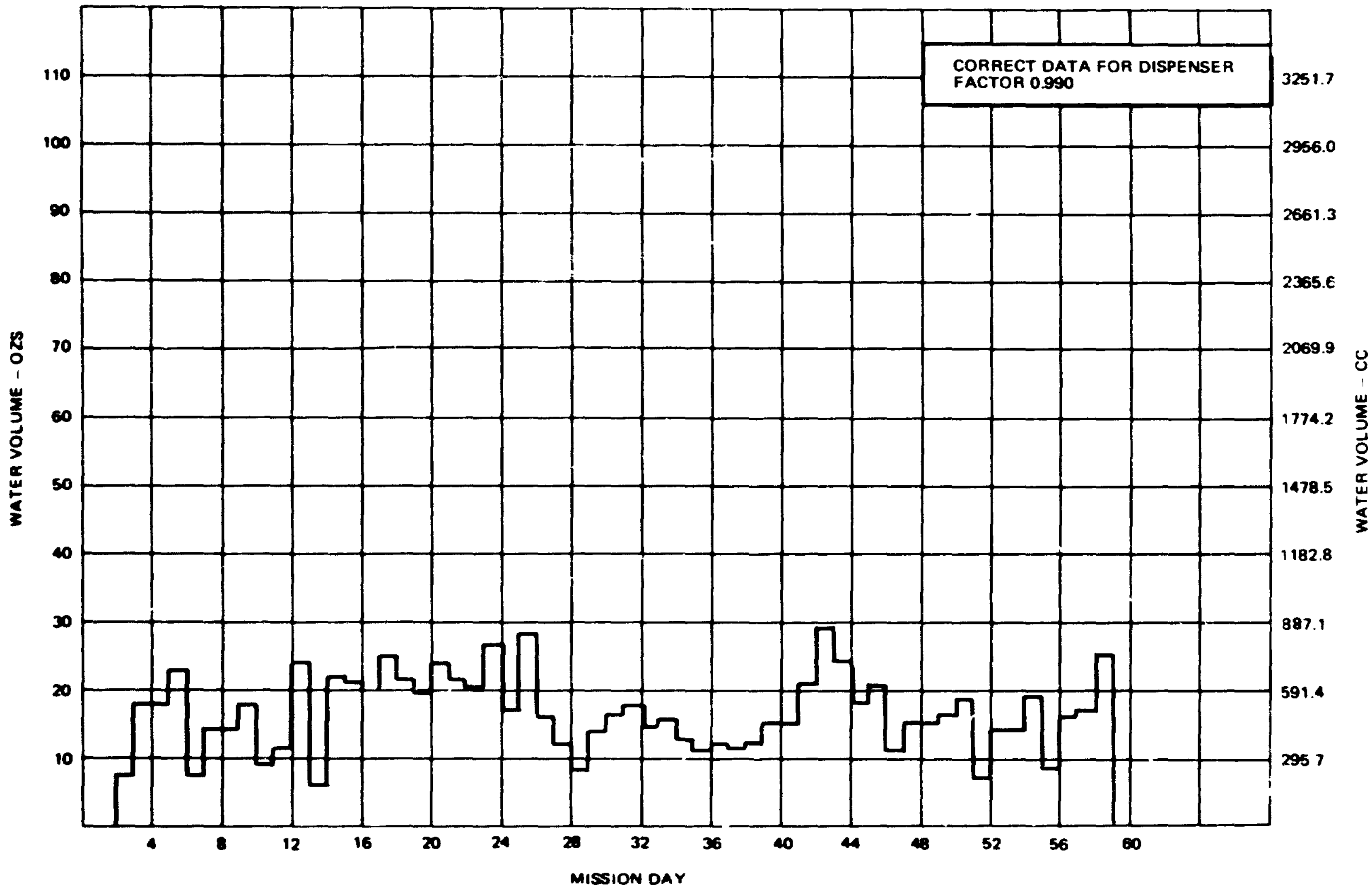


Figure 2.2.11.2-60. Daily Drinking Water Consumption CDR – SL-3

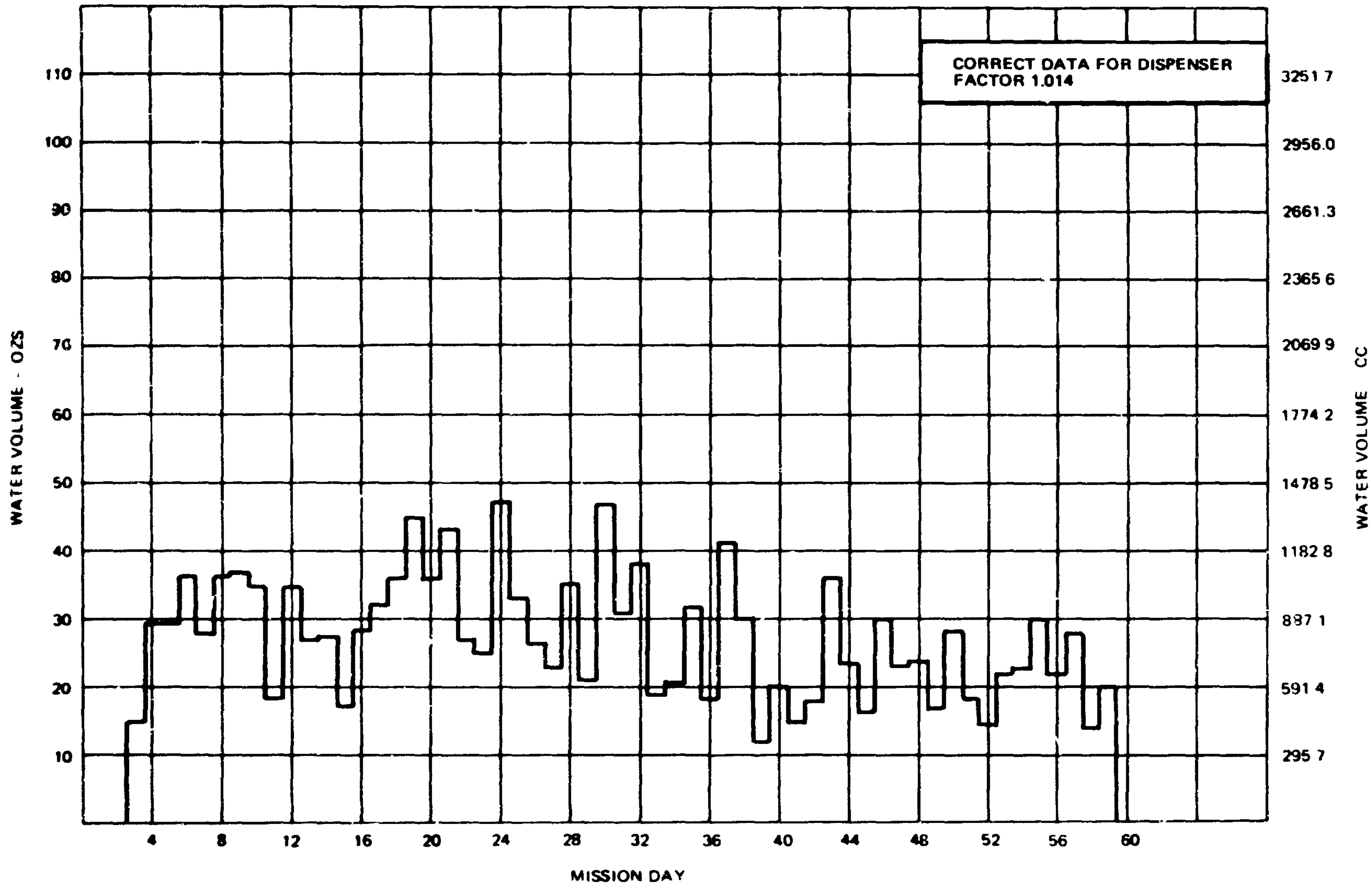


Figure 2.2.11.2-61. Daily Drinking Water Consumption SPT – SL-3

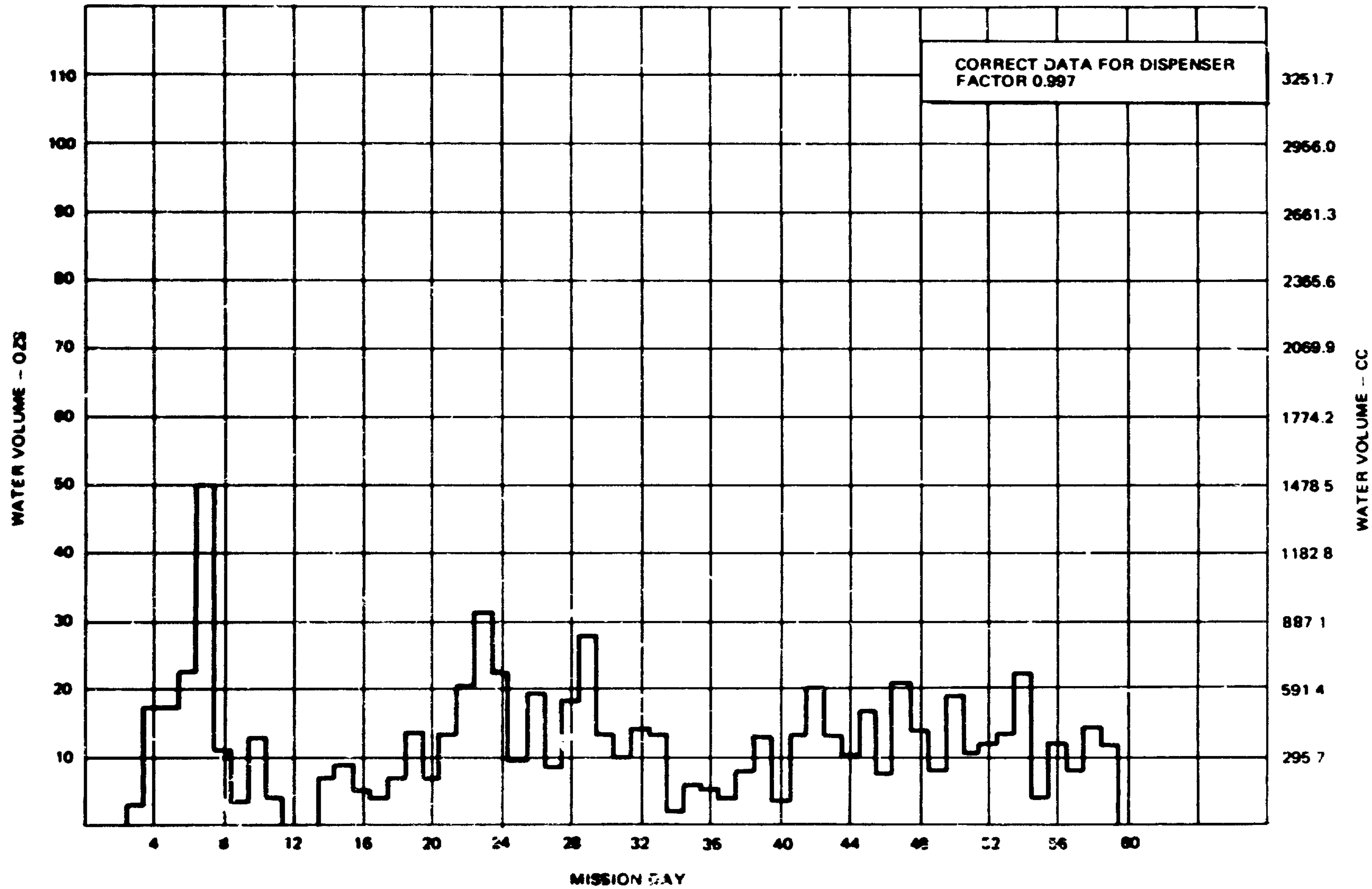


Figure 2.2.11.2-62. Daily Drinking Water Consumption PLT – SL-3

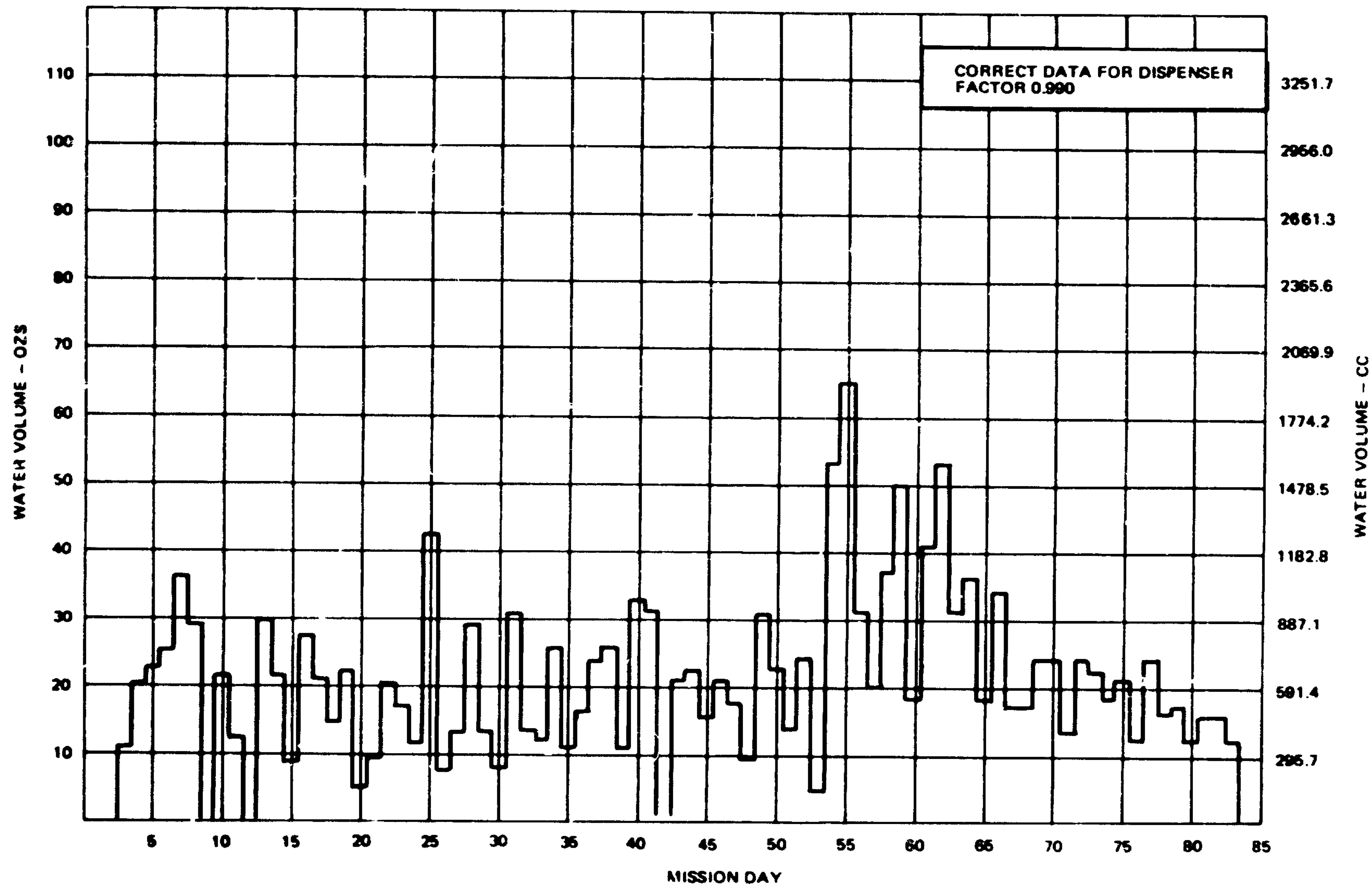


Figure 2.2.11.2-63. Daily Drinking Water Consumption CDR – SL-4

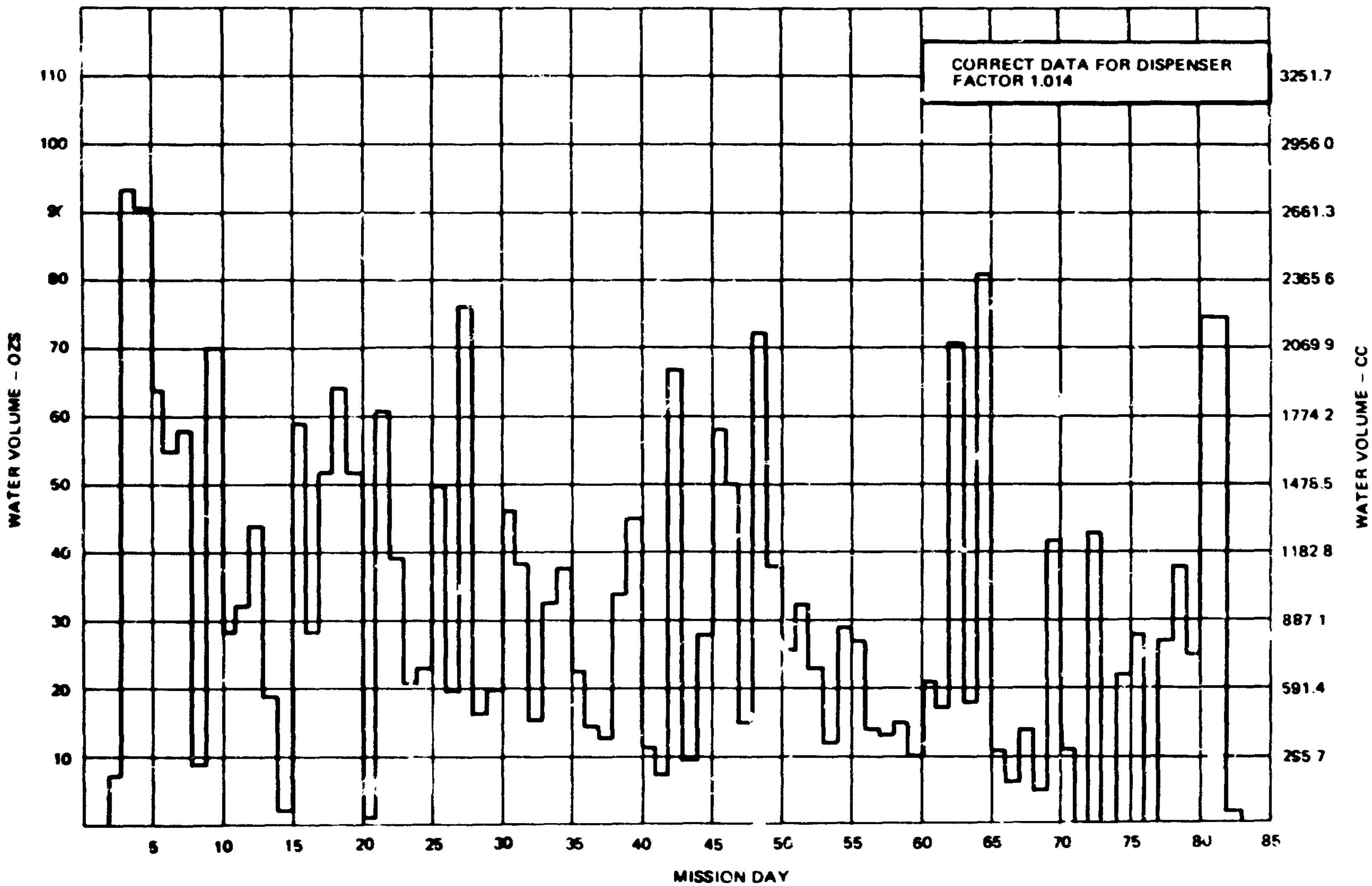


Figure 2.2.11.2-64. Daily Drinking Water Consumption SPT – SL-4

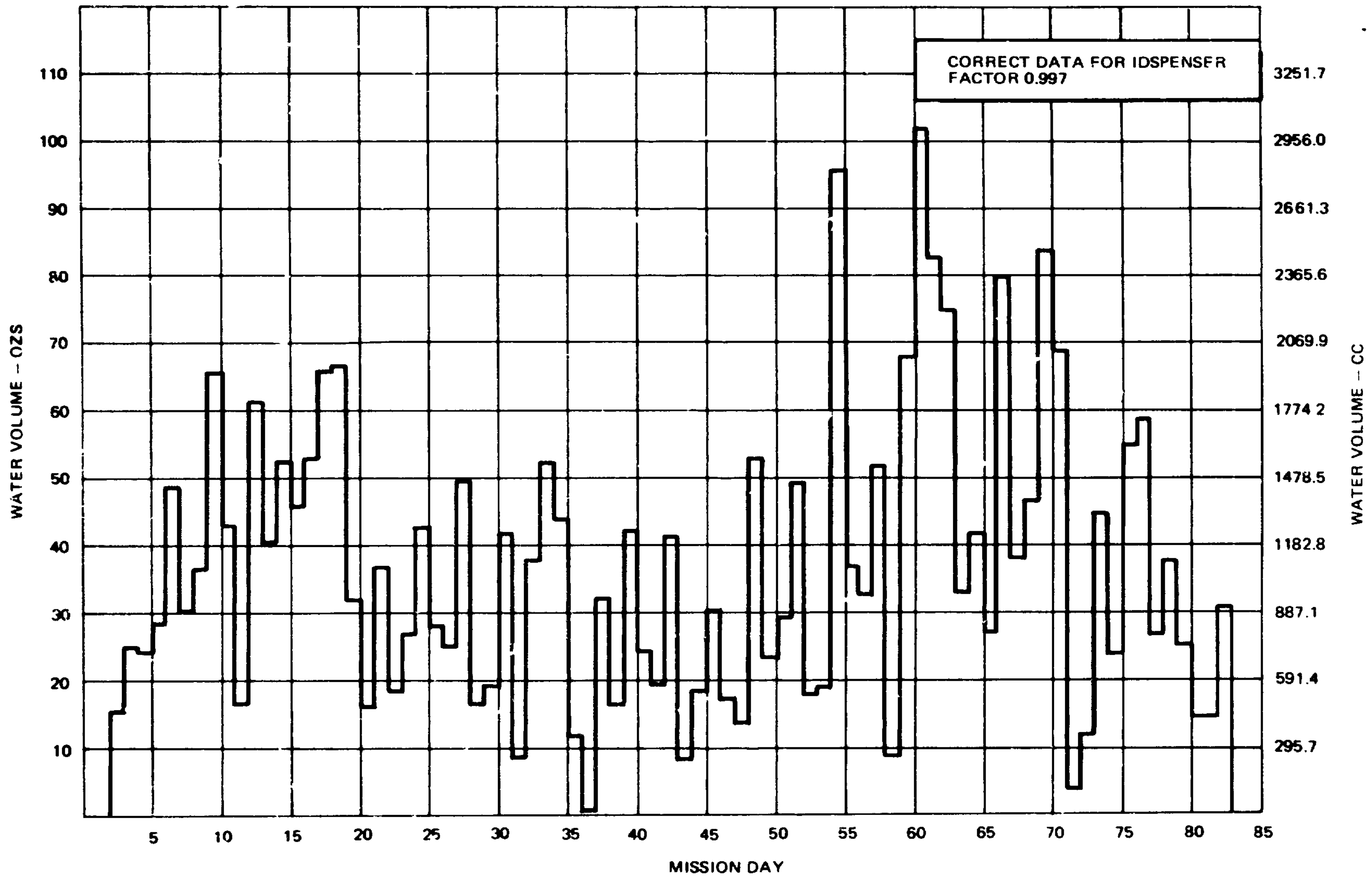


Figure 2.2.11.2-65. Daily Drinking Water Consumption PLT – SL-4

Water tanks were activated during the missions when required with no problems.

b. Blanket Heaters - The water tank blanket heaters were designed to maintain the water in the water tanks above 55°F (12.8°C) during the periods between the manned missions (SL-2, SL-3, and SL-4).

The water tank heaters were not operated during the SL-2 mission because they were not required due to the elevated ambient temperature within the vehicle. The water tanks, being a large thermal mass, were one of the factors contributing to he slow cool down of the vehicle elevated temperature after deployment of the sun shade. Because of the vehicle thermal problems, the heater blankets were not activated on the departure of the SL-2 crew. No problems or anomalies were reported during the SL-2 mission.

The water tank heaters were also not operated during any mission because they were not required due to the elevated ambient temperature within the vehicle. No problems or anomalies were reported during any mission.

c. N_2 Distribution Network - The N_2 distribution network for the water system provides a regulated gas supply at 35 psig (241 kN/m²) to each of the water tanks so that water will be available on demand. The source of the N_2 distribution network gas supply is the 4000 psig (27579 kN/m²) N_2 tanks in the Airlock Module (AM) which is regulated to 150 psig (1034 kN/m²) in the AM and then to 35 psig (241 kN/m²) as a part of the OWS N_2 distribution network. The crew readily activated the N_2 distribution network (for SL-2) with no reported problems or anomalies; however, earlier there was concern that the supply line from the AM might have been damaged when the Meteoroid Shield (MS) was torn away during launch. Concern has also been expressed about the vulnerability of this supply line to meteoroid strikes, but the probability of occurrence is low.

The regulated system pressure of 35 psig (241 kN/m^2) was verified in flight by attaching the portable water bottle (gas side) to the system and reading the gage on the bottle.

There were no problems or anomalies reported during the SL-2 mission.

During the unmanned period between SL-2 and SL-3, it was noted from telemetry (TM) that the 35 psig (241 kN/m^2) water tank gas pressure had decreased to 34 psig (234 kN/m^2). Investigation of the problem verified the position of supply shutoff valves and confirmed that the 4000 psig (27579 kN/m^2) source valve was shut off. Telemetry disclosed that the 150 psig (1034 kN/m^2) regulated locked up supply pressure had decreased to 4 psig (2.76 kN/m^2). Considering the volume of the backed up gas pressures, the decrease in the 35 psia (241 kN/m^2) water tank gas pressure is attributed to nominal allowable external gas leakage and no problem exists with the water pressurization system.

The pressure network was activated for SL-3 and SL-4 with no problems. There were no problems or anomalies reported during the SL-3 or SL-4 mission.

d. Tank N_2 Gas Chamber - The water tank N_2 gas chamber consists of a dome and metallic bellows in each of the water tanks. At launch each of the tank N_2 gas chambers was pressurized to 35 psig (241 kN/m^2) and then the gas pressurization valve on each tank was closed. On orbit during crew activation, the gas pressurization valves on the tanks in use were opened with all other tank valves remaining closed.

e. Biocide Management - Each of the water tanks was initially charged with an iodine (I_2) solution until the I_2 concentration in each tank was approximately 12 ppm. The I_2 concentration in the water system will decrease as a function of time and during dispensing because of the I_2 reacting to form iodides while in contact with various metal surfaces and while passing through the cation bed. The I_2 concentration of the water delivered for consumption will normally be a maximum of 6 ppm because of these losses.

From a biological viewpoint, in order to provide safe drinking water, the I_2 concentration must be 0.5 ppm or greater. An on-board color comparator is provided for the crew to use periodically to evaluate the I_2 concentration to ensure that the I_2 level is always above 2 ppm.

The crew periodically samples the I_2 levels and if necessary recharges the water tank with the 30,000 ppm I_2 solution using the iodine injector assembly. Figures 2.2.11.2-66 through -75 show the iodine concentration history for each water tank.

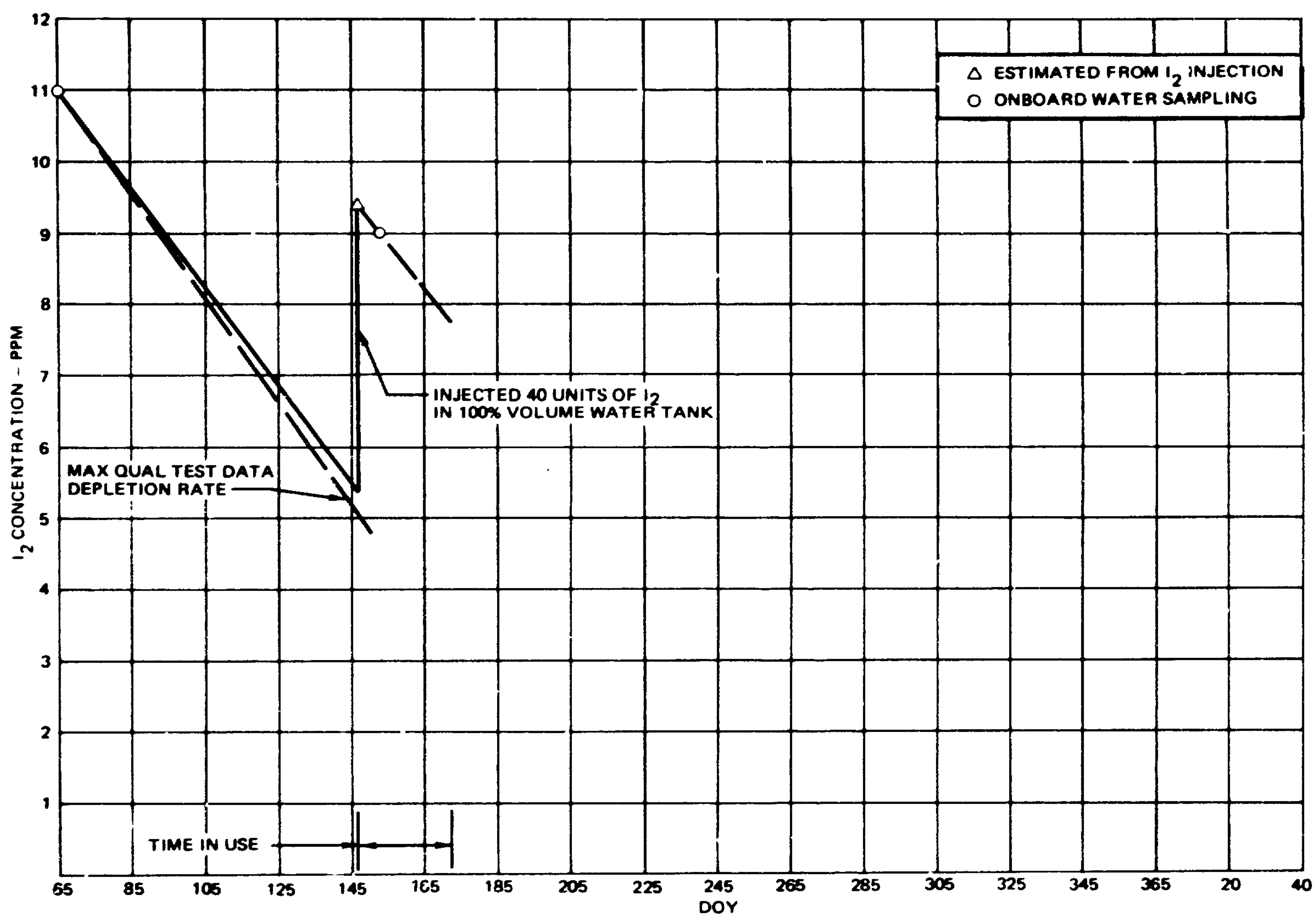


Figure 2.2.11.2-63. Water Tank No. 1 Iodine Depletion

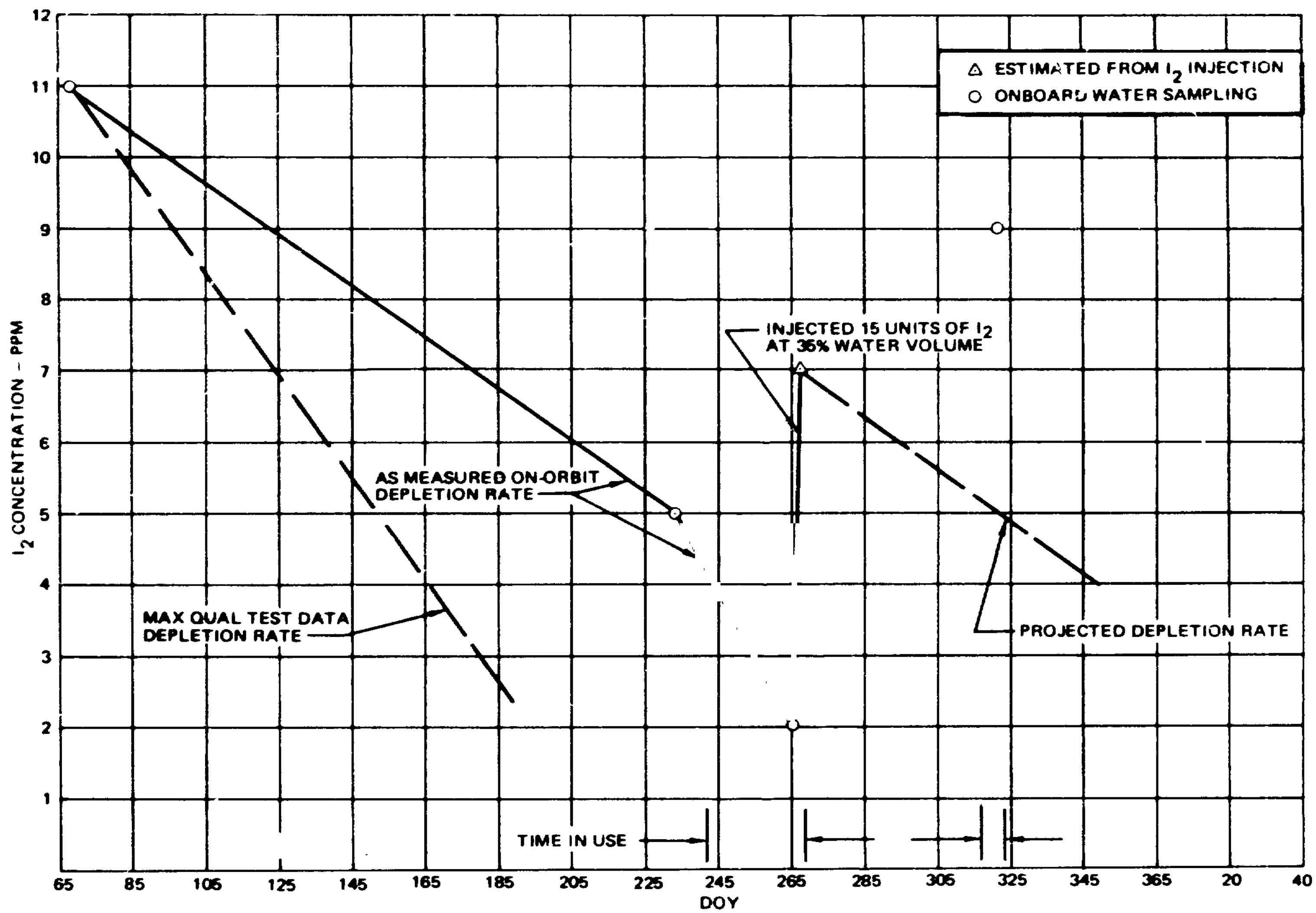


Figure 2.2.11.2-67. Water Tank No. 2 Iodine Depletion

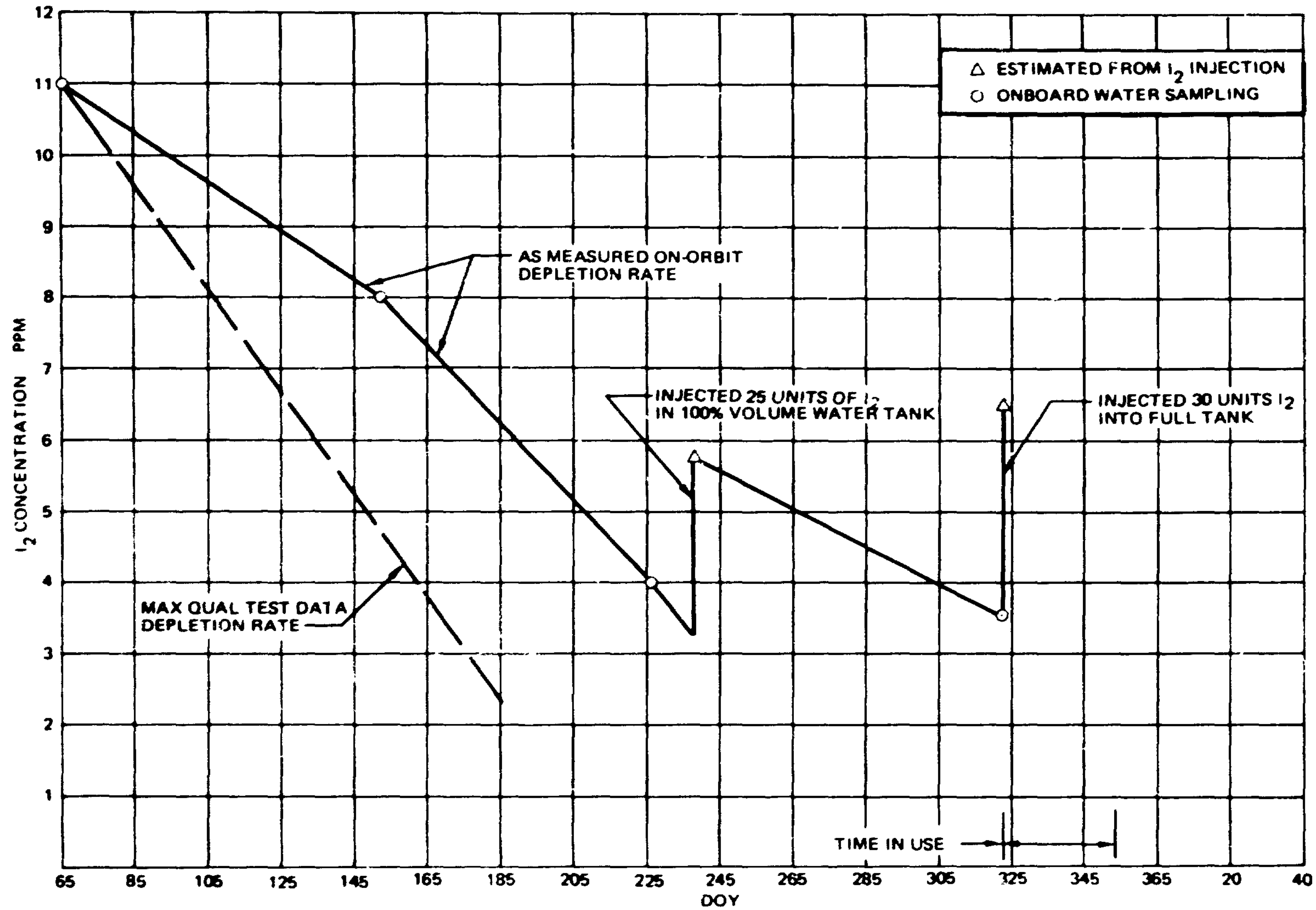


Figure 2.2.11.2-68. Water Tank No. 3 Iodine Depletion

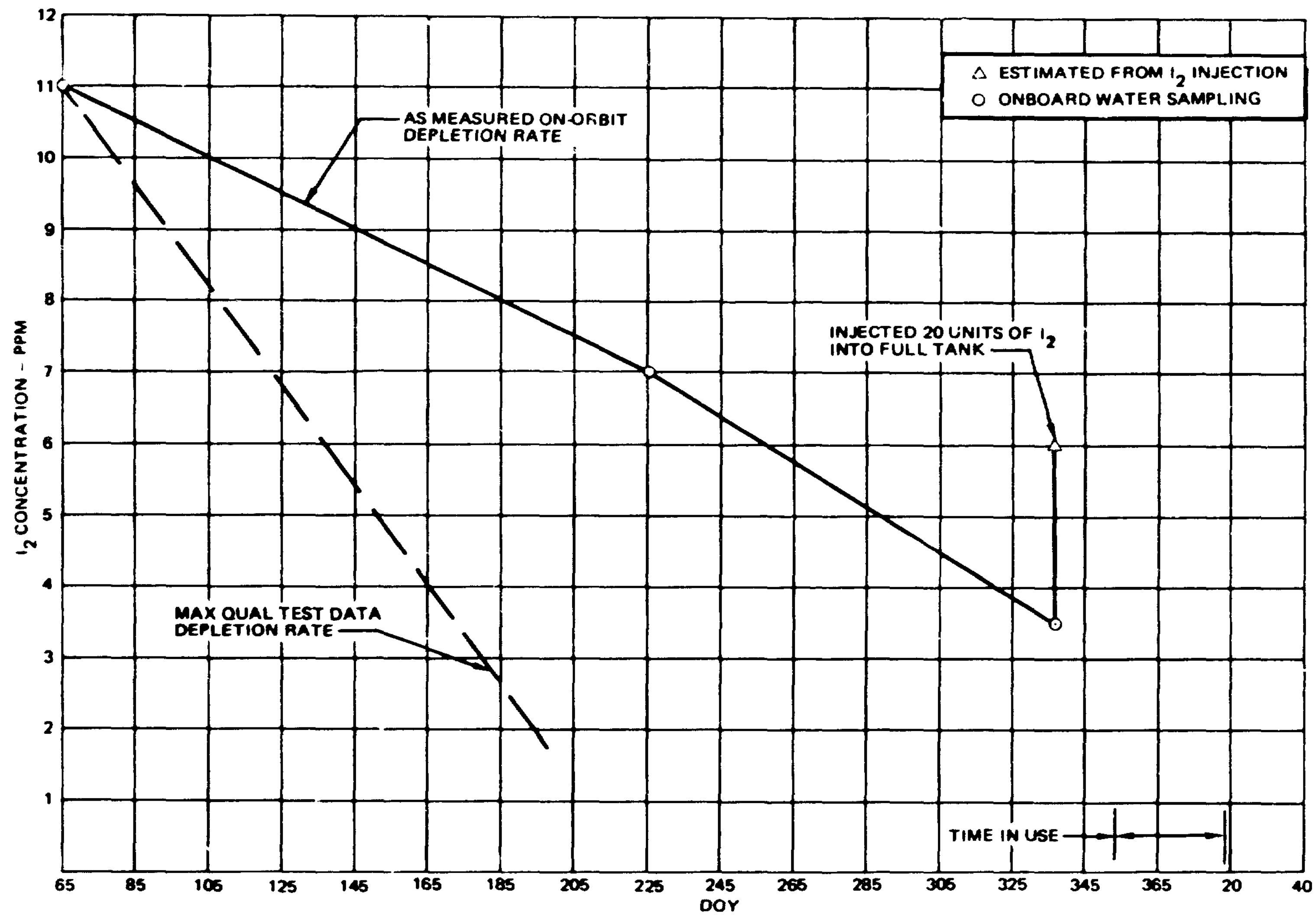


Figure 2.2.11.2-69. Water Tank No. 4 Iodine Depletion

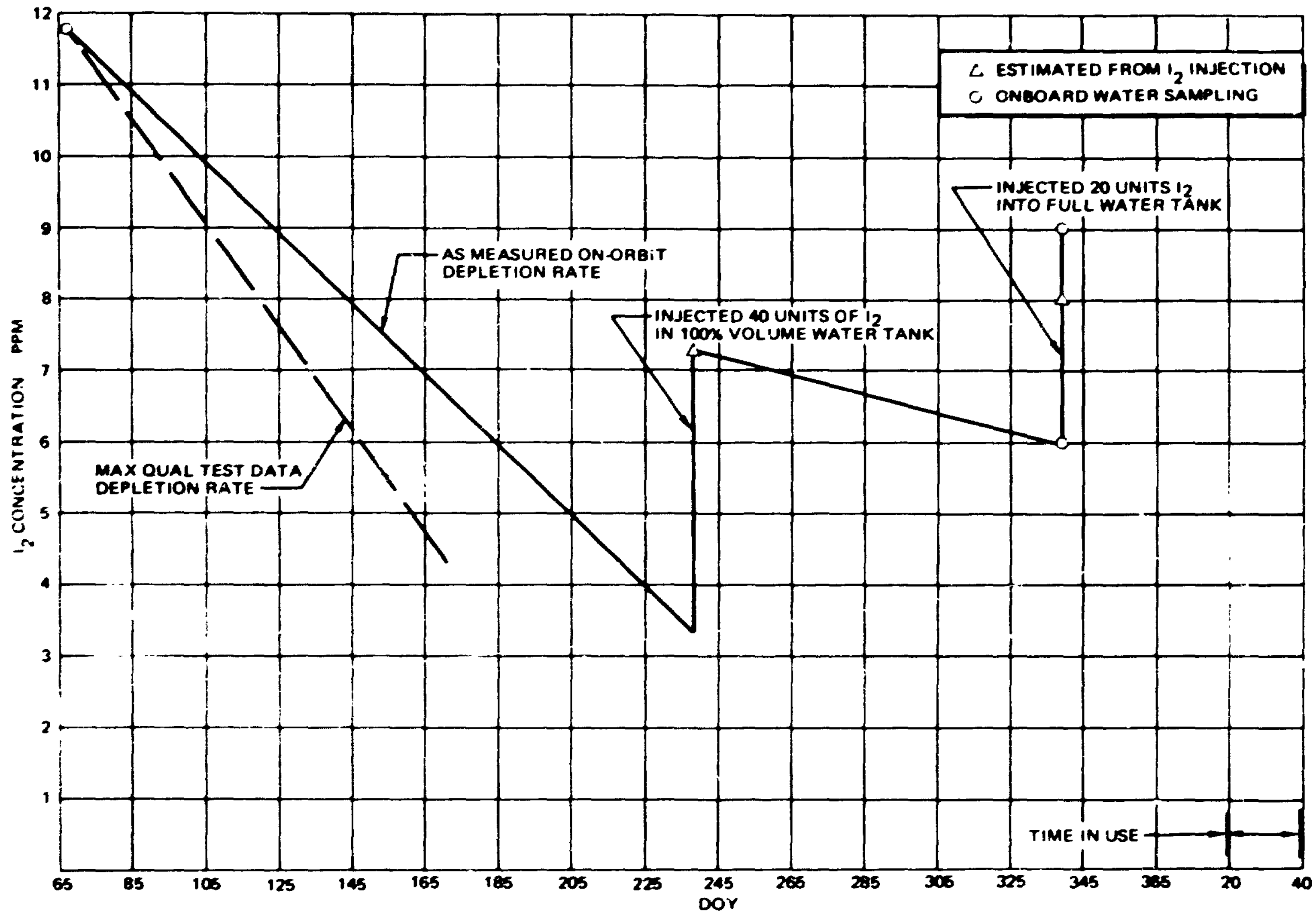


Figure 2.2.11.2-70. Water Tank No. 5 Iodine Depletion

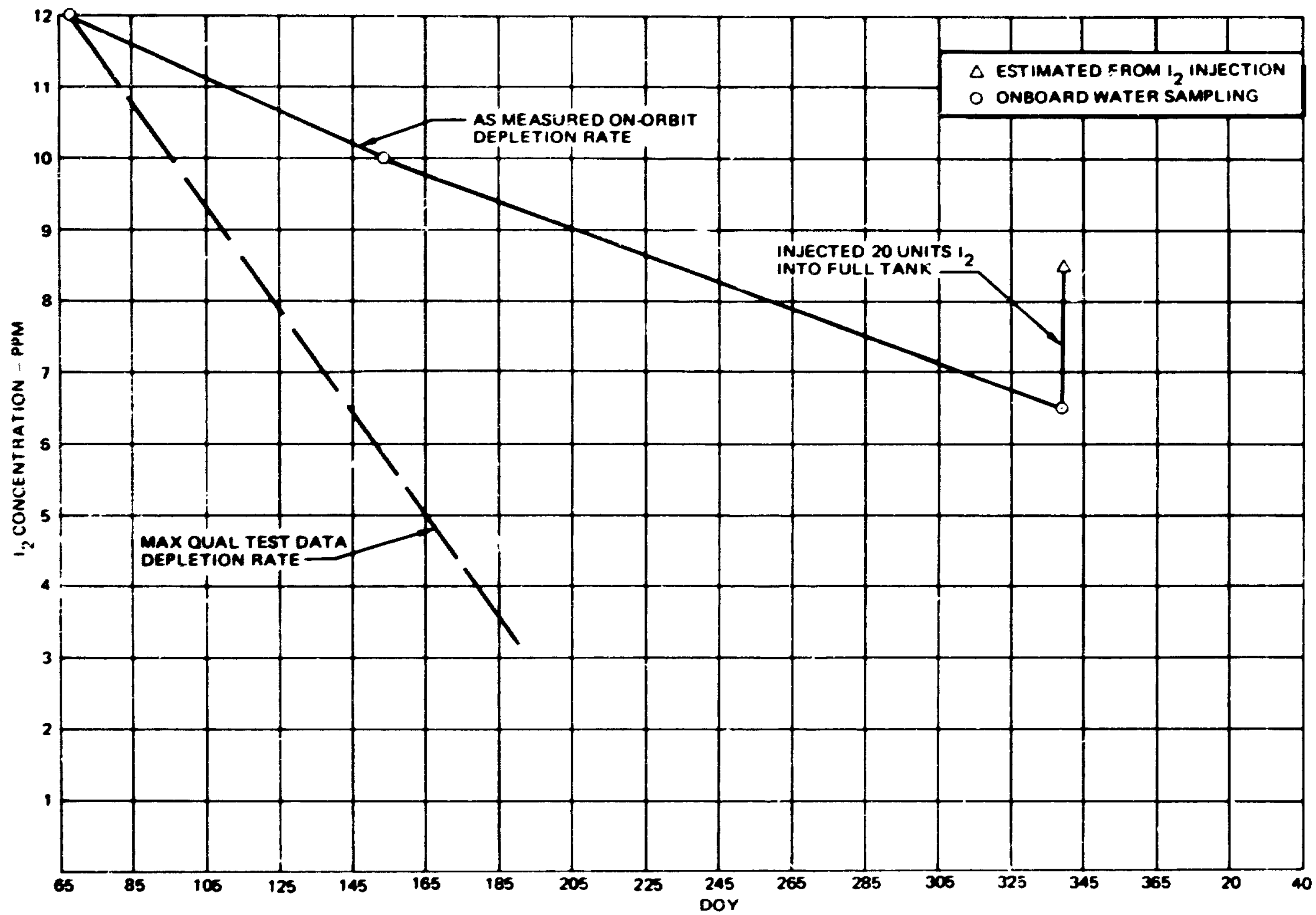


Figure 2.2.11.2-71. Water Tank No. 6 Iodine Depletion

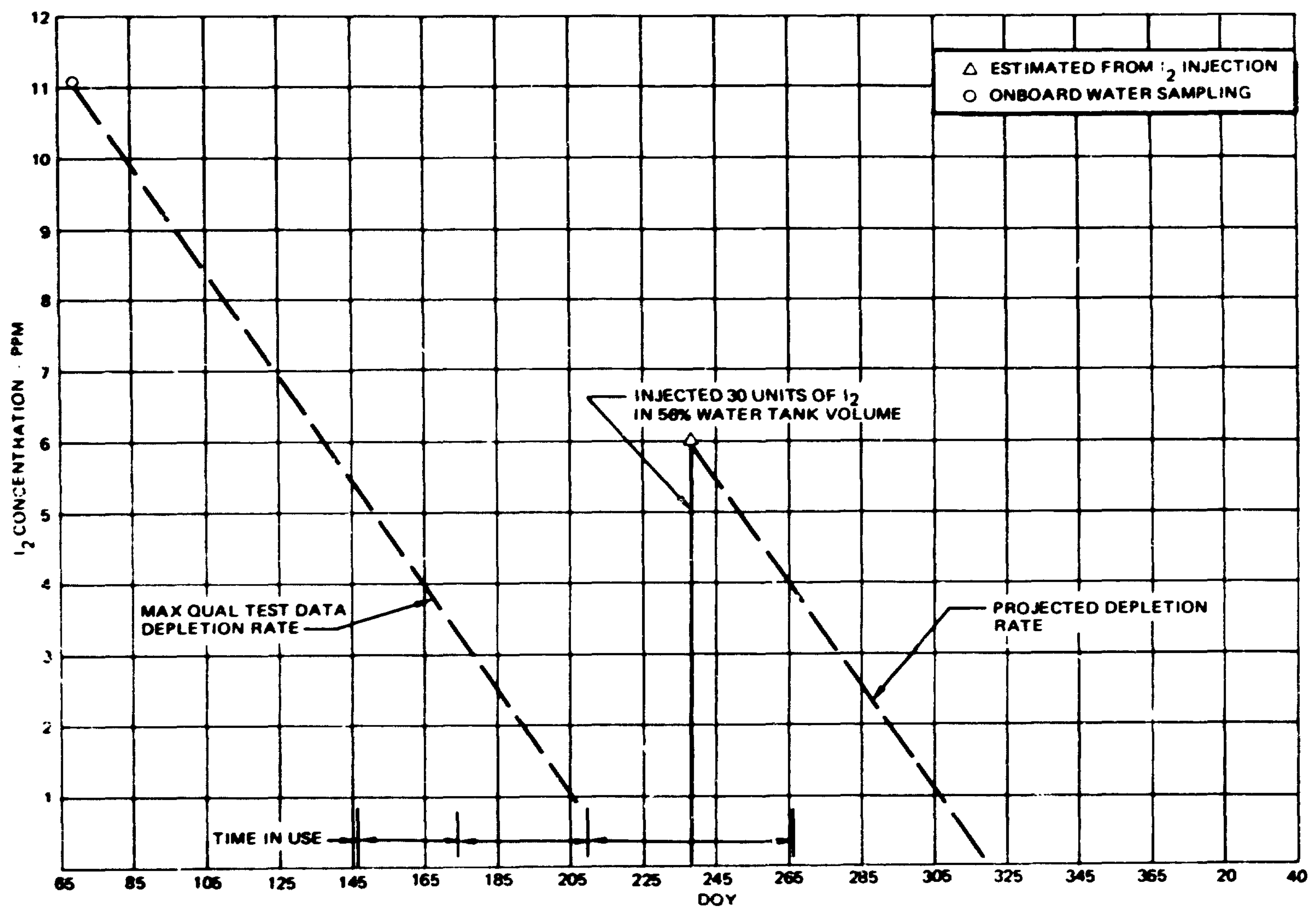


Figure 2.2.11.2-72. Water Tank No. 7 Iodine Depletion

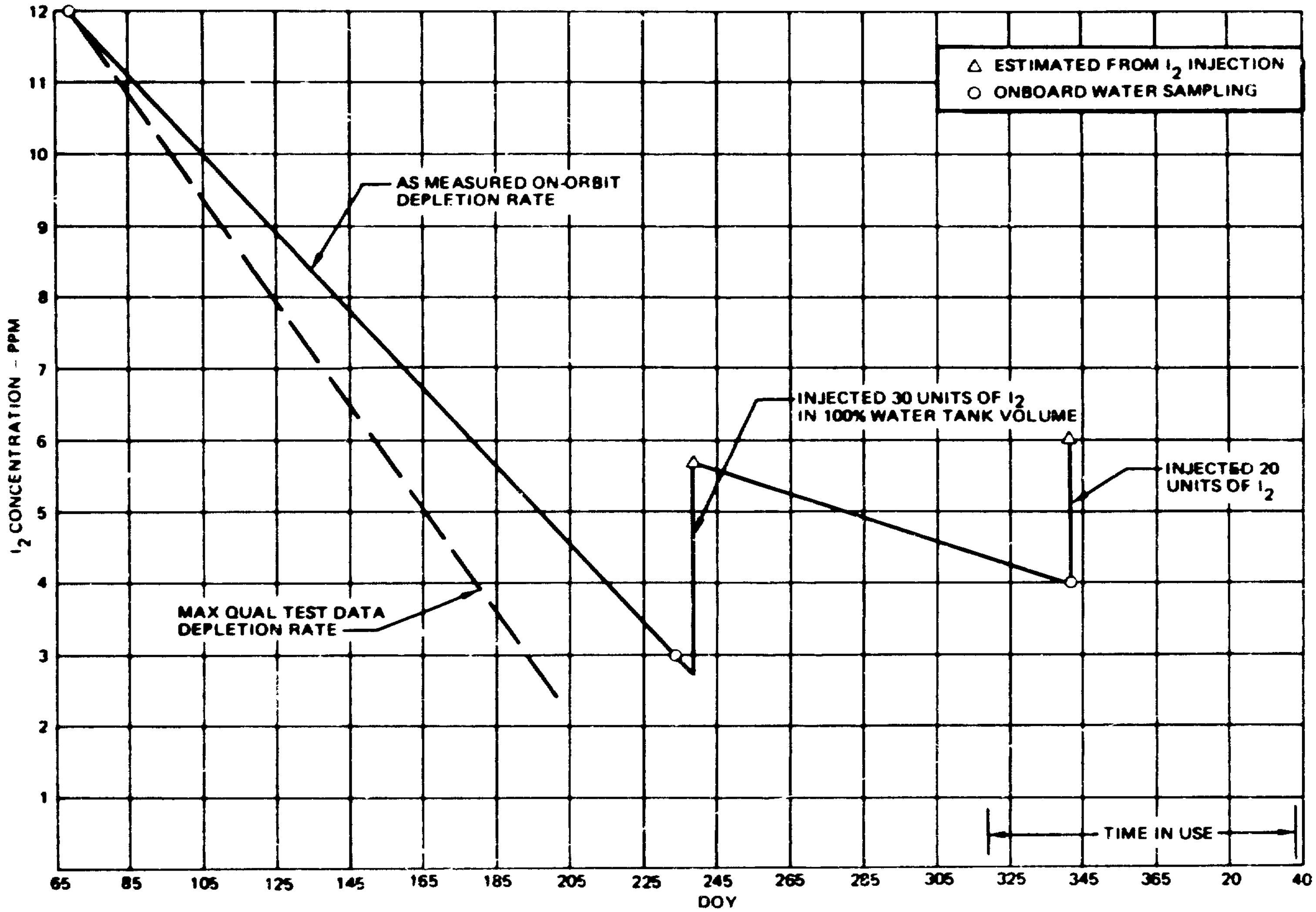


Figure 2.2.11.2-73. Water Tank No. 8 Iodine Depletion

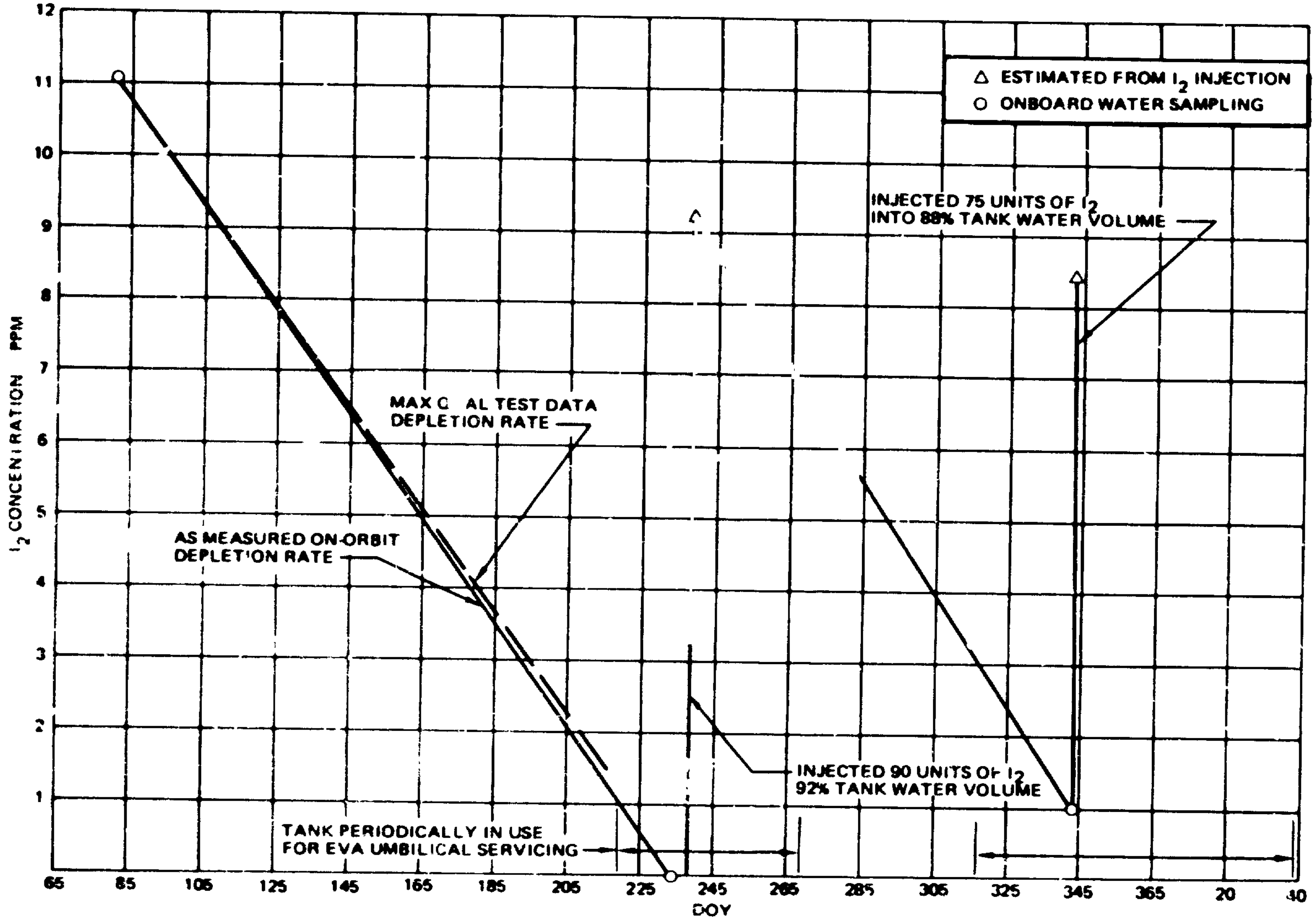


Figure 2.2.11.2-74. Water Tank No. 9 Iodine Depletion

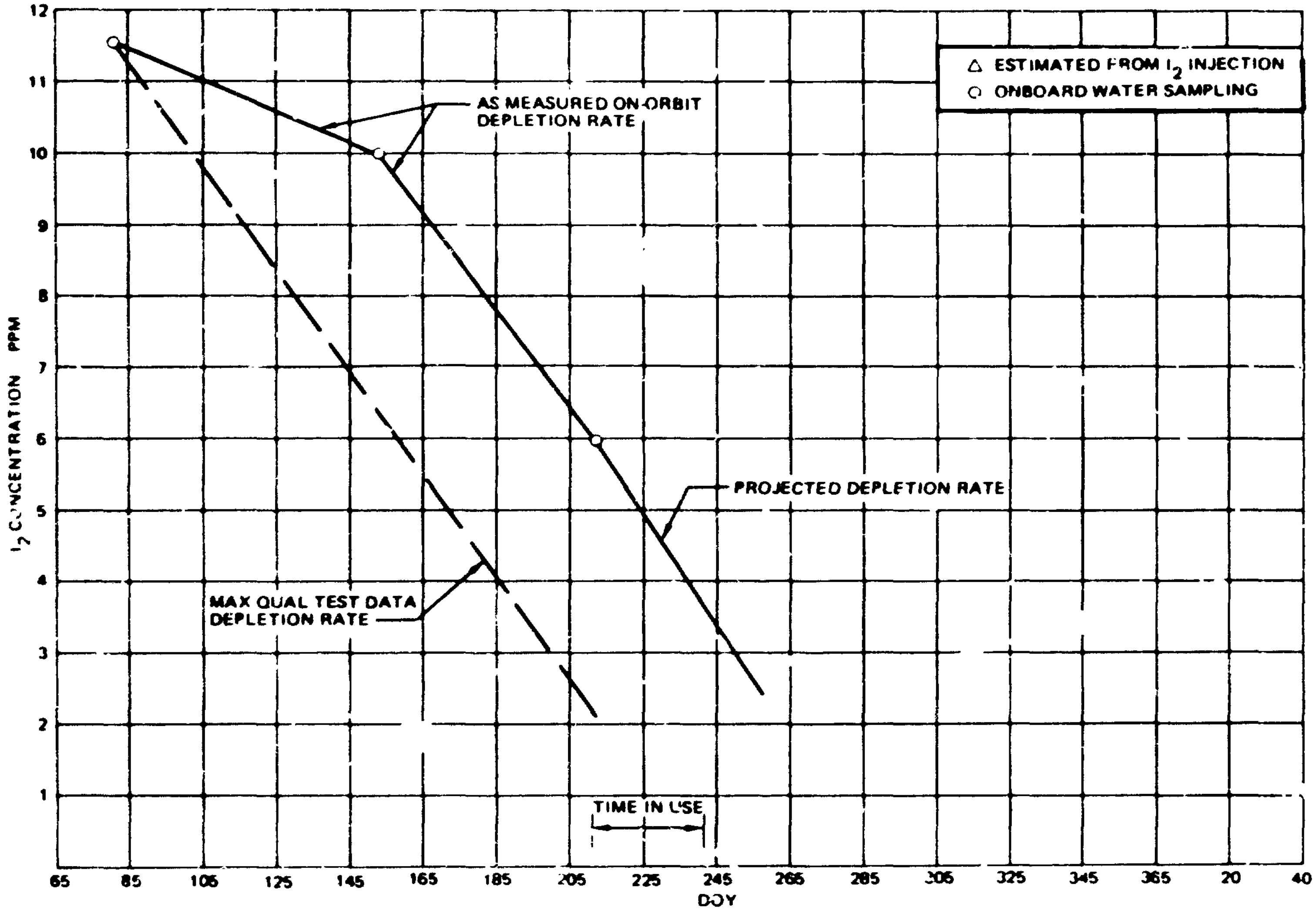


Figure 2.2.11.2-75. Water Tank No. 10 Iodine Depletion

During the SL-2, SL-3, and SL-4 missions the following water samplings and iodine injections were performed (HK 14G, 60R-1 and 60R-2) to maintain the OWS water pure:

Water Sampling

DOY	Water Tank or Noted	Iodine ppm
147	1	2.0
147	7	2.0
148	Wardroom Chiller	3.8
153	1	9.0
153	3	8.0
153	6	10.0
153	10	10.0
158	Wardroom Chiller	1.0
211	10	6.0
211	7	DATA NOT AVAILABLE
211	Wardroom Chiller	7.0
226	3	4.0
226	4	7.0
233	2	5.0
233	8	3.0
233	9	0.0
238	Wardroom Chiller	3.5
265	2	2.0
265	5	6.0
265	Wardroom Chiller	DATA NOT AVAILABLE
324	3	8.0-9.0
337	4	4.0
338	Water Chiller	9.0
339	5	6.0
340	5	9.0
340	6	6.0
341	8	4.0
342	9	1.0

Iodine Injections

DOY	Water Tank or Noted	Iodine Injected (Units)
14[illegible]	1	40
17[illegible]	Cation Filter	17
211	Wardroom Network Soak	40
238	3	25
238	5	40
238	7	30
238	8	30
238	9	90
267	2	15
267	Cation Filter	17
324	3	30
337	4	20
339	5	20
340	6	20
341	8	20
342	9	75

The SL-2 crew sampled the I_2 level in water Tank Nos. 1 and 7 as a part of the water system activation and found that the I_2 levels were much lower than they were predicted to be and so they recharged the Water Tank No. 1 with an additional input of the high concentration I_2 solution to raise the I_2 level in the tank by 4 ppm. Subsequently, the I_2 concentration anomaly was investigated at MDAC-W and it was proven that the low I_2 reading obtained by the SL-2 crew was because the water in the tanks was due to high cabin temperature. As the water temperature decreased, the measured I_2 concentrations again were approximately as predicted.

There is still one anomaly associated with the I_2 levels and the SL-2 mission. The SL-2 crew reported adding additional I_2 to the water tanks because the concentration was low while the water was hot, but after the tanks and the water had cooled off, the I_2 concentration was not above the predicted values. The anomaly could have been caused by the iodine injector assembly not injecting I_2, or the I_2 could be inadequately mixed in the tank.

The I_2 concentration reported from the chiller (3.8 on DOY 148 and 1 on DOY 158) is lower than expected based on the qualification test data. From the qualification test, the chiller was approximately 4.5 ppm and the I_2 level in the tank was from 8 to 6.5 ppm.

During the SL-2, SL-3, and SL-4 missions 28 water samples were taken. Each water sample requires a maximum of 1.4 cc of reagent to determine the water iodine concentration; therefore, 39.2 cc of reagent have been used through SL-4 mission. The amount of reagent loaded on board the OWS at KSC was 97 cc that was expellable. A plot of reagent utilization is included in Figure 2.2.11.2-76, which shows 108.0 cc of reagent remaining at the end of SL-3.

Also, during the SL-2, SL-3, and SL-4 missions, 529 units of iodine solution were injected into the OWS water system. The amount of iodine solution loaded on board the OWS at KSC was 2700 cc that was expellable. A plot of iodine solution utilization is included in Figure 2.2.11.2-77, which shows that 2231 cc remained at the end of SL-4.

f. Portable H_2O Tank - The portable H_2O tank was utilized for sterilization of the water distribution system during activation for SL-3 and SL-4 mission, and for a contingency in the case of failure of the normal distribution system. The portable H_2O tank was launched pressurized with N_2 to 25 psig (172 kN/m^2) maximum. The tank is then charged per the decal (40 units) with the I_2 solution containing 30,000 ppm I_2 so that when the tank is filled with approximately 26 lbs (11.8 kg) of water, the I_2 concentration is 100 ppm. This solution is injected into the H_2O distribution system.

The potable H_2O tank was utilized during all missions to check the N_2 system pressure and for initial Wardroom network sterilization. No problems or anomalies were reported by the SL-3 crew.

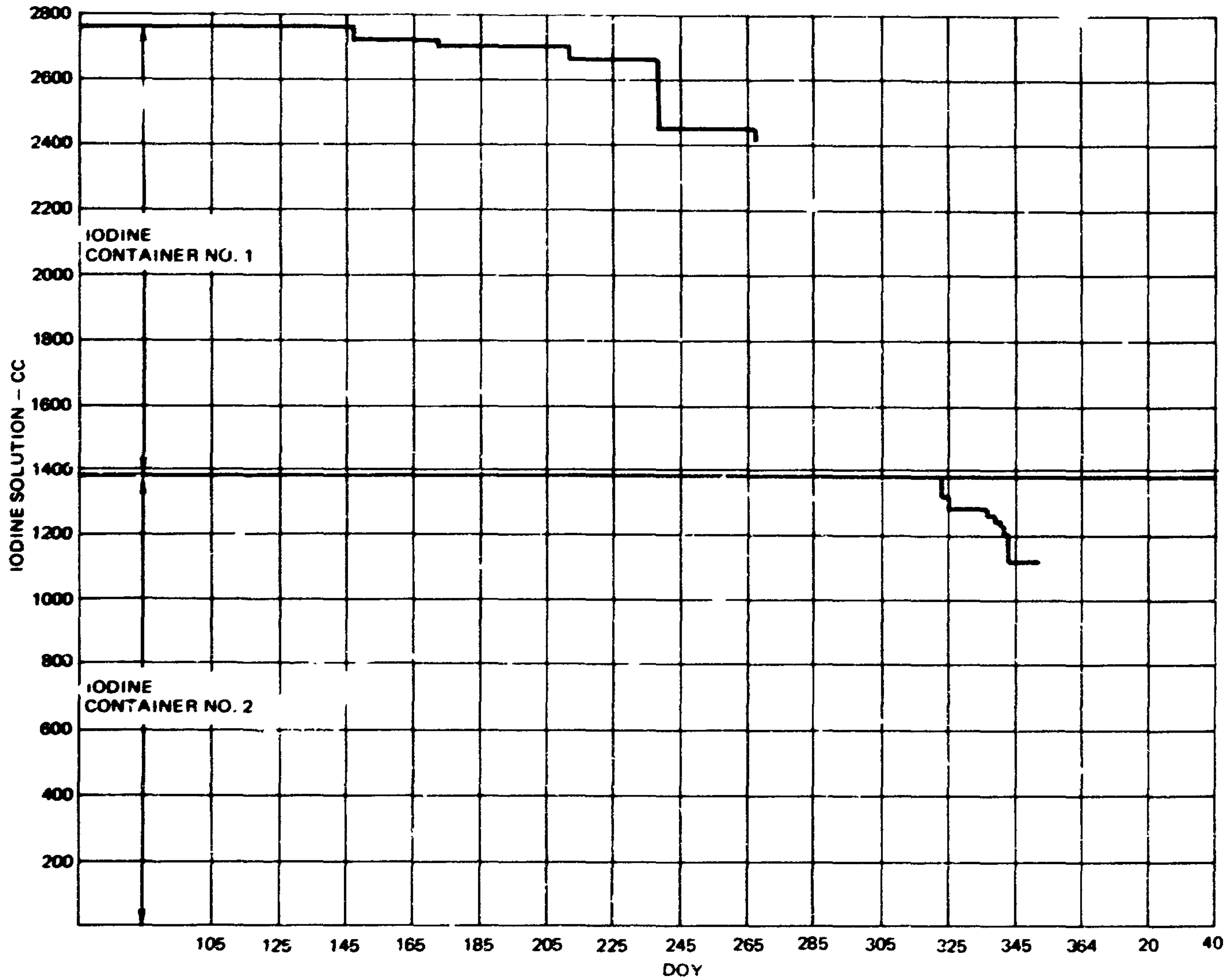


Figure 2.2.11.2-76. OWS Iodine Solution for Water Purification

g. Cation System - The water cation filter consists of a stainless steel container holding approximately 66 cubic inches (1082 cc) of ion exchange resin. The resin reacts with metal ions removing them as the water passes through the resin bed. The resin adversely affects the system by absorbing some of the iodine. The bed is pretreated prior to flight and post SL-2 and SL-3 to compensate for this absorption. Seventeen (17) ml of 30,000 ppm iodine was injected into the resin bed post SL-2 and SL-3.

There were no problems or anomalies reported during the SL-2 mission.

The ionic species levels and other data for all tanks prior to launch are shown in Tables 2.2.11.2-6 through -17.

The data obtained from the system samples during the mission are shown in Tables 2.2.11.2-18 through -20.

There were no problems or anomalies with the cation filter during any mission.

3/ H_2O Distribution

a. Wardroom System - The Wardroom distribution system consists of a flex line from the water tank to a hard line on the wall. The hard line goes down the wall underneath the floor and across the floor to the Wardroom table. It branches in the table to the heater and chiller. The heater connects to a food reconstitution dispenser and the chiller to three drinking dispensers.

During activation the system was evacuated and filled. The cation cartridge was the connected into the system. The

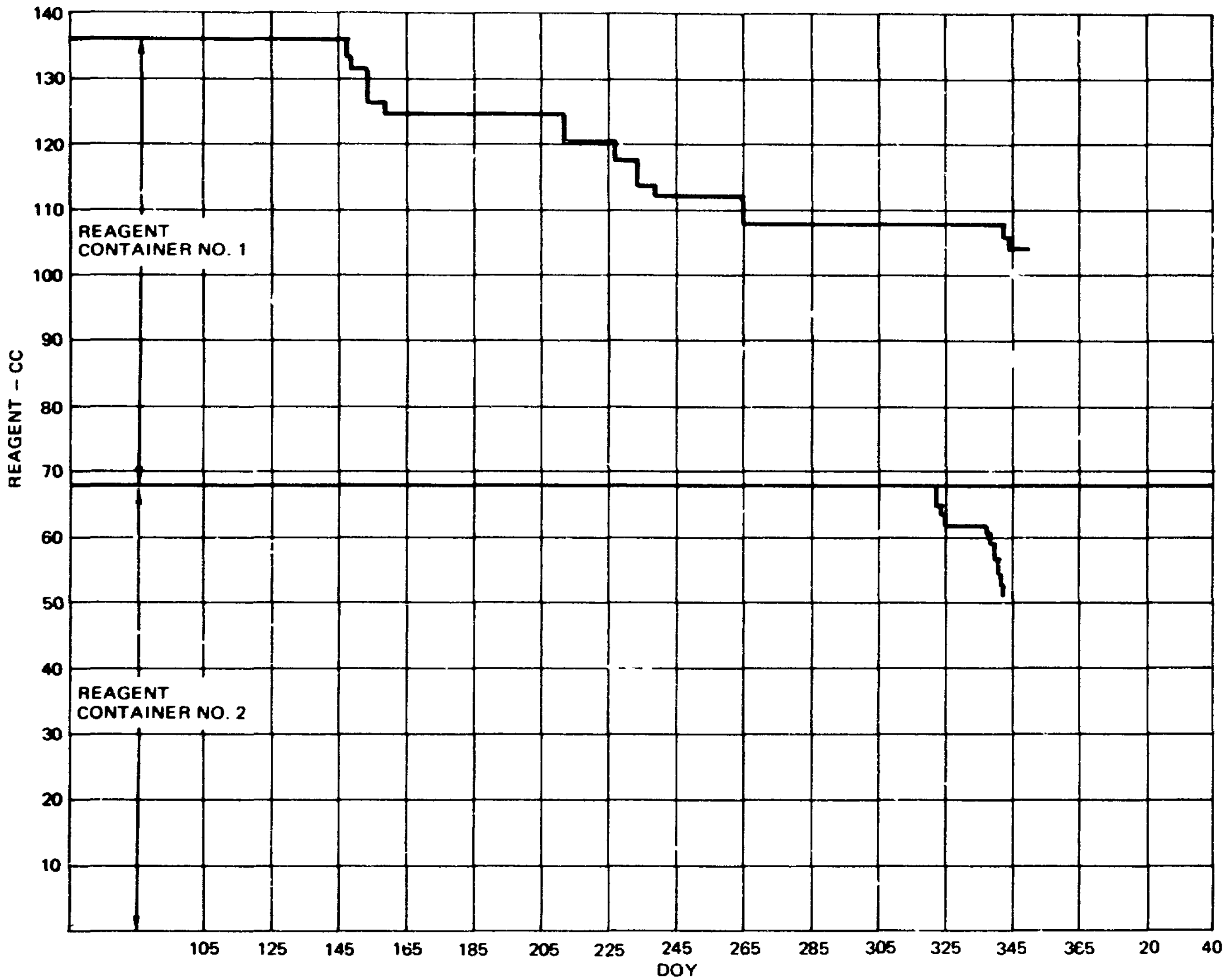


Figure 2.2.11.2-77. OWS Reagent for I_2 Determination

TABLE 2.2.11.2-6

TANK 1 POTABLE WATER ANALYSIS PRIOR TO LAUNCH, DOY 066

Properties	Limits	Results
Electrical Conductivity (Micromho/cm @ 25°C)	Reference Only	20
PH (@ 25°C)	4-8	5.1
Total Residue (mg/l)	91.	20.4
*Taste and Odor (at 45°C)	Reference only	
Turbidity (Units)	11	<0.2
*Color True (Units)	Reference only	
Dissolved Gases (% by Volume)	0.5	0.5
Biocide (ppm)	Reference only	11.0
<u>Particulate/500 ml</u>		
0-10 Microns	Reference only	40
10-25 Microns	Reference only	69
25-50 Microns	Reference only	95
50-100 Microns	Reference only	8
100-250 Microns	Reference only	3
<u>Sterility (Colonies/150 ml)</u>		
Total Bacteria	Negative	Negative
Total Coliform	Negative	Negative
Anaerobic Analysis	Negative	Negative
Yeast and Molds	Negative	Negative
<u>Ionic Species in mg/l</u>		
Cadmium	0.01	<0.005
Calcium	5.6	<0.02
Chromium (hex)	0.05	<0.02
Copper	1.0	<0.01
Iron	0.3	0.02
Lead	0.05	<0.05
Manganese	0.05	<0.01
Mercury	0.005	<0.005
Nickel	0.05	<0.02
Silver	0.05	<0.01
Zinc	5.0	<0.005
Iodide	Reference only	14.0
Selenium	Reference only	<0.01

*CONTAINS IODINE

TABLE 2.2.11.2-7
TANK 1 POTABLE WATER ANALYSIS PRIOR TO LAUNCH, DOY 096

Properties	Limits	Results
Electrical Conductivity (Micromho/cm @ 25°C)	Reference only	26
PH (@ 25°C)	4-8	4.4
Total Residue (mg/1	91.	19.7
*Taste and Odor (@ 45°C)	Reference only	
Turbidity (Units)	11	<0.2
*Color True (Units)	Reference only	
Dissolved Gases (% by Volume)	Reference only	<0.1
Biocide (ppm)	Reference only	10.4
Particulate/500 ml		
0-10 Microns	Reference only	Not req.
10-25 Microns	Reference only	Not req.
25-50 Microns	Reference only	Not req.
50-100 Microns	Reference only	Not req.
100-250 Microns	Reference only	Not req.
Sterility (Colonies/150 ml)		
Total Bacteria	Negative	Negative Growth
Total Coliform	Negative	Negative Growth
Anaerobic Analysis	Negative	Negative Growth
Yeast and Molds	Negative	Negative Growth
Ionic Species in mg/1		
Cadmium	0.01	<0.005
Calcium	5.0	<0.02
Chromium (hex)	0.05	<0.02
Copper	1.0	0.01
Iron	0.3	0.13
Lead	0.05	<0.05
Manganese	0.05	<0.01
Mercury	0.005	<0.005
Nickel	0.05	0.03
Silver	0.05	<0.01
Zinc	5.0	<0.005
Iodide	Reference only	14.2
Selenium	Reference only	<0.01

*CONTAINS IODINE

TABLE 2.2.11.2-8
TANK 10 POTABLE WATER ANALYSIS PRIOR TO LAUNCH, DOY 071

Properties	Limits	Results
Electrical Conductivity (Micromho/cm @ 25°C)	Reference only	21.
PH (@ 25°C)	4-8	4.9
Total Residue (mg/l)	91.	21.3
*Taste and Odor (@ 45°C)	Reference only	
Turbidity (Units)	11	0.2
*Color True (Units)	Reference only	
Dissolved Gases (% by Volume)	0.5	0.45
Biocide (ppm)	Reference only	9.5
Particulate/500 ml		
0-10 Microns	Reference only	110
10-25 Microns	Reference only	50
25-50 Microns	Reference only	20
50-100 Microns	Reference only	4
100-250 Microns	Reference only	3
Sterility (Colonies/150 ml)		
Total Bacteria	Negative	Negative
Total Coliform	Negative	Negative
Anaerobic Analysis	Negative	Negative
Yeast and Molds	Negative	Negative
Ionic Species in mg/l		
Cadium	0.01	<0.005
Calcium	5.0	<0.02
Chromium (hex)	0.05	<0.02
Copper	1.0	<0.01
Iron	0.3	<0.02
Lead	0.05	<0.05
Manganese	0.05	<0.01
Mercury	0.005	<0.005
Nickel	0.05	<0.02
Silver	0.05	<0.01
Zinc	5.0	<0.005
Iodide	Reference only	22.8
Selenium	Reference only	<0.01

*CONTAINS IODINE

TABLE 2.2.11.2-9
TANK 10 POTABLE WATER ANALYSIS PRIOR TO LAUNCH, DOY 096

Properties	Limits	Results
Electrical Conductivity (Micromho/cm @ 25°C)	Reference only	25
PH (@ 25°C)	4-8	4.7
Total Residue (mg/l)	91.	24.1
*Taste and Odor (@ 45°C)	Reference only	
Turbidity (Units)	11	<0.2
*Color True (Units)	Reference only	
Dissolved Gases (% by Volume)	Reference only	0.40
Biocide (ppm)	Reference only	11.4
Particulate/500 ml		
0-10 Microns	Reference only	Not req.
10-25 Microns	Reference only	Not req.
25-50 Microns	Reference only	Not req.
50-100 Microns	Reference only	Not req.
100-250 Microns	Reference only	Not req.
Sterility (Colonies/150 ml)		
Total Bacteria	Negative	Negative Growth
Total Coliform	Negative	Negative Growth
Anaerobic Analysis	Negative	Negative Growth
Yeast and Molds	Negative	Negative Growth
Ionic Species in mg/l		
Cadmium	0.01	<0.005
Calcium	[illegible].0	<0.02
Chromium (hex)	0.05	<0.02
Copper	1.0	0.0[illegible]
Iron	0.3	0.07
Lead	0.05	<0.05
Manganese	0.05	<0.01
Mercury	0.005	<0.005
Nickel	0.05	0.03
Silver	0.05	<0.01
Zinc	[illegible].0	<0.005
Iodide	Reference only	16.0
Selenium	Reference only	<0.01

*CONTAINS IODINE

TABLE 2.2.11.2-10

TANK 2 POTABLE WATER ANALYSIS PRIOR TO LAUNCH, DOY 065

Properties	Limits	Results
Electrical Conductivity (Micromho/cm @ 25°C)	Reference only	23.
PH (@ 25°C)	4-8	5.1
Total Residue (mg/l)	91.	21.4
*Taste and Odor (@ 45°C)	Reference only	
Turbidity (Units)	11	<0.2
*Color True (Units)	Reference only	
Dissolved Gases (% by Volume)	0.5	0.5
Biocide (ppm)	Reference only	13.4
Particulate/500 ml		
0-10 Microns	Reference only	410
10-25 Microns	Reference only	340
25-50 Microns	Reference only	360
50-100 Microns	Reference only	23
100-250 Microns	Reference only	10
Sterility (Colonies/150 ml)		
Total Bacteria	Negative	Negative
Total Coliform	Negative	Negative
Anaerobic Analysis	Negative	Negative
Yeast and Molds	Negative	Negative
Ionic Species in mg/l		
Cadmium	0.01	<0.005
Calcium	5.0	<0.02
Chromium (hex)	0.05	<0.02
Copper	1.0	<0.01
Iron	0.3	<0.02
Lead	0.05	<0.05
Manganese	0.05	<0.01
Mercury	0.005	<0.005
Nickel	0.05	<0.02
Silver	0.05	<0.01
Zinc	5.0	<0.005
Iodide	Reference only	19.0
Selenium	Reference only	<0.01

*CONTAINS IODINE

TABLE 2.2.11.2-11
TANK 2 POTABLE WATER ANALYSIS PRIOR TO LAUNCH, DOY 096

Properties	Limits	Results
Electrical Conductivity (Micromho/cm @ 25°C)	Reference only	27
PH (@ 25°C)	4-8	4.5
Total Residue (mg/l)	91.	23.0
*Taste and Odor (@ 45°C)	Reference only	
Turbidity (Units)	11	<0.2
*Color True (Units)	Reference only	
Dissolved Gases (% by Volume)	Reference only	0.4
Biocide (ppm)	Reference only	11.9
Particulate/500 ml		
0-10 Microns	Reference only	Not req.
10-25 Microns	Reference only	Not req.
25-50 Microns	Reference on y	Not req.
50-100 Microns	Reference only	Not req.
100-250 Microns	Reference only	Not req.
Sterility (Colonies/150 ml)		
Total Bacteria	Negative	Negative Growth
Total Coliform	Negative	Negative Growth
Anaerobic Analysis	Negative	Negative Growth
Yeast and Molds	Negative	Negative Growth
Ionic Species in mg/l		
Cadmium	0.01	<0.005
Calcium	5.0	<0.0[illegible]
Chromium (hex)	0.05	<0.02
Copper	1.0	<0.03
Iron	0.3	<0.07
Lead	0.05	<0.05
Manganese	0.05	<0.01
Mercury	0.005	<0.005
Nickel	0.05	0.03
Silver	0.05	<0.01
Zinc	5.0	<0.005
Iodide	Reference only	14.4
Selenium	Reference only	<0.01

*CONTAINS IODINE

TABLE 2.2.11.2-12
TANK 3 POTABLE WATER ANALYSIS PRIOR TO LAUNCH, DOY 068

Properties	Limits	Results
Electrical Conductivity (Micromho/cm @ 25°C)	Reference only	24.
PH (@ 25°C)	4-8	4.9
Total Residue (mg/l)	91.	21.4
*Taste and Odor (@ 45°C)	Reference only	
Turbidity (Units)	11	<0.2
*Color True (Units)	Reference only	
Dissolved Gases (% by Volume)	0.5	0.4
Biocide (ppm)	Reference only	11.0
Particulate/500 ml		
0-10 Microns	Reference only	310
10-25 Microns	Reference only	80
25-50 Microns	Reference only	40
50-100 Microns	Reference only	5
100-250 Microns	Reference only	2
Sterility (Colonies/150 ml)		
Total Bacteria	Negative	Negative
Total Coliform	Negative	Negative
Anaerobic Analysis	Negative	Negative
Yeast and Molds	Negative	Negative
Ionic Species in mg/l		
Cadmium	0.01	<0.005
Calcium	5.6	<0.02
Chromium (hex)	0.05	<0.02
Copper	1.0	<0.02
Iron	0.3	<0.02
Lead	0.05	<0.05
Manganese	0.05	<0.01
Mercury	0.005	<0.005
Nickel	0.05	<0.02
Silver	0.05	<0.01
Zinc	5.0	<0.005
Iodide	Reference only	16.4
Selenium	Reference	<0.01

*CONTAINS IODINE

TABLE 2.2.1[illegible]-13

TANK 3 POTABLE WATER ANALYSIS PRIOR TO LAUNCH, DOY 096

Properties	Limits	Results
Electrical Conductivity (Micromho/cm @ 25°C)	Reference only	27
PH (@ 25°C)	4-8	4.6
Total Residue (mg/l)	91.	21.3
*Taste and Odor (@ 45°C)	Reference only	
Turbidity (Units)	11	<0.[illegible]
*Color True (Units)	Reference only	
Dissolved Gases (% by Volume)	Reference only	0.5
Biocide (ppm)	Reference only	10.9
Particulate/500 ml		
0-10 Micro.	Reference only	Not req.
10-25 Microns	Reference only	Not req.
25-50 Microns	Reference only	Not req.
50-100 Microns	Reference only	Not req.
100-250 Microns	Reference only	Not req.
Sterility (Colonies/150 ml)		
Total Bacteria	Negative	Negative Growth
Total Coliform	Negative	Negative Growth
Anaerobic Analysis	Negative	Negative Growth
Yeast and Molds	Negative	Negative Growth
Ionic Species in mg/l		
Cadmium	0.01	<0.005
Calcium	5.6	<0.02
Chromium (hex)	0.05	<0.02
Copper	1.0	0.02
Iron	0.3	0.10
Lead	0.05	<0.05
Manganese	0.05	<0.01
Mercury	0.005	<0.005
Nickel	0.05	0.03
Silver	0.05	<0.01
Zinc	5.0	<0.005
Iodide	Reference only	1[illegible].5
Selenium	Reference only	<0.01

*CONTAINS IODINE

TABLE 2.2.11.2-14
TANK 4 POTABLE WATER ANALYSIS PRIOR TO LAUNCH, DOY 067

Properties	Limits	Results
Electrical Conductivity (Micromho/cm @ 25°C)	Reference only	25.
PH (@ 25°C)	4-8	4.9
Total Residue (mg/l)	91.	23.5
*Taste and Odor (@ 45°C)	Reference only	
Turbidity (Units)	11	<0.2
*Color True (Units)	Reference only	
Dissolved Gases (% by Volume)	0.5	0.5
Biocide (ppm)	Reference only	11.0
Particulate/500 ml		
0-10 Microns	Reference only	220
10-25 Microns	Reference only	100
25-50 Microns	Reference only	110
50-100 Microns	Reference only	5
100-250 Microns	Reference only	3
Sterility (Colonies/150 ml)		
Total Bacteria	Negative	Negative
Total Coliform	Negative	Negative
Anaerobic Analysis	Negative	Negative
Yeast and Molds	Negative	Negative
Ionic Species in mg/l		
Cadmium	0.01	<0.005
Calcium	5.6	<0.02
Chromium (hex)	0.05	<0.02
Copper	1.0	<0.02
Iron	0.3	<0.02
Lead	0.05	<0.05
Manganese	0.05	<0.01
Mercury	0.005	<0.005
Nickel	0.05	<0.02
Silver	0.05	<0.01
Zinc	5.0	<0.005
Iodide	Reference only	18.1
Selenium	Reference only	<0.01

*CONTAINS IODINE

TABLE 2.2.11.2-15
TANK 4 POTABLE WATER ANALYSIS PRIOR TO LAUNCH, DOY 096

Properties	Limits	Results
Electrical Conductivity (Micromho/cm @ 25°C)	Reference only	28
PH (@ 25°C)	4-8	4.6
Total Residue (mg/l)	91.	24.3
*Taste and Odor (@ 25°C)	Reference only	
Turbidity (Units)	11	<0.2
*Color True (Units)	Reference only	
Dissolved Gases (% by Volume)	Reference only	0.45
Biocide (ppm)	Reference only	12.4
Particulate/500 ml		
0-10 Microns	Reference only	Not req.
10-25 Microns	Reference only	Not req.
25-50 Microns	Reference only	Not req.
50-100 Microns	Reference only	Not req.
100-250 Microns	Reference only	Not req.
Sterility (Colonies/150 ml)		
Total Bacteria	Negative	Negative Growth
Total Coliform	Negative	Negative Growth
Anaerobic Analysis	Negative	Negative Growth
Yeast and Molds	Negative	Negative Growth
Ionic Species in mg/l		
Cadmium	0.01	<0.005
Calcium	5.6	<0.02
Chromium (hex)	0.05	<0.02
Copper	1.0	0.03
Iron	0.3	0.08
Lead	0.05	<0.05
Manganese	0.05	<0.01
Mercury	0.005	<0.005
Nickel	0.05	0.03
Silver	0.05	<0.01
Zinc	5.0	<0.005
Iodide	Reference only	18.0
Selenium	Reference only	<0.01

*CONTAINS IODINE

TABLE 2.2.11.2-16
TANK 5 POTABLE WATER ANALYSIS PRIOR TO LAUNCH, DOY 069

Properties	Limits	Results
Electrical Conductivity (Micromho/cm @ 25°C)	Reference only	21.
PH (@ 25°C)	4-8	4.9
Total Residue (mg/l)	91.	19.4
*Taste and Odor (@ 45°C)	Reference only	
Turbidity (Units)	11	<0.2
*Color True (Units)	Reference only	
Dissolved Gases (% by Volume)	0.5	0.3
Biocide (ppm)	Reference only	11.8
Particulate/500 ml		
0-10 Microns	Reference only	360
10-25 Microns	Reference only	290
25-50 Microns	Reference only	140
50-100 Microns	Reference only	4
100-250 Microns	Reference only	2
Sterility (Colonies/150 ml)		
Total Bacteria	Negative	Negative
Total Coliform	Negative	Negative
Anaerobic Analysis	Negative	Negative
Yeast and Molds	Negative	Negative
Ionic Species in mg/l		
Cadmium	0.01	<0.005
Calcium	5.6	<0.02
Chromium (hex)	0.05	<0.02
Copper	1.0	<0.01
Iron	0.3	<0.02
Lead	0.05	<0.05
Manganese	0.05	<0.01
Mercury	0.005	<0.005
Nickel	0.05	<0.02
Silver	0.05	<0.01
Zinc	5.0	<0.005
Iodide	Reference only	15.3
Selenium	Reference only	<0.01

*CONTAINS IODINE

TABLE 2.2.11.2-17

TANK 5 POTABLE WATER ANALYSIS PRIOR TO LAUNCH, DOY 096

Properties	Limits	Results
Electrical Conductivity (Micromho/cm @ 25°C)	Reference only	26
PH (@ 25°C)	4-8	4.6
Total Residue (mg/l)	91.	21.1
*Taste and Odor (@ 45°C)	Reference only	
Turbidity (Units)	11	<0.2
*Color True (Units)	Reference only	
Dissolved Gases (% by Volume)	Reference only	0.50
Biocide (ppm)	Reference only	10.3
Particulate/500 ml		
0-10 Microns	Reference only	Not req.
10-25 Microns	Reference only	Not req.
25-50 Microns	Reference only	Not req.
50-100 Microns	Reference only	Not req.
100-250 Microns	Reference only	Not req.
Sterility (Colonies/150 ml)		
Total Bacteria	Negative	Negative Growth
Total Coliform	Negative	Negative Growth
Anaerobic Analysis	Negative	Negative Growth
Yeast and Molds	Negative	Negative Growth
Ionic Species in mg/l		
Cadmium	0.01	<0.005
Calcium	5.6	<0.02
Chromium (hex)	0.05	<0.02
Copper	1.0	0.05
Iron	0.3	0.10
Lead	0.05	<0.05
Manganese	0.05	<0.01
Mercury	0.005	<0.005
Nickel	0.05	0.03
Silver	0.05	<0.01
Zinc	5.0	<0.005
Iodide	Reference only	[illegible].5
Selenium	Reference only	<0.01

*CONTAINS IODINE

TABLE 2.2.11.2-18
TANK 1 POTABLE WATER SL-1/SL-2 DATA FROM SAMPLE RETURNED FROM ORBIT

Properties	Limits	Results
Electrical Conductivity (Micromho/cm @ 25°C)	Reference only	3.6 x 10
PH (@ 25°C)	4-8	4.6
Total Residue (mg/l)	91.	
Taste and Odor (@ 45°C)	Reference only	
Turbidity (Units)	11	9 Nephelos Units
Color True (Units)	Reference only	<1
Dissolved Gases (% by Volume)	0.5	
Biocide (ppm)	Reference only	
Particulate/500 ml		
0-10 Microns	Reference only	
10-25 Microns	Reference only	
25-50 Microns	Reference only	
50-100 Microns	Reference only	
100-250 Microns	Reference only	
Sterility (Colonies/150 ml		
Total Bacteria	Negative	
Total Coliform	Negative	
Anaerobic Analysis	Negative	
Yeast and Molds	Negative	
Ionic Species in mg/l		
Cadmium	0.01	<0.01
Calcium	5.6	
Chromium (hex)	0.05	<0.01
Copper	1.0	<0.0[illegible]
Iron	0.3	0.1 Fil-tered/0.02
Lead	0.05	<0.05
Manganese	0.05	<0.01
Mercury	0.005	<0.005
Nickel	0.05	<0.05
Silver	0.05	
Zinc	5.0	0.11
Iodide	Reference only	25
Selenium	Reference only	<0.01
I_2		<0.05
Silicon		<0.5
Potassium		7.[illegible]
Magnesium		<0.5
Sodium		<0.1
Arsenic		<0.1
Aluminum		<0.[illegible]

TABLE 2.2.11.2-19
TANK 2 POTABLE WATER SL-3 DATA FROM SAMPLE RETURNED FROM ORBIT

Properties	Limits	Results
Electrical Conductivity (Micromho/cm @ 25°C)	Reference only	32
PH (@ 25°C)	4-8	4.8
Total Residue (mg/l)	91.	
Taste and Odor (@ 45°C)	Reference only	
Turbidity (Units)	11	5
Color True (Units)	Reference only	3 to 10
Dissolved Gases (% by Volume)	0.5	
Biocide (ppm)	Reference only	
Particulate/500 ml		
0-10 Microns	Reference only	
10-25 Microns	Reference only	
25-50 Microns	Reference only	
50-100 Microns	Reference only	
100-250 Microns	Reference only	
Sterility (Colonies/150 ml)		
Total Bacteria	Negative	
Total Coliform	Negative	
Anaerobic Analysis	Negative	
Yeast and Molds	Negative	
Ionic Species in mg/l		
Cadmium	0.01	.01
Calcium	5.6	.1
Chromium (hex)	0.05	.02
Copper	1.0	.01
Iron	0.3	.29
Lead	0.05	.02
Manganese	0.05	.01
Mercury	0.005	.005
Nickel	0.05	.03
Silver	0.05	.02
Zinc	5.0	.02
Iodide + Iodine	Reference only	33.4
Selenium	Reference only	
I_2		.05
Silicon		.5
Potassium		8.8
Magnesium		.5
Sodium		1.74
Aresnic		
Aluminum		.5
Additional Data		
[illegible] (ppm)		.1
Nitrate (ppm)		7.0
Nitrite (ppm)		.01

TABLE 2.2.11.2-20
POTABLE WATER - SL-4
DATA FROM SAMPLES RETURNED FROM ORBIT

Properties	Limits	ANALYSIS AT LOADING		ANALYSIS AT RETURN		
		TANK #1	TANK #5	TANK #1	TANK #5	CHILLER
Elec Conductivity (Micromho/cm at 25°C)	Ref. Only	20	21	233	310	45
PH (at 25°C)	4-8	5.1	4.9	1.8	7.8	4.9
Total Residue (mg/l)	91	20.4	19.4			
Taste and Odor (at 45°C)	Ref. Only					
Turbidity Units	11	<0.2	<0.2	24	17	16
Dissolved Gases (% by Volume)	.5	.5	.3			
Biocide (ppm)	Ref. Only	11.0	11.8	1.0	1.0	.7
Particulate/500 ml						
0-10 Microns	Ref. Only	40	360			
10-25 Microns	Ref. Only	69	290			
25-50 Microns	Ref. Only	95	140			
50-100 Microns	Ref. Only	8	4			
100-250 Microns	Ref. Only	3	2			
Sterility (Colonies/150 ml)						
Total Bacteria	Negative	Neg.	Neg.			
Total Coliform	Negative	Neg.	Neg.			
Anaerobic Analysis	Negative	Neg.	Neg.			
Yeast and Molds	Negative	Neg.	Neg.			
Ionic Species in mg/l						
Cadmium	.01	<.005	<.005	.013	.026	<.001
Calcium	5.6	<.02	<.02	25	40	.2
Chromium (hex)	.05	<.02	<.02	.024	.035	.015
Copper	1.0	<.01	<.01	>.005	<.005	<.005
Iron	.3	.02	<.02	.15	.26	.15
Lead	.05	<.05	<.05	>.05	<.05	<.05
Manganese	.05	<.01	<.01	.04	.03	<.005
Mercury	.005	<.005	<.005	.00125	.0005	.0001
Nickel	.05	<.02	<.02	.19	.07	<.01
Silver	.05	<.01	<.01	>.005	<.005	.005
Zinc	5.0	<.005	<.005	.01	.01	<.01
Iodide and Iodine	Ref. Only	11.0	15.3	16.4	18.5	11.9
Selenium	Ref. Only	<.01	<.01	<.01	<.01	<.01
I_2				1.0	1.0	.7
Silicone				.24	.24	.10
Potassium				5.2	5.9	9.6
Magnesium				.40	2.5	<.01
Sodium				.52	.62	.12
Arsenic				.05	<.05	<.05
Aluminum				.05	<.05	<.05
Additional Data						
Nitrogen (Total)				10.12	11.29	.424
Nitrate				.11	.08	.02
Nitrite				.01	.01	.004
Organic Carbon				27	30	1
Color				25	20	5
Amonia Nitrogen				10	11.2	.4
Chloride				13.5	13.0	13

system was purged by allowing water to flow through the heater into the waste tank for a reported period of 1/2 hours. The checklist called for 15 minutes [25 lbs (10.27 kg) of water flow]. Water tank dome movement indicated a dump of 20 lbs (8.96 kg) of water and waste tank pressure profile indicated actual dump lasted 14 minutes. The system was then purged through the chiller for five minutes.

On DOY 147 the pilot (PLT) reported he had a pretty tough time connecting the Wardroom supply hose on Water Tank No. 1, which he attributed to the elevated temperature of the tank (130 degrees). Difficulty could be attributed to thermal expansion of small amount of water between quick disconnect and shutoff valve on the tank. No further reports were received.

On DOY 148, the commander (CDR) reported the water system did have gas in it. He indicated if you were filling 7-1/2 oz. (.21 kg) of water in a coffee container, it would not handle it; you would have to get air out of the container. One-g use of container indicated ON/OFF valve on container was inadequate to prevent air from entering container. It was suspected system was free of air. The problem reported on orbit regarding the gas in the dispensed water was investigated by test using flight type food and the dispenser (reference Action Item 317 R1).

On DOY 150 a small leak was reported at the cold water food reconstitution dispenser. Problem disappeared next day. Several methods of troubleshooting were recommended but the problem was later identified as a liquid spill and not leakage.

On DOY 151, the PLT reported a need for a small finger hold on the food reconstitution dispensers in that it was difficult to press down on the valve, especially with a juice bag, which was filling and unpleating its accordian pleats at the same time.

Water system activation was reported started at 1326Z on Mission Day 2 of SL-3. Two problems were reported (in addition to the crew sickness problem) during the operation which increased the activation time required:

- The WMC system on-board pressure gage read off scale high, 2 psia (13.8 kN/m^2) regardless of the time system was evacuated to the waste tank. Later troubleshooting indicated a pressure transducer failure. The crew was instructed to vent overnight and then activate since gas in the WMC did not present a problem in the pressure indication were true.

  The flush of both the 100 ppm iodine and the deionization cartridge went slowly. This was caused by the waste tank pressure approaching the triple point (which would have caused liquid formation in the waste tank). This required that the flush be stopped until the waste tank pressure dropped. Later flight data indicated that the on-board pressure reading was .05 psia (0.345 kN/m^2) higher than noted in ground telemetry. SL-4 activation procedures took this into account.

During SL-4 activation of the water system, the crewman inadvertently closed the water supply valve on the portable tank with the dump line open during fill of the network for the 100 ppm iodine soak. The portable tank was refilled and injected with iodine and the activation was completed with no reported problems.

During the first few days of SL-4, while using Tank No. 2, the crew reported gas in the water. Previous such reports were attributed to the beverage containers. After changing to Tank No. 3 no further problems were reported.

Observation of bus current data on DOY 10 showed an abrupt increase in "ON" time of the Wardroom water heater. The heater resistance was estimated and showed an abrupt increase. Based upon the qualification heater behavior it is certain that one of the two heater elements failed. Note that the water temperature would still be correct and that the crewmen did not report a problem. Figure 2.2.11.2-78 shows the heater resistance trend during the mission compared to the qualification to function successfully throughout SL-4.

b. Urine Flush System - The urine flush system would have been connected to Water Tank No. 6 when utilized consists of a supply network to a dispenser in the WMC. The dispenser dispenses 50 ml increments of iodine water to flush the urine separators at the end of each daily use.

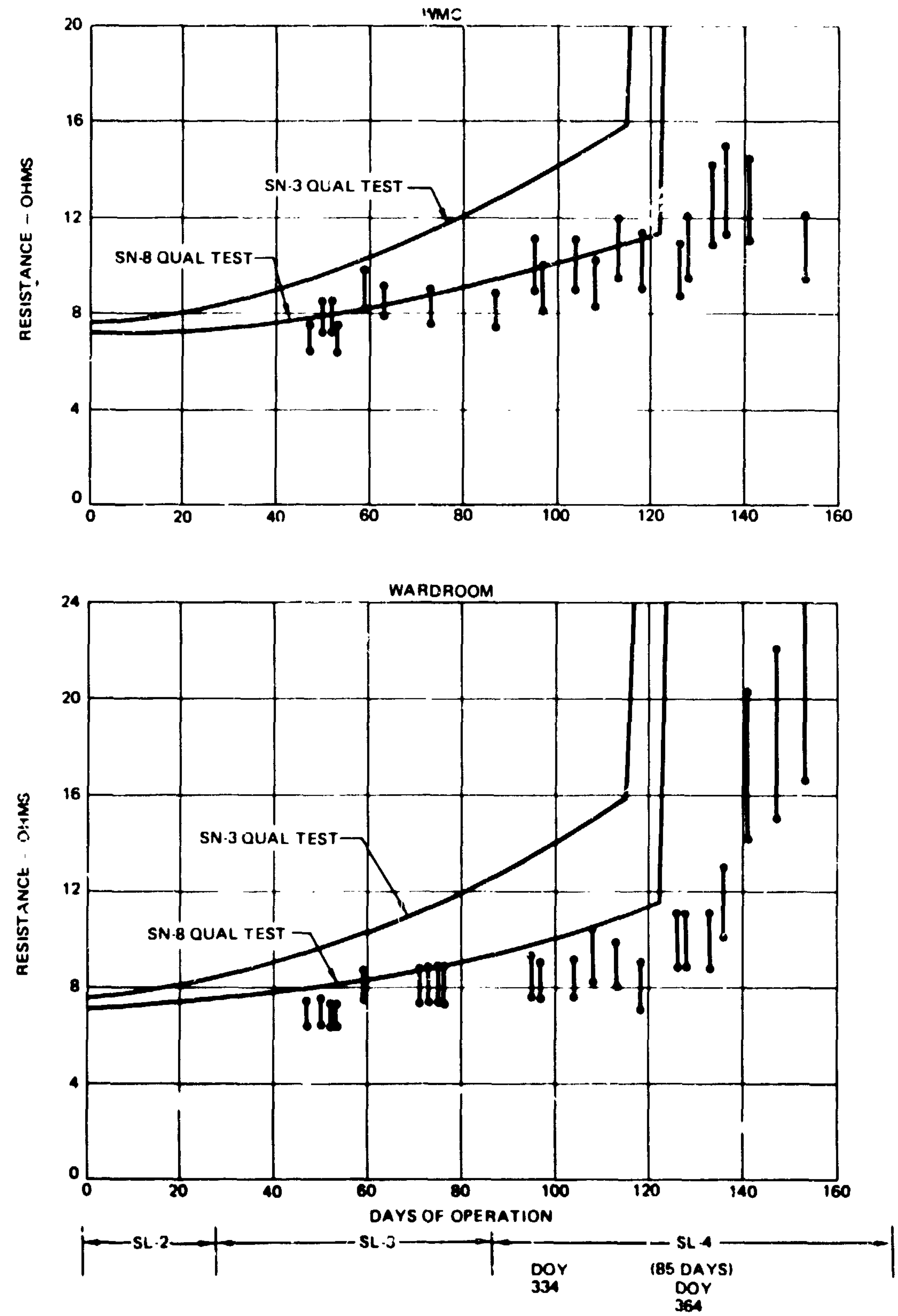


Figure 2.2.11.2-73 OWS 1 WATER HEATER RESISTANCE VS. DAYS OPERATING

The system was not activated or used on any mission. Microbial testing of the separators during system testing on the ground negated the need for daily flushing

c. Waste Management System - The waste management system consists of a flex line from Water Tank No. 7 for SL-? to a hard line network. The network goes to the personal hygiene cabinet in the Waste Management System (WMS) compartment where it connects to a water heater. The heated water in conjunction with washcloths and the washcloth squeezer is used for personal hygiene purposes.

During activation on DOY 147, the CDR requested a review of the requirement for less than .2 psia (1.38 kN/m^2) dump line pressure during evacuation per checklist procedure. The minimum obtainable during condensate tank dump was .77 psia (5.31 kN/m^2). Affect of higher pressure might have allowed gas in the system which would have been acceptable in the WMS. Gas would have purged out during normal use.

On DOY 167 a decrease in flow from the WMC dispenser was reported. The crew replaced the assembly with the spare unit and reported flow to be normal. Evidence of contamination on the replaced unit was reported. The unit was returned by the crew for failure analysis.

The failure analysis of the WMC dispenser returned from orbit disclosed that the seal in the WMC dispenser was undersized for the seal that was supposed to be installed. Further investigation disclosed that the material of the se was neoprene rather than viton. When the dispenser was disassembled at MDAC, it was observed that there was a white, powdery residue caked on the inlet snap ring and a white, flaky residue in all outlets that looked like a soap residue but was determined from analysis to be a corrosion product from iodine attacking the beryllium copper retaining ring. New seals of the proper material were supplied and a reworked spare dispenser was launched on SL-3

During SL-3 activation the dump line pressure transducer was found to be nonfunctional. Activation without the transducer was no problem. The network was used during the mission without problems or anomalies until mission day 56 when the washcloth squeezer seal (Bal-seal) was replaced due to leakage. Upon examination by the CDT the seal was folded back in at least one area, allowing water leakage past the squeezer piston. Three additional spare Bal-seals were carried up on SL-4.

The WMC network was activated on SL-4 with no problems. During the early days of SL-4 the washcloth squeezer was cleaned, lubricated, and the bearing screws loosened. This was accomplished as planned. No problems or anomalies were reported with the squeezer during SL-4. Deactivation on SL-4 was accomplished with no problems reported.

Observation of bus current data on DOY 028 showed an abrupt increase in "ON" time of the WMC water heater. Based on qualification heater behavior it is certain that one of the two heater elements failed. Note that the water temperature would still be correct and that the crewman did not report a problem. Observation of the current data showed that the heater continued to function successfully throughout SL-4.

4/ System Hardware Performance

a. The water subsystem successfully survived the launch environments including the elevated temperature due to the loss of the MS. Both the Wardroom and waste management systems were activated on SL-2 without incident. The regulated gas supply to the water tanks performed in a nominal manner. The water purification equipment was utilized by the crew and performed nominally except for the open question as to why Water Tank No. 1 did not indicate an increase in I_2 level of 4 ppm after injection by the crew.

Tables 2.2.11.2-21 through -23 show a summary of the action items for each mission.

b. The overall functional performance of the water subsystem during SL-2 mission was very good except for air in food containers based on the following comments from the crew:

Dump Tape 154-03 13:58:08

SPT The hand washer is quite useful, although I think in future design, we could arrange an enclosed one, so that you could actually work with water, rather than having to soak everything up in a washcloth. It's extremely useful to have a water dispenser in the head

C-5

OWS ACTION SUMMARY
SYSTEM: WATER
MISSION: SL-2

ITEM NO	OCCURRED ON (DATE)	A.I. NO. (REF)	DESCRIPTION	DISPOSITION
1	DOY 135	012-7	Elevated Temp. Effects	Max expected pressure no problem. Depletion of conc. iodine test in progress.
2	DOY 147	156	Water Tank #1 Iodine Level Low	Inaccuracies are present when using on-board equipment above 100°F (311°K). Cool sample was recommended.
3	DOY 147	157	Waste Mgt Water Dump Line Press High	Acceptable since gas in system will be purged from line during use.
4	DOY 147	158	Wardroom Water Heater Purge 1/2 Hour	No adverse effect on water sys except excess water loss. Water tank dome movement indicated a normal dump time [1.5 in. (3.8 cm) which equals ~20 S/B 25# for normal].
5	DOY 150	180	Cold Water Dispenser Leakage	Problem disappeared next day. Recommend several methods of troubleshooting. Expect problem is condensation 06-12-73.
6	DOY 135	021-7 MSTR 032	Elevated Temp Effects	Test complete. Depletion levels at 180° are small and should pose no problem except for long duration exposure.
7	DOY 168	269 275	Q.D. Leak Rate Test for Condensate Tank (AM) Leakage Indication	Male press cap leakage rate was far less than spec. req. problem traced to AM equipment.
8	DOY 167	267, 285 R1 MSTR 046	WMC Dispenser Failure	Decrease in flow from valve outlet. Replaced with spare. Crew reported evidence of contamination. Location unknown. Failure analysis to be performed on returned value.
9	DOY 172	295	WMC Seal Change Verification	AO's, FO's, and latest drawings collected for failure analysis.

ITEM NO	OCCURRED ON (DATE)	A.I. NO. (REF)	DESCRIPTION	DISPOSITION
1	DOY 210	502-1	Off Scale High Reading of WMC Pressure Measurement (Vacuum Dump System)	Complete vacuum fill and dump without measurement. No action taken to repair or replace.
2	DOY 225	538	Washcloth Squeezer Problems	Recommended seal replacement and overall inspection.
3	DOY 264	539-2	Washcloth Squeezer Detailed Procedure	Detail procedure for inspection and cleaning submitted.
4	DOY 265	539-1	Recommendations For Squeezer Troubleshooting and Spares	Preliminary for 539-2 above.
5	DOY 266	589	Water Tank Iodine Level Recommendation - SL-3 Termination	Recommended that SL-4 start using Tank 2; therefore, increase Tank 2 iodine level to 6 ppm at end of SL-3.
6	DOY 266	529-7	Washcloth Squeezer Seals for SL-4	Three spare seals delivered to KSC for SL-4 fly-up.

TABLE 2.2.11.2-22

OWS ACTION SUMMARY
SYSTEM: WATER
MISSION: SL-4

ITEM NO	OCCURRED ON (DATE)	A.I. NO. (REF)	DESCRIPTION	DISPOSITION
1	DOY 323	700 R1	Crew Reported Air in Drink Water	Cause suspected to be air in beverage containers as in past. Crew reported air eliminated with switch from Tank 2 to Tank 3.
2	DOY 341	617-5 R1	Return of Cation Filter	Cation filter will not be returned. Additional water samples will be returned to determine cation filter performance.
3	DOY 346	617-6 617-7 745	Procedure for Water Sample Return	Procedure Submitted.
4	DOY 010	735-1 735-2 735-3	Wardroom Water Heater Degradation	Heater continued to function with one of the two elements failed. Procedures proposed for various options. Heater functioned through SL-4.
5	DOY 030	749 749-R1	WMC Water Heater Increased "ON" Time	Heater continued to function with one of two elements failed. Procedures proposed for various options. Heater functioned through SL-4.

for taking a sponge bath and wiping things down, and a hand washer serves that function very nicely.

Dump Tape 154-03 14:03:06

SPT Okay, food reconstitution dispenser, no problems, really. You need a little something to react against when you're pushing the food down into the water dispenser. Generally, you either brace yourself with your thigh restraints or you put one hand on the edge of the food table and pull at that while you push down with the other hand. The water gun is just fine. It's an excellent piece of equipment.

Dump Tape 154-06 16:46:20

CDR The water gun works very well. We have no trouble with the water gun.

Dump Tape 155-12 22:43:45

CDR The one thing that we asked most, though...and this is a chronic problem...but to this day nobody has successfully got the gas..whatever gas it is, out of the water. We have problems rehydrating our food right now, especially with hot water. When we rehydrate the bags, fill them all the way up...we opened the seal inside on the food fold bag so that the food's already up...you go to cut it, and that makes that too difficult to handle and it blows the bag up.

Voice Tape 148:13:52

CDR The waste system does, in fact have gas in it. And if your're going to 7-1/2 ounces (.21 kg) of water in a coffee (garble) and it won't handle it. and You've got to let the air out and mess around with it.

Dump Tape 148-09 12:38:53

PLT Okay, B Channel. Just had a accident with an instant breakfast. There was a lot of air in the container before reconstitution, and there was quite a bit of instant breakfast powder leaking out the top before reconstitution. On reconstitution, it wouldn't accept 6 ounces (.17 kg) of water because there was too much air in it. And consequently, the water leaked out around the nozzle.

CDR Darn.

PLT In general, if you put less than the specified amount of fluid in, and don't get too much air in the water, and hold your finger over the nozzle while you're shaking it, you do better.

Dump Tape 151-09 19:23:20 19:24:16

PLT Food reconstitution dispenser: those water dispensers need some kind of handhold in their vicinity.

It's fairly difficult to press down on it, especially a juice bag, which is filling and unpleating its accordian style at the same time. I think we need some sort of small fingerhold, not a handhold, right around those water dispensers. The water gun works, as I suppose you know, it's easy to use. It takes about three shots of water before you get chilled water, but that's all right.

c. The iodine levels in the tanks remained above the predicted depletion.

d. The amount of water used by the crew (both Wardroom and personal hygiene) was less than allotted.

e. The portable water tank was not used by the crew except to verify the pressure in GN_2 supply system to the water tanks (SL-2).

f. The urine flush system was not used by the crew.

g. Both the Wardroom and waste management systems were deactivated without incident.

h. Some general system performance observations from the SL-2 Crew Technical Debriefing on July 10, 1973, are as follows:

   1. The water temperatures of the water in the tanks were high and are still fairly high because of the higher than normal temperature in the SWS.

   2. Crew was happy with the water allotment and felt it was adequate for their needs.

   3. It was easy to wash hands on orbit if the crewman is careful not to move too fast.

   4. Water from waste management dispenser did not bounce around.

   5. The crew stated that there was no iodine taste to the water or they became acclimatized to it. In any case, the CDR stated that it is the best water system he has ever flown.

6. Six (6) lbs (2.62 kg) of shower water is sufficient to rinse off after a shower.

i. Several questions were asked on water subsystem with crew comments at the SL-2 Crew Technical Debriefing on July 10, 1973, at NASA/JSC. The questions and responses follow:

1. Comment on being able to distinguish color using comparator on the low end. They apparently did not have any problems distinguishing color on the color comparator in the low end. On SL-2, Mission Day 3, during activation of the water system, the crew reported that the iodine concentration ran very close to zero which they estimated from the comparator as being between half and one part per million.

2. Was temperature of water for food and drink acceptable? Would you recommend any change for future design?

   The first slug of water from the heater system and the chiller system was cool and warm, respectively, as would be expected with a line from the units which are not conditioned. The crew reported that the water temperatures were excellent and were just about right and they stated that future designs would not have to be changed.

3. Describe location of leak reported on food reconstitution dispenser. Was leak continuous or periodic or one time?

   The "leak" was only observed the one time and after examining the dispenser and reflecting on the "leak" the crew decided that it was not a leak after all. The observed water was caused by a small water spill during a food container filling procedure. The crew reported that all spilled liquids adhered to corners of units or when applicable to thin edges and this is why the liquid was thought to be a leak.

4. Was there any condensation associated with the chiller?

There was never any condensation on the chiller and only minor condensation in several places in the entire Workshop.

5. Was hard tip end of drink gun any problem?

The hard tip end of the drink gun did not pose any problems and the use of the drink gun was a satisfactory and easy way to obtain drinking water.

6. Did drink gun rubber tip remain in place?

The rubber tip did not come off and no problems were encountered with its use.

7. Was iodine taste noticeable? Acceptable?

The iodine taste was not noticeable and the taste of the water was excellent. The crew reported that the water tasted better than any previous manned space mission.

8. Was temperature of water acceptable (for washing and shower)? Would you recommend any changes for future design?

The first slug of water was not hot as is inherent with the system design but in general the temperature of the water for washing and for showering was acceptable. The crew did not recommend any changes for possible future designs.

9. Was washcloth held up against dispenser? If not, how far away?

   The washcloth was always held up against the dispenser when the water was dispensed. The water was then absorbed by the washcloth in a short time. The crew stated that unless this was done the water could not be controlled. The crew also reported that the water dispensing pressure, although not causing any problems, was about as high as practical for present and future applications.

10. Was free water a problem?

    Free water was not a problem because of the way that they used the washcloth and the washcloth squeezer. Apparently, the crew felt that free water could become a problem if the dispensed water pressure were any higher than on SWS. Water did not bounce around from the water dispenser.

11. Was installation of squeezer bag any problem?

    The installation of the squeezer bag was easy and did not pose any problems.

12. Was bag dump performed every three days?

The squeezer bag was dumped every three days on a scheduled basis. It should be considered through that SL-2 crew water usage and, therefore, bag dump operations might not be typical because they did not use all of their allocated wash water.

13. Was bag fully expanded (bulged) prior to dump?

The bag was never allowed to fill up before dumping. The bag was usually about 2/3 full at most and the rubber bag never filled out to the cloth cover bag at the time that it was dumped.

14. During activation of Wardroom network, what pressure was reached when evacuating the system?

The crew reported that this was a misunderstanding of the people on the ground because the system was activated per the procedures [0.2 psia (1.38 kN/m^2) or less] but they had to wait a little for the pressures to decrease.

15. Was the air that was reported in the system due to the bag/container interface or actually coming from the system?

This item appears to be still somewhat controversial because everyone except the CDR seems to feel that the air is in the food containers and not in the water. The CDR states that he still thinks the air is in the water but had no proof to confirm his belief; however, he stated that this is the best water system he ever flew.

16. How well did tank bellows location work?

The tank bellows locator worked easily and well on all of the water tanks because of the magnet location stripe on the side of each of the water tanks. The tank bellows locator was used on the condensate tank to try and locate the bellows with less than spectacular results because there was apparently no location strips on the side of the tank.

j. Excerpts from the SL-1/SL-2 Technical Crew Debriefing are as follows:

SWS Activation

Kerwin I did the H_2O tank iodine. As I recall, the reading was low, but the procedure was fine. There wasn't any problem there.

Weitz Water system activation, again, per checklist, as I remember. The Wardroom water purge. Step 1 of the procedure said "verify the bellows in Water Tank 1 had moved about 2 in. (5.08 cm). If it moves about 1-1/2 in. (3.8 cm), do not continue and notify STDN." I notified Spaceflight Tracking and Data Network (STDN) that it moved about 1-1/2 in. (3.8 cm) and they said "continue." Apparently, the system worked normally after that. So i don't know what the distinction is between 2 in. (5.08 cm) and 1-1/2 in. (3.8 cm). Water purge, fire hose activation, and portable water tank restraint removal went per checklist.

SWS Deactivation

Conrad — The Workshop deactivation went right by the checklist. I can't say enough about Gary Doerre's group on both the activation and deactivation. Those checklists really worked well, other than the fact that it took a little longer to handle transfers than we expected.

Got the water system shut down, making up the extra drinks and everything. We had plently of water and drinks.

We deactivated the cation cartridge. I read you the procedures, that was no problem putting the iodine in it. Closeout of the Wardroom water system was no problem. Deactivation of the waste management compartment water system was no problem.

SWS Inflight Experiments

Kerwin — The foods were very edible. Anything that stays together the least amount is easy to eat that way in zero-g. It's a nice way to go. We used that method with the rehydrated foods also by cutting large sections off the top of those inner bags so that we had free access to the food.

Weitz — I cut as much off as I could.

Kerwin — As much as you can. You kind of squeeze it down sometimes and you get a little bit of food in the cone that you cut off the top, but it's not a problem. The problem with rehydratables is primarily related to air in the water, whether it be air or steam. It's worse with hot water, so there's probably a certain amount of water vapor involved.

It increases the volume of the bag so much when you rehydrate it that in many cases you couldn't get the tray lid back on. That meant that you could not rehydrate the food and then heat it, and let it sit in preparation for the next meal. That's unfortunate because many of those foods require long rehydration times to make them really palatable, things like the spaghetti, the macaroni.

The other problem I had with the drinks was that little insert that you had to put into the nozzle and then push forward with your teeth to get the drink out. When you let go of that thing, you were supposed to pull back on it to close the flap again. That was hard to do. You had to pull back just the right amount to close the flap but not too much or it would come completely out and then you'd have to reset it again. The upshot of it was that you'd either let go with your teeth and the drink would keep on coming out because you hadn't pulled it far enough or you'd get air into the drink. Then the next mouthful would be 90 percent air and 10 percent drink. We wound up swallowing a lot of air in the drinks. We need a better drink container.

Our fluid intake didn't present a problem. The water guns are extremely convenient. They're easy to use. The fact that you have one gun for each crewman and all you have to do is log the water once a day makes it easy. The fact that there are some calorie-free drinks on board, if you want to take something that tastes better than water, is a good thing.

The apple drink takes 12 hours to reconstitute. That's not a good one. The other drinks were okay.

SWS Human Factors

Kerwin You didn't like the bread.

Weitz I really didn't like it, but I didn't dislike it as much as you did.

Conrad We have a couple of comments on that. One of them was when we were restricted on the use of our heater. I think that one of the mistakes that we made was not letting some of that food reconstitute long enough and that added to the bad taste of it. I found out that if you reconstituted the peas, the beans, and the asparagus early, and then reheated them, I still didn't like them, but they were a lot easier to choke down than when I added the hot water, shook up the bag and then tried to get them down. They didn't reconstitute as well. There were several foods, the macaroni was another one, that needed to be reconstituted and let set. Spaghetti and meat sauce was another.

Now food preparation and consumption. We've talked about the rehydration, but we have not mentioned the gas. Now, I think the gas was probably too cold. I think there was some in the packages.

Kerwin Yes, there was some in the water, and there was some water vapor that came out when you used hot water. It was worse with the hot water, than with the cold.

Conrad We deliberately took some films of bags that were filled with hot water, that expanded them to their fullest.

When we got to the reconsituting, rehydratable hot food early we would have to let the air out of the package. We would have to go to the trouble of letting the air out of the package so that we could put it back into the can and put the lid on. An example was the fruit tray.

Kerwin Yes, you would have to let the air out of it, and that was not a terribly easy thing to do. In many cases, we walked by and Pete's tray lid would be popped off, because he was heating some food in there, and it was too big for the slot.

It was hard to get the tray on top of it. Something that was interesting to me was when you reconstituted one of those rehydratable food and it wound up with a lot of gas in it, it was a pyramid shaped package, with a big flat bottom, and a cone-shaped top. The air would pretty much concentrate on the top or cone-shaped part of the package. Now, that can't be gravity, so it must have to do with surface tension and the shape of the package. That's a point to keep in mind for future design, because you can make air concentrate. You got more surface tension around the sharp radius corners, where the food stuck in the bottom. That was lucky because it made it possible to cut the top off the packages, without losing a lot of food.

The food temperature was good. The only thing along that line was, of course, that we could not heat our coffee. You had to put it in with hot water and then you had to drink it quick before it cooled off. It was certainly hot enough to start with. But those drink containers did not lend themselves to sipping a drink, and drinking over a period of 5 or 10 minutes, as you ordinarily do with a cup of coffee, because they tended to suck back air. They cooled off very rapidly, and were a little bit difficult to drink out of. I think we need a better drink package for the future. We all thought the water was reasonable good.

Conrad — Yes, I was never really aware of any iodine taste or anything like that in it.

We ran between two and ten parts per million.

Weitz — I got nine out of one tank, but at the same time, that's the tank that was feeding the table but Joe and I both read one at the chiller.

Conrad — That's right. You showed me that.

I wasn't aware of any physical discomfort from gas in the water. I guess the place I was most aware of gas in the water, though, was the coffee. It seemed to have the most in it, because it was hot.

Weitz — Everybody swallows a lot of gas up there. I think that if you're going to operate successfully in zero-g, your body has to process that gas. You belch very little, therefore, you pass most of the gas in the form of flatus. You have a lot of flatus, and that's just part of living up there.

Did you belch at all?

Kerwin — Yes, I did.

Weitz — I never did.

Conrad — I never did either.

Kerwin — I think it was the phenomenon we saw in the packages. I would get a gas bubble near the top, in the stomach and out it would come. You're to swallow air and gas, and you have to pass it on through.

k. Both the Wardroom and waste management systems were activated without incident on SL-3. The regulated gas supply to the water tanks performed in a nominal manner. The water purification equipment was utilized by the crew and performed nominally.

l. The performance of the deionization cartridge will be determined from the analysis of the water sample returned by the crew.

m. The overall functional performance of the water subsystem during SL-3 mission was very good except for the two minor anomalies previously discussed in paragraph 2.2.11.2 D.3/.

n. During qualification testing a water heater element failed at about 120 mission days. Spare water heaters were placed aboard the Workshop which would be installed by the crew when failure occurred. Available current data has been used to determine the element resistance in an attempt to predict when failure will occur. Figure 2.2.11.2-78 shows the change in resistance that occurred during the missions.

o. Questions were prepared for crew comment. These questions and answers to those selected for crew comment follow.

   1. Comment on being able to distinguish color using comparator on low end. Answer: It worked quite well. It is a very acceptable way to go.

2. Was temperature of water for food and drink acceptable? Would you recommend any change for future design?

Answer: Yes - The CDR would have like to have had his water hotter but the other two crewmen thought it was just right. Suggest putting a temperature control in the future. Cold water was really great.

3. Was there any condensation associated with the chiller?

Answer: No condensation was noticed. We got a little leakage on the food dispenser - probably because we didn't get the bag on right. It was no real problem - not enough to bother about.

4. Did drink gun rubber tip remain in place? Answer: Yes.

p. Crew comments obtained from the Technical Crew Debriefing follow:

Waste Management Compartment Water Dump

Bean Nominal.

Urine Flush Water Dump

Bean We did not use it.

Wardroom Deactivation

Lousma The Wardroom water, when it was dumped - the pressure in the dump lines didn't want to come to its nominal value of 0.7 psi (4.8 kN/m^2) in less than 3 minutes, or something like that. We just pressed on according to the ground call. I think in dumping anything into the waste tank, the pressure never does come down rapidly, as it is supposed to, so the checklist ought to be changed to reflect that and there should be a procedure as to what to do when it doesn't.

Bean They ought to change the procedure.

Deactivation of Cat Ion Cartridge

Bean Nominal.

Closeout Wardroom Water System

Lousma When you evacuate the lines in the Wardroom water system and then turn off the flow to the tank you're using, and then disconnect the Wardroom water, for some reason, you don't have all the water out of the lines and you get about a cupful of water that comes out of the Wardroom water line when you disconnect it from its tank. That was the reason I had the big rags in front of me. This did not happen when the waste management water system was deactivated.

Deactivate WMC Water System

Bean Nominal.

Water System

Bean Water system was easy to work. Jack did most of the work. Every once in a while they'd want somebody else to measure the iodine and put in new. That was straight forward. We always measured it, told the ground and they came back and told us what to put in and we put it in. We never used the on-board chart that I know of, did we?

Lousma I always double checked it. They always gave us the right number.

Bean I found that we had to replace the seal on the washrag squeezer. The washrag squeezer is going to need to be dismantled and cleaned for the next crew. It looked like it was picking up some sort of grime and grit, either from dirt or soap or something on the moveable parts. Looked like a simple procedure, but by the time that it became rather obvious to us that something needed to be done, we were running out of time - optional time. So we didn't fix it. We reported it to the ground, but I think they need to go up there, dismantle it, clean it up, and reassemble it - it will be a lot better. They may need some lubricants. Also one of the things we noticed is, if you don't have that handle fully extended so that the piston is all the way out, then when you close the lid on the squeezer you stand a good chance of tearing the seal or folding it back and once you've done that, it just isn't the same. So it's important that when you're using that squeezer to make sure the handle is fully out before you lower the lock and engage it so that it doesn't catch the lip of the piston seal. I found it was much more fun to bathe in there when I did not worry about getting so much water around. It's like the crumbs from eating; they went around and kind of disturbed you for a little bit. After you got used to it, it wasn't bad and it made things go faster. I tended to throw a lot of water around in there whenever I bathed and it was a lot nicer and it didn't hurt anything. It just got the place a little wet and I had to clean it up, which was a lot better than trying to be so tidy all the time.

E. Conclusions and Recommendations - The water system provided satisfactory performance during the entire mission.

1/ The iodine level at the dispensers was maintained above 2.0 ppm as required. The water properties of the tanks checked through SL-3 were within specification.

2/ The ionic species levels were expected to exceed the specification during SL-4 (based upon qualification data) downstream of the cation filter. The allowable iron, chromium and nickel are 0.3, .050, and .050 mg/l, respectively. The measured iron, chromium and nickel were 0.15, $<.005$, and $<.01$ mg/l, respectively, during SL-4. These levels were determined to be satisfactory by NASA medical personnel prior to start of all Skylab missions.

3/ Water temperatures and quantities heated and chilled were also satisfactory for all uses except the shower. The shower requirements were not imposed on the water system design but it was reported by the crew that the six lbs (2.62 kg) obtained from the hygiene water heater were not hot enough [heated water is four lbs (1.8 kg)].

4/ There were reports of air in the water at the start of two missions; SL-3 determined the problem was not with the water, but with the food and food packages. The SL-4 crew again reported air in the water. After changing from Tank 2 to Tank 3, the crew reported on DOY 330 that there was no longer gas in the water.

The following is an outline of the significant problems or conditions reported and the resolutions:

1/ The SL-2 crew sampled the I_2 level in Water Tank Nos. 1 and 7 as a part of the water system activation and found the I_2 level was much lower than predicted. They recharged Water Tank No. 1 with an additional input of the high concentration I_2 solution to raise the I_2 level in the tank by 4 ppm. Subsequently, the I_2 concentration anomaly was investigated at MDAC-W and it was proved that the low I_2 reading obtained by the SL-2 crew was because the water in the tanks was hot due to high cabin temperature. As the water temperature decreased, the measured I_2 concentrations again were approximately as predicted.

   Although the SL-2 crew reported adding additional I_2 to the water tanks because the concentration was low while the water was hot, after the tanks and the water had cooled off, the I_2 concentration was not above the predicted values. This anomaly could have been caused by the iodine injector assembly not injecting I_2, or the I_2 could have been inadequately mixed in the tank. The equipment was later used with no problem

2/ On DOY 167 a decrease in flow from the WMC dispenser was reported. The crew replaced the assembly with the spare unit and reported flow to be normal. Evidence of contamination on the replaced unit was reported. The unit was returned by the crew for failure analysis.

The failure analysis of the WMC dispenser returned from orbit disclosed that the seal in the WMC dispenser was undersized for the seal that was supposed to be installed. Further investigation disclosed that the material of the seal was neoprene rather than viton. When the dispenser was disassembled at MDAC, a white powdery residue caked on the inlet snap ring and a white, flaky residue in all outlets that looked like a soap residue was observed. However, analysis determined the substance to be a corrosion product from iodine attacking the beryllium copper retaining ring. New seals of the proper material were supplied and a reworked spare dispenser was launched on SL-3.

3/ Near the end of SL-3 (Mission Day 56) the washcloth squeezer seal (Bal-Seal) was replaced to eliminate leakage. Upon examination by the CDR the seal was folded back in at least one area, allowing water leakage past the squeezer piston. It was also reported that the squeezer was beginning to get difficult to operate because of "grit, grime, dirt, or soap" on the moveable parts. A procedure was prepared for cleanup and lubrication during SL-4. Also, three additional Bal-Seals were sent up as spares. The squeezer was serviced and the bearing screws loosened as planned on SL-4. Subsequent operation was satisfactory throughout SL-4.

As stated above, the water system performance during the entire mission was successful and, therefore, only a few recommendations can be made for a future similar water system.

1/ The complexity of the OWS water dispenser is primarily due to the requirement to dispense to ±1 percent accuracy for medical experiment reasons. Assuming the medical experiments were eliminated, at least the drink dispensers could be simplified to an on-off valve design.

2/ The shower water quantity and temperature requirements were not imposed on the water system. Indications are that the water quantity heated for hygiene purposes would be increased if a similar shower were used on a future application.

3/ The crew reported a little difficulty holding the food packages on the reconstitution dispenser. Future food packages should include an improved holding area. Consideration could also be given to addition of some restraint on the table top or dispenser.

4/ The washcloth squeezer was intended to be a low cost improvement to the washcloth bathing scheme. The hardware performance and overall scheme were reasonably successful but it is felt that this is an area for improvement for future design. The OWS design did not eliminate cross contamination between crewmen since only one squeezer was provided. Also, it would be desirable to reduce the crew effort. A future scheme should allow wringing of a washcloth in much the same way as in one-g The development of a high flow air supply and liquid air separator would be an approach to consider.

5/ The problems noted in the mission results Section 2.2.11.2 1/ related to the failure of the water heater element were expected because of results obtained during long duration qualification tests. Spare water heaters were on board to allow replacement if required (but were not required on SL-4). A redesigned heater element incased in metal (Cal-Rod type) was designed and tested for the Backup OWS. The new configuration should be considered for any future project.

F. Development History - The configuration of the water system was changed after the Critical Design Review (CDR) because of requirement changes which resulted in Engineering Change Proposals (ECP's) and because of problems encountered during the development and qualification program. Table 2.2.11.2-4, OWS Water System Problem Summary, lists the significant problems encountered in the development and qualification program and a summary of the solutions. The solution in some cases was a material or configuration change. The approved ECP changes since CDR follow:

1/ Nitrogen Gas Supply for OWS Water System Pressurization, Metabolic Analyzer and Experiment Support System - This change necessitated connection to the AM nitrogen system rather than oxygen system. Also, use of nitrogen allowed use of materials which were not compatible with pure oxygen but with better performance characteristics.

2/ Optical Iodine Comparator Redesign - The optical iodine comparator was previously a cabinet mounted device. This change made the unit a hand-held device with a light diffuser that was illuminated from behind utilizing existing Workshop lighting.

3/ Addition of Washcloth Squeezer Test - A washcloth squeezer and waste water collection bag were added to the water system as a result of action items during the Progressive Crew Station Reviews. The initial design agreed was a sponge and piston type wringer. It was subsequently found that the sponge concept was unacceptable and as a result the washcloth and squeezer approach was developed and accepted.

4/ Design Fabricate and Test a Centrifugal Separator Urine Pooling System - The requirements initially established called for a urine capability. A complete urine flush waste network and dispenser was designed and tested. Subsequent test of the urine system showed that the flush capability was not needed and the water network was never used in flight.

11.3 Personal Hygiene System

A. Design Requirements - The design requirements for the personal hygiene equipment were:

1/ Toilet Tissues (Utility Wipes)

a. Toilet tissues and a dispenser shall be provided for use in the WMC.

b. A dispenser for the toilet tissue shall be easily accessible to an astronaut positioned on the fecal collector seat.

c. The chemical composition of the toilet tissues shall not alter the collected sample constituents.

2/ Waste Storage Containers - Storage containers for the waste management supplies and for processed samples shall meet the following requirements:

a. 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.

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

c. Storage containers shall be provided for used waste collection vehicles and the processed contents of each.

3/ Personal Hygiene Water Dispenser - The requirements for water to be used for personal hygiene activites were:

a. A supply of water shall be provided in the WMC for personal hygiene activities.

b. The water supply shall include a dispenser which delivers water at a temperature of 125 $^{+9}_{-5}$°F (52 $^{+5}_{-3}$°C) for skin cleansing.

c. The personal hygiene water dispenser shall be designed to prevent cross-contamination between astronauts.

4/ Personal Hygiene Equipment - Personal hygiene equipment was provided for the maintenance of skin health, personal cleanliness, grooming, and the collection and disposal of body particulate matter. The personal hygiene activities and equipment, with the exception of those related to tooth brushing, will be accommodated, within the WMC. Specific hygiene activities to be accommodated shall include body cleansing, brushing of the teeth, shaving, and nail and hair cutting. Provisions to accommodate tooth brushing shall be made in the wardroom. Special emphasis shall be placed on the prevention of cross-contamination between astronauts, between the astronauts and various pieces of equipment, and between different pieces of equipment. The major components of the personal hygiene equipment are:

a. Common personal hygiene modules

b. Individual personal hygiene modules

c. Skin cleansing equipment

5/ Common Personal Hygiene Module - A Common Personal Hygiene Module (CPHM) shall be provided and shall incorporate the following equipment:

a. The CPHM shall contain equipment items and supplies that will be shared by the astronauts, it shall be located in the WMC.

b. The CPHM shall contain:

1. General purpose tissues and dispenser
2. Wash cloths
3. Bath towels
4. Utility towels (wipes and dispenser)
5. Disinfectant pad dispenser (biocide wipes)

c. Dispensers for general purpose tissues and wipes shall be easily accessible to an astronaut seated on the fecal collector seat.

d. Wash cloths and bath towels shall be identified for each crewman's use.

e. The capability shall be provided to dry washcloths, towels, and toothbrushes.

f. Installed and portable holders shall be provided for the temporary restraint of the towels and washcloths. Portable holders shall be attached by means of snaps.

g. Pre-moistened disinfectant cotton pads, chemically treated with a 0.50 percent (nominal) solution of free iodine, shall be added for control of microbial growth.

6/ Individual Personal Hygiene Module - Individual Personal Hygiene Modules (IPHM) (GFP) and contents shall be stowed as specified in I-SL-008.

7/ Mirrors - An unbreakable mirror approximately 10 in. by 15 in. (254 by 381 mm) shall be mounted on the back side of the top locker door at each sleep station. An unbreakable mirror approximately 12 in. by 16 in. (300 by 400 mm) shall be mounted on the

WMC wall above the indentation opposite the fecal/urine collector. There shall be an unbreakable mirror covering the upper door of the WMC water module locker (except in the area of the hinges and latch).

8/ Body Cleansing - Skin Cleansing Equipment - The capability and supplies to wash, rinse and dry the whole body shall be provided. The "washcloth" concept shall be employed.

9/ Water Subsystem Expendables - The following requirements are from Saturn System Engineering Study Report OWS Expendables (MDC G0068-P, January 29, 1970).

a. Personal Hygiene Requirement (WMC) - Personal hygiene consists of a "sponge bath" using moistened washcloths. An allocation of 1.0 lbs. (0.45 Kg) of water per man-day is made for this type of body cleansing. If this method were used for the entire mission, the water requirements would be 1.0 x 3 x 140 = 420 lbs. (190 Kg).

b. Cleanup Requirement (WMC) - WMC cleanup consists of use of the utility wipes (possibly with a bactericide) for daily compartment cleaning. Four (4.0) lbs. (1.8 Kg) of water per day is allocated in order to cover contingencies during fecal and urine collection. 4.0 lbs. (1.8 Kg)/3 men/day x 140 days = 560 lbs. (250 Kg).

B. System Description - The Personal Hygiene Subsystem provided all the supplies and equipment necessary for the skin and dental health, good grooming and the hygiene needed for the three missions. The major hardware and equipment used for personal hygiene is listed as follows:

- o Wipes and Tissues
- o Biocide Wipes
- o Towels and Washcloths
- o Washcloth and Towel Drying Equipment
- o Hygiene Kits (GFE)
- o Mirrors
- o Washcloth Squeezer and Water Dispenser
- o Soap

Overall personal hygiene equipment location is illustrated by Figure 2.2.11.3-1.

1/ General Purpose Tissues and Utility Wipes - General purpose tissues were contained in fireproof aluminum foil lined pasteboard packages. There were 11 tissue packages each with

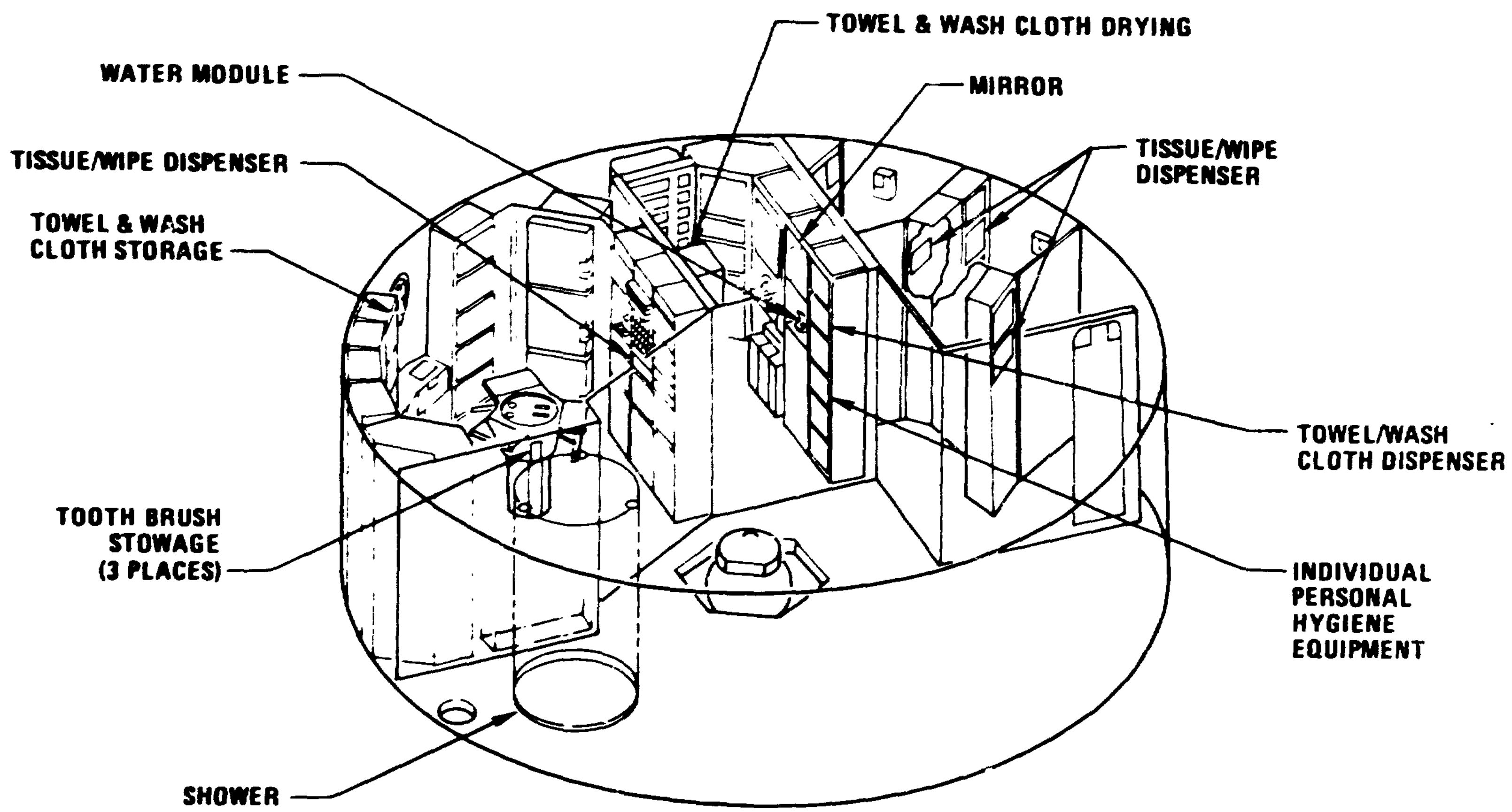


Figure 2.2.11.3-1. Personal Hygiene Equipment

a minimum of 392 tissues per package. This provided a usage rate of 12/man/day with a 10 percent contingency. Tissues were used for equipment and compartment cleansing, for personal use, and for small cleaning tasks. Upon completion of a given operation, the tissue was disposed of in a trash bag. Each tissue was fabricated from Kimberly Clark "Kay Dry" material and measures 5 by 8-7/16 in. (127 by 206 mm). The packages were provided with tear-out front sections and tear-out rear sections. The tear-out front section formed a cutout, which exposed the tissues when accessed through the opening in the dispenser. The tear-out rear section allowed the spring-feed device in the dispenser to advance the remaining tissue into an accessible position, replacing the removed tissue. There were 11 general purpose dispensing locations: six in the sleep compartment, four in the wardroom, and one in the WMC.

Utility wipes were contained in a package identical to the tissue packages. There were 23 wipe packages provided with a minimum of 196 wipes per package.

This provided a usage rate of 10 wipes/man/day with a 10% contingency. The wipes are used as toilet tissue, for equipment cleaning and for compartment cleaning. Each wipe was fabricated from Kimberly Clark "Kay Dry" material and me ures 5 by 16-7/8 in. (127 by 418 mm). The wipes are twice the length of the tissues. The packages are provided with tear-out front and rear sections as described for tissue packages.

Upon depletion of a wipe package, the package was removed from that dispenser and replaced with a fresh package obtained from wardroom stowage compartments. There were 11 utility wipe dispensing locations: seven in the wardroom, three in the sleep compartment, and one in the WMC. When used as toilet tissue, the wipes were obtained from their dispenser while the crewmember was seated on the fecal/urine collector. The tissue was then deposited in the fecal bag. The wipes that are used for equipment and compartment cleaning are deposited in a trash bag after use.

A wipe holder was provided as an aid when cleaning in confined areas and permits the restraint of the wipe while the crewman manipulates the holder into hard to get at areas.

Each tissue and wipe package had nomenclature, part numbers and serial number.

Figure 2.2.11.3-2 shows tissue and wipe dispensers.

2/ Biocide Wipes - Biocide wipes were contained in fireproof aluminum foil lined pasteboard packages. There were 5 biocide wipe packages provided each with 70 wipes per package. This provided a usage rate of 2/man/day with a 10% contingency. Biocide wipes were used for housekeeping tasks requiring disinfecting other than food spills. Each biocide wipe was fabricated from 6-1/2 by 7-1/2 in. (165 by 190 mm) Webril R-2201 (Cotton) and contained 12.0 ml Betadine solution in water. The Betadine had 5000 ppm available iodine. Each biocide wipe was wrapped in conolon 6000 film before being stowed in a package. The packages were provided with tear-out front

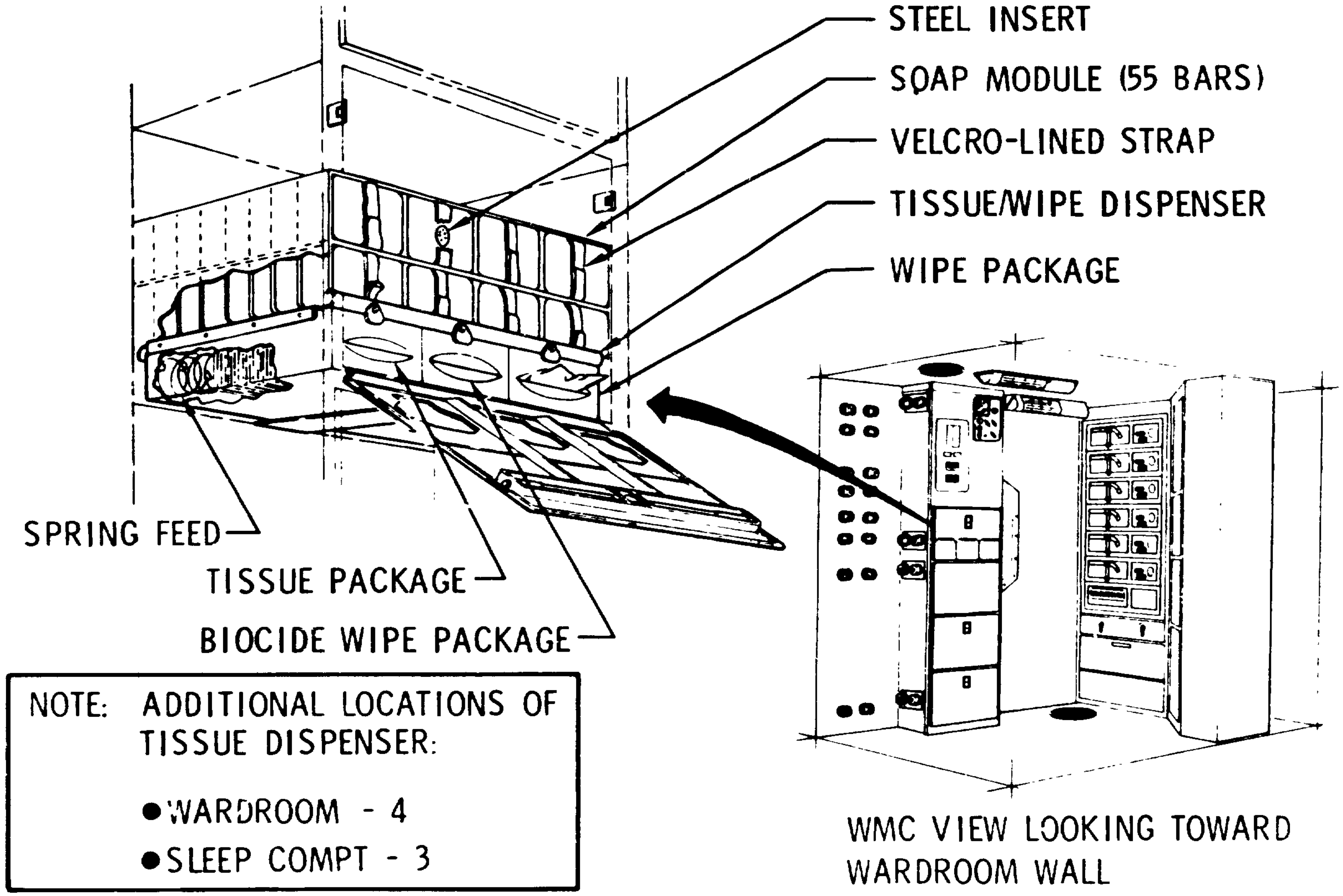


Figure 2.2.11.3-2. General Purpose Tissue/Soap Dispenser

sections and tear-out rear section. The tear-out front section formed a cutout which exposed the tissues when accessed through the opening in the dispenser. The tear-out rear section allowed the spring-feeding device in the dispenser to advance the remaining biocide wipes into an accessible position, replacing the removed biocide wipes. There was one biocide wipe dispensing location in the WMC. (See Figure 2.2.11.3-2.)

3/ Washcloth and Towels - Washcloths were provided in sheet aluminum boxes. There were 30 washcloth boxes provided each containing 28 washcloths. This provided a usage rate of 2/man/day. The washcloths were used for personal hygiene and vehicle cleaning. Each washcloth was 12 $in.^2$ (300 mm^2), and fabricated from rayon polynosic terrycloth. Each washcloth was edged with stitching of the crewman's color code; however, light blue stitching was used for the SPT color code of white.

The washcloth boxes had a 3 in. (76 mm) diameter hole in the face that allowed retrieval of individual washcloths. A spring-feeding device, integral to the box and located at the rear, advanced the remaining washcloths to an accessible position behind the opening, replacing the removed item. Three removable boxes, each having a crewman's identification color coded "Snoopy" decal on its face, were located in the WMC in the stowage compartment adjacent to the handwasher. A depleted box was replaced with a fresh box obtained from one of nine wardroom stowage compartments containing washcloth boxes. Washcloths are slightly moistened from the hot water dispenser in the handwasher. Then a small amount of soap is applied directly to the washcloth. After washing, the washcloths are transferred to the washcloth/towel drying area to be dried in preparation for another use. At the end of each day, the in-use washcloths are disposed of in a trash bag.

Towels were individually rolled and banded with three paper bands. The paper bands were easily removed and disposed of when a towel was put into use. There were 126 towels stowed in Locker S900 and 204 towels stowed in ring contained D418. Towels were also provided in a three-tiered aluminum towel dispenser that stowed 18 towels in their rolled and banded form. There were a total of five full towel dispensers provided. This provided a usage rate of 1/man/day for personal hygiene. Each towel was 14 by 32 in. (360 by 810 mm) in size and fabricated of rayon polynosic terrycloth. Each towel is edged with stitching of the crewman's color code; however, light blue stitching is used for the SPT color code of white.

One towel dispenser was located in the WMC, directly above the washcloth modules, and four towel dispensers were stowed in wardroom stowage compartments. The towels were dispensed from the WMC towel dispenser which was removed when emptied and replaced with a wardroom-stowed towel dispenser. The emptied towel dispenser was then refilled with towels from the D418 or S900 and then stowed in a wardroom stowage compartment for eventual reuse in the WMC.

The washcloth and towel dispenser are shown in Figure 2.2.11.3-3.

After use, the towels were transferred to the wash cloth and towel drying area to be dried in preparation for another use. At the end of each day, the in-use towels were disposed of in a trash bag.

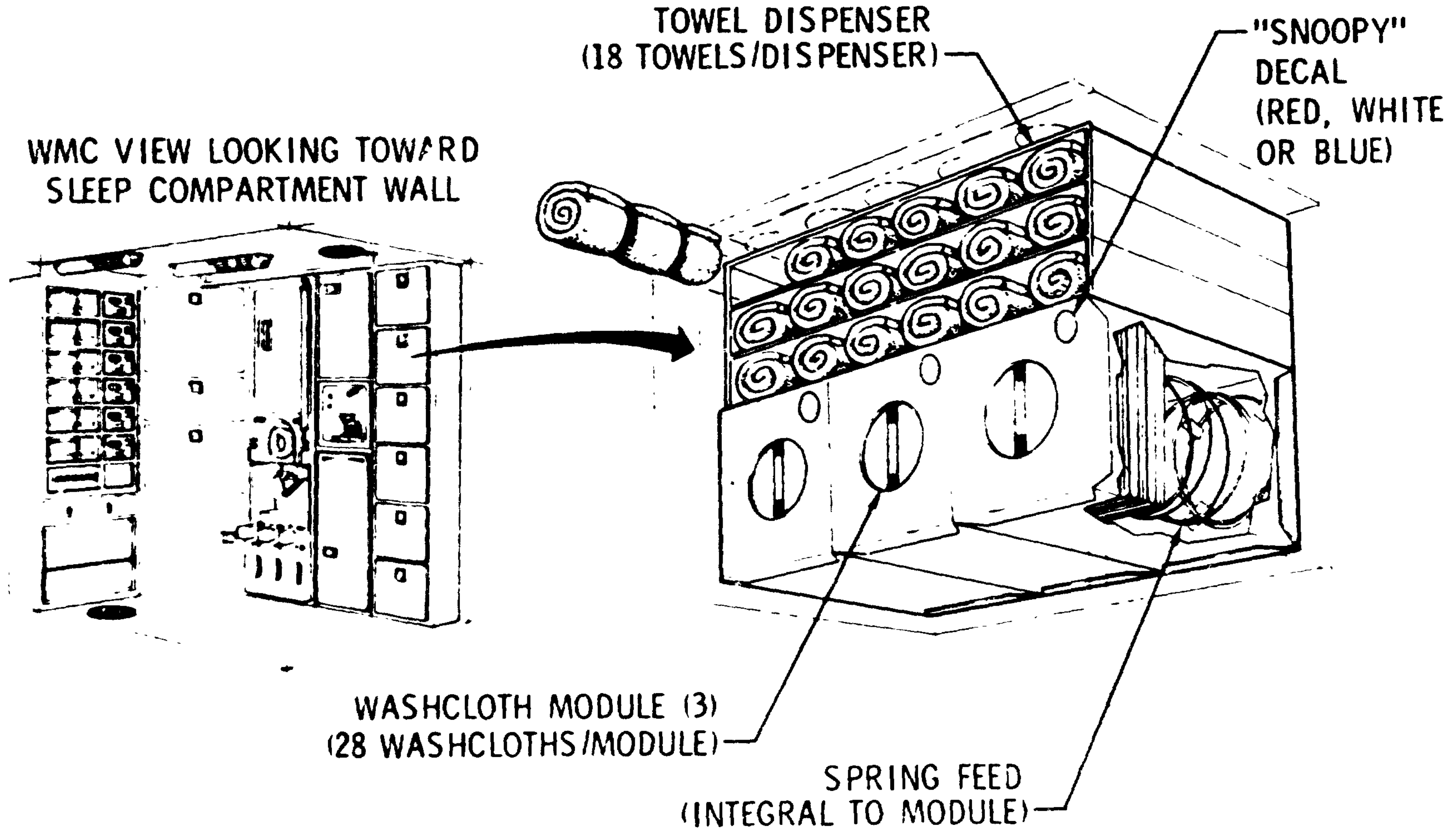


Figure 2.2.11.3-3. Towel and Washcloth Dispenser

4/ Washcloth and Towel Drying Equipment - Fluorelcarbon rubber towel and washcloth drying cups (towel holders) were provided in high usage and accessible areas in all compartments of OWS. Portable towel cups (6) were located in compartment E625 which would interface with snaps that were provided throughout the vehicle. Each cup had an "X" shape slit which accepted and retained an item to be dried. Design provisions were incorporated to facilitate cleaning of cups. Typical towel holders are shown in Figure 2.2.11.3-4.

5/ Hygiene Kits - GFE - One personal hygiene kit was provided in each of three lockers (H830, H832, H834) in WMC for the first mission. Locker S935 in the sleep compartment contained personal hygiene kits (6) for second and third mission crewmen plus hygiene resupply kit for all missions. The personal hygiene kits/pouches contain equipment for shaving, skin care, dental care, hair grooming, nail care and body deodorizing. The hygiene kit pouch had velcro attached to interface with mating velcro provided in various locations. The hygiene kit configuration is illustrated by Figure 2.2.11.3-5.

6/ Mirrors - Unbreakable polished stainless steel mirrors were located in the WMC and the sleep compartments. The two mirrors mounted in the WMC were used by the crewman for performing partial body cleansing, hair-brushing and trimming, and nail clipping. A CM-type articulating mirror was permanently attached to the stowage compartment door It was

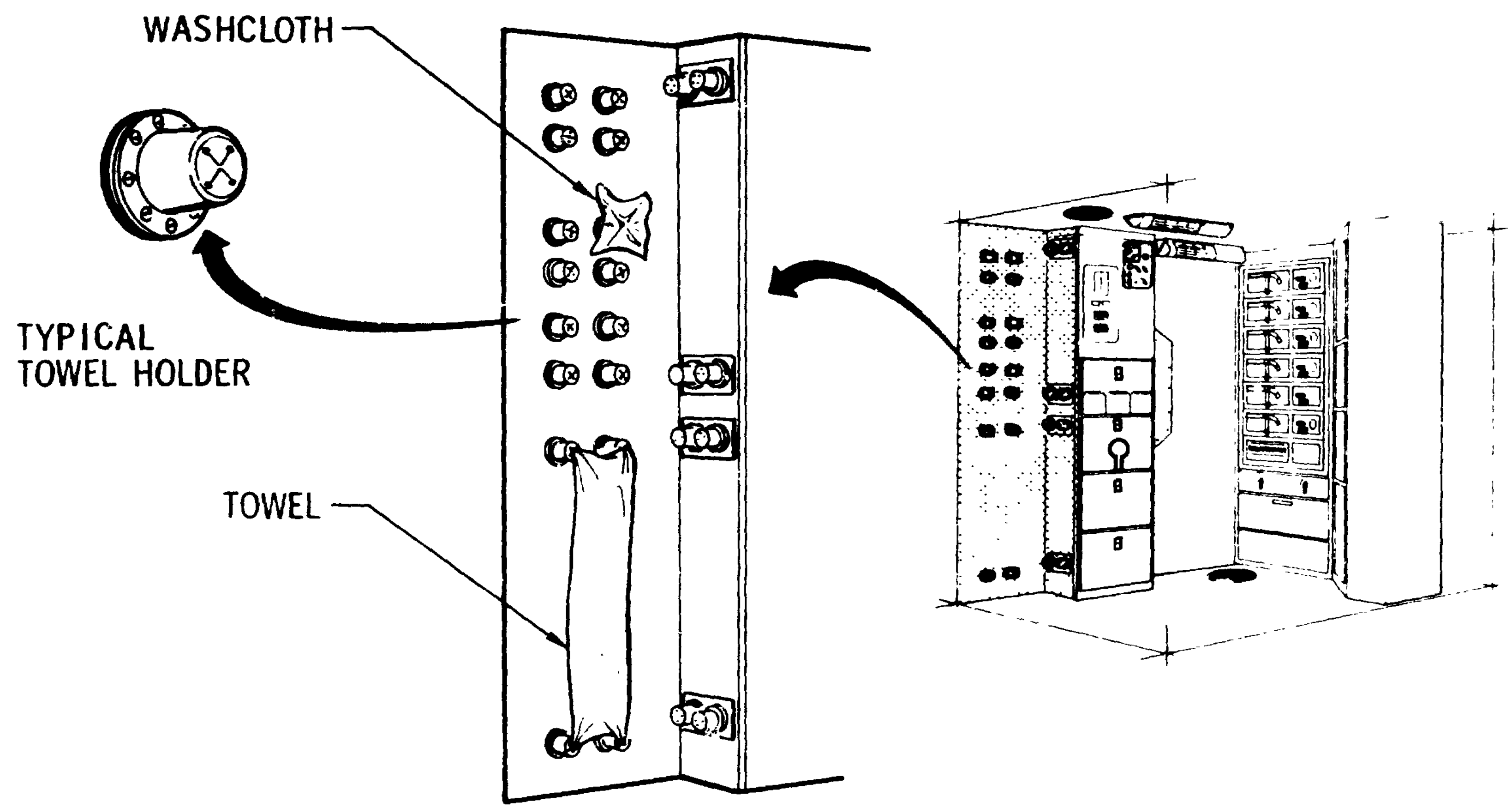
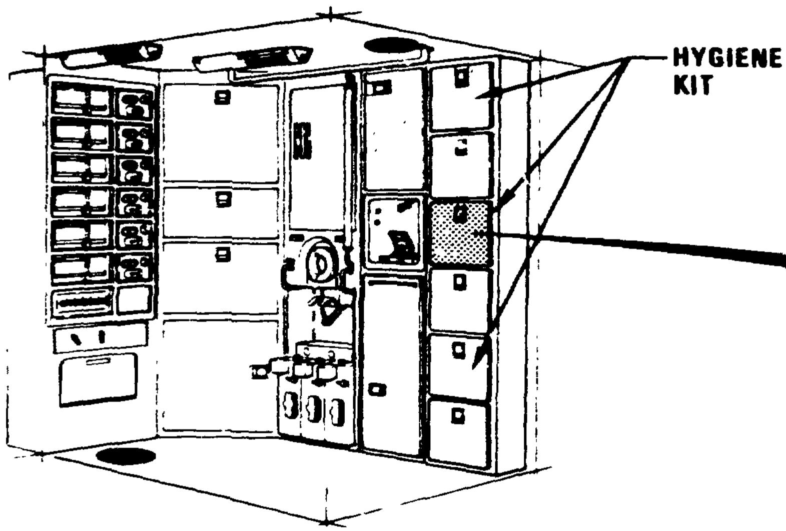


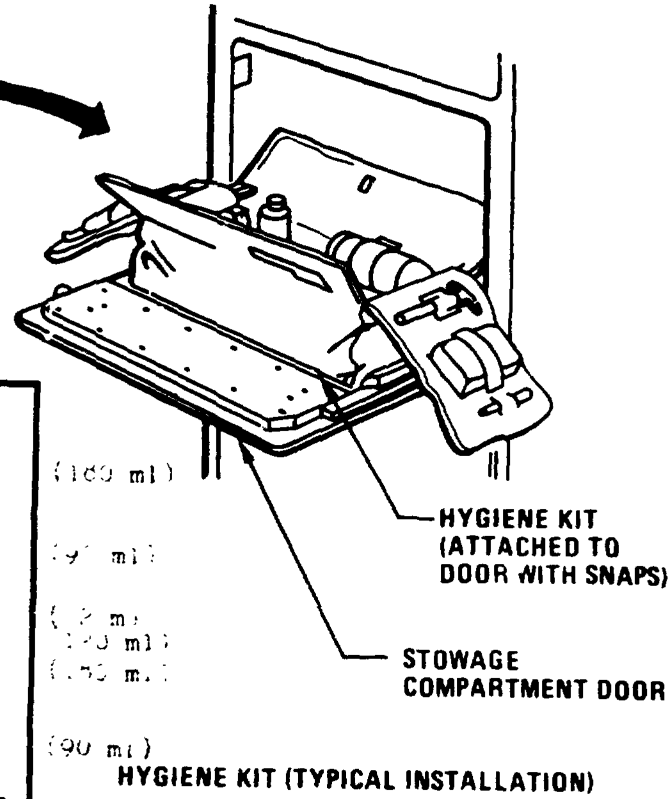
Figure 2.2.11.3-4. Washcloth/Towel Drying Area



WMC VIEW LOOKING TOWARD SLEEP COMPARTMENT WALL

PERSONAL HYGIENE KIT 1 LOCATIONS:
H830
H832
H834
PERSONAL HYGIENE KIT 2 LOCATION:
S935
PERSONAL HYGIENE KIT RESUPPLY LOCATION:
S935

TYPICAL HYGIENE KIT CONTENTS		
SHAVING CREAM	6 OZ	[illegible]
RAZOR	1	
STYPIC PENCIL	1	
TOOTHPASTE	3 OZ	[illegible]
TOOTHBRUSH	1	
DENTAL FLOSS	80 IN.	[illegible]
SOAP	4 OZ	[illegible]
EMOLIENT	6 OZ	[illegible]
SAFETY SWABS	30	
HAIR BRUSH	1	
HAIR CREAM	3 OZ	(90 ml)
NAIL CLIPPERS	1	
DEODORANT	1 1/2 OZ	
EXPECTORANT COLLECTOR	15	



HYGIENE KIT (TYPICAL INSTALLATION)

Figure 2.2.11.3-5. Personal Hygiene Kit

movable and easily reached while the crewman was seated on the fecal collector. The crewman used the articulating mirror during fecal collection functions. One mirror was bonded inside the top stowage compartment in each of the sleep areas for personal use by the crewman. Mirror locations are illustrated by Figure 2.2.11.3-6.

7/ Squeezer and Water Dispenser - A partial body cleansing facility was provided in the WMC water module locker of the WMC in the form of a handwasher unit. The unit consisted of the WMC H_2O dispenser and washcloth squeezer. Used in conjunction with the unit were soap bars, washcloths, towels and squeezer bag (with squeezer filters).

Hot water was dispensed through the WMC water dispenser valve, for use with washcloth and soap bar for cleansing.

The washcloth was placed in the washcloth squeezer and the squeezer handle was pulled down towards the crewman. This squeezed the excess water out of the washcloth into a squeezer bag. The water collected in the squeezer bag was drained through a squeezer filter into the waste tank via the normal drain (vacuum pump) system. Figure 2.2.11.3-7 depicts the squeezer location in the WMC water module. Figure 2.2.11.3-8 illustrates the squeezer and WMC H_2O dispenser operating characteristics. See section 2.2.11.2 water system for detail on squeezer and water dispenser.

8/ Soap - Soap was provided in bar form, individually packaged in aluminum foil. One soap bar was allocated to each crewman per two weeks for personal hygiene and five soap bars

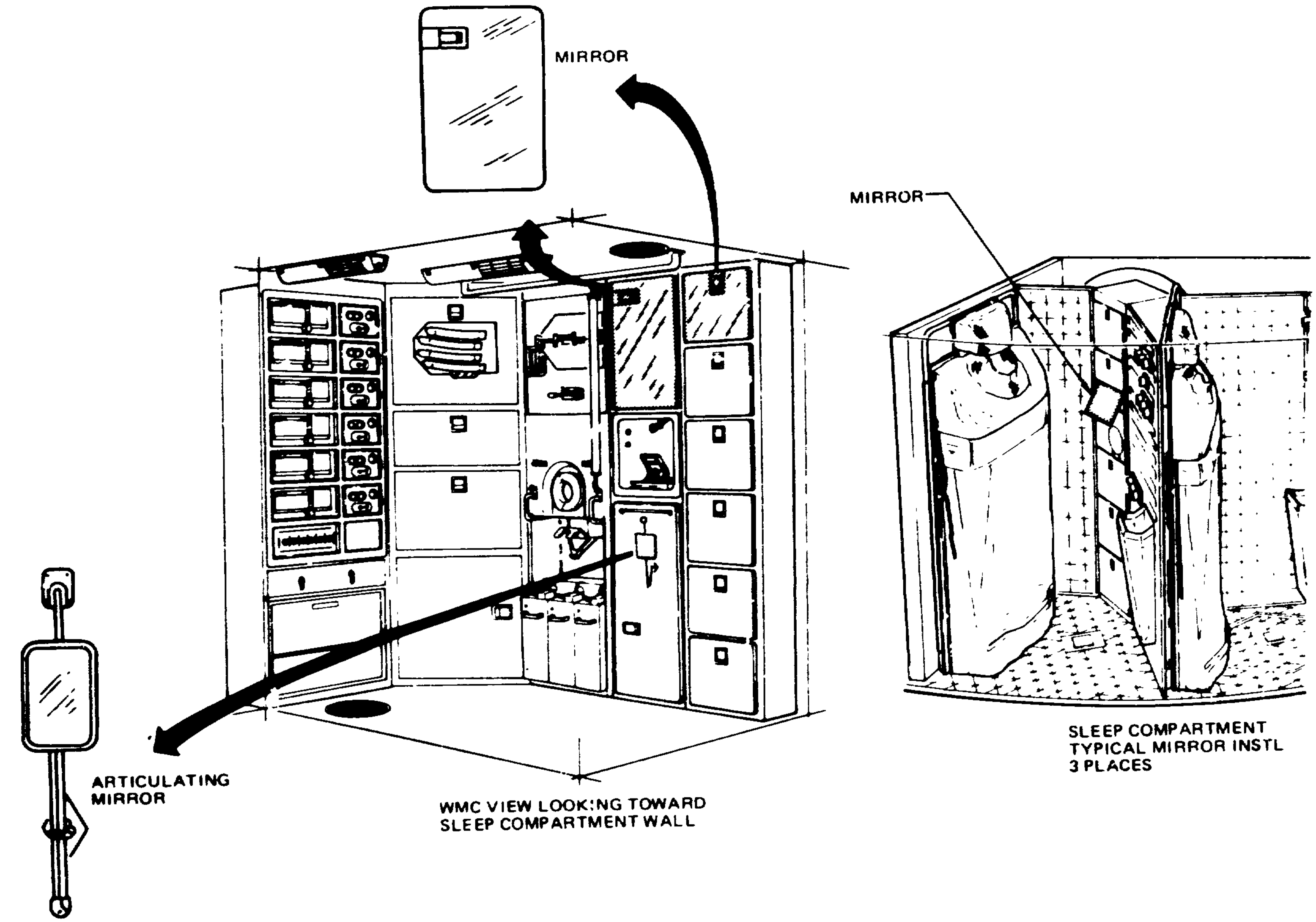


Figure 2.2.11.3-6. WMC/Sleep Compartment Mirror Locations

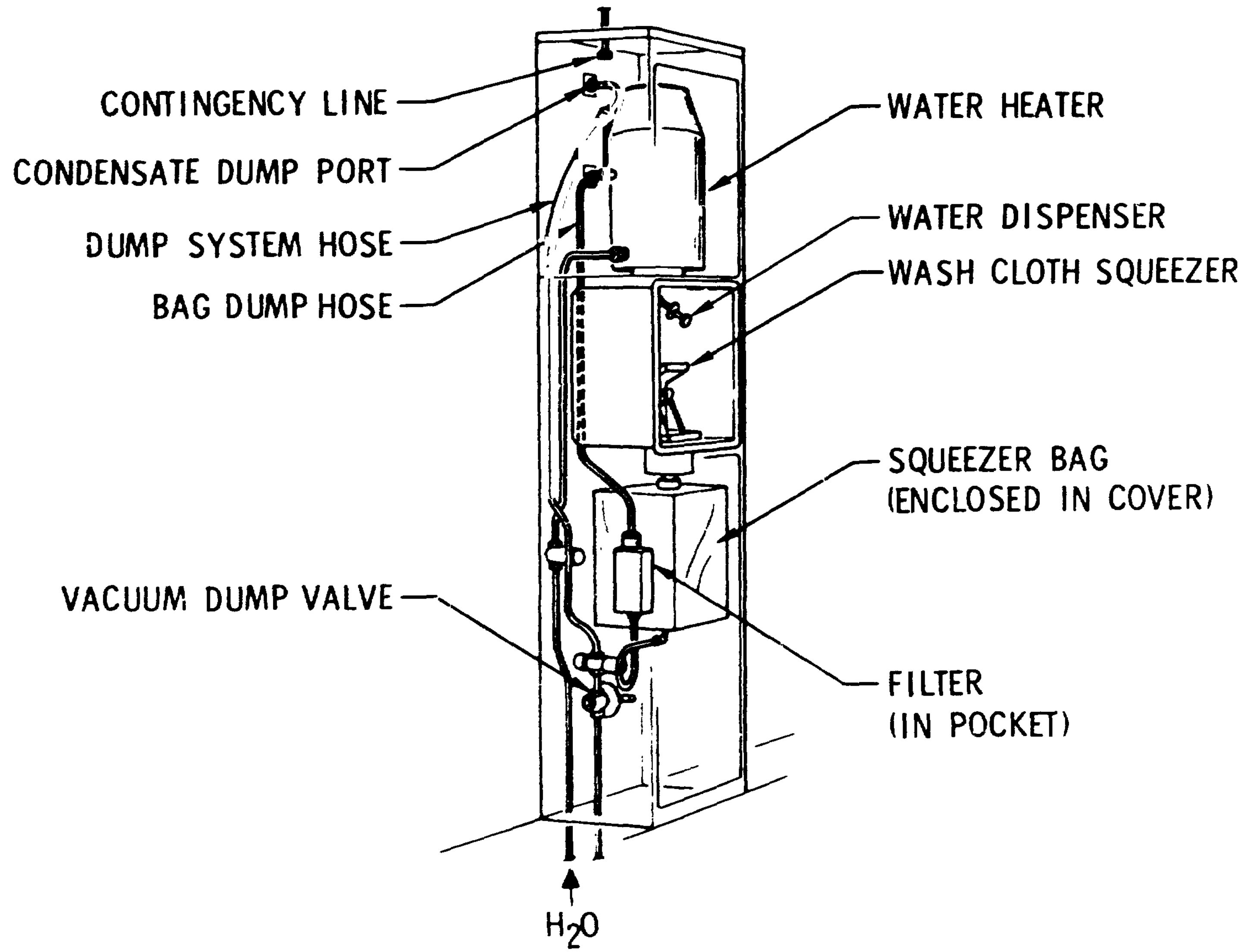


Figure 2.2.11.3-7. WMC Water Module

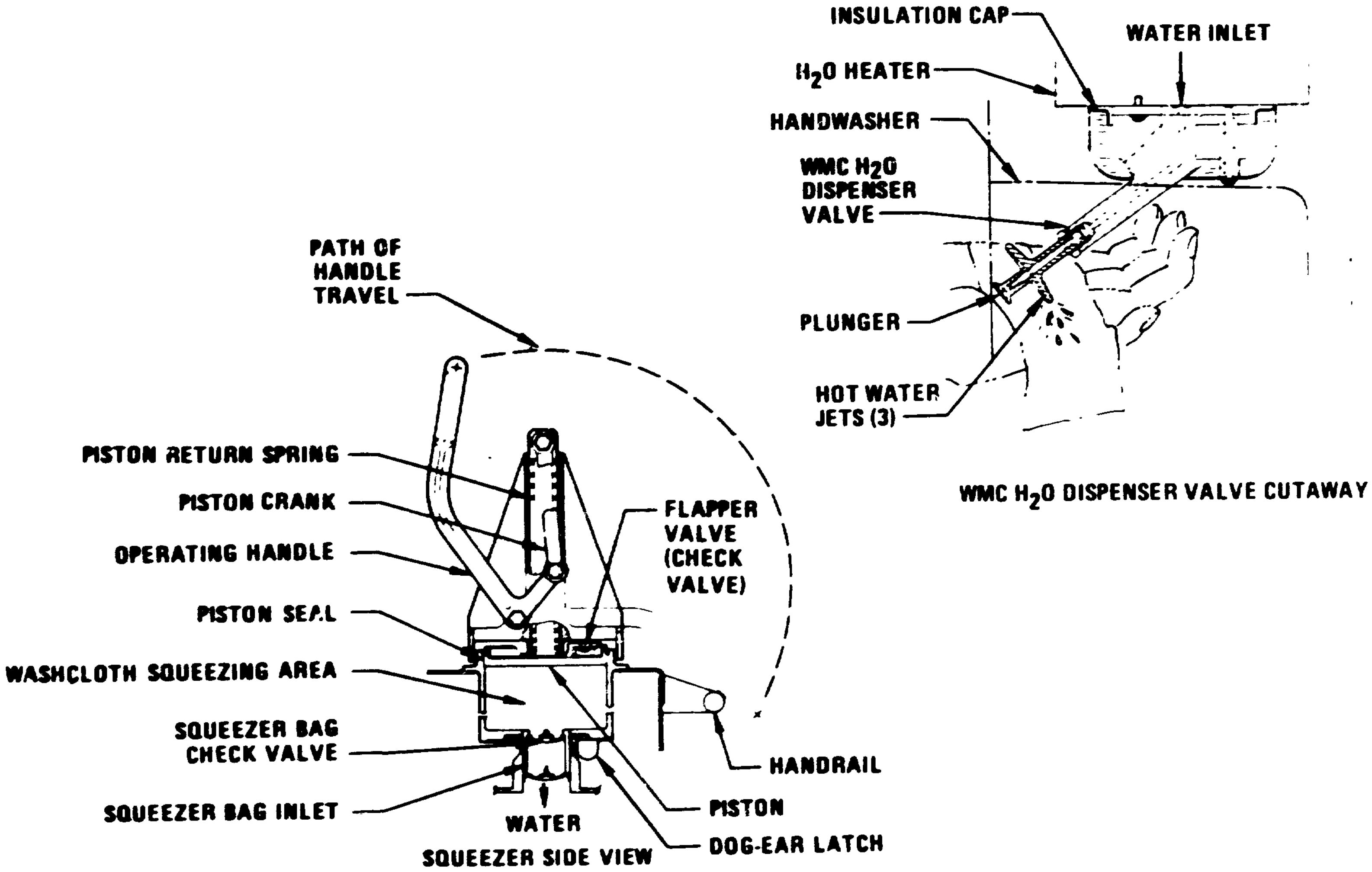


Figure 2.2.11.3-8. WMC Water Dispenser/Squeezer

per month were allocated for compartment and trash disposal airlock cleaning. Each soap bar measured 1 by 2 by 3 in. (25 by 50 by 75 mm), and contained Neutrogena, which acts as a mild antibacterial agent. Imbedded in the center of each soap bar was a stainless steel disc which provided a restraining mechanism for the soap when mated with the magnetic soap holders in the handwasher.

The handwasher contained four of these post-type soal holders, three for crewman soap restraint and one for the soap used in compartment and equipment cleaning.

The total soap provision of 55 bars was made readily available to the crew, in a soap module installed above the tissue dispenser in the WMC (Figure 2.2.11.3-2). The soap module was an Armalon bag compartmentized by dividers into eight segments. Each segment contained approximately seven soap bars banded together with a velcro-lined strap. The crewman used the strap to feed the bars of soap into an accessible position at the front of the module. After removal from the module, the soap was transferred to the handwasher for in-use restraint. At the end of each two-week period, the in-use soap was disposed of in a trash bag.

C. Testing - There were three line item tests performed for personal hygiene:

Line Item HS 17	Personal Hygiene Subsystem Qualification
Line Item HS 33	Cleansing Solution Test
Line Item HS 74	Biocide Wipe Packet Assembly

The Personal Hygiene Subsystem Qualification Test Line Item HS-17 (1t18430-1 TCD, Log 3299 CTCA, TM-DSV7-SSL-R-6993-TC) consisted of functional testing of various items of personal hygiene equipment, towel dispenser, washcloth dispenser, tissue and wipe dispensers, soap dispenser, towel and washcloth drying restraints, toothbrush and dental cream stowage restraints trash bag container. All testing was conducted under ambient conditions in the High Fidelity mockup or in a simulated locker compartment.

During the course of testing, the following Failure Reports, F04402, F04424, and F04406 were initiated against the washcloth dispenser, toothbrush/dental cream stowage restraint and the trash bag container, respectively.

The failure reports on the washcloth dispenser states that additional velcro fastener tape is required to keep the washcloth dispenser in place during the removal of washcloths, using one hand operation. Additional velcro tape was added to washcloth and towel dispensers.

Toothbrush and dental cream restraints failed due to lack of tension capability. The metal restraints were rebuilt using 1/2 hard stainless steel.

The personal hygiene subsystem hardware:

1B83297 Towel Dispensers

1B80720 Washcloth Dispensers

1B80900 Tissue and Wipe Dispensers

1B86303 Soap Dispenser

1B80705 Towel and Washcloth Drying Restraints

1B80604 Toothbrush/Dental Cream Restraints

1B80905 Trash Bag Containers

1B82542 General Purpose Trash Bags

This hardware was qualified for use in the Orbital Workshop. Their qualificaton is achieved in part by the functional testing of HS-17 because of hardware similarity.

The trash bag container has two retainer springs which provides a locking device to retain the general purpose trash bags. These two retainer springs lacked preload and therefore failed to retain trash bag in use position. The springs were redesigned.

After the above corrective actions were implemented testing continued to completion and no further anomalies were experienced.

The conclusion of HS-17 testing program proved that all dispensers functioned smoothly during a one-handed operation, and all restraints adequately retained its hardware within the compartments.

The following tests were performed in Line Item HS 33 test: (1T17782 TCD, Log 2860 CTCA, TM-DSV7-SSL-R-6993 TC):

1. Optimum liquid retention (water transport capability) of the Apollo washcloth.
2. Optimum quantities of water and cleansing agent required to perform OWS astronaut body cleansing activities.
3. Effectiveness of different soap forms (liquid, gel, solid) and to develop procedures associated with their use.
4. Drying rates of Apollo washcloths at different relative humidities.

The following are the conclusions of HS 33:

1. The optimum liquid retention of the Apollo washcloth is 100 cc.

2. For total body cleansing the material requirements were 1 washcloth, 2 rinse cloths, 1 towel, 320 cc of water and 3.4 gms of bar soap or 310 cc of water and 15 cc of liquid soap.

3. Both liquid and bar soap forms are suitable for use. Other forms are less desirable. Procedures associated with soap forms required usage of washcloth for water transport. A hand water transport technique was evaluated and found adequate for partial (but not total) body washing.

4. Washcloth drying rate (water weight vs. time) differs between 9.8 grams per hour at 40 percent relative humidity) and 6.8 grams per hour at 80 percent relative humidity.

Based on the results below of the Qualification Tests, Line Item HS 74 (1T43425 TCD, Log 3536 CTCA; TM-DSV7-SSL-R-6993 TC) tests have satisfactorily demonstrated: (1) the OWS Biocide Wipes Dispenser, and the OWS Biocide Wipes retained all functional qualities after exposure at the OWS launch pressure profile; (2) the available iodine loss rate during a prolonged storage period at ambient temperatures was highly acceptable for the 1B91023-503 Biocide Wipes, questionable for the -501 wipes, and unacceptable for the -1 wipes.

On the basis of superior iodine retention properties, the -503 Biocide Wipes are selected for Skylab flight usage.

OWS biocide wipes, P/N's 1B91023-1, -501, and -503; and the OWS biocide wipes dispenser, P/N 1B91924-1 were subjected to a series of qualification tests to evaluate: (1) the functional effects of exposure to the OWS launch pressure profile, (2) the available iodine loss rate during prolonged storage.

The OWS launch pressure profile tests did not result in any change in the functional qualities of the dispenser or any individual biocide wipe.

The life/shelf test results on available iodine loss rate are summarized below for the three different biocide wipe configurations. The packaging material was Conolon 6000 for all wipes.

No.	Biocide Substrate	Initial Iodine (ppm)	Test Period (Days)	Final Iodine (ppm)	% Loss	Notes
)23-1	Flex Pak Crepe Paper	2,500	182	133	94.6	Failed test at 154 days, below min. of 250 ppm.
)23-501	Flex Pak Crepe Paper	5,000	137	3,073	38.5	Acceptable min. 2,500 ppm but stability not established.
)23-505	WEBRILL R2201 (Cotton)	5,608	98	5,298	5.5	Loss rate indicated level of 4,400 ppm at end SL-4.

Flammability tests were run on aluminum foil covered pasteboard boxes used to show tissue and wipes. These tests were performed to ensure that the flammable tissues and wipes were protected and a waiver was obtained to use the tissues and wipes upon the positive results of the test.

Waivers were obtained for the use of the flammable washcloths and towels because they were stowed in metal lockers.

D. Mission Results

1/ General Purpose Tissues and Utility Wipes

The general purpose tissues and utility wipes apparently did not elicite any crew comments except for noting that cloth rags (used clothing) work better than paper wipes for housekeeping cleanup. Dispensing of the tissues and wipes was accomplished without any problems. The general purpose tissue and wipe packages were resupplied in dispenser locations without any difficulty.

2/ Biocide Wipes

Dispensing of biocide wipes from dispenser was accomplished without any problems. The biocide wipes package was resupplied into the dispenser location without any difficulty. Due to elevated temperatures inside the OWS, tests were run on biocide wipes to determine effect on the iodine solution in the biocide wipes. Mission Support Test Request (MSTR) 043 (AI #263) was run to analyze the thermal degradation of three biocide wipes that had been subjected to comparable OWS temperatures at JSC. It was concluded by the test that the iodine was stable with acceptable amount of concentration depletion. A second test MSTR 050 (AI #287) was run on biocide wipes. This test analyzed the thermal degradation of three biocide wipes returned by the SL-2 crew. The conclusion of the test was no detectable change in the depletion rate of available iodine of OWS biocide wipes over expected normal temperature depletion rates.

3/ Washcloths and Towels

The washcloths and towels were usedin a normal manner for personnal hygiene. They were also used for cleaning windows and for spillage wipe up. Towel consumption was greater than anticipated and required resupply from the CM.

4/ Washcloth and Towel Drying Station

The washcloth and towel drying station worked well. The towel and washcloth restraints were convenient and effective. The crews reported that relatively dry humidity and ventilation airflow dried washcloths and towels in a very satisfactory manner.

5/ Hygiene Kits (GFE)

The hygiene kits were used with no apparent problems. Items had to be resupplied on SL-3 because of damage to some of these items due to extreme environment seen inside OWS.

6/ Mirrors

The wall-mounted mirrors were used in a normal manner. Some crewmen noted that the surface finish was too dull for good visibility. The crew reported that the articulating mirror in the WMC was extremely useful and necessary for hygienic cleaning after fecal collection.

7/ Washcloth Squeezer and Water Dispenser

The washcloth squeezer and water dispenser were used frequently with a few small problems discussed in 2.2.11.2, Water Management System. The crews stated that the washcloth squeezer and water dispenser are basic requirements. The SL-4 crew expressed a desire for an enclosed water module to permit washing the hands in a more normal 1-g fashion. They noted that this could also be used for safety razor cleaning.

8/ Soap

The soap bars were adequate for personal hygiene. The soap bars were used while taking a shower instead of the liquid soap supplied for shower use. The soap consumption rate was far below anticipated levels.

E. Conclusions and Recommendations

1/ General Purpose Tissues and Utility Wipes

The general purpose tissues and utility wipes were adequate. The second mission crew reported using rags (old shirts and shorts) for cleaning instead of a general purpose tissue since cloth was faster and more esthetically pleasing. On future flights, a cloth should be considered for wiping up spills and cleaning tasks.

2/ Biocide Wipes

The biocide wipes left an iodine coloration on a wiped area that comes off with little or no problem. The second mission crew reported that their hands became yellowed during deactivation biocide cleaning but that it faded away several days later. The iodine solution used in the biocide wipes is an acceptable biocide.

3/ Washcloth and Towels

The washcloths and towels were assessed as adequate functionally. There were 89 extra towels launched on the SL-2 flight and 30 extra towels on the SL-4 flight. Towel allocations should be evaluated again for future flights.

4/ Washcloth and Towel Drying Station

The drying station provided a convenient and effective means of drying the towels and washcloths. The restraint approach should be standard equipment on future missions for towel and washcloth drying as well as a general fabric restraint.

5/ Hygiene Kits (GFE)

Hygiene kits were reported satisfactory. However, the crews requested personalized kits.

6/ Mirrors

Mirrors were reported positioned well for the activities requiring their uses. The polished stainless steel mirror surface was marginal. Future missions should consider a higher quality surface finish requirement.

7/ Washcloth Squeezer and Water Dispenser

The washcloth squeezer and water dispenser provided a satisfactory method for partial body cleaning and housekeeping. A desire for an enclosed water module for more convenient hand-washing on future missions was expressed by the crew. See 2.2.11.2, Water Management, for a more detailed discussion of the dispenser and squeezer.

8/ Soap

The soap was used with no apparent medical problems. The metal disc in the soap held the soap bar to the magnetic post in the water module sufficiently for zero-g application. Because of bacteria growth reported on terrestrial commercial samples, investigations should be made into this possible problem before the Neutrogena soap is used for future flights.

F. Development History - The personal hygiene system underwent relatively few changes during development. The washcloth and towel drying station was originally a cage-like area with elastic "bars" to house free floating washclothes and towels. The rubber drying cups were developed to individually restrain the wet towels and washcloths to assure more efficient drying.

Development history of the washcloth squeezer is covered in 2.2.11.2.

The personal hygiene soap was originally liquid in a dispenser mounted near the water valve in the WMC. Bar soap was chosen because of the more desirable characteristics of Neutrogena.

1.4 Body Cleansing System

A. Design Requirements

1/ Skin Cleansing Equipment - The capability and supplies to wash, rinse, and dry the whole body shall be provided. The "wash cloth" concept shall be employed. Reference Paragraph 2.2.11.3 Personal Hygiene System for a discussion on the design and equipment used.

2/ Whole Body Shower (WBS) - The WBS shall provide a facility for the maintenance of personal cleanliness, skin health, and grooming for three astronaut inhabitants of the Skylab. The general functional characteristics of the WBS are:

a. Permit three astronauts to shower at least once a week during Skylab missions or a total of 60 times.

b. To be operational at users convenience.

c. Easily attached to Skylab structure and capable of being easily folded down to minimum space when not in use or for installation at alternate locations.

d. Light weight construction.

e. Materials selection to consider minimal bacteria growth and ease of cleaning.

f. Adequate aids and restraints to assist astronauts in deployment, supply, use, or cleaning of the WBS.

g. Sanitary disposal of waste through the Skylab trash airlock.

h. Shall be capable of successful operation after countdown holds in excess of 12 hours.

The WBS shall be capable of delivering a flow of water at the shower nozzle of 800 ml/min. to 2 ml/min. for a minimum of 3 minutes. The WBS shall be capable of recovering the waste water during and after the shower with a suction head using the Skylab atmosphere. The waste water shall be separated from the atmosphere with a centrifugal separator. A hydrophobic separator shall be used as a backup to prevent any inadvertent escape of waste water. The waste water from the centrifugal separator shall be collected in disposable bags capable of being ejected through the Skylab trash airlock.

3/ Water Bottle Module - The water bottle module shall be portable and be capable of being pressurized from the Skylab nitrogen pressurization system, receiving water from the Skylab waste management system water heater, and delivering the water to the shower enclosure. These connections shall be made with quick disconnect couplings. The module shall be capable of receiving and expelling a minimum of 6 lbs (2.72 kg) of water. The module will be refilled with water each time the shower is used. The maximum operating pressure shall be 40 psid (276 kN/m^2). Normal operating pressures shall be from 10 to 25 psid (69 to 172 kN/m The module will receive the full 4 lb (1.81 kg) capacity of hot [140°F (60°C) maximum] water from the heater plus the additional cold water which follows the hot water. There shall be 3-way vent and shutoff valves on both the water and nitrogen portions of the module. When in the VENT position the gas valve shall allow the pressure inside and outside the water bottle to equalize during boost pressurization and subsequent venting. The TEST position of the water valve will be capped for flight. Venting will be accomplished through the water disconnect and mounting plug. When in the CLOSED position the valve shall isolate the couplings to allow safe uncoupling. The valves shall be in the OPEN position for normal operations. The valves shall have detents in each position. The nitrogen portion shall have a pressure gauge. The nitrogen portion shall have a relief valve which cracks and reseats in the range from 30 to 35 psid (207 to 241 kN/m^2).

4/ Shower Enclosure - The shower enclosure shall consist of two end ring closures and a translucent Beta cloth skirt with stiffening rings. One end ring closure, the floor closure, shall be attached to the floor grid in the crew quarters area. During storage, the other end ring closure, the ceiling closure, shall be attached coaxially to the floor closure with quick release fasteners. In this condition the skirt shall be compressed between the closures. For operation the ceiling closure shall be raised, extending the skirt, and attached to the ceiling with quick release fasteners. The skirt shall be permanently attached to the floor closure. The ceiling ring closure shall include the shower spray nozzle, the suction head, and the associated flexible hoses and quick disconnect couplings. The ceiling closure shall also include the stowage provisions for this equipment. The skirt shall have straps for handholds and restraints. At the option of the OWS crewmen the shower enclosure may be detached from the launch position using available hand tools.

5/ Centrifugal Separator - The separator shall be gear driven by a brushless direct current motor. The separator shall be capable of separating the entrained waste water from the air stream. There shall be a maximum of 300 ml of waste water per shower at a peak delivery rate of 1100 ml/min. The separator shall have a liquid/gas inlet, a liquid outlet, a a gas outlet, and an equalization pickup tap for the collection box. The pressure drop across the separator from the liquid/gas inlet to the gas outlet shall be a maximum of 4.0 in. (10.16 kg) H_2O at a flow rate of 5.0 cfm (.140 m^3/min), an inlet pressure of 5.0 psia (34.5 kN/m^2) and an inlet temperature of 70°F (21.1°C).

6/ Collection Box - The collection box shall have a replaceable impermeable elastomeric bag. The bag will be replaced each time the shower is used. The collection box shall have a hinged lid which is to be fastened with quick release fasteners. The bag shall be capable of containing 3000 ml of waste water. The inlet to the bag shall have a pinch clamp. ·e bags shall be supplied in a collapsed condition ready for installation. The bags after being filled with either water or gas and sealed in an overbag in a 6.2 psia (42.7 kN/m^2) atmosphere shall be capable of being expelled from the trash airlock into a zero psia atmosphere without rupture.

7/ Hydrophobic Separator - The hydrophobic separator shall prevent any inadvertant waste water from entering the Skylab. The hydrophobic separator shall have a minimum water retention capacity of 5 $in.^3$ (81.9 cm^3). The hydrophobic element shall be replaceable. The lid to the hydrophobic separator shall be attached with quick release fasteners. The pressure drop across the hydrophobic separator shall be maximum of 4.0 in. (10.16 cm) H_2O at a flow rate of 5.0 cfm (.140 m^3/min), an inlet pressure of 5.0 psia (34.5 kN/m^2) and an inlet temperature of 70°F (21.1°C).

8/ Power Module - The WBS shall use the Skylab power module without modification to provide the suction for recovery of the waste water.

B. System Description

1/ Location of Hardware - The whole body shower is a GFE system installed in the experiment compartment near the wardroom - experiment wall (reference Figure 2.2.11.4-1). Shower supplies consist of soap dispensers, hydrophobic filters, clamps and clips, various connectors and handles, and collection bags.

2/ Hardware Design Description - The shower is an enclosed compartment with a continuous airflow as a gravity substitute for "moving" water over the crewman in a somewhat conventional manner. A water bottle is filled from the WMC water system and is attached on the ceiling at the shower location. The water bottle is pressurized with GN_2 which serves as a force

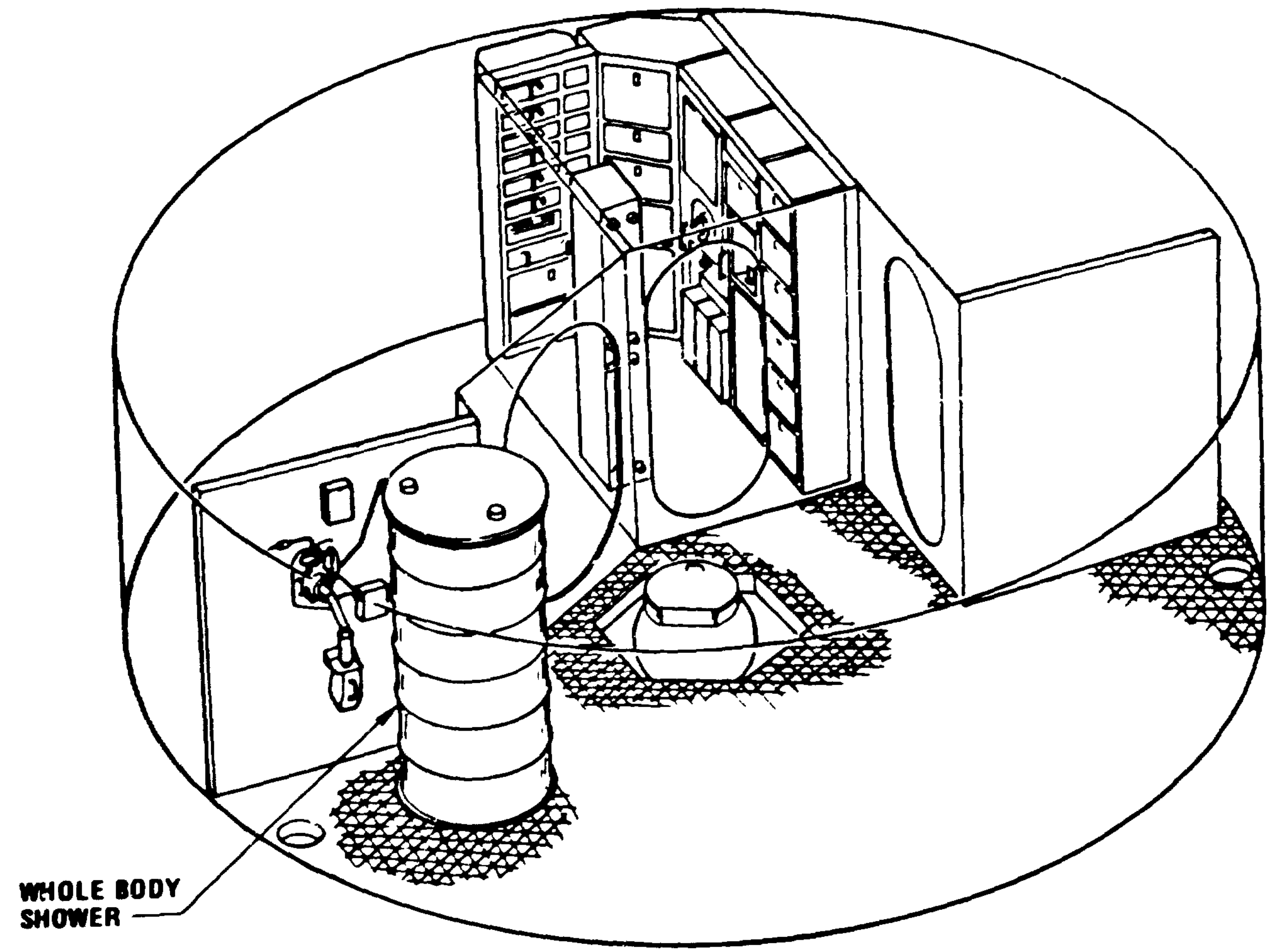


Figure 2.2.11-4 -1. Location of Personal Hygiene Equipment

to expell water into the shower. A crew operated spray nozzle in the shower is connected to the water bottle by a transfer hose. When the crewman operates the spray nozzle the pressure in the water bottle expels water through the spray nozzle onto the crewman. A suction head is provided to suck up water from the crewman and the shower interior. The suction head is connected to a centrifugal separator by hoses. A collection bag is connected to the separator to collect the water that is vacuumed up by the suction head. A power module is used to pull the air from the separator and a hydrophopic filter is placed between the separator and the power module to trap contaminance. This precludes contaminance through the power module into the OWS atmosphere. Shower configuration and schematic is illustrated by Figures 2.2.11.4 -2 and 2.2.11.4 -3.

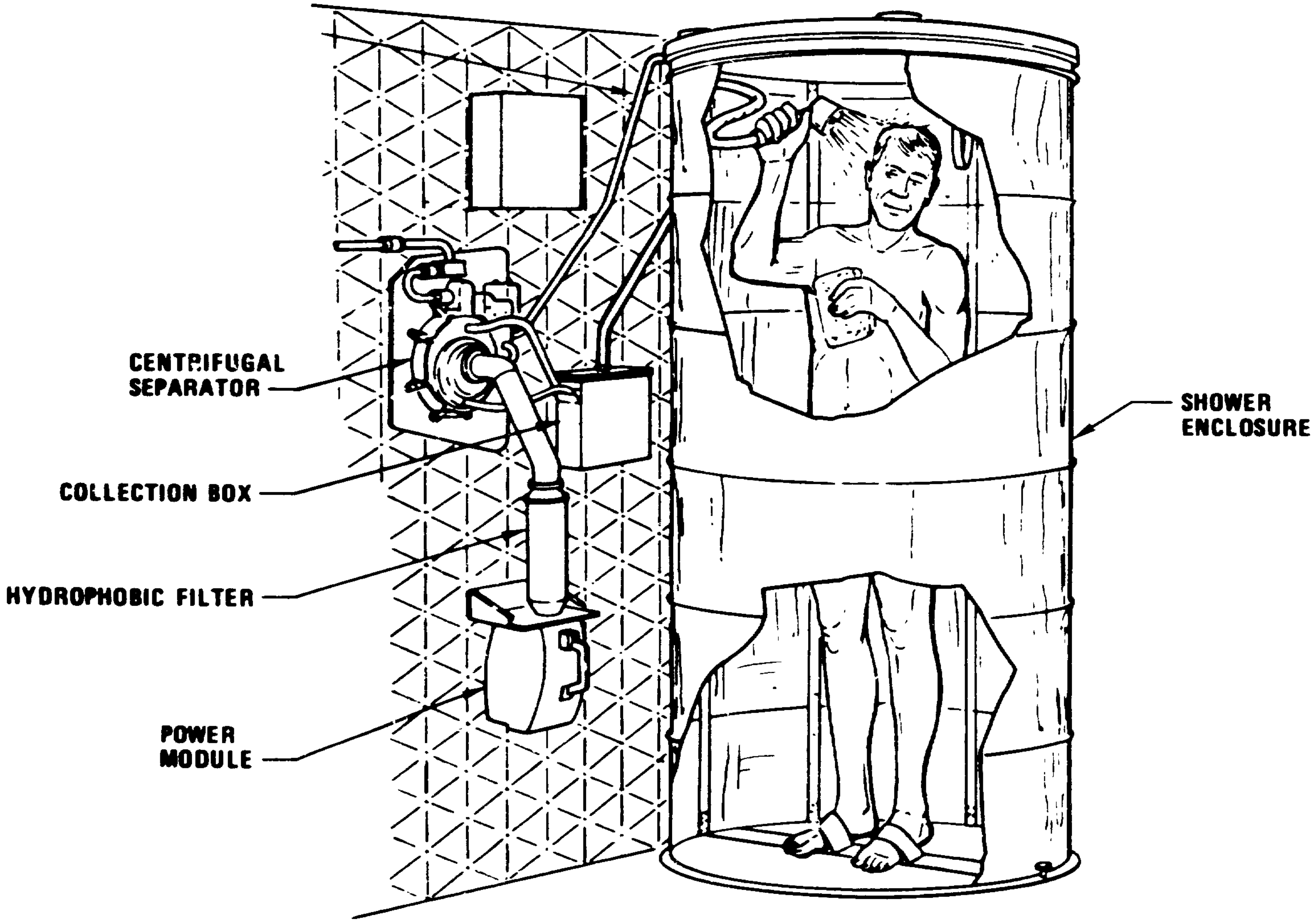


Figure 2.2.11.4 – 2. Whole Body Shower (Operational

SHOWER CENTRIFUGAL CONCEPT

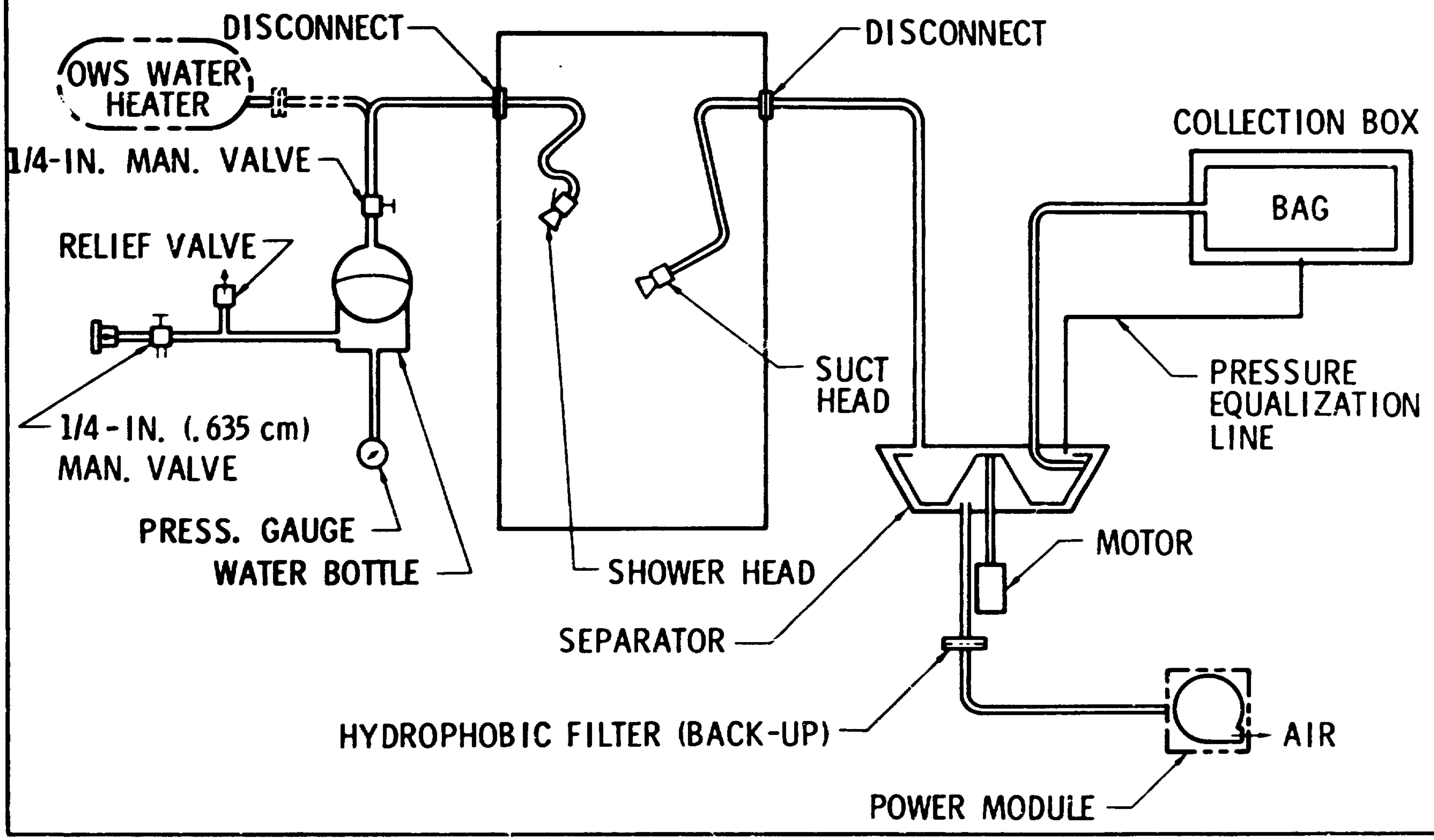


Figure 2.2.11.4-3

C. Testing - Various tests were conducted by MSFC on the whole body shower (WBS) to develop and qualify the equipment and techniques needed for successful body cleaning.

1/ Development - A study was made of a zero-gravity, whole body shower for use during the extended, manned orbital flights of the Skylab series. Subsystem components were developed and tested to verify conceptual proposals and to provide engineering data for system design. A large effort was devoted to the development of an air-water phase separator. Three concepts of air-water phase separation were investigated with a mechanically driven centrifugal design chosen over two passive types. A functionally high fidelity shower system was assembled using plexiglass shower enclosure for laboratory testing. Shower water was collected using a vacuum pick-up system and subsequently removed from the airstream for disposal with the centrifugal - type air-water phase separator. The system was tested in earth gravity and at both atmospheric and reduced air pressures. Test results indicated that the system design was feasible for the orbital workshop environment, and that an effective shower system could be assembled largely from modified OWS components.

2/ Qualification - The qualification test was performed on the Orbital Workshop Whole Body Shower, Water Bottle Module Assembly (MSFC Dwg. No. 20M32509, S/N 002). These tests were performed to determine if the Water Bottle Module Assembly could meet the requirements established by the MSFC Specification Control Dwg. 20M33020 and detailed in test procedure DOP-TMM-72-11.

One specimen was subjected to qualification testing. A summary of all testing is given in Table 2.2.11.4-1.

Two components malfunctioned during the qualification testing. During the life cycle test of the relief valve, the reseat pressure decreased from the required 29 psig (200 kN/m^2) down to 22 psig (152 kN/m^2). After 20 cycles of the required 100 installation cycles, a retaining spring in one of the quick release fasteners failed; however, the test was completed without further malfunctions.

In addition, an apparent leak in the diaphragm was caused by entrapped air which required approximately 3 hours to disperse. This condition was verified by S&E-QUAL.

The CCOH and destructive tests were performed after the system tests. Results of these tests were satisfactory.

The failure of the quick release fastener spring was considered insignificant since the water bottle could still be mounted satisfactorily. Also, there are three quick release fasteners on the bottle and one was sufficient to hold the bottle in zero "G". The low reseat pressure on the relief valve is also a minor problem; therefore, the water bottle was considered qualified and recommended for use on the Orbital Workshop Whole Body Shower System.

TABLE 2.2.11.4-1

TEST SUMMARY SHEET

OWS WHOLE BODY SHOWER WATER BOTTLE MODULE ASSEMBLY

TEST ENVIRONMENT	TEST REQUIREMENT	TEST RESULTS	REMARKS
Pre-Test Inspection	Visually examine for any damage or discrepancies. Record weight.	Gage glass scarred, one fitting dented, weight 15.25 lbs (6.9 kg).	Results satisfactory
Proof Pressure	80 psig (552 kN/m^2) for 5 min. on H_2O side and then on pressurization side.	No failure occurred	Results satisfactory
Relief Valve Test	At 28 psig (193 kN/m^2) on increasing pressure leakage shall not exceed 3.0×10^{-4} sccs. Cracking pressure shall be 38 psig (262 kN/m^2) maximum and reseat at 29 psig (200 kN/m^2) minimum.	Leakage 2.8×10^{-5} sccs, cracking pressure 36.5 psig (252 kN/m^2) and reseat was 34.4 psig (237 kN/m^2).	Results satisfactory
Leakage Test H_2O Portion	At 40 psig (276 kN/m^2) air, check diaphragm leakage, check joints and connections, check quick disconnect leakage (allowable 1.0×10^{-2} sccs when coupled), check shut-off valve seat leakage (allowable 1.0×10^{-3} sccs), coupling valve seat leakage allowable is 1.0×10^{-2} sccs. Connect and disconnect forces 30 lbs (13.6 kg) maximum.	No leakage from diaphragm, joints or connections, shut off valve seat or coupling seat. Connect force 26.2 lbs (11.9 kg). Disconnect force 17.2 lbs (7.8 kg).	Results satisfactory
Leakage Pressurization Portion	At 28 psig (193 kN/m^2) air, check diaphragm leakage, check leakage at vent port of pressurization valve, check for external leakage at joints and connections (no bubble leakage allowed). Leakage at the pressurization quick disconnect shall not exceed 1×10^{-2} sccs. Reset valve to CLOSED position. Leakage at vent port shall not exceed 1×10^{-3} sccs. Valve outlet seat leakage and disconnect coupling seat leakage shall not exceed 1×10^{-3} sccs. The connect and disconnect force shall not exceed 30 lbs (13.6 kg).	No leakage occurred during any of the leak checks. Connect force was 23.0 lbs (10.4 kg). Disconnect force was 7.0 lbs (3.17 kg).	Results satisfactory

OWS WHOLE BODY SHOWER WATER BOTTLE MODULE ASSEMBLY

TEST ENVIRONMENT	TEST REQUIREMENT	TEST RESULTS	REMARKS
Gage Accuracy	The gage must stay within plus or minus 2 psi (13.8 kN/m^2) in the range of 0 to 30 psig (207 kN/m^2) at 70 ± 5°F (21.1 ± 2.8°C).	Test was performed 3 times and the gage stayed within plus or minus 2 psi (13.8 kN/m^2) during all testing.	Results satisfactory
Expulsion Operation	With bottle [illegible] led and charged to 29 psig (193 kN/m^2), must be able to expell a minimum of 6 lbs (2.7 kg) of water.	6.20 lbs (2.8 kg) of water was expelled during the first test. 6.2 lbs (2.8 kg) was expelled during the second and third tests.	Results satisfactory
Total Leakage	With gas side charged to 7 psig (48.3kN/m^2), water side filled until gas pressure increased to 29 psig (193 kN/m^2). No leakage allowed for a storage period of 16 to 20 hours.	No leakage occurred during the 20 hours storage test.	Results satisfactory
Vibration	Assembly was subjected to Vehicle Dynamics, Sinusoidal Sweep, Lift-Off Random and Boost Random Vibration Tests.	Satisfactory	Results satisfactory
High Temperature	Withstand a temperature of +160°F (71.1°C) and relative humidity of 15% maximum for 4 hours. After high temperature, bottle must meet leakage requirements of para. 5.5 and 5.6 of DOP.	The module assembly withstood the high temp. without failure. No leakage occurred. The H_2O quick disconnect forces averaged 27.0 (12.2 kg) and 17.6 lbs (7.95 kg) for connect and disconnect, respectively. The pressurization disconnect forces averaged 21.7 (9.8 kg) and 6.6 lbs (2.98 kg) for connect and disconnect, respectively.	Results satisfactory

TABLE 2.2.11.4-1 (Continued)
TEST SUMMARY SHEET
OWS WHOLE BODY SHOWER WATER BOTTLE MODULE ASSEMBLY

TEST ENVIRONMENT	TEST REQUIREMENT	TEST RESULTS	REMARKS
Low Temperature	Withstand a temperature of zero degrees F for 4 hours. Without failure and meet requirements	The module assembly withstood the low temperature without failure. No leakage occurred during the leakage tests and all connect and disconnect forces were within specifications.	Results Satisfactory
Life Cycle Tests			
Installation Cycle	Module assembly must withstand 100 installation cycles.	After 20 cycles, one of the three quick release fasterners developed a broken retaining spring; the 100 cycles were completed satsifactorily.	Results Satisfactory
Expulsion Diaphragm	The diaphragm must withstand 500 cycles without failure. One cycle consists of slowly pressurizing liquid portion to 10 psig air and then vent to zero. Slowly pressurize gas portion to 10 psig (69 kN/m^2) air and then vent to zero. After each 50 cycles, perform leakage test.	After 168 cycles, a leak developed in the diaphragm. A new diaphragm was installed and test restarted. After 100 cycles, leakage reappeared. The test (500 cycles) was completed and the module assy. delivered to S&E-QUAL for analysis.	QUAL Lab and additional tests performed by S&E-ASTN-TMM concluded that the leakage was entrapped air.

TEST SUMMARY SHEET

OWS WHOLE BODY SHOWER WATER BOTTLE MODULE ASSEMBLY

TEST ENVIRONMENT	TEST REQUIREMENT	TEST RESULTS	REMARKS
Pressure Cycle	The assembly must withstand 1000 pressure cycles from 0 to 35 (241 kN/m^2) to 0 psig simultaneously on the liquid side and pressurization side of the bottle. After 1000 cycles perform proof, leakage, expulsion and connect and disconnect forces.	The 1000 cycles were performed without failure and all post tests were satisfactory. Connect and disconnect forces were less than 30 lbs (13.5 kg).	Results satisfactory
Gage Cycle	Gage shall withstand 300 pressure cycles from 0 to 40 (276 kN/m^2) to 0 psig air. Gage shall remain accurate within plus or minus 2 psig (13.8 kN/m^2).	The gage remained within the plus or minus 2 psig (13.8 kN/m^2) accuracy during the 300 cycles.	Results satisfactory
Relief Valve	Relief valve shall withstand 300 cycles of operation from crack to fully open to reseat. Cracking pressure shall not exceed 38 psig (262 kN/m^2) and reseat at not less than 29 psig (200 kN/m^2).	Initial cracking pressure was 36 psig(248 kN/m^2) and reseat was 32 psig (221 kN/m^2). After 300 cycles, the cracking pressure was 33 psig (228 kN/m^2) and the reseat was 22 psig (152 kN/m^2).	S&E-ASTN-EM agreed to accept the low reseat value.
Pressurization Vent and Shut-Off Valve	Valve must withstand 600 cycles of operation. With valve pressurized to 35 psig (241kN/m^2) air, each cycle shall consist of moving the valve from FILL to VENT to FILL position. Leakage shall not exceed 1.0 x 10^{-3} secs at 28 psig (193 kN/m^2).	No leakage occurred during the 600 cycle test.	Results satisfactory

TABLE 2.2.11.4-1 (Continued)

TEST SUMMARY SHEET

OWS WHOLE BODY SHOWER WATER BOTTLE MODULE ASSEMBLY

TEST ENVIRONMENT	TEST REQUIREMENT	TEST RESULTS	REMARKS
H_2O Test and Shutoff Valve	Valve must withstand 600 cycles of operation. With valve pressurized to 35 psig (241 kN/m^2) water, each cycle shall consist of moving the valve from OPEN to TEST to OPEN positions. Leakage shall not exceed 1.0 x 10^{-3} sccs at 40 psig (276 kN/m^2) air.	No leakage occurred during the 600 cycle test.	Results satisfactory
Pressurization Quick Disconnect	600 connect and disconnect cycles while pressurized to 35 psig (241 kN/m^2) air. Leakage shall not exceed 1.0 x 10^{-2} sccs at 40 psig (276 kN/m^2).	No leakage occurred during the 600 connect and disconnect tests.	Results satisfactory
Quick Disconnect H_2O	600 connect and disconnect cycles while pressurized to 35 psig (241 kN/m^2) water. No visible leakage at .sig (276 kN/m^2) water.	No leakage occurred during the 600 connect and disconnect tests.	Results satisfactory

D. Mission Results

1/ Hardware Anomalies - No anomalies were reported.

2/ Hardware Assessment - The first mission crew reported that the shower worked very well, but it took longer than expected for post shower cleaning.

The second mission crew reported they did not like the shower. The following are subjective observations of the mission crews:

On DOY 154 the SPT reported: "And as for the zero-g shower, it's a pleasant experience and I think it proves the feasibility and the principle that man can live in small close space. With water, he is not going to drown because the water does not fly through the air, it sticks to whatever is there, mostly you, partly the walls. Again I think the airflow in there is grossly inadequate. The method of containing the water and getting it into a compartment where you can throw it away is not good. It takes forever to dry both one's self and the walls using the inadequate little vacuum cleaner that we have. Some better method ought to be thought of. But the principle of crawling inside a shower and spraying yourself is great."

On DOY 154 the CDR reported: "The shower worked very well, but it took longer than expected. The amount of water is adequate. It sprayed the water on and it's very good. The only thing is the amount of time it takes to dry it up afterwards, which is a fair amount of time. There could be improvements to the water container and that on the back side of where the controls are. And other than the fact that it takes a little while to glop up the water, I think it's very good."

First Mission Crew Debriefing: There was no problem with soap in the separator or the filter clogging. Two times out of four when the shower H_2O collection bag was pulled out, water was in the line. Both times when the CDR had towels ready there was no H_2O. When he didn't there was H_2O and it had to be cleaned up. No filter was installed in the unit for the first three showers, therefore, it works with or without filters. The shower really worked well and we felt good after showering. You froze your tail off getting to a towel.

The first time we showered we used H_2O only. We weren't sure six lbs (2.71 kg) of water was enough to take a normal shower. The second time we showered we got in, soaped up and washed. Each time we used more water - six lbs (2.71 kg) of H_2O was enough. We used more and more soap in later showers. You probably left some soap on your body after you rinsed off.

The following second mission crew comments are from the Technical Crew Debriefing:

SPT - I would have (taken a shower) if I'd had more time just to fill the square and see how it went, or for the fun of it. But you judged the time it took; I guess it took between an hour and an hour and a half. Is that about right?

Including setup, take a shower, and then tear down again. I just didn't want to spend an hour and a half on something that was socially unnecessary for personal cleanliness. There is the towel and washrag bit, which I think was quite adequate to really maintain personal cleanliness.

PLT - It did take a lot of time. It seemed like the suction device didn't suck up near as much water as was squirted in there. One of the other reasons I didn't take any more showers, beside it taking just too much time and not doing that much better a job, was that the soap stuck to you and it stung. It had an odor that persisted for a couple days after you took the shower. I didn't like it so I didn't take any more showers.

CDR - I found that it was just too distasteful. Two parts, one is it took you a while to rig it up and usually by the time you rigged it up, you could have had a washrag bath. In the second part, it was right after you finished the shower part you were standing around inside that can trying to vacuum it and you'd bump into it and you'd get cold. It just was unpleasant; it was like taking a shower in a place where there was a draft. After you finished the shower and instead of being able to dry off you had to stand around inside the shower for an additional 10 minutes and halfway freeze. So it turned out to be easier just to forget the whole thing. Although it gets you nice and clean. I would recommend to have a shower in the future space station, but they have it connected into the plumbing just like the rest of the water. When you step in to take a shower and then when you get finished, turn off the shower and get out. You just leave the shower with water around on that area; you have revisions made so that the water's automatically sucked off.

PLT - I would like to have taken a shower and highly recommend having one in the future but the one that we had, I didn't like and I didn't like the soap.

On DOY 231 the CDR reported: One thing about that shower last night was kind of interesting - water tends to get in the crevices and in your hair and under your armpits or any place where there is an acute angle. First of all when you get the soap on there and then spray a little water on, the soap doesn't wash off; it sort of just hangs there in a glob. So when you open your eyes, you're looking right through soapy water, or you open your mouth to breathe, your breathing tastes of soapy water, which is a little bit unusual. Also, if you're not careful, you can get a big bubble in your mouth and nose and when you breathe in through either, you start taking a lot of water down. When you shake, the water doesn't appear to come off to easy; you have to sort of brush it off. When you get finally rinsed, and you want to dry off, you've got this water all over you now. And there must be a quart of it, kind of hanging on you, so you shake a bit, and some of it flies off, and some of it just sort of distends a little bit. It doesn't have a level surface anymore, but then when you stop shaking, it sort of comes back in contours around you again. You end up having to brush it off or put your hand around your arm and kind of swish it off; try to get it over on the walls where you can vacuum it. It makes you feel real good and clean at the end, but it's almost like bathing in kind of warm jello; it's not that rigid as jelly, but when it gets on you, it doesn't want to get off. It takes a couple of towels to get the water off because there is so much on you.

The following are third mission crew comments on the shower:
CDR - The only shortcoming of the shower, I would say, is the - is the suction head. It's just not flexible enough and it doesn't flow over the body well enough to remove the water. There's a reason I - necessary there and I don't think that's too difficult a thing. I think it could be very easily redesigned into something quite - quite nice and useful.

I suspect that what we'll need is a selection of heads just like we have for the vacuum cleaner. Because I think when you start cleaning up the shower and - and scooping up water around the shower that you probably need a wide head. But for the body you certainly need a soft head that'll follow the contours of the body a little better and pull the water off of you.

SPT - Shower: I have not used it yet. I use sponge baths, and what's good - I guess I really can't give you a rating; I guess I'd give it an adequate, but what scares me off is all the frapping (?) time it takes just to go in and get the - the thing set up and to clean up after. I find I could go on in and give myself a good sponge bath, and can do the job, just as well as that shower in about half the time. We've been pushed for time up here, so I just haven't had the - haven't had the time to, - the luxury to go on in there and try that. Looks like fun and I'll probably - I'm sure I will try it quite a few times.

SPT - What is the most disconcerting personal hygiene problem you have encountered? Probably, one is that you just don't have time to take a shower everyday. It takes a good 45 minutes to an hour. I like to enjoy that, but we don't have time for it. The other sponge bath works but it's not anywhere near as efficient. And ... clean and healthy feeling state that you can on the ground, usually exercise - after exercise taking a good soap bath, but here it's not possible.

As a general assessment, shower airflow was not completely adequate and the method of collecting water at the conclusion of a shower accounted for the extended length of the shower periods. It took considerable time to dry oneself and the walls, using the hard rubber suction head and the inadequate vacuum cleaner. Improvements in controls for the shower are needed - the shower curtain has crevice rings which were almost impossible to remove water from. The first crew reported that the basic principle is great and should be operated more frequently.

The second and third crews did not assess the shower as favorably as the first mission crew.

E. Conclusions and Recommendations - The shower system proved that taking a shower in somewhat a normal manner is practical in zero-G. The crews did comment that the system as designed took too long to vacuum up the water and the water temperature could be higher, and the quantity of water could be larger. It should be noted that the system was provided as an experiment using the water heater and blower that were available and not designed specifically for the shower system.

For future systems larger quantities of warmer water should be provided and a rapid means of collecting the water, possibly high velocity warm air, should also be provided.

F. Development History - During the latter period of waste management hardware deliveries, a NASA design shower was implemented. This shower contained components of the Waste Management System. A centrifugal separator similar to the urine separator but with a large Pitot tube and no filter was used and the spare blower was allocated to the shower.

2.11.5 Food Management System

A. Design Requirements

1/ Contract End Item Specification (CP2080JIC)

- Food Management - The Food Management Subsystem (FMS) shall be incorporated into the OWS and shall provide the equipment and supplies required for the storage, preparation, service, and waste collection of food for the three-man crews on Missions SL-2, SL-3, and SL-4. Food supplies for the SL missions are grouped into the general categories of (1) dehydrated, (2) intermediate moisture and wet pack, and (3) frozen. Food shall be stowed in the OWS prior to launch.

- GFP Components - The GFP components of the food system shall include Skylab food, food heating/serving trays, SMMD, and eating utensils. Meal size portions of individual foods will be packaged in small cans which, in turn, will be packaged in larger canisters designed to provide the necessary protection against pressure. Two thousand two hundred (2,200) lbs (1000 Kg) of packaged food will be supplied. The food/heating tray will attach to the table, and will contain all controls necessary for food heating. The SMMD shall be mounted in the food preparation area.

- Food Management Equipment - The food preparation equipment shall incorporate the following provisions:
  - Food preparation equipment shall be adequate to accommodate three crew members to eat simultaneously.

- The utensils shall be reusable and provisions shall be made to clean the utensils.
- Food preparation equipment shall fit into the wardroom with rigid attachments while in use.
- Trash bags for the storage of food wastes and wrappings shall be provided.
- Crew time required to operate the food preparation equipment shall be limited to a maximum of 5 minutes.

- Beverage Trays - Six beverage trays shall be provided in the Food Management Compartment.
- Internal Surface Temperature Variations - Maximum surface temperature of the food table in the area adjacent to table interface with food trays is 130°F (327.6°K).
- Interior Color Requirements -

  Wardroom Table - Off White (TFE)

  - Clear Anodize (STP0302-0201)
- Identification - The equipment inside the habitation area shall be marked or labeled, as required, to enhance crew performance and to promote crew safety.

2/ Interface Control Document (13M20926A) - Skylab Food to OWS, Physical and Functional

- Galley Provisions - The OWS provides a galley in the Wardroom. The galley will consist of the following provisions:
  - Compartment for the stowage of three (3) food tray covers. The covers will be retained in the compartment by spring clips.

- Area for the stowage of three (3) large and three (3) waste overcans. The waste overcans will be retained by spring clips at the base and a pliable orifice at the top. A spring-loaded door will cover open ends.
- One (1) Standard Stowage Compartment
- Three (3) trays for the stowage of beverage packs. The beverage packs will be secured in the trays.
- Eighteen (18) trays for the stowage of three hundred sixty (360) food cans (large and small).
- One (1) tray for the stowage of eighteen (18) pudding cans.

B. System Description - The Food Management Subsystem consisted of the equipment and supplies required for the storage, preparation and consumption of SWS foods. The three crewmen were provided with a 140-day supply of food and beverages and used the wardroom as a kitchen.

Food was stored in food boxes, galley trays, food freezers, and a food chiller. A galley, components of the food table, food trays and utensils were provided for the preparation and consumption of the meals.

1/ Food (GFP) - Food was provided in two forms: ambient temperature food and frozen food. The ambient temperature food consisted of dehydrated food and beverages, thermo-stabilized food (pre-prepared, moisturized food), dry bites and puddings. The frozen food consisted of thermo-stabilized food, some of which had to be heated prior to consumption. Food for all the Skylab missions was launched aboard SL-1. Ambient temperature foods (excluding beverages) and frozen foods were vacuum packed in single meal portions in food cans. Beverages were stored in the dehydrated state in beverage packs which collapsed (accordian style) to facilitate storage and drinking. Each can and beverage pack was labeled as to its contents and rehydration water quantity. (See Figure 2.2.11.5-1).

2/ Food Storage - Food cans and beverage packs were grouped and packed in menu form in food overcans. The overcans were stored in bundles in food boxes and in food freezers. Wardroom located galley trays and a food chiller permitted temporary stowage of food when preparing meals and when managing leftovers (Figure 2.2.11.5-2). (Reference: Section 2.2.13, Stowage System; and Section 2.2.11.7, Refrigeration System).

3/ Food Preparation and Consumption - The crew used the galley (in the wardroom) to provide their daily supply of food and also used the galley located equipment to prepare and dispose of food. At the food table the crew made final preparation of the food, and heated and ate their meals. Meals were eaten from food trays, using utensils.

- Galley - Initial food preparation was conducted at the galley. The seven stowage compartments and 22 galley trays which made up the galley permitted the galley to be the central area for meal preparation. The galley stowed the equipment and supplies used for meal preparation, consumption and cleanup after the meals.

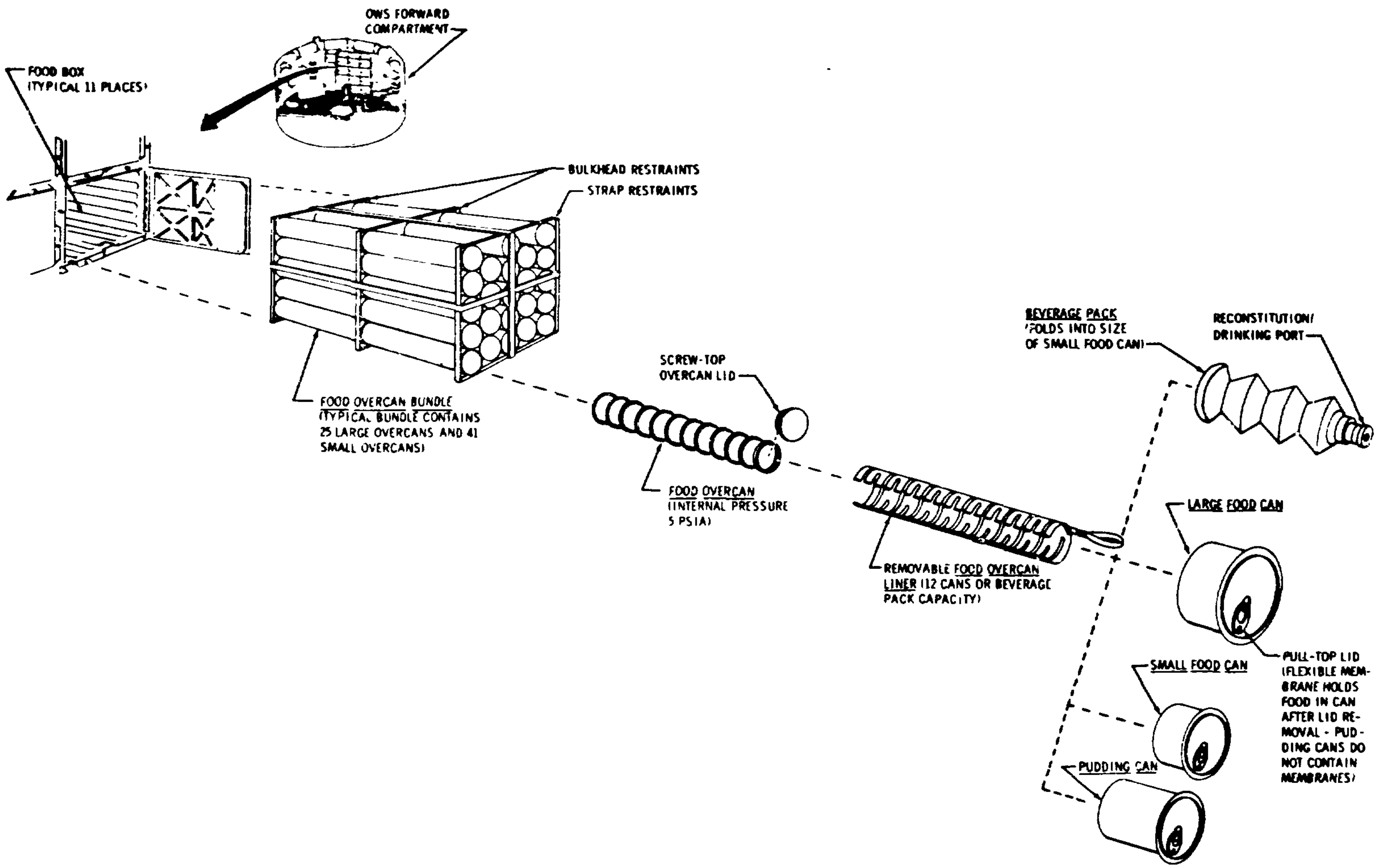
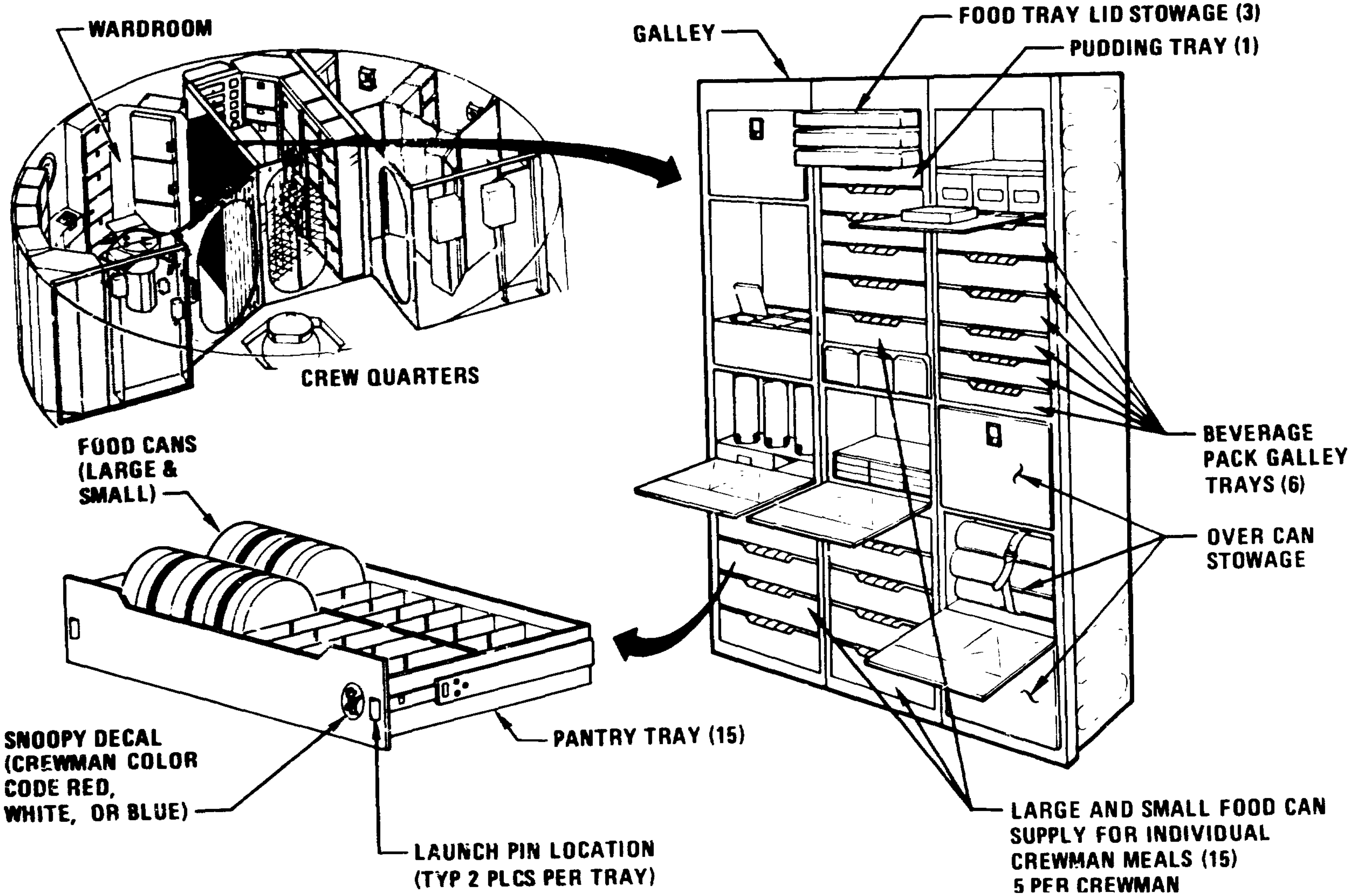


Figure 2.2.11.5-1. Skylab – Orbital Workshop Ambient Food Storage

SKYLAB - ORBITAL WORKSHOP
AMBIENT FOOD SUPPLY - DAILY



(Figure 2.2.11.5-2). The 22 galley trays, which stowed food cans and beverage packs, consisted of 5 galley trays per crewman for their individual menus, 1 galley tray for the weekly pudding supply, 1 galley tray per crewman for snacks (dry bites) and 1 galley tray per crewman for beverages. Each galley tray slid out on a track and could be completely removed from the galley. Each galley tray held 20 items: large and small food cans, pudding cans, or beverage packs in partitioned segments. Galley tray identification to particular crewman was accomplished using the color coded "Snoopy" decals. The galley trays initially stowed in food overcans. Upon removal of the food cans and beverage packs from the food overcans, the overcans were transferred to three of the stowage compartments within the galley allocated to stowage of empty overcans. Six of these empty overcans were installed in the food can disposal wells in the galley (Figure 2.2.11.5-3). This facility contained 6 food can disposal wells, 3 for large overcans and 3 for small overcans, which were accessed through separate spring-loaded, hinged lids. Empty food cans and beverage packs were disposed of in their appropriate size overcans in the disposal wells. When full, the overcans were placed in a disposal bag and replaced by empty overcans. A utensil stowage compartment in the galley stowed the eating utensils for all crewmen and a supply of food supplements. Two tissue

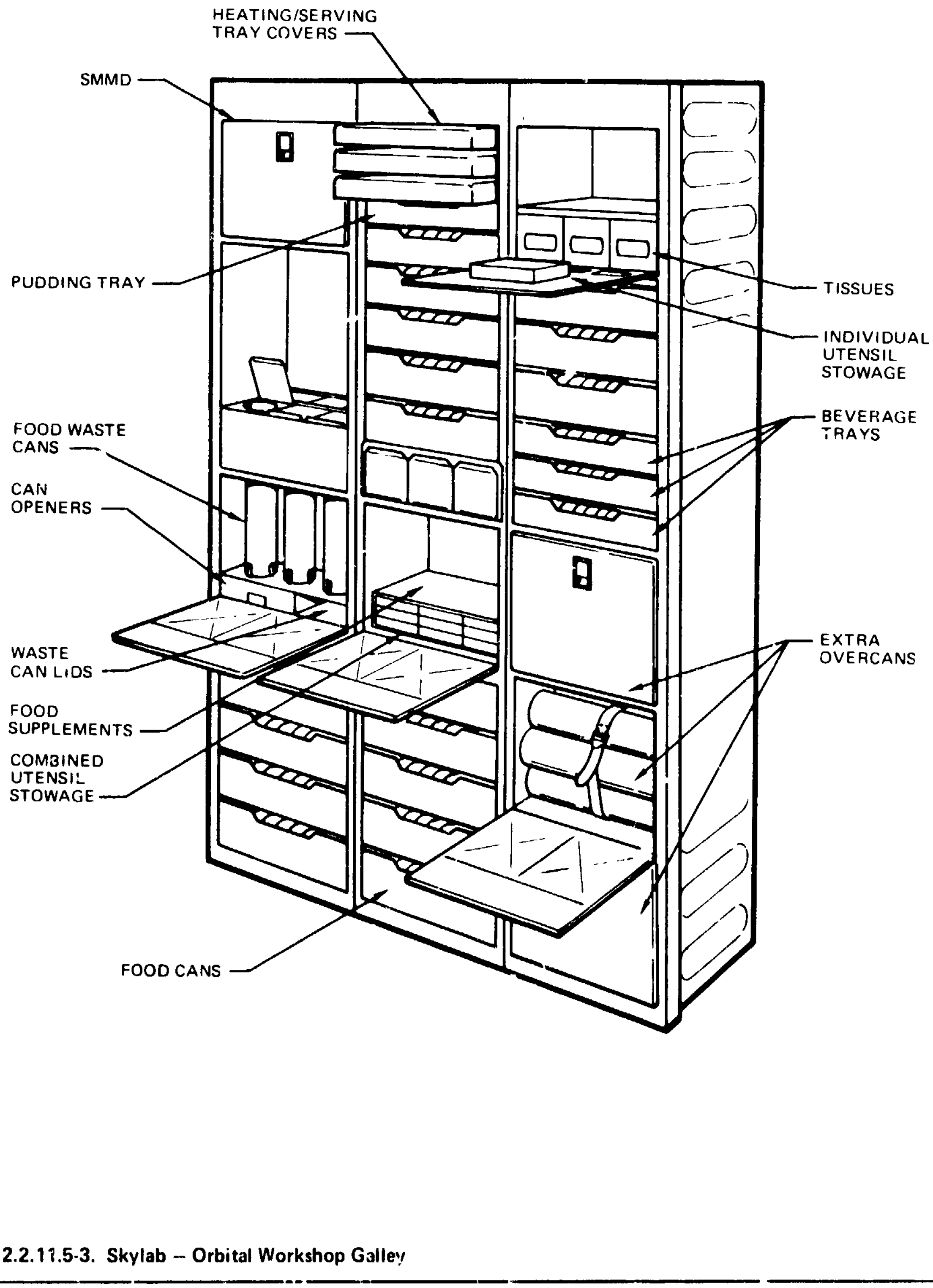
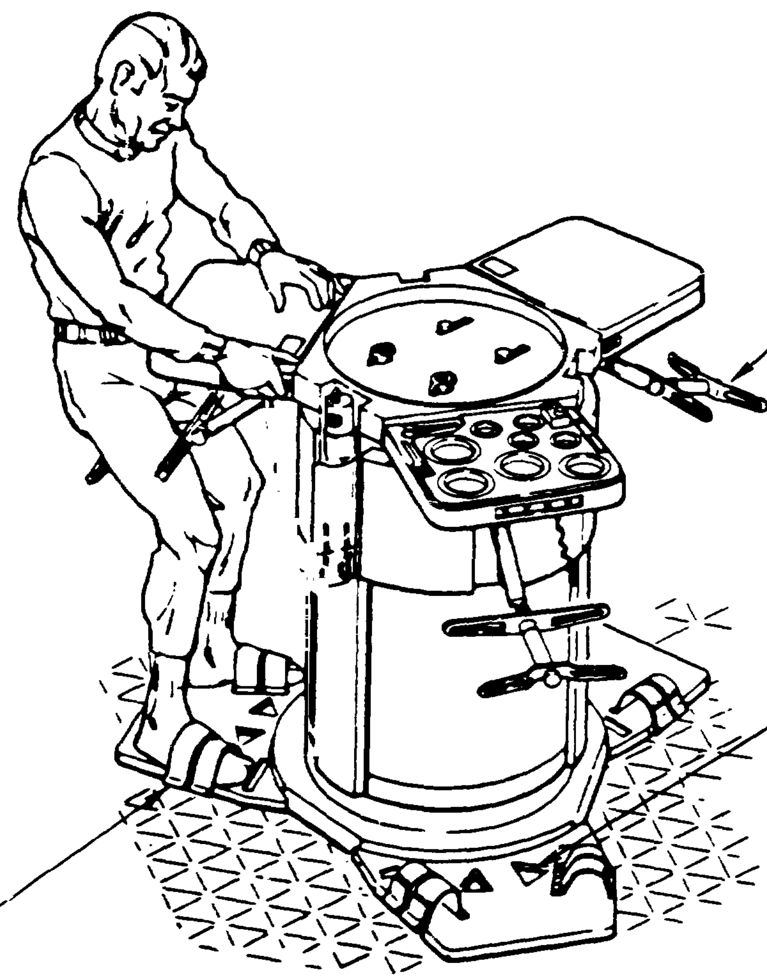


Figure 2.2.11.5-3. Skylab – Orbital Workshop Galley

dispensers were also provided to support the cleaning of the various food system implements and the galley equipment. A SMMD was stowed in the galley to weigh unconsumed food for documentation purposes.

- Food Table - Final food preparation and the consumption of the food was accomplished at the food table. The food table allowed 3 crewmen to simultaneously heat their food and to eat the meals in an efficient and comfortable manner. It also supported components of the water system (Figure 2.2.11.5-4). The food table pedestal houses the water chiller and the wardroom H_2O heater. The water chiller provided cold water to a cold wardroom water dispenser valve on the table's upper surface f... chilled reconstitution of dehydrated foods and beverages. In addition, the water chiller provided cold water to 3 H_2O guns for drinking water. One H_2O gun was allocated to each crewman and was mounted on the periphery of the table's pedestal. The wardroom H_2O heater provided hot water to a hot wardroom water dispenser valve on the table's upper surface for hot reconstitution of dehydrated foods and bevera s. Three eating stations at the food table served as a separate food heating and consumption facility for each crewman. Each eating station had a foot and thigh restraint to restrain the crewman in a comfortable manner. One H_2O gun was located at each eating station. A food tray which heated the crewman's food was provided a mount at each eating

SKYLAB - ORBITAL WORKSHOP
FOOD TABLE AND RESTRAINTS



station. OWS Bus 1 and OWS Bus 2 zero-G outlets were located at each station to provide bus power selection or that particular eating station's food tray. A removable table cover was stowed above the food table on the ceiling grid when not in use. A thigh restraint and foot restraint were located at each eating station to stabilize the crewman in a semi-seated position. (Reference: Section 2.2.1.2, Astronaut Aids).

- Food Heating/Serving Trays (GFP) - One portable food tray per crewman was used to heat frozen food in large food cans and to serve the crewman with his entire meal. The food trays contained 8 food can cavities, 4 for large food cans and 4 for small food cans (including pudding cans and beverage packs). Three of the large food can cavities were heated: individual cavity power switches and a timer controlled heater use. A removable food tray lid was used when the food was heating and was stowed in the food tray lid stowage area in the galley when not in use. Each of the three food trays and food tray lids were color coded with "Snoopy" decals. Two dial-type latches were located on the food tray to secure the tray to the food table mount. A zero-G receptacle was located under the food tray to supply power to the tray from the food table power outlets via a high power accessory adapter cable.

- Eating Utensils (GFP) - Reusable eating utensils were supplied in sets. One utensil set was allocated to each crewman and three additional sets were spares (12 total). A set consisted of a knife, spoon, and fork, all 3/4 size, and was made of magnetic stainless steel. The knife had a pointed tip to pierce and slice the flexible membranes contained in some food cans. The utensils were retained on the food trays with magnets and in the utensil stowage container in the galley or personal preference lockers, with utensil restraints (Figure 2.2.11.5-3). Disinfectant-moistened pads, obtained from a galley located tissue dispenser were used to cleanse the utensils after each use.
- Food Overcan Lid Removal Tools (Can Openers) (GFP) - Two sets of can tools were supplied to aid opening of the screw-type overcan lids in the event that they were too tightly screwed on. One set was for large overcans and one set for small overcans. One tool of each set was for grasping the overcan, the other was for grasping the overcan lid. The tools were stowed in the galley just below the waste cans (Figure 2.2.11.5-3).
- Can Crusher (GFP) - In the event the trash airlock became disabled, it would have been necessary to dispose of opened food cans by storing them in empty stowage freezers. To ensure adequate volume, the food cans would have been smashed flat in a manually operated can crusher prior to insertion into empty overcans.

C. Testing - A portion of the Crew Restraints Development Test, HS-1, was performed to determine the most appropriate restraining technique and table height for crewman positioned at the food table. Test results called for a 40 in (101.6 cm) table height, and adjustable foot and seat restraints. In the final design configuration, an adjustable "H" bar thigh restraint and fixed foot restraint were employed (Reference: Test Control Drawing (TCD) 1T16801, Component Test Control Authority (CTCA) Log. No. 3345, Test Report TM-DSV7-SSL-R-6901.)

D. Mission Results

In general, the galley and food table received favorable comment by the crew. However, the arrangement by menu of the food in the galley stowage was criticized by the second crew who preferred a general pantry scheme which would group all foods of a like kind in the same area. The crew also found that the access to galley stowage was awkward for the crewman assigned to the food table position opposite the galley. When the two crewmen were at the table on the galley side, the third crewman had to position himself over the table to gain access to the narrow space between the table and galley to reach his food supply.

The stowage restraints for small food cans and beverage packs would not hold these items in place in the galley drawers. The restraints for on-orbit stowage of the food utensils were also inadequate. The crew felt that the utensiles could have been more conveniently stowed with the food trays instead of in lockers. They also reported a need for a place to stow menus where they could be seen.

Control of food wastes was the most frequent crew topic. Food residue collected regularly on the six waste can covers in the galley. The covers were difficult to clean and had a tendancy to generate odors. This area required more frequent cleaning than all other bio-waste areas in the spacecraft. Because of their small volume, the waste cans (food overcans) required too frequent removal and disposal. A better method of cleaning utensils was also desired by the crew.

The table proved to be a convenient place to do mission planning activities. However, the crew noted a need for higher intensity lighting over the table and for various restraints on the table to retain papers, pens, etc.

Crew opinion was divided on the table height. Some felt it was too low and should be raised to chest height to facilitate eating.

E. Conclusions and Recommendations

Although the primary elements of the food management system performed satisfactorily, minor operational and design features became sources of irritation to the crew. Because of its frequently repeated use, food equipment deserves great attention to detail during the planning and design phase. A realistic evaluation through repeated usage of prototype hardware and operational procedures in a high fidelity interior mockup is a necessity. The food table, when not used for food service, became the center of mission operations activity. Being the only convenient work surface with adjacent body restraints, it was used for a variety of functions which were not considered during design. Because of this potential usage, similar to the traditional kitchen table, future designs should be based on total system needs and not limited to those solely associated with food management.

Since the operation of food storage and preparation facilities is so subjective, a high degree of flexibility should be a design requirement. It should be possible for each crew to rearrange the pantry to suit their own needs and desires.

Detailed attention should be given to maximizing the simplicity of clean up of equipment associated with food.

F. Development History - The food management equipment was redesigned as part of the wet to dry conversion and the incorporation of the wardroom. The initial wardroom installation had the food heating equipment mounted to the ceiling over the table. Subsequently, NASA directed that the food heaters be part of a GFP food tray. This change was associated with changing the food from plastic packs to metal cans.

The initial dry workshop design also included a perishable food chiller. The perishable food was subsequently deleted but the chiller was retained to support the Inflight Medical Support System (IMSS) and to keep prepared snacks or drinks cold during flight.

2.2.11.6 Sleep Support System - The Orbital Workshop provided three (3) individual sleep compartments, each containing a sleep support system (see Figure 2.2.11.6-1). The sleep support system equipment contained the following items:

Qty	Description
3	Sleep Restraint Assemblies
27	Stowed, Comfort Restraint/Top Blankets
12	Stowed, Bottom Blankets
27	Stowed, Pillow Covers
12	Stowed, Large Body Straps
24	Stowed, Small Body Straps
3	Privacy Curtains
3	Light Baffles
2	Privacy Partitions

A. Design Requirements (Ref: CP2080JIC) - Sleep equipment shall be provided in the sleep compartment to support sleeping for three astronauts. The sleep restraints shall not attempt to provide thermal protection for the crewman. Any thermal protection required shall be provided as GFP equipment. The sleep compartment shall consist of the following:

- o Sleep restraints
- o Privacy partitions (2)
- o Light baffles

1/ Sleep Restraints

a. The sleep restraints shall provide body restraint for the astronauts while sleeping.

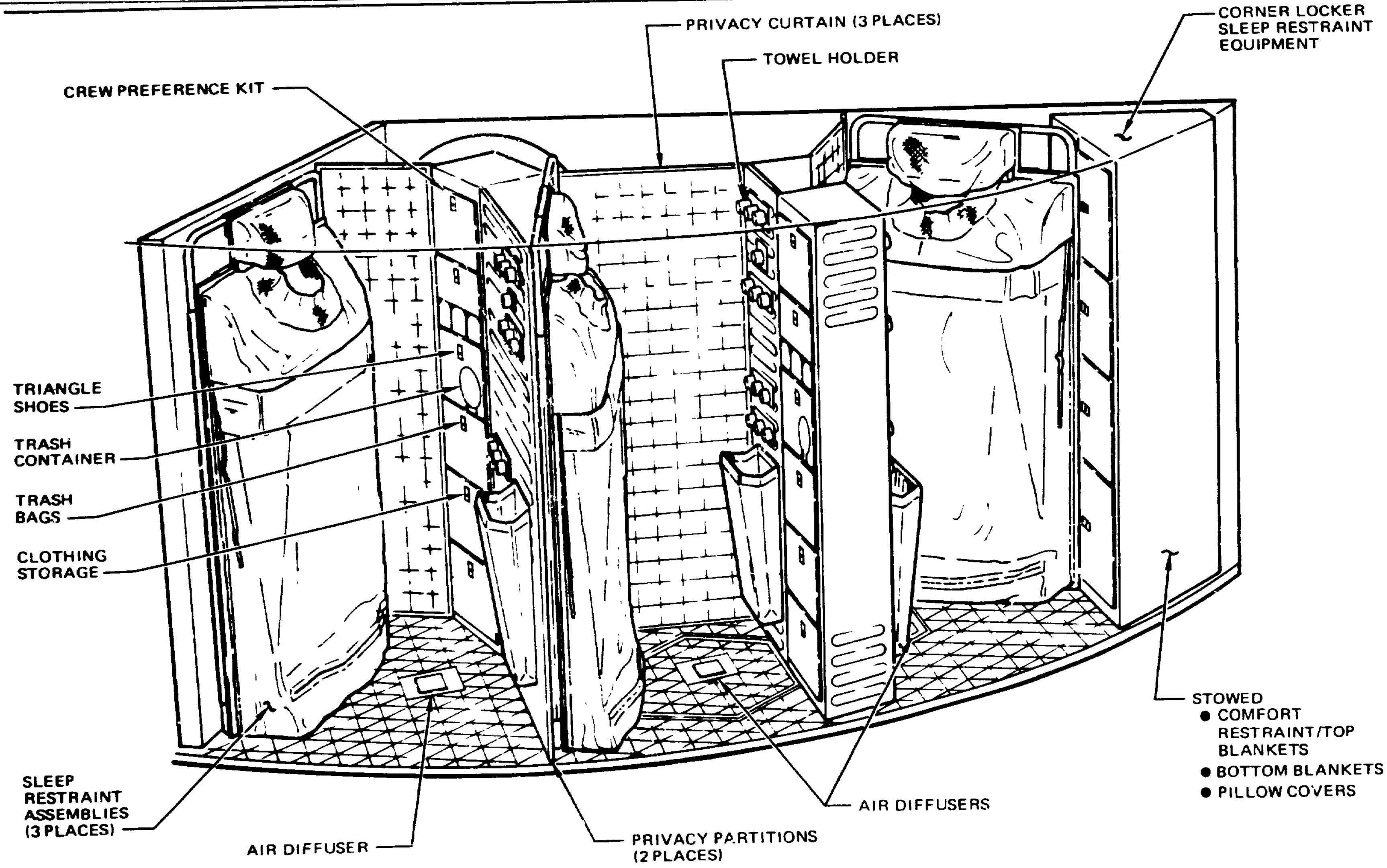


Figure 2.2.11.6-1. Sleep Compartment Equipment

b. The sleep restraints shall be identical in design but shall be adjustable to permit the astronauts to assume a sleeping position of their choice, including one similar to the fetal position.

c. The sleep restraints shall be secured in a manncr which will minimize restraint movement, drifting and gyration. The sleep restraint shall be secured in a manner which will preclude the crewman from strking his head on adjacent structure during uncontrolled motions during sleep.

d. A zipper, if employed, shall be operable from outside of the bag.

e. The sleep restraints shall be vented, when blankets are not in use.

2/ Privacy Partitions - Two privacy partitions shall be provided which will provide visual separation of the three sleep stations. Light Baffles - Light baffles shall be provided for on-orbit installation in each sleep compartment. The baffles shall as a minimum:

- o Be ventilated to permit air circulation.
- o Prevent light from being directed onto the head area of the sleep restraint.
- o Minimize transmission of reflected light.
- o Accommodate repeated installation and removal

3/ The MDAC-W sleep restraint baseline design requirements and production efforts were deleted by ECP 300 in March, 1971. The same ECP directed MDAC-W to evaluate the JSC designed sleep restraint. This action gave MDAC-W the responsibility to simplify the JSC design for production purposes, and to investigate new materials that met the flammability and offgassing requirements of the Orbital Workshop, and document the new design with customer review changes on production drawings.

4/ ECP 300 directed MDAC-W to build two prototype sleep restraints. One made from glass fabrics, and the other made from polybenzimidozole (PBI). Later direction from the customer deleted the glass fabric restraints and ordered (PBI) fabric restraints for production.

B. System Description

1/ Sleep Restraint Assembly - The sleep restraints provided for each of the three crewmen were identical in design; they provided variable thermal comfort and body restraining capability for each man. The sleep restraint consisted of the following hardware items:

a. Sleep Restraint Frame - The restraint frames were installed in a vertical position, mounted to the floor and ceiling grids via spring snaps and webbing assemblies. This attachment hardware gave the restraint the capability of being used and supported in a variety of locations, such as the Forward Compartment, MDA, and Experiment Compartment (see Figure 2.2.11.6-2). The three frames were approximately 36 x 72 in (915 x 1830mm), and utilize tubular weldment construction.

b. Thermal Back Assembly - The thermal back combines teflon coated glass fabric, durrette batting, PBI fabric and fluorel coated webbing, materials which provide crew thermal protection. The back assembly was attached to the sleep restraint frame via one of the two rows of snaps located around the

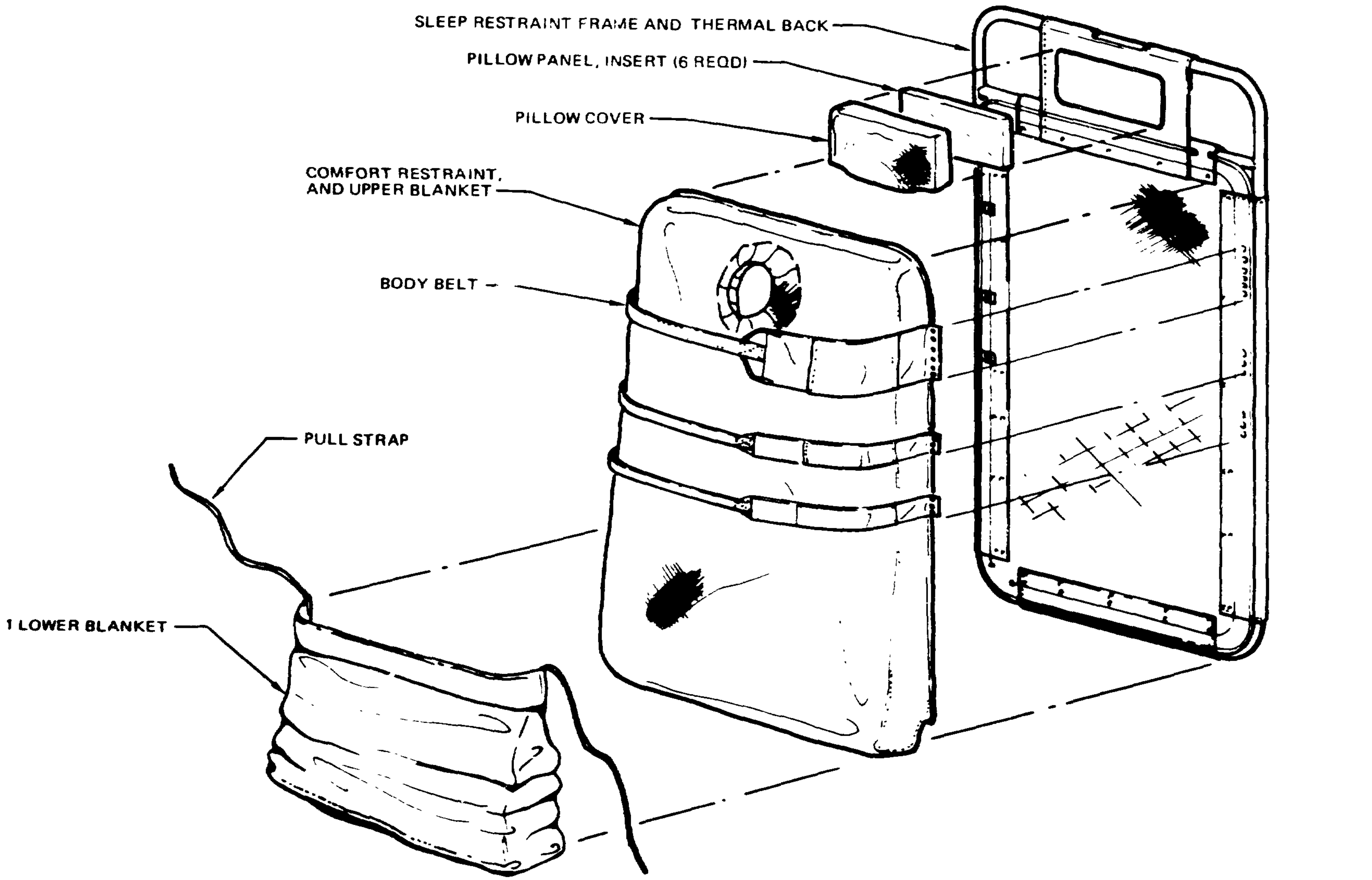


Figure 2.2.11.6-2. Blanket and Pillow Installation

periphery. The second row of snaps provided adjustment capability (see Figure 2.2.11.6-2).

c. Comfort Restraint and Top Blanket - The comfort restraint was basically a sleeping bag made from a PBI loose knit fabric. This material provided limited ventilation to the crewman. A stretchable knit fabric provided the upper or top blanket. The crewman's head was placed through the expandable opening which allowed the blanket to be spread over the shoulders and chest area of the crewman. The restraint and top blanket are attached to the thermal back by two zippers, one around each side of the periphery (see Figure 2.2.11.6-2). There were 27 comfort restraint/top blankets stowed in the sleep compartment. This provided a changeout every 14 days for each sleep restraint. The comfort restraint/top blankets were stowed in quantities of 11, 8, and 8, in Lockers S903, S902 and S901, respectively.

d. Bottom Blanket - The bottom blanket was made of heavy PBI fabric containing two spandex "vee" panels. This blanket attached to the bottom half of the thermal back by two zippers. The blanket was designed with a zippered pouch, located near the bottom of the frame. The pouch restrained the blanket during launch and when not in use (see Figure 2.2.11.6-2). There were 12 bottom blankets stowed (S901-6; S902-6) which provided a change out every 28 days for each sleep restraint.

e. Panel, Pillow Insert - The pillow inserts consist of a PBI covered, heat resistance foam panel. The sleep restraint contains six pillow inserts at launch. These inserts were kept in place by the attached pillow/head restraint cover. When in use the crewman selected the number of panels which provided the best head support. (See Figure 2.2.11.6-2.)

f. Pillow Cover/Head Restraint - The pillow cover stretched over the number of pillow panels used by the crewman. This cover was made of PBI fabric and attached by a zipper to the thermal back. The head restraint provided a means to restrain the head from drifting during sleep. This restraint was fabricated from PBI loose knit for ventilation. The restraint was placed over the crewman's forehead or over the entire head, at his option. One side of the restraint was attached to the pillow cover and the other side was attached via velcro by the crewman (see Figure 2.2.11.6-2). There were 27 pillow covers stowed in Locker S903 which provided a change out every 14 days for each sleep restraint.

g. Strap, Body - Three body straps were provided for each sleep restraint and were constructed from strech knit PBI fabric, spandex, PBI webbing, and fluorel coated webbings. The design of these belts allowed them to stretch as the crewman changes his sleeping positions during the sleep period. Adjustment in length is possibly by releasing the buckles. These straps were used to restrain the crewman's body while inside or outside the comfort restraints. Soiled straps were changed periodically, removal is accomplished by releasing the buckles at one end and disengaging snaps at the other end (see Figure 2.2.11.6-2). There were 1? large body straps and

24 small body straps stowed in D414 which provided a change of body straps every 28 days. One large and two small body straps are required for each sleep restraint.

2/ Privacy Curtains - A Teflon coated glass fabric privacy curtain was provided for each crewman's sleeping area. Each curtain stowed against a locker or wall which allowed the crewman's egress and ingress into the sleeping area. When placed in use position, the curtain separates each crewman's sleeping areas from the sleep compartment passage way. The curtain also served as a barrier to block light emanating from other sources in the crew's sleep quarters. The privacy curtains were not designed to block or reduce sound from entering the sleep compartments. Each curtain was held in the closed position with velcro, which mates to velcro on the lockers or walls. This feature was simple to operate and provided for breakaway emergency egress from sleeping area (see Figure 2.2.11.6-1).

Light Baffles - A fabric light baffle was provided for each crewman's sleeping area. The light baffle was designed to be supported by snaps and velcro that mate to snaps on the ceiling and velcro on the walls and lockers. When the baffle was installed it provided a light barrier from the forward compartment area. It was designed to allow ventilation while providing a non-reflective surface for the crewman. The light baffle in the center sleeping area has a section the size of the emergency escape exit, that was fastened with velcro for breakaway emergency egress. The light baffles were constructed from two layers of fabric. The inter-layer (side facing sleep compartment) was white Teflon coated glass fabric. The layer facing the ceiling was black

Teflon coated glass fabric. The louveres contain 4 layers of the above fabrics which provided stiffness (see Figure 2.2.11.6-3).

3/ Privacy Partitions - Two privacy partitions were provided in the sleep area. One was installed between sleep compartment one and two. This partition consisted of an aluminum corrugated panel and a standard stowage locker The second partition was installed between sleep compartment two and three. This partition is made up by the installation of two standard stowage lockers, adjacent each other (see Figure 2.2.11.6-1).

C. Testing

1/ Sleep Restraint - The glass fabric sleep restraint test (HS-69) was released on 10-11-71. This test was constructed to evaluate the following design considerations:

(Ref:) Line Item HS-69

CTCA, Log No. 3108

Test Control Drawing 1T42757

a. Function Operation - Verify functional operations of restraint components, ingress, egress, adjustment of body straps, comfort and capability to chang soiled components.

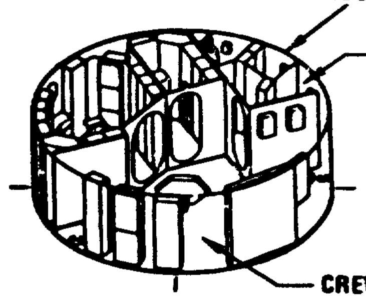
b. Material Weight Loss - Examine for particulate loss during folding, stowage, installation and life cycling.

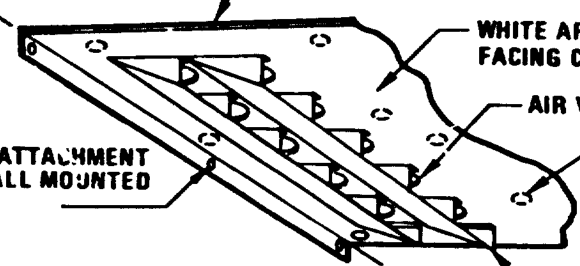
c. Material Abrasion - Verify that abrasion of sleep restraint will not generate excessive particles.

d. Stowage - Stowage test to verify fit and accessibility of sleep restraint components.

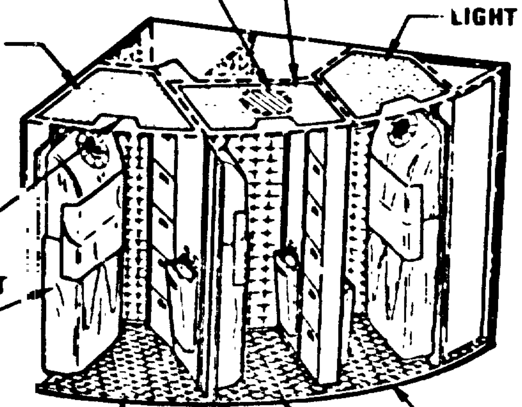
Testing of the (HS-69) glass fabric sleep restraint had just started, when NASA issued direction to MDAC-W to stop and delete

SKYLAB - ORBITAL WORKSHOP
SLEEP COMPARTMENT LIGHT BAFFLES





TYPICAL LIGHT BAFFLE SECTION



SLEEP COMPARTMENT VIEW LOOKING INBOARD

LIGHT BAFFLE FEATURES–

- BLOCK DIRECT LIGHT TRANSMISSION INTO THE EYES OF THE CREWMAN WHILE HE IS OCCUPYING THE SLEEP RESTRAINT
- AIR VENT OPENINGS ASSURE ADEQUATE SLEEP VENTILATION
- LIGHT BAFFLES ARE LAUNCHED IN A STOWAGE COMPARTMENT AND ARE INSTALLED AS REQUIRED ON THE CEILING GRID USING SNAPS
- THE HATCH LIGHT BAFFLE IS FITTED WITH VELCRO ON ITS PERIPHERY WHICH MATES WITH A VELCRO LINER ON LIGHT BAFFLE 2. SNAPS ARE NOT PROVIDED ON THE HATCH LIGHT BAFFLE

2.2.11.5-1

all testing on HS-69. New direction then was issued to MDAC-W to provide a new design of the sleep restraint utilizing PBI fabrics, with no testing required.

All PBI sleep restraint fabrics were subsequently approved by NASA through flammability waivers.

2/ Privacy Curtain Testing - No testing required other than fit check.

3/ Light Baffles Testing - No testing required other than fit check.

4/ Privacy Partition - No testing required.

D. Mission Results

1. Sleep Restraint

The sleep restraint frame was designed in such a way as to allow the crew to use the restraints in different locations within the vehicle. Mission 1 PLT and Mission 2 CDR took advantage of this design consideration, when temperatures of airflow was uncomfortable. The crew reported numerous times on the fact that the sleep restraints allowed them to sleep on their back, right side, left side, and stomach in a comfortable manner. The upper and lower blankets were used by all crew members when temperatures dropped within the vehicle and no problems were expressed during changeout of these soiled components. SPT Mission 2 reported that the environmental factors within the Workshop such as noise, temperature, airflow and illumination did not interfere with his sleeping. The variable height, pillow insert, design proved to be very useful to the crew. Most of them used different quantities of pillow inserts during the course of their missions. The head restraint was used most of the time by Mission 2 PLT and Mission 3 CDR, however, other crewmen expressed their usage as very little, or none. All the crew used their body belts throughout the sleep periods with ease and no discomfort. The SPT (Mission 1) called the restraint "an excellent thing" and he would like to add one additional body strap in the lower leg area. The CDR (Mission 2) remarked "the sleep restraint, I think, it works very well." He also suggested the body straps should have been designed as one large body cover, rather than three belts. PLT (Mission 1) thinks the restraint was "very good for sleeping" and he liked the soft (body straps) elastic restraints.

Later on in Mission 1 the CDR said the OWS sleep restraint was much better than the Apollo bag, because he could assume many comfortable positions. During Debriefing (Mission 1) PLT stated that he used his restraint in locations other than the sleep compartment, and this indicated the design was very functional. PLT (Mission 2) remarked "I enjoy sleeping in the bag." He suggested the addition of another body strap and the addition of second lower blanket. CDR (Mission 2) liked the way his head was restrained to the pillow. He would also like a method to restrict or reduce the volume inside the blankets, for better thermal control. The PLT (Mission 2) reports "the sleep restraints are very adequate." He was able to "sleep all night and very hard." The Mission 3 crew reported that they obtained excellent quality and duration of sleep. Mission 3 PLT felt that a zipper entry would be better than the elastic neck. The Mission 3 CDR said that a possible improvement might be to use a one piece elastic blanket instead of straps.

2/ Light Baffles

The light baffles were not used as often as planned due to the sleep configuration used by the Skylab missions. All OWS lights were off and the window shades were closed. The CDR (Mission 1) reported that the light baffle worked satisfactorily. He talked of using the baffle during reading. It is assumed he also used it during the sleep period. The PLT (MIssion 2) used his light baffle and he stated that it blocked light very well but created a ventilation problem. He suggested the baffles should be improved by stiffening the fabric louvres in such a way as to prevent them from collapsing during use. The third crew used the light baffles but did not experience any difficulty with airflow. They rated the light baffles as "very good" to "excellent."

3/ Privacy Curtains

Privacy curtains were not used as often as intended because the normal sleep configuration was with all lights off in OWS, the wardroom shades were closed and all three crewmen scheduled to sleep simultaneously. The curtain was used by the SPT every night and no problems were reported. The PLT (Mission 2) said "curtain works okay, I've no complaints about it at all." On DOY 227, SPT said the privacy curtains were very useful to keep out light. The Mission 1 SPT reported that he used his curtain every night. CDR used his curtain on occassion and the PLT did not use it at all. Second crew stated that curtains were very useful and they did act as a light barrier. The PLT sometimes left his curtain half way open during sleep period. There were no anomalies reported regarding privacy curtain hardware. The CDR (Mission 2) stated that the curtain worked fine for light control and privacy but that it should really be a door with sound-proofing. He expressed the need to shut off outside noises and to be able to play loud music without disturbing other crewmen. The Mission 3 crew rated the curtains "very good" to "excellent."

4/ Privacy Partitions

The crews have made no reports on usage or anomalies in regard to privacy partitions, therefore, it is assumed that the lockers and panels functioned as partitions as planned.

E. Conclusions and Recommendations

1/ Sleep Restraint Assemblies

The sleep restraints provided an excellent means for providing whole body restraint during sleep. The crews had no difficulty in obtaining comfortable, restful sleep. The adjustable features of the restraint accommodated most of the individual preferences of the various crewmen. Design changes that would enhance the utilization of the sleep restraint on future missions are:

a. Provide an additional adjustable blanket for more thermal control.

b. Add additional adjustable straps and/or adjustable blanket, for additional variation of amount of restraint.

c. Provide adjustment to minimize dead space inside the restraint for thermal control.

2/ Light Baffles

The light baffles were effective in blocking light from the forward compartment from entering the sleep compartments. The fabric air flow louvres had a tendency to collapse and restrict air flow. The light baffles are probably unique to the Orbital Workshop configuration. Future mission sleep compartments should have inherent capability to provide a dark environment.

3/ Privacy Curtains

The privacy curtains performed satisfactorily. They provided visual privacy and light control. Sound control was not a requirement but future missions should provide for reasonable sound isolation.

4/ Privacy Partition

The privacy partitions functioned as designed. Sound isolation of the sleep areas should be a requirement on future missions.

5/ Sleep Restraint Position

The airflow was designed to go from the feet toward the head. One crewman inverted his restraint to solve the effects of low humidity by having air flow down across his nostril as opposed to flowing up the nostril. The restrain and all body clearances should be such that will allow flexibility of positioning. Proper illumination should also be part of this consideration.

F. Development History - The sleep support system was evolved from two crewmen sleeping in a common compartment (the third slept in the CM) utilizing Apollo type sleeping bags. Individual sleep compartments were established as part of the wet to dry conversion. The light baffles were initiated to provide concurrent sleep and work capability. The baffles were originally metal louvers and evolved to fabric covers. The sleep restraints were originally Armalon fabric. To increase comfort, JSC designed a sleep restraint utilizing more comfortable fabric such as PBI net and Durette. Considerable effort was expended on developing comfortable beta cloth fabrics with only marginal success. The new sleep restraint also allowed better adjustment of thermal characteristics and allowed greater individual selection of the degree of body restaint.

2.2.11.7 Refrigeration System

A. Design Requirements - The CEI design requirements imposed upon the refrigeration system are shown in Tables 2.2.11.7-1 and 2.2.11.7-2. The final requirements were a result of system evolution and Customer re-evaluation of his own needs. In addition there were many implied requirements and commonly agreed to philosophy guidlines that were used in the design of the refrigeration system. They were as follows:

- OWS designs should include maximum usage of "off the shelf" hardware.
- OWS designs should minimize development of new hardware and advancing the "state-of-the-art".
- The refrigeration system, in particular must be designed for a minimum of crew activity to maintain system control and maximum of ease in usage (using freezers and chillers).
- All crew hazards should be eliminated or reduced to an acceptable hazard level. (Pump enclosure for protection against leaks from B-nuts.)
- Sufficient instrumentation should exist to verify design requirements have been met.

Design parameters on components as a result of the implemented configuration are shown in Table 2.2.11.7-3.

TABLE 2.2.11.7-1
REFRIGERATION SYSTEM DESIGN REQUIREMENTS

CEI Paragraph	Requirement	Verification Method
3.3.1.10.2.2.e	Urine Collector "The urine collector shall provide the capability to extract representative samples of 122 ml (min) from a homogenous pool for freezing."	Test HS41 Freezer
3.3.1.10.2.2.i	Urine Collector "The 24-hour urine pool shall be maintained at a temperature below 59°F (288°K). The temperature of the pool shall not exceed 59°F (288°K) for more than an accumulated time of 3 hours during the 24-hour period."	Test HS 62 Waste Management Test.HS19, Specimen 1 Refrig. Sys
3.3.1.10.2.5	Urine and Blood Freezer "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°K) within 3 hours, to 0°F (255.5°K) within 6 hours, and to below -2.5°F (254°K) within 8 hours after simultaneous insertion of the samples into the freezer. The freezer wall or sink temperature shall be no more than -6°F (252°K). The Wardroom food freezer, which will also be used for urine and blood sample storage during the 56-day mission, shall have a wall or sink temperature of no more than -2.5°F (254°K)."	Test HS41 Urine Freezer
3.3.1.10.2.6	Urine and Blood Return Container "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 (259.5°K) for 22 hours."	Test HS42 Urine Specimen Container
3.3.1.10.4.1	Water Subsystem General Requirements "Positive protection against freezing during all mission phases shall be provided."	Test HS19 Specimen 1 Refrig. Sys

Table 2.2.11.7-1

REFRIGERATION SYSTEM DESIGN REQUIREMENTS (Continued)

CEI Paragraph	Requirement	Verification Method
3.3.1.10.7.3.e	Food Stowage and Use Plan	
	"Frost buildup in the food freezers shall not impair removal of the food packages during normal use."	HS19 Specimen 1
3.3.1.10.9	Refrigeration Subsystems	
	"An active, closed-loop refrigeration subsystem using a space radiator shall be employed to provide the environmental conditioning required for water chilling and for food cooling and freezing."	HS19 Specimen 1

TABLE 2.2.11.7-2
ICD 13M20926 FOOD STORAGE REQUIREMENTS

FUNCTION	REQUIREMENTS
Frozen Food Storage	The OWS provides five freezer compartments for frozen food storage.
Freezer Compartment Limitations	1. Physical envelope: 13.03 in. (.331 m) x 16.56 in. (.421 m) x 17.07 in. (.433 m) (Nominal). 2. Weight: Compartment will support 100-lb (45.4 kg) (Maximum). 3. Temperature: -10°F ±10°F (250°K ±5.55°K).
Frozen Food Temperature	Frozen food will be supplied and installed at a temperature of 0 to -40°F (255°K to 233°K).
Fit Requirement of Food Package to Freezer	Food package shall be sized to fit freezer compartment minimum dimensions at -20°F (244°K). Food package shall be shimmed, or otherwise restrained, as required to eliminate loose fit in the freezer. Shims or alternate method of restraint shall be provided by JSC.
Allowable CG Tolerance	Minimum allowable CG tolerance of food package from geometrical CG is ±4.0 in. (.1016 m) along all principal axes of each compartment, except for the thrust axis in the aft direction for which no limit is imposed.
Refrigerator Storage	The OWS provides one refrigerator compartment for food storage.
Refrigeration Compartment Limitations	1. Physical envelope: 13.00 in. (.33m) x 16.60 in. (.422 m) x 17.0 in. (.432 m) (Nominal). 2. Weight: Compartment will support 100-lb (45.4 kg) (Maximum). 3. Temperature: $45\ ^{+0°F}_{-12°F}$ $(280\ ^{+0°K}_{-6.67°K})$
Fit Requirement of Food Package to Refrigerator	Food package shall be sized to fit refrigerator compartment minimum dimensions at 33°F (274°K). Food package shall be shimmed, or otherwise restrained as required, to eliminate loose fit in the refrigerator. Shims or alternate method of restraint shall be provided by JSC.
Allowable CG Tolerance	Maximum allowable CG tolerance of food package from the geometrical CG is ±4.0 in. (.1016 m) along all principal axes of compartment, except for the thrust axis in the aft direction, for which no limit is imposed.
Food Temperature	Food will be supplied and installed at a temperature of 45 to 33°F (280 to 274°K).

TABLE 2.2.11.7-3
MAJOR DESIGN PARAMETERS

COMPONENT/FUNCTION	REQUIREMENTS
Frozen food	0°F (255°K) maximum
Frozen urine	-2.5° (254°K) maximum
Chilled urine	+50°F (288°K) maximum
Chilled water	+33 to +45°F (274 to 278°K)
Chiller temperature control valve outlet temperature	36 to 42°F (275 to 278°K)
Detailed Sys & Component Para.	
System flow rate (design)	125 ±11 lb/hr (56.7 kg/hr) at 55 psid (379 kN/m^2)
System heat load	1,482 Btu/Hr (1565 x 10^3 j/hr) (est. max.)
Radiator capacity (nominal)	1,680 Btu/Hr (1783 x 10^3 j/hr)
Coolant volume (per loop)	1,016 in^3 (1663 x 10^{-5} m^3)
Pump Unit	
Operational life	2,250 hr (minimum)
Pump inlet temperature	40 to 85°F (277 to 302°K)
Pump pressure rise	55 psid (379 kN/m^2)
Pump inlet pressure	19 to 49 psia (131 to 338 kN/m^2)
Design discharge pressure	100 psig (689 kN/m^2) (maximum)
Power inlet (from inverters)	32 watts at 36 Hz
Accumulator volume (bellows compressed)	53 in^3 (8.68 x 10^{-5} m^3) at 47.5 psia (328 kN/m^2)
Relief valve cracking/reseat pressure	95 to 105 psid (655 to 725 kN/m^2)
Pump Inverter	
Supply voltage	24 to 30 vdc
Output frequency	36 ±0.35 Hz
Efficiency	40 percent
Maximum allowable operating temperature	180°F (356°K)
Regenerator Htr & Controller Para.	
Heating capacity (per loop)	75 w at 22.5 vdc
Voltage	21.5 to 27.5 vdc
Thermostats (overtemperature) open/close	165 ±5°F (347 ±2.8°K)/100 ±10°F (311 ±5.5°K)
Fluid inlet temperature	40 to 80°F (276 to 300°K)
Fluid control sensor	37 ±1°F (275 ±.55°K)
Regenerator Heat Exchanger	
Fluid temperature range	40 to 90°F (276 to 305°K)
Flow capacity	
Hot side	125 ±11 lb/hr (56.8 ±5 kg/hr)
Cold side	0 to 136 lb/hr (0 to 61.8 kg/hr)

TABLE 2.2.11.7-3
MAJOR DESIGN PARAMETERS (Continued)

COMPONENT/FUNCTION	REQUIREMENTS
Chiller Temperature Control Vlv	
Outlet temperature	39 ±3°F (277 ±1.67°K)
Flow capacity	125 ±11 lbs/hr (56.7 ±4.98 kg/hr)
Radiator Bypass Vlv & Controller	
Flow capacity	125 ±11 lb/hr (56.7 ±4.98 kg/hr)
Temperature range (in-orbit)	-5 to 25°F (252 to 269°K)
Solenoid voltage	12 to 16 vdc to radiator 24 to 32 vdc to bypass
Controller voltage	24 to 30 vdc
Thermal Capacitor	
Melting point (solid to liquid)	-14.07°F (247.5°K)
Heat of fusion	66.47 Btu/lb (31.9 x 10^3 j/kg)
Capacity	1,900 Btu (2005 x 10^3 j)
Flow capacity	125 ±11 lb/hr (56.7 ±4.98 kg/hr)
Radiator Relief Valve	
Crack pressure	30 to 38 psid (207 to 262 kN/m^2)
Relief pressure reseat	26 psid (179 kN/m^2) minimum
Relief flow capacity	136 lb/hr (61.7 kg/hr)
Differential pressure at flow capacity	38 psid (262 kN/m^2) maximum
Radiator Assembly	
Heat rejection capacity (Nominal)	1,680 Btu/hr (1775 x 10^3 j/hr)
Flow capacity	125 ±11 lb/hr (56.7 ±4.98 kg/hr)
Differential pressure	
Minimum	10 psid (68.9 kN/m^2)
Maximum	36 psid (248 kN/m^2)
Area	84 ft^2 (7.8 m^2)
Emissivity (degraded)	0.90
Absorptivity (degraded)	0.25
Temperature	
Inlet	-17 to 12°F (246 to 262°K)
Outlet	-85 to 10°F (208 to 261°K)

TABLE 2.2.11.7-3
MAJOR DESIGN PARAMETERS (Continued)

COMPONENT/FUNCTION	REQUIREMENTS
Urine freezer	
Flow capacity	125 ±11 lb/hr (56.7 ±4.98 kg/hr)
Differential pressure	2.5 ±0.2 psid (17.3 ±1.38 kN/m^2)
Temperature range	-19 to -2.5°F (245 to 254°K)
Wardroom food freezer	
Flow capacity	125 ±11 lb/hr (56.7 ±4.98 kg/hr)
Differential pressure	2.7 ±0.2 psid (18.6 ±1.38 kN/m^2)
Temperature range	-19.0 to -0°F (245 to 256°K)
Food storage freezer	
Flow capacity	125 ±11 lb/hr (56.7 ±4.98 kg/hr)
Differential pressure	4.4 ±0.3 psid (30.3 ±2.07 kN/m^2)
Temperature range	-17.5 to 0°F (246 to 256°K)
Water chiller	
Capacity	4 lbs (1.81 kg) H_2O
Flow capacity (coolant)	60 ±5 lb/hr (27.2 ±2.27 kg/hr)
Temperature range, inlet	36 to 42°F (275 to 279°K)
Recovery time (4 lbs H_2O)	1 hour
Food chiller	
Flow capacity	60 ±5 lb/hr (27.2 ±2.27 kg/hr)
Temperature range	
Inlet	36 to 42°F (275 to 279°K)
Urine chiller	
Flow capacity (coolant)	62 ±6 lb/hr (28.2 ±2.73 kg/hr)
Temperature range	
Inlet	36 to 44°F (275 to 280°K)
Outlet	59°F (288°K) (Maximum)

B. System Description - The refrigeration system (RS) is a low-temperature thermal control system that uses Coolanol-15 in a closed-loop circuit, dissipating heat through a ground heat exchanger cooled by GSE during prelaunch operation, and by an external radiator in orbit. The RS provides for freezing of food and urine, and for chilling of food, urine, and potable water. The RS controls temperature through a range of +42°F (279°K) to -20°F (244°K). The system has dual coolant loops and redundant components where necessary to provide a maintenance-free, reliable system. Schematics of the system are shown in Figures 2.2.11.7-1 through 2.2.11.7-3.

Each of the cooling circuits contains four pumps, with any pump capable of supplying normal flow requirements. The circuits are essentially identical and independent of each other, except for common utilization of the radiator, ground cooling heat exchanger, thermal capacitor, freezers, and chillers. However, these components have separate coolant paths. The location of the RS components are shown schematically in Figure 2.2.11.7-3.

The RS utilizes a single-phase liquid coolant, Coolanol-15. The coolant is circulated through the freezers and chillers to absorb heat; the heat is rejected to either an external space radiator (refer to Figure 2.2.11.7-4) or a thermal capacitor. The thermal capacitor, which consists of three in-series phase-changing wax compound heat sinks (UNDECANE, $C_{11}H_{24}$), absorbs RS heat when the surface temperature of the space radiator exceeds system operating temperatures and cannot be used for heat rejection. If the radiator surface temperature reaches 15 $\pm$2°F (264 $\pm$1.11°K), a control

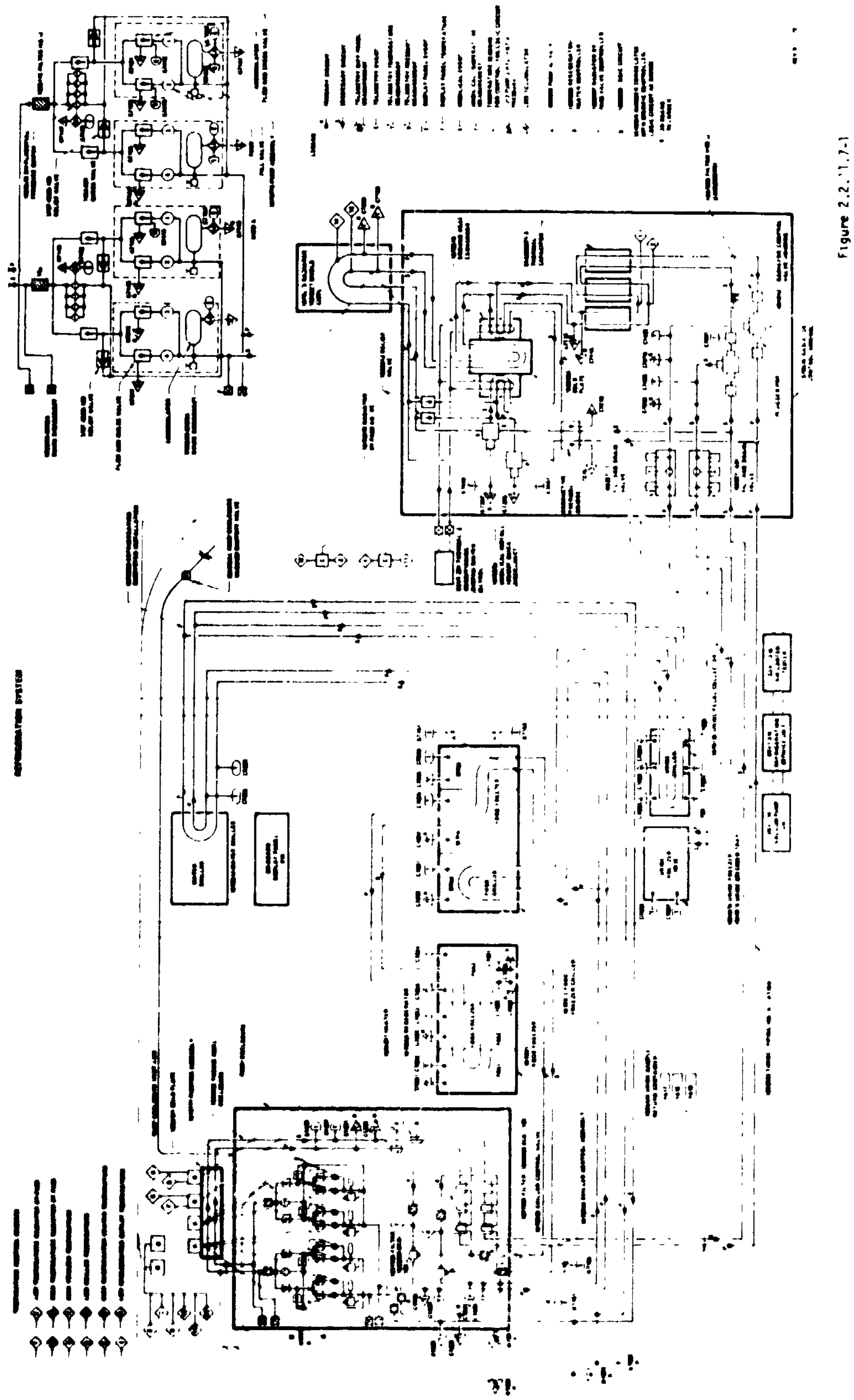
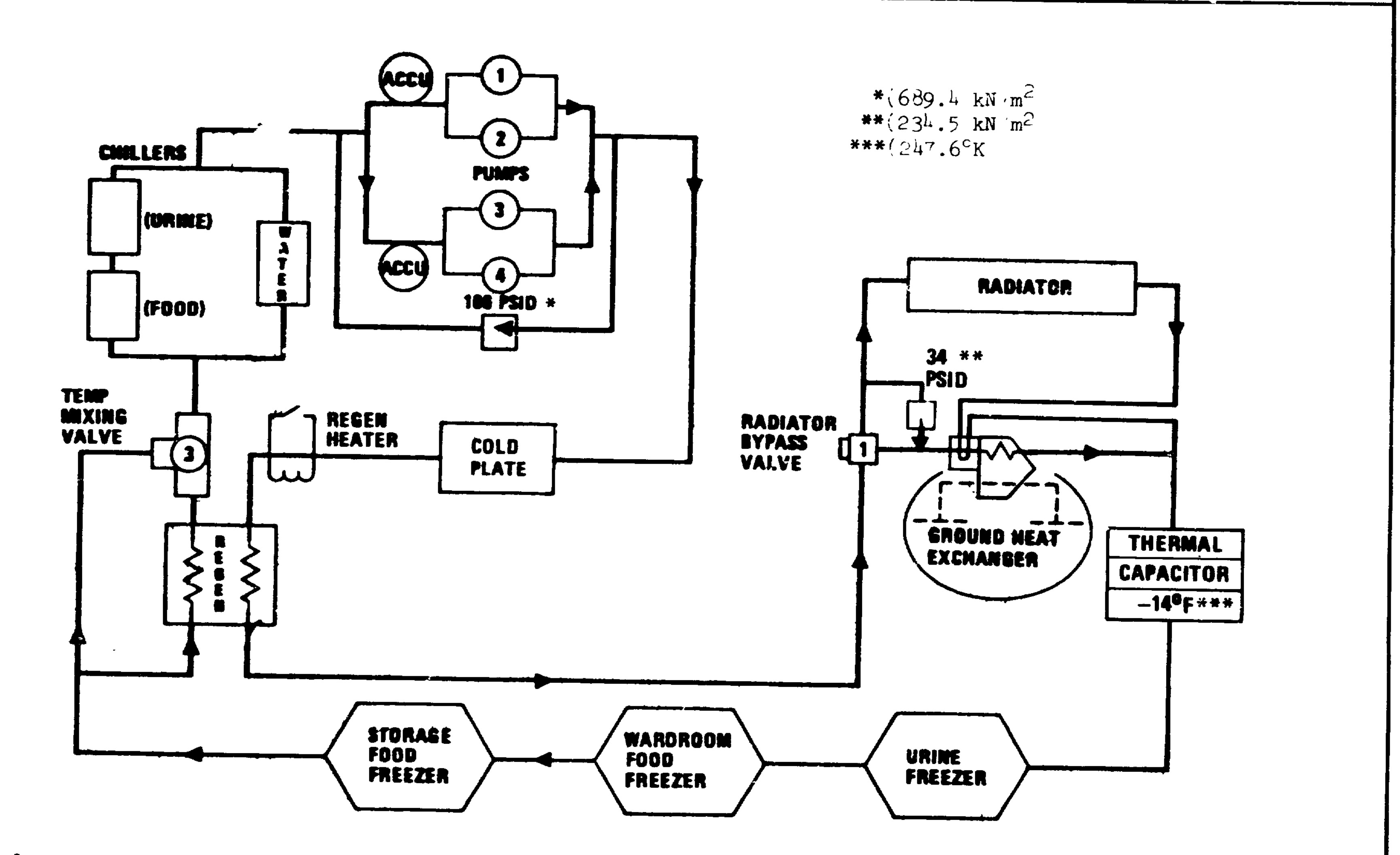


Figure 2.2.11.7-1

SKYLAB - ORBITAL WORKSHOP REFRIGERATION SYSTEM



SKYLAB - ORBITAL WORKSHOP
REFRIGERATION SUBSYSTEM INSTALLATION

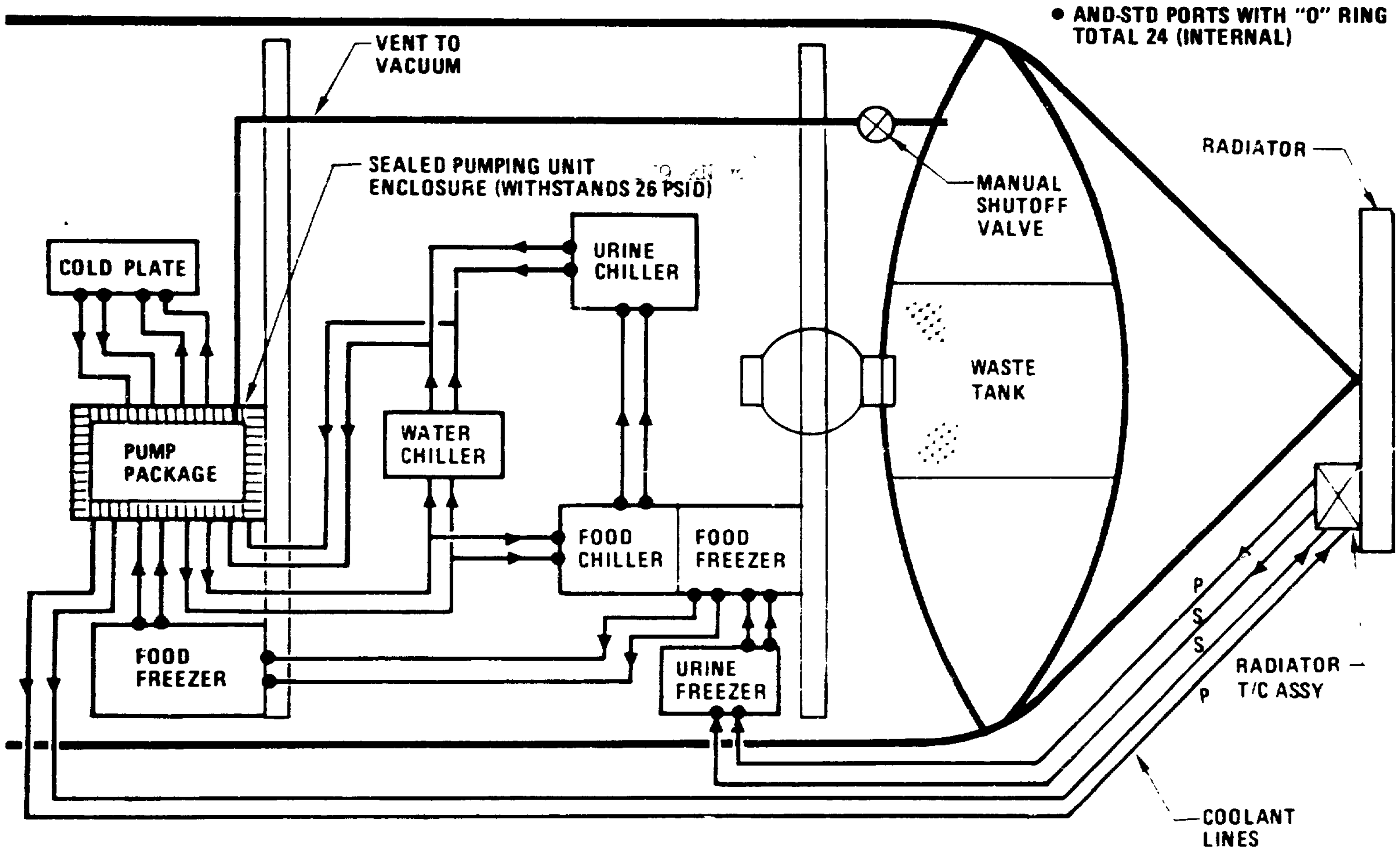
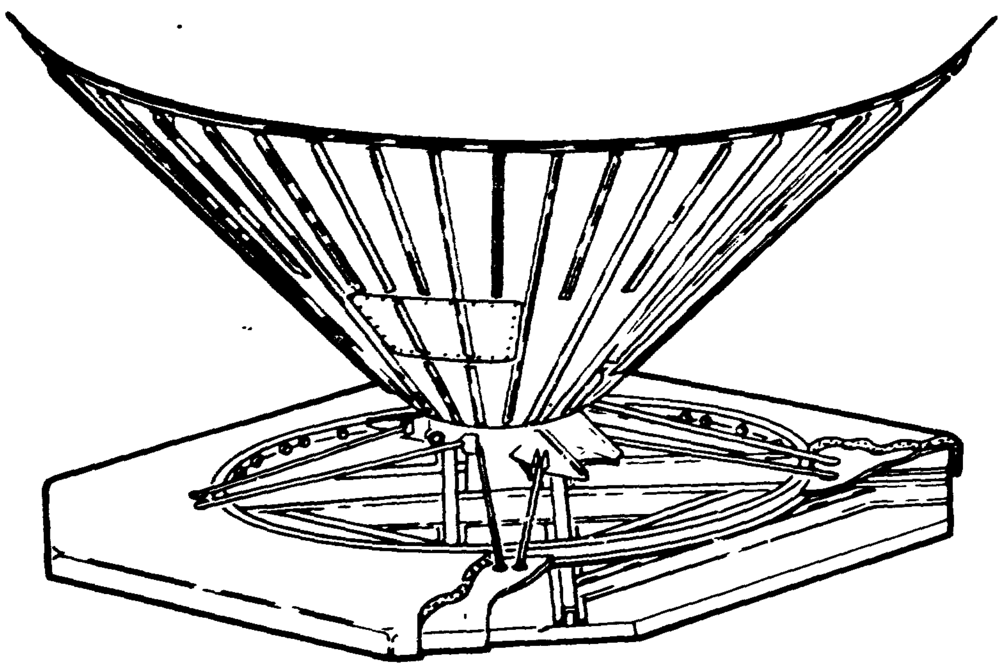


Figure 2.2.11.7-3

SKYLAB - ORBITAL WORKSHOP REFRIGERATION SUBSYSTEM RADIATOR



- EFFECTIVE AREA 84 FT^2
- MAX HEAT REJECTION CAPABILITY 1,680 BTU/HR
  (S-13 G COATING)
  α = 0.25 (ALLOWABLE UV DEGRADATION = 0.03)
  ε = 0.90 + 3 SIGMA RSS FLUXES
- ORBITAL TEMP RANGE $+40^0F$ -165^0F

PART NO. 1B81297

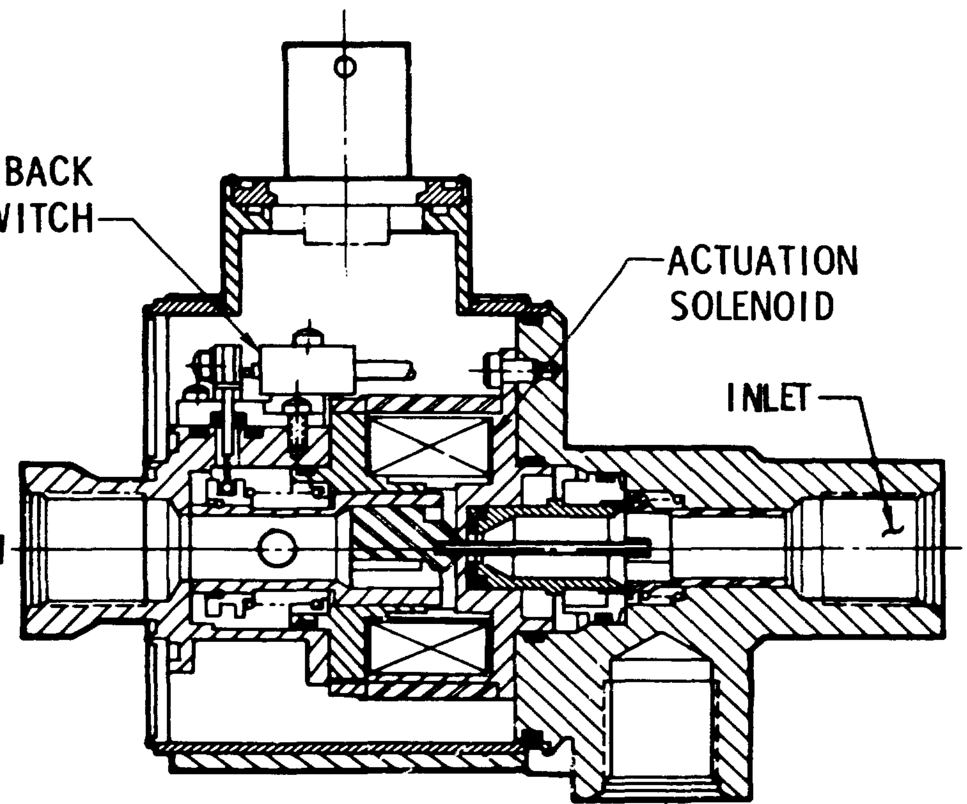
circuit driven by a temperature transducer on the radiator assembly actuates the radiator bypass valve to the radiator bypass position. The coolant flow is then directed past the radiator directly to the thermal capacitor units, where heat transfer from the coolant to the thermal capacitor occurs at essentially a constant temperature of -14°F (248°K) (phase-change temperature of UNDECANE).

When the radiator surface temperature drops to 0 ±2°F (256 ±1.1°K), the radiator temperature transducer causes the radiator bypass valve to open to the radiator position, allowing full flow of coolant through the radiator. The coolant from the radiator outlet passes through the thermal capacitor, which regenerates the phase-change was in preparation of the next warm cycle. During this period, a maximum temperature of -14°F (248°K) (phase-change temperature of UNDECANE) is maintained at the thermal capacitor.

As the radiator outlet temperature decreases, and the stored heat is absorbed from the thermal capacitor, the temperature of the coolant between the first and second thermal capacitor units eventually reach -34.5°F (236°K). At this temperature, the radiator bypass valve is actuated to cause the coolant to flow directly to the thermal capacitor units and bypass the radiator. This mode of operation continues until the temperature of the coolant between the first and second thermal capacitor units increases to -12.8°F (248°K) (first unit melted) and the radiator bypass valve is actuated to direct the coolant back through the radiator. Details of the radiator bypass valve are shown in Figure 2.2.11.7-5.

A 34-psid (234.5 kN/m^2) relief valve (Figure 2.2.11.7-6) is installed across the radiator. This maintains a maximum pressure differential

SKYLAB - ORBITAL WORKSHOP
REFRIGERATION SYSTEM RADIATOR BYPASS VALVE

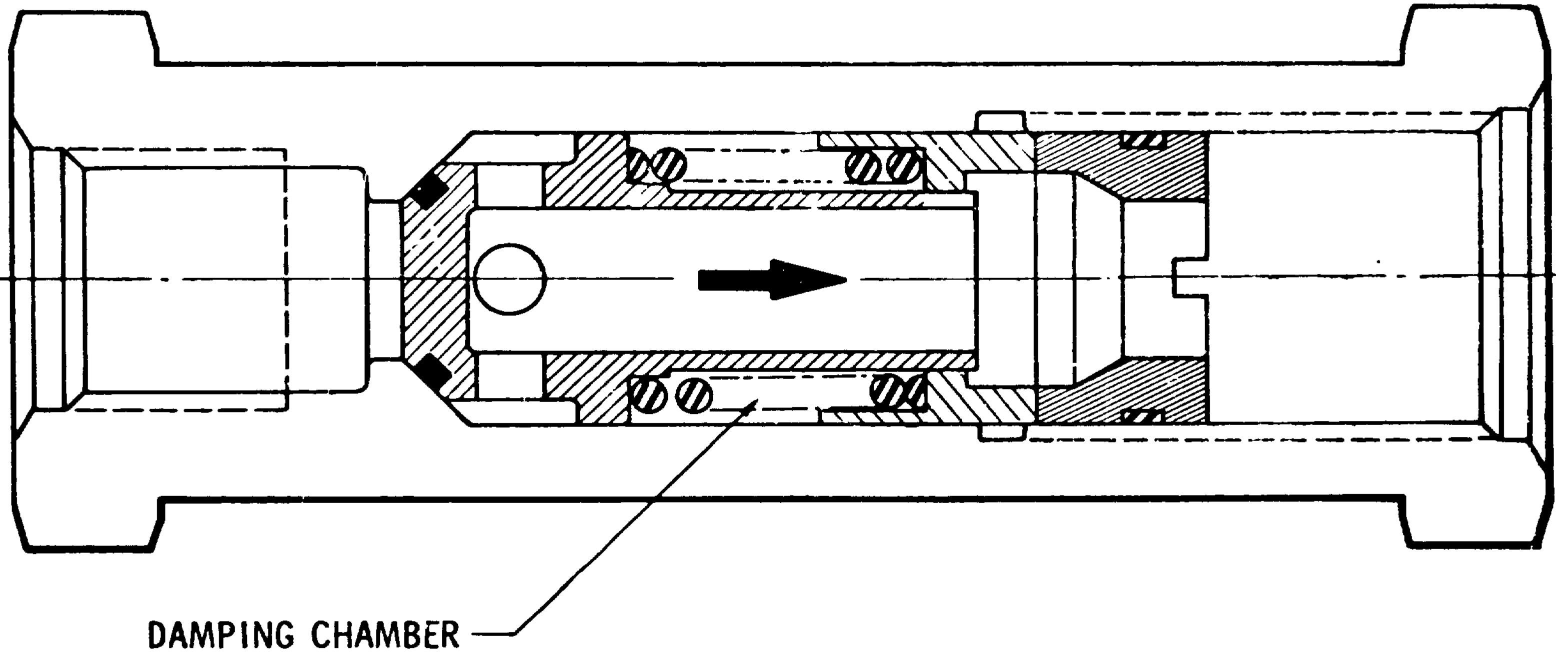


PART NO. 1B79878

CRITICALITY: LCC CATEGORY 2/3

SKYLAB ETC/LSS PANEL
REFRIGERATION SYSTEM RADIATOR
RELIEF VALVE 1B89613

CRACK 34 ±4 PSID (234.5 ±27.6 kN/m^2)
FULL FLOW 38 PSID (262 kN/m^2) MAX
RESEAT 26 PSID (179 kN/m^2) MIN



CRITICALITY: CRBC CATEGORY 2

Figure 2.2.11.7-6

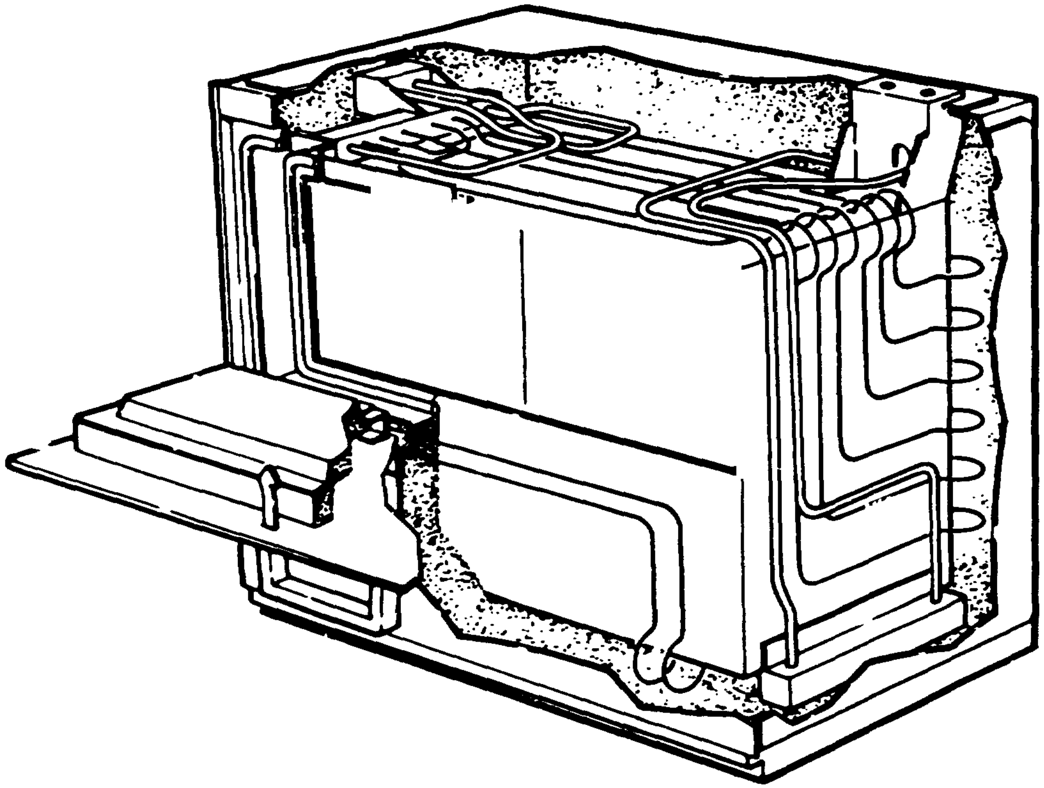
of 34 psid (234.5 kN/m^2) through the radiator in the event of coolant blockage or near-blockage, which could occur when extremely low temperature coolant exists in the radiator.

From the outlet of the last thermal capacitor unit, the coolant flows in series through the urine freezer (H810), the Wardroom food freezer (W756), the Wardroom food freezer (W755), food storage freezer (F533), food storage freezer (F552), and food storage freezer (F551). The urine and food freezers are shown pictorially in Figures 2.2.11.7-7 and 2.2.11.7-8.

The coolant is then controlled to 39 $\pm 3^\circ$F (277 $\pm 1.67^\circ$K) by means of the chiller thermal control valve (TCV), three regenerator heat exchangers, and a 75-watt heater (refer to Figures 2.2.11.7-9 thru 2.2.11.7-11). The 39 $\pm 3^\circ$F (277 $\pm 1.67^\circ$K) fluid temperature control at the outlet of the chiller TCV is achieved by proportional flow mixing of the regenerator outlet and the freezers outlet. The flow through the three regenerator heat exchangers is warmed by a counter-flowing coolant path from the regenerator heater. The coolant is routed in parallel paths, one through the water chiller (Figure 2.2.7.11-12) and one through the chilled food compartment (W754) and urine chiller (Figure 2.2.7.11-13). The paths unite, and a single path is routed to a pump assembly.

The pump assembly is essentially two two-pump packages in parallel. A two-pump package consists of two parallel pumps with discharge check valves and pump differential pressure transducers, a 53 in^3 (.868 mm^3) accumulator and a 100-psid (689.4 kN/m^2) bypass relief valve (refer to Figures 2.2.11.7-14 thru 2.2.11.7-16). The pump assembly outlet is routed through a 15-micron filter (shown in

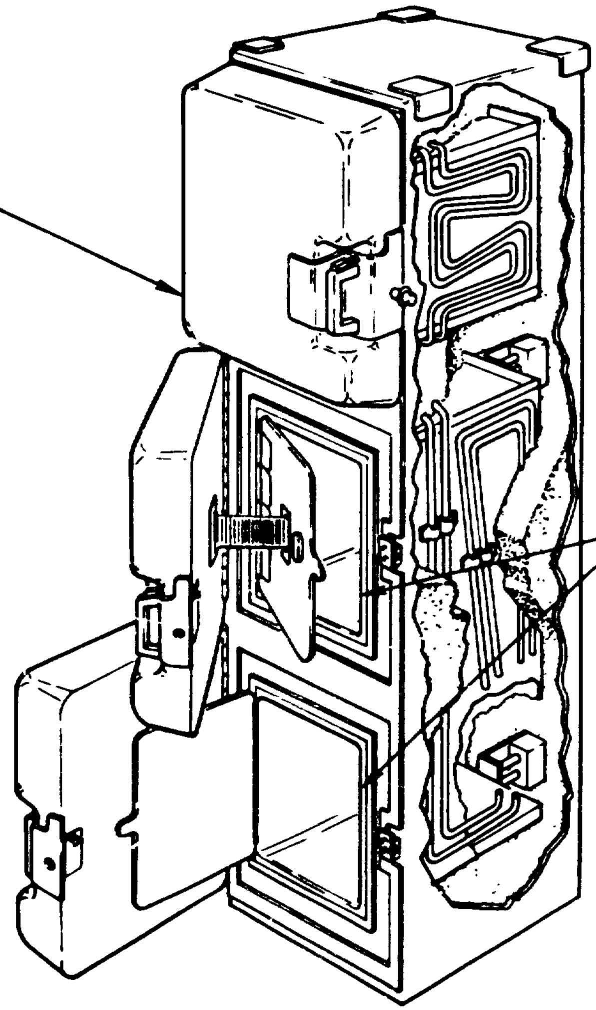
ORBITAL WORKSHOP REFRIGERATION SYSTEM URINE FREEZER



PART NO. 1B84675

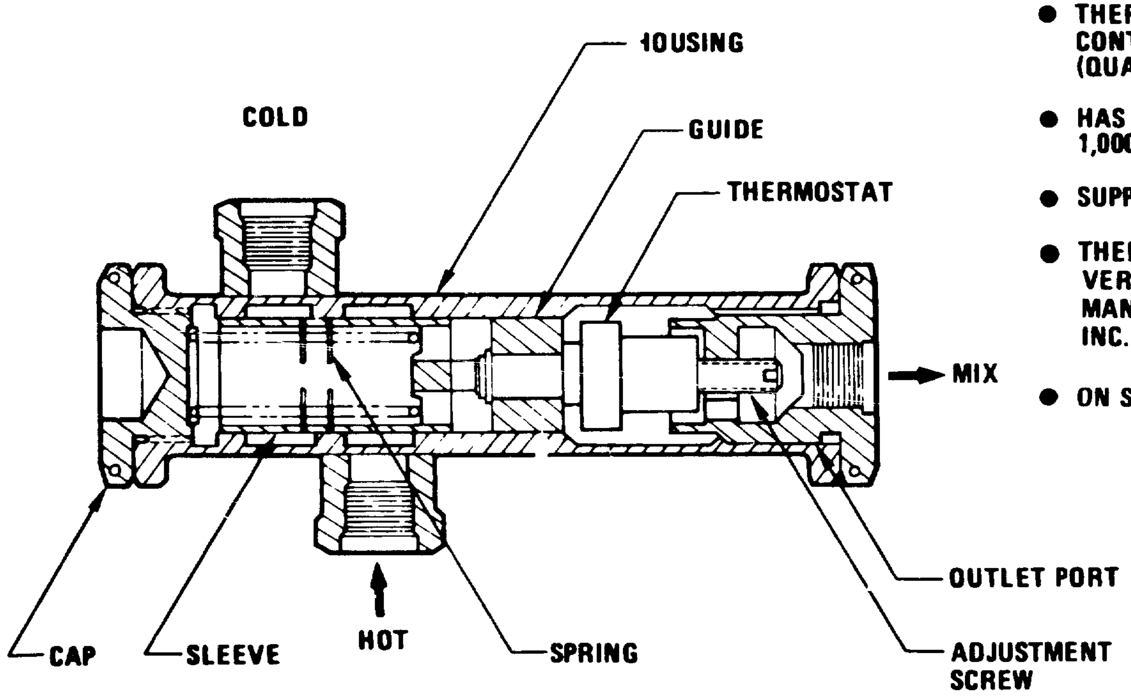
FIGURE 2.2.11.7-7

SKYLAB - ORBITAL WORKSHOP
REFRIGERATION SYSTEM
FOOD FREEZER



PART NO. 1B79911
PART NO. 1B79912

SKYLAB - ORBITAL WORKSHOP
REFRIGERATION SUBSYSTEM
CHILLER CONTROL VALVE



PART NO. 1B79859

- THERMALLY ACTIVATED SPOOL/SLEEVE CONTROL VALVE (QUALIFIED FOR GEMINI PROGRAM)
- HAS BEEN LIFE-CYCLE TESTED TO 1,000,000 CYCLES (AIRLOCK)
- SUPPLIER: AIRESEARCH
- THERMAL CONTROL ELEMENT (WAX) VERNATHERM ACTUATOR MANUFACTURED BY SCOVILLE INC.
- ON SET POINT, +39°F

CRITICALITY: LCC CATEGORY 2/3

Figure 2.2.11.7-9

SKYLAB ETC/LSS PANEL
REFRIGERATION SYSTEM REGENERATOR

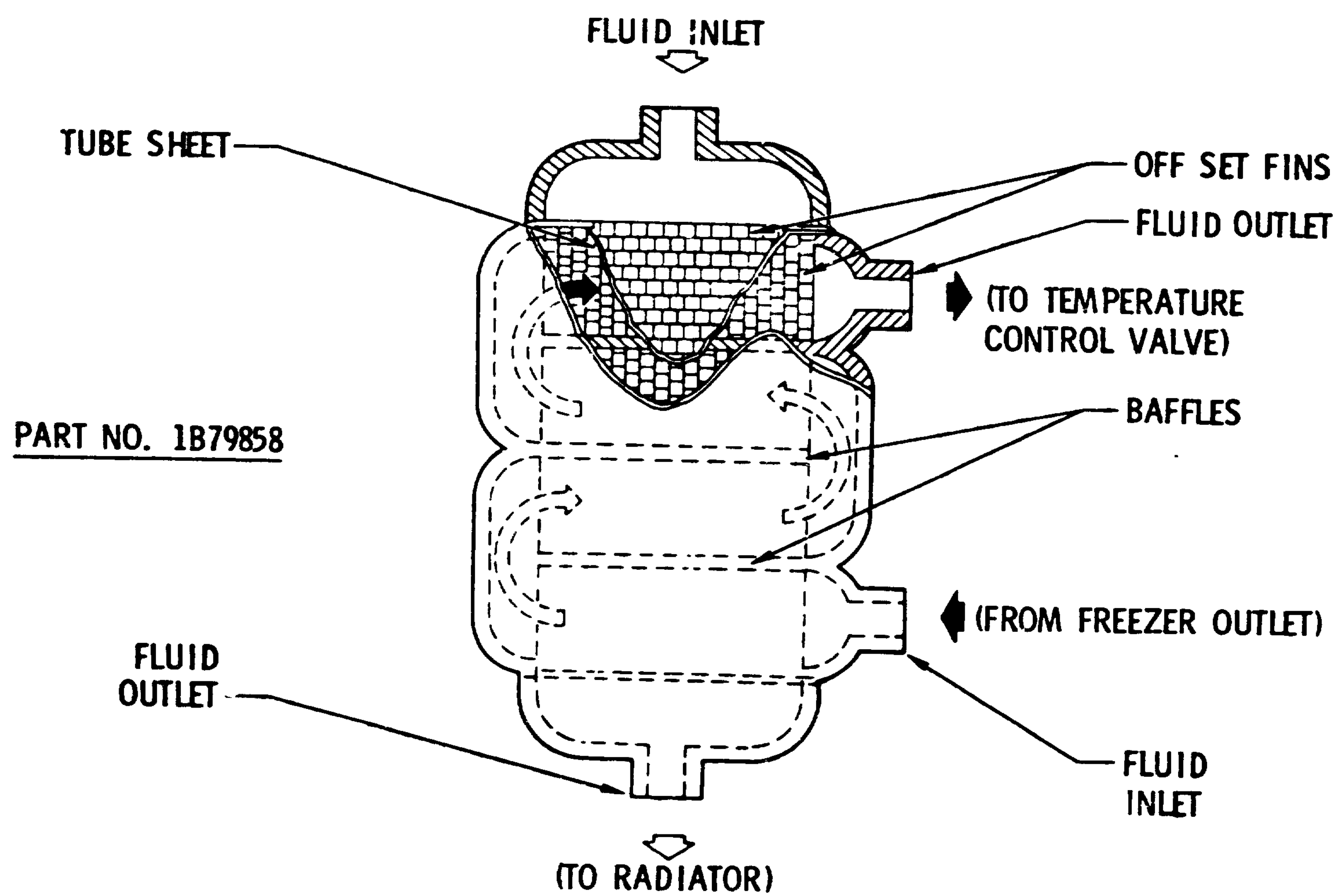
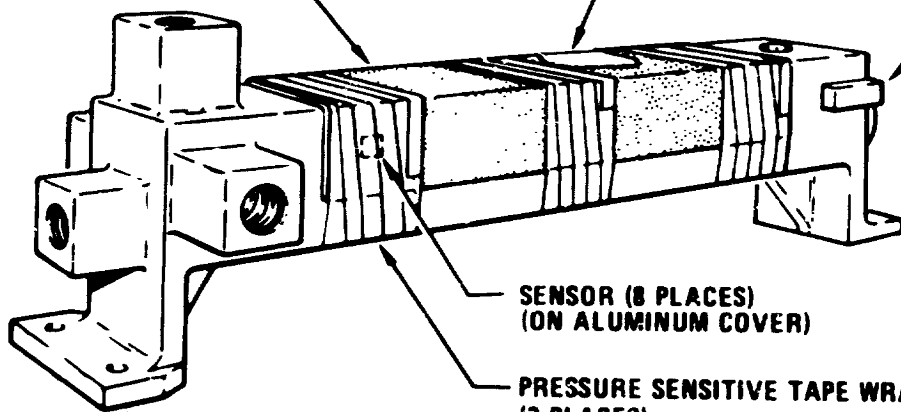


Figure 2.2.11.7.10

SKYLAB - ORBITAL WORKSHOP
REFRIGERATION SUBSYSTEM REGENERATOR HEATER
1B85387



NOTE:

OPERATING TEMPERATURE CONTROL RANGE
37.5°F -
158°F -
(BLANKET SURFACE TEMP)

- INCONEL/SILICON RUBBER HEATER ELEMENT (ELECTROFILM CORP)
- OPERATING OUTPUT 75 WATTS (255 BTU/HR
- OVERTEMPERATURE PROTECTION MAX TEMP ≤ 170°F
- MAX COOLANT RISE TIME – 3°F/MIN
- MDAC DESIGN AND FAB FOR OWS

CRITICALITY: LCC CATEGORY 2/3

Figure 2.2.11.7-11

WATER CHILLER

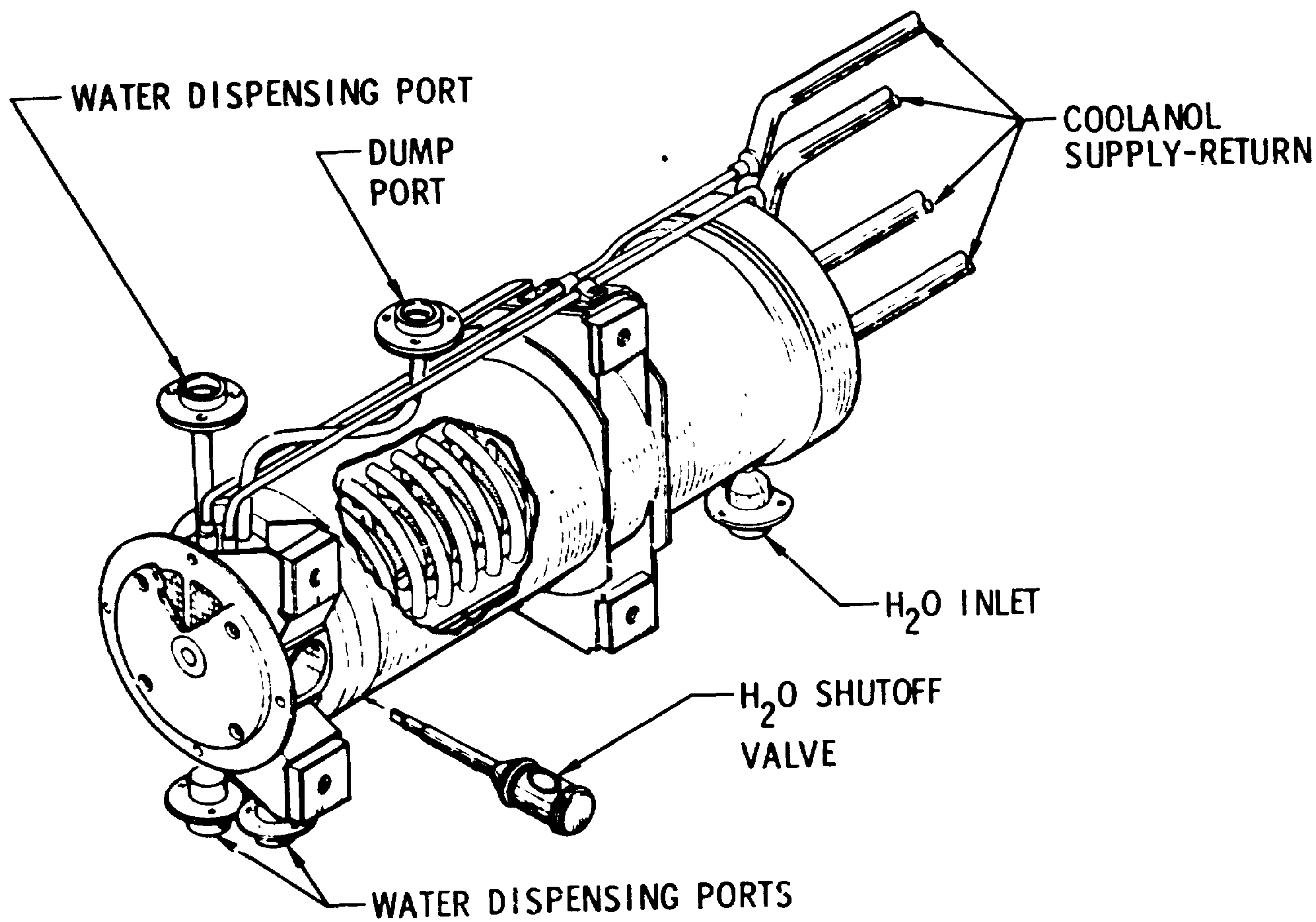


Figure 2.2.11.7-12

SKYLAB - ORBITAL WORKSHOP
CENTRIFUGAL SEPARATOR SYSTEM CHILLER
COMPARTMENT DETAILS

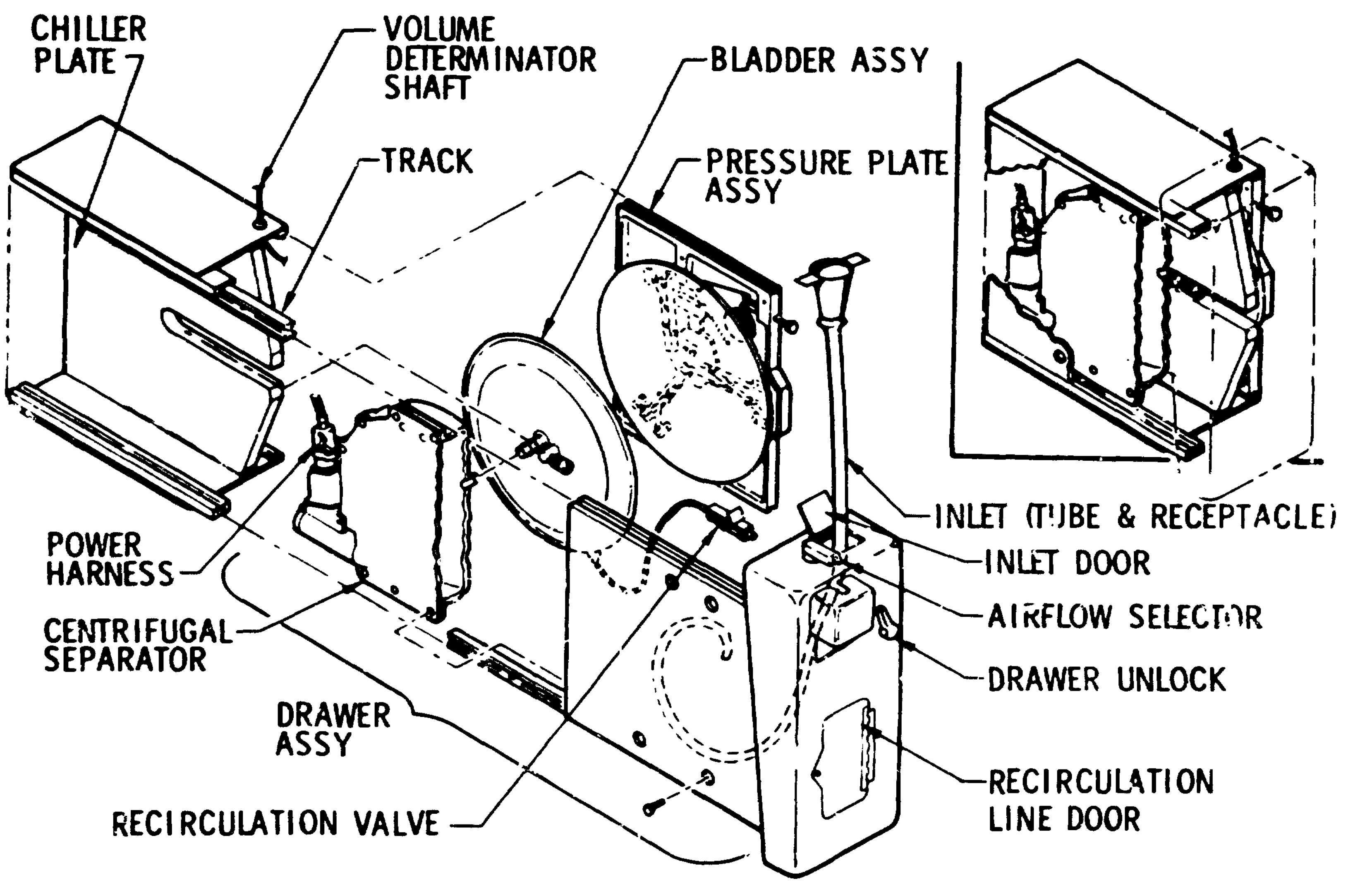
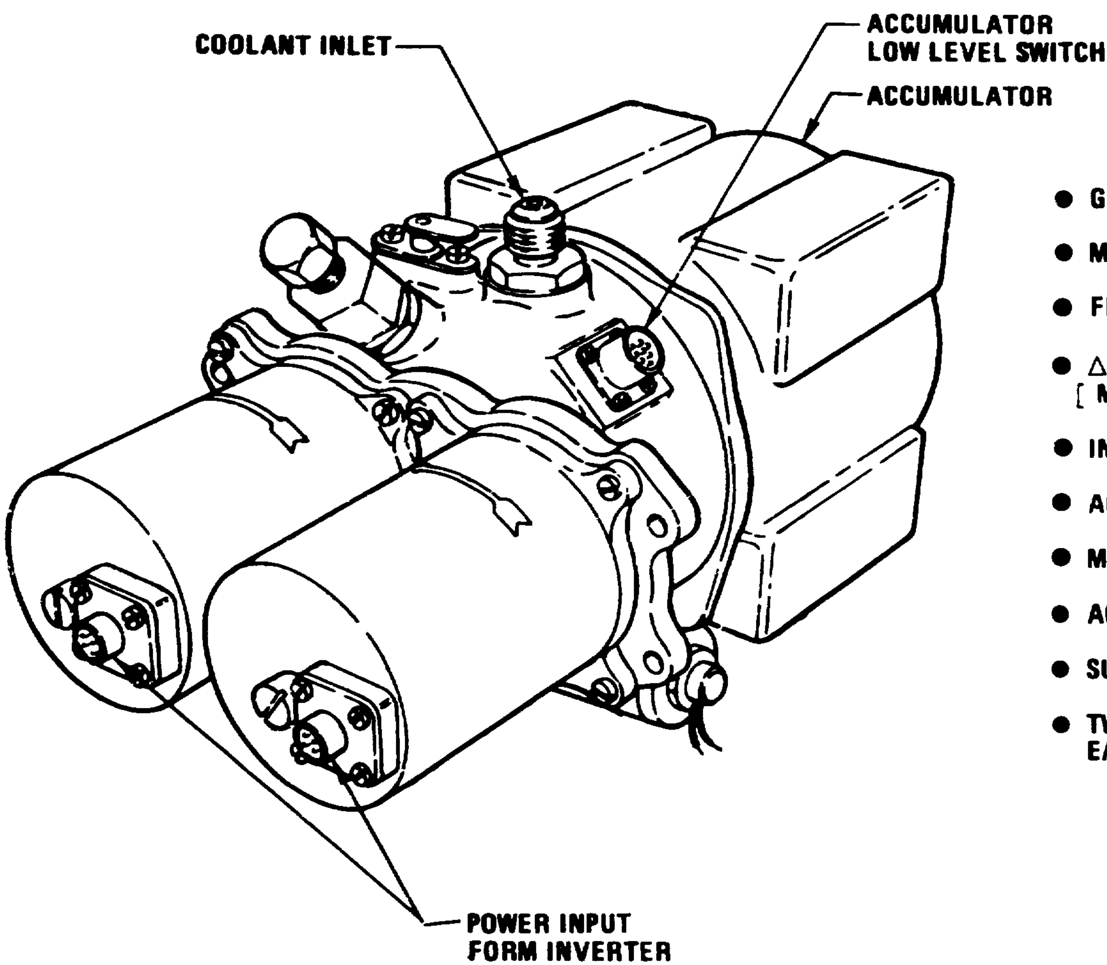


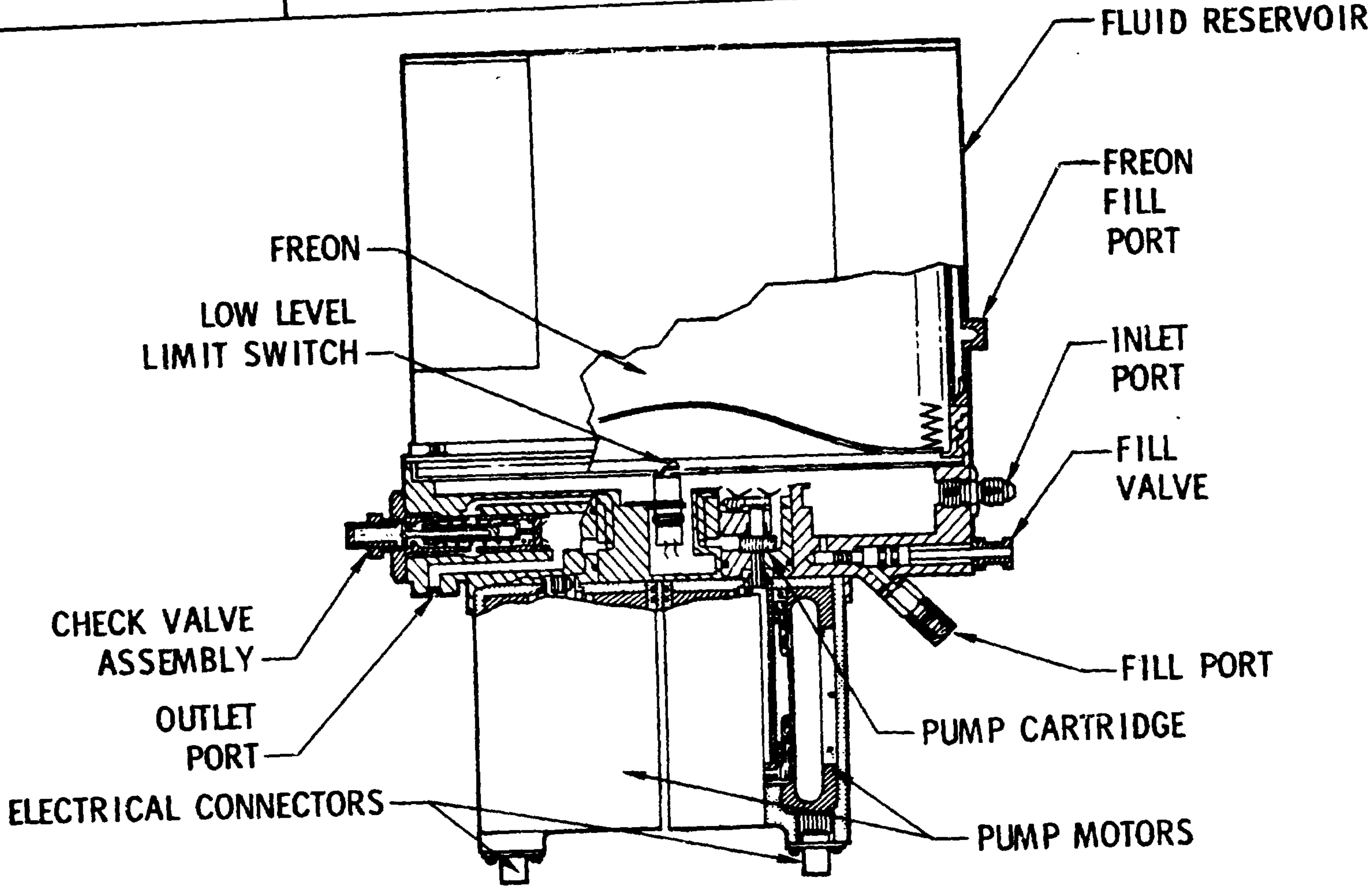
Figure 2.2.11.7-13

SKYLAB ETC/LSS PANEL REFRIGERATION SUBSYSTEM PUMP PACKAGE



- GEAR TYPE/POSITIVE DISPLACEMENT
- MIN OPERATING LIFE 2,250 HOURS
- FLOW RATE 125 ± 11 LBS/HR (56.7 ± .98 kg hr)
- ΔP 55 PSID (385 kN m²) NOMINAL
  [MAX ΔP 105 PSID (735 kN m²) RELIEF VALVE]
- INLET TEMP (OPERATING) 41 TO 50°F (275 to 283 K)
- ACCUMULATOR MINIMUM VOL 53-IN.³ (.868 m³)
- MAX POWER CONSUMPTION 75 VA
- ACCUMULATOR PRESSURANT – FREON 22
- SUPPLIER: AIRESEARCH
- TWO PUMPS OPERATED FOR 2,250 HOURS EACH AT MDAC-W

SKYLAB - ORBITAL WORKSHOP
REFRIGERATION SYSTEM PUMP



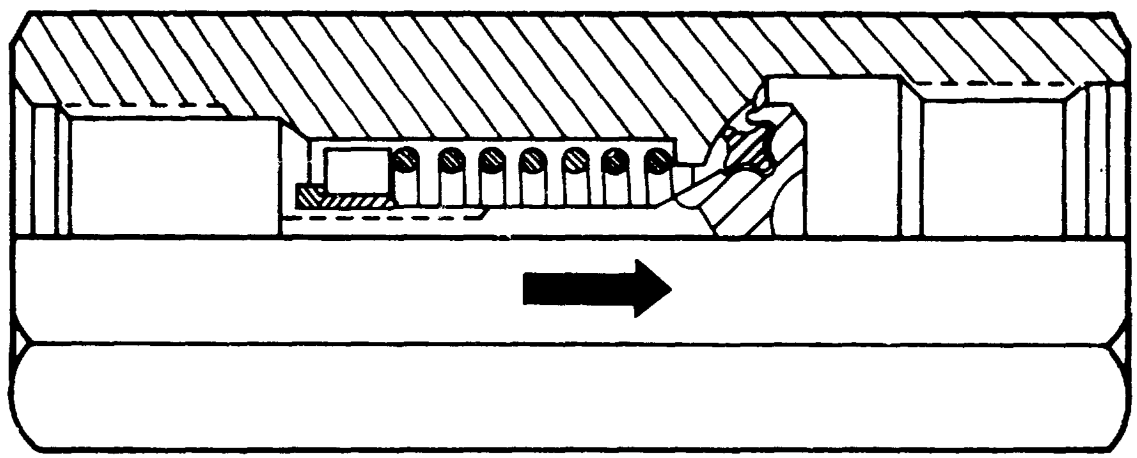
PART NO. 1B79778

CRITICALITY CATEGORY: LCC 2/3

Figure 2.2.11.7-15

SKYLAB - ORBITAL WORKSHOP
REFRIGERATION SYSTEM PUMP RELIEF VALVE

CRACK	95 PSID	(655 kN/m^2)	MIN
MAX FLOW	105 PSID	(725 kN/m^2)	MAX
RESEAT	94 PSID	(648 kN/m^2)	MIN



PART NO. 573T-4B6B-100 PUMP

CRITICALITY: LCC CATEGORY 2/3

Figure 2.2.11.7-17), through the inverter and heater control cold-plate, and to the regenerator heater.

The regenerator heater provides heat to allow coolant temperature regeneration to 36°F (275°K) under the coldest design conditions. From the regenerator heater, the flow passes through the three regenerator heat exchangers, and to either the radiator or thermal capacitor for heat rejection. A transducer, located between the chiller TCV inlet and the regenerator heat exchanger cold side outlet, causes the regenerator heater to energize and de-energize as the temperature reaches 37 ±1°F (275.5 ±.55°K).

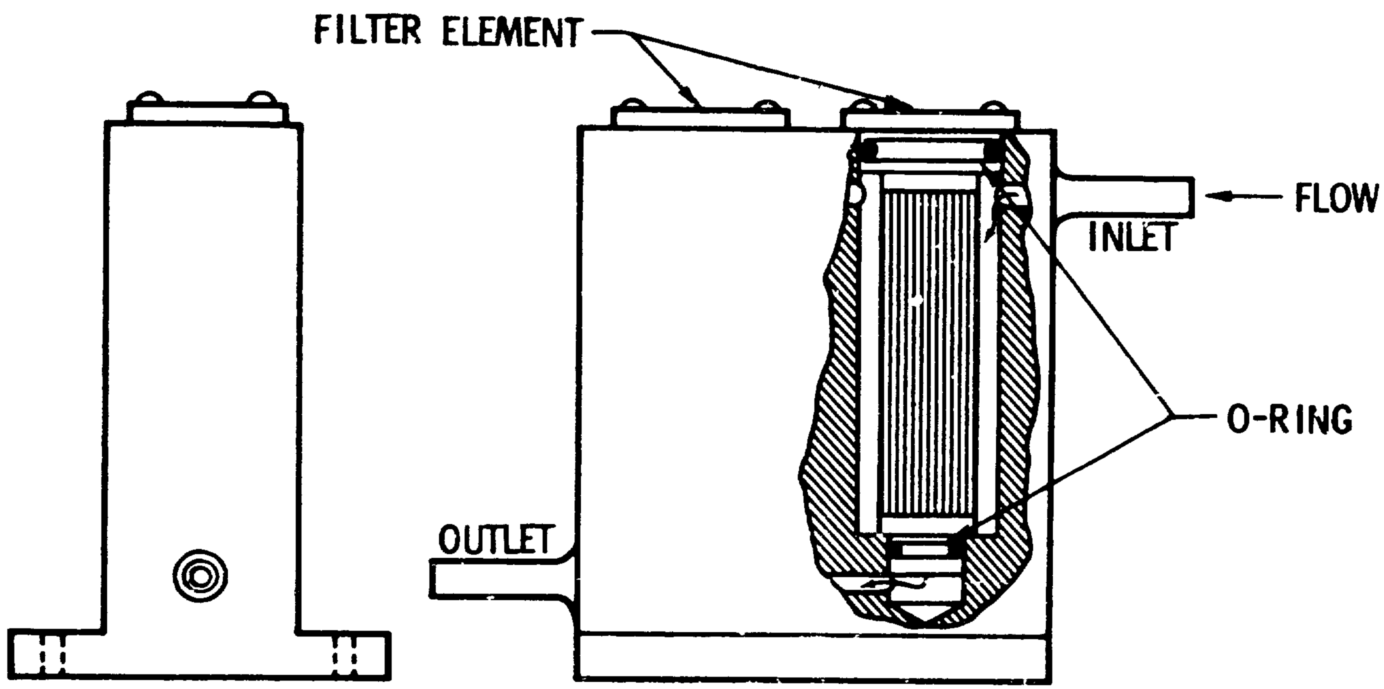
The RS contains a control logic unit that continuously monitors and automatically provides system switching to rectify the following malfunctions:

1/ A low differential pressure across the pump package. If the pump differential pressure should drop below 25 psid (172.5 kN/m²), the logic unit automatically switches off the active pump and activates the next pump. The sequence is primary pump Nos. 1, 2, 3, and 4 and then secondary pump Nos. 1, 2, 3, and 4. When secondary pump No. 4 is operating, and a low ΔP signal is received, the logic unit recycles back through pumps 1, 2, 3, and 4 of the primary loop. A 30-second delay in ΔP logic is provided to allow for pressure buildup after a pump has been switched on.

2/ A low pump package accumulator liquid level. When any one of the primary pumps is operating and both primary loop accumulators liquid levels drop below 5 in³ (8.18 x 10⁻⁵ m³), the logic unit automatically switches from the primary loop to

SKYLAB - ORBITAL WORKSHOP

REFRIGERATION SUBSYSTEM FILTER (15M)



PART NO. 1B85112

the secondary loop (pump 1). When any one of the secondary pumps is operating and both low secondary accumulators are sensed, the logic unit automatically cycles back to the primary loop (pump 1). After loop switching occurs there will be up to 2 minutes delay before the accumulator low liquid level monitor is enabled.

3/ A high freezer inlet temperature. The logic unit switches to the secondary loop (pump 1) when a primary pump is operating and a temperature equal to or greater than 1 $\pm 1^{\circ}$F (256 $\pm .55^{\circ}$K) is sensed at W756 food freezer inlet. There is no capability for automatic switching from secondary loop to primary loop as a consequence of a freezer high inlet temperature.

4/ A low chiller inlet temperature. The logic unit switches to the secondary loop (pump 1) when a primary pump is operating and a temperature equal to or less than 33.5 $\pm 1^{\circ}$F (274 $\pm .55^{\circ}$K) is sensed at the chiller TCV outlet. During secondary loop operation, no capability exists for automatic switching to primary loop due to chiller low temperature.

5/ A low logic unit voltage. When either loops logic voltage is sensed to be less than 5 vdc, RS loops will be switched to preclude logic errors due to amplifier malfunctions.

The RS logic unit also provides signals to the following Panel 616 malfunction indicator lights for both the primary and secondary loops:

- Pump Low ΔP
- Accumulator Low

- Inlet Temp Freezer High
- Inlet Temp Chiller Low

These indicator lights are latched on by the logic unit until the STATUS RESET switch is actuated.

Temperature control of the RS is initiated a short time before the mission food supply is placed in the OWS while the OWS is positioned in the VAB. A coolant pump is activated, and the radiator bypass valve is actuated to the bypass position. The heat from the RS is transferred through the ground cooling heat exchanger to a ground cooling cart via umbilicals. Just prior to liftoff the coolant (Glycol) is purged from the ground loop, and power to the RS primary and secondary logic systems is disabled, causing the operating pump to be deactivated. At liftoff the disconnects and umbilicals are disconnected.

Following S-II stage separation, the RS radiator shield, which protected the radiator surface from the S-II "plume", is jettisoned and the RS primary and secondary logic systems are enabled, causing pump No. 1 in the primary loop to be turned on. These functions are accomplished by automatic IU command. System heat loads are absorbed by a thermal capacitor until the RS radiator temperature drops to $0 \pm 2^{\circ}F$ ($255.5 \pm 1.1^{\circ}K$), activating the bypass valve to flow refrigerant through the radiator.

Normal operation and control of the RS during habitation is accomplished automatically by the RS controllers logic, which has the capability to select loops/pumps in the events of anomalies.

Visual displays along with refrigeration system pumps switches on panel 616 provide crew monitoring and backup control capabilities.

The RS remains operational during unmanned phases. Pumps were to be operated in a specific sequence during the entire mission in order to not exceed 2250 operating hours on any one pump. Pump No. 1 in the primary loop is manually turned on first prior to loading frozen food into the freezers. Pump No. 1 is manually turned off and pump No. 2 automatically turned on at the end of SL-2. Pump No. 2 is manually turned off and pump No. 3 automatically turned on at beginning of SL-3. Pump No. 3 is manually turned off and pump No. 4 automatically turned on at end of SL-3 and remains in operating until end of SL-4.

C. Test Program - Development, Qualification, and various special tests were performed in support of the design of the Refrigeration System. Summaries of these tests were presented in the following paragraphs and in Table 2.2.11.7-4. Significant problems occurring during the testing and their solutions are outlined in Table 2.2.11.7-5.

1/ Development Tests

These tests were conducted to optimize hardware configuration and identify potential areas of marginal design or performance. A limited amount of qualification testing was accomplished during the Development Test Program in order to meet the required program test schedule, and solve the various problems which occurred during qualification testing.

a. Radiator and Plume Shield Assembly Test - HS-31:

o Summary - The OWS Refrigeration System Radiator/Plume Shield Assembly (HS-31), and the Radiator Thermal Control Assembly (HS-19-4) were subjected to partial qualification and development tests concurrently in order to meet test schedule. The purpose of these tests was to: (1) determine the Radiator Flow and differential pressure characteristics, (2) determine the Radiator internal cleanliness level, following acoustic and vibration tests, (3) verify the Plume Shield Release Actuator structural and functional integrity, and (4) determine the effect of the vibration tests on the Radiator surface transducers.

Table 2.2.11.7-4

REFRIGERATION SYSTEM DEVELOPMENT AND QUALIFICATION
TEST LINE ITEMS

LINE ITEM	DESCRIPTION	TCD	TEST REPORT
DEVELOPMENT TESTS:			
HS-31	**Radiator and Plume** Shield Assembly (1B79875-1, 1B80667-1 **and** 1B84978-1)	1T18307	TM-DSV7-F&M-R-7060 TM-DSV7-F&M-R-6940-1 TM-DSV7-F&M-R-6940-4
HS-64	**Urine Freezer/Tray** Frost Test (1T41666)	1T41723	TM-DSV7-SSL-R-6888
HS-66	**Valve** Pressure Relief (1B89613-1)		Sterer Report DTR-29450, Rev. A
HS-77-1	**Radiator and** Plume Shield/Radiator Thermal Control **Assembly** (1B79875-1, 1B80667-1 and 1B84978-1)	1T43295	TM-DSV7-F&M-R-7068, Rev. A MDC G4234A
HS-77-2	**Radiator and** Plume Shield/Radiator Thermal Control Assembly (1B79874-1)	1T43295	TM-DSV7-F&M-R-7068 MDC G4234
HS-78	Potable Water Chiller (1B79914-505)		AiResearch Report 72-8439, Rev. 1 MDC G4087
QUALIFICATION TESTS:			
HS-19-1	Refrigeration System (1B79669-1)	1T17863	TM-DS77-SSL-R-6940 MDC G4180, Vol. I
HS-19-1A	Refrigeration System (61A830189-37)	1T17863	TM-DSV7-SSL-R-6940-7 MDC G4180, Vol. II
HS-19-1B	**Refrigeration** Subsystem Specimen 1B (1B79912	[illegible]	TM-DS77-SSL-R-6940-3
HS-19-1C	**Refrigeration** Subsystem Specimen 1C (1B79875-1	1T17863	TM-DSV7-SSL-R-6940-1

Table 2.2.11.7-4 (Continued)

LINE ITEM	DESCRIPTION	TCD	TEST REPORT
HS-19-1D	Refrigeration System (1B79660-1)	1T17863	TM-DSV7-SSL-R-6940-8 MDC G4180, Vol. II
HS-19-2&2A	Refrigeration System (1B82696-1, 1B86191-1, 1B79777-1, 1B79856-1 and 1B82698-1)	1T17863	TM-DSV7-F&M-R-6940-2 MDC G4180, Vol. V
HS-19-4	Refrigeration Subsystem Thermal Control Assembly Specimen 4 (1B79874-1)	1T17863	TM-DSV7-F&M-R-7060 TM-DSV7-F&M-R-6940-4
HS-19-5	Refrigeration System (1B79660-1)	1T17863	TM-DSV7-SSL-R-6940-5 MDC G4180, Vol. III & V
HS-19-6	Refrigeration Subsystem Coolant Pump Assembly (1B79778-1)	1T17863	TM-DSV7-F&M-R-6940-6 MDC G4180, Vol. IV
HS-35	Refrigeration Subsystem Control Logic Unit Qualification Test (1B82699-1)	1T41091	TM-DSV7-EE-R-6967
HS-36	Radiator Bypass Valve Controller (1B82697-501)	1T18261	TM-DSV7-EE-R-7027 MDC G4004
HS-41	Urine Freezer (1B84675-1)	1T19778	TM-DSV7-SSL-R-7038
HS-42	Urine Sample Return Storage Container (1B85443-1)	1T19777	TM-DSV7-SSL-R-7061, Rev. A TM-DSV7-ENV-R-7061, Suppl. 1
HS-76	Bypass Controller Monitor Module (1B80385-1)	1T43359	TM-DSV7-EE-R-7073, Rev. A
HS-85	Urine Freezer (Urine & Blood Samples) (XN1B84675-1)		TM-DSV7-SSL-R-7110 MDC G4150
HS-86	Urine and Blood Sample Return Container (1B85443-1,	1T43934	TM-DSV7-SSL-R-7111 MDC G4152

Table 2.2.11.7-4 (Continued)

LINE ITEM	DESCRIPTION	TCD	TEST REPORT
HS-88	Coolant Pump Inverter (1B82698-505)		TM-DSV7-EE-R-7145 MDC G4193
SPECIAL TESTS:			
ST-19	RSS Component Evaluation (61A830189-37, 1B89613-1, 1B79879-1, 1B79878-1, 61A830374-1, and 61A830371-3)	1T43343	MDC G4135

Table 2.2.11.7-5

REFRIGERATION SUBSYSTEM

TEST PROBLEM SUMMARY

ITEM	PROBLEM	SOLUTION
1	Thermal Capacitor Ruptured during Qualification Test	Capacitor redesigned to allow local thermal expansion of the undecane by unithermally distributing the ullage throughout the capacitor.
2	Radiator T/C Control Valve performed out of tolerance with cyclic temperature excursions	Valve was deleted from system and a new control method incorporated into system.
3	Radiator By-Pass Valve talk back failed to reflect actual valve position	Redesigned for increased reliability.
4	Chiller Control Valve operated out of specification	Replace Actuators - Initiated improved Storage Techniques

NOTE: Thermal tests of the radiator assembly were conducted in separate tests defined in Line Item HS-19-1C, and thermal, vibration and functional tests of the radiator thermal control assembly were conducted per HS-77.

All tests were accomplished with the radiator assembly and the thermal control assembly interconnected, and the plume shield and actuator in the in-flight configuration. Pre- and post vibration leakage and functional tests were accomplished. Pressure differential was measured across the radiator at flows from 25 to 175 lbs (11.35 to 79.5 kg) of Coolanol-15 per hour. Fluid sampling was accomplished throughout the tests. The plume shield actuator was subjected to teardown inspection, proof and load tests, spring rate and functional response time tests and functional endurance and burst pressure tests. Primary and secondary pistons were actuated individually, as well as simultaneously, at pressures from 250 to 510 psig (1723 to 3520 kN/m^2). One actuator was functionally cycled a total of 500 times, and another 1000 times at high, low, and ambient temperatures.

- Test Conclusions - The results indicated that (1) the radiator flow/pressure drop characteristics were satisfactory, (2) the internal radiator cleanliness level was below the maximum allowable; (3) the radiator/plume shield assembly suffered no visible degradation due to exposure to simulated launch environments (acoustic and vibration), (4) the plume shield release actuator performed satisfactorily following exposure to simulated launch environments, and (5) there was no change in the calibration of temperature transducers due to exposure to simulated launch environments.

Based upon the Engineering evaluation of the test data presented above, it was concluded that the HS-31 development tests satisfactorily verified the design requirements of the 1B79875-1 Radiator Assembly, the 1B80667-1 Plume Shield Assembly, and the 1B84978-1 Plume Shield Release Actuator Assembly. However, because of subsequent rework of the Radiator Assembly, all three of these items were subjected to additional vibration tests per Line Item HS-77, TCD No. 1T43295, Section I.

b. Urine Freezer/Tray Frost Test - HS-64:

o Summary - This development test was performed at MDAC-W at Huntington Beach, Ca. during June, 1971. The test specimen was comprised of a 1T41666 Urine Freezer and four (4) 1T41720 Urine Sample Trays. The purpose of this test was to determine the amount of frost buildup on a simulated urine freezer and on simulated urine sample trays as a result of OWS 56 day mission simulated flight crew procedures. This test was conducted in accordance with Test Control Drawing 1T41723.

Prior to test start, the weight of each urine sample tray was determined. During this test, the urine freezer containing the four (4) urine sample tray was stabilized at a temperature of -5° to -15°F (252 to 247°K). Air circulated across the freezer door just prior to and during each tray handling operation. The air was controlled within a dry bulb temperature range of 60 to 80°F (289 to 300°K) with a moisture content of 100 ±10 grains of water per pound of dry air (294 x 10-5 ±29.4 x 10-5 kg of water per kg of dry air). Airflow was adjusted to maintain a static pressure of 0.14 in. (34.8 N/m^2) of water at the diffuser inlet. Each urine sample tray was removed halfway from the freezer and exposed to the humid air for 60 ±10 seconds, reinserted in the freezer, and the freezer door closed. Freezer internal temperatures were then allowed to restabilize at -5 to -15°F (252 to 247°K). This procedure was repeated until a total of seven (7) handling procedures had been performed on this tray. The tray was then rotated 180 degrees and seven (7) handling procedures performed on the opposite side of the tray. This procedural technique was duplicated on each of the three (3) remaining trays to simulate the 56-day mission. At the conclusion of this test, each tray was weighed to determine the weight attributable to frost buildup.

A supplemental refreeze test was then performed. This test consisted of removal of all four (4) urine trays from the freezer and allowing the tray frost accumulations to melt at ambient conditions. The wet trays were then reinserted in the freezer and the tray temperatures allowed to reach -10°F (250°K). The trays were then removed from the freezer to evaluate possible removal difficulties.

Additionally, a urine "spill" was simulated by depositing 120 ml of water on the freezer interior. All four (4) trays were immediately inserted in the freezer and the freezer temperature lowered to -15°F (247°K). Ease of tray removal was then evaluated.

- Test Conclusions - The average tray frost thickness, using tray weight increase and tray surface areas, was 0.059 in. (.144 cm). No difficulty was encountered in tray removal or insertion during any of the above tests. At the conclusion of the simulated "spill" test, slight sticking of the trays to the freezer was noted, however, the trays could be removed with one hand without difficulty.

c. Valve Pressure Relief - HS-66:

- Summary - The development tests conducted on the refrigeration system radiator by-pass pressure relief valve were conducted by the supplier of the valve, Sterer Engineering and Manufacturing Company, in the supplier's test facility. The development test program consisted of subjecting one specimen to acceptance, low temperature, high temperature, life cycling and burst tests.

- Test Conclusions - All tests (acceptance, low temperature, high temperature, life cycling, burst) were completed satisfactorily. No failures or other discrepancies occurred during the tests.

d. Radiator and Plume Shield/Radiator Thermal Control Assembly - HS-77, Specimen 1:

- Summary - OWS radiator, plume shield and plume shield actuator were exposed (as an assembly) to simulated launch and boost vibration and to acoustic environment. Pre and post tests included proof, leakage and functional tests. The radiator (reworked to incorporate the latest production changes) and the plume shield actuator were diverted from HS-31 for these tests. The test specimen was filled with helium and pressurized to 50 psig (345 kN/m^2) during all dynamic testing. The plume shield was jettisoned following vibration and following acoustic testing.

- Test Conclusion - The result of HS-77 Specimen 1 testing indicated the launch configuration of the OWS Refrigeration System radiator, radiator plume shield and plume shield actuator satisfied the launch and boost vibration and acoustic requirements, and the shield jettison requirements.

e. Radiator and Plume Shield/Radiator Thermal Control Assembly - HS-77, Specimen 2:

- A Refrigeration System radiator thermal control assembly was subjected to proof and leak tests, vibration, functional and life cycle tests including a life cycle test of the three-segment thermal capacitor in a thermal vacuum environment. Life cycle tests were limited to the radiator bypass valve, radiator relief valve and the thermal capacitor, and were conducted following vibration test.

- o Test Conclusions - Based on the Engineering evaluation of the date obtained during HS-77, Specimen 2 testing, it was concluded that the development tests verified the design requirements of the radiator thermal control assembly.

f. Potable Water Chiller HF-78:

- o Summary - This development test was performed by AiResearch Manufacturing Company at Los Angeles, California, between December, 1971 and April, 1972. The purpose of this test was to demonstrate the capability of the 1B79914-505 Potable Water Chiller to satisfy the MDAC-W specified design requirements. One test specimen was utilized throughout testing which included the following tests: (1) proof and leakage, (2) water and coolant sides pressure drops, (3) dispenser shutoff handle operating torque, (4) ambient heat leak, water childown times, and dispensed water temperature, (5) steam sterilization, (6) dispenser shutoff valve cycle life, (7) biocide depletion, (8) vibration, and (9) burst pressure.

- o Test Conclusions - Based upon the engineering evaluation of the Development Test results, it was concluded that the 1B79914-505 Potable Water Chiller satisfied the specific design and performance requirements.

After subjecting the test specimen to a total of twelve (12) hours of steam sterilization, it was found that the dispenser shutoff valve handle torque was excessive. The unit's external shell and the insulating foam were removed to determine the cause of the shutoff valve problem. It was determined that the high temperature [275°F (408°K)] experienced by the unit has caused the foam to deform sufficiently to force the valve handle against the chiller stainless steel outer shell, causing the valve plug to become misaligned with the valve housing. Subsequent disassembly of the valve revealed scratches in the valve housing apparently caused by the forced misalignment of the valve plug within the valve housing. The valve housing was honed smooth, the valve reassembled into the unit, the chiller shell installed, and the thermal insulating foam replaced. The foam around the valve stem was relieved by using a circular cutter and removing the loose foam chips. A closer fitting valve stem guide was installed on the chiller shell to provide for proper centering of the valve stem. The test specimen was then subjected to four (4) steam cycles of three (3) hours each. The shutoff valve operating torque was checked after each cycle and found to satisfy the specified operating torque requirements. After completion of this portion of the test, all production and test units were modified to incorporate these latest design features.

After completion of vibration testing of the unit in two (2) of the three (3) axes, a small localized separation was noted between the chiller shell and the end plate at the dispenser end of the unit. The chiller shell is not a structural member, but merely provides a metallic enclosure for the internal thermal insulation, as well as a base to which a teflon coating is applied to achieve the required outer surface thermal emissivity. The apparent damage was not repaired and vibration testing was completed without further separation observed. No modifications were made to this unit relative to this phenomenon and no repetition of this was found on the HS-7 Qualification Test unit which also underwent vibration testing. Completion of development testing verified that the occurrence of this phenomenon in no way degrades the structural integrity, interface dimensions, nor the performance of the unit.

2/ Qualification Tests

These tests were conducted on production hardware to demonstrate that the design and production methods resulted in a product which fulfilled the design requirements established for usage. However, due to equipment malfunctions, some development testing was accomplished during the qualification test program. The qualification rationale for items listed on Table 2.2.11.7-6. are included in the Test and Assessment Document (TAD), MDC G0474C.

Table 2.2.11.7-6

REFRIGERATION SYSTEM ITEMS (TAD)

TEST AND ASSESSMENT DOCUMENT MDC G0474C

Item		Ref TAD Page
1B76778	PUMPING UNIT	6-1
1B79858	REGENERATOR CHILLER	6-3
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a. Refrigeration System - HS-19, Specimen 1:

- o Summary - The complete loop of the OWS Refrigeration System, thermally equivalent to the flight system, was subjected to functional tests in prelaunch, simulated ascent, and thermal vacuum (orbital habitation and storage) environments. Tests were conducted in the MDAC Space Simulation Laboratory. Test objectives were to evaluate and verify 1) initial system operation, 2) prelaunch functional operation, 3) simulated inhabited orbital functional operation, 4) simulated storage orbital functional operation, 5) simulated launch, ascent, insertion and orbital recovery functional operation, 6) control system operational characteristics, and 7) to observe and evaluate frost buildup on freezers.

- o Test Conclusions - Based on HS-19 Specimen 1 testing, the Refrigeration System of the OWS/Skylab, as defined by 1B79660-1, was found qualified to meet all mission thermal operational requirements.

b. Refrigeration System - HS-19, Specimen 1A:

- o Summary - A series of thermal tests were performed at ambient pressure in the MDAC Space Simulation Laboratory on a MDAC-ED fabricated thermal capacitor, P/N 61A830189-37. The purpose of the test was to determine the thermal characteristics and pressure drop of the unit for later use in evaluating the Refrigeration System thermal/vacuum tests (HS-19, Specimen 1). Test objectives were to obtain data with which to calculate 1) overall conductance, 2) freezing and melting points of the capacitor material (UNDECANE wax) 3) supercooling freeze point and/or melting point depression temperature (if any), 4) UNDECANE crystalline change temperature, 5) temperature characteristics during phase change, 6) coolant side pressure drop, and 8) coolant inlet vs. exist temperature histories. Testing conditions for which these data were obtained were basic freezing and thawing cycles and simulated ascent, orbital storage, and solar inertial hold at β angles of 0° and 73°.

o Test conclusions - The thermal and fluid flow characteristics of the RS thermal capacitor were determined at room temperature and pressure. Overall conductance between the coolant (Coolanol-15) and the phase change material (UNDECANE wax) was 645 Btu/Hr/°F (379 j/hr/°K). The freezing and melting points of the UNDECANE were between -13 and -16°F (624.8 and 624.6°K) (freezing) and between -16 and -13°F (246 and 248°K) (94% thaw). No supercooling or melting point depression effects were observed. The change from solid to crystalline structure occurred between -35 and -36.5°F (236 and 235°K). Pressure drop through the capacitor was 0.85 psid (5.87 kN/m^2) at -50°F (227.5°K) and 125 lbs (56.7 kg) per hour coolant flow. As a result of these tests the capacitor was qualified as to its thermal and fluid flow requirements. However, the capacitor failed structurally when subjected to rapid heating.

This capacitor was replaced with one of a new design (P/N 61A830371-3) and qualified in tests identified as Line Items ST-19, Specimen 6, and HS-77, Specimen 2.

c. Refrigeration Subsystem - HS-19, Specimen 1B:

- Summary - This qualification test was conducted by MDAC-W at the Space Simulation Laboratory at A3 during the test period of October 3 to December 18, 1971. The under under test was the Refrigeration Subsystem Specimen 1B. Wardroom Freezer/Chiller Part No. 1B79912, Serial No. 002. The objectives of this test were: (a) demonstrate that that internal frost buildup will not impair removal of the freezer contents; (b) verify satisfactory pressure drop in the coolant coils; and (c) establish that the door hinges, latches and seals will perform as required during the life cycle of the unit. Chilled Coolanol-15 was circulated through the freezer coils at operational flow rates and inlet temperature, and inlet and outlet pressures were measured. The surrounding air temperature, humidity and velocity were controlled and monitored. One of the three doors was periodically opened and closed to allow frost to form in an accelerated mode, in order to simulate the freezer life cycle. Photographs were taken of the interior frost buildup. The door was opened and closed a total of 200 times during the frost test, and an additional 1000 times during the latch and hinge test. Each 50 cycles in the frost test, the food container rack was removed and reinstalled to test the of removal. Some degree of difficulty was experienced in the rack removal, but this was attributed primarily to the fact that the prototype rack straps had broken early in the test, due to the 1-G environment. Test instrumentation (thermocouple wires) also contributed. However, the total degree of difficulty was considered to be relatively insignificant, and considered normal for the test conditions. The total accumulated frost buildup was found to be relatively low, thus verifying the calculated mechanical, operational and diffusion rates. The accumulation of frost did not impair the operation of the door hinges, latch and seals. All freezer surface temperatures, interior and exterior, were found to be in the normal operating range. The pressure drop requirement at each coolant flow rate was met. No signs of wear or damage were found on the door hinges, latch, handle and seals upon completion of the door cycle tests.

- Test Conclusions - These tests successfully qualified the 1B79912 Wardroom Freezer/Chiller Assembly of the Orbital Workshop Refrigeration Subsystem to operate normally in the space vehicle mission environment without significant frosting up of the freezer contents and without any degradation of the functional components thereof, during the life cycle of the unit. Additional thermal performance and frost buildup verification of the Freezer/Chiller was obtained from testing identified under Test Control Drawing 1T17863Y, Section I, Parts 1 and 1A.

d. Refrigeration Subsystem - HS-19, Specimen 1C:

- Summary - This qualification test was conducted by MDAC-W at Huntington Beach, California during September and October, 1971. The purpose of this test was to demonstrate the operational thermal performance capability of the 1B79875-1 radiator under simulated earth orbit thermo vacuum conditions. One 1B79875-1 radiator assembly, S/N 001, designated as test radiator 1T41060 was tested in a vacuum chamber with environmental conditions of less than 10^{-5} torr (1.333 x 10^{-3} N/m^2) pressure and -320°F (77.3°K) wall temperature. Orbital absorbed heat cycles, simulated with quartz lamps, were repeated while flowing RSS coolant through the radiator at operational coolant flowrates and inlet temperature conditions. Radiator backface temperatures were controlled to required values. Tests were conducted in accordance with Test Control Drawing 1T17863, Section I, Part 4.

- Test Conclusions - Test results indicated that radiator heat rejection for a maximum abosrbed heat flux condition was satisfactory. Coolant heat rejection of 1634 Btu/hr (1725 x 10^3 j/hr) orbital average was observed for a +16°F (264°K) 125 lb/hr (56.7 kg/hr) coolant inlet. The required minimum heat rejection is 1500 Btu/hr (1583 x 10^3 j/hr) at this condition. Radiator thermal performance for low absorbed heat flux conditions (cold operation) was acceptable and approximately as predicted by analysis.

Radiator coolant pressure drop measurements indicated acceptable radiator ΔP characteristics in relation to RSS ΔP capability.

Radiator backface heat leak values obtained from transient tests compared with calculated values and had the desired negligible effect on radiator fluid heat rejection.

These tests successfully qualified the 1B79875-1 (1T41060) Radiator Assembly of the Orbital Workshop Refrigeration Subsystem to reject the required maximum and minimum amounts of heat from the refrigeration subsystem coolant under operational conditions. Additional verification of the radiator thermal performance capability was obtained from testing identified under Test Control Drawing 1T17863, Section I, Parts 1 and 1A. The radiator structural integrity had been verified in tests conducted per Line Item HS-31, TCD 1T18307, and Line Item HS-[illegible], TCD 1T43295.

e. Refrigeration System - HS-19, Specimen 1D:

o **Summary** - The complete loop of the OWS Refrigeration System, thermally equivalent to the flight system, was subjected to thermal/vacuum testing. The purpose of the test was to evaluate the chiller circuit and freezer circuit heat leaks prior to system qualification in accordance with TCD 1T17863, Specimen 1. Test objectives were to determine 1) chiller circuit steady heat leak at ambient pressure and at room temperature and 90°F (305°K) wall temperature, 2) freezer circuit steady heat leak at ambient, storage, habitation and vacuum pressures, and at 70 and 90°F (294 and 305°K) wall temperatures, 3) water chiller and urine chiller simulator performance, and 4) component steady heat leaks.

- Test Conclusions - Heat transfer data obtained from thermal/vacuum tests of the Refrigeration System (as simulated in the MDAC Space Simulation Laboratory) were used to determine total heat leak of 1) the freezer circuit and 2) the chiller circuit. These data were obtained for the several combinations of pre-launch and orbital pressure and temperatures. In addition, the heat leak values of the individual freezers and chillers were obtained. Results indicated that the total heat leak of the freezer and chiller circuits was within the design heat rejection capability of the Refrigeration System assigned to these circuits, and that this portion of the system was qualified for use in the system thermal/vacuum tests defined as HS-19, Specimen 1.

f. Refrigeration System - HS-19, Specimen 2 & 2A:

- Summary - Prior to Specimen 2 assembly, the coolant pump inverter and regenerator heater control were subjected to non-operational and operation low and high temperature environmental tests.

The Specimen 2 assembly consisted of a pumping and chiller thermal control assembly together with the electrical equipment/cold plate assembly and interconnecting piping and wiring. Mass substitutes were used in locations where duplicate hardware would serve no purpose. Pre-vibration, proof pressure, leak, and extensive functional tests were performed. Vibration tests were accomplished with the loops charged with Coolanol-15, and particulate checks were made before and after vibration. Function was verified between vibration axes. Post vibration tests included sound level, EMI and susceptibility, and functional. One pump relief valve was subjected to a crack/reseat life test of 250 cycles. A pump was operated with chilled Coolanol-15 for a total life cycle period of 2250 hours, during which the fluid was periodically sampled for particulate contamination. One quick disconnect on the pump assembly was engaged and disengaged unpressurized for a life test of 100 cycles.

Specimen 2A demonstrated the pump relief valve function using the service panel isolation valve and operator quick disconnect on the pump jumper hose.

- Test Conclusions - The pumping and chiller thermal control assembly/inverter and regenerator heater control and cold plate assembly performed within acceptable limits throughout all testing. A pump relief valve, a pump assembly quick disconnect, and a pump all successfully completed life cycle tests. A test to develop checkout technique demonstrated that the operator quick disconnect on the pump jumper hose did not provide adequate control to perform the relief valve cracking check. However, a GSE relief valve at the service panel return QD with the operation of the isolation valve provided a satisfactory checkout method.

g. Refrigeration Subsystem Thermal Control Assembly - HS-19, Specimen 4:

- Summary - The 1B79874-1 Radiator Thermal Control Assembly, identified as P/N 1T18165-1, Specimen NO. 4 of Line Item HS-19 (Refrigeration Subsystem), was subjected to qualification tests concurrent with and integrated with the development tests of Line Item HS-31 (OWS Radiator and Plume Shield Assembly). The purpose of these tests was to demonstrate that the thermal controlling capability of the specimen assembly and the components thereof will not be degraded by exposure to simulated launch environment. The specimen was subjected to: (a) pre-vibration functional tests, (b) vibration functional tests, (b) vibration tests*, and (c) post-vibration functional tests. The Radiator Thermal Control Assembly consists of two coolant (Coolanol-15) fluid loops, Primary and Secondary. The two specimen loops

*Also subjected to acoustic tests in conjunction with HS-31.

contained a common thermal capacitor and two ground cooling heat exchangers, with umbilical connectors. The specimen primary fluid loop contained production components with the exception of the thermal capacitor, relief valve, and one of the two ground cooling heat exchangers; the secondary fluid loop contained mass simulated components equipped with fluid passages. A number of components, located in the primary fluid loop, satisfactorily completed the qualification tests. The secondary fluid loop was qualified by similarity. The relief valve (non-production unit) and thermal capacitor (mass simulated) were non-qualification test components during this period of testing. These and other components were qualified in later tests identified in Line Item HS-77, Test Control Drawing No. 1T43295, Section II. For the complete combined HS-19-4-HS-31 test results, see TM-DSV7-F&M-R-7060.

- Test Conclusions - The following components of the Radiator Thermal Control Assembly (1B7[illegible]-1) were successfully qualified under Line Item HS-19-4 tests: Radiator Bypass Valve, P/N 1B79878-1; Ground Cooling Heat Exchanger, P/N 1B79876-1; Radiator Control Valve, P/N 1B79879-1; coolant lines and fittings; and all temperature sensors in the control and telemetry instrumentation circuits (reference TM-DSV7-R&M-R-6940-1). As a result of anomalies that occurred in separate component tests (not part of this Line Item), certain design changes of the Thermal Control Assembly were necessary. Consequently, additional tests of the assembly were planned.

All components used in the current Radiator Thermal Control Assembly configuration (1B79874-505) were planned to be qualified in Line Item HS-77 tests (reference Test Control Drawing No. 1T43295, Section II). It was therefore concluded that the HS-19-4 qualification tests of the Radiator Control Assembly, while satisfactory at the time, did not qualify this item for flight use on the OWS because of subsequent design changes.

h. Refrigeration System - HS-19, Specimen 5:

- Summary - One complete loop of the OWS Refrigeration System, thermally equivalent to the flight system (except for an interim radiator thermal control assembly containing a 61A830189-37 thermal capacitor and a 1B79879-1 radiator control valve) was subjected to thermal/vacuum testing. The purpose of the test was to obtain system thermal data and to develop necessary operating procedures at an early date, prior to the availability of the production configuration of the radiator thermal control assembly. Test objectives were to evaluate 1) initial system activation, 2) prelaunch functional operation, 3) simulated inhabited orbital functional operation, 4) simulated storage orbital functional operation, 5) simulated launch, ascent, insertion and orbital recovery functional operation and 6) control system operational characteristics.

- Test Conclusions - Test results indicated that the RS system (as simulated in the MDAC Space Simulation Laboratory) was qualified for additional testing in accordance with TCD 1T17863, Specimen 1, within the limited capability of the interim radiator thermal control assembly to control temperatures throughout the range of RS operation. Complete checkout of test facilities was accomplished, operating procedures for system start-up were developed, food loading procedures were verified operationally, and freezer/chiller thermal data verified design requirements.

i. Refrigeration Subsystem Coolant Pump Assembly - HS-19, Specimen 6:

- Summary - A refrigeration system pump assembly was subjected to vibration and operated for a life cycle period of 2276.4 hours. The pump was operated in a closed test loop with chilled Coolanol-15 at an essentially constant flowrate. The fluid was periodically sampled for particulate contamination. The pump inlet and differential pressures were cycled in the pre-vibration test to simulate a typical orbital situation. The pressures were also cycled for the first 480 hours of post vibration operation, but thereafter the pump pressures were fixed at 17 psig (117.3 kN/m^2) inlet and 55 psid (379 kN/m^2).

- Test Conclusions - The pump assembly operated successfully without any abnormalities or failure trends for the entire life cycle period of 2276.4 hours.

j. Refrigeration Subsystem Control Logic Unit Qualification Test - HS-35:

- Summary - One unit, Part Number 1B82699-1, Serial Number 03, was tested as Line Item HS-35. The purpose of the Qualification Test was to verify that the part would function within required specification limits when subjected to the expected OWS environmental extremes of vibration, low temperature, high temperature and electomagnetic compatibility environments. Two Series Regulators, Part Number 1B85265 were replaced because of cracks. The unit that went through the environments had hairline cracks in the plasma spray at the mounting feet. The cracks did not extend into the bulk epoxy material. There were no functional failures.

- Test Conclusions - Based on the results of the qualification tests, it was the conclusion of the McDonnell Douglas Astronautics Company that the above unit was qualified for its intended installation on the Orbital Workshop.

k. Radiator Bypass Valve Controller - HS-36:

- Summary - One unit, Part Number 1B82697-501 (Serial Number 04), was tested as Line Item HS-36. The purpose of the qualification test was to verify that the part would function within specification limits when subjected to the expected OWS environmental extremes of low and high temperature, vibration, shock and electro-magnetic interference (EMI) testing. EMI tests were performed in conjunction with the Bypass Controller Monitor Module, P/N 1B80385-1, Line Item HS-76 and the data is included within the Technical Memorandum.

  Pre and post tests were performed to verify that the unit had not degraded functionally as a result of the environmental extremes.

- Test Conclusions - All specification requirements for the Radiator Bypass Valve Controller qualification testing were met. Failures are explained and retest noted below. Based on the results of the qualification tests, it was concluded by the McDonnell Douglas Astronautics Company that the above item was qualified for its intended installation on the Orbital Workshop.

Pertinent information regarding anomalies noted during the testing period is as follows:

1) During qualification testing the Voting Logic and Switch Module, P/N 1B80359-1, failed in two separate conditions. The output suddenly drew excessive current while it was operating in a random vibration environment.

   Failure reports F07914 and F06209 were issued against assembly P/N 1B82698-501 (S/N 04) and P/N 1B80359-1 (S/N 09) respectively for investigation of the first failure. A new module P/N 1B80359-1 (S/N 011) was obtained to continue the qualification test program. This module subsequently failed in the same manner as the S/N 09 module and failure reports F07951 and F03786 were issued to perform investigation of the second failure.

   Investigation of the two voting logic and switch modules showed the shorted outputs were caused by a short circuited transistor, Q12 (reference SFA W080). It was determined that the transistor had failed due to foreign matter in the devices which was identified as loose weld material splatter from the case welding.

A Loose Particle Detection (LPD) screen test for the ST 303-2S transistor replacing 1B84325-1, was implemented as the corrective action. The qualification test was completed successfully using the repaired Voting Logic and Switch Module, S/N 011 (re-identified to P/N 1B80359-501). Engineering drawing changes to replace the transistors were issued to change all next assembly usages for all effectivities.

2) During Electromagnetic Interference (EMI) Tests, the test specimen consisted of the Radiator Bypass Valve Controller (HS-36) and the Bypass Monitor Module (HS-76). The specimen failed to meet the broadband conducted and radiated interference tests when the radiator bypass valve controller was commanded to switch modes from radiator to bypass position or bypass to radiator position. These out-of-tolerance conditions were deferred until All Systems Test on the Orbital Workshop to determine if the levels interfere with other subsystems. No interference occurred during the All Systems Test.

The specimen also failed to meet the audio frequency conducted susceptibility test (reference F08513). When 1.1 VRMS was applied to the bypass valve controller, both outputs were turned on pulling them up to 28 volts. Although during this condition no power would be applied to the valve, the monitor module would erroneously trip causing system failure. The 1.1 VRMS, which is slighly over 3 volts peak-to-peak is 3 times greater than the actual noise levels on the vehicle which were measured during the All Systems Test.

1. Urine Freezer - HS-41:

   - Summary - This qualification test was conducted by MDAC-W at Huntington Beach, California during the period from January through March, 1972. The purpose of the test on the XN1B84675-1 Urine Freezer included (1) verification of the unit's ability to withstand, without degradation, the Skylab mission pressure profile, (2) determination of steady state heat leak into the specimen, (3) establishment of coolant differential and urine tray temperature transients, when 85°F (303°K) urine trays are inserted into the freezer, and (4) verification of maximum allowable freezing time of 122 ml urine samples. These tests were conducted in accordance with Test Control Drawing 1T19778.

     One XN1B84675-1 Urine Freezer was tested in an environmental chamber where ambient pressure was increased from 14.7 to 26 psia (101.3 to 179.4 kN/m^2) at a rate of 0.5 psi (3.45 kN/m^2) per minute and held for 1 hour. [illegible] ambient pressure was then decreased to 5 torr (6.67 kN/m^2) in 300 seconds.

This condition was maintained for 30 minutes, after which the chamber pressure was increased to 14.7 psia (101.3 kN/m^2) at a rate of 0.5 psi (3.45 kN/m^2) per minute. No physical degradation was detected during or following this portion of the test.

With the ambient air temperature and chamber wall temperature at 85°F (303°K), Coolanol-15 was circulated through the primary coolant loop of the test specimen at -12°F (248.5°K) and with a flowrate of 125 lb/hr (56.7 kg/hr). After inlet to outlet coolant differential temperature had stabilized, a differential temperature of 3.25°F (257°K) was measured. Based on this data, an ambient heat leak into the freezer of approximately 167 But/Hr (176.5 x 10^3 j/hr) was calculated [a unit heat leak of 164 Btu/Hr (173.3 x 10^3 j/hr) was predicted, based on an 80°F (300°K) environment and a -14°F (247°K) coolant inlet temperature].

After the test specimen had thermally stabilized, two urine sample trays at a temperature of 85°F (303°K) were inserted into the freezer. Temperature rise of the coolant and tray surfaces were recorded for a twenty-four hour period to define coolant differential and tray transient temperature/time characteristics.

Full size urine samples (122 ml), prechilled, to 59°F (289°K), were inserted in selected cubicles of the urine trays to verify that these sample temperatures can be lowered to -2.5°F (254°K) in a maximum of three (3) hours. This portion of the test also established the transient temperature characteristics of previously frozen adjacent samples in the same tray. The time required to lower the urine sample temperature to -2.5°F (254°K) ranged from 5.5 hrs to 6.35 hours. Although these freezing times did not satisfy the requirements of Test Control Drawing 1T19778, these freezing times were acceptable per the revised requirements of Configuration Control Board Directive 312-72-0127, dated 6-12-72. These revised requirements allow a maximum time of eight (8) hours for a sample to reach -2.5°F (254°K).

- Test Conclusions - These tests successfully qualified the 1B84675-1 (XN1B84675-1) Urine Freezer of the Orbital Workshop Refrigeration Subsystem to withstand the Skylab mission ambient pressure profile without degradation, and to freeze full size (122 ml) urine samples within the maximum time allotted under operational conditions. Additional verification of the Urine Freezer performance capability was obtained from testing specified in Test Control Drawing 1T17863 (Line Item HS-19, Specimens 1, 1D, and 5).

m. Urine Sample Return Storage Container - HS-42:

- Summary - These qualification tests were conducted by MDAC-W at Huntington Beach and Santa Monica, California, during the months of July through November 1972. The purpose of these tests was to verify the structural integrity and thermal performance capabilities of the 1B85443-1 Urine Return Container. The tests were designed to demonstrate the container's capability to withstand simulated mission ascent environments and to withstand descent environments while preserving a quantity of urine samples at a given temperature range over a specific length of time. Following launch pressure and vibration tests, the container was filled with frozen samples of urine, and subjected to functional tests conducted in environments simulating the maximum temperatures during activities required to pack in orbit and return the samples to earth. Testing was concluded by subjecting the specimen container to mechanical shock tests. All tests were conducted in accordance with Test Control Drawing No. 1T19777.

The test results indicated that the urine return container can successfully survive the vibration and pressure levels associated with mission ascent, and pressure and shock levels associated with descent. Functional test results indicate that the container's insulating capability is sufficient to provide the specified urine sample return time without exceeding the maximum allowable sample temperature.

- o Test Conclusions - These tests successfully qualified the 1B85443-1 Urine Return Container to withstand the mission requirements including thermal performance, pressure, vibration and mechanical shock. Additional requirements to add blood and half-size urine samples, and to reduce the number of full size samples resulted in a new thermal test, designated as Line Item HS-36, Test Control Drawing No. 1T43934. This test was also completed successfully.

n. Bypass Controller Monitor Module - HS-76:

- o Summary - One unit, Part Number 1B80385-1 (Serial Number 01), was tested as Line Item HS-76. The purpose of the qualification test was to verify that the part would function within specification limits when subjected to low and high temperature, vibration and shock testing. EMI tests, performed in conjunction with the Radiator Bypass Valve Controller, was submitted within the Line Item HS-36 Test Report.

  Pre and post tests were performed to verify the module did not degrade functionally as a result of the environmental extremes.

- o Test Conclusions - All specification requirements for the Bypass Controller Monitor Module Qualification Testing were met. Based on the results of the qualification tests, it was concluded by the McDonnell Douglas Astronautics Company that the above item was qualified for its intended installation on the Orbital Workshop.

Pertinent information regarding anomalies noted during the testing period is as follows:

1) During low temperature-operational testing, three abnormal state changes occurred. Connecting a ground strap from the specimen case to the 28 vdc power return, creating the same configuration as would be on the vehicle, lessening the modules susceptibleness to erroneous signals, was accomplished. Retests were performed and the results were satisfactory.

2) During shock testing-operational instrumentation disclosed relay contact discontinuities of 3 milliseconds in the radial axis, 30 to 50 microseconds in the thrust axis and 200 microseconds in the tangential axis. Analysis showed that as long as the relay contacts did not change state or remain open beyond the shock pulse duration, the relay chatter was acceptable.

o. Urine Freezer (Urine and Blood Samples) - HS-85:

- o Summary - This qualification test was conducted by MDAC-W at Huntington Beach, California, during the period from August to October, 1972. Phase I testing was performed to determine the maximum urine full size sample volume which can be frozen in the 1B84873 Urine Trays without causing tray distortion or sample protrusion above the tray top. The purpose of the Phase II test on the XN1B84675-1 Urine Freezer included (1) determination of the maximum time required to lower urine sample temperatures to -2.5°F (254°K), when stored in the same tray cubicle as blood samples, (2) verification of mission procedures for loading samples in the freezer, (3) determination of the temperature-time characteristics of the blood samples, and (4) evaluation of the thermal effects on a cubicle containing frozen urine or frozen urine and blood, when the adjacent cubicle is filled with warm urine samples. Phase III testing determined the feasibility of freezing 40 ml half samples in full size sample bags without protrusion of the half samples above the urine tray.

- o Test Conclusions - Based upon the engineering evaluation of the qualification test results, it was concluded that the above item was qualified for flight use on the OWS.

Phase I testing established that 130 ml was the maximum full size urine sample volume that could be frozen without urine tray distortion or sample protrusion above the tray top.

Phase II testing was performed on the XN1B84675-1 Urine Freezer with inlet coolant temperatures and flow rates simulating mission conditions. Air flow across the freezer door was also maintained throughout this test phase to simulate mission conditions. Initial Phase II testing was started with full size urine samples of 122 ml and half size samples of 55 ml. The early stages of testing revealed that the half samples protruded above the top of the urine tray. Testing was suspended, the half sample volume reduced to 40 ml, and Phase II testing reinitiated.

Sequential insertion of urine and blood samples into the freezer was performed to procedurally simulate the 28 day and 56 day missions. Procedural techniques were verified during this test and time-temperature characteristics of newly inserted urine and blood samples, as well as temperature transients of adjacent frozen urine and blood samples, were determined. The maximum times required to lower full size urine sample temperatures from 59 to 27°F (289 to 270°K), 0°F (255.5°K), and -2.5°F (254°K) were 3.2 hrs, 5.3 hrs, and 6.2 hrs, respectively. The maximum times required to lower half size urine sample temperatures from 59 to 27°F, F, and -2.5°F (289 to 270°K, 255.5°K, and 254°K) were 1.7 hrs, 3.2 hrs, and 3.4 hrs, respectively. The maximum time required to lower the 5 instrumented blood samples from room ambient temperature to -2.5°F (254°K) was 4.7 hrs. However, the equivalent time required for the other 4 blood samples averaged approximately 2 hrs. These freezing times satisfied the contractual requirements for this unit, except for the maximum time required to lower the urine full sample temperature from 59 to 27°F (289 to 270°K). The requirements for this freeze time was 3 hrs maximum; however, the 3.2 hours observed was deemed acceptable when all test tolerances were considered.

Phase III testing was performed on one urine tray using urine half samples and blood samples only, to determine if a half sample urine volume of 40 ml could be frozen without protrusion above the tray top. Protrusion was noted on the majority of the frozen half samples, thus failing to meet the test criteria. Half sample urine bags were subsequently redesigned, and acceptability verified under Line Item HS-90 (Reference: Waste Management System Qualification Test Program).

p. Urine and Blood Sample Return Container - HS-86:

- Summary - This qualification test was performed in the Space Simulation Laboratory of the McDonnell Douglas Astronautics Company-West, Huntington Beach, California, during the period 10 through 28 October 1972. The test was conducted in accordance with the requirements of Test Control Drawing 1T43934-A. The purpose of the test was to verify the 1B85443-1 Urine Return Container's capability to preserve biological specimen samples of urine and blood at or below the temperature of +17°F (264.5°K) for a minimum period of 22 hours, in environments simulating the maximum temperatures during activities required to pack the container in orbit and return the samples to Earth. The container was previously tested in accordance with Line Item HS-42 requirements, with urine samples only. The addition of blood samples was a new requirement for this test. Reference: TM-DSV-7-SSL-R-7061.

- Test Conclusions - This test successfully qualified the 1B85443-1 Urine Return Container to return from the Earth's orbit, biological specimen samples of urine and blood, at a temperature of +17°F (264.5°K) (or below) for a minimum period of time of 22 hrs, with a 1 degree (.555°K) tolerance, per the requirements of CP2080JIC, Change Order 817, ECP W555-C2. This unit was previously qualified to withstand mission environments, including pressure, vibration and mechanical shock, per Line Item HS-42, T.C.D. 1T19777. Ref: MDC No. G3973; TM-DSV7-SSL-R-7061.

q. Coolant Pump Inverter - HS-88:

- Summary - One (1) unit, part number 1B82698-505 (S/N 03) was tested as Line Item HS-88. The purpose of the qualification test was to verify that the part would function within required specification limits when subjected to the expected OWS environmental extremes of vibration, high and low temperature, and electromagnetic interference testing. Pre and post tests were performed to verify that the unit, which consists of nineteen (19) modules, associated connectors and wiring, had not degraded as a result of environmental exposure.

- Test Conclusions - Based on the engineering evaluation of the qualification test results, it was concluded that the above item was qualified for flight use on the Orbital Workshop. Pertinent information regarding the anomaly which occurred during EMI testing is as follows:

  1) During Electromagnetic Interference (EMI) testing, the inverter output cable bundle exceeded the conducted and radiated interference specification limits. This condition was anticipated since interference levels of this magnitude had been experienced previously on this cable; that is, the inverter redesign would not have affected the interference levels of the output cable.

2. Since no interference was noted with other subsystems during All Systems Test on the Orbital Workshop, this out of tolerance condition was considered acceptable.

3/ Special Tests

These tests are categorized as special tests since they do not meet the requirements of the standard OWS Development or Qualification Test Program.

a. RSS Component Evaluation - ST-19:

o Summary - This special test was performed by MDAC-W at Huntington Beach and Santa Monica, California between February, 1972 and June, 1972. The purpose of this test was to establish a Refrigeration Subsystem (RSS) operational configuration which would eliminate structurally destructive "hot" coolant pulses at the inlet to the thermal capacitor and/or verify that a new capacitor design could withstand these operational conditions.

This special testing was performed on six (6) separate and distinct test specimens, which were RSS components or candidate components for RSS usage.

- Test Conclusions - Based upon engineering evaluation of the special test results, OWS Refrigeration Subsystem modifications were implemented to achieve an acceptable system configuration. This special test was necessitated by a previous qualification test failure of the Refrigeration Subsystem 61A830189-37 Thermal Capacitor (reference: Line Item HS-19, Specimen 1).

  1. Test Specimen 1 - 61A830189-37 Thermal Capacitor.

     Structural and thermal testing was performed on this test specimen under various mission simulated conditions of coolant flow rate and inlet coolant temperature rates of change. Based on analytical criteria for structural failure, the original failure phenomenon was duplicated. Further testing was performed using different phase change materials; however, this test phase was terminated when the new thermal capacitor design of Test Specimens 5 and 6 was available for test.

  2. Test Specimen 2 - 1B89613-1 Radiator Relief Valve

     Testing of this test specimen at simulated mission radiator differential pressure rates of change and system flow rates established resultant coolant temperatures at the thermal capacitor inlet during "frozen bypass" conditions. Test specimen stability, cracking, full flow, and reseat characteristics could not be precisely evaluated due to dissimilarities between the test setup and RSS characteristics.

3. Test Specimen 3 - 1B79879-1 Radiator Control Valve

   Performance testing of this specimen did not conclusively verify that this unit could operate, without structural degradation, at cold port inlet temperatures as low as -120°F (188.5°K). Apparent valve sleeve movement was observed during test runs in this cold inlet port temperature range, but the detection of possible "sticking" is only capable of subjective evaluation. This component was subsequently deleted from the system baseline configuration and further-development of the unit terminated.

4. Test Specimen 4 - 1B79878-1 Radiator Bypass Valve

   This test specimen successfully completed more than two-hundred actuation cycles under simulated mission conditions. Open port differential pressure, closed port leakage, and actuation pull in voltage and current were within specified limits throughout testing. One anomaly was observed on the twenty-ninth actuation cycle when three (3) attempts were required to effect a valve poppet position change. This may have been caused by internal valve contamination subsequently found upon disassembly by the valve supplier.

5. Test Specimen 5 - 61A830374-1 Thermal Capacitor

The 61A830374-1 Thermal Capacitor (prototype) was subjected to simulated mission conditions, primarily to verify the unit's structural integrity when used in conjunction with the system modifications under consideration. The unit successfully completed all tests and measured unit surface strains during these tests were insignificant.

6. Test Specimen 6 - 61A830371-3 Thermal Capacitor

Three (3) 61A830371-3 Thermal Capacitors arranged in a series flow configuration successfully completed all phases of the specified performance tests. Thermal recovery, first series capacitor coolant outlet temperature, third series capacitor coolant outlet temperature, and test specimen coolant pressure losses were acceptable under all simulated mission conditions.

D. Mission Results

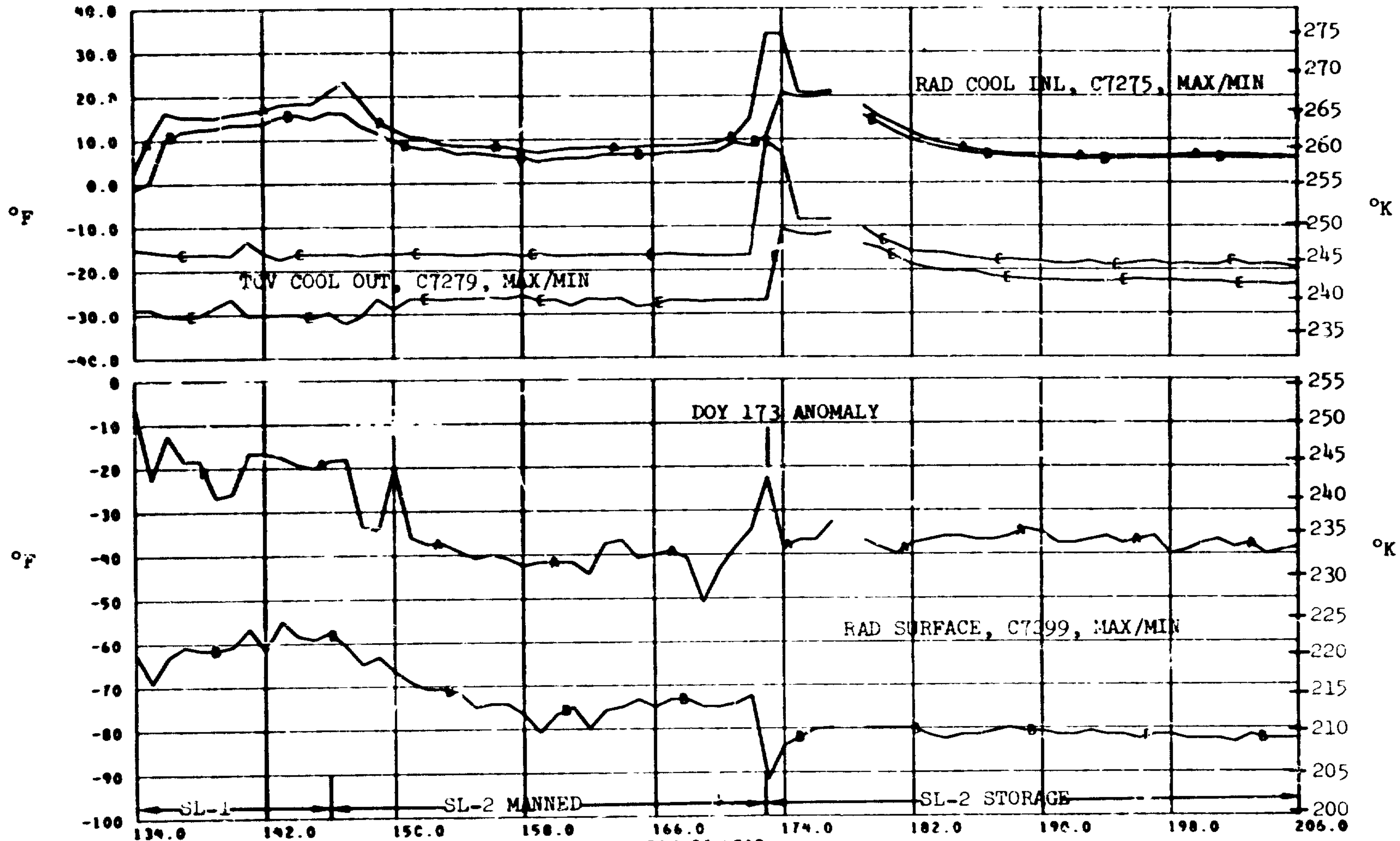
Refrigeration system flight data was recorded continuously throughout the total missions. Assessment of this flight data illustrating the effectiveness of the Refrigeration System (RS) is presented in the following paragraphs.

1/ Recorded flight data through SL-4 is shown in Figures 2.2.11.7-18 through 2.2.11.7-29 indicating the daily maximum and minimum values for pertinent RS parameters. A comparison of the system minimum and maximum temperatures with their respective CEI limits is summarized in Table 2.2.11.7-7. As shown, the Refrigeration System operated satisfactorily in maintaining all the required constituents within their respective CEI limits, except during the anomaly on day of year (DOY) 173, a low temperature excursion during SL-3 and a high temperature excursion during mission day (MD) 65, SL-4. These are discussed in paragraphs 2.2.11.7.D.4/,5/ and 6/.

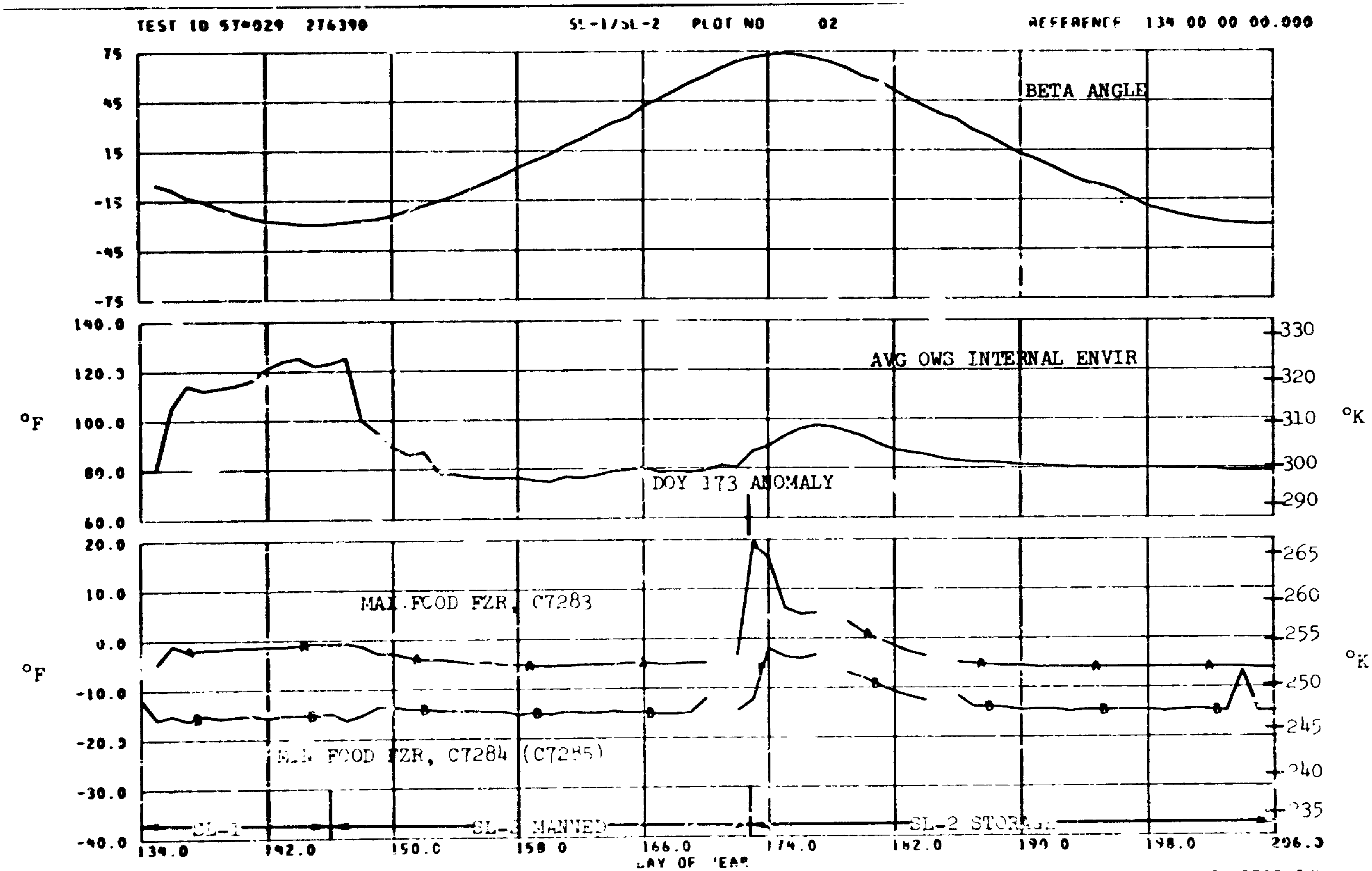
- The Refrigeration System was designed with a heat rejection capability compatible with a maximum OWS internal environmental temperature of 90°F (305°K). However, as shown in Figure 2.2.11.7-19, the RS maintained all temperatures within their limits even at OWS internal environments greater than 120°F (322°K). This was attributed to the orbital incident heat flux to the radiator with less than the +3σ design value; therefore, the radiator rejected more system heat.
- The flight data available in the short period following launch was limited by the lack of continuous ground station coverage. However, from this minimal data, the slope, trend, and probable minimum and maximum values of pertinent RS parameters for the time period of launch +6 hours could be ascertained. Refer to Figure 2.2.11.7-30.

RS PERFORMANCE DATA
Daily Minimum/Maximum

TEST ID 574029 276398 SL-1/SL-2 PLOT NO 01 REFERENCE 134 00 00 00.000



MEAS. NUMBER	CHANNEL ASGN.	TITLE	RANGE	UNITS	GRID-SYM
C7275-MAX	WP1B030A02LL01	MAX TEMP-RS,PAS CKTS RDTR,COL $	-25.0 TO 40.0	DEGF	AA
C7275-MIN	WP1B030A02LL01	MIN TEMP-RS,PAS CKTS RDTR,COL $	-25.0 TO 40.0	DEGF	AB
C7279-MAX	WP1A114A56LD22	MAX TEMP-RS,PCF TCV,COOL OUT	-50.0 TO 10.0	DEGF	AC
C7279-MIN	WP1A114A56LD22	MIN TEMP-RS,PCF TCV,COOL OUT	-50.0 TO 10.0	DEGF	AE
C7299-MAX	WP1A114A28LD15	MAX TEMP-RS,PR CKT RADIATOR,SU)	150.0 TO 60.0	DEGF	BA
C7299-MIN	WP1A114A28LD15	MIN TEMP-RS,PR CKT RADIATOR,SU)	150.0 TO 60.0	DEGF	BB

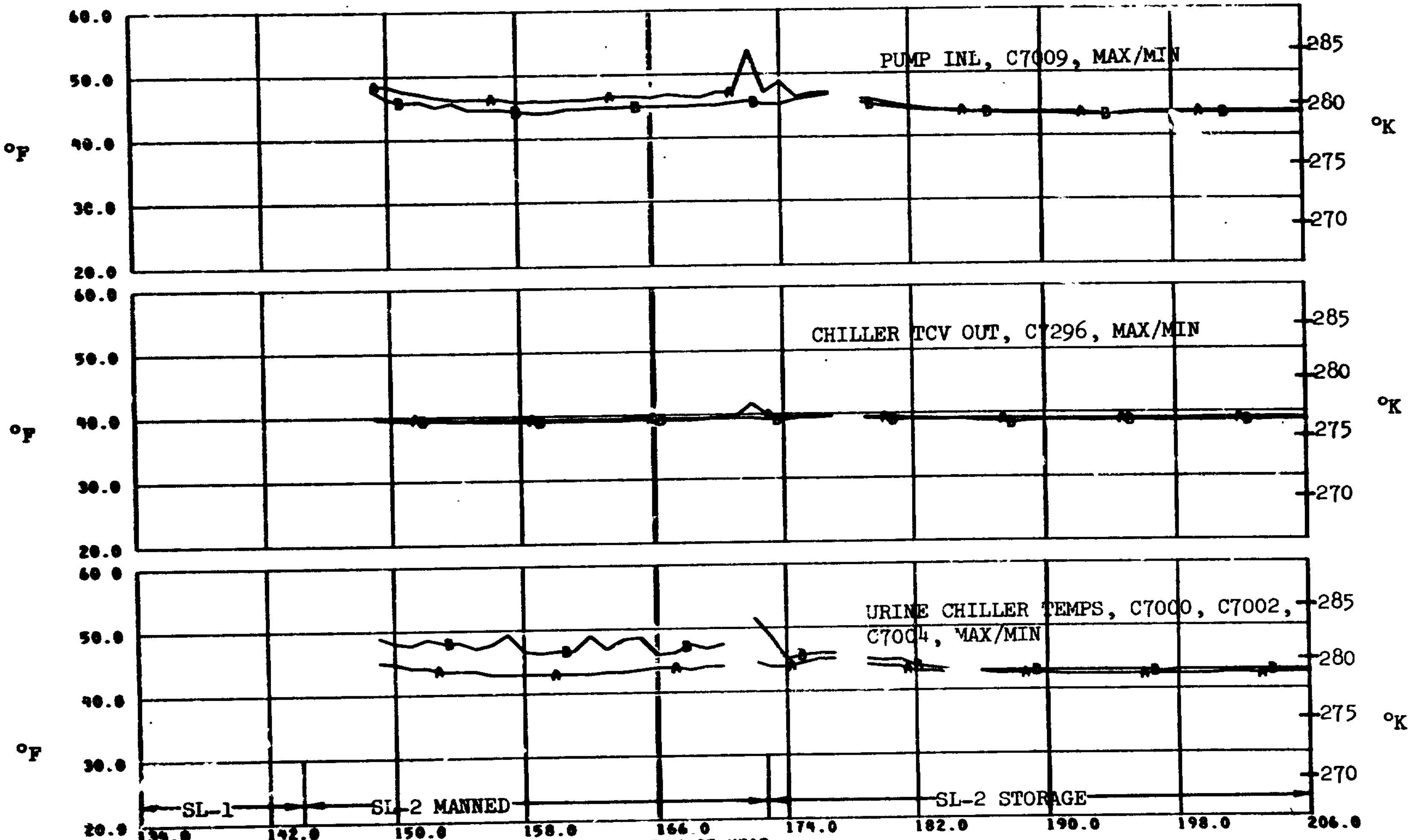


MEAS. NUMBER	CHANNEL ASGN.	TITLE	RANGE	UNITS	GRID-SYM
BETA-ANGLE	NONE	BETA ANGLE	100.0 TO 100.0	DEG	A
AVG-INT	NONE	AVERAGE INTERVAL TEMPERATURE	50 TO 150	DEGF	B
C7283-MAX	WP1A0F0A51LM20	MAX TEMP-FMS,F [illegible] STOR FRZR [illegible]	-25.0 TO 40.0	DEGF	CA
C7285-MIN	WP1B010A17LH04	MIN TEMP-FMS,[illegible] FOOD FRZR [illegible]	-25.0 TO 40.0	DEGF	CB

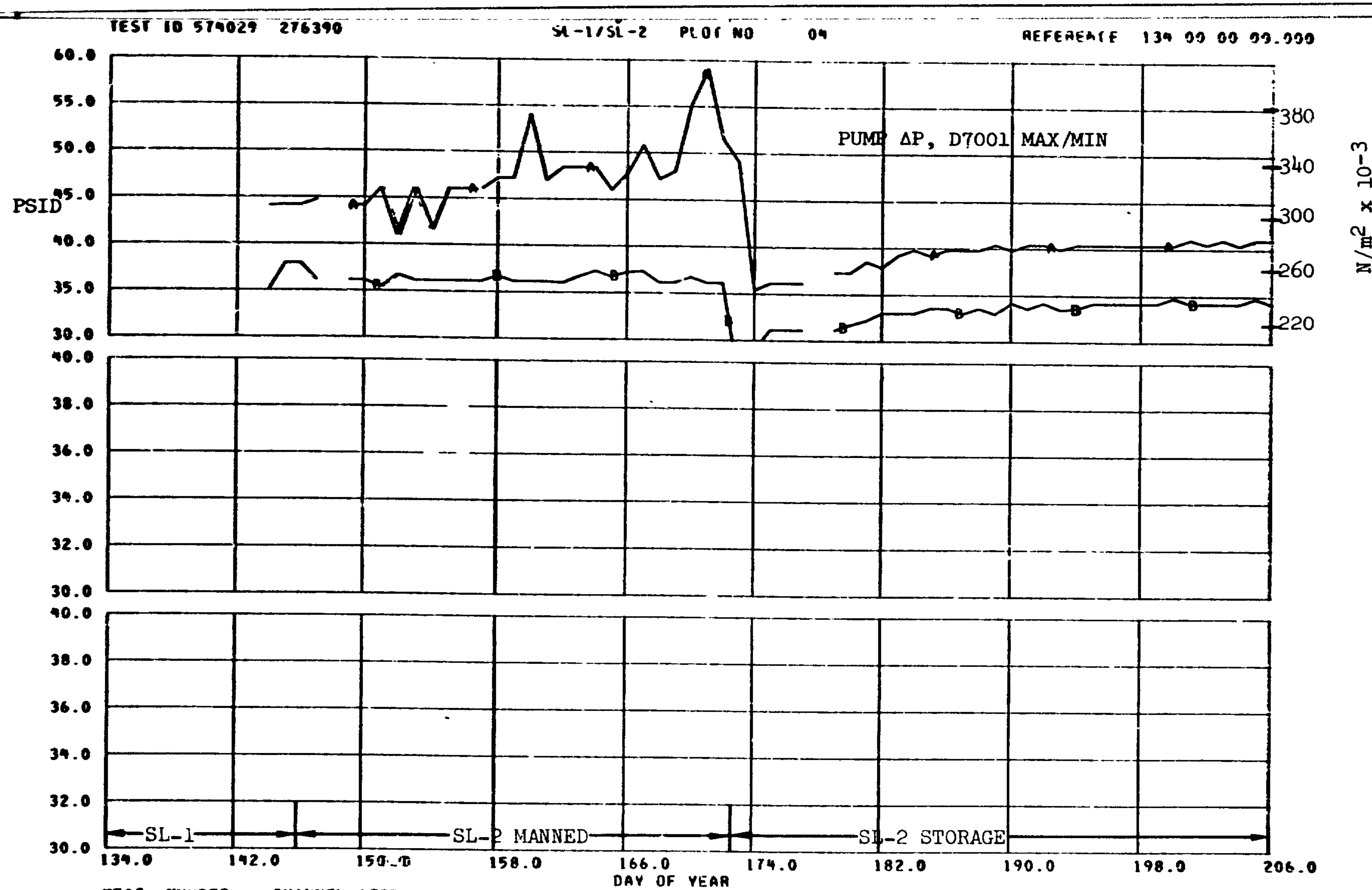
FIGURE 2.2.11.7-19

RS PERFORMANCE DATA
Daily Minimum/Maximum

TEST ID 574029 276390 SL-1/SL-2 PLOT NO 3 REFERENCE 13: 00 00 00.000



MEAS. NUMBER	CHANNEL ASGN.	TITLE	RANGE	UNITS	GRID-SYM
C7009-MAX	WP1A150A88L030	MAX TEMP-RS,PR LP,PUMP INLET	30.0 TO 70.0	DEGF	AA
C7009-MIN	WP1A150A88L030	MIN TEMP-RS,PR LP,PUMP INLET	30.0 TO 70.0	DEGF	AB
C7296-MAX	WP1A114A68LD25	MAX TMP-RS,PR CKT CH TCV,COOLO*	25.0 TO 55.0	DEGF	BA
C7296-MIN	WP1A114A68LD25	MIN TMP-RS,PR CKT CH TCV,COOLO*	25.0 TO 55.0	DEGF	BB
C7002-MIN	WP1B150A22L006	MIN TEMP-RS,URINE CHILLER NO.2	25.0 TO 100.0	DEGF	CA
C7004-MAX	WP1B010A14LJ04	MAX TEMP-RS,URINE CHILLER NO.3	25.0 TO 100.0	DEGF	CB



MEAS. NUMBER	CHANNEL ASGN.	TITLE	RANGE	UNITS	GRID-SYM
D7001-MAX	WP1B074A07HE53	MAX PRESS-RS,PR LOOP,PUMP DIFF	0 TO 150	PSID	AA
D7001-MIN	WP1B074A07HE52	MIN PRESS-RS,PR LOOP,PUMP DIFF	0 TO 150	PSID	AB
D7002-MAX	WP1B109A10HE51	MAX PRESS-RS,PR LOOP,PUMP INLE*	0.0 TO 60.0	PSIA	BA
D7002-MIN	WP1B109A10HE51	MIN PRESS-RS,PR LOOP,PUMP INLE*	0.0 TO 60.0	PSIA	BB
D7003-MAX	WP1B109A14HE52	MAX PRESS-RS,SN LOOP,PUMP INLE*	0.0 TO 60.0	PSIA	CA
D7003-MIN	WP1B109A14HE52	MIN PRESS-RS,SN LOOP,PUMP INLE*	0.0 TO 60.0	PSIA	CB

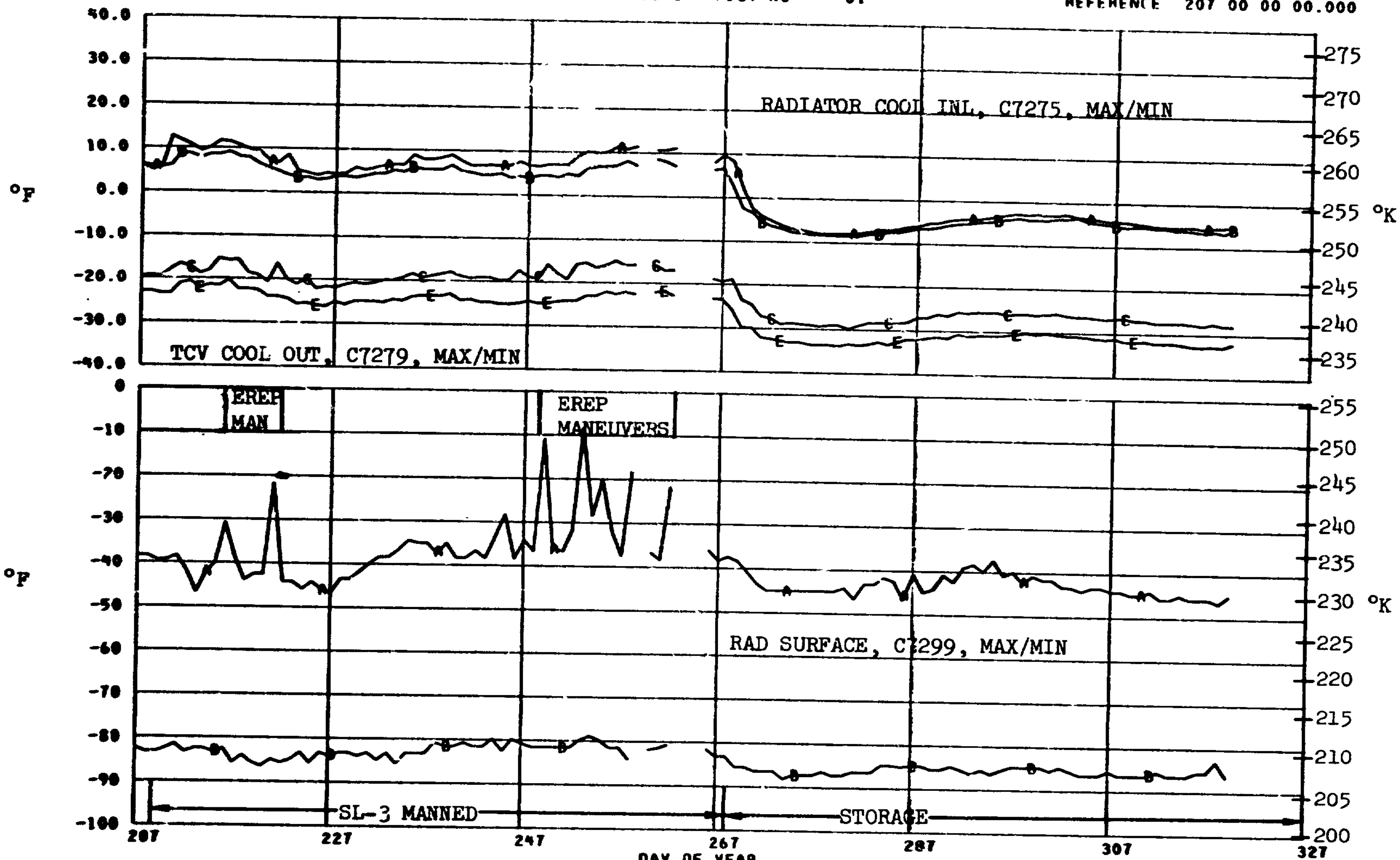
FIGURE 2.2.11.7-21

RS PERFORMANCE DATA
Daily Minimum/Maximum

TEST ID 574030 276390

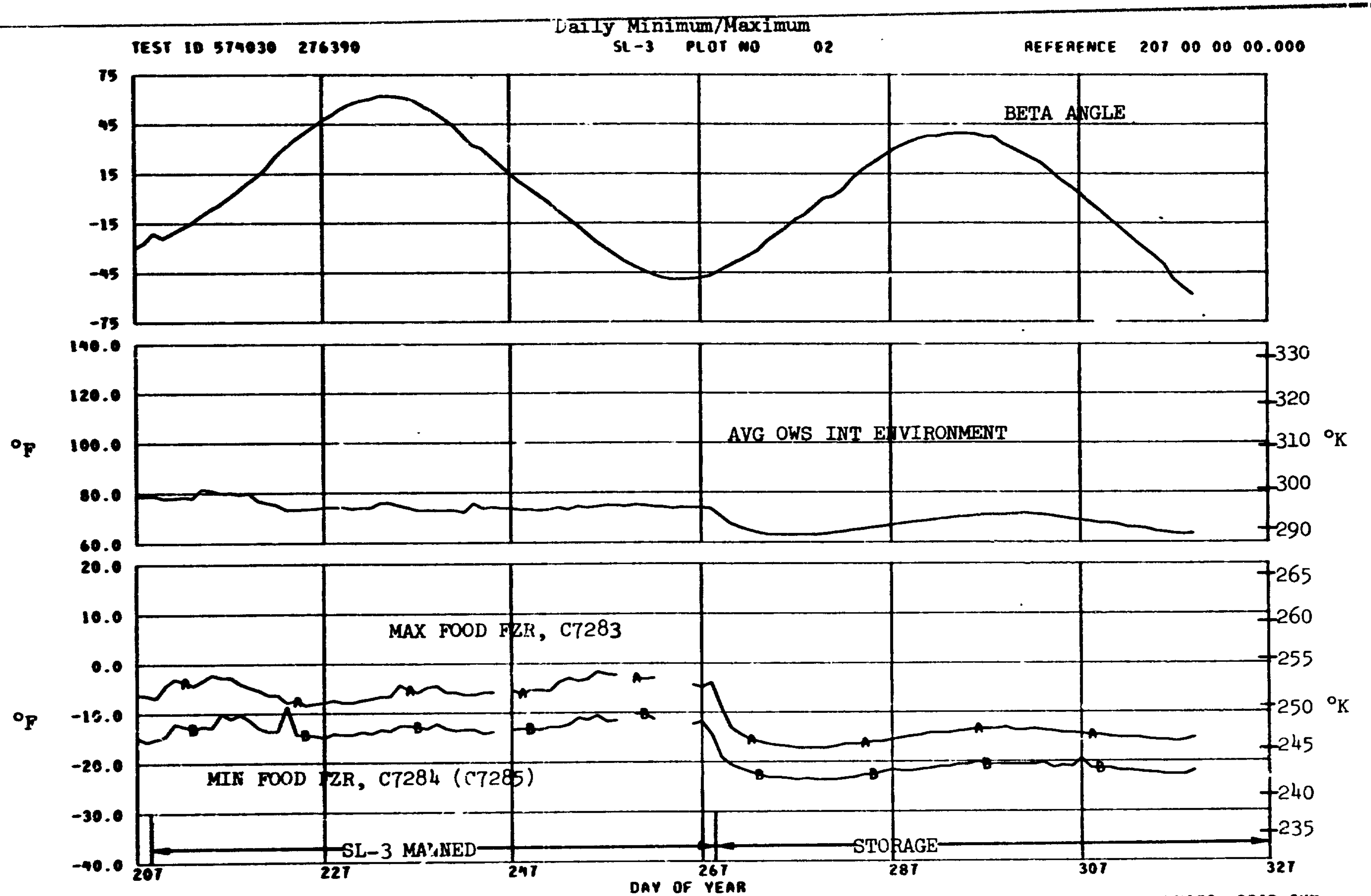
SL-3 PLOT NO 01

REFERENCE 207 00 00 00.000



MEAS. NUMBER	CHANNEL ASGN.	TITLE	RANGE	UNITS	GRID-SYM
C7275-MAX	WP1B030A02LL01	MAX TEMP-RS,PAS CKTS RDTR,COL $	-25.0 TO 40.0	DEGF	AA
C7275-MIN	WP1B030A02LL01	MIN TEMP-RS,PAS CKTS RDTR,COL $	-25.0 TO 40.0	DEGF	AB
C7279-MAX	WP1A114A56LD22	MAX TEMP-RS,PCF TCV,COOL OUT	-50.0 TO 10.0	DEGF	AC
C7279-MIN	WP1A114A56LD22	MIN TEMP-RS,PCF TCV,COOL OUT	-50.0 TO 10.0	DEGF	AE
C7299-MAX	WP1A114A28LD15	MAX TEMP-RS,PR CKT RADIATOR,SU)	150.0 TO 60.0	DEGF	BA
C7299-MIN	WP1A114A28LD15	MIN TEMP-RS,PR CKT RADIATOR,SU)	150.0 TO 60.0	DEGF	BB

FIGURE 2.2.11.7-22

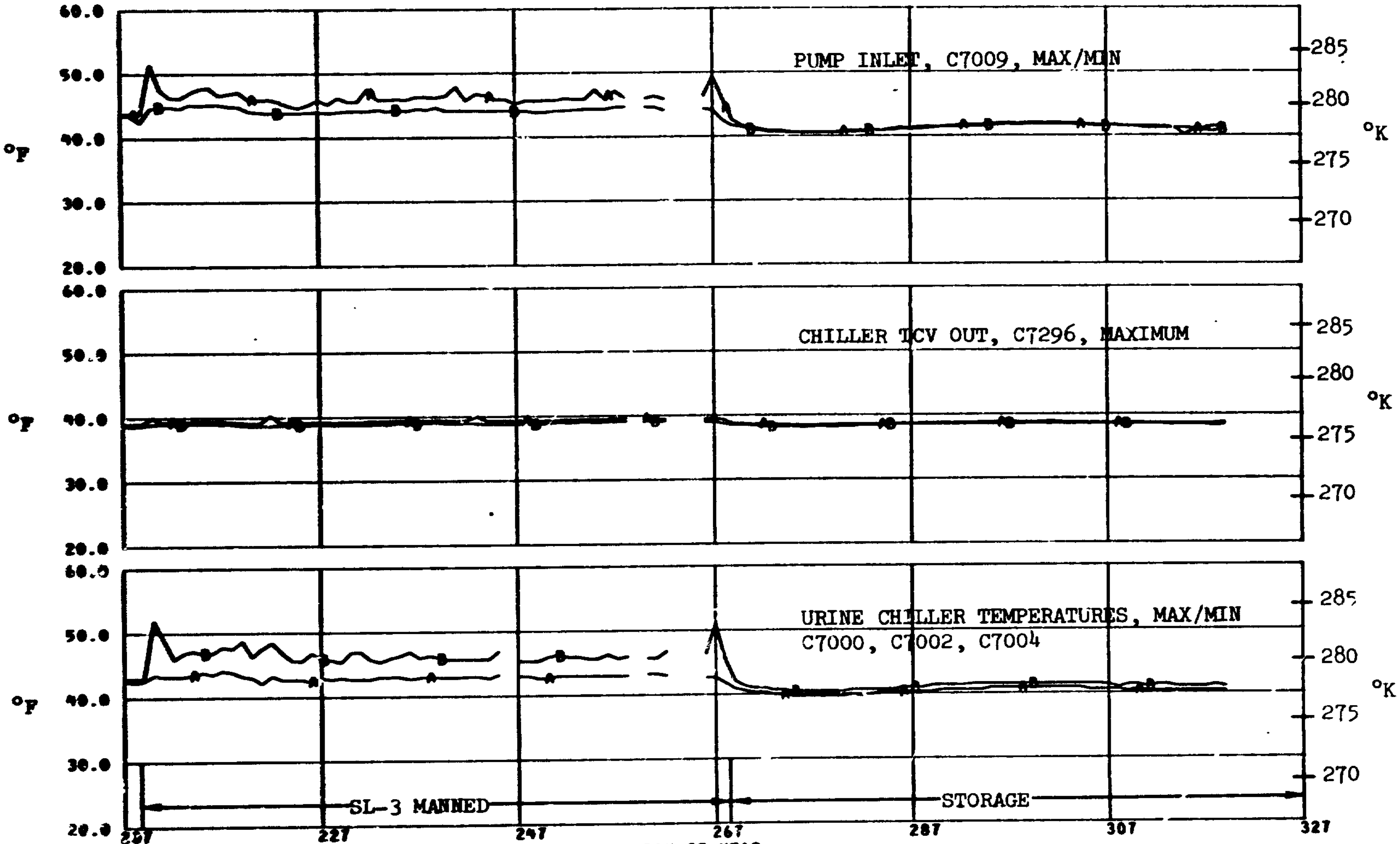


MEAS. NUMBER	CHANNEL ASGN.	TITLE	RANGE	UNITS	GRID-SYM
BETA-ANGLE	NONE	BETA ANGLE	100.0 TO 100.0	DEG	A
AVG-INT	NONE	AVERAGE INTERNAL TEMPERATURE	50 TO 150	DEGF	B
C7283-MAX	WP1A050A51LM20	MAX TEMP-FMS,FOOD STOR FRZR CMC	-25.0 TO 40.0	DEGF	CA
C7285-MIN	WP1B010A17LH04	MIN TEMP-FMS,WR FOOD FRZR COMP+	-25.0 TO 40.0	DEGF	CB

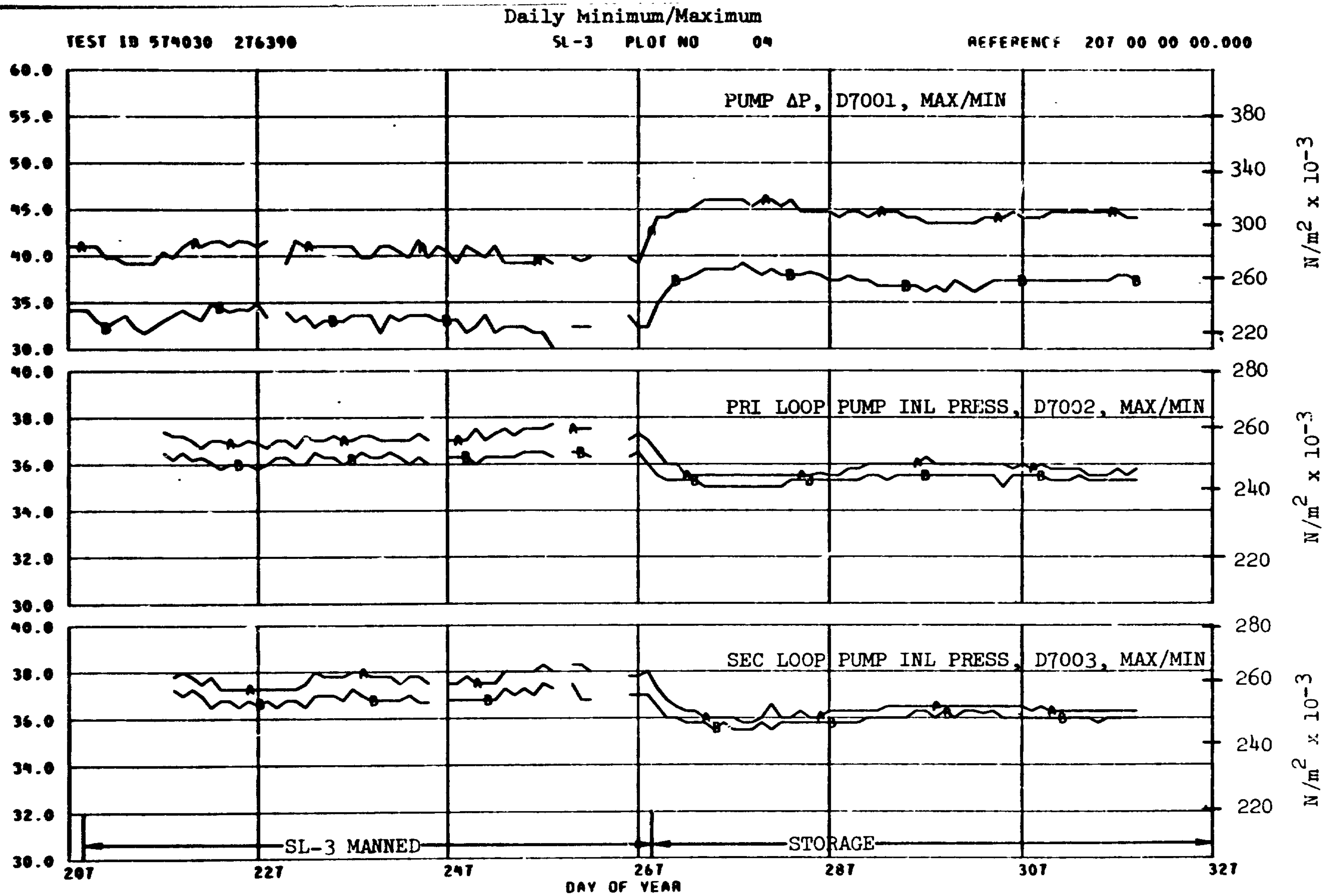
FIGURE 2.2.11.7-23

RS PERFORMANCE DATA
Daily Minimum/Maximum

TEST ID 574030 276390 SL-3 PLOT NO 03 REFERENCE 207 00 00 00.000



MEAS. NUMBER	CHANNEL ASGN.	TITLE	RANGE	UNITS	GRID-SYM
C7009-MAX	WP1A15CA08L030	MAX TEMP-RS,PR LP,PUMP INLET	30.0 TO 70.0	DEGF	AA
C7009-MIN	WP1A150A08L030	MIN TEMP-RS,PR LP,PUMP INLET	30.0 TO 70.0	DEGF	AB
C7296-MAX	WP1A114A68L025	MAX TMP-RS,PR CKT CH TCV,COOLO*	25.0 TO 55.0	DEGF	BA
C7296-MIN	WP1A114A68L025	MIN TMP-RS,PR CKT CH TCV,COOLO*	25.0 TO 55.0	DEGF	BB
C7002-MIN	WP1B150A22L006	MIN TEMP-RS,URINE CHILLER NO.2	25.0 TO 100.0	DEGF	CA
C7004-MAX	WP1B010A14LJ04	MAX TEMP-RS,URINE CHILLER NO.3	25.0 TO 100.0	DEGF	CB



MEAS. NUMBER	CHANNEL ASGN.	TITLE	RANGE	UNITS	GRID-SYM
D7001-MAX	WP1B074A07HE58	MAX PRESS-RS,PR LOOP,PUMP DIFF	0 TO 150	PSID	AA
D7001-MIN	WP1B074A07HE58	MIN PRESS-RS,PR LOOP,PUMP DIFF	0 TO 150	PSID	AB
D7002-MAX	WP1B109A10HT51	MAX PRESS-RS,PR LOOP,PUMP INLE*	0.0 TO 60.0	PSIA	BA
D7002-MIN	WP1B109A10HT51	MIN PRESS-RS,PR LOOP,PUMP INLE*	0.0 TO 60.0	PSIA	BB
D7063-MAX	WP1B109A14HT52	MAX PRESS-RS,SN LOOP,PUMP INLE*	0.0 TO 60.0	PSIA	CA
D7003-MIN	WP1B109A14HT52	MIN PRESS-RS,SN LOOP,PUMP INLE*	0.0 TO 60.0	PSIA	CB

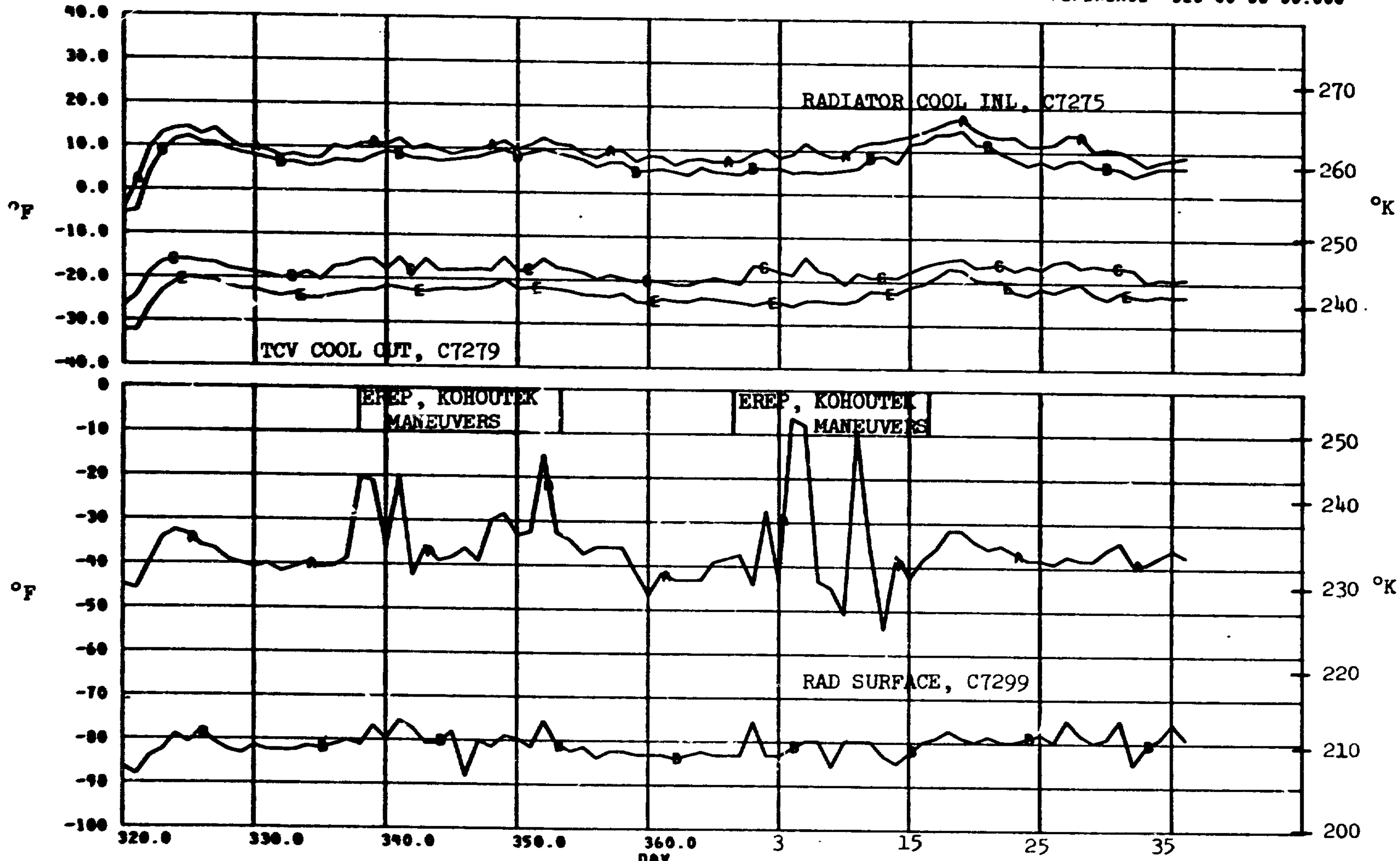
FIGURE 2.2.11.7-25

SL-4

RS PERFORMANCE DATA

Daily Minimum/Maximum

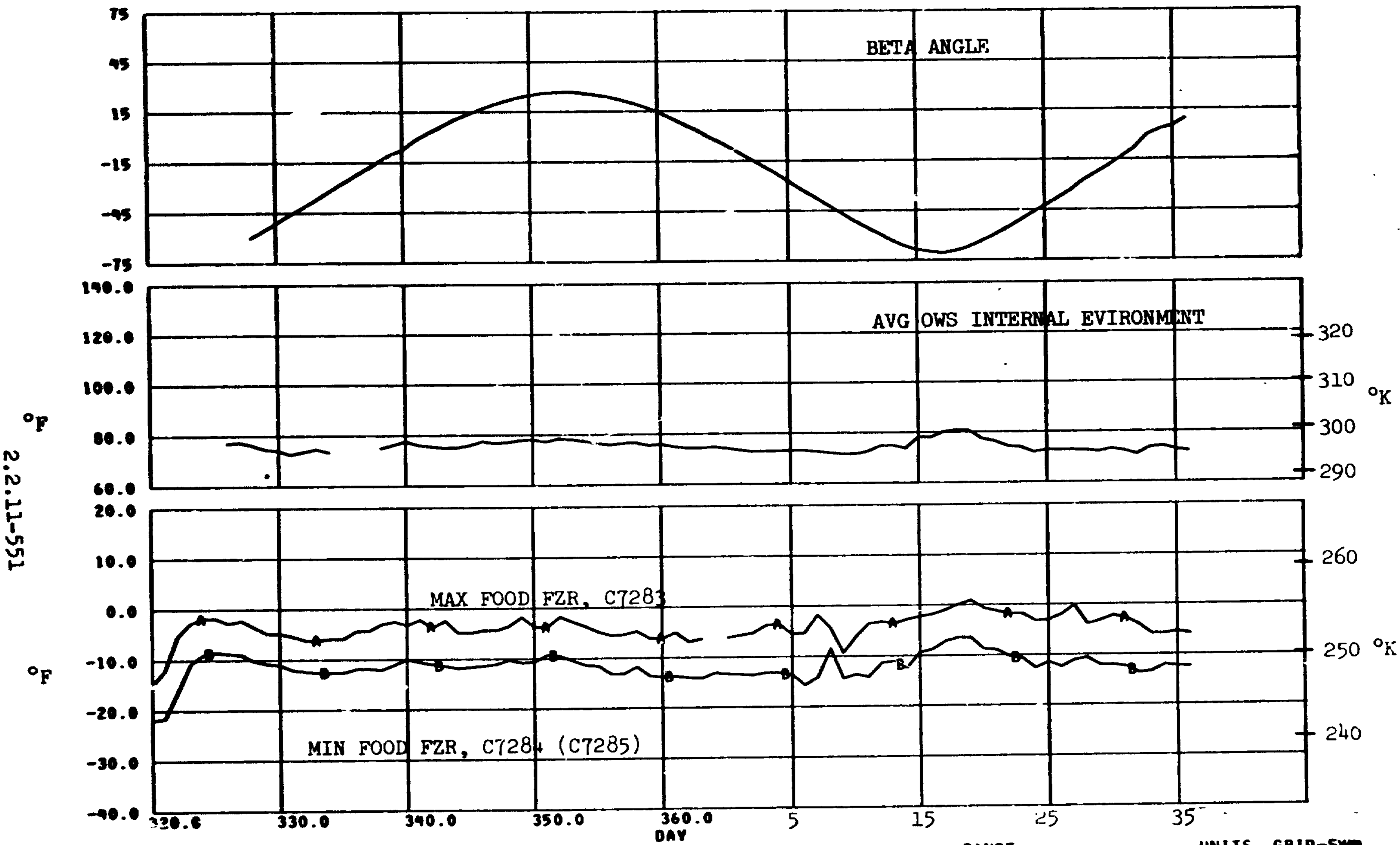
TEST ID 574031 265440 | TDO NO. 26544 PLOT NO 1 | REFERENCE 320 00 00 00.000



MEAS. NUMBER	CHANNEL ASGN.	TITLE	RANGE	UNITS	GRID-SYM
C7275-MAX	WP1B030A02LL01	MAX TEMP-RS,PAS CKTS RDTR,COL IN	-25.0 TO 40.0	DEGF	AA
C7275-MIN	WP1B030A02LL01	MIN TEMP-RS,PAS CKTS RDTR,COL IN	-25.0 TO 40.0	DEGF	AB
C7279-MAX	WP1A114A56LD22	MAX TEMP-RS,PCF TCV,COOL OUT	-50.0 TO 10.0	DEGF	AC
C7279-MIN	WP1A114A56LD22	MIN TEMP-RS,PCF TCV,COOL OUT	-50.0 TO 10.0	DEGF	AE
C7299-MAX	WP1A114A28LB15	MAX TEMP-RS,PR CKT RADIATOR,SURF	150.0 TO 60.0	DEGF	BA
C7299-MIN	WP1A114A28LD15	MIN TEMP-RS,PR CKT RADIATOR,SURF	150.0 TO 60.0	DEGF	BB

Daily Minimum/Maximum

TEST ID 574031 265440 TDO NO. 26544 PLOT NO 2 REFERENCE 320 00 00 00.000

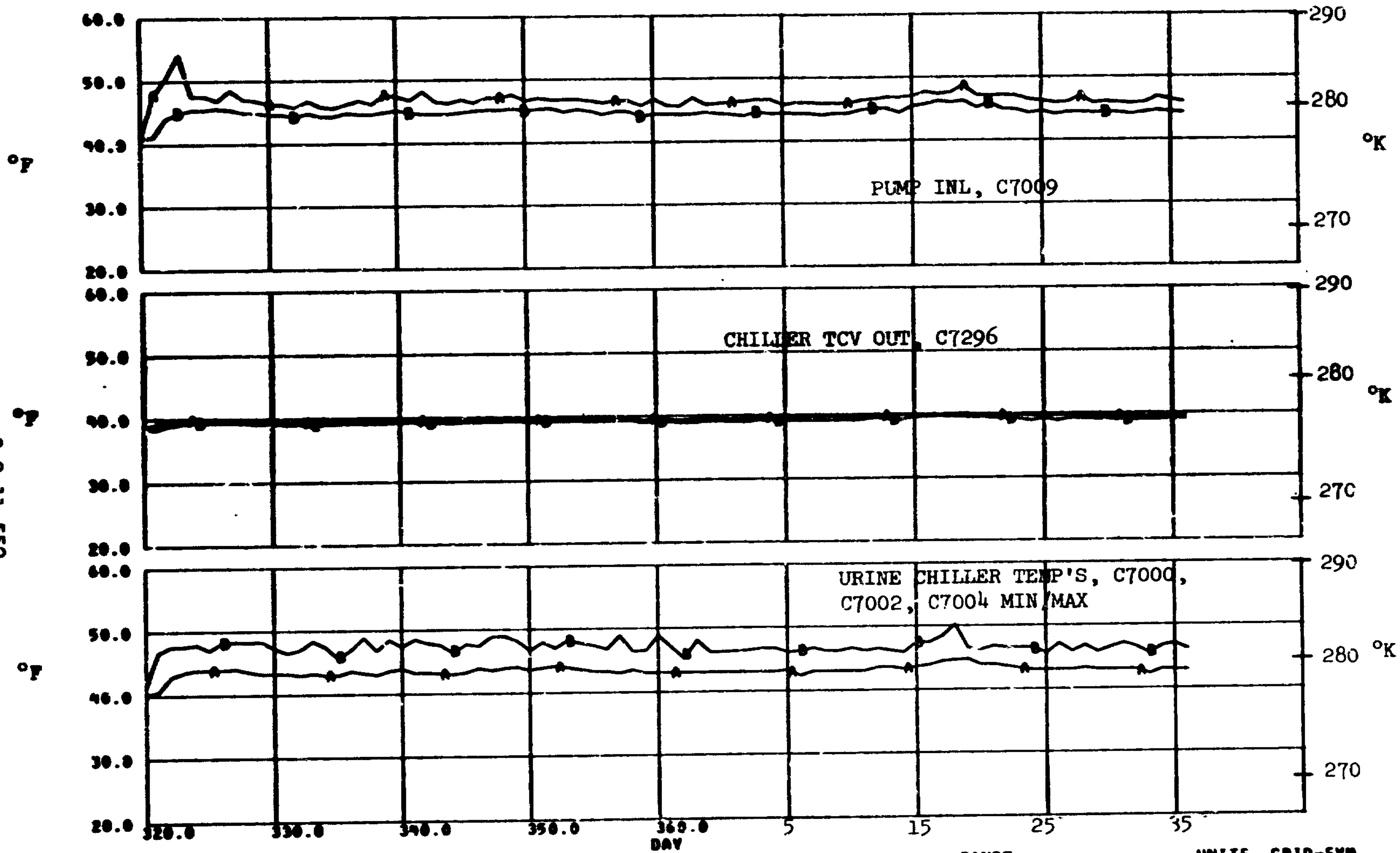


MEAS. NUMBER	CHANNEL ASGN.	TITLE	RANGE	UNITS	GRID-SYM
BETA-ANGLE	NONE	BETA ANGLE	100.0 TO 100.0	DEG	A
AVG-INT	NONE	AVERAGE INTERNAL TEMPERATURE	50 TO 150	DEGF	B
C7283-MAX	WP1A05CA51LM20	MAX TEMP-FMS,FOOD STOR FRZR CMP3	-25.0 TO 40.0	DEGF	CA
C7285-MIN	WP1B010A17LH04	MIN TEMP-FMS,WR FOOD FRZR COMPT2	-25.0 TO 40.0	DEGF	CB

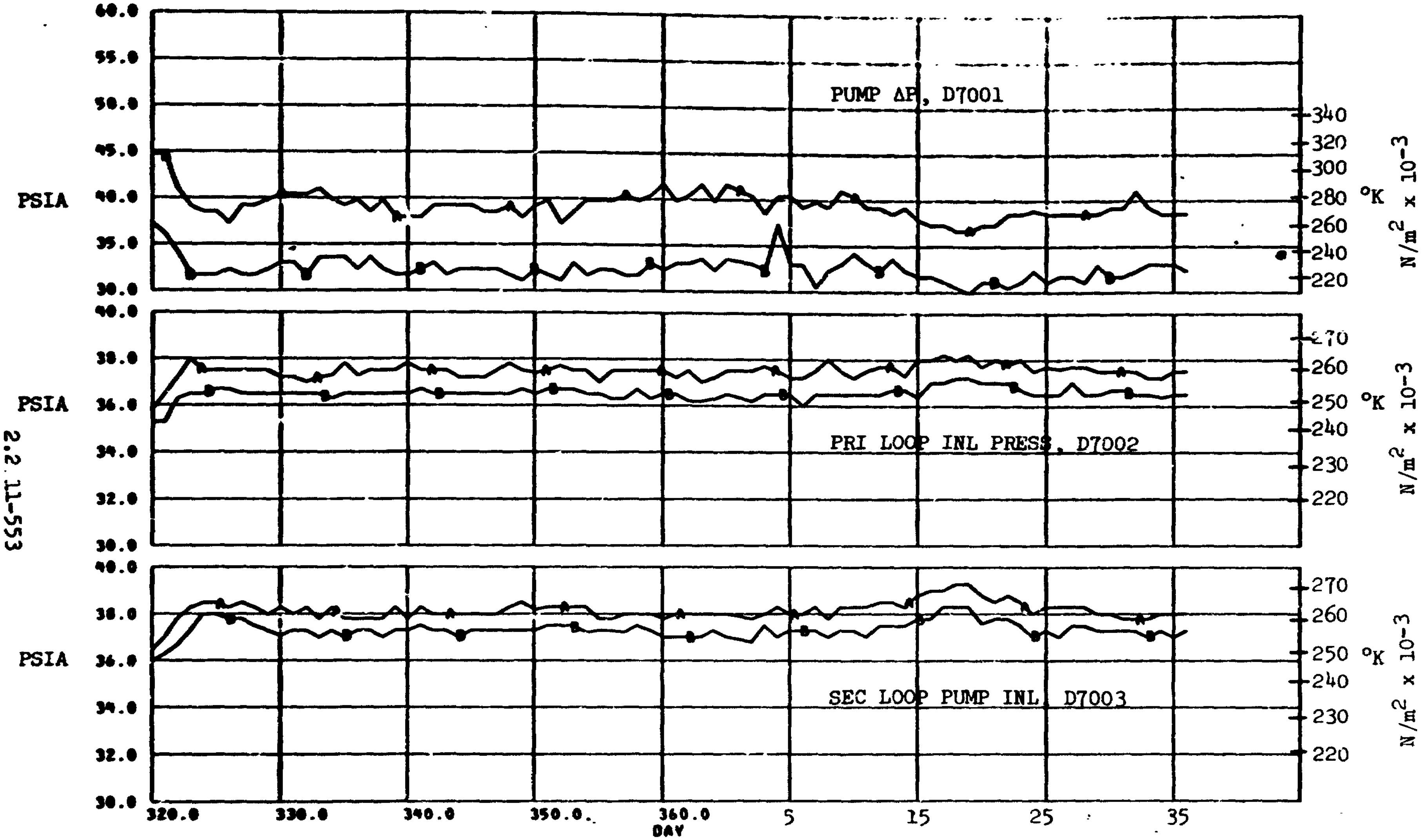
FIGURE 2.2.11.7-27

SL-4
RS PERFORMANCE DATA
Daily Minimum/Maximum

TEST ID 574031 265440 TDO NO. 26544 PLOT NO 3 REFERENCE 320 00 00 00.004



MEAS. NUMBER	CHANNEL ASGN.	TITLE	RANGE	UNITS	GRID-SYM
C7009-MAX	WP1A150A80L030	MAX TEMP-RS,PR LP,PUMP INLET	30.0 TO 70.0	DEGF	AA
C7009-MIN	WP1A150A80L030	MIN TEMP-RS,PR LP,PUMP INLET	30.0 TO 70.0	DEGF	AB
C7296-MAX	WP1A114A60LD25	MAX TMP-RS,PR CKT CH TCV,COOLOUT	25.0 TO 55.0	DEGF	BA
C7296-MIN	WP1A114A60LD25	MIN TMP-RS,PR CKT CH TCV,COOLOUT	25.0 TO 55.0	DEGF	BB
C7002-MIN	WP1B150A22L006	MIN TEMP-RS,URINE CHILLER NO.2	25.0 TO 100.0	DEGF	CA
C7004-MAX	WP1B010A14LJ04	MAX TEMP-RS,URINE CHILLER NO.3	25.0 TO 100.0	DEGF	CB



MEAS. NUMBER	CHANNEL ASGN.	TITLE	RANGE	UNITS	GRID-SYM
D7001-MAX	WP1B074A07HE58	MAX PRESS-RS,PR LOOP,PUMP DIFF	0 TO 150	PSID	AA
D7001-MIN	WP1B074A07HE58	MIN PRESS-RS,PR LOOP,PUMP DIFF	0 TO 150	PSID	AB
D7002-MAX	WP1B109A10HT51	MAX PRESS-RS,PR LOOP,PUMP INLET	0.0 TO 60.0	PSIA	BA
D7002-MIN	WP1B109A10HT51	MIN PRESS-RS,PR LOOP,PUMP INLET	0.0 TO 60.0	PSIA	BB
D7003-MAX	WP1B109A14HT52	MAX PRESS-RS,SN LOOP,PUMP INLET	0.0 TO 60.0	PSIA	CA
D7003-MIN	WP1B109A14HT52	MIN PRESS-RS,SN LOOP,PUMP INLET	0.0 TO 60.0	PSIA	CB

FIGURE 2.2.11.7-29

TABLE 2.2.11.7-7

REFRIGERATION SYSTEM PERFORMANCE SUMMARY - PRIMARY LOOP

Item	Req'ment	SL-1 Min.	SL-1 Max.	SL-2 Manned Min.	SL-2 Manned Max.	SL-2 Storage Min.	SL-2 Storage Max.	SL-3 Manned Min.	SL-3 Manned Max.	SL-3 Storage Min.	SL-3 Storage Max.
Capacitor Outlet Temp, °F	(°K)	-30.7	-13.4	-32.1	-16.0	-23.6	-8.4	-26.0	-15.0	-33.8	-23.6
(C7279)		(238.5)	(248)	(237.5)	(246.5) 9.6 *	(242)	(250.5) 6.8 *	(241)	(237)	(236.5)	(242)
					(261)		(259)				
Radiator Surface Temp, °F	(°K)	-68.9	-6.7	-80.6	-18.1	-83.9	-32.5	-86.4	-10.9	-88.1	-38.3
(C7299)		(216.5)	(252)	(210.5) -91.4 *	(245)	(208.5)	(237.5)	(207)	(249.5)	(206.5)	(234)
				(205)							
Radiator Inlet Temp, °F	(°K)	-1.22	18.3	4.9	23.2	4.9	34.0*	2.4	12.6	-8.4	2.5
(C7275)		(255)	(265.5)	(258)	(268) 34.2 *	(258)	(274.5)	(275.5)	(262)	(250.5)	(257)
					(274.5)						
Chiller Valve Outlet	39 ± 3			39.1	40.0	38.4	39.7	38.7	40.3	38.1	38.8
Temp, °F (C7296)	(277 ± 1.67)			(277.5)	(278)	(277)	(278)	(277)	(278)	(277)	(277)
(°K)											
Urine Chiller Temp, °F(°K)	59(288) Max			43.0	49.0	42.4	46.0	41.8	51.9	39.7	42.1
(C7000/C7002/C7004)	(CEI)			(279.5)	(283)	(279)	(281)	(278)	(284)	(278)	(279)
Frozen Food Temp, °F (°K)	-10° ± 10	-4.8	-0.6	-0.7	-16.1	-15.6	-4.8	-14.5	-1.7	-23.6**	-8.9
(C7283/C7284)	(250 ± 5.5) (CEI)	(253)	(255)	(255) 19.0 *	(246.5)	(247)	(253) 16.4 *	(247.5)	(249.5)	(242)	(250)
				(266)			(246.5)				
Urine Freezer Temp, °F(°K)	-2.5 Max (254)			-14.9	-6.2	-13.7	-8.3	-15.2	-6.2	-23.9	-17.5
	(CEI)			(247)	(252) 18.0 *		(250.5) 13.6 *	(247)	(252)	(242)	(245.5)
OWS Internal Environ-	RS designed	80.0	>120.0	75.0	(265) >120	78.0	(263) 97.0	72.0	82.0	63.0	72.0
mental Temp, °F (°K)	for 60 to 90 (289 to 305)	(300)	(322)	(297)	(322)	(298.5)	(309)	(295)	(300.5)	(290)	(295)

*Temperatures resulting from DOY 173 anomaly, reference para. 2.2.11.7D/4

**Temperature excursion as a result of low OWS internal environment, reference para. 2.2.11.7D/5

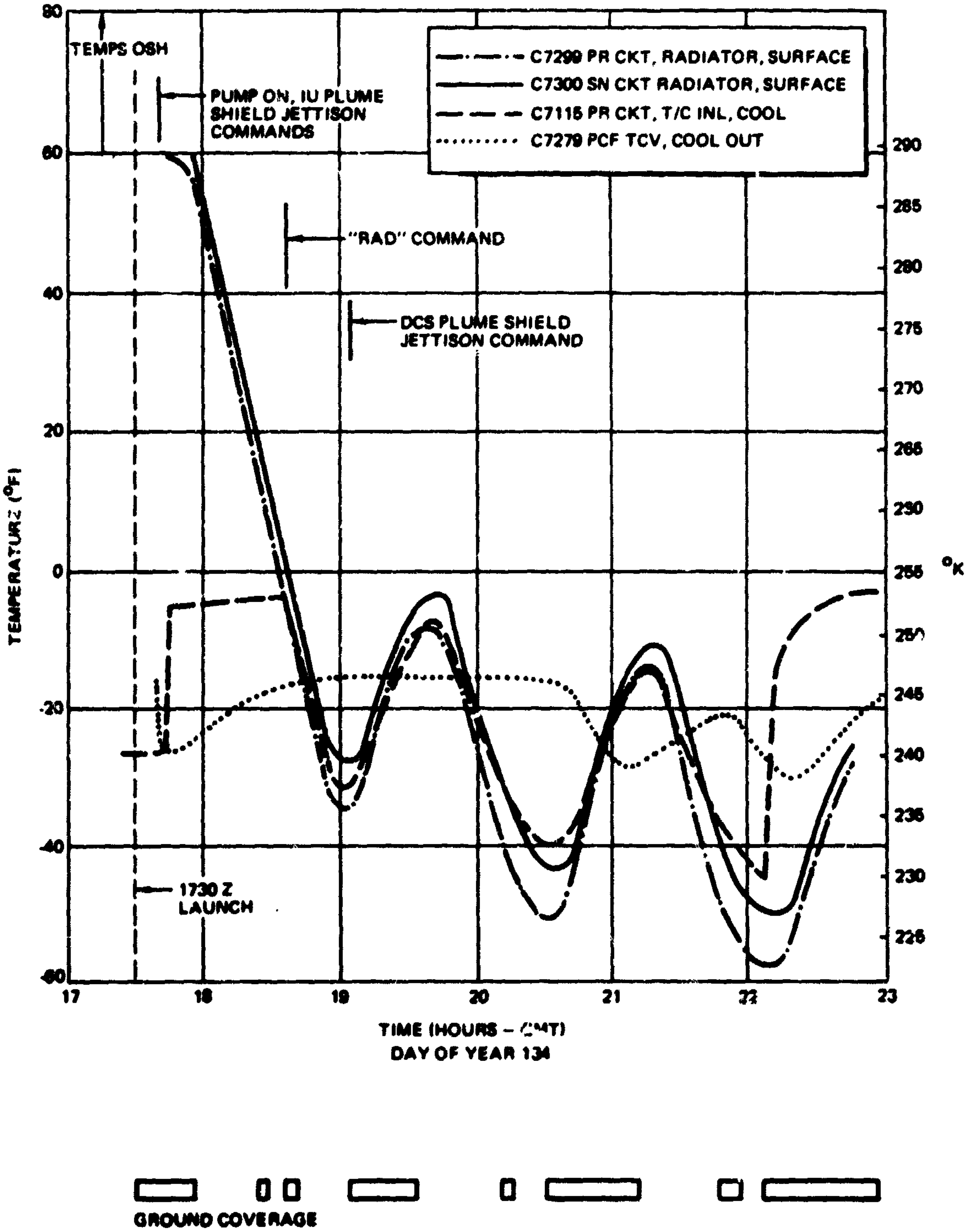


Figure 2.2.11.7.30 SL-1 REFRIGERATION SYSTEM DATA LAUNCH + 6 HOURS G.E.T.

Evaluation of this flight data from lift-off to approximately 6 hours GET indicates nominal refrigeration system performance. While the radiator plume shield jettison time could not be determined precisely from the available flight data, there was verification that the DCS command for shield jettison was sent at the nominal prescribed time (00:09:57.4 GET). Refrigeration system temperature data indicates the shield was jettisoned at, or near this nominal time. This conclusion is based on the following:

a. The RS bypass valve event data (K7326) indicated a switching event from bypass to radiator position consistent with the required PR CKT radiator surface temperature (C7299), and within the predicted elapsed time for a nominal shield jettison.

b. The slope of the PR CKT radiator surface temperature, C7299, (Figure 2.2.11.7-22) shows a continuous decreasing trend to its minimum during the first revolution, and follows the analytical and HS-19-1 predictions. A shield jettison at a time significantly later than nominal, but before the time of minimum radiator temperature, would appear as a change in slope at this jettison time. This slope change did not occur. Furthermore, a change in slope would result in a radiator temperature history that is inconsistent with the actual flight data.

c. A heat balance on the thermal capacitor from launch to first capacitor refreeze following launch further substantiates radiator surface temperature, capacitor inlet temperature and bypass valve event data. Any significant change in slope due to a late shield jettison, or failure to jettison, would not show a heat balance based on the thermal capacitor outlet temperature, C7279, for the same time span.

It should be noted that a backup DCS command was sent at 01:34:27 GET; however, jettison at this time could not have occurred based on evaluation of available data as indicated above.

- On DOY 136 and 137, various vehicle maneuvers were performed in order to lower the internal OWS environment. As a result, the RS radiator was positioned toward the sun. The maximum food freezer temperature, C7283, history is shown in Figures 2.2.11.7-31 and 2.2.11.7-32 for these periods, indicating the maximum CEI limit of 0°F (255.5°K) was not exceeded.

- Prior to DOY 173, the radiator bypass valve functioned normally as described in paragraph 2.2.11.7B. This is illustrated in Figure 2.2.11.7-33 showing a typical orbital cycle of the primary loop thermal capacitor inlet temperature during the early portion of the mission. As SL-2 progressed, the OWS internal ambient temperature decreased to a stabilized value. The radiator inlet (C7275) and outlet (C7299) temperatures subsequently lowered. Consequently, the radiator "Cold Bypass" cycle decreased to one per orbit.

- During SL-2 all the Z-LV (E) maneuvers were performed while the RS was coincidently in "Cold Bypass." Thus, the higher radiator heat flux due to these EREP maneuvers had no effect upon the internal RS temperatures (urine and food).

- Daily RS trend data for activation, EREP maneuver sequences, and deactivation periods for SL-3 is shown on Figures 2.2.11.7-34 through 2.2.11.7-38. During sequential EREP maneuvers, i.e., "back-to-back" EREP's within a 24-hour period, as illustrated on Figure 2.2.11.7-36, the RS maintained temperatures within their allowable limits. The maximum food temperature rise was under 5°F (258°K) with a 20-hour recovery. For a single EREP maneuver, the maximum rise was under 3°F (257°K) with an approximate 12-hour recovery.

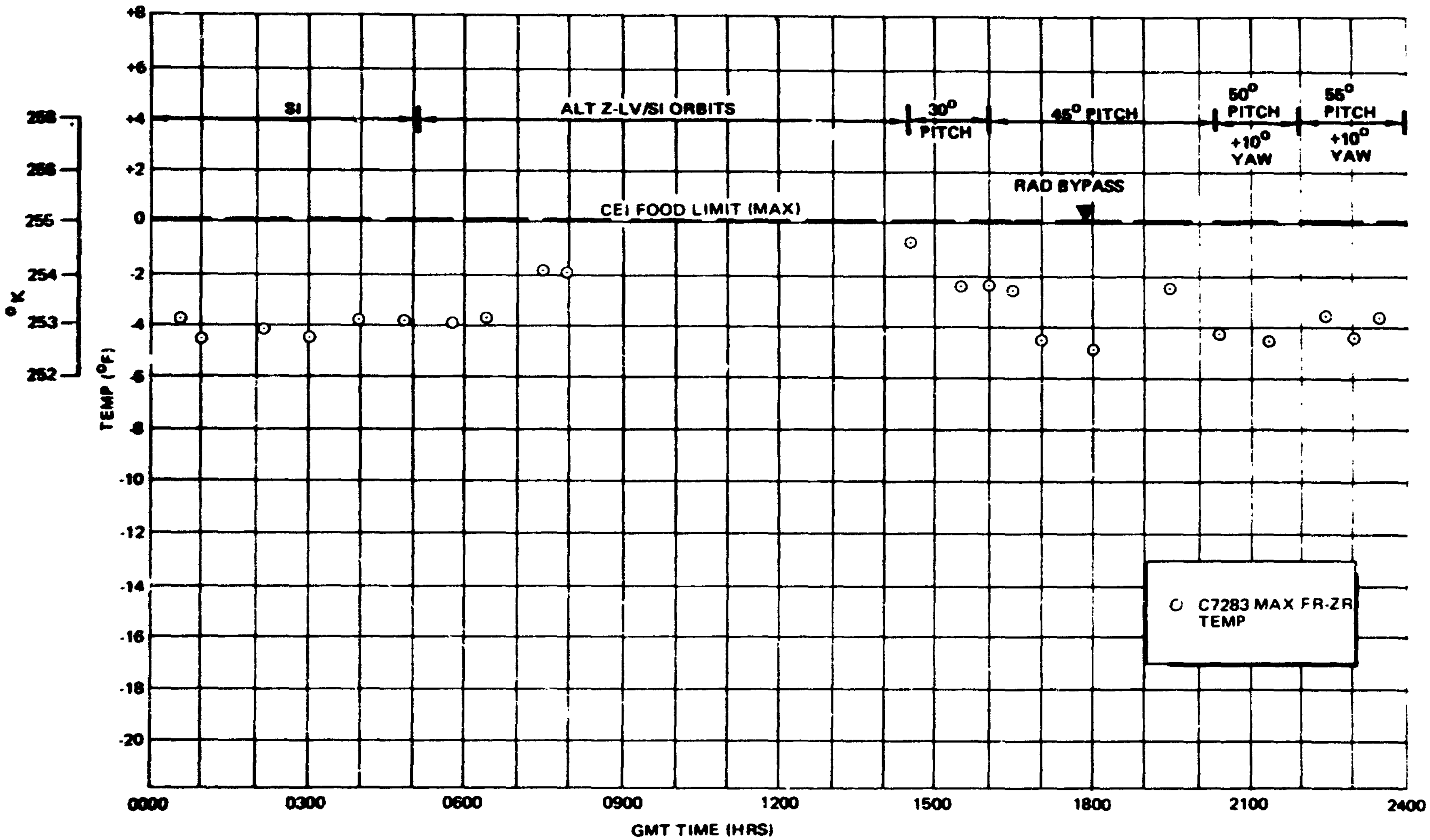


Figure 2.2.11.7-31. RS – Food Temperature History (Day 136 – 16 May 73)

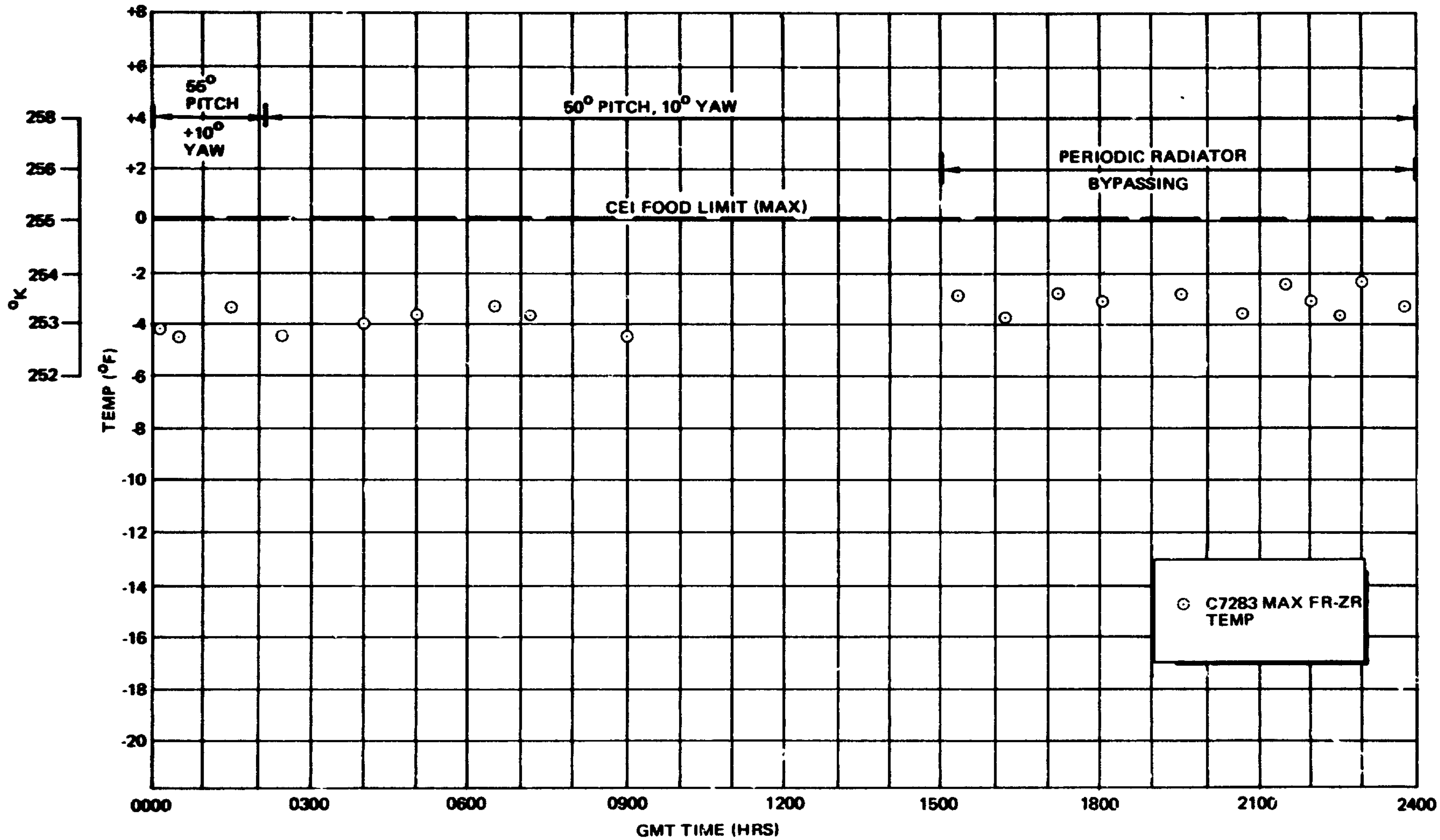


Figure 2.2.11.7-32. RS – Food Temperature History (Doy 137 – 17 May 73)

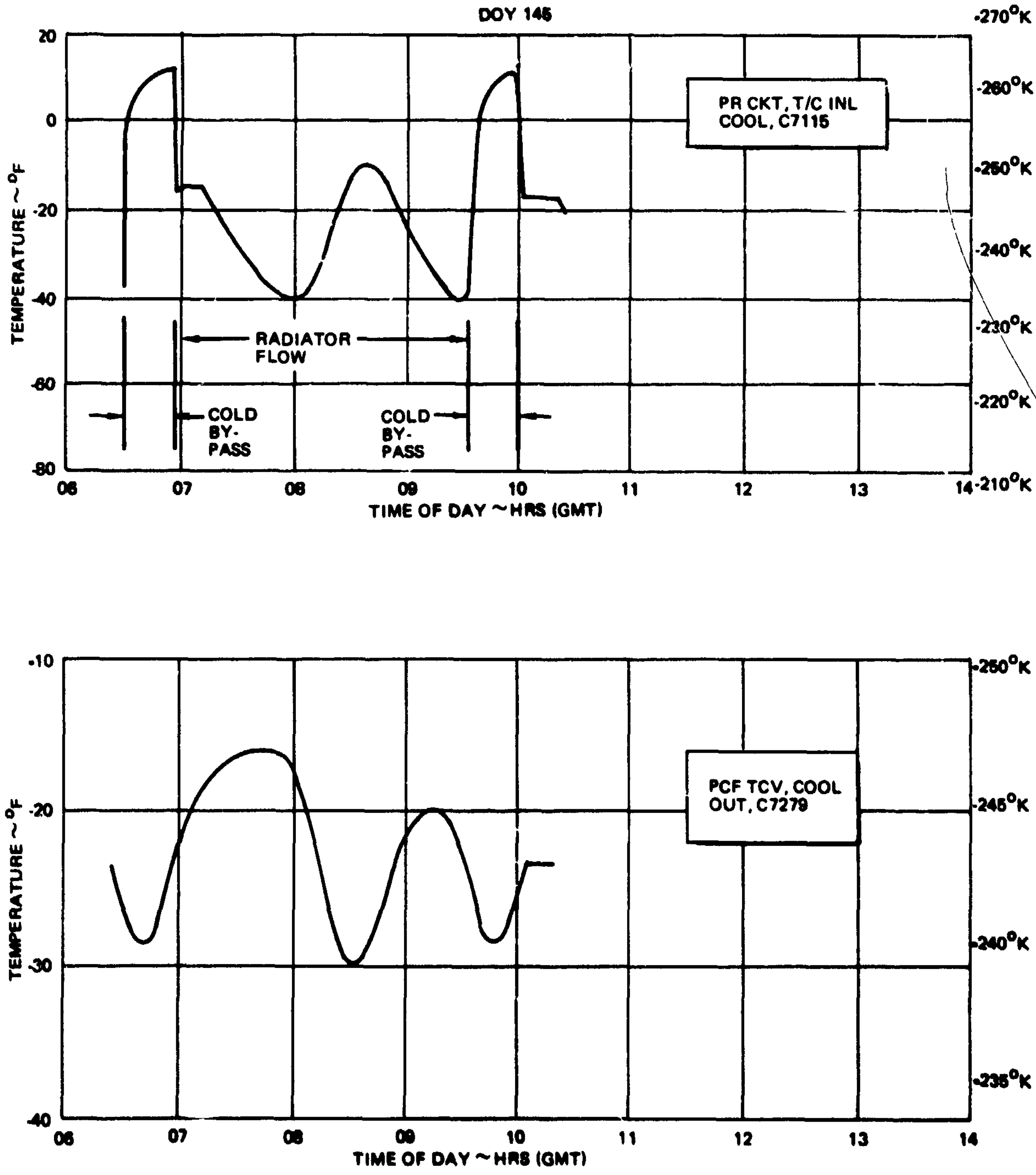


Figure 2.2.11.7-33. Radiator Bypass Valve Cycle

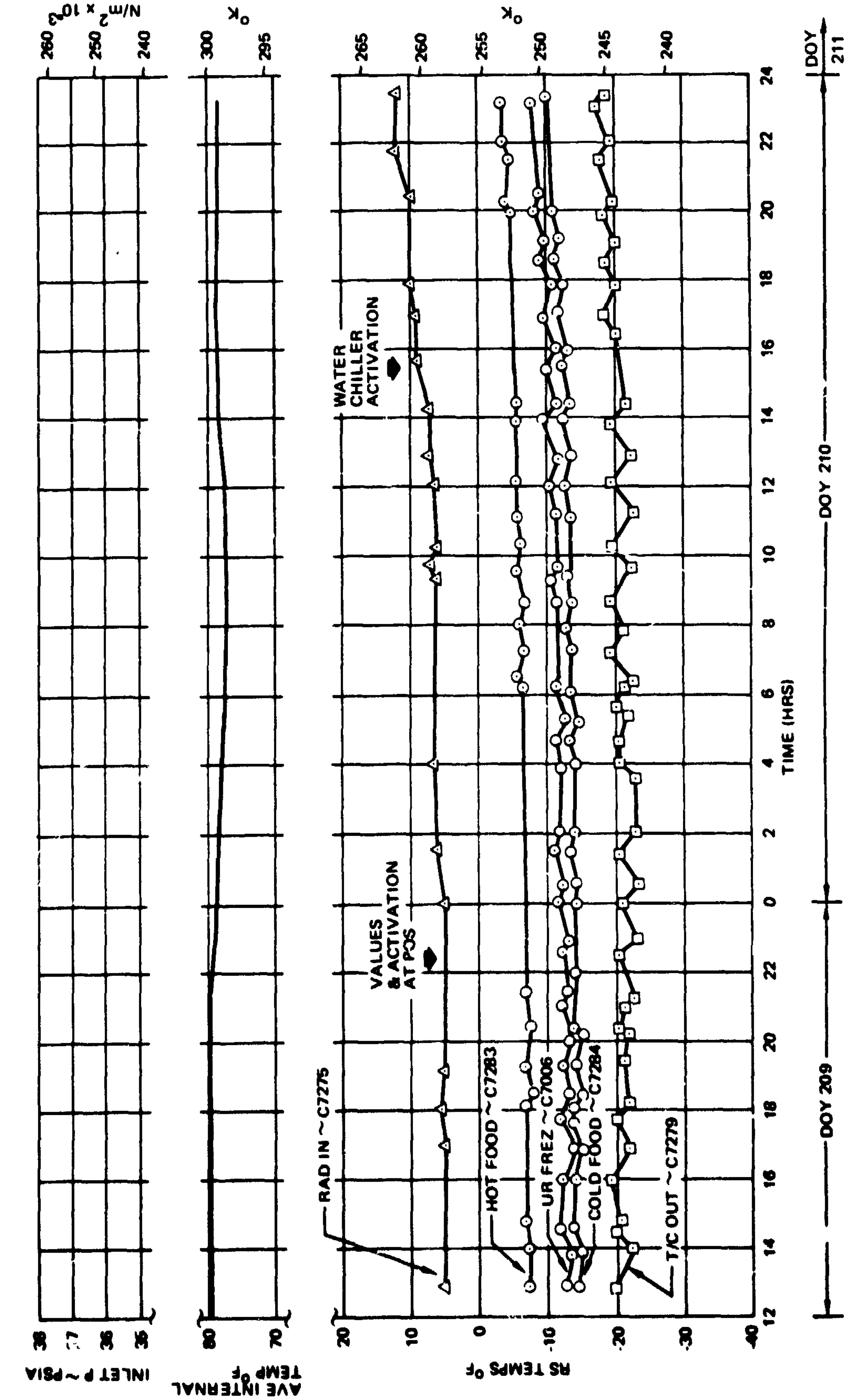


Figure 2.2.11.7-34. RS Performance Trend Data (Pre-Act./Act./Postact.)

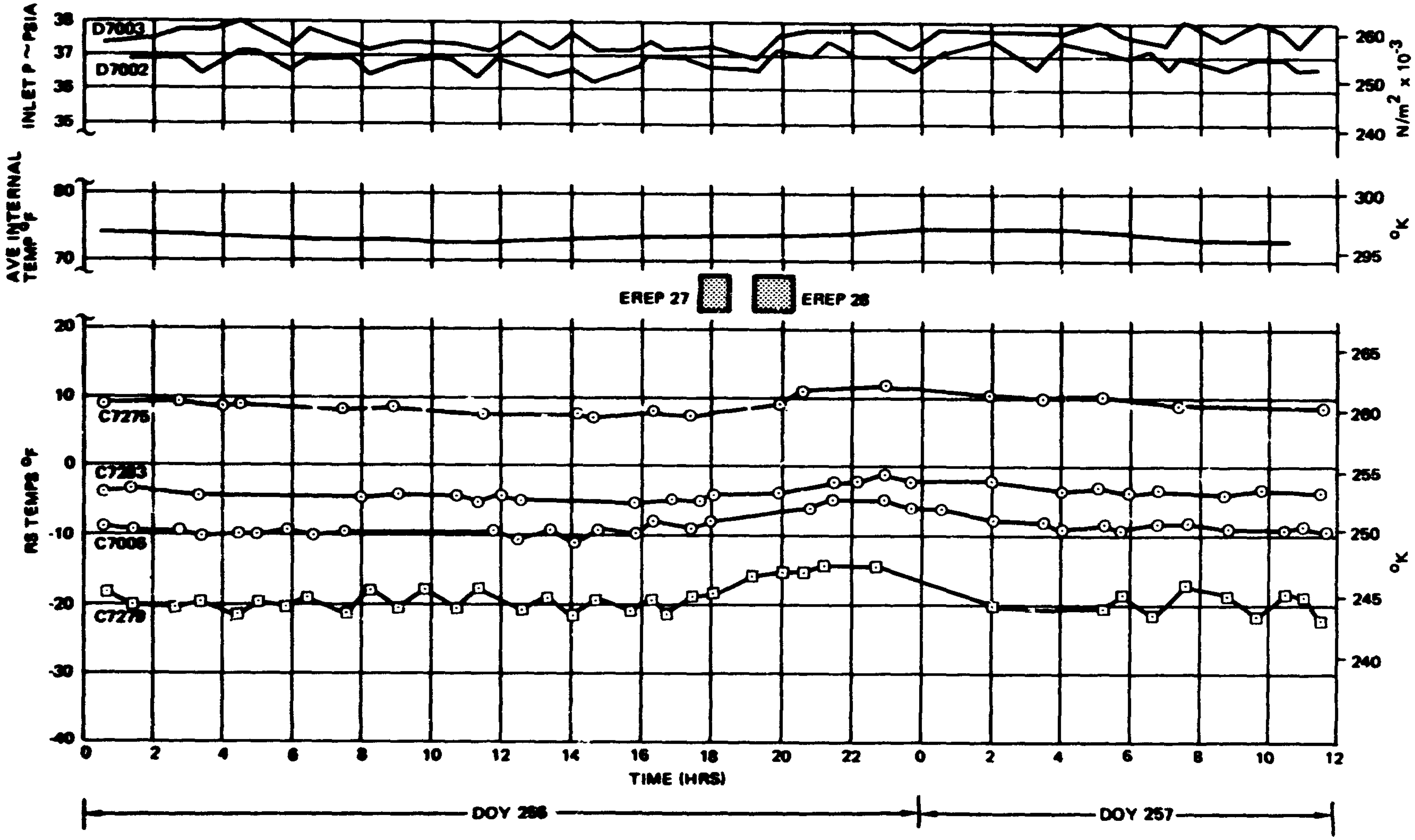


Figure 2.2.11.7-36. RS Performance Trend Data

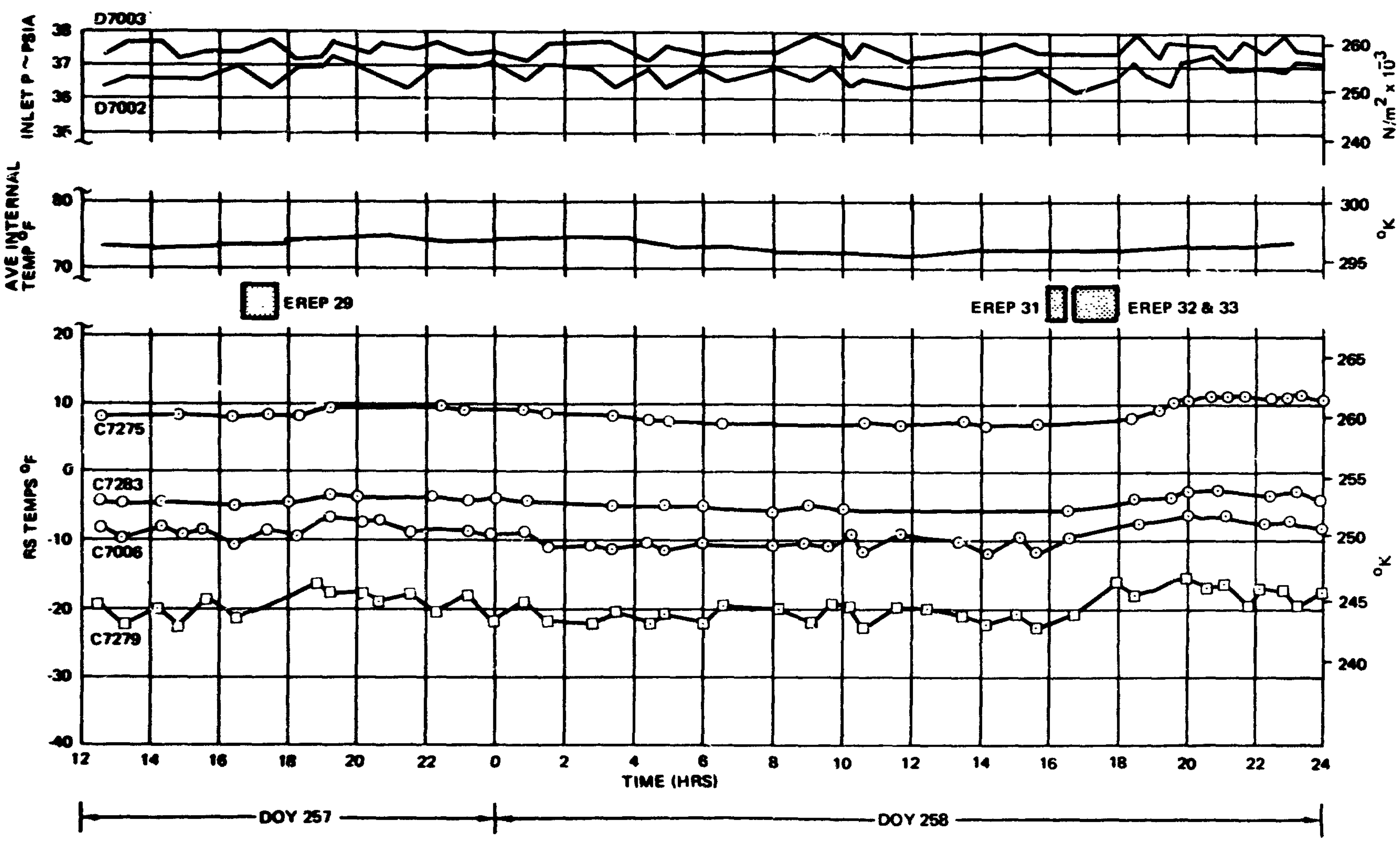


Figure 2.2.11.7-36. RS Performance Trend Data

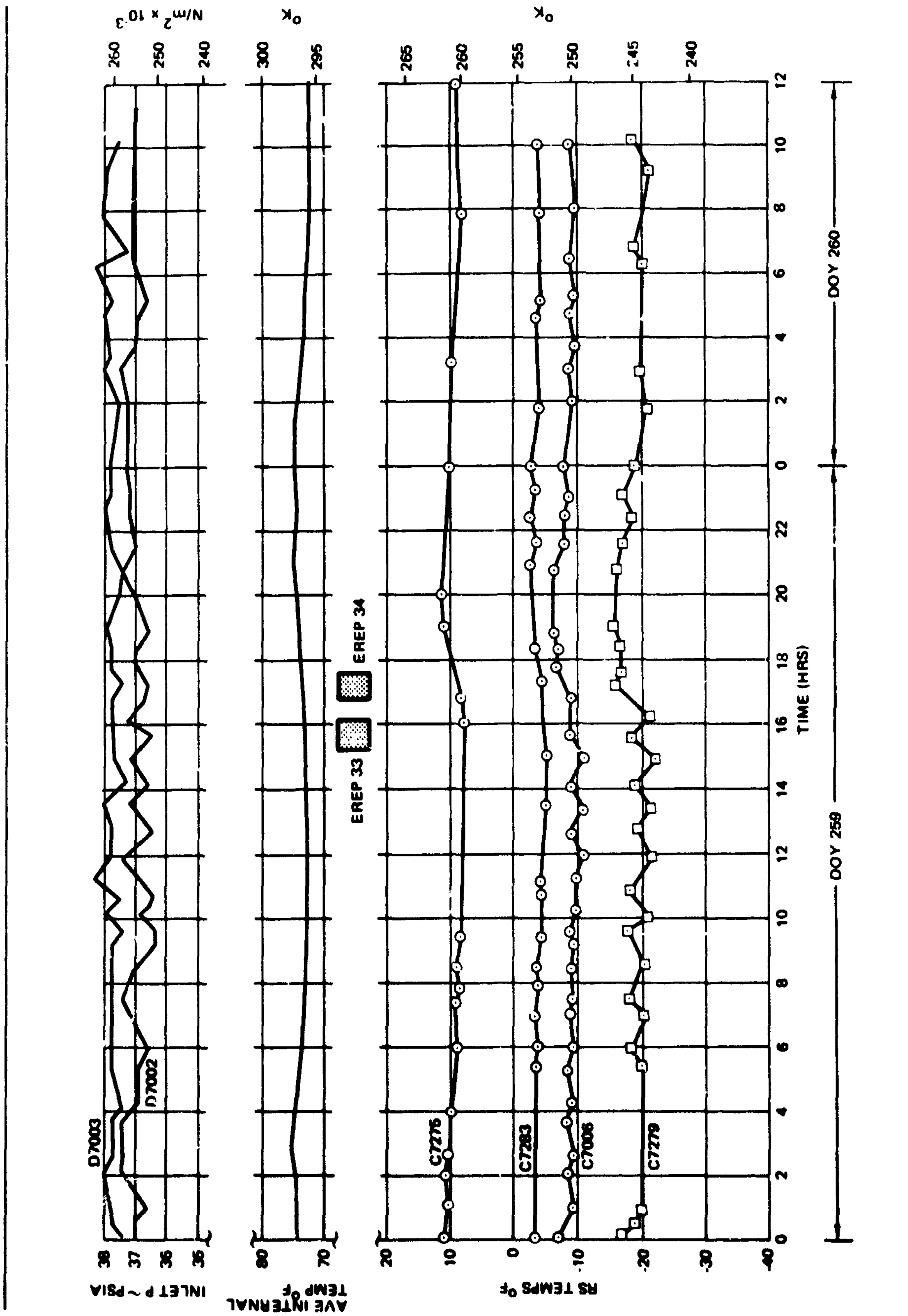


Figure 2.2.11.7-37. RS Performance Trend Data

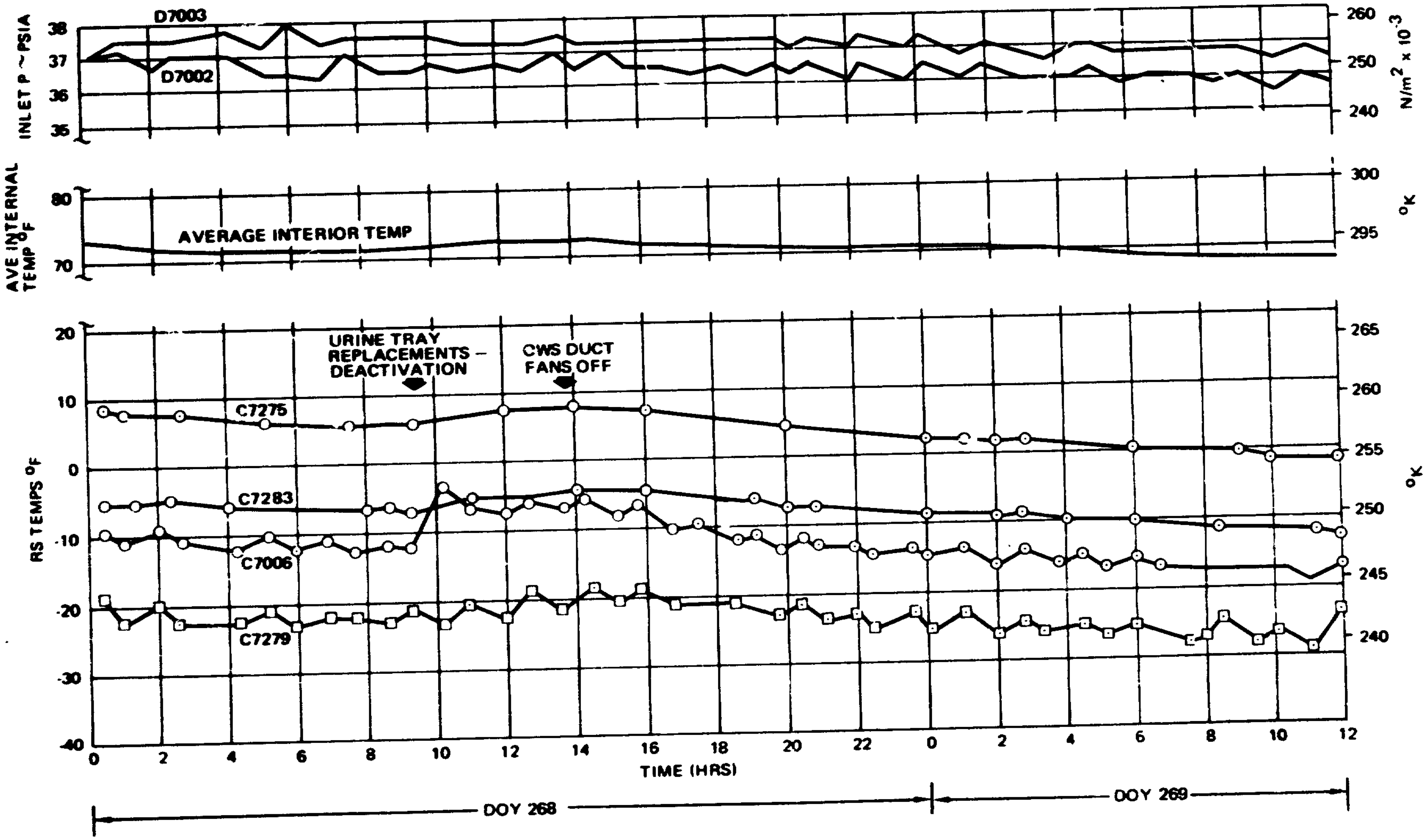


Figure 2.2.11.7-38. RS Performance Trend Data

2/ There was no apparent performance degradation or malfunction in any of the RS components other than the occurance of the anomaly on DOY 173. Summary of the major component performance characteristics are as follows:

- °The chiller control valve controlled within its required limits [39 $\pm$ 3°F (277.5 $\pm$ 1.67°K)] throughout the mission. Review of the chiller control valve outlet temperature trend, C7296, shown on Figures 2.2.11.7-20 and 2.2.11.7-24 does not indicate any performance degradation.

- °There was insufficient instrumentation to fully determine if radiator surface optical properties had degraded. However, the radiator surface temperature history (Figures 2.2.11.7-18 and 2.2.11.7-22) falls within a range that can be reasonably predicted for each portion of the mission (manned, unmanned; high, low β angle). Consequently, it has been concluded that there was no radiator degradation.

- °Primary loop pump number 1 accumulated 7270 hours running time which exceeded the qualification life of 2250 hours. Review of the pump ΔP, and of the system temperature difference (C7275 and C7279) as illustrated in the RS trend data, Figures 2.2.11.7-21 and 2.2.11.7-25, indicates no performance degradation. During SL-2, primary pump number 2 was operated for a total of 300 hours with no degradation of performance.

3/ Evaluation of the RS pressure and temperature data through the SL-3 mission indicates that there was no detectable Coolanol 15 leakage from either the primary or secondary coolant loops. Figures 2.2.11.7-39 through 2.2.11.7-42 are plots of 10-day average leakage tracking data for both RS loops. As shown, both loops have essentially constant "measurement error" and are well within the band of measurement tolerance. The allowable RS leakage rate is less than the allowable 12 in.^{3}/yr (19.65 x 10^{-5}m^3/yr).

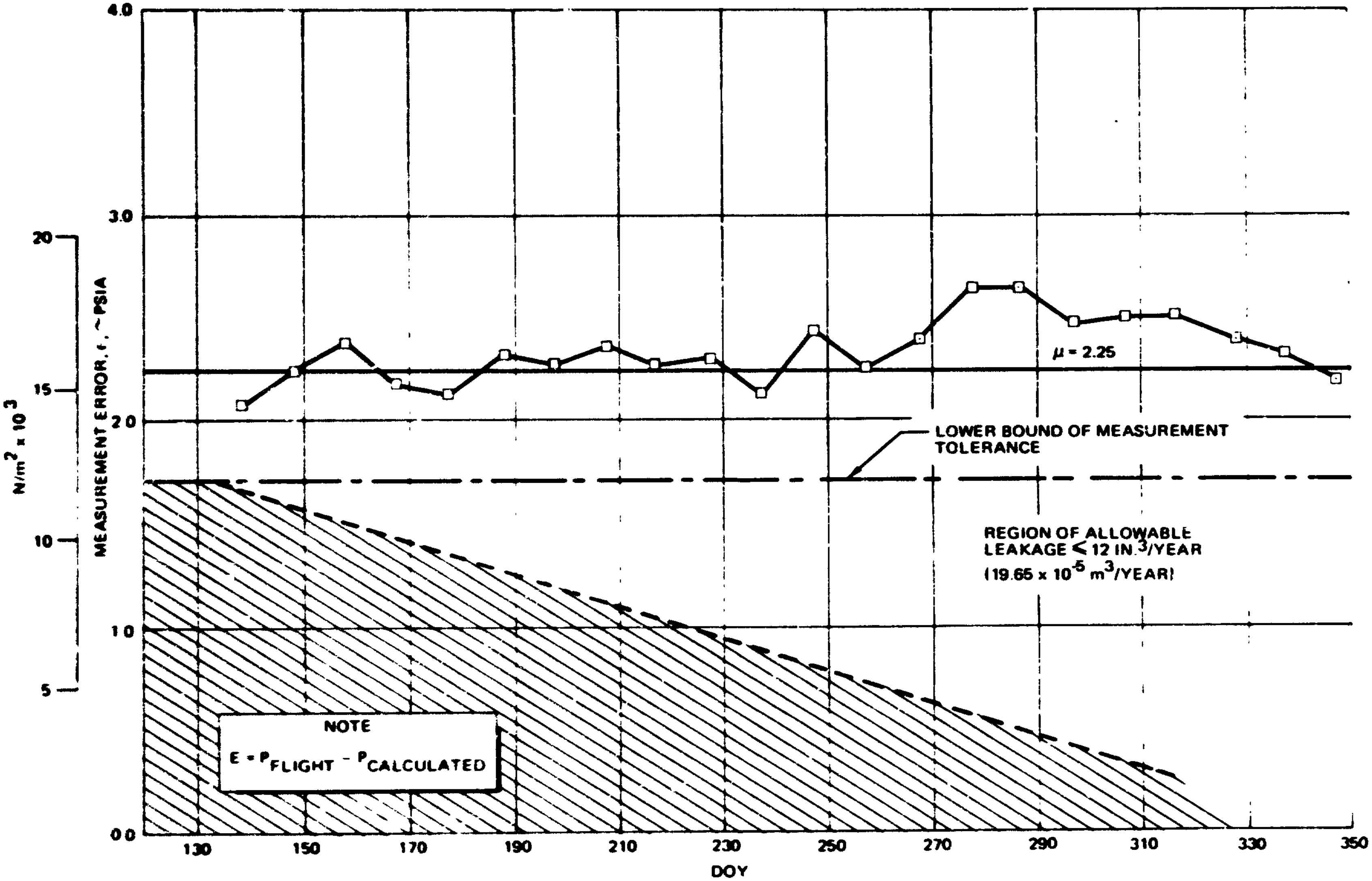


Figure 2.2.11.7-39. Refrigeration System Secondary Loop Leakage Tracking 10 Day ε Averages

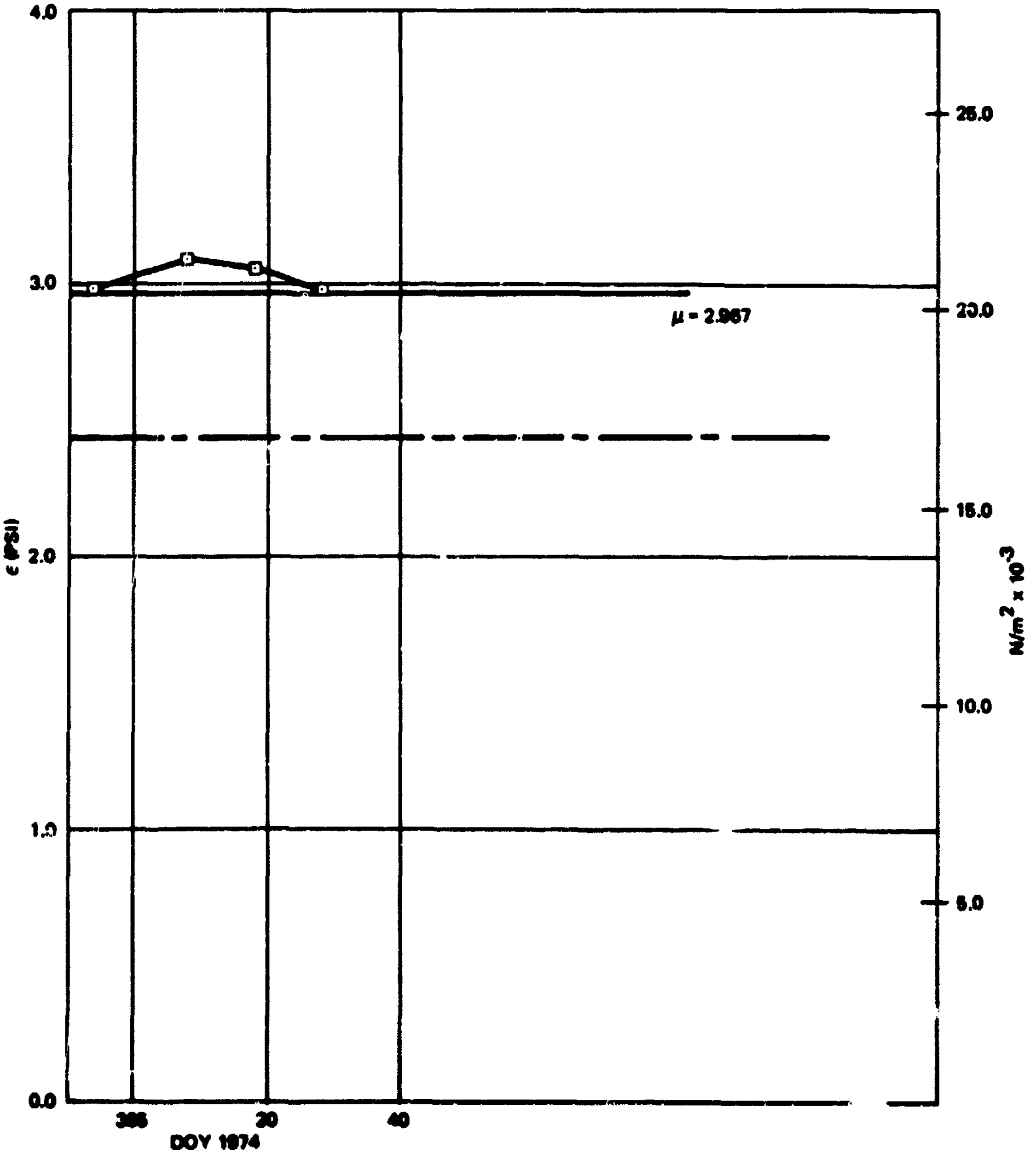


Figure 2.2.11.7-40. OWS Refrigeration System Primary Loop Leakage 10 Day ε Averages

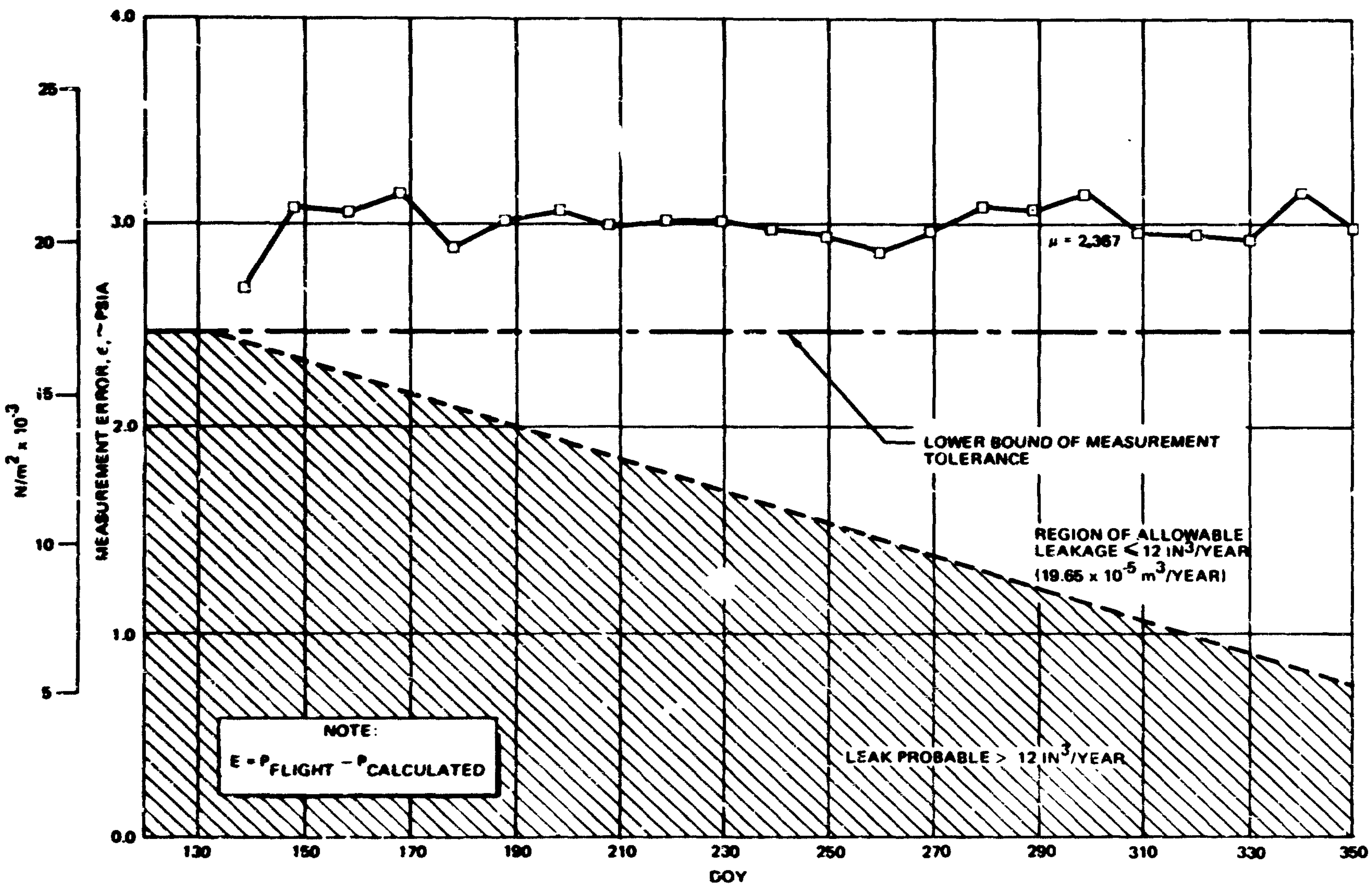


Figure 2.2.11.7-41. Refrigeration System Primary Loop Leakage Tracking 10 Day ε Averages

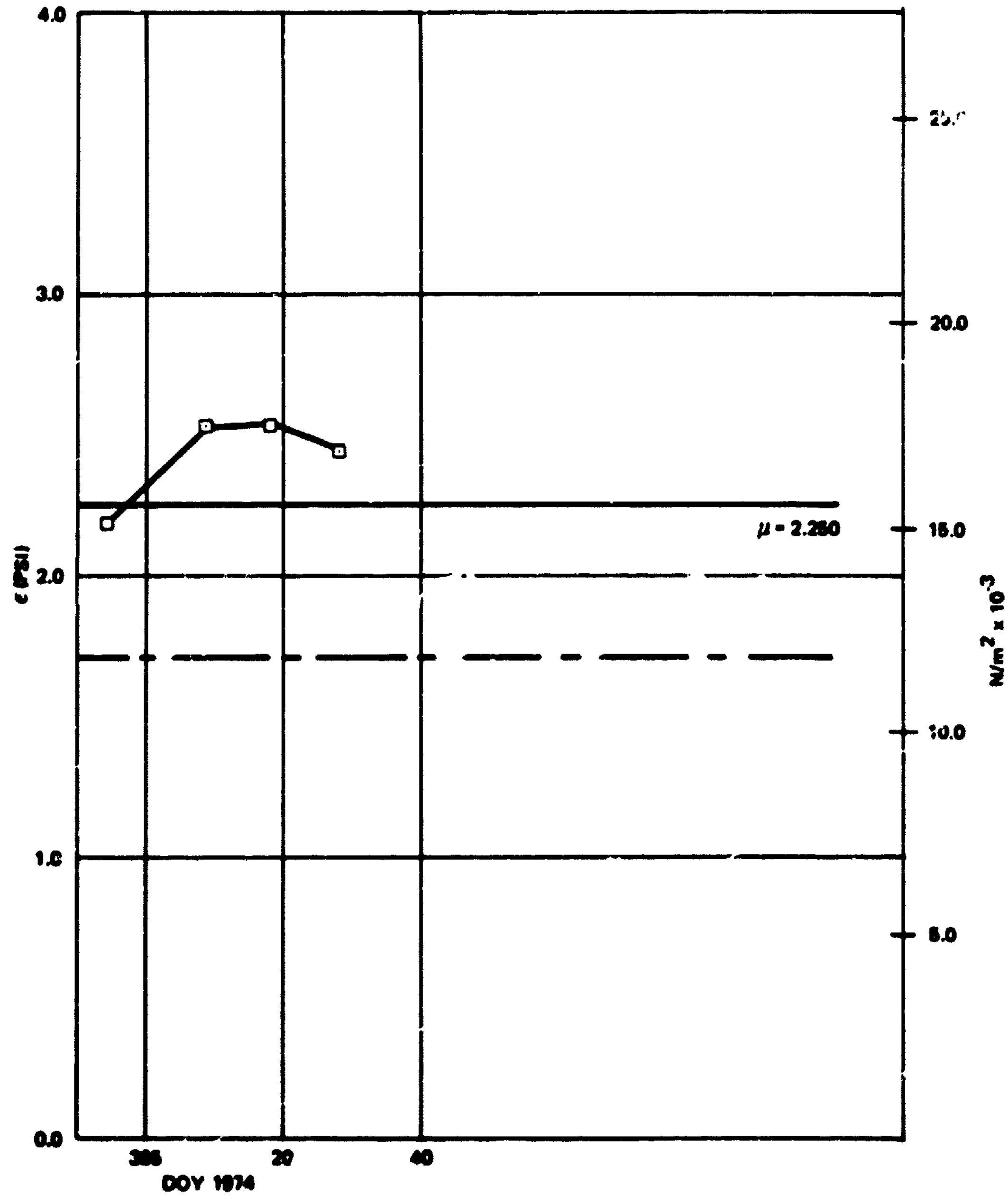


Figure 2.2.11.7-42. OWS Refrigeration System Seco· ·ary Loop Leakage 10 Day ε Averages

The method of predicting RS leakage was:

a. The loop pump inlet pressure was calculated based on a weighted average loop temperature distribution from flight data, and the known accumulator performance.

b. This calculated pump inlet pressure was compared to the flight recorded pressure. The average difference, based on sampled data for DOYs 176 to 219, was found to be 2.967 psi (20.45 kN/m^2) lower than flight pressure for the primary loop, and 2.25 psi (15.53 kN/m^2) lower for the secondary.

c. The "lower band of measurement tolerance" shown in Figures 2.2.7.11-39 through 2.2.7.11-42 includes the pressure transducer least bit error and a 0.3 psi(2.07 kN/m^2) pressure transducer repeatibility. Data above this "lower band of measurement tolerance line" indicates no detectable coolant leakage.

4/ Refrigeration System Operation was nominal until DOY 173. The only prior reported concern was during Mission Day 9, when the CDR reported that two of the crewmen had been awakened by a pitch change attributed to one of the motors in the cluster. A middle of the night search indicated to the crew that the change was centered in the area of the RS pump package.

An evaluation of possible causes for the pitch change was made. Refrigeration System data indicate normal system performance during the time in question. Past experience indicates that small changes in pump current are not detectable from TM data due to resolution and sample rate. Possible causes for a change in pump frequency are:

a. Pump response to change in ΔP caused by valve switching from bypass to radiator. Valve switching took place twice per orbit. The valve typically remained in the radiator position for 60 minutes and in the bypass mode for approximately 34 minutes. Switching did occur during the time of the crew report, as expected.

b. Previously observed momentary changes in inverter characteristics significant enough to cause an audible change in pump operation have not resulted in detectable changes in system performance via telemetry. These changes in inverter characteristics (related to noise induced clock pulses) were momentary rather than steady state as reported by the crew. None of the above noted changes were observed (during screening or KSC checkout) from the present flight inverters.

Because no degradation of system performance could be associated with the pitch change, the decision was made to continue using Primary Loop Pump 1. Refrigeration System performance was nominal during Primary Loop Pump switching from Pump #1 to Pump #2 on Mission Day 16.

The crew performed the procedure properly at 18:17Z and Primary Loop Pump 2 was activated by the onboard logic as Pump 1 flow and ΔP decreased in response to the crew's operation of the pump switch (PNL 616). No interruption of flow or ΔP decrease was detected via T/M.

Data obtained via MOPS indicated that at approximately 173:02:03 (at a time when a radiator bypass valve switched from bypass to radiator position was expected) an abrupt decrease in pump delta pressure was noted. This decrease indicated that the flow path of the coolant had suddently changed but not in the expected manner (a change to the radiator position would exhibit a rapid increase in delta pressure). Subsequent to this event, the thermal capacitor inlet temperature began a rapid rise. This event led to thawing of the thermal capacitor and the refrigeration system freezers eventually exceeded specification.

The onboard logic eventually sensed this failure and switched loops when the food freezer inlet temperature reached 1°F (256°K). However, the secondary loop, while operating for approximately 45 minutes, exhibited more rapid temperature rises than the primary.

A radiator freezeup was suspected because the Skylab was approaching the maximum β angle which results in the coldest RS radiator radiation environment. A decision was made to pitch the radiator into the sun (approximately 45°) to warm (and possibly thaw) the radiator coolant.

Significant radiator surface warming was indicated by approximately 6:40 GMT, DOY 173, with the maximum radiator surface temperature reaching approximately -20°F (244.5°K) before the SWS was returned to the solar inertial orientation at approximately 7:40 GMT, DOY 173. There was no apparent improvement in performance as a result of the maneuver.

Since the suspected low flow condition in the radiator may also have been caused by a malfunctioning bypass valve and/or the radiator relief valve, Ground Control decided to function the only components they had control of (Radiator Bypass Valve and Loop Flow).

The radiator bypass valve was cycled by enabling and disabling the primary loop by ground command, with the secondary loop disabled. This was done during the remainder of DOY 173 and the first 11 hours of 174. When a loop is disabled, the bypass valve switches to the bypass position and when a loop is enabled, the logic votes and in this case, switches it to the radiator position. Therefore, this loop switching resulted in cycling the bypass valve. The primary loop was cycled 113 times and the secondary loop 41 times before the primary loop pump 1 was allowed to run continuously beginning at 174:10:50:20. Average system temperatures began to exhibit a slow but consistent decrease.

By DOY 194, a thermal capacitor inlet temperature (C7115 was cycling between -14 and -24°F (247.5 and 242°K), the urine freezer was cycling between -11 and -13°F (255 and 253.5°K) and food freezers varied between -6 and -15°F (252 and 247°K). The radiator bypass valve never again automatically cycled to the bypass position.

The onset of refrigeration system temperature excursions was accompanied by a 5 psid (34.5 kN/m^2) drop in system differential pressure which indicated a possible fluid flow path around the refrigeration system radiator. Calculations using flight data indicated that approximately 35% to 68% of the total expected flow [125 lb/hr (56.7 kg/hr)] was passing through the radiator.

Preliminary test results using the HS-19 refrigeration system test specimen indicated that approximately 35% to 55% of the total expected radiator flow was required to duplicate flight temperature data. (The test radiator bypass valve was outfitted with a poppet micrometer adjustment).

It appeared from the above data that coolant flow was being bypassed around the radiator and was mixing with the reduced quantity of radiator flow prior to entering the thermal capacitor. The net result was a higher temperature of fluid entering the thermal capacitor.

Analytical results, using the G189 refrigeration system math model, were able to duplicate observed data and to predict expected on-orbit performance. A probable cause was leakage past the bypass poppet seat with the valve positioned in the radiator flow position.

Pressure drop and flow data developed in a radiator bypass valve test indicated the potential for large bypass leakage flows [greater than 20 lb/hr (9.08 kg/hr) for a relatively small displacement of the poppet off its sealing seat. Bypass valve seat openings in excess of 25 microns could cause significant valve leakage and would account for the observed on-orbit system performance.

The sensitivity of the radiator bypass valve to flow and external valve pressure drop is documented in AI 299-R29. The valve proved to be insensitive to flow forces so far as poppet movement was concerned.

The sensitivity of the bypass valve to particulate contamination was evaluated. Results for a 400 MIL-STD-1246A particle distribution, which is greater than refrigeration system design requirements, indicated that a force of approximately 0.13 lbs (.578 N) would be required to seal a contaminated seat. The bypass return spring force available has been calculated to be 0.5 lbs (2.22 N).

The HS-19 refrigeration system test specimen was used to duplicate on-orbit temperatures by bypassing fluid around the radiator. Predicted performance for the actuation sequence for SL-3 was determined. No adverse effects on the RS during activation was expected, nor did any occur.

5/ Following the anomaly on DOY 173, the radiator bypass valve circuit breaker was "opened." This prevented the valve from switching from the radiator position. Consequently the frozen food temperature varied as a function of OWS internal environment. Refer to Figure 2.2.11.7-43. During the unmanned portion of SL-3, the OWS internal temperature dropped to approximately 63°F (291°K). Consequently, the food temperatures oscillated about the specification limit, as indicated in Figure 2.2.11.7-43. Prior to SL-4 activation, the coldest freezer returned within specification limits due to an increase in OWS internal temperatures.

6/ During SL-4, MD 65 (DOY 019), the food storage freezer temperature C7283 exceeded 0°F (255.5°K) by approximately 1.0°F (.55°K) for a short period. This was due to an increase in OWS internal environment above 80°F (244°K). The food freezer temperatures vary directly as a function of the OWS internal environment - reference para 2.2.11.7.D/5. However, this short food freezer temperature excursion above 0°F (255.5°K) was of no consequence as all of the remaining frozen food at this concluding portion of the mission was stored in the wardroom freezer. During this period the wardroom freezer temperatures were below 0°F (255.5°K).

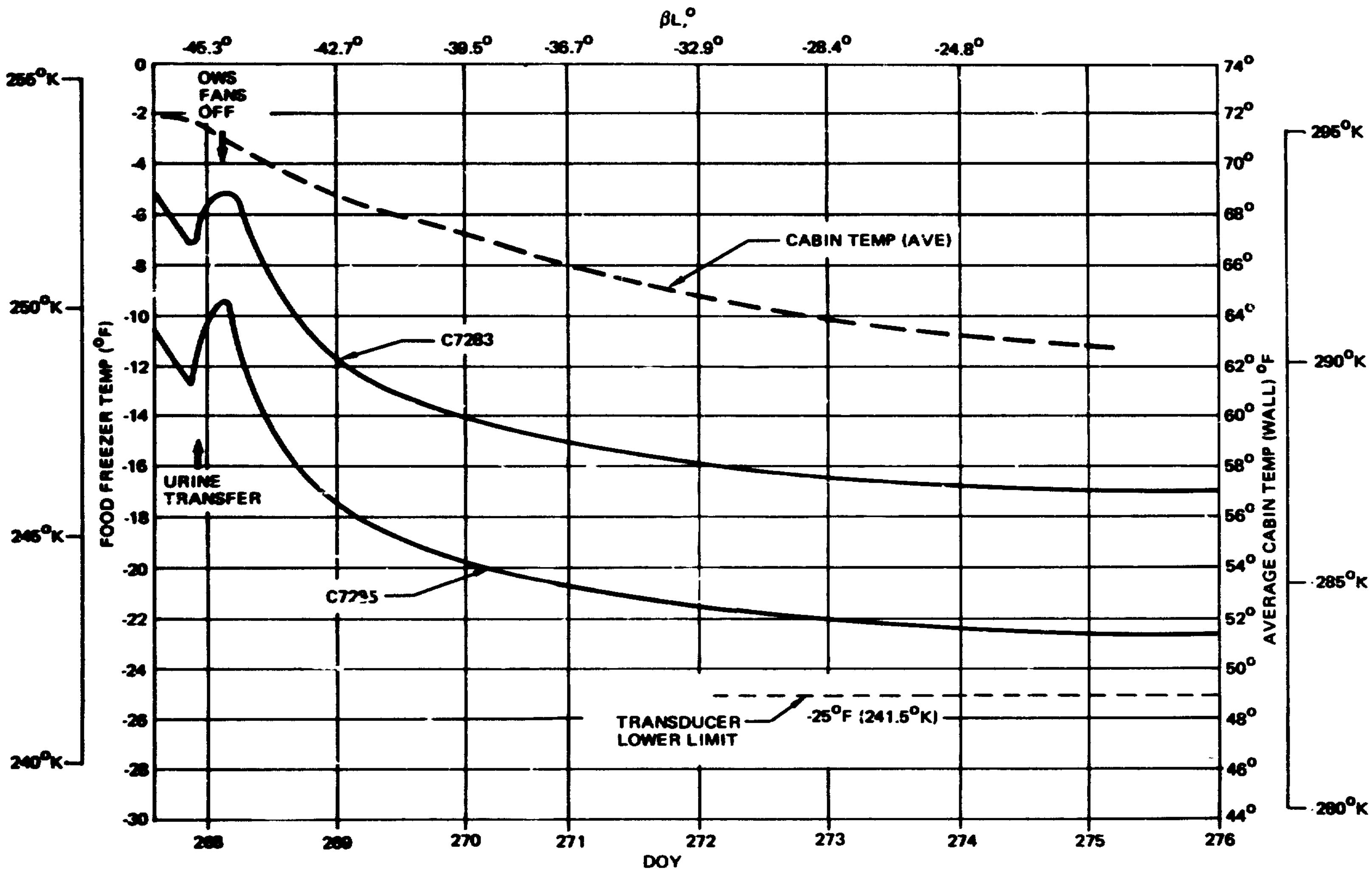


Figure 2.2.11.7-43. Refrigeration System Food Freezer Temperature Trend

7/ During SL-4 de-activation procedures on DOY 039 there was a real time indication of possible movement of the primary refrigeration system loop bypass valve.

It was reported during the SL-4 crew debriefing that the Refrigeration System post mission test setup procedure during DOY 039 was done correctly per procedure by positioning the primary loop bypass valve circuit breaker to "closed." It is assumed that this occurred at 03:52:24.

The following is an explanation based on available Mission Operations Planning System (MOPS) data, of the temperature, pressure and event trends which occurred after C/B activation.

a. Prior to 039:03:52:23, the RS performance was the same as that observed following the SL-3 activation, i.e., temperatures were within specification, the primary loop bypass valve circuit breaker was open, and the valve was locked in the radiator position. K7326 indicated BYP, which was normal with power removed from the valve controller.

b. It is assumed that at 039:03:52:24, the crew moved the valve circuit breaker to "closed", at which time K7326 indicated NOR. This was a proper indication since the valve had been in radiator position since DOY 173.

c. At 039:03:52:25, for some unexplained electrical and/or mechanical reason, the valve moved towards, or to the bypass position (K7326 indicated BYP). This appears to be a valid conclusion since the system delta pressure (D7001) decreased 2 psid (13.8 kN/m^2) from 32 psid (220.4 kN/m^2) to 29/30 psid (200/207 kN/m^2). Later events substantiate a valve movement.

d. Between 039:03:52:52 and 039:04:55:00, the delta pressure remained constant at 30/31 psid (207/214 kN/m^2) but the T Cap out temperature (C7279) warmed from -23.1 to 15.6°F (242.5 to 246.7°K), the melt temperature of the capacitor wax. This is consistent with the valve in bypass position as indicated by K7326 = BYP. The radiator inlet temperature (C7275) appears to have increased very little, from 7.0 to 7.7°F (259.2 to 259.7°K).

e. At 039:04:55:27, the valve position changed from BYP to NOR (K7326) and the system delta pressure simultaneously jumped approximately 7 psid (48.2 kN/m^2) to 37/38 psid (255/262 kN/m^2). These are normal system responses if the capacitor was in a melting condition and the temperature of the control sensors at the T Cap first segment outlet reached -12°F (248.7°K). Analysis of the end-of-mission test results led to the conclusion that a split flow condition also existed with the valve in the BYP position (valve poppets possibly both open simultaneously). Such a flow split could explain why it took 1:03 hours to get the -12°F (248.7°K) thermal capacitor signal which normally causes the bypass valve to move to the full radiator position. A full bypass flow would normally melt the first segment of the thermal capacitor in approximately 30 minutes with T Cap in=7.7°F (259.7°K). A split flow with a radiator/bypass flow mix of about -10°F (249.8°K) could account for the 1:03 hour bypass time.

With respect to paragraph c. above, there is one possibility that could cause the system to react as noted. When power was applied to the bypass valve controller, the initial "radiator" indication is valid. However, system reaction is as follows:

- o Bypass valve controller monitor comes up looking for a bypass signal.
- o The sensing bridges in the controller could have come up requesting bypass. This combination would then cause an immediate switch to bypass. The system would continue to operate in the bypass mode until the sensors internal to the thermal capacitor warmed to -12°F (248.7°K) requested radiator approximately one hour later as indicated by the data. The sensors, being basically resistive in response, could have randomly sent a bypass signal since they were temperature-wise closer to a cold bypass [-34°F ± 2°F (236.5 ± 1.1°K)], than a radiator request at -12° ± 2°F (248.7 ± 1.1°K). It is estimated that at turn-on with a thermal cap outlet temperature (C7279) of -23°F (242.6°K), the internal temperature of the thermal capacitor was approximately -26 to -28°F (240.9 to 239.8°K). This might cause the sensing bridges in the controller to request bypass at turn-on. This is a random type occurence. However, testing on the OWS backup controller showed that in whichever state the controller was found to come on (bypass or radiator), it would always thereafter come on in that mode. It, therefore, appears possible that the primary bypass valve controller would always come on looking for a bypass signal, and dependent on the thermal capacitors temperature, could have gone to the bypass position.

8/ Refrigeration System (RS) - End of mission (EOM) tests were performed to: (1) further evaluate system performance and to (2) determine whether the primary and secondary loop radiator bypass valves can be returned to their normal mode of operation. In order to accomplish (1), the system was operated for 2 hrs 45 min 45 sec (39:17:13.0 to 39:19:58:58 GMT) with both the primary and secondary loops running and then 3 hrs 49 min 17 sec (39:19:58:58 to 39:23:48:15 GMT) with the secondary loop only running. During the dual loop operation no trend of increased performance was noted. During secondary loop only operation data indicated that the thermal capacitor was melting and a split flow condition, worse than noted in the primary loop, existed. In addition, secondary loop performance was not sufficient to sustain the loop within prescribed limits. At 39:23:49:18 GMT the primary loop RS flush procedure was initiated and at 40:01:38:25 GMT the secondary loop flush procedure was initiated. After completion of the RS primary and secondary loop flushes, the split flow condition still existed and system performance did not improve.

9/ The pertinent RS action items are summarized for SL-1 through SL-3 in Tables 2.2.11.7-8 and 2.2.11.7-9.

RS ACTION ITEMS
SL-1 AND SL-2

ACTION ITEM	DESCRIPTION	REMARKS
004	Radiator Shield Jettison	Shield jettison backup command.
005	OWS constraints assuming loss of SAS and Meteoroid Shield	Turn off selected RS electrical components to save power.
010 A and B	Effects of One X-SI Orbit Followed by Several X-45° Orbits	Adequate time for real-time assessment of RS performance.
012-1	OWS Power Down Requirements	Defines RS electrical power consumption.
016	Alternate Z-LV and SI Orbits	System in a "net melting" condition and T Cap "melt-out" will occur.
		Recommends against losing RS redundancy.
020-2	Power Down Scrub	
020-3	45° Off Solar Inertial	Probably ok since ambient temperature is lower than in AI 010B response.
028	Refrigeration System Shutdown	Specifies RS components likely to burst if temperature of system exceeds safe temperature of 91°F (306°K).
031	Attitude Requirement for Best OWS Temperature Profile	-50° pitch attitude better than alternating SI and Z-LV orbits.
038	Impact of +50° Pitch SI Attitude on RS	T Cap melts after three orbits and food temperatures should rise at 4°F/hr (2.22°K/hr).
040	SL-2 Launch on 5-25 (DOY 145)	No RS impact providing no significant changes in environment or vehicle attitude.

TABLE 2.2.11.7-8

RS ACTION ITEMS
SL-1 AND SL-2

ACTION ITEM	DESCRIPTION	REMARKS
047	Skylab Attitude Until SL-2 Rendezvous	Use alternating Z-LV/SI. Return to -50° off SI when RS warming trend puts food temperatures in jeopardy.
049-1	CSM Plume Impingement on Radiator	No effect on radiator optical properties based on results of previous Apollo post-flight data.
053-R2	Mission Day 1 Flight Plan Review	Request Fly-around to examine main tunnel integrity as result of apparant high heat leak.
098 R1	Mission Day 1 Flight Plan Review	28° roll maneuver raises temperature of RS logic modules above qualification levels but is assessed as acceptable.
138 R1	Identify All Hardlines in Main and Aux Tunnels	No RS lines in Aux tunnel. Describes supply and return lines in main tunnel.
142	±20° Roll Maneuver	RS pump logic modules will go out of qualification temperature limits in 2-hours.
204	Refrigeration Pump Frequency Change	Comments on possible causes that could result in an audible and discernible change in pump frequency. No conclusion.
211	Power Down Candidates	Lists several primary and secondary RS electrical components as candidates.
238	Refrigeration System Primary Pump No. 1	Recommends switching from primary pump No. 1 to primary pump No. 2 by Mission Day 24-26 (DOY 168 - 170).
253	Verification of Normal RS Radiator Cover Jettison	Review of data indicated radiator shield was 1) not released prematurely and 2) was released at or very close to nominal time.

TABLE 2.2.11.7-8

RS ACTION ITEMS
SL-1 AND SL-2

ACTION ITEM	DESCRIPTION	REMARKS
299 and all revisions	RS Failure	DOY 173 anomaly: analyses, tests, troubleshooting, procedures, etc.
300	Alternate Freezer Concepts	Provides several concepts to circumvent urine freezer problems that may result from DOY 173 RS anomaly.
300 R1	Passive Urine Freezer System Preliminary Design	Provides one week preliminary design study of urine freezer utilizing anti-solar SAL.
306	OWS System Performance/Anomaly Summary	Summarizes three RS anomalies (DOY 149, 153, 173) and SL-3 readiness.
310	Flight Mission Rules	Proposes revisions to rules 6-108 and 6-113.
318	Freezer Contents - Post, SL-2	Tabulates contents of the five freezer compartments.
318 R1	Freezer Contents - Post, SL-2	Adds food transfer recommendations.
320 and 320 R1	Manned Vs Unmanned Management Plan	Provides freezer temperature rise rates for "no coolant flow."
320 R2	Manned Vs Unmanned Management Plan	Evaluates use of RS TM measurements to monitor system performance.
326	Qualification Test Reports Corrective Actions	Provides NASA requested data for HS-19 and HS-77 qualification tests.
327	Review SL-3 Activation Checklist	Recommends 1) opening primary loop bypass valve circuit breaker, 2) resetting RS status reset and 3) verifying that freezer high light is off.

TABLE 2.2.11.7-8

RS ACTION ITEMS
SL-1 AND SL-2

ACTION ITEM	DESCRIPTION	REMARKS
334	Review Proposed Changes to Flight Mission Rules	Comments on rules 6-106, 6-108 and 6-112.
342	ODB Update Based on SL-2 Flight Data	Provides new RS inputs to Section 3.0, Tables 3-66, 3-67, and 3-76.
343 thru R3	RS Malfunction Procedures	Reviews and provides requested inputs to RS malfunction procedures.
345	Gather Engineering Test Data to Help Resolve Refr. System Warm Up	Provides MSTR 064 with evaluation of effect of extremely cold coolanol on radiator ΔP, and effect on relief valve.
348 R1	EREP Pass Evaluation	T Cap not completely melted; refreeze within 4 revolutions.
350	Kohoutek Comet Assessment	Specifies required number of recovery orbits for RS following specified maneuvers.
351	Autoscan Elimination	Lists RS measurements required if autoscan is eliminated.
352	Skylab Inflight Problems	Track No. S-13 describes freezer ice/frost elimination. Crew reported no ice/frost observed inside freezer, only around door seals Track No. S-6 describes inadvertant overnight urine separator operation and resultant temperature effect on urine chiller.

TABLE 2.2.11.7-9

RS ACTION ITEMS
SL-3

ACTION ITEM	DESCRIPTION	REMARKS
500	Skylab Command Procedure RSS	Reviews THRM 4 malfunction procedures; comments on Blocks 1, 4, 10, 12, 14, 22, and 24.
509	Review MD9 EREP Plan	Urine specimens may exceed -2.5°F(254°K); frozen food may exceed 0°F (255.5°K); T Cap may thaw approximately 90%.
511-2	EREP Pie Chart	Same response as AI 509. Recommend complete refreeze of T Cap before under-taking subsequent EREP's.
512	Return Stowage for SL-3	At deactivation configure RS per MSFC Procedure IV, and open primary radiator bypass valve controller circuit breaker.
514	RSS Flushing Procedure	Uplinked procedure acceptable. Procedure not recommended for primary loop unless it degrades.
514-1	RSS Flushing Procedures	Verifies HK84M - PAD #6 procedures by performing them on Backup OWS.
514-2	RSS Flushing Procedures	Analyzes failure of HK84M to flush secondary loop and prepares troubleshooting logic diagram.
514-3	RS Flush Procedure	Provides test results of flush procedure (with modifications) on Backup OWS.
514-4	DOY229 RS Troubleshooting Procedure	Recommends a "Ground-manned" procedure to allow verification of procedure steps real time.
514-5	RS Troubleshooting Analysis & Recommendations	Reviews MSFC data tapes to evaluate value position during HK84M.
514-6	RS Secondary Loop Troubleshooting Procedure	Reviews ground/manned flushing procedure.

TABLE 2.2.11.7-9

RS ACTION ITEMS
SL-3

ACTION ITEM	DESCRIPTION	REMARKS
514-7	Secondary Loop RS Troubleshooting Procedure	Reviews procedure with two recommendations.
515-1 R1	Five Crewmen on Board for 20 Days - Effect of	Study indicates 1°F (.555°K), or less, increase in warmest food temperature.
517	Lo-level MUX "B"	RS can be adequately monitored with remaining measurements.
518	SL-3 Rescue Mission Stowage Items	Recommends additional frozen food for both 5 and 20 day extensions to mission.
524 and all revisions	AM Coolant Loop Resupply	Describes all effort associated with resupplying AM coolanol loops including bleeding OWS RS Secondary Loop.
525 and all revisions	OWS Subsystem Review	Updates RS performance and trend inputs on a continuing weekly basis.
530	Operation During Storage with Both AM Coolant Loops Inactive	Recommends operating RS continuously.
535 and all revisions	SL-3 Coolanol Servicing	Describes AM coolant loop resupply including bleeding RS. Develops procedures.
537-3	Potential for Reservicing Secondary RSS Loop	Specifies requirements for reservicing the RS after it has been bled to supply coolanol to AM coolant loop.
542	Heat Pipe Measurements	Specifies heat pipe temperatures including that on storage freezer.

TABLE 2.2.11.7-9

RS ACTION ITEMS
SL-3

ACTION ITEM	DESCRIPTION	REMARKS
549	HS-19 Support Termination	Removes HS-19 test specimen from space chamber and prepares it for storage.
553	Power Down Candidate List Update	Includes review of RS electrical components.
555	Urine Specimen Return Time	Recommends transferring specimens to return container as soon as T Cap outlet temperature reaches -11°F (249.5°K) in event of RS failure.
558	OWS System Status for SL-4	Evaluates RS anomaly and projects future performance.
562	SL-3 Troubleshooting Candidates	Includes flushing RS secondary loop in list.
565	Troubleshooting Procedure	Flush of RS is included in ZO-1887 troubleshooting list.
572	SL-3 RSS Deactivation	Reviews existing thermal conditions with those of DOY 173 anomaly for similarity. Recommends changes to deactivation procedures.
575	Anomalous Measurements List Update	Reviews unavailable - RS measurements due to low level MUX "B" loss.
576 and all revisions	OWS RSS Performance and Troubleshooting	Responds to several HOSC and FOMR queries relative to RS performance or troubleshooting in order to prepare for SL-4 mission.
579 and all revisions	Secondary Loop Flush by Pulling Connector J-5	Provides procedures, Backup OWS test results, RS dual loop analysis, etc., as a result of "pulling J-5 connector" to provide dual loop capability.

TABLE 2.2.11.7-9

RS ACTION ITEMS
SL-3

ACTION ITEM	DESCRIPTION	REMARKS
582	Unmanned Spacecraft Mgmt. Criteria for Use After SL-3	Reviews criteria, recommends changes and provides rationale for changes.
583	Effects of JOP-13 #1 and #2 on RS and OWS Temperatures	Review determined 3°F (1.67°K) rise in food freezer temperature with recovery within 24-hours.
585	SL-4 Unmanned Management Criteria Review	Recommends minor RS changes to criteria.
587	OWS Unmanned Data Requirements	Lists required RS measurements and frequency of data takes.
598 and all revisions	Deservicing of RSS Coolanol	Responds to a mixture of questions relative to RS troubleshooting, components, performance, use of AM servicing, etc.
599	Coolanol Transfer	Proposes method to reservice RS secondary loop with coolanol from primary AM loop.
606	Kohoutek AM Viewing Review	No RS impact results from 3 consecutive 50 minute daylight cycle observations.
612	Kohoutek 180° Roll Maneuver Evaluation	RS deferred to AI 612-4 for lack of necessary initial data.
612-1	Kohoutek 180° Roll Maneuver Detail Analysis	Supplies thermal data necessary to develop RS response.
612-4	Kohoutek 180° Roll Maneuver - RSS Detail Analysis	Warmest food temperature rises approximately 2°F (1.11°K). Seven orbits are required for recovery.
614 and -1	Extended Mission (84 Days) Impact on Consummables	Defines impact on daily urine sampling.

RS ACTION ITEMS
SL-3

ACTION ITEM	DESCRIPTION	REMARKS
615	Urine Return Container Temp. Characteristics	Provides temperature - time history of urine samples for an initial urine freezer sample temperature.
618 and R7	I&C Assessment for SWS Revisit in 1975	Specifies RS power requirements for active or disabled primary loop and power requirements for standby secondary loop.
621	Contingency Rendezvous Analysis	Maneuver will increase food freezer No. 3 temperature 3 to 5°F (1.67 to 2.78°K). 12-hours required for recovery.

E. Conclusions and Recommendations

1/ Review of the Refrigeration System performance data from lift-off through the present Skylab mission indicated the following:

- o The Refrigeration System operated satisfactorily and maintained all the required constituents within their respective CEI limits as defined in paragraph 2.2.11.7 A, except for (1) an anomaly which occurred on DOY 173; and (2) a low temperature excursion during SL-3 storage. However, there were no resulting consequences on the basic requirement of the refrigeration system as a result of these occurrences. These are discussed in paragraph 2 below.

- o Assessment of the flight data indicates no apparent performance degradation or malfunction in any of the RS components other than the occurrence of the anomaly on DOY 173.

- o There was no detectable leakage (Coolanol-15) from either the primary or secondary loops.

2/ A summary of the refrigeration system flight anomalies is as follows:

- o On DOY 173 a continuous increase occurred in the food freezer and radiator inlet temperatures. Assessment of the data indicated that a split flow condition existed between the radiator and radiator bypass branches. This was probably caused by a malfunctioned radiator bypass valve in which both radiator and bypass poppets were in a full flow position. "Cycling" of the valve was performed which resulted in an increase of performance due to an apparent partial closing of the bypass poppet. The RS was operated in this mode; however, the system performance from the standpoint of temperature control was equivalent to the nominal performance observed prior to the anomaly.

- The data obtained during the SL-3 storage period indicated the coldest freezer wall temperature decreased to approximately -24°F (242°K), which is below the CEI specification limit of -20°F (244°K). Following the anomaly on DOY 173, the radiator bypass valve circuit breaker was "opened" which prevented the valve from switching from the radiator position. Consequently, the frozen food temperatures varied as a function of the OWS internal temperature. During this unmanned period, the OWS internal temperature decreased to approximately 63°F (290.5°K). This caused the food temperatures to oscillate about the specification limit. Following SL-4 activation, the coldest freezer temperature returned well within the specification limits due to an increase in OWS internal temperatures. The food was loaded at KSC at -40°F (233°K); consequently, MDAC did not believe this low temperature was a problem.

3/ As a result of evaluation of the flight performance of the Refrigeration system, the following recommendations can be made:

- A one-element version of 15-micron filter, P/N 1B85112-1 should be added upstream of the Radiator Bypass Valve (RBV). The addition of this filter will prevent debris in excess of 15 microns from reaching the RBV, which was a suspected cause of RS problem on OWS No. 1.

- An orifice should be added in series with the existing radiator bypass branch orifice. The orifice will increase the radiator flow in the event of a split flow condition, caused by either a relief valve open malfunction or an RBV poppet position anomaly.

- The 100-micron filter, P/N 1B87205-1 should be removed from the downstream flow side of the thermal capacitor. This filter is a potential source of pressure increase due to ice plugging the filter element as the water in the coolant freezes out. The filter is no longer in the system since its original purpose was to protect the radiator control valve which was deleted.

F. Development History - Prior to the change from a wet to the final dry OWS design in mid-1969, the cooling/freezing requirements for food, water, etc., were handled by four separate Wet Workshop systems. Not all the requirements were introduced into the OWS program at the same time; hence, unique systems were developed to meet each requirement as it was introduced. All systems had to be portable to enable movement from their launch storage location in the Airlock Module into the passivated S-IVB stage or be capable of surviving a cryogenic environment. All wet refrigeration systems had to fit through the 43 in. (1.09 m) LH_2 tank forward dome door. The vehicle orbited with the X-axis perpendicular to the orbit plane, and was orbit stored in a gravity gradient mode without roll control. The techniques used to achieve temperature control were liquid ammonia evaporation, sublimation and thermoelectric heat pumps.

With the change to a dry Workshop, the equipment no longer had to be portable or survive a cryogenic environment. All systems could be permanently mounted inside the S-IVB stage (OWS). An access door was added to the vehicle which eliminated the maximum wet workshop limit. The vehicle orientation was fixed into an inverted hold +Z axis sun orientation for manned and storage phases. This meant that a predictable radiation environment existed.

The wet to dry workshop change allowed a different approach to meet refrigeration requirements because most system requirements were available and a predictable radiation environment existed. Since most of the cooling requirements fell into two categories, -10°F (249.8°K) and +40°F (277.6°K), a new refrigeration system was designed to (1) provide an integrated thermal control system, (2) eliminate the wet system problems of excessive power drain and cabin heat addition, (3) provide a method of maintaining food during extensive ground hold time periods, and (4) use standard techniques and materials, i.e., insulation and proven heat transfer mechanisms.

Design changes and system modifications that occurred during the program were:

1/ Deletion of the requirement for a microbiological sample freezer. This freezer was being designed to utilize thermoelectric heat pumps as well as the circulating coolant loop. Deletion simplified the system by eliminating the thermoelectrics and their associated electronic controls.

2/ Addition of the requirement to chill and freeze urine samples, and return them in a temperature controlled container. Satisfaction of the requirement added hardware, interfaces within the Workshop and the Command Module, and additional testing.

3/ Redesign to increase the area of the radiator to provide equivalent margin with increased heat loads (item 2/ above). Increased area was feasible because of an update in the clearance envelope between the radiator and the aft skirt with a one-retro rocket out separation configuration.

4/ Deletion of the requirement to store dry food in a conditioned environment. This change was concurrent with the addition of six dry food boxes and the decision to condition the OWS interior during ground checkout prior to launch. Two refrigerated dry food boxes were thus eliminated, and since one of the boxes also served to house the refrigerant pumps and associated equipment, a new design was initiated to house all refrigeration mechanical equipment in a single, evacuated enclosure. Crew safety was enhanced since many potential leak paths for Coolanol 15 were, in effect, outside the Workshop environment.

5/ Redesign of the potable water chiller to eliminate a metallic ion problem. The chiller was a gold brazed plate-fin heat exchanger. Biocide tests indicated that both the gold brazing and the CRES material reacted adversely with the water biocide agent (iodine). The chiller was redesigned for all-welded construction of a different, less susceptible CRES material.

6/ Addition of double O-ring seals in the food freezer mechanical connections to the fluid loop. Failure of some integrally brazed joints to pass leak tests led to a fitting redesign to provide a redundant seal.

7/ Redesign of the thermal capacitor to provide adequate ullage volume. Thermal tests of an all-aluminum, all-brazed capacitor resulted in mechanical failure when rapid expansion of the undecane wax overstressed the brazed joints. The capacitor was redesigned to provide enough ullage volume in each of the closed wax cells to prevent overpressurization.

2.2.11.8 Atmosphere System

A. Design Requirements, Habitation Area Vent System - This system was designed to permit:

1/ Overpressure protection for the OWS during all ground pressuration operations.

2/ Initial rapid non-propulsive venting of the OWS after passing maximum αQ.

3/ Additional non-propulsive venting as required throughout the remainder of the Skylab mission.

4/ Minimizing atmosphere leakage.

B. System Description - The habitation area vent system included two sets of valves: (1) a pair of parallel redundant, normally closed, pneumatically actuated vent and relief valves used for ground operations and initial blowdown, and (2) a set of quad-redundant solenoid valves used for venting for storage (Figure 2.2.11.8-1).

The pneumatic valves were identical to those used on the Saturn S-IVB except for a reduced relief setting. The latching vent valve is shown in Figure 2.2.11.8-2. These valves provided relief protection for the habitation area during launch and also provided for rapid blowdown of the habitation area after passing maximum αQ. The command venting function of the pneumatic valves could be operated only by the IU command system. The Skylab-2 crew placed a sealing device in the port for the pneumatic valves to minimize leakage of habitation area atmosphere.

SKYLAB - ORBITAL WORKSHOP
HABITATION AREA PRESSURE CONTROL SYSTEM

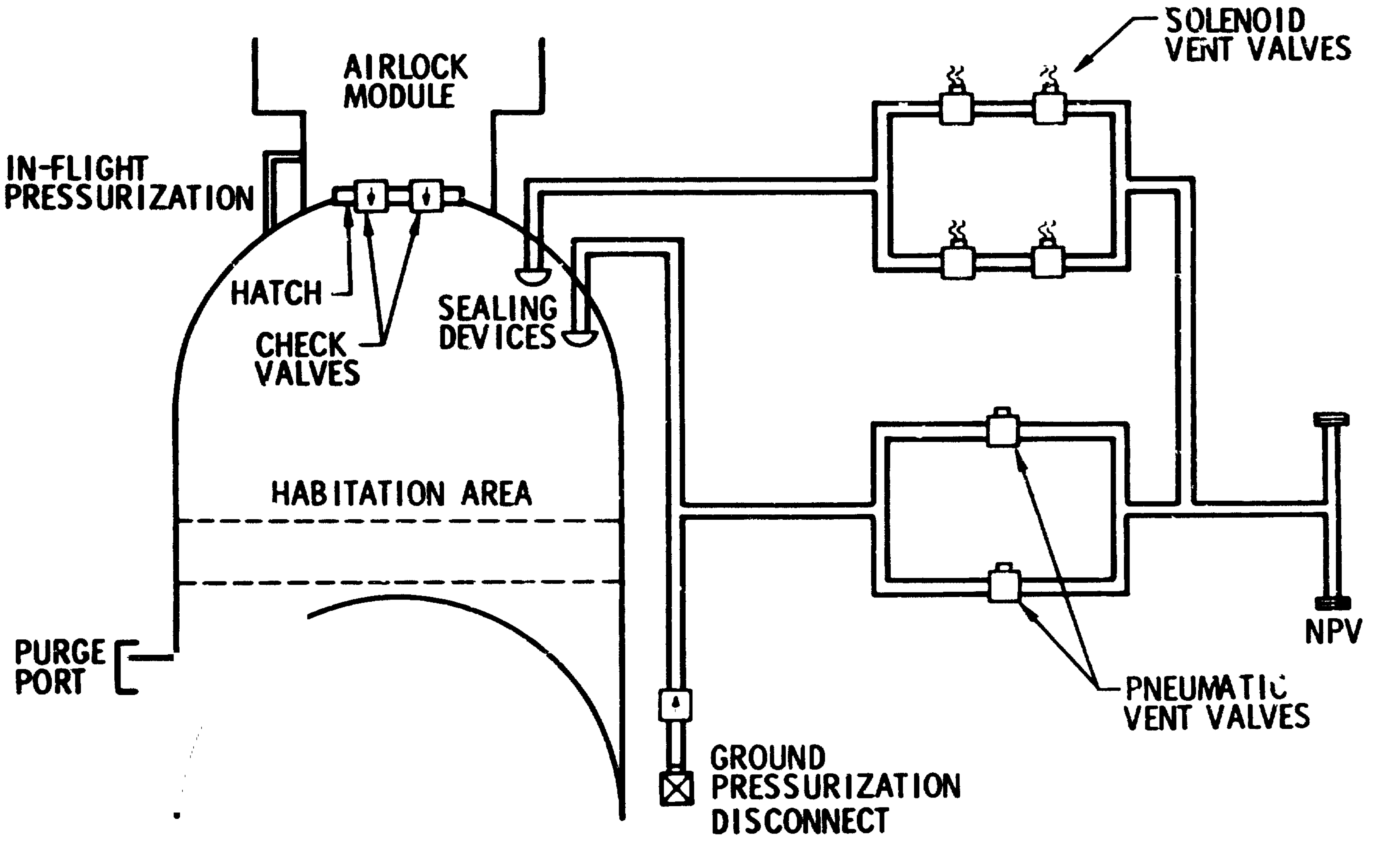
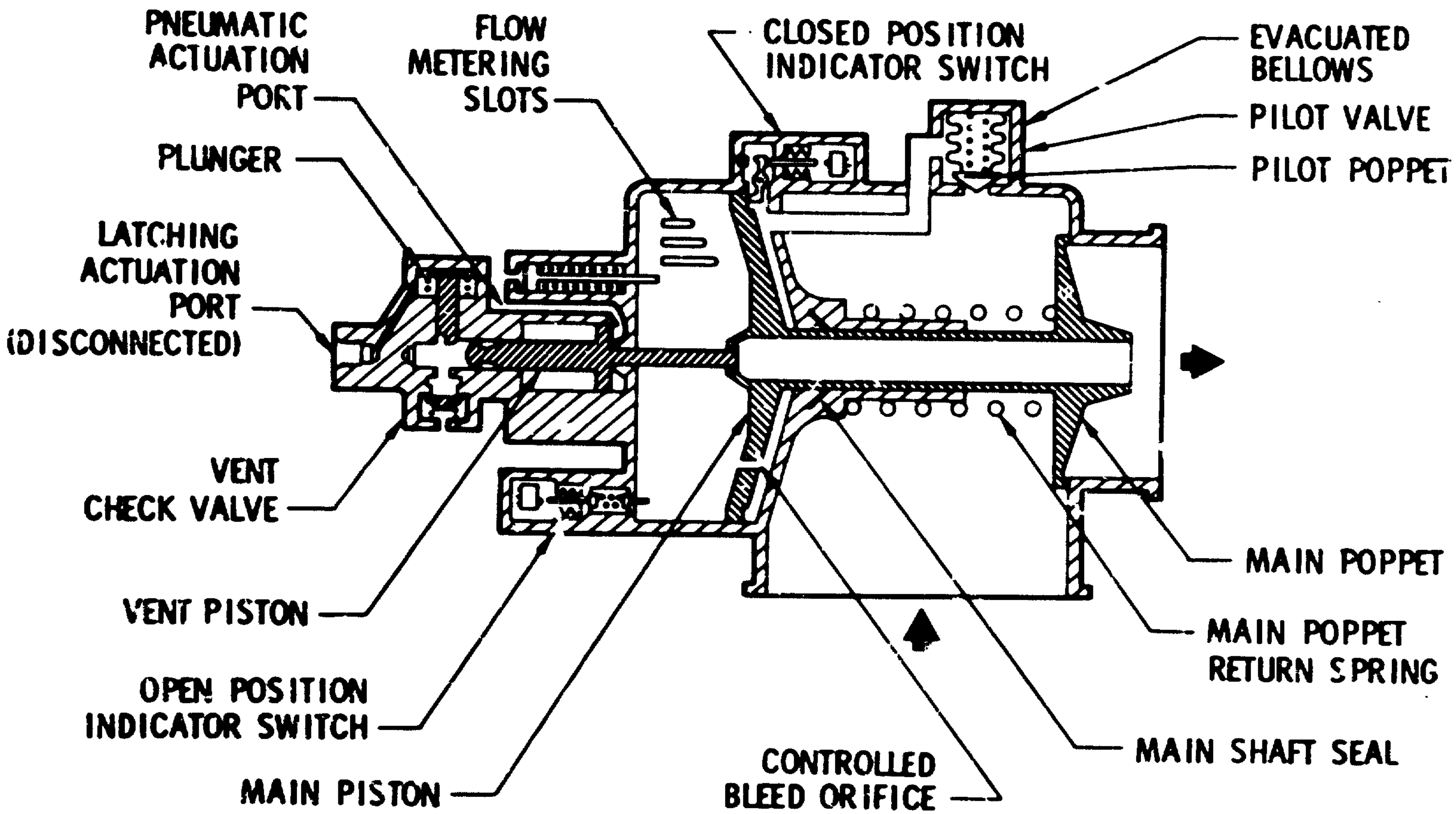


Figure 2.2.11.8-1

SKYLAB - ORBITAL WORKSHOP
HABITATION AREA
LATCHING VENT VALVE 1B74535-501



The solenoid valves (Figure 2.2.11.8-3) provided the capability for venting of the habitation area by ground action at any time during unmanned portions of the mission. The port for the solenoid valves was also provided with a sealing device which could be used during habitation periods.

The vent valves passed gases into two equal-length wrap-around ducts, each of which terminated in an orifice plate at the forward skirt. The orifice plates were in a plane parallel to the OWS centerline and were directed 180 degrees apart so that venting was nonpropulsive (Figure 2.2.11.8-4). The orifice plates were sized to control the rate of habitation area venting.

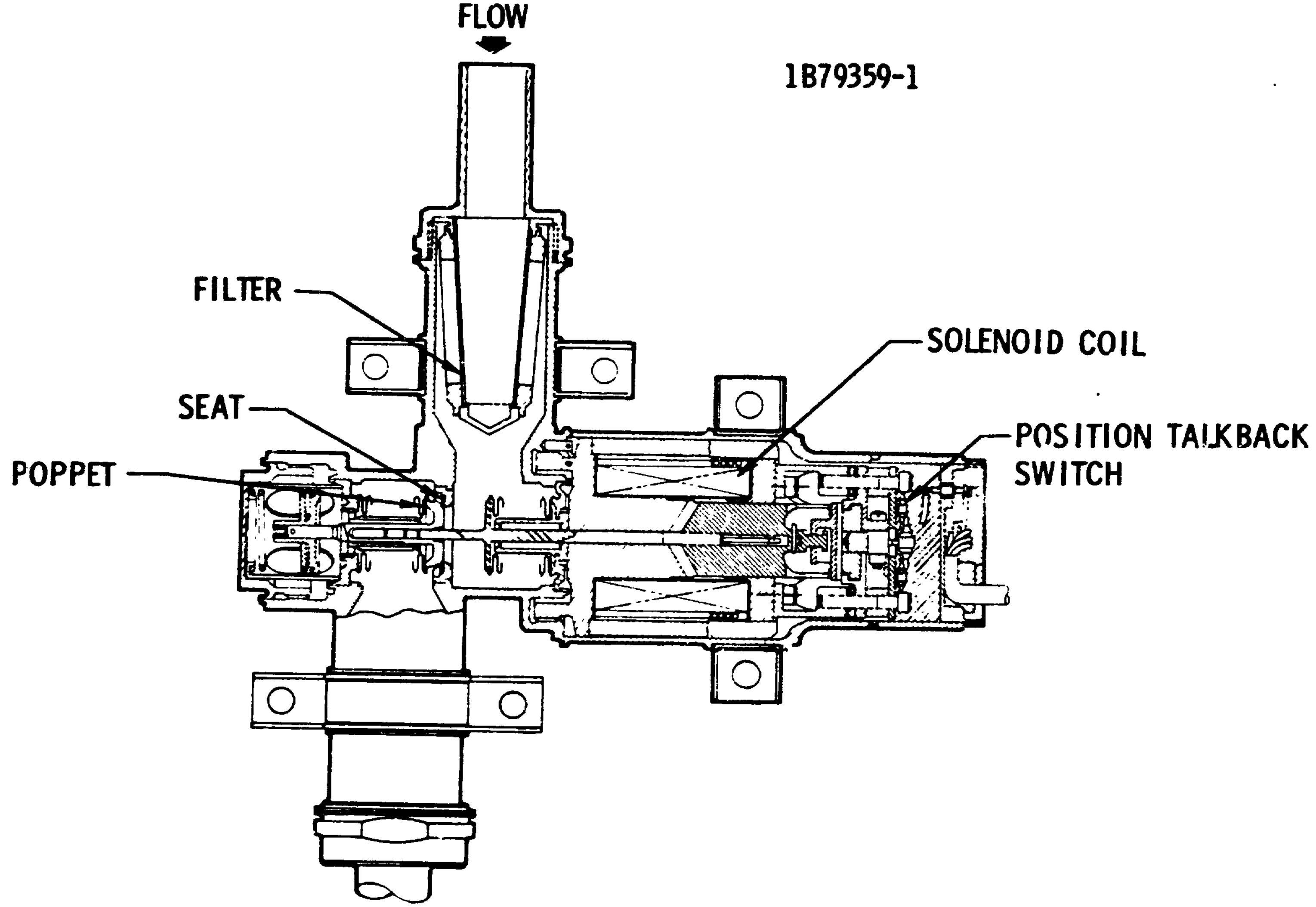
C. Testing - The habitation area vent subsystem was certified for the Skylab mission after successful completion of the following qualification test programs.

- o EC-4 Sealing device
- o EC-13 Solenoid latching vent valve
- o EC-15 Vent duct
- o EC-22 Vent and relief valve, and latching vent and relief valve
- o EC-38 Flex hose
- o EC-39 Hatch check valve

The purpose of each test program, problems encountered and resolution are listed below:

1/ EC-4 Sealing Device - The purpose of test was to determine if the planned installation of the sealing device was within

SKYLAB - ORBITAL WORKSHOP
HABITATION AREA SOLENOID VENT VALVE



ORBITAL WORKSHOP
PRESSURIZATION AND PRESSURE CONTROL SYSTEM
HABITATION AREA NONPROPULSIVE VENT

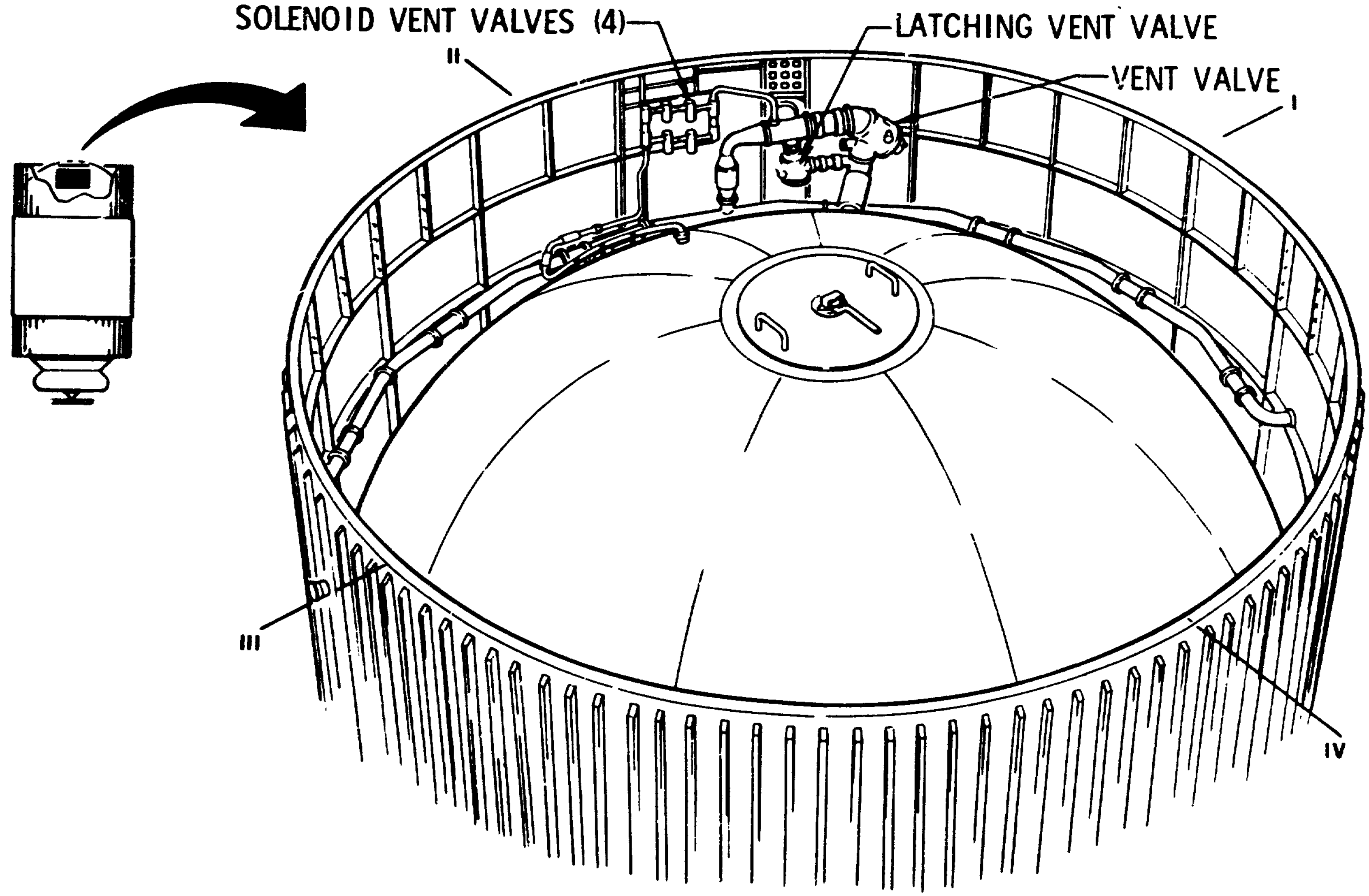


Figure 2.2.11.8-4

the astronauts capability and that the sealing device, after installation, would not leak beyond the established limits. The test specimen, sealing device and adapter, was subjected to proof, temperature and life cycling, vibration, thermal vacuum and leakage. The test specimen was successfully qualified for OWS usage. The problems and resolutions are noted below:

Problem: Retainer pin in handle dropped out during life cycle of -1 configuration. Cause of problem was breakage of retaining ring holding pin in place.

Solution: Redesigned pin to include threads. This allowed pin to be retained by nut instead of retainer ring. Reconfigurated sealing device to -501 and retested.

Problem: Excessive chips generated on adapter spring latch during life cycling. These chips deposited on seal but did not degrade sealing capabilities of sealing device. Could possibly contaminate breathing gas.

Solution: Changed material of latch on adapter to aluminum. The latch was corrosion resistant steel.

2/ EC-13 Habitation Area Solenoid (Latching) Vent Valve - The purpose of the test was to verify the ability of the solenoid latching valves to function properly after exposure to launch and boost flight environments, and the temperature extremes encountered in-orbit. The test specimen included a downstream flex tubing and a production module with valves installed in a quad/redundant configuration. One leg of the module used production valves and the other leg used dummy valves. The specimen was subjected to proof, electrical, leakage, flow, repeat cycles, vibration, thermal vacuum and cycling tests. The test specimen successfully completed the qualification test program without failures or problems.

3/ EC-15 Habitation Area Vent Duct - The purpose of this test was to qualify the fuel tank vent duct assembly to be used in the OWS to the higher dynamic environment expected. The vent duct was subjected to proof, leak and vibration tests. The specimen was successfully qualified without failures or problems.

4/ EC-22 Habitation Area Vent & Relief Valve, and Latching Vent & Relief Valve - The purpose of this test was to qualify the vent and relief valve, and the latching vent and relief valve to the higher dynamic environment expected in the Saturn V OWS vehicle. The test specimen was subjected to proof, leak, functional life cycling and vibration tests. The specimen was successfully qualified after initial problems with the shift in crack and reseat pressure in the vent and relief valve. After extensive analysis, the problem was attributed to improper stress relieving of the pilot poppet spring.

5/ EC-38 Habitation Area Flex Hose - The purpose of the test was to demonstrate the integrity of the habitation area vent flex hose after exposure to launch and boost flight environments. The test specimen was a production assembly containing three inline flex hose sections located between the forward dome and forward skirt. The specimen was subjected to proof, leak, vibration and burst tests. The specimen was successfully qualified without failures or problems.

6/ EC-39 Habitation Area Entry Hatch Check Valve - The purpose of the test was to qualify the existing S-IVB cryogenic check valve for OWS usage. The test specimen was a swing-type check valve with a metal-to-metal seat. The specimen was subjected to proof, leak, functional, and vibration tests. The specimen was successfully qualified without failures or problems.

D. Mission Results

1/ Pneumatic Vent Valve Operation - The pneumatic vent valves operated normally under IU command. The habitation area was vented from 23.1 to 1.1 psia (1.59×10^5 to $7.58 \times 10^3 N/m^2$) prior to initial orbital pressurization.

2/ Solenoid Vent Valve Operation

a. Prior to Initial OWS Habitation - During this period the OWS was subjected to high interior temperatures due to loss of the meteoroid shield during boost. The SWS was purged of any potentially toxic gasses by alternately pressurizing and venting five times. Solenoid vent valve operation was normal throughout these operations except that the OWS depressurization rate grew gradually slower toward the end of the five cycles. The SL-2 crew discovered that the solenoid vent inlet screen was partially clogged with debris. At the conclusion of the final vent, the talkback for valves 1 and 3 did not indicate CLOSED. Since valves 2 and 4 did indicate CLOSED, troubleshooting of this anomaly was postponed until Mission Day (MD) 162.

b. During SL-2 Mission - On MD 162 the crew conducted a troubleshooting procedure. All four solenoid valves were commanded OPEN and the crew reported flow. Then valves 1 and 3 were commanded CLOSED, and the valves responded normally; valves 2 and 4 were then closed. Exact cause of the anomaly is unknown; probable failure mode was particulate contamination.

At the conclusion of SL-2 the solenoid vent system was used to depressurize the SWS from 5.0 to 2.0 psia (3.45×10^4 to $1.38 \times 10^4 N/m^2$) for storage. Prior to repressurization for SL-3, the SWS was vented to 0.5 psia ($3.45 \times 10^3 N/m^2$). Both vents were normal.

c. During SL-3 Mission - The solenoid vent system was used at the conclusion of SL-3 when the SWS was vented from 5.0 to 2.0 psia (3.45×10^4 to $1.38 \times 10^4 N/m^2$) prior to repressurization with N_2. The pressurization procedure was modified to provide a 4-5 psi (2.75×10^4 - $3.45 \times 10^4 N/m^2$) atmosphere during storage to aid in "six-pack" cooling. On DOY 318 the SWS was depressurized to 0.8 psia ($5.52 \times 10^3 N/m^2$) and repressurized with O_2. Both vents were normal.

d. Post SL-4 - After undocking, the SWS was vented from 5.0 to .7 psia (3.45×10^4 to $4.8 \times 10^3 N/m^2$). Again vent operation was normal.

3/ Atmosphere Leakage - The solenoid vent valves and the pneumatic vent port sealing device contributed to maintaining the level of SWS leakage well below the allowable, as compared with a spec allowable of 5 lbm/day (2.3 kg/day). Combined leakage for the OWS/AM/MDA was measured at 2 lbm/day (.9 kg/day) for the OWS alone.

E. Conclusions and Recommendations

1/ The pneumatic vent valves fulfilled all ground and orbital design requirements.

2/ The only anomalies in the solenoid vent system performance were slow venting on DOY 145 due to a clogged filter and failure of valves 1 and 3 to give a closed indication on DOY 146, probably caused by particulate contamination. The use of an inlet screen with a finer mesh (finer than 100 microns) allowing more flow area might have prevented both problems.

3/ The overall low cabin atmosphere leakage rate verified the manufacturing and testing techniques used to assure OWS habitation area pressure integrity.

F. Development History - The habitation area vent system on the wet workshop consisted of the SIVB pneumatic vent valves and a crew operated valve for venting the residual hydrogen vapor. At the time of wet-to-dry conversion, it was decided to add capability to vent by ground command at any time in the mission. Since it is felt to be impractical to maintain a pneumatic supply throughout the mission, it was decided to replace the manual valve with a set of solenoid operated vent valves.

2.2.11.9 Vacuum System

A. Design Requirements, Waste Tank Systems - These systems were designed to provide means for disposal of solid, liquid, and gaseous waste materials without contaminating the Skylab optical environment or imposing a significant demand on the attitude control system and to provide a controlled vacuum source and large capacity reservoir for the collection of excess moisture from the cabin atmosphere.

B. System Description - This section describes the waste tank and the vacuum provisions which interfaced with the waste tank. These vacuum provisions were the two water dump systems, the waste processor exhaust line, the liquid urine dump system, and the refrigeration system pump enclosure vent line. The OWS portion of the condensate collection and dump system which interfaced with the WMC water dump system is also described. A schematic of these systems is shown in Figure 2.2.11.9-1.

1/ Waste Tank - The S-IVB LOX tank was utilized as a waste tank for disposing of all wet and dry materials and refuse collected in habitable areas of the orbital assembly. The waste tank was maintained below the triple point pressure of water by a non-propulsive vent system so that liquids entering the tank would immediately freeze. Fine mesh filter screens removed solids from the vent flow to avoid external contamination. The two vent ducts were equipped with heaters to prevent ice blockage if the triple point of water should be exceeded or from condensing water vapor.

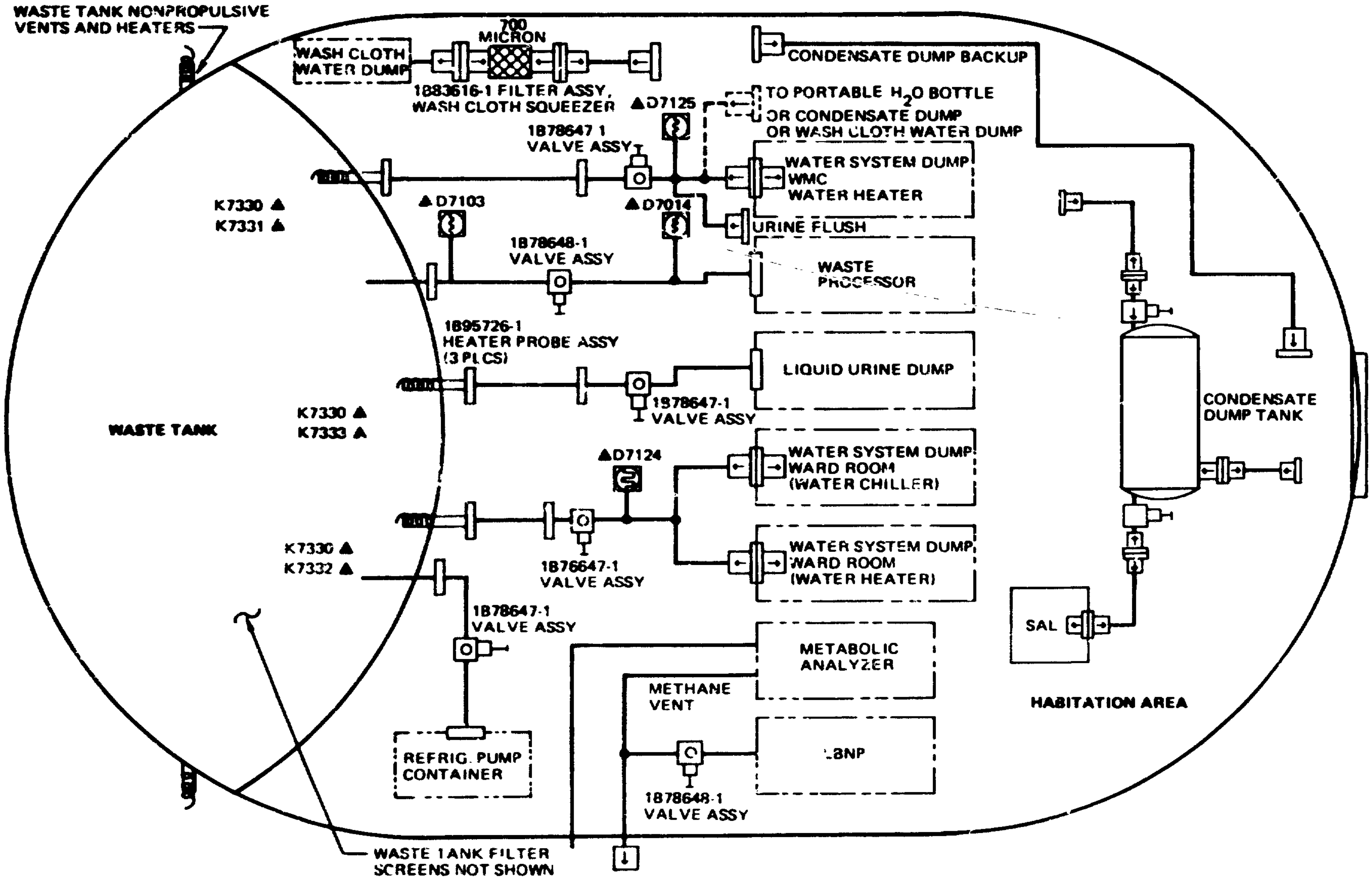


Figure 2.2.11.9-1. Schematic, Vacuum System

2/ Liquid Dump Systems - Both water dump systems and the urine dump system were essentially identical. The water dump systems were primary systems and the liquid urine dump system was a backup method of disposing of the daily accumulation of urine into the waste tank.

A separable connection was provided at the interface of each liquid dump system and its dump module in the wardroom or waste management compartment and was connected to a 1/2 in. (1.27 cm) hand operated ball valve located on a panel adjacent to the dump module. A 1/4 in. (.635 cm) stainless steel tube carried the liquid from the dump module to the valve and down to a liquid dump probe which extended into the waste tank through a flanged fitting in the common bulkhead. The dump probe had redundant heater elements to prevent blockage by ice. Separate control of each heater element was accomplished through use of a switch located on the control panel.

3/ Waste Processor Exhaust - The waste processor vacuum exhaust system provided a vacuum source necessary to operate six waste processors. Gases were vented from each of the waste processor chambers through an integral chamber vacuum valve assembly to a manifold. The manifold was connected to a one in. (2.54 cm) hand operated ball valve located on a panel below the waste processors. The valve was used to isolate the waste processors from waste tank pressures during launch. Gases passing through the valve from the processors were directed through a 1-1/2 in. (3.8 cm) stainless steel tube and a flexible line to a fitting on the waste tank/habitation area bulkhead.

4/ Refrigeration Pump Enclosure Vent - To minimize the possibility of refrigeration system coolant leakage into the habitation area, the pumping and chiller thermal control assemblies were enclosed within a pressure-tight container and vented overboard via a 1/4 in. (.635 cm) line from the container to a fitting on the waste tank common bulkhead. A normally open, hand operated ball valve was located in the vent line. The valve was used to isolate the pump enclosure from the waste tank in the event that an atmospheric leak developed. The vent lines were joined by brazed fittings to minimize leakage.

5/ Condensate Collection and Dump - The OWS portion of the condensate collection and dump system consisted of a condensate holding tank (identical to an OWS water tank) and a series of flex hoses with separable connectors. The tank was evacuated to a pressure of 0.5 psia (3.5×10^3 N/m^2) or less through the WMC water dump system and the anti-solar SAL to provide a vacuum source for the MOL SIEVE condensing heat exchanger water separator plates located in the AM. When the tank became full of liquid and/or gas, it was dumped through a flex hose to a connection on the WMC water dump system and on into the waste tank. A backup condensate dump line [1/4 in. (.635 cm)] allowed direct connection, utilizing a flex hose, between the AM condensate system and the WMC dump system.

C. Testing - The waste management vacuum outlet subsystem was certified for the Skylab mission after successful completion of the following development and qualification test program:

- o Development Tests

  HS-25 Vacuum outlet valves

  HS-73 Waste tank screen

  HS-80 Condensate dump system

  HS-81 Waste tank - small scale screen baffle

  HS-92 Backup liquid dump probe

- o Qualification Tests

  HS-7 Water system

  HS-26 Vacuum outlet system

  Phase I Urine and processor, lower portion, Sys.

  Phase II Urine and processor, upper portion, Sys.

  Phase III Urine dump system complete

  Phase IV LBNP and metabolic analyzer system

  HS-65 Long term vacuum exposure- 1/2 in. (1.27 cm) ball valve

  HS-87 Dump probe and condensate dump system

The purpose of each test program, problems encountered and resolutions are listed as follows:

1/ HS-7 Water Subsystem - The washcloth squeezer filter and flex hose (dump system) were qualified under this line item.

The basic test program was to subject the test specimen through its simulated usage and washwater dumps, to one 28-day mission and two 56-day missions. The filter was successfully qualified and the delta-P across the filter was well within the acceptable limits. However, the hose developed a leak during the testing which was attributed to the reinforcing spring breaking through the silicon liner. A new configuration hose was procured for retest and was successfully qualified for the OWS mission.

2/ HS-25 Vacuum Outlet Valves - The purpose of the test was to demonstrate the performance characteristics of the vacuum outlet system during simulated launch and orbital conditions of the Orbital Workshop. The urine dump system was tested to demonstrate its capability to operate in a vacuum environment and withstand the corrosive effects of urine. No major problems were uncovered in ball valve testing or with testing with urine.

3/ HS-26 Vacuum Outlet Systems - The objectives of this test were to demonstrate the capability of the systems to function properly after exposure to launch and boost flight environments and the capability of performing these orbital functions satisfactorily for a period of 28-days.

The test sp[illegible]en consisted of the urine dump system, two dump probes processor exhaust system (upper portion), refrigeration pump enclosure vent valve, and portions of the metabolic analyzer experiment and LBNP systems. To accommodate the different vibration tests and various system tests, the HS-26 program was divided into four phases:

- Phase I - Those portions of the urine dump and processor exhaust systems that were mounted on or adjacent to the common bulkhead, plus the refrigeration pump enclosure vent 1/2 in. (1.27 cm) ball valve mounted on the common bulkhead.

- Phase II - The urine dump 1/2 in. (1.27 cm) ball valve and processor exhaust 1 in. (2.54 cm) ball valve mounted on a common panel together with associated flex hoses and plumbing.

- Phase III - The complete urine dump system from the collector bag and manifold to the dump probe.

- Phase IV - A portion of the metabolic analyzer system and that portion of the LBNP experiment station that included the flex hoses and 1 in. (2.54 cm) ball valve.

The OWS structure and support brackets were used or simulated during each of the test phases to provide realistic vehicle installation conditions. The test program was successful except for burn-through problems with the heater element on the liquid dump probe. This problem was resolved by a dump probe redesign effort and the new probes were qualified under Line Items HS-87 and HS-92.

A problem associated with Phase IV testing is noted in the vacuum experiment section.

4/ HS-75 1/2 in. (1.27 cm) Ball Valve - Long Term Vacuum Exposure - The purpose of this test was to demonstrate functional capability of the 1/2 in. (1.27 cm) ball valve after vacuum exposure for periods of; operational 28-days, non-operational of 65-days and operational of 5-days. The ball valve demonstrated successful operation during vacuum exposure without failures or problems.

5/ HS-73 Waste Tank (Filter) Screen - The purpose of this development test was to determine the flow and pressure drop characteristics of different filter screens while flowing nitrogen gas, water vapor, urine and water to evaluate the effects of the residue and/or ice on the filter screen flow. No major problems were encountered during the test program. The test results in conjunction with HS-81 testing were used in the selection and design of the production filter screen in the waste tank.

6/ HS-80 Condensate Dump System - The purpose of this development test was to determine the performance of an improved dump probe in the urine dump system and the AM/OWS condensate system. The basic test program was to subject the probe to electrical, proof, leak, functional, vibration, urine dumps and condensate water dumps. The test results indicated that the urine dump system performance was acceptable. However, the AM/OWS condensate system water dumps were considered to be marginal. This problem was attributed to the high pressure drop in the system plumbing and the inability of the heater to consistantly vaporize off the ice bridging over the exit port. The condensate plumbing and dump probe were redesigned and retested under Line Items HS-87 and HS-92.

7/ HS-81 Waste Tank - Small Scale Screen Baffle - The purpose of the development test was to determine if a polyester cloth baffle could satisfactorily protect the filter screen from ice impingement and damage. Also, the effect of contamination on the filter screen was investigated. The test was for data only and the results were as follows:

- No damage to the cloth baffle or screen was visible.
- The cloth baffle did not prevent ice from impinging on the screen.
- The addition of a rubber baffle under the cloth baffle prevented ice from reaching the screen directly.
- Ice formed directly on the rubber baffle material would initially stick and then break loose. Ice formed on the cloth baffle would adhere tenaciously.

8/ HS-87 Dump Probe and Condensate Dump System - The purpose of this test was to qualify the redesigned liquid dump probe for use in the OWS condensate dump system. The test specimens were subject to extensive pretest and qualification test programs to demonstrate the units were able to function properly under simulated vehicle operating conditions in a space environment after being exposed to flight and boost vibration. There were several failures of the probe during the test program. All of these failures were subsequently attributed to the high acidity of the potting compound which attacked the heating element wire, causing an open circuit. The probe was redesigned with new potting compound and the test specimen was qualified with no failures or problems.

9/ HS-92 Backup Liquid Dump Probe Heater - The purpose of this test was to evaluate and qualify a backup liquid dump probe using a Cal-rod type element for possible use in the OWS Program. The specimens were subjected to a test program similar to HS-87, the basic heater probe qualification test program. The specimens were successfully tested with no failures or problems and this configuration probe was selected for flight usage.

D. Mission Results - All flight data indicate that the waste tank system was completely effective in providing for disposal of liquid and solid waste materials outside of the habitation area without interfering with optical experiments or imposing a load on the attitude control system. Discussions with MSFC Contamination MSG personnel have indicated that no traces of waste tank effluents were uncovered in any of their experiments. Evaluation of APCS data shows no measurable unbalanced venting, even during the largest liquid dumps into the waste tank.

The wardroom (WDM) and WMC water dump systems were each used once during each activation and once during each deactivation. In addition, the WMC water dump system was utilized approximately once every three days to dump waste wash water which had been collected in the wash cloth squeezer bag. On SL-2 the WMC water dump system was used once to dump AM condensate water using the OWS backup condensate dump line, and once to dump the OWS condensate holding tank. On SL-3 the WMC water dump system was used approximately 35 times for OWS condensate holding tank dumps due to a leakage problem in the condensate system. Three condensate holding tank dumps were performed during SL-4. In addition to this usage, the WDM and WMC water dump systems were used during SL-3 and SL-4, respectively, for cabin atmosphere pressure management in support of experiments on M509 and T020 (astronaut maneuvering units). By installing a purge fitting in the water dump line, cabin atmosphere could be vented slowly to a desired pressure.

The liquid urine dump system was not used during SL-2 or SL-3, except as required to pull a vacuum on the urine bags prior to their use. However, due to the extended SL-4 mission, the lack of urine collection bags, and the crew-reported problem of excessive force required to dispose of full urine bags through the trash airlock on SL-4 mission day 50, the liquid urine dump system was used approximately 17 times during the remaining portion of SL-4 to dispose of liquid urine. This use was in addition to its normal usage of evacuating the urine bags prior to their use.

The OWS condensate holding tank provided the capability for long periods of unattended condensate collection (as long as 56 days at one point in the mission). Flight data indicate leakage of cabin air into the tank (which could have increased required dumping frequency) was an order of magnitude less than spec. for the OWS portion of the system.

All vacuum systems performed as expected and without significant anomalies except for the following:

1/ The waste tank pressure reached the triple point pressure of water during some large quantity dumps, apparently due to a higher than expected rate of sublimation of the ice formed during the dumps. No adverse effects were observed resulting from this high pressure.

2/ The WMC water dump probe orifice became blocked on DOY 244. It was replaced with an on-board spare and no additional problems were experienced with this system. Subsequent investigation indicated that the problem was temporary blockage with ice and the probe could be kept on board as a spare.

3/ The urine dump system incurred a brief temporary blockage on DOY 005.

E. Conclusions and Recommendations - With the exception of the anomalies described above, which were of little consequence, the OWS vacuum systems performed well throughout the three missions. This smooth performance was the culmination of a long and difficult development program. It is recommended for future development of systems of this type, that a strong emphasis be placed on system development testing under conditions that simulate the in-flight environment as closely as possible.

F. Development History

Waste Tank - The waste tank concept originated in the days of the wet workshop. The original plan was to dispose of urine by dumping it overboard through a fitting installed by the crew in the side of the fuel tank. When NASA tests revealed that this would be detrimental to the solar arrays, it was decided to have the crew punch a hole in the common bulkhead and install a heated dump probe so that urine could be dumped into the LOX tank. The LOX tank was to be vented through the existing non-propulsive vent system and a second latching vent valve was added for reduncancy.

In the wet-to-dry conversion studies, the LOX tank (now called the waste tank) was found to be a desirable place to dump all sorts of waste materials. The trash airlock was installed in the common bulkhead and two additional heated dump probes were added for flushing and draining various water systems. Also added were fittings for venting waste processor exhaust gases and refrigeration pump coolant leakage into the waste tank. Since propellants were no longer being carried, it was possible to pre-install all of this hardware.

In the original OWS LOX tank non-propulsive vent system, flow passed through one port in the tank, two parallel valves and two 20 ft. (6.09 m) long wraparound ducts to nozzles on opposite sides of the tank. Analytical stuides showed that one of the two wraparound ducts would be subjected to temperatures well below the freezing poing of water so that the duct was likely to become partially or completely blocked, leading to unbalanced thrust. Since this would have placed a large load on the APCS, it was decided to redesign the vent system to its present configuration. The power cost for heating the present one ft. (.305 m) long duct to prevent freezing was an order of magnitude less than what would have been required for the original wraparound ducts.

The original waste tank vent system had a small filter screen covering the vent port. Because of concern that this screen would become completely blocked with trash bags, it was replaced by large area screens which separated the waste tank into compartments. The largest compartment received trash bags from the trash airlock. Each vent outlet was in a separate screened-off compartment and these two compartments were connected by a duct made of screen material to assure balanced venting. The liquid dump outlets were separated by screens from the trash area to prevent trash bags from freezing to the dump probes and possible blocking them.

The original large screens were rather coarse (16 mesh) since their objective was to control migration of the trash bags. It was later decided to use the screens to prevent overboard venting of any solid waste that might interfere with optical experiments and the 16 mesh screen was replaced with Dutch twill woven screens having 2 micron filtering capability. Extensive developmental tests verified the filtering capability of the new screens but indicated that they could become blocked when urine was dumped on them. A baffle was then added to prevent direct impingement of the dumped urine on the screens.

The extensive design and developmental work involved in the waste tank concept paid off during the mission where vast quantities of waste materials were disposed of with very little difficult and with no discernible effect of the optical environment.

Waste Tank Heated Liquid Dump Proge - The original heated probe was 3 1/2 in. (8.89 cm) long and extended only 1/2 in. (1.27 cm) beyond the waste tank bulkhead. A Kapton heater blanket was wrapped around the 1/4 in. (.635 cm) diameter silver tube and held in position with a coil spring. Front and back heaters were sized at 7 1/2 watts each.

During qualification testing, the heater blanket overheated and failed due to poor thermal contact between the blanket and silver tube. Two attempts to improve the thermal contact (using Eccobond to bond the blanket to the OD of the silver tube and using Nomex yarn woven over the heater blanket to hold the blanket against the silver tube) were unsuccessful.

A decision was made to redesign. The basic objectives were to double the heater power and to increase the heat flux to the probe tip. The length of probe was increased 6 in. (15.24 cm) to reduce ice bridging potential. Reduncant heater circuits were maintained and each circuit was positioned lengthwise over the entire length with a watt density of 3 watts/in at the probe tip and a watt density of 1 watt/in at the upper end of the probe. The orifice at the tip was angled and located radially to expel liquid parallel to the waste tank baffle, thereby preventing ice buildup.

The heating element was located between an inner and outer tube [3/16 in. (.476 cm) x 3/8 in. (.95 cm) OD]. Two parallel design approaches were taken for the heater element. Brief details of each configuration are as follows:

1/ Ceramic tubes and wire ribbon heating element - This method used twelve 1/6 in. (.159 cm) diameter alumina tubes located radially around the 3/16 in. (.476 cm) diameter silver tube. The nichrome wire ribbon was threaded through the alumina tubes in a configuration necessary to produce the required watt density of the heater element. Sub-assembly of alumina tubes and ribbon was bound to the silver tube with Nomex thread; then the total assembly, inner and outer silver tubes, were brazed together.

2/ Cal-rod type heater element - This method consisted of a spiral wound cal-rod type heater consisting of a 1/16 in. (.159 cm) diameter nickel tube filled with silicate quartz which insulates and hermetically seals the nichrome wire heater element. The metal sheathed element is then wound around the inner 347 cres tube and furnace brazed in position. Complete assembly was then accomplished by addition of the outer 347 cres tube.

Both probe configurations were built, qual tested and delivered. A decision was made to install the cal-rod type configuration on the flight vehicle because of its superior strength.

Condensate Collection - It was originally planned to dispose of waste water collected in the AM condensate system by daily dumping through the AM water dump system. Concern over the impact of this dumping on nearby optical experiments led to development of a system for dumping the condensate water into the waste tank. An attempt was made to install a set of plumbing to dump water accumulated in the AM reservoir directly into the waste tank through one of the existing dump probes. Development testing showed that pressure drop through the long length of line and the several components involved resulted in insufficient driving pressure at the probe to insure continuous flow without freezing. It was found possible to solve this problem, and also significantly reduce the amount of crew effort involved in condensate disposal, by installing a large reservoir (similar to the existing water tanks) in the OWS, sufficiently close to the probe to eliminate the pressure drop problem. The large reservoir provided capability to collect for up to 100 days before dumping was required.

2.2.11.10 Pneumatic Control System

A. Design Requirements - Pneumatic Control System (PCS) - This system was designed to provide pneumatic power for operation of the following:

1/ The Habitation Area (HA) pneumatic vent valves (2).

2/ The waste tank vent actuators.

3/ The Refrigeration System (RS) radiator shield jettison mechanism.

B. System Description - The system consists of (1) a 4.5 ft^3 ($7.1 \times 10^{-2} m^3$) storage sphere; (2) four actuation control modules; (3) associated piping, two pressure transducers and a quick disconnect fitting for pressurization. (Figure 2.2.11.10-1.) The sphere was pressurized to 450 psia (3.1×10^6 N/m^2) prior to liftoff.

C. Testing - Since the OWS pneumatic control system was essentially the same as the S-IVB stage system, no qualification or development testing was required.

D. Mission Results - The pneumatic control system operated normally under Instrument Unit (IU) control to perform all design requirements. The storage sphere was then vented to 35 psia (241×10^3 N/m^2).

E. Conclusions and Recommendations - The pneumatic control system fulfilled all ground and orbital design requirements.

F. Development History - The OWS pneumatic system was essentially the same as that used on the Saturn S-IVB Stage except that the regulator was removed. This simplification was the result of a shorter required operational life (1 hr. vs. 7 hrs. on S-IVB) and

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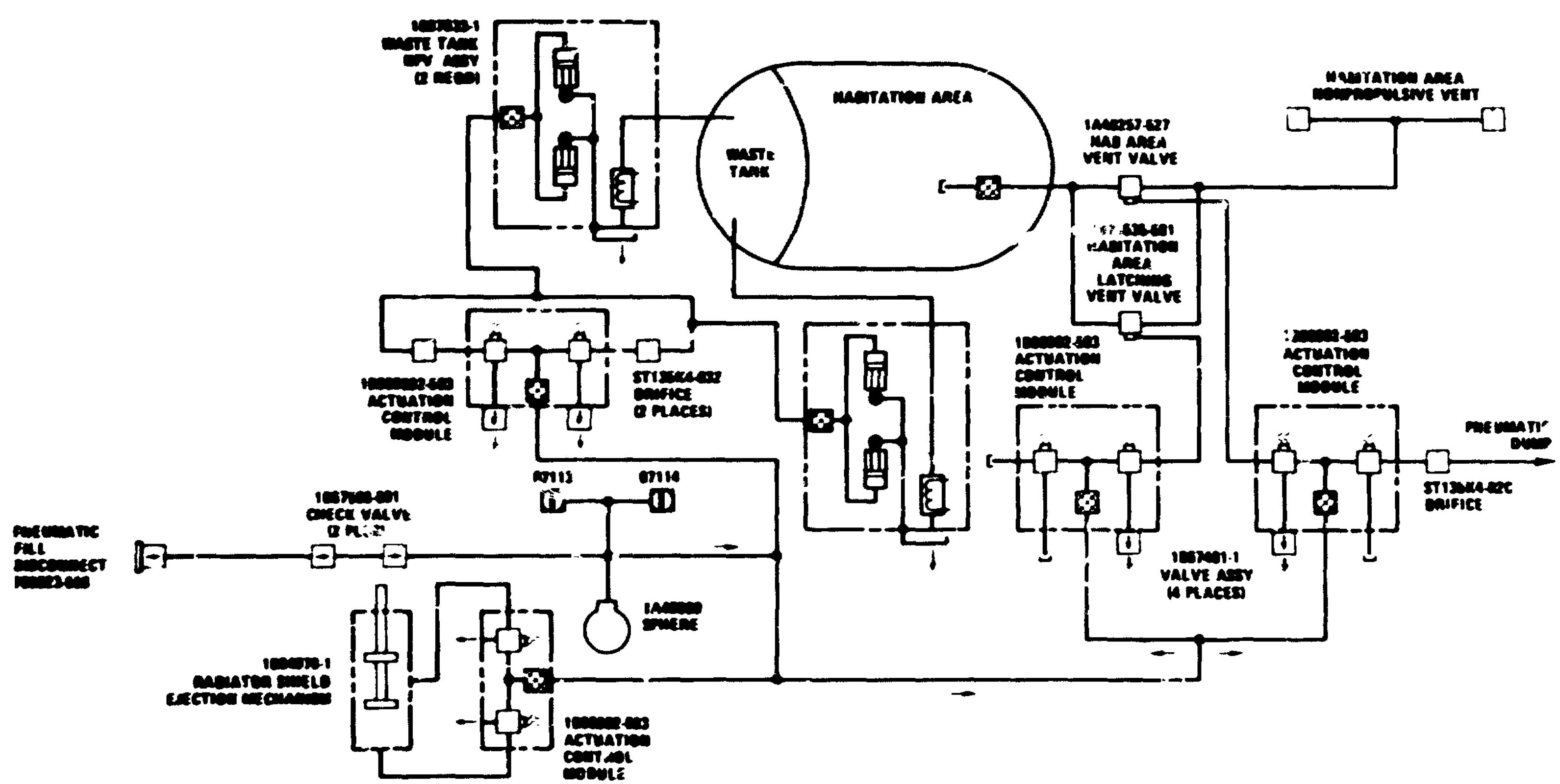

FIGURE 2.2.11.10-1

confidence in the system's low leakage capability built up during the S-IVB Program which permitted lowering the supply pressure to a level within the operational range of the actuators.

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