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SECTION 2

SUBSECTION 2.7

ENVIRONMENTAL CONTROL SYSTEM (ECS)

2.7.1 INTRODUCTION.

The environmental control system (ECS) is designed to provide the flight crew with a conditioned environment that is both life-supporting, and as comfortable as possible. The ECS is aided in the accomplishment of this task through an interface with the electrical power system, which supplies oxygen and potable water. The ECS also interfaces with the electronic equipment of the several Apollo systems, for which the ECS provides thermal control, with the lunar module (LM) for pressurizing the LM, and with the waste management system to the extent that the water and the urine dump lines can be interconnected.

The ECS is operated continuously throughout all Apollo mission phases. During this operating period the system provides the following three major functions for the crew:

- Spacecraft atmosphere control
- Water management
- Thermal control.

Control of the spacecraft atmosphere consists of regulating the pressure and temperature of the cabin and suit gases; maintaining the desired humidity by removing excess water from the suit and cabin gases; controlling the level of contamination of the gases by removing CO<sub>2</sub>, odors, and particulate matter; and ventilating the cabin after landing. There are provisions for pressurizing the lunar module during docking and subsequent CSM/LM operations. (Refer to subsection 2.13 for a description of the docking procedures.)

Water management consists of collecting, sterilizing, and storing the potable water produced in the fuel cells, and delivering chilled and heated water to the crew for metabolic consumption, and disposing of the excess potable water by either transferring it to the waste water system or by dumping it overboard. Provisions are also made for the collection and storage of waste water (extracted in the process of controlling humidity), delivering it to the glycol evaporators for supplemental cooling, and dumping the excess waste water overboard.

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Thermal control consists of removing the excess heat generated by the crew and the spacecraft equipment, transporting it to the cab heat exchanger (if required), and rejecting the unwanted heat to space, either by radiation from the space radiators, or in the form of steam by boiling water in the glycol evaporators.

Five subsystems operating in conjunction with each other provide the required functions:

- Oxygen subsystem
- Pressure suit circuit (PSC)
- Water subsystem
- Water-glycol subsystem
- Post-landing ventilation (PLV) subsystem.

The oxygen subsystem controls the flow of oxygen within the command module (CM); stores a reserve supply of oxygen for use during entry and emergencies; regulates the pressure of oxygen supplied to the subsystem and PSC components; controls cabin pressure in normal and emergency (high flow-rate) modes; controls pressure in the water tanks and glycol reservoir; and provides for PSC purge via the DIRECT O<sub>2</sub> valve.

The pressure suit circuit provides the crew with a continuously conditioned atmosphere. It automatically controls suit gas circulation, pressure, and temperature; and removes debris, excess moisture, odors, and carbon dioxide from both the suit and cabin gases.

The water subsystem (potable section) collects and stores potable water; delivers hot and cold water to the crew for metabolic purposes; and augments the waste water supply for evaporative cooling. The waste water section collects and stores water extracted from the suit heat exchanger, and distributes it to the water inflow control valves of the evaporators, for evaporative cooling.

The water-glycol subsystem provides cooling for the PSC, the potable water chiller, and the spacecraft equipment; and heating or cooling for the cabin atmosphere.

The postlanding ventilation subsystem provides a means for circulating ambient air through the command module cabin after landing.

2.7.2 FUNCTIONAL DESCRIPTION.

The environmental control system operates continuously throughout all mission phases. Control begins during preparation for launch and

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continues through recovery. The following paragraphs describe the operating modes and the operational characteristics of the ECS from the time of crew insertion to recovery.

2.7.2.1 Spacecraft Atmosphere Control.

During prelaunch operations the SUIT CIRCUIT RETURN VALVE is closed; and the DIRECT O<sub>2</sub> valve is opened slightly (approximately 0.2 pound per hour flowrate) to provide an oxygen purge of the PSC. Just before prime crew insertion the O<sub>2</sub> flowrate is increased to 0.6 pound per hour. This flow is in excess of that required for metabolic consumption and suit leakage. This excess flow causes the PSC to be pressurized slightly above the CM cabin. The slight overpressure maintains the purity of the PSC gas system by preventing the cabin gases from entering the PSC.

Any changes made in the pressure or composition of the cabin gas during the prelaunch period is controlled by the ground support equipment through the purge port in the CM side hatch.

As soon as the crew connects into the PSC, the suit gas becomes contaminated by CO<sub>2</sub>, odors, moisture, and is heated. The gases are circulated by the suit compressor through the CO<sub>2</sub> and odor absorber assembly where a portion of the CO<sub>2</sub> and odors are removed; then through the heat exchanger, where they are cooled and the excess moisture is removed. Any debris that might get into the PSC is trapped by the debris trap or on felt pads on the upstream side of each LiOH cartridge.

When the crew is partially suited or in a shirtsleeve environment they contaminate the cabin gases. Since the contaminants can only be removed in the PSC, the crew must necessarily configure the PSC to allow for an adequate flow of gas out of the PSC into the cabin and back into the PSC through the suit return hoses and the SUIT CIRCUIT RETURN VALVE in order to provide the required scrubbing. This can be accomplished for the "partially suited" mode by disconnecting and installing cap screens on the return hoses and opening the SUIT CIRCUIT RETURN VALVE. For the shirtsleeve mode it can be accomplished by disconnecting the inlet hoses and placing the flow control valve in the CABIN FLOW position in addition to the preceding steps.

During the ascent, the cabin remains at sea level pressure until the ambient pressure decreases a nominal 6 psi. At that point the CABIN PRESSURE RELIEF valve vents the excess gas overboard, maintaining cabin pressure at 6 psi above ambient. As the cabin pressure decreases, a relief valve in the O<sub>2</sub> DEMAND REGULATOR vents suit gases into the cabin to maintain the suit pressure slightly above cabin pressure.

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Sometime after attaining orbit it will be necessary to close the DIRECT O<sub>2</sub> valve to conserve oxygen. (Refer to Volume 2, Apollo Operations Handbook for the procedure.) After the DIRECT O<sub>2</sub> valve is closed, make-up oxygen for the PSC is supplied by the DEMAND REGULATOR when the SUIT CIRCUIT RETURN VALVE is closed or from the cabin via the cabin pressure regulator when the SUIT CIRCUIT RETURN VALVE is open.

During normal space operations, the cabin pressure is maintained at a nominal 5 psia by the cabin pressure regulator, at flowrates up to 1.4 pounds of oxygen per hour. In the event a high leak rate develops, the EMERGENCY CABIN PRESSURE regulator will supply oxygen at high flow rates to maintain the cabin pressure above 3.5 psia for more than 5 minutes, providing the leak is effectively no larger than a 1/2-inch hole.

When performing depressurized operations the suit circuit pressure is maintained above 3.5 psia by the O<sub>2</sub> DEMAND REGULATOR; the cabin pressure regulator shuts off automatically to prevent wasting oxygen.

In event of meteorite puncture during shirtsleeve operations, the EMERGENCY CABIN PRESSURE regulator will maintain the cabin pressure at a safe level until the crew can don their suits.

Prior to entry SUIT CIRCUIT RETURN VALVE is closed, isolating the suit circuit from the cabin; the O<sub>2</sub> DEMAND REGULATOR then controls suit pressure. Cabin pressure is maintained during the descent by the cabin pressure regulator until the ambient pressure rises to a maximum of 0.9 psi above cabin pressure. At that point the cabin relief valve will open, allowing ambient air to flow into the cabin. As the cabin pressure increases, the O<sub>2</sub> DEMAND REGULATOR admits oxygen into the suit circuit to maintain the suit pressure slightly below the cabin, as measured at the suit compressor inlet manifold.

After spacecraft landing, the cabin is ventilated with ambient air by postlanding ventilation fan and valves. When the CM is floating upright in the water, the POST LANDING VENT switch is placed in the HIGH (day) or LOW (night) position. Either of these positions will supply power to open both vent valves and start the fan. In the HIGH position, the fan will circulate 150 cubic feet per minute (cfm); LOW, 100 cfm.

2.7.2.2 Water Management.

In preparing the spacecraft for the mission the potable and waste water tanks are partially filled to ensure an adequate supply for the early stages of the mission. From the time the fuel cells are placed in operation until CSM separation, the fuel cells replenish the potable water

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supply. A portion of the water is chilled and made available to the crew through the drinking fixture and the food preparation unit. The remainder is heated, and is delivered through a separate valve on the food preparation unit.

From the time the crew connects into the suit circuit until entry, the water accumulator pumps are extracting water from the suit heat exchanger and pumping it into the waste water system. The water is delivered to the glycol evaporators through individual water control valves. Provision is made for dumping excess waste water manually when the tank is full.

Bacteria from the waste water system can migrate through the isolating valves into the potable water system. A syringe injection system is incorporated to provide for periodic injection of bactericide to kill bacteria in the potable water system.

2.7.2.3 Thermal Control.

Thermal control is provided by two water-glycol coolant loops (primary and secondary). During prelaunch operations ground servicing equipment cools the water-glycol and pumps it through the primary loop, providing cooling for the electrical and electronic equipment, and the suit and cabin heat exchangers. The cold water-glycol is also circulated through the reservoir to make available a larger quantity of coolant for use as a heat sink during the ascent. Additional heat sink capability is obtained by selecting maximum cooling on the CABIN TEMP selector, and placing both cabin fans in operation. This cold soaks the CM interior structure and equipment. Shortly before launch, one of the primary pumps is placed in operation, the pump in the ground servicing unit is stopped, and the unit is isolated from the spacecraft system.

During the ascent the radiators will be heated by aerodynamic friction. To prevent this heat from being added to the CM thermal load, the PRIMARY GLYCOL TO RADIATORS valve is placed in the PULL TO BYPASS position at approximately 75 seconds before launch. The coolant then circulates within the CM portion of the loop.

The heat that is generated in the CM, from the time that the ground servicing unit is isolated until the spacecraft reaches 110K feet, is absorbed by the coolant and the prechilled structure. Above 110K feet it is possible to reject the excess heat by evaporating water in the primary glycol evaporator.

After attaining orbit the reservoir is isolated from the loop to maintain a reserve quantity of coolant for refilling the primary loop in case of

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loss of fluid by leakage. The PRIMARY GLYCOL TO RADIATORS valve is placed in the position (control pushed in) to allow circulation through the radiators and the radiator outlet temperature sensors. If the radiators have cooled sufficiently (radiator outlet temperature is less than the inlet) they will be kept on-stream; if not, they will be bypassed until sufficient cooling has taken place. After the radiators have been placed on-stream, the glycol temperature control is activated (GLYCOL EVAP TEMP IN switch in AUTO); and the CABIN TEMP selector is positioned as desired.

The primary loop provides thermal control throughout the mission unless a degradation of system performance requires the use of the secondary loop.

Several hours before CM-SM separation the system valves are positioned so that the primary loop provides cooling for the cabin heat exchanger, the entire cold plate network, and the suit heat exchanger. The CABIN TEMP control valve is placed in the MAX COOL position, and both cabin fans are turned on to cold-soak in the CM interior structure.

Prior to separation the PRIMARY GLYCOL TO RADIATORS, and the GLYCOL TO RADIATORS SEC valves are placed in the BYPASS position to prevent loss of coolant when the CSM umbilical is cut. From that time (until approximately 110K feet spacecraft altitude) cooling is provided by water evaporation.

### 2.7.3 OXYGEN SUBSYSTEM.

The oxygen subsystem shares the oxygen supply with the electrical power system. Approximately 640 pounds of oxygen is stored in two cryogenic tanks located in the service module. Heaters within the tanks pressurize the oxygen to 900 psig for distribution to the using equipment.

Oxygen is delivered to the command module through two separate supply lines, each of which enters at an oxygen inlet restrictor assembly. Each assembly contains a filter, a capillary line, and a spring-loaded check valve. The filters provide final filtration of gas entering the CM. The capillaries which are wound around the hot glycol line, serve two purposes; they restrict the total O<sub>2</sub> flow rate to 7.5 pounds per hour maximum, and they heat the oxygen to prevent it from entering the CM in a liquid state. The check valves serve to isolate the two supply lines.

Downstream of the inlet check valves the two lines tee together and a single line is routed to the OXYGEN-S/M SUPPLY valve on panel 326. This valve is used in flight as a shutoff valve to back up the inlet check valves during entry. It is closed prior to CM-SM separation.

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The outlet of the S/M SUPPLY valve is connected in parallel to the OXYGEN-SURGE TANK valve (panel 326) and to a check valve on the OXYGEN CONTROL PANEL (panel 351). The SURGE TANK valve is normally open during flight, and is closed only when it is necessary to isolate the surge tank from the system. The surge tank stores approximately 3.7 pounds of oxygen at 900 psig for use during entry, and for augmenting the SM supply when the operational demand exceeds the flow capacity of the inlet restrictors. The OXYGEN SURGE TANK PRESSURE RELIEF and shutoff valve on panel 375 prevents overpressurization of the surge tank, and provides a means for shutting off the flow in case of relief valve failure. The relief valve operates at  $1045 \pm 25$  psid. A pressure transducer puts out a signal proportional to surge tank pressure, for telemetry and for display to the crew. This signal shares the indicator used for displaying O<sub>2</sub> CRYOGENIC TANK #1 PRESSURE. The signal source is selected by the O<sub>2</sub> PRESS IND switch, which is located beneath the indicator on panel 2. The outlet of the check valve (on the OXYGEN CONTROL PANEL) is connected to both the OXYGEN-PLSS valve on panel 326, and the MAIN REGULATOR on panel 351.

The PLSS valve is used for controlling the flow of oxygen to and from the cabin repressurization package. The package consists of three one-pound capacity oxygen tanks connected in parallel; a toggle-type fast acting REPRESS O<sub>2</sub> valve on panel 601 for dumping oxygen into the cabin at very high flowrates; a toggle valve and regulator on panel 600 for supplying oxygen to the emergency O<sub>2</sub> face masks; a relief and shut-off valve on panel 602 to protect the package against overpressurization; and a direct-reading pressure gauge on panel 602 for monitoring package and pressure when the PLSS valve is closed. (More accurate pressure indication can be had by placing the PLSS valve in the FILL position and monitoring SURGE TANK pressure.) Opening the REPRESS O<sub>2</sub> valve, with the PLSS valve in the FILL position, will dump both the package tanks and the surge tanks at a rate that will pressurize the command module from 0 to 3 psia in one minute. When the PLSS valve is in the ON position, the package tanks augment the surge tank supply for entry and emergencies. The package tanks are filled by placing the PLSS valve to the FILL position, the O<sub>2</sub> PRESS IND switch (MDC-2) to the SURGE TANK position, and monitoring surge tank pressure on the CRYOGENIC TANKS PRESSURE O<sub>2</sub> 1 indicator. When the indicator reads  $900 \pm 35$  psi, both the surge tank and package tanks are full.

THE MAIN REGULATOR reduces the supply pressure to 85-110 psig for use by the subsystem components. The regulator assembly is a dual unit which is normally operated in parallel. Two toggle valves at the inlet to the assembly provide a means of isolating either of the units in case of failure, or for shutting them both off. Integral relief valves limit the

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downstream pressure to 140 psig maximum. The output of the MAIN REGULATOR passes through a flowmeter, then is delivered to the WATER & GLYCOL TANKS PRESSURE regulator, the cabin pressure regulator, EMERGENCY CABIN PRESSURE regulator (all on panel 351), the O<sub>2</sub> DEMAND REGULATOR (panel 380), the DIRECT O<sub>2</sub> valve (panel 7), and the WATER ACCUMULATOR valves (panel 382).

The output of the flowmeter is displayed on the O<sub>2</sub> FLOW indicator (panel 2), which has a range of 0.2 to 1.0 pound per hour. Nominal flow for metabolic consumption and cabin leakage is approximately 0.43 pound per hour. Flow rates of 1 pound per hour or more with a duration of  $16.5 \pm 1.5$  seconds will illuminate the O<sub>2</sub> FLOW HI light on the caution and warning panel (panel 2). The warning is intended to alert the crew to the fact that the oxygen flow rate is greater than is normally required. It does not necessarily mean that a malfunction has occurred, since there are a number of flight operations in which a high-oxygen flow rate is normal. These cases will be noted, when applicable, in the descriptions that follow. A pressure transducer at the outlet of the MAIN REGULATOR provides data for telemetry only.

The WATER & GLYCOL TANKS PRESSURE regulator assembly (panel 351) is a dual unit, normally operating in parallel, which reduces the 100-psi oxygen to  $20 \pm 2$  psig (relative to cabin) for pressurizing the positive expulsion bladders in the waste and potable water tanks, and in the glycol reservoir. Integral relief valves limit the downstream pressure to  $25 \pm 2$  psi above cabin pressure. INLET and OUTLET SELECTOR valves are provided for selecting either or both regulators and relief valves, or for shutting the unit off. When changing the position of the selector valves for the purpose of isolating a malfunctioning unit, it is necessary to place both selector valves in the same position in order to eliminate the possibility of cross-feeding oxygen through the outlet selector valve if it is left in the normal position. If a cross-selection is made (inlet selector to 1; outlet selector to 2, or vice versa), flow through the assembly is blocked.

The cabin pressure regulator controls the flow of oxygen into the cabin to make up for depletion of the gas due to metabolic consumption, normal leakage, or for repressurization. The assembly consists of two absolute pressure regulators operating in parallel, and a manually operated CABIN REPRESS valve. The regulator is designed to maintain cabin pressure at  $5 \pm 0.2$  psia at flow rates up to 1.4 pounds per hour. (O<sub>2</sub> FLOW HI light on.) Losses in excess of this value will result in a continual decrease in cabin pressure. When cabin pressure falls to 3.5 psia minimum, the regulator will automatically shut off to prevent wasting the oxygen supply. Following depressurization, the cabin can be repressurized by manually opening the CABIN REPRESS valve. The CABIN REPRESS valve will flow a minimum of 6 pounds per hour. The O<sub>2</sub> FLOW HI light will be on.

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The EMERGENCY CABIN PRESSURE regulator provides emergency protection for the crew in the event of a severe leak in the cabin. The assembly consists of two absolute pressure regulators, either of which can handle the maximum flow rate, and a selector valve for selecting either or both of the regulators, or for shutting the unit off. The regulator valve starts to open when cabin pressure decreases to 4.6 psia; and at 4.2 psia the valve is full-open, flooding the cabin with oxygen. The regulator can supply oxygen to the cabin at a flow rate of 0.67 pound per minute minimum (O<sub>2</sub> FLOW HI light on), to prevent rapid decompression in case of cabin puncture. The regulator is capable of providing flow rates which will maintain cabin pressure above 3.5 psia for a period of 5 minutes, against a leakage rate equivalent to 1/2-inch-diameter cabin puncture. The regulator is normally used during shirt-sleeve operations, and is intended to provide time for donning pressure suits before cabin pressure drops below 3.5 psia. During pressure suit operations, the regulator is shut off to prevent unnecessary loss of oxygen in case of unplanned cabin depressurization.

The O<sub>2</sub> DEMAND REGULATOR (figure 2.7-1) supplies oxygen to the suit circuit whenever the suit circuit is isolated from the cabin (return air SHUTOFF VALVE closed), and during depressurized operations. It also relieves excess gas to prevent overpressurizing the suits. The assembly contains redundant regulators; a single relief valve for venting excess suit pressure; an inlet selector valve for selecting either or both regulators; and a SUIT TEST valve for performing suit integrity tests.

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Each regulator section consists of an aneroid control, and a differential diaphragm housed in a reference chamber. The diaphragm pushes against a rod connected to the demand valve; the demand valve will be opened whenever a pressure differential is sensed across the diaphragm. In operation, there is a constant bleed flow of oxygen from the supply into the reference chamber, around the aneroid, and out through the control port into the cabin. As long as the cabin pressure is greater than 3.75 psia (nominal), the flow of oxygen through the control port is virtually unrestricted, so that the pressure within the reference chamber is essentially that of the cabin. This pressure acts on the upper side of the diaphragm, while suit pressure is applied to the underside of the diaphragm through the suit sense port. The diaphragm can be made to open the demand valve by either increasing the reference chamber pressure, or by decreasing the sensed suit pressure.

The increased pressure mode occurs during depressurized operations. As the cabin pressure decreases, the aneroid expands. At 3.7 psia the aneroid will have expanded sufficiently to restrict the outflow of oxygen through the control port, thus increasing the reference chamber pressure. When the pressure rises approximately 3-inch H<sub>2</sub>O pressure above the sensed suit pressure, the demand valve will be opened.

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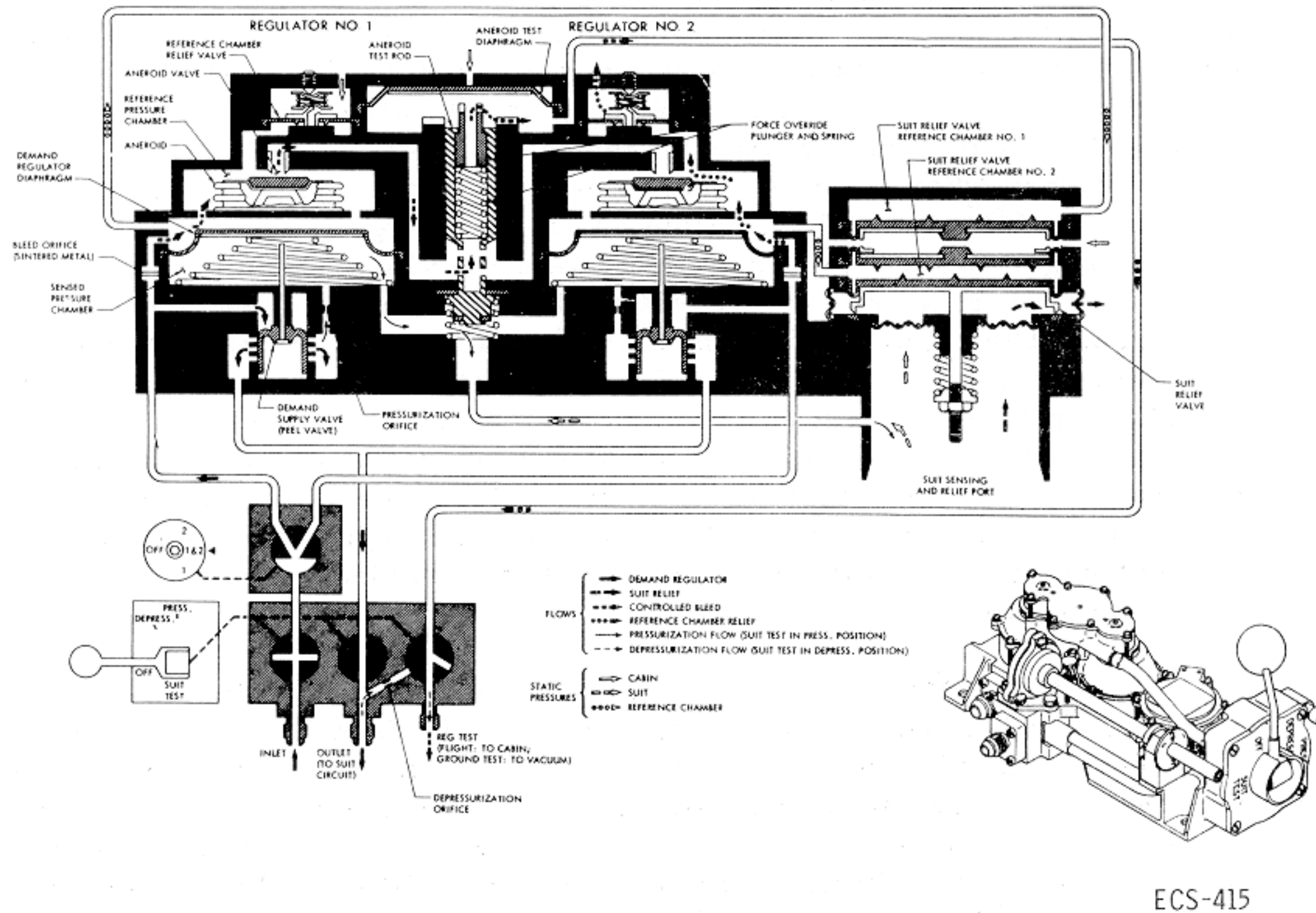


Figure 2.7-1. O<sub>2</sub> Demand Regulator

Decreased pressure mode occurs whenever the suit circuit is isolated from the cabin, and cabin pressure is above 5 psia. In the process of respiration, the crew will exhale carbon dioxide and water vapor. In circulating the suit gases through the CO<sub>2</sub> and odor absorber, and the suit heat exchanger, the CO<sub>2</sub> and water are removed. The removal reduces the pressure in the suit circuit, which is sensed by the regulator on the underside of the diaphragm. When the pressure drops approximately 3-inch H<sub>2</sub>O pressure below cabin, the diaphragm will open the demand valve.

The regulator assembly contains a poppet-type relief valve which is integral with the suit pressure sense port. During operations where the cabin pressure is above 3.75 psia, the relief valve is loaded by a coil spring which allows excess suit gas to be vented whenever suit pressure rises to 2- to 9-inch H<sub>2</sub>O above cabin pressure. When the cabin pressure decreases to 3.75 psia, the reference chamber pressure is increased by the throttling effect of the expanding aneroid. The reference chamber pressure is applied, through ducts, to two relief valve loading chambers which are arranged in tandem above the relief valve poppet. The pressure



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in the loading chambers acts on tandem diaphragms which are forced against the relief valve poppet. The relief value of the valve is thus increased to 3.75 psia plus 2- to 9-inch H<sub>2</sub>O.

The SUIT TEST valve provides a means for pressurizing and depressurizing the suit circuit, at controlled rates, for performing suit integrity tests. Placing the SUIT TEST valve in the PRESS position supplies oxygen through a restrictor to pressurize the suit circuit to a nominal 4 psi above cabin, in not less than 75 seconds. The maximum time required for pressurizing or depressurizing the suits depends upon the density of the suit and cabin gases at the time the test is performed. It will take a longer time to perform the pressurizing or depressurizing during prelaunch than in orbit because of the higher density of the gas at sea level pressure. Placing the SUIT TEST valve in the DEPRESS position will depressurize the suits in not less than 75 seconds. Moving the SUIT TEST valve from the PRESS position to OFF will dump the suit pressure immediately. Also, if any one of the three suits is vented to cabin, while the SUIT TEST valve is in the PRESS position, all three suits will collapse immediately. This is due to the restrictor in the pressurizing port, which prevents the O<sub>2</sub> DEMAND REGULATOR from supplying the high oxygen flow rate required for maintaining the pressure in the other two suits.

The DIRECT O<sub>2</sub> valve on panel 7 is a screw-actuated poppet valve capable of metering oxygen into the suit circuit of flow rates from 0 to 0.67 pound per minute (at 85 psig inlet pressure). The control end of the poppet valve is connected to a bellows assembly, which provides both the internal seal and the force required for closing the valve. When the knob is rotated counterclockwise, the screw mechanism moves inward contacting a follower on the bellows assembly forcing the poppet valve off its seat, thus opening the valve. When the knob is rotated clockwise the screw moves outward allowing the bellows assembly to close the valve. Because there is no mechanical connection between the screw and the bellows assembly, the valve will actually be closed before the screw mechanism has been rotated to the extreme clockwise position. Under average operating conditions, it will require approximately 30-degree rotation counterclockwise from the extreme clockwise position to crack the valve open.

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#### 2.7.4 PRESSURE SUIT CIRCUIT.

The pressure suit circuit (PSC) is a circulating gas loop which provides the crew with a continuously conditioned atmosphere throughout the mission. The gas is circulated through the PSC by two centrifugal compressors, which are controlled by individual switches on panel 4. Normally only one of the compressors is operated at a time; however, the individual switches provide a means for connecting either or both of the compressors to either a-c bus.

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A differential pressure transducer connected between the compressor inlet and outlet manifolds provides a signal to the SUIT COMPR  $\Delta P$  indicator (MDC-2); to telemetry; and to the caution and warning system, which will illuminate the SUIT COMPRESSOR light at a  $\Delta P$  of 0.22 psig or less. Another differential pressure transducer connected between the compressor inlet manifold and the cabin, provides a signal to the SUIT-CAB  $\Delta P$  indicator (MDC-2); and to telemetry. An absolute pressure transducer connected to the compressor inlet manifold provides a signal to the PRESS SUIT indicator (MDC-2); and to telemetry.

The gas leaving the compressor flows through the CO<sub>2</sub> and odor absorber assembly. The assembly is a dual unit containing two absorber elements in separate compartments with inlet and outlet manifolds common to both. A diverter valve in the inlet manifold provides a means of isolating one compartment or the other (without interrupting the gas flow) for the purpose of replacing a spent absorber. An interlock mechanism between the diverter valve handle and the cover handles is intended to prevent opening both compartments at the same time. A pressure interlock device on each canister cover extends a pin into a slot in the cover handle whenever the internal pressure is one psi above cabin pressure. A manual bleed valve on each canister cover provides a means of bleeding down the canister pressure so the cover can be opened in a depressurized cabin. The absorber elements contain lithium hydroxide and activated charcoal for removing carbon dioxide and odors from the suit gases. Orlon pads on the inlet and outlet sides trap small particles and prevent absorbent materials from entering the gas stream.

From the filter the gas flows through the suit heat exchanger where the gases are cooled and the excess moisture is removed. The heat exchanger assembly is made up of two sets of broad flat tubes through which the coolant from the primary and secondary loops can be circulated. The coolant flow/bypass is controlled by two valves located on the coolant control panel (382). The SUIT HT EXCH PRIMARY GLYCOL valve is a motor-driven valve with manual override; the motor is controlled by the SUIT CIRCUIT-HEAT EXCH switch on MDC-2. The SUIT HT EXCH SECONDARY GLYCOL valve must be positioned manually. The space between the tubes forms passages through which the suit gases flow. The coolant flowing through the tubes absorbs some of the heat from the suit gases. As the gases are cooled to about 55°F, the excess moisture condenses out and is removed from the heat exchanger by one or both of a pair of water accumulator pumps.

The water accumulators are piston-type pumps, which are actuated by oxygen pressure (100 psi) on the discharge stroke, and by a return spring for the suction stroke. The oxygen flow is controlled by the two WATER ACCUMULATOR selector valve assemblies located on the COOLANT CONTROL PANEL (382). Each valve assembly contains a selector valve, a solenoid valve, and an integral bypass. When the

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selector valve is in the RMTE position, oxygen flow is controlled by the solenoid valve; when in the MAN position, the oxygen flows through the bypass directly to the pump. The solenoid valve can be controlled automatically by signals from the central timing equipment by placing the SUIT CIRCUIT-H<sub>2</sub>O ACCUM switch (panel 2) in either AUTO 1 or AUTO 2. In the automatic mode the central timing equipment signal will cause one of the accumulators to complete a cycle every ten minutes. If it becomes necessary to cycle the accumulators at more frequent intervals the solenoid valve can be controlled manually by placing the AUTO switch in the OFF position, and placing the adjacent H<sub>2</sub>O ACCUM switch to the ON position for either No. 1 or 2 accumulator. When exercising manual control, either by means of the switch or the selector valve, it is necessary to hold that particular control on for 10 seconds then return it to the OFF position.

The cool gas (55°F nominal) flows from the heat exchanger through the suit flow limiters and the flow control valves, into the suits. The suit temperature is measured at the heat exchanger outlet, and is displayed on the SUIT TEMP indicator (panel 2) and telemetered.

A suit flow limiter is installed in each suit supply duct to restrict the gas flow rate through any one suit. The flow limiter is a tube with a Venturi section, sized to limit flow to 0.7 pound per minute. The limiter offers maximum resistance to gas flow through a torn suit, when cabin pressure is near zero psia. The O<sub>2</sub> demand regulator will supply oxygen at flow rates up to 0.67 pound per minute (for at least 5 minutes) to maintain pressure in the circuit while the torn suit is being repaired.

The flow control valves (panels 300, 301, 302) are part of the suit hose connector assembly. These valves provide a means for adjusting the gas flow through each suit individually, and are fully modulating from OFF to the FULL FLOW position. When operating in a shirtsleeve environment with the inlet hose disconnected from the suit, placing the flow control valve in the CABIN FLOW position will allow approximately 12 cubic feet of suit gas per minute to flow into the cabin.

A suit flow relief valve is installed between the suit heat exchanger outlet and the compressor inlet, and is intended to maintain a relatively constant pressure at the inlets to the three suits by relieving transient pressure surges. The SUIT FLOW RELIEF valve control (panel 382) provides a means for manually closing the valve by placing the control in the OFF position. Placing the control in AUTO removes the restraint and allows the valve to operate as a relief valve. There is no provision for manually opening the valve. It is planned to place the control in the OFF position for the duration of the mission to ensure maximum flow through the SUIT CIRCUIT.

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The gas leaving the suits flows through the debris trap assembly, into the suit compressor. The debris trap is a mechanical filter for screening out solid matter that might otherwise clog or damage the suit compressors. The trap consists of a stainless steel screen designed to block particles larger than 0.040 inch, and a bypass valve which will open at differential pressure of 0.5 inch H<sub>2</sub>O in the event the screen becomes clogged.

The SUIT CIRCUIT RETURN VALVE (panel 381) is installed on the debris trap upstream of the screen. The valve permits cabin gases to enter the suit circuit for scrubbing. The valve consists of two flapper-type check valves, and a manual shutoff valve, all in series. The manual VALVE provides a means for isolating the suit circuit from the cabin manually by means of a remote control located on panel 381. This is done to prevent inducting cabin gases into the suit circuit, in the event the cabin gases become contaminated.

The SUIT CIRCUIT RETURN VALVE is located at the suit compressor inlet manifold, which is normally 1 to 2 inches of water pressure below cabin pressure. The differential pressure causes cabin gases to flow into the suit circuit when the manual valve is open. The reconditioned cabin gases are recirculated through the suits and/or cabin. During emergency operation, the check valve prevents gases from flowing into the depressurized cabin from the suit circuit.

A CO<sub>2</sub> sensor is connected between the suit inlet and return manifold. The output signal is delivered to the PART PRESS CO<sub>2</sub> indicator (panel 2); to telemetry; and to the caution and warning system. At a CO<sub>2</sub> partial pressure of 7.6 mm hg, the CO<sub>2</sub> PP HI light on panel 2 will be illuminated.

#### 2.7.5 WATER SUBSYSTEM.

The water subsystem consists of two individual fluid management networks which control the collection storage, and distribution of potable and waste water. The potable water is used primarily for metabolic purposes. The waste water is used solely as the evaporant in the primary and secondary glycol evaporators. Although the two networks operate and are controlled independently, they are interconnected in a manner which allows potable water to flow into the waste system under certain conditions described below.

Potable water produced in the fuel cells is pumped into the CM at a flow rate of approximately 1.5 pounds per hour. The water flow through the hydrogen separator to a check valve, on the WATER CONTROL PANEL (352), and to the inlet ports of the POTABLE TANK INLET and WASTE TANK INLET valves (panel 352). The hydrogen separator consists of a series of tubes (made of 25 percent silver and 75 percent palladium) through which the water flows, encased in a can which is vented to space. Hydrogen,

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in both the dissolved and free states, passes through the walls of the tubing into the can and flows overboard. The separator is installed in the right-hand equipment bay behind the waste management panel, and is connected into the system through flexible hoses and quick-disconnects, which are accessible through a door at the bottom of panel 252. The check valve at the inlet prevents loss of potable water after CM-SM separation.

The POTABLE TANK INLET is a manual shutoff valve used for preventing the flow of fuel cell water into the potable system in the event the fuel cell water becomes contaminated. The pH HI talkback (panel 3) shows a "barberpole" when the water pH factor exceeds a value of 9.

The WASTE TANK INLET is an in-line relief valve, with an integral shutoff valve. The relief valve allows potable water to flow into the waste water tank whenever the potable water pressure is 6 psi above waste water pressure. This pressure differential will occur when the fuel cells are pumping water, and either the potable water tank is full, or the POTABLE TANK INLET valve is closed; or when the waste water tank is completely empty and the glycol evaporators are demanding water for cooling. In the latter case, the water flow is only that quantity which is demanded. The shutoff valve provides a means of blocking flow in case the relief valve fails. If such a failure occurs, potable water can flow through the valve (provided the potable water pressure is higher than the waste), until the two pressures are equal. Reverse flow is prevented by a check valve downstream of the WASTE TANK INLET valve.

In the event that both water tanks are full at the time the fuel cells are pumping, the excess potable water will be dumped overboard through the PRESSURE RELIEF valve on panel 352. However, automatic dumping through the relief valve is not desirable because the pumps in both the potable and waste water systems discharge water intermittently, rather than in a steady stream. Dumping water through the relief valve in spurts results in some flash-freezing, which could result in a temporary blockage of the dump line. To preclude this the PRESSURE RELIEF valve has been modified by removing the poppet of one of the two relief valves, so that it can be used as a dump valve, to dump water in a steady stream. During flight the waste water tank quantity will be maintained below 75 percent by manually dumping the excess water. This means that normally an ullage will be maintained to receive the potable water, instead of dumping it overboard.

Water flows from the control panel to the potable water tank, the FOOD PREPARATION WATER unit (panel 305), and the water chiller. Chilled water is delivered to the FOOD PREPARATION WATER unit; and to the drinking water dispenser through the DRINKING WATER SUPPLY valve (panel 304).

The water chiller cools and stores 0.5 pound of potable water for crew consumption. The water chiller is designed to supply 6 ounces of 50°F water every 24 minutes. The unit consists of an internally baffled reservoir containing a coiled tube assembly which is used as the coolant

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conduit. The baffles are used to prevent the incoming hot water from mixing with and raising the temperature of the previously chilled water.

The FOOD PREPARATION WATER unit heats potable water for use by the crew, and allows manual selection of hot or cold potable water. The cold potable water is supplied by the water chiller. The unit consists of an electrically heated water reservoir and two manually operated valves, which meter water in 1-ounce increments. The insulated reservoir has a capacity of 1.9 pounds of water. Thermostatically controlled heating elements in the reservoir heat the water and maintain it at 154°F nominal. Two metering valves dispense either hot or cold water, in 1-ounce increments, through a common nozzle. The hot water delivery rate is approximately 10 ounces every 30 minutes.

The DRINKING WATER SUPPLY valve on panel 304 provides a means for shutting off the flow of water to the drinking water dispenser (water pistol), in case of a leak in the flex hose.

The waste water and potable water is stored in positive expulsion tanks, which with the exception of capacity, are identical in function, operation, and design. The positive expulsion feature is obtained by an integrally supported bladder, installed longitudinally in the tank. Water collector channels, integral with the tank walls, prevent water from being trapped within the tank by the expanding bladder. Quantity transducers provide signals to the H<sub>2</sub>O QUANTITY indicator on panel 2. The signal source is selected by the H<sub>2</sub>O QTY IND switch located below and to the left of the indicator on panel 2.

Waste water extracted from the suit heat exchanger is pumped into the waste water tank, and is delivered to the EVAP WATER CONTROL-PRIMARY and -SECONDARY valves on panel 382. When the tank is full, excess waste water is dumped overboard through the water PRESSURE RELIEF valve. The EVAP WATER CONTROL valves consist of a manually operated inlet valve and a solenoid valve. When the inlet valves are in AUTO, the solenoid valves control water flow to the evaporators. The PRIMARY solenoid valve is controlled automatically when the GLYCOL EVAP-H<sub>2</sub>O FLOW switch (panel 2) is in AUTO, and manually when the switch is ON. The SECONDARY solenoid valve is controlled automatically when the SEC COOLANT LOOP EVAP switch is in EVAP. There is no manual control provided.

#### 2.7.6 WATER-GLYCOL COOLANT SUBSYSTEM.

The water-glycol coolant subsystem consists of two independently operated closed coolant loops. The primary loop is operated continuously throughout the mission, unless damage to the equipment necessitates shut-down. The secondary loop is operated at the discretion of the crew, and provides a backup for the primary loop. Both loops provide cooling for the suit and cabin atmospheres, the electronic equipment, and a portion of the potable water supply. The primary loop also serves as a source of heat for the cabin atmosphere when required.

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2.7.6.1 Coolant Flow.

The coolant is circulated through the loops by pumping unit consisting of two pumps, a full-flow filter, and an accumulator for the primary loop; and a single pump, filter, and accumulator for the secondary loop. The purpose of the accumulators is to maintain a positive pressure at the pump inlets by accepting volumetric changes due to changes in coolant temperature. If the primary accumulator leaks, it can be isolated from the loop by means of the PRIM GLY ACCUM (panel 378). Then the reservoir must be placed in the loop to act as an accumulator. Accumulator quantity is displayed on the ACCUM PRIM/SEC indicator on panel 2. (The signal source is selected by the ECS INDICATORS rotary switch on panel 2.) The primary pumps are controlled by the ECS GLYCOL PUMPS rotary switch on panel 4, which permits either of the pumps to be connected to either a-c bus. The secondary pump is controlled by a three-position toggle switch SEC COOLANT LOOP-PUMP on panel 2, which allows the pump to be connected to either a-c bus.

The output of the primary pump flows through a passage in the evaporator steam pressure control valve to de-ice the valve throat. The coolant next flows through the GLYCOL TO RADIATORS-PRIM valve (panel 377), through the radiators, and returns to the CM. The GLYCOL TO RADIATORS-PRIM valve is placed in the BYPASS position; prior to launch to isolate the radiators from the loop, and prior to CM-SM separation to prevent loss of coolant when the CSM umbilical is cut. During space operations the valve is in the NORMAL position.

Coolant returning to the CM flows to the GLYCOL RESERVOIR valves (panel 326). From prelaunch until after orbit insertion, the reservoir INLET and OUTLET valves are open and the bypass valve is closed, allowing coolant to circulate through the reservoir. This provides a quantity of cold coolant to be used as a heat sink during the early stage of launch. After orbit insertion, the reservoir is isolated from the primary loop (by opening the BYPASS valve, and closing the INLET and OUTLET valves) to provide a reserve supply of coolant for refilling the loop in the event a leak occurs. Refilling is accomplished by means of the PRIM ACCUMR FILL valve (panel 379). Prior to entry, the reservoir is again placed in the loop.

The coolant flow from the evaporator divides into two branches. One branch carries a flow of 33 pounds per hour to the inertial measurement unit (IMU), and into the coldplate network. The other branch carries a flow of 167 pounds per hour to the water chiller, then through the SUIT HI EXCH PRIMARY GLYCOL valve (panel 382) and the suit heat exchanger to the PRIMARY CABIN TEMP control valve (panel 303).

The PRIMARY CABIN TEMP control valve routes the coolant to either the cabin heat exchanger or to the coldplate network. The valve is positioned automatically by the cabin temperature control, or manually by

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means of an override control on the face of the valve. The valve is so constructed that in the cabin full cooling mode, the flow of coolant from the suit heat exchanger (167 pounds per hour) is routed first through the cabin heat exchanger and then through the thermal coldplates where it joins with the flow (33 pounds per hour) from the IMU. In the cabin full heating mode, the total flow (200 pounds per hour) is routed through the thermal coldplates first, where the water-glycol absorbs heat; from there it flows through the cabin heat exchanger. In the intermediate valve positions, the quantity of cool or warm water-glycol flowing through the heat exchanger is reduced in proportion to the demand for cooling or heating. Although the amount of water-glycol flowing through the cabin heat exchanger will vary, the total flow through the thermal coldplates will always be total system flow. An orifice restrictor is installed between the cabin temperature control valve and the inlet to the coldplates. Its purpose is to maintain a constant flow rate through the coldplates by reducing the heating mode flow rate to that of the cooling mode flow rate. Another orifice restrictor, located in the coolant line from the IMU, maintains a constant flow rate through this component regardless of system flow fluctuations. The total flow leaving the PRIMARY CABIN TEMP valve enters the primary pump and is recirculated.

The output of the secondary pump flows through a passage in the secondary evaporator steam pressure control valve for de-icing the valve throat. The coolant next flows through the GLYCOL TO RADIATORS-SEC valve (panel 377), through the radiators, and returns to the CM. The GLYCOL TO RADIATORS-SEC valve is placed in the bypass position, prior to CM-SM separation to prevent loss of coolant when the CSM umbilical is severed. After returning to the CM the coolant flows through the secondary evaporator, the SUIT HT EXCH SECONDARY GLYCOL valve, and the suit heat exchanger to the SECONDARY CABIN TEMP control valve (panel 303). The SECONDARY CABIN TEMP control valve regulates the quantity of coolant flowing through the cabin heat exchanger in the cooling mode (there is no heating capability in the secondary loop). The coolant from the secondary cabin temp control valve and/or the cabin heat exchanger then flows through redundant passages in the coldplates for the flight critical equipment and returns to the secondary pump inlet.

2.7.6.2 Glycol Temperature Control.

The heat absorbed by the coolant in the primary loop is transported to the radiators where a portion is rejected to space. If the quantity of heat rejected by the radiators is excessive, the temperature of the coolant returning to the CM will be lower than desired (45°F nominal). If the temperature of the coolant entering evaporator drops below a nominal 43°F, the mixing mode of temperature control is initiated. The automatic control (GLYCOL EVAP-TEMP IN switch, AUTO position) opens the PRIMARY GLYCOL EVAP INLET TEMP valve (panel 382), which allows a sufficient quantity of hot coolant from the pump to mix with the coolant returning from the radiators, to produce a mixed temperature at the inlet



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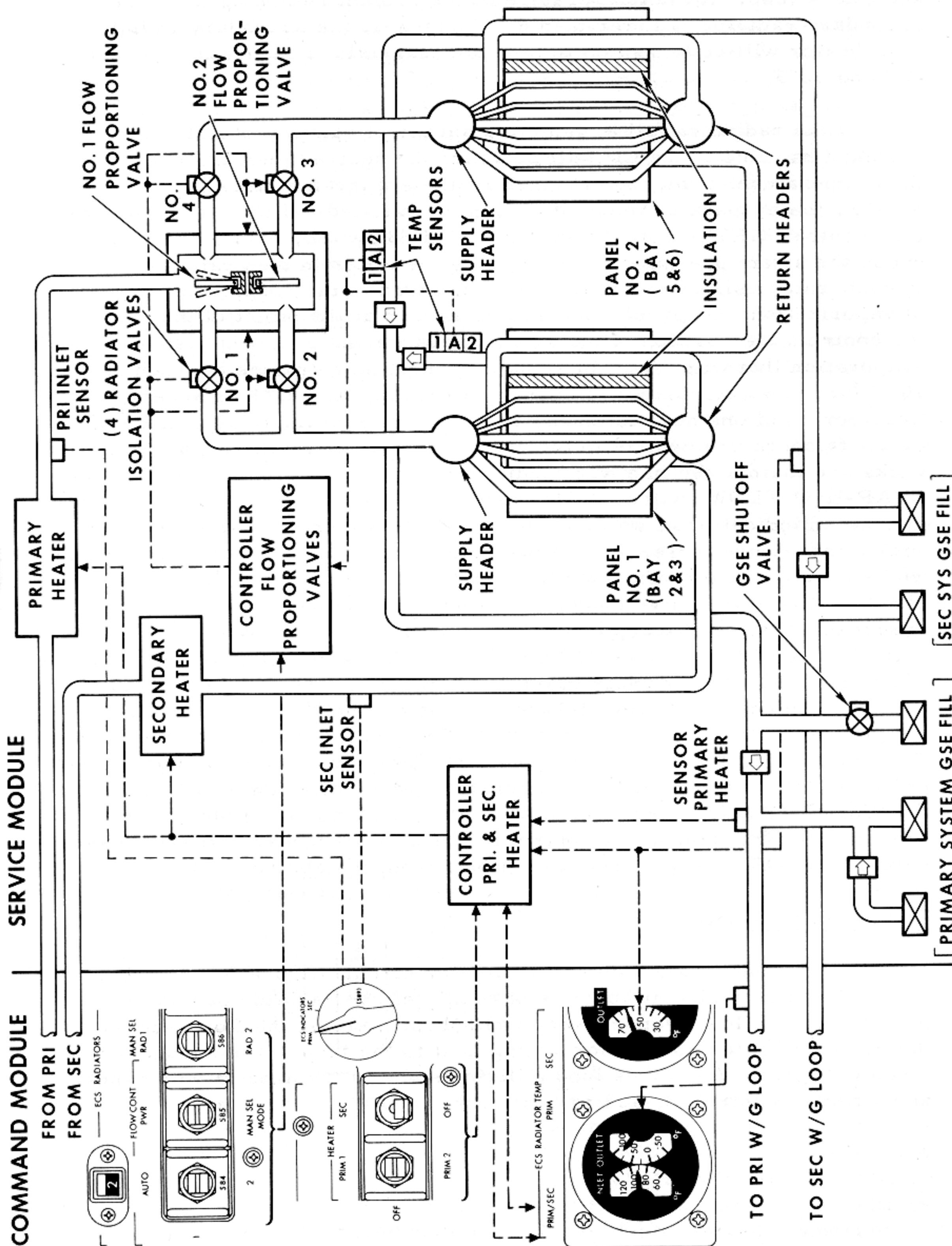
to the evaporator between 43° and 48°F. There is no mixing mode in the secondary loop. If the temperature of the coolant returning from the secondary radiator is lower than 45°F nominal, the secondary radiator inlet heater will be turned on to maintain the outlet temperature between 42° and 48°F.

If the radiators fail to radiate a sufficient quantity of heat, the coolant returning to the CM will be above the desired temperature. When the temperature of the coolant entering the evaporator rises to 48° to 50.5°F, the evaporator mode of cooling is initiated. The glycol temperature control (GLYCOL EVAP-STEAM PRESS switch, AUTO position) opens the steam pressure valve allowing the water in the evaporator wicks to evaporate, using some of the heat contained in the coolant for the heat of vaporization. A glycol temperature sensor at the outlet of the evaporator controls the position of the steam pressure valve to establish a rate of evaporation that will result in a coolant outlet temperature between 38° to 45°F (an evaporator outlet temperature range of  $41.5 \pm 5^\circ\text{F}$  is acceptable for a period of one hour following a transition from the mixing mode of glycol temperature control to the evaporative mode). The evaporator wicks are maintained in a wet condition by the wetness control (GLYCOL EVAP-H<sub>2</sub>O FLOW switch, AUTO position), which uses the wick temperature as an indication of water content. As the wicks become dryer, the wick temperature increases and the water control valve is opened. As the wicks become wetter, the wick temperature decreases and the water valve closes. The evaporative mode of cooling is the same for both loops, except that there is backup control for the primary loop only. The PRIMARY GLYCOL EVAP INLET TEMP valve can be positioned manually when the TEMP IN switch is in the MAN position. The steam pressure valve can be controlled remotely by placing the STEAM PRESS switch to the MAN position, and using the INCR/DECR switch to position the valve. The water control valve can be opened remotely by placing the H<sub>2</sub>O FLOW switch to ON. The secondary evaporator is controlled automatically when the SEC COOLANT LOOP switch is in the EVAP position; placing the switch in RESET causes the control to close the secondary steam pressure valve. The OFF position removes power from the control.

2.7.6.3 ECS Radiator Control.

Each coolant loop includes a radiator circuit (figure 2.7-2). The primary radiator circuit consists basically of two radiator panels, in parallel with a flow-proportioning control for dividing the flow between them, and a heater control for adding heat to the loop. The secondary circuit consists of a series loop utilizing some of the area of both panels, and a heater control for adding heat to the loop.

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Figure 2.7-2. ECS Radiator Subsystem



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The radiator panels are an integral part of the SM skin and are located on opposite sides of the SM (panel 1 in bays 2 and 3; panel 2 in bays 5 and 6). With the radiators being diametrically opposite, it is possible that one primary panel may "see" deep space while the other "sees" the sun, earth, or moon. These extremes in environments, provide for large differences in panel efficiencies and outlet temperatures. The panel seeing deep space can reject more heat than the panel receiving external radiation; therefore, the overall efficiency of the subsystem can be improved by increasing the flow to the cold panel. The higher flow rate reduces the transit time of the coolant through the radiator, which decreases the quantity of heat radiated.

Flow through the radiators is controlled by a dual flow-proportioning valve assembly, four radiator isolation valves, and a solid-state electronic controller. The flow-proportioning valve assembly (figure 2.7-3) consists of two vane-type proportioning valves each driven by an individually controlled torque motor. The assembly has a common inlet port, and each of the valves has two outlet ports, one going to the supply lines for radiator panel No. 1, and the other going to panel 2. A radiator isolation valve is installed between each of the valve outlet ports and the supply line for each

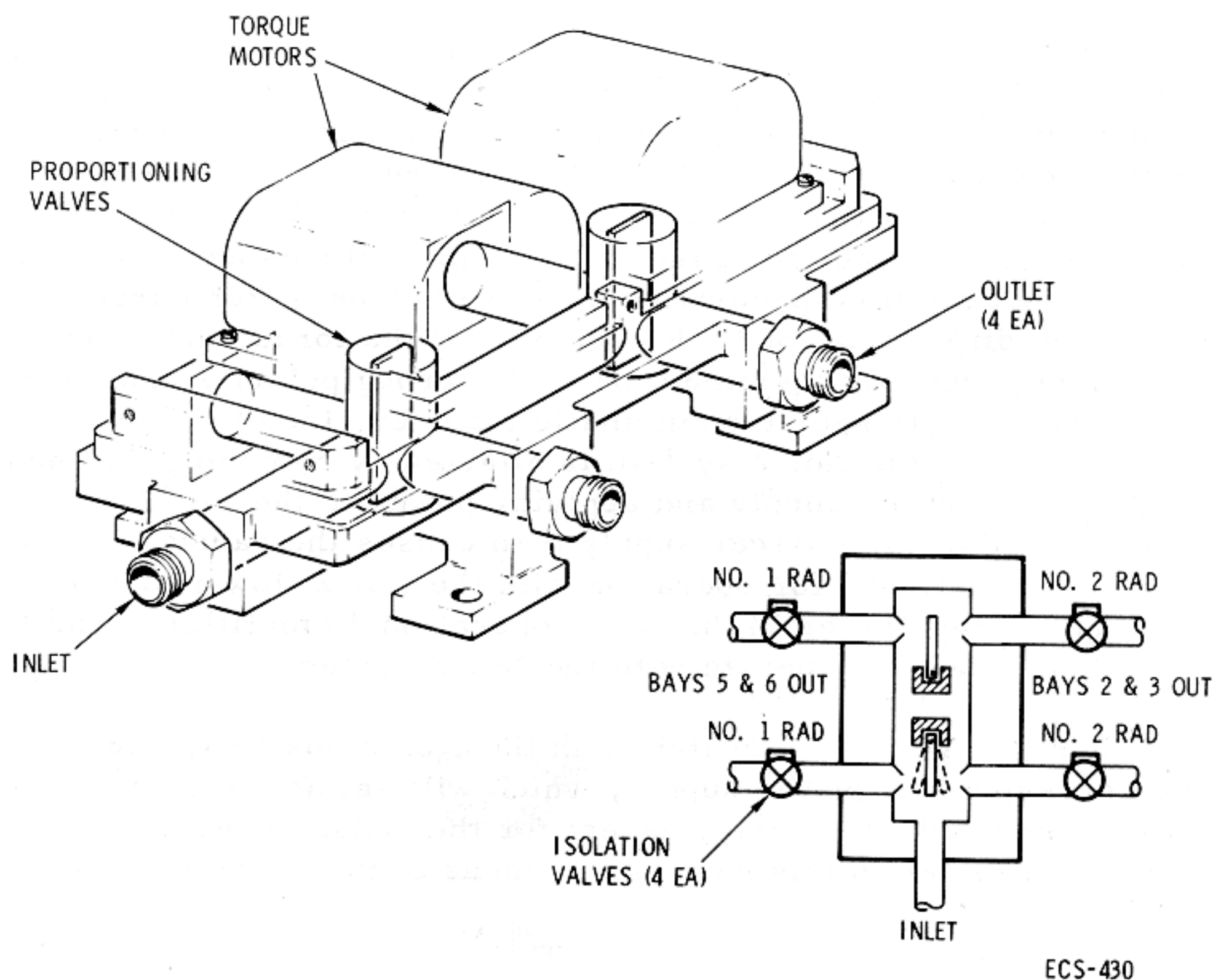


Figure 2.7-3. Space Radiators Flow Proportioning Valve

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of the radiator panels. The controller not only contains the circuits for controlling the position of the flow-proportioning valves, it also contains radiator isolation valve selection logic, a failure-sensing logic, and redundant power supplies.

Power is supplied to the controller through the two FLOW CONT switches in the ECS RADIATORS switch group on panel 2. Placing the PWR-MAN SEL MODE switch in the PWR position, routes d-c power to the AUTO-1-2 switch, which is used for selecting the operating mode of the controller. When the AUTO-1-2 switch is placed in the AUTO position, and the PWR-MAN SEL MODE switch is in PWR, 28 vdc is applied to the No. 1 power supply of the controller through the internal automatic transfer circuit. The output of the power supply goes to the No. 1 operational amplifier which controls the No. 1 flow-proportioning valve; the failure sensing logic circuit, which controls the electrical state of the auto transfer circuit; and to the control circuit for the four radiator isolation valves, which will position the valves for operation on the No. 1 flow-proportioning system. Three temperature sensors are located in the outlet line from each of the primary radiator panels. The first pair of sensors are connected to the temperature bridge of the No. 1 operational amplifier, the second pair to the No. 2 amplifier, and the third pair to the failure-sensing logic amplifier.

During operation, if a difference in radiator panel outlet temperature occurs, the flow-proportioning valve will be positioned to increase the coolant flow to the cooler radiator panel. At a temperature differential of 10°F the flow-proportioning valve will be "hard over," diverting approximately 95 percent of the flow to the cold radiator. The failure-sensing logic is monitoring radiator panel outlet temperatures and the magnitude and polarity of the flow-proportioning valve torque motor current. If a temperature differential of 15°F occurs, and the torque motor current is less than 90 percent of maximum or of the wrong polarity, the failure-sensing logic will trigger the automatic transfer circuit. The transfer from the No. 1 to the No. 2 system is effected by removing the input power from the No. 1 power supply and applying power to the No. 2 power supply. The output of the No. 2 power supply then causes the radiator isolation valves to be positioned for operation with the No. 2 flow-proportioning valve, and applies power to the No. 2 operational amplifier. The failure-sensing logic does not operate with the No. 2 system.

When the AUTO-1-2 switch is in the 1 or 2 position, power is applied to the corresponding power supply, which will set up the system for operation as described previously, except for the failure sensing and transfer circuits. Transfer in this case is by means of the AUTO-1-2 switch.

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In situations where the radiator inlet temperature is low and the panels have a favorable environment for heat rejection, the radiator outlet temperature starts to decrease and thus the bypass (flow through the PRIMARY GLYCOL EVAP INLET TEMP valve) ratio starts to increase. As more flow is bypassed, the radiator outlet temperature decreases until the  $-20^{\circ}\text{F}$  minimum desired temperature would be exceeded. To prevent this from occurring, an in-line heater upstream of the radiator is automatically turned on when radiator mixed outlet temperature drops to  $-15\pm 1^{\circ}\text{F}$  and remains on until  $-10\pm 0.5^{\circ}\text{F}$  is reached. The controller provides only on/off heater control which results in a nominal 450 watts being added to the coolant each time the heater is energized. Power for the controller comes from the ECS RADIATORS HEATER switch in the PRIM 1 or PRIM 2 position. Switching to the redundant heater system is accomplished by the crew, if the temperature decreases to  $-20^{\circ}\text{F}$ .

If the radiator outlet temperature falls below the desired minimum, the effective radiator surface temperature will be controlled passively by the selective stagnation method. The two primary circuits are identical, each consisting of five tubes in parallel and one downstream series tube. The two panels, as explained in the flow proportioning control system, are in parallel with respect to each other. The five parallel tubes of each panel have manifolds sized precisely to provide specific flow-rate ratios in the tubes, numbered 1 through 5. Tube 5 has a lower rate than tube 4, and so on, through tube 1 which has the higher flow. It follows, that for equal fin areas the tube with the lower flow rate will have a lower coolant temperature. Therefore, during minimum CM heat loads, stagnation begins to occur in tube 5 as its temperature decreases; for as its temperature decreases, the fluid resistance increases, and the flow rate decreases. As the fin area around tube 5 gets colder, it draws heat from tube 4 and the same process occurs with tube 4. In a fully stagnated condition, there is essentially no flow in tubes 3, 4, and 5, and some flow in tubes 1 and 2, with most of it in tube 1.

When the CM heat load increases and the radiator inlet starts to increase, the temperature in tube 1 increases and more heat is transferred through the fin towards tube 2. At the same time, the PRIMARY GLYCOL EVAP INLET TEMP valve starts to close and force more coolant to the radiators, thus helping to thaw the stagnant portion of the panels. As tube 2 starts to get warmer and receives more flow, it in turn starts to thaw tube 3, etc. This combination of higher inlet temperatures and higher flow rates quickly thaws out the panel. The panels automatically provide a high effectiveness (completely thawed panels operating at a high-average fin temperature) at high-heat loads, and a low effectiveness (stagnated panels operating at a low-average fin temperature) at low-heat loads.

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The secondary radiator consists of four tubes which are an integral part of the ECS radiator panel structure. Each tube is purposely placed close to the hottest primary radiator tubes (i.e., the number 1 and the downstream series tube on each panel) to keep the water-glycol in the secondary tubes from freezing while the secondary circuit is inoperative. The "selective stagnation" principle is not utilized in the secondary radiator because of the "narrower" heat load range requirements. This is also the reason the secondary radiator is a series loop. Because of the lack of this passive control mechanism, the secondary ECS circuit is dependent on the heater control system at low-heat loads and the evaporator at high-heat loads for control of the water-glycol temperature.

The secondary heater control receives power through the ECS RADIATORS HEATER switch in the SEC position. The secondary heaters differ from the primary in that they can be operated simultaneously. When the secondary outlet temperature reaches 45°F the No. 1 heater comes on, and at 42°F the No. 2 heater comes on; at 44°F No. 2 goes off, and at 45°F No. 1 goes off.

2.7.7 ELECTRICAL POWER DISTRIBUTION.

The electrical power required for the operation of the environmental control system is 28 volts dc and 115/200 volts 400 cycles 3-phase ac. (See figures 2.7-4 and 2.7-5.) The larger motors of the system utilize 200-volt 3-phase power, whereas the smaller motors and control circuits operate from a single phase of the ac at 115 volts. Except for the post-landing ventilation system, those components using 28 volts dc will receive power from the fuel cells before CSM separation and from batteries after separation. The postlanding ventilation system will operate from batteries, exclusively.

2.7.8 ECS PERFORMANCE AND DESIGN DATA.

The following table provides performance and design data for system components that operate automatically without direct control. Components that operate in response to crew control are described in AOH, Volume 1, section 3. Components are identified by the AiResearch item number and nomenclature.

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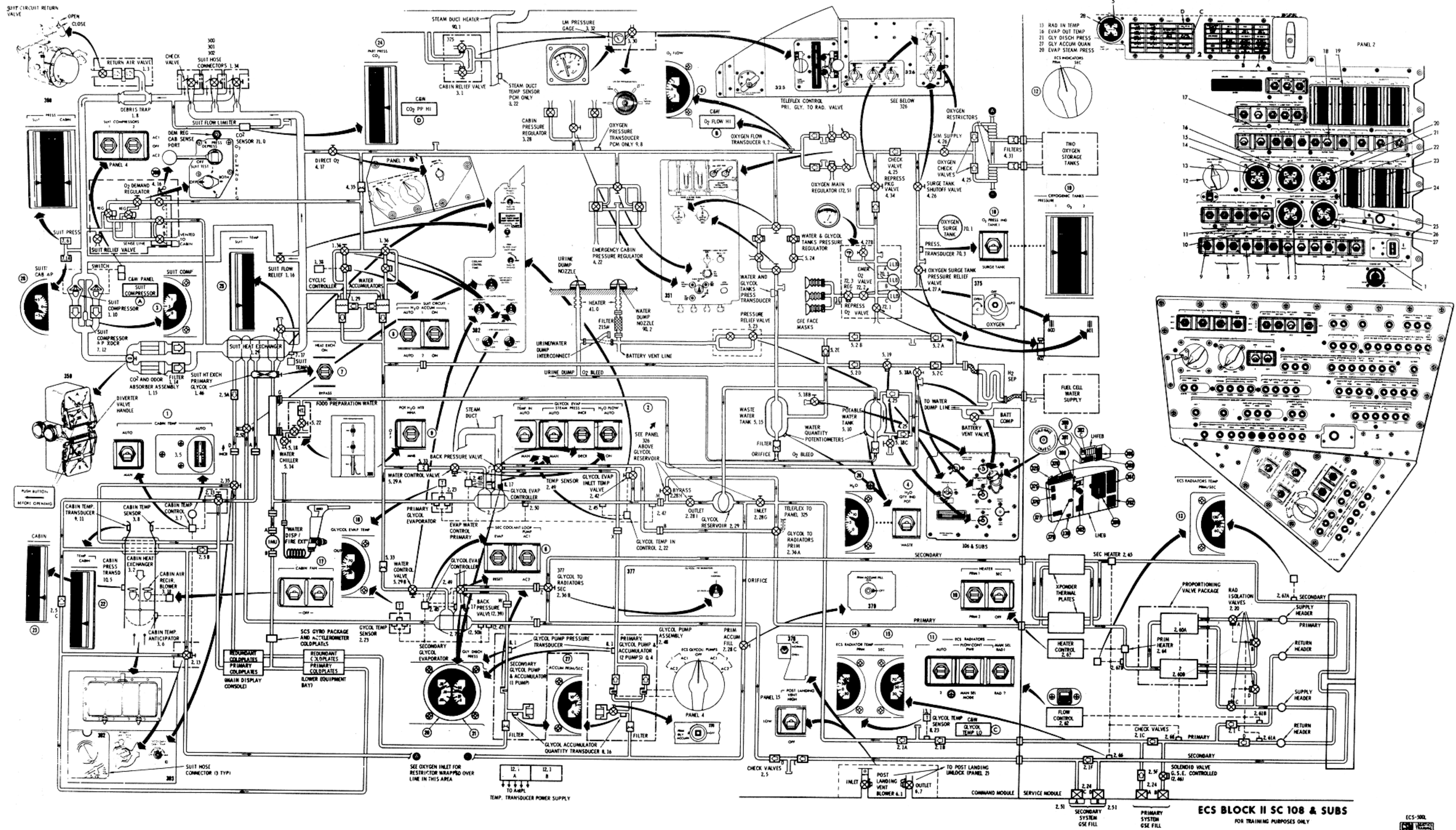


Figure 2.7-4. Environmental Control System Schematic

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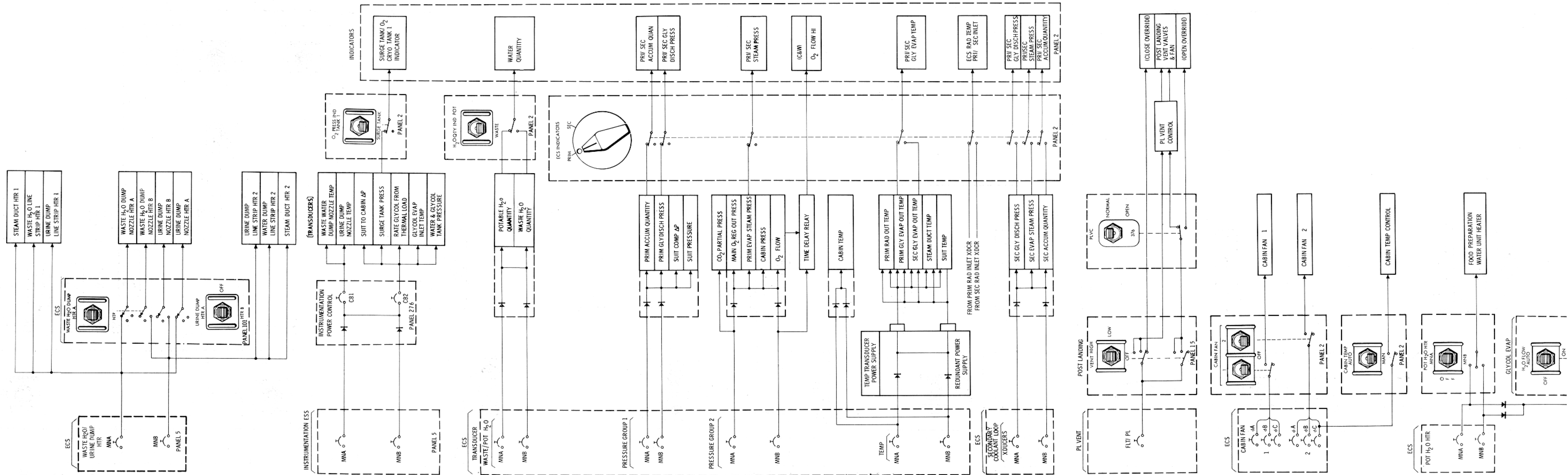


Figure 2.7-5. Environmental Control System Power Distribution (Sheet 1 of 2)

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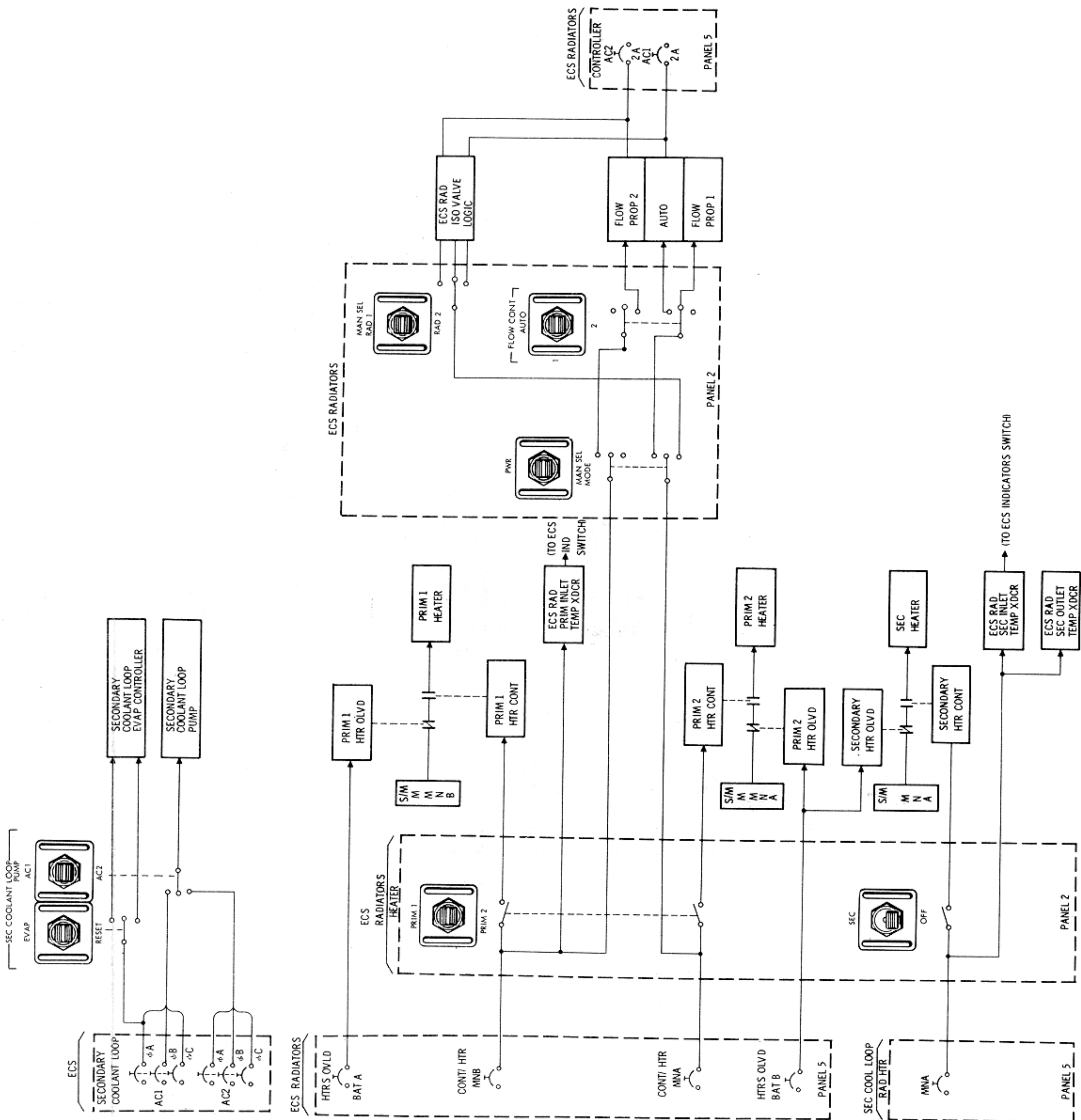
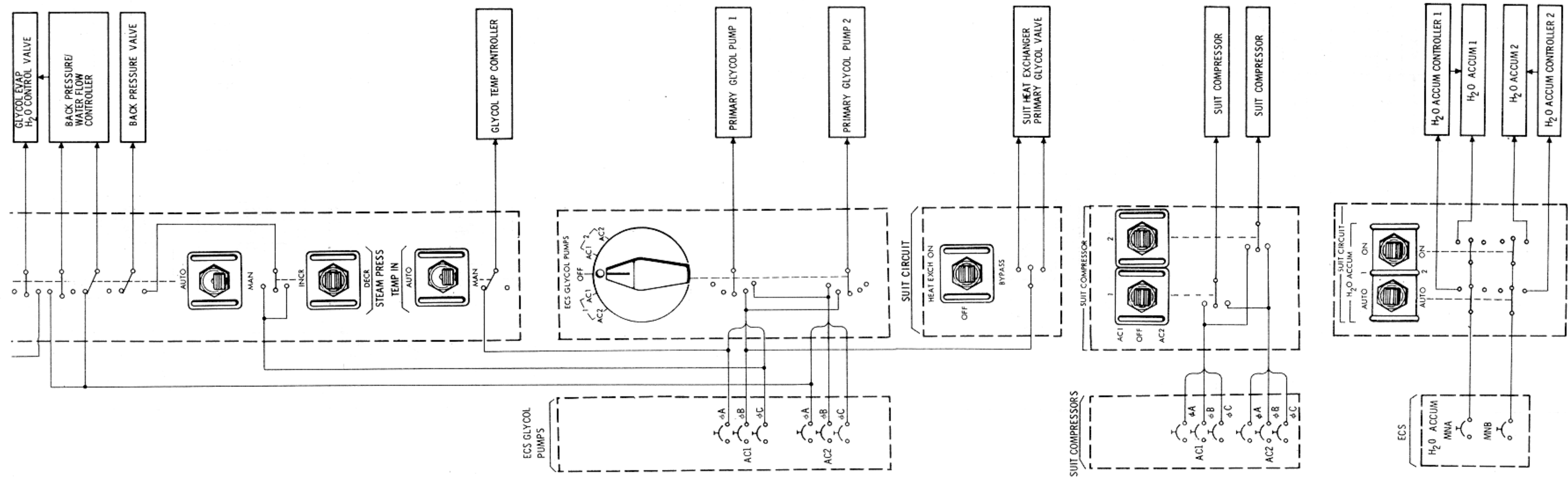


Figure 2.7-5. Environmental Control System Power Distribution (Sheet 2 of 2)

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Item Number	Nomenclature	Location	Type	Function	Performance Characteristics
1.8	Debris trap	ECU	Mechanical filter with integral bypass	Prevents debris from entering the suit compressors.	Filtration = 0.04 in. Pressure drop = 0.25 in. H <sub>2</sub> O max. Bypass valve cracks at 0.5 in. H <sub>2</sub> O max.
1.10	Suit compressor	ECU	Centrifugal blower (2)	Circulates gases through the suit circuit.	Normal Operation = 35 cfm with 0.38 psi pressure rise at 5 psia; 33.6 cfm with 0.27 psi pressure rise at 3.5 psia.
1.29	Suit heat exchanger	ECU	2 pass, suit gas to water-glycol heat exchanger, and water separator	Cools suit gas and removes excess water to control humidity.	Cooling = 2100 Btu/hr total minimum.
1.31	Suit flow limiter	LHFEB	Venturi tube (3)	Limit the flow of gas to any one suit in case a suit becomes torn in a depressurized cabin.	Choked flow = 0.7 lb/minute O <sub>2</sub> max. at 3.5 psia and 70°F.
2.6 (2.7)	Primary (secondary) glycol evaporators	ECU	Evaporative heat exchanger (2)	Cools water-glycol by evaporation of waste water into low-pressure steam with minimum water carry-over into steam duct.	Heat transfer = 7620 Btu/hr. Steam water content = 1 percent max.

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Item Number	Nomenclature	Location	Type	Function	Performance Characteristics
2.20	Space radiator isolation valves	S/M	Electrically actuated, rotary shut-off valve (4)	Controlled by flow-proportioning controller, or by flow control switches to isolate space radiators.	Actuation time = 17 sec max. for full rotational stroke. Power req. = 8 va max. at 115 v, 10, 400 cps.
2.29	Glycol reservoir	LHEB	Tank with oxygen-pressurized bladder for W/G expulsion at zero G	Contains reserve supply of W/G; substitutes for failed accumulator.	Capacity = 8.2 lb W/G at 70°F.
2.39	Back pressure valve	ECU	Electrically actuated pinch valve	Controls "steam" pressure in W/G evaporator.	Actuation time = 58 sec max. full closed to full open. Power req. = 8 va (0.07a) at 115 v.
2.48	Glycol pumping unit	LHEB	Centrifugal impeller motor driven through magnetic coupling (two primary, one secondary)	Circulates W/G through the primary and/or secondary coolant loops.	Inlet press = 7.5 psig. Pump $\Delta P$ = 34 psid with 200-240 lb/hr flow rate. Power requirements = 115v, 30, 400 cps, 52 W max.

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Item Number	Nomenclature	Location	Type	Function	Performance Characteristics
3.2	Cabin heat exchanger	LHFEB	Plate fin, sandwich construction, cabin gas-to-water glycol heat exchanger	Used to control cabin gas temperature.	Heat transfer rate: Primary heating = 236 Btu/hr. Primary cooling = 892 Btu/hr. Secondary cooling = 1132 Btu/hr.
3.28	Cabin pressure regulator	LHEB 351	Two flow-limited, absolute pressure regulators with integral repressurization valve	Maintain cabin at normal pressure (nonemergency) and shut-off during depressurized cabin (emergency).	Hi pressure lock-up = 5.2 psia nominal. Control range = 5.2 to 4.8. Total range = 5.2 to 3.5 psia. Demand flow = 0.7 lb/hr each.
4.25	Hi press O <sub>2</sub> check	LHEB	Spring-loaded umbrella	Allows O <sub>2</sub> flow in one direction only.	Flow = 0.75 lb/min at 5 psid.
4.35	O <sub>2</sub> filter	LHEB	Mechanical	Provides filtering for O <sub>2</sub> supply to water accumulators and demand regulator.	10 microns nominal. 25 microns absolute.
5.10	Potable water tank	Aft Compartment	Cylindrical tank with pressurized bladder	Stores drinking water.	Capacity = 36 + 3, -0 lb H <sub>2</sub> O at 150°F.
5.14	Water chiller	ECU	Heat exchanger	Utilizes 45° W/G to cool drinking water.	W/G flow = 167 lb/hr. W/G temp 45°F. Water in = 150°F. Water out = 55°F max. With above inlet conditions and 6 fl oz H <sub>2</sub> O withdrawn in 10 sec. max. at 24 min intervals.

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Item Number	Nomenclature	Location	Type	Function	Performance Characteristics
5.15	Waste water tank		Cylindrical tank with pressurized bladder	Stores water for evaporative cooling.	Capacity = 56 + 3, -0 lb H <sub>2</sub> O at 150°F.
5.29	Evaporator water control valves (primary and secondary)	LHEB 382	Normally closed solenoid valve in series with two-way selector valve	Controls water flow to primary and secondary W/G evaporators.	Flow capacity 24 lb/hr H <sub>2</sub> O at 0.5 psid Power requirement = 6 va at 28 vdc.
5.33	Water filter (primary and secondary)	LHEB ECU	Filter cartridge plus bypass valve that opens for clogged cartridge	Filters waste water at inlet to primary and secondary W/G evaporators.	Filtration - = 10 microns absolute Bypass relief = 3 psid

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