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Environmental Control and Life Support System

ECLSS 21002

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Final Version

**This document has been reviewed and updated.
No subsequent updates to this document are anticipated or required due to
the approaching shuttle program closure.**

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Environmental Control and Life Support System

ECLSS 21002

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PREFACE

The contents of this document were provided by the Shuttle Systems Group, Shuttle Systems Training Branch, Space Flight Training & Facility Operations, Mission Operations Directorate (MOD), Lyndon B. Johnson Space Center (JSC), National Aeronautics and Space Administration (NASA). Technical documentation support was provided by Integrated Documentation Services (IDS). Any questions concerning this training manual or any recommendations should be directed to the Shuttle Systems Document Controller, Tina Weber, DT36, 281-244-7679, or to the training manual Book Manager, Michael Sadowski, DT36, 281-244-7335.

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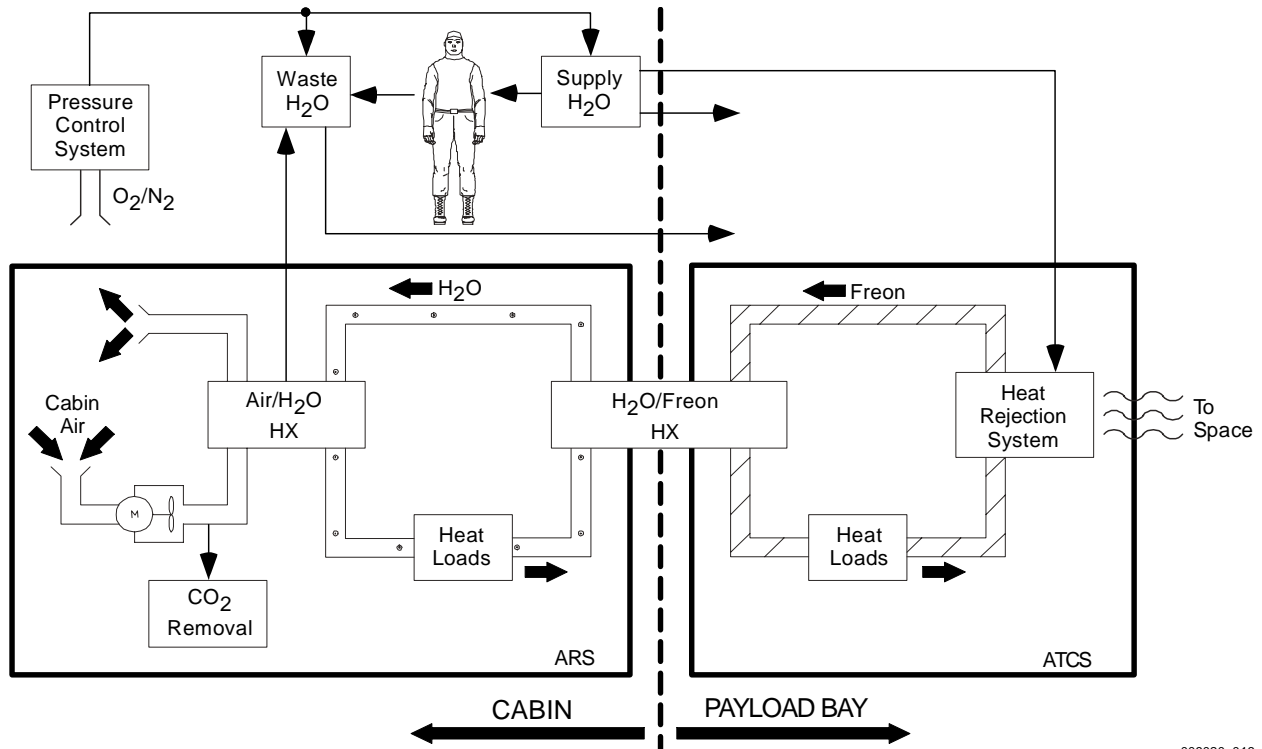
1.0 INTRODUCTION

The Environmental Control and Life Support System (ECLSS) maintains the thermal stability of the orbiter and provides a pressurized, habitable environment in the crew compartment for the crew and onboard avionics. ECLSS also stores water and crew liquid waste.

ECLSS may be functionally divided into four systems as shown in Figure 1-1. Each system is described in detail later in this book.

- a. Pressure Control System (PCS) - The PCS pressurizes the crew compartment with a breathable mixture of oxygen (O_2) and nitrogen (N_2). N_2 also is used to pressurize the supply and wastewater tanks.
- b. Atmospheric Revitalization System (ARS) - The ARS circulates air and water through the crew compartment to remove heat, control humidity, and maintain carbon dioxide (CO_2) concentrations within tolerable levels.
- c. Active Thermal Control System (ATCS) - Two Freon loops collect waste heat from orbiter systems and transfer that heat overboard.
- d. Supply and wastewater system - The supply water system stores water produced by the fuel cells for drinking, personal hygiene, and orbiter cooling. The wastewater system stores crew liquid waste and wastewater from the humidity separator.

Additionally, the external airlock of the orbiter is considered part of ECLSS, but it is covered in a separate section of this document.



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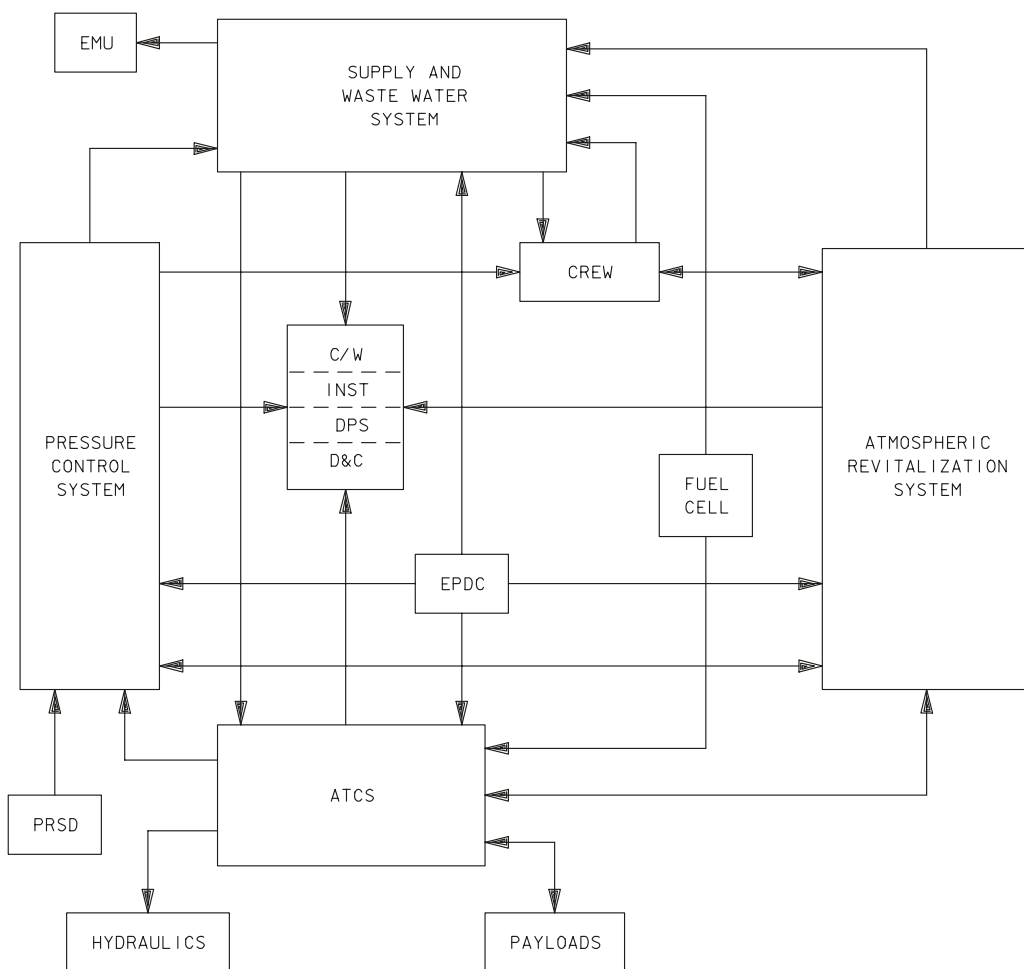
Figure 1-1. ECLSS overview Environmental Control and Life Support System Interfaces

The ECLSS interfaces are described in Section 1.1 and are shown in Figure 1-2.

1.1 PRESSURE CONTROL SYSTEM INTERFACES

- a. Fuel cell Power Reactant Storage and Distribution (PRSD) system - The PRSD system supplies cryogenic O_2 to the PCS.
- b. Supply and wastewater system - The water tanks are pressurized by N_2 .
- c. ATCS - The cryogenic O_2 is warmed by the ATCS Freon loops in the O_2 restrictors.
- d. ARS - The PCS provides air circulation necessary for O_2 and N_2 control and to prevent localized concentrations of O_2 or N_2 .
- e. Crew - The crew breathes O_2 and N_2 . The crew also controls cabin pressure to meet mission requirements such as Extravehicular Activity (EVA) and International Space Station (ISS) docked operation.
- f. Caution and Warning (C/W) - Sensor outputs are continuously checked for out-of-limits conditions.
- g. Instrumentation (INST) - Sensor outputs are conditioned for display and telemetry.

- h. Data Processing System (DPS) - Sensor outputs are provided for Systems Management (SM) conditioning, monitoring, and display of PCS parameters on Cathode-Ray Tube (CRT) displays (or the equivalent Multifunction Display Unit (MDU) if upgraded to the Multifunction Electronic Display System (MEDS)) and dedicated display meters.
- i. Onboard Display and Control (D&C) - Dedicated meters provide the crew with system information. Switches, circuit breakers, and talkbacks allow the crewmembers to monitor and control system configurations.
- j. Electrical Power Distribution and Control (EPDC) - The EPDC distributes electrical power to operate the PCS controls and equipment.



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Figure 1-2. ECLSS interfaces

1.2 ATMOSPHERIC REVITALIZATION SYSTEM INTERFACES

- a. Supply and wastewater system - Humidity condensate removed from the cabin air is stored in the wastewater tank. Supply water (drinking water) is chilled by the ARS.
- b. ATCS - The ATCS takes the waste heat collected by the ARS water loops and transfers the heat overboard.
- c. PCS - The PCS maintains a controlled cabin pressure at a density adequate for heat transfer (minimum of 8 psi) from air-cooled equipment to the water loops.
- d. Crew - The crewmembers' presence in the cabin produces humidity, CO₂, and heat that must be removed.
- e. INST - Sensor outputs are conditioned for display and telemetry.
- f. C/W - Sensor outputs are continuously checked for out-of-limits conditions.
- g. DPS - Sensor outputs are provided for SM conditioning, monitoring, and display of ARS parameters on CRT displays and dedicated display meters.
- h. D&C - Dedicated meters provide the crew with system information. Switches and circuit breakers allow the crewmembers to monitor and control the system and verify system configuration.
- i. EDPC - The EDPC distributes electrical power to operate the ARS controls and equipment.

1.3 ACTIVE THERMAL CONTROL SYSTEM INTERFACES

- a. ARS - The ARS collects waste heat from inside the crew compartment and passes the heat to the ATCS in the water/Freon interchanger.
- b. Supply and wastewater system - Supply water is used by the Flash Evaporator System (FES) to cool the Freon loops.
- c. PCS - The ATCS Freon loops warm the PCS cryogenic O₂ in the O₂ restrictors.
- d. Hydraulics - The ATCS Freon loops warm the orbiter hydraulic fluid.
- e. Fuel cells - The fuel cell O₂/H₂ reaction produces heat. This heat is transferred to the Freon loops in the fuel cell Heat Exchanger (HX).
- f. Payloads - The ATCS Freon loops provide cooling for payloads (e.g., SpaceHab).
- g. C/W - Sensor outputs are continuously checked for out-of-limits conditions.
- h. INST - Sensor outputs are conditioned for display and telemetry.

- i. DPS - Sensor outputs are provided for SM conditioning, monitoring, and display of ATCS parameters on CRT displays and dedicated display meters.
- j. D&C - Dedicated meters provide the crew with system information. Switches, circuit breakers, and talkbacks allow the crewmembers to monitor and control system configurations.
- k. EPDC - The EPDC distributes electrical power to operate the ATCS controls and equipment.

1.4 SUPPLY AND WASTEWATER SYSTEM INTERFACES

- a. ARS - Humidity condensate removed from the cabin air is stored in the wastewater tank. The ARS chills supply water to provide cold drinking water for crew consumption.
- b. PCS - The water tanks are pressurized by N₂.
- c. ATCS - Supply water is used by the FES to cool the Freon loops.
- d. Fuel cells - The fuel cell O₂/H₂ chemical reaction produces water, which is stored in the supply water tanks.
- e. Crew - The crewmembers use supply water for drinking and personal hygiene. The crewmembers' liquid waste is stored in the wastewater tanks.
- f. Extravehicular Mobility Unit (EMU) - Supply water is used to recharge the EMU in the airlock.
- g. C/W - Sensor outputs are continuously checked for out-of-limits conditions.
- h. INST - Sensor outputs are conditioned for display and telemetry.
- i. DPS - Sensor outputs are provided for SM conditioning, monitoring, and display of supply and wastewater system parameters on CRT displays and dedicated display meters.
- j. D&C - Dedicated meters provide the crew with system information. Switches, circuit breakers, and talkbacks allow the crewmembers to monitor and control system configuration.
- k. EPDC - The EPDC distributes electrical power to operate the supply and wastewater system controls and equipment.

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2.0 PRESSURE CONTROL SYSTEM

The crew compartment (cabin) is normally pressurized to 14.7 psia to provide the crew with a habitable O₂/N₂ environment. This pressurization also provides the cabin atmosphere necessary to cool the cabin air-cooled equipment. Positive and negative pressure relief valves protect the structural integrity of the cabin from over- and underpressurization. The PCS N₂ is used to pressurize the supply and wastewater tanks. The PCS also supplies breathing O₂ directly to the Launch and Entry Suit (LES) helmets.

The 14.7 psia cabin atmosphere is maintained by either of the two PCS systems. These O₂/N₂ systems are commonly referred to as PCS system 1 and PCS system 2. At 14.7 psia, the crew compartment is normally pressurized with approximately 40 pounds of O₂ and 130 pounds of N₂. This 20 percent O₂ and 80 percent N₂ atmosphere closely resembles the atmosphere at sea level on Earth. Each PCS system can be broken down into three functional components: the O₂ system, the N₂ system, and the O₂/N₂ manifold.

2.1 OXYGEN SYSTEM

The fuel cell PRSD system supplies the PCS with O₂ from the same cryogenic tanks used to supply the fuel cells. The O₂ is maintained at a pressure of 811 to 875 psia by heaters in the O₂ tanks. The high-pressure O₂ enters the PCS through the O₂ supply valves (Figure 2-1). These valves are latching solenoid valves. If power to an O₂ supply valve is lost, it will remain in its present position.

After passing through the O₂ supply valve, the O₂ flow is then limited by an O₂ restrictor. Freon warms the O₂ in the restrictor to a comfortable temperature before it flows into the cabin. PCS system 1 has one 23.9 ± 1 lb/hr flow restrictor, while PCS system 2 has two parallel 12.0 ± 0.5 lb/hr flow restrictors. The flow restrictors protect the fuel cell cryogenic system pressure from being depleted by an excessive demand from the PCS. Freon loop 1 warms the PCS system 1 O₂, and Freon loop 2 warms the PCS system 2 O₂.

Next, the O₂ piping penetrates the 576 bulkhead and enters the crew compartment. Check valves inside the cabin prevent the reverse flow of O₂ in both PCS systems. Downstream of the check valves, O₂ system 1 and O₂ system 2 are connected by an O₂ crossover line. This O₂ crossover line allows both O₂ systems to supply O₂ to the crossover manifold. O₂ systems 1 and 2 can be separated by closing either of the two O₂ crossover valves (Figure 2-1). The O₂ crossover manifold supplies oxygen to the LES helmet regulators, the direct O₂ valve, and the airlock EMU O₂ supply lines (Figure 2-2).

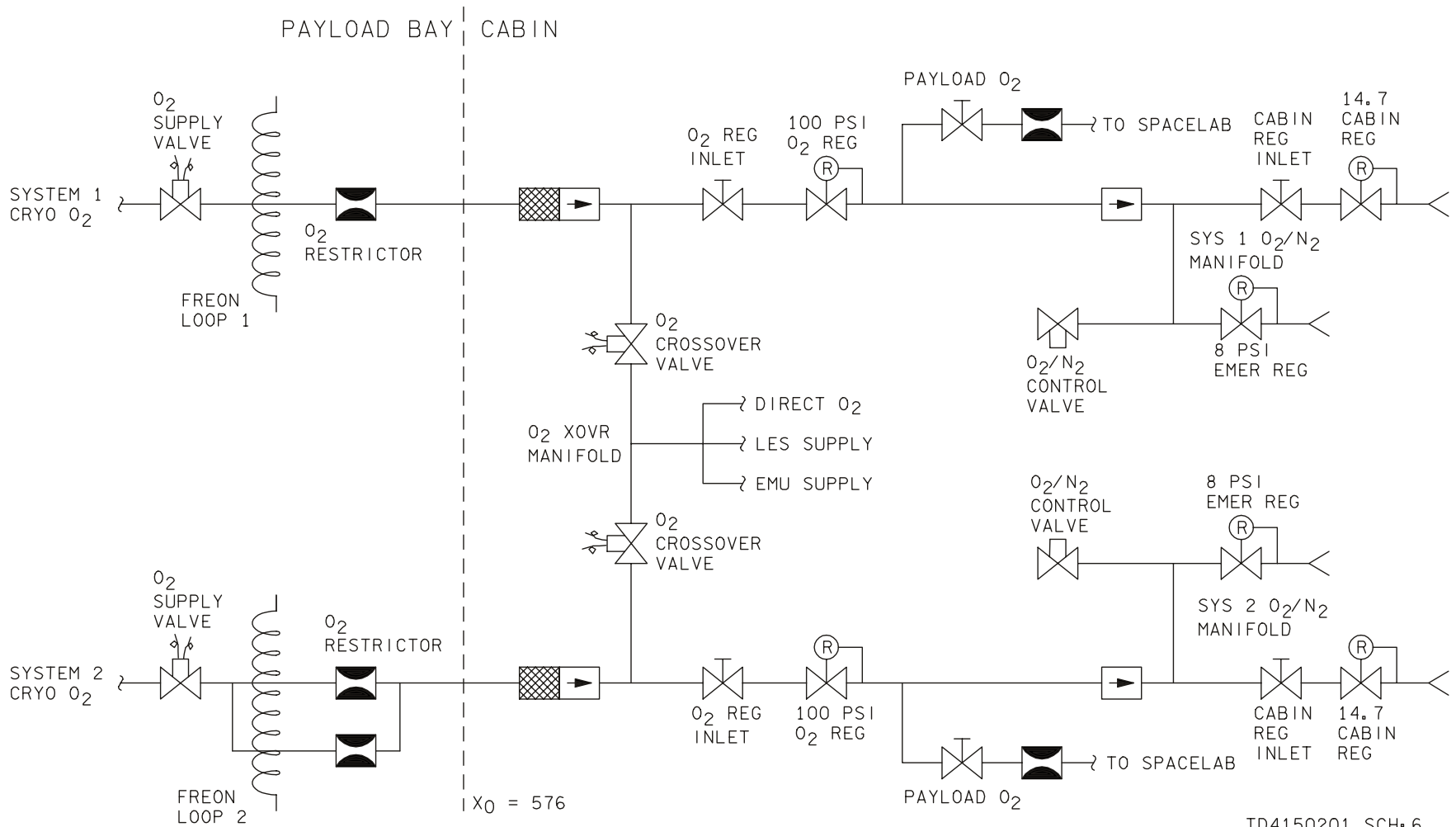


Figure 2-1. Oxygen system

The O₂ crossover valves are solenoid-powered valves that close if power is lost. Two parallel Launch and Entry Helmet (LEH) regulators step the high-pressure (~840 psia) O₂ pressure down to 100 psig. The two LEH regulator inlet valves on Panel C7 isolate the LEH regulators when they are not in use. Check valves downstream of the LEH regulators prevent the reverse flow of O₂. O₂ is supplied to the LES during ascent and entry by connecting the LES O₂ supply hose to the LEH Quick Disconnects (QDs). These QDs are located on Panel C6 on the flight deck and on Panels MO32M and MO69M on the ceiling of the middeck. Once the QD connection is made, the O₂ flow is initiated by opening the associated LEH O₂ valve. A direct O₂ valve allows approximately 20 lb/hr of O₂ flow into the middeck. The direct O₂ valve is located on the center console aft of the pilot's left leg on Panel C5.

The airlock EMU O₂ supply valves send high-pressure O₂ to the airlock for EMU servicing and to the ISS during O₂ transfer operations.

The emergency O₂ kit has been removed from all of the orbiters. The line has been capped to protect the integrity of the piping. The manual O₂ emergency valve and an auto O₂ emergency valve are kept closed to isolate the nonfunctioning regulator outside the cabin (Figure 2-1).

Downstream of the O₂ crossover line, there is an O₂ regulator inlet valve (Figure 2-2). When the O₂ regulator inlet valve is open, the 100-psig O₂ regulator steps the O₂ pressure down to 100 psia. The 100 psia O₂ then flows through a check valve and into the O₂/N₂ manifold. This 100 psia O₂ can only fill the O₂/N₂ manifold when the higher pressure N₂ (200 psia) is shut off from the manifold. The capability also exists to supply 100 psia O₂ to payloads by opening the payload O₂ valves.

Associated with the 100 psig O₂ regulator is a relief valve that cracks at 245 psig and reseats at 215 psig. The relief valve relieves into the cabin to protect the PCS from an O₂ regulator failure. The O₂ regulator is a psig regulator that controls the O₂ pressure to 100 ± 10 psig above cabin pressure.

2.2 NITROGEN SYSTEM

The PCS nitrogen supply is nominally provided by four tanks located in the payload bay, but all orbiters are capable of carrying additional N₂ tanks. As mission duration increases, the amount of N₂ lost to normal vehicle leakage and wet trash venting also increases. In addition, operation of the Regenerable Carbon Dioxide Removal System (RCRS) (see Appendix C) consumes N₂ in the overboard vent cycle. Since longer missions provide additional opportunities for extravehicular activities, a large volume of N₂ is required for cabin and airlock repressurization.

Recent enhancements have increased the N₂ capacity to eight tanks (see Figure 2-3). The additional tanks are identical to the N₂ tank hardware currently in use.

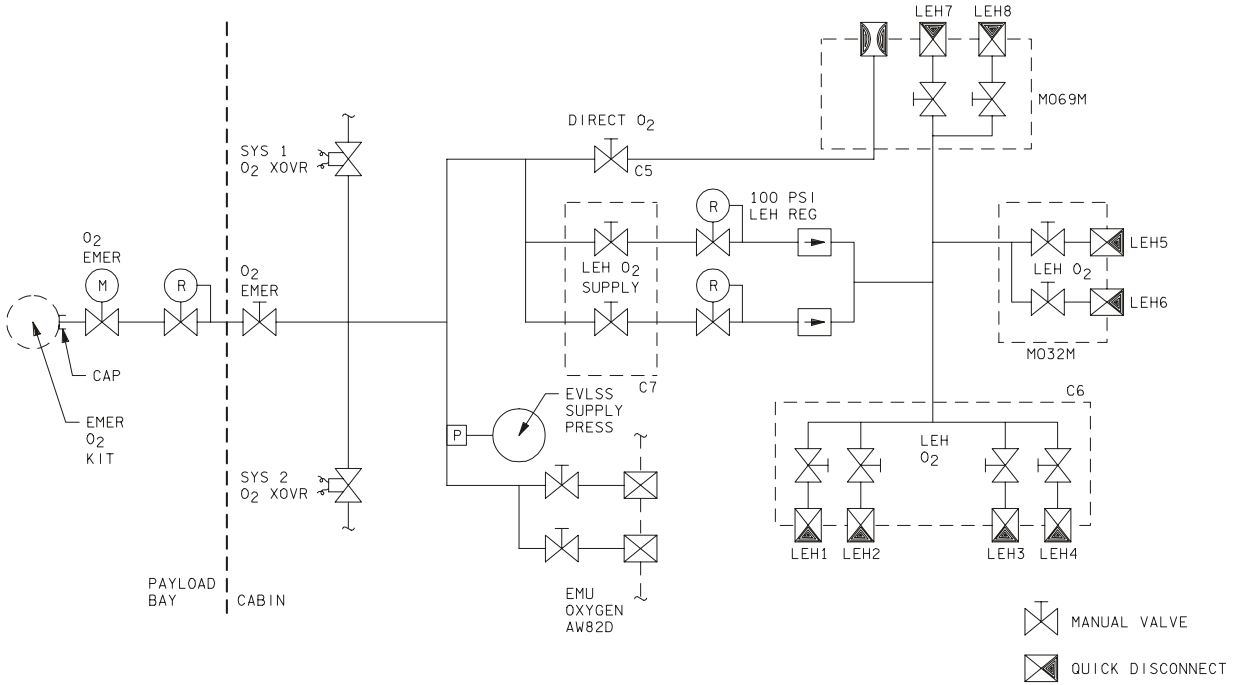


Figure 2-2. O₂ Crossover manifold

At least four N₂ tanks are permanently installed on all vehicles. The permanent tanks for PCS 1 have been relocated to the aft payload bay. The tanks are designated as system 1, tanks 3 and 4. This move was necessary to adjust the vehicle center of gravity to a more favorable position. PCS 2 tanks 1 and 2 are also permanent and are located in the forward right side of the payload bay. Up to four additional tanks may be installed as mission kits. These extra tanks are not permanently installed in the vehicles; they are installed when needed on a flight-specific basis.

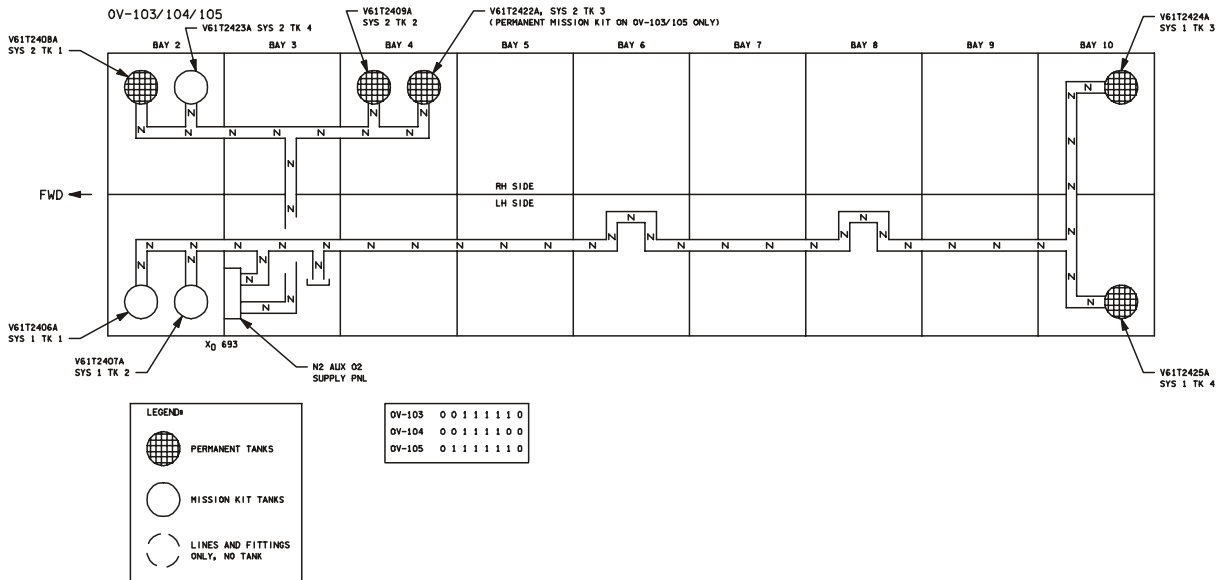


Figure 2-3. Location of N₂ tanks

The 3300 psia N₂ flows out of the tanks, through the N₂ supply valves, and into the N₂ supply manifold (Figure 2-4). After passing through the N₂ regulator inlet valve, the 200 psig N₂ regulator steps the N₂ pressure down to 200 psia. The N₂ regulator inlet valve can be manually closed to isolate the N₂ regulator.

The N₂ supply and N₂ regulator inlet valves are motor-driven valves. If power to the valves is lost, the valves will remain in their present position. There are no heaters in the N₂ tanks; the feed is driven by pressure only. Associated with the 200 psig N₂ regulator is a relief valve that cracks at 275 psig and reseats at 245 psig. The relief valve relieves overboard through the vacuum vent line to protect the N₂ system from overpressurization due to an N₂ regulator failure. The N₂ regulator controls the N₂ pressure to 200 ± 15 psig above ambient pressure. High-pressure N₂ can be supplied to the Manned Maneuvering Unit (MMU) by opening the MMU gaseous nitrogen (GN₂) isolation valve. This valve is located between the N₂ tanks and the N₂ supply valves (Figure 2-4). N₂ can be transferred to the ISS through PCS N₂ System 1 only.

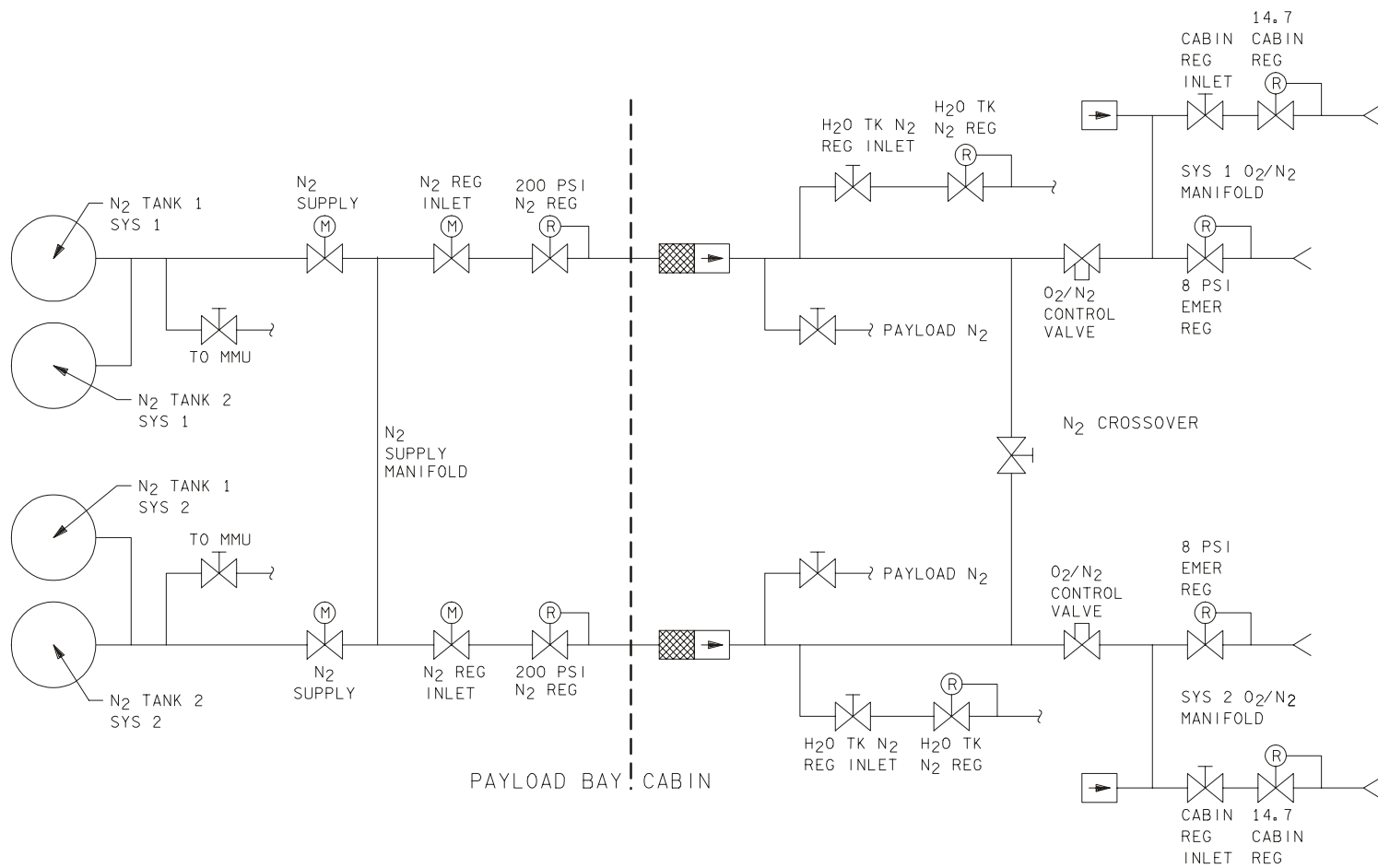
Next, the 200-psig N₂ piping penetrates the 576 bulkhead and enters the crew compartment. A check valve inside the cabin prevents reverse flow of N₂. The 200-psig N₂ pressure is then stepped down again by the water tank N₂ regulator and is used to pressurize the supply and wastewater tanks. An N₂ crossover valve makes it possible to connect PCS system 1 N₂ to PCS system 2, and vice versa. The flow of 200-psig N₂ into the O₂/N₂ manifold is controlled by the O₂/N₂ controller. The capability also exists to supply 200 psig N₂ to a payload by opening the payload N₂ valves.

2.3 OXYGEN/NITROGEN MANIFOLD

The 14.7 psia cabin regulator controls the cabin pressure to 14.7 psia when the 14.7 regulator inlet valve is open (Figure 2-5). The O₂/N₂ control valve controls the flow of N₂ into the O₂/N₂ manifold. Whatever gas (O₂ or N₂) is in the O₂/N₂ manifold will flow into the cabin when the cabin pressure drops below 14.7 psia. This “makeup” flow will continue as long as the cabin pressure is less than 14.7 psia and the 14.7 cabin regulator inlet valve is open. An 8-psia emergency regulator provides flow to maintain a cabin pressure of 8 psia in the event of a large cabin leak. There is no regulator inlet valve to isolate the 8 psia emergency regulator; therefore, it is always configured to provide makeup flow.

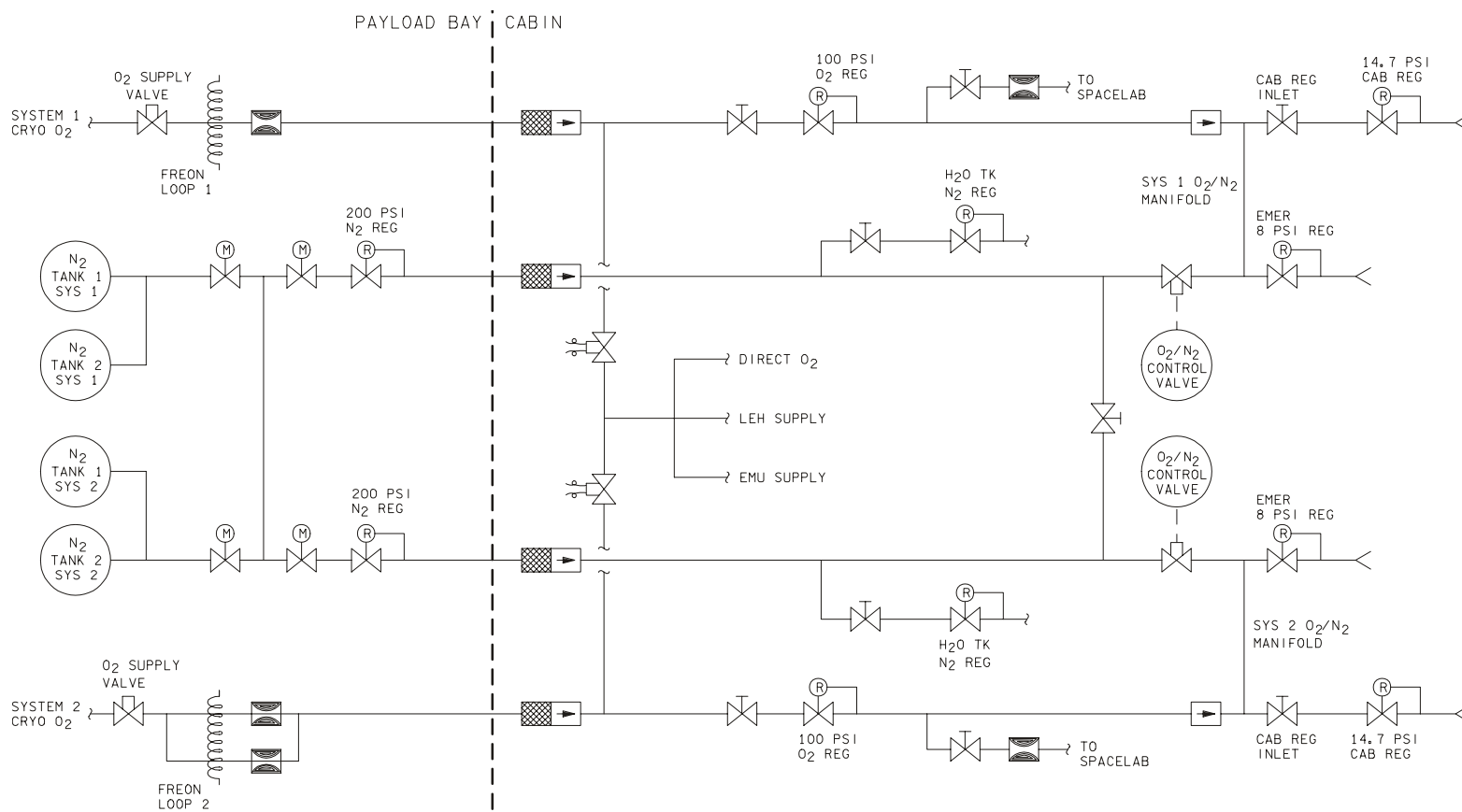
The 14.7-psi regulator cabin regulator regulates the cabin pressure to 14.7 ± 0.2 psia and is capable of a maximum flow of at least 75 lb/hr per specifications. The 8-psi emergency regulator is designed to regulate to 8 ± 0.2 psia and is capable of a maximum flow of at least 75 lb/hr per specifications. Both the 14.7- and 8-psi regulators flow into the cabin through ports on Panel MO10W, located in the Waste Collection System (WCS) compartment. The crewmembers can hear the regulators when they flow if they are in the vicinity.

The O₂/N₂ control valve position can be controlled manually by the crew or automatically by the O₂/N₂ controller. What follows is a discussion of O₂/N₂ control valve operation.



TD4150203. SCH. 4

Figure 2-4. Nitrogen system



TD4150204, SCH 4

Figure 2-5. Pressure control system

2.3.1 Oxygen/Nitrogen Control Valve Manually Open

With the O₂/N₂ control valve open, 200 psi N₂ fills the O₂/N₂ manifold and forces the O₂ check valve to close. If the cabin pressure drops below 14.7 psia, the gas in the O₂/N₂ manifold will flow into the cabin, and N₂ will flow into the O₂/N₂ manifold to replenish it (Figure 2-6).

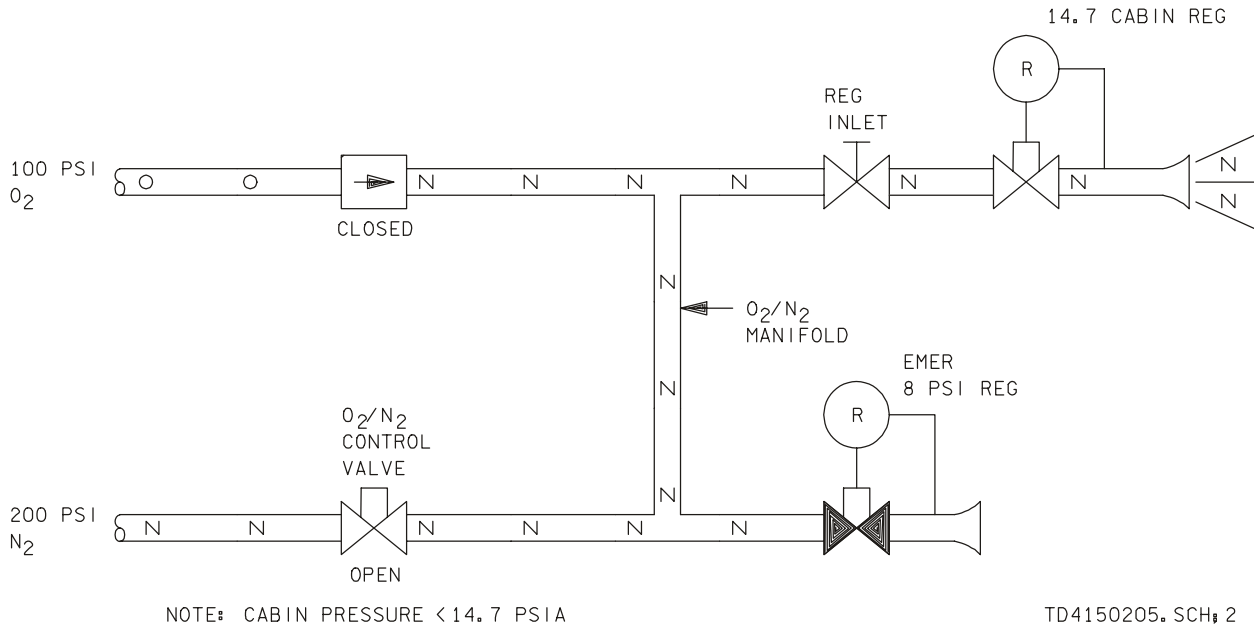
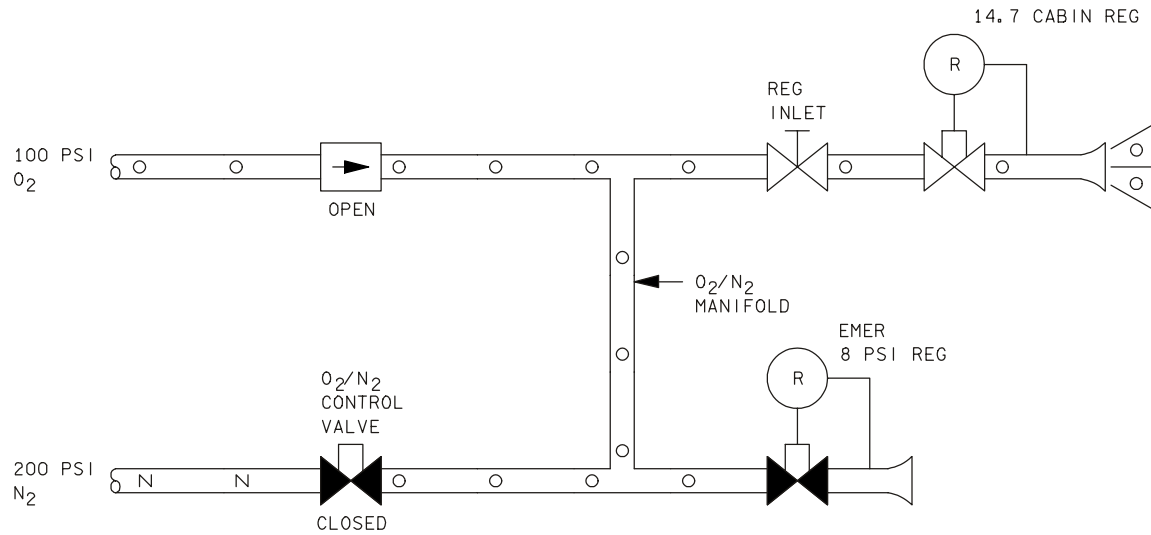


Figure 2-6. O₂/N₂ control valve open

2.3.2 Oxygen/Nitrogen Control Valve Manually Closed

With the O₂/N₂ control valve closed, no N₂ is available to replenish the O₂/N₂ manifold. If the cabin pressure drops below 14.7 psia, the gas in the O₂/N₂ manifold will flow into the cabin. Once the pressure in the O₂/N₂ manifold drops below 100 psi, the O₂ check valve will open and 100 psi O₂ will flow into the O₂/N₂ manifold to replenish it (Figure 2-7).



NOTE: CABIN PRESSURE < 14.7 PSIA

TD4150206. SCH 2

Figure 2-7. O₂/N₂ control valve closed

2.3.3 Auto Control of the Oxygen/Nitrogen Control Valve

On orbit, the O₂/N₂ control valve on the active PCS is placed in AUTO. This position enables automatic management of the O₂/N₂ control valve by the O₂/N₂ controller. The valve will be opened or closed to maintain the correct amount of O₂ in the atmosphere based on the partial pressure of oxygen (PPO₂) in the cabin. At PPO₂ less than 2.95 psia, the valve is closed to enable O₂ to flow through the 14.7 cabin regulators if the cabin pressure drops below 14.7 psia. If PPO₂ is greater than 3.45 psia, the valve opens and allows N₂ to flow through the system. At PPO₂ levels between 2.95 and 3.45 psia, the valve remains in its previous position until the upper or lower PPO₂ limit is reached and the valve changes position. (Note: Historical data show that actual control is maintained at 3.1 ± 0.05. The 2.95 to 3.45 range is the original specification requirement.)

PPO₂ sensor A data are used by O₂/N₂ controller 1 to determine when to open and close the system 1 O₂/N₂ control valve. Likewise, PPO₂ data from sensor B are used by O₂/N₂ controller 2. The PPO₂ SNSR/VLV switch is used to determine which controller drives which control valve. When the switch is in NORMAL, O₂/N₂ controller 1 manages the position of O₂/N₂ control valve on PCS 1, while controller 2 governs the position of the valve on system 2.

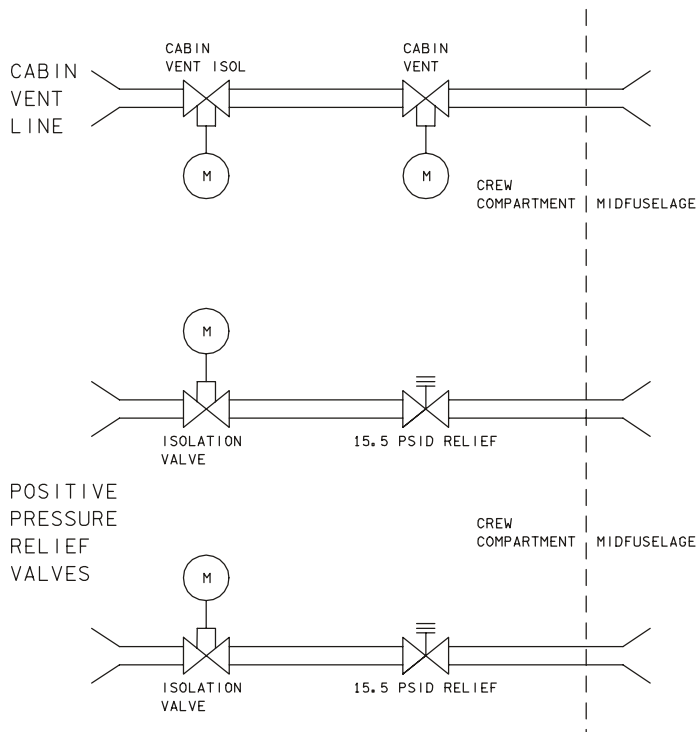
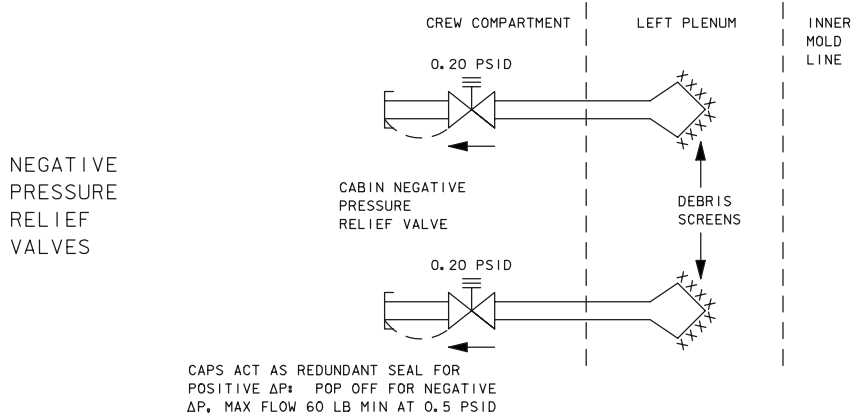
This configuration can be reversed, however, so that controller 1 controls the PCS 2 O₂/N₂ control valve, and controller 2 manages the PCS 1 valve by taking the PPO₂ SNSR/VLV switch to REVERSE. This capability prevents the loss of a PPO₂ sensor from resulting in the loss of automatic control of one of the two PCSs.

2.4 OVER/UNDERPRESSURIZATION PROTECTION

The structural integrity of the orbiter crew compartment is maintained by positive and negative pressure relief valves. The two positive pressure relief valves protect the crew compartment from overpressurization. These positive pressure relief valves will crack at 15.5 psid, reach full flow by 16.0 psid, and reseal again below 15.5 psid. Motor-driven cabin relief isolation valves are located in series with the relief valves (Figure 2-8). Should a relief valve fail open, it can be isolated, and the alternate relief valve will still provide overpressurization protection. The positive pressure relief valves are located behind the back wall of the WCS compartment and relieve into the payload bay (Figure 2-8).

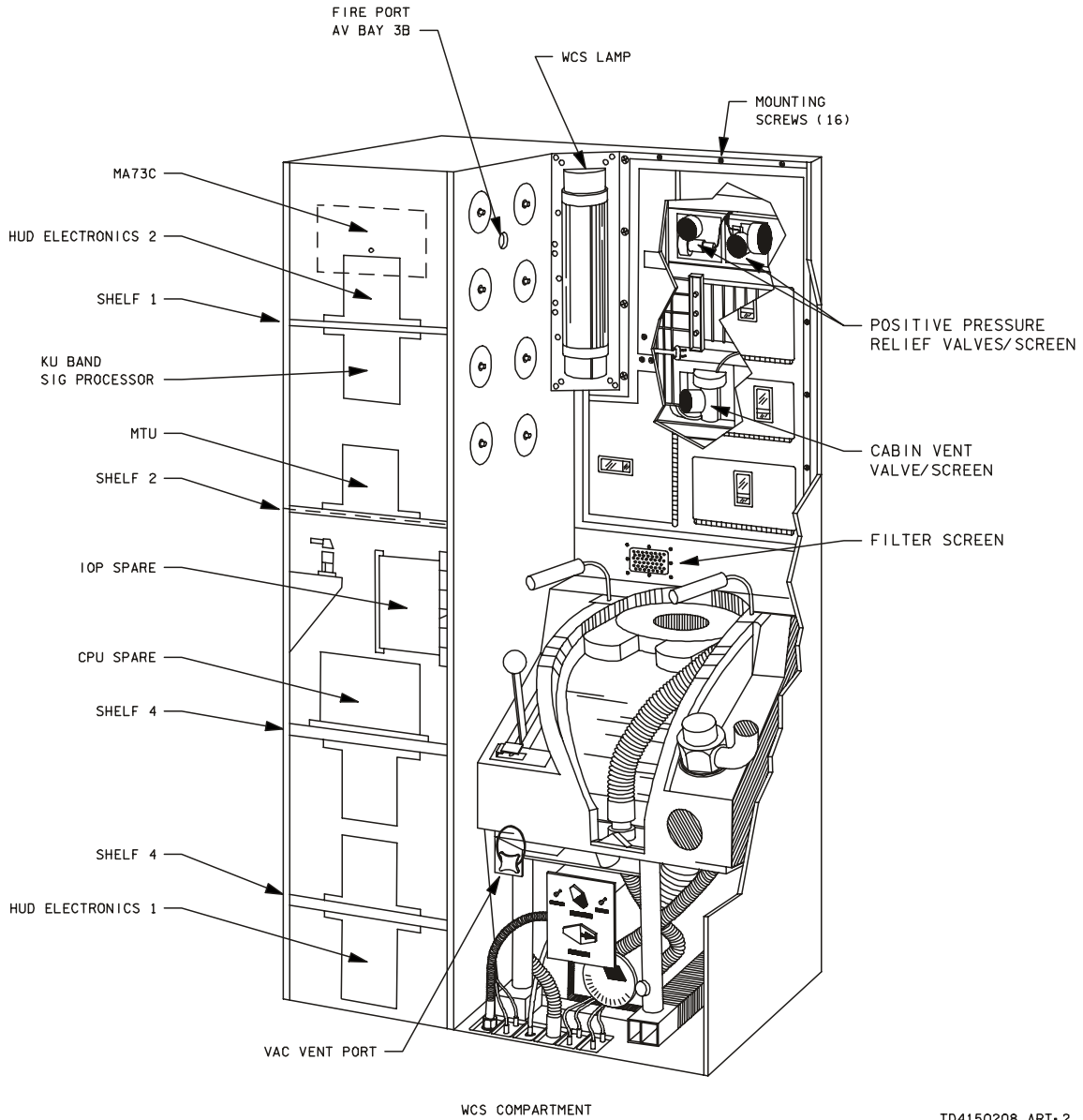
The two negative pressure relief valves protect the crew compartment from being crushed if ambient pressure rises above the pressure in the cabin. These negative pressure relief valves will crack when ambient pressure is 0.2 psid greater than cabin pressure. The negative pressure relief valves are located below the side hatch. Caps are provided as a redundant seal to prevent leakage overboard (Figure 2-8). When the pressure outside the cabin increases above cabin pressure, the relief valves will crack, the caps will pop off, and air will flow into the cabin to equalize the pressure.

The cabin vent isolation and cabin vent valves are used to vent the cabin to the payload bay while the orbiter is on the ground. These two motor-controlled valves are in series. They are located behind the back wall of the WCS compartment and vent into the payload bay (Figure 2-9). Prelaunch cabin pressure integrity checks ensure that there are no leaks in the cabin prior to lift-off. During this cabin leak check, the cabin pressure is increased to 16.7 psia by ground support personnel. The cabin pressure is then monitored for 35 minutes to verify that no pressure decay is occurring. During this time, the cabin vent and cabin vent isolation valves are alternately opened and closed to verify that each valve holds pressure. At the end of the leak check, both valves are opened to allow the cabin pressure to bleed back down to ambient pressure. Once the pressure has equalized, both valves are closed. The cabin vent line has a very high flow capability, 1080 lb/hr at 2 psid; therefore, it is very important that these valves never be opened after lift-off. One of the actions in the Post Insertion Checklist procedures is to disable power to the cabin vent and cabin vent isolation valves to safe them.



TD4150207, SCH, 1

Figure 2-8. Cabin vent/negative and positive pressure relief valves



TD4150208. ART. 2

Figure 2-9. Cabin vent/positive pressure relief valves

2.5 PRESSURE CONTROL SYSTEM CONTROLS

The switches that control PCS systems 1 and 2 are located primarily on Panel L2 and Panel MO10W. The switches on Panel L2 (Figure 2-10) operate the electrically controlled PCS valves. The valves themselves are actually located outside the crew compartment. The layout of the atmosphere pressure control portion of Panel L2 is a schematic of the PCS. The switches and associated talkbacks indicate the position of the valves. The manual valves located on Panel MO10W are drawn on the schematic for completeness but are denoted by a circle with an X in the middle, which represents a switch on another panel.

Panel MO10W is located on the ceiling of the WCS compartment (Figure 2-11). All the manual valves, the 14.7-psi regulators, the 8-psi regulators, the 100-psig O₂ regulators, the water tank regulators, and some sensors are physically located behind Panel MO10W. The toggle switches on Panel MO10W control the valves located directly behind the panel. Any N₂ or O₂ flowing into the cabin through the 14.7 or 8-psi regulators flows through Panel MO10W. All the O₂/N₂ switches control manual isolation valves; the valves are either open or closed. Panel MO10W has a schematic drawn on it, but it is not easily understood because of the layout of the valves.

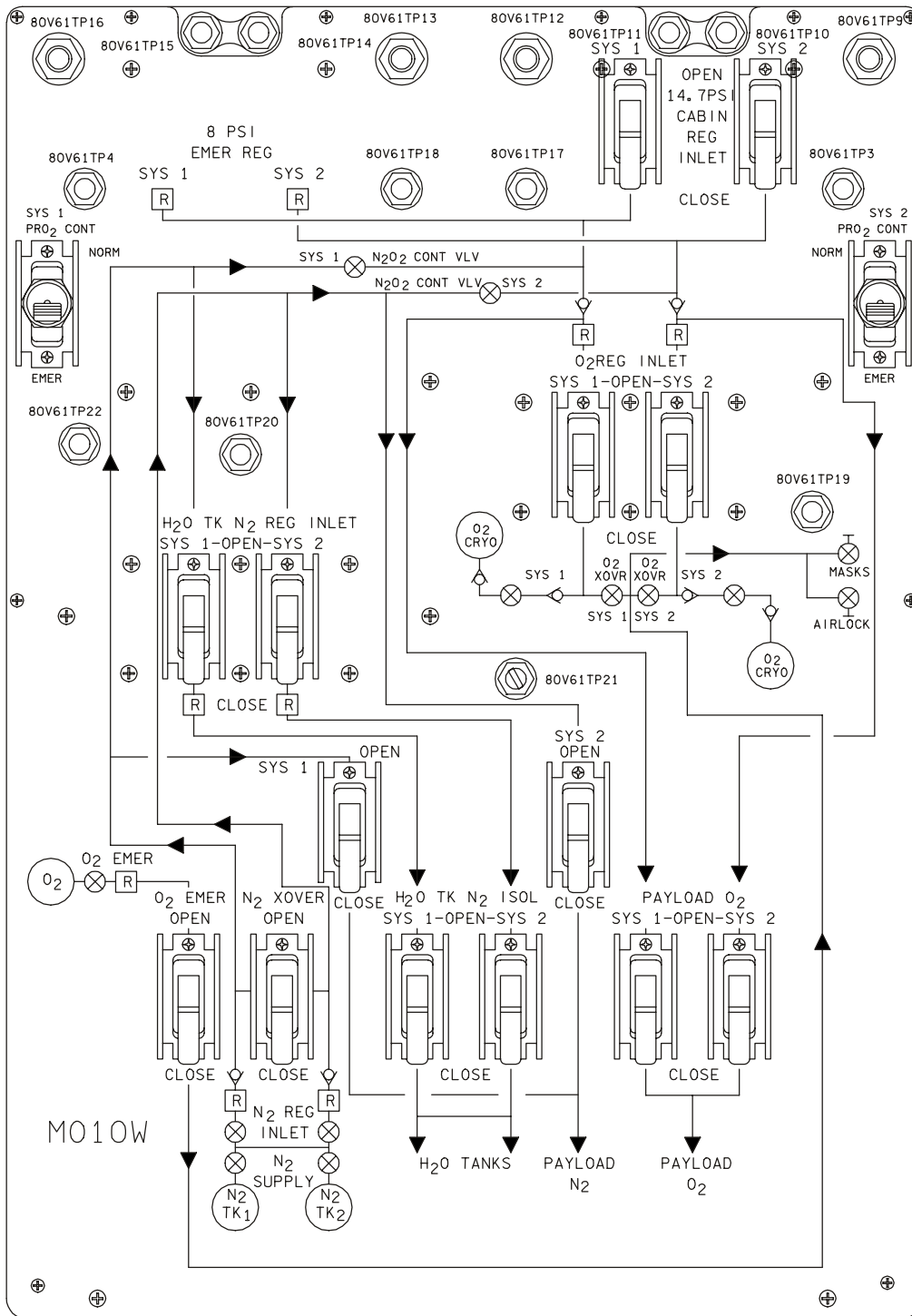
Panel C5, located by the pilot's left leg, contains the direct O₂ valve switch (Figure 2-10). The direct O₂ valve allows direct O₂ flow into the middeck through an orifice on Panel MO69M. Direct O₂ flow is used for 10.2 psia cabin maintenance (see Section 2.7.3) and configuring the crew cabin in response to several failure scenarios. Isolation valve switches and hose connections for LES helmets are labeled as LEH O₂ and are located on Panels C6, MO69M, and MO32M (Figure 2-12). This labeling is a remnant from early in the shuttle program when the LEH was used, rather than the complete LES in use today. The two LEH O₂ SUPPLY switches on Panel C7 allow the LEH regulators to be isolated from the O₂ crossover manifold.

The top portion of Panel L2 contains the CABIN VENT ISOL and CABIN VENT switches and talkbacks (Figure 2-12). The CABIN RELIEF A and CABIN RELIEF B switches and talkbacks are also located on Panel L2.

ECLSS pressurization controls are listed in Table 2-1.

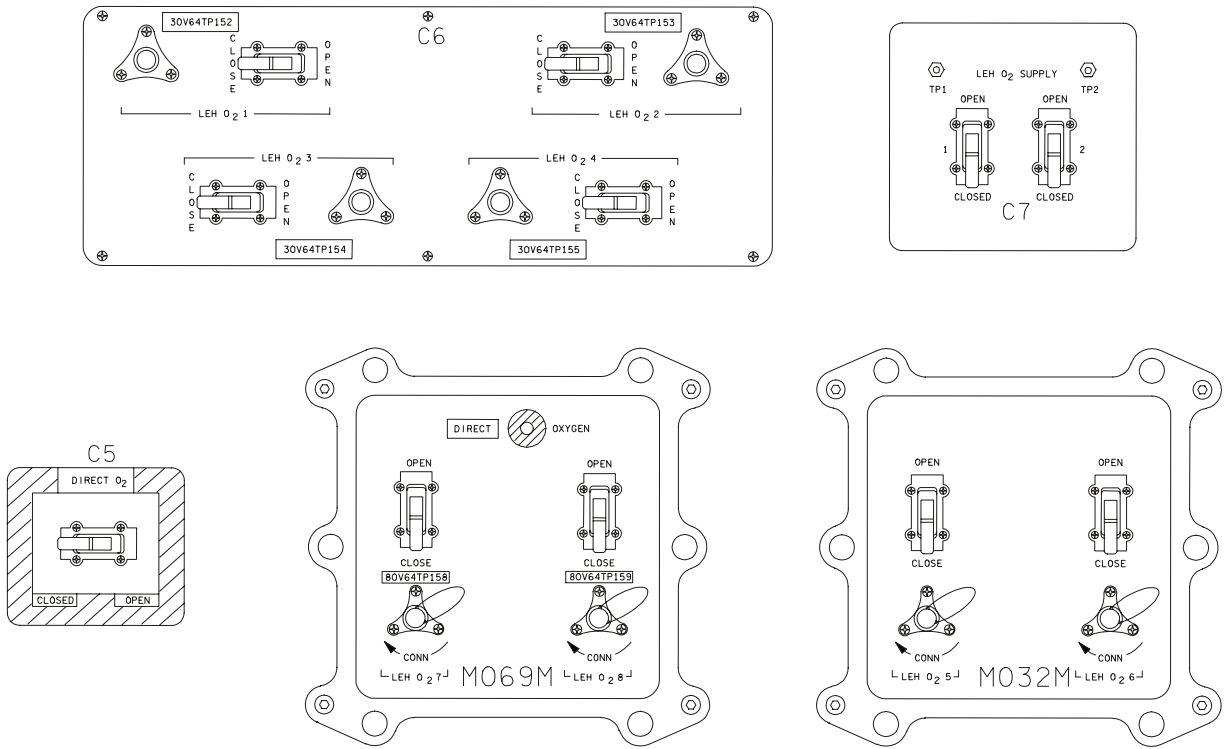
The circuit breakers that power the motor-driven valves are located on Panels MNA O14, MNB O15, and MNC O16 (Figure 2-13). Some of these circuit breakers also power PCS instrumentation.

The MANNED MANUV UNIT GN₂ SPLY ISOL VLV A and B switches supply high-pressure N₂ to service the MMU and through system B only, to the ISS. These switches and their talkbacks are located on Panel R13L (Figure 2-14). If power is lost, the valve will retain its present position, and the talkback will go barberpole. The circuit breakers that power the valves are located on Panel ML86B (Figure 2-14).



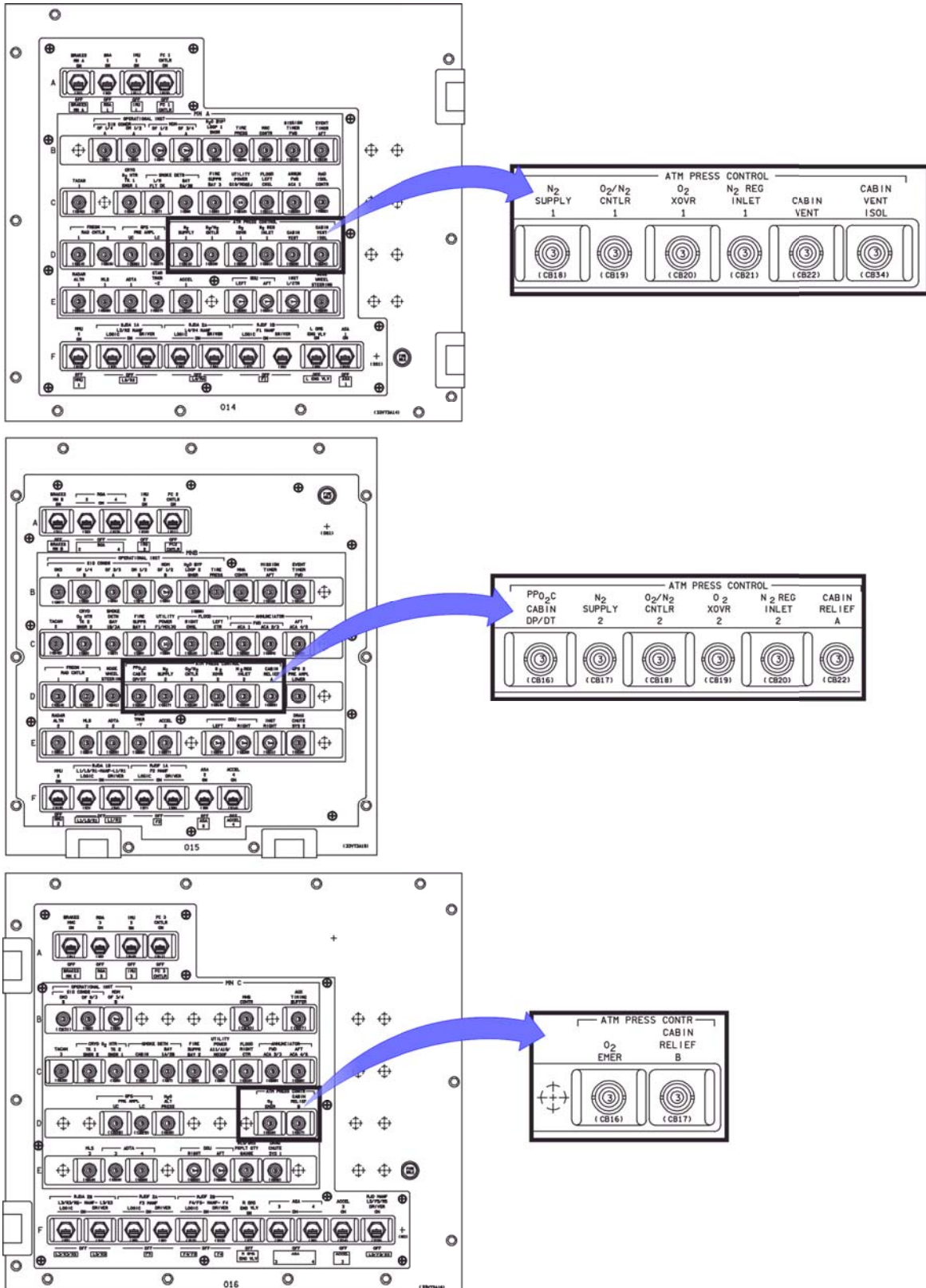
TD4150210, PNL 1

Figure 2-11. Panel MO10W - PCS



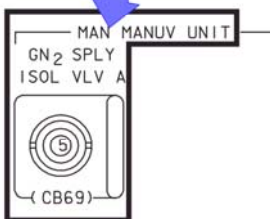
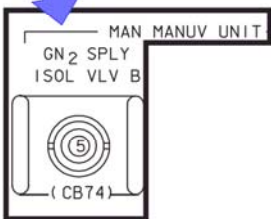
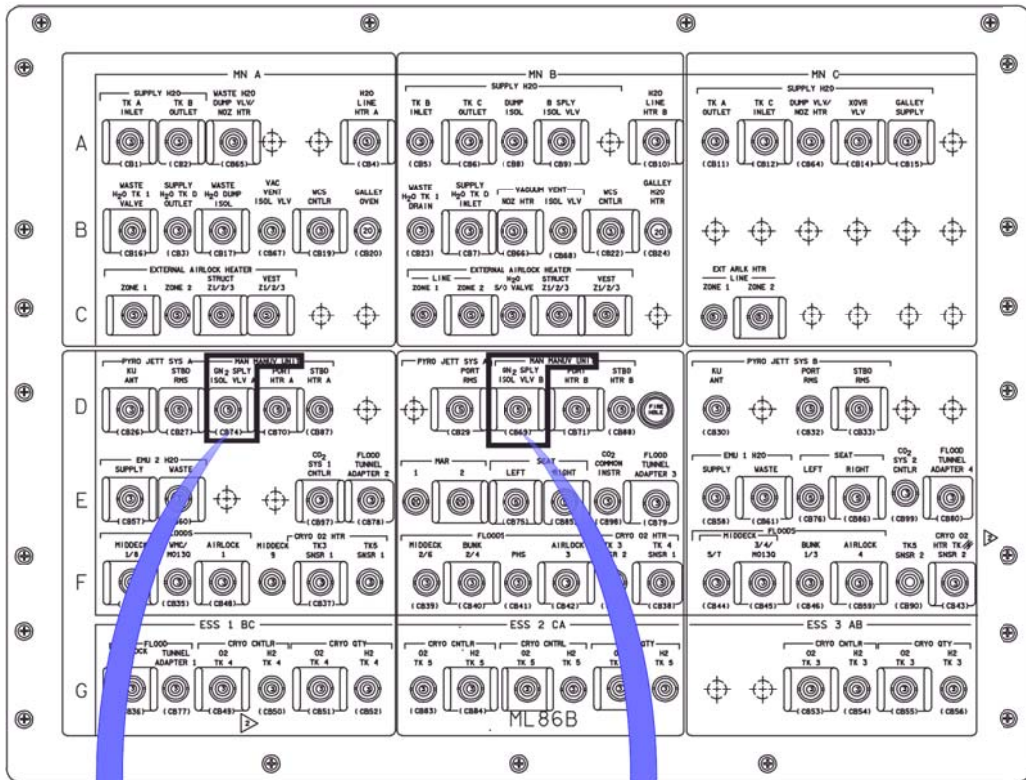
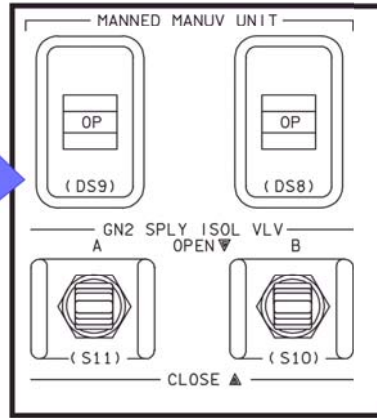
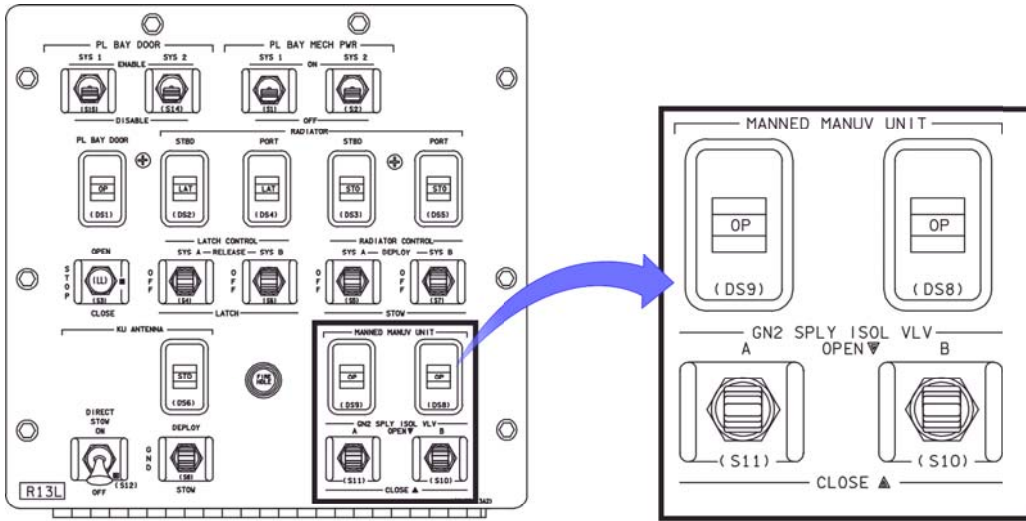
TD4150211, PNL 2

Figure 2-12. Overview panels - PCS



usa006020_037

Figure 2-13. Overhead panels - PCS



usa006020_036

Figure 2-14. MMU - PCS

2.6 PRESSURE CONTROL SYSTEM INSTRUMENTATION/DISPLAYS

2.6.1 Instrumentation

Crew insight into PCS performance is provided by ECLSS instrumentation and Dedicated Signal Conditioners (DSCs). In addition to powering the O₂/N₂ controllers, the O₂/N₂ CNTLR circuit breakers on overhead Panels MNA O14 and MNB O15 (Figure 2-13) power the following transducers:

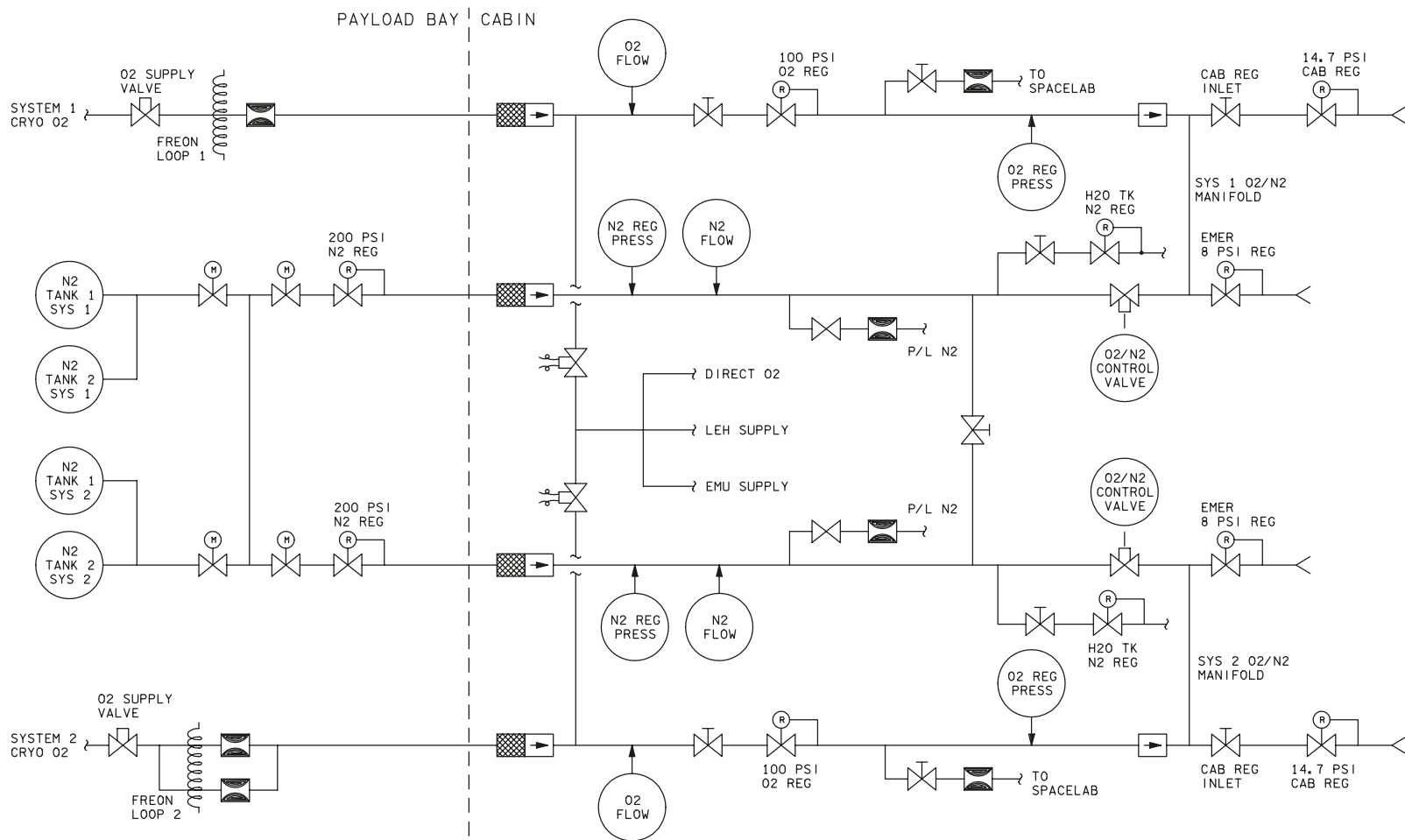
O ₂ /N ₂ CNTLR 1	O ₂ /N ₂ CNTLR 2
Cabin pressure	PPO ₂ sensor B
PPO ₂ sensor A	System 2 O ₂ flow
System 1 O ₂ flow	System 2 N ₂ flow
System 1 N ₂ flow	O ₂ /N ₂ CNTLR valve position
O ₂ /N ₂ CNTLR valve position	

Backup dP/dT is available only with the Backup Flight Software (BFS) during Operational Sequence (OPS) 1, OPS 3, and OPS 0. It is a calculated value based on the rate of change of cabin pressure over time (psia/min). The computation is updated every 5 seconds. The current cabin pressure is compared to the pressure 30 seconds earlier. The backup dP/dT computation is fed by the cabin pressure transducer; therefore, if it fails, the backup dP/dT computation data are no good. The PPO₂ C/CABIN dP/dT circuit breaker on overhead Panel MNB O15 powers PPO₂ sensor C and the cabin dP/dT sensor. The cabin dP/dT sensor is a hardware dP/dT sensor; it is available in all OPS modes in Primary Avionics Software System (PASS) or BFS.

The O₂ concentration computation takes the average of PPO₂ sensors A, B, and C and divides the result by cabin pressure. If one of the PPO₂ sensors fails, it can be removed from the computation. If the cabin pressure sensor fails, the alarms generated by the computation can be inhibited. The O₂ concentration computation is available only in the PASS SM flight software, on SM SYS SUMM 1.

The equivalent dP/dT computation is available in both the PASS and BFS flight software on SM SYS SUMM 1. The cabin dP/dT sensor and the cabin pressure sensor provide the inputs to the calculation. The computation multiplies the cabin dP/dT by 14.7 and divides the result by the cabin pressure. This way, if the leak rate remains constant, the equivalent dP/dT will remain constant because it is adjusted to a reference pressure of 14.7 psia. The cabin dP/dT will decrease as the pressure in the cabin drops.

The N₂ systems 1 and 2 tank quantities and the emergency O₂ tank quantity are derived from a Pressure/Volume/Temperature (PVT) computation performed by the PASS SM computer. The rest of the PCS instrumentation is powered by DSCs. Figure 2-15 shows where some of the PCS instrumentation is located.



TD4150216, SCH 3

Figure 2-15. PCS instrumentation

2.6.2 CRT Displays

The crew has insight into PCS status on the following CRT displays, dependent on mission phase. Backup dP/dT appears only on BFS SM SYS SUMM 1. PASS SM SPEC 66 is the main display for PCS information during orbit operations.

OPS mode	CRT display	Figure number
OPS 1 (ascent)	BFS SM SYS SUMM 1	2-17
OPS 2 (4) (orbit)	PASS SM SPEC 66	2-16
	PASS SM SYS SUMM 1	2-18
OPS 3 (entry)	BFS SM SYS SUMM 1	2-17

2.6.3 Dedicated Displays

Crew-dedicated displays (meters) located on Panel O1 (Figure 2-19) enable the crew to monitor critical PCS parameters at all times. The CABIN dP/dT meter enables the crew to monitor the pressure integrity of the cabin. An increase in cabin pressure will result in a positive dP/dT. A leak out of the cabin will result in a negative dP/dT.

The O₂/N₂ FLOW meter rotary switch enables the crew to monitor system 1 or 2, O₂ or N₂ flow. The CABIN PRESSURE is also displayed on a meter. A toggle switch enables the crew to view either PPO₂ SENSOR A or B on a single meter. These meters are all driven by the same sensors that are shown on the CRT displays.

```

XXX/XXX/ 066      ENVIRONMENT XX X DDD/HH:MM:SS
                    DDD/HH:MM:SS
CABIN              AV BAY 1 2 3
dP/dT ± .XXS PRESS XX.XXS TEMP XXXXS XXXXS XXXXS
PPO2 AIRLK P XX.XS FAN ΔP X.XXS X.XXS X.XXS
A X.XXS FAN ΔP X.XXS SUPPLY H2O
B X.XXS HX OUT T XXXS QTY A XXXS PRESS XXXS
C X.XXS CABIN T XXXS B XXXS DMP LNT XXXS
PPCO2 XX.XS C XXXS NOZ T A XXXS
                    D XXXS B XXXS
O2 FLOW X.XS X.XS WASTE H2O
REG P XXXS XXXS QTY 1 XXXS PRESS XXXS
N2 FLOW X.XS X.XS DUMPLNT XXXS
REG P XXXS XXXS NOZ T A XXXS
O2/N2 CNTL VLV XXS XXS B XXXS
H2O TK N2 P XXXS XXXS VAC VT NOZ T XXXS
N2 QTY XXXS XXXS CO2 CNTLR 1XS 2XS
EMER O2 REG P XXXXS FILTER P X.XXS
                    PPCO2 XX.XS
                    TEMP XXX.XS
IMU FAN A B C ΔP BED A PRESS XX.XS XX.XS
HUMID SEP XS XS XS ΔP B PRESS XX.XS XX.XS
                    ΔP X.XXS X.XXS
                    VAC PRESS X.XS
                    (XX)

```

SPEC 66

OI-30

JSC-19590-116, Systems Management Level C
Flight Software Requirements, STS-116 Base 2
Cycle (OI-30), November 2003, page 6.1-2.

```

2011/ /066      ENVIRONMENT 4 000/01:02:46
                    000/00:00:00
CABIN              AV BAY 1 2 3
dP/dT -.00 CABIN P 14.8 TEMP 96 87 76
PPO2 AIRLK P 14.8 FAN ΔP 3.34 3.36 4.20
A 3.09 FAN ΔP 5.86 SUPPLY H2O
B 3.09 HX OUT T 47 QTY A 44 PRESS 34
C 3.09 CABIN T 68 B 47 DMP LNT 88
PPCO2 0.8 C 98 NOZ T A 56
                    D 98 B 56
O2 FLOW 0.0L 0.0L WASTE H2O
REG P 100 100 QTY 1 5 PRESS 18
N2 FLOW 0.0L 0.0L DMP LNT 70
REG P 205 205 NOZ T A 61
O2/N2 CNTL VLV N2 02 VAC VT NOZ T 113
H2O TK N2 P 18 18 CO2 CNTLR 1 2
N2 QTY 131 131 FILTER ΔP 0.05
EMER O2 QTY 1 REG P 4L PPCO2 2.6
                    TEMP 67.7
IMU FAN A B C ΔP BED A PRESS 14.7 0.0L
HUMID SEP * 4.5 B PRESS 0.0L 0.0L
                    ΔP 2.25 0.0L
                    VAC PRESS 0.0L
SPEC 66 PRO

```

CRT_Spec 66 OI-30.CNV, Michael M Hoekman USA/DT36 281-244-7179

Figure 2-16. PASS SM SPEC 66

The ENVIRONMENT display is an SM display (DISP 66) available in SM OPS 2 and 4; the display provides data on the pressure control system.

Parameter characteristics

CRT name	Units	Displayed range	Status indicators				
CABIN dP/dT	psi/min	+0.45 to -0.55	M	H	L		
PPO ₂ A,B,C	psia	0 to 5	M	H	L	↑	↓
PPCO ₂	mm Hg	0 to 30	M	H	L	↑	
PRESS	psia	0 to 20	M	H	L	↑	↓
AIRLOCK P	psid	-20 to +20	M	H	L	↑	↓
O ₂ FLOW	lbm/hr	0 to 5	M	H	L	↑	
REG P	psia	0 to 300	M	H	L	↑	
N ₂ FLOW	lbm/hr	0 to 5	M	H	L	↑	
REG P	psia	0 to 300	M	H	L	↑	↓
O ₂ /N ₂ CNTL VLV	text	O ₂ or N ₂	M				
H ₂ O TK N ₂ P	psia	0 to 20	M	H	L		↓
N ₂ QTY	lb	0 to 120	M	H	L		↓
EMER O ₂ REG P	psia	0 to 1500	M	H	L	↑	

```

XXXX / XXX / 078      SM SYS SUMM 1      XX X DDD/HH:MM:SS
                      BFS DDD/HH:MM:SS

SMOKE      1/ A      2/ B
CABIN      XX.XS
L/R FD     XX.XS XX.XS
AV BAY     1 XX.XS XX.XS
           2 XX.XS XX.XS
           3 XX.XS XX.XS
CABIN
PRESS      XX.XXS
dP/dT      ± .XXS
BU / EQ ± .XXS ± .XXS
PPO2       X.XXS X.XXS
FAN ΔP     X.XXS
HX OUT T   XXXS
O2 FLOW    X.XS X.XS
N2 FLOW    X.XS X.XS
IMU FAN ΔP X.XXS
ΔV FC1    FC2    FC3
SS1 XXXS  XXXS  XXXS
SS2 XXXS  XXXS  XXXS
SS3 XXXS  XXXS  XXXS
TOTAL AMPS XXXXS
KW        XXS

DC VOLTS   1/ A      2/ B      3/ C
FC          XX.XS   XX.XS   XX.XS
MAIN        XX.XS   XX.XS   XX.XS
ESS         XX.XS   XX.XS   XX.XS
CNTL 1     A        B        C        A
           XXX.XS  XXX.XS  XXX.XS
           2     XXX.XS  XXX.XS  XXX.XS
           3     XXX.XS  XXX.XS  XXX.XS
AC VOLT    φA      XXXS   XXXS   XXXS
           φB      XXXS   XXXS   XXXS
           φC      XXXS   XXXS   XXXS
AMPS       φA      XX.XS  XX.XS  XX.XS
           φB      XX.XS  XX.XS  XX.XS
           φC      XX.XS  XX.XS  XX.XS
FUEL CELL  PH XXS   XXS    XXS
AMPS       XXXS   XXXS   XXXS
REAC VLV   XX     XX     XX
STACK T    ±XXXS ±XXXS ±XXXS
EXIT T     XXXS   XXXS   XXXS
COOL P     XXXS   XXXS   XXXS
PUMP       XXS    XXS    XXS
    
```

SPEC 78 BFS OI-30

STS 83-0020V2-30-A, Space Shuttle Orbiter Operationa Flight Level C
Functional Subsystem Software Requirements, Displays and Controls
Volume 2: Systems Management, May 30, 2003

```

0001/ /078      SM SYS SUMM 1      5 000/00: 25: 39
                      BFS 000/00: 00: 00

SMOKE      1/ A      2/ B      DC VOLTS   1/ A      2/ B      3/ C
CABIN      - 0.0    - 0.0    FC          29.6   29.8   30.2
L/R FD     - 0.0    - 0.0    MAIN        29.6   29.6   30.0
AV BAY     - 0.0    - 0.0    ESS         28.7   28.7   28.8
           - 0.0    - 0.0    CNTL 1     A        B        C        A
           - 0.0    - 0.0              28.0   28.0   28.0
           CABIN    14.7    PRESS      28.0   28.0   28.0
           dP/dT     - .00    dP/dT      28.0   28.0   28.0
           BU/EQ    - .00    - .00    AC VOLT    φA      117   117   117
           PPO2      3.26   3.26    φB      117   117   117
           FAN ΔP     6.00    φC      117   117   117
           HX OUT T   .67     AMPS       φA      5.0   5.4   2.5
           O2 FLOW    0.0L   0.0L    φB      4.0   5.8   2.7
           N2 FLOW    0.0L   0.0L    φC      4.4   6.2   2.8
           IMU FAN ΔP 4.44    FUEL CELL  PH PH↓
           ΔV FC1    FC2    FC3    AMPS       172   190   188
           SS1 20    17    17    REAC VLV   OP     OP     OP
           SS2 17    21    12    STACK T    +204  +204  +203
           SS3 9     23    23    EXIT T     150   150   150
           TOTAL AMPS 570    COOL P     60    59    60
           KW        17     PUMP
    
```

CRT_Spec 78 PASS OI-30.CNV, Michael M Hoekman, USA/DT36 281-244-7179

Figure 2-17. BFS SM SYS SUMM 1

The SM SYS SUMM 1 display is an SM display (DISP 78) available in the BFS; the display provides summary data on the pressure control system.

Parameter characteristics

CRT name	Units	Displayed range	Status indicators				
CABIN dP/dT	psia/min	+0.45 to -0.55	M	H	L		
BU	psia/min	-1 to +1	M	H	L		↓
dP/dT EQ	psia/min	-2 to +2	M	H	L		↓
PRESS	psia	0 to 20	M	H	L	↑	↓
PPO ₂	psia	0 to 5	M	H	L	↑	↓
O ₂ FLOW	lbm/hr	0 to 5	M	H	L	↑	
N ₂ FLOW	lbm/hr	0 to 5	M	H	L	↑	

XXXX / XXX / 078		SM SYS SUMM 1	XX X	DDD/HH:MM:SS DDD/HH:MM:SS
SMOKE	1 / A	2 / B		
CABIN	XX.XS	XX.XS	DC VOLTS	1 / A 2 / B 3 / C
L/R FD	XX.XS	XX.XS	FC	XX.XS XX.XS XX.XS
AV BAY	1 XX.XS	XX.XS	MAIN	XX.XS XX.XS XX.XS
	2 XX.XS	XX.XS	ESS	XX.XS XX.XS XX.XS
	3 XX.XS	XX.XS		A B C
	CABIN		CNTL	1 XXX.XS XXX.XS XXX.XS
PRESS	XX.XS		2 XXX.XS XXX.XS XXX.XS	3 XXX.XS XXX.XS XXX.XS
dP / dT-EQ	± .XXS	± X.XXS	AC	
O2 CONC	XX.XS		VOLT	ΦA XXXS XXXS XXXS
PPO2	X.XXS	X.XXS	ΦB	XXXS XXXS XXXS
FAN ΔP	X.XXS		ΦC	XXXS XXXS XXXS
HX OUT T	XX.XS		AMPS	ΦA XX.XS XX.XS XX.XS
O2 FLOW	XX.XS	XX.XS	ΦB	XX.XS XX.XS XX.XS
N2 FLOW	XX.XS	XX.XS	ΦC	XX.XS XX.XS XX.XS
IMU FAN	AXS	BXS CXS	FUEL CELL	
ΔV	FC1	FC2	AMPS	XXXS XXXS XXXS
SS1	XXXS	XXXS	REAC VLV	XX XX XX
SS2	XXXS	XXXS	STACK T	±XXXS ±XXXS ±XXXS
SS3	XXXS	XXXS	EXIT T	XXXS XXXS XXXS
TOTAL AMPS	XXXXXS		COOL P	XXXS XXXS XXXS
	KW	XXS	PUMP	XXS XXS XXS

SPEC 78
PASS
OI-30

STS 83-0020V2-30-A, Space Shuttle Orbiter Operations Flight Level C
Functional Subsystem Software Requirements, Displays and Controls
Volume 2: Systems Management, May 30, 2003

0001/ /078		SM SYS SUMM 1	5	000/00± 25± 39 000/00± 00± 00
SMOKE	1/A	2/B		
CABIN	- 0.0		DC VOLTS	1/A 2/B 3/C
L/R FD	- 0.0 - 0.0		FC	29.6 29.8 30.2
AV BAY	- 0.0 - 0.0		MAIN	29.6 29.6 30.0
	- 0.0 - 0.0		ESS	28.7 28.7 28.8
	- 0.0 - 0.0			A B C
	CABIN		CNTL	1 28.0 28.0 28.0
PRESS	14.7		2 28.0 28.0 28.0	3 28.0 28.0 28.0
dP/dT-EQ	- .00	- .000	AC	
O2 CONC	22.1		VOLT	ΦA 117 117 117
PPO2	3.26	3.26	ΦB	117 117 117
FAN ΔP	6.00		ΦC	117 117 117
HX OUT T	67		AMPS	ΦA 5.0 5.4 2.5
O2 FLOW	0.0L	0.0L	ΦB	4.0 5.8 2.7
N2 FLOW	0.0L	0.0L	ΦC	4.4 6.2 2.8
IMU FAN	A B* C		FUEL CELL	
ΔV	FC1	FC2	AMPS	172 190 188
SS1	20	17	REAC VLV	0P 0P 0P
SS2	17	21	STACK T	+ 204 + 204 + 203
SS3	9	23	EXIT T	150 150 150
TOTAL AMPS	570		COOL P	60 59 60
	KW	17	PUMP	

SYS SUMM

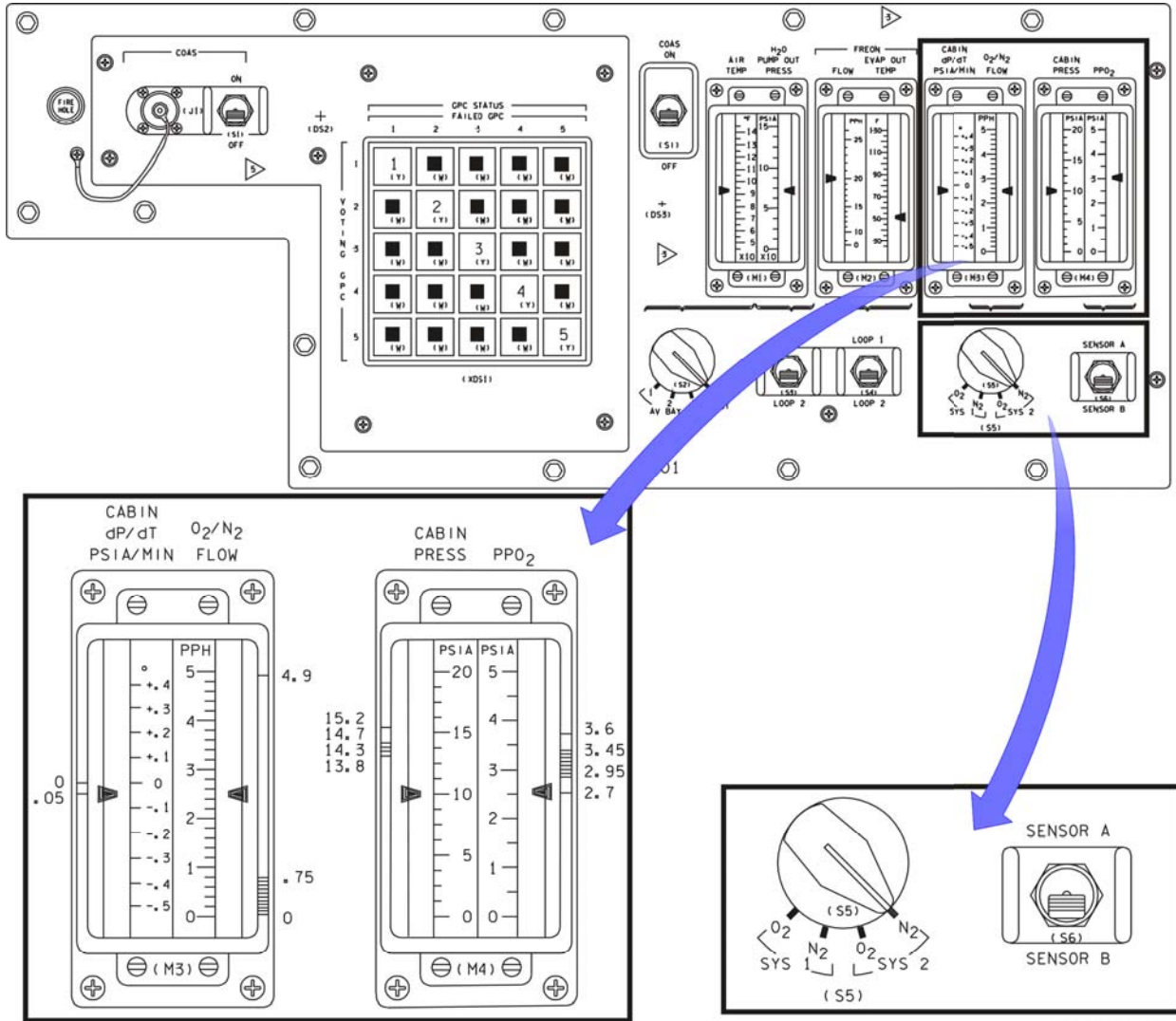
CRT_Spec 78 PASS OI-30.CNV, Michael M Hoekman, USA/DT36 281-244-7179

Figure 2-18. PASS SM SYS SUMM 1

The SM SYS SUMM 1 display is an SM display (DISP 78) available in SM OPS 2 and 4; the display provides summary data on the pressure control system.

Parameter characteristics

CRT name	Units	Displayed range	Status indicators				
CABIN dP/dT	psi/min	+0.45 to -0.55	M	H	L		
dP/dT EQ	psi/min	-2 to +2	M	H	L		↓
O2 CONC	%	0 to 1000	M	H	L	↑	↓
PRESS	psia	0 to 20	M	H	L	↑	↓
PPO2	psia	0 to 5	M	H	L	↑	↓
O2 FLOW	lbm/hr	0 to 5	M	H	L	↑	
N2 FLOW	lbm/hr	0 to 5	M	H	L	↑	



usa006020_035

Figure 2-19. PCS meters - Panel O1

2.6.4 Caution and Warning

The CABIN ATM light on the Panel F7 matrix (Figure 2-20) will illuminate if one of the following parameters is out of limits: (Default values for a 14.7 psi cabin configuration only are shown in the table.)

ID	CRT name	Units	Lower limit	Upper limit
V61R2105A	O ₂ FLOW 1	lb/hr	-	4.9
V61R2205A	O ₂ FLOW 2	lb/hr	-	4.9
V61P2405A	CABIN PRESS	psia	13.8	15.2
V61P2511A	PPO ₂ A	psia	2.7	3.6
V61P2513A	PPO ₂ B	psia	2.7	3.6
V61R2553A	N ₂ FLOW 1	lb/hr	-	4.9
V61R2554A	N ₂ FLOW 2	lb/hr	-	4.9

O ₂ PRESS	H ₂ PRESS	FUEL CELL REAC	FUEL CELL STACK TEMP	FUEL CELL PUMP
CABIN ATM	O ₂ HEATER TEMP	MAIN BUS UNDERVOLT (R)	AC VOLTAGE	AC OVERLOAD
FREON LOOP (R)	AV BAY/ CABIN AIR	IMU	FWD RCS (R)	RCS JET
H ₂ O LOOP	RGA/ACCEL	AIR DATA (R)	LEFT RCS (R)	RIGHT RCS (R)
_____	LEFT RHC (R)	RIGHT/AFT RHC (R)	LEFT OMS (R)	RIGHT OMS (R)
PAYLOAD WARNING (R)	GPC	FCS SATURATION (R)	OMS KIT	OMS TVC (R)
PAYLOAD CAUTION	PRIMARY C/W	FCS CHANNEL	MPS (R)	_____
BACKUP C/W ALARM (R)	APU TEMP	APU OVERSPEED	APU UNDERSPEED	HYD PRESS

(34V73A7A2)

TD4150220, PNL 2

Figure 2-20. Panel F7 C/W matrix

2.7 PRESSURE CONTROL SYSTEM NOMINAL OPERATION

2.7.1 Ascent

For ascent, both 14.7 psia cabin regulator inlet valves are closed to isolate the 14.7-psia cabin regulators. If a cabin leak develops, this configuration conserves N_2 by not allowing any makeup flow into the cabin until the cabin pressure drops below 8 psia. The O_2 regulator inlet valves are closed, directing all the O_2 to the O_2 crossover manifold to supply the LES helmets. The O_2/N_2 control valve on PCS system 1 is open to allow N_2 to pressurize the O_2/N_2 manifold. The O_2/N_2 control valve on PCS system 2 is closed. Nothing is configured to flow through the emergency 8-psia regulators on PCS system 2. The crew will close the visor of their LES helmet shortly before lift-off and breathe 100 percent O_2 until shortly after Solid Rocket Booster Separation (SRB SEP).

2.7.2 Orbit

The PCS system remains in the ascent configuration until early in the flight plan when the orbit PCS configuration is performed. The PCS configuration to system 1 is typically called for on Flight Day (FD)-1. The 14.7-psia cabin regulator inlet valve on the selected PCS is opened. This enables the cabin regulator to automatically maintain the cabin pressure at 14.7 psia. The O_2 regulator inlet valve is opened, and the selected system O_2/N_2 control valve is taken to AUTO. This enables the O_2/N_2 controller to control whether O_2 or N_2 flows into the O_2/N_2 manifold based on cabin PPO_2 level. An O_2 bleed orifice is installed in LEH QD-8 (Figure 2-21) during the presleep activities on FD-1 or postsleep activities on FD-2 (depending on current PPO_2 levels). The O_2 bleed orifice is sized based on crew size and compensates for the crew's metabolic O_2 usage by flowing O_2 directly into the cabin. This helps keep the PPO_2 level stable when the cabin pressure is greater than 14.7 psia and the cabin regulators are not flowing. The PCS is reconfigured to PCS system 2 halfway through the mission.

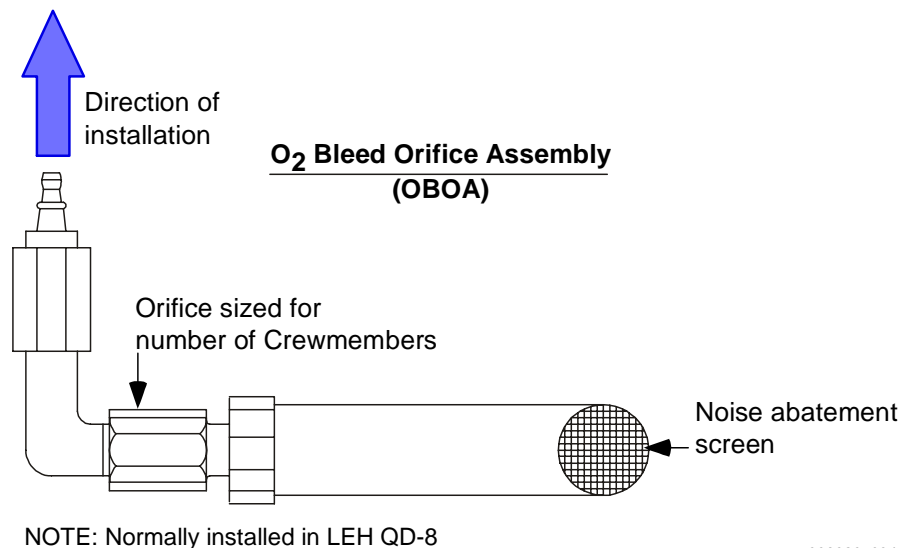


Figure 2-21. O₂ bleed orifice assembly

2.7.3 10.2 psia Cabin

The 10.2-psia cabin protocol was developed by the flight surgeons to minimize the risk of decompression sickness (bends) for the crewmembers preparing for an EVA. The EVA crewmembers must prebreathe pure O₂ before they go EVA to help flush the N₂ out of their body tissue. The following 10.2 cabin protocol options have been developed:

- a. Option 1
 - 1. 60-minute initial prebreathe on Quick Don Mask (QDM)
 - 2. 12 hours at 10.2 psia cabin pressure
 - 3. 75-minute final prebreathe in suit
- b. Option 2
 - 1. 60-minute initial prebreathe on QD
 - 2. 24 hours at 10.2 psia cabin pressure
 - 3. 40-minute final prebreathe in suit
- c. Option 3 - 4-hour prebreathe in suit

For scheduled EVAs, option 1 or 2 is chosen to minimize the in-suit prebreathe just prior to the EVA. The cabin is depressurized to 10.2 psia using the airlock depressurization valve located in the airlock. Since there is no 10.2 psia cabin regulator, the cabin pressure and the PPO₂ levels must be manually managed during 10.2 psia cabin operations.

2.7.4 Entry

The PCS configuration is the same for entry as it was for ascent.

Table 2-1 lists the ECLSS pressurization controls.

Table 2-1. ECLSS pressurization controls

Panel	Type	Nomenclature/ position	Function	Remarks
L2	3-pos toggle (spring-loaded)	CABIN RELIEF A-B/ ENABLE-CLOSE	Enables and closes the cabin 15.5 psid relief valves	2 switches
L2	Talkback	CABIN RELIEF/ OP - BARBERPOLE - CL	Indicates the position OP or CL of cabin relief VLV. Barberpole is a transition state	2 talkbacks
L2	3-pos toggle (spring-loaded)	CABIN VENT VENT ISOL/ OPEN-CLOSE	Opens and closes the vent isolation valve	VENT ISOL and VENT VALVE are in series
L2	3-pos toggle (spring-loaded)	CABIN VENT VENT/ OPEN - CLOSE	OPEN - cabin atmosphere is vented to ambient. CLOSE - overboard venting is inhibited	
L2	Talkback	CABIN VENT VENT ISOL/ OP - BARBERPOLE - CL	Indicates the position of the vent isolation valve. Barberpole is a transition state.	
L2	Talkback	CABIN VENT VENT/ OP - BARBERPOLE - CL	Indicates the position of the cabin vent valve	
L2	3-pos toggle (spring-loaded)	ATM PRESS CONTROL O ₂ SYS 1/2 SUPPLY/ OPEN - CLOSE	Opens and closes the O ₂ system supply valves	2 switches
L2	Talkbacks	ATM PRESS CONTROL O ₂ SYS 1/2 SUPPLY/ OP - CL	Indicates open or closed status of O ₂ supply valve	If power to the valve is lost, the valve will remain in present position, but TB indicates CL
L2	Switch	ATM PRESS CONTROL O ₂ EMER/ OPEN - CLOSE	Opens and closes the emergency O ₂ valve	1 talkback; valve not used; line is capped, tank removed

Table 2-1. ECLSS pressurization controls (continued)

Panel	Type	Nomenclature/ position	Function	Remarks
L2	Talkbacks	ATM PRESS CONTROL O ₂ EMER/ OP - BARBERPOLE - CL		cb on Panel O16 always open. TB indicates BARBERPOLE.
L2	2-pos toggle	ATM PRESS CONTROL O ₂ XOVR SYS 1/2/ OPEN - CLOSE	Opens or closes the O ₂ crossover valves. In the CLOSE position, the valve is unpowered	2 switches
L2	3-pos toggle (spring-loaded)	ATM PRESS CONTROL N ₂ SYS 1/2 SUPPLY/ OPEN - CLOSE	Opens or closes the N ₂ supply valve	2 switches
L2	Talkback	ATM PRESS CONTROL N ₂ SYS 1/2 SUPPLY/ OP - BARBERPOLE - CL	Indicates the position of the N ₂ supply valve. Barberpole is a transition state	2 talkbacks
L2	3-pos toggle (spring-loaded)	ATM PRESS CONTROL N ₂ SYSTEM 1/2 REG INLET/ OPEN - CLOSE	Opens or closes the N ₂ regulator inlet valve	2 switches
L2	Talkback	ATM PRESS CONTROL N ₂ SYSTEM 1/2 REG INLET/ OP - BARBERPOLE - CL	Indicates the positions of the regulator inlet valve. Barberpole is a transition state	2 talkbacks
L2	3-pos toggle	ATM PRESS CONTROL O ₂ /N ₂ CNTLR VLV SYS 1/2/ OPEN - AUTO - CLOSE	OPEN - The controller valve flows N ₂ AUTO - The valve is automatically controlled by the controller CLOSE - the O ₂ /N ₂ valve is closed. No N ₂ flows to the cabin regulator; when required, O ₂ will flow for repress	2 switches

Table 2-1. ECLSS pressurization controls (continued)

Panel	Type	Nomenclature/ position	Function	Remarks
L2	2-pos toggle	ATM PRESS CONTROL PPO ₂ SNSR VLV/ NORM - REVERSE	NORM - Controller 1 controls system 1. Controller 2 controls system 2. REVERSE - Controller 1 controls system 2. Controller 2 controls system 1	
MO10W	2-pos toggle	14.7 PSI CABIN REG INLET SYS 1/2/ OPEN - CLOSE	Isolates the cabin 14.7 regulator	2 switches
MO10W	2-pos toggle	PPO ₂ CNTLR SYS 1/2/ NORM - EMER	Selects either 2.95 - 3.45 control band or 1.95 - 2.95 control band	2 switches
MO10W	2-pos toggle	O ₂ REG INLET SYS 1/2/ OPEN - CLOSE	Isolates the O ₂ regulators (100 psi) from the cryo source	2 switches
MO10W	2-pos toggle	H ₂ O TK N ₂ REG INLET SYS 1/2/ OPEN - CLOSE	OPEN position permits N ₂ flow to the H ₂ O regulators to pressurize H ₂ O tank with N ₂	2 switches
MO10W	2-pos toggle	H ₂ O TK N ₂ ISOL SYS 1/2/ OPEN - CLOSE	Isolates the H ₂ O TK pressure manifold from N ₂ system	2 switches
MO10W	2-pos toggle	O ₂ EMER/ OPEN - CLOSE	Isolates the O ₂ emergency regulator from the O ₂ XOVER	Valve remains closed
MO10W	2-pos toggle	N ₂ XOVER/ OPEN - CLOSE	Permits crossflow between SYS 1 and 2 N ₂ systems downstream of the N ₂ regulators	
MO10W	2-pos toggle	PAYLOAD O ₂ SYS 1/2/ OPEN - CLOSE	Isolates the O ₂ system from the payload interface	2 switches
O1	Rotary	O ₂ /N ₂ FLOW/ O ₂ -SYS 1-N ₂ O ₂ -SYS 2-N ₂	Selects SYS 1 or 2 O ₂ - N ₂ flow for display	

Table 2-1. ECLSS pressurization controls (continued)

Panel	Type	Nomenclature/ position	Function	Remarks
O1	2-pos toggle	PPO ₂ SENSOR/A-B	Selects sensor A or B for meter input	
O14	Circuit breaker	MNA ATM PRESS CONTROL N ₂ SUPPLY 1	Provides Main A power to the N ₂ SYS 1 SUPPLY switch on Panel L2	1 cb
O14	Circuit breaker	MNA ATM PRESS CONTROL O ₂ /N ₂ CNTLR 1	Provides Main A power to the SYS 1 O ₂ /N ₂ CNTLR VLV switch on Panel L2	1 cb
O14	Circuit breaker	MNA ATM PRESS CONTROL O ₂ XOVR 1	Provides Main A power to the SYS 1 O ₂ XOVR switch on Panel L2	1 cb
O14	Circuit breaker	MNA ATM PRESS CONTROL N ₂ REG INLET	Provides Main A power to the SYS 1 N ₂ REG INLET switch on Panel L2	1 cb
O14	Circuit breaker	MNA ATM PRESS CONTROL CABIN VENT	Provides Main A power to the CABIN VENT switch on Panel L2	1 cb
O14	Circuit breaker	MNA ATM PRESS CONTROL CABIN VENT ISOL	Provides Main A power to the CABIN VENT ISOL SWITCH, Panel L2	1 cb
O15	Circuit breaker	MNB ATM PRESS CONTROL PPO ₂ C CAB dP/dT	Provides Main B power to the dP/dT sensor and PPO ₂ C sensor power supply	1 cb
O14	Circuit breaker	MNA ATM PRESS CONTROL CABIN VENT	Provides Main A power to the CABIN VENT switch on Panel L2	1 cb
O14	Circuit breaker	MNA ATM PRESS CONTROL CABIN VENT ISOL	Provides Main A power to the CABIN VENT ISOL SWITCH, Panel L2	1 cb

Table 2-1. ECLSS pressurization controls (continued)

Panel	Type	Nomenclature/ position	Function	Remarks
O15	Circuit breaker	MNB ATM PRESS CONTROL PPO ₂ C CAB dP/dT	Provides Main B power to the dP/dT sensor and PPO ₂ C sensor power supply	1 cb
O15	Circuit breaker	MNB ATM PRESS CONTROL N ₂ SUPPLY 2	Provides Main B power to the SYS 2 N ₂ SUPPLY switch on Panel L2	1 cb
O15	Circuit breaker	MNB ATM PRESS CONTROL O ₂ /N ₂ CNTLR 2	Provides Main B power to the SYS 2 O ₂ /N ₂ CNTLR VLV switch on Panel L2	1 cb
O15	Circuit breaker	MNB ATM PRESS CONTROL N ₂ REG INLET 2	Provides Main B power to the SYS 2 N ₂ REG INLET switch on Panel L2	1 cb
O15	Circuit breaker	MNB ATM PRESS CONTROL CABIN RELIEF A	Provides Main B power to the CABIN RELIEF A switch on Panel L2	1 cb
O16	Circuit breaker	MNC ATM PRESS CONTROL O ₂ EMER	Provides Main C power to the O ₂ EMER switch on Panel L2	1 cb system deactivated; cb kept open
O16	Circuit breaker	MNC ATM PRESS CONTROL CABIN RELIEF B	Provides Main C power to the CABIN RELIEF B switch on Panel L2	1 cb
C5	2-pos toggle	DIRECT O ₂ / OPEN - CLOSE	Allows O ₂ flow into the cabin	
C6	2-pos toggle	LEH O ₂ 1 (2, 3, 4)/ OPEN - CLOSE	Opens the O ₂ supply to the LEH QDs	4 switches
C7	2-pos toggle	LEH O ₂ SUPPLY/ OPEN - CLOSE	Isolates the left regulators from the O ₂ supply	2 switches
MO32M	2-pos toggle	LEH O ₂ 5 (6)/ OPEN - CLOSE	Opens the O ₂ supply to the LEH QDs	2 switches
MO69M	2-pos toggle	LEH O ₂ 7 (8)/ OPEN - CLOSE	Opens the O ₂ supply to the LEH QDs	2 switches

Table 2-1. ECLSS pressurization controls (concluded)

Panel	Type	Nomenclature/ position	Function	Remarks
R13L	2-pos toggle	MANNED MANUV UNIT GN ₂ SPLY ISOL VLV A (B)/ OPEN - CLOSE	Supplies N ₂ to the MMU	2 valves
R13L	Talkback	MANNED MANUV UNIT GN ₂ SPLY ISOL VLV/ OP - BARBERPOLE - CL	Indicates the position of the MMU GN ₂ supply isolation valve	2 talkbacks
ML86B	Circuit breaker	MANNED MANUV UNIT GN ₂ SPLY ISOL VLV A (B)	Provides MNA (MNB) power to the MMU GN ₂ supply isolation valve on Panel R13L	2 circuit breakers

2.8 PRESSURIZATION SYSTEM PERFORMANCE, LIMITATIONS, AND CAPABILITIES

a. Crew cabin volume with external airlock	2475 ft ³
b. External airlock volume	185 ft ³
c. Cabin pressure regulators flow capacity at 100 psid (SPEC)	75 lb/hr
1. Regulated pressure	14.7 psia
2. Minimum emergency pressure	8.0 psia
d. N ₂ tank volume	8181 in ³
e. N ₂ tank operating range	285 to 3300 psig
f. N ₂ tank burst pressure	4950 psig
g. N ₂ tank operating temp range	-65° to 200° F
h. Emergency O ₂ tank (identical to N ₂ tanks)	No longer installed; line capped
i. Cryo O ₂ tanks maximum operating pressure	1035 psig
j. Cryo O ₂ tanks proof pressure	1138.5 psig
k. Cryo O ₂ tanks burst pressure	1552 psig
l. Cryo O ₂ tanks operating range	811 to 875 psig
m. ECLSS O ₂ budget	2.08 lb/man-day

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3.0 ATMOSPHERIC REVITALIZATION SYSTEM

The ARS circulates air and water through the crew compartment to remove heat, control humidity, and condition the cabin air. The cabin air picks up heat, moisture, CO₂, odor, dust, debris, and particles of skin and hair from the crew. The Avionics (Av) and electronic equipment located in the cabin also generate heat that is picked up by the air. The ARS air system consists of a network of fans that circulates the air through the cabin, the Av Bays, and the Inertial Measurement Units (IMUs).

The ARS water coolant loops collect heat from the air at the air/water heat exchanger (HX). The water coolant loops also provide conductive cooling for electronic equipment mounted directly on water-cooled coldplates. The crew compartment is kept thermally stable because the waste heat collected by the water coolant loops is passed outside the cabin to the ATCS Freon coolant loops.

3.1 ARS AIR SYSTEM

The ARS air system is functionally divided into three separate air circulation systems. The cabin fans circulate the cabin air, the Av Bay fans circulate air in Av Bays 1, 2, and 3A, and the IMU fans draw air in from the cabin to cool the IMUs. A fourth air system circulates air into the external airlock via booster fans. This system is discussed later.

3.2 CABIN AIR

Refer to Figure 3-1 for this discussion. The cabin fan draws warm air into the cabin fan ducting where filters remove particles suspended in the air. The cabin fan blows a portion of the air through the lithium hydroxide (LiOH) canisters where CO₂ and odor are removed. On extended duration flights, LiOH may be replaced with the Regenerable Carbon Dioxide Removal System (RCRS). See Appendix C for a discussion of the RCRS. Just upstream of the cabin HX, the cabin temperature control valve bypasses some of the warm air around the cabin HX to maintain a comfortable cabin temperature. The warm cabin air is then routed through the cabin HX where the air is cooled by the water coolant loops. The humidity in the cabin air is condensed out on a slurper bar in the cabin HX. The humidity separator creates a suction that draws the condensate away from the HX and drives it to the wastewater tank. An Ambient Temperature Catalytic Oxidizer (ATCO) removes carbon monoxide (CO) from the air. The cool conditioned cabin air and the warm bypassed air then come together again and flow back into the cabin through the return air ducts.

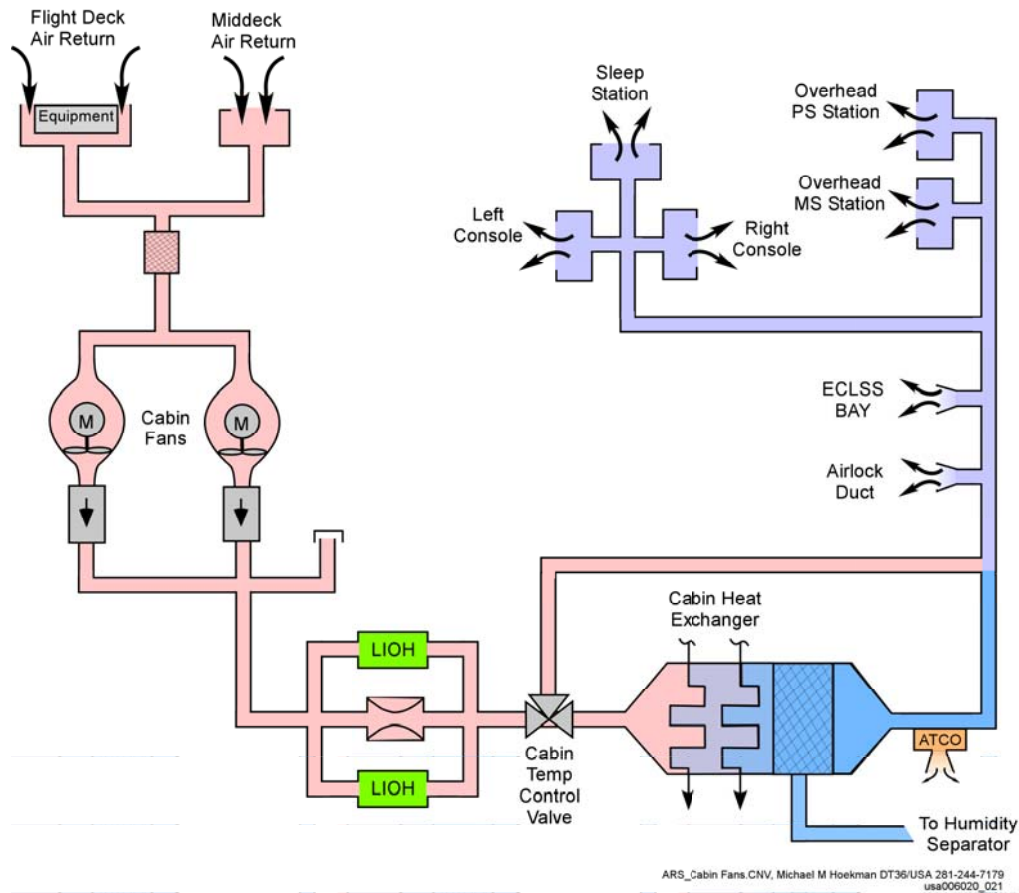


Figure 3-1. Cabin air system

3.2.1 Cabin Fan

One of two cabin fans is used at all times. The cabin fan draws air past electronic equipment to provide that equipment with forced air cooling (Table 3-1 at the end of Section 3). The cabin fans are located below the middeck floor in the ECLSS bay (Figure 3-2). Access to the fans is provided by Panel MD79G. The cabin fan filter is also accessible through Panel MD79G.

Each fan is powered by a three-phase, 115-volt Alternating Current (AC) motor. These 495-watt motors produce a nominal flow rate of 1400 lb/hr through the cabin air ducting. A check valve located at the outlet of each fan (Figure 3-1) prevents air from backflowing through the non-operating fan. This flapper-type check valve will open if there is a 2 psi differential pressure across the valve. A cabin fan will not start on two phases of AC. However, if the cabin fan is already operating when a phase of AC is lost, the fan will continue to run on two phases of AC. A cabin fan can be started on “2-1/2 phases” of AC, with the extra half phase being provided by the induced voltage generated by other rotating equipment (that is, fans and pumps) running on that AC bus. If a phase of AC is lost with a short, then the induced voltage will not be usable and starting the cabin fan will not be possible.

3.2.2 LiOH Canisters

Odor and CO₂ are removed from the cabin air by the LiOH canisters. A flow orifice directs approximately 120 lb/hr of air through each of the two LiOH canisters (Figure 3-1). Activated charcoal in the canister controls odor; CO₂ is removed from the air when the CO₂ reacts with the LiOH to produce lithium carbonate. The LiOH canisters are changed out periodically during the mission on a predetermined schedule, generally one or two times per day based on the number of crewmembers. The LiOH canisters are located in the ECLSS bay and are accessible through the MD54G opening in the middeck floor (Figure 3-2). Up to 30 spare LiOH canisters are located in the ECLSS bay below Panel MD52M.

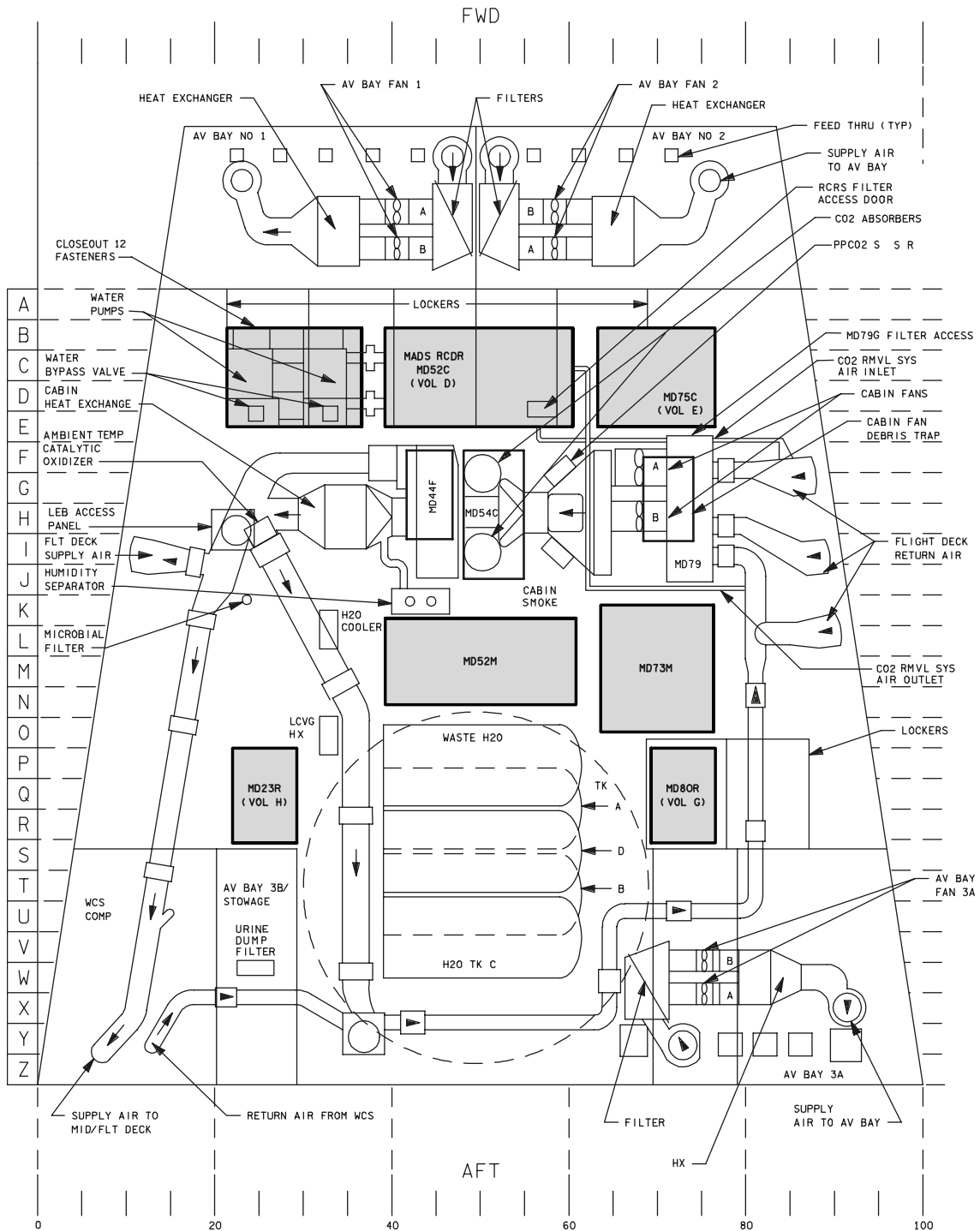
CAUTION

During LiOH canister change out, both cabin fans should be turned off. Dust from the LiOH canisters kicked up by the cabin fan has caused eye and nose irritation on previous missions. LiOH dust may also be a contributing factor to the humidity separator failures.

3.2.3 Cabin Temperature Control Valve

The cabin temperature control valve is a variable position valve that controls the flow of air that bypasses the cabin HX (Figure 3-1). The ratio of warm bypassed air and cool air from the cabin HX determines the cabin temperature. The cabin temperature control valve may be positioned manually by the crew or automatically by one of the two cabin temperature controllers. The cabin temperature controller is a motor-driven actuator that adjusts the cabin temperature control valve to achieve the temperature selected on the cabin temperature rotary knob located on Panel L1. The cabin temperature control valve and the two cabin temperature controllers are located in the ECLSS bay below Panel MD44F (Figure 3-2).

LOWER EQUIPMENT BAY (OV103)



TD4150302. ART 3
td415b_003b.cnv

Figure 3-2. ECLSS bay – View looking down through middeck floor

LOWER EQUIPMENT BAY (OV104)
FWD

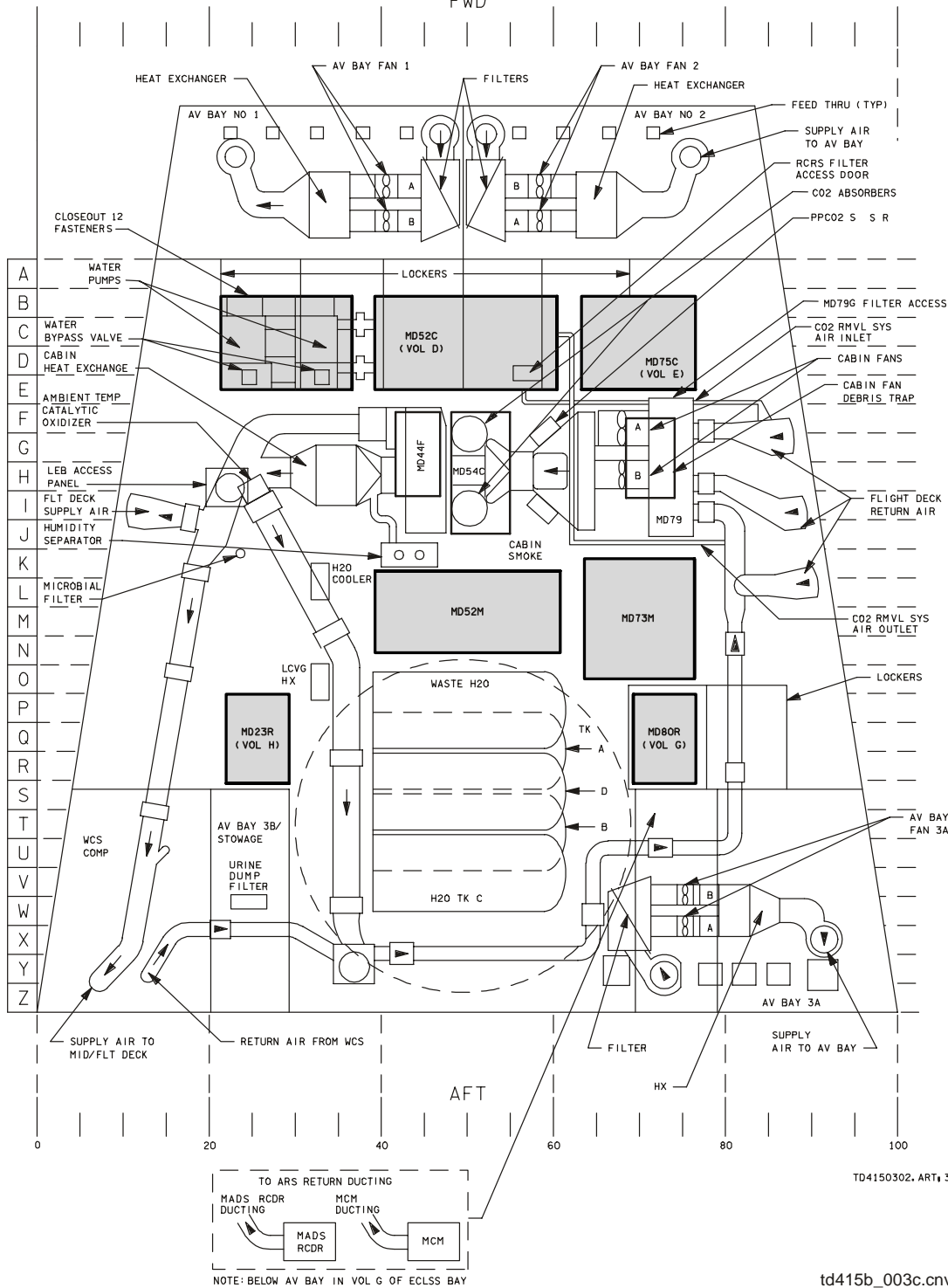


Figure 3-2. ECLSS bay – View looking down through middeck floor (continued)

LOWER EQUIPMENT BAY (OV105)

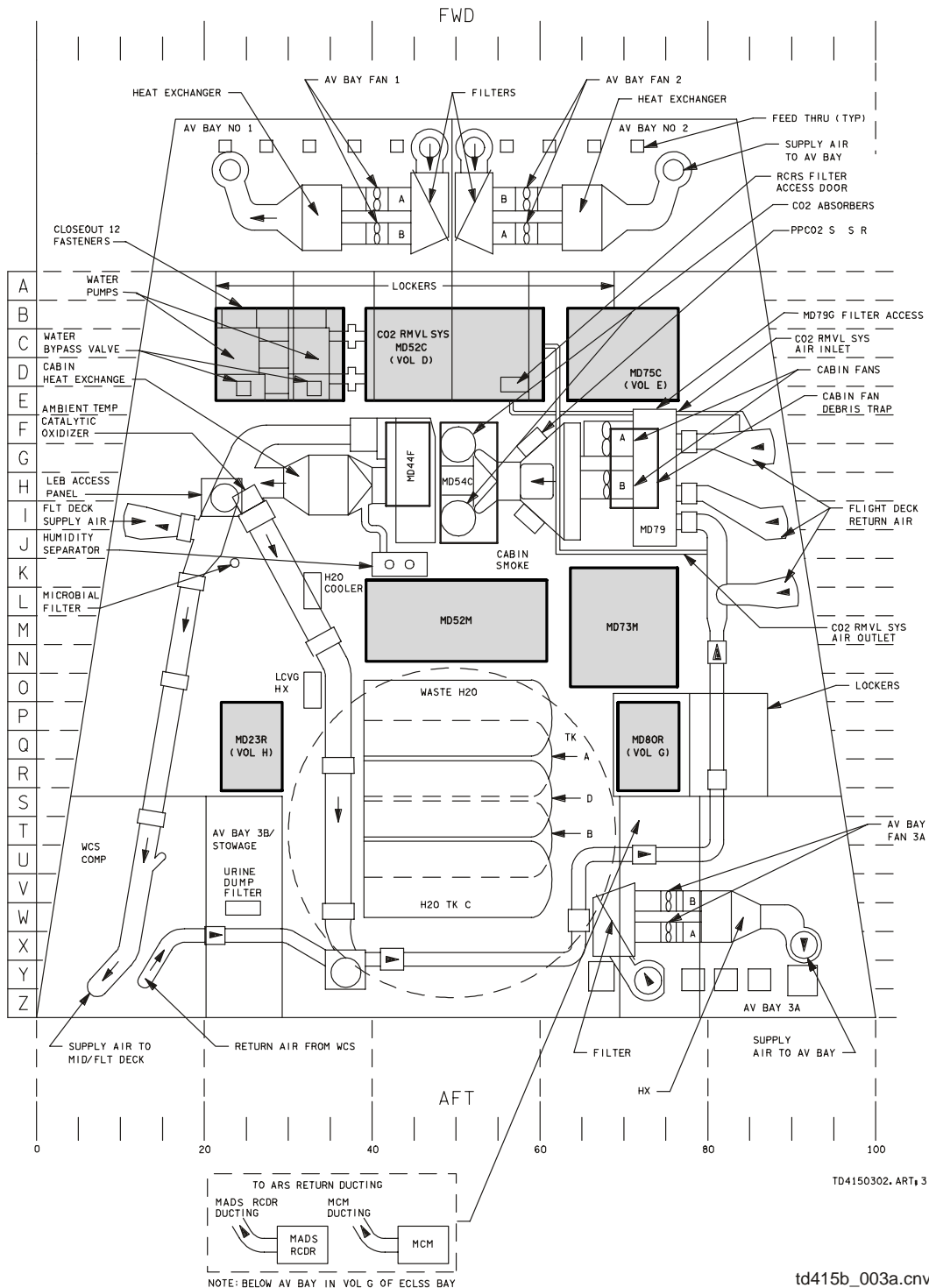
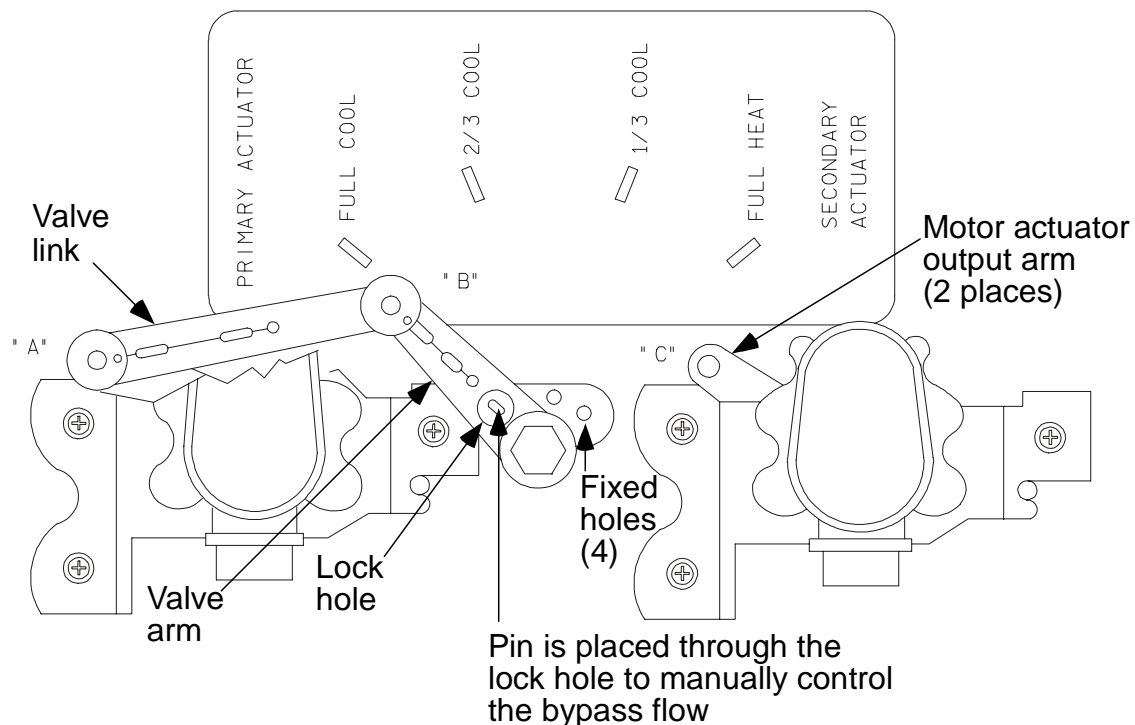


Figure 3-2. ECLSS bay – View looking down through middeck floor (concluded)

In manual mode, the crew can position the cabin temperature control valve in one of four positions by pinning the valve arm to one of the four fixed holes (FULL COOL, FULL HEAT, etc.) (Figure 3-3). To use the auto mode, the valve arm must be pinned to the valve arm linkage, and the valve arm linkage must be pinned to either the primary or secondary cabin temperature controller actuator. Once this is completed and the cabin temperature controller is powered, the rotary switch can be adjusted to increase or decrease the cabin air temperature. If the active cabin temperature controller malfunctions, the valve arm linkage must be physically disconnected and pinned to the alternate cabin temperature controller actuator before the alternate controller can be selected. The total travel time from full cool to full hot is a maximum of 4 minutes in the auto mode.



usa006020_040

Figure 3-3. Cabin temperature controller

3.2.4 Cabin Heat Exchanger

The cabin HX transfers heat that has been picked up by the cabin air to the ARS water coolant loop. The cabin fan blows warm cabin air through the air/water HX, and the air is cooled (Figure 3-1). The humidity in the cabin air condenses out on a slurper bar in the cabin HX. The condensate is drawn away from the cabin HX and into the humidity separator.

3.2.5 Humidity Separator

Two humidity separators are located adjacent to the cabin HX in the ECLSS bay below the middeck floor (Figure 3-2). One humidity separator is used at all times. Each

humidity separator is powered by a three-phase, 115-volt AC motor. The humidity separator fan develops a suction that draws water-laden air away from the cabin HX. The air/condensate mixture is separated by a centrifugal rotating drum. The condensate is drawn off and stored in the wastewater tank. For ISS missions, the condensate is stored in a CWC (Contingency Water Container). This reduces the number of wastewater dumps required while docked. The dehumidified air is returned to the ECLSS bay at the rate of 37 lb/hr (Figure 3-4).

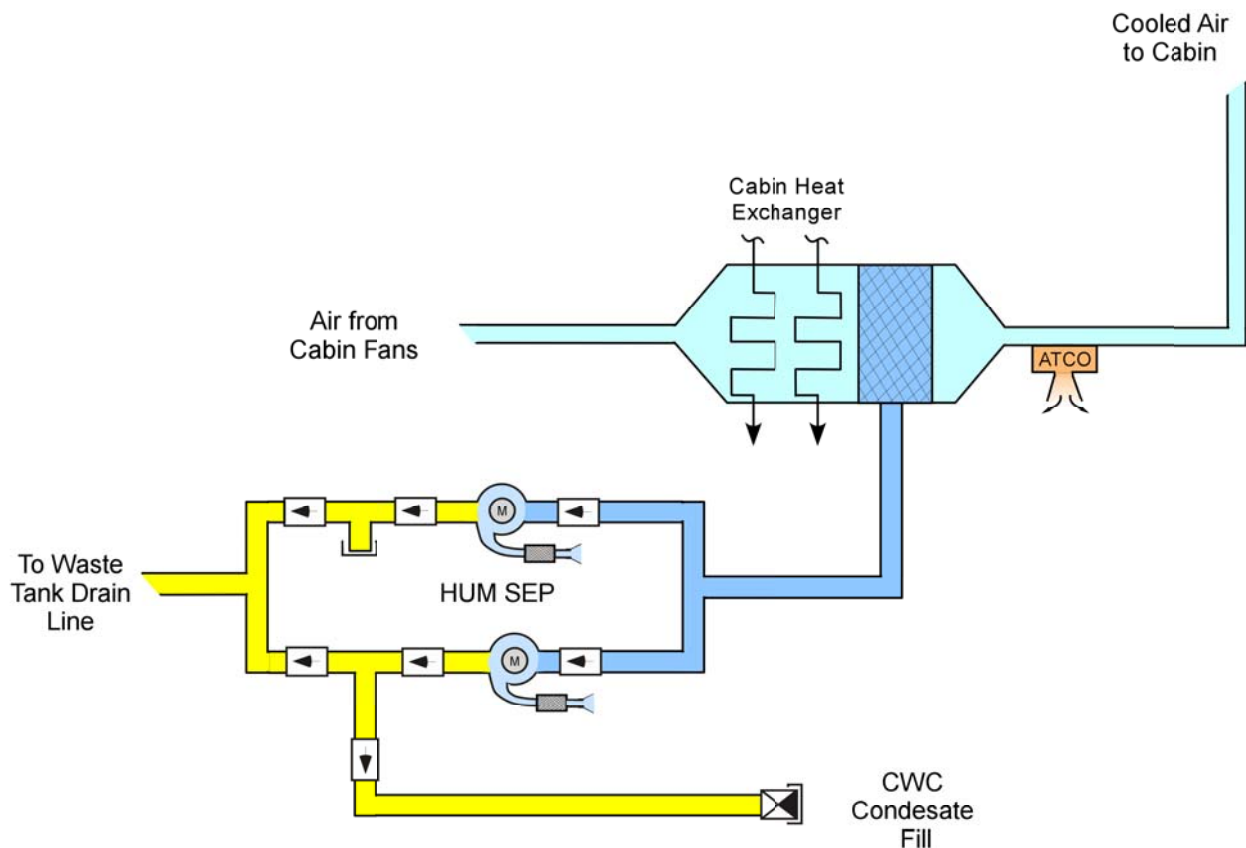


Figure 3-4. Humidity separator

3.2.6 Ambient Temperature Catalytic Oxidizer

The ATCO removes CO generated by the crew and from the off-gassing of nonmetallic materials in the cabin. The ATCO is located just past the cabin HX (Figure 3-1). The CO is converted to CO₂ by catalytic oxidation, and the CO₂ is then removed by the LiOH canisters. The catalyst is 2 percent platinum on carbon.

3.2.7 Avionics Bay Fans

Since convective cooling requires the presence of gravity to create air currents, which then carry off heat, no convection occurs in microgravity. The Av Bay fans circulate air through the Av Bays to replace convective cooling with continual forced air cooling. Av Bays 1, 2, and 3A each have two fans, one of which is used at all times. Each Av Bay functions as an enclosed air circulation system but is not completely airtight. The Av Bay fans are located in the ECLSS bay below the middeck floor level under their respective Av Bays (Figure 3-2). The fans draw air across the avionics equipment. The air picks up the heat generated by this equipment and is blown through the Av Bay HX, where the heat picked up from the Av Bay is transferred to the ARS H₂O loop (Figure 3-5).

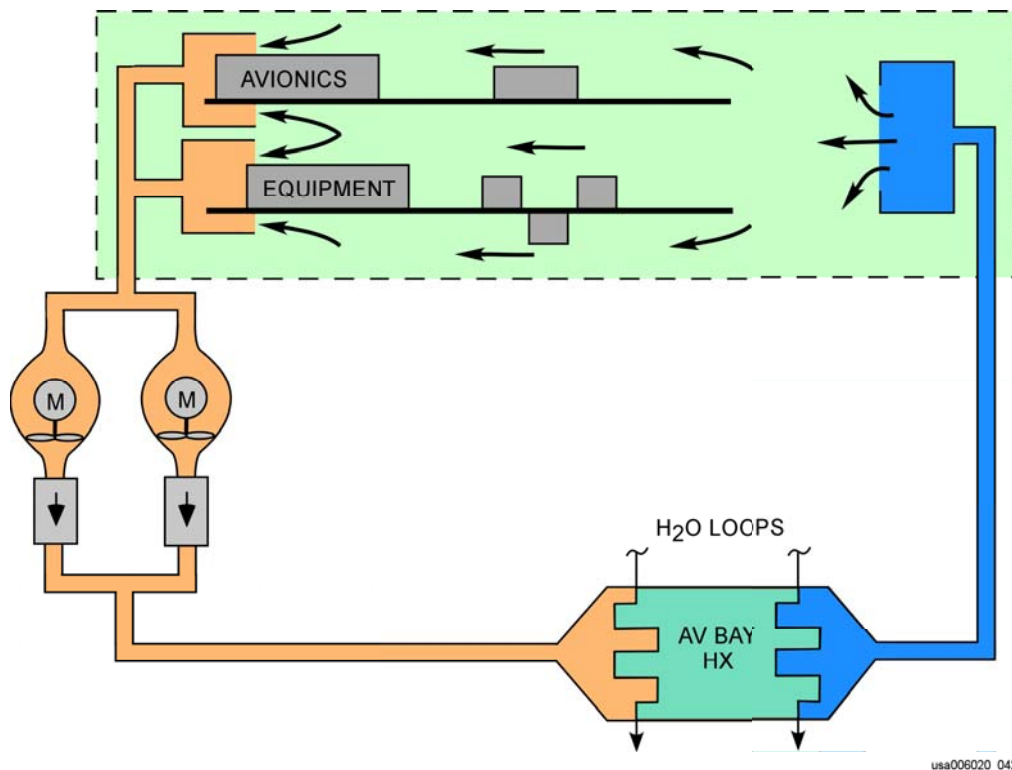
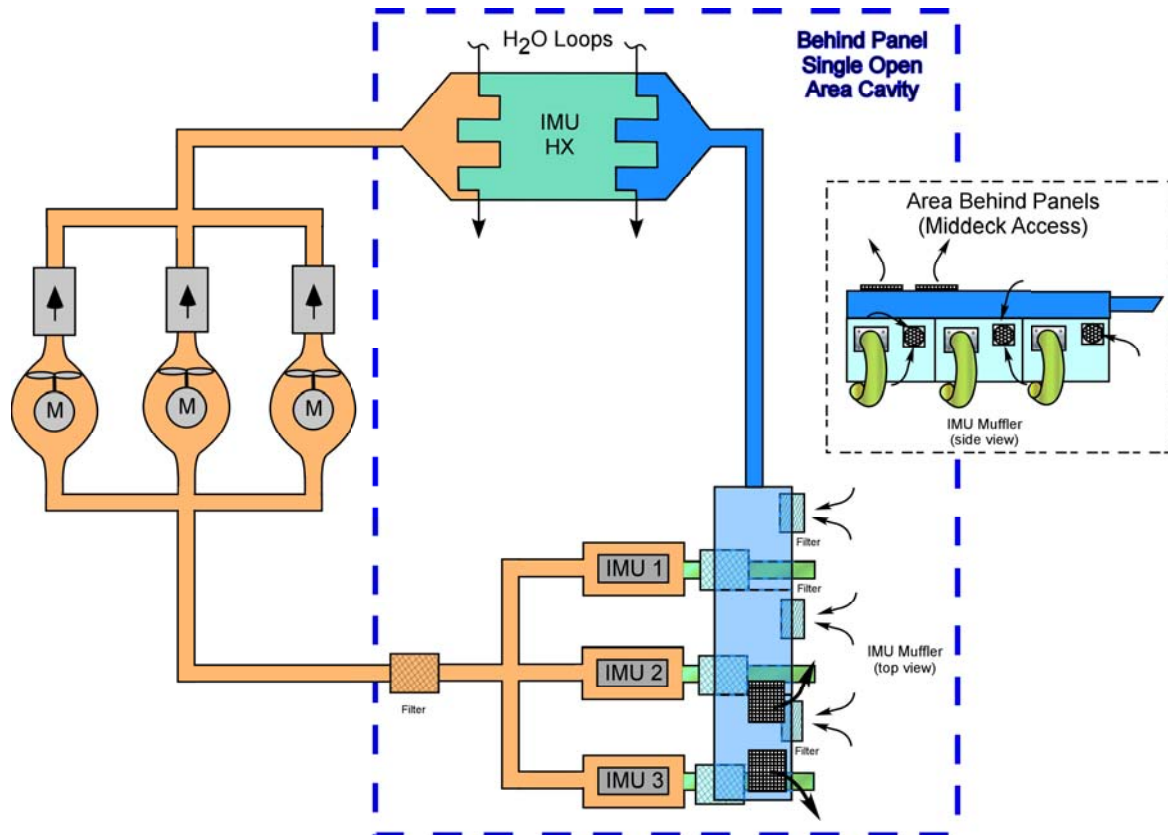


Figure 3-5. Av Bay fans

Each fan in Av Bays 1 and 2 is powered by a three-phase, 115-volt AC motor. These 111-watt motors produce a normal flow rate of 875 lb/hr through the Av Bays. The Av Bay fans will start and run on two phases of AC. A check valve located at the outlet of each fan prevents air from backflowing through the non-operating fan. The flapper-type check valve will open when the fan develops 1 psi of differential pressure across the valve. Current plans involve replacing Av Bay 3A fans with three-phase, 115-volt, 495-watt cabin fans. The replacement fans are capable of flowing 1400 lb/hr through the Av Bay for additional middeck cooling for payloads that will be stowed in middeck lockers. Each of the orbiters will continue to use a standard Av Bay fan in Av Bay 3 until it is upgraded. A list of the air-cooled equipment for each Av Bay is contained in Tables 3-2, 3-3, 3-4, and 3-5 located at the end of Section 3.

3.2.8 Inertial Measurement Unit Fans

The IMU fans provide cooling by drawing cabin air over the IMUs that picks up the heat generated by the IMUs (Figure 3-6). There are three fans, one of which is normally on. The warm air is then blown through the IMU HX where the heat is transferred to the ARS water coolant loops. The cool air is then returned to the cabin.



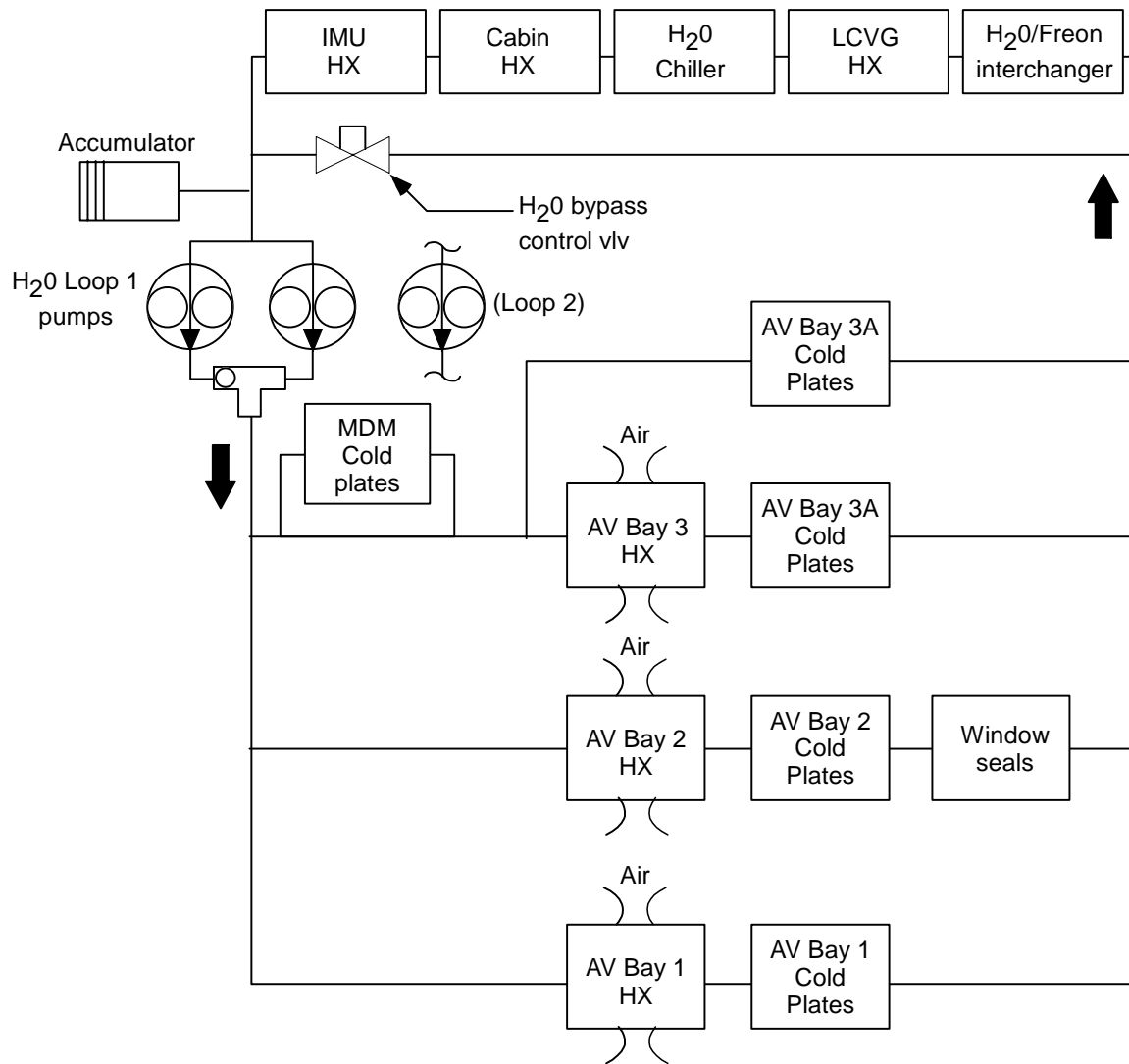
usa006020_043

Figure 3-6. IMU fans

Each fan is powered by a three-phase, 115-volt AC motor. These 50-watt motors produce a nominal flow rate of 144 lb/hr. The IMU fans will start and run on two AC phases. A check valve located at the outlet of each fan prevents air from back flowing through the non-operating fans. The flapper-type check valve will open when the fan develops 1 psi of differential pressure across the valves.

3.3 ATMOSPHERIC REVITALIZATION SYSTEM WATER

The ARS water coolant loops circulate water through the crew compartment to collect excess heat and transfer it to the ATCS Freon coolant loops. There are two water coolant loops, only one of which is active at a time. Both of the water loops flow side by side through all of the HXs and coldplates that they service. Downstream of the pump package, the water flow splits into three legs to cool the Av Bays (Figure 3-7). The water loops also provide thermal conditioning for the seals around all the windows.



usa006020_004

Figure 3-7. H₂O coolant loop 1

The warm water then either flows through the water/Freon interchanger where it is cooled or bypasses the interchanger and returns to the pump package. The water bypass valve determines the amount of water that will flow through or bypass the interchanger. The water cooled in the interchanger then flows through the liquid-cooled garment HX, the galley water chiller, the cabin HX, and the IMU HX before it joins the bypass flow and returns to the pump package.

3.3.1 Water Pumps

Water loop 1, the backup water loop, has two pumps. Water loop 2, the normally active loop, has only one pump. The water pumps are located in the ECLSS bay below the forward lockers (Figure 3-2). These centrifugal pumps are powered by three-phase, 115-volt AC motors. A ball-type check valve on water loop 1 prevents water from backflowing through the non-operating pump (Figure 3-7). The pump outlet pressure from the active pump positions a check ball against a seal to close off the inactive pump outlet. An accumulator on each loop compensates for any thermally induced volume changes and maintains the head pressure on the pump to prevent cavitation. The accumulator is pressurized with N₂. When the accumulator bellows is fully extended, the accumulator has 1.81 pounds of water. When the accumulator is bottomed out, 0.19 pounds of water remain in the accumulator.

3.3.2 Av Bay 1 Leg

The water flows through the Av Bay 1 air/water heat HX (Figure 3-7). Heat is picked up from the air in Av Bay 1. The water then flows through 25 ft² of coldplates. Water-cooled equipment is mounted directly on metal plates with water flowing through them to provide direct conductive cooling. (Table 3-2 at the end of the section contains a list of the coldplated equipment in Av Bay 1.)

3.3.3 Av Bay 2 Leg

The flow through the Av Bay 2 leg is similar to the flow through Av Bay 1. In addition to cooling the Av Bay HX and 30 ft² of coldplates, the water loop thermally conditions the seals around all of the orbiter windows (Figure 3-7). (Table 3-3 at the end of the section contains a list of the coldplated equipment in Av Bay 2.)

3.3.4 Av Bay 3 Leg

A small portion of this leg provides cooling to the Multiplexer/Demultiplexer (MDM) coldplate, while the majority of the flow bypasses this coldplate (Figure 3-7). The flow splits again for Av Bays 3A and 3B. The Av Bay 3A leg cools the Av Bay HX and 32 ft² of coldplates. Av Bay 3B is a separate compartment that contains only water-cooled equipment. The Av Bay 3B leg cools 5 ft² of coldplates. (Tables 3-4 and 3-5 at the end of the section contain a list of the coldplated equipment in Av Bay 3.)

3.3.5 Water/Freon Interchanger

The heat collected by the water coolant loop is transferred to the ATCS Freon coolant loops in the water/Freon interchanger (Figure 3-8). The interchanger is located outside the crew compartment to keep the toxic Freon 21 outside the cabin. The water bypass valve is a variable position diverter valve that determines the amount of water that will flow through the interchanger. The water bypass valve has two modes of operation, manual and auto. The manual mode of operation enables the crew to increase or decrease the bypass flow by means of an increase/decrease switch. Normally, the water bypass valve is preset on the ground to allow 950 lb/hr of water flow through the

interchanger. If the crew takes the H₂O LOOP BYPASS switch to INCR, the amount of flow bypassing the interchanger will increase, and the interchanger flow will decrease. Likewise, by taking the switch to DECR, the crew can decrease bypass flow and increase interchanger flow. In auto mode, the water loop bypass controller governs the position of the bypass valve. The bypass valve will be actuated to maintain the temperature at the exit of the water loop pump at 63° F.

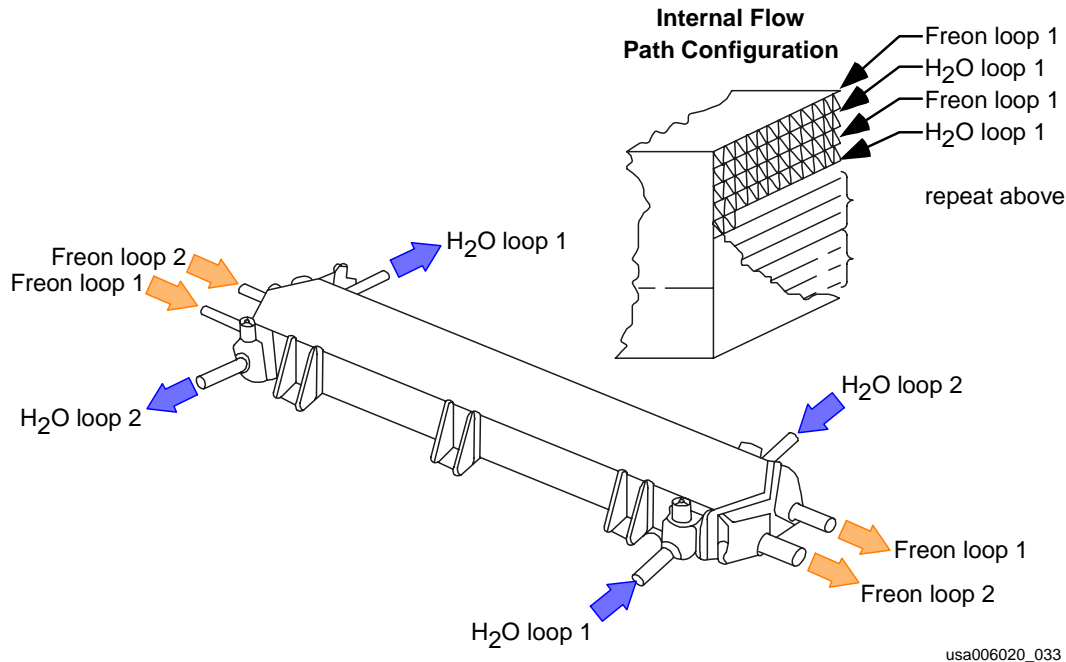


Figure 3-8. H₂O/Freon interchanger

3.3.6 Interchanger Mismatch

For normal operations, only one water loop is active. Running two water loops for long periods of time is undesirable. Two operating loops will flow too much water through the water/Freon interchanger and result in a significant increase in the cabin temperature. This occurs because two active water loops are capable of picking up more heat than the HX can transfer to the Freon loops. Over time, the water loops will accumulate heat, and cooling efficiency will decrease. The water/Freon interchanger will begin to rise as soon as the thermal transfer rate of the interchanger is exceeded. This will affect the interchanger leg of the water loop causing reduction in cooling capability of the liquid cooling and ventilation garment (LCVG), H₂O chiller, cabin and IMU HX. When the interchanger out leg approaches 63° F, cooling capability will also be lost on the Av Bay legs of the water loops.

3.3.7 Liquid-Cooled Garment Heat Exchanger

The LCVG HX is used to cool the water loops that cool the LCVG before and after an EVA. The LCVG HX is in the airlock.

3.3.8 Water Chiller

The water chiller is used to cool the crew's potable water from the supply water tanks.

The cabin HX and the IMU HX have already been discussed in this section under the heading, Cabin Air.

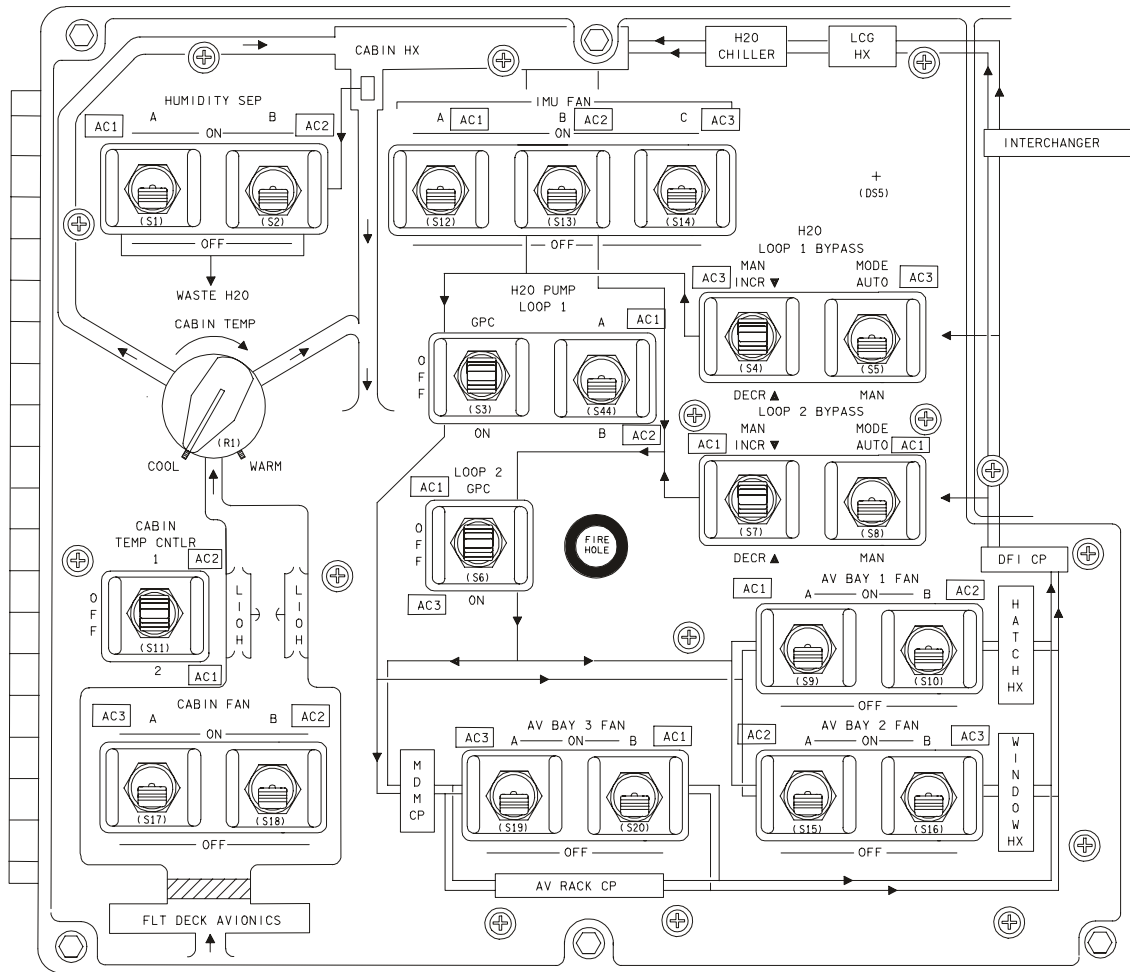
3.4 ATMOSPHERIC REVITALIZATION SYSTEM CONTROLS

The switches that control the ARS air and ARS water systems are located on the left-hand side of Panel L1 (Figure 3-9). The layout of Panel L1 is a schematic of the cabin air ducting and the water coolant loops. With this in mind, it should be much easier to locate switches on the panel.

The circuit breakers that provide the AC power to operate the fans, pumps, controllers, and signal conditioners are located in the center of Panel L4 (Figure 3-10).

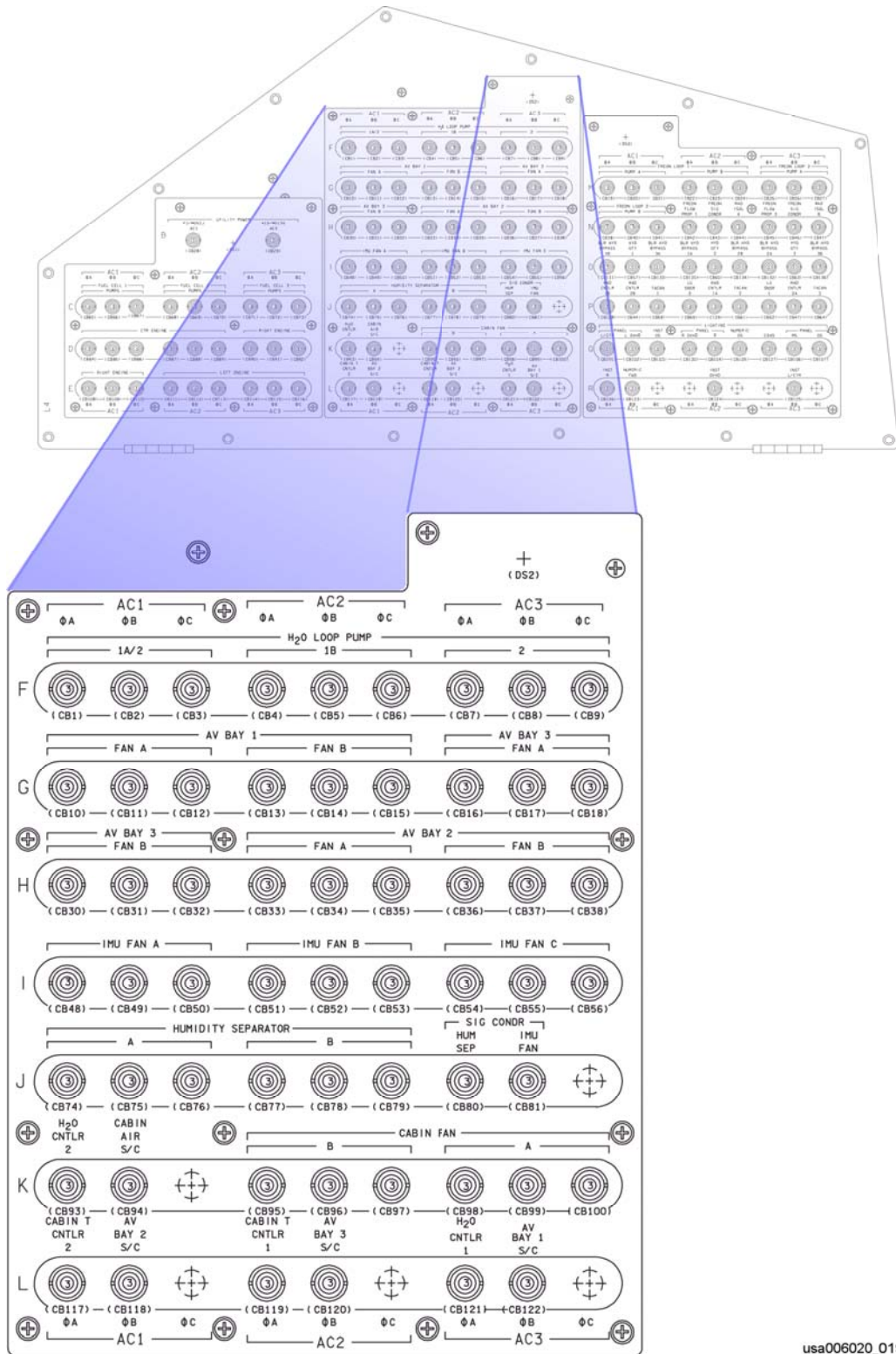
The circuit breakers that provide DC power to the H₂O BYP LOOP ½ SNSR are located on Panels MNA O14 and MNB O15 (Figure 3-11).

A detailed listing of the ARS controls is in Table 3-6.



TD4150309. PNL 1

Figure 3-9. Panel L1 – ARS



usa006020_019

Figure 3-10. Panel L4 – ARS

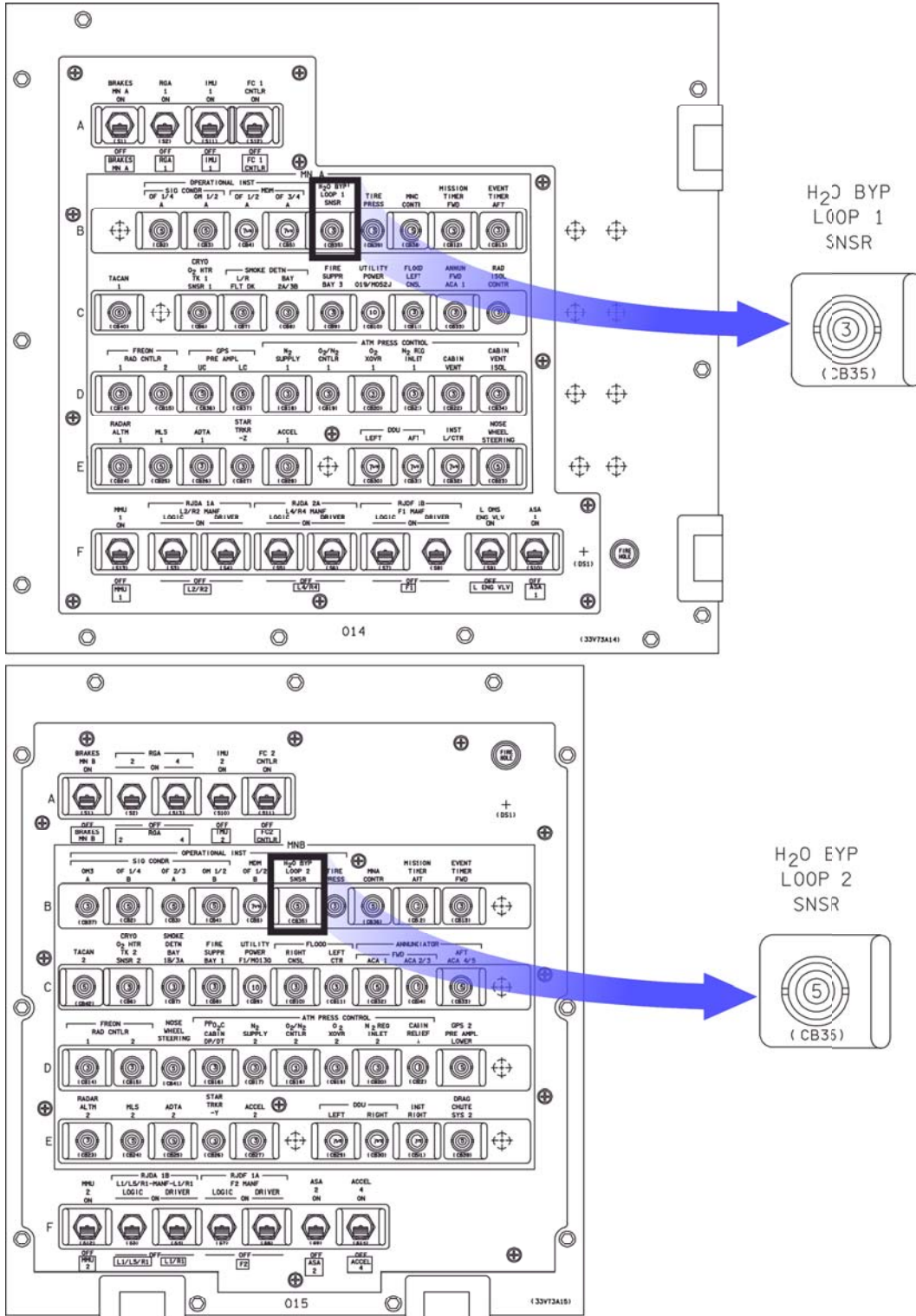


Figure 3-11. Overhead/Panels 014 with H₂O BYP LOOP 1 SNRS and 015 with H₂O EYP LOOP 2 SNRS circuit breakers

usa006020_018

3.5 ATMOSPHERIC REVITALIZATION SYSTEM INSTRUMENTATION AND DISPLAYS

Crew insight into ARS performance is provided by ECLSS instrumentation and DSCs (Figure 3-12). The CABIN AIR signal conditioner powers the cabin fan delta pressure, cabin humidity (Mission Control Center (MCC) insight only), and CO₂ partial pressure transducers. The three Av Bay signal conditioners power Av Bay temperature and Av Bay fan delta pressure sensors in each Av Bay (Figure 3-13). The HUM SEP and IMU FAN signal conditioners power speed sensors that check to be sure that the IMU fan and humidity separator are operating normally. In addition to powering the cabin temperature controller, the CABIN CNTLR 1 circuit breaker powers the cabin HX air outlet temperature and cabin temperature sensors. The H₂O BYP LOOP 1 SNSR signal conditioner powers the water loop 1 interchanger flow sensor and the IMU fan delta pressure sensor (Figures 3-14 and 3-15). The H₂O BYP LOOP 2 SNSR signal conditioner just powers the interchanger flow sensor on water loop 2. In addition to providing the power to drive the water bypass valve, the H₂O CNTLR powers all of the instrumentation on the water loop pump package. The accumulator quantity, pump outlet pressure, pump outlet temperature, and pump delta pressure sensors are all powered by the H₂O CNTLR.

3.5.1 CRT Displays

ARS data are available to the crew on the following CRT displays (see Figures 3-16 to 3-20), dependent on mission phase.

OPS mode	CRT display	Figure number
OPS 1 (ascent)	BFS SM SYS SUMM 1	3-16
	BFS SM SYS SUMM 2	3-18
OPS 2 (4) (orbit)	PASS SM SPEC 66	3-19
	PASS SM SPEC 88	3-20
	PASS SM SYS SUMM 1	3-17
	PASS SM SYS SUMM 2	3-18
OPS 3 (entry)	BFS SM SYS SUMM 1	3-16
	BFS SM SYS SUMM 2	3-18

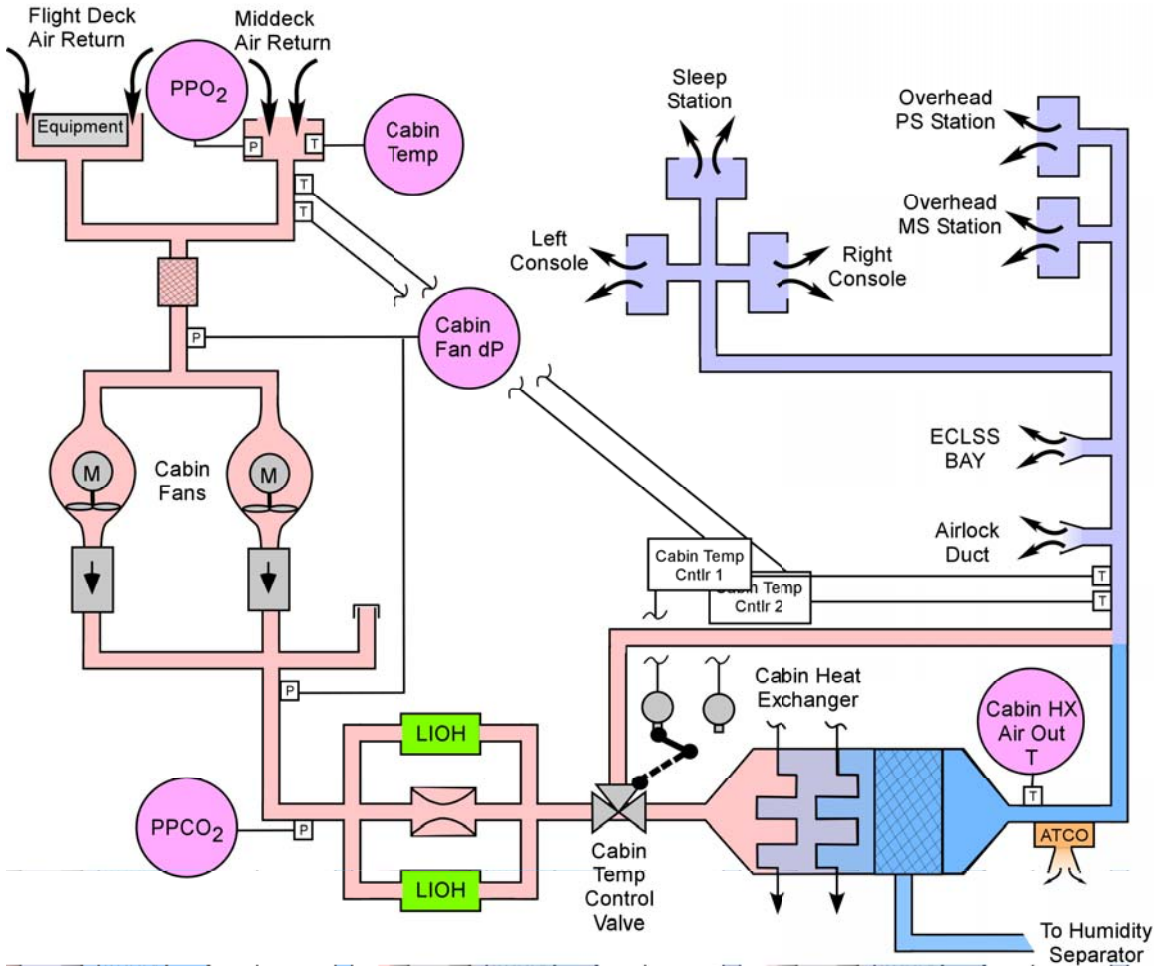


Figure 3-12. Cabin air system instrumentation

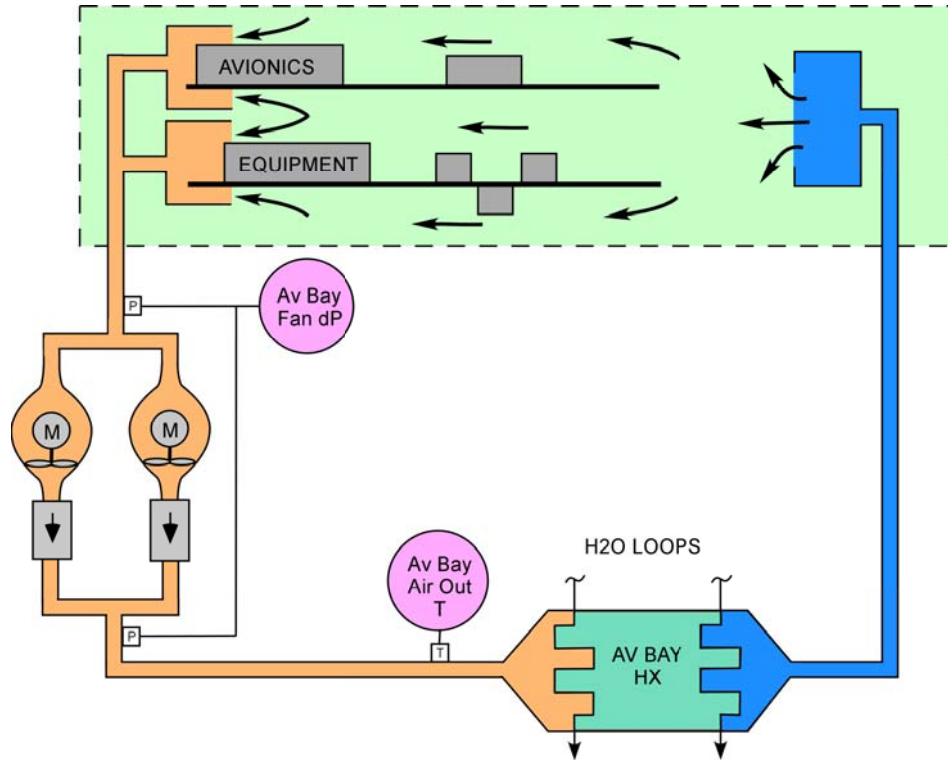
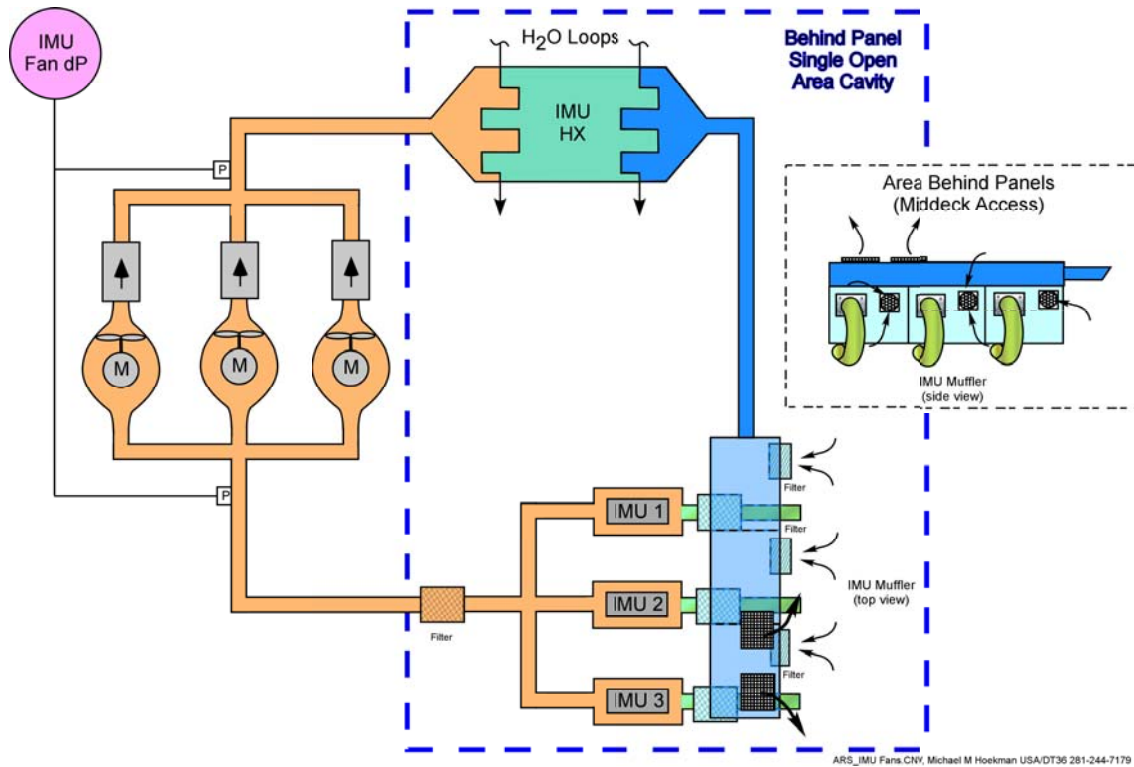


Figure 3-13. Av Bay fan instrumentation



ARS_IMU Fans CNY, Michael M Hoekman USA/DT36 281-244-7179

Figure 3-14. IMU fan instrumentation

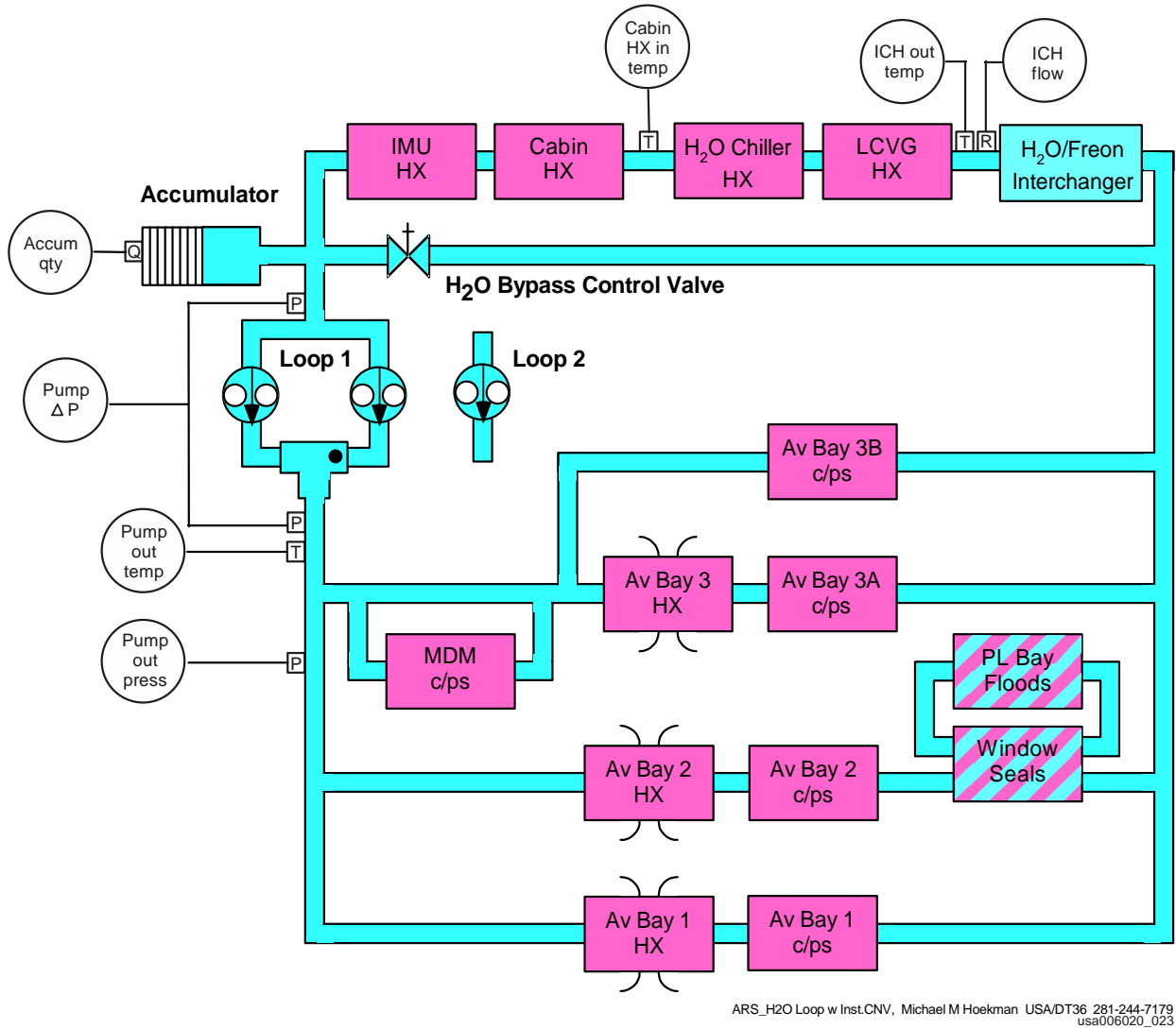


Figure 3-15. H₂O coolant loop instrumentation

XXXX / XXX / 078	SM SYS SUMM 1	XX X	DDD/HH:MM:SS
		BFS	DDD/HH:MM:SS
SMOKE	1 / A	2 / B	
CABIN	XX.XS	XX.XS	
L/R FD	XX.XS	XX.XS	
AV BAY	1 XX.XS	XX.XS	
	2 XX.XS	XX.XS	
	3 XX.XS	XX.XS	
CABIN			
PRESS	XX.XXS		
dP / dT	± .XXS		
BU / EQ	± .XXS	± .XXS	
PPO2	X.XXS	X.XXS	
FAN ΔP	X.XXS		
HX OUT T	XXS		
O2 FLOW	X.XS	X.XS	
N2 FLOW	X.XS	X.XS	
IMU FAN ΔP	X.XXS		
ΔV	FC1	FC2	FC3
SS1	XXS	XXS	XXS
SS2	XXS	XXS	XXS
SS3	XXS	XXS	XXS
TOTAL AMPS	XXXS		
KW	XXS		
DC VOLTS	1 / A	2 / B	3 / C
FC	XX.XS	XX.XS	XX.XS
MAIN	XX.XS	XX.XS	XX.XS
ESS	XX.XS	XX.XS	XX.XS
CNTL	1	A	B
	2	XXX.XS	XXX.XS
	3	XXX.XS	XXX.XS
AC			
VOLT	ΦA	XXXS	XXXS
	ΦB	XXXS	XXXS
	ΦC	XXXS	XXXS
AMPS	ΦA	XX.XS	XX.XS
	ΦB	XX.XS	XX.XS
	ΦC	XX.XS	XX.XS
FUEL CELL	PH	XXS	XXS
AMPS	XXXS	XXXS	XXXS
REAC VLV	XX	XX	XX
STACK T	±XXS	±XXS	±XXS
EXIT T	XXS	XXS	XXS
COOL P	XXS	XXS	XXS
PUMP	XXS	XXS	XXS

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STS 83-0020V2-30-A, Space Shuttle Orbiter Operationa Flight Level C
Functional Subsystem Software Requirements, Displays and Controls
Volume 2: Systems Management, May 30, 2003

0001/ /078	SM SYS SUMM 1	5	000/00# 25# 39
		BFS	000/00# 00# 00
SMOKE	1 / A	2 / B	
CABIN	- 0.0		
L/R FD	- 0.0	- 0.0	
AV BAY	- 0.0	- 0.0	
	- 0.0	- 0.0	
	- 0.0	- 0.0	
CABIN			
PRESS	14.7		
dP / dT	- .00		
BU / EQ	- .00	- .00	
PPO2	3.26	3.26	
FAN ΔP	6.00		
HX OUT T	67		
O2 FLOW	0.0L	0.0L	
N2 FLOW	0.0L	0.0L	
IMU FAN ΔP	4.44		
ΔV	FC1	FC2	FC3
SS1	20	17	17
SS2	17	21	12
SS3	9	23	23
TOTAL AMPS	570		
KW	17		
DC VOLTS	1 / A	2 / B	3 / C
FC	29.6	29.8	30.2
MAIN	29.6	29.6	30.0
ESS	28.7	28.7	28.8
CNTL	1	A	B
	2	28.0	28.0
	3	28.0	28.0
AC			
VOLT	ΦA	117	117
	ΦB	117	117
	ΦC	117	117
AMPS	ΦA	5.0	5.4
	ΦB	4.0	5.8
	ΦC	4.4	6.2
FUEL CELL	PH	PH↓	
AMPS	172	190	188
REAC VLV	0P	0P	0P
STACK T	+204	+204	+203
EXIT T	150	150	150
COOL P	60	59	60
PUMP			
SYS SUMM			

CRT_Spec 78 PASS OI-30.CNV, Michael M Hoekman, USA/DT36 281-244-7179

Figure 3-16. BFS SM SYS SUMM 1

The SM SYS SUMM 1 display is an SM display (DISP 78) available in the BFS; the display provides summary data on the ARS.

Parameter characteristics

CRT name	Units	Displayed range	Status indicators				
CABIN FAN ΔP	in. H ₂ O	0 to 8	M	H	L	↑	↓
HX OUT T	° F	+45 to +145	M	H	L	↑	
IMU FAN ΔP	in. H ₂ O	0 to 7	M	H	L	↑	↓

```

XXXX / XXX / 078      SM SYS SUMM1      XX X DDD/HH:MM:SS
                      DDD/HH:MM:SS
SMOKE                1/ A      2/ B
CABIN                XX.XS
L/R FD              XX.XS  XX.XS
AV BAY              1 XX.XS  XX.XS
                   2 XX.XS  XX.XS
                   3 XX.XS  XX.XS
-----
CABIN
PRESS              XX.XXS
dP/dT-EQ ± .XXS ± X.XXS
O2 CONC            XXX.XS
PPO2              X.XXS  X.XXS
FAN ΔP            X.XXS
HX OUT T          XXXS
O2 FLOW           XX.XS  XX.XS
N2 FLOW           XX.XS  XX.XS
IMU FAN           AXS BXS CXS
ΔV FC1            FC2      FC3
SS1 XXXS          XXXS    XXXS
SS2 XXXS          XXXS    XXXS
SS3 XXXS          XXXS    XXXS
TOTAL AMPS        XXXXS
KW                XXS
DC VOLTS          1/ A      2/ B      3/ C
FC                XX.XS  XX.XS  XX.XS
MAIN              XX.XS  XX.XS  XX.XS
ESS               XX.XS  XX.XS  XX.XS
-----
CNTL              1 A-----B-----C-----A
                  2 XXX.XS  XXX.XS  XXX.XS
                  3 XXX.XS  XXX.XS  XXX.XS
AC
VOLT             ♂A      XXXS  XXXS  XXXS
                  ♂B      XXXS  XXXS  XXXS
                  ♂C      XXXS  XXXS  XXXS
AMPS             ♂A      XX.XS  XX.XS  XX.XS
                  ♂B      XX.XS  XX.XS  XX.XS
                  ♂C      XX.XS  XX.XS  XX.XS
FUEL CELL
AMPS             XXXS  XXXS  XXXS
REAC VLV         XX     XX     XX
STACK T          ±XXXS ±XXXS ±XXXS
EXIT T           XXXS  XXXS  XXXS
COOL P           XXXS  XXXS  XXXS
PUMP            XXS   XXS   XXS

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STS 83-0020V2-30-A, Space Shuttle Orbiter Operations Flight Level C
Functional Subsystem Software Requirements, Displays and Controls
Volume 2: Systems Management, May 30, 2003

```

0001/ /078      SM SYS SUMM 1      5 000/00: 25: 39
                      000/00: 00: 00
SMOKE                1/ A      2/ B
CABIN                - 0.0 - 0.0
L/R FD              - 0.0 - 0.0
AV BAY              - 0.0 - 0.0
                   - 0.0 - 0.0
                   - 0.0 - 0.0
-----
CABIN
PRESS              14.7
dP/dT-EQ          - .00 - .000
O2 CONC           22.1
PPO2              3.26  3.26
FAN ΔP            6.00
HX OUT T          67
O2 FLOW           0.0L  0.0L
N2 FLOW           0.0L  0.0L
IMU FAN           A      B*     C
ΔV FC1            FC2      FC3
SS1 20            17      17
SS2 17            21      12
SS3 9             23      23
TOTAL AMPS        570
KW                17
DC VOLTS          1/ A      2/ B      3/ C
FC                29.6  29.8  30.2
MAIN              29.6  29.6  30.0
ESS               28.7  28.7  28.8
-----
CNTL              1 28.0  28.0  28.0
                  2 28.0  28.0  28.0
                  3 28.0  28.0  28.0
AC
VOLT             ♂A      117   117   117
                  ♂B      117   117   117
                  ♂C      117   117   117
AMPS             ♂A      5.0   5.4   2.5
                  ♂B      4.0   5.8   2.7
                  ♂C      4.4   6.2   2.8
FUEL CELL
AMPS             172   190   188
REAC VLV         0P    0P    0P
STACK T          +204 +204 +203
EXIT T           150  150  150
COOL P           60   59   60
PUMP
SYS SUMM

```

CRT_Spec 78 PASS OI-30.CNV, Michael M Hoekman, USA/DT36 281-244-7179

Figure 3-17. PASS SM SYS SUMM 1

The PASS SM SYS SUMM 1 display is an SM display (DISP 78) available in the SM OPS 2 and 4; the display provides summary data on the ARS.

Parameter characteristics

CRT name	Units	Displayed range	Status indicators				
CABIN FAN ΔP	in. H ₂ O	0 to 8	M	H	L	↑	↓
HX OUT T	° F	+45 to +145	M	H	L	↑	
IMU FAN A, B, C	in. H ₂ O	0 to 7	M	H	L	↑	↓

```

XXXX / XXX /079      SM SYS SUMM 2  XX X DDD /HH:MM:SS
                      BFS DDD /HH:MM:SS
CRYO TK 1 2 3 4 5 MANF1 MANF2
H2 PRESS XXXS XXXS XXXS XXXS XXXS XXXS XXXS
O2 PRESS XXXS XXXS XXXS XXXS XXXS XXXS XXXS
HTR T1 ± XXXS ± XXXS ± XXXS ± XXXS ± XXXS ± XXXS ± XXXS
T2 ± XXXS ± XXXS ± XXXS ± XXXS ± XXXS ± XXXS ± XXXS
-----
APU 1 2 3 HYD 1 2 3
TEMP EGT XXXS XXXS XXXS PRESS XXXS XXXS XXXS
B / U EGT XXXS XXXS XXXS ACUM P XXXS XXXS XXXS
OIL IN XXXS XXXS XXXS RSVR T XXXS XXXS XXXS
OUT XXXS XXXS XXXS
GG BED XXXS XXXS XXXS QTY XXXS XXXS XXXS
INJ XXXS XXXS XXXS
SPEED % XXXS XXXS XXXS W/B
FUEL QTY XXXS XXXS XXXS H2O QTY XXXS XXXS XXXS
PMP LK P XXS XXS XXS BYP WLV XXXS XXXS XXXS
OIL OUT P XXXS XXXS XXXS
FU TK VLV
A T XXXS XXXS XXXS THERM CNTL 1 2
B T XXXS XXXS XXXS H2O PUMP P XXXS XXXS
AV BAY 1 2 3 FREON FLOW XXXS XXXS XXXS
TEMP XXXS XXXS XXXS EVAP OUT T XXXS XXXS
FAN ΔP X.XXS X.XXS X.XXS

```

SPEC 79 BFS OI-30

STS 83-0020V2-30-A, Space Shuttle Orbiter Operational Flight Level C
Functional Subsystem Software Requirements, Displays and Controls
Volume 2: Systems Management, May 30, 2003.

```

0001/ /079      SM SYS SUMM 2      5 000/00:26:25
                      BFS 000/00:00:00
CRYO TK 1 2 3 4 5 MANF1 MANF2
H2 PRESS 221 220 200 200 200 220 220
O2 PRESS 824 824 810 810 810 824 824
HTR T1 - 73 - 73 -250 -250 -250
T2 - 73 - 73 -250 -250 -250
-----
APU 1 2 3 HYD 1 2 3
TEMP EGT 893 679 903 PRESS 3048 3050 3056
B / U EGT 912 679 903 ACUM P 3064 2592 3056
OIL IN 250 250 250 RSVR T 175 169 195
OUT 260 250 260
GG BED 511H 511H 511H QTY 76 77 73
INJ 1239 1161 1242
SPEED % 93 101 102 W/B
FUEL QTY 69 71 66 H2O QTY 98 98 98
PMP LK P 14 14 14 BYP VLV BYP BYP W/B
OIL OUT P 60 28 62
FU TK VLV
A T 61 62 62 THERM CNTL 1 2
B T 61 62 62 H2O PUMP P 24 63
AV BAY 1 2 3 FREON FLOW 2350 2351
TEMP 106 106 89 EVAP OUT T 39 39
FAN ΔP 3.34 3.36 4.24

```

SYS SUMM

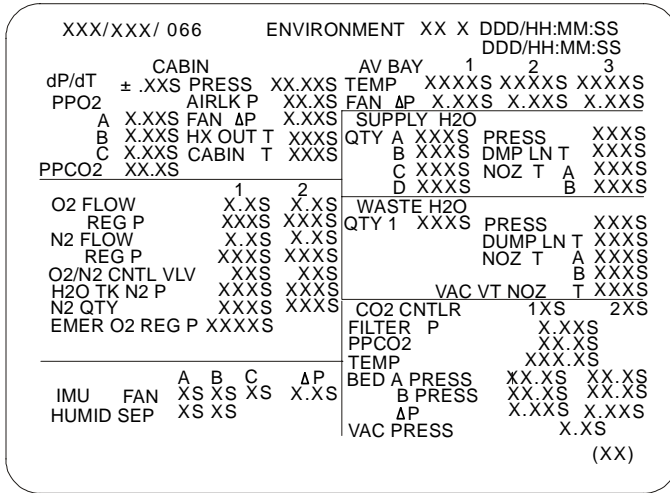
CRT_Spec 79 BFS OI-30.CNV, Michael M Hoekman, USA/DT36 281-244-7179

Figure 3-18. SM SYS SUMM 2

The SM SYS SUMM 2 display is an SM display (DISP 79) available in the BFS and in PASS SM OPS 2 and 4; the display provides summary data on the ARS.

Parameter characteristics

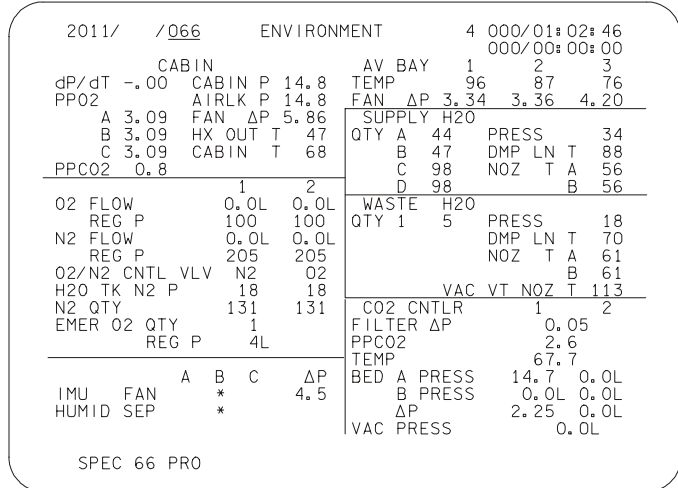
CRT name		Units	Displayed range	Status indicators				
AV BAY	TEMP	° F	45 to 145	M	H	L	↑	
	FAN ΔP	in. H ₂ O	0 to 5	M	H	L	↑	↓
THERM CNTL H ₂ O PUMP P		psia	0 to 150	M	H	L	↑	↓



SPEC 66

OI-30

JSC-19590-116, Systems Management Level C
Flight Software Requirements, STS-116 Base C
Cycle (OI-30), November 2003, page 6.1-2.



CRT_Spec 66 OI-30.CNV, Michael M Hoekman USA/DT36 281-244-7179

Figure 3-19. SPEC 66 ENVIRONMENT

The ENVIRONMENT display is an SM display (DISP 66) available in SM OPS 2 and 4; the display provides data on the ARS.

Parameter characteristics

CRT name	Units	Displayed range	Status indicators				
CABIN FAN ΔP	in. H ₂ O	0 to 8	M	H	L	↑	↓
HX OUT T	° F	+45 to +145	M	H	L	↑	
CABIN T	° F	+32 to +122	M	H	L	↑	
IMU FAN A, B, C	Off/on	Blank or '*'	M				↓
ΔP	in. H ₂ O	0 to 7.0	M	H	L	↑	↓
HUMID SEP	Off/on	Blank or '*'	M				↓
AV BAY TEMP	° F	+45 to +145	M	H	L	↑	
FAN ΔP	in. H ₂ O	0 to 5	M	H	L	↑	↓

```

XXXX/XXX/O88  APU/ENVIRON THERM XX X DDD/HH:MM:SS
FREON LOOP 1 2 DDD/HH:MM:SS
ACCUM QTY XXXX XXXX H2O LOOP 1 2
FREON ISOL XXXX XXXX PUMP OUT P XXXXX XXXXS
FREON FLOW XXXXX XXXXS OUT T XXXXX XXXXS
PL HX FLOW XXXXX XXXXS ICH FLOW ΔP XXXXX XXXXS
AFT CP FLOW XXXX XXXX ICH FLOW XXXXX XXXXS
RAD IN T XXXX XXXX OUT T XXXXX XXXXS
RAD OUT T XXXX XXXX CAB HX IN T XXXXX XXXXS
EVAP OUT T XXXX XXXX ACCUM QTY XXXXX XXXXS
EVAP TEMP APU FUEL T 1 2 3
HILD IB/OB XXXX XXXX TK SURF ±XXXX ±XXXX ±XXXX
NOZ XXXX XXXX TK HTR ±XXXX ±XXXX ±XXXX
TOP FWD/AFT XXXX XXXX TEST LN 1 ±XXXX ±XXXX ±XXXX
L/R DUCT XXXX XXXX TEST LN 2 ±XXXX ±XXXX ±XXXX
L/R NOZ XXXX XXXX FEED LN ±XXXX ±XXXX ±XXXX
EVAP FDLN T A B PUMP LN ±XXXX ±XXXX ±XXXX
FWD XXXX XXXX DRN LN 1 ±XXXX ±XXXX ±XXXX
MID 1 XXXX XXXX DRN LN 2 ±XXXX ±XXXX ±XXXX
MID 2 XXXX XXXX OUT ±XXXX ±XXXX ±XXXX
AFT XXXX XXXX BYP LN ±XXXX ±XXXX ±XXXX
TOPPING XXXX XXXX GG SPLY LN XXXX XXXX
ACCUM XXXX XXXX
HI LOAD XXXX XXXX H2O LN INJ ±XXXX ±XXXX ±XXXX
(X)
    
```

SPEC 88

OI-30

JSC-19590-116, Systems Management Level C
Flight Software Requirements, STS-116 Base 2
Cycle (OI-30), November 2003, page 6.11-1.

CRT Display Processing Logic					
MSID	Nomenclature	BIT Configuration			
		01	02	03	04
V6JX1233E	FCL 1 ISOL Vlv - Radiator Flow	0	1	0	1
V6JX1234E	FCL 1 ISOL Vlv - Radiator Isolated	0	0	1	1
V6JX1433E	FCL 2 ISOL Vlv - Radiator Flow	0	1	0	1
V6JX1434E	FCL 2 ISOL Vlv - Radiator Isolated	0	0	1	1
	Default CRT Text	(Blank)	RAD	ISOL	ERR

JSC-19590-116, Systems Management Level C Flight
Software Requirements, STS-116 Base 2 Cycle (OI-30)
November 2003, page 6.11-9 & 6.11-10.

```

2011/ /O88  APU/ ENVIRON THERM 4 000/01: 02: 10
FREON LOOP 1 2 000/00: 00: 00
ACCUM QTY 30 30 H2O LOOP 1 2
FREON ISOL RAD RAD PUMP OUT P 24 63
FREON FLOW 2165 2165 OUT T 89 66
PL HX FLOW 286 286 ΔP 0L 39
AFT CP FLOW 277 277 ICH FLOW 4L 958
RAD IN T 113 105 OUT T 39 43
RAD OUT T 44 43 CAB HX IN T 39 43
EVAP OUT T 39 39 ACCUM QTY 45 55
EVAP TEMP APU FUEL T 1 2 3
HILD IB/OD 259 259 TK SURF + 69 + 67 + 68
NOZ 315 TK HTR + 69 + 67 + 68
TOP FWD/AFT 247 247 TEST LN 1 + 64 + 64 + 64
L/R DUCT 157 157 TEST LN 2 + 64 + 64 + 64
PING L/R 53 53 FEED LN + 64 + 64 + 64
EVAP FDLN T A B PUMP LN + 64 + 64 + 64
FWD 75 75 DRN LN 1 + 64 + 64 + 64
MID 1 75 74 DRN LN 2 + 64 + 64 + 64
MID 2 79 75 OUT + 86 + 88 + 90
AFT 77 77 BYP LN + 86 + 88 + 90
TOPPING 77 77 GG SPLY LN + 88 + 88 + 88
ACCUM 77 77
HI LOAD 77 77 H2O LN INJ+ 75 + 75 + 75
    
```

SPEC 88 PRO

CRT_Spec 88 OI-30.CNV, Michael M Hoekman USA/DT36 281-244-7179

Figure 3-20. SPEC 88 APU/ENVIRON THERMAL

The APU/ENVIRON THERM display is an SM display (DISP 88) available in SM OPS 2 and 4; the display provides data on the ARS H₂O loops.

Parameter characteristics

CRT name		Units	Displayed range	Status indicators				
H ₂ O LOOP	PUMP OUT P	psia	0 to 150	M	H	L	↑	↓
	OUT T	° F	32 to 122	M	H	L	↑	↓
	ΔP	psid	0 to 60	M	H	L	↑	↓
	ICH FLOW	lbm/hr	0 to 1400	M	H	L	↑	↓
	OUT T	° F	20 to 70	M	H	L		↓
	CAB HX IN T	° F	32 to 122	M	H	L	↑	↓
	ACCUM QTY	Percent	0 to 100	M	H	L	↑	↓

3.5.2 Dedicated Displays

Crew dedicated displays (meters) on Panel O1 (Figure 3-21) enable the crew to monitor critical ARS parameters at all times. The air temperature meter allows the crew to monitor the temperature in Av Bays 1, 2, and 3 and the cabin HX air outlet temp. The water loop 1 and 2 pump outlet pressure can also be monitored. The meters are driven by the same sensors that are shown on the CRT displays.

3.5.3 Caution and Warning

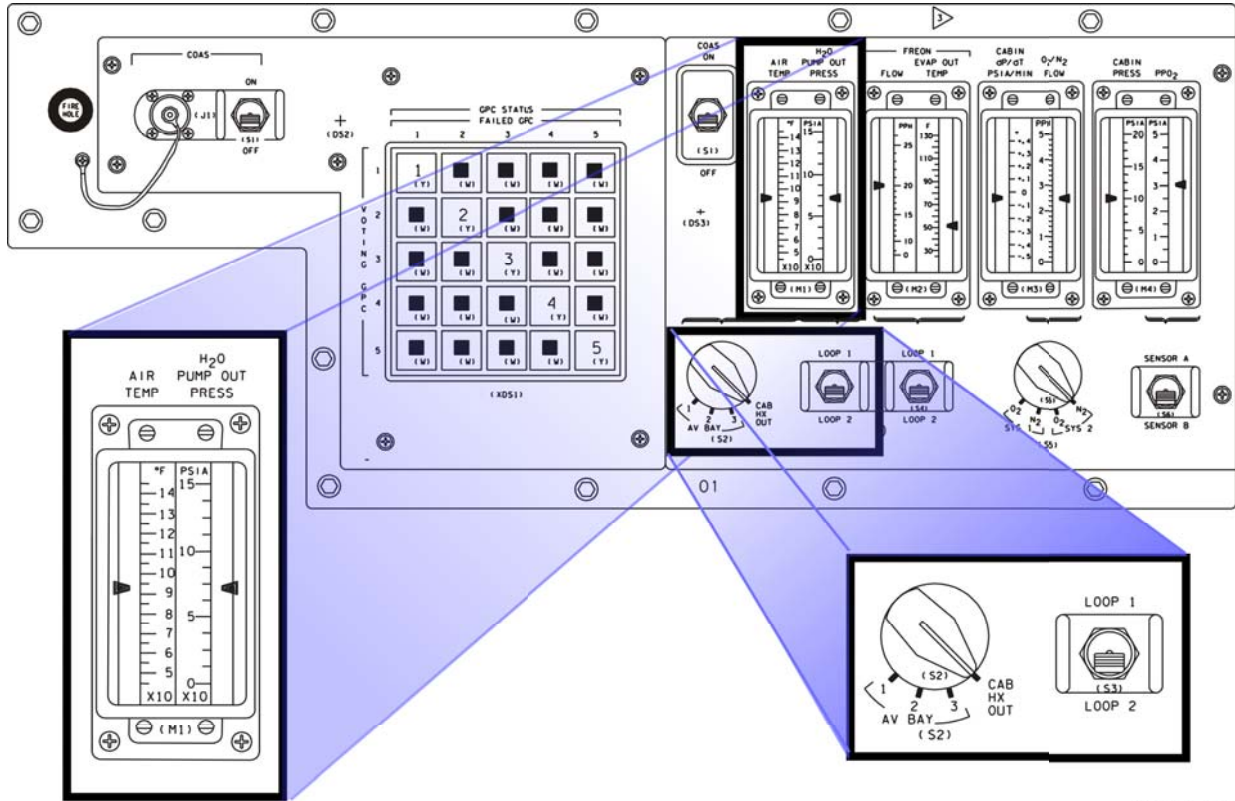
The H₂O LOOP light on Panel F7 (Figure 3-22) will illuminate if one of the following parameters is out of limits:

ID	CRT name	Units	Lower limit	Upper limit
V61P2600A	H ₂ O PUMP OUT P1	psia	19.5	79.5
V61P2700A	H ₂ O PUMP OUT P2	psia	45	81

Since water loop 2 is nominally the operating loop, its C&W limits are set higher to annunciate a degraded loop. Water loop 1 is normally deactivated; therefore, its C&W limits are set to bracket the expected pressure of a non-operating loop.

The AV BAY/CABIN AIR light will illuminate if one of the following ARS air parameters is out of limits:

ID	CRT name	Units	Lower limit	Upper limit
V61R2556A	CABIN FAN ΔP	in. H ₂ O	2.8	7.04
V61T2635A	CAB HX AIROUT T	° F		145
V61T2645A	AV BAY 1 TEMP	° F		130
V61T2650A	AV BAY 2 TEMP	° F		130
V61T2661A	AV BAY 3 TEMP	° F		130



usa006020_017

Figure 3-21. ARS meters – Panel O1

O ₂ PRESS	H ₂ PRESS	FUEL CELL REAC	FUEL CELL STACK TEMP	FUEL CELL PUMP
CABIN ATM	O ₂ HEATER TEMP	MAIN BUS UNDERVOLT (R)	AC VOLTAGE	AC OVERLOAD
FREON LOOP (R)	AV BAY/CABIN AIR	IMU	FWD RCS (R)	RCS JET
H ₂ O LOOP	RGA/ACCEL	AIR DATA (R)	LEFT RCS (R)	RIGHT RCS (R)
————	LEFT RHC (R)	RIGHT/AFT RHC (R)	LEFT OMS (R)	RIGHT OMS (R)
PAYLOAD WARNING (R)	GPC	FCS SATURATION (R)	OMS KIT	OMS TVC (R)
PAYLOAD CAUTION (R)	PRIMARY C/W	FCS CHANNEL	MPS (R)	————
BACKUP C/W ALARM (R)	APU TEMP	APU OVERSPEED	APU UNDERSPEED	HYD PRESS

(34V73A7A2)

TD4150319. PNL 8 1

Figure 3-22. Panel F7 caution and warning matrix

3.6 ATMOSPHERIC REVITALIZATION SYSTEM NOMINAL OPERATION

3.6.1 Ascent

The ARS is already configured for ascent at crew ingress. One cabin fan, one humidity separator, one IMU fan, and one fan in each Av Bay are already operating. The cabin temperature controller is off, the cabin temperature control valve arm is pinned to the valve arm linkage, and the valve arm linkage is pinned to the actuator on cabin temperature controller 1. The cabin temperature control valve is positioned in the FULL COOL position by powering the controller and adjusting the rotary switch to the COOL position. Once the FULL COOL position is reached, cabin temperature controller 1 is unpowered. The HUM SEP and the IMU FAN signal conditioners are unpowered to protect against an AC to AC bus short causing loss of a main engine. (The wire bundle that carries power to these signal conditioners did short on STS-6.) Water loop 2 is on, and water loop 1 is off during ascent. Water loop 1 pump A control buses (cb's) are opened to preclude an AC3 bus to AC1 bus short due to a relay failure on water loop 2, which would cause the loss of a main engine during powered flight. The circuit breakers are kept open for all phases of flight. Both water bypass valves are positioned to flow ~950 lb/hr through the water/Freon interchanger. If no failures occur during ascent, then no actions are required to manage the ARS.

3.6.2 Orbit

The orbit air and water configuration is largely the same on orbit as for ascent. However, cabin temperature controller 1 is activated, water loop 1 is set to the GPC position, and water loop bypass mode 2 is set to AUTO.

For ISS missions, condensate from the humidity separator is stored in a CWC. This reduces the number of wastewater dumps needed while docked.

While in SM OPS 2, the General Purpose Computer (GPC) position causes the inactive water loop to be cycled on periodically. This periodic cycling thermally conditions the inactive water loop and prevents large temperature differences from forming throughout the loop. The cycling sequence is initiated any time an OPS transition is made into SM OPS 2. When an OPS transition is made, the pump will receive a 6-minute ON command, then remain off for 240 minutes (4 hours). The pump will cycle on for 6 minutes every 4 hours.

By using auto mode for control of the water loop 2 bypass valve, the water loop pump out temperature will be maintained at a constant value. This process greatly assists in stabilizing the cabin temperature.

3.6.3 Special Features

The pump on water loop 2 is powered by AC3 when its switch is in the ON position and by AC1 when in the GPC position. AC1 power, however, is supplied by the same circuit breakers that have been pulled to protect against the relay failure mentioned earlier.

Therefore, to power either water loop 1 pump A by means of the ON or GPC switch position, or to power loop 2 by means of the GPC position, the circuit breakers must be in the closed position. In this case, if both loops are in the GPC position while there is an ON command present from the GPC, both loops will be running. The GPC position creates a path for the SM GPC to command water loop 1 pumps through PL MDM 1 and to command the water loop 2 pump through PL MDM 2. During ascent and entry, the BFS provides a continuous on command so AC1 becomes a readily available alternate power source for the water loop 2 pump. On orbit, the SM GPC provides a 6 minute ON command followed by a 4 hour OFF command to provide loop conditioning. This cycle can be converted to a continual ON command by changing the length of the "on cycle" via SM SPEC 60 or TMBU.

If the situation arises where no PASS SM or BFS computers are available, the water loop pumps can still be commanded in the GPC position using Real-Time Commands (RTCs). The RTCs can be issued by way of a ground uplink or by way of crew inputs on DPS UTILITY SPEC 1. The RTCs must be issued through the computer that has control of the payload Multiplexer/Demultiplexers (MDMs). It would take a severe loss of system redundancy for the use of RTCs to ever be required.

3.6.4 Atmospheric Revitalization System Cooling Tables

Refer to Tables 3-1 through 3-5 for methods of cooling equipment in the cabin, Av Bay 1, Av Bay 2, Av Bay 3A, and Av Bay 3B. Table 3-6 lists the ECLSS controls (ARS). These tables may be found in the Pocket Checklists at the beginning of the ECLSS section.

Table 3-1. Cabin air-cooled equipment cooling matrix

Forced air cooled	Free flow air cooled
CRT 1, 2, 3, 4	D&C meters and indicators
Digital Display Unit (DDU) 1, 2, 3 (103, 104)	All lights
Alpha Mach Indicator (AMI), Ascent Vertical Velocity Indicator (AVVI) L, R (103, 105)	Mission and event timers
Cabin fan A, B	C/W status display
Inertial Measurement Units (IMUs) 1, 2, 3	C/W annunciator assemblies
IMU fans	Annunciator Control Assembly (ACA) annunciator lights (5)
Closed-Circuit Television (CCTV) monitors	Speaker mike units (2)
Remote Control Unit/Video Switching Unit (RCU/VSU)	Audio terminal units (8)
Manipulator Controller Interface Unit (MCIU)	Portable TV cameras, monitors, and camcorders
Display Electronic Unit (DEU) 1, 2, 3, 4 (103, 105)	Teleprinter
Master Modular Auxiliary Data System (MADS) recorder	Video tape recorder
MS and PS Station	Computer Annunciator Matrix (CAM)
Integrated Display Processors (IDPs) (104)	Cabin temperature controller 1 and 2
	Waste Management System (WMS)
	Humidity separator
	Smoke detectors – cabin, L and R flight deck
	Rotational hand controllers (3)
	Speed brake thrust controllers (2)
	Translational hand controllers (2)
	Rudder pedal assembly (2)
	Heads Up Display (HUD) (2)
	DDU 1, 2, 3 (104)
	ADC 1A, 1B, 2A, 2B

Table 3-2. Av Bay 1 equipment-cooling matrix

Forced air cooled	Free flow air cooled	Water cooled
GPC 1, 4 Tactical Air Navigation (TACAN) 1 Microwave Landing System (MLS) RF and Decoder 1 Air data 1, 3 Av Bay fan 1A, 1B	Backup Flight Controller (BFC) 1 (engage) Computer Interface Unit (CIU) Accelerometer no. 1 and 4 Landing gear prox box 1 AC1 inverter distribution and control Brake/skid control 1 Smoke detector A and B Current sensor 1 ADTA 1	AC1 inverters Forward load controller 1 Forward power controller 1 Forward motor controller 1 MDM FF1, OF1, PL1, LF1 Dedicated Signal Conditioner (DSC) OF1 Audio center no. 1 and no. 2 Extravehicular Life Support System (EVLSS) power supply battery charger Mass memory unit no. 1 Reaction Jet Driver Forward (RJDF) no. 1A, 1B Payload recorder Pulse-Code Modulation Master Unit (PCMMU) 1 Payload data interleaver Radar altimeter no. 1

Table 3-3. Av Bay 2 equipment-cooling matrix

Forced air cooled	Free flow air cooled	Water cooled
GPC 2, 5 TACAN 2 MLS RF and Decoder 2, 3 Air data 2, 4 Av Bay fan 2A, 2B	BFC 2, 3 (engage) Accelerometer no. 2 and 3 Landing gear prox box 2 AC2 inverter distribution and control Brake/skid control 2 Smoke detector A and B Current sensors 2	AC2 inverters Forward load controller 2 Forward power controller 2 Forward motor controller 2 MDM FF2, FF4, OF2, PL2 DSC OF2 Payload interrogator no. 1 and 2 Mass memory unit no. 2 RJDF no. 2A and 2B PCMMU 2 S-band PI RF coax SW OPS recorder 1 and 2 Radar altimeter no. 2 Payload signal processor 1 and 2

Table 3-4. Av Bay 3A equipment-cooling matrix

Forced air cooled	Free flow air cooled	Water cooled
GPC 3 TACAN 3 Av Bay fan 3A, 3B C/W Limit Module Space to Space Orbiter Radio (SSOR)	S-band Frequency Modulation (FM) multiplexer S-band quad antenna switch assembly S-band FM signal processor S-band SW beam antenna control assembly S-band FM RF switch Current sensor 3 AC3 inverter distribution and control Smoke detector A and B	AC3 inverters Forward load controller 3 Forward power controller 3 Forward motor controller 3 MDM FF3, OF3 Dedicated signal conditioner OF3 Network Signal Processor (NSP) 1, 2 EBIA (bypass switch) Ku-band signal processor Communications Security (COMSEC) unit no. 1, 2, and 3 UHF-ATC/EVA transceiver Ku-band rad/ omm. assembly no. 1 and 2 Ground command initiation unit A, unit B S-band power amp no. 1 and 2 S-band pre-amp 1, 2 S-band transponder no. 1 and 2 S-band FM transmitter 1 and 2

Table 3-5. Av Bay 3B equipment-cooling matrix

Forced air cooled	Free flow air cooled	Water cooled
N/A	N/A	Master timing unit Ku-band signal processor Heads-up display electronics 1, 2 Global positioning satellite 2

Table 3-6. ECLSS controls (ARS)

Panel	Type	Nomenclature/ position	Function	Remarks
L1	2-pos toggle	HUMIDITY SEP A/B/ ON – OFF	ON – Applies power to run the humidity separator OFF – Removes humidity separator power	2 switches
L1	Rotary switch	CABIN TEMP/ COOL-WARM	Controls temperature between 65 ^o and 80 ^o	
L1	3-pos toggle	CABIN TEMP CNTRL/1 – OFF – 2	Selects operation of one of two temp controllers. Controller bypasses air around cabin HX	
L1	2-pos toggle	CABIN FAN A/B/ ON – OFF	Powers cabin fan A/B circulating cabin air	2 switches – Only one active at a time
L1	2-pos toggle	IMU FANS A – B – C/ ON – OFF	Applies power to the IMU fans	3 switches – Only one active at a time
L1	2-pos toggle	H ₂ O PUMP LOOP 1/ A – B	Selects pump A or B for loop 1 operation	
L1	3-pos toggle	H ₂ O PUMP LOOP LOOP ½/ GPC – OFF – ON	GPC – Computer turns loop on periodically to prevent freezing. Length of operation and frequency of cycle are software controllable OFF – Pump off ON – Pump is powered and circulates water	Only one pump active at a time
L1	2-pos toggle	LOOP ½ BYPASS MODE/ AUTO – MAN	Selects bypass valve mode of operation	2 switches – Auto not used
L1	3-pos toggle (spring-loaded center)	LOOP ½ BYPASS MAN/ INCR – DECR	Controls the position of the water bypass valve when the mode switch is in the MAN position	2 switches – Increasing bypass flow increases flow bypassing the interchanger
L1	2-pos toggle	AV BAY ½/3 FANS A – B/ ON – OFF	Circulates the air in the avionics bay	6 switches – One fan in each bay active at a time

Table 3-6. ECLSS controls (ARS) (continued)

Panel	Type	Nomenclature/ position	Function	Remarks
L4	Circuit breaker	AC1 φA-φB-φC H ₂ O LOOP PUMP 1 ^a /2	Provides 3-phase AC1 power to LOOP 1 PUMP A H ₂ O PUMP switch on Panel L1. Also provides 3-phase AC1 power to H ₂ O PUMP LOOP 2 GPC position on Panel L1	3 cb's
L4	Circuit breaker	AC2 φA-φB-φC H ₂ O LOOP PUMP 1B	3-phase AC2 power to LOOP 1 PUMP B switch on Panel L1	3 cb's
L4	Circuit breaker	AC3 φA-φB-φC H ₂ O LOOP PUMP 2	3-phase AC3 power to LOOP 2 H ₂ O PUMP switch on Panel L1	3 cb's
L4	Circuit breaker	AC1 AV BAY 1 FAN A	3-phase AC1 power to AVIONICS BAY 1 FAN A switch on Panel L1	3 cb's
L4	Circuit breaker	AC2 AV BAY 1 FAN B	3-phase AC2 power to AVIONICS BAY 1 FAN B switch on Panel L1	3 cb's
L4	Circuit breaker	AC3 AV BAY 3 FAN A	3-phase AC3 power to AVIONICS BAY 3 FAN A switch on Panel L1	3 cb's
L4	Circuit breaker	AC1 AV BAY 3	3-phase AC1 power to AVIONICS BAY 3 FAN B switch on Panel L1	3 cb's
L4	Circuit breaker	AC2 AV BAY 2 FAN A	3-phase AC2 power to AVIONICS BAY 2 FAN A switch on Panel L1	3 cb's
L4	Circuit breaker	AC3 AV BAY 2 FAN B	3-phase AC3 power to AVIONICS BAY 2 FAN B switch on Panel L1	3 cb's
L4	Circuit breaker	AC1 IMU FAN A	3-phase AC1 power to IMU FAN A switch on Panel L1	3 cb's
L4	Circuit breaker	AC2 IMU FAN B	3-phase AC2 power to IMU FAN B switch on Panel L1	3 cb's
L4	Circuit breaker	AC3 IMU FAN C	3-phase AC3 power to IMU FAN C switch on Panel L1	3 cb's

Table 3-6. ECLSS controls (ARS) (continued)

Panel	Type	Nomenclature/ position	Function	Remarks
L4	Circuit breaker	AC1 HUMIDITY SEPARATOR A	3-phase AC1 power to HUMIDITY SEPARATOR A switch on Panel L1	3 cb's
L4	Circuit breaker	AC2 HUMIDITY SEPARATOR A	3-phase AC2 power to HUMIDITY SEPARATOR B switch on Panel L1	3 cb's
L4	Circuit breaker	AC3 SIG CONDR HUM SEP	AC3 ϕ A power to humidity separator signal conditioners	1 cb
L4	Circuit breaker	AC3 SIG CONDR IMU FAN	AC3 ϕ B power to IMU FAN signal conditioner	1 cb
L4	Circuit breaker	AC1 H ₂ O CNTLR 2	AC1 ϕ A power to H ₂ O controller 2	1 cb
L4	Circuit breaker	AC1 CABIN AIR S/C	AC1 ϕ B power to cabin air signal conditioner	1 cb
L4	Circuit breaker	AC2 CABIN FAN B	AC2 3-phase power to the CABIN FAN B switch on Panel L1	3 cb's
L4	Circuit breaker	AC3 CABIN FAN A	AC3 3-phase power to CABIN FAN A switch on Panel L1	3 cb's
L4	Circuit breaker	AC1 CABIN CNTLR 2	AC1 ϕ A power to cabin temperature controller 2 switch on Panel L1	1 cb
L4	Circuit breaker	AC1 AV BAY 2 S/C	AC1 ϕ B power to the avionics bay 2 signal conditioner	1 cb
L4	Circuit breaker	AC2 CABIN T CNTLR 1	AC2 ϕ A power to cabin temperature controller 1 switch on Panel L1	1 cb
L4	Circuit breaker	AC2 AV BAY 3 S/C	AC2 ϕ B power to the avionics bay 3 signal conditioner	1 cb
L4	Circuit breaker	AC3 H ₂ O CNTLR	AC3 ϕ A power to H ₂ O controller 1	1 cb

Table 3–6. ECLSS controls (ARS) (concluded)

Panel	Type	Nomenclature/ position	Function	Remarks
L4	Circuit breaker	AC3 AV BAY 1 S/C	AC3 ϕ B power to the avionics bay 1 signal conditioner	1 cb
O1	Rotary	AIR TEMP/ AV BAY 1, 2, 3 - CAB HX OUT	Selects input to air temperature meter	
O1	2-pos toggle	H ₂ O PUMP OUT PRESS/ LOOP 1 – LOOP 2	Selects loop ½ to pump out pressure meter	
O14	Circuit breaker	MNA H ₂ O BYP LOOP 1 SNSR	Provides power for the H ₂ O loop 1 inter-changer flow rate sensor and the IMU fan Δ P sensor	1 cb
O15	Circuit breaker	MNB H ₂ O BYP LOOP 2 SNSR	Provides power for the H ₂ O loop 2 inter-changer flow rate sensor	1 cb

3.6.5 ARS Systems Performance, Limitations, and Capabilities

a. Cabin air velocity range	15 to 40 ft/min
b. Nominal air velocity	25 ft/min
c. Cabin air flow	1400 lb/hr
d. Avionics bay air flow	875 lb/hr/bay
e. Nominal dew point range	39° to 61° F
f. H ₂ O separator inlet flow (air and H ₂ O)	37 to 41 lb/hr
1. Outlet flow (air)	37 lb/hr
2. (H ₂ O)	0 to 4 lb/hr
g. CO ₂ removed by LiOH	2.11 lb/man/day
h. H ₂ O centrifugal pumps design pressure	90 psig
i. H ₂ O centrifugal pumps proof pressure	135 psig
j. H ₂ O centrifugal pumps flow range	970 ± 15 lb/hr
k. H ₂ O centrifugal pumps inlet pressure	18 to 35 psig
l. H ₂ O centrifugal pumps pressure rise	46.5 ± 1.2 psid
m. H ₂ O accumulator volume	56 in ³
n. H ₂ O accumulator capacity	1.81 lb
o. H ₂ O loop volume (without accumulator)	1810 in ³
p. H ₂ O loop capacity	65.3 lb

4.0 ACTIVE THERMAL CONTROL SYSTEM

4.1 BASIC FUNCTIONS

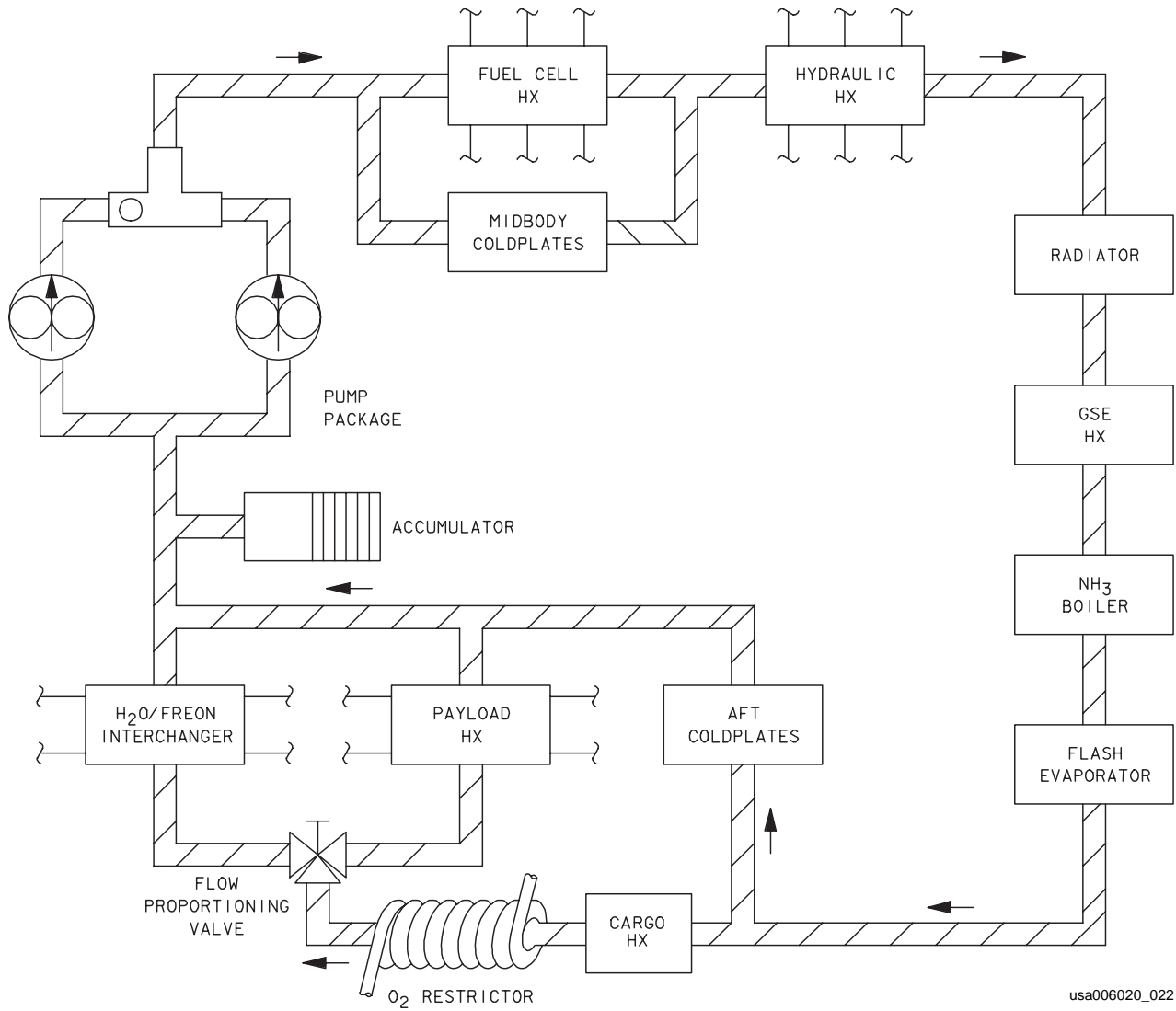
The ATCS performs three basic functions:

- a. Transfers heat from heat sources to heat sinks using the Freon coolant loops
- b. Cools or heats orbiter subsystems through HXs and coldplate interfaces
- c. Rejects waste heat by various means dependent on mission phase

4.1.1 Heat Sinks and Heat Sources

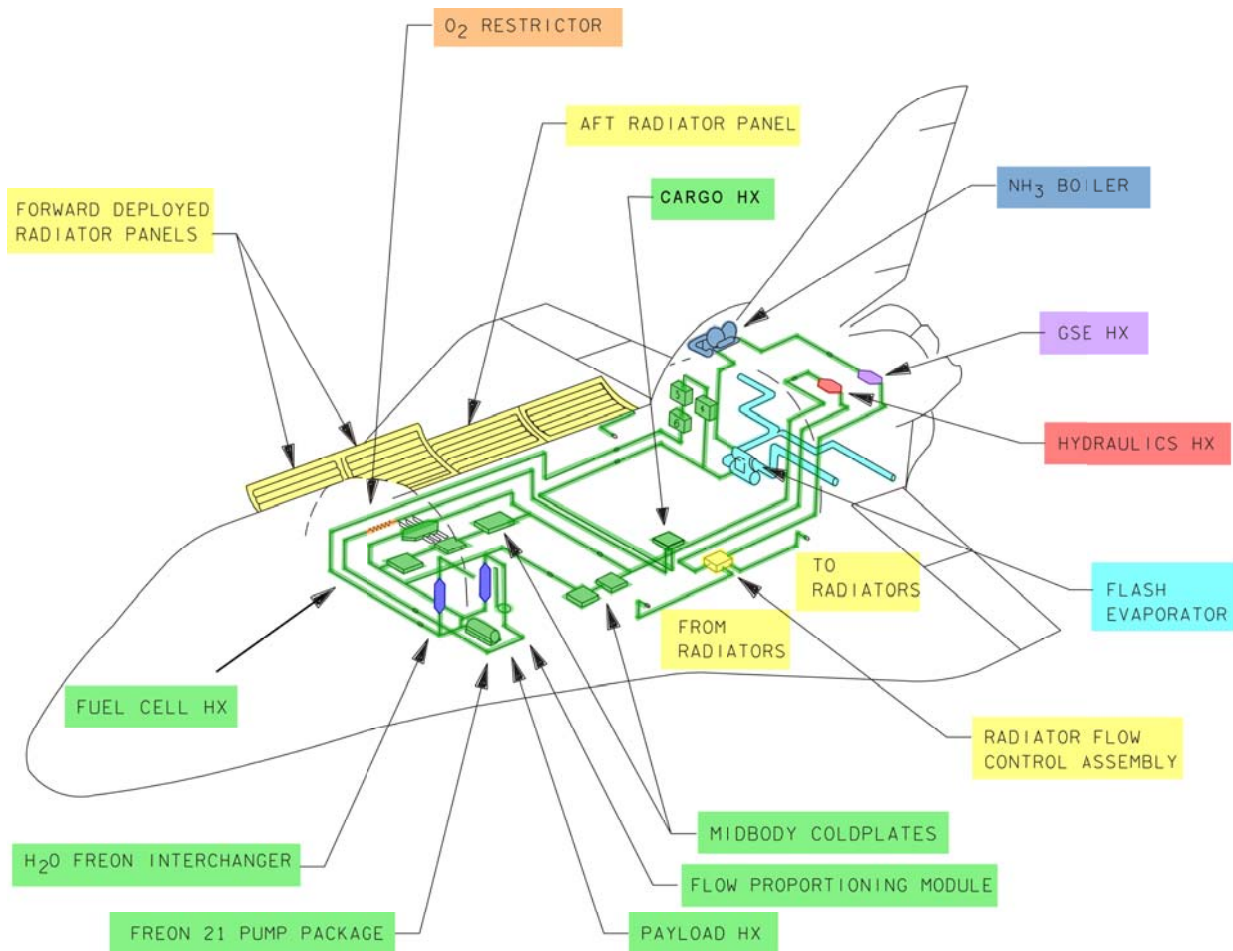
Heat sinks	Heat sources
<ul style="list-style-type: none">• Radiators• Ground Support Equipment (GSE) HX• NH₃ boiler• Flash evaporator• Hydraulic HX• O₂ restrictor	<ul style="list-style-type: none">• Fuel cell HX• Midbody coldplates• Aft coldplates• Payload HX• Water/Freon Interchanger (ICH)

Figure 4-1 shows the Freon coolant loops; Figure 4-2 shows the locations of ATCS components.



usa006020_022

Figure 4-1. ATCS Freon coolant loop (typical)



ATCS_Ovrww Shuttle Color.CNV, Michael M Hoekman USA/DT36 281-244-7179
usa006020_016

Figure 4-2. ATCS components locations

4.2 FREON PUMPS

Each Freon loop has two pumps known as A and B. Both loops have a pump running at all times, typically the B pump. The Freon pump package is located in the midbody of the orbiter below the payload bay liner (Figure 4-2). These centrifugal pumps are powered by three-phase, 115-volt AC motors. A ball-type check valve prevents Freon from backflowing through the non-operating pump (Figure 4-1). An accumulator on each loop compensates for any thermally induced volume changes in the loop, as well as maintains the head pressure on the pump to prevent cavitation. Freon 21 will boil at 100° F and 40 psia. The accumulator is pressurized with N₂. When the accumulator bellows is fully extended, approximately 80 lb of Freon are in the accumulator.

If the B pump is unable to be turned on by the crew, the pump may be commanded on by using RTCs. The RTCs can be issued by way of a ground uplink or by way of crew inputs on DPS UTILITY SPEC 1. The RTCs must be issued through the computer that has control of the payload MDMs.

4.3 AFT COLDPLATES

The avionics in aft Av Bays 4, 5, and 6 and the Rate Gyro Assemblies (RGAs) are mounted on Freon-cooled coldplates. A typical coldplate assembly is shown in Figure 4-3. Both Freon loops flow through each coldplate, one above the other. The avionics in the Av Bays are arranged on parallel cooling shelves (Figure 4-4 and Table 4-1). Approximately 12 percent of the total Freon loop flow is routed through the aft coldplates, while the remaining flow goes through the O₂ restrictor, the H₂O/Freon ICH, and the payload HXs (Figure 4-1).

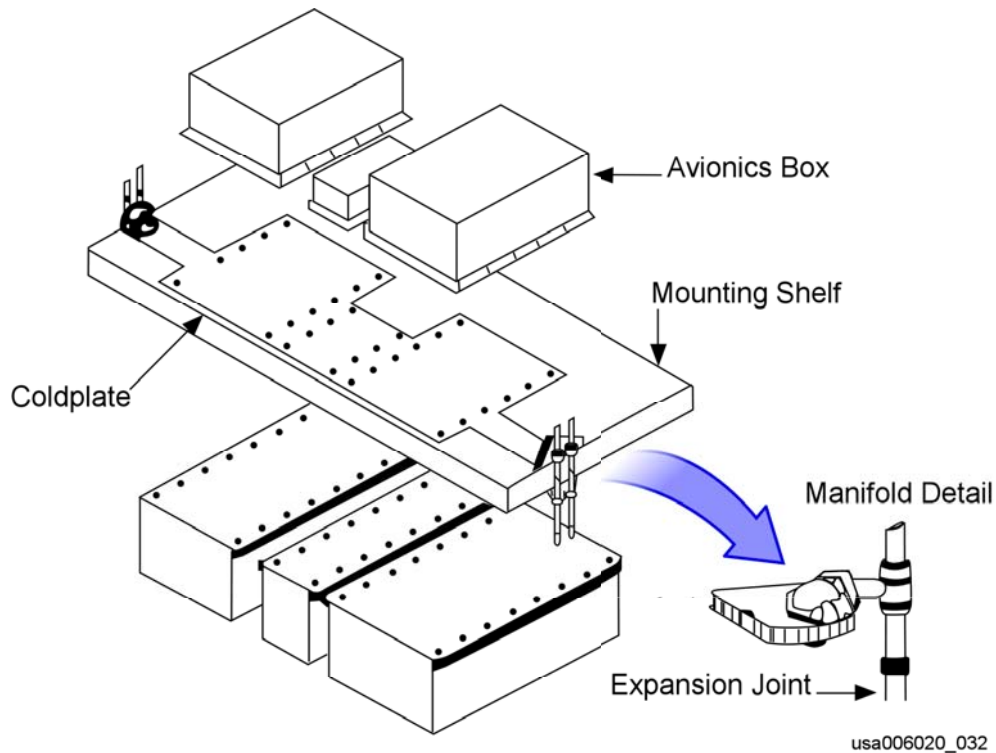
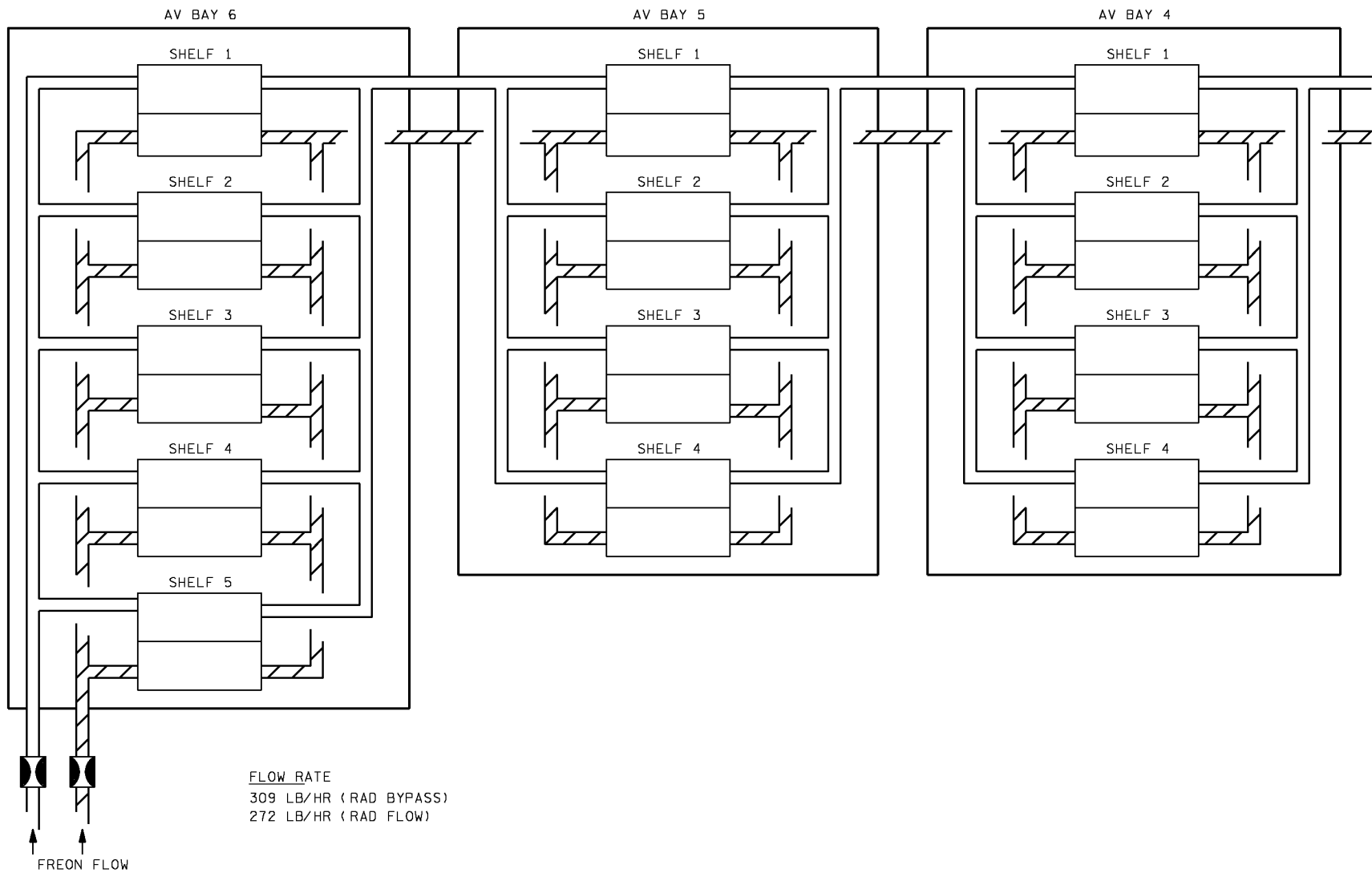


Figure 4-3. Typical coldplate assembly



TD4150404. ART. 2

Figure 4-4. Aft Av Bay coldplate configuration

Table 4-1. Aft coldplate-cooling matrix

Shelf number	Aft Av Bay 4	Aft Av Bay 5	Aft Av Bay 6
1	Ullage press S/C no. 1 DBIA no. 1 RJDA 1 ^a , 1B ASA no. 1 DSC no. 1	Ullage press S/C no. 2 DSC no. 2 ASA no. 2 PT sensor DBIA no. 2	Ullage press S/C no. 3 DP S/C rear ASA no. 3 DSC no. 3 OA3 MDM
2	FA1 MDM MEC no. 1 OA1 MDM	OA2 MDM MFC no. 2 FA2 MDM	FA3 MDM ATVC no. 3 LA MDM
3	APU 1 controller ATVC no. 1 MCA no. 1 EIU no. 1	APU 2 controller ATVC no. 2 MCA no. 2 EIU no. 2	APU 3 controller ATVC no. 4 MCA no. 3 EIU no. 3
4	MNA ALC 1 MNA APC 4 MNA APC 1	MNB ALC 2 MNB APC 5 MNB APC 2	MNC ALC 3 MNC APC 6 MNC APC 3
5	N/A	N/A	RJDA 2 ^a , 2B ASA no. 4 FA4 MDM

4.4 GROUND SUPPORT EQUIPMENT HEAT EXCHANGER

The GSE HX acts as the heat sink for the Freon loops prelaunch and postlanding. Prelaunch cooling is provided by a ground servicing system that interfaces with the GSE HX through the Time-Zero (T – 0) umbilical panel (Figure 4-5). During launch, the ground servicing coolant flow will be terminated at T minus 6 seconds, and the GSE plumbing will disconnect by T minus 0. Postlanding, GSE cooling is provided through a portable cooling cart located at the nominal end of the mission landing site. Cooling cart hookup to the T – 0 umbilical panel usually occurs within 30 minutes of landing. The GSE HX also can be used for payload heat rejection. The GSE HX has more heat rejection capability than the Payload (PL) HX. It has been used as a heat sink for the Radioisotope Thermoelectric Generator (RTG) cooling loops on the Galileo and Ulysses missions.

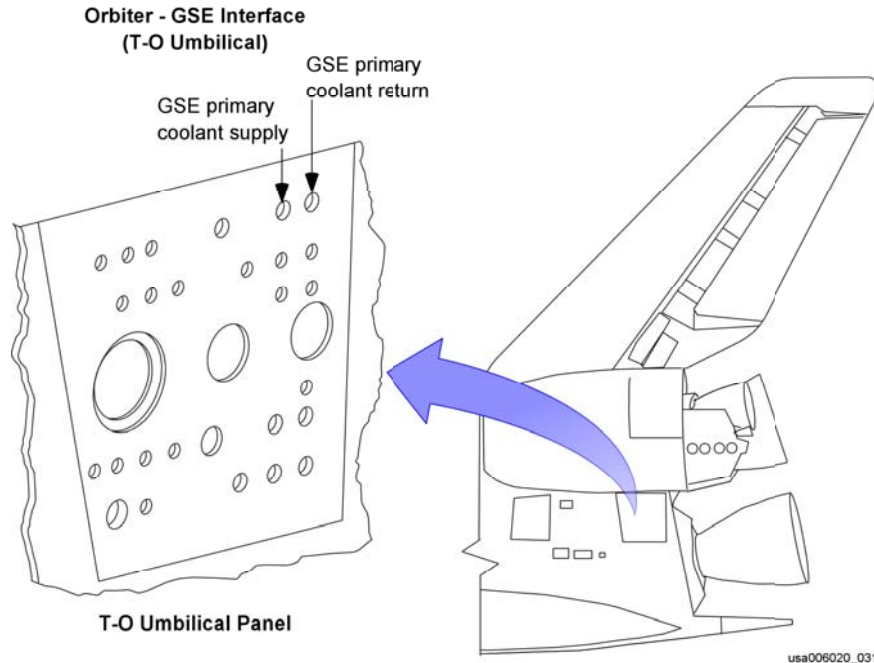


Figure 4-5. Orbiter-GSE interface

4.5 MIDBODY COLDPLATES

The port and starboard midbody coldplates act as a heat source for the Freon loops. The avionics, power distribution, and control equipment mounted on the coldplates receive cooling from both Freon loops. (See Table 4-2 and Figure 4-6.)

Table 4-2. Midbody coldplate-cooling matrix

Port, Panel 1	MNA DA1 MNA MPC1
Starboard, Panel 2	MNB DA2 MNB MPC2, APCU 1 and 2
Starboard, Panel 3	MNC DA3 MNC MPC3
Starboard, Panel 4	MMCA 1 MMCA 2 Cryo heater controllers 2 and 4 DBIA PL bay floodlight electronics assembly
Port, Panel 5	MMCA 3 MMCA 4 Cryo heater controllers 1 and 3 MJCA 1

4.6 HYDRAULIC HEAT EXCHANGER

The hydraulic system acts as a heat sink for the Freon loops. The hydraulic HX utilizes the Freon heat to keep the orbiter's idle hydraulic systems warm while on orbit.

4.7 FUEL CELL HEAT EXCHANGER

The fuel cell coolant loops act as a heat source for the Freon loops. Fuel cell waste heat is transferred to the Freon loops in the fuel cell HX (see Figure 4-6).

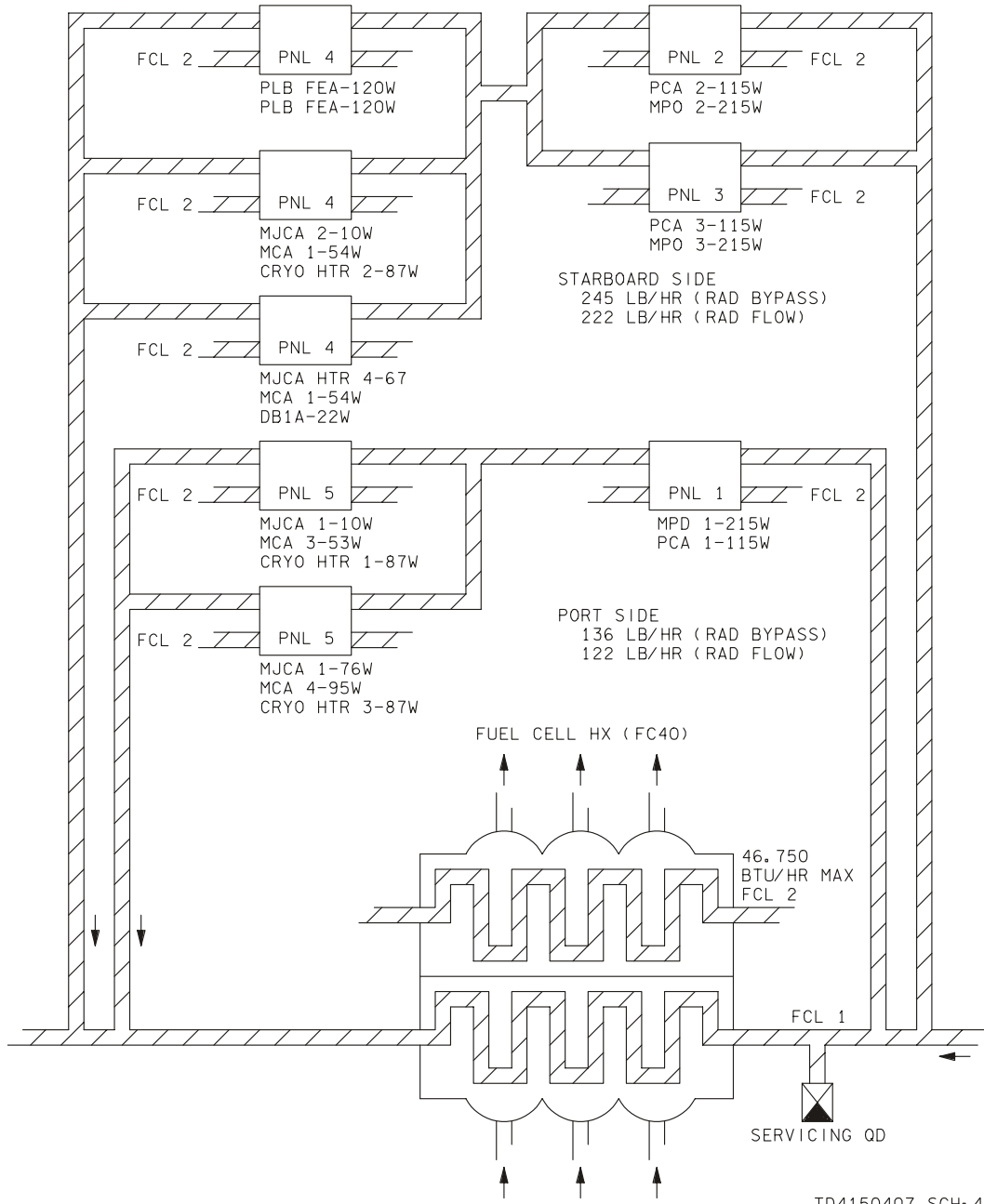
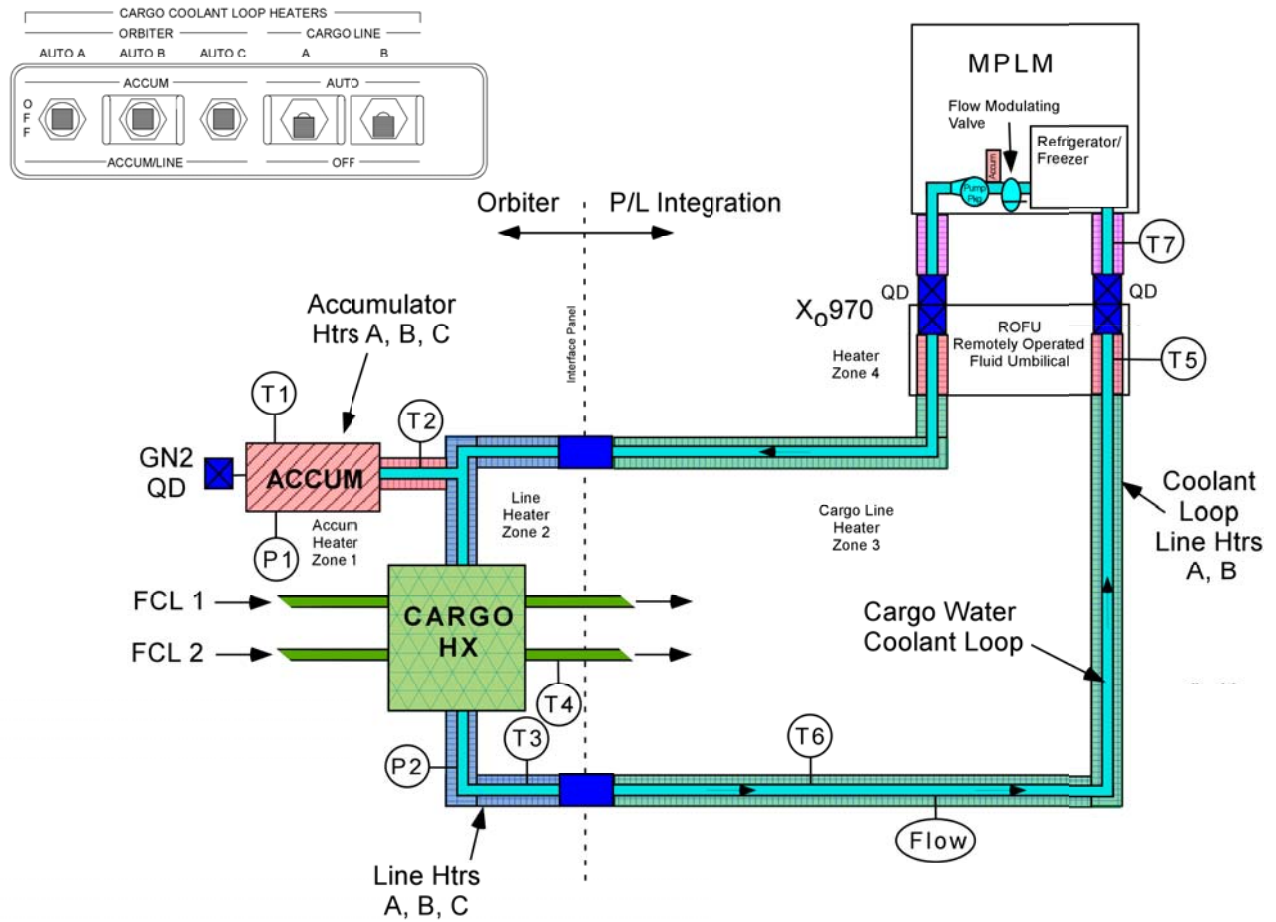


Figure 4-6. Fuel cell HX/midbody coldplates

4.8 CARGO HEAT EXCHANGER

The cargo heat exchanger has been added as an interface for active Multipurpose Logistics Module (MPLM) missions where environmental control is required in the MPLM for its payloads. The Heat exchanger is a FREON/WATER interchanger. Freon from the shuttle runs through the heat exchanger whether an MPLM is present or not. The MPLM information will be displayed on SPEC 168 CRYO PALLET/CARGO in both BFS and PASS. More information will be provided as MPLM information is made available. OV103 has been modified and OV105 is being modified in 2004. OV104 will not be modified until after STS114 and STS117.

PANEL A14: PROPOSED LAYOUT



Cargo HX.CNV Michael M Hoekman USA/DT36 281-244-7179

Figure 4-7. Cargo Heat Exchanger

4.9 OXYGEN RESTRICTORS

Pressure control system 1 oxygen is warmed by Freon loop 1 as it flows through a 23.9 lb/hr O₂ restrictor. (See Figure 4-8) Freon loop 2 warms the PCS system 2 oxygen as it flows through two parallel 12.0 lb/hr O₂ restrictors. If either Freon loop fails or is turned off, the associated PCS O₂ supply valve must be closed. Closing this valve prevents an O₂ leak at the O₂ restrictor. An O₂ leak will result when no heating is provided by the Freon loop to the Viton seals of the restrictor.

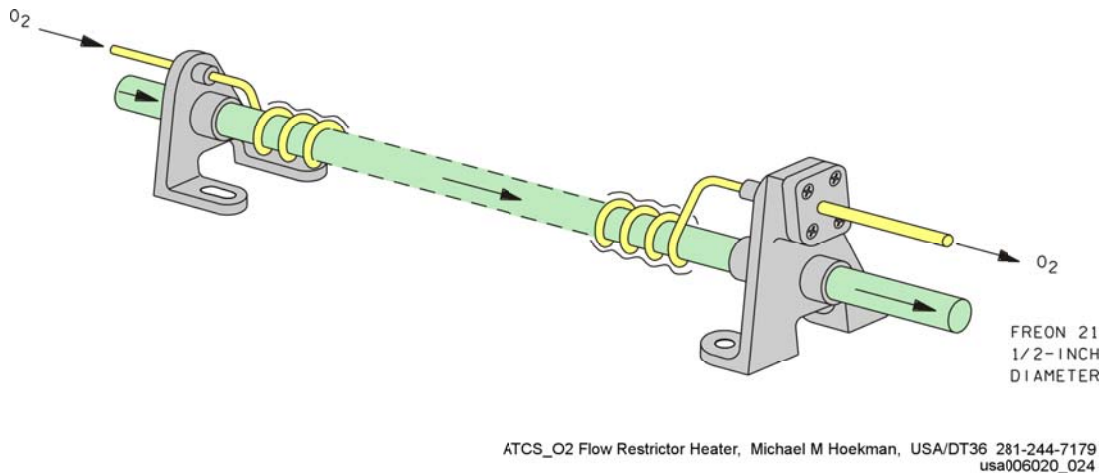


Figure 4-8. O2 Flow Restrictor/Heater

4.10 WATER/FREON INTERCHANGER

The heat collected by the active H₂O coolant loop is transferred to the Freon coolant loops in the water/Freon ICH (Figure 4-2). The water/Freon ICH is a heat source for the Freon loops. Both water loops and both Freon loops pass over one another in the counterflow plate-fin HX. The water/Freon ICH is located outside the crew compartment to keep the toxic Freon 21 outside the cabin (Figure 4-1).

4.11 PAYLOAD HEAT EXCHANGER

Payloads that require supplemental cooling can be cooled by the Freon coolant loops through the payload HX interface (Figure 4-2). When used, the payload HX is a heat source for the Freon loops. The payload HX can accommodate two payload coolant loops. The payload coolant can be either Freon or water. The payload HX has been used as a heat sink for Spacelab and SpaceHab missions.

4.12 FLOW PROPORTIONING VALVE

The flow-proportioning valve proportions the amount of Freon flowing through the water/Freon ICH and the payload HX (Figure 4-1). In the ICH position, approximately 90 percent of the flow goes through the water/Freon ICH and 10 percent through the payload HX. In the Payload (PL) position, approximately 43 percent goes through the payload HX, and 57 percent flows through the water/Freon ICH.

4.13 RADIATORS

The radiators act as a heat sink for the Freon coolant loops. The radiators are mounted on the inside of the payload bay doors. When the payload bay doors are open, during orbit operations, the radiators are the primary source of cooling for the Freon loops. Each radiator consists of four panels, with the forward two mechanically deployable should the need for an increased cooling capacity arise. (See Figure 4-9.) Deploying the radiators results in approximately a 10 percent increase in cooling efficiency. During deorbit prep, the Freon in the radiators is “cold soaked” by positioning the orbiter in a “cold” attitude. This “cold soak” is saved for use as a heat sink during the latter stages of entry. Radiator cooling efficiency is extremely dependent on vehicle attitude. Freon loop 1 flows through the radiator panels located on the port payload bay door; loop 2 flows through the panels on the starboard door. The flow through each radiator is controlled by a flow control assembly. Each flow control assembly consists of two radiator controllers, a flow control valve, a rad/bypass valve, and four temperature sensors (see Figure 4-10).

Two electronic radiator controllers are provided for each loop for redundancy. The radiator controllers are commonly referred to as Auto A and Auto B. The radiator controller logic is functionally divided into two areas. One part of the logic controls commands to the flow control valve, while the other controls commands to the rad/bypass valve (see Figure 4-10).

The flow control valve is a mixing valve that mixes cold Freon from the radiator panels with hot Freon from the Freon loop. The active radiator controller adjusts the flow control valve to maintain the desired radiator out temperature. The radiator out temperature control point is selectable to either $38^{\circ} \pm 2^{\circ}$ F or $57^{\circ} \pm 2^{\circ}$ F by means of the radiator out temperature switch. A dedicated temperature sensor provides the input to the radiator controller logic, and the controller adjusts the flow control valve accordingly to achieve the desired radiator outlet temperature. The position of the flow control valve cannot be adjusted manually.

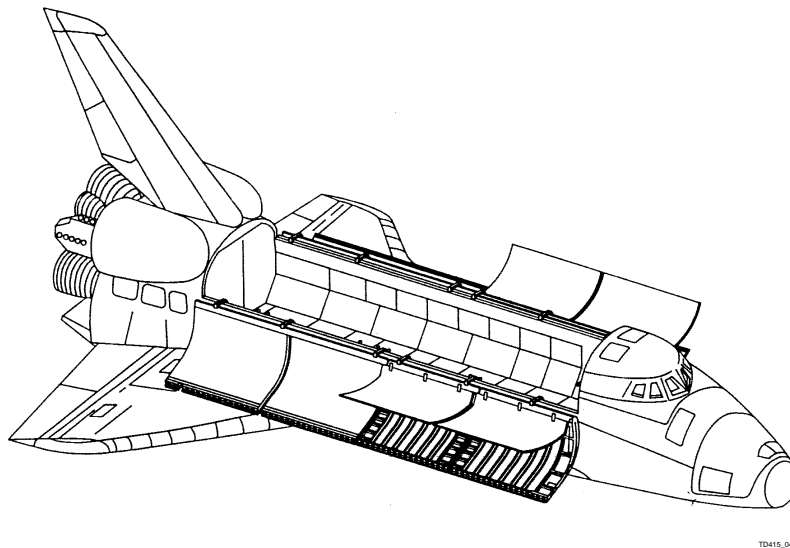
The rad/bypass valve is a two-position valve. The BYPASS position bypasses the radiators so that they are not used as a source of cooling. The RAD position allows the Freon to flow through the radiators and into the Freon loop. When operating in the auto mode, the rad/bypass valve position is controlled by the radiator controller. The crew can position the rad/bypass valve manually by using the manual select switch when operating in manual mode.

The rad/bypass valve portion of the rad controller logic is continually monitoring for an undertemp condition. If the radiator out temperature drops below $33^{\circ} \pm 0.5^{\circ}$ F, the undertemp logic will command the rad/bypass valve to BYPASS. This undertemp protection will keep the water in the stagnant water loop from freezing in the water/Freon ICH. When either radiator controller is active, backup undertemp protection is provided by the alternate radiator controller. If either radiator controller detects an undertemp condition, it can command the rad/bypass valve to bypass the radiator (See Figure 4-11).

Even when the rad/bypass valve is in the bypass position, there is still a very small amount of Freon that flows through the radiators to prevent the Freon from freezing.

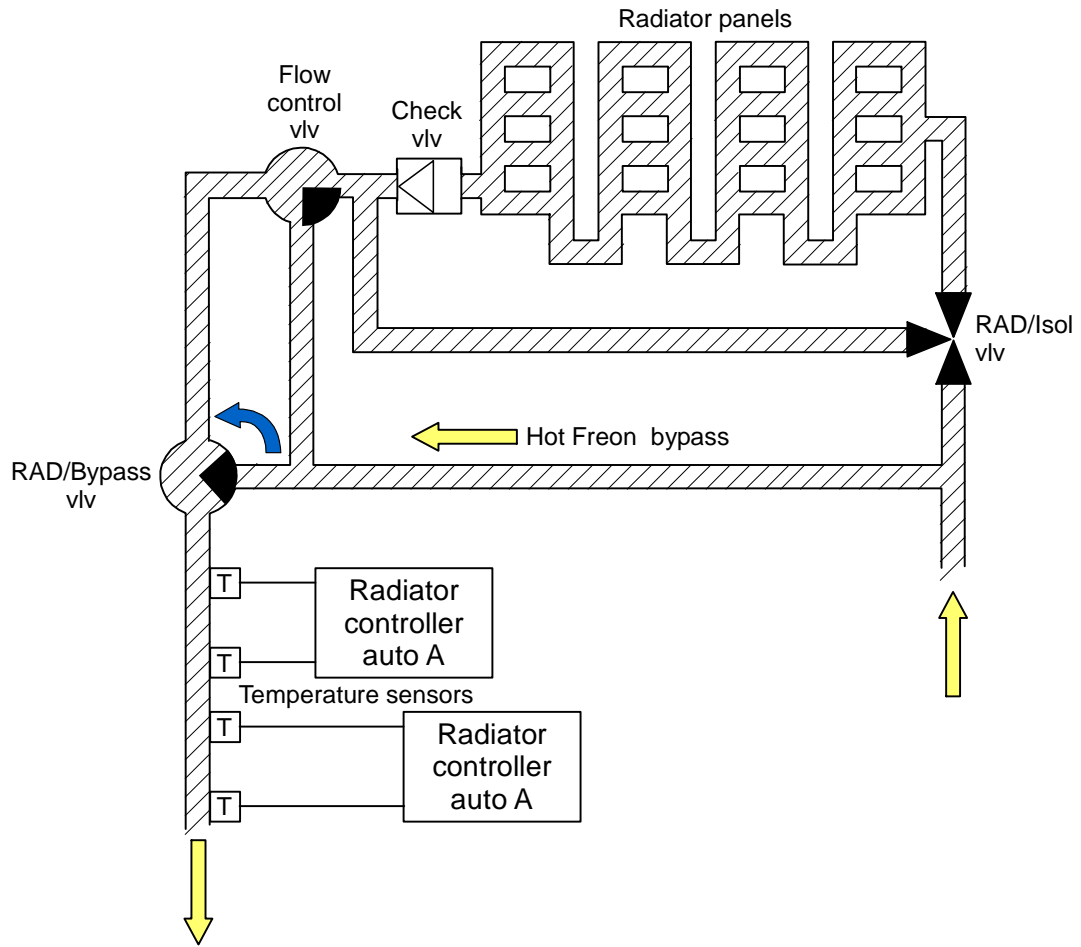
In the event of a Freon loop leak, capability exists to divert the Freon flow from the radiators through the radiator isolation leg by means of the radiator isolation hardware. The radiator isolation leg redirects the flow past the radiator through the flow control valve. A check valve keeps Freon from back flowing into the radiator and leaking out. A likely place for a leak on orbit in a Freon loop would be in the radiators since they are large panels that are exposed to micrometeor hits. When operating in the auto mode on orbit, if the accumulator quantity drops for more than 5 seconds below the preset lower limit of 12 percent (or as manually set) but is greater than zero and does not have an "M" due to loss of data, then a command is sent to isolate the radiator. If an OPS transition is requested while the commands are being issued, the OPS transition will be held out until the commands are terminated. (USA001547, Space Shuttle Computer Program Development Specification, OI-30 CPN-2, 27 Feb 03) The crew can manually control the radiator isolation hardware by using the manual select switch when operating in manual mode.

Each radiator controller receives inputs from two dedicated temperature sensors. One sensor feeds the temperature data to the flow control valve logic. The other sensor provides the temperature data used by undertemp protection logic. The radiator controller logic is powered by the MNA and MNB overhead panel buses. The rad/bypass valve is driven with single-phase AC power. The flow control valve is powered by the MNA and MNB overhead panel buses. The rad isol valve is also driven with single-phase AC power. The rad isol controller is powered by the MNA overhead panel bus.



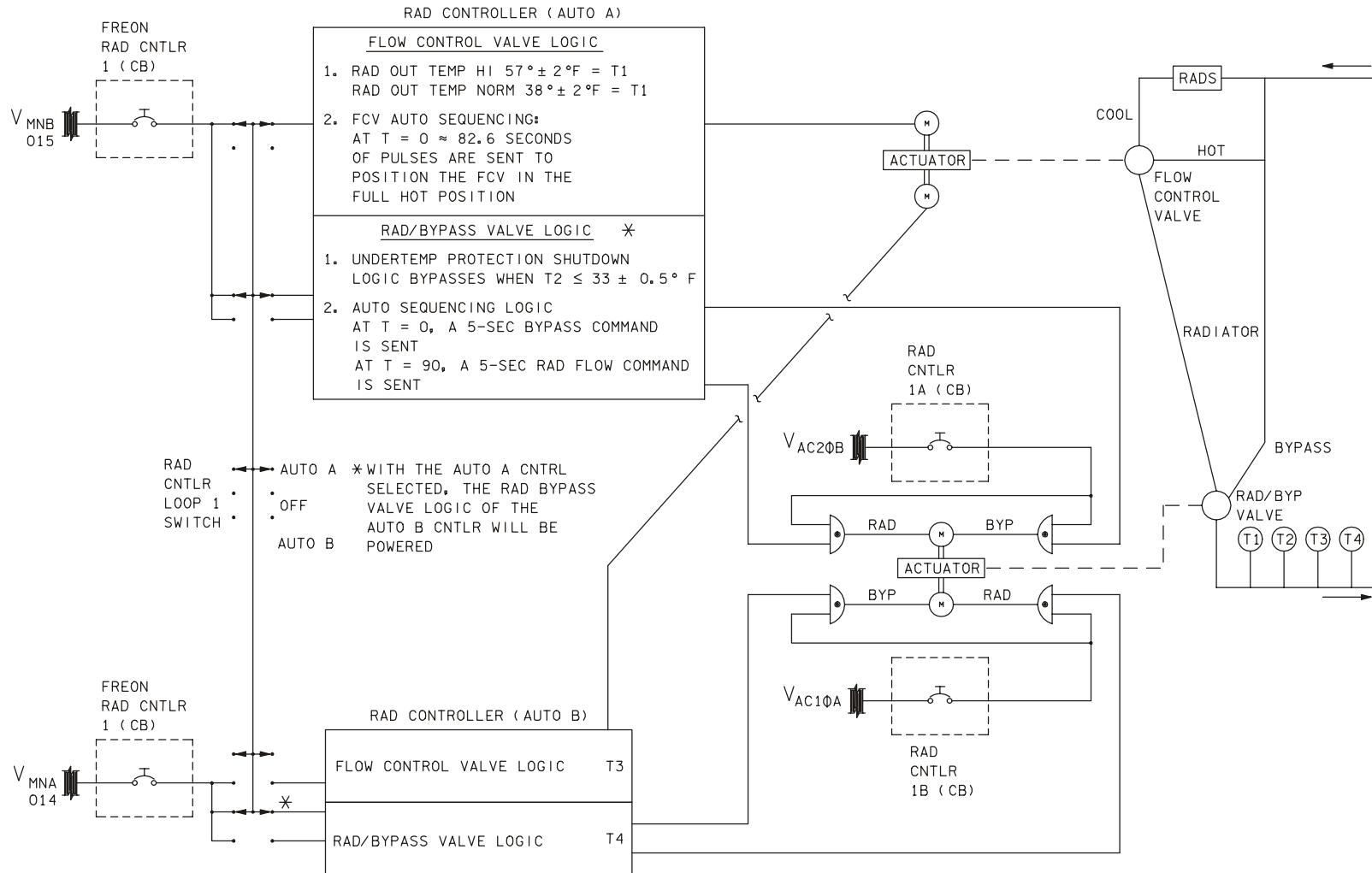
TD415_048

Figure 4-9. Freon radiator panels



usa006020_001

Figure 4-10. Radiator/flow control assembly overview



TD4150411, SCH 3

Figure 4-11. Radiator controller detailed

4.13.1 Radiator Coldsoak

During the deorbit prep timeframe, a radiator coldsoak is performed to store cool Freon in the radiators for use as a heat sink later during entry. The coldsoak process begins 4 hours before the deorbit burn. The orbiter is maneuvered to a tail-sun attitude to enhance the radiator cooling. The coldsoak is initiated by shifting the radiator out temperature control point from 38° to 57° F. The topping FES is restarted to keep the Freon evap out temperature stable at 39° F. The fact that the radiators are only cooling the Freon to 57° F instead of 38° F provides the coldsoak. Much less radiator Freon is required to achieve a 57° F radiator out temperature. Consequently, the reduced flow through the radiator causes the Freon to stay in the radiators longer and become cooler. An hour after the coldsoak is initiated, the radiators are manually bypassed to store the cool Freon for entry.

During entry, the radiator auto startup sequence is performed when $V = 12k$ (vehicle relative velocity of 12,000 ft/s) which corresponds to roughly 176,000 feet. Radiator flow is initiated approximately 11 minutes before touchdown. The radiators provide the cooling until the coldsoak runs out 10 to 15 minutes after touchdown. NH_3 cooling is then initiated upon MCC request. The NH_3 provides the cooling until the GSE hookup is complete 30 to 45 minutes after touchdown.

4.13.2 Radiator Controller Auto Startup Sequence

The radiator controller auto startup sequence prevents a cold slug of radiator Freon from freezing the water loop interfaces during radiator activation. The sequence is described below and in Figure 4-12.

Initial Conditions

The rad/bypass valve mode switch must have auto mode selected. Auto mode enables the radiator controller logic to control the position of the rad/bypass valve.

T = 0

Selecting radiator controller A auto (B auto) initiates the auto startup sequence. The rad controller issues a command to drive the rad/bypass valve to bypass. At the same time, commands are issued to bypass the radiators with the flow control valve.

T = 5 seconds

The rad/bypass valve command is terminated because the valve should be in the bypass position after 5 seconds. The Flow Control Valve (FCV) continues to be commanded to the bypass position for 85 more seconds. The time it takes to reach the bypass position depends on the initial position of the FCV.

T = 90 seconds

The commands to the FCV are terminated. The rad/bypass valve is commanded to rad flow now that the FCV has the radiators bypassed.

T = 95 seconds

The rad/bypass valve open command is terminated since the valve should now be in radiator flow. The flow control valve begins to open up and allows the cool radiator Freon to mix with the hot bypass Freon to achieve the control point temperature (38° For 57° F).

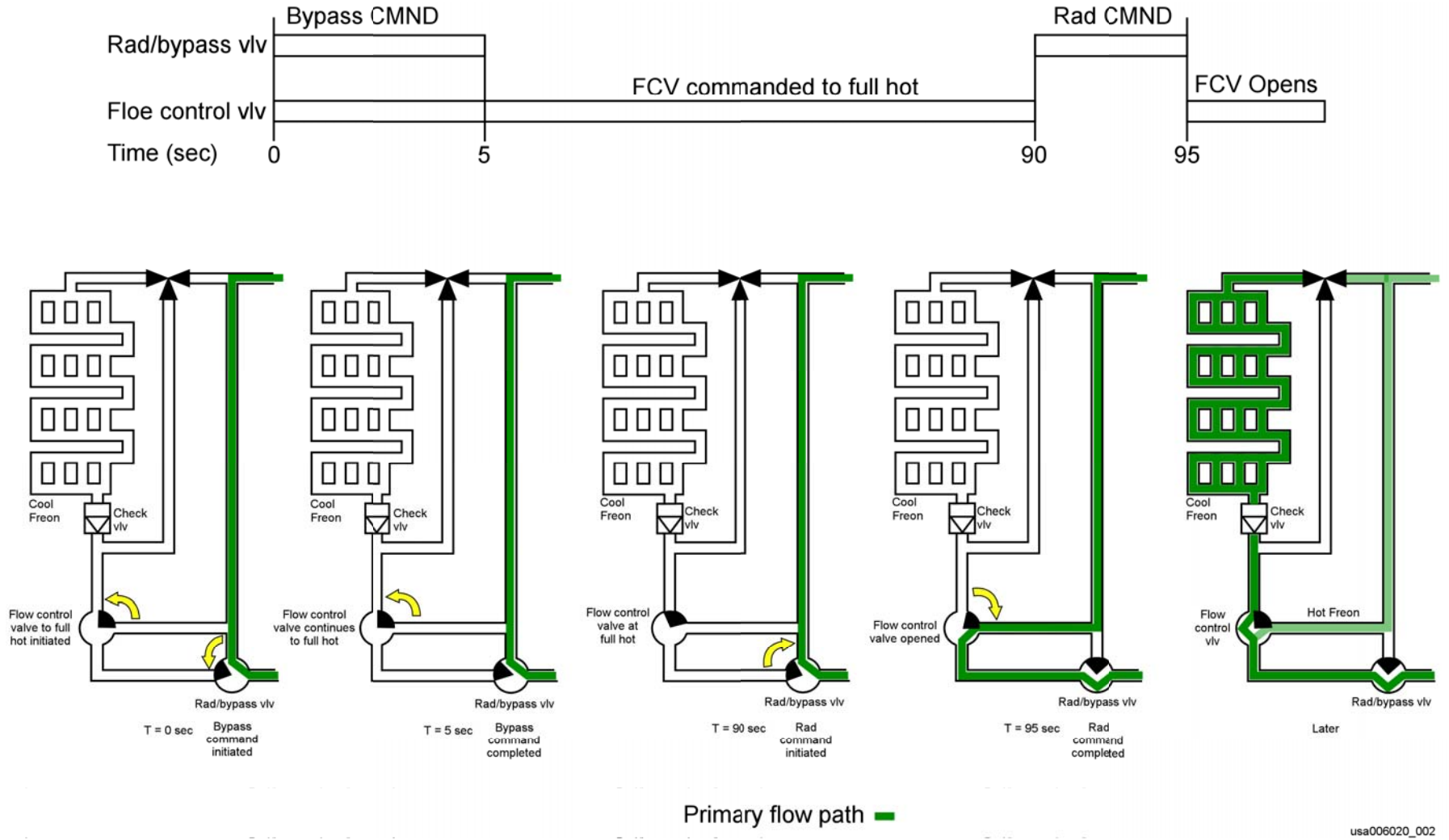


Figure 4-12. Radiator controller auto startup sequence

4.14 AMMONIA BOILER SYSTEM

The ammonia (NH₃) boiler system acts as a heat sink by evaporating liquid anhydrous NH₃ on both Freon loops in the NH₃ boiler HX. The resultant superheated vapor is vented overboard. The Freon loops are cooled by NH₃ during the latter stages of ascent abort entries and postlanding. The NH₃ boiler system consists of two parallel systems (systems A and B) that supply NH₃ to the NH₃ boiler. Each system is made up of an NH₃ storage tank, an isolation valve, an overboard relief valve, two flow control valves, a controller, three temperature sensors, and a feedline to the NH₃ boiler (Figure 4-13).

The system utilizes the low boiling point of NH₃ to cool the Freon loops at relatively low altitudes. When NH₃ is sprayed on the Freon loops in the NH₃ boiler, it immediately vaporizes and carries the Freon heat away. The NH₃ controller adjusts the NH₃ spray to control the Freon temperature exiting the NH₃ boiler to $34^{\circ} \pm 3^{\circ}$ F.

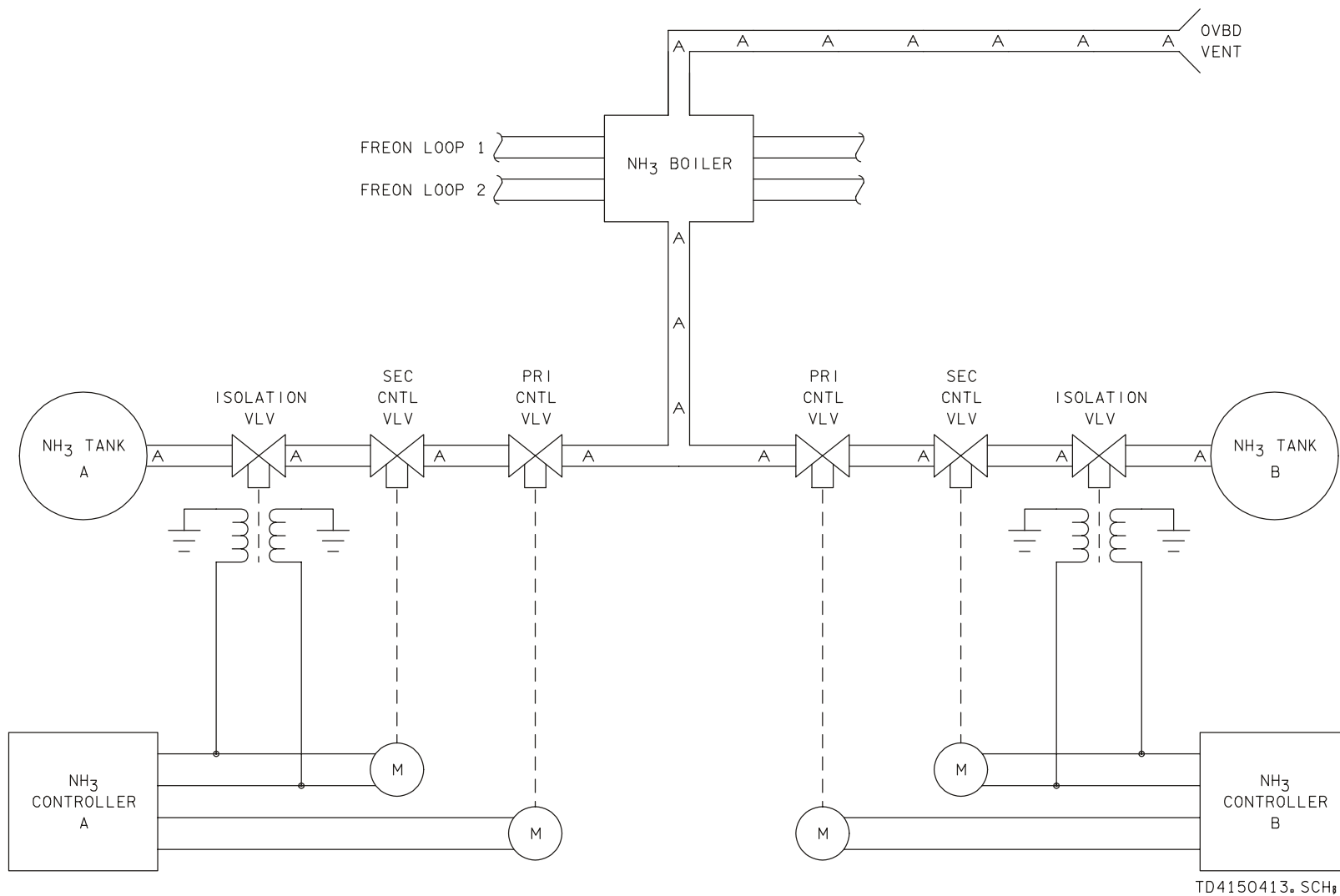
An NH₃ controller is functionally divided into three sections:

- a. Primary controller
- b. Secondary controller
- c. Undertemp switchover logic

Each of these sections receives data from a dedicated temperature sensor on the Freon loop at the NH₃ boiler outlet. The undertemp switchover logic will cause switchover from the primary to secondary controller if the primary controller controls below 31.25° F for more than 10 seconds. Switchover from the secondary to the primary controller does not occur.

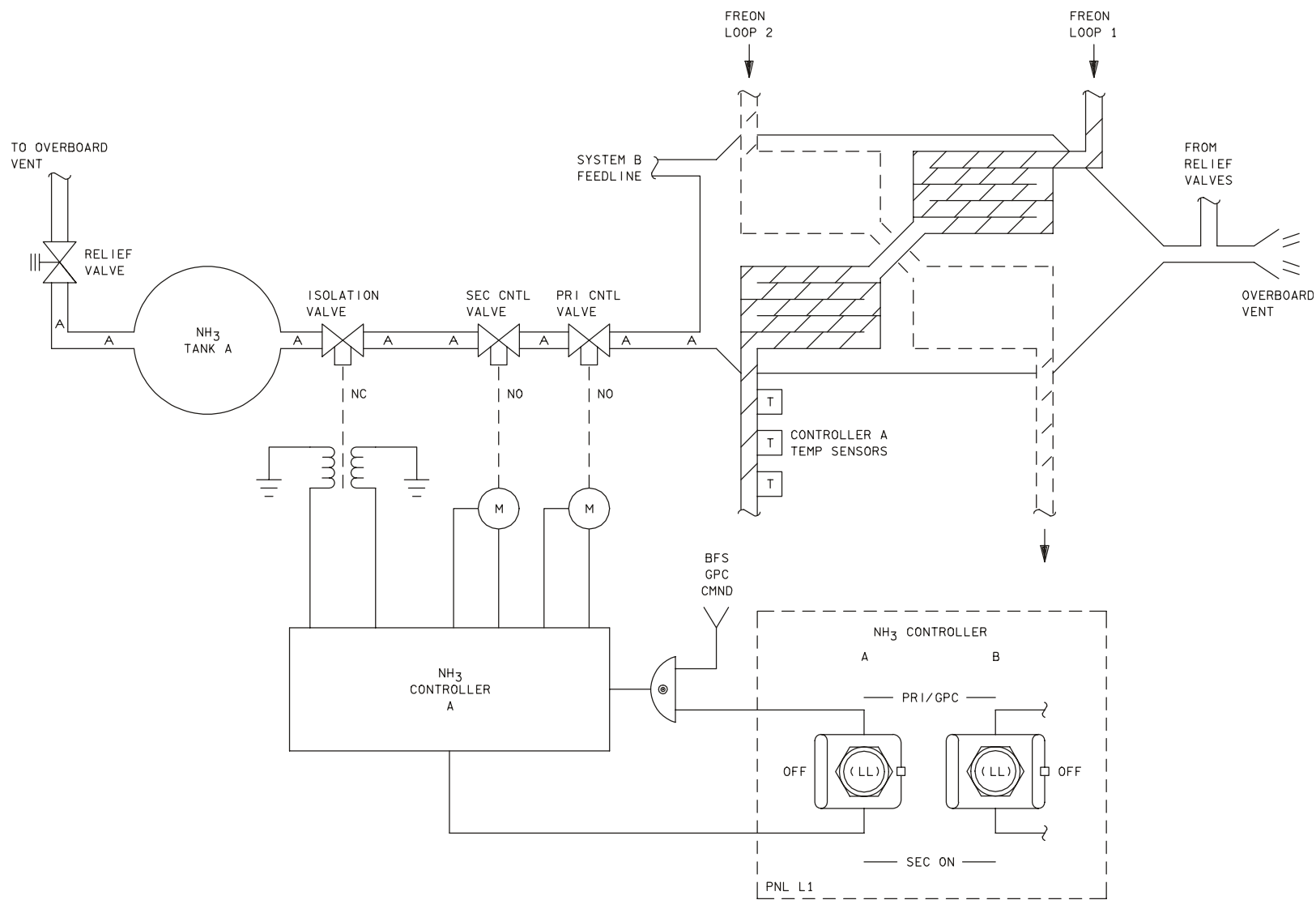
The two switches that control NH₃ systems A and B are located on the lower right of Panel L1 (Figure 4-14). The PRI/GPC position allows the BFS software to initiate NH₃ cooling below 120,000 feet by enabling the primary controller. The SEC/ON position manually initiates NH₃ cooling, using the secondary controller.

In case of an ascent abort, the NH₃ B select switch is placed in the PRI/GPC position prelaunch. This switch position enables the BFS SM software to initiate NH₃ cooling. During a Transoceanic Abort Landing (TAL) or Abort Once Around (AOA), NH₃ cooling is initiated at either Major Mode (MM) 304 and <120,000 feet or MM305. During a Return to Launch Site (RTL), the MM602 transition causes NH₃ cooling to be initiated. The NH₃ cooling is not required for a normal end of mission entry. The radiator coldsoak will provide the Freon cooling until the coldsoak runs out postlanding. If NH₃ cooling is desired for a normal entry, it can be manually selected (SEC/ON) below Entry Interface (EI), 400,000 feet. Gravity is required to keep the NH₃ at the tank outlet. No bladder separates the NH₃ from its helium (He) pressurant. If an NH₃ controller is manually activated (SEC/ON) while in zero g, the He pressurant could leak out, making that system unusable (Figure 4-15).



TD4150413, SCH# 1

Figure 4-13. NH₃ boiler



TD4150414, SCH, 1

Figure 4-14. NH₃ system: functional diagram

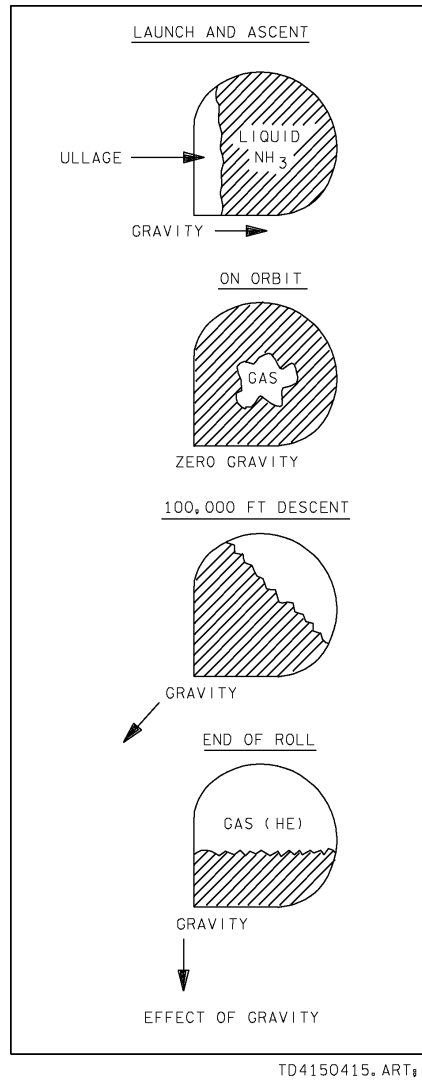


Figure 4-15. NH₃ tank orientation

4.14.1 Power/MDM Requirements for Ammonia Controller Operation

The power/MDM requirements for NH₃ controller operation are shown in the following chart.

	NH ₃ A		NH ₃ B	
	PRI/GPC	SEC/ON	PRI/GPC	SEC/ON
Switch discretes	CNTL BC3	CNTL AB1 CNTL CA2	CNTL BC2	CNTL AB2 CNTL CA1
Logic power	MNA ALC1	MNC ALC3	MNC ALC3	MNB ALC2
MDM "GPC" commands	PL1 and PL2	N/A	PL2	N/A

4.14.2 NH₃ Telemetry

No NH₃ system telemetry is visible on crew displays. The crew can indirectly monitor an active NH₃ system by watching the Freon evap out temperature on the Panel O1 meter or on SM SYS SUMM 2 crew display.

The flight controllers have additional insight and can monitor the telemetry parameters as shown in Table 4-3.

Table 4-3. Telemetry parameters

NH ₃ CNTLR A (B) PRI/GPC CMDs 1 = ON	V63S1178E (1182E)
NH ₃ CNTLR A (B) SEC ON, 1 = ON	V63S1186E (1190E)
NH ₃ ON command	V98X0729X
NH ₃ SYS A (B) tank temp	V63T1180A (1188A)
NH ₃ SYS A (B) tank press	V63P1196A (1197A)
NH ₃ SYS A (B) sec flow controller activate	V63X1198E (1199E)
NH ₃ evaporator discharge temperature aft fuselage	V63T1181A

4.15 FLASH EVAPORATOR SYSTEM

The FES acts as a heat sink for the Freon loops. Water from the supply water tanks is sprayed onto the Freon loops in the high load and topping heat exchangers. This water “flashes” to steam at low ambient pressure and carries heat away from the Freon loops. The resultant steam is vented overboard (Figure 4-16). The FES is used as a primary source of cooling during ascent and entry and is also used as a supplement to radiator cooling during orbit operations.

The FES consists of two evaporators, three electronic logic controllers, two water feedlines with pulser valves, and two overboard steam ducts.

The high load and topping evaporators are located in the aft of the vehicle (Figure 4-16). Both evaporators are identically sized cylindrical heat exchangers about the size of an office wastebasket. The spray nozzles on the hi load evaporator are larger, giving the high load a larger heat rejection capacity (Table 4–4).

Table 4-4. FES heat rejection capacity***

FES operations	Maximum heat rejection (BTU/hr)*
Pri A or B (39° F)	
High load and topping	148,000
Topping only	39,000
Secondary (62° F)	
High load	113,100
Topping	76,800**

*Assumes both loops operating using a primary controller during test.

**Using both nozzles allows for greater spray volume than in primary where only one nozzle is used.

***See SSSH and technical extract A80-15239, Shuttle Orbiter Flash Evaporator, JR Nason and AA Decrasantic, 4TC, Hamilton Std. Published in International Aerospace Abstracts, A1AA – 1979.

The FES water feedlines provide the FES with water from the supply water tanks. Their 100-foot long feedlines are commonly referred to as the A supply and B supply feedlines. The FES feedlines are routed beneath the payload bay envelope and into the aft fuselage. Thermostatically controlled heaters are wrapped around the FES feedlines to keep them warm. Each FES feedline has two sets of heaters.

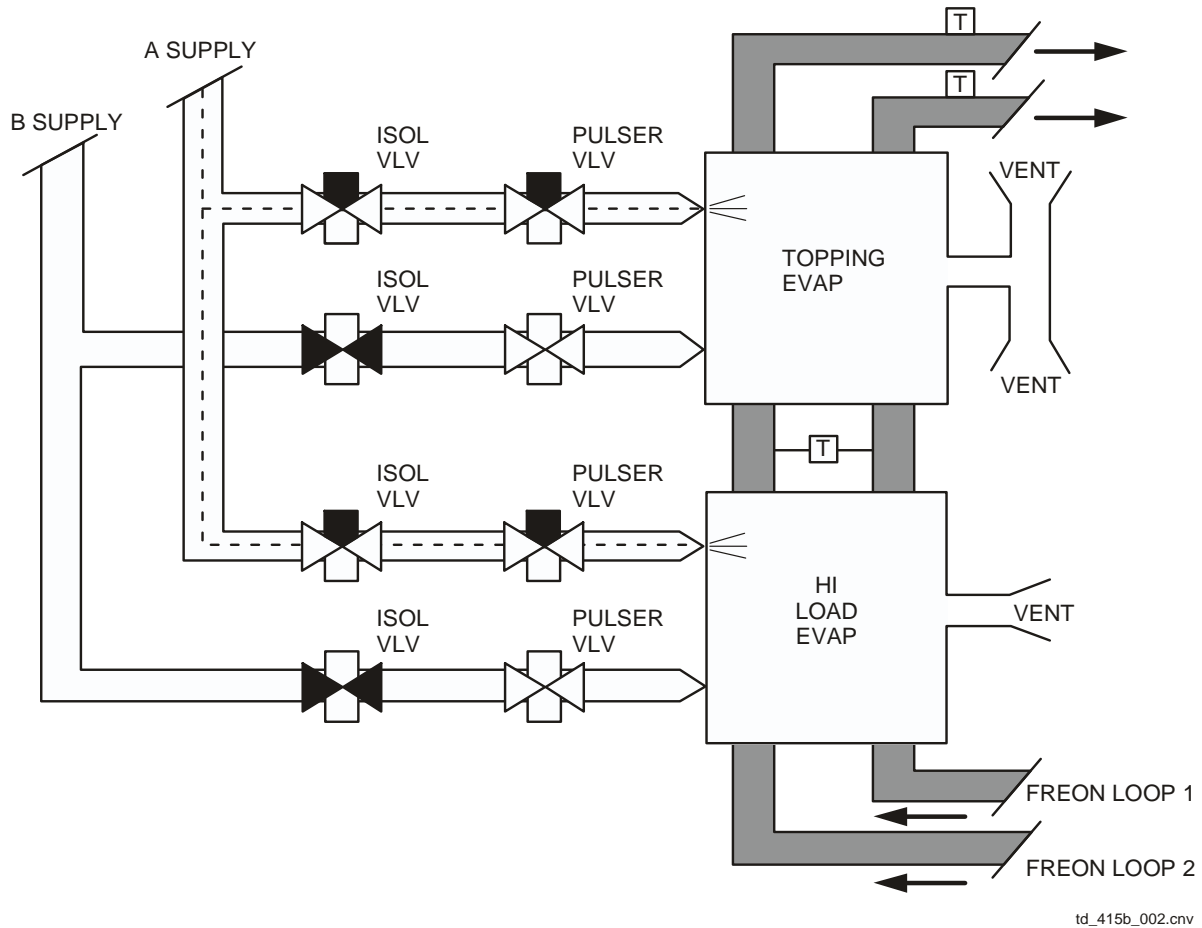


Figure 4-16. Flash evaporator system overview

Utilizing inputs from dedicated temperature sensors, each of the three electronic FES controllers can control the operation of the FES (Figure 4-17). Only one controller is selected at a time. The controllers are commonly referred to as the primary A (PRI A), primary B (PRI B), and secondary (SEC) controllers. PRI A and PRI B control the spray of A supply and B supply water (respectively) into the evaporators. The PRI A and PRI B controllers control to $39^{\circ} \pm 1^{\circ}$ F, while the secondary controller controls to $62^{\circ} \pm 2^{\circ}$ F.

The primary controllers have two modes of operation: high load enabled and topping only. If the high load evaporator is enabled, the primary controller will spray water into both the high load and the topping evaporators to achieve the 39° F control point. If the high load is off, the primary controller will spray water only into the topping evaporator in an attempt to control to 39° F.

The secondary controller also has two modes of operation: high load only and topping only. If the high load evaporator is enabled, the secondary controller will spray water into the high load evaporator only. The source of the water is selectable with the SEC A SPLY/B SPLY switch. If the high load is off, the secondary controller will spray water into the topping evaporator only from both the A and B supply feedlines in an alternate pulsing fashion that may have overlapping pulse at high heat loads.

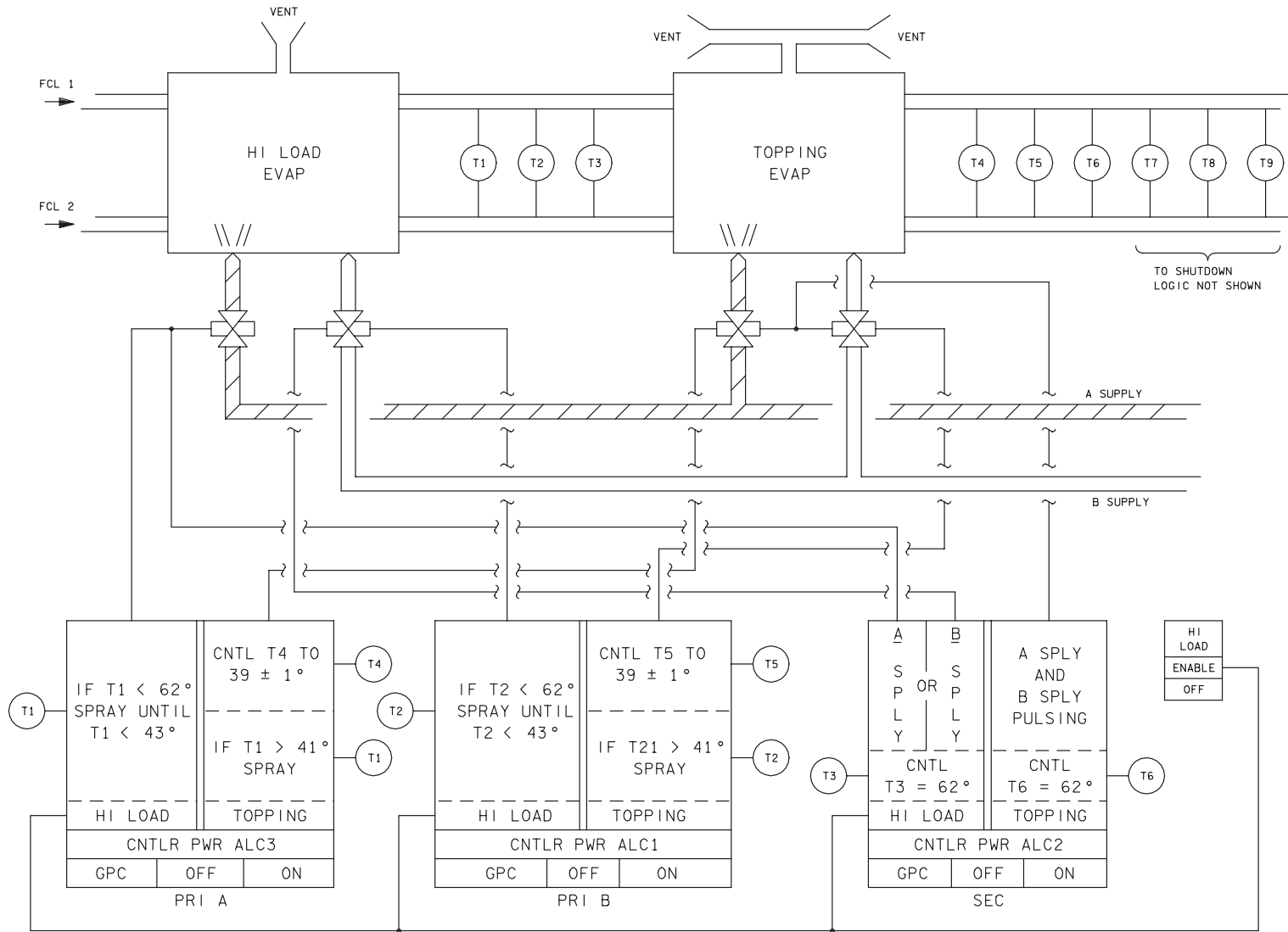
The overboard steam ducts provide the path for the steam to vent overboard. The evaporator duct and nozzle temperatures are maintained by thermostatically controlled heaters. The topping evaporator duct vents to both sides of the orbiter so that it is essentially a nonpropulsive vent. The high load evaporator vents in the orbiter -Y axis and is propulsive.

The PRI A and PRI B FES controllers have undertemp and overtemp shutdown logic that will turn off the FES if it is not controlling to the $39^{\circ} \pm 1^{\circ}$ F control point. The undertemp and overtemp shutdown logic receives its input from a dedicated temperature sensor (Figure 4-17). The SEC controller does not utilize this undertemp or overtemp protection. The secondary controller will attempt to control the evap out temperature to $62^{\circ} \pm 2^{\circ}$ F. If the heat load is too great, the secondary controller will just spray as much water as it can and control to a warmer temperature.

The cooling rate shutdown circuits are active only when the Freon shutdown temperature at the evaporator outlet is above $41.5^{\circ} \pm 0.25^{\circ}$ F. The rate of change is calculated by holding an initial shutdown temperature sensor reading 5 seconds after turn-on and comparing it to an updated sample 19 to 22 seconds later. The result of this first comparison is ignored, but subsequent sample comparisons at 29- to 32-second intervals can produce a shutdown signal. To avoid a rate shutdown, the cooling rate of change must be greater than 0.082 ± 0.047 deg F/sec. The rate monitor is disabled as soon as the Freon outlet shutdown sensor temperature has decreased to less than 41.5° F. The rate shutdown functions as the overtemp shutdown, and it is how an overtemp shutdown is accomplished.

The undertemperature shutdown logic is activated whenever the Freon outlet shutdown sensor temperature is less than $37^{\circ} \pm 0.25^{\circ}$ F with the FES midpoint temperature greater than 41° F (i.e., when the FES is active). To prevent an inadvertent shutdown during startup or a transient condition, the undertemperature condition must be present for greater than 22 ± 3 seconds for the shutdown command to be generated. When the midpoint temperature (Freon temperature inlet to topping evaporator) drops below 40° F and the topping evaporator is in standby, the undertemperature shutdown feature is inhibited. This is necessary because the low temperature shutdown setpoint is within the shuttle radiator outlet temperature control band of $38^{\circ} \pm 2^{\circ}$ F.

Temperature sensors at the midpoint in Freon loop flow between the high load and topping evaporators provide inputs to the primary controllers. These sensors are instrumental in FES control and shutdowns.



TD4150418, SCH 2

Figure 4-17. FES controller functional diagram

4.16 ENVIRONMENTAL CONTROL AND LIFE SUPPORT SYSTEM COOLING MANAGEMENT

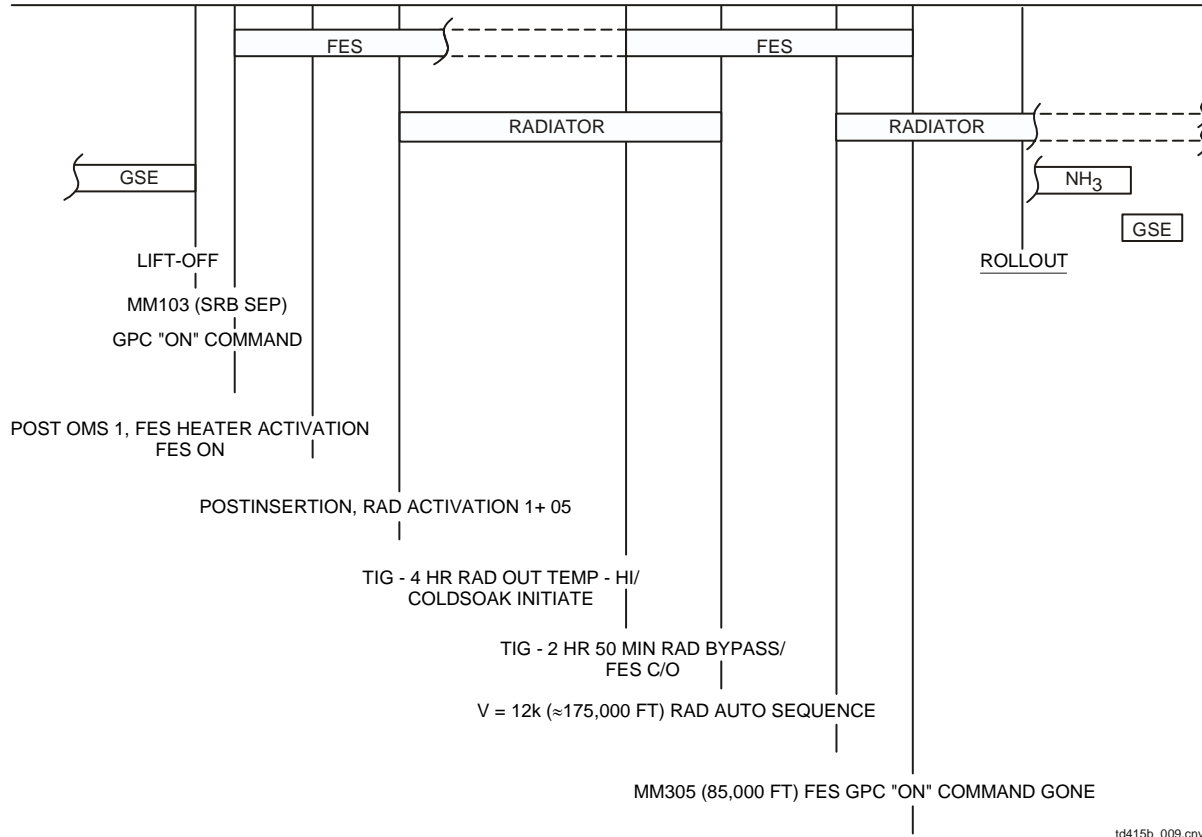
Depending on the mission phase, the Freon cooling loops are cooled four different ways (see Figure 4-18). Prior to launch, cooling is provided by way of the GSE. After lift-off, there is no active cooling until after SRB SEP. It takes the orbiter slightly more than 2 minutes to reach an altitude where water evaporation provides effective cooling. Until that time, sufficient “thermal inertia” is in the Freon loops to limit the temperature increase so that no active heat rejection is required.

At the Major Mode 103 transition (SRB SEP), the FES receives a GPC “ON” command from the BFS and begins providing active cooling. The FES continues to be the primary cooling source through the ascent phase and on into the post insertion timeframe. During the Post Insertion Checklist procedures, flow is initiated through the radiators, the payload bay doors are opened, and the radiators become the primary source of cooling. The FES may be left on to provide supplemental cooling when necessary. If the orbiter is in a warm attitude, radiator cooling efficiency may decrease and the FES may be needed to provide additional cooling to achieve the desired Freon loop temperatures.

During the deorbit prep procedures, the radiators are “coldsoaked” to provide cooling for use later during entry. The radiator coldsoak process lowers the temperature of Freon in the radiators by changing the radiator control temperature from 38° to 57° F. Since less cool Freon from the radiators is required to control to this high temperature, flow through the radiators is slower. As a result, the Freon spends a longer period in the radiators exposed to space and becomes colder than if the flow control valve were controlling for a 38° F radiator out temperature. The FES is used to cool the Freon from 57° to 39° F. After approximately 1 hour of coldsoak, the radiators are bypassed, trapping the cold Freon in the radiators. At this point, the FES provides all the cooling to the Freon loops. The FES supplies cooling during the rest of the deorbit, through EI, and down to V = 12k (approximately 175,000 feet).

At V = 12k, the radiators are activated, since below 100,000 ft the atmospheric pressure is too high for the FES to cool effectively. Radiator flow is reinitiated after the auto startup sequence is complete. The cool Freon stored in the radiators is used as the primary source of cooling from this point through rollout.

Once the orbiter is on the ground and the radiator coldsoak is depleted, the NH₃ boiler is activated. The MCC calls the crew to request the NH₃ activation. The NH₃ boilers are used as the primary cooling source until the GSE cooling cart hookup is complete. Then the NH₃ cooling is deactivated, and GSE cooling is initiated.



td415b_009.cnv

Figure 4-18. ECLSS cooling management

For ascent aborts, the thermal management of the Freon cooling is somewhat different (see Figure 4-19). The FES still provides the cooling after SRB SEP. The cooling management during the entry portion is what has changed. The NH₃ boilers provide the cooling during the lower stages of the abort entry. The NH₃ is used for cooling during the entry phase of an ascent abort because the orbiter lifts off without a radiator coldsoak, and the FES functions normally only at low atmospheric pressure (above 100,000 ft).

For a TAL or an AOA, the NH₃ boiler receives a GPC "ON" command from the BFS at MM304 and 120,000 ft. For an RTLS, the NH₃ boiler receives a GPC "ON" command from the BFS at External Tank Separation (ET SEP) (MM602). The NH₃ boiler will provide the cooling from this point through landing. The NH₃ boilers can provide cooling for approximately 1 hour.

4.17 ACTIVE THERMAL CONTROL SYSTEM CONTROLS

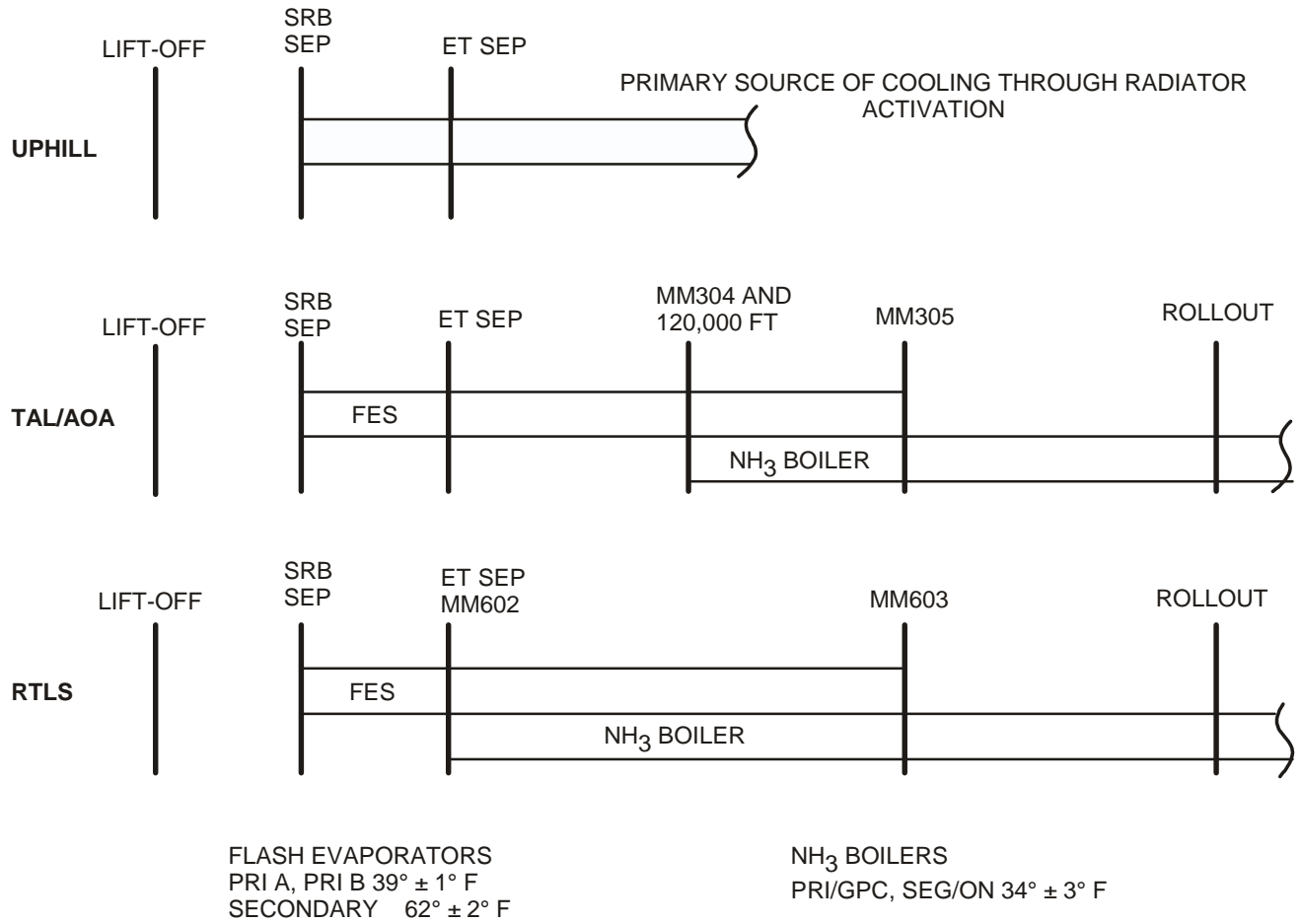
The switches and circuit breakers that control the ATCS are located on Panels L1, L2, L4, O14, O15, and O17. The majority of the switches are located on Panel L1 (Figure 4-20). The layout of this half of Panel L1 is a schematic of the Freon loops.

The FLASH EVAP FEEDLINE HTR switches are located on Panel L2 (Figure 4-21). There is one switch for the A SUPPLY water line and one for the B SUPPLY water line heaters. The switches have three positions, 1, OFF, and 2.

The circuit breakers that provide power to the radiator controller logic are located on Panels O14 and O15 (Figure 4-22). The FREON RAD CNTLR 1 and 2 circuit breakers on Panel O14 provide MNA power to the AUTO B RAD controllers. The FREON RAD CNTLR 1 and 2 circuit breakers on Panel O15 provide MNB power to the AUTO A RAD controllers. The circuit breakers that provide AC power to the radiator rad/bypass valve motors are located on Panel L4 row P (Figure 4-23). The RAD CNTLR 1B circuit breaker provides AC1 phase A power to drive the RAD/BYPASS valve on Freon loop 1. The circuit breakers that provide AC power to the Freon flow proportioning valve motors are located on Panel L4 row N (Figure 4-23). For example, the FREON FLOW PROP 1 circuit breaker provides phase A power to drive the flow proportioning valve on Freon loop 1. The circuit breakers that provide AC power to the Freon pumps are also located on Panel L4 on rows M and N. The FREON LOOP 1 PUMP A circuit breakers provide three phases of AC1 power to Freon pump 1A.

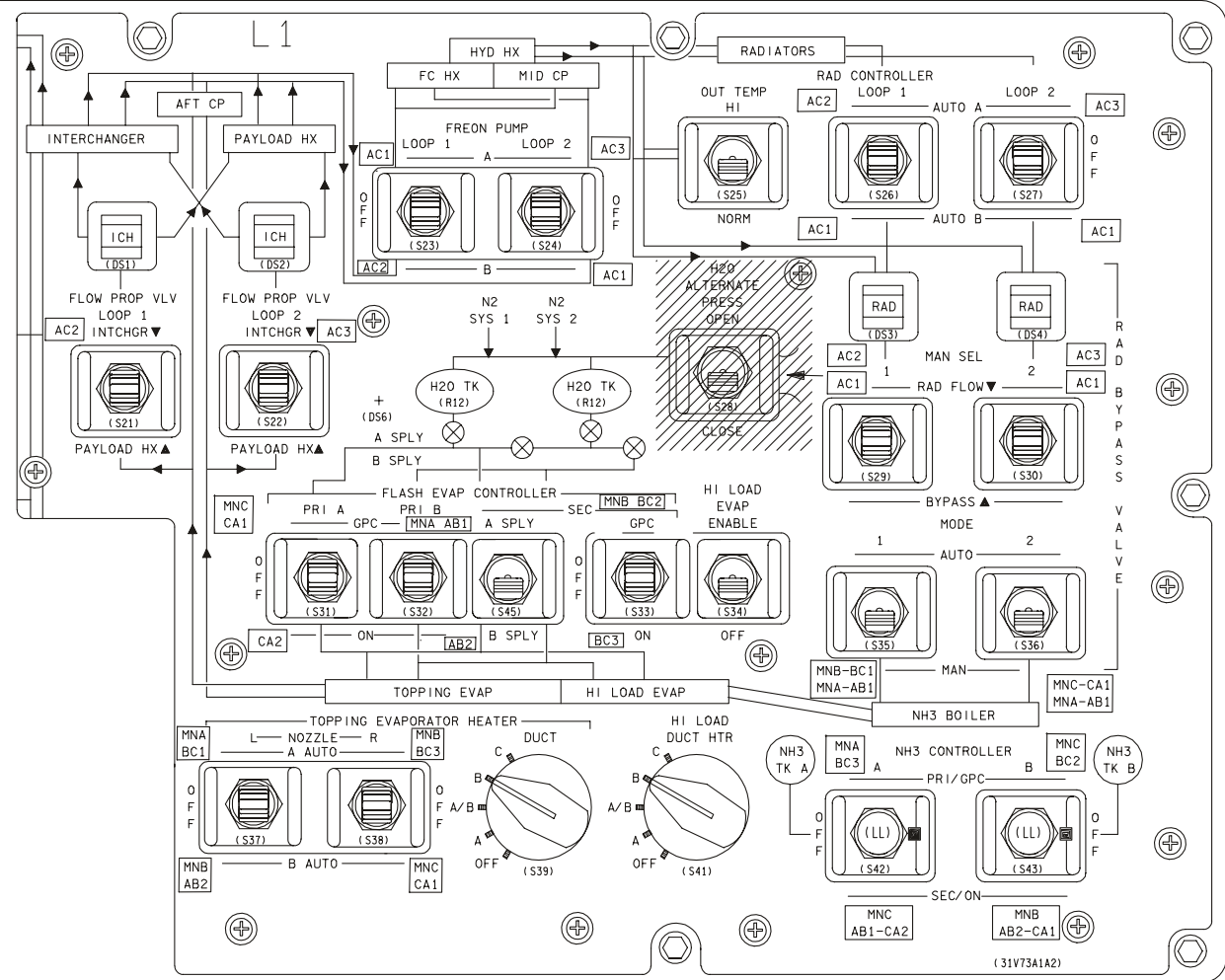
The circuit breakers that provide AC power to the rad isol valve motors are located on Panel L4 row N (Figure 4-22). The circuit breaker that provides power to the rad isol controller logic is located on Panel O14.

The ATCS controls are listed in Table 4-5.



td415b_010.cnv

Figure 4-19. Ascent/abort thermal management



TD4150420. PNL 2

Figure 4-20. Panel L1 – ATCS

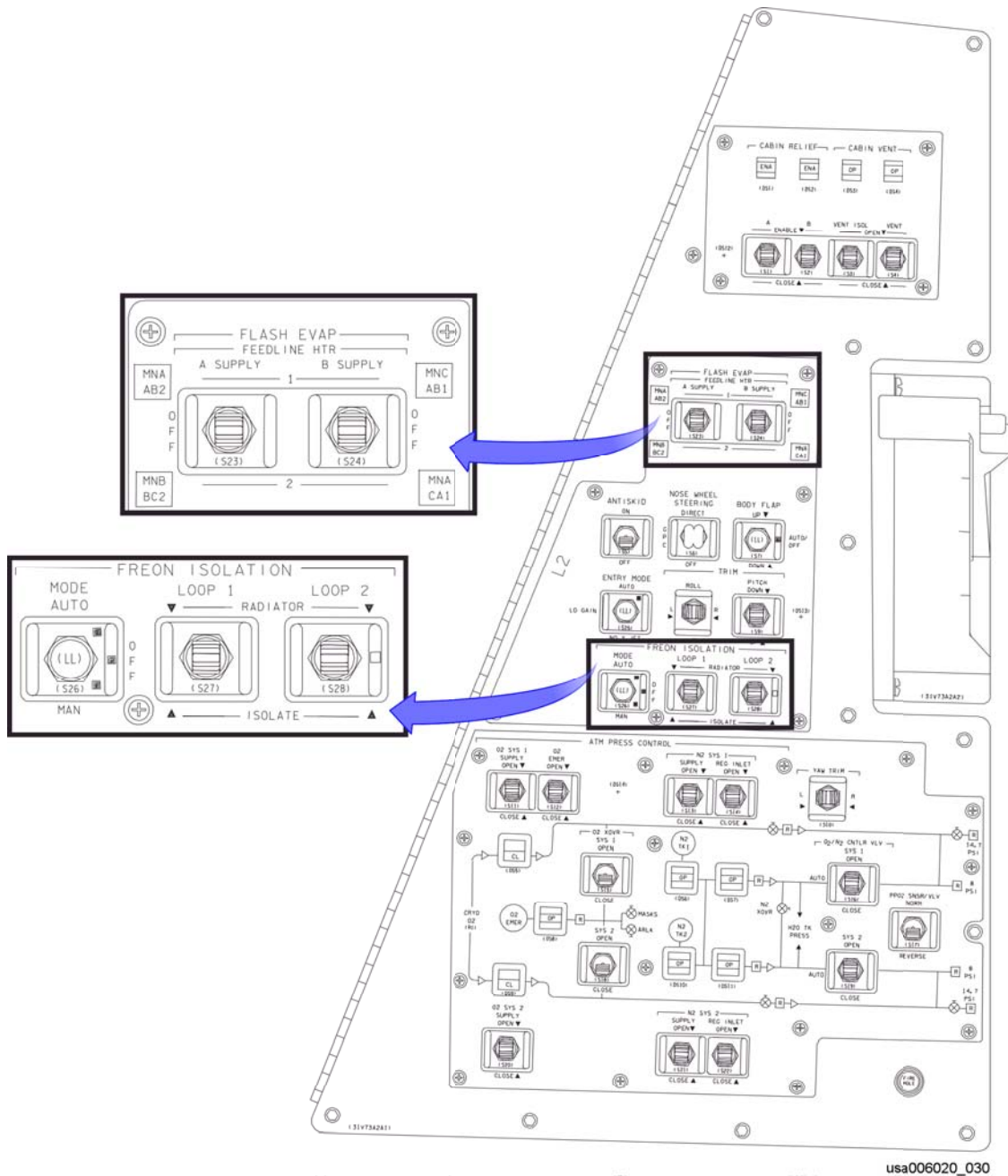
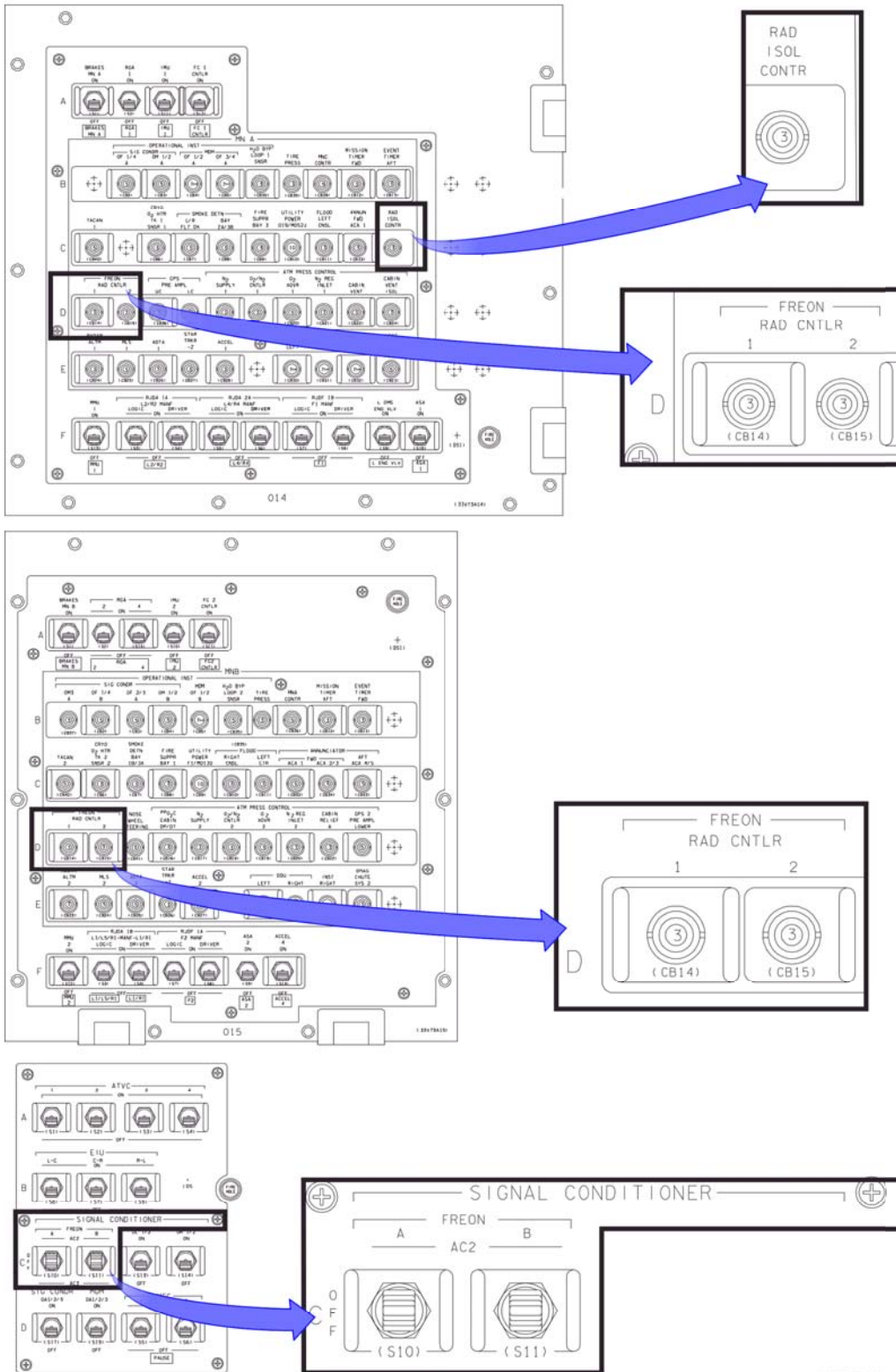
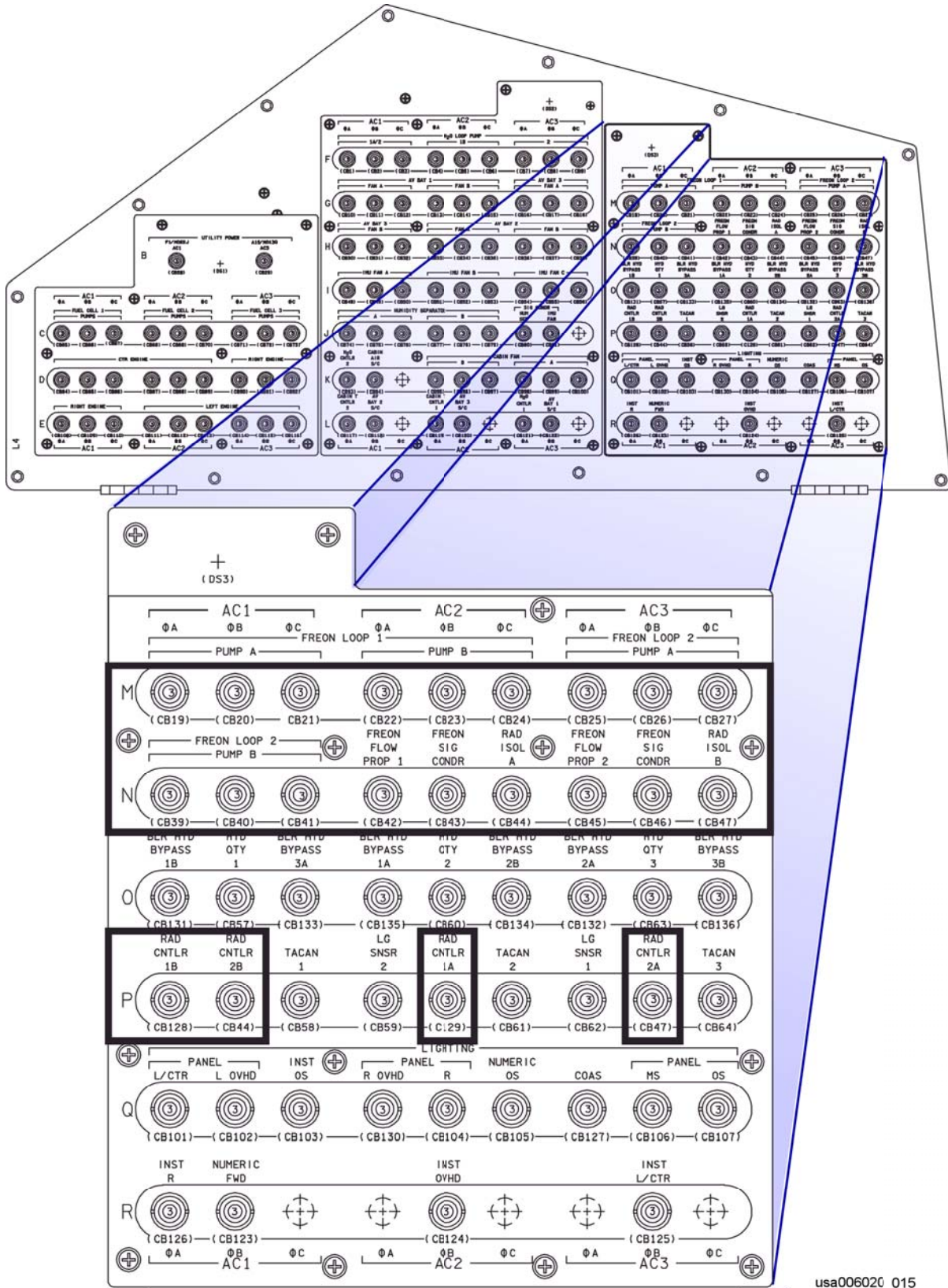


Figure 4-21. Panel L2 – ATCS



usa006020_029.

Figure 4-22. Overhead panels – ATCS



usa006020_015

Figure 4-23. Panel L4 – ATCS

4.17.1 Active Thermal Control System Instrumentation/Displays

Crew insight into ATCS system performance is provided by ECLSS instrumentation and DSCs (Figure 4-24). The Freon signal conditioners power the following transducers:

Freon S/C A

Freon loop 1 payload HX flow rate
 Freon loop 2 accum quantity
 Freon loop 2 interchanger flow rate

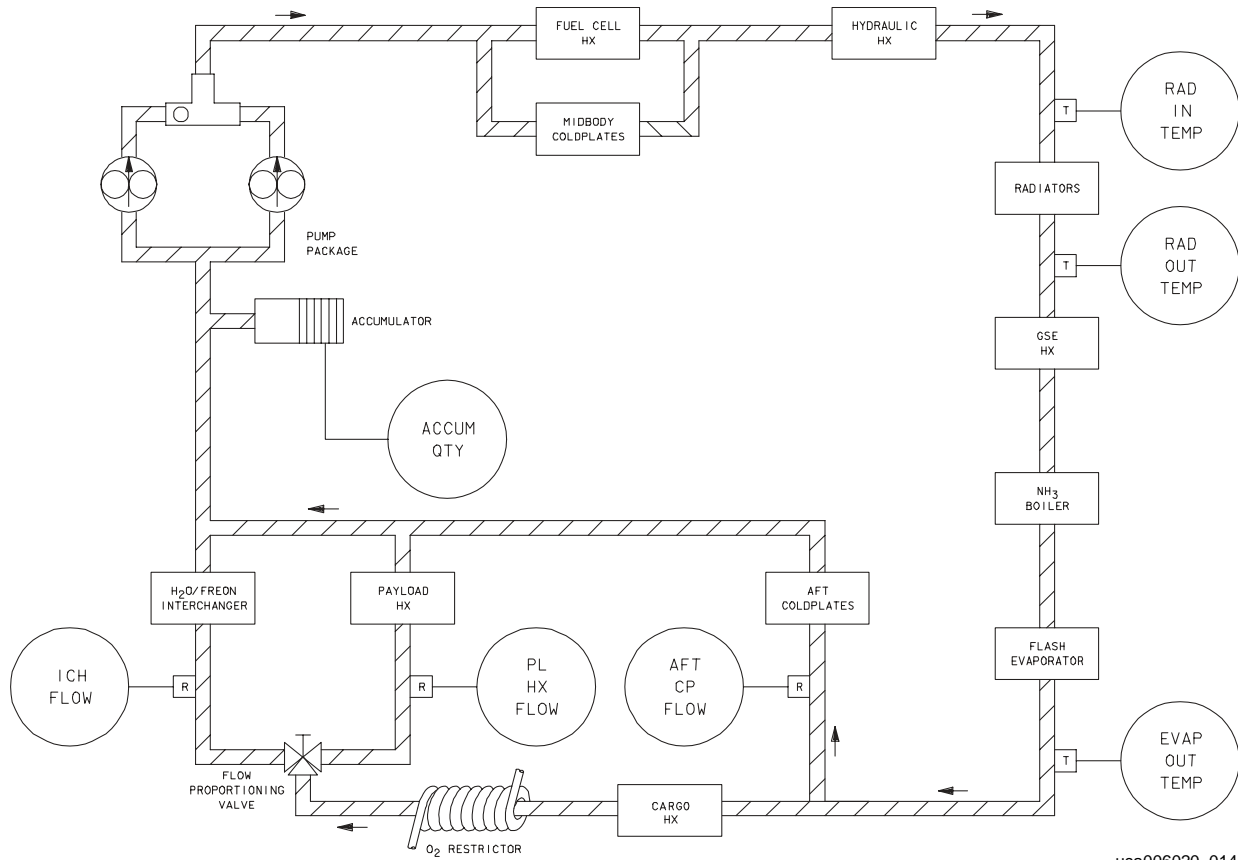
Freon S/C B

Freon loop 2 payload HX flow rate
 Freon loop 1 accum quantity
 Freon loop 1 interchanger flow rate

4.17.2 CRT Displays

The crew has insight into ATCS status on the following CRT displays, dependent on mission phase. SPEC 88 is the primary display for ATCS system information during orbit operations.

OPS mode	CRT display	Figure number
OPS 1 (ascent)	BFS SM SYS SUMM 2	4-26
	BFS SM0 THERMAL	4-27
OPS 2 (4) (orbit)	PASS SM SPEC 88	4-25
	PASS SM SYS SUMM 2	4-26
OPS 3 (entry)	BFS SM SYS SUMM 2	4-26
	BFS SM0 THERMAL	4-27



usa006020_014

Figure 4-24. Freon coolant loop instrumentation

4.17.3 RAD ISOL Display Logic

CRT Display Processing Logic					
MSID	Nomenclature	BIT Configuration			
		01	02	03	04
V6JX1233E	FCL 1 ISOL Vlv – Radiator Flow	0	1	0	1
V6JX1234E	FCL 1 ISOL Vlv – Radiator Isolated	0	0	1	1
V6JX1433E	FCL 2 ISOL Vlv – Radiator Flow	0	1	0	1
V6JX1434E	FCL 2 ISOL Vlv – Radiator Isolated	0	0	1	1
	Default CRT Text	(Blank)	RAD	ISOL	ERR

JSC-19590-116, Systems Management Level C Flight Software Requirements, STS-116 Base 2 Cycle (OI-30) November 2003, page 6.11-9 & 6.11-10

```

XXXX/XXX/088 APU/ENVIRON THERM XX X DDD/HH:MM:SS
FREON LOOP 1 2 DDD/HH:MM:SS
ACCUM QTY XXXS XXXS H2O LOOP 1 2
FREON ISOL XXXS XXXS PUMP OUT P XXXXS XXXXS
FREON FLOW XXXXS XXXXS OUT T XXXXS XXXXS
PL HX FLOW XXXXS XXXXS ΔP XXXXS XXXXS
AFT CP FLOW XXXS XXXS ICH FLOW XXXXS XXXXS
RAD IN T XXXS XXXS OUT T XXXXS XXXXS
RAD OUT T XXXS XXXS CAB HX IN T XXXXS XXXXS
EVAP OUT T XXXS XXXS ACCUM QTY XXXXS XXXXS
EVAP TEMP APU FUEL T 1 2 3
HILD IB/OB XXXS XXXS TK SURF ±XXXS ±XXXS ±XXXS
NOZ XXXS XXXS TK HTR ±XXXS ±XXXS ±XXXS
TOP FWD/AFT XXXS XXXS TEST LN 1 ±XXXS ±XXXS ±XXXS
L/R DUCT XXXS XXXS TEST LN 2 ±XXXS ±XXXS ±XXXS
L/R NOZ XXXS XXXS FEED LN ±XXXS ±XXXS ±XXXS
EVAP FDLN T A B PUMP LN ±XXXS ±XXXS ±XXXS
FWD XXXS XXXS DRN LN 1 ±XXXS ±XXXS ±XXXS
MID 1 XXXS XXXS DRN LN 2 ±XXXS ±XXXS ±XXXS
MID 2 XXXS XXXS OUT ±XXXS ±XXXS ±XXXS
AFT XXXS XXXS BYP LN ±XXXS ±XXXS ±XXXS
TOPPING XXXS XXXS GG SPLY LN XXXS XXXS XXXS
ACCUM XXXS XXXS
HI LOAD XXXS XXXS H2O LN INJ ±XXXS ±XXXS ±XXXS
(XX)

```

SPEC 88

OI-30

JSC-19590-116, Systems Management Level C
Flight Software Requirements, STS-116 Base 2
Cycle (OI-30), November 2003, page 6.11-1.

CRT Display Processing Logic					
MSID	Nomenclature	BIT Configuration			
		01	02	03	04
V6JX1233E	FCL 1 ISOL Vlv - Radiator Flow	0	1	0	1
V6JX1234E	FCL 1 ISOL Vlv - Radiator Isolated	0	0	1	1
V6JX1433E	FCL 2 ISOL Vlv - Radiator Flow	0	1	0	1
V6JX1434E	FCL 2 ISOL Vlv - Radiator Isolated	0	0	1	1
	Default CRT Text	(Blank)	RAD	ISOL	ERR

JSC-19590-116, Systems Management Level C Flight
Software Requirements, STS-116 Base 2 Cycle (OI-30)
November 2003, page 6.11-9 & 6.11-10.

```

2011/ /088 APU/ENVIRON THERM 4 000/01: 02: 10
FREON LOOP 1 2 000/00: 00: 00
ACCUM QTY 30 30 H2O LOOP 1 2
FREON ISOL RAD RAD PUMP OUT P 24 63
FREON FLOW 2165 2165 OUT T 89 66
PL HX FLOW 286 286 ΔP OL 39
AFT CP FLOW 277 277 ICH FLOW 4L 958
RAD IN T 113 105 OUT T 39 43
RAD OUT T 44 43 CAB HX IN T 39 43
EVAP OUT T 39 39 ACCUM QTY 45 55
EVAP TEMP APU FUEL T 1 2 3
HILD IB/OB 259 259 TK SURF + 69 + 67 + 68
NOZ 315 TK HTR + 69 + 67 + 68
TOP FWD/AFT 247 247 TEST LN 1 + 64 + 64 + 64
L/R DUCT 157 157 TEST LN 2 + 64 + 64 + 64
PING L/R 53 53 FEED LN + 64 + 64 + 64
EVAP FDLN T A B PUMP LN + 64 + 64 + 64
FWD 75 75 DRN LN 1 + 64 + 64 + 64
MID 1 75 74 DRN LN 2 + 64 + 64 + 64
MID 2 79 75 OUT + 86 + 88 + 90
AFT 77 77 BYP LN + 86 + 88 + 90
TOPPING 77 77 GG SPLY LN + 88 + 88 + 88
ACCUM 77 77
HI LOAD 77 77 H2O LN INJ+ 75 + 75 + 75

```

SPEC 88 PRO

CRT_Spec 88 OI-30.CNV, Michael M Hoekman USA/DT36 281-244-7179

Figure 4-25. SPEC 88 APU/environ therm

The APU/ENVIRON THERM display is an SM display (DISP 88), available in SM OPS 2 and 4, which provides the crew with data on the ATCS Freon loops and heaters.

Parameter characteristics

CRT name		Units	Displayed range	Status indicators				
FREON LOOP	ACCUM QTY	Percent	0 to 100	M	H	L		↓
	RAD ISOL	Text	RAD, ISOL, BLANK or ERR					
	FREON FLOW	lbm/hr	730 to 2700	M	H	L		↓
	PL HX FLOW	lbm/hr	199 to 1300	M	H	L		↓
	AFT CP FLOW	lbm/hr	0 to 500	M	H	L		↓
	RAD IN T	° F	0 to 160	M	H	L		
	RAD OUT T	° F	25 to 130	M	H	L		↓
	EVAP OUT T	° F	25 to 130	M	H	L	↑	↓
EVAP TEMP	HI LOAD INBD	° F	0 to 400	M	H	L	↑	↓
	OUTBD	° F	0 to 400	M	H	L	↑	↓
	NOZZLE	° F	0 to 400	M	H	L	↑	↓
	TOPPING FWD	° F	0 to 400	M	H	L	↑	↓
	AFT	° F	0 to 400	M	H	L	↑	↓
	L	° F	0 to 250	M	H	L	↑	↓
	R	° F	0 to 250	M	H	L	↑	↓
	EVAP FDLN T FWD	° F	0 to 160	M	H	L	↑	↓
	MID 1	° F	0 to 160	M	H	L	↑	↓
	MID 2	° F	0 to 160	M	H	L	↑	↓
	AFT	° F	0 to 160	M	H	L	↑	↓
	TOPPING	° F	0 to 160	M	H	L	↑	↓
	ACCUM	° F	0 to 160	M	H	L	↑	↓
	HI LOAD	° F	0 to 250	M	H	L	↑	↓

The SM SYS SUMM 2 display is an SM display (DISP 79), available in the BFS and PASS SM OPS 2 and 4, which provides summary data on the ATCS thermal control.

XXXX / XXX / 079		SM SYS SUMM 2			XX	X	DDD / HH:MM:SS
					BFS	DDD / HH:MM:SS	
CRYO TK	1	2	3	4	5	MANF1	MANF2
H2 PRESS	XXXX	XXXX	XXXX	XXXX	XXXX	XXXX	XXXX
O2 PRESS	XXXX	XXXX	XXXX	XXXX	XXXX	XXXX	XXXX
HTR T1	± XXXS	± XXXS	± XXXS	± XXXS	± XXXS	± XXXS	± XXXS
T2	± XXXS	± XXXS	± XXXS	± XXXS	± XXXS	± XXXS	± XXXS
APU	1	2	3	HYD	1	2	3
TEMP EGT	XXXX	XXXX	XXXX	PRESS	XXXX	XXXX	XXXX
B / U EGT	XXXX	XXXX	XXXX	ACUM P	XXXX	XXXX	XXXX
OIL IN	XXXX	XXXX	XXXX	RSVR T	XXXX	XXXX	XXXX
OUT	XXXX	XXXX	XXXX	QTY	XXXX	XXXX	XXXX
GG BED	XXXX	XXXX	XXXX	W/B			
INJ	XXXX	XXXX	XXXX	H2O QTY	XXXX	XXXX	XXXX
SPEED %	XXXX	XXXX	XXXX	BYP VLV	XXXX	XXXX	XXXX
FUEL QTY	XXXX	XXXX	XXXX	THERM CNTL	1	2	
PMP LK P	XXS	XXS	XXS	H2O PUMP P	XXXX	XXXX	
OIL OUT P	XXXX	XXXX	XXXX	FREON FLOW	XXXX	XXXX	
FU TK VLV				EVAP OUT T	XXXX	XXXX	
A T	XXXX	XXXX	XXXX				
B T	XXXX	XXXX	XXXX				
AV BAY	1	2	3				
TEMP	XXXX	XXXX	XXXX				
FAN ΔP	X.XXS	X.XXS	X.XXS				

SPEC 79 BFS OI-30

STS 83-0020V2-30-A, Space Shuttle Orbiter Operational Flight Level C
Functional Subsystem Software Requirements, Displays and Controls
Volume 2: Systems Management, May 30, 2003.

0001/ /079		SM SYS SUMM 2			5	000/00:26:25	
					BFS	000/00:00:00	
CRYO TK	1	2	3	4	5	MANF1	MANF2
H2 PRESS	221	220	200	200	200	220	220
O2 PRESS	824	824	810	810	810	824	824
HTR T1	- 73	- 73	-250	-250	-250		
T2	- 73	- 73	-250	-250	-250		
APU	1	2	3	HYD	1	2	3
TEMP EGT	893	679	903	PRESS	3048	3050	3056
B / U EGT	912	679	903	ACUM P	3064	2592	3056
OIL IN	250	250	250	RSVR T	175	169	195
OUT	260	250	260	QTY	76	77	73
GG BED	511H	511H	511H	W/B			
INJ	1239	1161	1242	H2O QTY	98	98	98
SPEED %	93	101	102	BYP VLV	BYP	BYP	W/B
FUEL QTY	69	71	66	THERM CNTL	1	2	
PMP LK P	14	14	14	H2O PUMP P	24	63	
OIL OUT P	60	28	62	FREON FLOW	2350	2351	
FU TK VLV				EVAP OUT T	39	39	
A T	61	62	62				
B T	61	62	62				
AV BAY	1	2	3				
TEMP	106	106	89				
FAN ΔP	3.34	3.36	4.24				

SYS SUMM

CRT_Spec 79 BFS OI-30.CNV, Michael M Hoekman, USA/DT36 281-244-7179

Figure 4-26. SM SYS SUMM 2

Parameter characteristics

CRT name	Units	Displayed range	Status indicators				
THERM CNTL FREON FLOW	lbm/hr	570 to 2600	M	H	L		↓
EVAP OUT T	° F	25 to 130	M	H	L	↑	↓

```

0001 / / THERMAL XX X DDD/ HH:MM:SS
BFS DDD/ HH:MM:SS
HYD SYS TEMP BDYFLP RD/ SB L OB L IB R IB R OB
PRIME ±XXXX ±XXXX ±XXXX ±XXXX ±XXXX ±XXXX
STBY 1 ±XXXX ±XXXX ±XXXX ±XXXX ±XXXX ±XXXX
BRAKE PRESS
1/3 XXXXX XXXXX XXXXX XXXXX
2/3 XXXXX XXXXX XXXXX XXXXX
HTR TEMP L/ A R/ B FREON LOOP 1 2
PRPLT ACCUM QTY XXXX XXXX
POD RAD OUT T XXXX XXXX
OMS CRSFD SS SSSSSSS H2O SUP P XXXX
EVAP TIRE PRESS
HI LOAD SSS MG LEFT RIGHT
TOP DUCT SS IB XXXX XXXX XXXX XXXX
NOZ S OB XXXX XXXX XXXX XXXX
FDLN SSSS SSSS NG XXXX XXXX XXXX XXXX
HYD BLR/ HTR S 1 S 2 S 3
APU
GG/ FU PMP HTR SSSSS SSSSS SSSSS
TK/ FU LN HTR SSSSSS SSSSSS
PUMP/ VLV SS SS

```

SMO THERM

OI-30

STS 83-0020V2-30-A, Space Shuttle Orbiter Operations Flight Level C
Functional Subsystem Software Requirements, Displays and Controls
Volume 2: Systems Management, May 30, 2003

```

0001/ THERMAL 5 000/00# 26# 03
BFS 000/00# 00# 0
HYD SYS TEMP BDYFLP RD/ SB L OB L IB R IB R OB
PRIME +306H +164 +172 +142 +172 +1
STBY 1 +306H +151 +161 +163 +163 +161
BRAKE PRESS
HYD SYS 1/3 25 25 25 25
2/3 25 25 25 25
HTR TEMP L/ A R/ B FREON LOOP 1 2
PRPLT ACCUM QTY 32 32
POD RAD OUT T 38 38
OMS CRSFD SS SSSSSSS H2O SUP P 16
EVAP TIRE PRESS
HI LOAD SSS MG LEFT RIGHT
TOP DUCT SS IB 415 415 415 415
NOZ S OB 415 415 415 415
FDLN SSSS SSSS NG 450 450 450 450
HYD BLR/ HTR H 1 H 2 H 3
APU
GG/ FU PMP HTR H H H
TK/ FU LN HTR
PUMP/ VLV
RESUME

```

CRT_BFS SMO THERM OI-30, Michael M Hoekman USA/DT36 281-244-7179

Figure 4-27. BFS THERMAL display

The THERMAL display is a BFS display (OPS/0001), which provides the crew data on the ATCS Freon loops and heaters.

Parameter characteristics

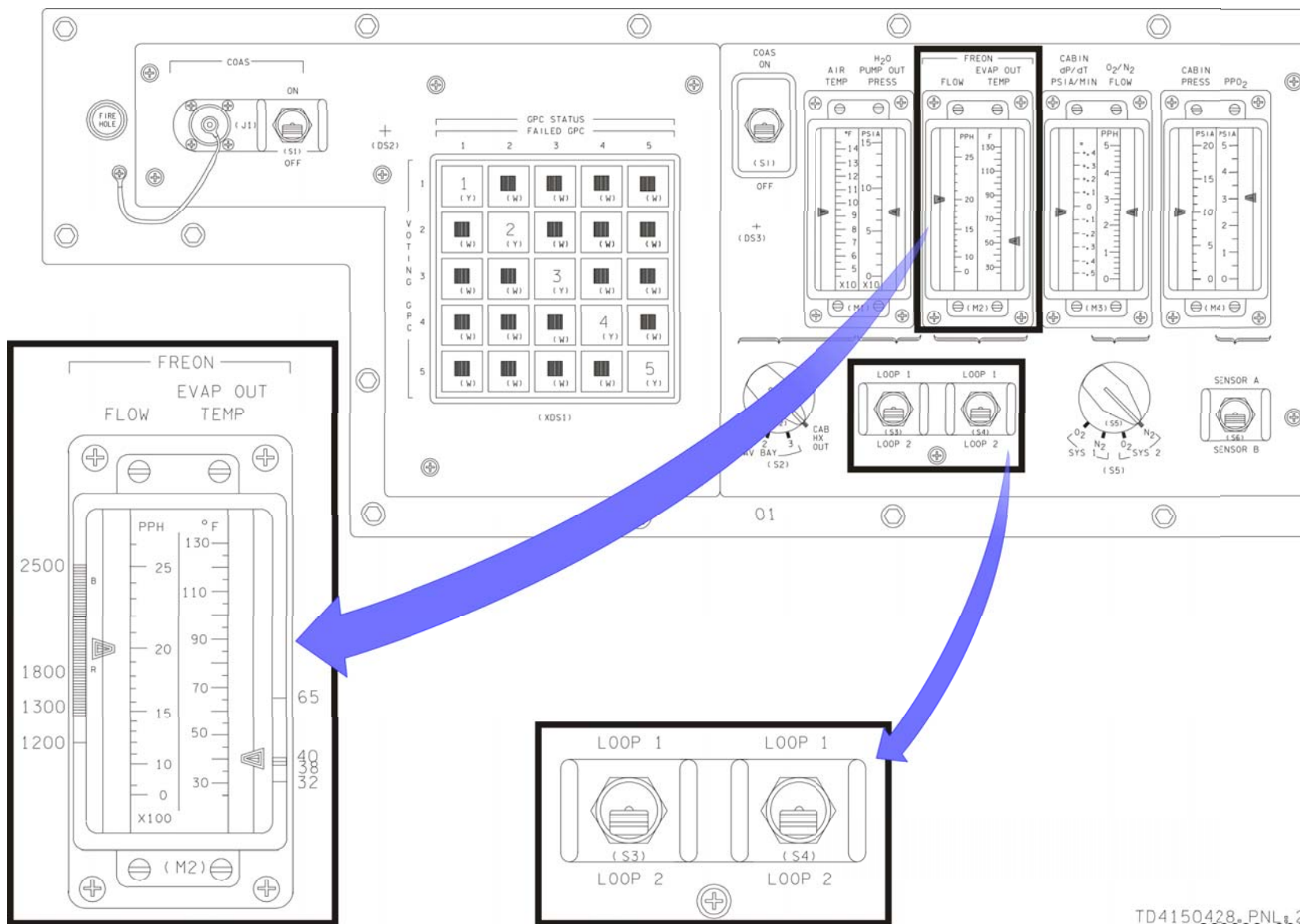
CRT name	Units	Displayed range	Status indicators				
HTR TEMP EVAP HI LOAD TOP DUCT NOZ FDLN			M	H	L	↑	↓
			M	H	L	↑	↓
			M	H	L	↑	↓
			M	H	L	↑	↓
FREON LOOP ACCUM QTY RAD OUT T	Percent ° F	0 to 100	M	H	L		↓
		25 to 130	M	H	L	↑	↓

Note: A blank display field denotes normal operation. '↑' and '↓' indicate heater or thermostat failures in a series heater line. Level detection limits are shown on SM displays. "M," "H," and "L" denote data transfer or sensor failures unrelated to heater control. CRT titles are aligned to panel switches needed to select different heater circuits.

4.17.4 Dedicated Displays

Crew-dedicated displays (meters) located on Panel O1 (Figure 4-28) enable the crew to monitor critical ATCS system parameters during all mission phases. The FREON FLOW meter permits the crew to monitor the Freon flow to the H₂O/Freon ICH (Figure 4-24). The FREON LOOP 1/LOOP 2 switch allows the crew to select between loop 1 and loop 2 on the meter.

The FREON EVAP OUT TEMP meter displays the evap out temperature on the Freon loop selected by the switch.



TD4150428_PNL 2
usa006020_028

Figure 4-28. ATCS meters – Panel O1

4.17.5 Caution and Warning

The FREON LOOP light on the Panel F7 matrix (Figure 4-29) will illuminate if one of the following parameters is out-of-limits.

ID	CRT name	Units	Lower limit	Upper limit
V63R1100A	Freon Flow 1	lb/hr	1200	
V63T1207A	Evap Out T 1	° F	32.2	64.8*
V63R1300A	Freon Flow 2	lb/hr	1200	
V63T1407A	Evap Out T 2	° F	32.2	64.8*

*Upper limit is 115° F for ascent.

O ₂ PRESS	H ₂ PRESS	FUEL CELL REAC	FUEL CELL STACK TEMP	FUEL CELL PUMP
CABIN ATM	O ₂ HEATER TEMP	MAIN BUS UNDERVOLT (R)	AC VOLTAGE	AC OVERLOAD
FREON LOOP (R)	AV BAY/CABIN AIR	IMU	FWD RCS (R)	RCS JET
H ₂ O LOOP	RGA/ACCEL	AIR DATA (R)	LEFT RCS (R)	RIGHT RCS (R)
—————	LEFT RHC (R)	RIGHT/AFT RHC (R)	LEFT OMS (R)	RIGHT OMS (R)
PAYLOAD WARNING (R)	GPC	FCS (R) SATURATION	OMS KIT	OMS TVC (R)
PAYLOAD CAUTION	PRIMARY C/W	FCS CHANNEL	MPS (R)	—————
BACKUP C/W ALARM (R)	APU TEMP	APU OVERSPEED	APU UNDERSPEED	HYD PRESS

(34V73A7A2)

TD4150429. PNL 2

Figure 4-29. Panel F7 C/W matrix

Table 4-5. ATCS controls

Panel	Type	Nomenclature/ position	Function	Remarks
L1	3-pos lever lock	NH ₃ BOILER A – B/ PRI/GPC – OFF – SEC/ON	PRI/GPC – BFS will turn the ammonia boiler on or off during ascent and entry OFF-NH ₃ controller is not powered SEC/ON – Ammonia boiler is powered and will operate	2 switches
L1	2-pos toggle	HI LOAD EVAP/ ENABLE – OFF	ENABLE – Hi load evap can operate OFF – Hi load evap operation is inhibited	
L1	3-pos toggle	FLASH EVAP CONTROLLER SEC/ GPC – OFF – ON	GPC – BFS turns the controller ON/OFF during ascent and entry OFF – Evap controller is not powered ON – controller is powered	
L1	3-pos toggle	FLASH EVAP PRI A – PRI B/ GPC – OFF – ON	GPC – BFS turns the controller ON/OFF during ascent and entry OFF – EVAP controller is not powered ON – Controller is powered	2 switches
L1	2-pos toggle	FLASH EVAP CONTROLLER SEC/ A SPLY – B SPLY	Selects the water supply feedline for the secondary controller	
L1	3-pos toggle	TOPPING EVAPORATOR HEATER L – NOZZLE – R/ A AUTO – B AUTO	Selects and turns on one of two redundant duct nozzle heaters	2 switches
L1	3-pos toggle (spring-loaded center)	FLOW PROP VLV LOOP ½/ INTCHGR – PAYLOAD HX	Selects one of two positions for the Freon flow proportioning valve	2 switches

Table 4-5. ATCS controls (continued)

Panel	Type	Nomenclature/ position	Function	Remarks
L1	Talkback	FLOW PROP VLV LOOP 1/2/ ICH – PL – BARBER POLE	ICH – 2162 lb/hr flow through the H ₂ O/Freon in interchanger PL – 1423 lb/hr flow through the H ₂ O Freon interchanger	2 talkbacks
L1	3-pos toggle	FREON PUMP LOOP 1/2/ A – OFF – B	A – Turns Freon pump A on in loop 1/2 B – Turns Freon pump B on in loop 1/2	2 switches
L1	2-pos toggle	RAD CONTROLLER OUT TEMP/ HI – NORM	Hi – Radiator controls to 57° F out temp NORM – Radiator controls to 38° F out temp	
L1	3-pos toggle	RAD CONTROLLER LOOP 1 – LOOP 2/ AUTO A – OFF – AUTO B	AUTO A – Powers the A controller in Freon loop 1/2 OFF – Controllers are not powered AUTO B – Powers the B controller in loop 1/2	2 switches
L1	Talkback	RAD CONTROLLER LOOP 1/2/ RAD – BP – BYP	RAD – Indicates that the RAD/BYPASS valve is in radiator flow BYP – Indicates that the RAD/BYPASS valve is bypassing the radiators	2 talkbacks
L1	2-pos toggle	BYPASS VALVE MODE 1 – 2/ AUTO – MAN	AUTO – Radiator controller controls radiator bypass valve MAN – Bypass valve is controlled by the MAN SEL switch	2 switches
L1	3-pos toggle (spring-loaded)	BYPASS VALVE MAN SEL/ RAD FLOW-BYPASS	RAD FLOW – Bypass valve is positioned for radiator flow BYPASS – Freon flow bypasses the radiator	2 switches

Table 4-5. ATCS controls (continued)

Panel	Type	Nomenclature/ position	Function	Remarks
L1	Rotary switch	TOPPING EVAPORATOR HEATER DUCT/ OFF – A – A/B – B – C	Selects and turns on the duct heater for the topping evaporator	
L1	Rotary switch	HI LOAD DUCT HTR/ OFF – A – A/B – B – C	Selects and turns on duct heater for hi- load evaporator	
L2	3-pos toggle	FLASH EVAP FEDLINE HTR A SUPPLY – B SUPPLY/ 1 – OFF – 2	Selects and turns on the flash evaporator feedline heater	2 switches
L2	3-pos lever switch	FREON ISOLATION MODE	Allows the radiator isolation to be in AUTO, OFF, or MANUAL.	
L2	3-pos toggle (spring-loaded)	FREON ISOLATION – LOOP 1/LOOP 2	RAD FLOW – Valve is positioned for radiator flow ISOLATE – Freon flow isolates from the radiator	2 switches
L4	Circuit breaker	AC1 FREON LOOP 1 PUMP A	AC1 3 – Phase power to FREON LOOP 1 PUMP A switch on Panel L1	3 cb's
L4	Circuit breaker	AC2 FREON LOOP 1 PUMP B	AC2 3 – Phase power to FREON LOOP 1 PUMP B switch on Panel L1	3 cb's
L4	Circuit breaker	AC3 FREON LOOP 2 PUMP A	AC3 3 – Phase power to FREON LOOP 2 PUMP A switch on Panel L1	3 cb's
L4	Circuit breaker	AC1 FREON LOOP 2 PUMP B	AC1 3 – Phase power to FREON LOOP 2 PUMP A switch on Panel L1	3 cb's
L4	Circuit breaker	AC2 FREON FLOW PROP 1	AC2 ϕ A power to FREON FLOW PROPORTIONING VALVE 1 switch on Panel L1	1 cb
L4	Circuit breaker	AC2 FREON SIG CONDR	AC2 ϕ B power to the Freon signal conditioner	1 cb

Table 4-5. ATCS controls (concluded)

Panel	Type	Nomenclature/ position	Function	Remarks
L4	Circuit breaker	AC3 FREON FLOW PROP 2	AC3 ϕ A power to FREON FLOW PROPORTIONING VALVE 2 switch on Panel L1	1 cb
L4	Circuit breaker	AC3 FREON SIG CONDR	AC3 ϕ B power to the Freon signal conditioner	1 cb
L4	Circuit breaker	AC1 RAD CNTLR 1B	AC1 ϕ A power to radiator controller 1B	1 cb
L4	Circuit breaker	AC1 RAD CNTLR 2B	AC1 ϕ B power to radiator controller 2B	1 cb
L4	Circuit breaker	AC2 RAD CNTLR 1A	AC2 ϕ B power to radiator controller 1A	1 cb
L4	Circuit breaker	AC3 RAD CNTLR 2A	AC3 ϕ B power to radiator controller 2A	1 cb
L4	Circuit breaker	AC2 RAD ISOL A	AC2 ϕ C power to rad isol valve motor 1	1 cb
L4	Circuit breaker	AC3 RAD ISOL B	AC3 ϕ C power to rad isol valve motor 2	1 cb
O1	2-pos toggle	FREON EVAP OUT FLOW-TEMP	Selects loop 1 or 2 data for display on Freon meters	
O14	Circuit breaker	MNA FREON RAD CNTLR 1 – 2	Provides main A power to the radiator controllers	2 cb's
O14	Circuit breaker	MN A RAD ISOL CNTLR	Provides main A power to the rad isol controller	1 cb
O15	Circuit breaker	MNB FREON RAD CNTLR 1 – 2	Provides the main B power to the radiator controllers	2 cb's
O17	2-pos toggle	SIGNAL CONDITIONER FREON A/B/ AC2/AC3	Provides selectable AC2/AC3 power to the Freon loop signal conditioners	2 cb's

4.17.6 ATCS Systems Performance, Limitations, and Capabilities

a. Freon 21 loop

1. Freon 21 boiling point at 14.7 psi	48° F
2. Freon 21 freezing point	-211° F
3. Total flow (2 loops)	5336-5972 lb/hr
4. Net positive suction head	35 psia minimum
5. Accumulator operating pressure	230 psig
6. Accumulator proof pressure	345 psig
7. Accumulator burst pressure	460 psig
8. Accumulator volume	1658.8 in ³

b. Radiator

1. Basic heat rejection capability	61,100 Btu/hr
2. Operating pressure	320 psia max.

c. Ammonia boiler – Heat rejection ability 113,200 Btu/hr

d. Flash evaporator

1. Primary controllers

Max. capability:	Topping only	39,000 Btu/hr
	Topping and Hi load	148,000 Btu/hr

2. Secondary controller

Max. capability:	Topping	76,800 Btu/hr
	Hi load	113,100 Btu/hr

5.0 SUPPLY AND WASTEWATER SYSTEM

The supply water storage system stores water generated by the fuel cells for FES cooling and crew consumption. The wastewater storage tank stores crew liquid waste and humidity condensate. The PCS system N_2 provides the supply and waste tank pressurization. The vacuum vent line provides a controlled overboard bleed to vacuum from the cabin.

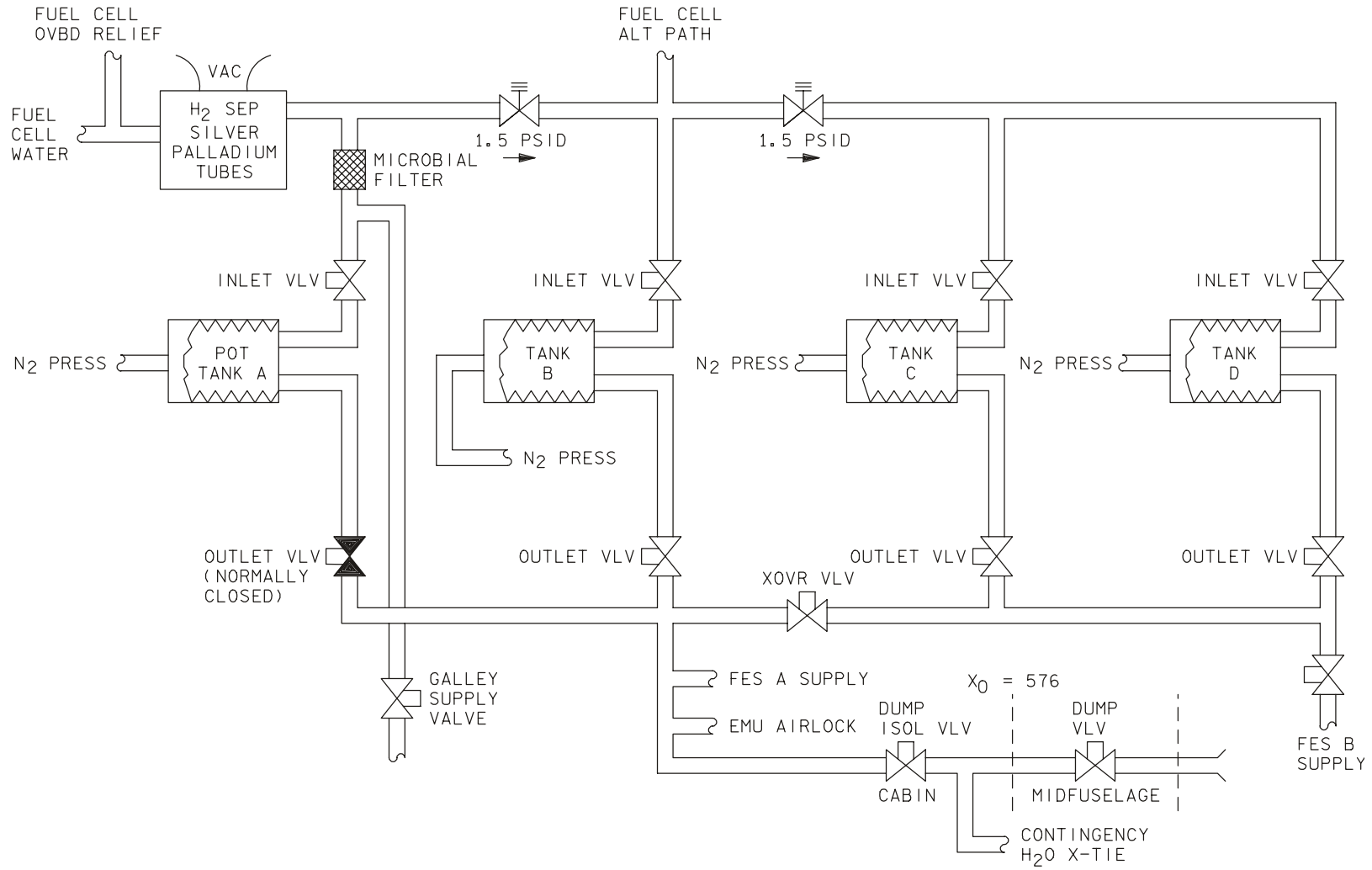
5.1 SUPPLY WATER STORAGE SYSTEM

The supply water storage system consists primarily of four water tanks that are pressurized with N_2 from the PCS (Figure 5-1). These 165-lb capacity tanks are located below the middeck floor (Figure 5-2). Each tank has a bellows, a quantity sensor, a tank inlet and outlet valve, and a hydrophobic filter. The water stored in the water tanks is generated by the fuel cells. Water tank A is sterile and is reserved for storing potable water. Water tanks A, B, C, and D may all be used to supply water to the FES for cooling. The capability exists to dump excess water overboard to create the necessary ullage in the tanks to store the fuel cell product water. Filtered water is routed to the galley for crew consumption. Water in the supply water tanks can be routed to the airlock and used for EMU reservicing.

Fuel cell product water is transferred to the supply water storage tanks by the pressure difference between the fuel cells and the supply water tanks themselves. The H_2 -enriched water from the fuel cell flows through the H_2 separators. The H_2 separator removes any residual H_2 from the water as it flows to the supply water tanks. The silver palladium tubes of the H_2 separators attract the H_2 . The H_2 passes through the walls of the tubes and is vented overboard through the vacuum vent line.

The water then flows through the microbial filter before entering water tank A. The microbial filter adds iodine to the water, which acts as a disinfectant to prevent microbial growth in tank A. Tank A is sterilized prelaunch and its outlet valve is kept closed to ensure that only filtered water enters the tank. Tank A is used for storing potable water for crew consumption. This filtered potable water is routed to the galley via the galley supply valve. For ISS missions, tanks A and B are used for storing potable water so that there is more water available to transfer to the station via the CWC bags.

If water tank A is full or if the tank A inlet valve is closed, the water pressure will increase, crack the 1.5 psid check valve, and allow water flow into water tank B. If water tank B is full, the next 1.5 psid check valve will crack and the water will fill water tanks C and D. By manipulating the tank inlet and outlet valves, the water tanks can be selectively filled and/or dumped overboard.



TD4150501. SCH# 5

Figure 5-1. Supply water storage system

The outlet side of the four water tanks is plumbed together to form an outlet manifold. As stated earlier, for non-ISS missions the water tank A outlet valve is kept closed to preserve the sterility of the tank A water. The crossover valve between the tank B and C outlets breaks this manifold into two parts, the A-B side and the C-D side. This crossover valve is normally kept closed with tank C isolated from lift-off until post-insertion. When it is open, with tank C isolated, tanks B and D act as a single large tank. The A-B side of the crossover valve supplies water to the FES A supply water feedline and the EMU airlock feedline. The supply water dump line is also on the A-B side of the manifold. The C-D side of the manifold supplies water to the FES B supply water feedline. There is a valve to isolate the FES B supply feedline. The FES A supply feedline cannot be isolated directly. FES PRI A normally uses tank B water during ascent. If FES PRI B is used during ascent, the water is supplied by tank D. The FES H₂O feedlines are kept warm outside the cabin by thermostatically controlled electrical resistance wire wrapped heaters.

Once on orbit, the fuel cells produce more water than the crew needs for drinking and FES cooling. The excess water must be dumped overboard periodically to make room for the water the fuel cells are producing. This is accomplished by performing a supply water dump. The supply water dump nozzle heaters are turned on to keep the dump nozzle from freezing during the water dump. Thermostatically controlled line heaters keep the portion of the dump line outside the cabin warm. The dump isolation valve and the dump valve are then opened to dump the water overboard. A supply water dumpline purge device is inserted into the potable water inlet on the contingency crosstie panel in the WCS. This allows air into the dump lines when the dump is complete, allowing a more efficient purge of the lines. Before this device was used, water remaining in the lines would on occasion freeze, forcing the dump valve open and causing a little water to “burp” overboard. When the desired amount has been dumped, the dump isol valve is closed, the dump valve is cycled to remove excess water in the lines then finally left closed, and the dump isol is opened. If the supply water dump does not work or if there are mission-specific payload constraints that prevent the use of the supply water dump line, ullage may be created by using the FES for cooling. In a supply water dump through the FES, the radiators are taken to the higher radiator out temperature control point of 57° F. The FES is then used to cool the Freon to 39° F. This FES operation consumes more water than is produced, resulting in a net reduction of water in the tanks. A supply water dump using the FES is slower than a nominal dump through the supply water dump line. If neither of these methods works, water may be dumped through the wastewater dump line by connecting the contingency crosstie hose and performing the backup water dump In-Flight Maintenance (IFM) procedure.

The normal water management plan is to keep as much water in the water tanks as possible to make it to the next water dump opportunity. See Figure 5-2 for a typical mission water management plan. The top plot shows the total quantity of all four water tanks and the total of tanks C and D. The bottom plot shows the water quantity in tank A and tank B. Normally, water tank C is kept full for contingency purposes. This reserve of supply water is required to provide water for FES cooling in case of a deorbit wave-off (where the payload bay doors remain closed) or a contingency deorbit.

On-orbit water management is accomplished by dumping and filling tanks A and B. Supply water dumps are usually scheduled at 12-hour intervals unless there are mission-specific payload constraints. This allows for performing the supply water dumps during the pre- and postsleep activities. Up to 210 lb of water may be dumped to obtain the required ullage. At least 76 percent (128 lb) of water must remain in tank A. This is the amount of water that is necessary to sustain five crewmembers over a 96-hour Minimum Duration Flight (MDF) time period (128 lb assumes a metabolic requirement of 6 lb/per person per day).

For ISS docking missions, a supply water transfer may be performed. In this case, the water tank valve configuration on orbit will be different: tank B inlet and the crossover valves closed, everything else open. This allows tanks A and B to be used for potable water storage, and C and D are used for supply water storage. Instead of dumping the excess water overboard, the water will be transferred to the ISS either through dedicated transfer lines or through manually filled water transfer bags filled at the galley. FES Pri B will be used on orbit so that the potable water in tanks A and B will not be used for the FES.

The supply water tank quantity sensor indicates water quantity by sensing the water tank bellows position. If the tank is full, the gauge will indicate \approx 100 percent. If the water tank bellows develops a leak, the bellows will seek its neutral spring rate position and indicate a tank quantity between 60 to 70 percent. The hydrophobic filter prevents water that has leaked past a failed bellows from getting into the water tank N₂ manifold (Figure 5-3).

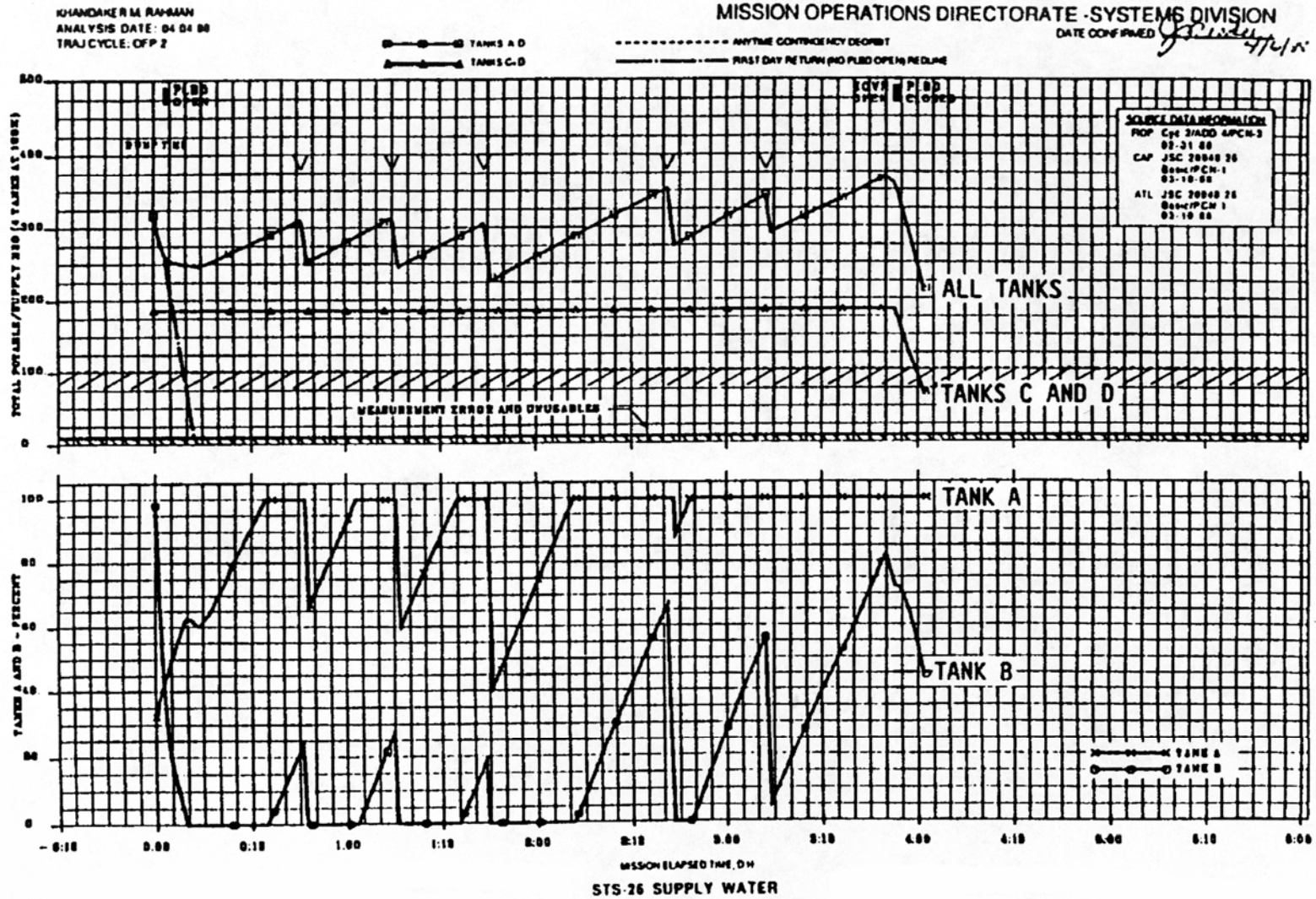
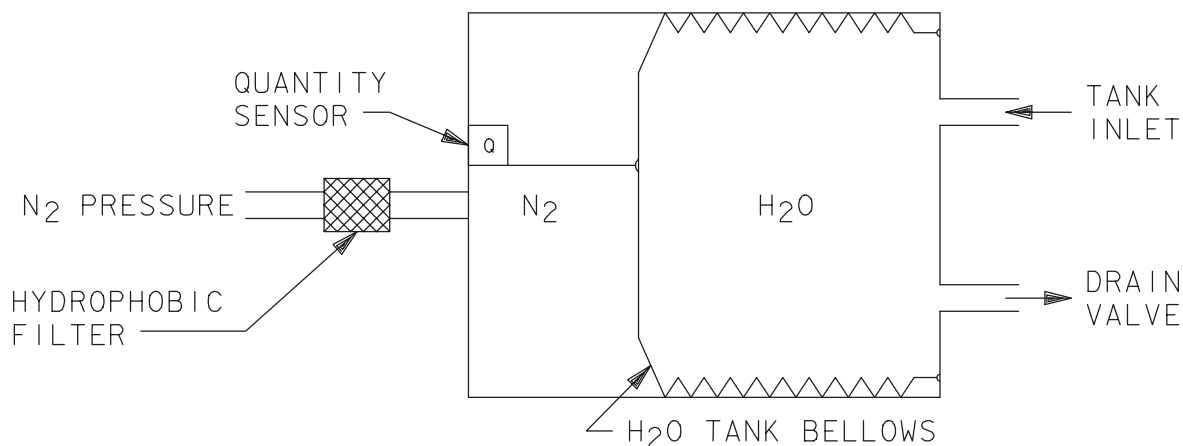


Figure 5-2. Typical water plan for a mission



TD4150503. SCH 3

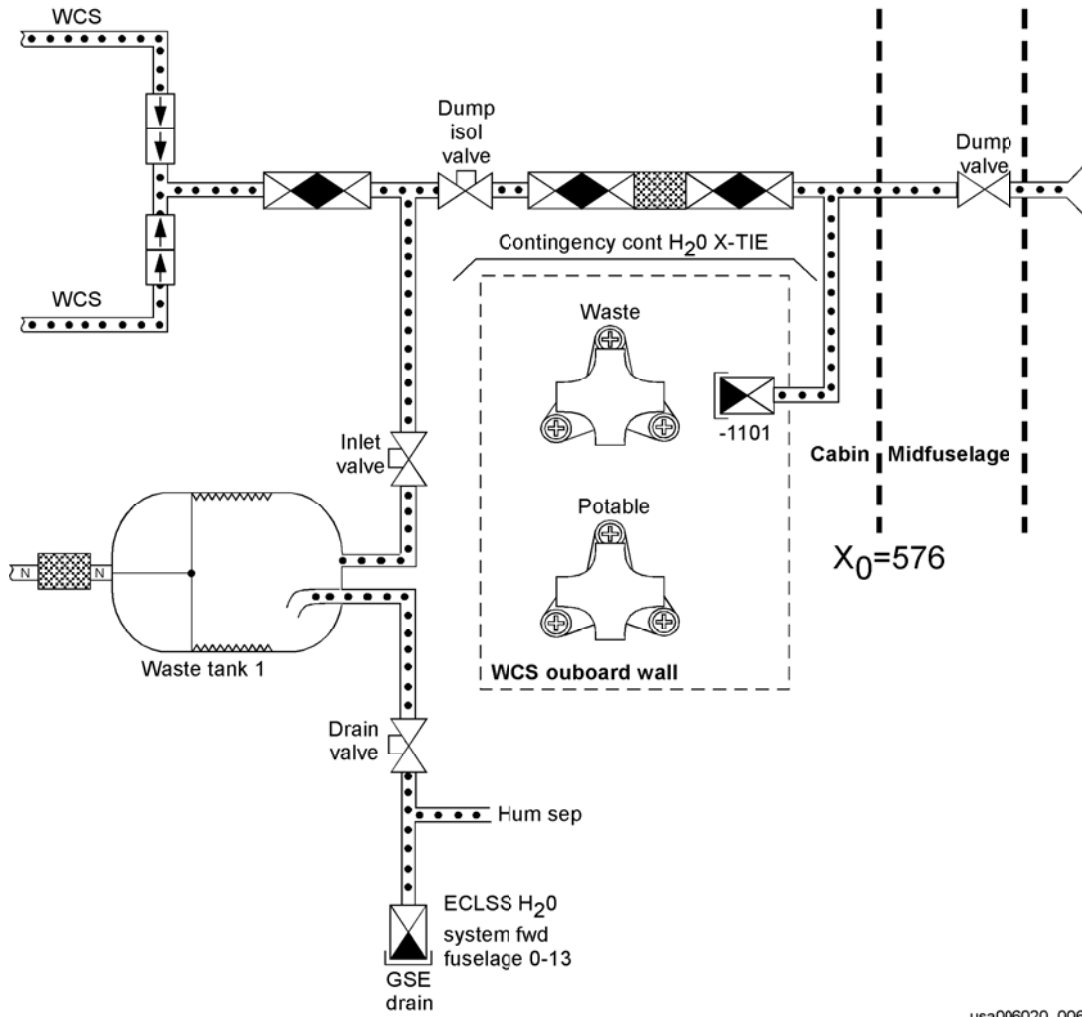
Figure 5-3. Typical water tank

5.2 WASTEWATER STORAGE SYSTEM

The wastewater storage system consists of one wastewater tank that is pressurized with N_2 . The waste tank is physically identical to a supply water tank and also is located below the middeck floor (Figure 5-2). The waste tank stores crew liquid waste (urine) and humidity condensate in a sanitary manner until it can be disposed. The waste tank has an inlet valve and a drain valve (Figure 5-4). The drain valve is used only during ground servicing and is kept closed and unpowered during flight. The inlet valve functions as both the tank inlet and outlet. Wastewater can be dumped overboard by way of the wastewater dump line. The contingency water crosstie enables the supply water dump line to be connected to the wastewater dump line. This allows supply water to be dumped through the waste line or vice versa. The contingency water crosstie QDs are located on the wall of the WCS compartment.

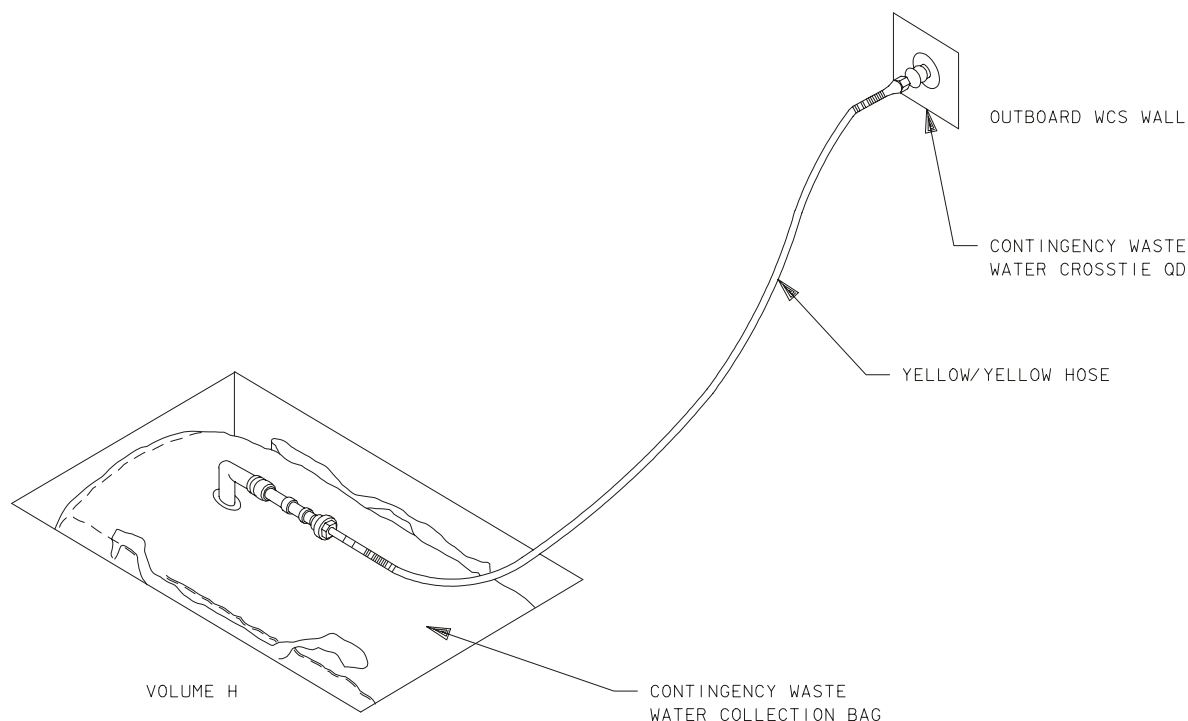
The normal waste tank management plan is to dump the waste tank via the wastewater dump line when the tank quantity reaches 80 percent. The waste dump nozzle heaters are enabled to prevent ice formation on the nozzle. Thermostatically controlled heaters keep the portion of the dump line outside the cabin from freezing. The dump isol valve and dump valve are then opened to allow the wastewater to dump overboard. In case the waste tank cannot be dumped overboard, a collapsible contingency wastewater collection bag known as a CWC (Figure 5-5) is flown to provide additional ullage. The wastewater tank can be dumped into the contingency wastewater collection bag by way of the contingency water crosstie. The production of wastewater on previous flights has been as high as 6.2 lb per person per day. Mission duration and the number of crewmembers flying make wastewater management very mission specific.

For ISS missions, humidity condensate is collected in a CWC to reduce the number of waste dumps needed while docked to the ISS.



usa006020_006

Figure 5-4. Wastewater storage system



TD4150505, ART. 3

Figure 5-5. Contingency water collection bag

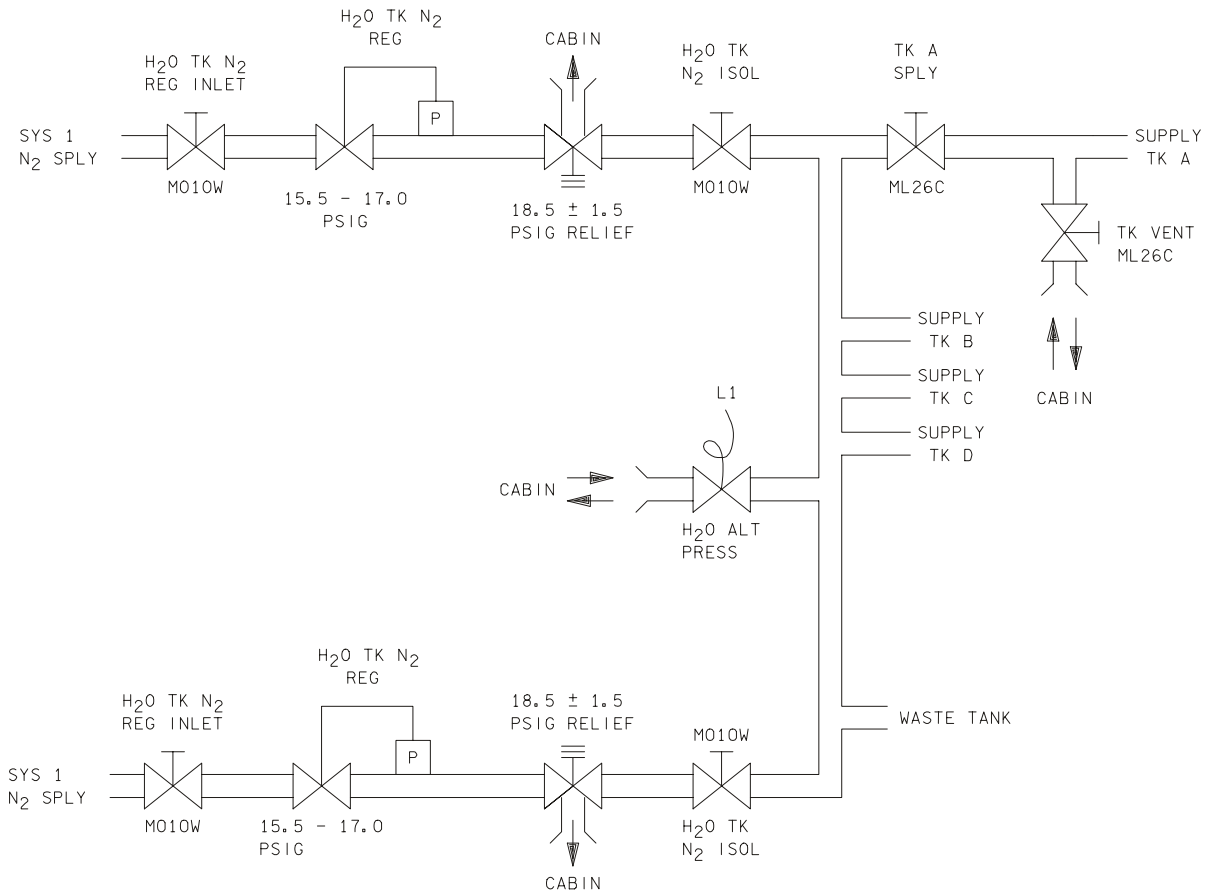
5.3 SUPPLY AND WASTEWATER PRESSURIZATION SYSTEM

The supply and wastewater tanks are normally pressurized with PCS system N₂. This N₂ pressure is controlled to 15.5 to 17.0 psi above cabin pressure and provides the force necessary to move the water through the system; 200 psig N₂ from PCS systems 1 and 2 passes through the water tank N₂ regulator inlet valves (Figure 5-6) and is stepped down to between 15.5 to 17.0 psig by the H₂O tank N₂ regulator. The H₂O tank N₂ regulator is flow limited to 1 lb/hr. To protect against overpressurization, two relief valves are provided that relieve into the cabin at 18.5 ± 1.5 psig. The N₂ then passes through the H₂O tank N₂ isolation valves and pressurizes the H₂O tank N₂ manifold. This common manifold provides pressurization to the waste tank and all of the supply water tank bellows.

During ascent, water tank A must be vented to the cabin. During launch, the orientation of the orbiter and vehicle acceleration both work against the flow of fuel cell product water into the supply water tanks. If the water tanks were pressurized with N₂, the water would not make it into the water tanks. It would relieve overboard since overboard relief offers the path of least resistance (Figure 5-1). This is not desirable since if the overboard relief path fails, the fuel cells will flood and stop producing electricity. To vent water tank A, the tank A supply valve is closed. This isolates tank A from the rest of the H₂O tank N₂ manifold. Then the tank vent valve is opened (vent) to vent tank A to the cabin (Figure 5-6). Tank A remains vented until post insertion.

Then the tank vent valve is reconfigured to the closed (PRESS) position, and the tank A supply valve is reopened to let N₂ pressurize tank A.

The tank A supply and tank vent valves are also used to vent the entire H₂O tank N₂ manifold. The tank A supply valve is kept open and the tank vent valve is taken to vent in order to vent all the water tanks to cabin pressure. If a water leak is suspected, taking the N₂ pressure off the water tanks will stop the leak if the leak is inside the cabin. The water alternate press valve provides a backup method of venting the H₂O tank N₂ manifold to the cabin.



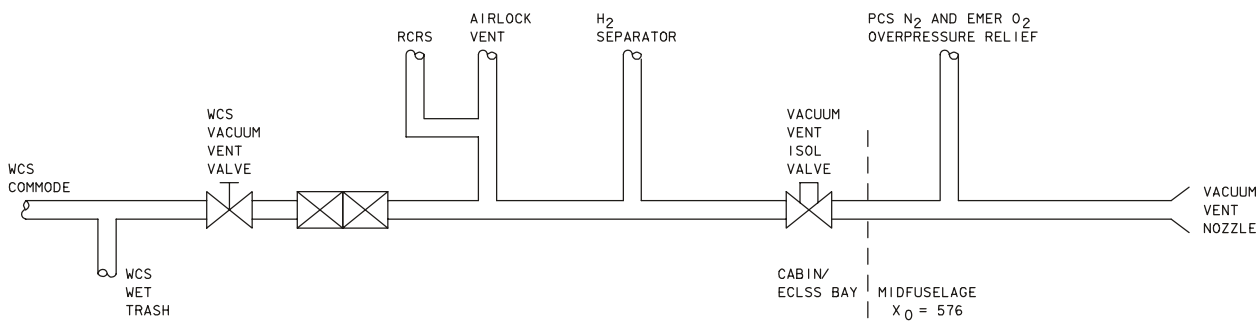
TD4150506. SCH# 6

Figure 5-6. Water tank N₂ pressurization

5.4 VACUUM VENT SYSTEM

The vacuum vent system provides the orbiter with a controlled overboard bleed. The vacuum vent line is a pipe with an inside diameter of 1.93 in. The pipe originates inside the cabin and vents outside to space (Figure 5-7). The vacuum vent isolation valve isolates the portion of the vacuum vent line located inside the cabin. Even with the vacuum vent isolation valve closed, an orifice plate in the valve still allows an overboard flow of 3.0 ± 0.25 lb/hr at a cabin pressure of 14.7 psia. The purpose of the orifice plate is to allow the H₂ removed by the fuel cell H₂ separators to vent overboard even if the vacuum vent isolation valve is closed.

The vacuum vent isolation valve is closed during ascent and entry. The vacuum vent system is activated during orbit operations. When the vacuum vent isol valve is opened, the line and nozzle heaters are activated. The heaters prevent water vapor from freezing in the vacuum vent line. The WCS uses the vacuum vent line to provide the vacuum required for operation. The WCS commode vents overboard during WCS operation. A small amount of cabin air continuously bleeds overboard through the WCS wet trash compartments to help keep WCS odors to a minimum. The RCRS vents CO₂ to space if installed (see Appendix C).



TD4150507.SCH 4

Figure 5-7. Vacuum vent system

5.5 SUPPLY AND WASTEWATER SYSTEM CONTROLS

The switches that control the supply and wastewater system are located primarily on Panels R11, ML31C, ML26C, ML86B, L1, and O16. The switches on Panels R11 and ML31C (Figure 5-8 and Figure 5-9) control the electrically controlled supply water system valves. The panel layout is a schematic representation of the supply water system. Talkbacks indicate the position of the valves. The talkbacks will indicate either open, closed, or barberpole. If power to a valve is lost, the valve will remain in its present position, but the talkback will indicate barberpole. All of the valves on Panel R11 are of this same type. The SUPPLY H₂O DUMP VLV ENABLE/NOZ HTR switch activates the dump nozzle heaters and powers the SUPPLY H₂O DUMP VLV. The supply H₂O dump valve cannot be opened unless the nozzle heater is powered.

Panel ML31C also houses the controls for the wastewater and vacuum vent systems.

The circuit breakers on rows A and B of Panel ML86B provide the power used to drive the valves and heaters on Panels R11 and ML31C (Figure 5-10). The MNA H₂O LINE HTR A and MNB H₂O LINE HTR B circuit breakers provide power to the supply water dump line, wastewater dump line, and vacuum vent line heaters.

The Panel ML26C (Figure 5-11) switches are used to vent the supply H₂O tank N₂ manifold to the cabin. The SUPPLY H₂O GN₂ TK A SPLY valve is a two-position manual valve. If OPEN, tank A is pressurized by the H₂O tank N₂ manifold. If CLOSED, tank A is isolated from N₂ pressurization. The SUPPLY H₂O GN₂ TK VENT valve is also a two-position manual valve. If in PRESS, tank A is pressurized by the H₂O tank N₂ manifold. If in VENT, the pipe stub is opened and vents tank A to cabin pressure (Figure 5-6).

The H₂O ALTERNATE PRESS switch on Panel L1 is a remotely powered valve that can also be used to vent the H₂O tank N₂ manifold to cabin pressure (Figure 5-11). The power for the H₂O alternate press valve comes from the H₂O ALT PRESS circuit breaker located on Panel O16 row D.

The H₂O tank N₂ switches were discussed in the pressure control system controls and displays section.

A detailed listing of supply and wastewater system controls is contained in Table 5-1.

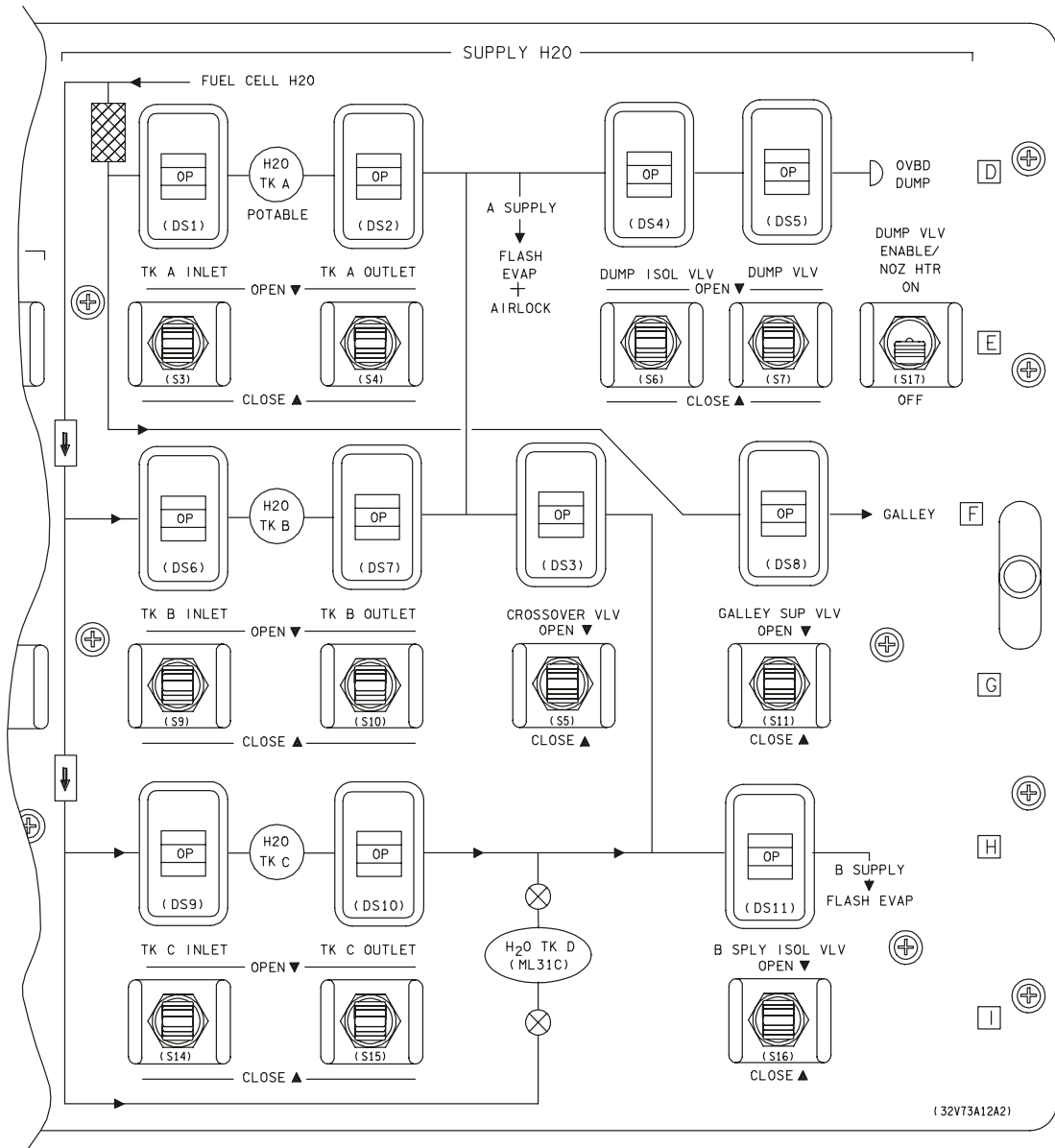
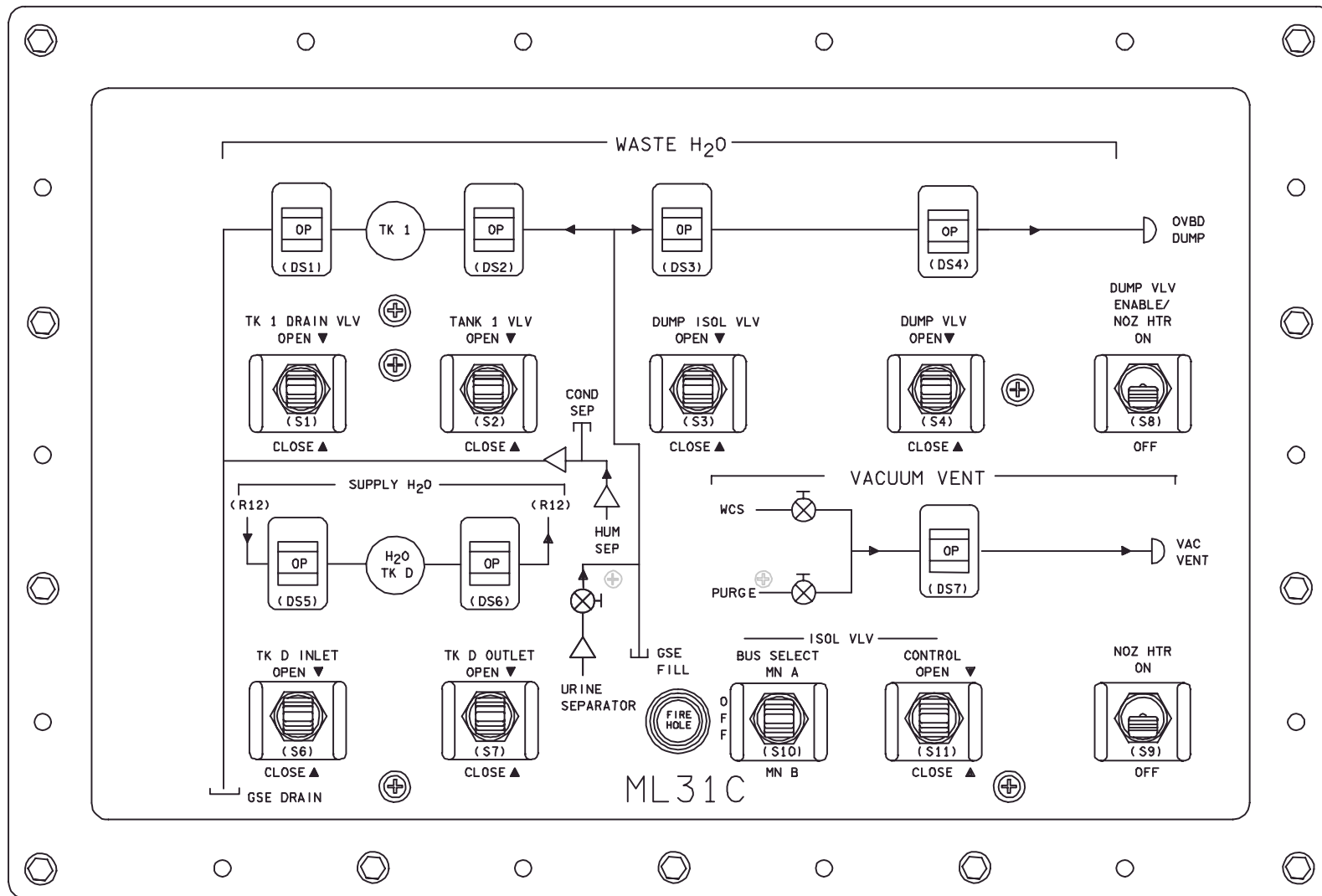
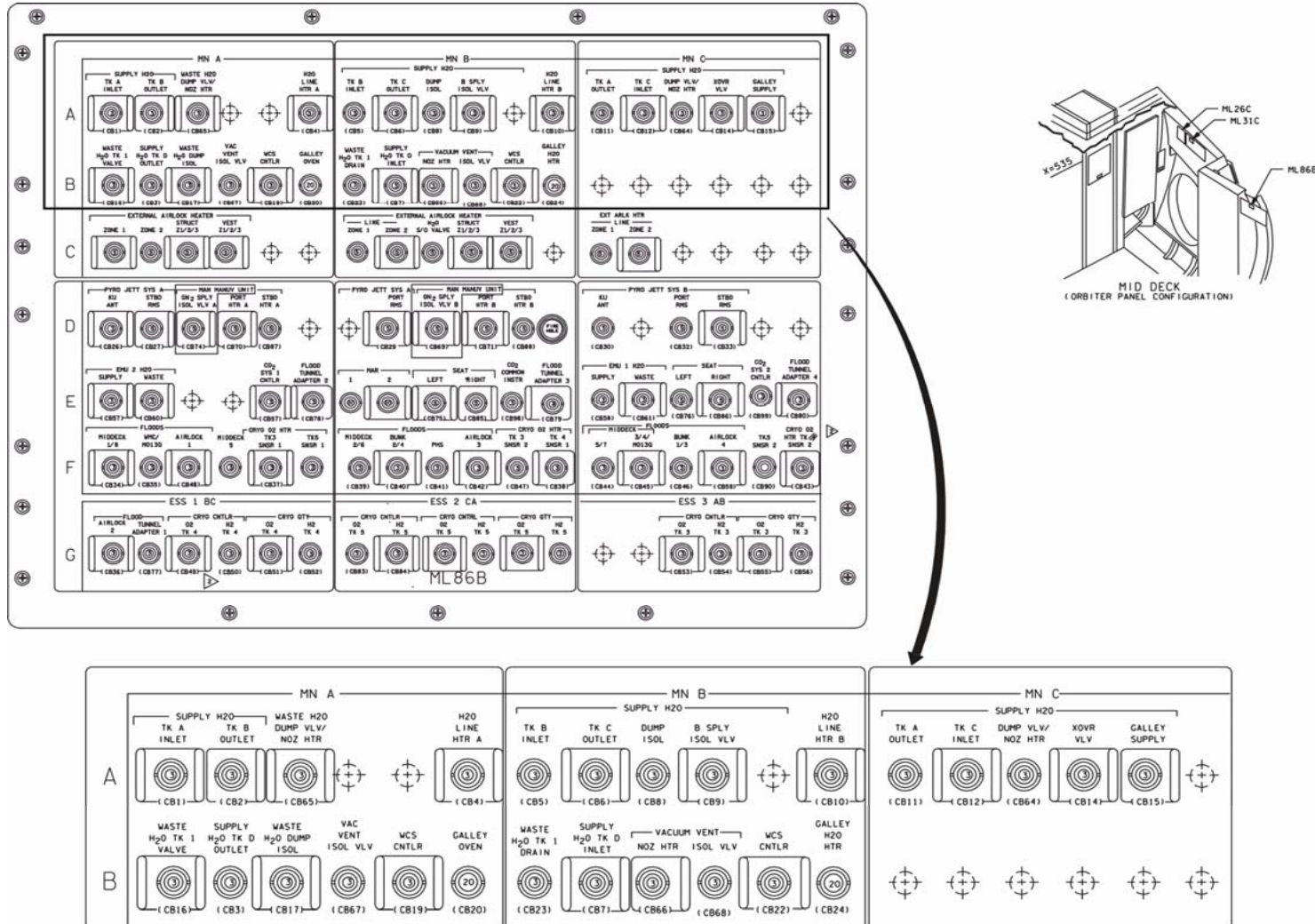


Figure 5-8. Panel R11 – Water



usa006020_015

Figure 5-9. Panel ML31C – Water



usa006020_009

Figure 5-10. Panel ML86B – Water

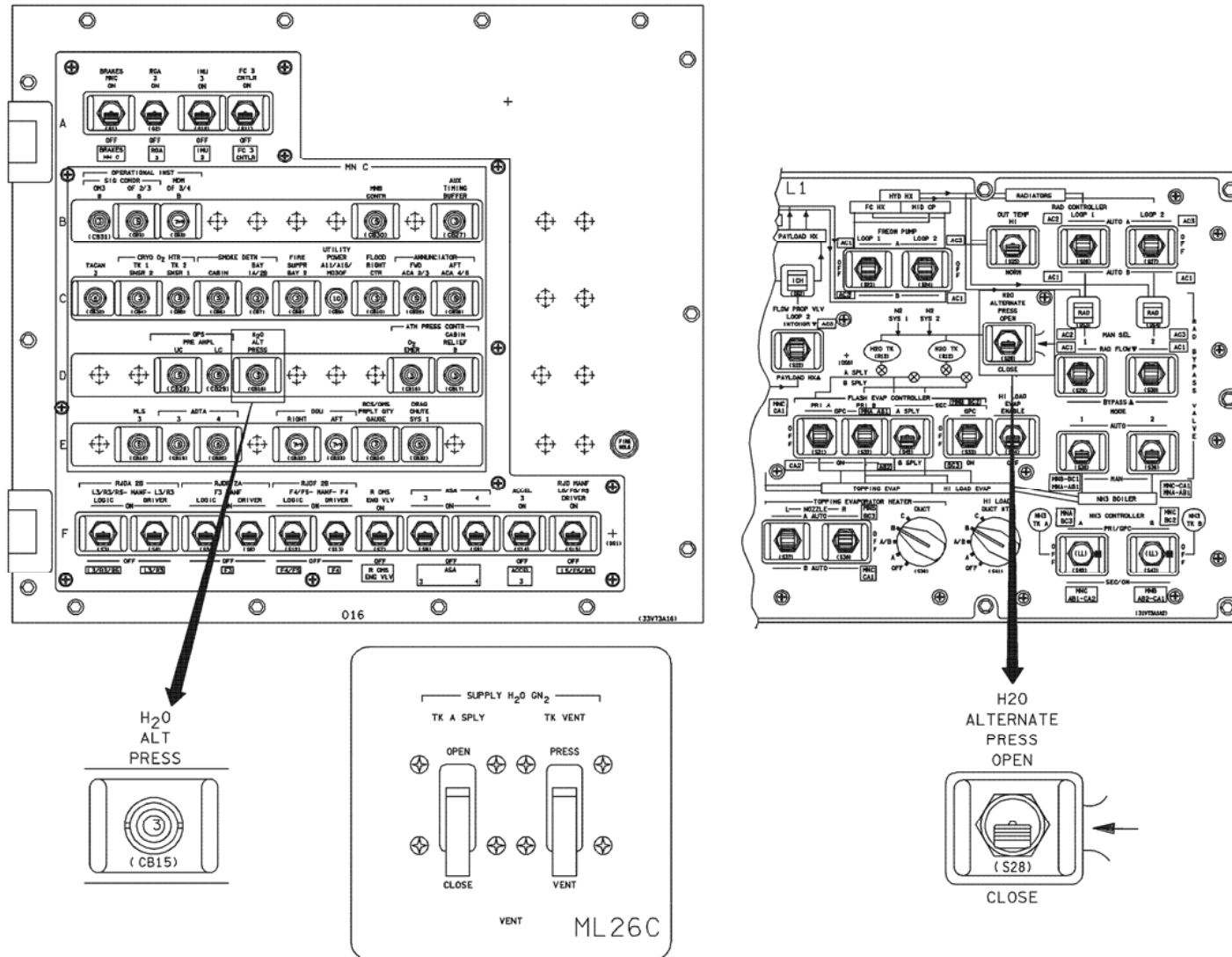


Figure 5-11. Water system pressurization controls

5.6 SUPPLY AND WASTEWATER SYSTEM INSTRUMENTATION/DISPLAYS

5.6.1 CRT Displays

The crew has insight into supply and wastewater system performance on the following CRT displays, dependent on mission phase. SPEC 66 is the primary display for water system information during orbit operations. The supply water pressure data on the BFS thermal display are valid only during MM104-106, MM301-303, and orbit OPS 0.

OPS mode	CRT display	Figure number
OPS 1 (ascent)	BFS SM0 THERMAL	5-12
OPS 2 (4) (orbit)	PASS SM SPEC 66	5-13
OPS 3 (entry)	BFS SM0 THERMAL	5-12

5.6.2 Dedicated Displays

The EVLSS water supply pressure is available on Panel AW82D in the airlock (Figure 5-14). This shows the supply water pressure on the tank A and B outlet portion of the supply water system (Figure 5-14). This parameter is used during EMU airlock operations.

5.6.3 Instrumentation

The instrumentation points visible to the crew are shown on Figure 5-15, Figure 5-16, Figure 5-17, and Figure 5-18.

0001 / /		THERMAL		XX X	DDD/HH:MM:SS
				BFS	DDD/HH:MM:SS
HYD	SYS TEMP	BDYFLP	RD/SB	L OB	L IB R IB R OB
	PRIME	±XXXX	±XXXX	±XXXX	±XXXX ±XXXX ±XXXX
	STBY 1	±XXXX	±XXXX	±XXXX	±XXXX ±XXXX ±XXXX
		BRAKE PRESS			
		1/3	XXXXX	XXXXX	XXXXX XXXXX
		2/3	XXXXX	XXXXX	XXXXX XXXXX
HTR TEMP	L/A	R/B	FREON LOOP		1 2
PRPLT			ACCUM QTY	XXXX	XXXX
POD	SSSSSSS	SSSSSSS	RAD OUT T	XXXX	XXXX
OMS CRSFD	SS		H2O SUP P	XXXX	
EVAP			TIRE PRESS		
HI	LOAD	SSS	MG	LEFT	RIGHT
TOP	DUCT	SS	IB	XXXX	XXXX XXXX XXXX
	NOZ	S	OB	XXXX	XXXX XXXX XXXX
FDLN		SSSS	NG	XXXX	XXXX XXXX XXXX
HYD BLR/HTR	S	1	S	2	S 3
APU					
GG/FU PMP HTR	SSSSS		SSSSS		SSSSS
TK/FU LN HTR	SSSSSS		SSSSSS		SSSSSS
PUMP/VLV	SS		SS		SS

SMO THERMAL OI-30

STS 83-0020V2-30-A, Space Shuttle Orbiter Operations Flight Level C
Functional Subsystem Software Requirements, Displays and Controls
Volume 2: Systems Management, May 30, 2003

0001/		THERMAL		5	000/00#	26#	03
				BFS	000/00#	00#	0
HYD	SYS TEMP	BDYFLP	RD/SB	L OB	L IB	R IB	R OB
	PRIME	+306H	+164	+172	+142	+172	+1
	STBY 1	+306H	+151	+161	+163	+163	+161
		BRAKE PRESS					
		HYD SYS	1/3	25	25	25	25
			2/3	25	25	25	25
HTR TEMP	L/A	R/B	FREON LOOP		1	2	
PRPLT			ACCUM QTY	32	32		
POD			RAD OUT T	38	38		
OMS CRSFD			H2O SUP P	16			
EVAP			TIRE PRESS				
HI	LOAD		MG	LEFT	RIGHT		
TOP	DUCT		IB	415	415	415	415
	NOZ		OB	415	415	415	415
FDLN			NG	450	450	450	450
HYD BLR/HTR							
APU							
GG/FU PMP HTR	H		H		H		
TK/FU LN HTR							
PUMP/VLV							
RESUME							

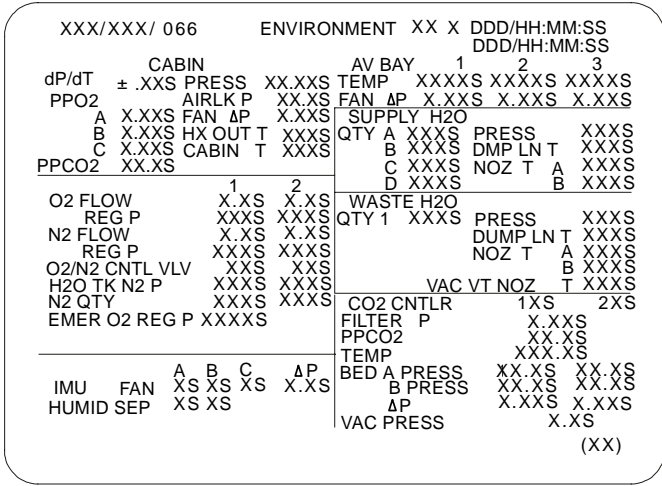
CRT_BFS SMO THERM OI-30, Michael M Hoekman USA/DT36 281-244-7179

Figure 5-12. BFS SMO THERMAL

The THERMAL display is a BFS display (OPS/0001) that provides the crew data on the supply H₂O system.

Parameter characteristics

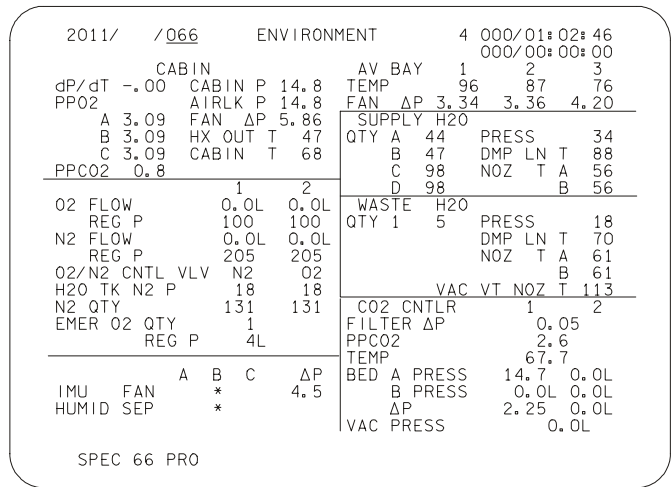
CRT name	Units	Displayed range	Status indicators				
H ₂ O SUPPLY P	psia	0 to 50	M	H	L	↑	↓



SPEC 66

OI-30

JSC-19590-116, Systems Management Level C
Flight Software Requirements, STS-116 Base 2
Cycle (OI-30), November 2003, page 6.1-2.



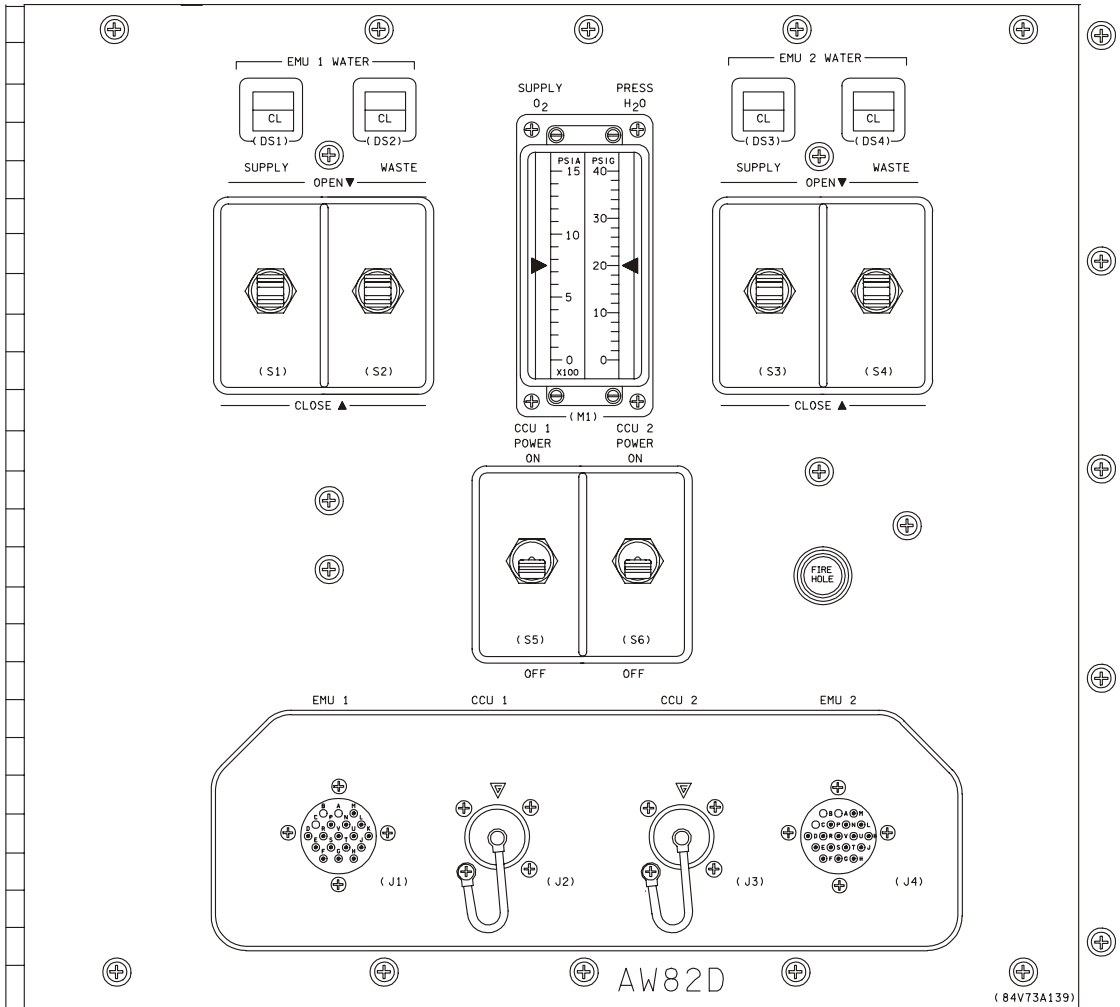
CRT_Spec 66 OI-30.CNV, Michael M Hoekman USA/DT36 281-244-7179

Figure 5-13. SPEC 66 ENVIRONMENT

The ENVIRONMENT display is an PASS SM display (DISP 66), available in PASS SM OPS 2 and 4, which provides data on the supply and wastewater system.

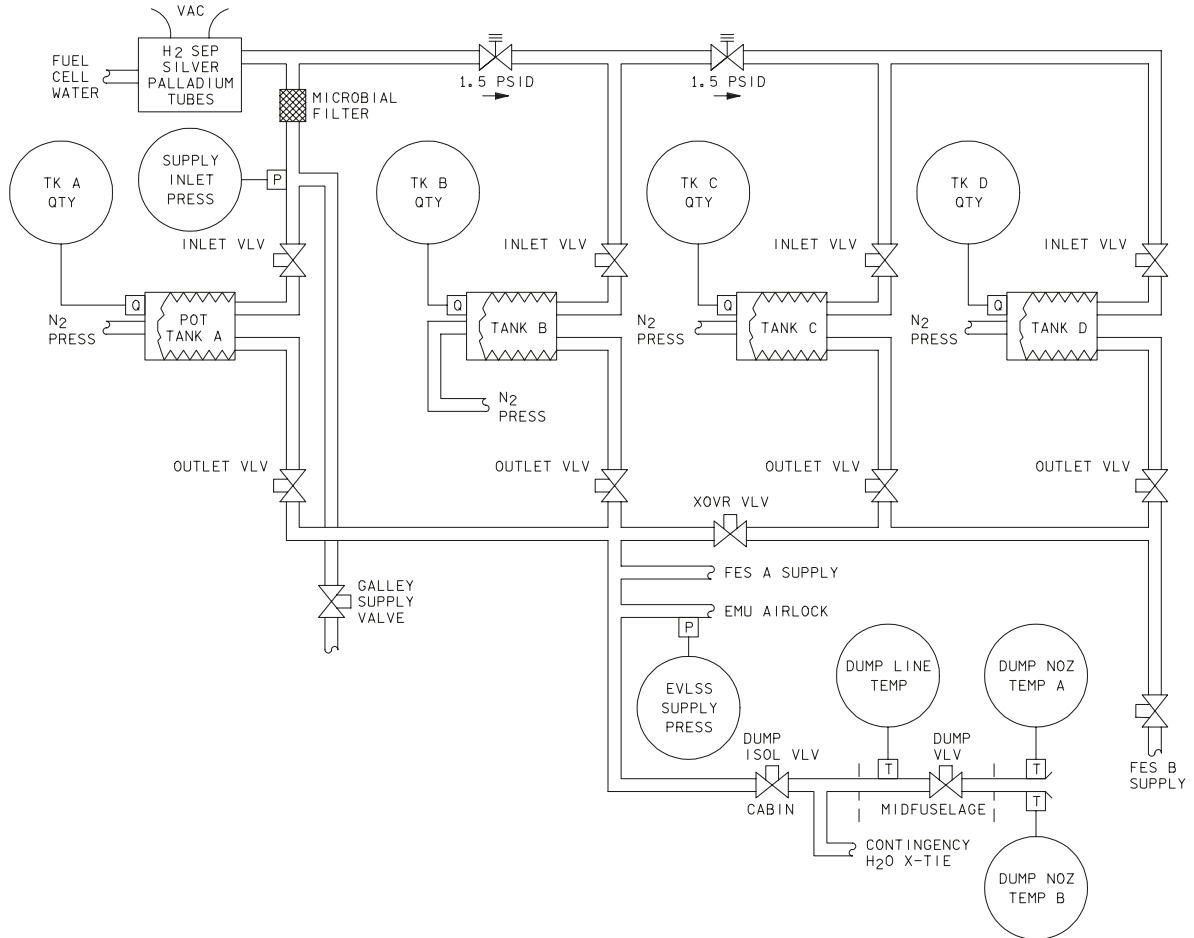
Parameter characteristics

CRT name	Units	Displayed range	Status indicators				
WASTE QTY 1	percent	0 to 100	M	H	L	↑	↓
PRESS	psig	0 to 30	M	H	L	↑	↓
DUMP LN T	° F	25 to 130	M	H	L	↑	↓
NOZ T A, B	° F	0 to 400	M	H	L	↑	
VAC VT NOZ T	° F	75 to 300	M	H	L	↑	
H ₂ O SUPPLY QTY A, B, C, D	percent	0 to 100	M	H	L	↑	↓
PRESS	psia	0 to 50	M	H	L	↑	↓
DUMP LN T	° F	25 to 130	M	H	L	↑	↓
NOZ T A, B	° F	0 to 400	M	H	L	↑	
H ₂ O TK N ₂ P	psia	0 to 20	M	H	L		↓



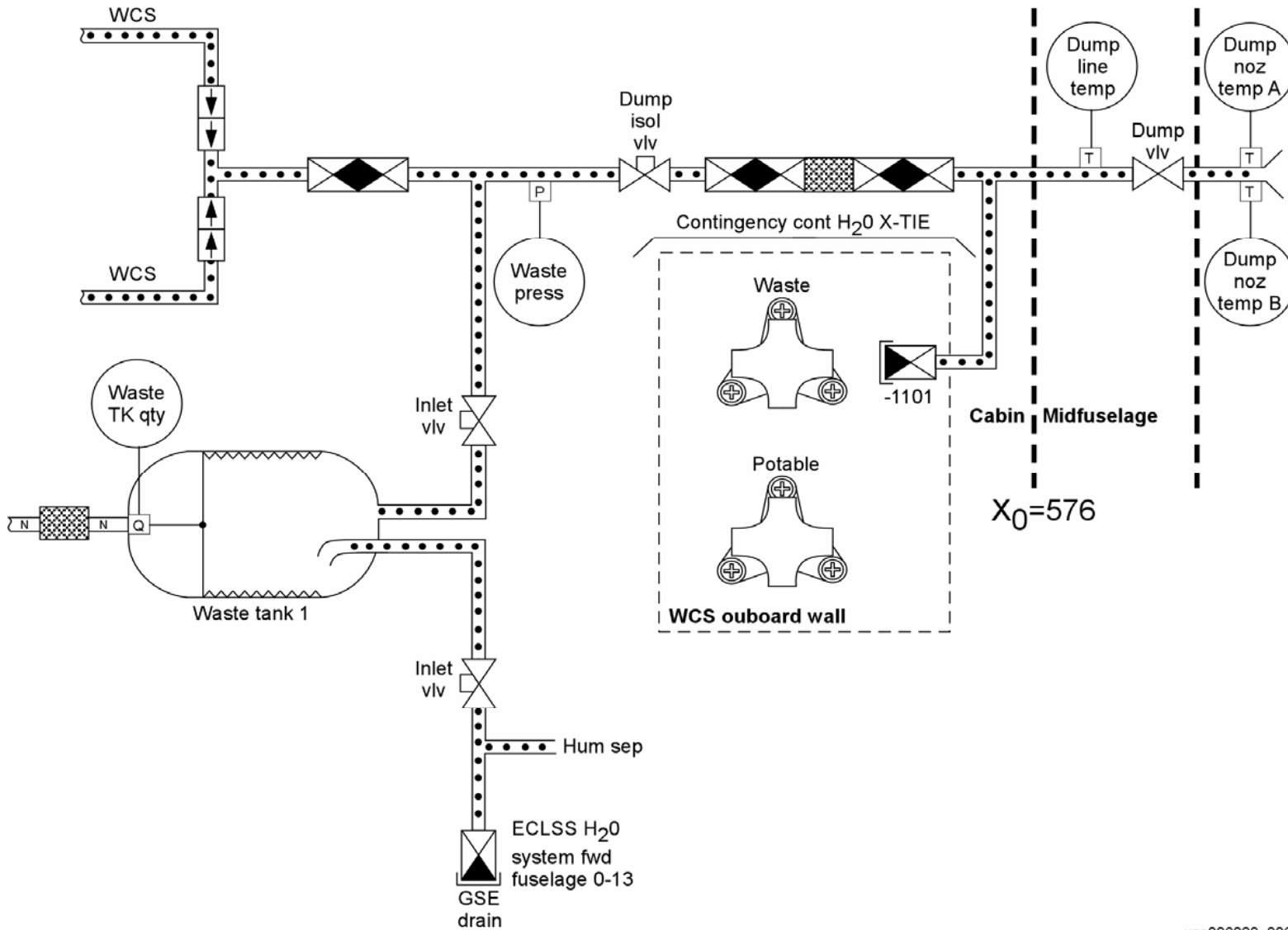
TD4150514, PNL 1

Figure 5-14. EVLSS H₂O supply pressure meter



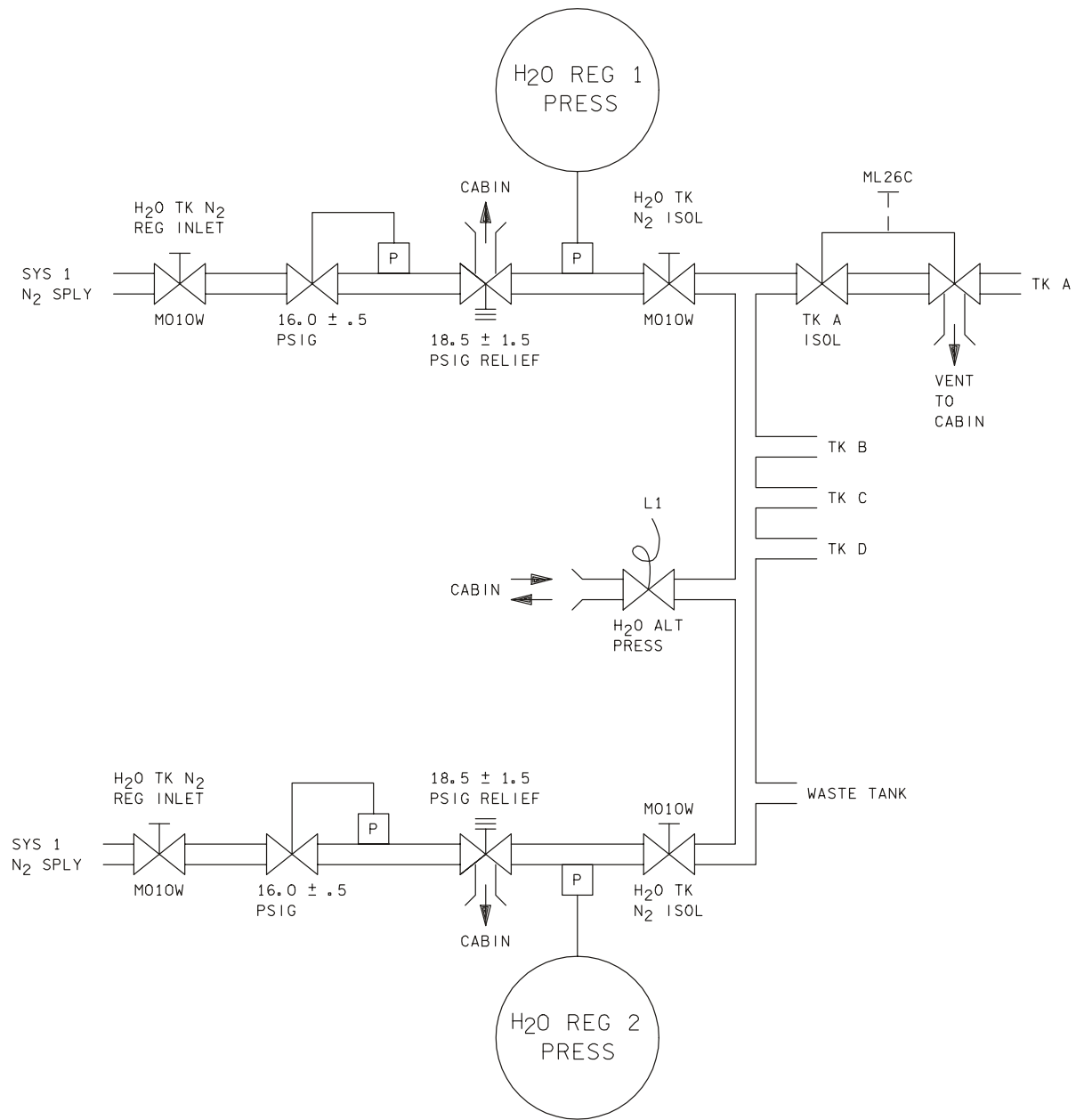
TD4150515. SCH 3

Figure 5-15. Supply water system instrumentation



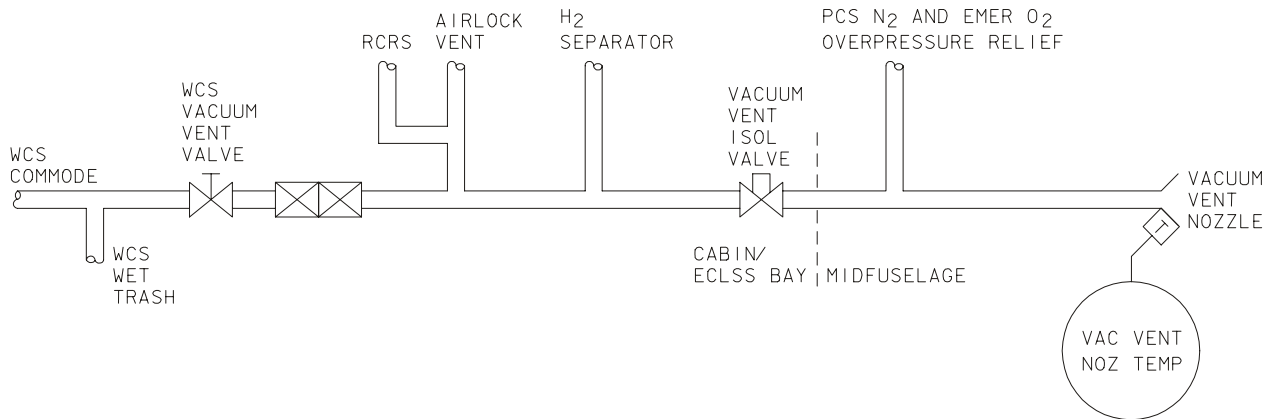
usa006020_006

Figure 5-16. Wastewater system instrumentation



TD4150517. SCH, 3

Figure 5-17. Water tank N₂ pressurization instrumentation



TD4150518, SCH 4

Figure 5-18. Vacuum vent system instrumentation

Table 5-1. Supply and wastewater system controls

Panel	Type	Nomenclature/ position	Function	Remarks
L1	2-pos toggle	H ₂ O ALT PRESS/ OPEN – CLOSE	Opens to provide an alternate vent source for the H ₂ OTK N ₂ manifold to vent to cabin	
ML31C	3-pos toggle (spring-loaded)	WASTE H ₂ O TK 1 DRAIN VLV/ OPEN – CLOSE	Opens/closes wastewater tank 1 outlet valve	
ML31C	Talkback	WASTE H ₂ O TANK 1 DRAIN VLV/ OP – CL – BARBERPOLE	Indicates the position of the tank 1 drain valve	
ML31C	3-pos toggle (spring-loaded)	WASTE H ₂ O TANK 1 VALVE/ OPEN – CLOSE	Opens/closes tank 1 inlet valve	
ML31C	Talkback	WASTE H ₂ O TANK 1 VALVE/ OP – CL – BARBERPOLE	Indicates the position of the tank 1 valve	
ML31C	3-pos toggle (spring-loaded)	SUPPLY H ₂ O TK D INLET/ OPEN – CLOSE	Opens/closes the tank D inlet valve	

Table 5-1. Supply and wastewater system controls (continued)

Panel	Type	Nomenclature/ position	Function	Remarks
ML31C	Talkback	SUPPLY H ₂ O TK D INLET/ OP – CL – BARBERPOLE	Indicates the position of the tank D inlet valve	
ML31C	3-pos toggle (spring-loaded)	SUPPLY H ₂ O TK D OUTLET/ OPEN – CLOSE	Opens/closes the tank D outlet valve	
ML31C	Talkback	SUPPLY H ₂ O TK D OUTLET/ OP – CL – BARBERPOLE	Indicates the position of the tank D outlet valve	
ML31C	3-pos toggle (spring-loaded)	WASTE H ₂ O DUMP ISOL VLV/ OPEN – CLOSE	Opens/closes the waste dump isolation valve	
ML31C	Talkback	WASTE H ₂ O DUMP ISOL VLV/ OP – CL – BARBERPOLE	Indicates the position of the dump isolation valve	
ML31C	3-pos toggle (spring-loaded)	WASTE H ₂ O DUMP VLV/ OPEN – CLOSE	Opens/closes the waste overboard dump valve	Valve operation inhibited unless DUMP VLV ENABLE/ NOZ HTR is on
ML31C	Talkback	WASTE H ₂ O DUMP VLV/ OP – CL – BARBERPOLE	Indicates the position of the waste over-board dump valve	
ML31C	2-pos toggle	WASTE H ₂ O DUMP VLV ENABLE/NOZ HTR/ ON – OFF	Turns on-off the dump nozzle heater and provides power to the waste H ₂ O dump valve	
ML31C	3-pos toggle	VACUUM VENT ISOL VLV BUS SELECT/ MNA – OFF – MNB	Routes/removes MNA/MNB power to the vacuum vent ISOL valve control switch for the vacuum vent isol valve	

Table 5-1. Supply and wastewater system controls (continued)

Panel	Type	Nomenclature/ position	Function	Remarks
ML31C	3-pos toggle (spring-loaded)	VACUUM VENT ISOL VLV CONTROL/ OPEN – CLOSE	Opens/closes the vacuum vent isol valve	
ML31C	Talkback	VACUUM VENT ISOL VLV CONTROL/ OP – CL – BARBERPOLE	Indicates the position of the vacuum vent isol valve	
ML31C	2-pos toggle	VACUUM VENT NOZZLE HEATER/ ON – OFF	Turns vacuum vent nozzle heater on-off	
ML86B	Circuit breaker	MNA SUPPLY H ₂ O TK A INLET	Main A power to tank A inlet switch on Panel R11	1 cb
ML86B	Circuit breaker	MNA SUPPLY H ₂ O TK B OUTLET	Main A power to tank B outlet switch on Panel R11	1 cb
ML86B	Circuit breaker	MNA H ₂ O LINE HTR A	Main A power to H ₂ O dump and vacuum vent line heaters	1 cb
ML86B	Circuit breaker	MNB SUPPLY H ₂ O TK B INLET	Main B power to H ₂ O tank B inlet switch on Panel R11	1 cb
ML86B	Circuit breaker	MNB SUPPLY H ₂ O TK B OUTLET	Main B power to H ₂ O tank C outlet switch on Panel R11	1 cb
ML86B	Circuit breaker	MNB SUPPLY H ₂ O DUMP ISOL	Main B power to the dump ISOL switch on Panel R11	1 cb
ML86B	Circuit breaker	MNB SUPPLY H ₂ O B SPLY ISOL VLV	Main B power to the B SPLY isolation switch on Panel R11	1 cb
ML86B	Circuit breaker	MNB H ₂ O LINE HTR B	Main B power to H ₂ O dump and vacuum vent line HTRS	1 cb
ML86B	Circuit breaker	MNC SUPPLY H ₂ O TK A OUTLET	Main C power to H ₂ O TK A OUTLET switch on Panel R11	1 cb

Table 5-1. Supply and wastewater system controls (continued)

Panel	Type	Nomenclature/ position	Function	Remarks
ML86B	Circuit breaker	MNC SUPPLY H ₂ O TK C INLET	Main C power to H ₂ O TK C INLET switch on Panel R11	1 cb
ML86B	Circuit breaker	MNC SUPPLY H ₂ O DUMP VLV/NOZ HTR	Main C power to dump valve nozzle heater switch on Panel R11	1 cb
ML86B	Circuit breaker	MNC SUPPLY H ₂ O XOUR VLV	Main C power to crossover valve switch on Panel R11	1 cb
ML86B	Circuit breaker	MNC SUPPLY H ₂ O GALLEY SUPPLY	Main power to galley supply switch on Panel R11	1 cb
ML86B	Circuit breaker	MNA WASTE H ₂ O TK 1 VLV	Main A power to tank 1 valve on Panel ML31C	1 cb
ML86B	Circuit breaker	MNA SUPPLY H ₂ O TK D OUTLET	Main A power to tank D outlet switch on Panel ML31C	1 cb
ML86B	Circuit breaker	MNA WASTE H ₂ O DUMP ISOL A	Main A power to dump isolation switch on Panel ML31C	1 cb
ML86B	Circuit breaker	MNA VAC VENT ISOL VLV	Main A power to vacuum vent isolation valve on Panel ML31C	1 cb
ML86B	Circuit breaker	MNA WCS CNTLR	Main A power to WCS controller ML31C	1 cb
ML86B	Circuit breaker	MNA GALLEY OVEN	Main A power to galley oven	1 cb
ML86B	Circuit breaker	MNB WASTE H ₂ O TK 1 DRAIN	Main B power to tank 1 drain switch on Panel ML31C	1 cb
ML86B	Circuit breaker	MNB SUPPLY H ₂ O TK D INLET	Main B power to tank D inlet switch on Panel ML31C	1 cb
ML86B	Circuit breaker	MNB VAC VENT NOZ HTR	Main B power to vacuum vent nozzle heater switch on Panel ML31C	1 cb

Table 5-1. Supply and wastewater system controls (continued)

Panel	Type	Nomenclature/ position	Function	Remarks
ML86B	Circuit breaker	MNB VAC VENT ISOL VLV	Main B power to vacuum vent isolation valve switch on Panel ML31C	1 cb
ML86B	Circuit breaker	MNB WCS CNTLR	Main B power to WCS controller on Panel ML31C	1 cb
ML86B	Circuit breaker	MNB GALLEY H ₂ O HTR	Main B power to galley H ₂ O heater	1 cb
ML86B	Circuit breaker	MNA WASTE H ₂ O DUMP VLV NOZ HTR	Main A power to dump valve enable/nozzle heater switch on Panel ML31C	
R11	3-pos toggle (spring-loaded)	SUPPLY H ₂ O TK A INLET/ OPEN – CLOSE	Opens/closes the supply H ₂ O tank A inlet valve	
R11	Talkback	SUPPLY H ₂ O TK A INLET/ OP – CL – BARBERPOLE	Indicates the OPEN- CLOSE position of the tank A inlet valve	
R11	3-pos toggle (spring-loaded)	SUPPLY H ₂ O TK A OUTLET/ OPEN – CLOSE	Opens/closes the tank A outlet valve	
R11	Talkback	SUPPLY H ₂ O TK A OUTLET/ OP – CL – BARBERPOLE	Indicates the position of the supply H ₂ O tank A outlet valve	
R11	3-pos toggle (spring-loaded)	SUPPLY H ₂ O TK B INLET/ OPEN – CLOSE	Opens/closes the tank B inlet valve	
R11	Talkback	SUPPLY H ₂ O TK B INLET/ OP – CL – BARBERPOLE	Indicates the OPEN- CLOSE position of the tank B inlet valve	
R11	3-pos toggle (spring-loaded)	SUPPLY H ₂ O TK B OUTLET/ OPEN – CLOSE	Opens/closes the tank B outlet valve	

Table 5-1. Supply and wastewater system controls (continued)

Panel	Type	Nomenclature/ position	Function	Remarks
R11	Talkback	SUPPLY H ₂ O/ TK B OUTLET/ OP – CL – BARBERPOLE	Indicates the OPEN- CLOSE position of the tank B outlet valve	
R11	3-pos toggle (spring-loaded)	SUPPLY H ₂ O TK C INLET/ OPEN-CLOSE	Opens/closes the tank C inlet valve	
R11	Talkback	SUPPLY H ₂ O TK C INLET/ OP – CL – BARBERPOLE	Indicates the OPEN- CLOSE position of the tank C inlet valve	
R11	3-pos toggle (spring-loaded)	SUPPLY H ₂ O TK C OUTLET/ OPEN – CLOSE	Opens/closes the tank C outlet valve	
R11	Talkback	SUPPLY H ₂ O TK C OUTLET/ OP – CL – BARBERPOLE	Indicates the OPEN- CLOSE position of the tank C outlet valve	
R11	3-pos toggle (spring-loaded)	SUPPLY H ₂ O CROSSOVER VLV/ OPEN – CLOSE	Opens/closes the crossover valve permitting isolation or crossfeeding of the A/B flash evap feedlines	
R11	Talkback	SUPPLY H ₂ O CROSSOVER VALVE/ OP – CL – BARBERPOLE	Indicates the OPEN- CLOSE position of the crossover valve	
R11	3-pos toggle (spring-loaded)	SUPPLY H ₂ O DUMP ISOL VLV/ OPEN – CLOSE	Opens/closes the overboard dump isolation valve	
R11	Talkback	SUPPLY H ₂ O DUMP ISOL VLV/ OP – CL – BARBERPOLE	Indicates the OPEN- CLOSE position of the dump isolation valve	

Table 5-1. Supply and wastewater system controls (continued)

Panel	Type	Nomenclature/ position	Function	Remarks
R11	3-pos toggle (spring-loaded)	SUPPLY H ₂ O DUMP VLV/ OPEN – CLOSE	Opens/closes the overboard dump valve	Valve operation inhibited unless DUMP VLV ENABLE/ NOZ HTR is on
R11	Talkback	SUPPLY H ₂ O DUMP VLV/ OP – CL – BARBERPOLE	Indicates the OPEN- CLOSE position of the overboard dump valve	
R11	2-pos toggle	SUPPLY H ₂ O DUMP VLV ENABLE/ NOZ HTR/ ON – OFF	Turns on-off the dump valve nozzle heater and provides power to the dump valve switch	
R11	3-pos toggle (spring-loaded)	SUPPLY H ₂ O GALLEY SPLY VLV/ OPEN – CLOSE	Opens/closes the potable water for crew consumption and hygienic use	
R11	Talkback	SUPPLY H ₂ O GALLEY SPLY VLV/ OP – CL – BARBERPOLE	Indicates the OPEN- CLOSE position of the galley supply valve	
R11	3-pos toggle (spring-loaded)	SUPPLY H ₂ O B SPLY ISOL VLV/ OPEN – CLOSE	Opens/closes the B supply isolation valve which provides water to the flash evaporator feedline B	
R11	Talkback	SUPPLY H ₂ O B SPLY ISOL VLV/ OP – CL – BARBERPOLE	Indicates the OPEN- CLOSE position of the B supply isolation valve	
O16	Circuit breaker	MNC H ₂ O ALT PRESS	MNC power to the H ₂ O ALT PRESS switch on Panel L1	1 cb
L1	2-pos toggle	H ₂ O ALTERNATE PRESS/ OPEN – CLOSE	Opens the H ₂ O tank N ₂ manifold to the cabin	

Table 5-1. Supply and wastewater system controls (concluded)

Panel	Type	Nomenclature/ position	Function	Remarks
ML26C	2-pos manual	SUPPLY H ₂ O GN ₂ TK A SPLY/ OPEN – CLOSE	Allows tank A to be pressurized with N ₂	
ML26C	2-pos manual	SUPPLY H ₂ O GN ₂ TK VENT/ PRESS – VENT	Allows tank A to be vented into the cabin	

5.6.4 Water and Waste Management Systems Performance, Limitations, and Capabilities

- | | |
|---|--------------------------|
| a. Fuel cell – ECLSS | Interface 100° to 220° F |
| b. Maximum flow rate (from fuel cells) | 10.7 lb/hr |
| c. Maximum back pressure | 40 psia |
| d. Minimum back pressure | 10 psia |
| e. Storage usable capacity | 165 lb/tank |
| f. Proof pressure | 37.5 psid |
| g. Burst pressure | 50 psid |
| h. Operating temperature range | 60° to 120° F |
| i. g limit | 5.0g |
| j. Operating pressure range (pressurant side) | 15.5 to 20.0 psig |
| k. Supply temp from tank | 75° F |
| l. Tank flow rate | 0 to 165 lb/hr |
| m. Water dump average flow capacity | 2 to 2.3 lb/min |

6.0 EXTERNAL AIRLOCK SYSTEM

The orbiter airlock is used to allow crewmembers to safely stay in the pressurized crew compartment while doing operations, such as docking or EVA, in vacuum. The external airlock is mounted in the payload bay, in which the hatch at the $X_0 = 576$ bulkhead (middeck hatch) opens to the transfer tunnel, airlock, and tunnel adapter. (See Figure 6-1.)

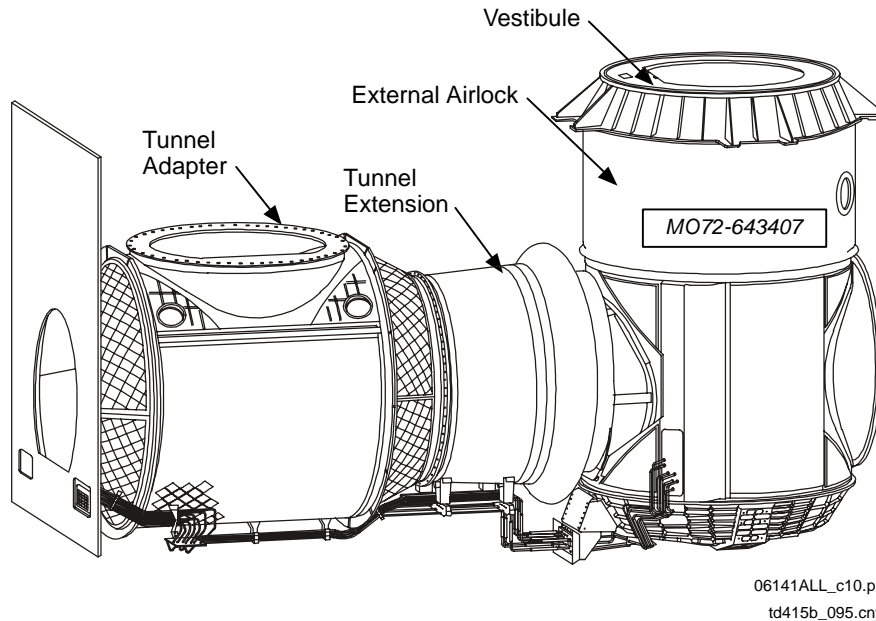


Figure 6-1. External airlock with tunnel adapter (fwd), tunnel extension, and vestibule

6.1 ASSOCIATED AIRLOCK VOLUMES

6.1.1 Tunnel Adapter

The tunnel adapter provides a method for EVA access with a pressurized module. It is a 130 ft³ volume with an EVA hatch on top, and the capability to add another hatch at the aft end.

For the external airlock, the tunnel adapter may be installed either forward or aft of the external airlock, depending on mission requirements; for example, obtaining improved visual clearances for ISS docking missions by moving the tunnel adapter further aft.

6.1.2 Vestibule

The vestibule is located on top of the external airlock and is used only during docking and undocking operations. When docking and undocking, the vestibule is at vacuum, while the external airlock is pressurized; this prevents having to vent the much larger volume of the airlock and allows for more efficient leak checks. The vestibule is a relatively small 50 ft³ in volume; it can be vented to vacuum and can be pressurized from the airlock.

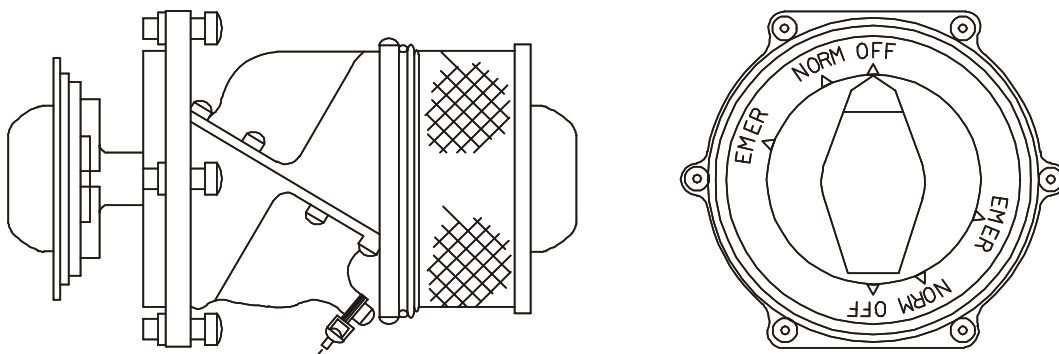
6.1.3 Tunnel Extension

Also known as the transfer tunnel or transition section, this 43 ft³ volume provides access to the external airlock volume itself. The external airlock and the tunnel extension are always flown together and are considered one volume. It has no heaters or controls and is always forward of the airlock.

6.2 EQUALIZATION, DEPRESS, AND ISOLATION VALVES

The equalization valves are located on all hatches and are used to equalize the airlock with cabin pressure, or to isolate the airlock from the middeck if the hatch is closed. They also are used as a backup method for airlock depress. Two valves are used for redundancy. Each valve consists of a removable cap and a three-position switch (OFF, NORM, EMER).

The OFF position allows no flow. The NORM position allows 240 lb/hr flow at 14.5 psid, and the EMER position allows 1278 lb/hr of flow at 14.5 psid. (See Figure 6-2.)



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td415b_096.cnv

Figure 6-2. Airlock equalization valve

The airlock depressurization valve (also known as the depress valve) and its associated cap are located on Panel AW82B. It is used to depress the cabin to 10.2 psia and to depressurize the airlock to vacuum for EVA. The airlock depressurization line cap is in series with the airlock depress valve and must be removed to perform an airlock depressurization. The airlock depress valve is a three-position rotary switch (CLOSED,

5, 0) that must be pushed in to allow rotation. The CLOSED position allows no flow. Position 5 normally is used to depressurize the airlock to 5 psia, hence the name “5,” and is also used in depressurizing the cabin from 14.7 to 10.2 psia. Position 5 opens a 0.59-inch-diameter orifice to vacuum. The zero position is used to depress the airlock from 5 to 0 psia. Position 0 opens a 1.02-inch-diameter orifice to vacuum. The airlock depress valves have been modified for the external airlock to vent overboard directly into the payload bay through a “T” that is designed to be nonpropulsive.

For docking missions, the airlock also has a vestibule on top that mates with the Pressurized Mating Adapter (PMA) on the ISS. Valves on Panel A6L depressurize the vestibule (before undocking), and the equalization valves on the hatch pressurize the vestibule before hatch opening (post-docking).

A cabin purge valve has been installed in the middeck floor. The valve has a number of detent positions to purge the cabin at 8 psi depending on the number of crewmembers wearing QDMs following a fire or toxic spill (see Figure 6-3). The cabin purge system vents overboard through the vacuum vent system.

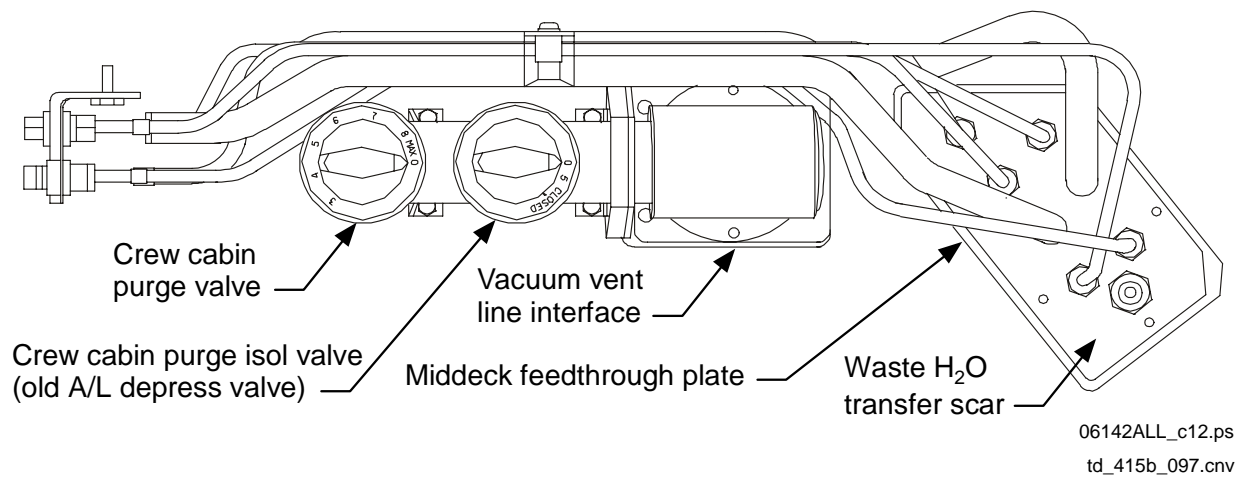


Figure 6-3. Cabin purge valve assembly

If the tunnel adapter is flown, a payload isolation valve is installed in the duct on the tunnel adapter side of the aft hatch to provide protection against leaks in volumes aft of the tunnel adapter hatch (see Figure 6-4). This is used when the tunnel is taken to vacuum in support of an EVA. It provides a seal to keep the module from leaking through the duct into the evacuated tunnel adapter.

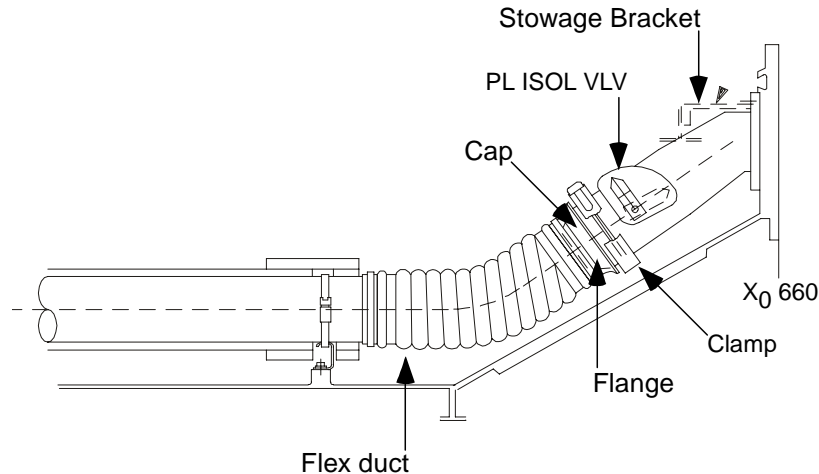


Figure 6-4. Payload isolation valve assembly

6.3 AIR AND WATER TRANSFER

For various reasons and in various capacities, air and water are transferred either to the ISS or to the EMUs, or both. Oxygen is provided to the EMUs for EVA crewmembers, and is transferred to the ISS along with nitrogen. Supply water is provided for EMU cooling during EVA and for crewmember drinking; wastewater is returned from the EMUs following an EVA.

Water is supplied via the airlock for the EMU feedwater system, used for cooling crewmembers via sublimation during an EVA, and for crewmember consumption. Since the water comes from the supply water system on the A-B outlet leg, it must be purified before flowing to the ISS. The water passes through a filter and a check valve on its way to the airlock in order to prevent contamination from passing from the EMU to the orbiter. To provide an isolation capability against leaks, a water shutoff valve is downstream of the filter/check valve package. After an EMU water recharge, an ullage dump is performed through the wastewater return line back to the waste tank.

Water also flows into and out of the airlock in two closed LCVG coolant loops, one for each EMU, for chilling the LCVG ("long underwear") while hooked into the Servicing and Cooling Umbilical (SCU). This water is cooled by the orbiter water loops at the LCVG heat exchanger.

The portions of the supply and wastewater lines in the payload bay are wrapped with triply redundant heaters for thermal conditioning. Thermostatically controlled electrical resistance heaters in two zones on the LCVG lines prevent freezing.

An O₂ line through the airlock provides 900 psi O₂ for EMU servicing; in the case of the external airlock, it provides ISS transfer directly from the orbiter cryo O₂ supply. Oxygen flowing into the ISS will come from the EMU supply line, which is fed from the O₂ crossover manifold in the PCS. The EMU oxygen switches on Panel AW82B enable PCS systems 1 and 2 O₂ to be used to service the EMUs. On the airlock floor is the

EMU O₂ isol valve, a manual O₂ shutoff valve to protect against leaks into the airlock or overboard via the transfer line into the payload bay. The EVLSS O₂ P sensor upstream of this valve drives the gauge in the airlock on Panel AW82B.

In case an EVA is required to perform a contingency undocking, a manual EVA isolation valve is installed on the outside of the airlock to allow crewmembers to vent and cut the O₂ line while still maintaining the capability for EMU servicing. This valve is accessible only on EVA on Panel AW64(E) (see Figure 6-5).

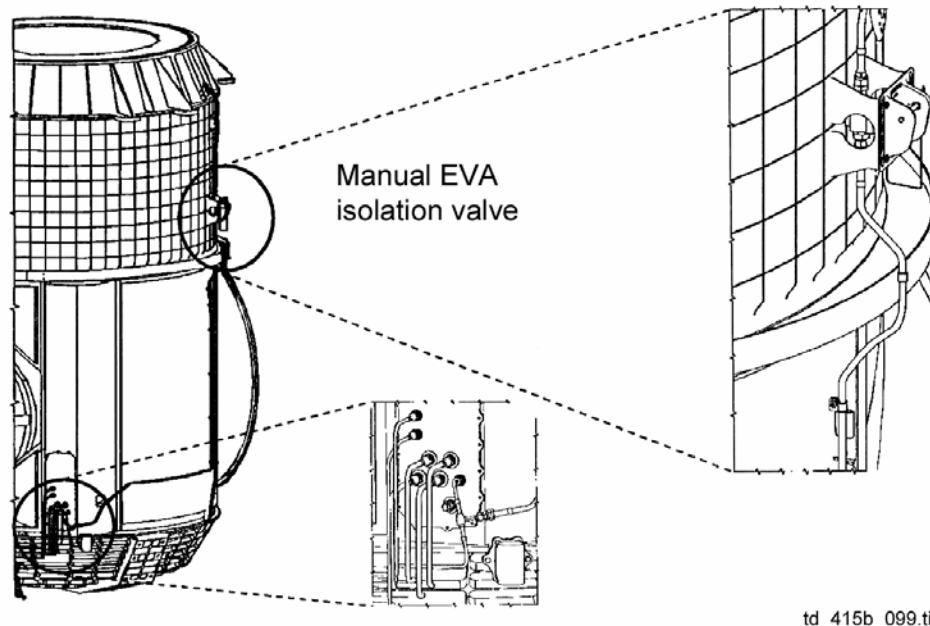


Figure 6-5. Manual EVA isolation valve

Nitrogen transfer to the ISS is connected into the orbiter PCS at the MMU A GN₂ supply. In this configuration, the MMU A GN₂ supply isol valve on Panel R13L controls the flow of N₂. The lines are all completely external to the airlock.

6.4 AIRLOCK BOOSTER FANS AND DUCTWORK

Because the airlock does not have vents to circulate orbiter-conditioned air from the cabin fan, ductwork must manually be set up by the crew to provide it. The ductwork for both the airlock has two major functions in circulating air:

- a. Humidity control via conditioned air from orbiter ARS
- b. Prevention of pockets of CO₂, O₂, or N₂

Additionally, the ductwork provides other functions for the airlock and tunnel adapter:

- a. Condensation control of airlock and upper hatch window, where the docking camera is mounted
- b. Thermal conditioning of the airlock avionics bay, installed under the floor
- c. Supply of orbiter-conditioned air to a docked ISS or a module in the payload bay

Two booster fans (see Figure 6-6), used one at a time, provide supplemental airflow for a module or the ISS. Although the fan filter is not easily accessible on orbit, flight experience has shown that filter cleaning during a mission is not required. The fans, installed in the tunnel adapter (if present) or the tunnel extension (if the tunnel adapter is not present or is mounted in the aft position) are powered by a three-phase, 115-volt AC motor. The 180-watt motors produce a normal flow of 541 to 767 lb/hr. The ARS interface to the fans and ductwork is via a middeck floor fitting; in the airlock configuration, the fitting has been moved closer to the X_o = 576 bulkhead. The fans are controlled via Panel MO13Q. If there is no pressurized module and there are no plans for docking with the ISS, the booster fan is not required to be flown.

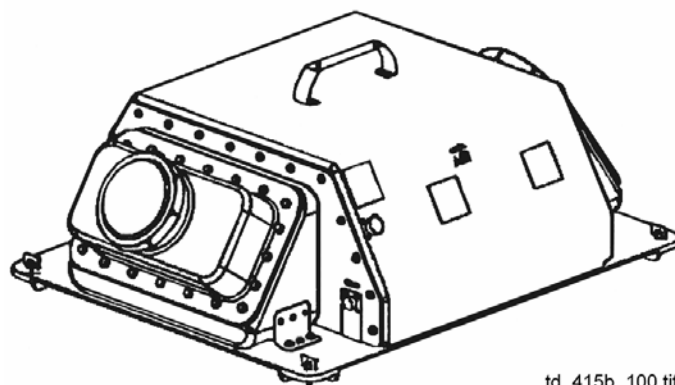


Figure 6-6. Booster fan

The configuration of the ARS ductwork is highly dependent on mission requirements and varies according to the availability of a booster fan or a tunnel adapter. See Figure 6-7 for an example of the airlock ductwork configuration.

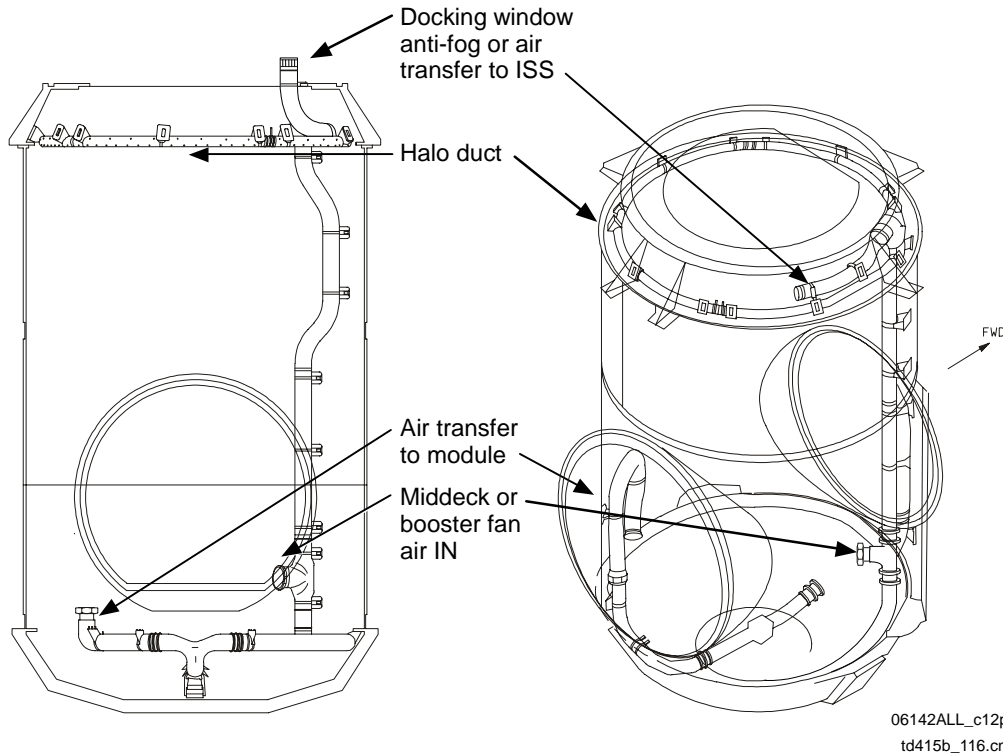


Figure 6-7. Airlock ductwork configuration

6.5 HEATERS

Six fluid lines run outside the pressurized volume to provide servicing capability for the EMUs in the airlock and potable water transfer to the ISS. These six lines are as follows:

- a. One LCG supply and one return line (for SCU/EMU 1)
- b. One LCG supply and one return line (for SCU/EMU 2)
- c. One potable water supply
- d. One wastewater return

The six lines are broken up into two zones separated by a QD Panel. The fluid lines in each zone are individually wrapped with three strings of line heaters, used one at a time, and are controlled by thermostats that enable or disable all six heaters in that zone. See Figure 6-8.

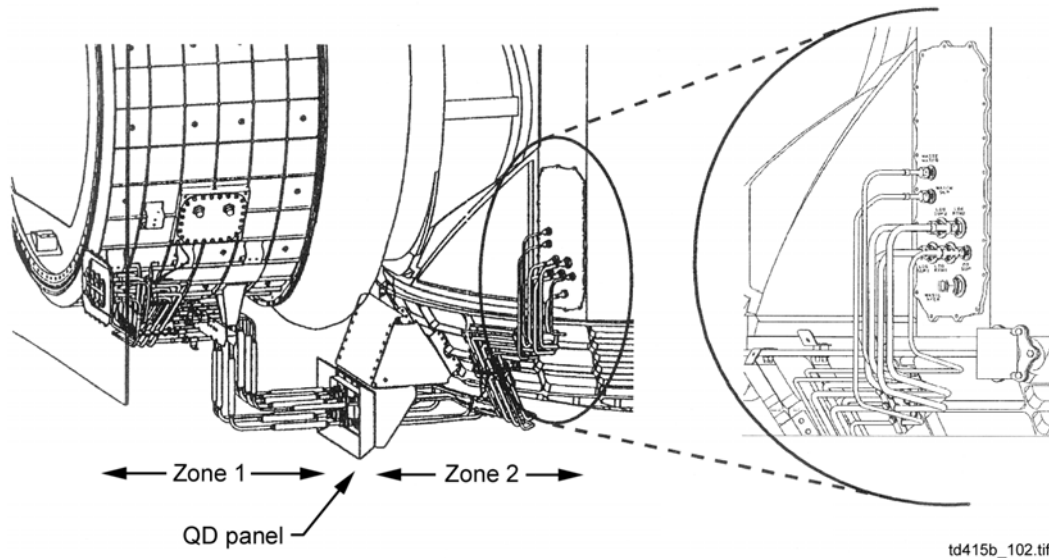


Figure 6-8. Payload bay line routing

Additionally, thermal conditioning of the airlock is provided by a series of structural patch heaters located around the outside shell of the airlock in three zones: the forward and aft halves of the airlock upper bulkhead and the lower bulkhead keel fitting. The heaters are designed to maintain the airlock internal temperature above freezing, especially when the airlock is at vacuum, due to the water lines that run inside the airlock for EMU servicing and ISS water transfer. The heaters are designed also to help prevent the buildup of condensation on the internal walls and hatches and in the docking avionics bay. The structural heaters are dually redundant.

As part of the docking system, the vestibule heaters are technically not considered part of ECLSS, but they are briefly discussed here with the rest of the airlock system for completeness. The vestibule heaters are structural patch heaters of the same type as the airlock structural heaters; they are dually redundant and are broken up into three zones, which are activated via a single circuit breaker.

All heaters are controlled via circuit breakers on Panel ML86B.

6.6 HATCHES

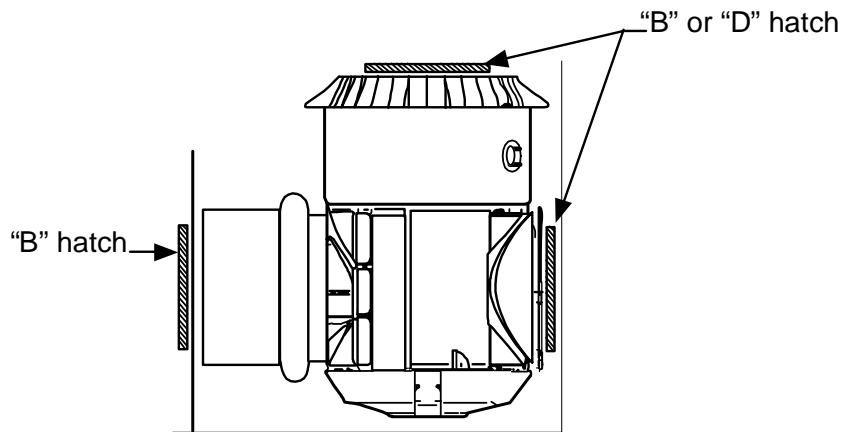
Orbiter hatches can be either a “B” type or a “D” type.

- a. “B” type – Capable of holding pressure in one direction only, as in the case of the always-pressurized orbiter and the sometimes-depressurized airlock.
- b. “D” type – Capable of holding pressure in either direction; for example, if a pressurized module aft of the airlock stays pressurized during an EVA when the airlock is depressurized, it can also protect against a depressurization of that module while the airlock remains pressurized.

All airlock hatches are essentially identical with respect to their size, structure, gauges, actuators, and valves. The distinctions are in the hinges and number of latches that differentiate them and drive their location in the vehicle. However, the nomenclature of the hatches can be confusing due to the fact that the original naming convention did not evolve with the modifications and additions to the orbiters.

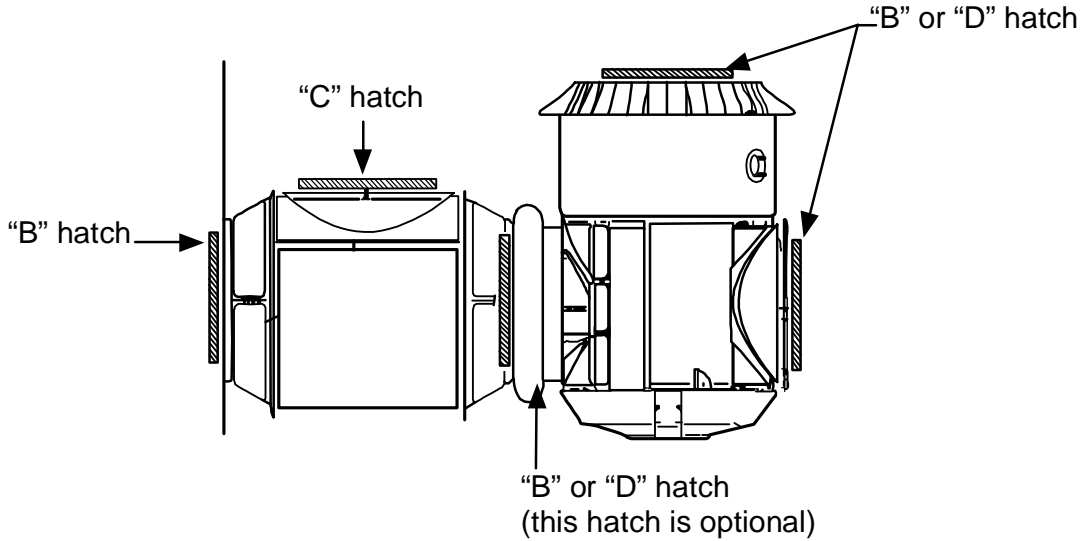
The hatch names (in particular, “B” type and “D” type) generally reflect their capability. See Figures 6-12 and 6-13.

- a. Middeck hatch – The middeck hatch is always a “B” type; located between the $X_0 = 576$ bulkhead and the payload bay.
- b. Upper hatch – The upper hatch is typically a “B” type for EVA, but may be a “D” type for docking; located at the top of the external airlock or Orbiter Docking System (ODS).
- c. Aft hatch – The aft hatch is a “B” type if there is no pressurized module; otherwise, it is a “D” type; located at the aft end of the airlock.
- d. Tunnel adapter hatch – The tunnel adapter hatch is the C-hatch, a “B” type; located on top of the tunnel adapter for EVA access.



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Figure 6-9. Airlock, no tunnel adapter



usa006020_026

Figure 6-10. Airlock with tunnel adapter (fwd)

The EVA hatch depends on whether or not the shuttle has a pressurized module aft of the airlock (such as a SpaceHab) connected through another tunnel extension. If there is another module, then the EVA hatch is the overhead hatch in the tunnel adapter; otherwise, it is the hatch on the aft of the airlock (which leads to a pressurized module if one is there). While the tunnel adapter can be mounted either forward or aft of the airlock, depending on mission requirements, the nomenclature remains the same.

6.7 AIRLOCK SYSTEM CONTROLS

See Figure 6-11, Figure 6-12, Figure 6-13, Figure 6-14, Figure 6-15, Figure 6-16, and Figure 6-17 for the various panels.

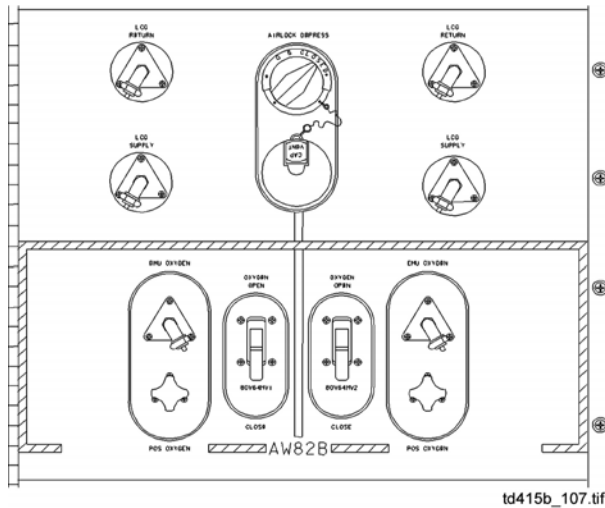
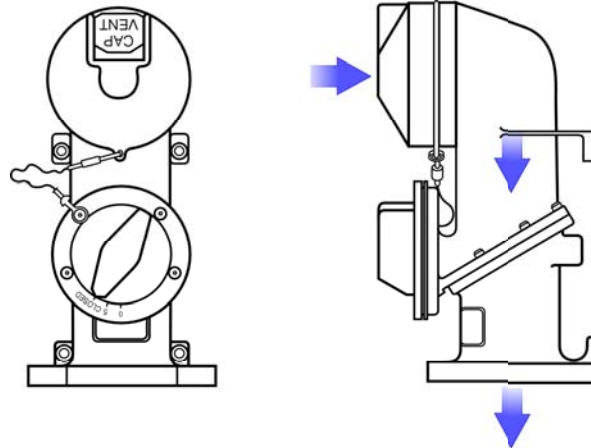
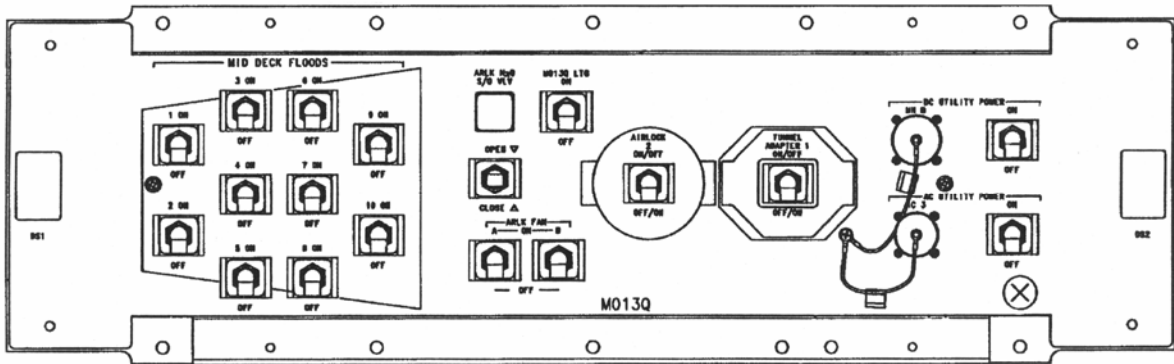


Figure 6-11. Panel AW82B



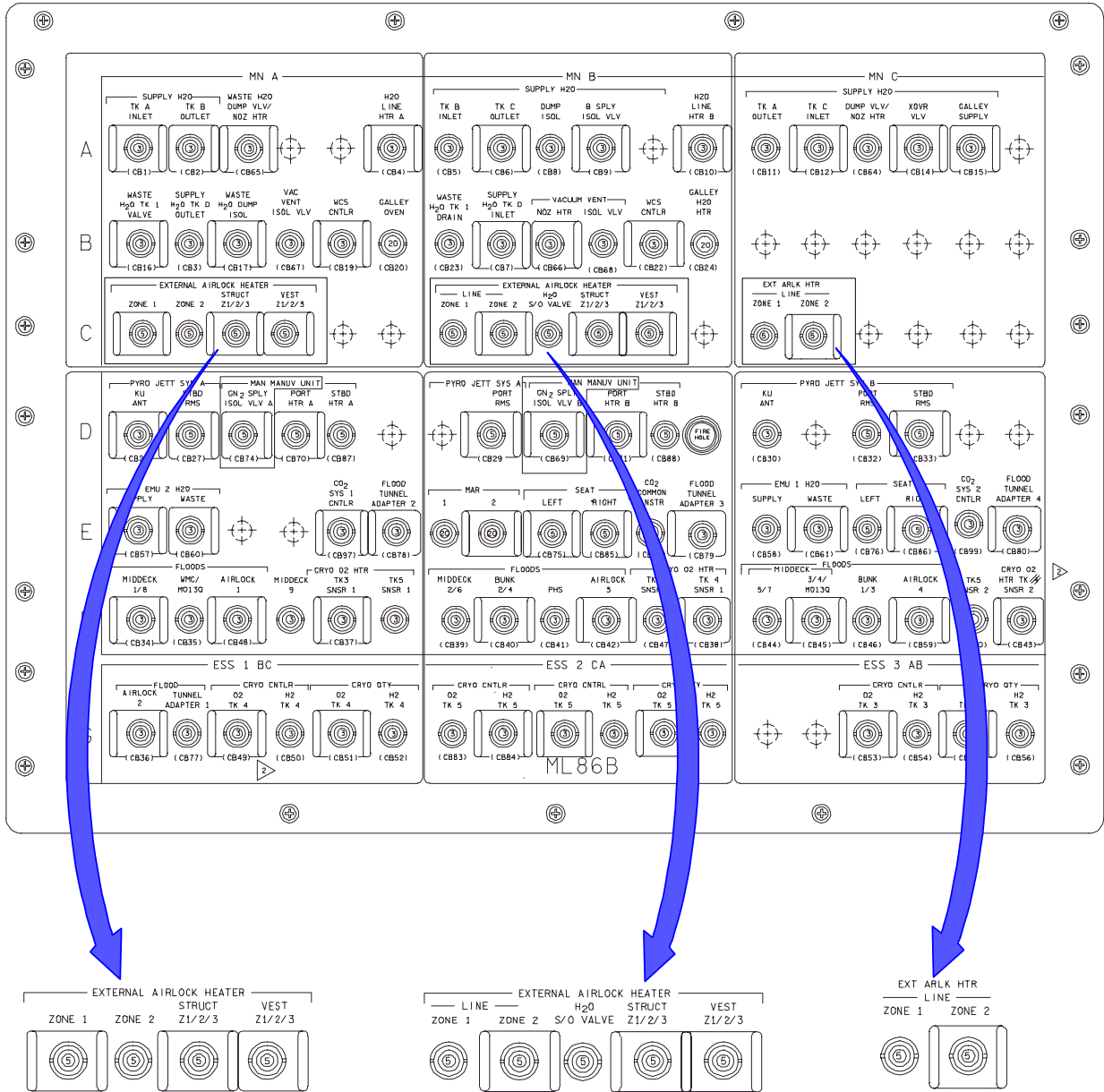
usa006020_025

Figure 6-12. Airlock vent valves on AW82B



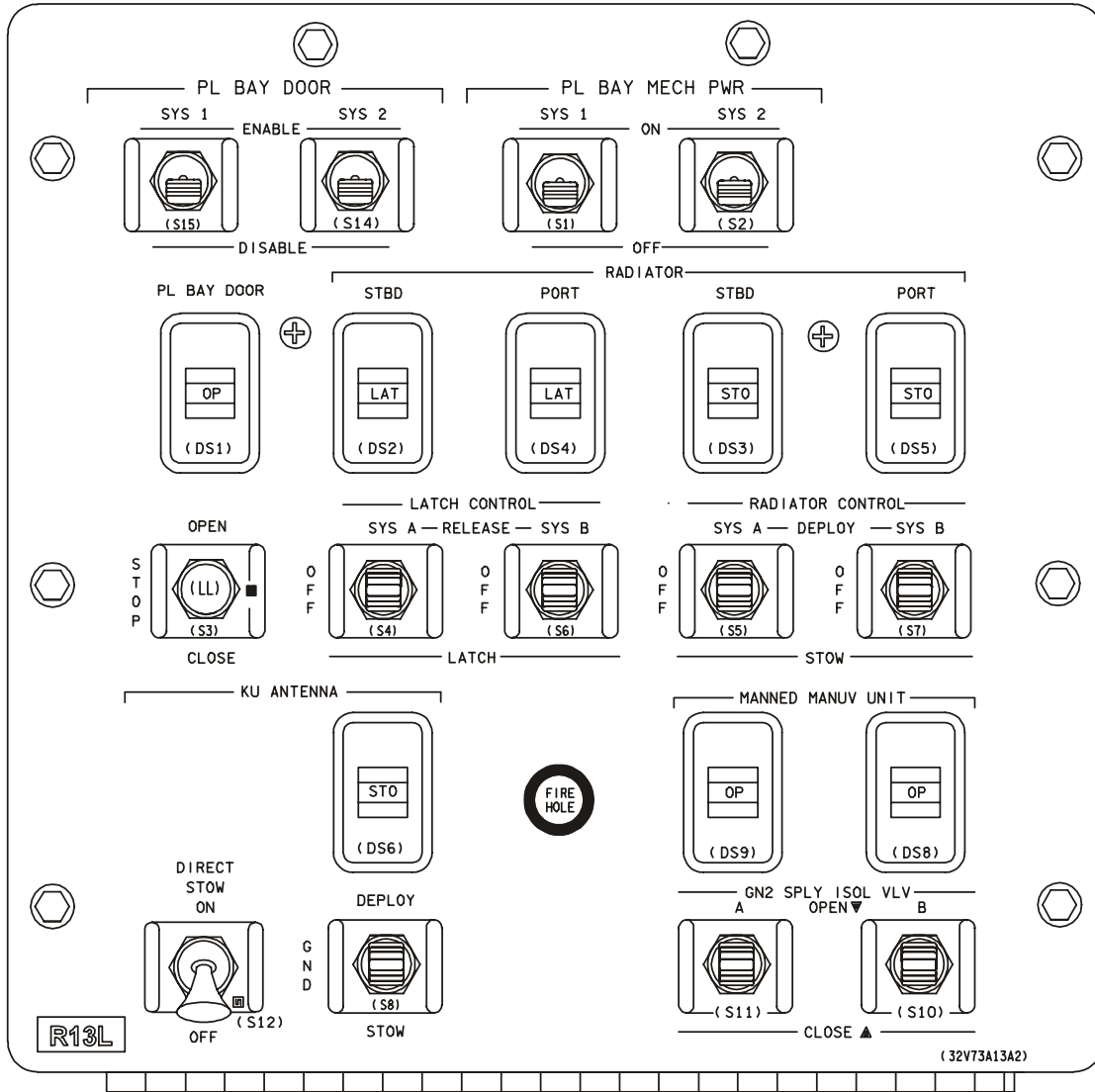
td415b_109.tif

Figure 6-13. Panel MO13Q



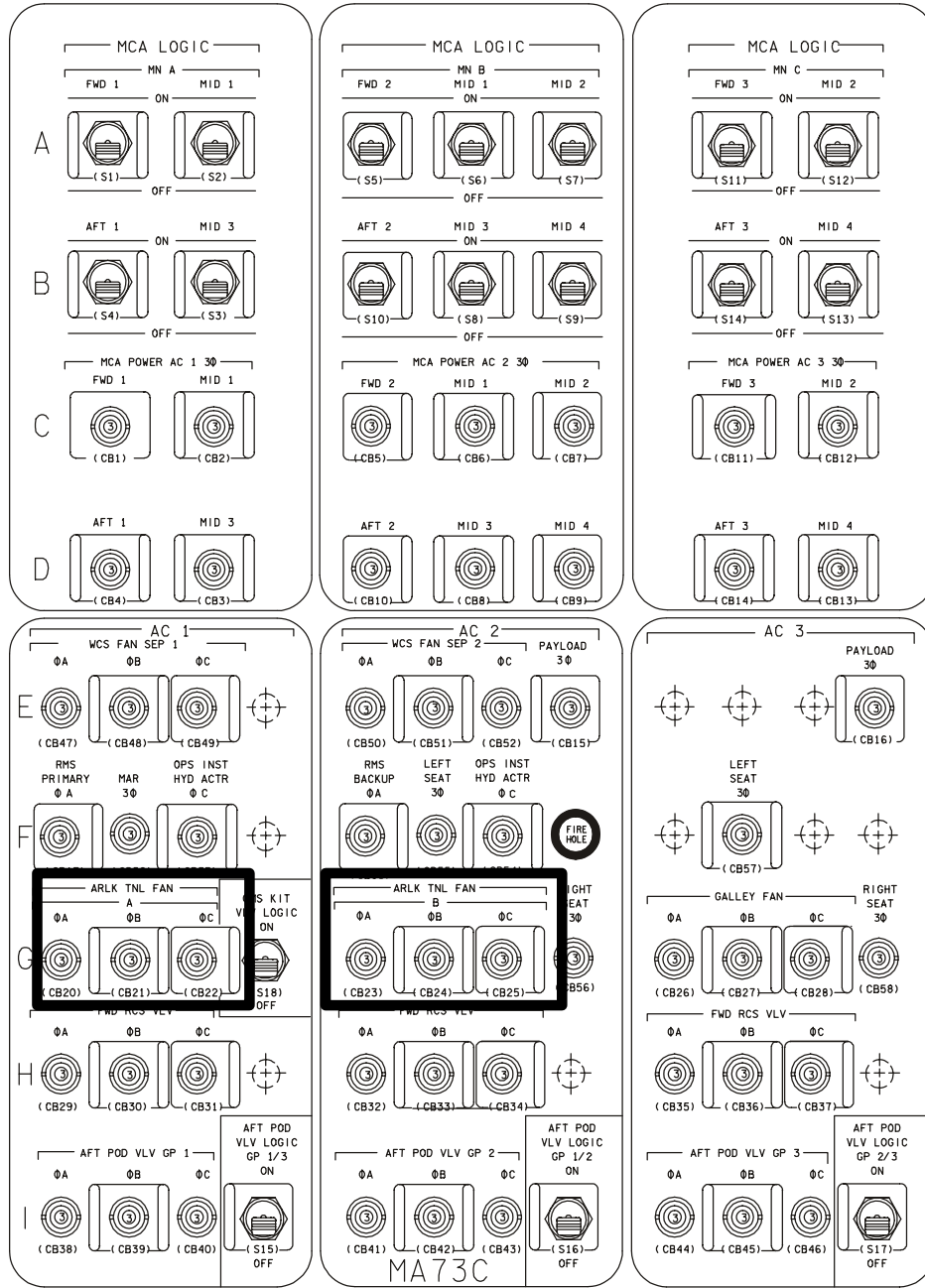
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Figure 6-14. Panel ML86B



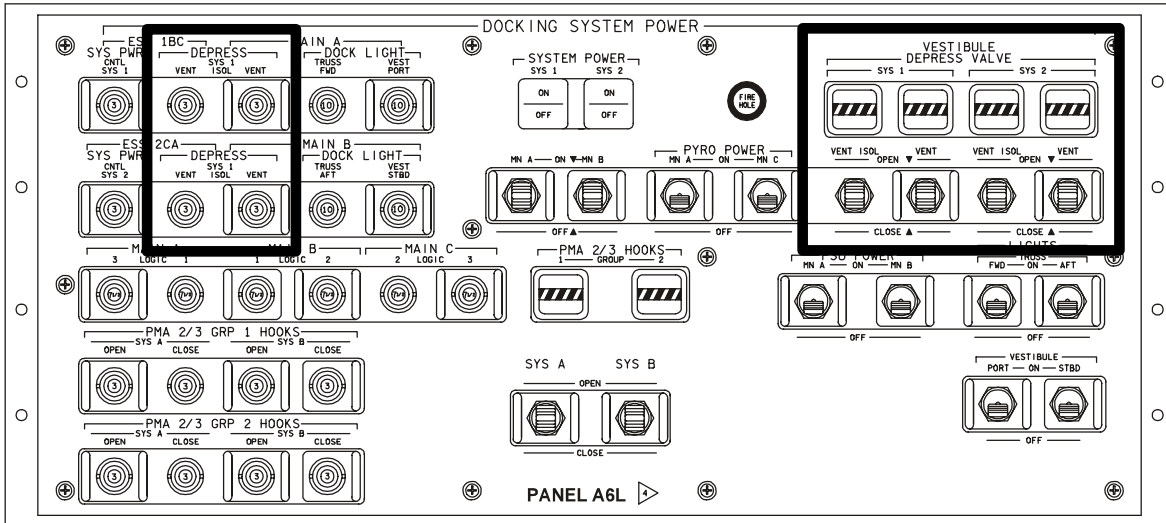
R13L.ps

Figure 6-15. Panel R13L



MA73c.ps

Figure 6-16. Panel MA73C



A6L.ps
td415_A6L.cnv

Figure 6-17. Panel A6L

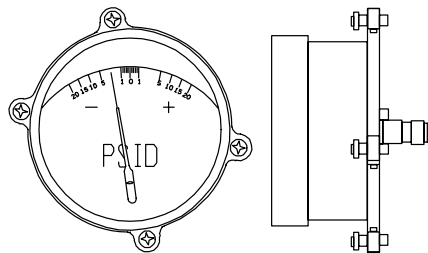
6.8 AIRLOCK INSTRUMENTATION AND DISPLAYS

6.8.1 Instrumentation

Crew insight into airlock performance is provided by sensors throughout the airlock and its associated hardware. There are no DSCs. Data are provided to the crew and Mission Control Center on various air and water pressures, water and structure temperatures, and vestibule valve status. It is worth noting that structural temperature sensors, whether internal or external, are located to monitor the automatic thermostat function of the externally mounted heater strings. They are not designed to monitor actual structure temperature or internal airlock temperatures.

6.8.2 Dedicated Displays

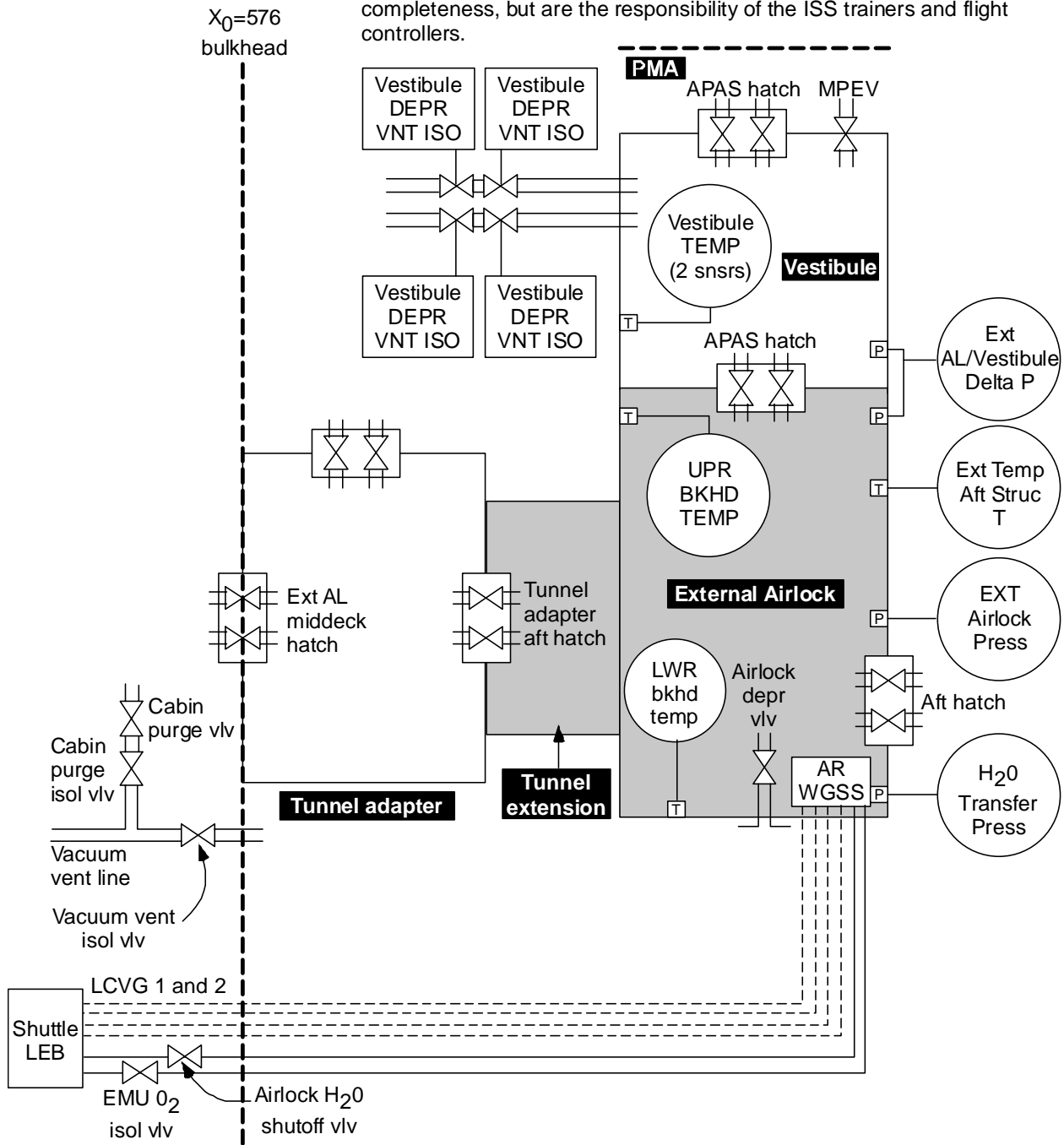
The difference in pressure across the various airlock hatches is displayed on a meter on each side of the hatch and thus accommodates the middeck and EVA crewmembers. See Figure 6-18. For a schematic of the airlocks, see Figure 6-19. Note that the tunnel adapter may be forward or aft of the airlock, depending on mission requirements.



06031ALL c26.ps

Figure 6-18. Airlock delta pressure gauge

Note: The APAS (Androgynous Peripheral Attachment System) hatch and MPEV (Manual Pressure Equalization Valve) are shown here for completeness, but are the responsibility of the ISS trainers and flight controllers.



Notes:

1. Each hatch has two equalization valves.
2. The tunnel adapter may be forward or aft of the airlock, depending on mission requirements.

usa006020_007

Figure 6-19. Airlock schematic

6.8.3 CRT Displays

The EXTERNAL AIRLOCK display (DISP 177) is available in SM OPS 2 only (see Figure 6-20). It provides information on airlock atmosphere, vestibule depress valves, water lines, and structural heaters. The associated hardware is present on all vehicles, but the display is present on all flights to keep the software load generic.

Note that on the display, the “Internal Temp” parameters refer to the physical location of the sensor inside the airlock, but their sole function is to monitor the externally mounted thermostat. They can provide no insight into the air temperature of the airlock.

XXXX/XXX/177		EXTERNAL AIRLOCK XX X XXX/ XX:XX:XX XXX/ XX:XX:XX	
EXT A/L PRESS A/L - VEST ΔP	XX.XXS XX.XXS	VESTIBULE DEP VLV 1 XX/XX ISOL VLV 1 XX/XX DEP VLV 2 XX/XX ISOL VLV 2 XX/XX TEMP 1/2 XXX/ XXX	
INTERNAL TEMP UPR BKHD T LWR BKHD T EXTERNAL TEMP AFT STRUC T	XXXX XXXX XXXX		
EXT A/L LINE TEMP H2O SPLY T LCG2 SPLY T O2 SPLY LN T	ZN1 ZN2 XXXX XXXS XXXX XXXS XXXX XXXS		
H2O LINE PRESS LCG SPLY P H2O XFER P	1 2 XX.XXS XX.XXS XX.XXS		

JSC-19590-116, Systems Management Level C
Flight Software Requirements, STS-116 Base 2
Cycle (01-30), November 2003, page 6.21-3.

(XX)

SPEC 177

OI-30

2011/ /177		EXTERNAL AIRLOCK		2 000/02± 41± 46 000/00± 00± 00	
EXT A/L PRESS A/L-VEST ΔP	14.60 14.64	VESTIBULE DEP VLV 1 / ISOL VLV 1 / DEP VLV 2 / ISOL VLV 2 / TEMP 1/2 3/ 3			
INTERNAL TEMP UPR BKHD T LWR BKHD T EXTERNAL TEMP AFT STRUC T	45 45 45				
EXT A/L LINE TEMP H2O SPLY T LCG2 SPLY T O2 PNL T	ZN1 ZN2 60 60 60 60 60 60				
H2O LINE PRESS LCG SPLY P H2O XFER P	1 2 0.56 0.32 15.04				

SPEC 177 PRO

CRT_SPEC 177 OI-30.CNV, Michael M Hoekman USA/DT36 281-244-7179

Figure 6-20. SPEC 177 EXTERNAL AIRLOCK

Parameter characteristics

CRT name	Units	Displayed range	Status indicators				
EXT A/L PRESS	psia	0 to 20	M	H	L	↑	↓
A/L - VEST ΔP	psia	-20 to +20	M	H	L		
INTERNAL TEMP							
UPR BKHD T	° F	0 to 160		H	L	↑	↓
LWR BKHD T	° F	0 to 160		H	L	↑	↓
EXTERNAL TEMP							
AFT STRUC T	° F	0 to 160		H	L	↑	↓
EXT A/L LINE TEMP							
H2O SPLY T ZN1	° F	0 to 160		H	L	↑	↓
ZN2	° F	0 to 160		H	L	↑	↓
LCG2 SPLY T ZN1	° F	0 to 160		H	L	↑	↓
ZN2	° F	0 to 160		H	L		↓
QD PNL T ZN2	° F	0 to 160		H	L		↓
H2O LINE PRESS							
LCG SPLY P 1	psig	0 to 40	M	H	L		
2	psig	0 to 40	M	H	L		
H2O XFER P	psig	0 to 40		H	L		
VESTIBULE							
DEP VLV 1	OP/CL	OP/CL					
ISOL VLV 1	OP/CL	OP/CL					
DEP VLV 2	OP/CL	OP/CL					
ISOL VLV 2	OP/CL	OP/CL					
TEMP 1	° F	-74 to 175		H	L		
2	° F	-74 to 175		H	L		

6.9 AIRLOCK NOMINAL OPERATION

6.9.1 Hatches

The middeck (inner) hatch is generally opened during the post-insertion timeframe to provide the crew with additional stowage for launch and entry suits, seats, and other items that are not usually used on orbit. In deorbit prep, the hatch is closed early to keep it from interfering with stowage locations of middeck stowage bags. On orbit, the inner hatch is always left open except during EVA operations.

6.9.2 Heaters

Since each heater string (water line, structure, and vestibule) is individually capable of maintaining proper thermal conditioning, only one string is operated at a time. The MNA heater string is activated during post insertion and is swapped with the MNB heater string during the mid-mission heater reconfig. The MNC water line heaters are not normally used.

6.9.3 Airlock Depress

Airlock depress operations are typically performed for docking/undocking and EVA.

6.9.3.1 Docking

For a mission in which the shuttle will dock with ISS, a set of protocols has been developed that covers the critical time periods before docking, during docking, and immediately after docking and undocking.

- a. Before docking – The Airlock/ODS is prepared for crew egress, and the inner airlock hatch and the equalization valves are closed, isolating the airlock. After docking, the crews wait to see whether the airlock pressure decreases, which indicates a leak. Following a successful leak check, the middeck hatch is reopened. Meanwhile, the pressure differential across the ODS hatch to the vestibule is checked to ensure that no leak exists there either. The vestibule is then pressurized and after another leak check, the equalization valves are opened, which may trigger a Dp/Dt klaxon if the two volumes are at different pressure. Finally, the hatch is opened.
- b. Before undocking – The PMA hatch and then the ODS hatch are closed, both with all equalization valves closed. The vestibule is depressurized from the orbiter flight deck; after a leak check, the orbiter undocks from the ISS.

6.9.3.2 EVA

For a mission in which crewmembers perform an EVA, the cabin is first depressurized to 10.2 psia (from 14.7) using the airlock depress valve and various PCS valves. While the cabin is depressurizing, the crew manipulates the PCS valves to maintain the proper

oxygen content in the atmosphere, and the airlock depress valve is typically opened twice during the procedure. Note that while the cabin is depressurizing, the hardware Dp/Dt sensor annunciates with a klaxon. The “5” position on the depress valve allows the cabin to depress to 10.2 psia in about a half hour.

6.10 AIRLOCK SYSTEM CONTROLS

Table 6-1. Airlock controls

Panel	Type	Nomenclature/ position	Function	Remarks
AW82B	2-pos toggle	OXYGEN/ OPEN – CLOSE	Isolates O ₂ supply to airlock	2 switches
AW82B	Rotary	AIRLOCK DEPRESS/ CLOSED – 5 – 0	Enables the airlock to be vented to space via the vacuum vent line	Switch must be depressed to allow rotation
Inner and outer hatches	Rotary	EQUALIZATION VALVE OFF – NORM – EMER	Inner hatch valves equalize airlock pressure with cabin pressure. Outer hatch valves equalize airlock pressure with ambient pressure	2 valves per hatch
Middeck floor	Rotary	EMU O ₂ ISOL VALVE	Isolates leaks in the O ₂ transfer lines	
A6L	Circuit Breaker	DEPRESS SYS 1 (2) VENT	Provides MNA (MNB) power to Vestibule Depress Vent Valve on A6L	2 cb's
A6L	Circuit Breaker	DEPRESS SYS 1 (2) VENT ISOL	Provides ESS1BC (ESS2CA) power to Vestibule Depress Vent Isol Valve on A6L	2 cb's
A6L	3-pos toggle (spring loaded)	VESTIBULE DEPRESS VALVE VENT SYS 1 (2)/OPEN/CLOSE	Vents the Vestibule to vacuum	2 valves
A6L	3-pos toggle (spring loaded)	VESTIBULE DEPRESS VALVE VENT SYS 1 (2)/OPEN/CLOSE	Vents the Vestibule to vacuum	2 valves

Table 6-1. Airlock controls (continued)

Panel	Type	Nomenclature/ position	Function	Remarks
A6L	Talkback	VESTIBULE DEPRESS VALVE VENT SYS 1 (2)/OP – BP – CL	Indicates the position of the vestibule depress valves	2 talkbacks
A6L	3-pos toggle (spring loaded)	VESTIBULE DEPRESS VALVE VENT ISOL SYS 1 (2)/OPEN/CLOSE	Isolates the vestibule vent valve if it fails open to vacuum	2 valves
A6L	Talkback	VESTIBULE DEPRESS VALVE VENT ISOL SYS 1 (2)/OP – BP – CL	Indicates the position of the vestibule depress vent isol valves	2 talkbacks
AW64(E)	2-pos toggle	GO ₂ XFER ISOLATION VLV	Isolates O ₂ flow to transfer interface in the event of an EVA to aid in undocking	Can be accessed only during EVA
MA73C	Circuit breaker	AC 1 Φ A - Φ B - Φ C ARLK FAN A	3-phase AC power to Airlock Fan A on Panel MO13Q	3 cb's
MA73C	Circuit breaker	AC 2 Φ A - Φ B - Φ C ARLK FAN B	3-phase AC power to Airlock Fan B on Panel MO13Q	3 cb's
ML86B	Circuit breaker	MNA EXTERNAL AIRLOCK HEATER LINE ZONE 1 HTR A	Provides MNA power to external airlock water supply lines in zone 1	ML86B
ML86B	Circuit breaker	MNA EXTERNAL AIRLOCK HEATER LINE ZONE 2 HTR A	Provides MNA power to external airlock water supply lines in zone 2	ML86B
ML86B	Circuit breaker	MNA EXTERNAL AIRLOCK HEATER STRUC Z1/2/3 HTR A	Provides MNA power to airlock structure heaters in zones 1, 2, and 3	ML86B
ML86B	Circuit breaker	MNA EXTERNAL AIRLOCK HEATER VEST Z1/2/3 HTR A	Provides MNA power to airlock vestibule heaters in zones 1, 2, and 3	ML86B
ML86B	Circuit breaker	MNB EXTERNAL AIRLOCK HEATER LINE ZONE 1 HTR B	Provides MNB power to external airlock water supply lines in zone 1	ML86B

Table 6-1. Airlock controls (continued)

Panel	Type	Nomenclature/ position	Function	Remarks
ML86B	Circuit breaker	MNB EXTERNAL AIRLOCK HEATER LINE ZONE 2 HTR B	Provides MNB power to external airlock water supply lines in zone 2	ML86B
ML86B	Circuit breaker	MNB EXTERNAL AIRLOCK HEATER H ₂ O S/O VLV	Provides power to the Airlock H ₂ O Shutoff Valve on Panel MO13Q	ML86B
ML86B	Circuit breaker	MNB EXTERNAL AIRLOCK HEATER STRUC Z1/2/3 HTR B	Provides MNB power to airlock structure heaters in zones 1, 2, and 3	ML86B
ML86B	Circuit breaker	MNB EXTERNAL AIRLOCK HEATER VEST Z1/2/3 HTR	Provides MNB power to airlock vestibule heaters in zones 1, 2, and 3	
ML86B	Circuit breaker	MNC EXTERNAL AIRLOCK HEATER LINE ZONE 1 HTR C	Provides MNC power to external airlock water supply lines in zone 1	
ML86B	Circuit breaker	MNC EXTERNAL AIRLOCK HEATER LINE ZONE 2 HTR C	Provides MNC power to external airlock water supply lines in zone 2	
ML86B	Circuit breaker	MANNED MANUV UNIT GN ₂ SPLY ISOL VLV B	Provides power to MMU GN ₂ Supply Isol Vlv	
MO13Q	2-pos toggle	ARLK FAN A (B)	Airlock and Tunnel Adapter booster fan	2 switches
ML86B	Circuit breaker	MNB EXTERNAL AIRLOCK HEATER VEST Z1/2/3 HTR	Provides MNB power to airlock vestibule heaters in zones 1, 2, and 3	
ML86B	Circuit breaker	MNC EXTERNAL AIRLOCK HEATER LINE ZONE 1 HTR C	Provides MNC power to external airlock water supply lines in zone 1	
ML86B	Circuit breaker	MNC EXTERNAL AIRLOCK HEATER LINE ZONE 2 HTR C	Provides MNC power to external airlock water supply lines in zone 2	
ML86B	Circuit breaker	MANNED MANUV UNIT GN ₂ SPLY ISOL VLV B	Provides power to MMU GN ₂ Supply Isol Vlv	
MO13Q	2-pos toggle	ARLK FAN A (B)	Airlock and Tunnel Adapter booster fan	2 switches

Table 6-1. Airlock controls (concluded)

Panel	Type	Nomenclature/ position	Function	Remarks
MO13Q	3-pos toggle (spring loaded)	ARLK H ₂ O S/O VLV	Isolates the water transfer lines between the shuttle and ISS	
MO13Q	Talkback	ARLK H ₂ O S/O VLV/ OP – CL	Indicates position of H ₂ O shutoff valve	
R13L	3-pos toggle (spring loaded)	MANNED MANUV UNIT GN ₂ SPLY ISOL VLV B/OP – CL	Provides N ₂ transfer from orbiter PCS to ISS	N ₂ System 2 only
R13L	Talkback	OP – BP – CL		
Middeck floor	Rotary	CABIN PURGE VALVE/ 3 – 4 – 5 – 6 – 7 – 8 – MAX	Allows cabin purge at 8 psia. Settings reflect number of crewmembers on QDM during purge	Switch must be depressed to allow rotation
Middeck floor	Rotary	CABIN PURGE ISOL VALVE/0 – 5 – CLOSED	Isolates cabin purge valve in case stuck open. Flow rate is greater than the purge valve, so 0 or 5 setting does not matter	Switch must be depressed to allow rotation
Tunnel adapter	2-pos toggle	PAYLOAD ISOL VLV	Isolates leaks downstream of the tunnel adapter hatch	

6.10.1 Airlock System Performance, Limitations, and Capabilities

Volume (ft³)

- a. Airlock 185
- b. Tunnel extension 43
- c. Tunnel adapter 130
- d. Vestibule 40
- e. EMU Subtract 10 ft³ for each suit

6.10.2 References

Most of the information in this section is based on material in the Environmental Systems Console Handbook, Volume 5 (Airlock/EVA), JSC-19935, Rev. C (Oct. 1997).

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APPENDIX A
ACRONYMS AND ABBREVIATIONS

AC	Alternating Current
ACA	Annunciator Control Assembly
ACCUM	Accumulator
ALT	Alternate
AMEU	Aft Master Events Unit
AMI	Alpha Mach Indicator
AOA	Abort Once Around
ARS	Atmospheric Revitalization System
ATCO	Ambient Temperature Catalytic Oxidizer
ATCS	Active Thermal Control System
ATM	Atmosphere
Av	Avionics
AVVI	Ascent Vertical Velocity Indicator
BFC	Backup Flight Controller
BFS	Backup Flight System
C/P	Coldplate
C/W	Caution and Warning
C&W	Caution and Warning
CAB	Cabin
CAM	Computer Annunciation Matrix
CAP	Crew Activity Plan
cb	control bus
CCTV	Closed-Circuit Television
CDR	Commander
CIU	Computer Interface Unit
CNTL	Controller
CO	Carbon Monoxide
CO ₂	Carbon Dioxide
COMSEC	Communications Security
CRT	Cathode Ray Tube
CWC	Contingency Water Container
D&C	Display and Control
DC	Direct Current

DDU	Digital Display Unit
DEU	Display Electronic Unit
DFI	Developmental Flight Instrumentation
DMP	Dump
dp/dt	delta pressure/delta time
DPS	Data Processing System
DPU	Data Processing Unit
DSC	Dedicated Signal Conditioner
ECLSS	Environmental Control and Life Support System
EDO	Extended Duration Orbiter
EI	Entry Interface
EMER	Emergency
EMU	Extravehicular Mobility Unit
ENA	Enable
EPDC	Electrical Power Distribution and Control
EPS	Electrical Power System
ET-SEP	External Tank Separation
EVA	Extravehicular Activity
EVAP	Evaporator
EVLSS	Extravehicular Life Support System
FCL	Freon Coolant Loop
FCV	Flow Control Valve
FD	Flight Day
FE 21	Freon 21
FES	Flash Evaporator System
FM	Frequency Modulation
FREQ	Frequency
GN ₂	Gaseous Nitrogen
GPC	General Purpose Computer
GSE	Ground Support Equipment
H ₂	Hydrogen
H ₂ O	Water
He	Helium
HUD	Head Up Display
HX	Heat Exchanger

HYD	Hydraulics
Hz	Hertz
ICH	Interchanger
IDP	Integrated Display Processor
IFM	In-Flight Maintenance
IMU	Inertial Measurement Unit
INST	Instrumentation
INTCHGR	Interchanger
ISOL	Isolation
ISS	International Space Station
JSC	Johnson Space Center
KSC	Kennedy Space Center
LCVG	Liquid Cooling and Ventilation Garment
LEH	Launch and Entry Helmet
LES	Launch and Entry Suit
LiOH	lithium hydroxide
MADS	Modular Auxiliary Data System
MCC	Mission Control Center
MCIU	Manipulator Controller Interface Unit
MDF	Minimum Duration Flight
MDM	Multiplexer/Demultiplexer
MDU	Multifunction Display Unit
MECO	Main Engine Cutoff
MEDS	Multifunction Electronic Display System
MLS	Microwave Landing System
MM	Major Mode
MMU	Manned Maneuvering Unit
MOD	Mission Operations Directorate
MPLM	Multipurpose Logistics Module
MS	Mission Specialist
N ₂	Nitrogen
NEG	Negative
NH ₃	Ammonia

NOZ	Nozzle
NSP	Network Signal Processor
O ₂	Oxygen
ODS	Orbiter Docking System
OFI	Operational Flight Instrumentation
OPS	Operational Sequence
PASS	Primary Avionics Software System
PCMMU	Pulse-Code Modulation Master Unit
PCS	Pressure Control System
PEI	Polyethylenimine
PEV	Pressure Equalization Valve
PL	Payload
PMA	Pressurized Mating Adapter
PNL	Panel
POT	Potable
PPCO ₂	Partial Pressure Carbon Dioxide
PPO ₂	Partial Pressure Oxygen
PRI	Primary
PROP	Proportioning
PRSD	Power Reactant and Storage Distribution System
PS	Payload Specialist
psi	pounds per square inch
psia	pounds per square inch absolute
psid	pounds per square inch differential
psig	pounds per square inch gauge
PVT	Pressure Volume Temperature
PW	Pulse Width
QD	Quick Disconnect
QDM	Quick Don Mask
QTY	Quantity
RAD	Radiator
RCRS	Regenerable Carbon Dioxide Removal System
RCU	Remote Control Unit
REG	Regulator
REST	Restrictor

RGA	Rate Gyro Assembly
RJDF	Reaction Jet Driver Forward
rpm	revolutions per minute
RTC	Real-Time Command
RTG	Radioisotope Thermoelectric Generator
RTLS	Return to Launch Site
SCU	Servicing and Cooling Unit
SEC	Secondary
SM	Systems Management
SRB SEP	Solid Rocket Booster Separation
SSOR	Space to Space Orbiter Radio
SW	Software
SYS	System
T - 0	Time-zero
TACAN	Tactical Air Navigation
TAL	Transoceanic Abort Landing
TEMP	Temperature
TK	Tank
TM	Telemetry
VCV	Vacuum Cycle Valve
VSU	Video Switching Unit
WCS	Waste Collection System
WMS	Waste Management System

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APPENDIX B ECLSS CREWMEMBERS' HANDBOOK

B.1 CABIN PRESS LEAK

Crew reaction to a cabin leak consists of four basic steps:

1. Attempting to isolate the leak
2. Assessing the leak magnitude
3. Selecting the applicable abort mode
4. Configuring the cabin to support entry

For an unisolatable cabin leak, an abort will be declared based on the following criteria:

RTLS/TAL	if $dP/dT > -0.15$ psia/min
AOA	if $dP/dT > -0.08$ psia/min (NO COMM)
AOA	if $dP/dT > -0.02$ psia/min (MCC CALL REQUIRED)

CAUTION

Always close the cabin relief isolation valves on Panel L2 before declaring an abort; the cabin leak may just be a relief valve failed open.

B.2 CABIN PRESS HIGH

A leak into the cabin is assumed. The sources of possible O₂ and N₂ flow into the cabin are isolated.

CAUTION

Open visors before closing O₂ supply valves.

NOTE

Always check for a thermally induced problem. A cabin fan failure, a H₂O loop failure, or a Freon loop cooling problem could all result in an increase in cabin pressure.

B.3 CABIN PPO₂ ABNORMAL

CAUTION

A cabin PPO₂ level less than 2.24 at 14.7 psia will require the crew to don their LEH to breathe normally.

CAUTION

The O₂ concentration in the cabin must be maintained below 25.9 percent at 14.7 psia (28.5 percent at 10.2 psia). All cabin material has been fire qualification tested to be nonfire propagating below these concentration levels.

WARNING

An O₂ concentration above 40 percent will cause the Halon 1301 fire suppressant to act as a fuel. It will actually help propagate a fire instead of putting it out.

B.4 H₂O LOOP PRESS LOW

The failure mode is assumed to be a pump failure or a loop leak. The action of switching loops is delayed until after MECO.

WARNING

Switching H₂O pumps pre-MECO could cause the loss of two main engine controllers. The ac startup spike caused by selecting a “new” pump may cause the main engine controllers powered by that ac bus to fail.

NOTE

If the H₂O loop failure is real, then the CABIN HX OUT TEMP and the AV BAY AIR OUT TEMPs should be noticeably increasing. Verify using Panel O1 meter.

NOTE

Be sure to verify that the newly selected H₂O pump is working. The PUMP OUT P should be approximately 60 to 65 psia, and the CABIN HX OUT TEMP and the AV BAY AIR OUT TEMPs should be stable and/or decreasing.

Did any electrical bus failures occur? If so, check the CDR bus loss cue card for actions.

NOTE

The GPC position on H₂O LOOP 2 acts as an alternate power source for the pump when the BFS has control of the PL MDMs. If AC3 fails, H₂O LOOP 2 can be powered by AC1 by selecting the GPC switch position as long as the appropriate circuit breakers on Panel L4 are pushed in.

NOTE

If the H₂O loop leaked out into the cabin, the PUMP OUT P should be approximately equal to cabin pressure (i.e., 15). If the leak were to space, then the pressure would be 0.

B.5 CABIN FAN FAIL

WARNING

Switching cabin fans pre-MECO could cause the loss of two main engine controllers. The AC startup spike caused by selecting a new cabin fan may cause the main engine controllers powered by that AC bus to fail.

NOTE

On orbit, an airflow check can be made to verify that the fan has actually failed or that the alternate fan has started.

NOTE

If the cabin fan failure is real, then the cabin pressure and dP/dT should be increasing as the cabin temperature rises. Verify using Panel O1 meter.

Did any electrical bus failures occur? If so, check the CDR bus loss cue card for actions.

B.6 AV BAY FAILURE RECOGNITION

1. Fan failure

NOTE

If the Av Bay fan failure is real, then the Av Bay temperature will decrease due to the location of the temperature sensor. The temperature sensor is located below the middeck floor in the fan plenum near the Av Bay/H₂O loop air/H₂O heat exchanger. When airflow is lost, the temperature sensor seeks the temperature of the H₂O loop. Verify using Panel O1 meter.

WARNING

If a fan failure is confirmed, √ MCC, switch fans, even pre-MECO. If air cooling is not restored, the TACAN (if ac powered) in the Av Bay may overheat and fail causing an AC bus short. This AC short will cause the main engine controllers powered by that AC bus to fail. However, pre-MECO switching of Av Bay 3 fan (if upgraded to a cabin fan type) is not allowed per Flight Rules.

NOTE

Upgrades to orbiter TACANs (DC- vice AC-powered) now allow delay of switching fans until post-MECO (√ MCC) depending on affected Av Bay. The TACAN and MLS in the Av Bay should be powered down ASAP if cooling cannot be restored.

2. Signal conditioner failure

Insight into Av Bay fan performance has been lost. To protect against a subsequent failure, both fans are selected.

NOTE

Check for an AC bus failure. The Av Bay signal conditioners are powered by AC phase Bs.

NOTE

The signature for an Av Bay signal conditioner failure is:

AV BAY TEMP	45L
AV BAY FAN DELTA P	0.00L

on BFS, SM SYS SUMM 2.

3. Temperature high

Activate both fans in the Av Bay. If no joy, switch H₂O loops.

NOTE

Av Bay fan status is monitored only by fan delta pressure. It is possible to have degraded air circulation in an Av Bay without annunciating a delta pressure alarm.

NOTE

A flow restriction in the leg of the H₂O loop servicing the Av Bay could cause a temperature increase in that Av Bay.

NOTE

The TACAN and MLS in the Av Bay should be powered down ASAP if cooling cannot be restored.

B.7 FREON FLOW LOW

Freon pumps must be switched ASAP to determine if the Freon loop in question has been lost.

Did any electrical bus failures occur? If so, check the CDR bus loss cue card for actions.

WARNING

The loss of both Freon loops results in the loss of all fuel cell cooling. Fuel cell lifetime becomes extremely critical. Loss of two Freon loops requires that the abort mode that allows the earliest possible landing be selected.

Analysis performed by Rockwell International gives the following estimates for fuel cell lifetime:

- Without a purge, the fuel cells will flood in about 18 minutes assuming a power level of 8 kWh (2.67 kWh/fuel cell).
- With a purge, the fuel cells will exceed the stack temperature upper limit in about 50 minutes assuming a power level of 12.54 kWh (4.18 kWh/fuel cell).

B.8 H₂O LOOP PRESS HIGH

A Freon-to-H₂O loop leak can cause the pressures in the H₂O loop to rise to 135 psig or even higher if the H₂O loop is operating. Some of the seals of the H₂O loop components are incompatible with Freon 21. Operating the affected H₂O loop will circulate the Freon 21 and accelerate the seal degradation.

CAUTION

If an H₂O loop press high alarm annunciates, deactivate the affected loop. Deactivating the pump decreases the probability the H₂O loop will leak into the cabin and expose the crew to toxic Freon 21.

B.9 LOSS OF 1 FREON LOOP

Oxygen demand by the PCS system exposes the O₂ restrictor seals to cryogenic temperatures. The absence of warm Freon flowing through the O₂ restrictors will cause the seals to fail and leak cryogenic oxygen into the midbody.

CAUTION

If a Freon loop fails, or is turned off because of a powerdown, the associated O₂ supply valve must be closed to prevent the O₂ restrictor from being damaged.

NOTE

NH₃ controllers must be switched if Freon loop 2 fails during an abort.

The NH₃ B controller is placed in the PRI/GPC position prelaunch to provide cooling during aborts. The NH₃ B controller receives temperature inputs from dedicated temperature sensors located on Freon loop 2. If Freon loop 2 is lost, NH₃ controller B will not function properly because it is receiving inputs from a stagnant loop. The NH₃ A controller will work fine since it utilizes temperature sensors on Freon loop 1.

B.10 EVAP OUT TEMP HIGH (RADIATORS COLD SOAKED)

This is really two separate procedures. One for a velocity <12k and one for a velocity >12k. The evap out temperature must be kept under control to keep the avionics and fuel cells within normal operating temperatures.

B.10.1 Case 1 - V<12k

During entry with the velocity <12k, the Freon cooling is being provided by the cold soaked radiators. An EVAP OUT TEMP HIGH alarm during this timeframe would most likely be caused by a radiator controller malfunction (i.e., a RAD/BYP valve failed to the bypass position). The procedure calls for taking Freon loop 1 to bypass, which increases the flow rate in Freon loop 1. Loop 2 is assumed to be in radiator flow. These steps ensure that loop 2 is the slower flowing Freon loop. NH₃ B is then activated by taking the switch on L1 to PRI/GPC.

NOTE

An inadvertent trip to bypass may occur if there is a great enough difference in the temperature between the Freon in the last radiator panel and the Freon in the line leading from the last panel to the flow control valve assembly. This has occurred on previous flights and will not recur when the same controller is selected for the second time.

NOTE

The PRI/GPC position of the NH₃ controller is active for entry during the following major modes:

Entry, TAL, and AOA: MM304 and an altitude <120k ft or MM305

RTLS: MM602 and MM603

B.10.2 Case 2 - V>12k

When the velocity >12k (entry), the Freon cooling is provided by the FES. The EVAP OUT TEMP HIGH procedure is written to deal with the loss of a FES controller, an evaporator (HI LOAD or TOPPING), or the total loss of FES cooling. If the FES is totally lost, the radiator cold soak will be utilized early. NH₃ cooling will be used below V = 12k when the radiator cold soak runs out.

B.11 EVAP OUT TEMP HIGH (RADIATORS NOT COLD SOAKED)

This procedure is written to cover the loss of cooling during ascent or the loss of cooling during an entry without a radiator cold soak.

During ascent the Freon cooling is provided by the FES. The Evap Out Temp High procedure is written to deal with the loss of an FES controller, an evaporator (HI LOAD or TOPPING), or the total loss of FES cooling. This portion of the procedure differs from the radiators cold soaked procedure because of the high power levels experienced during ascent. If the HI LOAD or TOPPING evaporator fails, the evaporator's duct and nozzle heaters are turned off to reduce power requirements. The number of times the FES controllers are cycled during troubleshooting is minimized to prevent additional ice formation. A frozen evaporator or duct will only be made worse by spraying additional water into the evaporator. Radiator flow is initiated to utilize the thermal mass of the radiators to help support the evaporators until the pocket checklist powerdown can be performed.

NOTE

If a total loss of FES cooling occurs, the Ascent Pocket Checklist will call for an emergency payload bay door opening. This will allow the radiators to be used as the primary source of cooling as soon as possible.

During the lower stages of ascent abort entries, the NH₃ boilers are the primary source of Freon cooling. If an EVAP OUT TEMP HIGH annunciation occurs, the NH₃ cooling is not working properly. The NH₃ controller SEC/ON position is selected. The SEC/ON position of the NH₃ controller has no auto switchover logic. The PRI/GPC position of the NH₃ controller has auto switchover logic that provides undertemp protection. If the PRI/GPC controller controls too cool, control of the NH₃ boiler will automatically switch to the SEC/ON controller.

NOTE

The NH₃ boilers can be used for cooling during entry below EI by selecting the SEC/ON position. There is no bladder between the NH₃ and its helium pressurant; gravity is required to keep the heavier NH₃ at the tank outlet. If NH₃ use is attempted above EI, all of the pressurant could rush out of the tank rendering it useless.

NOTE

The FES stops functioning at an altitude of approximately 100,000 feet because the atmospheric pressure becomes too great for H₂O to flash effectively.

B.12 EVAP OUT TEMP LOW

If the Freon evap out temperature drops below 32°, the H₂O in the H₂O coolant loop and/or the payload H₂O loop (if flown) might freeze. Frozen H₂O could damage the H₂O/Freon HX and cause a Freon loop leak. Severe damage could cause loss of two Freon loops.

CAUTION

If an EVAP OUT TEMP LOW annunciation occurs, activate both H₂O loops.

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APPENDIX C EXTENDED DURATION ORBITER MODIFICATIONS

C.1 INTRODUCTION

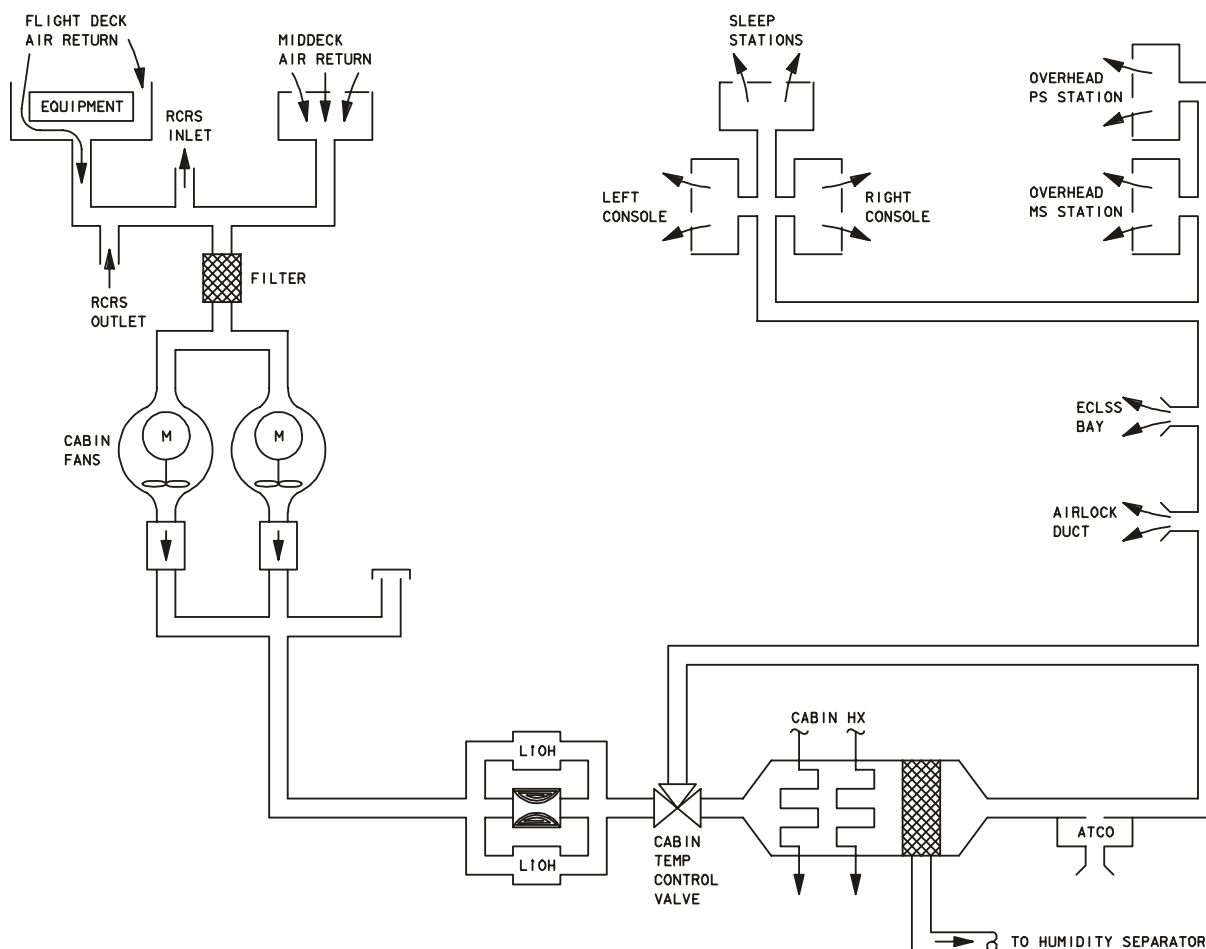
As science experiments aboard the shuttle increase in complexity, longer duration missions become more desirable in order to maximize the amount of time available for experiments. The orbiter was originally designed to support 8-day missions with 2 contingency days. In order to increase mission duration to up to 16 + 2 days, the Extended Duration Orbiter (EDO) modifications were designed. Changes in the baseline vehicle included an improved system to remove carbon dioxide (CO₂) from the cabin atmosphere through the Regenerable CO₂ Removal System (RCRS) and increased consumables capacity, including nitrogen (N₂) in mission kits, and hydrogen and oxygen in a cryo pallet. All orbiters can hold the cryo pallet. In addition, *Endeavour* (OV-105) was originally assembled with the EDO modifications. The N₂ upgrade was discussed earlier (see Chapter 2). Due to weight considerations and shorter ISS missions, the RCRS hardware was removed from OV-105, leaving no vehicles as an RCRS-compatible vehicle.

C.2 REGENERABLE CARBON DIOXIDE REMOVAL SYSTEM

The length of a mission is in part limited by the life support consumables carried onboard the vehicle. However, ensuring an adequate supply of consumables for manned missions of extended duration becomes very expensive in terms of cost, storage, and weight requirements. In order to reduce the onboard volume and weight requirements of lithium hydroxide (LiOH) for removal of CO₂ from the cabin atmosphere, EDO modifications incorporated an RCRS. (For a discussion of LiOH for CO₂ removal, refer to the ECLSS Training Manual, Page 3-3.) Although regenerable life support system hardware is often more expensive to develop and more power intensive to operate than expendable systems, it becomes both cost and weight effective as mission duration increases.

C.2.1 Carbon Dioxide Removal

A portion of cabin air is drawn from the Atmospheric Revitalization System (ARS) upstream of the cabin fan and forced through the RCRS for CO₂ removal. CO₂ removal is accomplished by using two identical chemical beds made up of solid amine resin. One bed adsorbs CO₂ while the other bed regenerates. After passing through the resin bed, the scrubbed air is returned to the ARS airstream just upstream of the cabin fan filter to approximately the same place as the RCRS inlet for recirculation to the cabin. Figure C-1 illustrates how the RCRS is integrated into the ARS airstream. Approximately 6 percent of the total ARS airflow flows through the RCRS.



TD4150C03, SCH 1

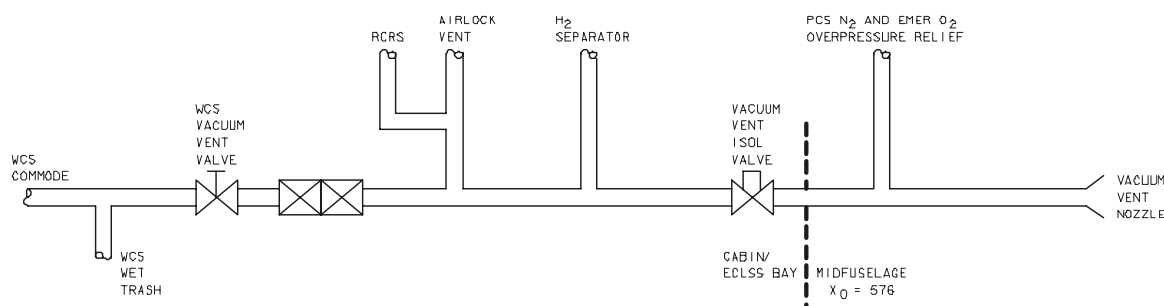
Figure C-1. Atmospheric Revitalization System

The resin consists of a Polyethylenimine (PEI) sorbent coating on a porous polymeric substrate. Essentially, small (0.5 mm) porous spheres of the substrate are coated with PEI and allowed to dry. The porous base increases the surface area of the adsorbent and therefore the adsorption capacity. Upon exposure to cabin air, the resin combines with water vapor in the air to form a hydrated amine, which, in turn, reacts with CO₂ to form a weak bicarbonate bond. Water is required for the adsorption process to take place, since dry amine cannot react with CO₂ directly.

While one bed adsorbs CO₂, the alternate bed regenerates by desorbing CO₂ from the solid amine resin with thermal treatment and vacuum venting. Heat generated by the adsorbing bed is transferred to the regenerating bed. The heat breaks the bicarbonate bonds on the resin, releasing CO₂. The desorbing bed is also vented to vacuum, discharging the liberated CO₂ overboard. Since a vacuum is necessary for operation of the RCRS, the system can be used only on orbit. LiOH must still be used for CO₂ removal during ascent and entry.

C.2.2 RCRS Hardware

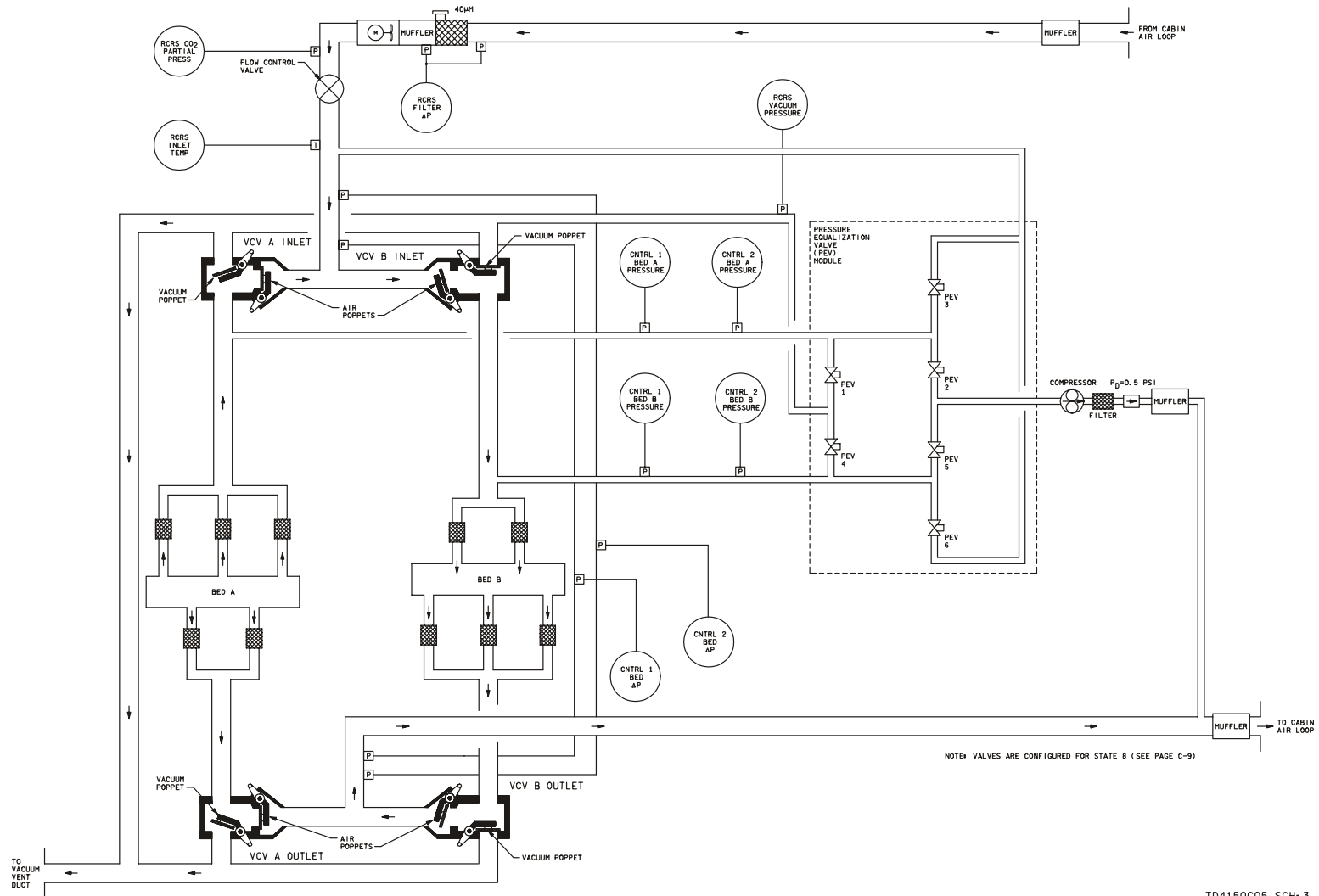
The RCRS is located in volume D under the middeck floor near the LiOH assembly and the cabin temperature controller. The RCRS uses the existing vacuum vent line in the orbiter to vent the desorbing bed. (For a discussion of the orbiter vacuum vent, refer to the ECLSS Training Manual, Page 5-10.) Figure C-2 shows the vacuum vent system interface.



TD4150507, SCH 4

Figure C-2. RCRS/Vacuum Vent Interface

In addition to the two chemical beds, which are referred to as bed A and bed B, the major components of the RCRS unit include a set of vacuum cycle valves, a set of pressure equalization valves, an RCRS fan, an ullage-save compressor, and two redundant controllers. These components are illustrated in Figure C-3.



TD4150C05. SCH 3

Figure C-3. RCRS Components

The vacuum desorption process is controlled by four vacuum cycle valve (VCV) assemblies. A valve assembly is located at the inlet and outlet of each bed. The valves are used to direct airflow through the bed during the adsorption cycle, to open the bed to vacuum to desorb the bed, and to provide bed isolation. To provide these functions, each VCV assembly has two poppets, as shown in Figure C-4. One poppet allows airflow through the bed while the other exposes the bed to vacuum; therefore, the poppets in each VCV assembly are referred to as the air poppet and the vacuum poppet. Two actuators drive the poppets, which are connected to the appropriate actuator with linkages. Actuator A moves the bed A air poppets and the bed B vacuum poppets, while actuator B drives the bed A vacuum poppets and the bed B air poppets. Furthermore, the actuator is sized to prevent an inadvertent opening of the poppets if the ΔP across the poppet is greater than 3.4 psi.

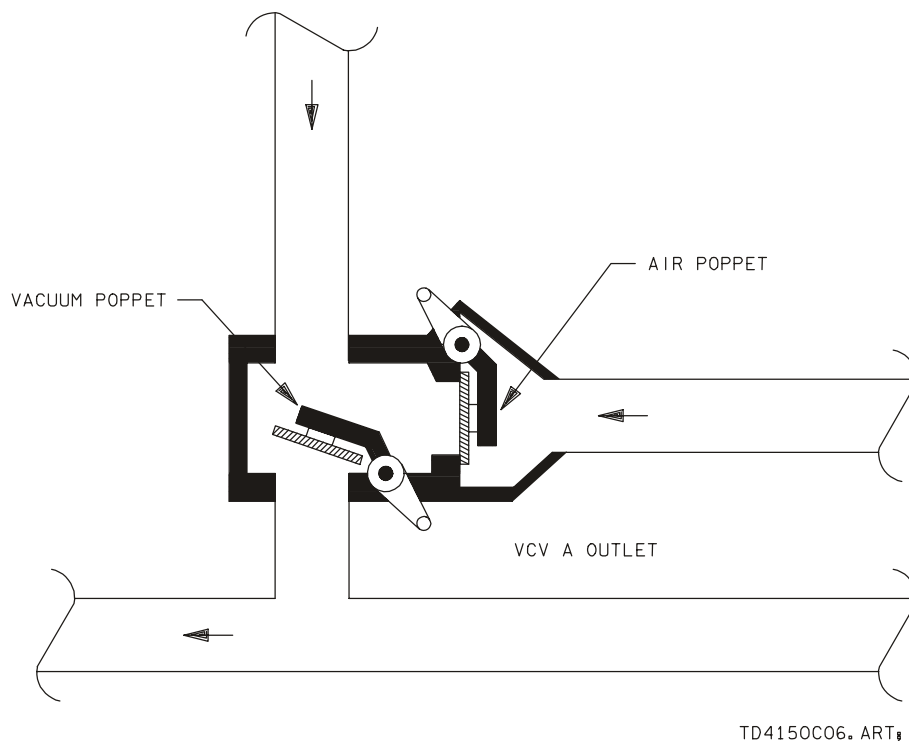


Figure C-4. Vacuum Cycle Valve

Six Pressure Equalization Valves (PEVs) are used to equalize and manipulate the pressure of the chemical beds and allow the ullage-safe compressor to evacuate the beds. Each of these solenoid valves has two coils that open the valve when energized. Each controller operates one of the two coils; therefore, the loss of a coil or a controller does not result in loss of the system. The valves are designed to automatically close with loss of power.

The RCRS fan is needed to force air through the adsorbing bed to remove CO_2 efficiently. Just downstream of the fan is a two-position valve that adjusts the airflow through the RCRS. The two positions are sized for 4 to 5 and 6 to 7 crewmembers, respectively, and the appropriate one is set prelaunch. Finally, a filter/muffler

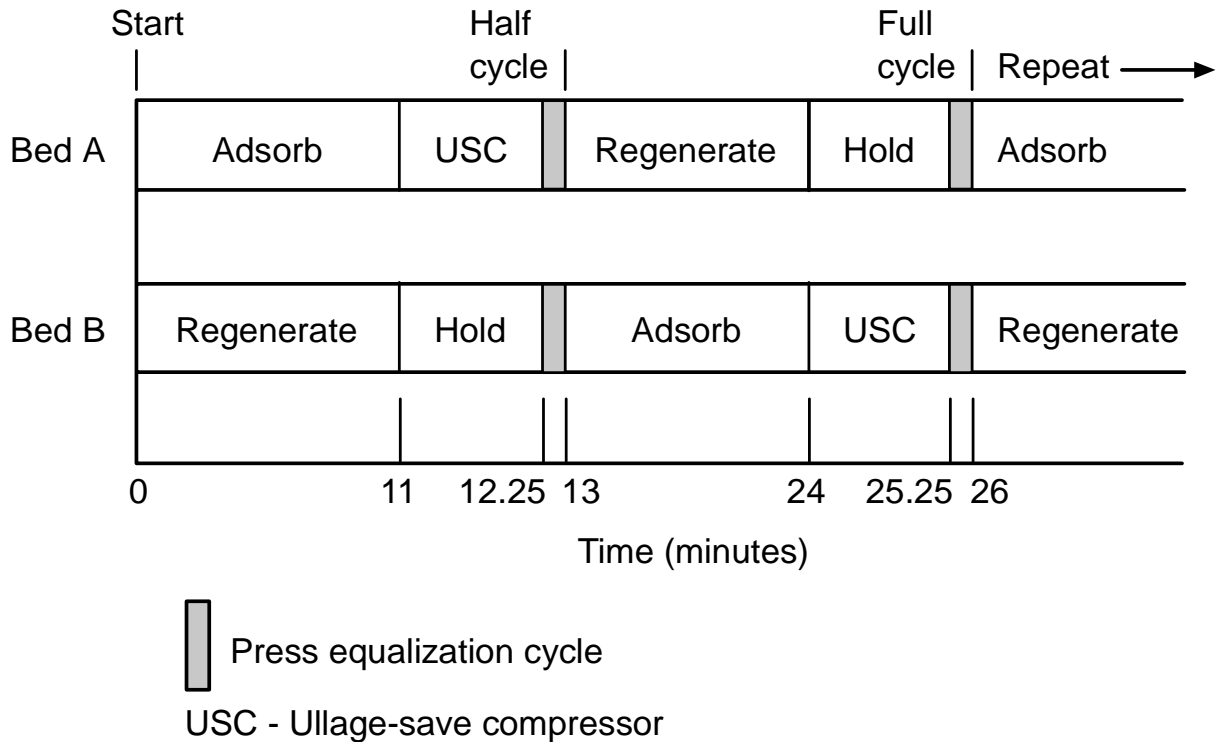
assembly is located upstream of the fan. The filter prevents particulate material from entering the fan and solid amine beds, while the muffler reduces the noise of the fan through the inlet ducts. If necessary, the filter may be accessed during flight for cleaning by removing two lockers and opening the access panel.

The ullage-save compressor evacuates the desorbing bed at the start of each desorption cycle. The air removed from the bed is routed back to the cabin. This process reduces the volume of cabin air vented to vacuum. Depending upon the original cabin pressure, 70 to 80 percent of the air in the bed is saved. A muffler is located at the compressor outlet to reduce the noise of the compressor. It is important to note that if the compressor fails, the RCRS still operates. However, a greater volume of cabin air is lost to vacuum during regeneration cycles, as has occurred in flight before.

The RCRS controller governs the operation of the RCRS cycles. Control logic from the active controller supplies output signals and power to the various components and instrumentation. The controller also receives input from instrumentation for fault detection. Only one of the two RCRS controllers is active at one time. If both controllers are activated simultaneously, controller 1 overrides controller 2. Otherwise, the active controller continues to run. No procedure calls for two controllers to be powered at any one time.

C.2.3 Operations

The RCRS operational sequence is actually a cyclic process. After an initial startup period, immediately after RCRS activation, the sequence repeats every 26 minutes. Originally, the system was designed for 30-minute cycles; however, the time was reduced to improve adsorption performance. The process is summarized in Figure C-5.



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Figure C-5. RCRS Operational Sequence

Each of the steps in the operational sequence, which are called states, is discussed in the following paragraphs. The description of each state is accompanied by graphs illustrating the pressure in the bed versus time for the duration of the state. In all of the figures illustrating bed pressure, a solid line represents 14.7 psia cabin pressure while a dotted line indicates 10.2 psia operations. When only a solid line is shown on a graph, the bed pressure is independent of cabin pressure.

Startup

The controller initiates a startup sequence to vent bed A to vacuum immediately after the RCRS controller is powered. This event purges ammonia that has accumulated in the bed due to the degradation of solid amine. This sequence occurs only when the RCRS controller is initially powered. To purge bed A, all the VCV poppets are closed. PEV 1 opens, venting the bed to vacuum. After 2 minutes, PEV 1 is closed. PEVs 3 and 4 are opened, repressing bed A and venting bed B to vacuum. This procedure equalizes pressure across the bed A air poppets and the bed B vacuum poppets in preparation for bed A to adsorb CO₂.

1. State 1 - Open Vacuum Cycle Valves

Actuator A rotates clockwise, opening the airstream poppets on bed A and the vacuum poppets on bed B. All PEVs are closed. This process opens bed A to the cabin airstream flow and bed B to vacuum.

2. State 2 - Adsorb A/Regenerate B

Bed A begins to adsorb CO₂ from the ARS cabin air stream. At the same time, bed B is regenerated by desorbing CO₂ from the resin. This adsorption cycle lasts 10 minutes, 54 seconds (Figure C-6).

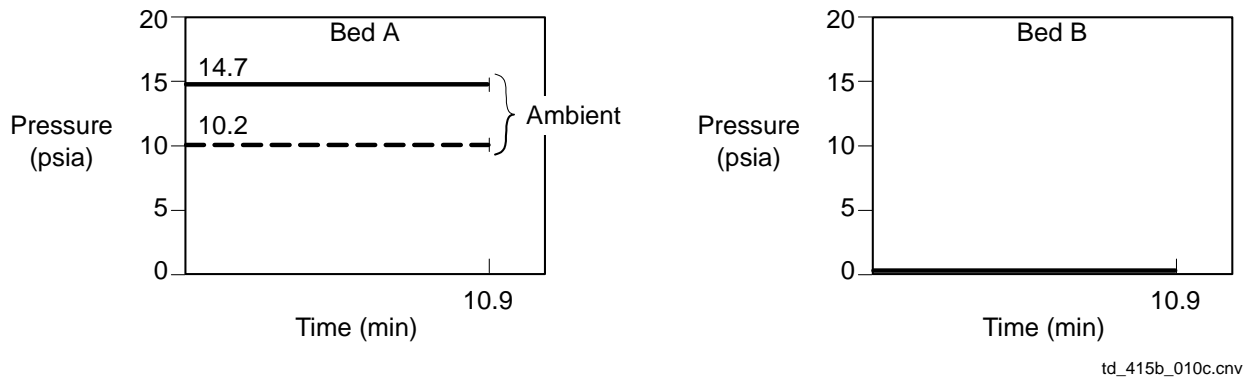


Figure C-6. State 2 Bed Pressures

3. State 3 - Isolate Beds

At the end of the bed A adsorption cycle, all VCVs close by rotating VCV actuator A counterclockwise. This rotation closes the inlets and outlets to both beds. Bed pressures remain the same as they were in state 2 (Figure C-6).

4. State 4 - Ullage-Save Bed A

Bed A is depressurized in preparation for regeneration. The ullage-save compressor draws the cabin air out of the bed through PEV 2 for 75 seconds, which reduces the pressure to about 3 psia, assuming an initial pressure of 14.7 psia (Figure C-7). This step conserves consumables, decreasing the amount of cabin air lost during the regeneration cycle.

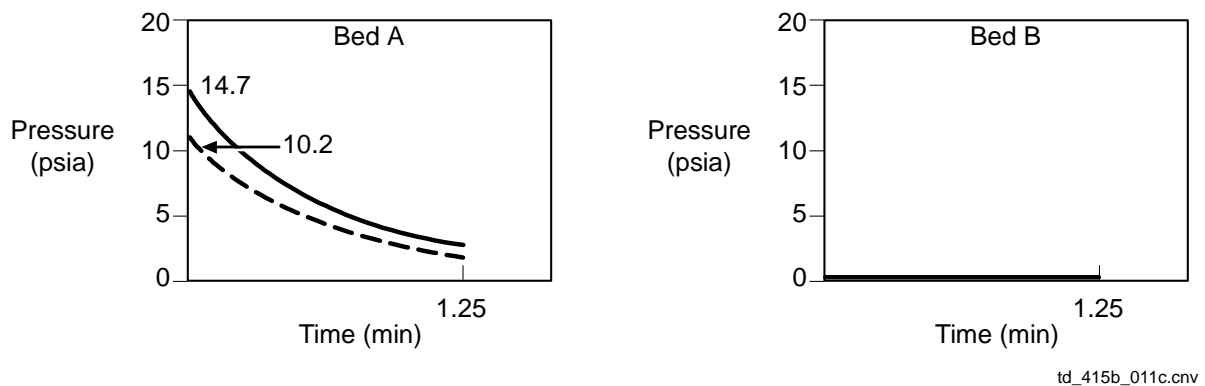


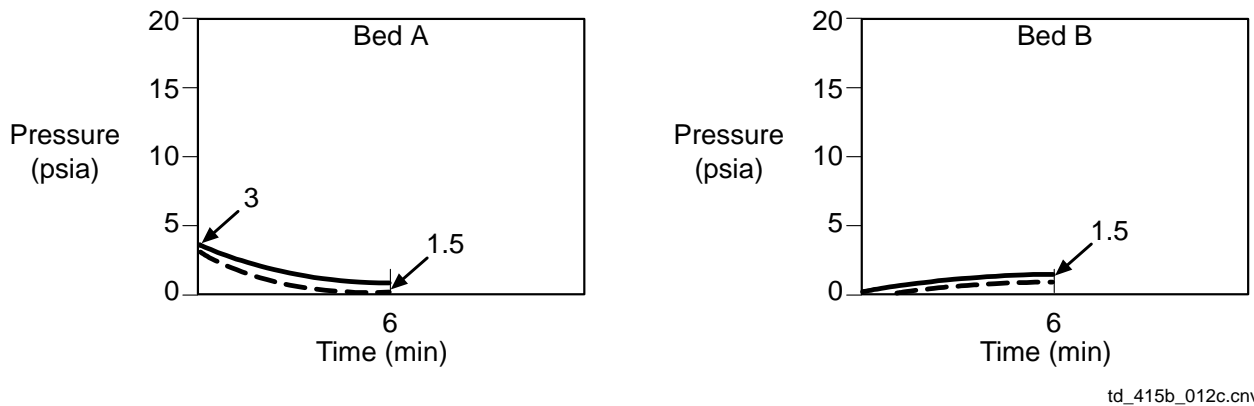
Figure C-7. State 4 Bed Pressures

5. State 4D - Verify Ullage Save

This state turns off the ullage-save compressor.

6. State 5 - Equalize Bed Pressure

The beds are interconnected by opening PEVs 2 and 5. This opening equalizes the pressure within both beds, further conserving cabin air (Figure C-8). By equalizing bed pressure, half of the air remaining in the bed about to be regenerated is transferred to the alternate bed. This step recovers approximately 10 percent of the total bed air volume. Together, states 4 and 5 save up to 90 percent of the cabin air in the regenerating bed, which reduces the amount of air lost to vacuum during the regeneration cycle to approximately 1.6 lb/day.



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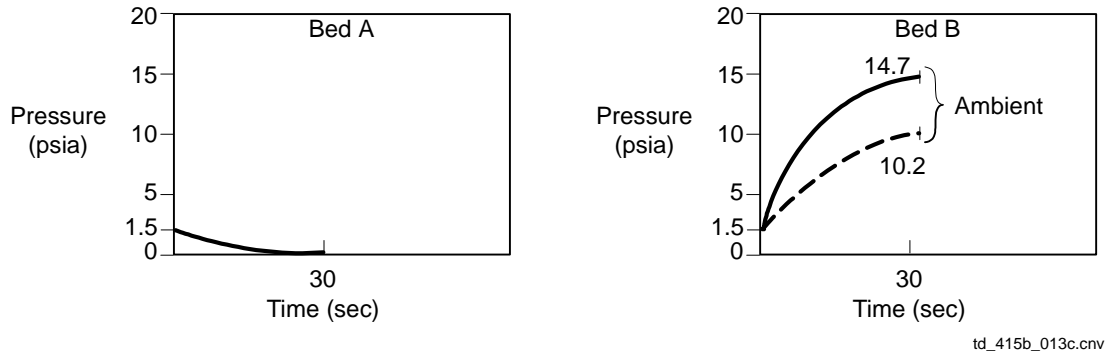
Figure C-8. State 5 Bed Pressures

7. State 5D - Verify Bed Equalization

PEVs 2 and 5 are closed.

8. State 6 - Equalize Valve Pressure

To begin the second adsorption/regeneration cycle, bed A is depressed, and bed B is repressurized with cabin air by opening PEVs 1 and 6, respectively. A dP/dT of -0.02 is expected as bed B is repressurized. The bed pressures are shown in Figure C-9. This 30-second step permits the VCVs to open during state 7 by equalizing the pressure on either side of the poppets. These valves cannot operate against a delta pressure of greater than 3.4 psi, a limitation that was designed to prevent opening a bed to both cabin air and vacuum. This process completes one half cycle of the RCRS operational sequence.



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Figure C-9. State 6 Bed Pressures**9. State 6D - Verify State 6**

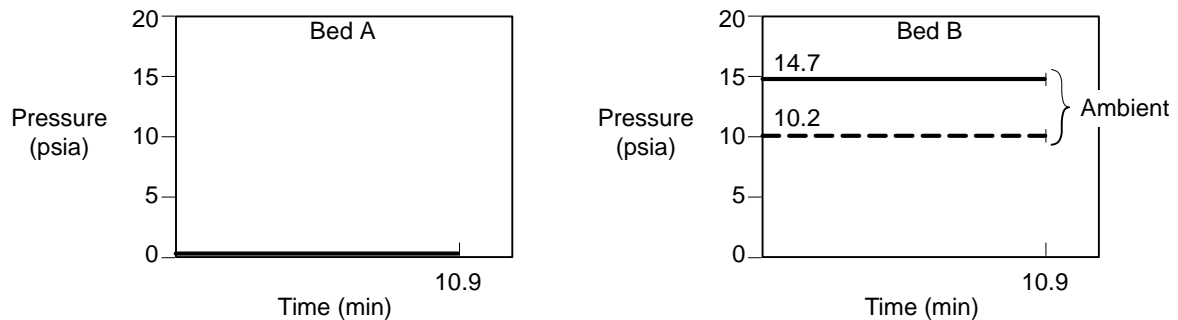
PEVs 1 and 6 are closed.

10. State 7 - Open Vacuum Cycle Valves

The second half-cycle begins by rotating VCV actuator B clockwise, opening the bed A VCV vacuum poppets and the bed B VCV air poppets. Bed pressure remains the same as in state 6.

11. State 8 - Adsorb B/Regenerate A

This is a 10-minute, 54-second step, during which bed B adsorbs CO₂, and bed A desorbs CO₂ to vacuum. Bed pressure is shown in Figure C-10.



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Figure C-10. State 8 Bed Pressures**12. State 9 - Isolate Beds**

VCV actuator B rotates counterclockwise, closing the inlet and outlet to beds A and B.

13. State 10 - Ullage-Save Bed B

After the beds are isolated, bed B begins a 75-second ullage-save cycle. PEV 5 opens, and bed B is depressed to 3 psia by the ullage-save compressor, as shown in Figure C-11.

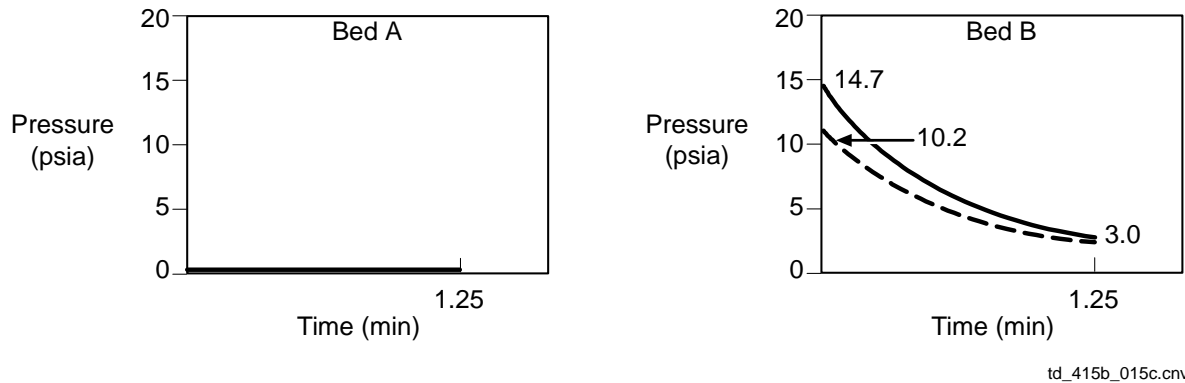


Figure C-11. State 10 Bed Pressures

14. State 10D - Verify Ullage Save

The ullage-save compressor is turned off.

15. State 11 - Equalize Bed Press

The pressure in beds A and B is equalized by opening PEVs 2 and 5. The pressure in bed A increases, while the pressure in Bed B decreases, as shown in Figure C-12. After 6 seconds, these valves are closed.

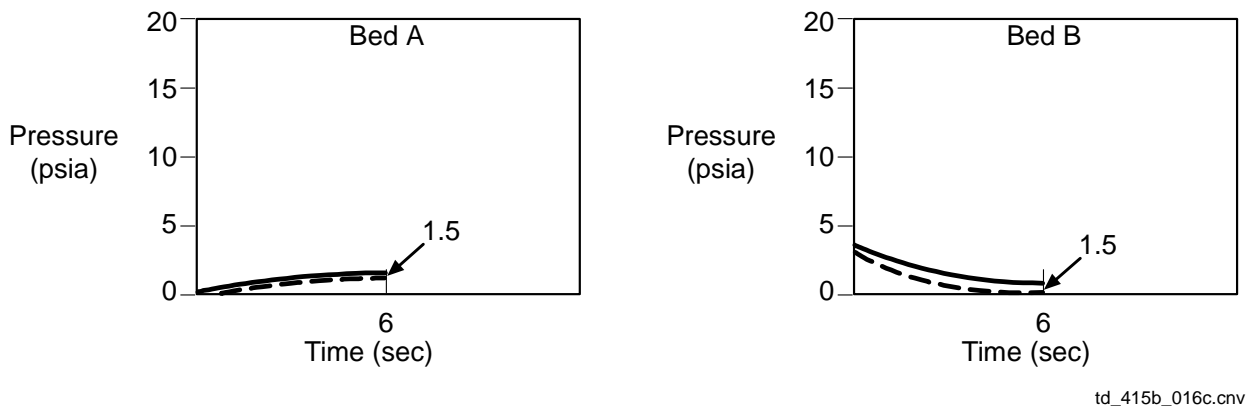


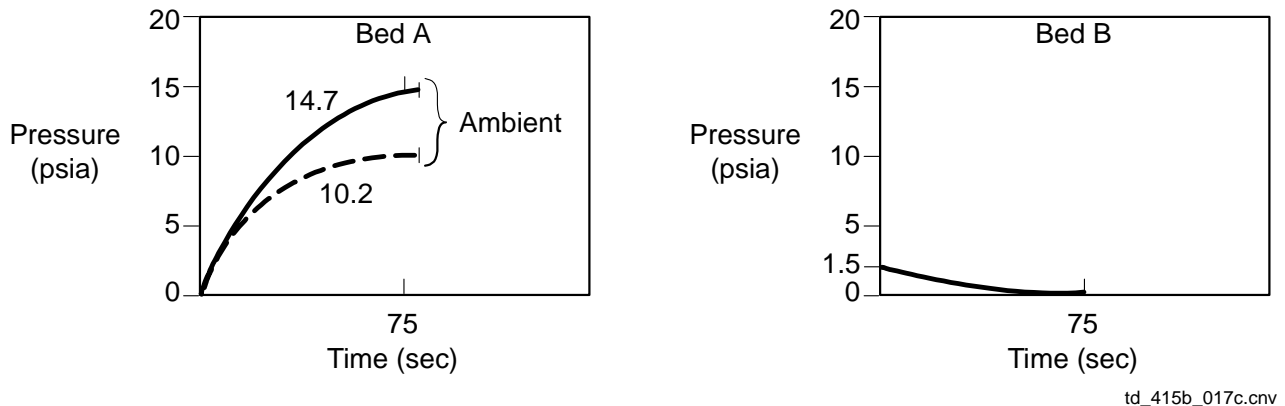
Figure C-12. State 11 Bed Pressures

16. State 11D - Verify Bed Equalization

PEVs 2 and 5 are closed.

17. State 12 - Equalize Valve Pressure

To complete the 26-minute RCRS cycle, bed A is repressurized with cabin air by opening PEV 3. Bed B is vented to vacuum by opening PEV 4. These bed pressures are illustrated in Figure C-13. At the end of 30 seconds, these valves are closed. The cycle starts again at state 1, with bed A prepared to adsorb CO₂ and bed B about to desorb CO₂ to vacuum.



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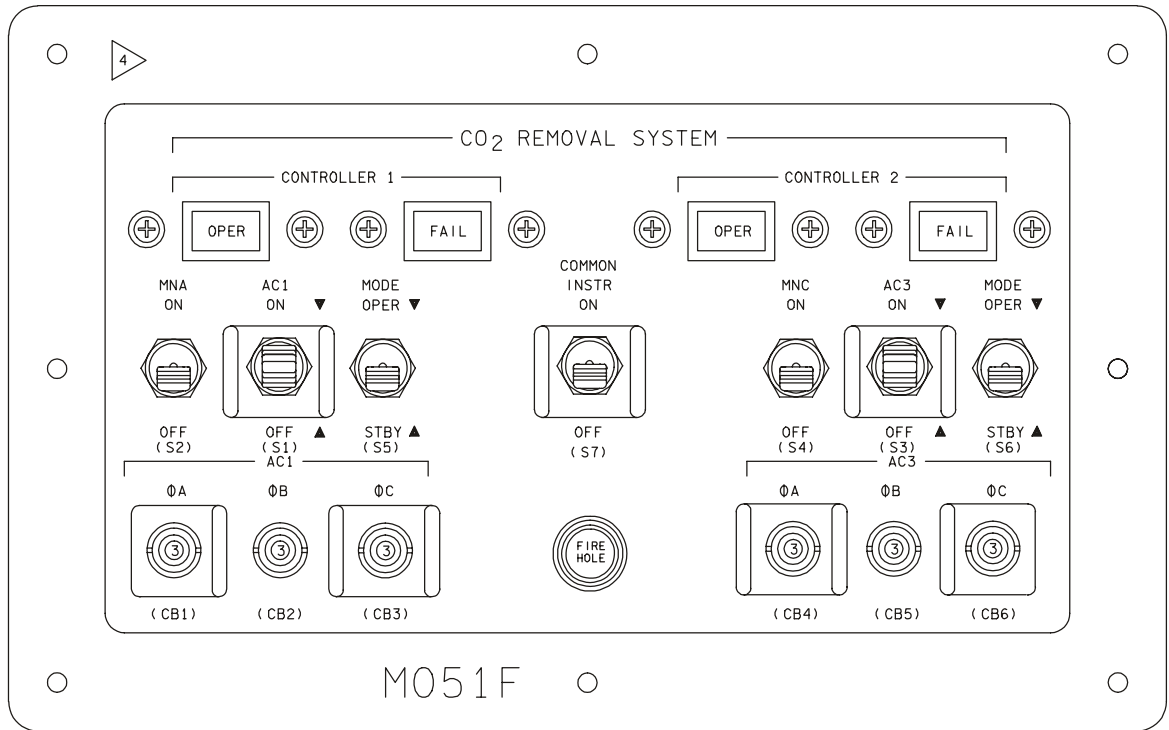
Figure C-13. State 12 Bed Pressures

18. State 12D - Verify State 12

PEVs 3 and 4 are closed.

C.3 CONTROLS

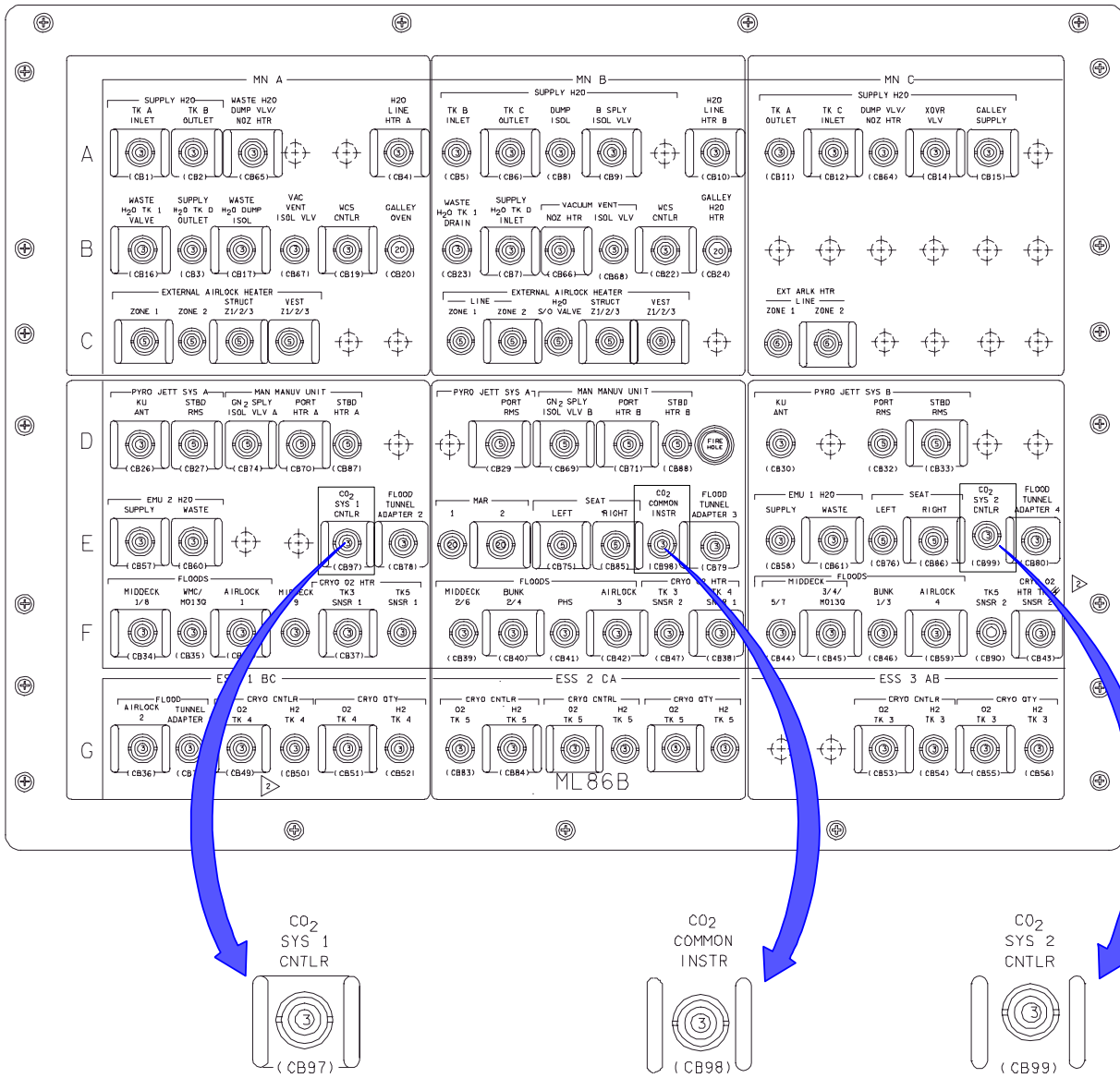
The control switches for the RCRS are located on Panel MO51F, which is illustrated in Figure C-14. Both ac and dc power for controllers 1 and 2 are connected from this panel, using the ac and dc power switches. There is also a mode switch for each of the controllers. This three-position momentary switch controls two functions: OPER, which starts the RCRS operational sequence, and STBY, which takes the controller to the standby mode and stops the operational sequence. Finally, a common instrumentation switch provides power to the RCRS common instrumentation (discussed in the following section). MO51F also has status lights for each controller. The appropriate light will illuminate for an operational state or a failed state based on the active controller.



TD4150C16. PNL 1

Figure C-14. Panel MO51F

Circuit breakers for the ac power sources are found beneath the power switches on Panel MO51F. Panel ML86B:E (Figure C-15) has circuit breakers to supply DC power to each controller as well as the common instrumentation. Controller 1 receives power from AC 1 and MN A, while controller 2 is powered by AC 3 and MN C. The common instrumentation sensors are powered by MN B.



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Figure C-15. Panel ML86B

C.4 INSTRUMENTATION AND DISPLAYS

The RCRS has a variety of sensors used to monitor the health of the system. Controllers 1 and 2 each provide power to their associated bed pressure sensors and bed delta pressures. All other instrumentation, called common instrumentation, is used to monitor the RCRS performance regardless of which controller is being used. In other words, these sensors have no redundancy. The common instrumentation includes the CO₂ partial pressure sensor, the vacuum pressure sensor, the filter delta pressure sensor, and the air inlet temperature. Power for these sensors is provided through the common instrumentation power switch on Panel MO51F from the circuit breaker on ML86B. The range and power source for each sensor are shown in Table C-1.

The common instrumentation has no control function; it is downlinked only for system evaluation.

Table C-1. RCRS sensors

Sensors	Range	Power
Bed pressure A1	0 - 20 psia	Controller 1
Bed pressure B1	0 - 20 psia	Controller 1
Bed pressure A2	0 - 20 psia	Controller 2
Bed pressure B1	0 - 20 psia	Controller 2
Bed delta pressure 1	0 - 5 in. H ₂ O	Controller 1
Bed delta pressure 2	0 - 5 in. H ₂ O	Controller 2
Inlet temperature	32° - 133° F	Common
CO ₂ partial pressure	0 - 30 mm Hg	Common
Vacuum pressure	0 - 5 mm Hg	Common
Filter delta pressure	0 - 3 in. H ₂ O	Common

Crew insight into RCRS operation is found on SPEC 66 - ENVIRONMENT, shown in Figure C-16. This SM display is available in OPS 2 and 4.

XXXX/XXX/066		ENVIRONMENT		XX X	DDD/HH:MM:SS	DDD/HH:MM:SS
CABIN		AV BAY		1	2	3
dP/dT ±.XXS	PRESS XX.XXS	TEMP	XXXXS	XXXXS	XXXXS	
PP02	AIRLK P XX.XS	FAN ΔP	X.XXS	X.XXS	X.XXS	
A X.XXS	FAN ΔP X.XXS	SUPPLY H2O				
B X.XXS	HX OUT T XXXS	QTY A	XXXXS	PRESS	XXXXS	
C X.XXS	CABIN T XXXS	B	XXXXS	DMP LN T	XXXXS	
PPCO2 XX.XS		C	XXXXS	NOZ T A	XXXXS	
		D	XXXXS	B	XXXXS	
O2 FLOW	X.XS X.XS	WASTE H2O				
REG P	XXXXS XXXS	QTY 1	XXXXS	PRESS	XXXXS	
N2 FLOW	X.XS X.XS			DMP LN T	XXXXS	
REG P	XXXXS XXXS			NOZ T A	XXXXS	
O2/N2 CNTL VLV	XXS XXS	VAC VT NOZ T XXXS				
H2O TK N2 P	XXXXS XXXS	CO2 CNTLR 1XS 2XS				
N2 QTY	XXXXS XXXS	FILTER ΔP		X.XXS		
EMER O2 REG P	XXXXS	PPCO2		XX.XS		
		TEMP		XXX.XS		
IMU FAN A B C ΔP	XS XS XS X.XS	BED A PRESS	XX.XS	XX.XS		
HUMID SEP XS XS		B PRESS	XX.XS	XX.XS		
		ΔP	X.XXS	X.XXS		
		VAC PRESS	X.XS			
						(XX)

Figure C-16. SPEC 66 - Environment

The RCRS information is displayed in the lower right corner. Table C-2 shows the parameter characteristics for the outlined portion of Figure C-16.

Table C-2. SPEC 66 RCRS parameter characteristics

CRT name	Units	Displayed range	Status indicators					
CO ₂ CNTLR 1, 2	off/on	Blank or *	M					↓
FILTER ΔP	in. H ₂ O	0 to 3	M	H	L	↑		↓
PPCO ₂	mm Hg	0 to 30	M	H	L	↑		
TEMP	° F	32 to 133	M	H	L			
BED A PRESS	psia	0 to 20	M	H	L			
B PRESS	psia	0 to 20	M	H	L			
ΔP	in. H ₂ O	0 to 5	M	H	L			
VAC PRESS	mm Hg	0 to 5	M	H	L	↑		↓

Note: [1]: Parameter is a multidiscrete indication that requires AC power and DC power ON discrete. An "*" indicates that the system is powered but not operating. A "↓" will appear for only 6 seconds from time of failure. Controller FAIL light on Panel MO51F will remain latched during shutdown.

C.5 FAULT DETECTION

The fault detection logic of the RCRS monitors the status of various parameters, compressor RPM, and the position of valves in the RCRS. If a fault is detected, the logic will shut down the RCRS and turn on the fault light for the appropriate controller on Panel MO51F. In addition, telemetry for the fail discrete will be set to "1" for 6 seconds, then returned to "0." However, the fault light remains lit even after the fail discrete returns to "0."

As mentioned previously, the RCRS will continue to operate with increased cabin air loss in the event of a compressor failure. Thirty seconds after the compressor is turned on, it checks to ensure that the pressure in the bed being evacuated is less than two thirds of the bed pressure at the start of the compressor cycle. If the check fails, the compressor is inhibited until the controller is cycled off and back on or until the alternate controller is selected. No fault light or telemetry is set for a compressor failure. There is no crew indication for this failure case, except that the bed pressure will not decrease as expected during a ullage-save cycle.

C.6 FAULT MESSAGES

There are two messages specific to the RCRS. The messages are S66 CO₂ RL SYS and S66 CO₂ RL SYS PCO₂. Some of the typical causes for each message are as follows.

- a. S66 CO₂ RL SYS - This message is annunciated when the RCRS controller fails or when the fault detection logic detects an incorrect pressure in either of the two removal beds.
- b. S66 CO₂ RL SYS PCO₂ - This message is annunciated when the partial pressure of carbon dioxide is detected to be out of limit.

C.7 REFERENCES

1. Oulette, F. A.; Winkler, H. E.; and Smith, G. S.: The Extended Duration Orbiter Regenerable CO (sic) Removal System. Proceedings of the 20th Intersociety Conference on Environmental Systems, Williamsburg, VA, 1990.
2. Drawing 6.12, sheets 1 and 2. Space Shuttle Systems Handbook, Rev. E, DCN-1. JSC-11174.
3. Wydeven, T.: A Survey of Some Regenerative Physico-Chemical Life Support Technology. NASA N89-12207, Ames Research Center, 1989.

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Training Materials Evaluation

Please answer the following questions regarding the lesson you just completed. Your feedback will allow us to produce more effective training materials. When complete, mail to: **Shuttle Systems Group/DT36.**

TITLE/CODE OF LESSON: Environmental Control and Life Support System/ECLSS 21002

SIZE OF AUDIENCE/CLASS: _____

1. How well did this lesson meet its purpose?

For each statement below, mark one box on the scale:

- a. *The lesson objectives are clearly stated.*
- b. *The lesson objectives are clearly defined.*
- c. *The lesson effectively teaches skills and information.*
- d. *The lesson meets its purpose and objectives.*

Strongly Disagree					Strongly Agree
<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>

2. How satisfying is the content of this lesson?

For each statement below, mark one box on the scale:

- a. *The information is structured in a logical flow.*
- b. *The content is clear.*
- c. *The content is complete.*
- d. *The level of detail is correct for this information.*
- e. *The amount of information is effective.*
- f. *The graphics contribute to my understanding.*

Strongly Disagree					Strongly Agree
<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>

3. How appealing was the presentation of this lesson?

For each statement below, mark one box on the scale:

- a. *The overall presentation is appealing.*
- b. *The visuals chosen are appropriate for the lesson.*
- c. *The visuals make the information more interesting.*
- d. *The graphics are legibly reproduced.*
- e. *The audio/visual or print quality is good.*

Strongly Disagree					Strongly Agree
<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>

4. How valuable is this information?

For each statement below, mark one box on the scale:

- a. *The lesson teaches skills and information I need.*
- b. *The lesson meets my expectations.*
- c. *This information is useful for later reference.*
- d. *I would recommend this lesson to others.*

Strongly Disagree					Strongly Agree
<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>

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EXPLAIN ANY NEGATIVE ANSWERS IN SPECIFIC TERMS
THANK YOU IN ADVANCE FOR YOUR ASSISTANCE!**

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