2.9 ENVIRONMENTAL CONTROL AND LIFE SUPPORT SYSTEM (ECLSS)

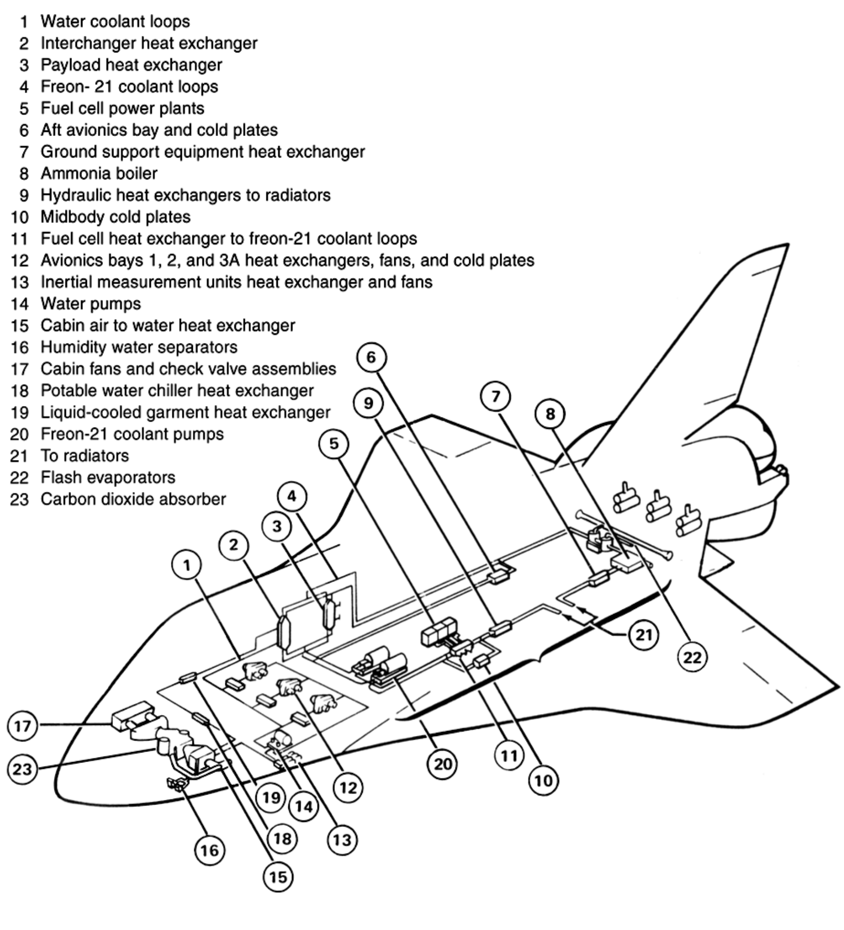
CONTENTS

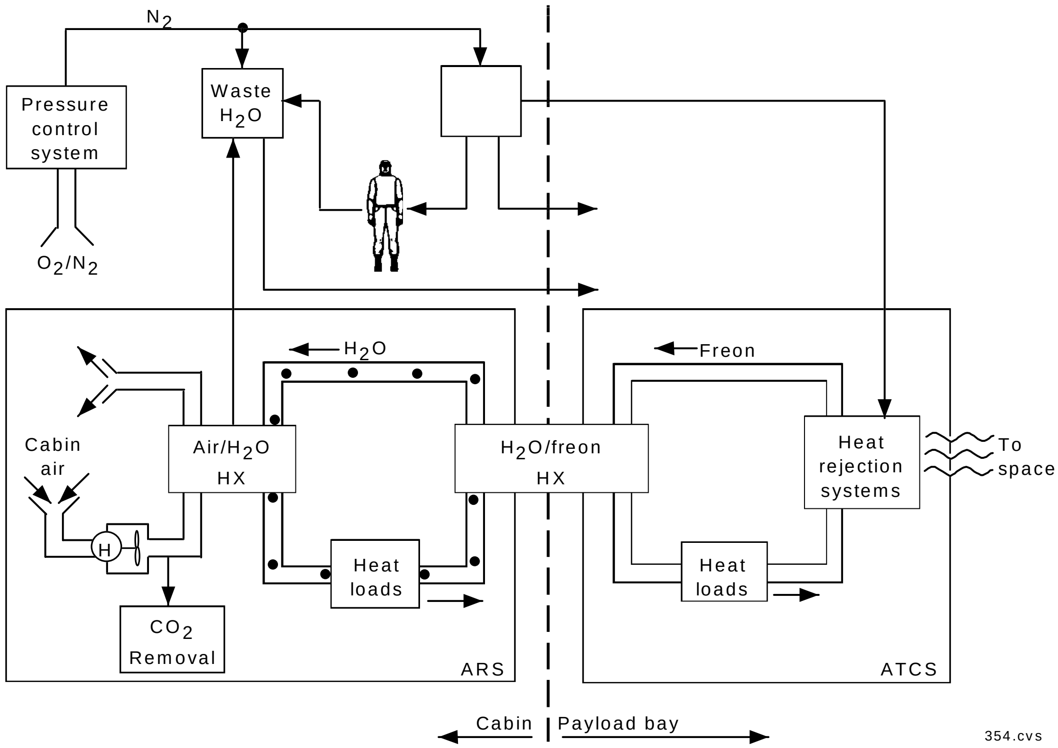
Description

The ECLSS maintains the orbiter's thermal stability and provides a pressurized, habitable environment for the crew and onboard avionics. The ECLSS also manages the storage and disposal of water and crew waste.

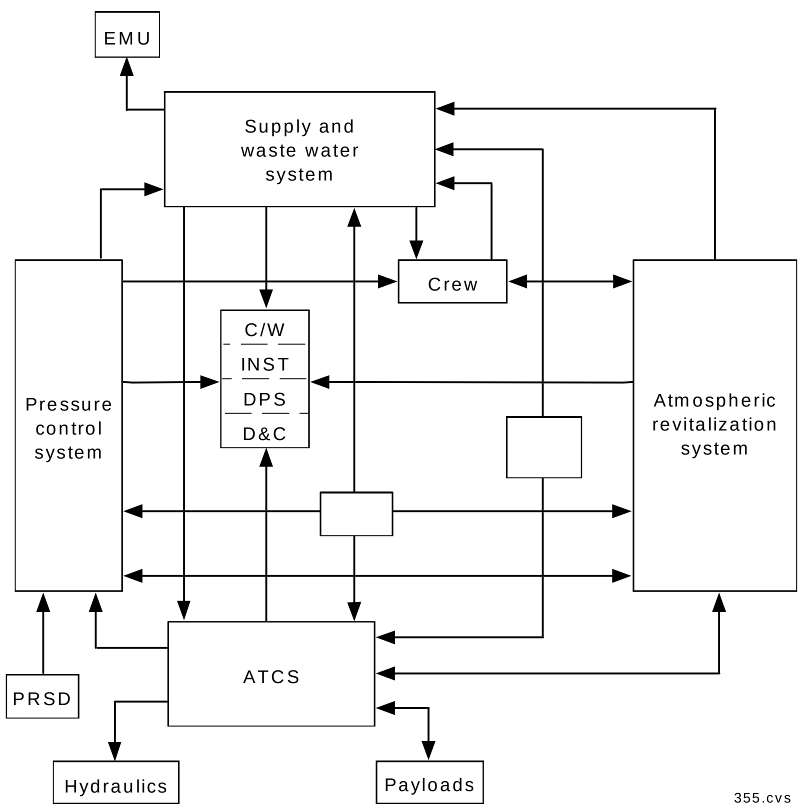
ECLSS is functionally divided into four systems:

1. **Pressure control system**, which maintains the crew compartment at 14.7 psia with a breathable mixture of oxygen and nitrogen. Nitrogen is also used to pressurize the supply and wastewater tanks.
2. **Atmospheric revitalization system**, which uses air circulation and water coolant loops to remove heat, control humidity, and clean and purify cabin air.
3. **Active thermal control system**, which consists of two Freon loops that collect waste heat from orbiter systems and transfer the heat overboard.
4. **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. The system also has the capability to dump supply and wastewater overboard.





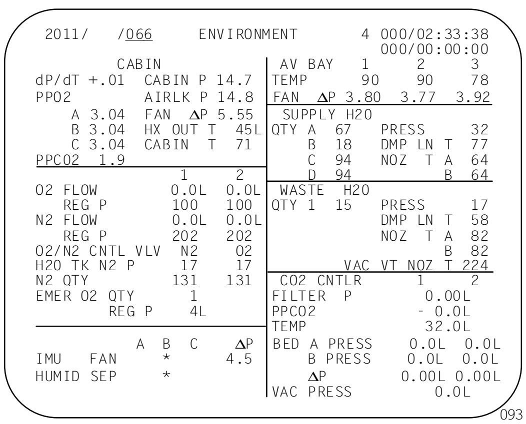
Environmental Control and Life Support System Overview



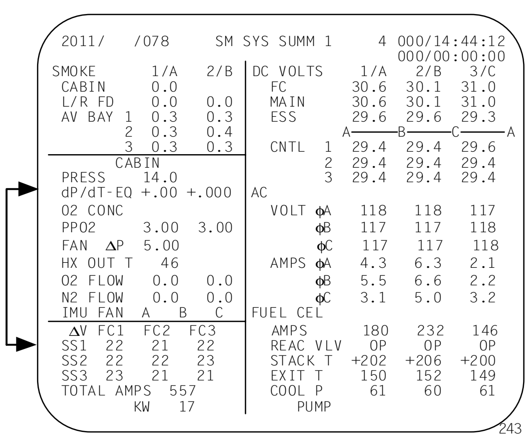
Environmental Control and Life Support System Interfaces

The crew compartment provides a life-sustaining environment for the flight crew. The crew cabin volume with the airlock inside the middeck is 2,475 cubic feet (2,325 cubic feet for the orbiter cabin and 150 cubic feet for the airlock). For EVA, the airlock is depressurized and repressurized. Under normal circumstances, the cabin may be depressed to 10.2 psia to ease prebreathe requirements prior to an EVA. When the airlock is located outside the middeck in the payload bay, the crew cabin volume is 2,625 cubic feet. The external airlock volume varies and is based on mission-specific configuration. The external airlock is covered in detail in the Orbiter Docking System (ODS) section of this document.

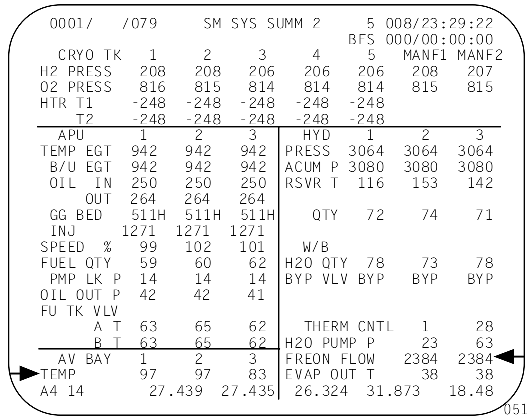
Most ECLSS parameters can be monitored during ascent and entry on BFS DISP 78 (SM SYS SUMM 1) and BFS DISP 79 (SM SYS SUMM 2) displays. On orbit ECLSS parameters are also available on SM DISP 66 (ENVIRONMENT) and SM DISP 88 (APU/ENVIRON THERM) displays.



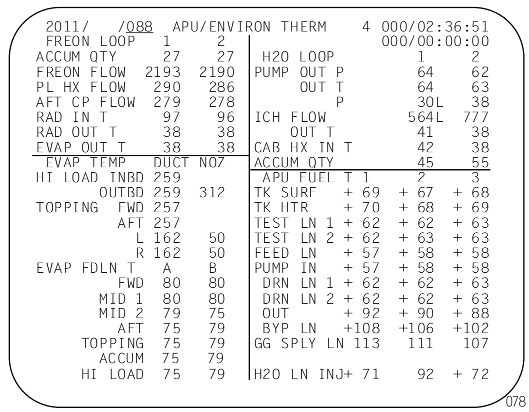
ENVIRONMENTAL Display (DISP 66)



ECLSS Parameters on the BFS SM SYS SUMM 1 (DISP 78) Display



ECLSS Parameters on the BFS SM SYS SUMM 2 (DISP 79) Display



APU/ENVIRON THERM Display (DISP 88)

Pressure Control System

The pressure control system normally pressurizes the crew cabin to 14.7 ± 0.2 psia. It maintains the cabin at an average 80-percent nitrogen (130 pounds) and 20-percent oxygen (40 pounds) mixture that closely resembles the atmosphere at sea level on Earth. The system also provides the cabin atmosphere necessary to cool cabin-air-cooled equipment. Oxygen partial pressure is maintained automatically between 2.95 and 3.45 psi, with sufficient nitrogen pressure of 11.5 psia added to achieve the cabin total pressure of 14.7 ± 0.2 psia. Positive and negative pressure relief valves protect the structural integrity of the cabin from over- and underpressurization respectively. The pressure control system nitrogen is used to pressurize the supply and wastewater tanks. The system also provides breathing oxygen directly to the launch and entry suit helmets and to emergency breathing masks.

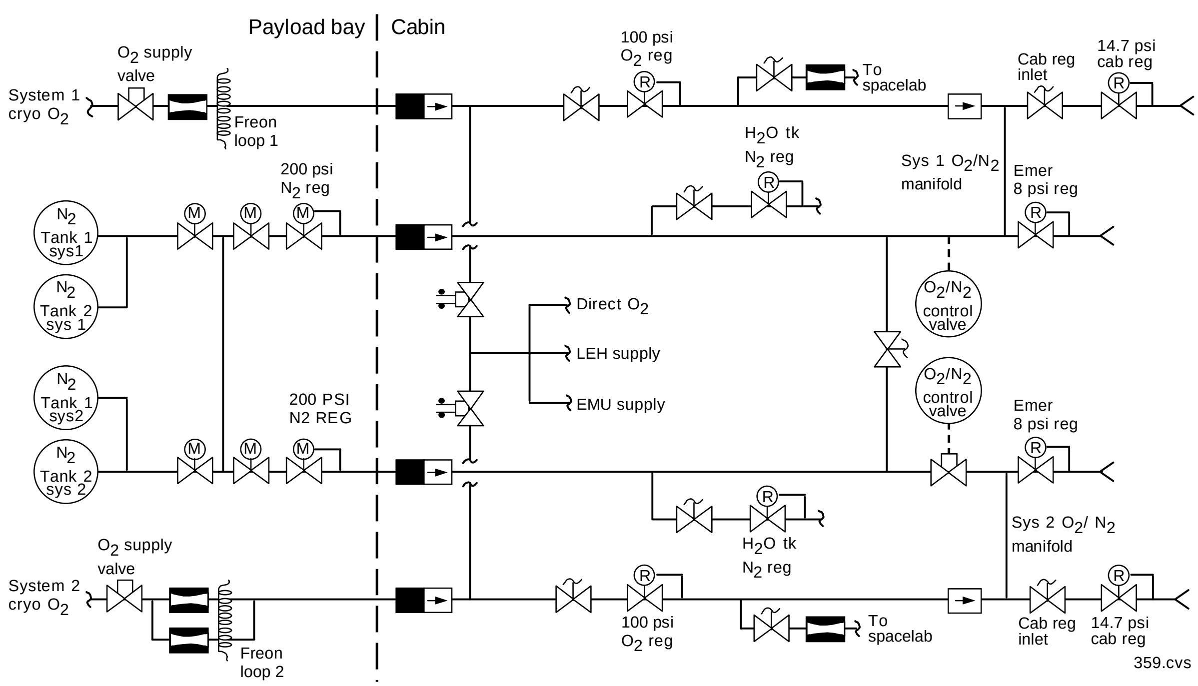
Cabin pressure is maintained by either of two pressure control systems (designated PCS 1 and PCS 2). Each pressure control system consists of a liquid oxygen storage system and a gaseous nitrogen storage system. The PCS oxygen is supplied from the electrical power system's (EPS) cryogenic oxygen in the midfuselage of the orbiter. The cryogenic supercritical oxygen storage system is controlled by electrical heaters within the tanks and supplies oxygen to the ECLSS pressure control system at a pressure of 803 to 883 psia in a gaseous state. The nitrogen storage tanks are serviced to a nominal pressure of 2,964 psia at 80° F. Normal on-orbit operations use one oxygen and one nitrogen supply system.

Cabin pressure is controlled by the nitrogen/oxygen control and supply panels, the PPO_2 sensor, and pressure relief valves. The nitrogen/oxygen control panel selects and regulates primary (pressure control system 1) or secondary (pressure control system 2) oxygen and nitrogen. The system 1 and system 2 nitrogen/oxygen supply panels are located in the lower forward portion of the midfuselage. Both O_2 and N_2 supply systems 1 and 2 have a crossover capability. This allows the respective systems to be tied together.

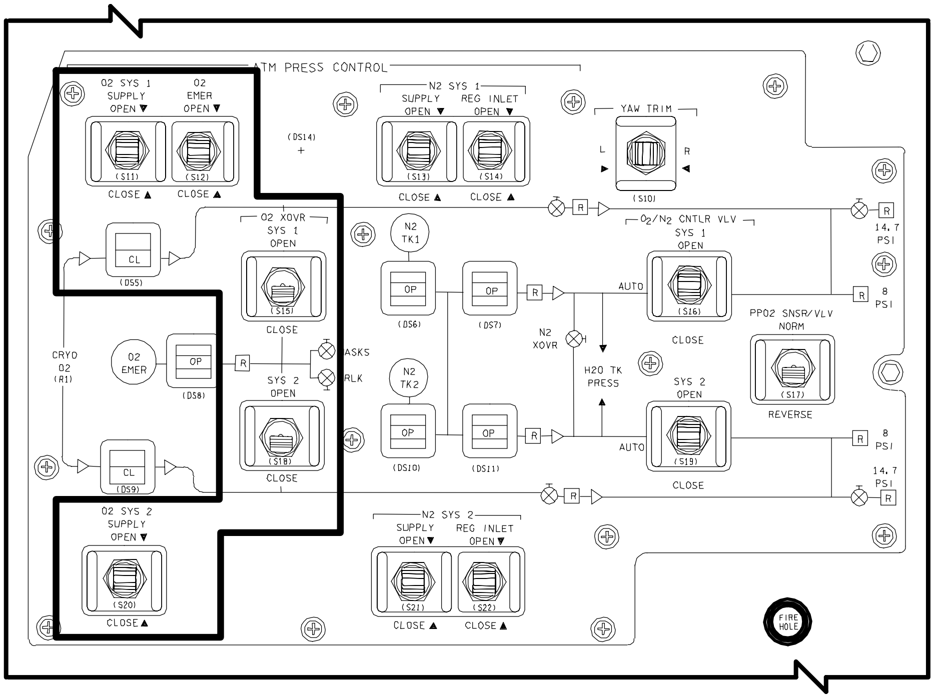
The oxygen supply system provides the "makeup" cabin oxygen gas for flight crew consumption and makeup for cabin leakage. The nitrogen system provides nitrogen for pressurizing the cabin and the potable and wastewater tanks. Each crew member uses an average of 1.76 pounds of oxygen per day. Up to 7.7 pounds of nitrogen and 9 pounds of oxygen are used per day for normal loss of crew cabin gas to space and metabolic usage. The potable and wastewater tanks are pressurized to 17 psig in order to expel water from the tanks for use by the crew or dumping overboard.

Oxygen System

Oxygen from the power reactant storage and distribution system (cryogenic oxygen supply system) is routed to the pressure control oxygen system 1 and system 2 supply valves. These valves are controlled by the *ATM PRESS CONTROL O2 SYS 1 SUPPLY* and *O2 SYS 2 SUPPLY* switches on panel L2. When one of the switches is momentarily positioned to *OPEN*, the corresponding valve opens to permit oxygen to flow through an oxygen restrictor at a maximum flow of approximately 25 pounds per hour for either system 1 or 2. The Oxygen restrictor also functions as a heat exchanger with the Freon



Pressure Control System

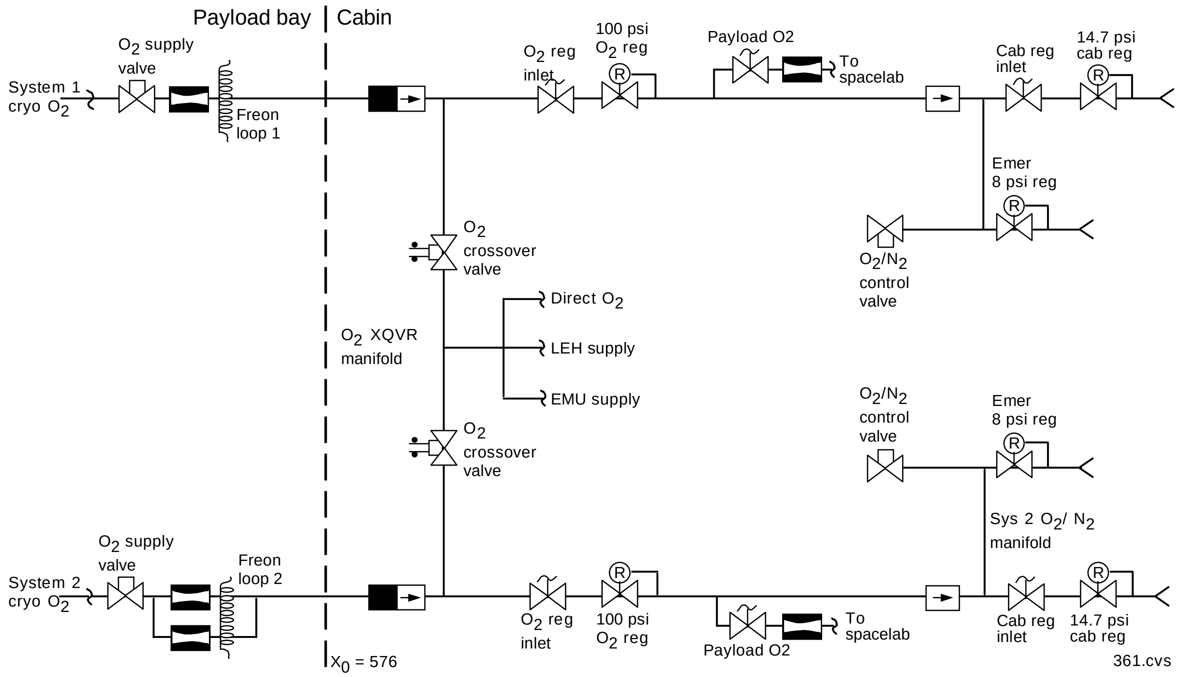


ATM PRESS CONTROL 02 SYS SUPPLY and XOVR Switches and Talkbacks on Panel L2

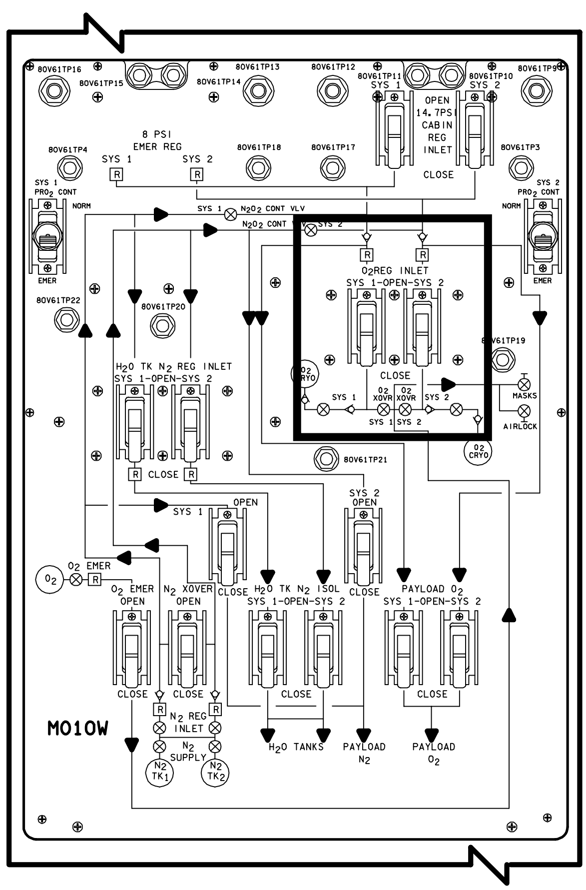
coolant loop, warming the oxygen supplied to the oxygen regulator of that system before it flows into the cabin. Freon loop 1 warms system 1 oxygen, and loop 2 warms system 2. A talkback indicates *OP* when the O_2 supply valve is open. When the switch is momentarily positioned to *CLOSE*, the valve is closed, isolating that oxygen supply system. The talkback indicates *CL*.

Next, the oxygen piping penetrates the bulkhead and enters the crew compartment. A check valve downstream of the Freon loop heat exchanger prevents oxygen from flowing from one supply source to the other when the crossover valves are open. Downstream of the oxygen check valve, oxygen systems 1 and 2 are connected by a crossover valve that permits system 1 and system 2 to be interconnected. The crossover valves are controlled by the *ATM PRESS CONTROL O2 XOVR SYS 1* and *SYS 2* switches on panel L2. When one of the switches is positioned to *OPEN*, the associated oxygen supply system is directed to the launch and entry helmet O_2 supply 1 and 2 manual valves, airlock oxygen 1 and 2 extravehicular mobility unit, and direct O_2. If both switches are positioned to *OPEN*, oxygen supply systems 1 and 2 are interconnected. When a switch is positioned to *CLOSE*, that oxygen supply system is isolated from the crossover feature. The crossover valves are normally open.

Downstream of the oxygen crossover line is an oxygen regulator inlet manual valve. When the valve is manually positioned to *OPEN* by the *O_2 REG INLET* switch on panel MO10W, oxygen is directed to a regulator, which reduces the oxygen supply pressure to 100 ± 10 psig. Each regulator valve is composed of a manual toggle ON/OFF valve, a regulator, and a relief valve. The relief valve relieves pressure at 245 psig and reseats at 215 psig. The relief pressure is vented into the crew cabin. The regulated O_2 then passes through another check valve that prevents downstream nitrogen from entering the oxygen system. The oxygen enters a manifold that is shared by the nitrogen system. This manifold is connected to its 14.7 psi cabin regulator inlet manual valve and the 8 psi regulator. Between the oxygen regulator and the oxygen check valve, the oxygen is fed to the payload oxygen manual valve for use by the payload if required. This valve, as well as the 14.7 cabin pressure manual valve, is located on panel MO10W. "Make up" O_2 for metabolic usage is provided by a bleed orifice inserted on orbit into LEH quick disconnect 8 on panel MO69M.

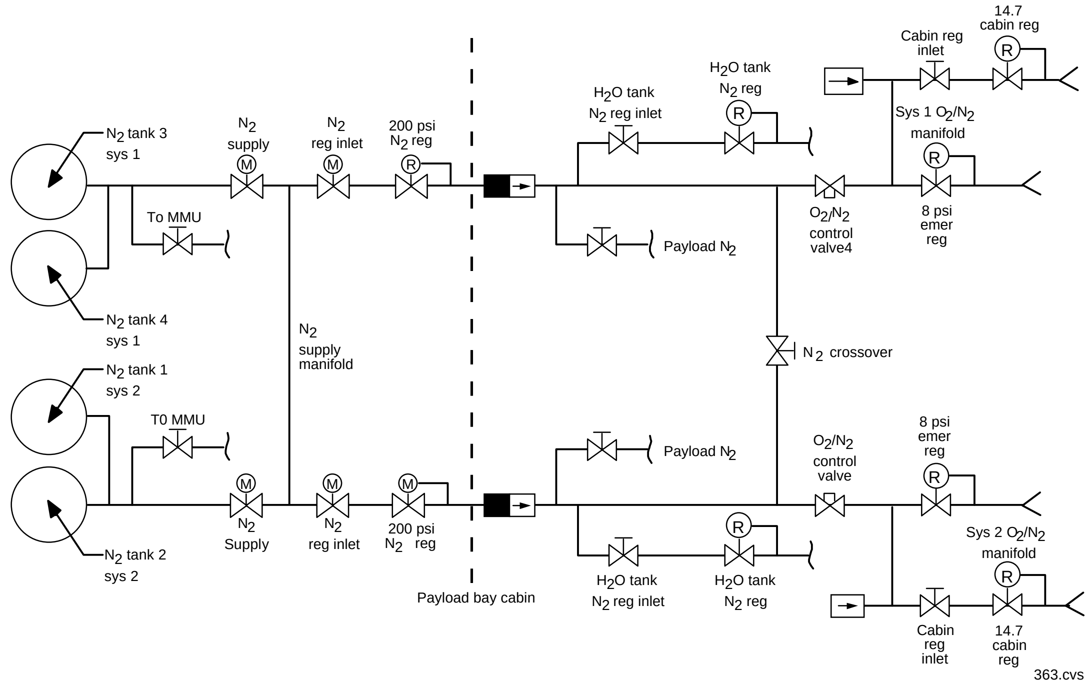


Oxygen System



O_2 REG INLET Switches on panel MO10W

Note: OV-102 has tanks 2, 3, and 4 on Sys 1; OV-103 and -105 have an additional tank 3 on Sys 2.



Nitrogen System for Nominal Mission OV-104

Nitrogen System

Gaseous nitrogen is supplied from two nitrogen systems, consisting of either two or three nitrogen tanks (depending on orbiter) per system that are permanently mounted in the payload bay. System 1 is mounted on the port side and system 2 is on the starboard side. All four orbiters have been modified to perform extended duration orbiter (EDO) missions. OV-104 is the only orbiter with four nitrogen tanks; OVs-102, -103, and -105 each have five tanks. In all configurations, tanks 1 and 2 are installed on the forward end of the payload bay, and tanks 3 and 4 are installed on the aft end. Tanks 1 and 2 (one or both) on system 1 may be installed only as a mission kit.

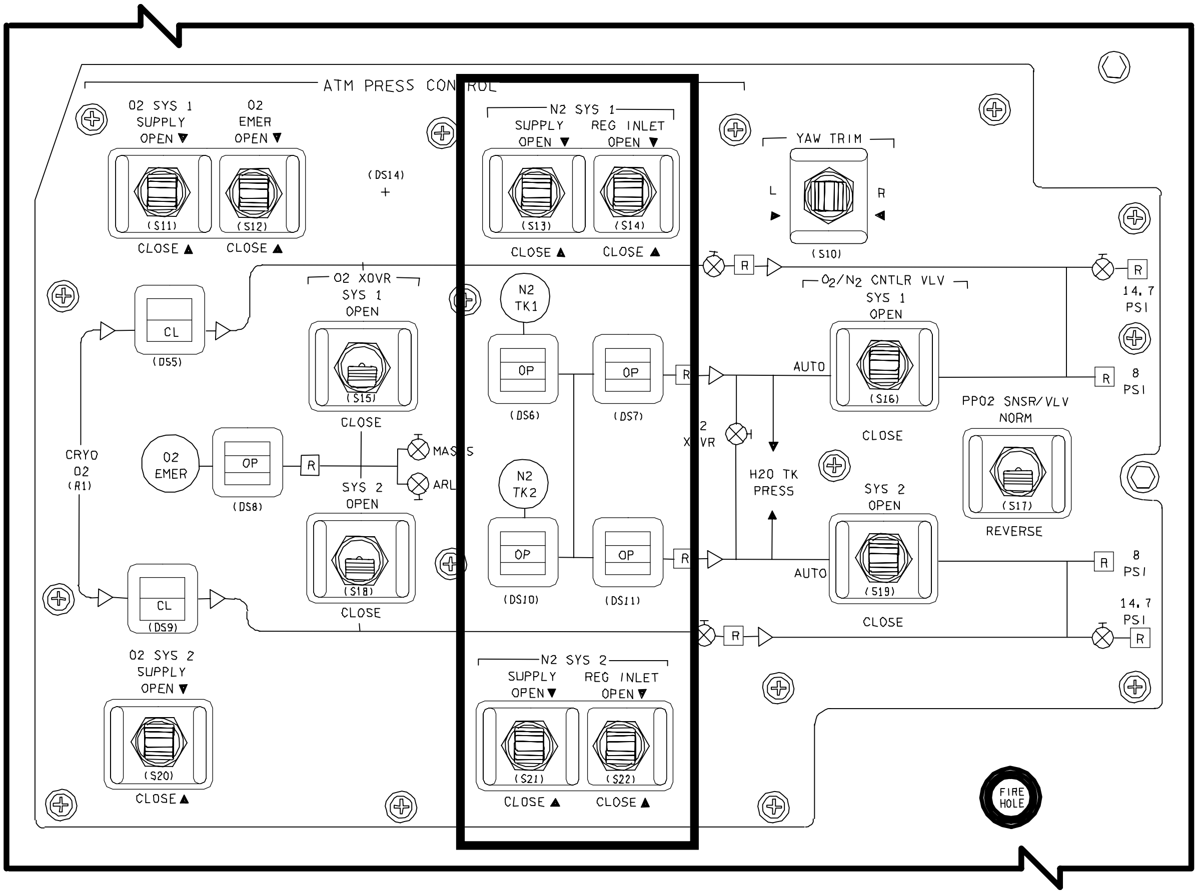
OV-102
- System 1 tanks 2, 3, 4
- System 2 tanks 1, 2

OV-103, -105
- System 1 tanks 3, 4
- System 2 tanks 1, 2, 3

OV-104
- System 1 tanks 3, 4
- System 2 tanks 1, 2

The nitrogen supply tanks are constructed of filament-wound Kevlar fiber with a titanium liner. Each nitrogen tank is serviced to a nominal pressure of 2,964 psia at 80° F, with a volume of 8,181 cubic inches. The nitrogen tanks in each system (two or three nominally, with up to four tanks on EDO missions) are manifolded together.

The primary and secondary nitrogen supply systems are controlled by the atmosphere pressure control nitrogen supply valves in each system. Each valve is controlled by its corresponding *ATM PRESS CONTROL N2 SYS 1* and *SYS 2 SUPPLY* switch on panel L2. When a switch is momentarily positioned to *OPEN*, nitrogen flows to both atmosphere pressure control system regulator inlet valves, since both sets of tanks are manifolded together downstream of the supply valve. A talkback near the switch indicates barberpole when the motor-operated valve is in transit, and *OP* when the supply valve is open. When the switch is positioned to *CLOSE*, that nitrogen supply system is isolated from the nitrogen system regulator inlet valve, and the talkback indicator shows *CL*.



ATM PRESS CONTROL N2 SYS SUPPLY and REG INLET Switches and Talkbacks on Panel L2

The nitrogen regulator inlet valve in each nitrogen system is controlled by its respective *ATM PRESS CONTROL* N_2 *SYS REG INLET* switch on panel L2. When the switch is positioned to *OPEN*, that system's nitrogen at source pressure is directed to the system's nitrogen regulator. A talkback indicator below the *SYS 1* switch and above the *SYS 2* switch indicates barberpole when the motor-operated valve is in transit, and *OP* when the valve is open. When the switch is positioned to *CLOSE*, the supplied nitrogen is isolated from the system's nitrogen regulator, and the talkback indicator indicates *CL*.

The nitrogen regulators in supply systems 1 and 2 reduce the pressure to 200 ± 15 psig. Each nitrogen regulator is a two-stage regulator with a relief valve. The relief valve relieves pressure at 295 psig into the vacuum vent line and reseats at 245 psig.

The pressure regulated nitrogen of each system is directed to the nitrogen manual crossover valve, the manual water tank regulator inlet valve, the payload manual nitrogen supply valve, and the oxygen and nitrogen controller valve in each system. The manual valves are controlled from panel MO10W, and the controller valve is controlled from the panel L2 *O2/N2 CNTLR VLV* switch.

The nitrogen crossover manual valve connects both regulated nitrogen systems when the valve is open and isolates the nitrogen supply systems from each other when closed. Normally, the valve is always closed. A check valve between the nitrogen regulator and nitrogen crossover valve in each nitrogen-regulated supply line prevents back flow from one nitrogen source supply to the other if the nitrogen crossover valve is open. The nitrogen system can supply at least 125 lb/hr from each system.

Oxygen/Nitrogen Manifold

The O_2/N_2 control valve controls the flow of either N_2 or O_2 into the O_2/N_2 manifold, depending on the partial pressure of oxygen in the cabin. Whatever gas (O_2/N_2) is in the O_2/N_2 manifold will flow into the cabin when the cabin pressure drops below 14.7 psia, and the 14.7 regulator valve is open. This "makeup" flow will continue as long as the cabin pressure is less than 14.7. 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 flow.

The 14.7 psi cabin regulator regulates the cabin pressure to 14.7 ± 0.2 psia and is capable of a maximum flow of 75 to 145 lb/hr. The 8 psi emergency regulator is designed to regulate to 8 ± 0.2 psia and is also capable of a maximum flow of 75 to 145 lb/hr. Both the 14.7 and 8 psi regulators flow into the cabin through a port in panel MO10W located above the waste management system compartment. Regulators consist of two stages: a low-flow regulator (0 to 0.75 lb/hr) for small demand when the cabin pressure is near 14.7 psia and a high flow regulator (0.75 to at least 75 lb/hr) for high demand when cabin pressure is significantly below 14.7 psia.

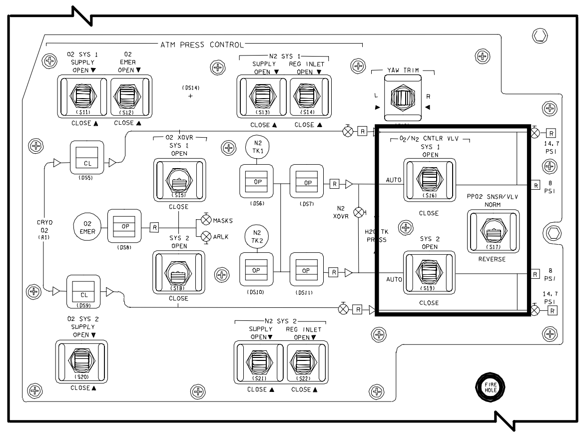
NOTE

> Crewmembers should be aware that the regulators make a noticeable sound when they flow oxygen or nitrogen into the cabin. It is most noticeable in the vicinity of the waste management system compartment. Additionally, use of the WCS during high N_2 flow is not advisable due to the possibility of hypoxia.

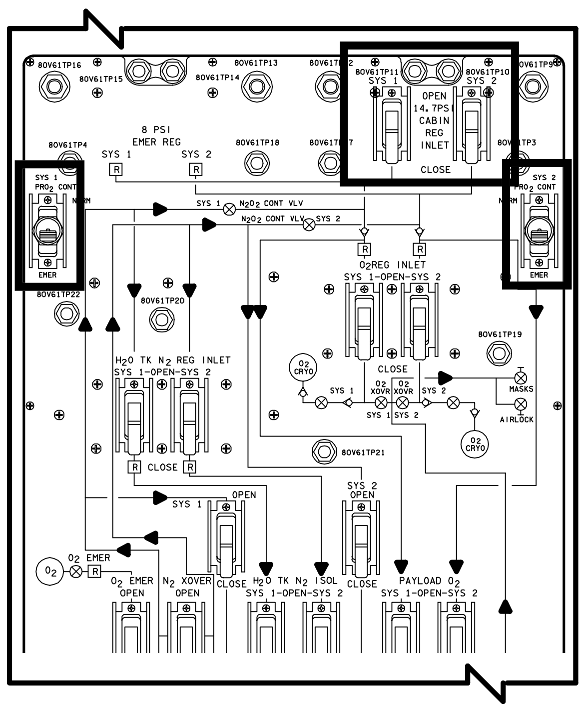
PPO_2 Control

The partial pressure of oxygen (PPO_2) in the crew cabin is controlled automatically during orbit by one of two O_2/N_2 controllers. Two PPO_2 sensors (A and B) located under the mission specialist station provide inputs to the PPO_2 control systems 1 and 2 controller and switches, respectively.

When either the *SYS 1* or *SYS 2 PPO_2 CONT* switch on panel MO10W is positioned to *NORM*, and the *PPO2 SNSR/VLV* switch on panel L2 is also positioned to *NORM*, electrical power is supplied to the corresponding *ATM PRESS CONTROL O_2/N_2 CNTLR VLV* switches on panel L2 for system 1 or 2. When the *O_2/N_2 CNTLR VLV* switch on panel L2 is positioned to *AUTO*, electrical power automatically energizes or deenergizes the corresponding O_2/N_2 control valve.



PPO2 SNSR/VLV and O_2/N_2 CNTRL VLV Switches on Panel L2



PPO_2 CONT and CABIN REG INLET Switches on Panel MO10W

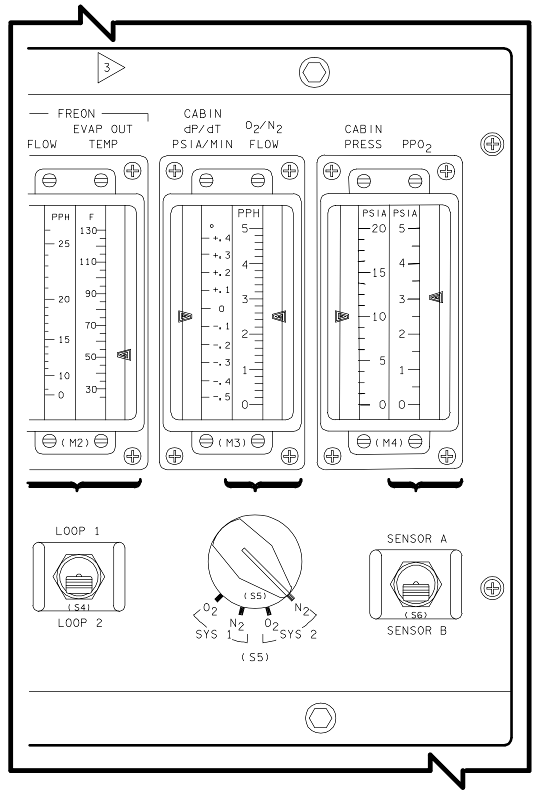
When the corresponding PPO_2 sensor determines that oxygen is required in the crew cabin to maintain the level above 2.95 psi, the O_2/N_2 control valve is automatically closed. When the 200-psi nitrogen in the manifold drops below 100 psi, the corresponding oxygen system flows oxygen through its check valve into the manifold and through the 14.7 psi cabin regulator into the crew cabin. When the PPO_2 sensor determines that the oxygen in the crew cabin is at 3.45 psi, the corresponding O_2/N_2 control valve is automatically opened. The 200-psi nitrogen enters the O_2/N_2 manifold and closes the corresponding oxygen system's check valve and flows through the 14.7 psi regulator into the crew cabin whenever the cabin pressure drops below 14.7 psia ± 0.2. The *OPEN* and *CLOSE* positions of the *O_2/N_2 CNTLR VLV SYS 1* and *SYS 2* switches on panel L2 permit the flight crew to manually control the O_2/N_2 valve in each system and manually switch between O_2 and N_2 systems. The *REVERSE* position of the *PPO2 SNSR/VLV* switch on panel L2 allows O_2/N_2 CNTLR SYS 1 to control O_2/N_2 CNTLR VLV SYS 2, and vice versa.

The SYS 1 and SYS 2 PPO_2 CNTLR switches were designed to control the PPO_2 level (via the O_2/N_2 CNTLR) of the cabin between the normal range (2.95-3.45 at 14.7 psi) or the emergency range (1.95-2.45 at 8 psi). The control range can be determined by positioning the switch in NORM or EMER. The EMER position is procedurally never used.

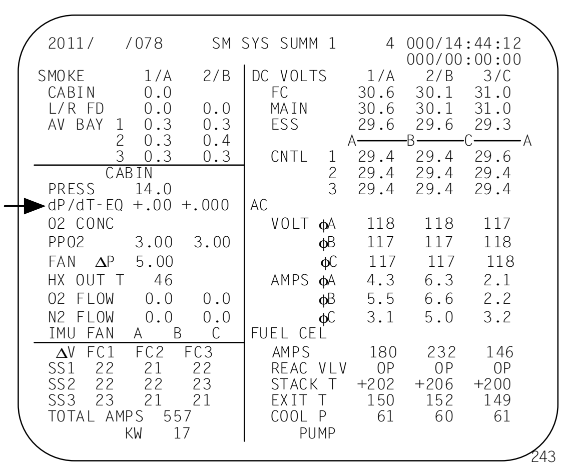
The oxygen systems 1 and 2 and nitrogen systems 1 and 2 flows can be monitored via the O_2/N_2 FLOW meter on panel O1. The flow of the selected system is displayed on the meter in pounds per hour.

PPO_2 sensors A and B monitor the oxygen partial pressure and the signal to the *SENSOR* switch on panel O1. When the switch is positioned to *SENSOR A*, oxygen partial pressure from sensor A is monitored on the PPO_2 meter on panel O1 in psia. If the switch is set on *SENSOR B*, oxygen partial pressure from sensor B is monitored. The cabin pressure sensor output is routed directly to the CABIN PRESS meter on panel O1 and is displayed in psia. These parameters can also be viewed on CRT displays SM SYS SUMM 1 (PPO2) and DISP 66, ENVIRONMENT (PPO2 A, B, C).

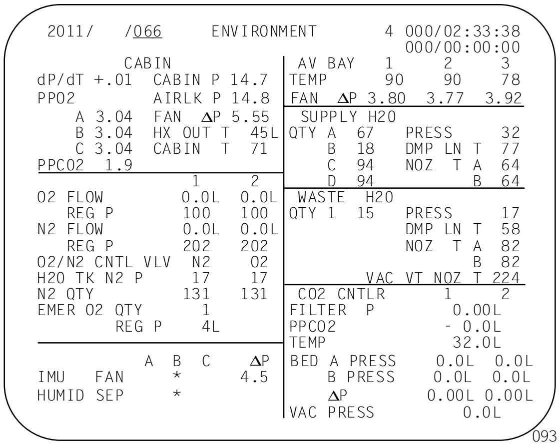
If the change in pressure versus change in time (dP/dT) decreases at a rate of 0.08 psi per minute or greater, a klaxon will sound in the crew cabin, and the *MASTER ALARM* pushbutton light indicators will be illuminated. The normal cabin dP/dT is zero psi per minute plus or minus 0.01 psi.



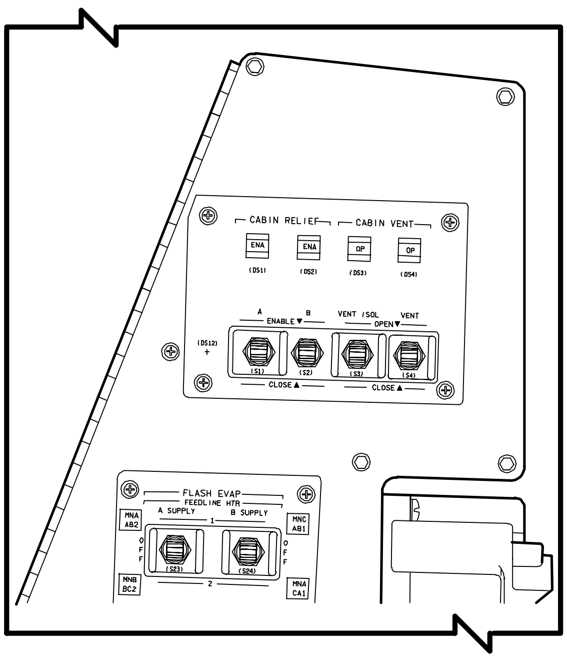
Meters and Switches on Panel O1 (Transducers also supply information for SM SYS SUMM 1, DISP 66, and C/W.)



The SM SYS SUMM 1 display is an SM display (DISP78) available in SM OPS and 4



The ENVIRONMENT display is an SM display (DISP 66) available in SM OPS 2 and 4



CABIN RELIEF and CABIN VENT Switches and Talkbacks on Panel L2

Cabin Relief Valves

Two positive pressure relief valves are in parallel to provide overpressurization protection of the crew module cabin above 15.5 psid. The valves will crack at 15.5 psid, reach full flow by 16.0 psid, and reseat again below 15.5 psid. Each cabin relief valve is controlled by its corresponding *CABIN RELIEF* switch on panel L2. When the switch is positioned to *ENABLE*, the motor-operated valve opens, exposing cabin pressure to a corresponding positive pressure relief valve. The relief valve maximum flow capability is 150 pounds per hour at 16.0 psid. A talkback indicator above the switch indicates barberpole when the motor-operated valve is in transit, and *ENA* when the motor-operated valve is open. When the switch is positioned to *CLOSE*, the corresponding motor-operated valve isolates cabin pressure from the relief valve and the talkback indicator indicates *CL*.

Vent Isolation and Vent Valves

The cabin vent isolation valve and cabin vent valve are in series to vent the crew cabin to ambient pressure while the orbiter is on the ground or to vent the cabin on orbit in an extreme emergency. Approximately 1 hour and 30 minutes before lift-off, the cabin is pressurized to approximately 16.7 psi for leak checks. Cabin pressure is then monitored for 35 minutes to verify that no pressure decay occurs. During this time, the cabin vent and cabin vent isolation valves are alternately opened and closed to verify that each holds pressure.

The cabin vent isolation valve is controlled by the *VENT ISOL* switch on panel L2, and the cabin vent valve is controlled by the *VENT* switch. Each switch is positioned to *OPEN* to control its respective motor-operated valve. When both valves are open, the cabin pressure is vented into the midfuselage. The maximum flow capability through the valves at 0.2 psid is 900 pounds per hour.

A talkback indicator above each switch indicates the position of the respective valve: Barberpole when the valve is in transit and *OP* when it is open.

> **WARNING**
>
> Because of the high flow capability of the cabin vent isolation valves, these valves should never be opened after lift-off.

Negative Pressure Relief Valves

If the crew cabin pressure is lower than the pressure outside the cabin, two negative pressure relief valves in parallel will open at 0.2 psid, permitting flow of ambient pressure into the cabin. Caps over each valve provide a positive pressure seal and will pop off when the valve opens. No crew controls are necessary.

Water Tank Regulator Inlet Valve

The H_2O TK N_2 REG INLET valve in each nitrogen system permits nitrogen to flow to its regulator and H_2O TK N_2 ISOL SYS 1, 2 valve. The REG inlet and isolation manual valves are on panel MO10W. The regulator in each nitrogen system reduces the 200 psi supply pressure to 15.5 to 17.0 psig. Each regulator is a two-stage regulator with the second stage relieving pressure into the crew cabin at a differential pressure of 18.5 ± 1.5 psig.

Airlock Depressurization and Equalization Valves

The airlock pressure is maintained equal with cabin pressure via the airlock equalization valves located on the cabin/airlock hatch. During normal operations the airlock hatch is open. The airlock depressurization valve is used to depressurize the cabin to 10.2 psia and to depressurize the airlock for EVA.

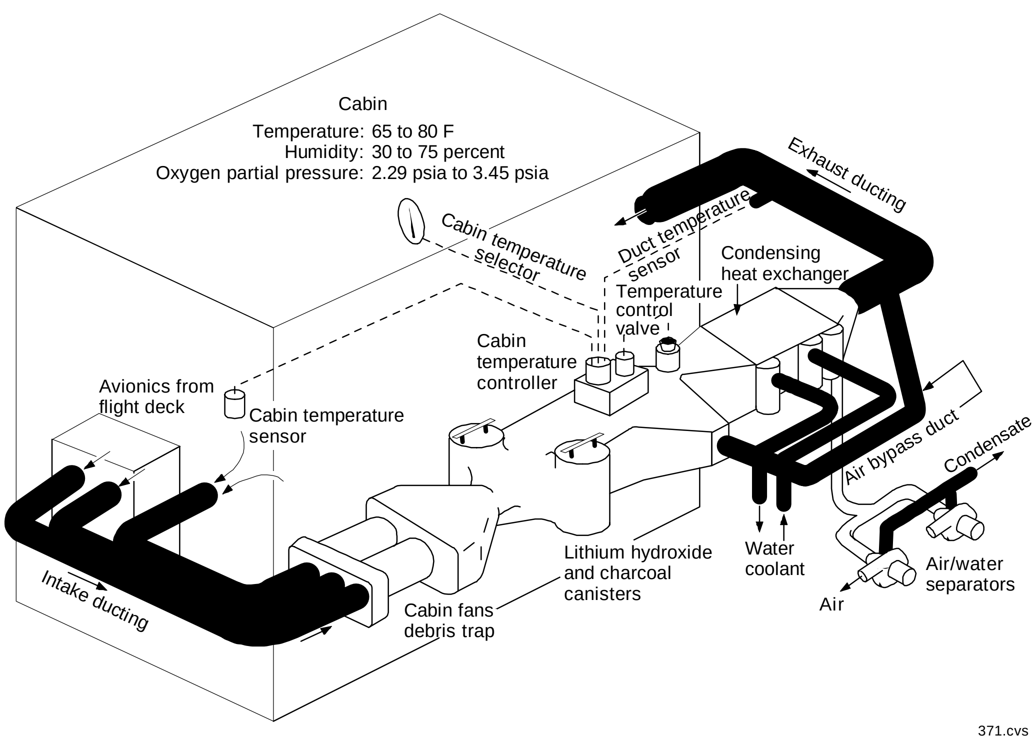
Atmospheric Revitalization System

The atmospheric revitalization system (ARS) circulates air and water throughout the cabin to control ambient heat, relative humidity (between 30 and 65 percent), carbon dioxide, and carbon monoxide levels. The ARS also provides cooling for cabin avionics.

Cabin air is circulated around the cabin to remove heat and humidity. The heated air is then ducted (via cabin fans) to the cabin heat exchanger, where it is cooled by the water coolant loops. The water coolant loop system collects heat from the cabin heat exchanger, the inertial measurement unit heat exchanger, some of the cold plated electronic units in the avionics bays, and the avionics bay heat exchangers. It transfers heat to the Freon/water heat exchanger of the active thermal control system. The active thermal control system expels the heat overboard.

Cabin Air Flow

Except for ducting, all air loop components are located under the middeck floor. The air circulated through the flight crew cabin also picks up odor, carbon dioxide, debris, and additional heat from electronic units in the crew cabin. Based on the crew cabin volume of 2,300 cubic feet and 330 cubic feet of air per minute, one volume crew cabin air change occurs in approximately 7 minutes, and approximately 8.5 air changes occur in 1 hour.



Cabin Air

The heated cabin air is drawn through the cabin loop and through a 300-micron filter by one of two cabin fans. Each cabin fan (A and B) is controlled by its respective *CABIN FAN* switch on panel L1. Normally, only one fan is used.

Each fan is powered by a three-phase, 115-volt ac motor. These 495-watt motors produce a nominal flow rate of 1,400 lb/hr through the cabin air ducting. A check valve located at the outlet of each fan prevents air from backflowing through the nonoperating fan. This flapper-type check valve will open if there is a 2 inch H_2O (.0723 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 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.

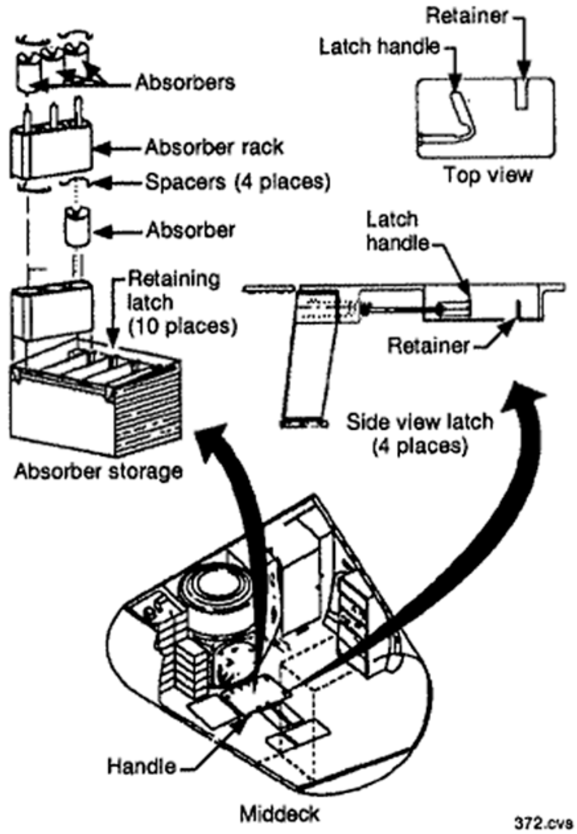
Lithium Hydroxide Canisters

The cabin air leaves the cabin fan at a rate of about 1,400 lb/hr. An orifice in the duct directs approximately 120 lb/hr to each of two lithium hydroxide canisters, where carbon dioxide is removed, and activated charcoal removes odors and trace contaminants. The canisters are changed periodically on a predetermined schedule, generally one or two times a day, through an access door. (For larger crews, the canisters are changed more frequently.) Each canister is rated at 48 man-hours. Up to 30 spare canisters are stored under the middeck floor in a locker between the cabin heat exchanger and water tanks.

CAUTION

During lithium hydroxide canister changeout, the cabin fan(s) should be turned off. Dust from the canisters kicked up by a cabin fan has caused eye and nose irritation. Lithium hydroxide dust may also be a contributing factor to humidity separator failures.

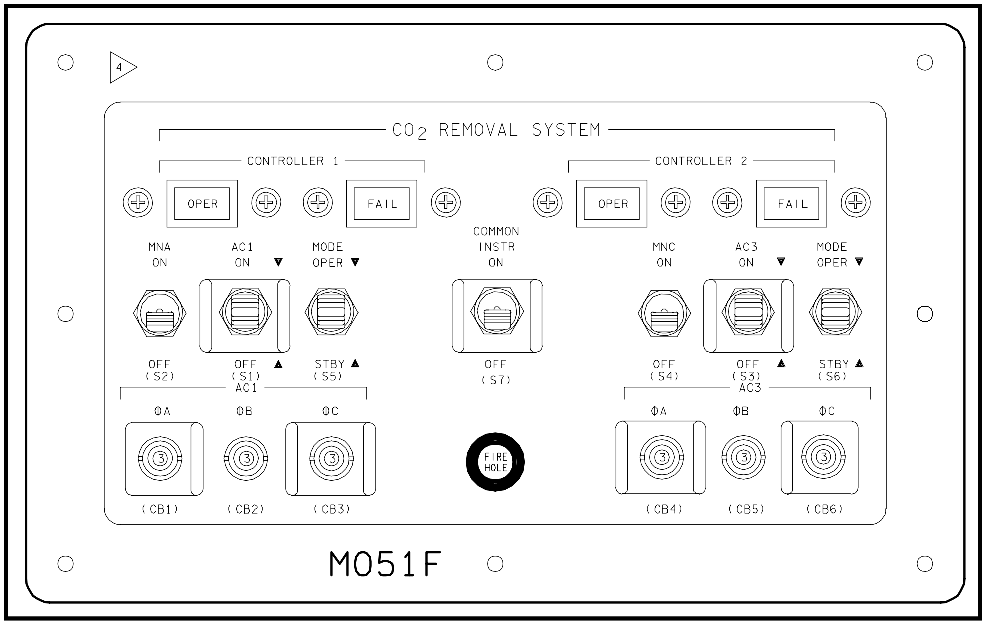
OV-102 utilizes lithium hydroxide canisters only during launch and landing. On orbit, the regenerable carbon dioxide system (RCRS), incorporated as part of the EDO modifications, is the primary system. LiOH canisters also provide backup to the RCRS on this vehicle. OVs-104 and -105 are also capable of supporting the RCRS. OV-103 is not configured for RCRS and has only the LiOH system for carbon dioxide removal.



Carbon Dioxide Absorbers

Regenerable Carbon Dioxide Removal System

The ability to use the RCRS in the EDO orbiters solved a major weight and volume stowage problem encountered when attempting to conduct 10 to 16 day duration missions for a crew of up to seven astronauts. Carbon dioxide removal is accomplished by passing cabin air through one of two identical solid amine resin beds. The resin consists of a polyethylenimine (PEI) sorbent coating on a porous polymeric substrate. Upon exposure to carbon dioxide laden cabin air, the resin combines with water vapor in the air to form a hydrated amine which reacts with carbon dioxide to form a weak bicarbonate bond. Water is required for the process since dry amine cannot react with the carbon dioxide directly. While one bed adsorbs carbon dioxide, the other bed regenerates with



CO_2 Removal System Panel MO51F

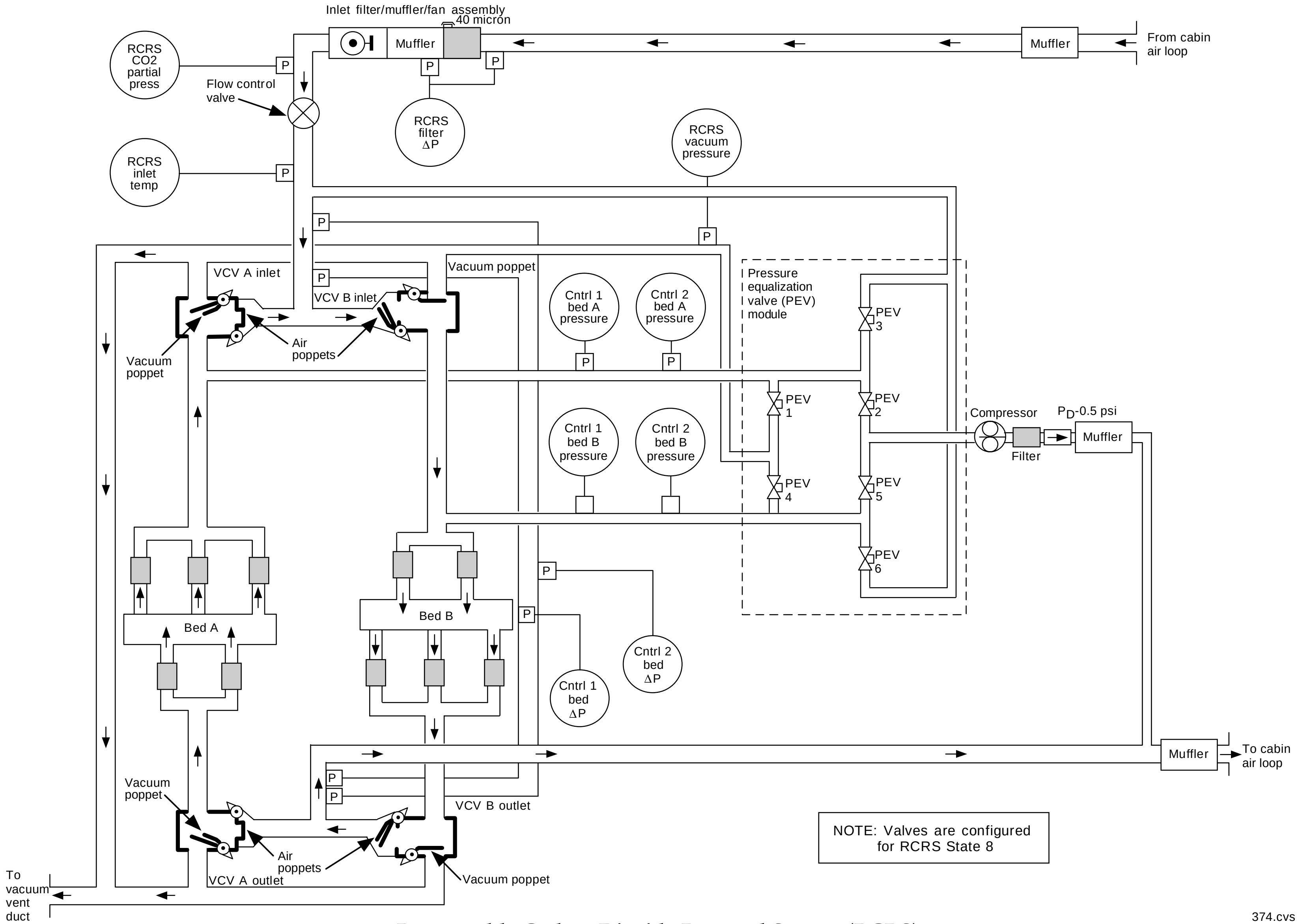
thermal treatment and vacuum venting. This latter requirement prevents the use of the RCRS during ascent or entry. The adsorption/regeneration process runs continuously with the beds automatically alternating processes every 13 minutes. A full cycle is made up of two 13 minute cycles. An RCRS configured vehicle uses a single LiOH canister for launch and another for entry. An activated charcoal canister in the other CO_2 absorber slot removes odors. It is changed out mid mission on 10+ day flights.

The RCRS is located in volume D under the middeck floor. In addition to the two chemical beds, the major components of the RCRS include a set of vacuum cycle and pressure equalization valves, an RCRS fan, an airflow control valve, an ullage-save compressor, and two redundant controllers (1 and 2). The airflow control valve is set prelaunch for either a crew size of "4" or "5 to 7" crewmembers. These two positions select airflow through the RCRS of 72 or 110 lb/hr respectively. The control switches for the RCRS are located on panel MO51F. Both ac and dc power for the 1 and 2 controllers are operated from this panel. Each controller has a three position momentary switch for selection of *OPER* or *STBY*. This panel also has status lights for each controller which illuminate *OPER* or *FAIL* as appropriate. Crew insight into RCRS operation is found on SPEC 66 ENVIRONMENT in OPS 2 or 4.

The scrubbed air is then forced through the rest of the ARS. Cabin air is then directed to the crew cabin heat exchanger where heat is transferred to the water coolant loop. Humidity condensation that forms in the heat exchanger is pushed by the air flow to the slurper. One of two humidity separators draws air and water from the slurper. In the humidity separator, centrifugal force separates the water from the air. The fan separator removes up to approximately 4 pounds of water per hour. The water is routed to the wastewater tank, and the air is ducted through the exhaust for return to the cabin.

There are two fan separators (A and B) controlled individually by *HUMIDITY SEP A* and *B* switches on panel L1. Normally, only one fan separator is used. The relative humidity in the crew cabin is maintained typically between 30 and 65 percent in this manner.

A small portion of the revitalized and conditioned air from the cabin heat exchanger is ducted to the carbon monoxide removal unit, which converts carbon monoxide to carbon dioxide. A bypass duct carries warm cabin air around the cabin heat exchanger and mixes it with the revitalized and conditioned air to control the crew cabin air temperature in a range between 65° and 80° F.

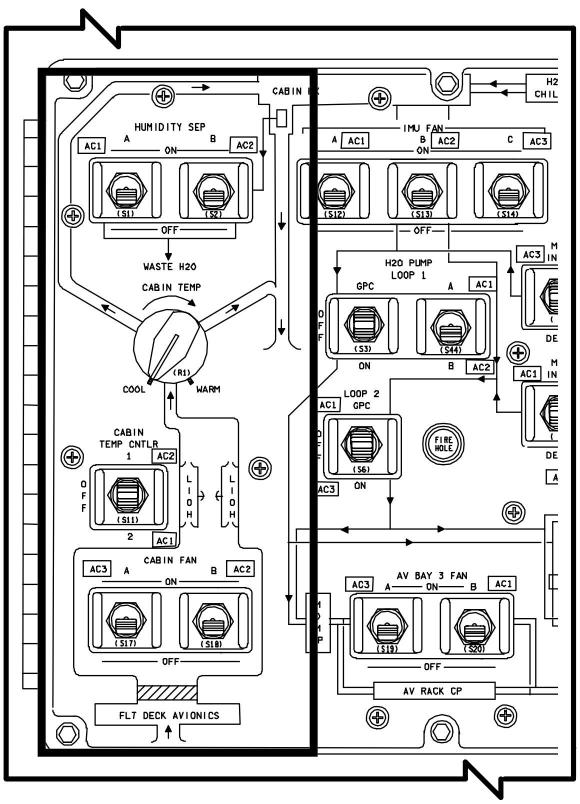


Regenerable Carbon Dioxide Removal System (RCRS)

Cabin Air Temperature Control

The cabin temperature control valve is a variable position valve that proportions the volume of air that bypasses the cabin heat exchanger. The 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 by the *CABIN TEMP* rotary switch on panel L1. The cabin temperature control valve and the two controllers are located in the ECLSS bay below panel MD44F.

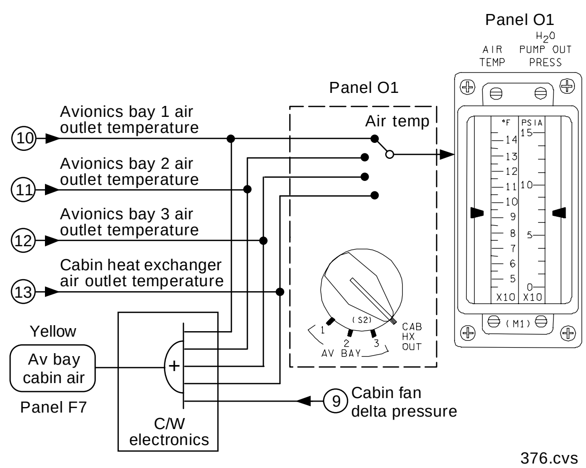
When the C*ABIN TEMP CNTLR* switch on panel L1 is positioned to *1*, it enables controller 1. The rotary *CABIN TEMP* switch elects and automatically controls the bypass valve by diverting 0 to 70 percent of the air flow around the cabin heat exchanger, depending on the position of the switch.



HUMIDITY SEP, CABIN TEMP, CABIN TEMP CNTLR, and CABIN FAN Switches on panel L1

The controllers are attached to a single bypass valve by an actuator arm. If controller 1 malfunctions, the actuator arm linkage must be removed from controller 1 by the flight crew at panel MD44F and connected manually to controller 2 before the *CABIN TEMP CNTLR* switch on panel L1 is positioned to *2*. This enables controller 2 and permits the rotary *CABIN TEMP* switch to control controller 2 and the single bypass control valve. The *CABIN TEMP CNTLR* switch's *OFF* position removes electrical power from both controllers, the rotary switch, and automatic control of the single bypass valve. For ascent and entry, the *CABIN TEMP* is set to full *COOL* to ensure maximum air cooling during these relatively warm phases of flight.

The air from the cabin heat exchanger and the bypassed air come together in the supply duct downstream of the heat exchanger and are exhausted into the crew cabin through the CDR and PLT consoles and through various station duct outlets into the crew cabin.



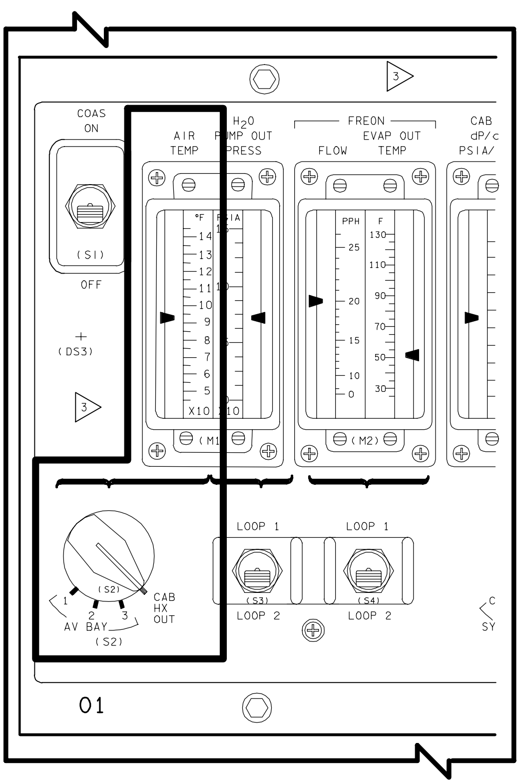
Avionics Bay and Cabin Heat Exchanger Temperature Monitoring and Caution/Warning, Crew Cabin Air

Cabin Temperature Monitoring

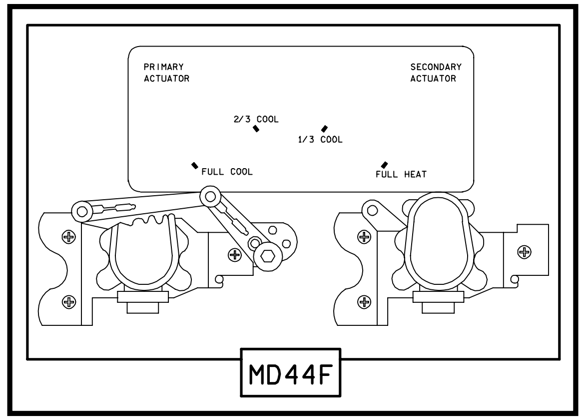
The cabin heat exchanger outlet temperature is transmitted to a rotary switch below the AIR TEMP meter on panel O1. When the switch is positioned to *CAB HX OUT*, the temperature can be monitored on the meter. The cabin heat exchanger outlet temperature provides an input to the yellow *AV BAY/CABIN AIR* caution and warning light on panel F7. The light is illuminated if the cabin heat exchanger outlet temperature is above 145° F, if avionics bay 1, 2, or 3 temperatures exceed 130° F, or if the cabin fan delta pressure is less than 4.2 inches of water or above 6.8 inches of water.

Manual Temperature Control

If cabin temperature controllers 1 and 2 or the *CABIN TEMP* rotary switch on panel L1 are unable to control the single bypass valve, the flight crew can position the single bypass valve actuator drive arm to the desired position and pin the bypass valve arm to one of four fixed holes (*FULL COOL*, *FULL HEAT*, etc.) on panel MD44F. The *FULL COOL* position establishes the maximum cabin air flow rate to the cabin heat exchanger, the *2/3 COOL* position establishes a flow rate that provides approximately two-thirds of the maximum cooling capability, the *1/3 COOL* position establishes a flow rate that provides approximately one-third of the maximum cooling, and the *FULL HEAT* position establishes the minimum cabin air flow rate to the cabin heat exchanger.



AIR TEMP Meter and Switch on Panel O1



Manual Temperature Controls on Panel MD44F

Avionics Bay Cooling

Cabin air is also used to cool the three avionics equipment bays and some of the avionics units in the bays. Each of the three avionics equipment bays in the middeck has a closeout cover to minimize air interchange and thermal gradients between the avionics bay and crew cabin; however, the covers are not airtight. For all practical purposes, the air circulation is closed loop within the bay. The electronic avionics units in each avionics bay meet outgassing and flammability requirements to minimize toxicity levels.

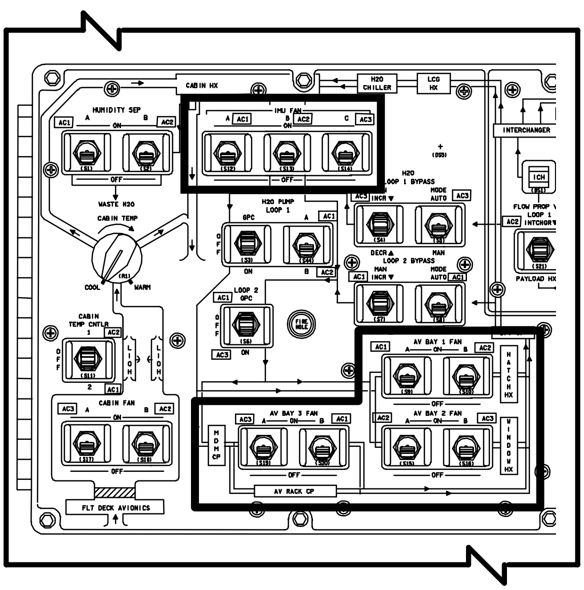
Each of the three avionics equipment bays has identical air-cooling systems. Two fans per bay are controlled by individual *AV BAY 1, 2, 3 FAN A* and *B* switches on panel L1. Normally, only one fan is used at a time. When the A or B switch for an avionics bay is positioned to *ON*, the fan draws air from the floor of the avionics bay through the applicable air-cooled avionics units and a 300-micron filter into the avionics bay fan.

The avionics bay fan outlet directs the air through that avionics bay heat exchanger, located beneath the middeck crew compartment floor. The water coolant loops flow through the heat exchanger to cool the fan outlet air, and the cooled air is returned to the avionics bay. A check valve in the outlet of the fan that is not operating prevents a reverse flow through that fan.

The air outlet from the fan in each avionics bay is monitored and transmitted to a rotary switch on panel O1. When the switch is positioned to *AV BAY 1, 2*, or *3*, that avionics bay's fan outlet temperature can be displayed on the AIR TEMP meter. The air outlet temperature of each avionics bay also provides an input to the yellow *AV BAY/CABIN AIR* caution and warning light on panel F7. This light is illuminated if any of the avionics bay outlet temperatures are above 130° F. The *OFF* position of the *A* or *B* switch removes power from that avionics bay fan.

Inertial Measurement Unit (IMU) Cooling

The three IMUs are cooled by one of three fans drawing cabin air through a 300-micron filter and across the three IMUs. The fans are located in avionics bay 1. The fan outlet air flows through the IMU heat exchanger located on the flight deck and is cooled by the water coolant loops before returning to the crew cabin. Each IMU fan is controlled by the *IMU FAN* switches on panel L1. The *ON* position turns the corresponding fan on, and the *OFF* position turns it off. Normally, one fan is sufficient because one fan cools all three IMUs. A check valve is installed on the outlet of each fan to prevent a reverse air flow through the fans that are not operating.



IMU FAN and AV BAY FAN Switches on Panel L1

Spacelab Air Revitalization

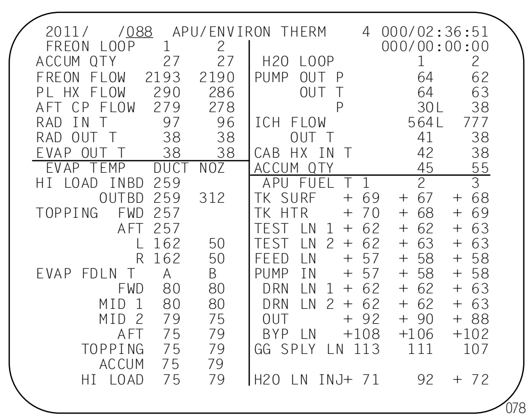
If the payload bay contains the Spacelab module, a kit is installed to provide ducting for the flow of cabin air from the middeck through the airlock and tunnel to the module. Information about the kit and its operation is provided in Section 2.21.

Water Coolant Loop System

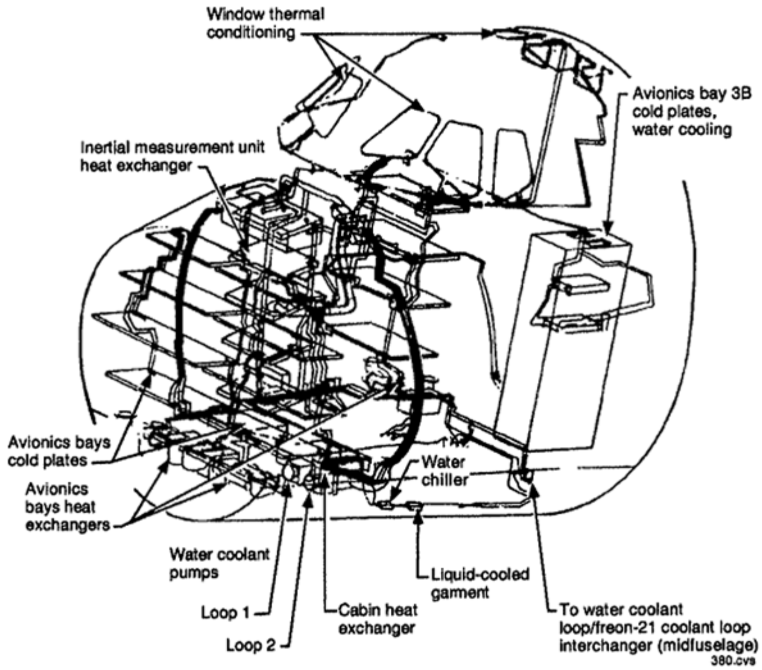
The water coolant loops circulate water through the crew compartment to collect excess heat and transfer it to the Freon coolant loops. Two complete, separate water coolant loops flow side by side and can operate at the same time, although only one is active at any given time. Loop 2 is normally the active loop. The only difference between loops 1 and 2 is that loop 1 (the backup) has two water pumps, and loop 2 has one pump. The water pumps are located in the ECLSS bay below the forward lockers. The pumps are powered by three-phase, 115-volt ac motors.

Some electronic units in each of the avionics equipment bays and in the cabin are mounted on cold plates. The water coolant loops flow through the cold plates, and the heat generated by the electronics unit is transferred to the cold plate and then to the water coolant loop, which carries heat from the electronic unit. The cold plates mounted on the shelves in each avionics equipment bay are connected in a series-parallel arrangement with respect to the water coolant loop flow.

Status of the water loops can be monitored on the APU/ENVIRON THERM display (DISP 88), which is available in SM OPS 2 and 4. The information is found in the items under H2O LOOP.



APU/ENVIRON THERM Display (DISP 88)



Crew Cabin Water Coolant Loops

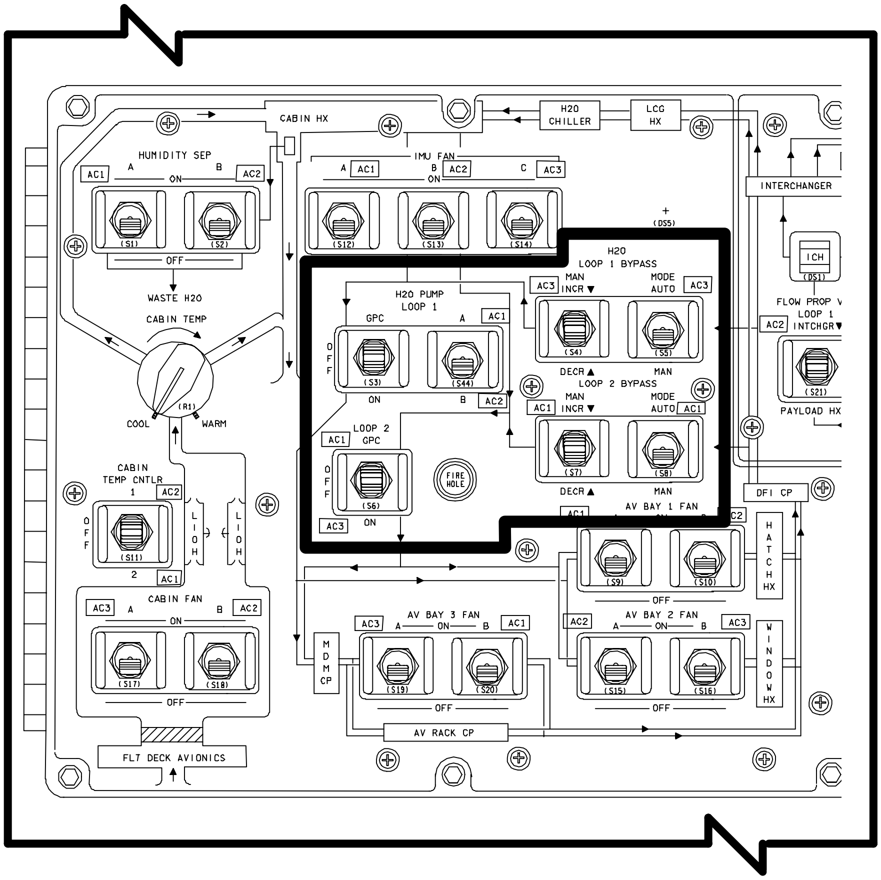
Water Loop Pumps

The water pumps in coolant loop 1 are controlled by the *H_2O PUMP LOOP 1 A* and *B* switch on panel L1 in conjunction with the *H_2O PUMP LOOP 1 GPC, OFF, ON* switch beside it. The *GPC* position enables the general-purpose computer to command the loop 1 pump, which is selected by the *H_2O PUMP LOOP 1 A* or *B* switch, to circulate water through water coolant loop 1. The *ON* position energizes the loop 1 pump. A ball-type check valve downstream of each water pump in loop 1 prevents reverse flow through the non-operating pump. The *OFF* position removes electrical power from both the A and B pumps of loop 1.

Water pump 2 is controlled by the *H_2O PUMP LOOP 2* switch on panel L1. When the switch is positioned to *GPC*, water pump 2 is commanded by the GPC to circulate water through water coolant loop 2. The *ON* position energizes water pump 2 to circulate water through water coolant loop 2. The *OFF* position removes electrical power from water coolant loop 2 pump.

Water Loop Flow

Water loops 1 and 2 are routed side by side through the same areas. Downstream of each water pump, water flow splits into three parallel paths. One is through the avionics bay 1 air/water heat exchanger and cold plates. A second is through the avionics bay 2 air/water heat exchanger and cold plates, payload bay floodlight cold plates, and thermal conditioning of the crew cabin windows. A third is through the crew cabin MDM flight deck cold plates, the avionics bay 3A air/water heat exchanger and cold plates, and the avionics bay 3B cold plates. The three parallel paths in each coolant loop then rejoin upstream of the Freon/water heat interchanger. The flow path splits again with one parallel path in each water coolant loop flowing through the Freon/water interchanger, where the water loop is cooled. The cooled water then flows through the liquid-cooled garment heat exchanger, potable water chiller, cabin heat exchanger, and IMU heat exchanger to the respective water coolant loop 1 and 2 pump package. The other parallel path in each water coolant loop, containing warm water, bypasses the interchanger and heat exchanger, rejoining the loop at the loop pump package. A valve installed in the bypass path controls the amount of bypass flow, thus controlling the mixed water temperature out of the pump package.



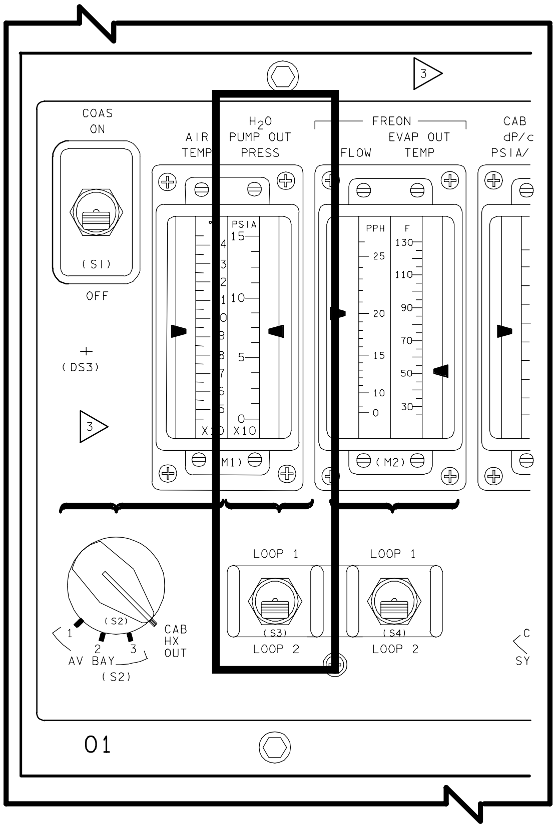
H_2O Loop Switches on Panel L1

The bypass valve is controlled by bypass controllers. The bypass controller in each water coolant loop is enabled by corresponding *H_2O LOOP 1* and *2 BYPASS MODE* switches on panel L1. When the switch is positioned to *AUTO*, the water bypass controller and bypass valve automatically control the amount of water in the coolant loop that bypasses the Freon/water interchanger and heat exchangers. When the water pump's outlet temperature is 65.5° F, the loop's bypass valve is fully closed, and all the loop flow is directed to the Freon/water interchanger to provide maximum cooling.

When the bypass controller senses that the water pump's outlet temperature is 60.5° F, the controller bypasses a maximum amount of water around the Freon/water interchanger, reducing the heat rejection rate and increasing the water temperature out of the pump outlet. When the *H_2O LOOP BYPASS MODE* switch for the coolant loop is positioned to *MAN*, the flight crew sets the corresponding *H_2O LOOP MAN INCR/DECR* switch on panel L1 to manually control the bypass valve in that water coolant loop.

The bypass valve is manually adjusted before launch to provide a flow of approximately 950 pounds per hour through the Freon/water interchanger, and the control system remains in the manual mode until post insertion. On orbit, the active water coolant loop's H_2O LOOP BYPASS MODE switch is set to AUTO and the bypass valve automatically controls the loop so that the water pump's outlet temperature remains at 63° F.

The accumulator in each water coolant loop provides a positive pressure on the corresponding water pump inlet and accommodates thermal expansion and dampens pressure surges in that water coolant loop when the pump is turned on or off. Each accumulator is pressurized with gaseous nitrogen at 19 to 35 psi.



H_2O PUMP OUT PRESS Meter and Switch on Panel O1 (The same transducer feeds SM DISP 88)

NOTE

For normal operations, only one water loop is active (usually loop 2). Running two water loops for long periods of time is undesirable. Two operating loops will flow too much water through the Freon/water 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 two Freon loops can carry away. Over time, the water loops will start to heat up, and cooling efficiency will decrease.

The pressure at the outlet of the water pump in each water coolant loop is monitored and transmitted to the H_2O PUMP OUT PRESS meter on panel O1. The appropriate loop is selected by the switch below the meter. When the switch is positioned to *LOOP 1* or *LOOP 2*, the corresponding water coolant loop's pressure in psia is monitored on the meter.

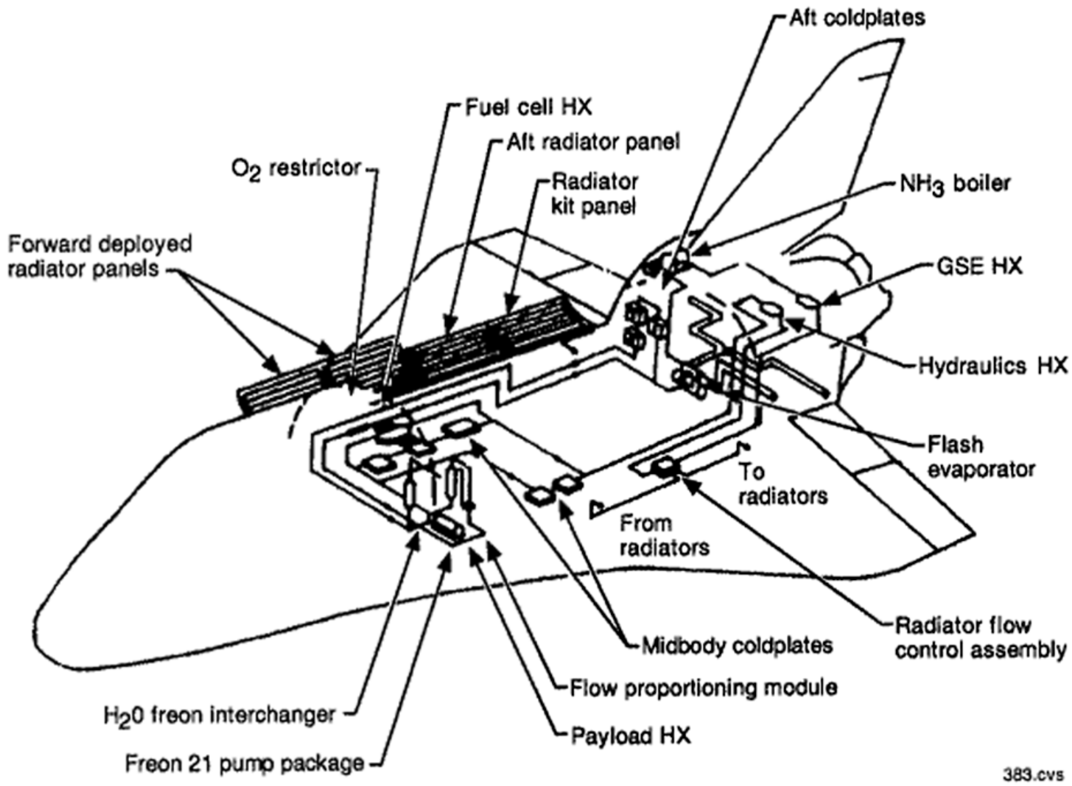
The yellow *H_2O LOOP* caution and warning light on panel F7 will be illuminated if the outlet pressure of the water coolant loop 1 pump is less than 19.5 psia or greater than 79.5 psia, or if the outlet pressure of the loop 2 pump is less than 45 psia or greater than 81 psia. The pump inlet and outlet pressure of each coolant loop are monitored and transmitted to the systems management GPC for CRT readout on the DISP 88 APU/ENVIRON THERM display (PUMP OUT P).

Active Thermal Control System

The active thermal control system provides orbiter heat rejection during all phases of the mission after solid rocket booster separation. The system consists of two complete, identical Freon coolant loops, cold plate networks for cooling avionics units, liquid/liquid heat exchangers, and three heat sinks: radiators, flash evaporators, and ammonia boilers.

Freon Loops

Two Freon coolant loops transport excess heat from the water/Freon interchanger, fuel cell heat exchanger, payload heat exchanger, and midbody and aft avionics electronic units. The Freon loops then deliver the heat to the heat sinks. Each loop has a pump package consisting of two pumps and an accumulator. The pump package is located in the midbody of the orbiter below the payload bay liner. One pump in each loop is active at all times. The metal bellows-type accumulator in each loop is pressurized with gaseous nitrogen to provide a positive pressure on the pumps and permit thermal expansion in that coolant loop. When the accumulator bellows is fully extended, approximately 80 lb of Freon is in the accumulator (normally only 20 to 30 percent of this amount is used). A ball check valve downstream of the pumps in each coolant loop prevents a reverse flow through the non-operating pump in the loops. The pumps in each coolant loop are controlled individually by the *FREON PUMP* switches on panel L1. When either switch is positioned to *A* or *B*, the corresponding Freon pump in that loop operates. The *OFF* position of each switch prohibits either Freon pump in that coolant loop from operating.



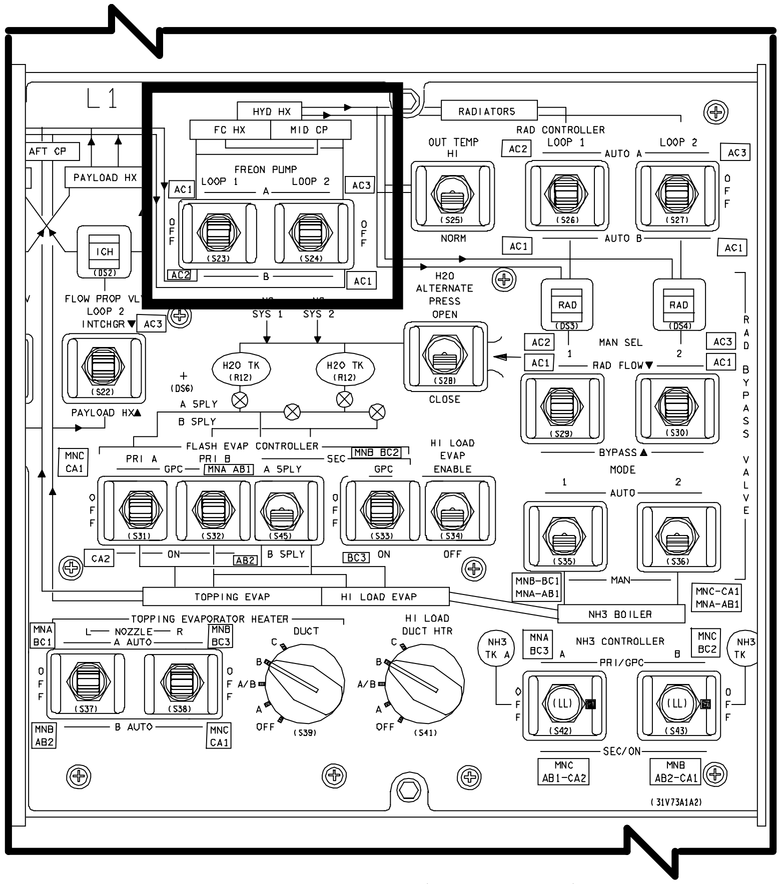
Active Thermal Control System Component Locations

When a Freon pump is operating, Freon is routed in parallel paths through the fuel cell heat exchanger and the midbody cold plate network to cool electronic avionics units. The Freon coolant converges to one flow path before entering the hydraulics heat exchanger.

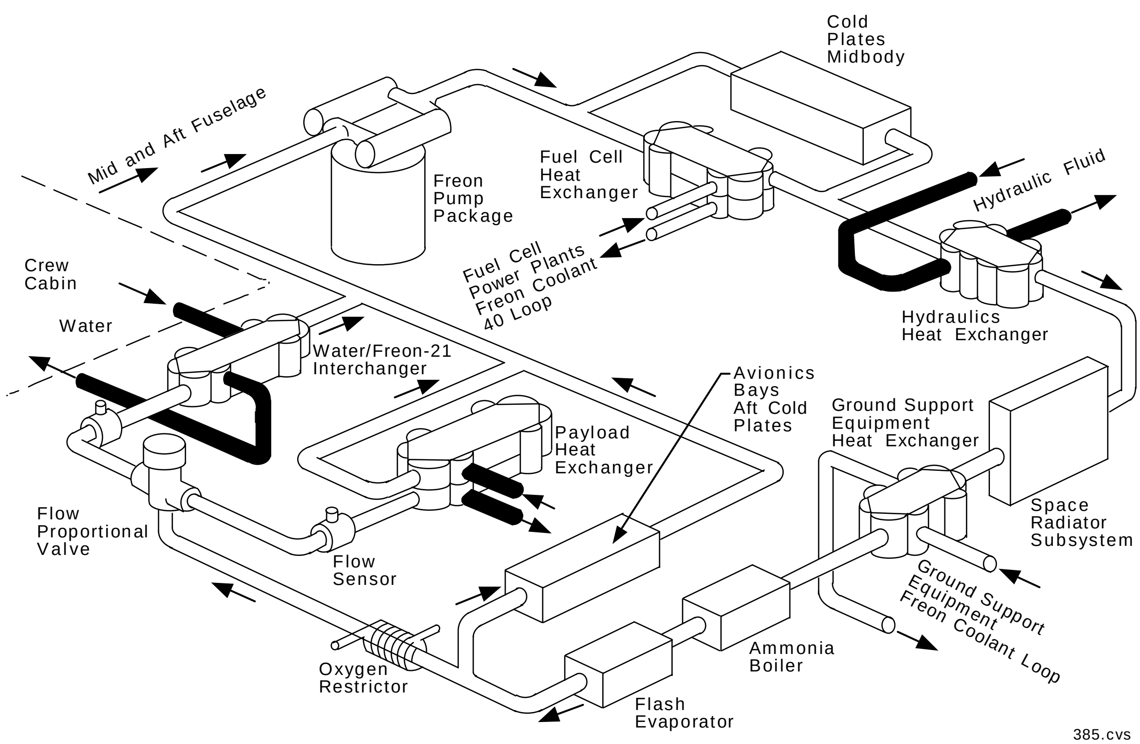
The Freon flows from the hydraulic fluid heat exchanger to the radiators, which are bypassed through a bypass valve during ascent and entry unless cold soak cooling from the radiators is being used. The warmest portion of the Freon loop is at the outlet of the hydraulic system heat exchanger.

When the payload bay doors are opened on orbit, radiators located on the inside of the payload bay doors are used for heat rejection to space. The Freon coolant flows through the ground support equipment heat exchanger used for ground cooling, ammonia boilers, and flash evaporator located in the aft fuselage. It is then divided into two parallel paths. One path flows through the ECLSS oxygen restrictor to warm the cryogenic oxygen from the power reactant storage and distribution system for the ECLSS to 40° F. It then flows through a flow-proportioning valve module in the lower forward portion of the midfuselage into parallel paths to the payload heat exchanger and atmospheric revitalization system interchanger (both located in the lower forward portion of the midfuselage) and returns to a series flow. The second path flows through aft avionics bays 4, 5, and 6 to cool electronic avionics equipment in each avionics bay. It also flows through cold plates to cool four rate gyro assemblies and then returns to a series flow. The parallel paths return in series to the Freon coolant pump in that Freon coolant loop.

The FREON FLOW meter on panel O1 permits the crew to monitor the Freon flow to the Freon/water interchanger. The switch below the meter selects the loop to be monitored. Freon loop status can also be monitored under the FREON LOOP area on the APU/ENVIRON THERM display (DISP 88) and the BFS THERMAL display (FREON Loop 1, 2) in OPS 1. The yellow *FREON LOOP* caution and warning light on panel F7 will illuminate if Freon flow in either loop is less than 1200 pph.



FREON PUMP Switches on Panel L1



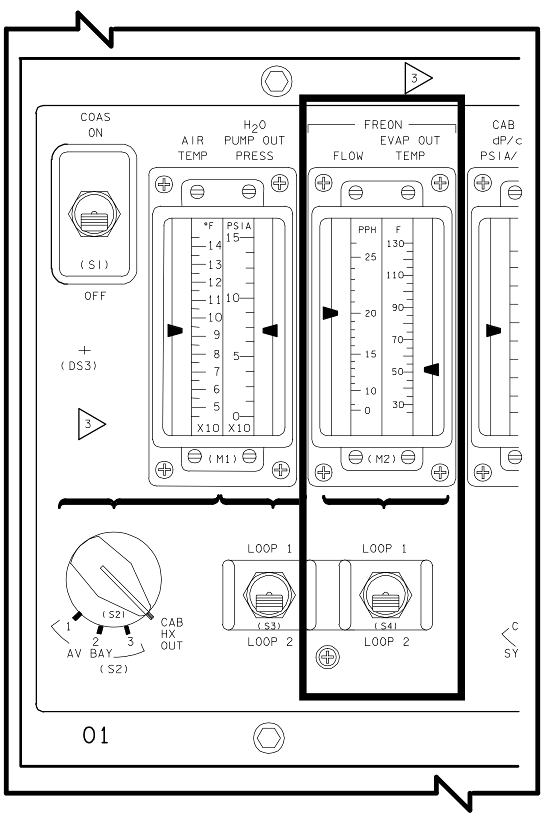
Freon Coolant Loop

Radiators

Radiators act as a heat sink for the coolant loops. The radiator system consists of four radiator panels attached to the inside of each payload bay door. The two forward radiator panels on each payload bay door are deployable when the doors are opened on orbit. The heat rejection requirements of the orbiter for a specific mission will determine if the forward radiators are to be deployed. The third and fourth radiator panels are fixed to the aft underside of the aft right and left payload bay doors and are not deployable.

The maximum heat rejection capability is 61,100 Btu per hour. When the payload bay doors are closed, the radiators are usually bypassed.

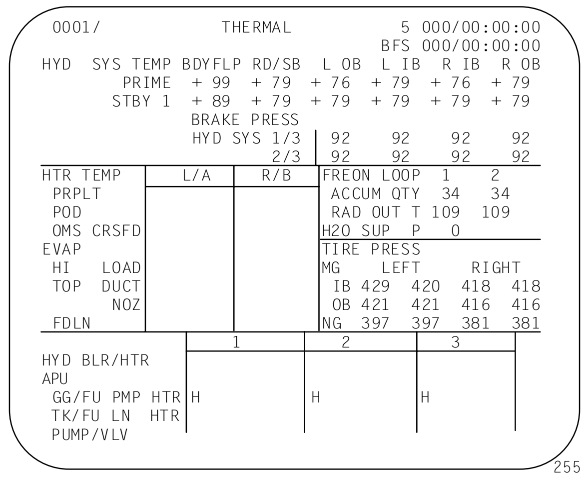
The radiator panels on the left and right sides are configured to flow in series, while flow within each panel is parallel through a bank of tubes connected by an inlet and outlet connector manifold. The radiator panels on the left side are connected in series with Freon coolant loop 1. The radiator panels on the right side are connected in series with Freon coolant loop 2.



FREON FLOW Meter and Switch on Panel O1

The radiator panels provide an effective heat dissipation area of 1,195 square feet on orbit. Each radiator panel is 10 feet wide and 15 feet long. The Freon tubing in the radiator panels is more than 1 mile long.

For ascent, the radiators are normally bypassed since the doors are closed. Radiator flow is established shortly before the doors are opened on orbit. During deorbit preparations, prior to closing the doors, the Freon in the radiators is "cold-soaked" by positioning the orbiter in a tail Sun attitude. This cold soak is saved for use as a heat sink during the latter stages of entry.

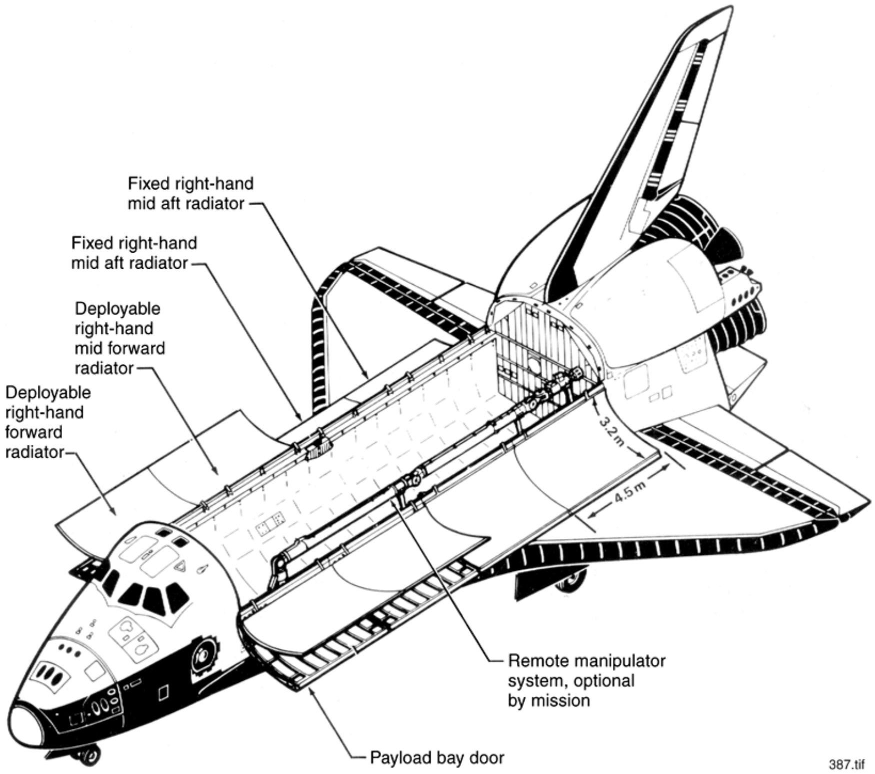


BFS THERMAL DISPLAY

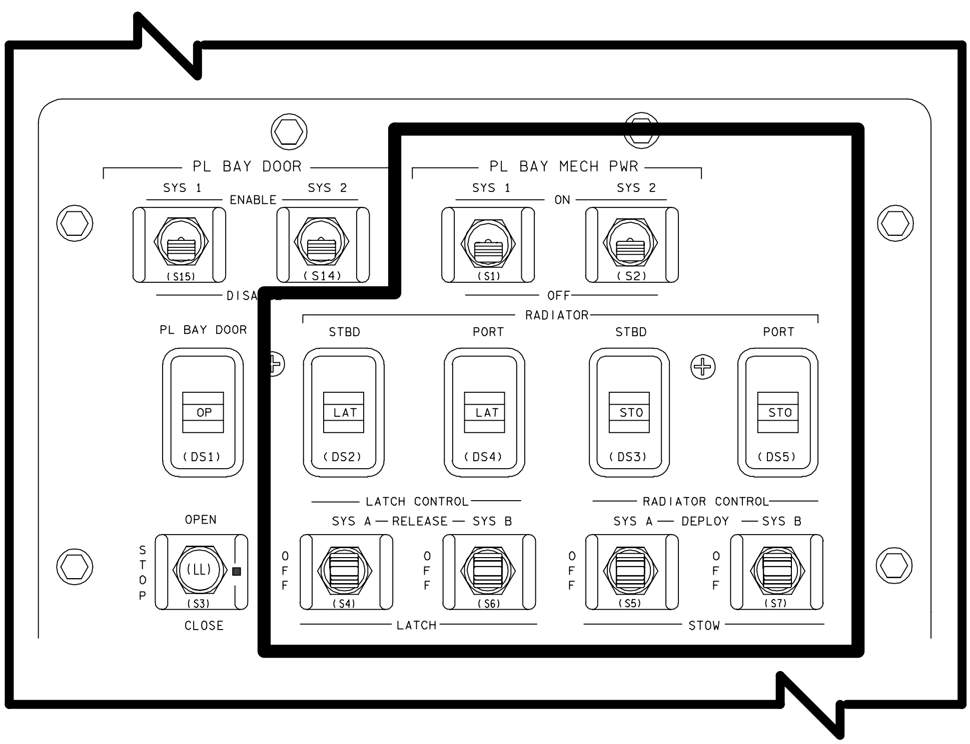
Radiator Mounting and Construction

The deployable radiators are secured to the inside of the right and left payload bay doors by six motor-operated latches. When the payload bay doors are opened on orbit, and the mission dictates that the deployable radiators be deployed, the six motor-driven latches unlatch the radiators from the payload bay doors, and a motor-driven torque-tube-lever arrangement deploys the forward radiators at 35.5° from the payload bay doors. Deploying the forward radiators provides more surface area, and thus greater heat rejection.

The aft fixed radiator panels are attached to the payload bay doors by a ball joint arrangement at 12 locations to compensate for movement of the payload bay door and radiator panel caused by the thermal expansion and contraction of each member.



Payload Bay Radiators



RADIATOR DEPLOY and STOW Switches and Talkbacks on Panel R13L

The radiator panels are constructed of an aluminum honeycomb face sheet 126 inches wide and 320 inches long. The forward deployable radiator panels are two-sided and have a core thickness of 0.9 of an inch. They have longitudinal tubes bonded to the internal side of both face sheets. Each of the forward deployable panels contains 68 tubes spaced 1.9 inches apart.

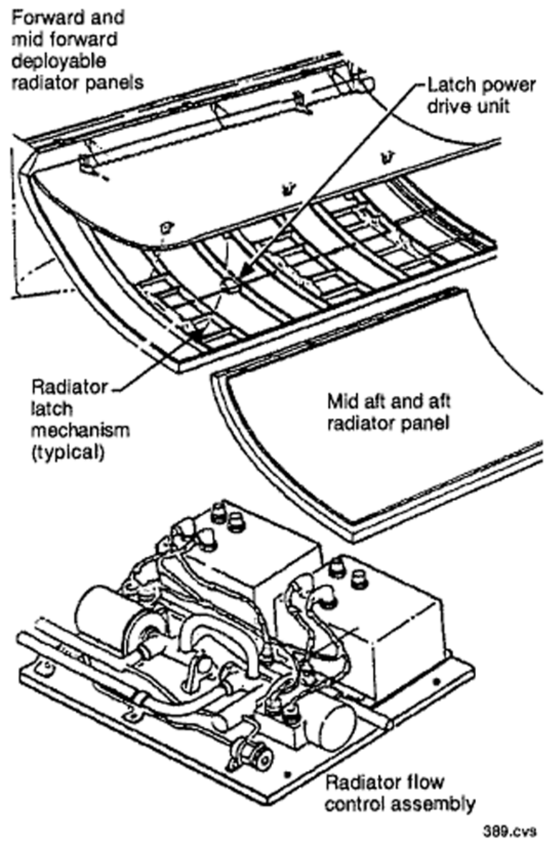
Each tube has an inside diameter of 0.131 of an inch. Each side of the forward deployable radiator panels has a coating bonded by an adhesive to the face sheet consisting of silver-backed Teflon tape for proper emissivity properties. The aft fixed panels are one-sided, and their cores are 0.5 inch thick. They have tubes only on the exposed side of the panel and a coating bonded by an adhesive to the exposed face sheet. The aft panels contain 26 longitudinal tubes spaced 4.96 inches apart. Each tube has an inside diameter of 0.18 inch. The additional thickness of the forward radiator panels is required to meet deflection requirements when the orbiter is exposed to ascent acceleration.

Radiator Deploy Systems

There are two radiator deploy systems, each of which drives one of two motors on each door. The systems drive the radiator panels away from the payload bay doors (deployed) or to the stowed position, using two reversible three-phase ac motors. It takes 40 seconds to deploy or stow the radiators.

The crew deploys and stows the radiators using switches on panel R13L. To deploy, the *PL BAY MECH PWR SYS 1* and *SYS 2* switches are positioned to *ON* to provide power to the panel switches. Both *RADIATOR LATCH CONTROL* switches are set concurrently to *RELEASE*; after 30 seconds, they are set to *OFF.* The *RADIATOR CONTROL* switches are then both concurrently set to *DEPLOY*; after 50 seconds, they are set to *OFF.* The *PL BAY MECH PWR* switches are then set to *OFF*.

To stow the radiators, the *PL BAY MECH PWR* switches are again positioned to *ON*. The *RADIATOR CONTROL* switches are both concurrently set to *STOW*, and after 50 seconds to *OFF.* The *LATCH CONTROL* switches are then positioned to *LATCH*, and after 30 seconds, to *OFF.* The *PL BAY MECH PWR* switches are then positioned to *OFF*.



Radiators and Radiator Flow Control Valve Assembly

Single Radiator Operations

It is possible to deploy either the port side or the starboard side radiator independently. This cannot be done directly with switches, because each controls motors on both sides. In order to deploy only one radiator, circuit breakers must be pulled to disable motors on one side. Single radiator operations may be done in case of a contingency situation, such as failure of one radiator or necessary Ku-Band antennae pointing, or a planned situation, such as flying in an attitude such that one door must remain partially closed to protect against debris strikes.

Radiator Flow Control

A radiator flow control valve assembly in each Freon coolant loop controls the temperature of that loop through the use of variable flow control, which mixes hot bypassed Freon coolant flow with the cold Freon coolant from the radiators. The radiator bypass valve allows Freon to either flow through the radiator or bypass the radiator completely.

In the automatic mode, the *RAD CONTROLLER LOOP 1* and *LOOP 2* switches on panel L1 are positioned to *AUTO A* or *AUTO B* to apply electrical power to the corresponding radiator flow controller assembly. The *RAD CONTROLLER MODE* switch is positioned to *AUTO*, and the *RAD CONTROLLER OUT TEMP* switch on panel L1 is positioned to *NORM* or *HI*.

With the *RAD CONTROLLER OUT TEMP* switch on panel L1 positioned to *NORM*, the radiator outlet temperature in Freon coolant loops 1 and 2 is automatically controlled at 38° F (±2°); in *HI*, the temperature is automatically controlled at 57° F (± 2°).

NOTE

The flash evaporator is activated automatically when the radiator outlet temperature exceeds 41° F to supplement the radiators' ability to reject excess heat.

The talkback indicators below the *RAD CONTROLLER* switches on panel L1 indicate the position of the bypass valve in that Freon coolant loop. The indicators show *BYP* when the bypass valve in that Freon coolant loop is in the bypass position, barberpole when the motor-operated bypass valve is in transit, and *RAD* when the bypass valve is in the radiator flow position.

When the *RAD CONTROLLER MODE* switch on panel L1 is positioned to *MAN* for the Freon coolant loop selected, the automatic control of the radiator bypass valve in that loop is inhibited, and the flight crew controls the bypass valve manually using the *RAD CONTROLLER LOOP 1, LOOP 2, RAD FLOW BYPASS* switches on panel L1.

When the switch is positioned to *BYPASS*, the loop's motor-operated bypass valve permits that Freon coolant loop to bypass the radiators. When the switch is positioned to *RAD FLOW*, the valve permits coolant to flow through the radiators. The *RAD CONTROLLER LOOP 1* and *2* talkback indicators for the Freon coolant loop indicate *BYP* when the bypass valve in that loop is in bypass, and barberpole when it is in transit.

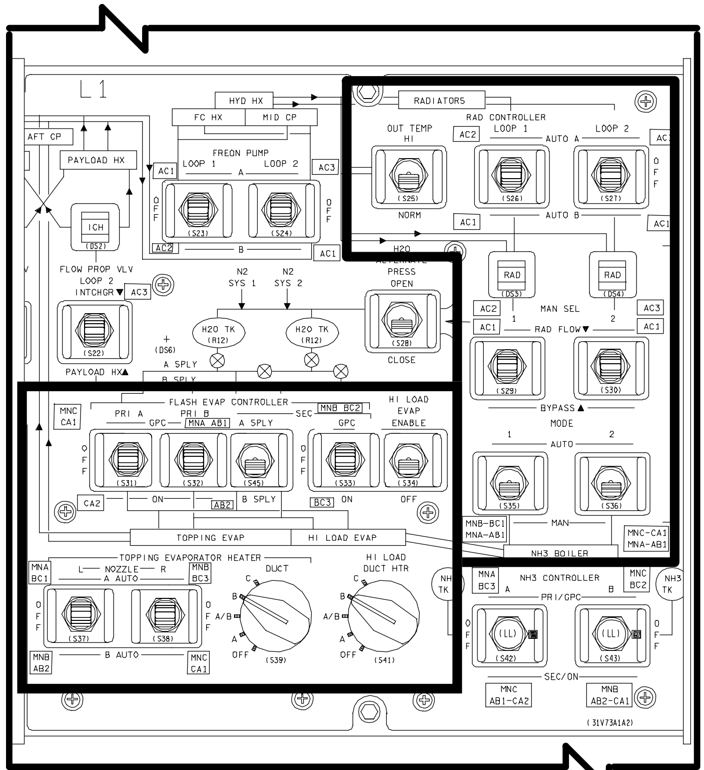
NOTE

The flow control valve cannot be controlled manually; it can only be controlled automatically using the controller. The bypass valve, however, can be operated manually or automatically.

Flash Evaporator System

The flash evaporators reject heat loads from Freon coolant loops 1 and 2 by evaporating supply water in a vacuum. The flash evaporators are used during ascent above 140,000 feet, and they supplement the radiators on orbit if required. They also reject heat loads during deorbit and entry to an altitude of approximately 100,000 feet.

The flash evaporators are located in the aft fuselage of the orbiter. There are two evaporators, a high-load evaporator and a topping evaporator. Two major differences are that the high-load evaporator has a higher cooling capacity and only one overboard vent on the left side of the vehicle. The topping evaporator vents steam equally to the left and right sides of the orbiter, which is non-propulsive. The evaporators are cylindrical shells with dual water spray nozzles at one end and a steam exhaust duct at the other end. The shell is composed of two separate finned packages, one for each Freon loop. The hot Freon from the coolant loops flows around the finned shell, and water is sprayed onto the shell by water nozzles from either evaporator. The water vaporizes, cooling the Freon coolant loops. In the low-pressure atmosphere above 100,000 feet, water vaporizes quickly. Changing water liquid to vapor removes approximately 1,000 Btu per hour per pound of water. The water for the evaporators is obtained from the potable water storage tanks through water supply systems A and B.



RAD CONTROLLER SWITCHES AND Talkbacks and
FLASH EVAP CONTROLLER Swithces on Panel L1

Flash Evaporator Controllers

The flash evaporators have three controllers: primary A, primary B, and secondary. The primary A and B controllers have two separate, functionally redundant shutdown logic paths (undertemperature and rate of cooling). Secondary has no shutdown. The flash evaporator controllers are enabled by the *FLASH EVAP CONTROLLER* switches on panel L1. The *PRI A* switch controls primary controller A, the *PRI B* switch controls primary controller B, and the *SEC* switch controls the secondary controller.

When the *PRI A*, *PRI B*, or *SEC* switch is positioned to *GPC*, the corresponding controller is turned on automatically during ascent by the BFS computer as the orbiter ascends above 140,000 feet. During entry, the BFS computer turns the corresponding controller off as the orbiter descends to 100,000 feet. The *ON* position of the switch provides electrical power directly to the corresponding flash evaporator controller. The *OFF* position of the switch removes all electrical power and inhibits flash evaporator operation.

The primary A controller controls water flow to the flash evaporator from water supply system A through water feed line A. The primary B controller controls water flow to the flash evaporator from water supply system B through water feed line B.

NOTE

> When a primary controller is enabled, both evaporators can be used simultaneously.

The secondary controller controls water flow to the high load flash evaporator from water supply system A through feed line A if the *FLASH EVAP CONTROLLER SEC* switch on panel L1 is in the *A SPLY* position, and if the *HI LOAD EVAP* switch is in the *ENABLE* position. If the switch is in the *B SPLY* position, and the *HI LOAD EVAP* switch is in the *ENABLE* position, the secondary controller controls water flow to the flash evaporator from water supply system B through feed line B. When the secondary controller is used, and the *HI LOAD EVAP* switch is *OFF*, both the A and B water supply systems will feed the topping evaporator in an alternate pulsing fashion. When the secondary controller is used, and the *HI LOAD EVAP* switch is in the *ENABLE* position, the topping evaporator is disabled.

The primary A and B controllers modulate the water spray in the evaporator to keep the Freon coolant loops' evaporator outlet temperature stable at 39° F. The secondary controller modulates the water spray in the evaporator to control the Freon coolant loops' evaporator outlet temperature at 62° F. The temperature sensors are located at the outlets of both evaporators.

The applicable flash evaporator controller pulses water into the evaporators, cooling the Freon. The steam generated in the topping evaporator is ejected through two sonic nozzles at opposing sides of the orbiter aft fuselage to reduce payload water vapor pollutants on orbit and to minimize venting thrust effects on the orbiter's guidance, navigation, and control system.

The high-load evaporator is used in conjunction with the topping evaporator during ascent and entry when higher Freon coolant loop temperatures impose a greater heat load that requires a higher heat rejection. The *HI LOAD EVAP* switch on panel L1 must be in the *ENABLE* position for high-load evaporator operation. After leaving the high-load evaporator, Freon flows through the topping evaporator for additional cooling. The steam generated by the high-load evaporator is ejected through a single sonic nozzle on the left side of the orbiter aft fuselage. The high-load evaporator would not normally be used on orbit because it has a propulsive vent and might pollute a payload.

NOTE

Norm jets are required to control vehicle attitude when the FES high load is used on orbit.

FES Auto Shutdown

Each primary controller has an automatic shutdown capability to protect the evaporator from over- or undertemperature conditions. The evaporator's outlet temperature is monitored to determine whether a thermal shutdown of the evaporator is warranted. If the evaporator outlet temperature goes below 37° F for 20 seconds or more, an undertemperature shutdown of the evaporator occurs. If the evaporator outlet temperature is greater than 41° F for 55 seconds, an overtemperature shutdown of the evaporator occurs. If the evaporator is shut down, electrical power to the affected controller must be recycled to reenable operations.

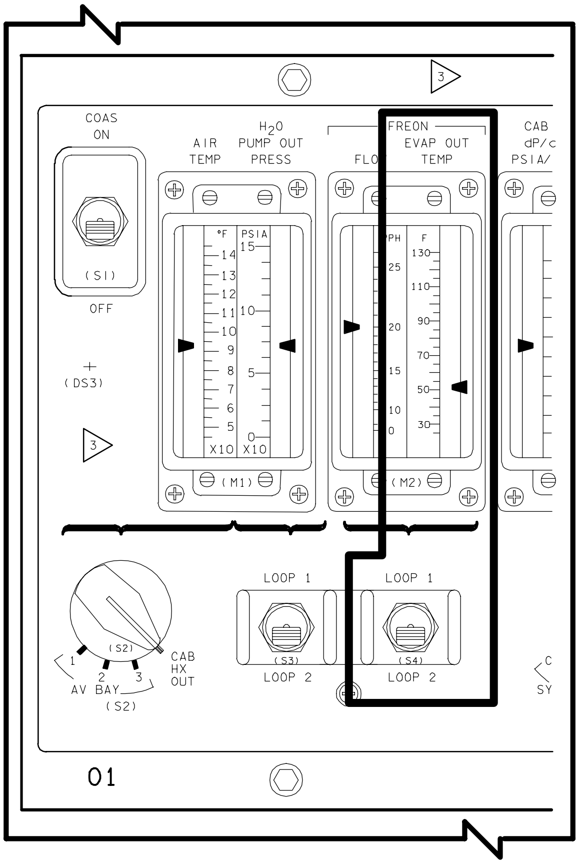
Temperature Monitoring

The evaporator outlet temperature of Freon coolant loops 1 and 2 is transmitted to panel O1. When the switch below the FREON meter on panel O1 is positioned to *LOOP 1* or *LOOP 2*, the evaporator outlet temperature of Freon coolant loops 1 or 2 can be monitored in degrees Fahrenheit on the FREON EVAP OUT TEMP meter or on the DISP 79 SM SYS SUMM 2 display (EVAP OUT T). If the outlet temperature drops below 32.2° F or rises above 64.8° F, the red *FREON LOOP* caution and warning light on panel F7 will be illuminated. (The upper limit for ascent is 115° F.)

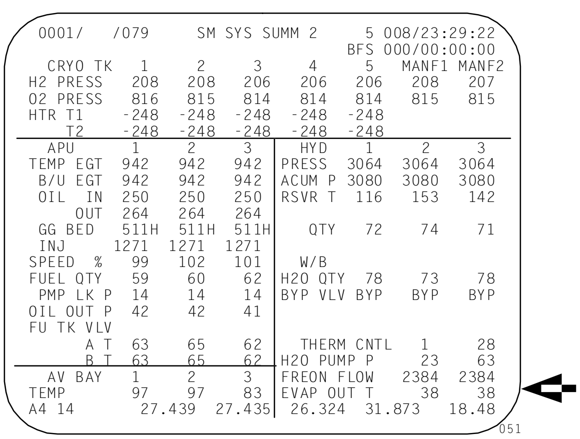
FES Heaters

Electrical heaters are employed on the topping and high-load flash evaporators' steam ducts to prevent freezing. The *HI LOAD DUCT HTR* rotary switch on panel L1 selects the electrical heaters. Switch positions *A* and *B* provide electrical power to the corresponding thermostatically controlled heaters on the high-load evaporator steam duct and steam duct exhaust. The *A/B* position provides electrical power to both thermostatically controlled heaters. The *C* position provides electrical power to both thermostatically controlled C heaters. The *OFF* position removes electrical power from all the heaters.

The *TOPPING EVAPORATOR HEATER DUCT* rotary switch on panel L1 selects the thermostatically controlled electrical heaters on the topping evaporator. Positions *A* and *B* provide electrical power to the corresponding heaters, while *A/B* provides electrical power to both A and B heaters. The *C* position provides power to the C heaters and part of the B heaters. The *OFF* position removes electrical power from all the heaters.



FREON EVAP OUT TEMP Meter and Switch on Panel O1



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 topping evaporator's left and right nozzle heaters are controlled by the *TOPPING EVAPORATOR HEATER L(R) NOZZLE* switches on panel L1. When the switches are positioned to *A AUTO* or *B AUTO*, electrical power is provided to the corresponding left and right nozzle heaters, and the corresponding nozzle temperature is maintained between 40° and 70° F. The *OFF* position removes electrical power from both heater systems.

FES Water Dumps

The flash evaporator topping evaporator can be used to dump excess water from the supply water storage tanks, if required, on orbit. When the *RAD CONTROLLER OUT TEMP* switch on panel L1 is placed in *HI*, the radiator flow control valve assembly controls that radiator outlet at 57° F. Since the topping evaporator controls to 39° F, water is used up at a rate of about 25 lb/hr, thus dumping excess water.

Ammonia Boilers

The ammonia boiler system acts as a heat sink by using the low boiling point of ammonia to cool the Freon coolant loops when the orbiter is below 400,000 feet during entry or on the ground after landing. The resultant superheated vapor is vented overboard. Two complete, individual ammonia storage and control systems feed one common boiler containing ammonia passages and the individual Freon coolant loops 1 and 2. Each system consists of a storage tank, an isolation valve, an overboard relief valve, two control valves, a controller, three temperature sensors, a pressure sensor and a feedline to the boiler.

The ammonia boiler is a shell-and-tube system with a single pass of ammonia on the ammonia side and two passes of each Freon coolant loop through the boiler. The ammonia flows in the ammonia tubes and the Freon coolant loop flows over the tubes, cooling the Freon coolant loops. When the ammonia flows over the warm Freon coolant lines in the boiler, it immediately vaporizes, and the heat and boiler exhaust are vented overboard in the upper aft fuselage of the orbiter next to the bottom right side of the vertical tail.

The ammonia system is normally used during entry if the radiators have not been cold-soaked. If radiator cooling is used during entry, the ammonia system is activated post-landing when radiator outlet temperatures reach 55° F. The ammonia boiler operations are used post-landing until a ground cooling cart is connected to the ground support equipment heat exchanger.

Storage Tanks

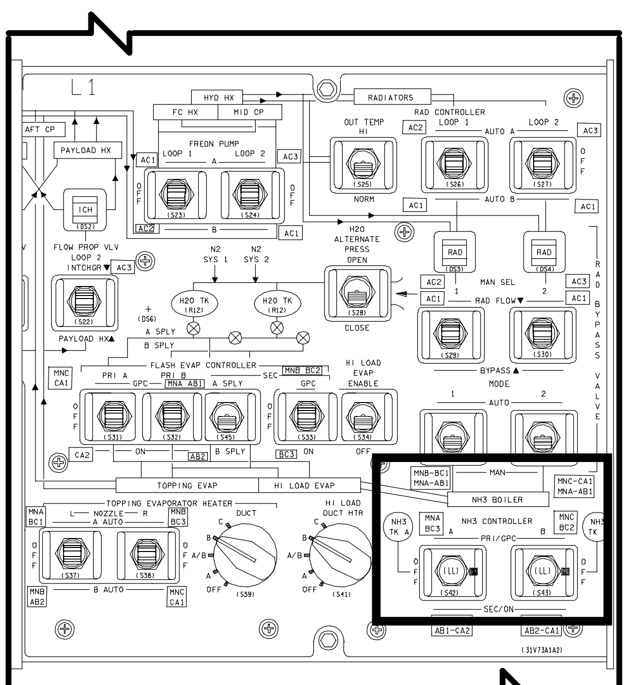
Each ammonia boiler storage tank contains a total of 49 pounds of ammonia (approximately 30 minutes of cooling), all of which is usable. Each tank is pressurized with gaseous helium at a maximum operating pressure of 550 psia. Downstream of each ammonia storage tank to the common boiler are three control valves: a normally closed isolation valve, a normally open secondary control valve, and a normally open primary control valve. A relief valve in each ammonia boiler storage system provides overpressurization protection of that ammonia storage tank.

Primary Ammonia Boiler Controller

The primary controller in the ammonia system controller energizes the ammonia system isolation valve, permitting ammonia to flow to two motor-operated controller valves. The controller also commands the primary motor-operated valve to regulate the flow to the ammonia boiler. Ammonia boiler supply systems A and B are enabled by the corresponding *NH_3 CONTROLLER* switches on panel L1. If required, one of the switches (usually *B*) is positioned to *PRI/GPC* before entry, which enables the GPC to control electrical power to the primary and secondary controllers within the ammonia controllers. When the orbiter descends through 120,000 feet, the backup flight system computer commands the selected ammonia system controller on.

Ammonia Boiler Control Sensors

Three temperature sensors are located on each Freon coolant loop. One sensor is associated with the primary controller and its motor-operated valve to regulate ammonia system A flow to maintain Freon coolant loop 1 and 2 temperatures at the outlet of the ammonia boiler at 35° F, ± 3° F. A second sensor is associated with the ammonia system A controller fault detection logic. If the Freon coolant loop 1 temperature drops below 31.25° F for longer than 10 seconds, the fault detection logic automatically inhibits the primary controller, which removes power from the ammonia system A isolation valve and the primary control valve. The logic switches to the secondary controller in the ammonia system A controller, which energizes a redundant coil in the ammonia system supply A isolation valve and closes the secondary control valve. It commands the isolation valve to full open and allows the secondary controller to control the secondary control valve to regulate the ammonia A flow to the ammonia boiler.



NH_3CONTROLLER Switches on Panel L1

The third sensor is associated with the secondary controller and secondary motor-operated valve. It regulates ammonia supply system A flow to maintain the Freon coolant loop 1 and 2 temperatures at the outlet of the ammonia boiler at 34° F. This automatic switchover is only from the primary to the secondary.

Secondary Controller

When the *NH_3 CONTROLLER A* or *B* switch on panel L1 is positioned to *SEC/ON*, the A or B ammonia system controller is electrically powered and enabled directly (no computer command is required). The secondary controller in the ammonia system controller energizes the system's isolation valve open, permitting ammonia to flow to two motor-operated controller valves. The secondary controller commands the primary controller's motor-operated valve to the open position and the secondary controller's motor-operated valve to regulate the ammonia flow to the ammonia boiler. The three temperature sensors on each Freon coolant loop operate and control Freon coolant loop 1 and 2 temperature in the same manner as in the *PRI/GPC* mode. Fault detection logic does not exist in the secondary controller.

The *OFF* position of the *NH_3 CONTROLLER* switches removes all electrical power from the ammonia system controller, rendering the ammonia system inoperative.

Supply and Wastewater Systems

The supply water system provides water for flash evaporator system cooling, crew consumption, and hygiene. The supply water system stores water generated by the fuel cells, and the wastewater system stores waste from the crew cabin humidity separator and from the flight crew. Four supply water tanks and one wastewater tank are located beneath the crew compartment middeck floor.

Data on the supply and wastewater system can be monitored on the ENVIRONMENT display (DISP 66) under H2O SUPPLY and WASTE items and on the BFS THERMAL display ($H_2$0 SUP P).

Supply Water System

The supply water system consists of four water tanks that are pressurized with nitrogen from the pressure control system. Each of the four potable water tanks has a usable capacity of 168 pounds, is 35.5 inches in length and 15.5 inches in diameter, and weighs 39.5 pounds dry.

The three fuel cells generate a maximum of 25 pounds of potable water per hour (about 0.81 pound of water per kilowatt hour). The product water from all three fuel cells flows to a single water relief control panel. The water can be directed to potable water tank A or to the fuel cell water relief nozzle. Normally, the water is directed to water tank A.

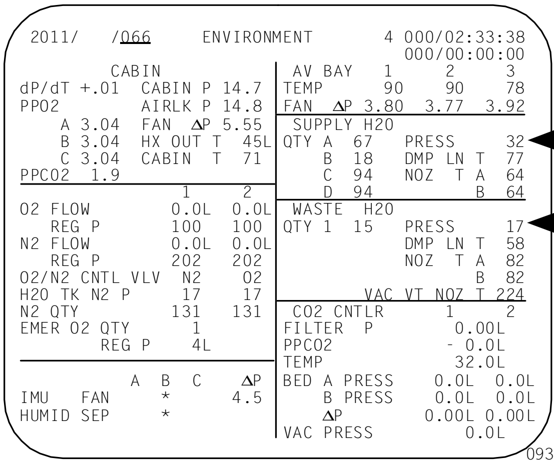
The product water lines from all three fuel cells were modified to incorporate a parallel (redundant) path of product water to potable water tank B in the event of a blockage of the primary water path to the tanks. If such a blockage were to occur, pressure would build up and relieve through the redundant paths to potable water tank B.

Instrumentation

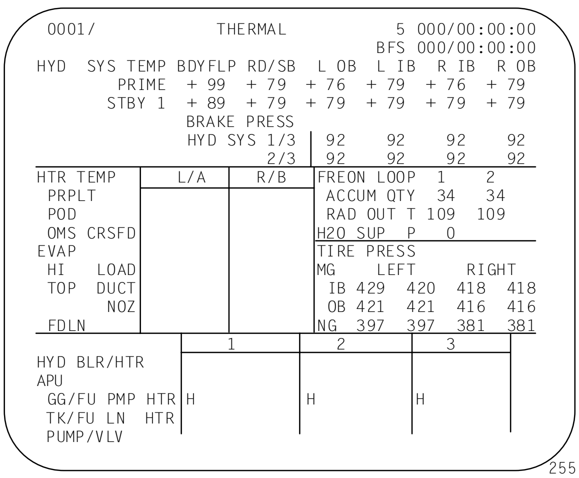
Temperature sensors are installed on each of the redundant paths; in addition, a pressure sensor is transmitted to telemetry and can be monitored on the BFS THERMAL display. A pH sensor is located at the common product water outlet of the water relief panel. It provides a redundant measurement of fuel cell health and water purity. A single measurement of water purity in each fuel cell is also provided. If a single fuel cell pH sensor indicated high, the flight crew would be required to sample the potable water to verify the proper pH.

Hydrogen Separators

The hydrogen-enriched water from the fuel cells flows through the single water relief panel through two hydrogen separators to potable water tank A. The separator removes 85 percent of the excess hydrogen. The hydrogen separators consist of a matrix of silver palladium tubes, which have an affinity for hydrogen. The hydrogen is dumped overboard through a vacuum vent. The redundant water line to tank B does not pass through the hydrogen separator. Water passing through the hydrogen separators can be stored in all four potable water tanks: A, B, C, and D.



H_2O System Parameters on the ENVIRONMENT Display (DISP 66)

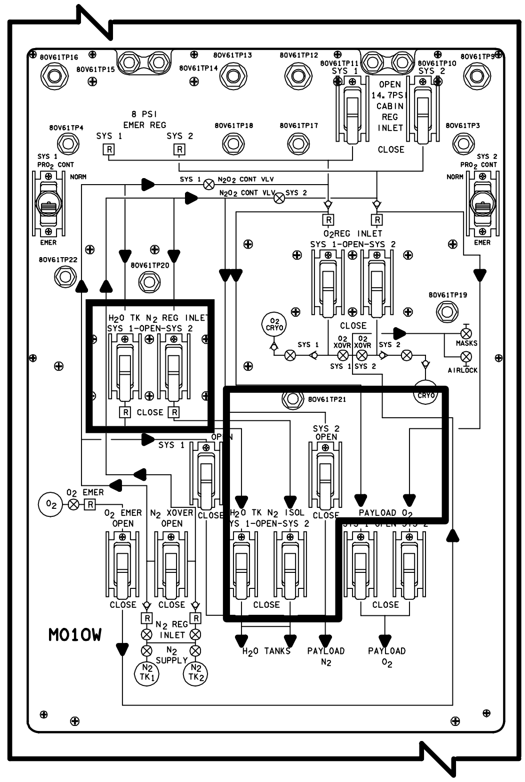


BFS THERMAL Display

Microbial Filter

The water entering tank A, which is sterilized before launch, passes through a microbial filter that adds approximately one-half parts per million iodine to the water to prevent microbial growth. The water stored in tank A is normally used for flight crew consumption; tanks B, C, and D are used for flash evaporator cooling. The water from the microbial check valve is also directed to a galley supply valve. If the water tank A inlet valve is closed, or tank A is full, water is directed to tank B through a 1.5 psid check valve where it branches off to tank B. If the tank B inlet valve is closed, or tank B is full of water, the water is directed through another 1.5 psid check valve to the inlets to tanks C and D.

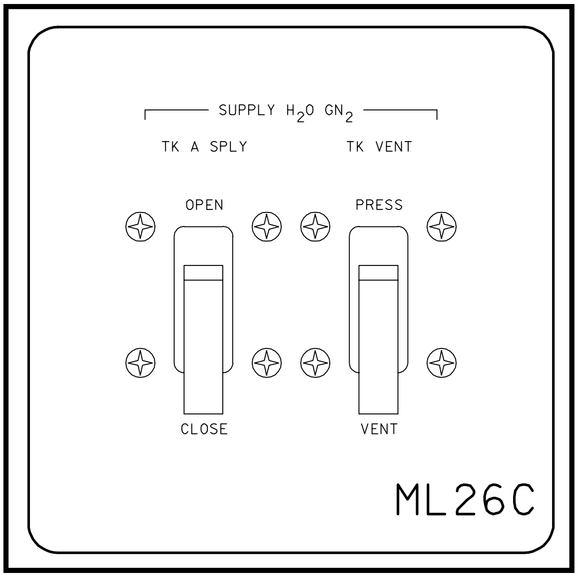
Each potable water tank has an inlet and outlet valve that can be opened or closed selectively to use water; however, the tank A outlet valve normally remains closed to isolate the treated water from the untreated water in the other tank.



Nitrogen Supply System Valves on Panel MO10W

Tank Pressurization

Each potable water and wastewater tank is pressurized with gaseous nitrogen from the crew compartment nitrogen supply system. The nitrogen and water are separated by a metal bellows. Nitrogen supply systems 1 and 2 can be used individually to pressurize the water tanks with nitrogen at 15.5 to 17.0 psig. Nitrogen supply system 1 is controlled by the *H_2O TK N_2 REG INLET* and *H_2O TK N_2 ISOL SYS 1* manual valves on panel MO10W. Nitrogen supply system 2 is controlled by the *SYS 2* manual valves on panel MO10W. The regulator in each nitrogen supply system controls the nitrogen pressure to the tanks at 15.5 to 17 psig, and a relief valve in each nitrogen supply system will relieve into the crew cabin if the nitrogen supply increases to 18.5 ± 1.5 psig, to protect the tanks from overpressurization.



Manual Valves on Panel ML26C

Tank Depressurization

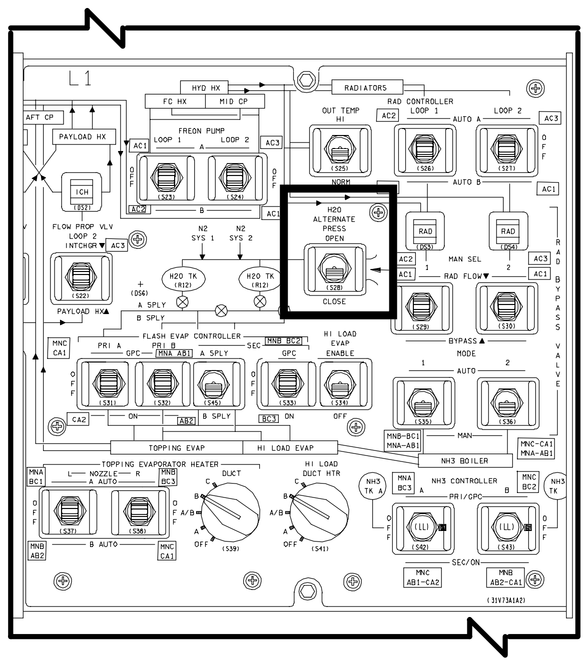
All the tanks can be vented to cabin pressure, but tank A is normally depressed for ascents, as described here. For only tank A, inlet nitrogen pressure is controlled by the *SPLY H_2O GN_2 TK A SPLY* and *TK VENT* manual valves on panel ML26C. When the tank A supply valve is closed, the tank is isolated from the nitrogen supply. When the tank A valve is opened, the tank is pressurized by the crew cabin atmosphere. For launch, the tank A supply valve is closed, and the tank vent is opened, which lowers tank A pressure. The fuel cell water head pressure is lower to help prevent flooding of the fuel cells during ascent. On orbit, the tank A supply valve is opened, and the tank A vent to the cabin is closed, allowing nitrogen supply pressure to tank A.

Alternate Water Pressurization

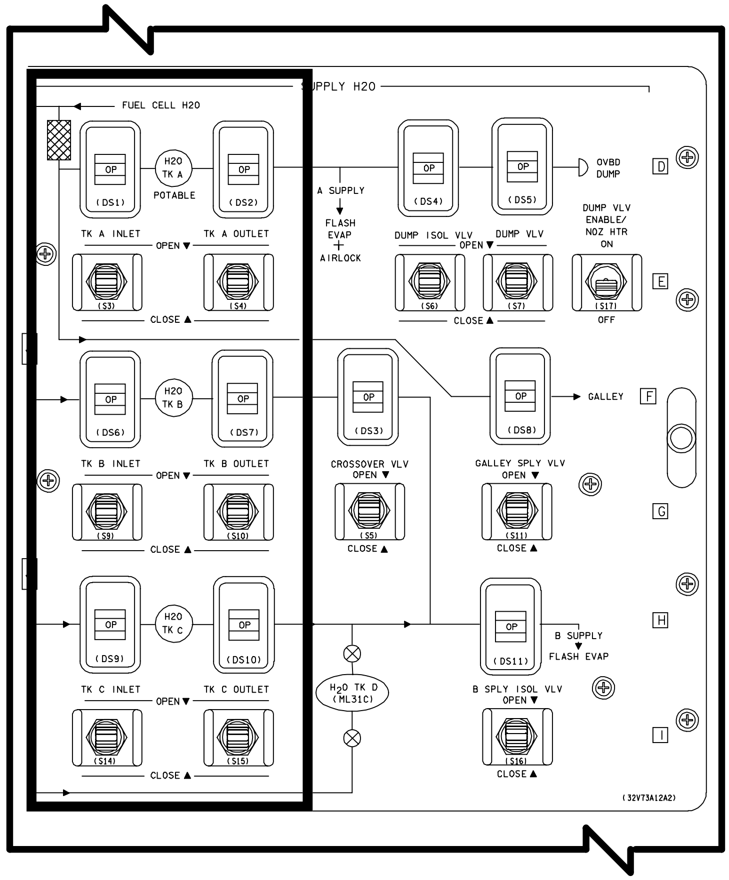
If neither nitrogen supply system 1 nor 2 can be used to pressurize the water tanks, the *H_2O ALTERNATE PRESS* switch on panel L1 can be positioned to *OPEN*, which would apply the crew cabin pressure to the water tanks. Normally, this switch is positioned to *CLOSE* to isolate the cabin pressurization system from the water tank pressurization system.

Supply Water Tank Inlet Valves

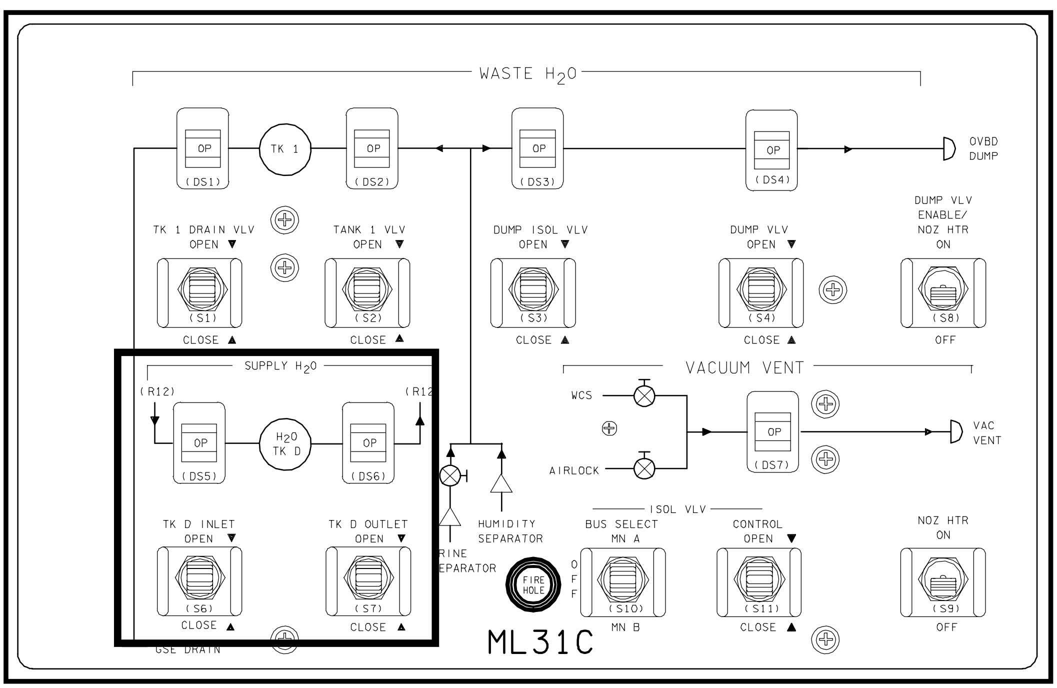
Potable water tank A, B, and C valves are controlled from panel R11L, and tank D valves are controlled from panel ML31C. When the *SUPPLY H2O TK A INLET*, *TK B INLET*, or *TK C INLET* switch on panel R11L is positioned to *OPEN*, the inlet valve for the tank permits water into that tank. A talkback indicator above the corresponding switch indicates *OP* when the corresponding valve is open, barberpole when the valve is in transit, and *CL* when that valve is closed. When the switch is positioned to *CLOSE*, the water inlet to that tank is isolated from the inlet water supply. The *SUPPLY H_2O TK D INLET* switch and talkback indicator are located on panel ML31C and operate in the same manner as the switches and talkbacks for tanks A, B, and C.



H_2O ALTERNATE PRESS Switch on Panel L1



TKT and OUTLET Switches and Talkbacks on Panel R11L



TK INLET and OUTLET Switches and Talkbacks on Panel ML31C

Tank Outlet Valves

Positioning the *SUPPLY H2O TK A, B,* or *C OUTLET* switch on panel R11L to *OPEN* permits water from the corresponding tank to flow from the tank into the water outlet manifold due to the tank nitrogen pressurization system. A talkback indicator above the switch would indicate *OP* when that valve is open, barberpole when it is in transit, and *CL* when it is closed. The *CLOSE* position of each switch isolates that water tank from the water outlet manifold. The *SUPPLY* H_2O *TK D OUTLET* switch and talkback indicator are located on panel ML31C and operate in the same manner as the tank A, B, and C switches and talkback indicators on panel R11L.

If the potable water tank B outlet valve is opened (normally tank A is used only for crew consumption), water from the corresponding tank is directed to the water outlet manifold. The tank A and B water is then available to the extravehicular mobility unit fill in the airlock, to the flash evaporator water supply system A, and to the water dump. The tank A outlet valve is normally closed to prevent contamination of the water in tank A. Thus, tank B would supply water to flash evaporator water supply system A and to the EMU fill in the airlock. If it is necessary to provide space for storing water in tank A and/or B, tank A and/or B water can be dumped overboard.

An external airlock water transfer valve and line will be installed on the orbiters with docking capability. The valve and line will provide capability to transfer water from the orbiter's supply H_2O system to Mir or the space station. This configuration is covered in more detail in the ODS section of this document

Tank C or D is normally saved full of water for contingency purposes. If the tank C or D outlet valve is opened, water from either tank is directed to the water outlet manifold. The water is then available to the flash evaporator B water supply.

Supply Water Crossover Valves

A crossover valve installed in the water outlet manifold is controlled by the *SUPPLY H2O CROSSOVER VLV* switch on panel R11L. When the switch is positioned to *OPEN*, the crossover valve opens and allows tank A or B (also C or D) to supply flash evaporator water supply systems A and B, the EMU fill in the airlock, and water dump. A talkback indicator above the switch indicates *OP* when the crossover valve is opened, barberpole when the valve is in transit, and *CL* when the valve is closed. The *CLOSE* position isolates the water manifold between the tank A and B outlets and the tank C and D outlets.

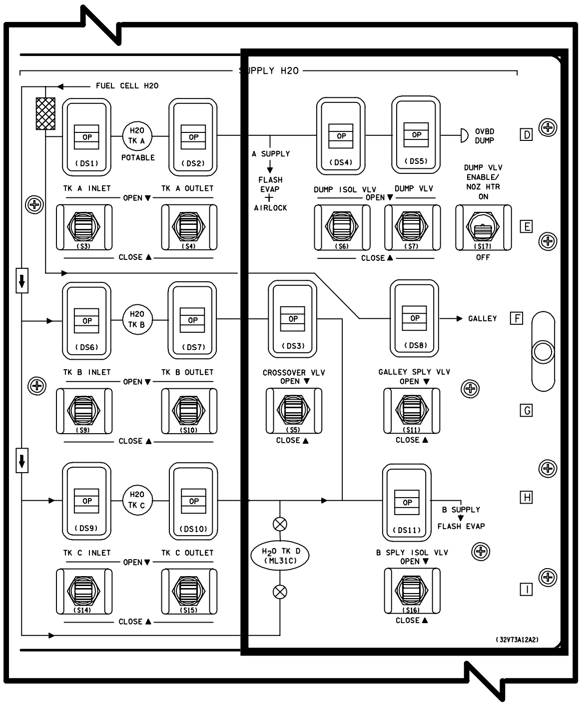
Supply Isolation Valve

Water from supply system A is routed directly to the flash evaporator. Water from system B is routed to an isolation valve in the system. The valve is controlled by the *SUPPLY H2O B SPLY ISOL VLV* switch on panel R11L. When the switch is positioned to *OPEN*, water from supply system B is directed to the flash evaporator. A talkback above the switch indicates *OP* when the valve is opened, barberpole when it is in transit, and *CL* when the valve is closed. The *CLOSE* position isolates water supply system B from the flash evaporator.

Supply Water Dumps

Potable water from all the tanks can be dumped overboard, if necessary, through a dump isolation valve and a dump valve. Potable water from tank C or D can also be dumped overboard, if necessary, through the crossover valve and through the dump isolation valve and dump valve. The overboard dump isolation valve is located in the crew cabin, and the dump valve is located in the midfuselage. The dump isolation valve is controlled by the *SUPPLY H2O DUMP ISOL VLV* switch on panel R11L. The dump valve is controlled by the *SUPPLY H2O DUMP VLV* switch on panel R11L.

The *SUPPLY H2O DUMP VLV ENABLE/NOZ HTR* switch on panel R11L must be positioned to *ON* to supply electrical power to the *SUPPLY H2O DUMP VLV* switch. The *ON* position also applies power to the nozzle heaters, which warm the nozzles to prevent freezing when the dump valve is opened. When the *DUMP VLV* and *DUMP ISOL VLV* switches are positioned to *OPEN*, the corresponding valve is opened, which allows potable water to be dumped overboard. A talkback indicator above each switch indicates *OP* when the corresponding valve is open, barberpole when it is in transit, and *CL* when it is closed. Closing either valve inhibits the dumping of potable water. At the completion of the dump, each switch is positioned to *CLOSE* to close the corresponding valve. The nozzle heater is then deactivated by placing the *SUPPLY H2O DUMP VLV ENABLE/NOZ HTR* switch to *OFF*.



SUPPLY H20 CROSSOVER VLV, ISOL VLV, and DUMP VLV Switches and Talkback on Panel R11L

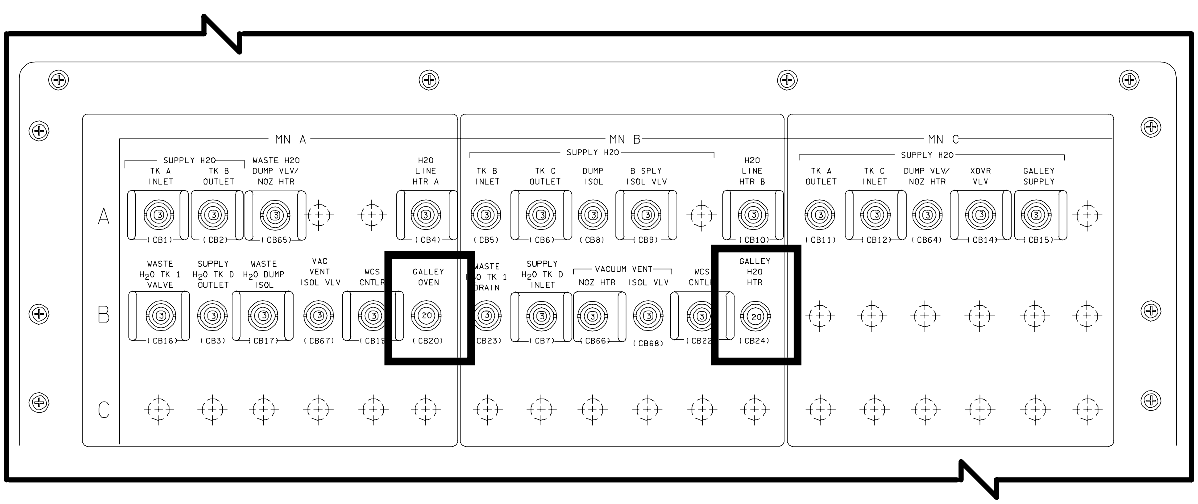
Contingency Crosstie

A contingency crosstie connection exists in the supply water overboard dump line between the dump isolation valve and dump valve. A corresponding crosstie connection exists in the wastewater overboard dump line between the dump isolation valve and dump valve. These crosstie connections permit the joining of the wastewater system through a flexible hose to the supply water system for emergency dumping of wastewater through the supply water dump (and vice versa).

Dump Nozzle Heaters

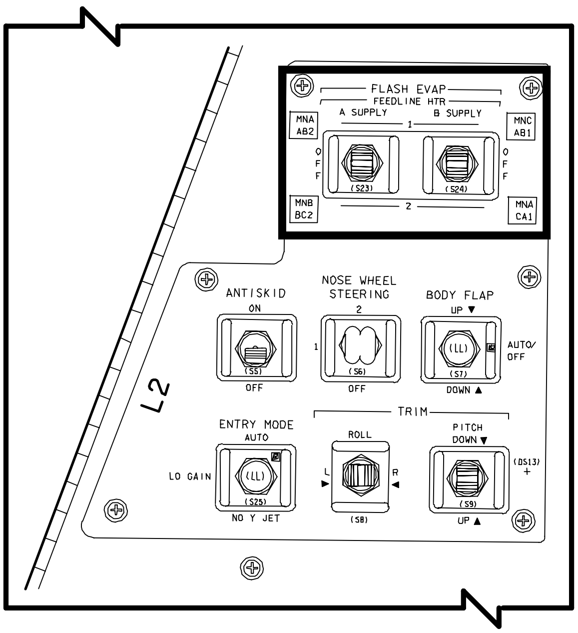
The supply water dump nozzle employs a heater to prevent freezing of the supply water dump nozzle at the midfuselage. The dump nozzle heater is powered when the *SUPPLY H2O DUMP VLV ENABLE/NOZ HTR* switch on panel R11L is positioned to *ON*. When the switch is positioned to *OFF*, it removes electrical power from the nozzle heater, as well as the *SUPPLY H2O DUMP VLV* switch, which causes the dump valve to close.

The supply water line upstream of the water dump nozzle has electrical heaters on the line to prevent supply water from freezing. The A and B heaters on the line are thermostatically controlled and are powered by the *H_2O LINE HTR A* and *B* circuit breakers on panel ML86B. (These circuit breakers also provide power to thermostatically controlled heaters on the wastewater line and the waste collection system vacuum vent line.)



H2O LINE HTR Circuit Breakers on Panel ML86B

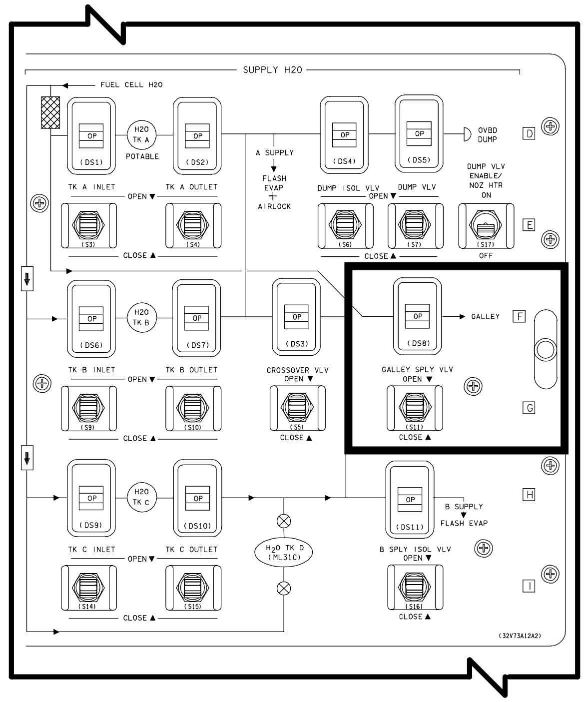
The supply water feed lines to the flash evaporators are approximately 100 feet long. To prevent the water in the lines from freezing, redundant heaters are installed along the length of the water lines. The heaters are controlled by the *FLASH EVAP FEEDLINE HTR A SUPPLY* and *B SUPPLY* switches on panel L2. When a switch is positioned to *1*, it enables the thermostatically controlled heaters on the corresponding supply line to automatically control the temperature on that line. When a switch is positioned to *2*, it enables the redundant thermostatically controlled heater system on the corresponding supply line. The *OFF* position of each switch inhibits heater operation on the corresponding supply line.



FLASH EV AP FEEDLINE HTR Switches on Panel L2

Galley Water Supply

The galley supply valve in the supply water line from the microbial filter of tank A permits or isolates the supply water from the galley or water dispenser. When the *SUPPLY H2O GALLEY SUP VLV* switch on panel R11L is positioned to *OPEN*, supply water is routed through parallel paths: one path flows through the atmospheric revitalization system water coolant loop water chiller for cooling of the supply water, and the other path bypasses the water chiller with ambient temperature water. A talkback indicator above the switch indicates *OP* when the valve is open, barberpole when the valve is in transit, and *CL* when the valve is closed. The *CLOSE* position of the switch isolates the potable supply water from the middeck ECLSS supply water panel.



GALLEY Water Supply Switch and Talkback on Panel R11L

If the galley is not available/manifested for a flight, the chilled water and ambient water are connected to an Apollo water dispenser to dispense ambient and chilled water for drinking and food reconstitution.

Wastewater System

A single wastewater tank receives wastewater from the humidity separator and the waste management system. The tank is located beneath the crew compartment middeck floor next to the potable water tanks.

The wastewater tank holds 168 pounds, is 35.5 inches long and 15.5 inches in diameter, and weighs 39.5 pounds dry. It is pressurized by gaseous nitrogen from the same source as the potable water tanks.

Wastewater is directed to the wastewater tank 1 inlet valve, which is controlled by the *WASTE* H_2O *TANK 1 VLV* switch on panel ML31C.

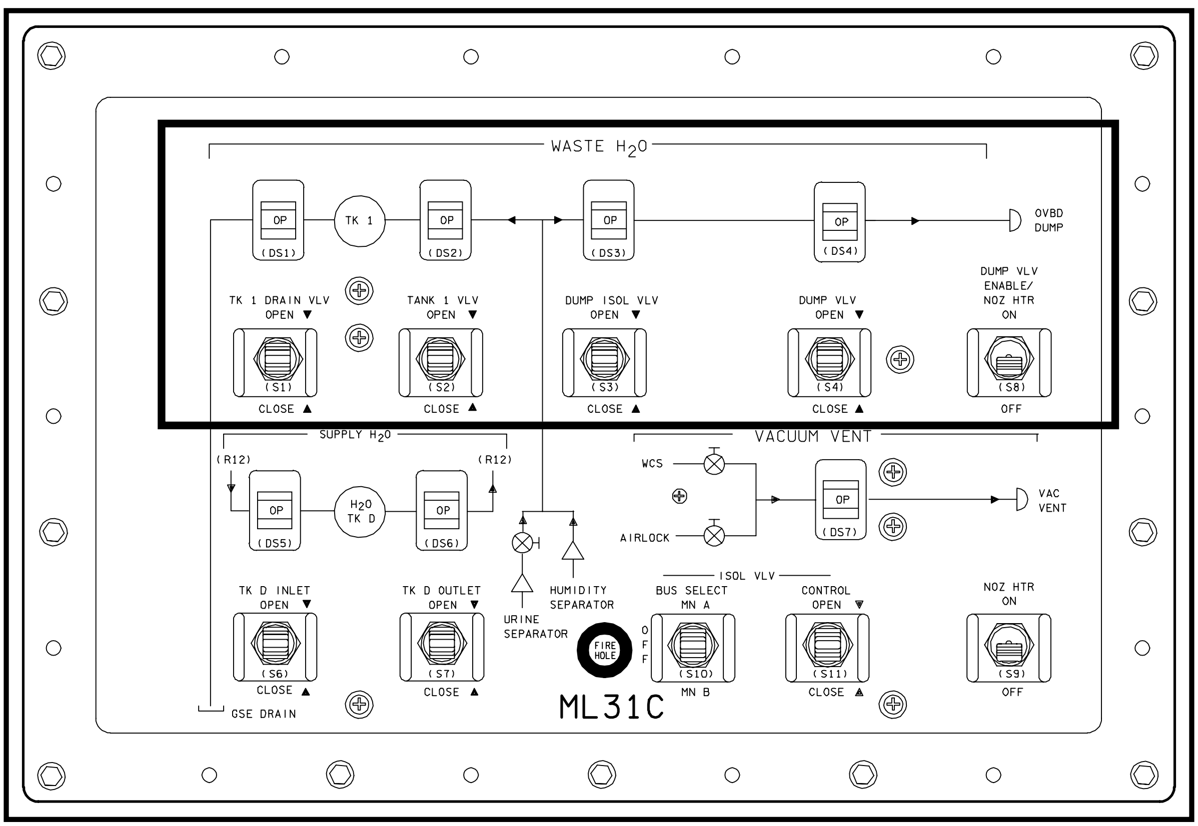
When the switch is positioned to *OPEN*, wastewater is directed to the wastewater tank. A talkback indicator above the switch indicates *OP* when the valve is open, barberpole when the valve is in transit, and *CL* when the valve is closed. Positioning the switch to *OFF* closes the wastewater tank inlet, isolating the wastewater tank from the wastewater collection system. When the valve is open, wastewater from the tank can also be directed to the wastewater dump for overboard dumping. The waste tank outlet (or drain) is always closed, except for ground draining of the tank.

Wastewater Dumps

The wastewater dump isolation valve and wastewater dump valve in the wastewater dump line allow wastewater to be dumped overboard through the wastewater dump. The *WASTE H_2O DUMP ISOL VLV* switch on panel ML31C positioned to *OPEN* allows wastewater to be directed to the wastewater dump valve. A talkback indicator above the switch indicates *OP* when the valve is open, barberpole when the valve is in transit, and *CL* when the valve is closed.

In order for wastewater to be dumped overboard, the wastewater dump valve must be opened. It is controlled by the *WASTE H_2O DUMP VLV ENABLE/NOZ HTR* and *WASTE H_2O DUMP VLV* switches on panel ML31C. When the *WASTE H_2O DUMP VLV ENABLE/NOZ HTR* switch is positioned to *ON*, electrical power is supplied to the wastewater dump heaters and the *WASTE H_2O DUMP VLV* switch.

When the *WASTE H_2O DUMP VLV* switch is positioned to *OPEN*, the dump valve allows wastewater to be dumped overboard. A talkback indicator above the switch indicates *OP* when the valve is open, barberpole when the valve is in transit, and *CL* when the valve is closed. If wastewater is dumped overboard, the *DUMP ISOL VLV* switch is positioned to *CL* upon completion of the dump. The *WASTE H_2O DUMP VLV* is positioned to *CLOSE*, and the *WASTE H_2O DUMP VLV ENABLE/NOZ HTR* switch is set to *OFF*.



WASTE H_2O System Switches and Talkbacks on Panel ML31C

CAUTION

If the *DUMP VLV ENABLE/NOZ HTR* switch is positioned to *OFF* before the *DUMP VLV* switch is positioned to *CLOSE*, the dump valve will remain open. The heaters at the wastewater dump prevent wastewater from freezing at the overboard dump.

The wastewater dump line, upstream of the waste dump nozzle, has electrical heaters on the line to prevent wastewater from freezing. The thermostatically controlled A and B heaters are powered by the *H_2O LINE HTR A* and *B* circuit breakers on ML86B. (These circuit breakers also provide power to thermostatically controlled heaters on the supply water line and waste collection system vacuum vent line.)

Contingency Crosstie

The contingency crosstie quick disconnect in the wastewater overboard dump line between the dump isolation valve and dump valve permits wastewater to be joined with the supply water system through a flexible hose for emergency dumping of supply water through the wastewater dump or using wastewater for the flash evaporators.

Wastewater Tank Draining

The wastewater tank 1 drain valve controls the draining of the wastewater tank during ground operations through the ground support equipment flush and drain. When the *WASTE H_2O TK 1 DRAIN VLV* switch on panel ML31C is positioned to *OPEN*, the valve permits the draining and flushing of the wastewater tank. The drain line is capped during flight. A talkback indicator above the switch indicates *OP* when the valve is open, barberpole when the valve is in transit, and *CL* when the valve is closed.

Operations

Pressure Control System

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 nitrogen 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 launch and entry suit helmets. The O_2/N_2 control valve on pressure control system 1 is open to allow N_2 to pressurize the O_2/N_2 manifold. The O_2/N_2 control valve on pressure control system 2 is closed. This would normally allow oxygen to flow to the O_2/N_2 manifold, but since the oxygen regulators are closed, nothing is configured to flow through the emergency 8 psia regulators on pressure control system 2. The crew will close the visors of their launch and entry suit helmets shortly before lift-off and breathe 100 percent O_2 until shortly after solid rocket booster separation.

The pressure control system remains in the ascent configuration until early in the flight plan when the orbit pressure control system configuration is performed. The pressure control system configuration to system 1 is called for in the flight day 1 EZ activities block. The 14.7 psia cabin regulator inlet valve on the selected pressure control system 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. During the postsleep activities on flight day 2, an O_2 bleed orifice is installed in launch and entry helmet QD-5. The O_2 bleed orifice is sized based on number of crew 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. A reconfiguration to pressure control system 2 is performed halfway through the mission.

A 10.2 psia cabin protocol was developed by the flight surgeons to minimize the risk of decompression sickness (bends) for crewmembers preparing for an EVA. The EVA crewmembers must prebreathe pure O_2 before they go EVA to help flush N_2 out of their body tissue. The following 10.2 cabin protocol options have been developed:

- Option 1
  - 60-minute initial prebreathe on launch and entry suit helmet
  - 12 hours at 10.2 psia cabin pressure
  - 75-minute final prebreathe in suit
- Option 2
  - 60-minute initial prebreathe on launch and entry suit helmet
  - 24 hours at 10.2 psia cabin pressure
  - 40-minute final prebreathe in suit
- 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 PPO_2 levels must be manually managed during 10.2 psia cabin operations.

The pressure control system configuration is the same for entry as it was for ascent.

Atmospheric Revitalization System

The atmospheric revitalization system is already configured for ascent at crew ingress. One cabin fan, one humidity separator, one inertial measurement unit fan, and one fan in each avionics bay are already operating. 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 humidity separators and the IMU fan signal conditioners are unpowered to protect against an ac to ac bus short, which could cause loss of a main engine controller. (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. Both water bypass valves are positioned to flow approximately 950 lb/hr through the Freon/water interchanger.

If no failures occur during ascent, then no actions are required to manage the atmospheric revitalization system in OVs 103 and 104 (OV 105 if flown without the RCRS) with the exception of scheduled LiOH canister change outs. During the post insertion period for RCRS configured vehicles, the crew will activate the system. Every 13 minutes the RCRS will automatically switch chemical beds between regeneration and adsorption as part of a 26 minute full regeneration cycle with no further crew actions for nominal operations. Mid-mission (on 10+ day flights) the activated charcoal canister will be changed out. The operating cabin fan(s) should be turned off for removal and installation of canisters.

The orbit fan and pump configuration is the same on orbit as for ascent, except water loop 1 is set to the *GPC* position and the BYPASS controller for water loop 2 is set to the AUTO position. While in SM OPS 2 (or SM OPS 4), the *GPC* position enables the inactive water loop to be cycled on periodically. This periodic cycling prevents the inactive water loop from freezing in the Freon/water interchanger. The cycling sequence is initiated any time an OPS transition is made into SM OPS 2 (or SM OPS 4). When an OPS transition is made, the pump will receive a 6-minute *"ON"* command, then remain off for 4 hours. The pump will cycle on for 6 minutes every 4 hours.

The pump on water loop 2 is powered by AC3 when its switch is in the *ON* position. The *GPC* position of the *WATER PUMP LOOP 2* switch provides an alternate power source for the pump during ascent and entry. When the backup flight system computer has control of the payload MDMs, the *GPC* position powers the loop 2 pump with AC1 power. Since water loop 2 has only one pump, this enables the pump to remain powered even if AC3 should fail. The *GPC* position of the *WATER LOOP 1 PUMP* switch has no special function during ascent and entry; it acts just like the *OFF* position.

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

Cooling Management

Depending on the mission phase, the Freon cooling loops are cooled four different ways. Prior to launch, cooling is provided by the ground support equipment. After lift-off, there is no active means of cooling until after solid rocket booster separation. 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 solid rocket booster separation, the flash evaporator system receives a GPC "ON" command from the BFS and begins providing active cooling. The flash evaporator system 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 topping flash evaporator system may be left on to provide supplemental cooling when necessary. If the orbiter is in a warm attitude, the radiator panels may not be effective enough to provide the desired cooling. The flash evaporator system can provide the additional cooling necessary to achieve the desired Freon loop temperatures.

During the deorbit prep procedures, the radiators are "cold soaked" for use later during entry. The radiator coldsoak process stores cool Freon in the radiator panels. This is accomplished by changing the radiator control temperature from 38° to 57° F. The flash evaporator system is reactivated to cool the Freon loops from 57° to 39° F. Since less cool Freon from the radiator panels is required to achieve the 57° F RAD OUT temperature, the Freon stays in the radiator panels longer and becomes even cooler. After being in this configuration for a little over an hour, the radiators are bypassed, and the flash evaporator system begins providing all the cooling. The flash evaporator system provides the cooling during the rest of the deorbit, through entry interface, and on down to V = 12k (approximately 175,000 ft). Additionally, during deorbit prep for RCRS configured vehicles, the crew will replace the LiOH canister, and deactivate the RCRS. The operating cabin fan(s) should be turned off during this procedure.

At V = 12k, the radiators are put through their auto startup sequence, and radiator flow is reinitiated. Below 100,000 ft, the atmospheric pressure is too high for the flash evaporator system to cool effectively. Normally, the radiator coldsoak is used as the primary source of cooling from this point through rollout.

Once radiator coldsoak is depleted, the ammonia boilers are used as the primary cooling source until the ground support equipment cooling cart hookup is complete. Then the ammonia cooling is deactivated, and ground support equipment cooling is initiated.

For ascent aborts, the thermal management of the Freon cooling is somewhat different. The flash evaporator system still provides the cooling after solid rocket booster separation. The cooling management during the entry portion changes. The ammonia boilers provide the cooling during the lower stages of the abort entry. The ammonia is used for cooling during the entry phase of an ascent abort because the orbiter lifts off without a radiator coldsoak, and the flash evaporator system functions normally only at low atmospheric pressure (above 100,000 ft).

For a transoceanic abort landing or an abort once around, the ammonia boiler receives a GPC "ON" command from the BFS at MM 304 and 120,000 ft. For a return to launch site abort, the ammonia boiler receives a GPC "ON" command from the BFS at external tank separation (MM 602). The ammonia boiler will provide the cooling from this point through landing. The ammonia boilers can provide cooling for approximately 1 hour.

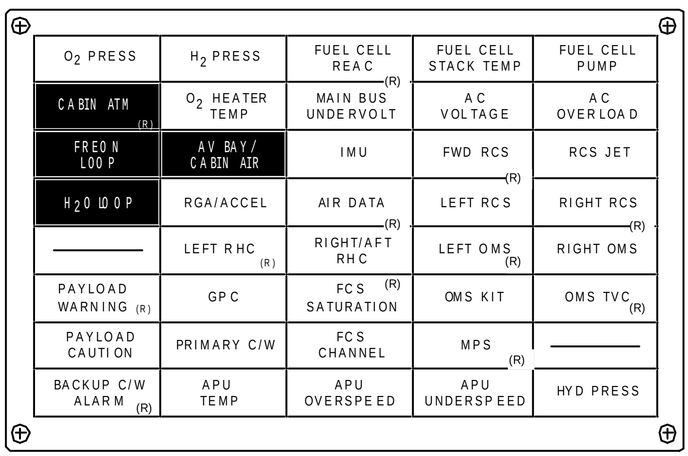
ECLSS Caution and Warning Summary

- The red *CABIN ATM* caution and warning light on panel F7 is illuminated for any of the following monitored parameters: (1) cabin pressure below 13.8 psia or above 15.2 psia, (2) PPO_2 below 2.7 psia or above 3.6 psia, (3) oxygen flow rate above 4.9 pounds per hour, and (4) nitrogen flow rate above 4.9 pounds per hour.

- The yellow *AV BAY/CABIN AIR* C/W light will illuminate for the following conditions: any avionics bay temperature higher than 130° F, the heat exchanger out temperature higher than 145° F, or cabin fan delta P below 4.2 inches of water or greater than 6.8 inches.

- The yellow *H_2O LOOP* C/W light will illuminate if the outlet pressure of water coolant loop pump 1 is less than 19.5 psia or greater than 79.5 psia, or if pump 2 pressure is less than 45 psia or greater than 81 psia.

- The yellow *FREON LOOP* light will illuminate if Freon flow in either coolant loop is less than 1200 pph, or if either loop's evap out temperature is less than 32.2° F or greater than 64.8° F (upper limit for ascent is 115° F.)



ECLSS Caution and Warning :Lights on Panel F7

ECLSS Summary Data

- The functions of the ECLSS are to maintain the orbiter's thermal stability, provide a pressurized, habitable environment for the crew and onboard avionics, and store water and liquid waste.

- The four components of the ECLSS are the pressure control, atmospheric revitalization, active thermal control, and supply and wastewater systems.

- The pressure control system pressurizes the crew cabin at 14.7 psia, pressurizes the supply and wastewater tanks, and provides breathing oxygen directly to the launch and entry suit helmets, and emergency breathing masks.

- The main components of the pressure control system are oxygen and nitrogen systems, tanks, and valves.

- The atmospheric revitalization system circulates air through the crew compartment to control relative humidity between 30 and 65 percent, maintain carbon dioxide and carbon monoxide at non-toxic levels, air filtration, control temperature and ventilation in the crew compartment, and provide avionics cooling. The water loop provides cooling for the crew and avionics.

- The atmospheric revitalization system consists of cabin air loops, water coolant loops, fans, and heat exchangers and interchangers.

- The active thermal control system provides orbiter heat rejection during all phases of the mission.

- The active thermal control system consists of two complete, identical Freon coolant loop systems, cold plate networks for cooling avionics units, liquid/liquid heat exchangers, and radiators, flash evaporators, and ammonia boilers.

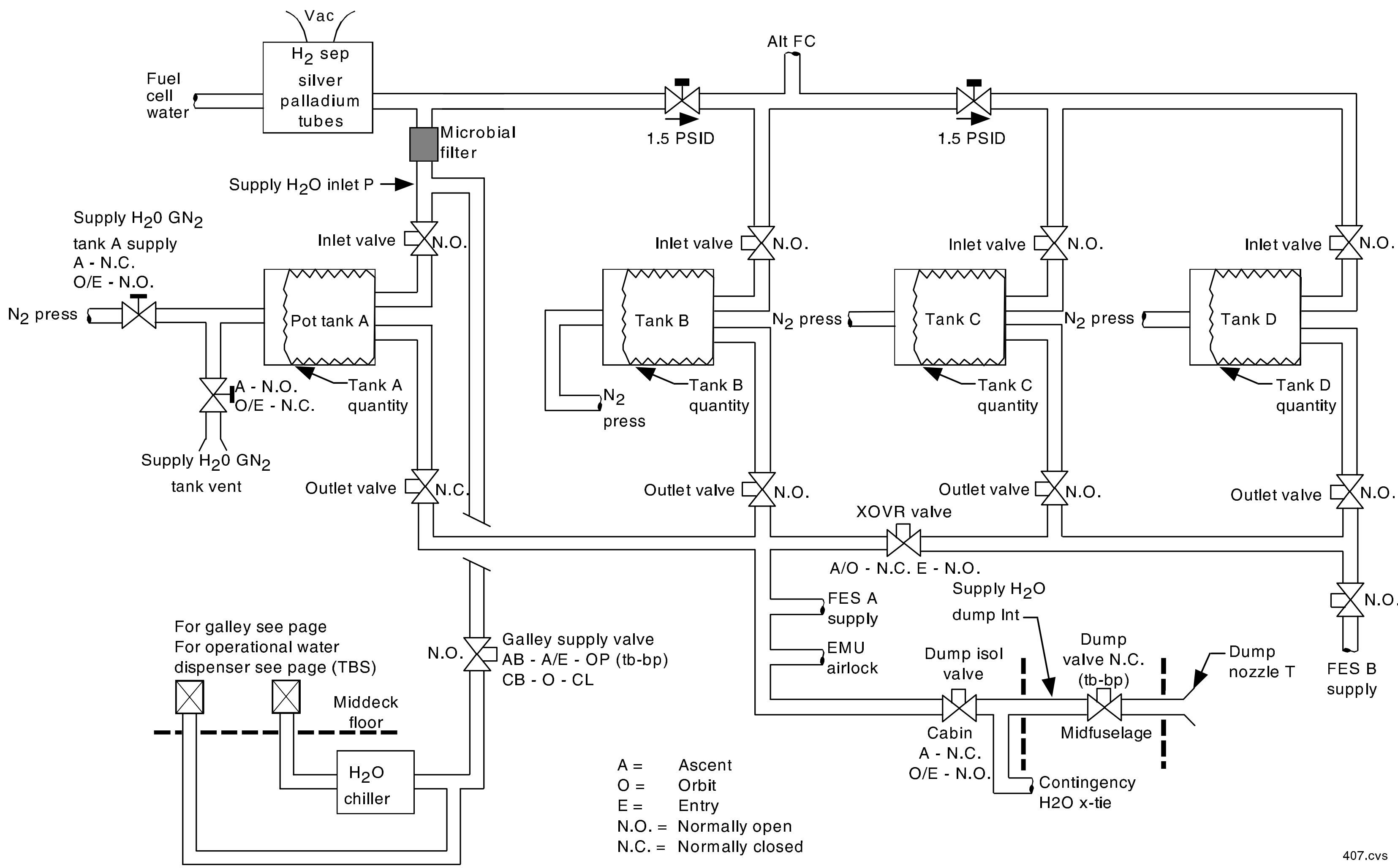
- The supply water system stores potable water generated by the fuel cells. The supply water is used for flash evaporator system cooling, crew consumption, and hygiene.

- The wastewater system stores waste from the crew cabin humidity separator and from the crew.

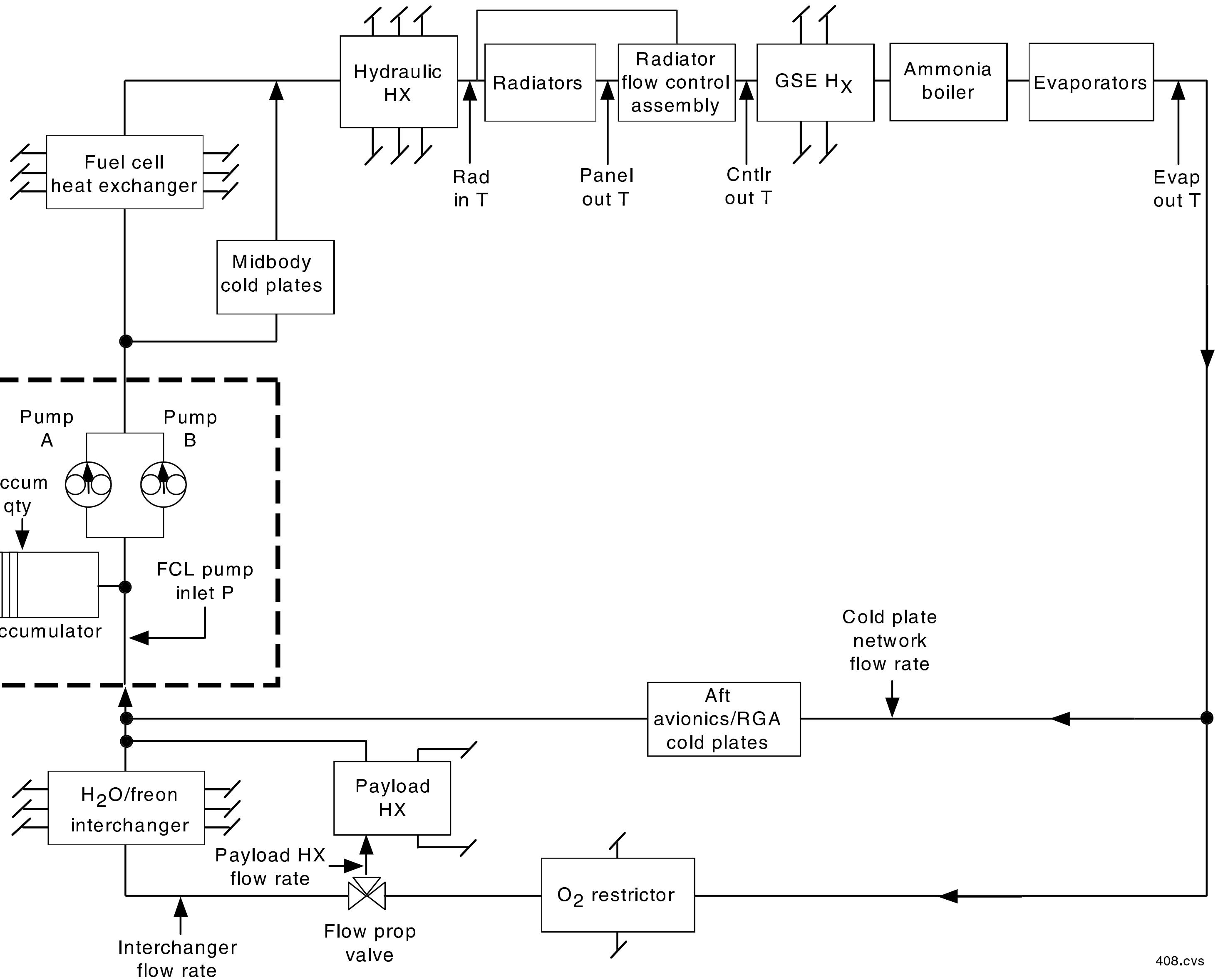
- Four supply water tanks and one wastewater tank are located beneath the crew compartment middeck floor.

- Panels that control the major portion of ECLSS functions are panels L1, L2, MO10W, and R11L. Panels ML31C, ML86B, MA73C, R13L, MO51F, and MD44F also control ECLSS functions.

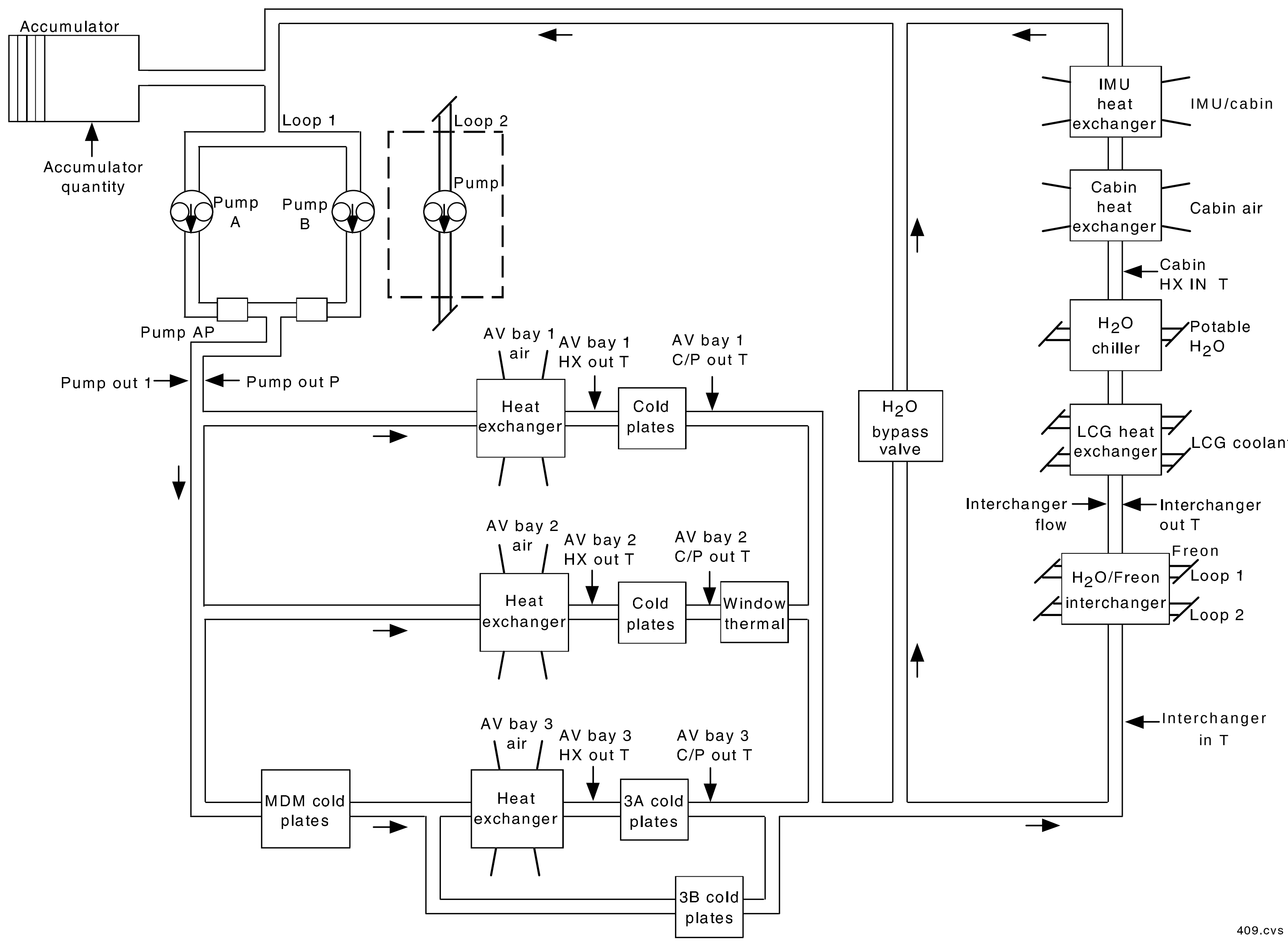
- ECLSS status can be monitored on panel O1 and on the following CRT displays: ENVIRONMENT (DISP 66), SM SYS SUMM 1, SM SYS SUMM 2, APU/ENVIRON THERM (DISP 88), and BFS THERMAL.



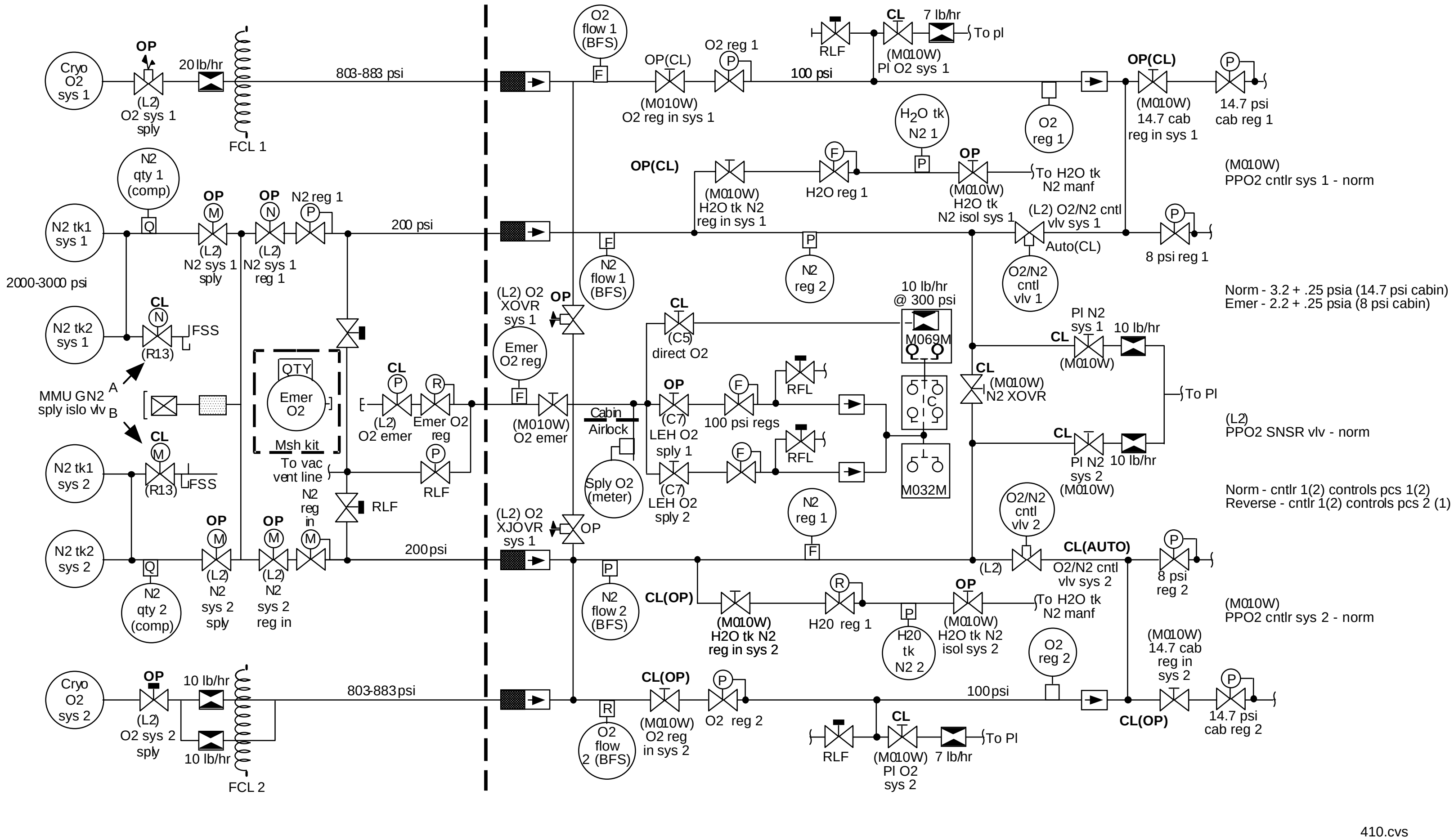
Supply Water Storage System


Hydraulic HX
Radiators
Radiator flow control assembly
GSE HX
Ammonia boiler
Evaporators
Fuel cell heat exchanger
Rad in T
Panel out T
Cntlr out T
Evap out T
Midbody cold plates
Pump A
Pump B
Accum qty
Accumulator
FCL pump inlet P
Cold plate network flow rate
Aft avionics/RGA cold plates
H2O/freon interchanger
Payload HX
Payload HX flow rate
O2 restrictor
Interchanger flow rate
Flow prop valve
408.cvs

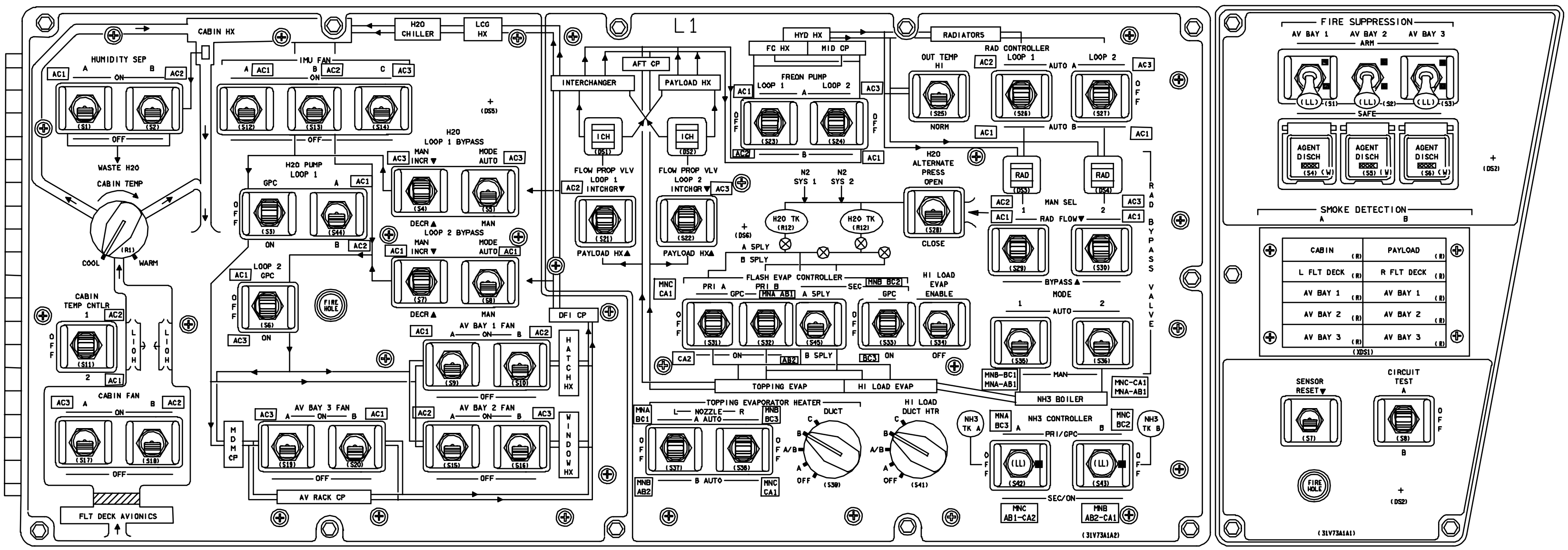
Freon Flow


Accumulator
Accumulator quantity
Loop 1
Loop 2
Pump A
Pump B
Pump
Pump AP
Pump out 1
Pump out P
AV bay 1 air
AV bay 1 HX out T
AV bay 1 C/P out T
Heat exchanger
Cold plates
AV bay 2 air
AV bay 2 HX out T
AV bay 2 C/P out T
Heat exchanger
Cold plates
Window thermal
AV bay 3 air
AV bay 3 HX out T
AV bay 3 C/P out T
MDM cold plates
Heat exchanger
3A cold plates
3B cold plates
H2O bypass valve
IMU heat exchanger
IMU/cabin
Cabin heat exchanger
Cabin air
Cabin HX IN T
H2O chiller
Potable H2O
LCG heat exchanger
LCG coolant
Interchanger flow
Interchanger out T
Freon
H2O/Freon interchanger
Loop 1
Loop 2
Interchanger in T
409.cvs

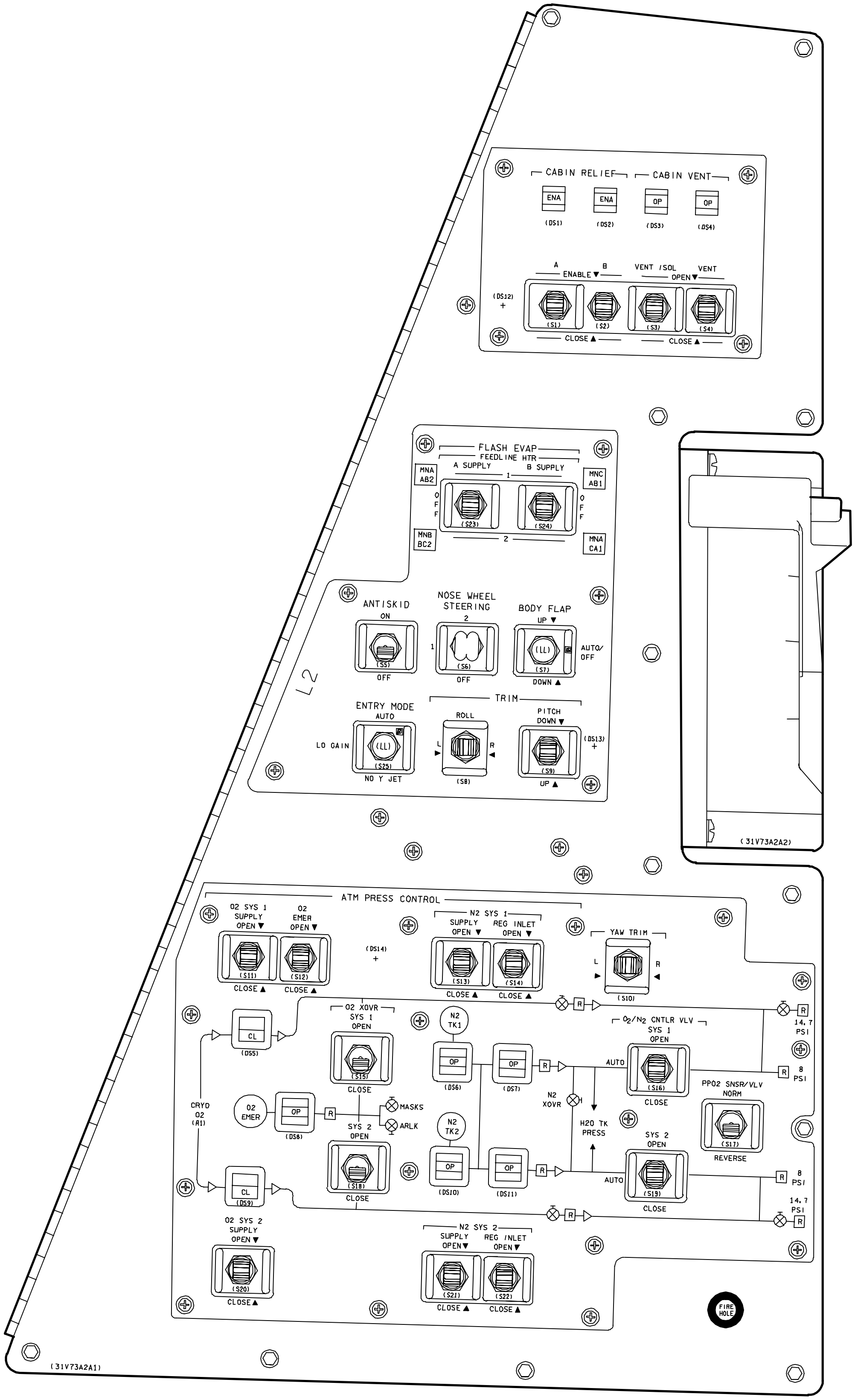
Water Loops



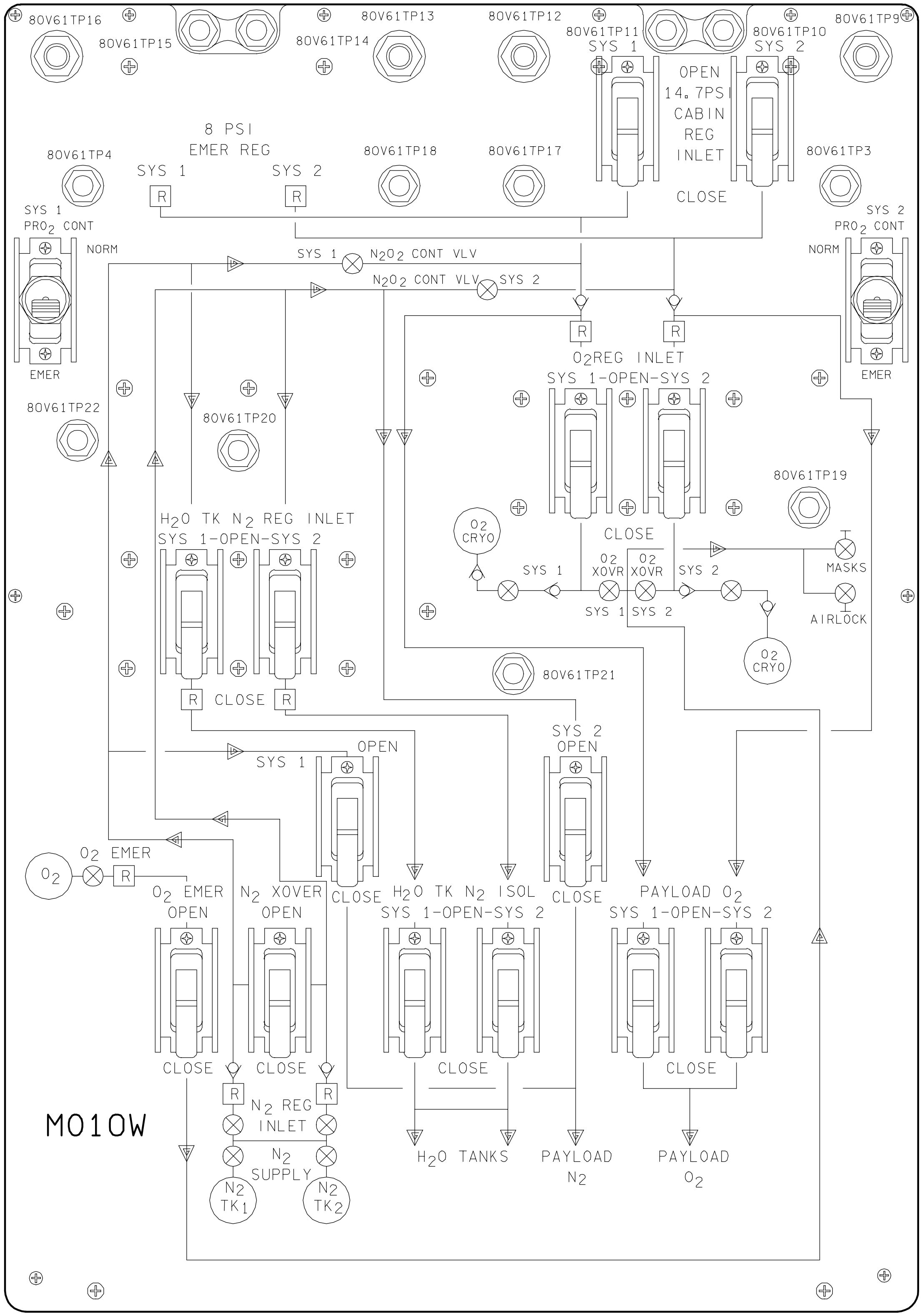
Pressure Control System (Orbit)


L1
CABIN HX
H2O CHILLER
LCG HX
HUMIDITY SEP
IMU FAN
OFF
ON
WASTE H2O
CABIN TEMP
COOL
WARM
H2O PUMP LOOP 1
GPC
H2O LOOP 1 BYPASS
MAN INCR
MODE AUTO
DECR
MAN
LOOP 2 BYPASS
LOOP 2 GPC
FIRE HOLE
CABIN TEMP CNTLR
CABIN FAN
AV BAY 1 FAN
AV BAY 2 FAN
AV BAY 3 FAN
HATCH HX
WINDOW HX
MDM CP
AV RACK CP
FLT DECK AVIONICS
DFI CP
AFT CP
INTERCHANGER
PAYLOAD HX
FLOW PROP VLV LOOP 1 INTCHGR
FLOW PROP VLV LOOP 2 INTCHGR
PAYLOAD HX
HYD HX
FC HX
MID CP
FREON PUMP
LOOP 1
LOOP 2
RADIATORS
RAD CONTROLLER
OUT TEMP HI
NORM
AUTO A
AUTO B
H2O ALTERNATE PRESS
OPEN
CLOSE
N2 SYS 1
N2 SYS 2
H2O TK
A SPLY
B SPLY
MAN SEL
RAD FLOW
BYPASS
MODE
AUTO
RAD BYPASS VALVE
FLASH EVAP CONTROLLER
PRI A
PRI B
SEC
HI LOAD EVAP ENABLE
TOPPING EVAP
HI LOAD EVAP
NH3 BOILER
TOPPING EVAPORATOR HEATER
NOZZLE
A AUTO
B AUTO
DUCT
HI LOAD DUCT HTR
NH3 CONTROLLER
PRI/GPC
SEC/ON
NH3 TK A
NH3 TK B
FIRE SUPPRESSION
AV BAY 1
AV BAY 2
AV BAY 3
ARM
SAFE
AGENT DISCH
SMOKE DETECTION
CABIN
PAYLOAD
L FLT DECK
R FLT DECK
SENSOR RESET
CIRCUIT TEST

Panel L1



Panel L2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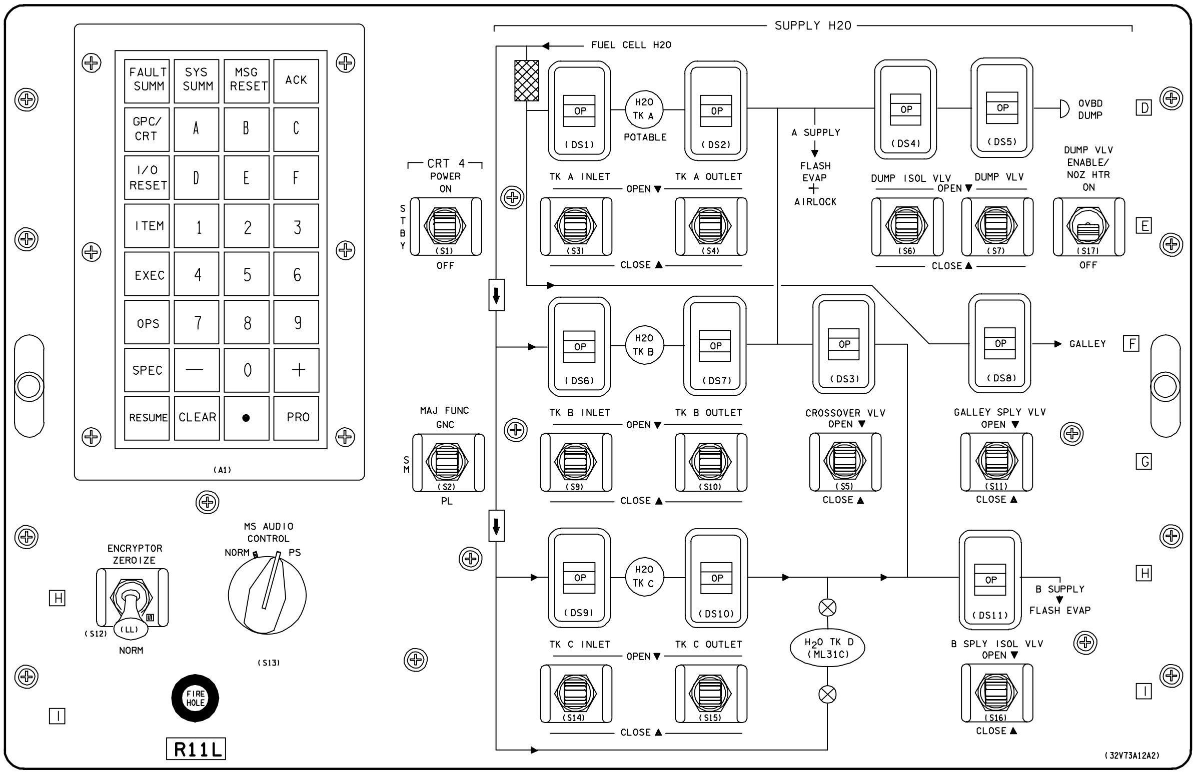
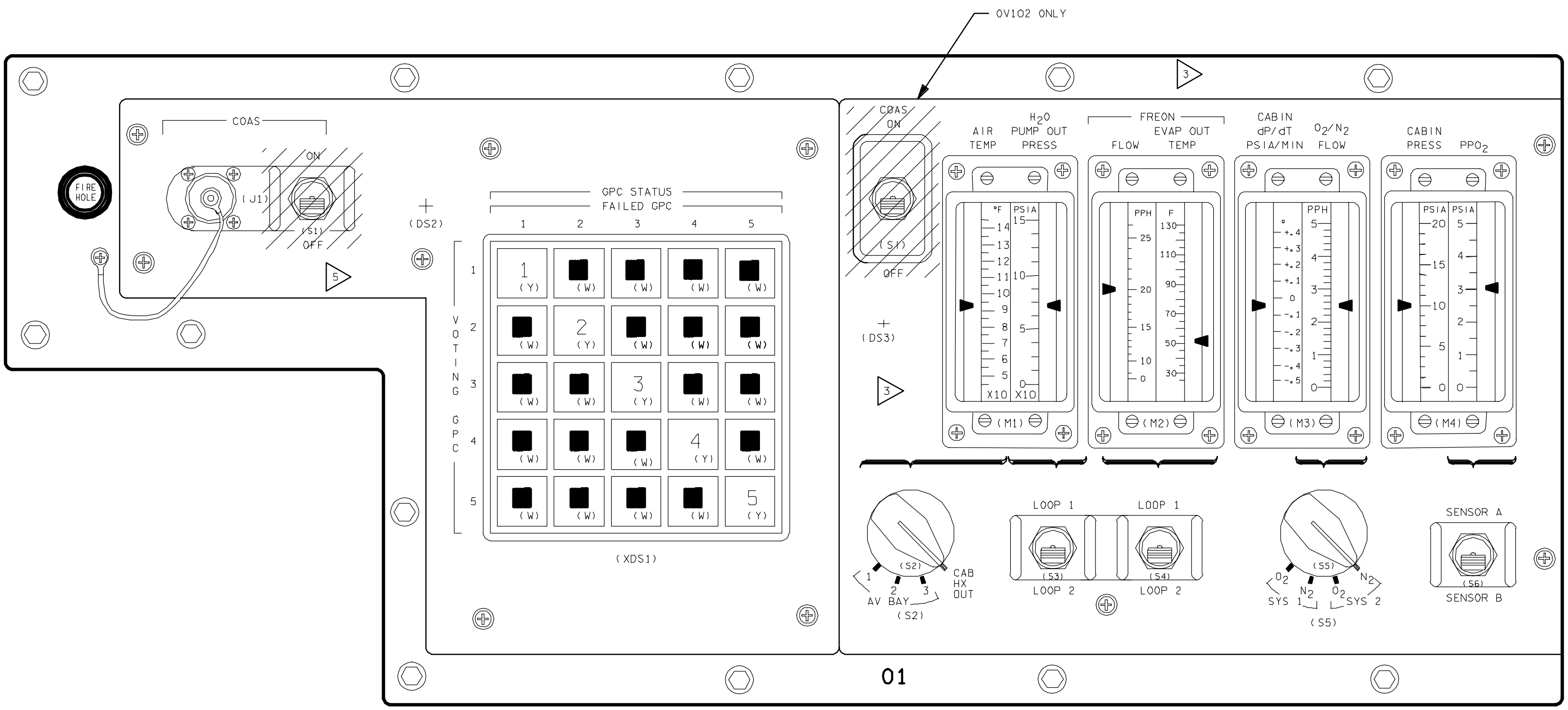
80V61TP15
80V61TP14
80V61TP13
80V61TP12
80V61TP11
80V61TP10
80V61TP9
SYS 1
SYS 2
OPEN
14.7PSI
CABIN
REG
INLET
CLOSE
8 PSI
EMER REG
SYS 1
SYS 2
80V61TP4
80V61TP18
80V61TP17
80V61TP3
SYS 1
PRO2 CONT
NORM
EMER
SYS 2
PRO2 CONT
NORM
EMER
SYS 1 N2O2 CONT VLV
N2O2 CONT VLV SYS 2
O2REG INLET
SYS 1-OPEN-SYS 2
CLOSE
80V61TP22
80V61TP20
80V61TP19
H2O TK N2 REG INLET
SYS 1-OPEN-SYS 2
CLOSE
O2
CRYO
SYS 1
O2
XOVR
O2
XOVR
SYS 2
SYS 1
SYS 2
MASKS
AIRLOCK
O2
CRYO
80V61TP21
SYS 2
OPEN
SYS 1
OPEN
CLOSE
CLOSE
O2 EMER
O2
O2 EMER
OPEN
N2 XOVER
OPEN
H2O TK N2 ISOL
SYS 1-OPEN-SYS 2
PAYLOAD O2
SYS 1-OPEN-SYS 2
CLOSE
CLOSE
CLOSE
CLOSE
N2 REG
INLET
N2
SUPPLY
N2
TK1
N2
TK2
H2O TANKS
PAYLOAD
N2
PAYLOAD
O2
MO10W

Panel MO10W


SUPPLY H2O
FUEL CELL H2O
FAULT SUMM
SYS SUMM
MSG RESET
ACK
GPC/ CRT
A
B
C
I/O RESET
D
E
F
ITEM
1
2
3
EXEC
4
5
6
OPS
7
8
9
SPEC
—
0
+
RESUME
CLEAR
PRO
(A1)
CRT 4
POWER
ON
STBY
OFF
MAJ FUNC
GNC
SM
PL
H2O TK A
POTABLE
H2O TK B
H2O TK C
TK A INLET
TK A OUTLET
TK B INLET
TK B OUTLET
TK C INLET
TK C OUTLET
OPEN
CLOSE
A SUPPLY
FLASH EVAP
AIRLOCK
DUMP ISOL VLV
DUMP VLV
OVBD DUMP
DUMP VLV ENABLE/ NOZ HTR
ON
OFF
CROSSOVER VLV
GALLEY SPLY VLV
GALLEY
H2O TK D (ML31C)
B SUPPLY
FLASH EVAP
B SPLY ISOL VLV
ENCRYPTOR ZEROIZE
NORM
MS AUDIO CONTROL
NORM
PS
FIRE HOLE
R11L
(32V73A12A2)

Panel R11L


OV102 ONLY
COAS
ON
OFF
FIRE HOLE
GPC STATUS
FAILED GPC
VOTING GPC
(XDS1)
AIR TEMP
H2O PUMP OUT PRESS
FREON
FLOW
EVAP OUT TEMP
CABIN dP/dT PSIA/MIN
O2/N2 FLOW
CABIN PRESS
PPO2
LOOP 1
LOOP 2
AV BAY
CAB HX OUT
SYS 1
SYS 2
SENSOR A
SENSOR B
O1

Panel O1

```
 2011/   /066      ENVIRONMENT        4 000/02:33:38
                                        000/00:00:00
         CABIN                 | AV BAY   1      2     3
dP/dT +.01  CABIN P 14.7       |TEMP      90     90    78
PPO2        AIRLK P 14.8       |FAN  ΔP 3.80   3.77  3.92
   A 3.04   FAN  ΔP 5.55       | SUPPLY H2O
   B 3.04   HX OUT T  45L      |QTY A  67    PRESS     32
   C 3.04   CABIN  T  71       |    B  18    DMP LN T  77
PPCO2  1.9                     |    C  94    NOZ  T A  64
                  1     2      |    D  94           B  64
O2 FLOW          0.0L  0.0L    | WASTE  H2O
   REG P         100   100     |QTY 1  15    PRESS     17
N2 FLOW          0.0L  0.0L    |             DMP LN T  58
   REG P         202   202     |             NOZ  T A  82
O2/N2 CNTL VLV    N2    O2     |                    B  82
H2O TK N2 P       17    17     |         VAC VT NOZ T 224
N2 QTY           131   131     | CO2 CNTLR        1     2
EMER O2 QTY        1           |FILTER  P        0.00L
        REG P      4L          |PPCO2           - 0.0L
                               |TEMP             32.0L
             A  B  C     ΔP    |BED A PRESS    0.0L  0.0L
IMU   FAN       *        4.5   |    B PRESS   0.0L  0.0L
HUMID SEP       *              |    ΔP       0.00L 0.00L
                               |VAC PRESS        0.0L
                                                        093
```

ENVIRONMENT (DISP 66)

```
 2011/   /088  APU/ENVIRON THERM    4 000/02:36:51
 FREON LOOP    1     2   |                000/00:00:00
ACCUM QTY      27    27  | H2O LOOP          1     2
FREON FLOW   2193  2190  |PUMP OUT P         64    62
PL HX FLOW    290   286  |     OUT T         64    63
AFT CP FLOW   279   278  |         P         30L   38
RAD IN T       97    96  |ICH FLOW          564L  777
RAD OUT T      38    38  |    OUT T          41    38
EVAP OUT T     38    38  |CAB HX IN T        42    38
 EVAP TEMP   DUCT NOZ    |ACCUM QTY          45    55
HI LOAD INBD 259         | APU FUEL T 1      2     3
       OUTBD 259  312    |TK SURF   + 69  + 67  + 68
TOPPING  FWD 257         |TK HTR    + 70  + 68  + 69
         AFT 257         |TEST LN 1 + 62  + 62  + 63
           L 162   50    |TEST LN 2 + 62  + 63  + 63
           R 162   50    |FEED LN   + 57  + 58  + 58
EVAP FDLN T   A    B     |PUMP IN   + 57  + 58  + 58
         FWD  80   80    | DRN LN 1 + 62  + 62  + 63
       MID 1  80   80    | DRN LN 2 + 62  + 62  + 63
       MID 2  79   75    | OUT      + 92  + 90  + 88
         AFT  75   79    | BYP LN   +108  +106  +102
     TOPPING  75   79    |GG SPLY LN 113   111   107
       ACCUM  75   79    |
     HI LOAD  75   79    |H2O LN INJ+ 71    92  + 72
                                                     078
```

APU/ENVIRON THERM (DISP 88)

```
 2011/   /078      SM SYS SUMM 1      4 000/14:44:12
                                        000/00:00:00
SMOKE       1/A    2/B  |DC VOLTS     1/A   2/B   3/C
 CABIN      0.0         |   FC        30.6  30.1  31.0
 L/R FD     0.0    0.0  |   MAIN      30.6  30.1  31.0
 AV BAY 1   0.3    0.3  |   ESS       29.6  29.6  29.3
        2   0.3    0.4  |            A-----B-----C-----A
        3   0.3    0.3  |   CNTL  1   29.4  29.4  29.6
      CABIN             |         2   29.4  29.4  29.4
 PRESS     14.0         |         3   29.4  29.4  29.4
→dP/dT-EQ +.00 +.000    |AC
 O2 CONC                |   VOLT φA    118   118   117
 PPO2       3.00  3.00  |        φB    117   117   118
 FAN  ΔP   5.00         |        φC    117   117   118
 HX OUT T    46         |   AMPS φA    4.3   6.3   2.1
 O2 FLOW    0.0    0.0  |        φB    5.5   6.6   2.2
 N2 FLOW    0.0    0.0  |        φC    3.1   5.0   3.2
 IMU FAN   A    B    C  |FUEL CEL
  ΔV FC1   FC2   FC3    |   AMPS       180   232   146
 SS1  22    21    22    |   REAC VLV    OP    OP    OP
 SS2  22    22    23    |   STACK T   +202  +206  +200
 SS3  23    21    21    |   EXIT T     150   152   149
 TOTAL AMPS  557        |   COOL P      61    60    61
         KW   17        |      PUMP
                                                     243
```

SM SYS SUMM 1

```
 0001/             THERMAL              5 000/00:00:00
                                      BFS 000/00:00:00
HYD  SYS TEMP BDYFLP RD/SB  L OB  L IB  R IB  R OB
          PRIME  + 99  + 79  + 76  + 79  + 76  + 79
         STBY 1  + 89  + 79  + 79  + 79  + 79  + 79
                 BRAKE PRESS
                 HYD SYS 1/3 | 92    92    92    92
                         2/3 | 92    92    92    92
HTR TEMP   |  L/A  |  R/B  |FREON LOOP  1    2
 PRPLT     |       |       | ACCUM QTY  34   34
 POD       |       |       | RAD OUT T 109  109
 OMS CRSFD |       |       |H2O SUP  P   0
EVAP       |       |       |TIRE PRESS
 HI   LOAD |       |       |MG     LEFT      RIGHT
 TOP  DUCT |       |       | IB 429  420  418  418
       NOZ |       |       | OB 421  421  416  416
 FDLN      |       |       |NG  397  397  381  381
                |     1     |    2    |    3    |
HYD BLR/HTR     |           |         |         |
APU             |           |         |         |
 GG/FU PMP HTR  |H          |H        |H        |
 TK/FU LN  HTR  |           |         |         |
 PUMP/VLV
                                                     255
```

BFS THERMAL

```
 0001/   /079      SM SYS SUMM 2      5 008/23:29:22
                                    BFS 000/00:00:00
  CRYO TK   1     2     3     4     5   MANF1 MANF2
H2 PRESS   208   208   206   206   206   208   207
O2 PRESS   816   815   814   814   814   815   815
HTR T1    -248  -248  -248  -248  -248
    T2    -248  -248  -248  -248  -248
  APU       1     2     3   |  HYD    1     2     3
TEMP EGT   942   942   942  |PRESS  3064  3064  3064
 B/U EGT   942   942   942  |ACUM P 3080  3080  3080
 OIL  IN   250   250   250  |RSVR T  116   153   142
     OUT   264   264   264  |
 GG BED   511H  511H  511H  |   QTY   72    74    71
 INJ     1271  1271  1271   |
SPEED  %    99   102   101  |  W/B
FUEL QTY    59    60    62  |H2O QTY  78    73    78
 PMP LK P   14    14    14  |BYP VLV BYP   BYP   BYP
OIL OUT P   42    42    41  |
FU TK VLV                   |
      A T   63    65    62  |  THERM CNTL   1    28
      B T   63    65    62  |H2O PUMP P    23    63
  AV BAY    1     2     3   |FREON FLOW  2384  2384←
→TEMP       97    97    83  |EVAP OUT T    38    38
A4 14        27.439 27.435  | 26.324  31.873   18.48
                                                     051
```

SM SYS SUMM 2

ECLSS Rules of Thumb

NOTE

Numbers presented here are for typical orbit power and heat loads and may vary significantly depending on attitude and power loading.

- Supply water tanks fill at about 1.5 percent per; hour depending on fuel cell load (.8 lb/kW hr ÷ 16 lb over 1%; 14 kW typical orbit power load).
- Water tanks empty at about 100 percent per hour for a water dump, about 50 percent per hour when using the FES high load evaporator for cooling with payload bay doors closed, and about 16 percent per hour when using the FES topping evaporator for supply water dumps on orbit with the doors open.
- On-orbit cold soak is good for 20 to 30 minutes of cooling. Prelaunch Freon conditioning is good for 2 to 3 minutes of cooling.
- NH_3 boiler supply is good for 25 minutes of ground cooling.
- A single cryo O_2 tank is good for about 2 to 3 days of orbit usage depending on crew size and power level. H_2 tanks are sized to match O_2 usage.
- A single LiOH canister is usable for about 48 man-hours.