

# Shuttle Flight Operations Manual

Vol 3

Volume 3  
Environmental Control and Life  
Support Systems (ECLSS)

Flight Operations Directorate  
Crew Training and Procedures Division

Final  
March 3, 1979

RECEIVED  
MARCH 1979

**NASA**

National Aeronautics and  
Space Administration

Lyndon B. Johnson Space Center  
Houston, Texas

FLIGHT OPERATIONS DIRECTORATE

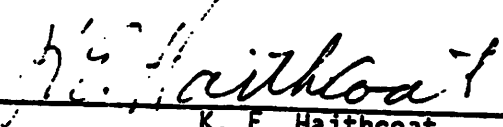
Final

OFT SHUTTLE FLIGHT OPERATIONS MANUAL

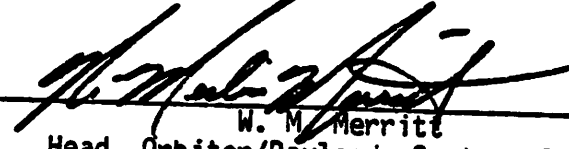
Vol 3 - Environmental Control and Life Support Systems

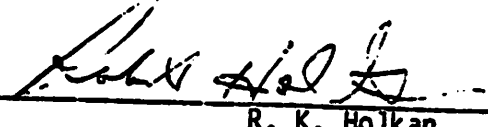
March 3, 1979

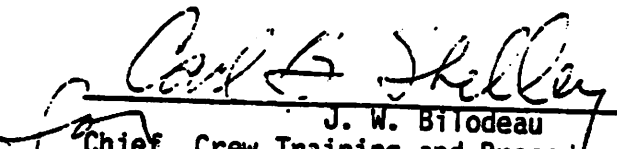
PREPARED BY:

  
\_\_\_\_\_  
K. E. Haithcoat  
Orbiter/Payloads Systems Section

APPROVED BY:

  
\_\_\_\_\_  
W. M. Merritt  
Head, Orbiter/Payloads Systems Section

  
\_\_\_\_\_  
R. K. Holkan  
Chief, Flight Training Branch

  
\_\_\_\_\_  
J. W. Bilodeau  
Chief, Crew Training and Procedures Division

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION  
LYNDON B. JOHNSON SPACE CENTER  
HOUSTON, TEXAS

# Shuttle Flight Operations Manual

U01 3

Volume 3  
Environmental Control and Life  
Support Systems (ECLSS)

Flight Operations Directorate  
Crew Training and Procedures Division

Final  
March 3, 1979

**NASA**

National Aeronautics and  
Space Administration

Lyndon B. Johnson Space Center  
Houston, Texas

FLIGHT OPERATIONS DIRECTORATE

Final

OFT SHUTTLE FLIGHT OPERATIONS MANUAL

Vol 3 - Environmental Control and Life Support Systems

March 3, 1979

PREPARED BY:

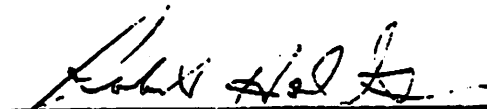


K. E. Haithcoat  
Orbiter/Payloads Systems Section

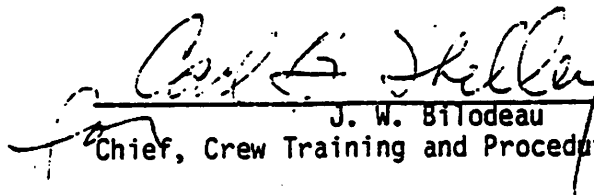
APPROVED BY:



W. M. Merritt  
Head, Orbiter/Payloads Systems Section



R. K. Holkan  
Chief, Flight Training Branch



J. W. Bilodeau  
Chief, Crew Training and Procedures Division

## DOCUMENT ORGANIZATION

The Shuttle Flight Operations Manual (SFOM) will be published in separate individually bound volumes. Publication of the preliminary editions of the volumes will be staggered throughout 1979.

The following listing of all SFOM volumes shows the responsible book managers to whom all technical questions should be addressed. Requests for single copies of specific SFOM volumes should be addressed to the book manager in writing or by telephone. Multiple-copy requests for a specific volume must be addressed to the book manager in writing stating the number of copies required and giving a brief statement of justification. Requests for a complete set of SFOM volumes must be addressed to the Division Chief/CTPD in writing including a statement of justification.

<u>VOLUME</u>	<u>TITLE</u>	<u>BOOK MANAGER</u>	<u>PHONE NUMBER</u>
1	Caution and Warning	CG6/T. Ward	(713) 483-2651
2	Electrical Power System	CG6/H. Baxter	-2651
3	Environment Control and Life Support Systems	CG6/K. Haithcoat	-4794
4	Communications & Instrumentation	CG3/E. Rainey	-2213
	A. Audio	E. Rainey	-2213
	B. S-Band	T. Bruce	-2213
	C. Ku-Band	R. DePaolo	-2213
	D. TV	B. Fulbright	-2213
	E. Instrumentation	G. Steinbeck	-2213
5	Data Processing System	CG6/R. Lanier	-3291
6	Guidance, Navigation, and Control Hardware	CG6/A. Accola	-3291
7	Applications Software	CG6/M. Brekke	-4637
8	Propulsion		
	A. Main Propulsion System	CG6/M. Price (RI)	-4637
	B. Solid Rocket Booster System	W. Chanis	-4637
	C. Orbital Maneuvering System	M. Hernandez	-2651
	D. Reaction Control System	K. Black	-2651
9	Auxiliary Power Unit/Hydraulics	CG6/J. Sidwell	-2651
10	Structures and Mechanical	CG6/J. Poffinbarger	-4794
	A. ET Umbilical Doors System	L. VandeZande	-2651
	B. Active Vent System	L. VandeZande	-2651
	C. Payload Bay Door/Radiator System	B. Hahne	-2651
	D. Landing/Deceleration System	J. Poffinbarger	-4794
11	Aerodynamic Performance	CG6/D. Zwingman	-3048
12	Crew Systems	CG3/R. Snyder	-2541
13	Shuttle Displays and Controls	CG3/T. Neal	-2541
14	Shuttle CRT Displays	CG5/M. Gremillion	-4271
15	Extravehicular Activity	CG3/J. Covington	-2541
16	Payload Deployment and Retrieval Systems	CG5/B. Kain	-2611
17	Payload Carrier Systems	CG6/G. Laski	-4794
18	Shuttle Upper Stages	CG6/R. Benson	-4794
19	Spacelab Support Systems	CG6/A. Holt	-4794

## CONTENTS

Section	Page
1. <u>INTRODUCTION</u> . . . . .	1-1
2.     SYSTEMS DESCRIPTION . . . . .	2-1
2.1    ATMOSPHERE PRESSURIZATION . . . . .	2-1
2.1.1    Interfaces . . . . .	2-1
2.1.2    Pressurization System Description . . . . .	2-1
2.1.3    Pressurization System Controls and Displays . . . . .	2-8
2.2    AIR REVITALIZATION SYSTEM . . . . .	2-25
2.2.1    Interfaces . . . . .	2-25
2.2.2    ARS System Description . . . . .	2-25
2.2.3    ARS Displays and Controls . . . . .	2-30
2.2.4    ARS Systems Performance, Limitations, and Capabilities . . . . .	2-46
2.3    ACTIVE THERMAL CONTROL SYSTEM . . . . .	2-46
2.3.1    Interfaces . . . . .	2-46
2.3.2    ATCS System Description . . . . .	2-46
2.3.3    ATCS Controls and Displays . . . . .	2-52
2.3.4    ATCS Systems Performance, Limitations, and Capabilities . . . . .	2-65
2.4    SUPPLY AND WASTE H <sub>2</sub> O MANAGEMENT SYSTEM . . . . .	2-65
2.4.1    Interfaces . . . . .	2-65
2.4.2    Supply and Waste Water Management System Description . . . . .	2-65
2.4.3    Supply Water and WMS Controls and Displays . . . . .	2-67
2.4.4    Water and WMS Systems Performance, Limitations, and Capabilities . . . . .	2-80

## TABLES

Table	Page
2-I     ECLSS PRESSURIZATION CONTROLS . . . . .	2-19
2-II    ECLSS CONTROLS (ARS) . . . . .	2-42
2-III   ATCS CONTROLS . . . . .	2-61
2-IV    H <sub>2</sub> O MANAGEMENT . . . . .	2-74

## FIGURES

Figure		Page
1-1	ECLSS locations . . . . .	1-2
1-2	ECLSS aft equipment locations . . . . .	1-3
2-1	Pressurization System . . . . .	2-2
2-2	Pressurization System . . . . .	2-3
2-3	Pressurization System . . . . .	2-5
2-4	O <sub>2</sub> /N <sub>2</sub> controller data flow . . . . .	2-6
2-5	Relief and vent valves . . . . .	2-7
2-6	Panel L2 . . . . .	2-9
2-7	Panel L2 . . . . .	2-10
2-8	Panel M010W . . . . .	2-12
2-9	Panel O1 . . . . .	2-13
2-10	C&W display, panel F7 . . . . .	2-14
2-11	Display S66 . . . . .	2-15
2-12	SM SYS SUMM 1 display . . . . .	2-16
2-13	BFS display . . . . .	2-17
2-14	Air circulation . . . . .	2-26
2-15	Humidity separators . . . . .	2-28
2-16	H <sub>2</sub> O loops . . . . .	2-29
2-17	Panel L1, ARS controls . . . . .	2-31
2-18	Display S66 . . . . .	2-33
2-19	Display S88 . . . . .	2-34
2-20	SM SYS SUMM 1 display . . . . .	2-35
2-21	SM SYS SUMM 2 display . . . . .	2-36
2-22	BFS display . . . . .	2-37
2-23	Panel O1 . . . . .	2-38
2-24	C&W display, panel F7 . . . . .	2-39
2-25	C&W display, panel F7 . . . . .	2-40
2-26	Freon flow . . . . .	2-47
2-27	Radiator control . . . . .	2-49
2-28	Ammonia boilers . . . . .	2-50
2-29	Evaporators . . . . .	2-51
2-30	Panel L1, ATCS controls . . . . .	2-53
2-31	Panel O1 . . . . .	2-55
2-32	C&W display, panel F7 . . . . .	2-56
2-33	Display S88 . . . . .	2-58
2-34	SM SYS SUM 2 display . . . . .	2-59
2-35	BFS display . . . . .	2-60
2-36	Supply H <sub>2</sub> O storage . . . . .	2-66
2-37	N <sub>2</sub> pressure . . . . .	2-68
2-38	Waste water storage . . . . .	2-69
2-39	Panel R12 . . . . .	2-70
2-40	Panel ML31C, waste H <sub>2</sub> O . . . . .	2-72
2-41	Display S66 . . . . .	2-73

## SECTION 1 INTRODUCTION

The Orbiter Environmental Control and Life Support System (ECLSS) is comprised of the following:

- o Pressurization System
- o Air Revitalization System
- o Active Thermal Control System
- o Supply/Waste H<sub>2</sub>O System

These systems interact to provide a habitable environment for man in outer space. Figures 1-1 and 1-2 show ECLSS equipment locations in the Orbiter.

The Pressurization System provides a 14.7 psia O<sub>2</sub>/N<sub>2</sub> atmosphere. Partial pressure of oxygen is 3.2 psia. If circumstances are encountered requiring lower cabin pressure, the capability exists to control cabin pressure at 8.0 psia with 2.2 psia partial pressure of oxygen.

The Air Revitalization System (ARS) controls the relative humidity between 30 and 65 percent. Carbon dioxide (CO<sub>2</sub>) and carbon monoxide (CO) are controlled to non-toxic levels. The ARS also picks up heat by circulating the atmosphere. At the cabin heat exchanger, the heat is transferred to the water cooling loops. The water cooling loops pick up additional heat and transfer the heat to the Active Thermal Control System (ATCS) at the water/Freon interchanger.

The ATCS collects additional heat and transfers the heat to the exterior of the spacecraft via the GSE heat exchanger, the radiators, the evaporators, or the ammonia boilers.

The Supply Water System stores water for crew consumption and cooling (flash evaporator). Excess water can be dumped overboard. The Waste Water System stores waste liquid (humidity separators and crew waste) and metabolic waste (feces, emesis, etc.). Solid waste remains in the Waste Management System until ground servicing. Liquid waste can be dumped overboard, or, in a contingency, used in the flash evaporators.



1-2

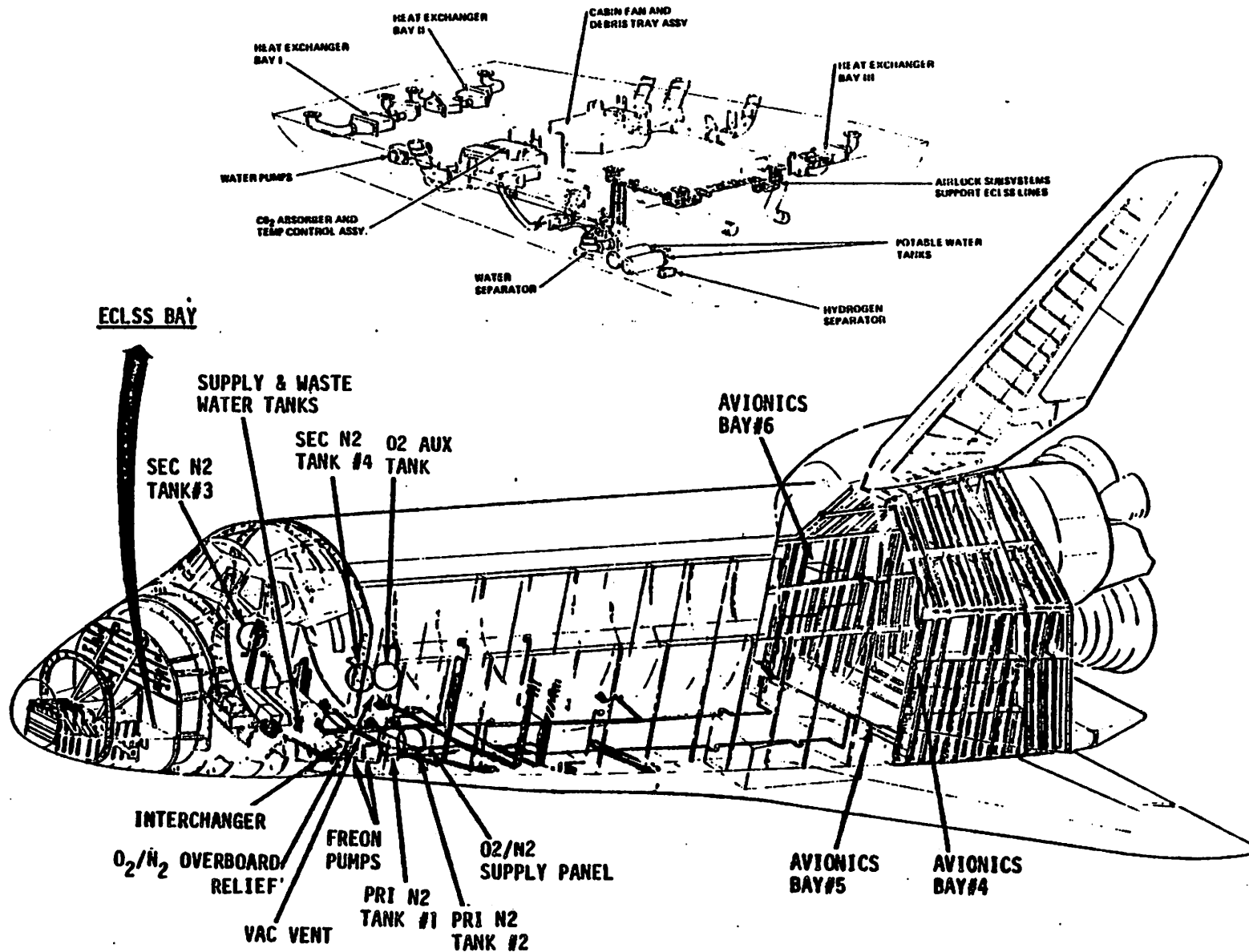
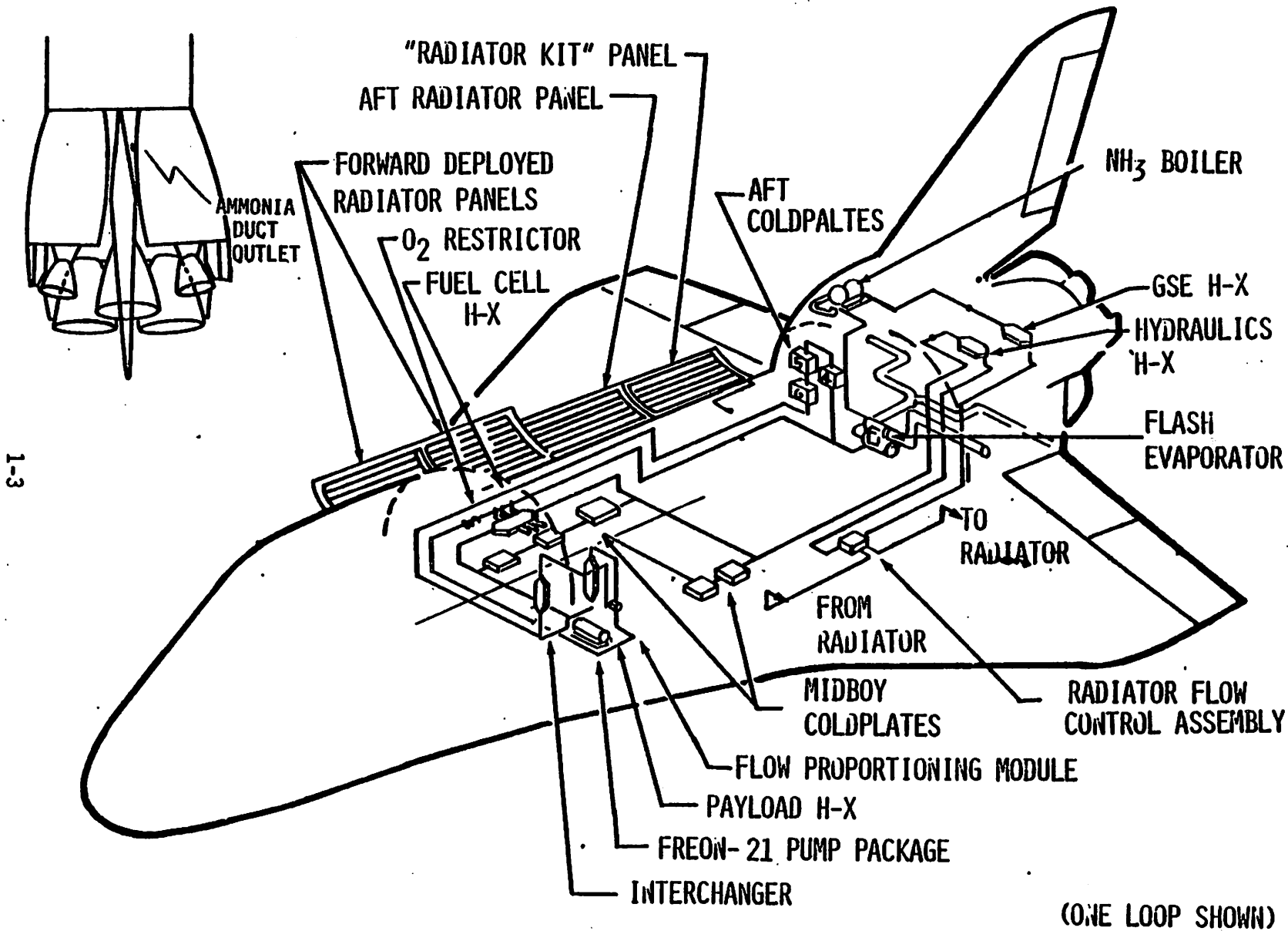


Figure 1-1.- ECLSS locations.

3-ECLSS



1-3

Figure 1-2. - ECLSS aft equipment locations.

3-ECLSS

## SECTION 2 SYSTEMS DESCRIPTION

### 2.1 ATMOSPHERE PRESSURIZATION

#### 2.1.1 Interfaces

The Atmosphere Pressurization System receives oxygen ( $O_2$ ) from the same cryo source that feeds the fuel cells. This source is located in the payload bays. The pressure is heater controlled and is provided to the ECLSS supply valve at approximately 850 psia. The Electrical Power System (EPS) provides power to the telemetry and pressurization control electronics. The crew control interface is via Panel L2, Panel O1, and the CRT. The Pressurization System interfaces with the ARS. The ARS cleanses and cools the gas used in the cabin for pressurization. Nitrogen ( $N_2$ ) is also used to pressurize the water tanks. Cabin gas is used to carry away bodily waste and odors into the Waste Management System (WMS).

#### 2.1.2 Pressurization System Description (fig. 2-1)

The Orbiter is normally pressurized with 40 lb of  $O_2$  and 130 lb of  $N_2$ . For the first few flights, the cabin pressure regulator will be adjusted to control at 14.5 psia. This 0.2 psi decrease from normal sea level atmospheric pressure is deemed necessary to prevent structural damage in the event of explosive decompression.

The Pressurization System consists of two  $O_2$  systems, two  $N_2$  systems, and one emergency  $O_2$  system. The two  $O_2$  systems are supplied by the cryogenic oxygen supply in the payload bay. The oxygen is controlled by heaters to a pressure between 835 and 852 psia. This oxygen, in gaseous form, is supplied to the ECLSS supply valve.

Oxygen flowing through the  $O_2$  supply valve next passes through the  $O_2$  restrictor. The  $O_2$  restrictor, basically a heat exchanger with hot Freon counter-flowing the  $O_2$ , will warm the  $O_2$ . The  $O_2$  restrictor has a maximum  $O_2$  flow capability of 10 lb/hr. A check valve downstream of the  $O_2$  restrictor prevents reverse flow of oxygen. Downstream of the  $O_2$  check valve is a crossover manifold (see fig. 2-1). This manifold provides an interface between  $O_2$  system 1 and system 2. The  $O_2$  next goes through a manual  $O_2$  regulator input valve to the 100 psi regulator which steps the  $O_2$  pressure from 850 psi down to 100 psi. The  $O_2$  then passes through another check valve to the  $O_2/N_2$  manifold. Off of the  $O_2/N_2$  manifold, oxygen is provided to the 14.5 and 8 psi regulators which valve  $O_2$  and  $N_2$  to the Shuttle cabin, as required, to maintain cabin pressure.

The nitrogen interfaces with the  $O_2$  system at the  $O_2/N_2$  manifold (see fig. 2-2). The nitrogen supply, located in the payload bay, consists of four tanks, with two tanks for each system. The  $N_2$  passes through a motorized supply inlet valve at an initial pressure of 3300 psi. System 1 and system 2 are then manifolded together. Off of the  $N_2$  supply manifold, the  $N_2$  passes through a regulator inlet valve to the 200 psi regulator.

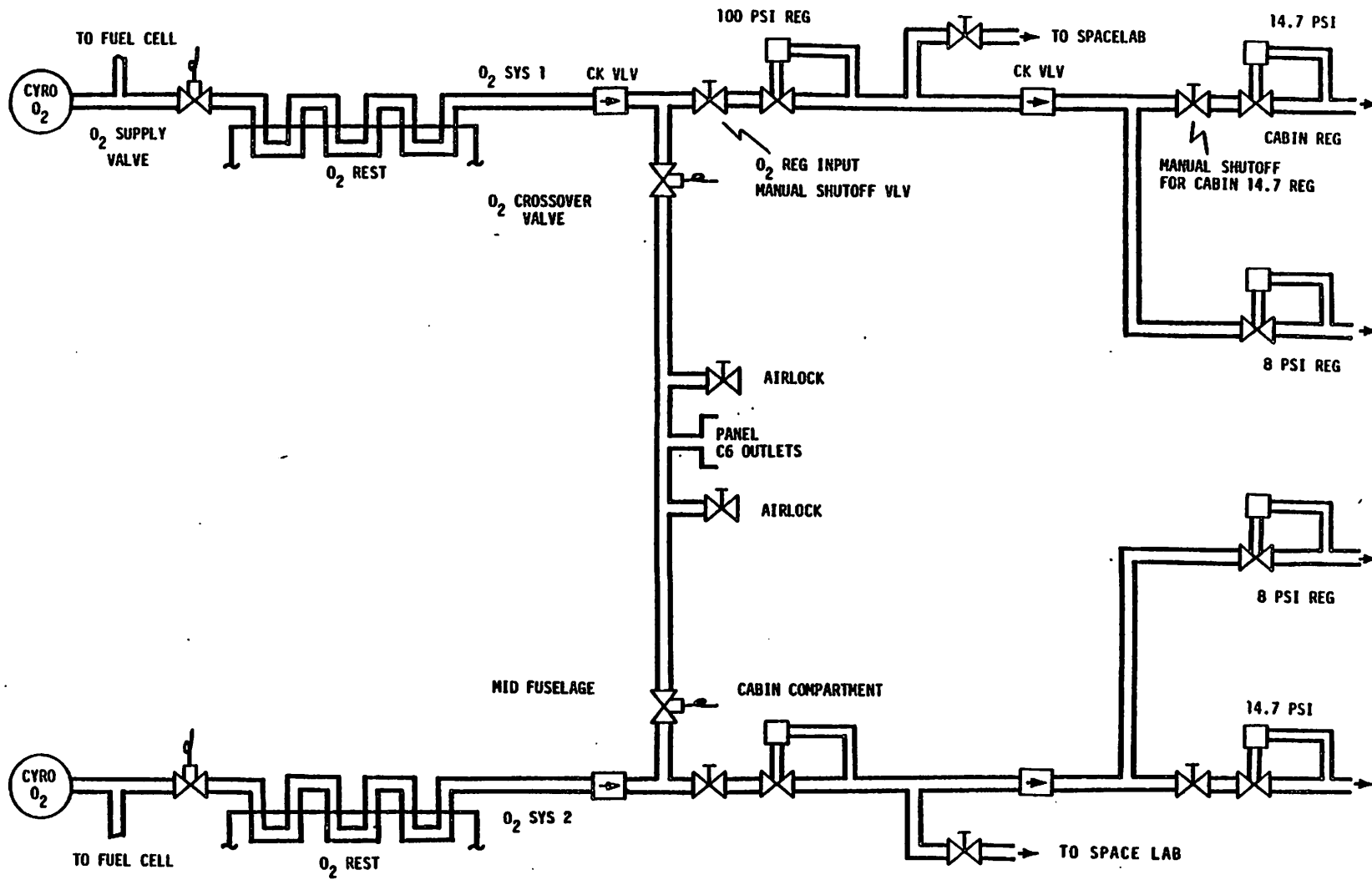


Figure 2-1. - Pressurization System.

2-3

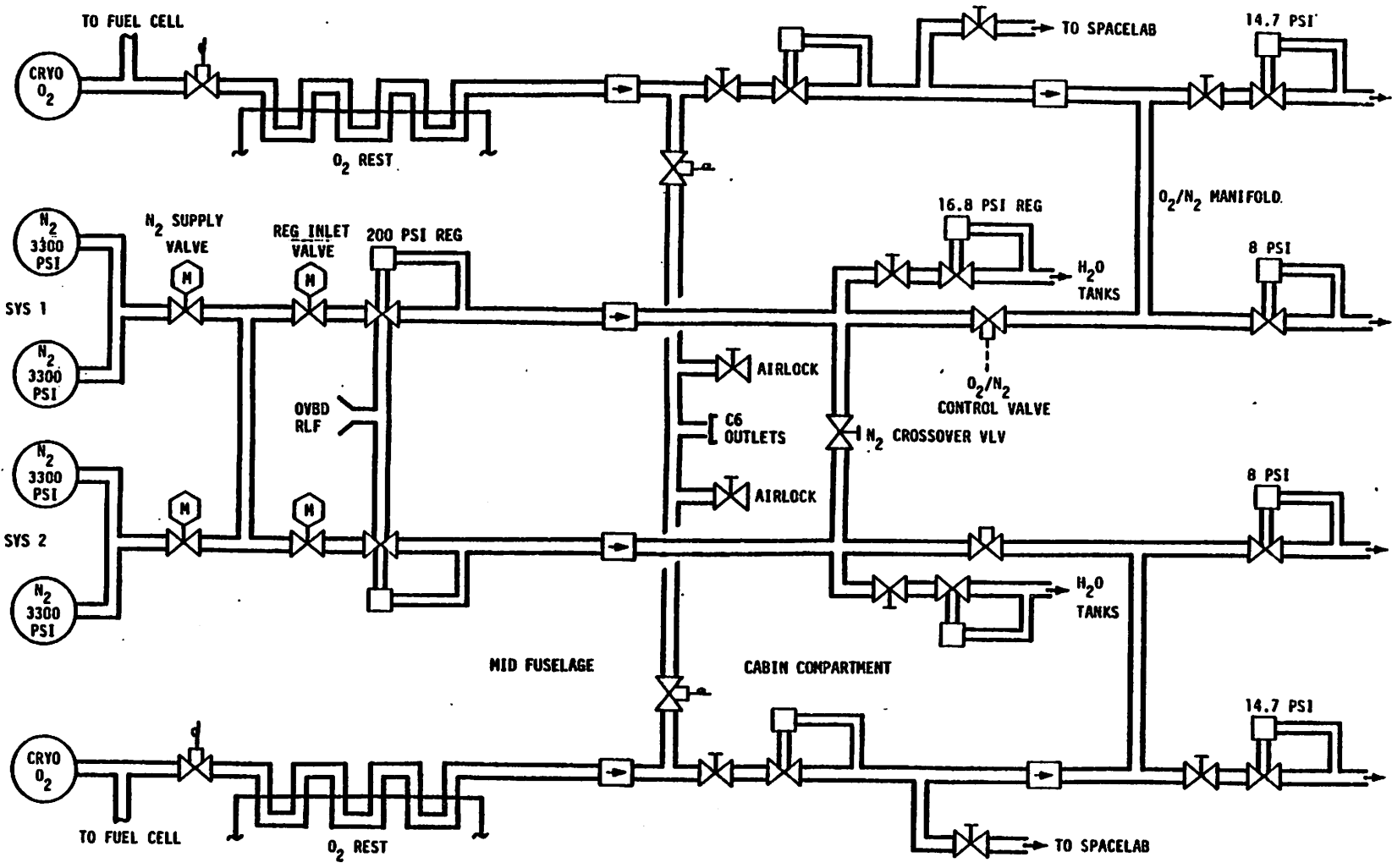


Figure 2-2. - Pressurization System.

3-ECLSS

This regulator steps the nitrogen pressure down to 200 psi. The nitrogen then passes through a check valve to another manifold. Flow through this manifold is controlled by a manual N<sub>2</sub> crossover valve. Pressure for the water tanks comes from this point on the N<sub>2</sub> system. The O<sub>2</sub>/N<sub>2</sub> control valve controls the flow of nitrogen into the O<sub>2</sub>/N<sub>2</sub> manifold to provide a partial pressure of oxygen in the crew compartment of 3.2 psi at 14.5 psi cabin pressure, or 2.2 psi at 8 psi cabin pressure.

The emergency O<sub>2</sub> pressurization system consists of one tank initially pressurized to 3300 psi, a 300 psi regulator, and two valves (see fig. 2-3). Flow to the emergency regulator is through a motorized control valve. Flow from the emergency regulator is controlled by a manual O<sub>2</sub> emergency valve on the O<sub>2</sub>/N<sub>2</sub> control panel. The emergency O<sub>2</sub> system then interfaces with the O<sub>2</sub> system 1 and system 2 at the O<sub>2</sub> crossover manifold.

The partial pressure of oxygen in the cabin is controlled by one of two O<sub>2</sub>/N<sub>2</sub> controllers. These controllers sense the partial pressure of oxygen in the cabin and open or close the O<sub>2</sub>/N<sub>2</sub> control valve located in the nitrogen system (see fig. 2-4). When the control valve is open, N<sub>2</sub> at 200 psi fills the O<sub>2</sub>/N<sub>2</sub> manifold and closes the check valve immediately downstream of the 100 psi O<sub>2</sub> regulator. When the O<sub>2</sub>/N<sub>2</sub> control valve closes, the nitrogen in the manifold immediately bleeds down through the cabin regulators, and the 100 psi O<sub>2</sub> fills the manifold.

Cabin relief valves prevent the cabin from being overpressurized (see fig. 2-5). The vent isolation and vent valves provide a capability to vent the cabin to ambient pressure. This vents directly into the payload bay. The negative relief valves provide flow into the cabin if for some reason the cabin is at a lower pressure than the exterior of the cabin compartment. The positive pressure relief valves open automatically at 15.5 psi. They can be isolated by solenoid actuated valves at the cabin inlet to the relief valves.

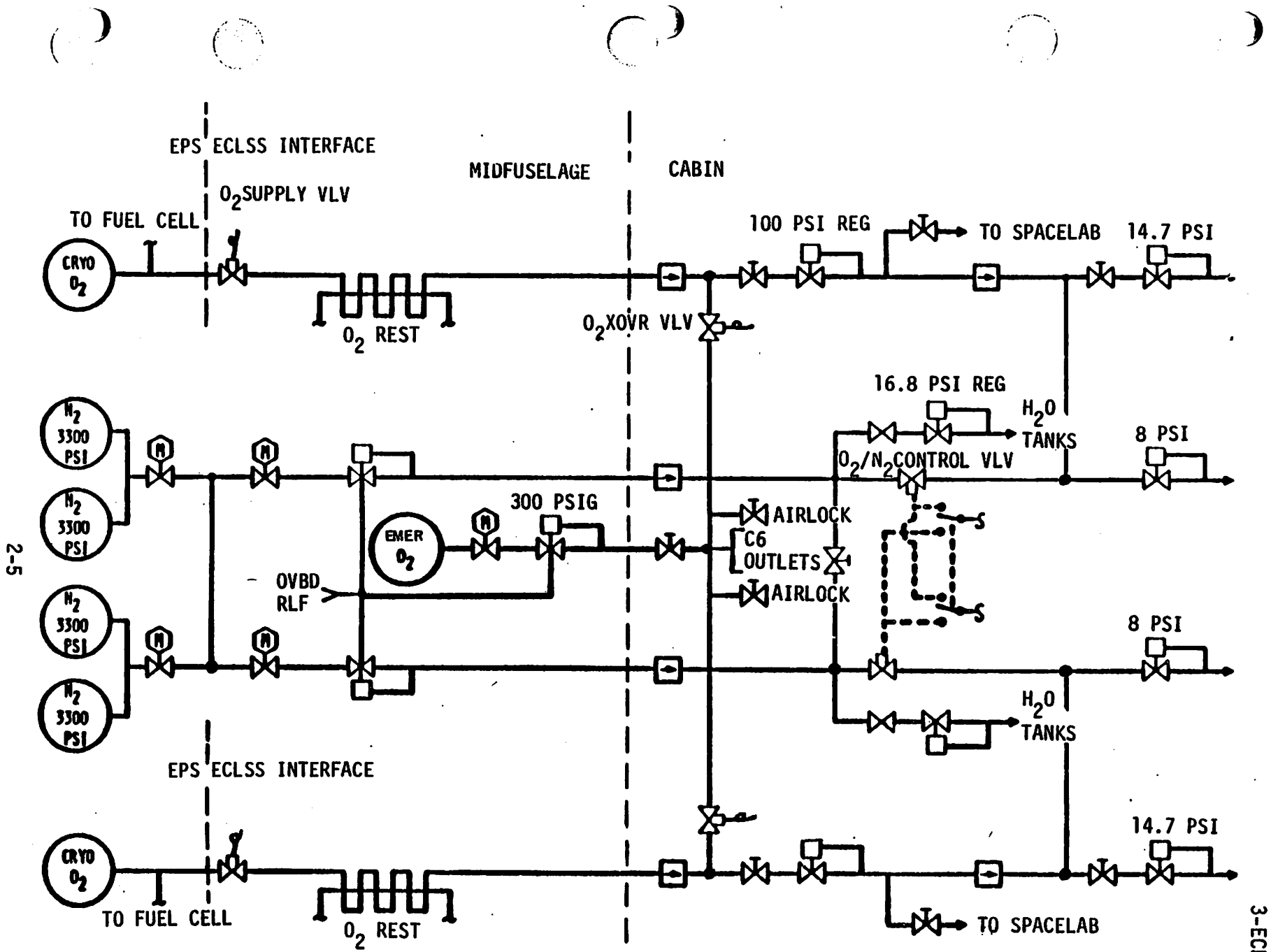


Figure 2-3.- Pressurization System.

2-5

3-ECLSS

2-6

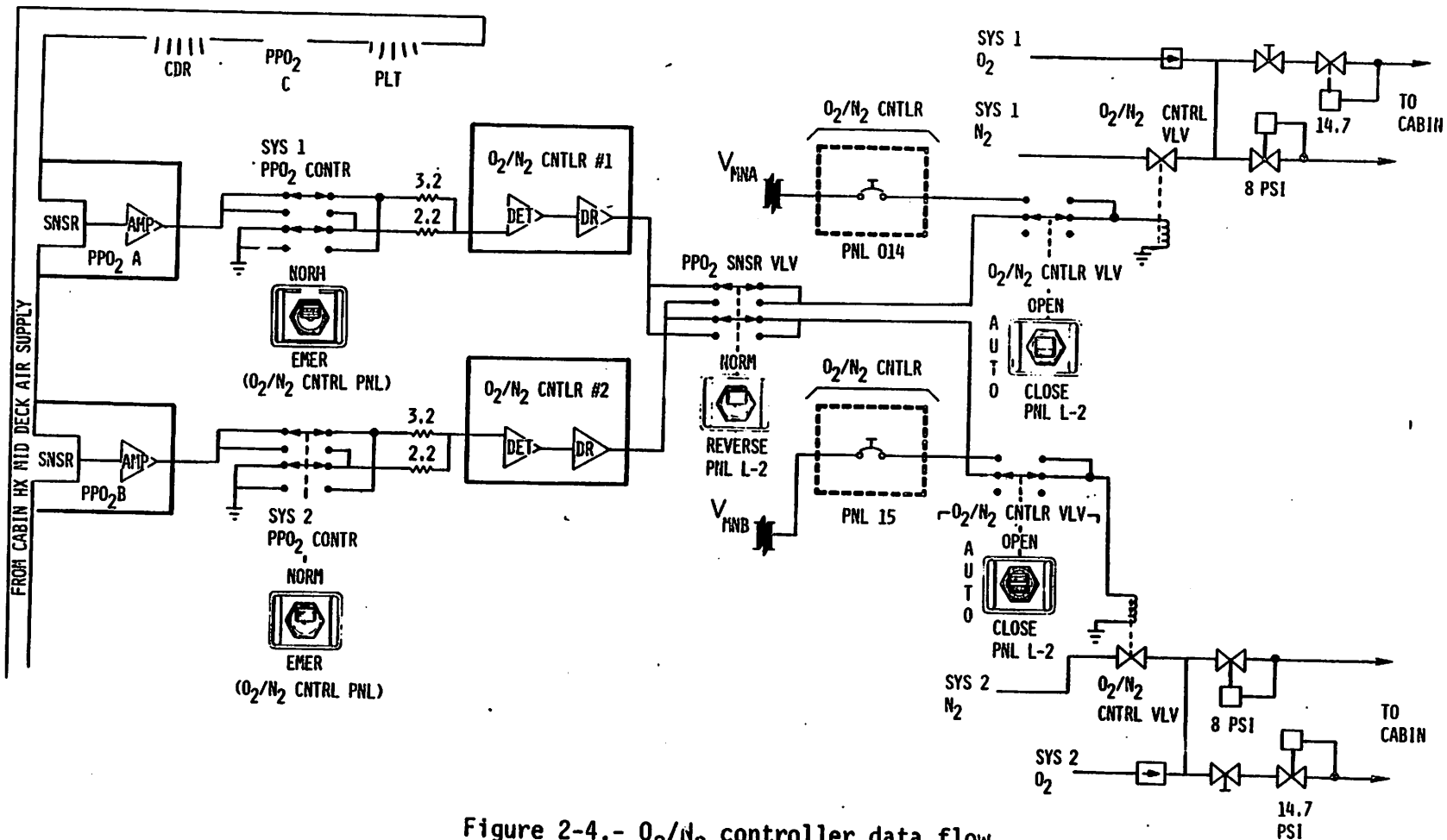


Figure 2-4.-  $O_2/N_2$  controller data flow.

3-ECLSS



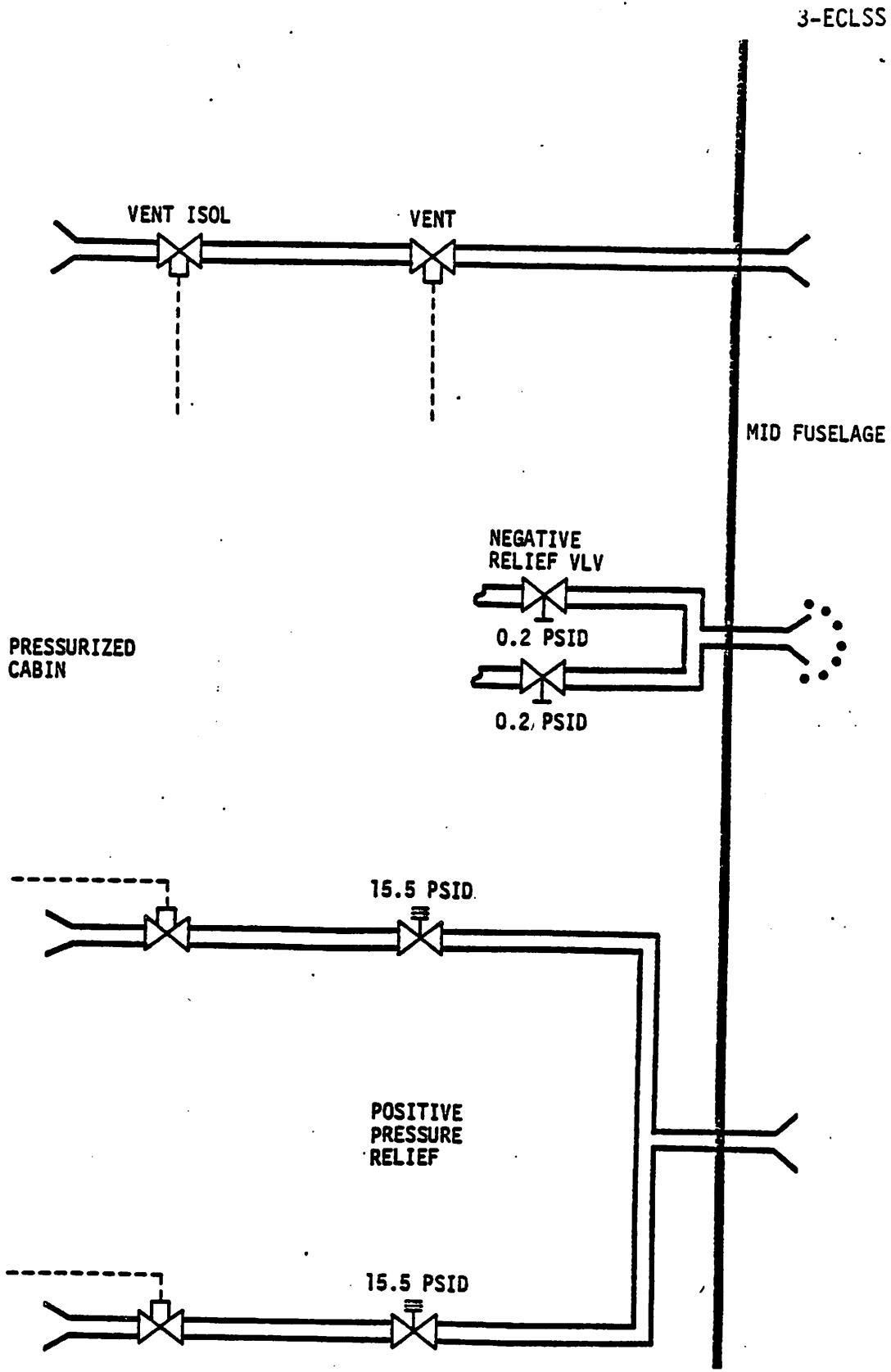


Figure 2-5.- Relief and vent valves.

### 2.1.3 Pressurization System Controls and Displays

Circuit breakers (cb's) for the Pressurization System are located on overhead Panels 014, 015, and 016. Table 2-I lists the purpose of each cb. Displays for the Pressurization System are located on overhead Panels 01, CRT pages S66, SM 1, and BFS Display. Panel F7 contains the caution and warning "CABIN ATM" light. See figures 2-9, 2-10, 2-11, 2-12, and 2-13.

Panels L2 and M010W contain the Pressurization System control switches. L2 (fig. 2-6) contains the switches for the electrically controlled pressurization valves. It has a schematic of the O<sub>2</sub>/N<sub>2</sub> systems. The O<sub>2</sub> system 1 supply switch in the upper left-hand corner controls flow to O<sub>2</sub> system 1 from the cryo system. The O<sub>2</sub> system 2 supply switch is in the lower left-hand corner. Talkbacks which indicate the open or closed state of these valves are located between the switches. The O<sub>2</sub> supply valves are solenoid actuated. When power is removed from the solenoid, the valve remains in its last commanded position, but the talkbacks will read closed. The O<sub>2</sub> emergency switch is located next to the O<sub>2</sub> system 1 supply switch. It controls the emergency O<sub>2</sub> motor control valve. The talkback is located directly below the switch about the center of the panel. If power is lost to this switch, the valve remains in its last commanded position and the talkback will go barberpole (bp). The O<sub>2</sub> XOVER switches SYS 1 and SYS 2 provide an interface between the emergency O<sub>2</sub> system and O<sub>2</sub> systems 1 and 2. The O<sub>2</sub> masks and airlock are also fed from this manifold. The O<sub>2</sub> XOVER switches control solenoid operated valves. When power is lost, these valves go closed. There are no talkbacks associated with these valves. The N<sub>2</sub> SYS 1 and SYS 2 supply switches control motor controlled valves which remain in their last commanded position when power is lost. If power is lost, the talkbacks go barberpole. The N<sub>2</sub> regulator inlet switches provide power to motor controlled valves. If power is lost, the valves remain in their last commanded position and the talkbacks go barberpole. The O<sub>2</sub>/N<sub>2</sub> CNTLR VLV switch is a three-position switch. When unpowered, the valve goes to the closed position. In the open position, the valve is powered open. The "AUTO" position permits valve control by the PPO<sub>2</sub> controller. When the PPO<sub>2</sub> content is below the cabin control level (3.2 psi at 14.5 psi cabin pressure), power is removed from the solenoid and the valve goes closed. O<sub>2</sub> at 100 psi flows into the O<sub>2</sub>/N<sub>2</sub> manifold and through the cabin regulator as the cabin pressure drops below its control level. When the PPO<sub>2</sub> level rises above its control point, the O<sub>2</sub>/N<sub>2</sub> control valve is powered open, N<sub>2</sub> at 200 psi flows into the O<sub>2</sub>/N<sub>2</sub> manifold and forces the check valve downstream of the O<sub>2</sub> 100 psi regulator closed, and N<sub>2</sub> then flows through the cabin regulator. The PPO<sub>2</sub> SNSR VLV NORM-REVERSE switch causes O<sub>2</sub>/N<sub>2</sub> controller 1 to control system 2 and controller 2 to control system 1. In the NORM position, each controls its own valve.

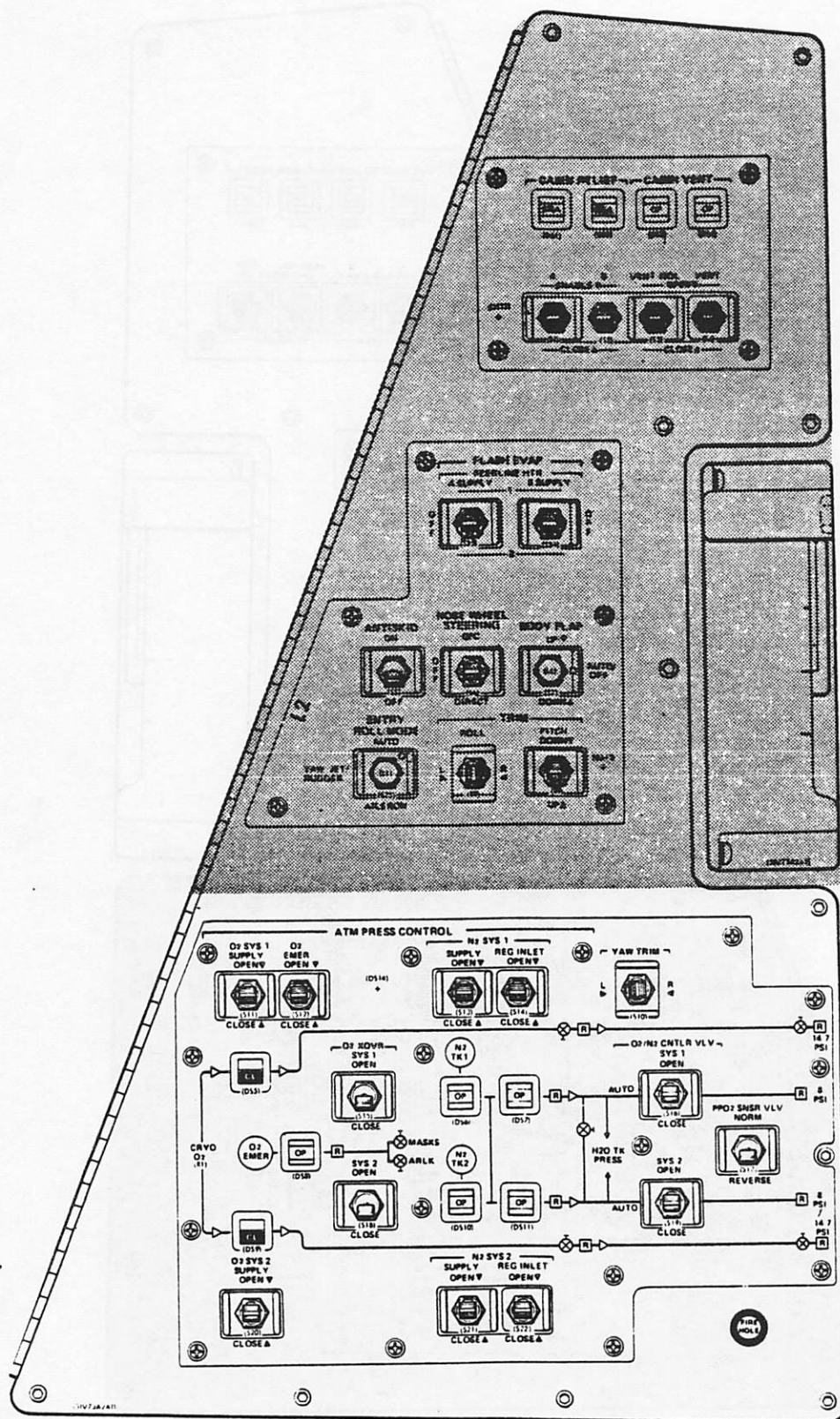


Figure 2-6.- Panel L2.

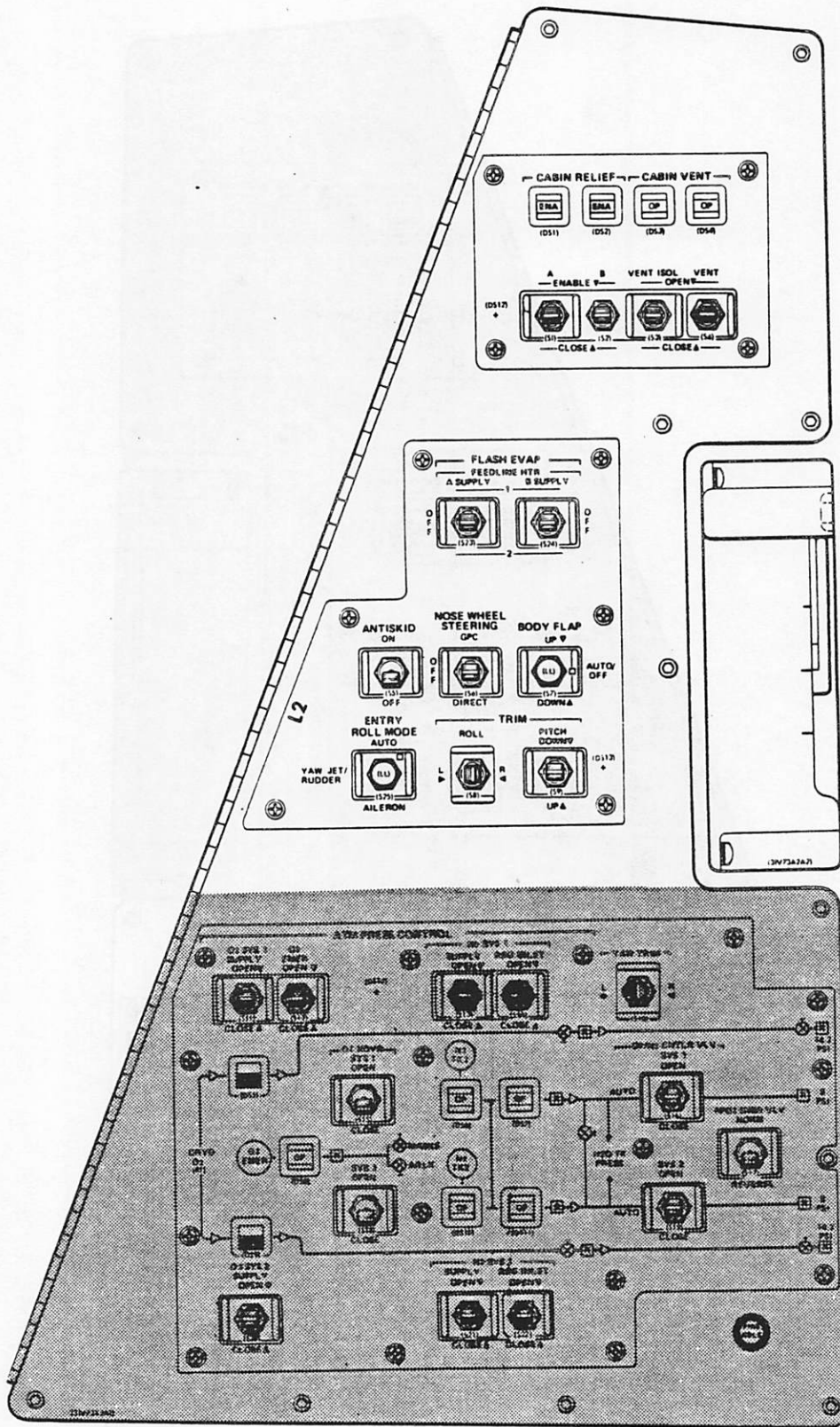


Figure 2-7.- Panel L'2.

Forward on Panel L2 are the cabin relief and cabin vent switches. The cabin relief switches enable the 15.5 psi relief valves. The cabin vent switches open the overboard vent line and dump the cabin pressure.

Panel M010W contains the manual valves associated with the Pressurization System. It also has a panel schematic. Starting with the O<sub>2</sub> EMER tank and following the schematic, we come to the O<sub>2</sub> EMER manual valve. The Panel L2 schematic does not reflect this switch, but Panel M010W shows it to be located downstream of the 300 psi emergency regulator, just prior to the O<sub>2</sub> crossover manifold. Note that the Panel L2 controls are shown in graphic form on this schematic. The manual 12.5 psi cabin reg valves must be closed when we go to 8 psi cabin pressure. Should we decide to operate at 8 psi cabin pressure, the SYS 1 and 2 PPO<sub>2</sub> CONTR NORM-EMERG switches on either side of the panel must be placed to the EMER position. This causes the PPO<sub>2</sub> to be controlled at 2.2 psi, rather than the normal 3.2 psi. The payload O<sub>2</sub> SYS 1/SYS 2 switches provide a positive control of O<sub>2</sub> to the payload outlet. At the lower left corner, the N<sub>2</sub> TK 1 and TK 2 are shown. The N<sub>2</sub> XOVER switch permits an interface between the two N<sub>2</sub> systems. The manual H<sub>2</sub>O TK N<sub>2</sub> regulator inlet valves can be used to isolate the H<sub>2</sub>O tank pressure regulators. At the bottom of the panel are the H<sub>2</sub>O TK N<sub>2</sub> isolation valves which will isolate the water pressurization manifold.

The right-hand dual meter on overhead Panel 01 gives a readout of the PPO<sub>2</sub> in the Shuttle cabin. The toggle switch directly beneath the meter permits selection of either sensor A or sensor B. The left side of this dual meter reflects the cabin pressure in psia. The O<sub>2</sub>/N<sub>2</sub> flow and the cabin  $\Delta P/\Delta T$  can be monitored on the next dual meter. The rotary switch under the O<sub>2</sub>/N<sub>2</sub> flow meter provides a selectable input to that meter. CRT Displays containing pressurization data are displays S66, SM 1, and BFS. Figures 2-11, 2-12, and 2-13 are reproductions of these displays. The BFS display is the only one available during launch and entry. Displays S66 and SM-1 are available while in orbit.

Panel F7 (fig. 2-10) is the caution and warning matrix. The CABIN ATM light will illuminate if one of the following parameters exceeds its limit:

ID	CRT NAME	UNITS	LOWER LIMIT	UPPER LIMIT
V61R2105A	O <sub>2</sub> FLOW 1	LB/HR	--	4.9
V61R2205A	O <sub>2</sub> FLOW 2	LB/HR	--	4.9
V61P2405A	CABIN PRESS	PSIA	14.0	15.4
V61P2511A	PPO <sub>2</sub> A	PSIA	2.8	3.6
V62P2513A	PPO <sub>2</sub> B	PSIA	2.8	3.6
V61R2553A	N <sub>2</sub> FLOW 1	LB/HR	--	4.9

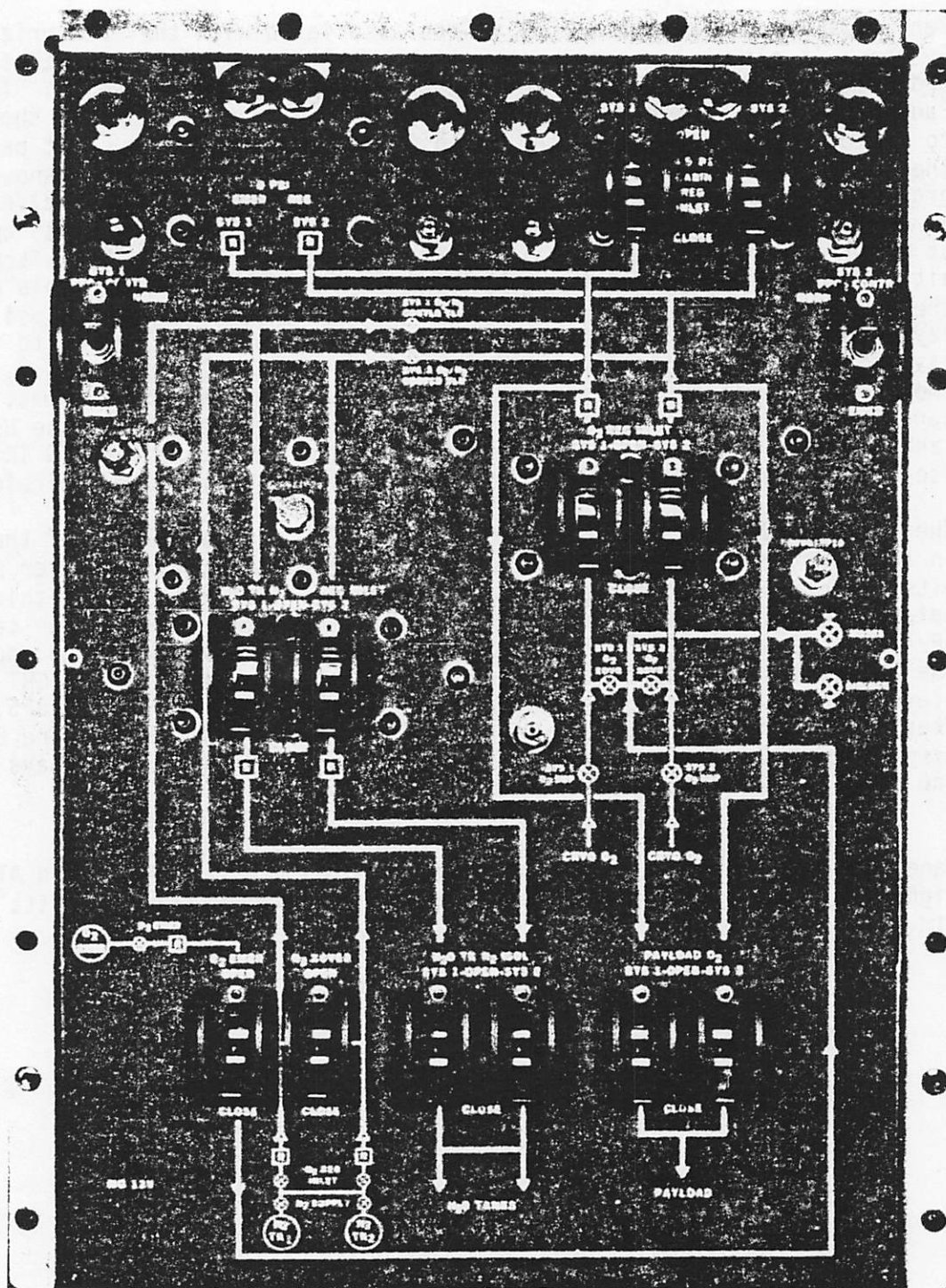


Figure 2-8.- Panel M010W.

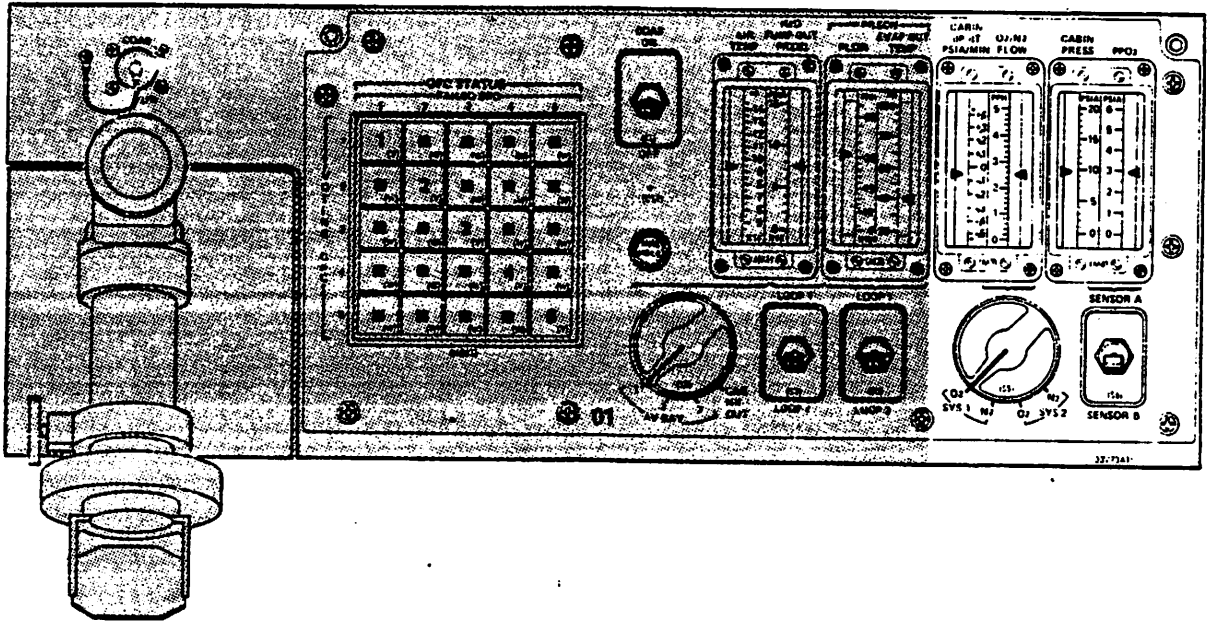


Figure 2-9.- Panel 01.

O <sub>2</sub> PRESS	H <sub>2</sub> PRESS	FUEL CELL RHAC (R)	FUEL CELL STACK TEMP	FUEL CELL PUMP
<b>CABIN ATM</b> (R)	O <sub>2</sub> HEATER TEMP	MAIN BUS UNDERVOLT (R)	AC VOLTAGE	AC OVERLOAD
FREON LOOP	AV/BAY/ CABIN AIR	IMU	FWD RCS (R)	RCS SET
FWD LOOP	ROLL ACCEL	AIR DATA (R)	LEFT RCS (R)	RIGHT RCS (R)
(R)	LEFT RMC (R)	RIGHT/AFT RMC (R)	LEFT OMS (R)	RIGHT OMS (R)
PAYLOAD WARNING (R)	GPC	FCS (R) SATURATION	OMS KEY	OMS TVC (R)
PAYLOAD CAUTION	PRIMARY C/W	FCS CHANNEL	MFS (R)	_____
BACKUP C/W ALARM (R)	APU TEMP	APU OVERSPEED	APU UNDERSPEED	MVD PRESS

(DAVIDA2)

Figure 2-10.- C&W Display, Panel F7



2011 / /066 ENVIRONMENT 2 237/14:35:02  
000/01:30:00

CABIN

dP/dT +.0 CABIN P 14.5 AV BAY 1 2 3  
 PPO2 A 3.2 AIRLK P 14.5 TEMP 90 90 90  
 B 3.2 FAN ΔP 0.25 FAN P 0.12 0.12 0.15  
 C 3.2 HX OUT T 65  
 CABIN T 75

H2O

	1	2	SUPPLY			
O2 FLOW	0.0	0.0	QTY A	100	PRESS	30
REG P	100	0	B	50	DMP LN T	75
N2 FLOW	1.1	0.0	C	98	NOZ T A	60
REG P	200	0	D	98	B	60
O2/N2 CNTL VLV	N2	N2	E	98		
H2O TK N2 P	16	16	F	98		
N2 QTY	70	70				
EMER O2 QTY	55		WASTE			
REG P	300		QTY 1	80	PRESS	17
					DMP LN T	60
	A	B	C	ΔP	NOZ T A	60
IMU FAN *				3.0	B	60
HUMID SEP *					VAC VT NOZ T	100

2-15

Figure 2-11.- Display S66.

3-ECLSS

2011/ /078		SM SYS SUMM 1		2 237/14:35:02		
				000/01:30:00		
EMERGENCY						
SMOKE	1/A	2/B	DC VOLTS	1/A	2/B	3/C
AV BAY 1	0.0	0.0	FC	29.7	29.9	38.0
	2	0.0	MAIN	29.7	29.8	0.0
	3	0.0	CNTL AB	29.8	29.8	29.7
dP/dT	+ .0		BC	29.8	29.7	29.8
			CA	29.8	29.7	29.8
			ESS	29.6	29.8	29.6
CABIN						
PRESS	14.5		AC			
PPO2	3.7	3.7	VOLT A	115	114	0
FAN P	0.31		B	115	114	0
HX OUT T	65		C	115	114	0
O2 FLOW	0.0	0.0	AMP A	4.1	5.6	0.0
N2 FLOW	1.1	0.0	B	4.7	4.1	0.0
			C	3.9	4.2	0.0
IMU FAN A*	B	C				
FUEL CELL						
TOTAL AMPS	415		AMPS	205	210	0
KW	12		REAC VLV	OP	OP	CL
			STACK T	+191	+186	+284
			PUMP			P

Figure 2-12.- SM SYS SUMM 1 display.

2-17

/ / 078				SM SYS SUMM 1			5 237/14:35:02		
							RFS 000/01:30:00		
EMERGENCY									
SMOKE		1/A	2/B	DC VOLTS	1/A	2/B	3/C		
AV BAY	1	0.0	0.0	FC	29.7	29.9	38.0†		
	2	0.0	0.0	MAIN	29.7	29.8	0.0†		
	3	0.0	0.0	CNTL AB	29.8	29.8	29.7		
dP/dT		+..0		BC	29.8	29.7	29.8		
				CA	29.8	29.7	29.8		
				ESS	29.6	29.8	29.6		
CABIN									
PRESS		14.5		AC					
PPO2		3.7	3.7	VOLT φA	115	114	0†		
FAN ΔP		0.31		φB	115	114	0†		
HX OUT T		65		φC	115	114	0†		
O2 FLOW		0.0	0.0	AMP φA	4.1	5.6	0.0		
N2 FLOW		1.1	0.0	φB	4.7	4.1	0.0		
				φC	3.9	4.2	0.0		
IMU FAN	A*	B	C	FUEL CELL					
TOTAL AMPS		415		AMPS	205	210	0†		
KW		12		REAC VLV	OP	OP	CL†		
				STACK T	+191	+186	+284†		
				PUMP			ΔP†		

Figure 2-13.- BFS display.

3-ECLSS

The following CRT SM messages will be displayed on the CRT displays listed, under the conditions identified opposite the message:

CRT	MAJOR FIELD	MINOR FIELD	CLASS	CONDITIONS
S66-SM1-BFS	CABIN	N <sub>2</sub>	2	FLOW RATE > 4.9 LB/HR
S66-SM1-BFS	CABIN	O <sub>2</sub>	2	O <sub>2</sub> FLOW > 4.9 LB/HR
S66-SM1-BFS	CABIN	PPO <sub>2</sub>	2	PPO <sub>2</sub> < 2.8 or > 3.6 PSIA < 1.9 AT 8 PSI
S66-SM1-BFS	CABIN	PPO <sub>2</sub>	3	PPO <sub>2</sub> < 2.8 or > 3.6 PSIA < 1.9 AT 8 PSI
6-SM1-BFS	CABIN	PRESS	2	CABIN PRESS < 13.8 > 15.0 PSIA
S66-SM1-BFS	CABIN	PRESS	3	CABIN PRESS < 13.8 or > 15.0 PSIA
66 SM2	CABIN		3	O <sub>2</sub> REG PRESS SYS 1(2) > 135 PSIA
			3	EMER O <sub>2</sub> REG PRESS > 1000 PSIA
			3	H <sub>2</sub> O REG PRESS < 13 PSIG or > 22 PSIG
			3	N <sub>2</sub> REG PRESS > 260 PSIA < 150 PSIA
			3	CABIN TEMP < 80°F
			3	HUMIDITY SEP A/B SPEED ↓ UNDERSPEED
			3	EMER O <sub>2</sub> QTY < 55 LBS
			3	N <sub>2</sub> SUPPLY QTY < 50 LBS
			3	AIRLOCK DIFF PRESS - TBD

TABLE 2-I.- ECLSS PRESSURIZATION CONTROLS

PANEL	TYPE	NOMENCLATURE/ POSITION	FUNCTION	REMARKS
L2	3-pos toggle (spring-loaded)	CABIN RELIEF A - B ENABLE - CLOSE	Enables and closes the cabin 15.5 psi relief valves.	
L2	talkback	CABIN RELIEF OP - CLS	Indicates the posi- tion OP or CLS of cabin relief VLV.	2 talkbacks
L2	3-pos toggle (spring-loaded)	VENT ISOL OPEN - CLOSE	Opens and closes the vent isola- tion valve.	
L2	3-pos toggle (spring-loaded)	VENT OPEN - CLOSE	OPEN-cabin atmos- phere is vented to ambient. CLOSE-overboard vent- ing is inhibited.	
L2	talkback	CABIN VENT VENT ISOL OP - CLS	Indicates the posi- tion of the vent isolation valve.	
L2	talkback	CABIN VENT VENT OP - CLS	Indicates the posi- tion of the cabin vent valve.	2 switches
L2	3-pos toggle	ATM PRESS CONTROL O <sub>2</sub> SYS 1/2 SUPPLY OPEN - CLOSE	Opens and closes the O <sub>2</sub> system supply valves.	
L2	talkbacks	ATM PRESS CONTROL O <sub>2</sub> SYS 1/2 SUPPLY OP - CL	Indicates the OPEN or CLOSED position of the O <sub>2</sub> system supply valves.	2 talkbacks
L2	3-pos toggle (spring- loaded)	ATM PRESS CONTROL O <sub>2</sub> EMER OPEN - CLOSE	Opens the emer- gency O <sub>2</sub> supply valve.	
L2	talkback	ATM PRESS CONTROL O <sub>2</sub> EMER OP-BARBERPOLE-CL	Indicates the OPEN or CLOSED status of the emergency O <sub>2</sub> supply valve. Barberpole is a transition state.	

TABLE 2-I.- ECLSS PRESSURIZATION CONTROLS

PANEL	TYPE	NOMENCLATURE/ POSITION	FUNCTION	REMARKS
L2	2-pos toggle	O <sub>2</sub> XOVR SYS 1/2 OPEN-CLOSE	Opens or closes the O <sub>2</sub> crossover valves. In the CLOSE position, the valve is unpowered.	2 switches
L2	3-pos toggle (spring-loaded)	N <sub>2</sub> SYSTEM 1/2 SUPPLY OPEN-CLOSE	Opens or closes the N <sub>2</sub> supply valve.	2 switches
L2	talkback	N <sub>2</sub> SYSTEM 1/2 SUPPLY OP-BARBERPOLE-CL	Indicates the position of the N <sub>2</sub> supply valve. Barberpole is a transition state.	2 talkbacks
L2	3-pos toggle (spring-loaded)	N <sub>2</sub> SYSTEM 1/2 REG INLET OPEN-CLOSE	Opens or closes the N <sub>2</sub> regulator inlet valve.	2 switches
L2	talkback	N <sub>2</sub> SYSTEM 1/2 REG INLET OP-BARBERPOLE-CL	Indicates the positions of the regulator inlet valve. Barberpole is a transition state.	2 talkbacks
L2	3-pos toggle	O <sub>2</sub> /N <sub>2</sub> CNTLR VLV SYS 1/2 OPEN-AUTO-CLOSE	OPEN-The controller valve flows N <sub>2</sub> . AUTO-The valve is automatically controlled by the controller. CLOSE-The O <sub>2</sub> /N <sub>2</sub> valve is closed. No N <sub>2</sub> flows to the cabin regulator.	2 switches
L2	2-pos toggle	PPO <sub>2</sub> SNSR VLV NORM-REVERSE	NORM-Controller 1 controls system 1. Controller 2 controls system 2. REVERSE-Controller 1 controls system 2. Controller 2 controls system 1.	

TABLE 2-I.- ECLSS PRESSURIZATION CONTROLS

PANEL	TYPE	NOMENCLATURE/ POSITION	FUNCTION	REMARKS
MO10W	2-pos toggle	SYS 1/2 14.5 PSI CABIN REG INLET OPEN-CLOSE	Isolates the cabin 14.5 regulator.	2 switches
MO10W	2-pos toggle	SYS 1/2 PPO <sub>2</sub> CONTR NORM-EMER	Selects either a 3.2 or 2.2 psia O <sub>2</sub> control level.	2 switches
MO10W	2-pos toggle	SYS 1/2 O <sub>2</sub> REG INLET OPEN-CLOSE	Isolates the O <sub>2</sub> regs (100 psi) from the cyro source.	2 switches
MO10W	2-pos toggle	SYS 1/2 H <sub>2</sub> O TK N <sub>2</sub> REG INLET OPEN-CLOSE	OPEN position permits nitrogen flow to the H <sub>2</sub> O regulators.	2 switches
MO10W	2-pos toggle	SYS 1/2 H <sub>2</sub> O TK N <sub>2</sub> ISOL OPEN-CLOSE	Isolates the H <sub>2</sub> O TK pressure man- ifold.	2 switches
MO10W	2-pos toggle	O <sub>2</sub> EMER OPEN-CLOSE.	Isolates the O <sub>2</sub> emergency regulator from the O <sub>2</sub> XOVER.	
MO10W	2-pos toggle	N <sub>2</sub> XOVER OPEN-CLOSE	Permits crossflow between SYS 1 & 2 N <sub>2</sub> systems down stream of the N <sub>2</sub> regs (200 psi).	
MO10W	2-pos toggle	SYS 1/2 PAYLOAD O <sub>2</sub> OPEN-CLOSE	Isolates the O <sub>2</sub> system from the payload interface.	2 switches

TABLE 2-I.- ECLSS PRESSURIZATION CONTROLS

PANEL	TYPE	NOMENCLATURE/ POSITION	FUNCTION	REMARKS
01	rotary	O <sub>2</sub> /N <sub>2</sub> FLOW O <sub>2</sub> -SYS 1-N <sub>2</sub> O <sub>2</sub> -SYS 2-N <sub>2</sub>	Selects SYS 1 or 2 O <sub>2</sub> -N <sub>2</sub> flow for display.	
01	2-pos toggle	PPO <sub>2</sub> SENSOR A/B	Selects Sensor A or B for meter input.	
014	circuit breaker	MN A ATM PRESS CONTROL N <sub>2</sub> SUPPLY 1	Provides Main A power to the N <sub>2</sub> System 1 Supply switch on Panel L2.	1 cb
014	circuit breaker	MN A ATM PRESS CONTROL O <sub>2</sub> /N <sub>2</sub> CNTLR 1	Provides Main A power to the Sys- tem O <sub>2</sub> /N <sub>2</sub> Controller switch on Panel L2.	1 cb
014	circuit breaker	MN A ATM PRESS CONTROL O <sub>2</sub> XOVER 1	Provides Main A power to the Sys- tem 1 O <sub>2</sub> Crossover switch on Panel L2.	1 cb
014	circuit breaker	MN A ATM PRESS CONTROL N <sub>2</sub> REG INLET 1	Provides Main power to the System 1 N <sub>2</sub> Regulator Inlet switch on Panel L2.	1 cb
014	circuit breaker	MN A ATM PRESS CONTROL CABIN VENT	Provides Main A power to the cabin vent switch on Panel L2.	1 cb
014	circuit breaker	MN A ATM PRESS CONTROL CABIN VENT ISOL	Provides Main A power to the cabin vent isolation valve on Panel L2.	1 cb
015	circuit breaker	MN B ATM PRESS CONTROL CABIN dP/dT	Provides Main B power to the dP/dT sensor power supply.	1 cb



TABLE 2-I.- ECLSS PRESSURIZATION CONTROLS

PANEL	TYPE	NOMENCLATURE/ POSITION	FUNCTION	REMARKS
015	circuit breaker	MN B ATM PRESS CONTROL N <sub>2</sub> SUPPLY 2	Provides Main B power to the System 2 N <sub>2</sub> supply switch on Panel L2.	1 cb
015	circuit breaker	MN B ATM PRESS CONTROL O <sub>2</sub> /N <sub>2</sub> CNTLR 2	Provides Main B power to the System 2 O <sub>2</sub> /N <sub>2</sub> Controller switch on Panel L2.	1 cb
015	circuit breaker	MN B ATM PRESS CONTROL N <sub>2</sub> REG INLET 2	Provides Main B power to the System 2 N <sub>2</sub> Regulator Inlet switch on Panel L2.	1 cb
015	circuit breaker	MN B ATM PRESS CONTROL CABIN RELIEF A	Provides main B power to the Cabin Relief A switch on Panel L2.	1 cb
016	circuit breaker	MN C ATM PRESS CONTROL O <sub>2</sub> EMER	Provides Main C power to the O <sub>2</sub> Emergency switch on Panel L2.	1 cb
016	circuit breaker	MN C ATM PRESS CONTROL CABIN RELIEF B	Provides Main C power to the Cabin Relief B switch on Panel L2.	1 cb

### 2.1.4 Pressurization System Performance, Limitations, and Capabilities

Crew cabin volume with airlock inside . . . . .	2325 ft <sup>3</sup>
Crew cabin volume with airlock outside : . . . . .	2625 ft <sup>3</sup>
Emergency O <sub>2</sub> tank volume . . . . .	8181 in <sup>3</sup>
Emergency O <sub>2</sub> tank operating range . . . . .	285 to 3300 psig
Emergency O <sub>2</sub> tank burst pressure . . . . .	4950 psig
Emergency O <sub>2</sub> tank operating temp range . . . . .	-65° to 200° F
Emergency O <sub>2</sub> tank external leakage . . . . .	1.0 x 10 <sup>-4</sup> sec He activate
N <sub>2</sub> tanks (identical to emergency O <sub>2</sub> tanks)	
N <sub>2</sub> loaded . . . . .	212 lb
Budget margin (OFT-1) . . . . .	29.8 lb
Cryo O <sub>2</sub> tanks maximum operating pressure . . . . .	1035 psig
Cryo O <sub>2</sub> tanks proof pressure . . . . .	1138.5 psig
Cryo O <sub>2</sub> tanks burst pressure . . . . .	1552 psig
Cryo O <sub>2</sub> tanks operating range . . . . .	850 - 875 psig
ECLSS O <sub>2</sub> budget . . . . .	112 lb
Budget margin (OFT-1) . . . . .	71 lb
Cabin pressure regulators flow capacity at 100 psid . .	75 lb/hr
Regulated pressure . . . . .	14.7 psia
Minimum emergency pressure . . . . .	8.0 psia

## 2.2 AIR REVITALIZATION SYSTEM

### 2.2.1 Interfaces

The gas which pressurizes the Shuttle cabin is circulated by the ARS. Heat picked up by the ARS is transferred to the ATCS at the H<sub>2</sub>O Freon interchanger. The EPS provides ac and dc power to run the fans, pumps, and control electronics. The Waste Management System (WMS) stores the humidity removed from the atmosphere.

### 2.2.2 ARS System Description

The air circulated throughout the cabin picks up heat, moisture, odor, CO<sub>2</sub>, bits and particles of skin and hair, etc., from the crew and from the equipment. Additional heat is picked up from the electronics. The circulated air is pulled through the middeck and flight deck return air ducts to the filter, where particles of lint, hair, etc., are removed.

There are two cabin fans (fig. 2-14), only one used at a time, each capable of pulling 1400 lb of air per hr through the filter. The fans turn at 11,200 rpm. Normal delta pressure across the fans is 0.1 to 0.3 psid. The fans propel the air to the LiOH canisters. An orifice in the duct directs 120 lb/hr of air through each LiOH canister. The canisters contain a mixture of activated charcoal, which removes odor, and LiOH, which removes the CO<sub>2</sub>. LiOH combines with CO<sub>2</sub> to make lithium carbonate and This is an anhydrous system and net water out is zero. Heat at the rate of 875 Btu/lb CO<sub>2</sub> is also generated. Canisters located under the middeck floor will be changed when the partial pressure of CO<sub>2</sub> reaches 5.0 mm/Hg, or, for a crew of four, one canister approximately each 12 hr. Canister storage is under the middeck floor between the heat exchanger and the water tanks.

Two cabin temperature controllers respond to the cabin temperature control on Panel L1. Only one controller is used at a time. Each controller senses the temperature in the supply and return air ducts and controls the temperature between 65° F and 80° F at the temperature selected by the crew. The controllers are attached to a bypass valve by an actuator arm. The bypass valve may be thought of as a diverting panel that never gets fully closed. Zero to 70 percent of the air flow can be diverted around the cabin heat exchanger by the bypass valve. If one of the controllers malfunctions, the actuator arm must be physically removed from the malfunctioning controller and attached to the standby controller before power is applied to the standby controller. Full travel time (full closed to full open or vice versa) is 4 min maximum.

The cabin heat exchanger is where the heat that has been collected is transferred to the water coolant loop. The cabin air passes through the heat exchanger and is cooled. Water condensing in the heat exchanger is carried away by air flow from the humidity separator. Thus, excess moisture is removed from the atmosphere.

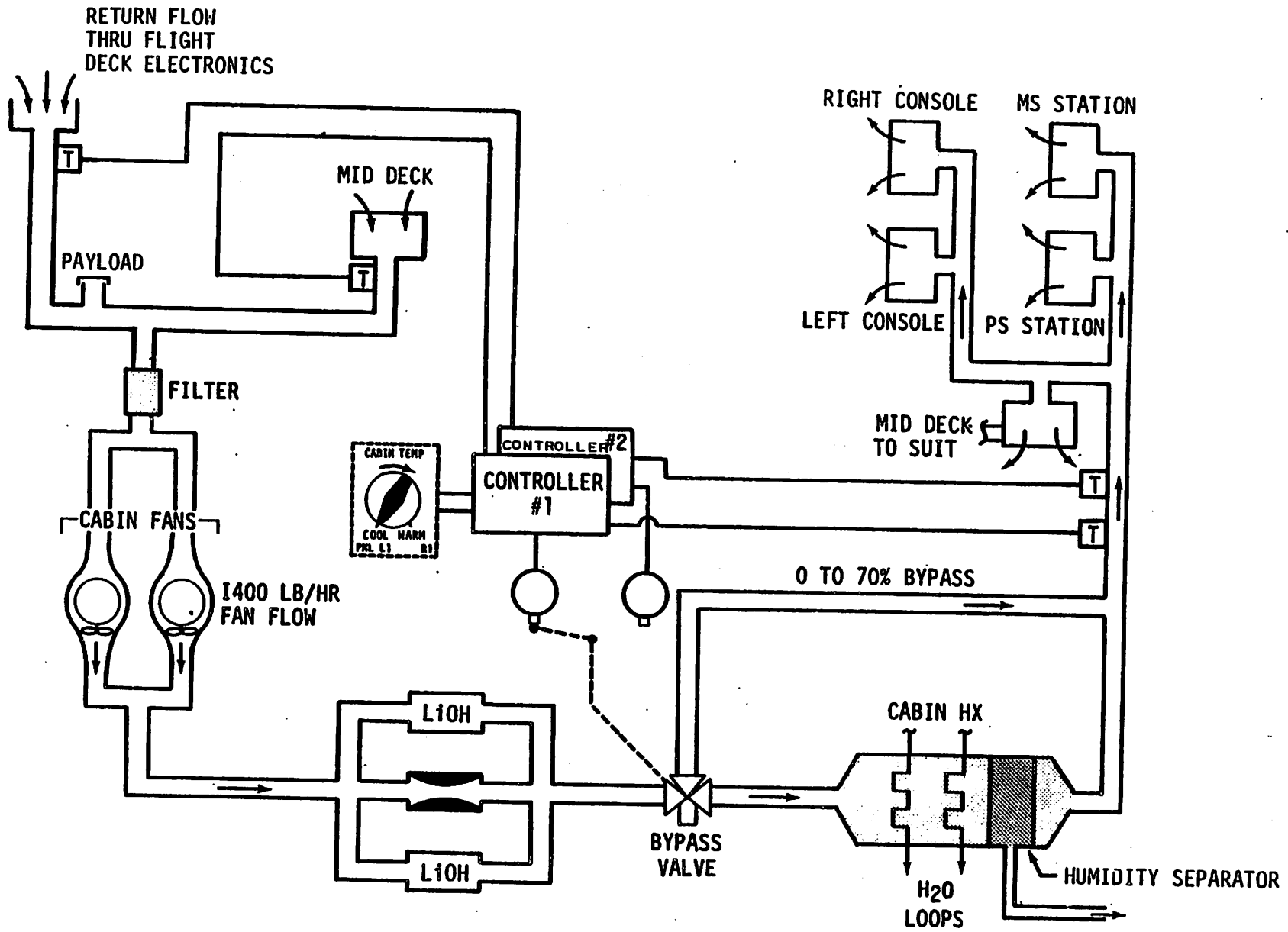


Figure 2-14.- Air circulation.

Recent approval for a carbon monoxide removal device was obtained. The design is not complete for this device, but it is to be included later in the program. It is to be called the "Ambient Temperature Catalytic Oxydizer." The air from the heat exchanger and the bypassed air then comes together in the conditioned air supply ducts and is exhausted into the cabin compartment through the consoles, middeck, and the mission specialist and payload specialist station supply air outlets.

The humidity separator (fig. 2-15) dewpoint temperature range is 39° F to 61° F. The separator motors turn at 5430 to 5700 rpm. Air is drawn across cold plates in the cabin heat exchanger. Temperature change as the cabin air passes over these cold plates causes condensation on the cold plates. Air flow by the centrifugal fans of the humidity separators carries this condensation to the fan, where centrifugal force separates the water and air. The air is returned to the cabin and the water is forced into the waste tank. This system can remove from 0 to 4 lb of water per hr. Only one of the separators is used at a time.

The IMU's are cooled by air drawn from the cabin through a 300 micron filter. The three IMU fans are in parallel, and either one of the three will provide the required air flow. Before the air is returned to the cabin, it is cooled by the IMU heat exchanger. There is a 600 micron filter just upstream of the fans to provide fan protection.

There are two fans for each avionics bay. One fan in each bay will provide the required air flow. Each bay has an enclosed air circulation system, but it is not airtight and some air can pass between the avionics bays and the cabin. Each avionics bay has a heat exchanger to cool the air as it is circulated.

There are two complete and separate water coolant loops (fig. 2-16) in the Shuttle spacecraft. They flow side by side through the same areas. The only difference is that loop 1 has two pumps and loop 2 has one pump. In H<sub>2</sub>O loop 1, there is a "ball type" check valve downstream of the pumps. This prevents reverse flow through the standby pump. Also downstream of the pump, the flow splits three ways. One leg goes through Avionics Bay 1 heat exchanger and cold plates. This leg also provides thermal conditioning for the hatch. Another leg does the same thing for Avionics Bay 2 and the cabin windows. The third leg goes through the MDM cold plates. A predetermined amount of water bypasses these cold plates via the parallel orifice. It then splits again for Avionics Bay 3A and Bay 3B cold plates. The coolant flow comes back together again and flows to the H<sub>2</sub>O/Freon interchanger. A controlled amount of water bypasses the H<sub>2</sub>O/Freon interchanger by way of the H<sub>2</sub>O bypass controller valve. The bypass controller senses the pump-out temperature, and will bypass a maximum amount of water at a pump-out temperature of 60.5° F. At 65.5° F, the bypass valve will be fully closed. Heat is removed from the water coolant loop at the H<sub>2</sub>O/Freon interchanger. The flow goes through the liquid cooled garment heat exchanger, the cabin heat exchanger, and the IMU heat exchanger, after which it joins with the bypass flow. The accumulator keeps a positive suction pressure on the pumps and provides for thermal expansion in the H<sub>2</sub>O loop. Pump delta pressure is normally about 49.3 ± 1.2 psid.

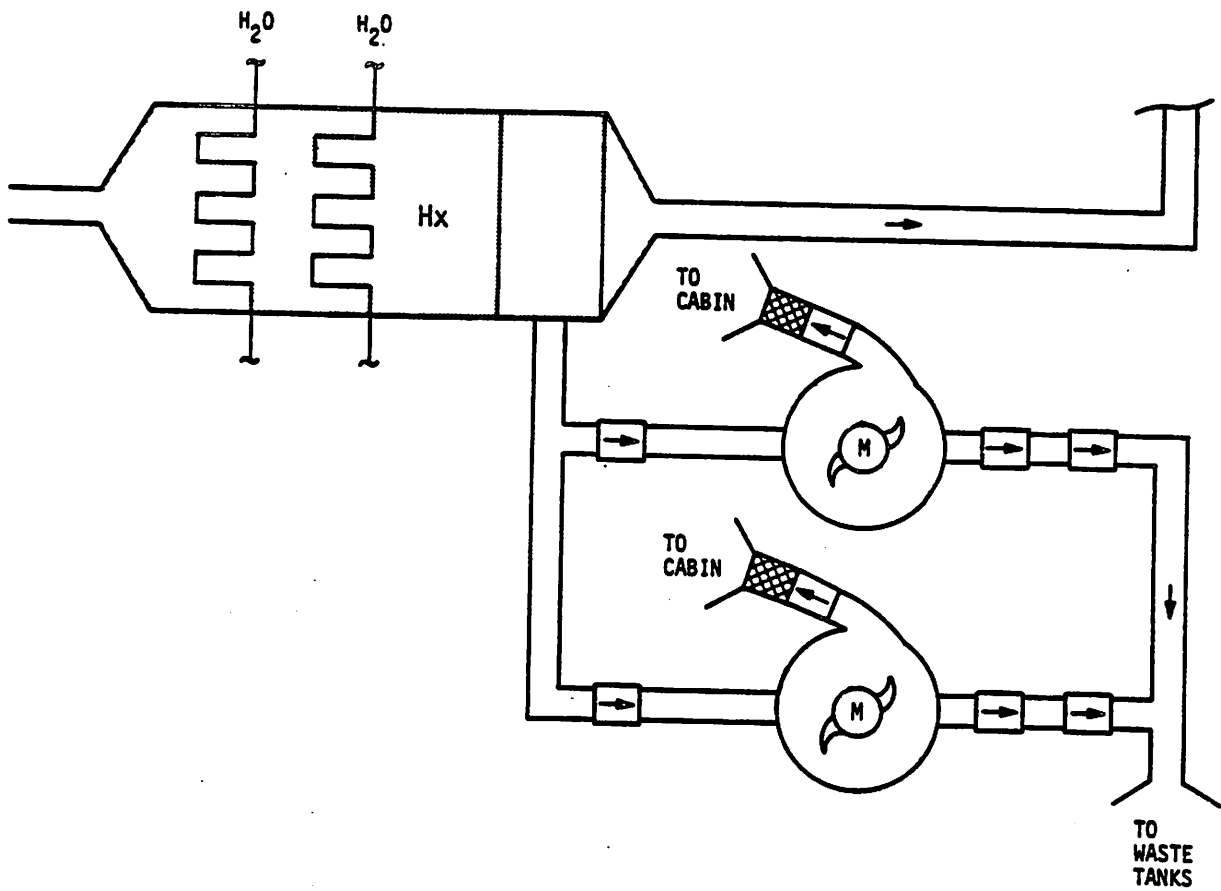


Figure 2-15.- Humidity separators.

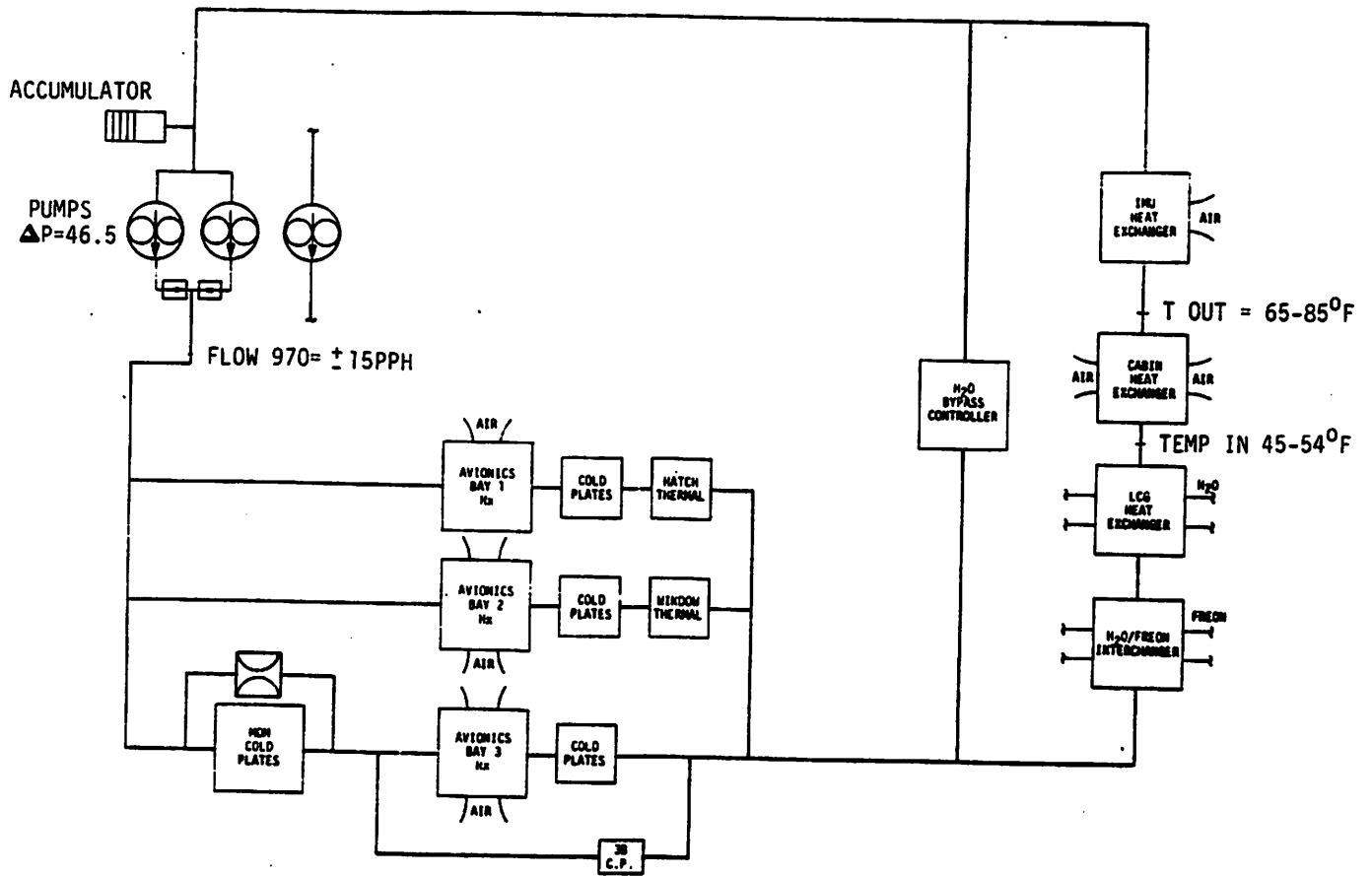


Figure 2-16.- H<sub>2</sub>O loops.

Each loop will flow from 1100 to 1300 lb/hr of water. Both water loops will be used for ascent and entry. Loop 2 will be used on-orbit. H<sub>2</sub>O PUMP LOOP 1 A/B switch selects the pump to be used in loop 1. The GPC OFF/ON switch for loop 1 when in the GPC position will cycle the pump selected by the A/B switch on for 2 to 10 min every 120 to 360 min to prevent freezing. The time the pump runs and the frequency of the cycle can be changed by keyboard entry. The LOOP 2 GPC OFF/ON switch operates the same way. The LOOP 1/2 BYPASS switches operate in the automatic mode as noted above, controlling water temperature between 60.5° F and 65.5° F. In the manual mode, the INCR/DECR switch controls the amount of water that bypasses the H<sub>2</sub>O/Freon interchanger. For OFT, the water loops will probably be operated in the manual mode. For ascent and entry, the H<sub>2</sub>O Freon interchanger flow will be set for about 600 lb/hr flow in each loop. On-orbit with only one loop operational, the flow will be set for about 960 lb/hr.

### 2.2.3 ARS Displays and Controls

Circuit breakers for the ARS are on Panel L4 to the commander's left. Panel L1 contains the switches for controlling the system.

The CABIN FAN switches on the lower left corner of the panel (fig. 2-17) turn the cabin fans on and off. Directly above the cabin fans is the CABIN TEMP CNTLR switch which controls power to either cabin temperature controller 1 or 2. If it is necessary to change controllers, the temperature control actuator arm under the middeck must be physically disconnected from the failed controller and reconnected to the standby controller prior to applying power to the standby controller. The CABIN TEMP rotary switch can be set at the crew's discretion. One direction is full cool and the other is full hot. There are no temperature graduations on this control. You simply set it by "feel".

Directly above the CABIN TEMP controller are the two HUMIDITY SEP switches. These switches control power to the humidity separator fans. One of these separators will be selected ON at all times. To the right of the HUMIDITY SEP switches are the three IMU FAN switches. These IMU fans are in parallel and one at a time is used to cool the IMU's. Opposite the CABIN FAN switches are six AV BAY switches for avionics bays 1, 2, and 3. One fan per bay is used at a time. The interconnecting lines on this panel indicate the flow path of the H<sub>2</sub>O coolant loops. The IMU and AV BAY switches indicate the heat loads placed on the water loops by these subsystems. The H<sub>2</sub>O pump, loop 1 control switches are two switches which control the pumps in loop 1. Loop 1 has two pumps, A and B. One pump at a time is used in loop 1. The pump to be used is selected by the A-B select switch. The LOOP 1 GPC- OFF-ON switch, when placed in the GPC position, configures the pump selected so the GPC can turn the pump on for 6 ± 4 min each 240 ± 120 min. This is to prevent freezing of the static H<sub>2</sub>O loop. The period of pump operation and frequency of "turn on" is adjustable in OPS 2 by calling display S-60 on the CRT. H<sub>2</sub>O loop 2 has only one pump. This pump is controlled by the LOOP 2 GPC-OFF-ON switch in the same manner loop 1 is controlled. There is a difference, however. In loop 2, the GPC position uses a different power source than the ON position. We use this difference during launch and entry to provide increased capability. The



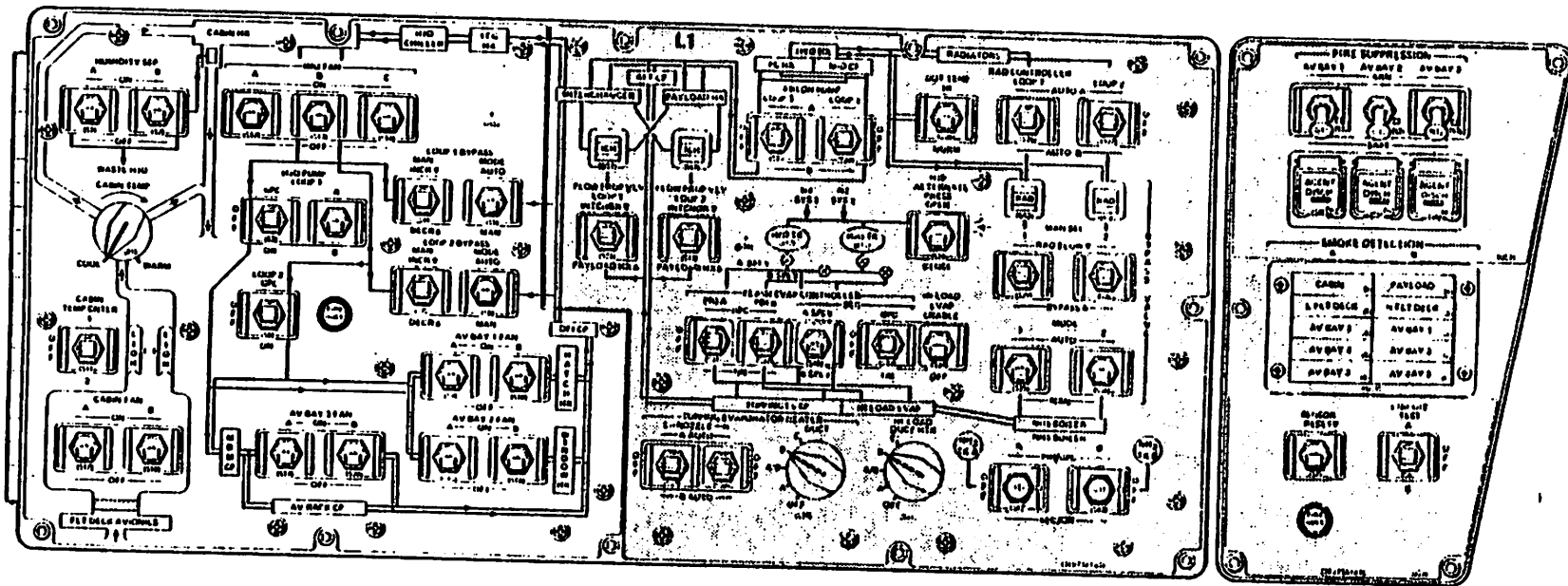


Figure 2-17.- Panel L1, ARS controls.

GPC command for loop 2 pump is set to ON in the BFS program. During launch and entry, we operate both H<sub>2</sub>O loops in the ON switch position. If we experience an AC3 bus failure, by placing the LOOP 2 GPC-OFF-ON switch to GPC, loop 2 pump can be powered by bus AC1. This capability is only available during launch and entry.

The LOOP 1/2 BYPASS switches are just to the right of the pump switches. The MODE AUTO/MAN switch selects either automatic or manual control of the bypass valve. For OFT we expect to fly the missions in the MAN position. When in the MAN position, the MAN INCR/DECR switch controls the H<sub>2</sub>O bypass valve. When both loops are operating, flow through the interchanger is set to ~ 600 lb/hr. When only one loop is operating, the flow is set to ~ 950 lb/hr. The interchanger flow is set by manipulating the INCR/DECR switch. The INCR position of this switch increases the bypass flow and decreases the flow through the interchanger.

The overhead Panel 01 left-hand dual meter (fig. 2-23) shows the AIR TEMP and H<sub>2</sub>O PUMP OUT PRESS. The rotary switch and the toggle switch below the meter give a selectable input to the meter.

CRT displays containing ARS Data are S66, S88, SM1, SM2, and BFS. BFS is available for launch and entry. The others are available on-orbit.

The H<sub>2</sub>O LOOP light on Panel F7 (fig. 2-24) will be illuminated if one of the following parameters exceeds its limits:

ID	CRT NAME	UNITS	LOWER LIMIT	UPPER LIMIT
V61P2600A	H <sub>2</sub> O PUMP OUT P1	PSIA	45	79.5
V61P2700A	H <sub>2</sub> O PUMP OUT P2	PSIA	45	81

The AV BAY CABIN AIR light (fig. 2-25) will illuminate if one of the following parameters exceeds its limit:

ID	CRT NAME	UNITS	LOWER LIMIT	UPPER LIMIT
V61R2556A	FAN ΔP	PSID	0.1	0.3
V61T2635A	HX OUT T	Deg F		65
V61T2645A	AV BAY 1 TEMP	Deg F		139
V61T2650A	AV BAY 2 TEMP	Deg F		139
V61T2661A	AV BAY 3 TEMP	Deg F		139

2011 / /066 ENVIRONMENT 2 237/14:35:02  
000/01:30:00

CABIN

dP/dT +.0 CABIN P 14.5 AV BAY 1 2 3  
PPO2 A 3.2 AIRLK P 14.5 TEMP 90 90 90  
B 3.2 FAN ΔP 0.25 FAN P 0.12 0.12 0.15  
C 3.2 HX OUT T 65  
CABIN T 75

H2O

	1	2	SUPPLY		
O2 FLOW	0.0	0.0	QTY A 100	PRESS	30
REG P	100	0	B 50	DMP LN T	75
N2 FLOW	1.1	0.0	C 98	NOZ T A	60
REG P	200	0	D 98	B	60
O2/N2 CNTL VLV	N2	N2	E 98		
H2O TK N2 P	16	16	F 98		
N2 QTY	70	70			
EMER O2 QTY	55		WASTE		
REG P	300		QTY 1 80	PRESS	17

	A	B	C	ΔP	
IMU FAN *				3.0	
HUMID SEP *					
					VAC VT NOZ T 100

2-33

Figure 2-18.- Display S66.

3-ECISS

2-34

2011 / /088 APU/ENVIRON THERM				2 083/16:05:26			
				000/01:26:42			
FREON LOOP	1	2		H2O LOOP	1	2	
ACCUM QTY	36	45		PUMP OUT P	68	23	
FREON FLOW	1500	150		OUT T	65	76	
PL HX FLOW	1000	100		ΔP	43	0	
AFT CP FLOW	270	270		ICH FLOW	50	0	
RAD IN T	100	95		OUT T	43	45	
CNTRLR OUT T	38	38		CAB HX IN T	43	45	
EVAP OUT T	37	38		ACCUM QTY	43	52	
DFI FLOW	460						
EVAP TEMP DUCT NOZ				APU			
HI LOAD INBD	255	320		FUEL T	1	2	3
OUTBD	252	320		TK SURF	+ 60	+ 61	+ 60
TOPPING FWD	260			TK HTR	+ 61	+ 62	+ 59
AFT	260			ISOL VLV	+ 60	+ 63	+ 58
L	155	50		TEST LN	+ 59	+ 59	+ 58
R	155	50		FEED LN	+ 61	+ 60	+ 63
EVAP FDLN T	A	B		PUMP IN	+ 62	+ 59	+ 64
FWD	70	70		DRN LN	+ 61	+ 60	+ 61
MID 1	70	70		OUT	+100	+102	+101
MID 2	70	70		BYP LN	+100	+101	+102
AFT	70	70					

Figure 2-19.- Display S88.

3-ECLASS

2011 / /078 SM SYS SUMM 1 2 237/14:35:02  
 000/01:30:00

EMERGENCY

SMOKE	1/A	2/B	DC VOLTS	1/A	2/B	3/C
AV BAY 1	0.0	0.0	FC	29.7	29.9	38.0
2	0.0	0.0	MAIN	29.7	29.8	0.0
3	0.0	0.0	CNTL AB	29.8	29.8	29.7
dP/dT	+ .0		BC	29.8	29.7	29.8
			CA	29.8	29.7	29.8
			ESS	29.6	29.8	29.6

CABIN

PRESS	14.5		AC			
PP02	3.7	3.7	VOLT A	115	114	0
FAN P	0.31		B	115	114	0
HX OUT T	65		C	115	114	0
O2 FLOW	0.0	0.0	AMP A	4.1	5.6	0.0
N2 FLOW	1.1	0.0	B	4.7	4.1	0.0
			C	3.9	4.2	0.0

IMU FAN A\* B C

TOTAL AMPS 415  
 KW 12

FUEL CELL

AMPS	205	210	0
REAC VLV	OP	OP	CL
STACK T	+191	+186	+284
PUMP			P

2-35

Figure 2-20. - SM SYS SUMM 1 display.

3-ECLSS

2011 / / 079 SM SYS SUMM 2 XX 2 237/14:35:12  
 000/01:35:10

CRYO TK	1	2	3	4
H2 PRESS	225	225	225	225
O2 PRESS	950	950	950	950
HTR T1	+ 75	+ 78	+ 10	+ 76
T2	+ 75	+ 77	+ 9	+ 75

APU	1	2	3	HYD	1	2	3
TEMP EGT	950	850	80	PRESS	301	55	62
B/U EGT	850	750	70	RSVR T	80	95	70
OIL IN	220	215	85	QTY	80	78	50
OUT	260	255	80				
SPEED %	82	84	0	W/B			
FUEL QTY	73	75	99	H2O QTY	68	70	99
PMP LK P	0	0	0	BYP VLV	W/B	W/B	BYP
OIL OUT P	80	80	15				
				THERM CNTL	1	2	
AV BAY				H2O PUMP P	70	15	
TEMP	90	90	90	FREON FLOW	1500	0	
FAN ΔP	0.1	0.1	0.2	EVAP OUT T	37	78	

2-36

Figure 2-21.- SH SYS SUMM 2 display.

3-ECLSS

/ /078 SM SYS SUMM 1 5 237/14:35:02  
 RFS 000/01:30:00

EMERGENCY

SMOKE	1/A	2/B
AV BAY 1	0.0	0.0
	2 0.0	0.0
	3 0.0	0.0
dP/dT	+.0	

CABIN

PRESS	14.5	
PP02	3.7	3.7
FAN ΔP	0.31	
HX OUT T	65	
O2 FLOW	0.0	0.0
N2 FLOW	1.1	0.0

IMU FAN	A*	B	C
---------	----	---	---

TOTAL AMPS	415
KW	12

DC VOLTS	1/A	2/B	3/C
FC	29.7	29.9	38.0†
MAIN	29.7	29.8	0.0†
CNTL AB	29.8	29.8	29.7
	BC	29.8	29.7
	CA	29.8	29.7
ESS	29.6	29.8	29.6

AC

VOLT φA	115	114	0†
φB	115	114	0†
φC	115	114	0†
AMP φA	4.1	5.6	0.0
φB	4.7	4.1	0.0
φC	3.9	4.2	0.0

FUEL CELL

AMPS	205,	210	0†
REAC VLV	OP	OP	CL†
STACK T	+191	+186	+284†
PUMP			ΔP†

2-37

Figure 7.1. Figure 2-22.- BFS display.

3-ECLSS

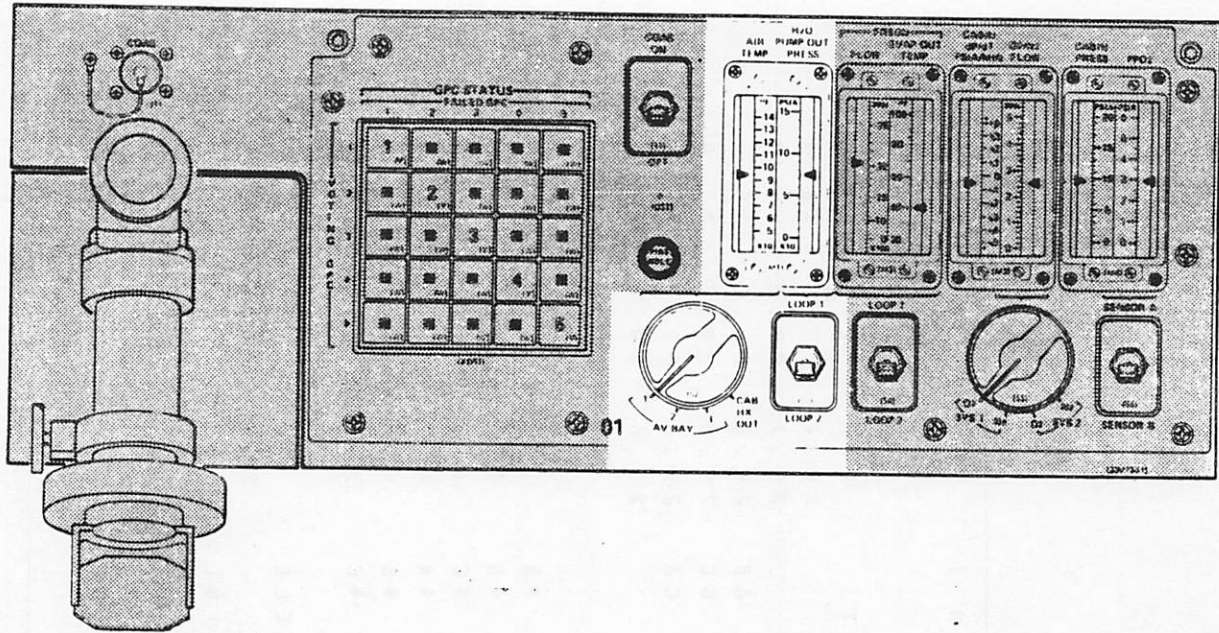


Figure 2-23.- Panel 01.



O <sub>2</sub> PRESS	H <sub>2</sub> PRESS	FUEL CELL REAC (R)	FUEL CELL STACK TEMP	FUEL CELL PUMP
CABIN AIR (R)	O <sub>2</sub> HEATER TEMP	MAIN BUS UNDERVOLT (R)	AC VOLTAGE	AC OVERLOAD
FRESH LOOP	AIR BAY CABIN AIR	IRU	FWD RCS (R)	RCS JET
H <sub>2</sub> O LOOP	RG/ACCEL	AIR DATA (R)	LEFT RCS (R)	RIGHT RCS (R)
	LEFT RHC (R)	RIGHT/AS RHC (R)	LEFT OMS (R)	RIGHT OMS (R)
PAYLOAD WARNING (R)	GPI	RCS (R)	OMS KIT	OMS TVC (R)
PAYLOAD CAUTION	PRIMARY OIW	FCS CHANNEL	MPS (R)	
BACKUP OIW ALARM (R)	APU TEMP	APU OVERSPEED	APU UNDERSPEED	HYD PRESS

(34V73A7A)

Figure 2-24.- C&W Display, Panel F7

O <sub>2</sub> PRESS	H <sub>2</sub> PRESS	FUEL CELL REAC (R)	FUEL CELL STACK TEMP	FUEL CELL PUMP
CABIN ATM (R)	O <sub>2</sub> HEATER TEMP	MAIN BUS UNDERVOLT (R)	AC VOLTAGE	AC OVERLOAD
FRON LOOP	AV BAY CABIN AIR	IRU (R)	FWD HOS (R)	RCS JET
H <sub>2</sub> O LOOP	HGA/ACCEL	AIR DATA (R)	LEFT RCS (R)	RIGHT RCS (R)
(R)	LEFT RMC (R)	RIGHT/AFT RMC (R)	LEFT OMS (R)	RIGHT OMS (R)
PAYLOAD WARNING (R)	GPC	FCS (R)	OMS KIT	OMS TVC (R)
PAYLOAD CAUTION	PRIMARY CW	SATURATION		
BACKUP C/W ALARM (R)	APU TEMP	FCS CHANNEL	MPS (R)	
		APU OVERSPEED	APU UNDERSPEED	HYD PRESS

(34V7347A-7)

Figure 2-25.- C&W Display, Panel F7

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

(34073A7A)

Figure 2-24.- C&W Display, Panel F7

O <sub>2</sub> PRESS	H <sub>2</sub> PRESS	FUEL CELL HEAD (R)	FUEL CELL STACK TEMP	FUEL CELL PUMP
CABIN ATM (R)	O <sub>2</sub> HEATER TEMP	MAIN BUS UNDERVOLT (R)	AC VOLTAGE	AC OVERLOAD
FREON LOOP (R)	AV BAY CABIN AIR	IMU	FWD RCS (R)	RCS JET
H <sub>2</sub> O LOOP	REA/ACCEL	AIR DATA (R)	LEFT RCS (R)	RIGHT RCS (R)
(R)	LEFT RND (R)	RIGHT/AFT RNC (R)	LEFT OMS (R)	RIGHT OMS (R)
PAYLOAD WARNING (R)	GPD	FCS (R) SATURATION	OMS KIT	OMS TVC (R)
PAYLOAD CAUTION	PRIMARY C/W	FCS CHANNEL	MPS (R)	
BACKUP C/W ALARM (R)	APU TEMP	APU OVERSPEED	APU UNDERSPEED	NVD PRESS

(34V7347A2)

Figure 2-25.- C&amp;W Display, Panel F7

The following CRT SM messages will be displayed on the CRT displays listed under the conditions identified opposite the messages:

CRT	MAJOR FIELD	MINOR FIELD	CLASS	CONDITIONS
S66 SM2	BFS AV BAY	FAN	3	AV BAY 1 $\Delta P < 0.04$ or $> 0.17$ psia
			3	AV BAY 2 $\Delta P < 0.04$ or $> 0.17$ psia
			3	AV BAY 3 $\Delta P < 0.04$ or $> 0.20$ psia
S66 SM2	BFS AV BAY	TEMP	2	AV BAY 1 OUTLET AIR TEMP $> 139^{\circ}F$
			2	AV BAY 2 OUTLET AIR TEMP $> 139^{\circ}F$
			2	AV BAY 3 OUTLET AIR TEMP $> 139^{\circ}F$
			3	AV BAY 1 OUTLET AIR TEMP $> 139^{\circ}F$
			3	AV BAY 2 OUTLET AIR TEMP $> 139^{\circ}F$
			3	AV BAY 3 OUTLET AIR TEMP $> 139^{\circ}F$
S66-SM1-BFS	CABIN	FAN	2	CABIN FAN $\Delta P < 0.1$ or $> 0.3$ psid
S66-SM1-BFS	CABIN	H x T	2	CABIN HX AIR OUT T $> 65^{\circ}F$
S88-SM2-BFS	H <sub>2</sub> O PUMP P	1	2	H <sub>2</sub> O PUMP OUT PRESS $< 45$ psia or $> 79.5$ psia $< 20$ (static)
		2	2	H <sub>2</sub> O PUMP OUT PRESS $< 45$ psia or $> 81$ psia $< 20$ (static)
		1	3	H <sub>2</sub> O PUMP OUT PRESS $< 50$ psia or $> 79.5$ psia $< 20$ (static)
		2	3	H <sub>2</sub> O PUMP OUT PRESS $< 50$ psia or $> 81$ psia $< 20$ (static)
S88	THERMAL	H <sub>2</sub> O	3	H <sub>2</sub> O LOOP 1/2 ACCUM QTY $< 20\%$ or $> 80\%$
			3	LOOP 1/2 H <sub>2</sub> O PUMP OUTLET TEMP $< 60$ or $> 90^{\circ}F$
			3	CABIN HX INLET TEMP LOOP 1/2 $< 36^{\circ}F$ or $> 55^{\circ}F$
			3	H <sub>2</sub> O LOOP 1/2 INTCHGR OUTLET LINE TEMP $< 35^{\circ}F$
			3	H <sub>2</sub> O LOOP 1/2 INTCHGR FLOW $< 550$ lb/hr ( $> 20$ lb/hr)
			3	H <sub>2</sub> O PUMP DELTA P LOOP 1/2 $< 35$ or $> 50$

TABLE 2-II.- ECLSS CONTROLS (ARS)

PANEL	TYPE	NOMENCLATURE/ POSITION	FUNCTION	REMARKS
L1	2-pos toggle	HUMIDITY SEP A/B ON-OFF	ON-3 $\phi$ ac power to run the humidity separator.  OFF-Removes humidity separator power.	2 switches
L1	rotary sw	CABIN TEMP COOL-WARM	Controls temp between 65 $^{\circ}$ and 80 $^{\circ}$ .	
L1	3-pos toggle	CABIN TEMP CNTRL 1-OFF-2	Selects opera- tion of one of two temp con- trollers. Cntrl bypasses air around cabin HX.	
L1	2-pos toggle	CABIN FAN A/B ON/OFF	Powers Cabin Fan A/B circulating cabin air.	2 switches
L1	2-pos toggle	H <sub>2</sub> O PUMP LOOP 1 A/B	Selects Pump A or B for Loop 1 operation.	
L1	3-pos toggle	H <sub>2</sub> O PUMP LOOP LOOP 1/2 GPC-OFF-ON	GPC-Computer turns loop "on" period- ically to prevent freezing. Length of operation and fre- quency of cycle are software controllable. OFF-Pump off ON-Pump is powered and circulates water.	2 switches
L1	2-pos toggle	IMU FANS A-B-C ON-OFF	Applies power to the IMU fans.	3 switches
L1	2-pos toggle	LOOP 1/2 BYPASS MODE AUTO/MAN	Selects bypass valve mode of operation.	2 switches
L1	3-pos toggle (spring-loaded center)	LOOP 1/2 BYPASS MAN INCR/DECR	Controls the position of the water bypass valve when the mode switch is in the MAN position.	2 switches

TABLE 2-II.- ECLSS CONTROLS (ARS) - continued

PANEL	TYPE	NOMENCLATURE/ POSITION	FUNCTION	REMARKS
L4	circuit breaker	AC1 $\phi A-\phi B-\phi C$ H <sub>2</sub> O LOOP PUMP 1 A/2	Provides 3-phase AC1 power to Loop 1 Pump A H <sub>2</sub> O pump GPC-OFF -ON switch on Panel L1.	3 cb's
L4	circuit breaker	AC2 $\phi A-\phi B-\phi C$ H <sub>2</sub> O LOOP PUMP 1 B	3-phase AC2 power to Loop 1 pump B, GPC-OFF-ON switch on Panel L1.	3 cb's
L4	circuit breaker	AC3 $\phi A-\phi B-\phi C$ H <sub>2</sub> O LOOP PUMP 2	3-phase AC-3 power to Loop 2 H <sub>2</sub> O Pump, GPC-OFF-ON switch on Panel L1.	3 cb's
L4	circuit breaker	AC1 AV BAY 1 FAN A	3-phase AC1 power to Avionics Bay 1 Fan A switch on Panel L1.	3 cb's
L4	circuit breaker	AC2 AV BAY 1 FAN B	3-phase AC2 power to Avionics Bay 1 Fan B switch on Panel L1.	3 cb's
L4	circuit breaker	AC3 AV BAY 3 FAN A	3-phase AC3 power to Avionics Bay 3 Fan A switch on Panel L1.	3 cb's
L4	circuit breaker	AC1 AV BAY 3	3-phase AC1 power to Avionics Bay 3 Fan B switch on Panel L1.	3 cb's
L4	circuit breaker	AC2 AV BAY 2 FAN A	3-phase AC2 power to Avionics Bay 2 Fan A switch on Panel L1.	3 cb's
L4	circuit breaker	AC3 AV BAY 2 FAN B	3-phase AC3 power to Avionics Bay 2 Fan B switch on Panel L1.	3 cb's
L4	circuit breakers	AC1 IMU FAN A	3-phase AC1 power to IMU Fan A switch on Panel L1.	3 cb's

TABLE 2-II.- ECLSS CONTROLS (ARS) - continued

PANEL	TYPE	NOMENCLATURE/ POSITION	FUNCTION	REMARKS
L4	circuit breakers	AC2 IMU FAN B	3-phase AC2 power to IMU Fan B switch on Panel L1.	3 cb's
L4	circuit breakers	AC3 IMU FAN C	3-phase AC3 power to IMU Fan C switch on Panel L1.	3 cb's
L4	circuit breakers	AC1 HUMIDITY SEPARATOR A	3-phase AC1 power to Humidity Separator A switch on Panel L1.	3 cb's
L4	circuit breakers	AC2 HUMIDITY SEPARATOR A	3-phase AC2 power to Humidity Separator B switch on Panel L1.	3 cb's
L4	circuit breaker	AC3 SIG CONDR HUM SEP	AC3 $\phi$ A power to humidity separator signal conditioners.	1 cb
L4	circuit breaker	AC3 SIG CONDR IMU FAN	AC-3 $\phi$ B power to IMU Fan signal conditioner.	1 cb
L4	circuit breaker	AC1 H <sub>2</sub> O CNTLR 2	AC1 $\phi$ A power to H <sub>2</sub> O Controller 2.	1 cb
L4	circuit breaker	AC1 CABIN AIR S/C	AC1 $\phi$ B power to the cabin air signal conditioner.	1 cb
L4	circuit breaker	AC2 CABIN FAN B	AC2 3-phase power to the Cabin Fan B switch on Panel L1.	3 cb's
L4	circuit breaker	AC3 CABIN FAN A	AC3 3-phase power to Cabin Fan A switch on Panel L1.	3 cb's
L4	circuit breaker	AC1 CABIN T CNTLR 2	AC1 $\phi$ A power to Cabin Temperature Controller 2 switch on Panel L1.	1 cb
L4	circuit breaker	AC1 AV BAY 2 S/C	AC1 $\phi$ B power to the Avionics Bay 2 Signal Conditioner.	1 cb



TABLE 2-II.- ECLSS CONTROLS (ARS) - continued

PANEL	TYPE	NOMENCLATURE/ POSITION	FUNCTION	REMARKS
L4	circuit breaker	AC2 CABIN T CNTLR 1	AC2 $\phi$ A power to Cabin Temperature Controller 1 switch on Panel L1.	1 cb
L4	circuit breaker	AC2 AV BAY 3 S/C	AC2 $\phi$ B power to the Avionics Bay 3 Signal Conditioner.	1 cb
L4	circuit breaker	AC3 H <sub>2</sub> O CNTLR	AC3 $\phi$ A power to H <sub>2</sub> O Controller 1.	1 cb
L4	circuit breaker	AC3 AV BAY 1 S/C	AC3 $\phi$ B power to the Avionics Bay 1 Signal Conditioner.	1 cb
01	rotary	AIR TEMP AV BAY 1,2,3 - CAB. HX OUT	Selects input to Air Temp meter.	
01	2-pos toggle	H <sub>2</sub> O PUMP OUT PRESS LOOP 1 - LOOP 2	Selects Loop 1/2 to Pump Out Press meter.	
014	circuit breaker	MN B H <sub>2</sub> O BYP LOOP 1 SNSR	Provides power for the H <sub>2</sub> O Loop 1 interchanger flow rate sensor and the IMU fan $\Delta$ P sensor.	1 cb
015	circuit breaker	MN B H <sub>2</sub> O B LOOP 2 SNSR	Provides power for the H <sub>2</sub> O Loop 2 interchanger flow rate sensor.	1 cb

## 2.2.4 ARS Systems Performance, Limitations, and Capabilities

Cabin air velocity range . . . . .	15 - 40 ft/min
Nominal air velocity . . . . .	25 ft/min
Cabin air flow . . . . .	1400 lb/hr
Avionics bay air flow . . . . .	875 lb/hr/bay
Nominal dew point range . . . . .	39 <sup>o</sup> to 61 <sup>o</sup> F
H <sub>2</sub> O separator inlet flow (air and H <sub>2</sub> O) . . . . .	37 to 41 lb/hr
Outlet flow (air) . . . . .	37 lb/hr
(H <sub>2</sub> O) . . . . .	0 - 4 lb/hr
LiOH cannister effective lifetime . . . . .	2 men - days
H <sub>2</sub> O centrifugal pumps design pressure . . . . .	90 psig
H <sub>2</sub> O centrifugal pumps proof pressure . . . . .	135 psig
H <sub>2</sub> O centrifugal pumps flow range . . . . .	970 ± 15 lb/hr
H <sub>2</sub> O centrifugal pumps inlet pressure . . . . .	18-35 psig
H <sub>2</sub> O centrifugal pumps pressure rise . . . . .	46.5 ± 1.2 psid
H <sub>2</sub> O accumulator volume . . . . .	50 in <sup>3</sup>
H <sub>2</sub> O accumulator capacity . . . . .	1.81 lb

## 2.3 ACTIVE THERMAL CONTROL SYSTEM

### 2.3.1 Interfaces

The ATCS interfaces with the ARS at the H<sub>2</sub>O/Freon interchanger. At the interchanger, heat collected by the ARS is transferred to Freon. The heat is then transferred to Ground Support Equipment (GSE) or into space. The EPS and Pressurization Systems have heat removed by the ATCS. The Hydraulic System is warmed at the hydraulic heat exchanger by hot Freon. Power for the ATCS pumps and electronics is received from the EPS. ATCS telemetry is available to the crew and transmitted to the ground.

### 2.3.2 ATCS System Description

There are two complete and identical Freon coolant loops (see fig. 2-26). Each loop has a pump package consisting of two pumps and an accumulator. One pump per loop is active at all times. The accumulator is a metal bellows type and is pressurized with GN<sub>2</sub>. The accumulator provides for thermal expansion and keeps a positive suction pressure on the pumps. Immediately downstream of the pumps and just prior to the fuel cell heat exchanger, a predetermined amount (286 lb/hr) of Freon branches off and flows through the midbody cold plates.

The primary flow goes through the fuel cell heat exchanger where it provides cooling for the three fuel cells. The flow to the midbody cold plates and the fuel cell heat exchanger reunites prior to passing through the hydraulic heat exchanger. This hydraulic heat exchanger interface is primarily to warm the hydraulic fluid. A bypass valve in the hydraulic fluid lines sends hydraulic fluid to the exchanger when the hydraulic fluid drops below a predetermined temperature.

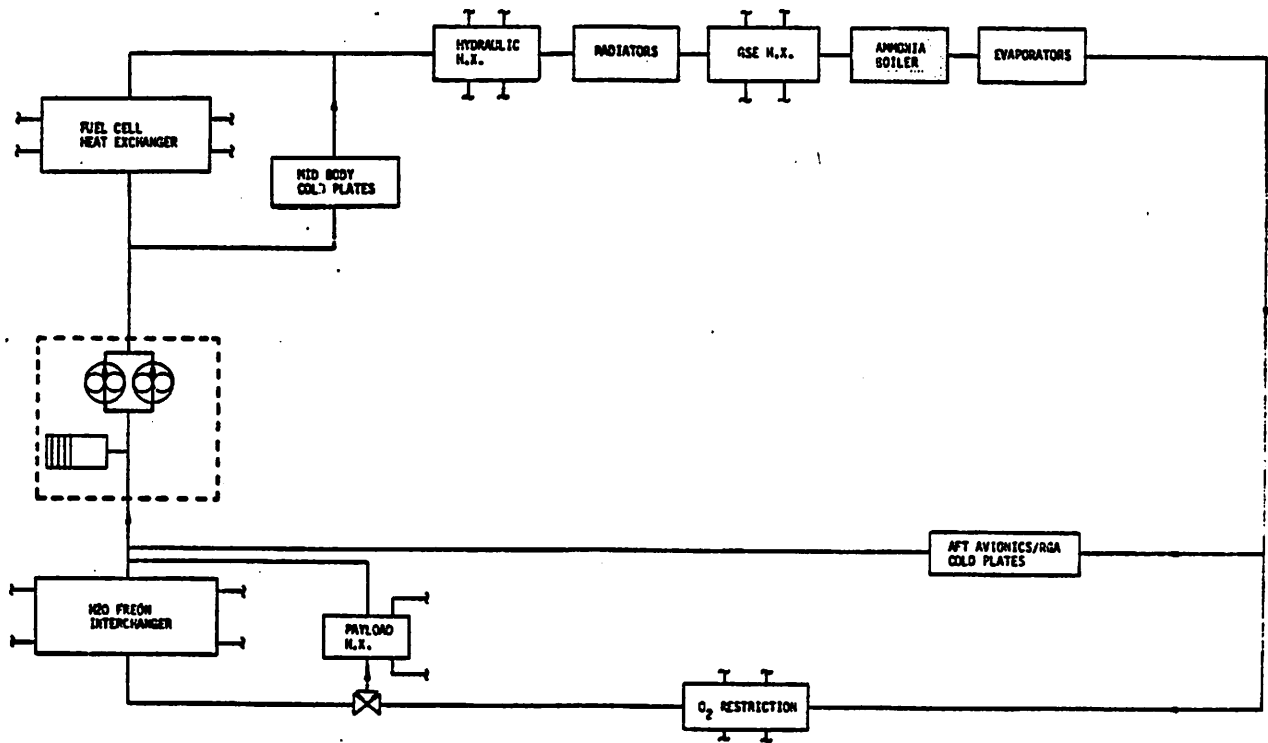


Figure 2-26.- Freon flow.

The Freon next goes through the radiators, which are used on-orbit as a primary thermal radiator to space. The flow then passes through the GSE heat exchanger, which is used on the ground for heat removal, and on to the ammonia boiler. The ammonia boiler is used during entry below 100,000 ft. It is commanded on by the BFS at ~100,000 ft and remains on for the remainder of the flight.

The evaporators, next in the line of flow, are commanded on by the BFS at 140,000 ft during ascent. They are used on-orbit to supplement the radiators. Upon entry, the BFS commands them off below 100,000 ft.

The Freon flow branches again downstream of the evaporators. The aft avionics/rate gyro assembly cold plates are cooled by 213 lb/hr flow. Main flow goes through the O<sub>2</sub> restrictor to warm the makeup oxygen and then to the Freon Proportioning Valve. This valve has two positions (PAYLOAD HX and INTCHGR). In the PAYLOAD HX position, 1099 lb/hr flows through the payload HX and 1423 lb/hr through the interchanger. In the INTCHGR position, the payload HX receives 174 lb/hr; the interchanger, 2348 lb/hr. The payload heat exchanger for OFT-1 will be used to cool the DFI coolant loop. The primary Freon flow picks up the heat from the water loop at the H<sub>2</sub>O/Freon interchanger. All three branches then reunite and flow back to the pump. For launch, loops 1 and 2 will be operating Pump A. The power for the pumps is monitored by the BFS. If the main dc power bus for either of these pumps drops below 20 V, the other pump in the package is commanded on by the BFS.

The radiator controller LOOP 1/2 switch (see fig. 2-27), determines whether the A or B controller in each loop will control radiator Freon flow. The controller will bypass an amount of Freon around the radiator to control the temperature of the Freon. The OUT TEMP HI-NORM switch will cause the controller to control the radiator temperature out at 57° F in the HI position. In the NORM position, it controls to 38° F. The HI position is used to force evaporator operation. The MODE AUTO-MAN switches select the bypass valve mode of operation. In the manual mode, the MAN SEL RAD FLOW-BYPASS switch permits placing the radiator bypass valve to full radiator bypass or full radiator flow.

The ammonia boilers are used below 100,000 ft during entry (see fig. 2-28). Both controllers A and B are placed in the PRI/GPC position prior to entry. As the spacecraft descends below 100,000 ft, the BFS commands the controllers on. If the switches are placed to the SEC ON position, the controllers will operate. If they are placed to the SEC ON when the spacecraft is on-orbit, there is a great possibility the helium blanket pressurizing the ammonia will leak away and cause the system to be unusable. The ammonia tanks each contain 46 lb of usable ammonia. One tank would be sufficient for entry. Normal control temperature is 34° F.

The evaporator (see fig. 2-29) is located in the aft end of the spacecraft. It is usually referred to in the plural, since there are two evaporators contained in one envelope. The theory of operation is quite simple. The evaporators are cylindrical. Water is sprayed into the inner core. In the low pressures above 100,000 ft, the water quickly vaporizes. In changing state from liquid to vapor it removes approximately 1000 Btu/hr per pound of water. Hot freon flows from the duct end of the

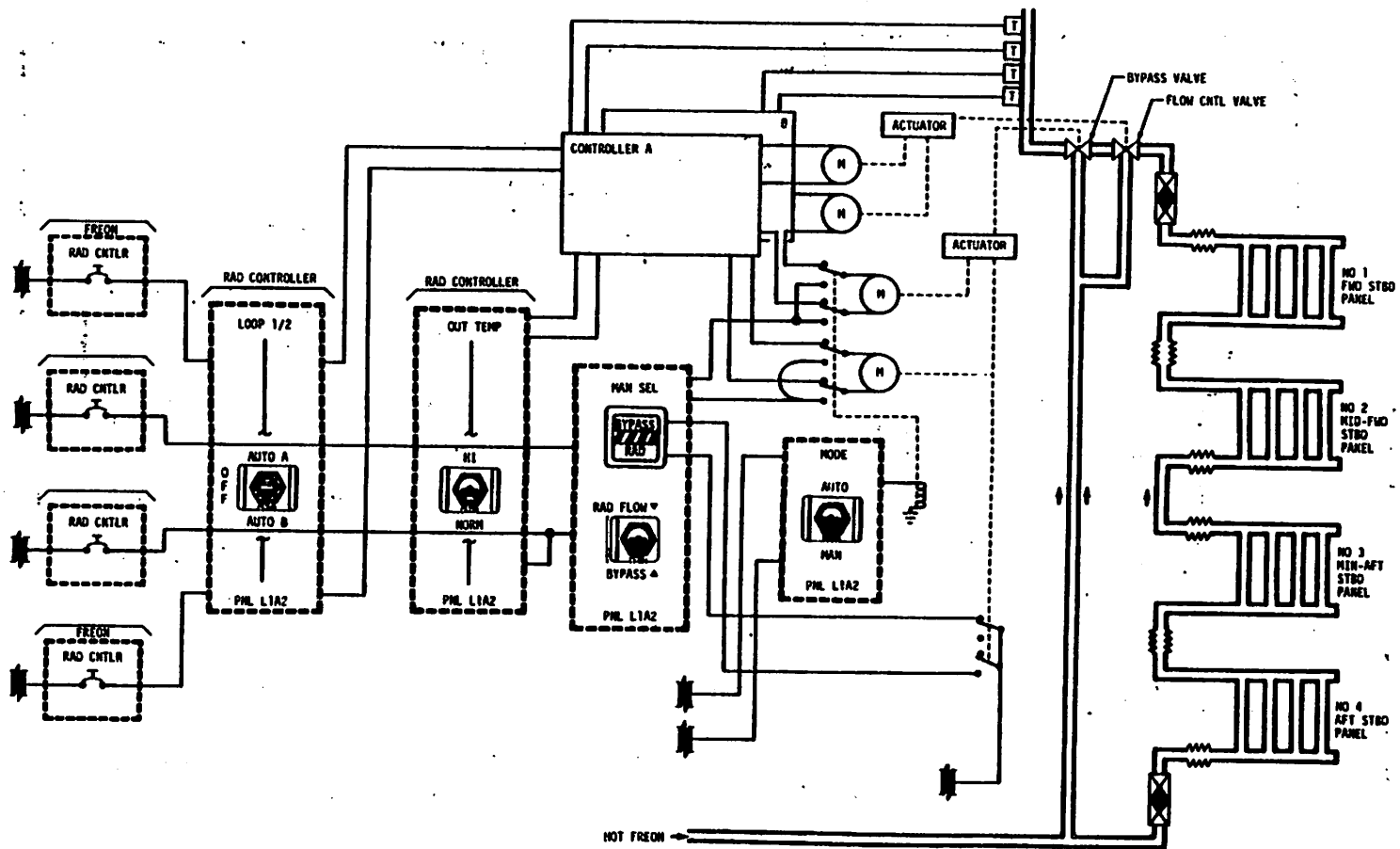
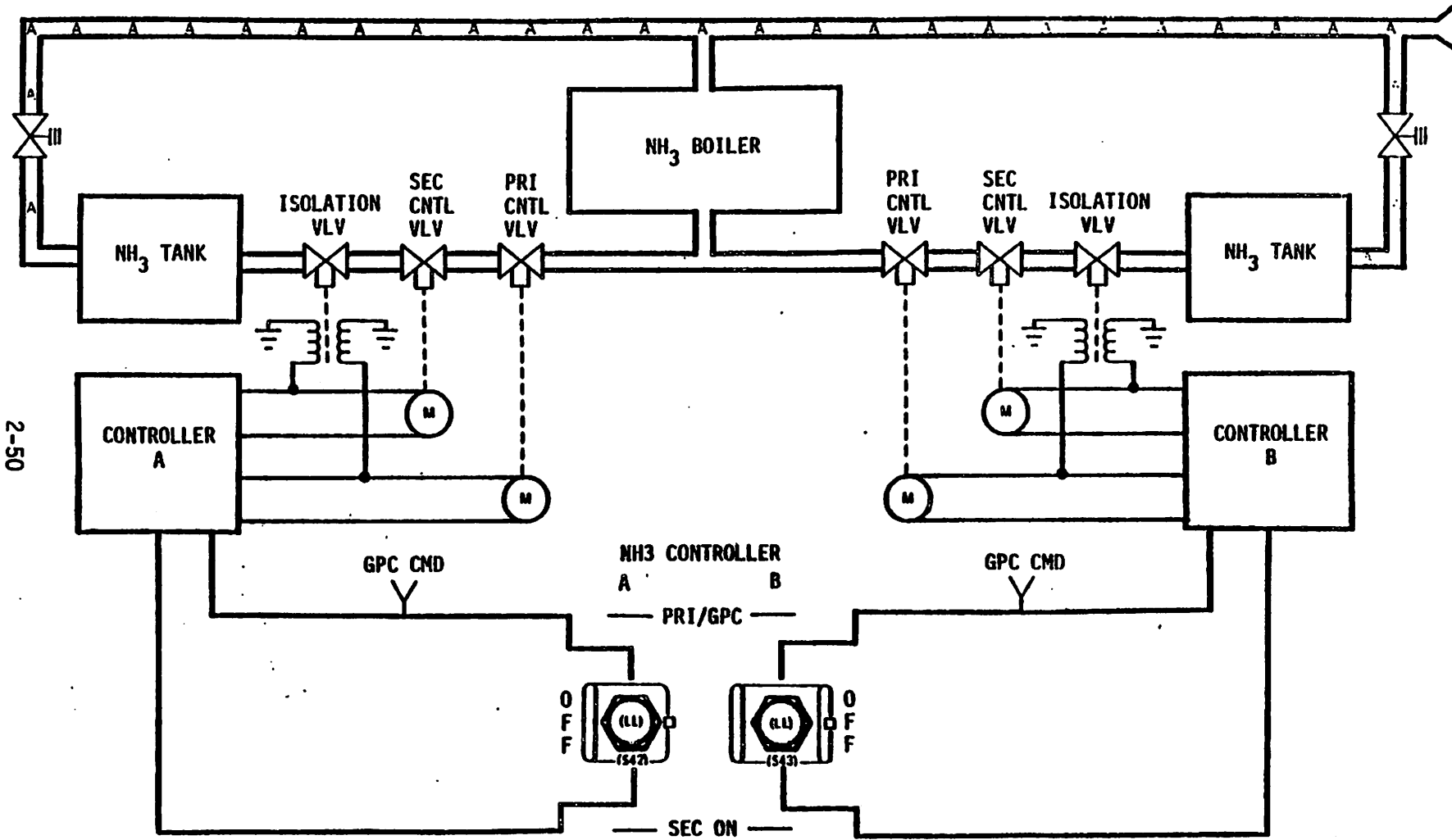


Figure 2-27: - Radiator control.



2-50

Figure 2-28.- Ammonia boilers.

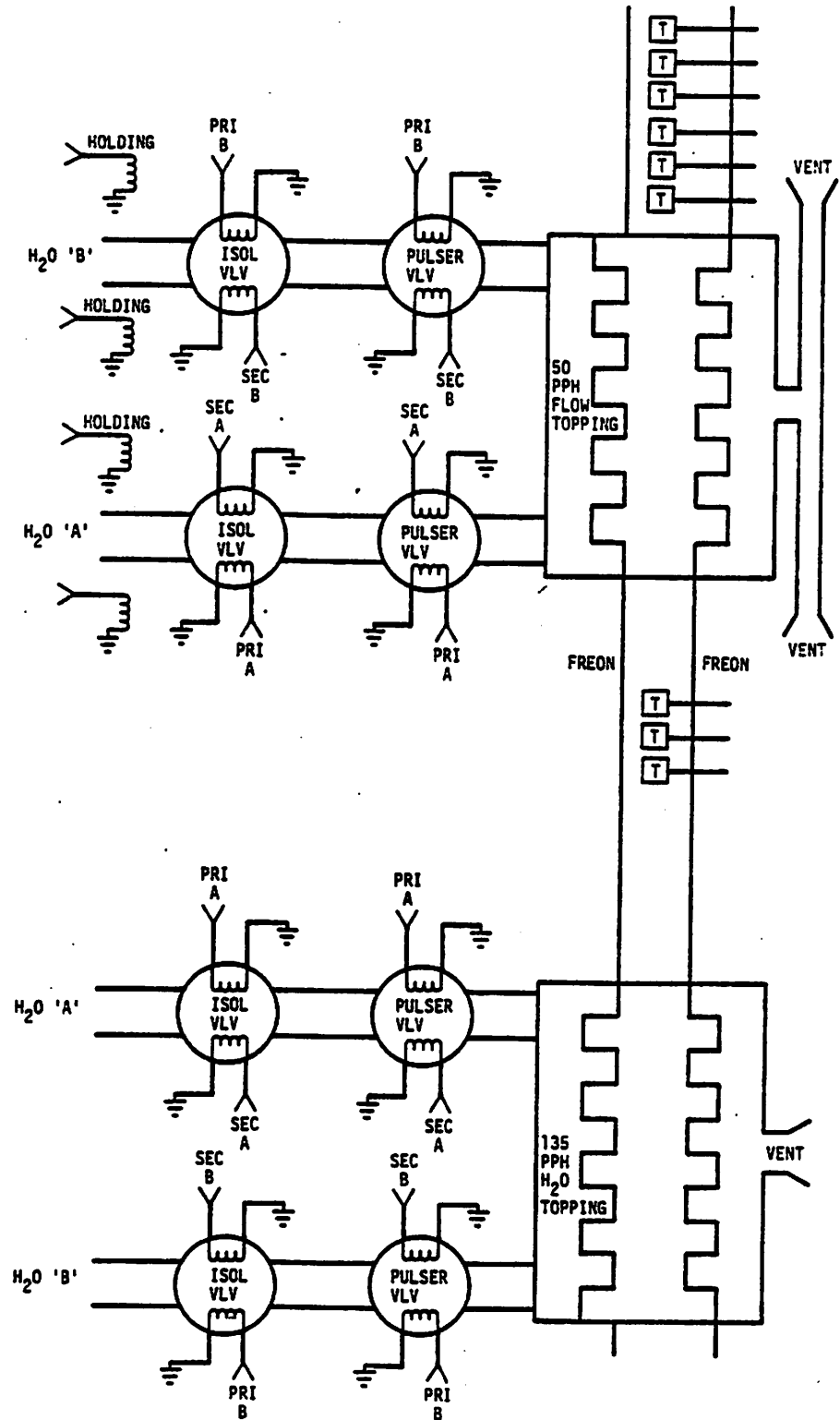
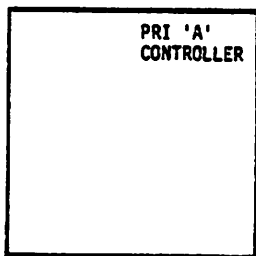
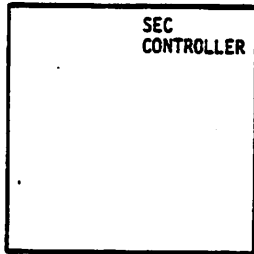
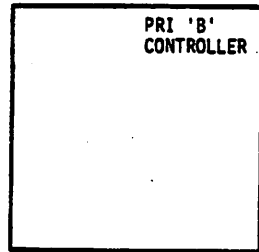


Figure 2-29.- Evaporators.

evaporator around the core and exits at the water inlet end. The temperature of the Freon is controlled to approximately 39° F. Hot Freon entering the evaporators goes first through the hi-load evaporator. Freon temperatures will be sensed and the controllers will "pulse" water into the evaporators to maintain the topping evaporation temperature out at 39° F. The hi-load evaporator has an isolation valve and a pulse valve on each of the water supply lines. Only one of the supply lines is normally used at a time. On the hi-load evaporator, the isolation and the pulser valve both pulse at the rate determined by the controller, based on the Freon temperature. The topping evaporator has an isolation valve and an integral pulser shutoff valve. Holding coils have been incorporated in the topping evaporator to hold the isolation valves open and minimize power consumption. Only the pulsing valves pulse on the topping evaporator. The hi-load evaporator will not be used when the payload doors are open because of possible pollution. It is also a propulsive vent, while the topping evaporator is not.

There are three evaporator controllers. Primary A and Primary B are basically identical. Primary A controller uses the A feedline; the Primary B controller uses the B feedline. The secondary controller feedline is selectable when the HI LOAD EVAP ENABLE-OFF switch S45 is in the enable position. When the secondary controller is used and HI LOAD EVAP is enabled, the topping evaporator is disabled. When the secondary controller is used and the hi-load evaporator is off, both feedlines feed the topping evaporator.

### 2.3.3. ATCS Controls and Displays

The circuit breakers controlling power to the ATCS are located on Panel L4. These circuit breakers feed power to the control switches on Panel L1 (see fig. 2-30). Both of the Freon loops in the ATCS are kept operating throughout the flight. The pumps which propel the Freon are controlled by the FREON PUMP LOOP 1 - LOOP 2 A/B switches in the upper center of Panel L1. Only one pump in each loop can be operated at a time. If during launch, the BFS commands the alternate pump on, there is no way of recognizing this action. The OUT TEMP HI-NORM switch selects the control out temp of the radiators. HI controls to 57° F and NORM to 38° F. The RAD CONTROLLER LOOP 1 - LOOP 2 AUTO A/AUTO B switches select either the A or B controller for each loop. Below the radiator controller switch are two talkbacks and four switches. The switches are labeled MAN SEL 1 - 2 RAD FLOW/BYPASS and MODE 1 - 2 AUTO/MAN. The talkbacks reflect the position of the radiator bypass valve. The mode switch, when in AUTO, causes the controller to control the bypass valve. In the MAN position of the mode switch, the MAN SEL switch controls the position of the radiator bypass valve. At the bottom right corner of Panel L1 is the NH<sub>3</sub> BOILER A-B PRI/GPC/ OFF/SEC ON switch. The PRI GPC position of this switch configures the system so it can be activated by the BFS. The SEC ON position manually activates the ammonia boiler.

The H<sub>2</sub>O ALTERNATE PRESS OPEN/CLOSE switch when open allows cabin pressure into the H<sub>2</sub>O pressurization system for the H<sub>2</sub>O tanks. In an emergency, this might provide sufficient pressure to provide water to the evaporators. The FLASH EVAP CONTROLLER PRI A, PRI B SEC GPC/OFF/ON



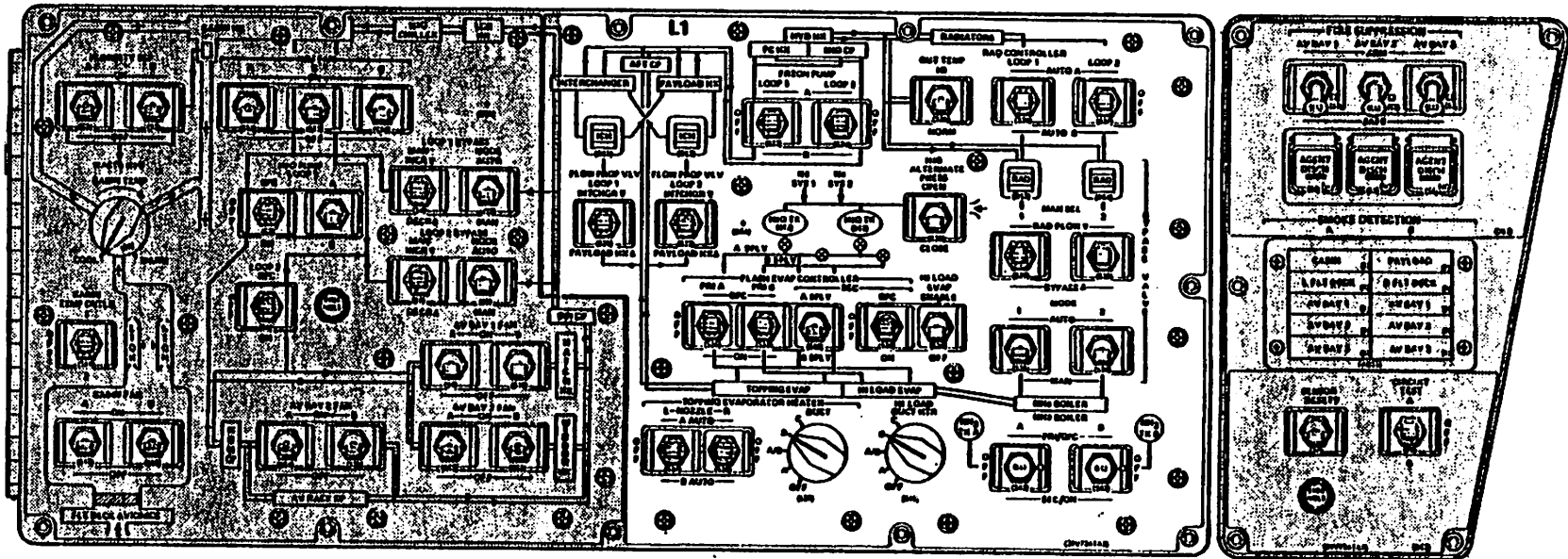


Figure 2-30.- Panel L1, ATCS controls.

switches control the evaporator controllers. Only one of these controllers is used at a time. The GPC position permits the BFS to turn the evaporator on at 140,000 ft and off at 100,000 ft. The ON position manually turns the evaporator on. The secondary controller will be used only in a contingency situation. The SEC ASPLY/BSPLY switch selects the water supply for the secondary controller when the HI LOAD EVAP switch is in the ENABLE position. When the HI LOAD EVAP is OFF, both H<sub>2</sub>O feedlines feed the topping evaporator. The two rotary heater switches and the two toggle heater switches at the bottom of the panel are self explanatory. The FLOW PROP VALVE LOOP 1 - LOOP 2 INTCHR/ PAYLOAD switches position the proportioning valve to either the payload or interchanger position. In the interchanger position, which will be used for ascent and entry, the greater portion of the Freon flow passes through the interchanger. On-orbit, the payload position will be used, and in that position the flow is approximately divided between the two heat exchangers.

The overhead Panel 01 dual meter labeled FREON FLOW - EVAP OUT TEMP (fig. 2-31) reflects the interchanger Freon flow and the EVAP OUT temperature. The toggle switch directly under this meter selects either Loop 1 or Loop 2 as meter inputs.

If the light labeled FREON LOOP on the Panel F7 C&W matrix illuminates (fig. 2-32), it is because one of the following parameters has exceeded its limits:

ID	CRT NAME	UNITS	LOWER LIMIT	UPPER LIMIT
V63R1100A	Freon Flow 1	lb/hr	1200	
V63T1207A	Evap Out T 1	Deg F	32	49.6
V63R1300A	Freon Flow 2	lb/hr	1200	
V63T1407A	Evap Out T 2	Deg F	32	49.6

The following CRT SM messages will be displayed on the CRT displays listed under the conditions identified opposite the messages:

MAJOR CRT	MINOR FIELD	FIELD	CLASS	CONDITIONS
S88-SM2-BFS	Freon Flow	1	2	FCL Freon Flow $\leq$ 1200 lb/hr
S88-SM2-BFS	Freon Flow	2	2	FCL Freon Flow $\leq$ 1200 lb/hr
S88-SM2-BFS	Freon Flow	1	3	FCL Freon Flow $\leq$ 1200 lb/hr
S88-SM2-BFS	Freon Flow	2	3	FCL Freon Flow $\leq$ 1200 lb/hr
S88-SM2-BFS	Evap Out T	1	2	Evap Out Temp $\leq$ 32° F or $>$ 49.6° F
		2	2	Evap Out Temp $\leq$ 32° F or $>$ 49.6° F
S88	Thermal	Evap	3	Flash Evap Hi Load Duct Temp $>$ 300° F or $\leq$ 150° F
			3	Flash Evap Hi Load Nozzle Temp $>$ 350° F or $\leq$ 200° F
			3	Flash Evap Feedline Temp -1 $>$ 110° F or $\leq$ 60° F
			3	Flash Evap Feedline Temp -2 $>$ 110° F or $\leq$ 60° F

Reserved

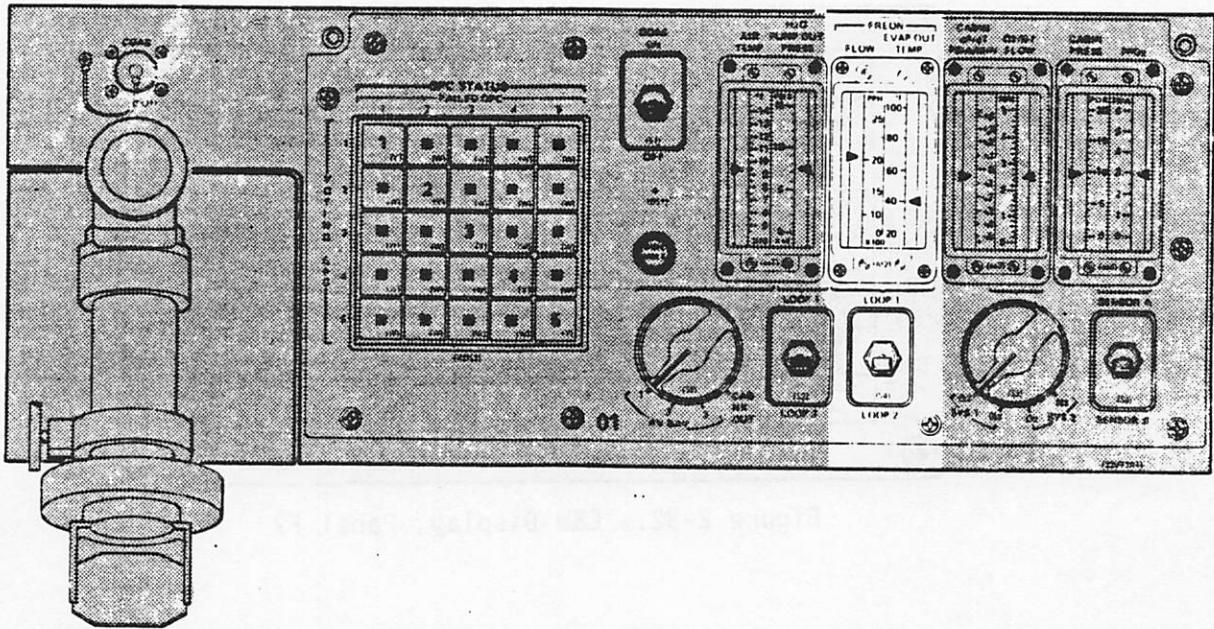


Figure 2-31.- Panel 01.

O <sub>2</sub> PRESS	H <sub>2</sub> PRESS	FUEL CELL REAC (R)	FUEL CELL STACK TEMP	FUEL CELL PUMP
CABIN ATM (R)	O <sub>2</sub> HEATER TEMP	MAIN BUS UNDERVOLT (R)	AC VOLTAGE	AC OVERLOAD
FREON LOOP (R)	A/BAY CABIN AIR	DMU (R)	FWD RCS (R)	RCS JET
H <sub>2</sub> O LGDP	HGA/ACCEL	AIR DATA (R)	LEFT RCS (R)	RIGHT RCS (R)
(R)	LEFT RHC (R)	RIGHT/RT RHC (R)	LEFT OMS (R)	RIGHT OMS (R)
PAYLOAD WARNING (R)	GFC	FCS (R) SATURATION	OMS KIT	OMS TVC (R)
PAYLOAD CAUTION	PRIMARY CAV	FCS CHANNEL	NPS (R)	---
BACKUP C/W ALARM (R)	APU TEMP	APU OVERSPEED	APU UNDERSPEED	HYD PRESS

(34V73A7A.7)

Figure 2-32.- C&W Display, Panel F7

CRT	MAJOR FIELD	MINOR FIELD	CLASS	CONDITIONS
			3	Flash Evap Topping Duct Temp Fwd & Aft > 300° F or ≤ 150° F Left & right > 300° F or ≤ 50° F
			3	Flash Evap Nozzle Temp - Left > 300° F or < 40° F
			3	Flash Evap Nozzle Temp - Right > 300° F or < 40° F
S88	Thermal	Frn	3	FCL 1/2 Payload Hx Flow Rate ICH < 150 lb/hr PL < 500 lb/hr
			3	FCL 1/2 Cold Plate Network Flow Rate < 200 lb/hr
			3	FCL 1/2 Accumulator Qty < 12%
			3	FCL 1/2 Rad Outlet Temp "CNTLR OUT T" < 320 F
			3	Midbody DFI Loop Flowrate ≤ 350 lb/hr

CRT Displays containing ATCS Data are SM88 (fig. 2-33), SM2 (fig. 2-34), and BFS (fig. 2-35).

2011 / /088 APU/ENVIRON THERM				2 083/16:05:26		
				000/01:26:42		
FREON LOOP	1	2	H2O LOOP	1	2	
ACCUM QTY	36	45	PUMP OUT P	68	23	
FREON FLOW	1500	150	OUT T	65	76	
PL HX FLOW	1000	100	ΔP	43	0	
AFT CP FLOW	270	270	ICH FLOW	50	0	
RAD IN T	100	95	OUT T	43	45	
CNTRLR OUT T	38	38	CAB HX IN T	43	45	
EVAP OUT T	37	38	ACCUM QTY	43	52	
DFI FLOW	460					
EVAP TEMP	DUCT	NOZ	APU			
HI LOAD INBD	255	320	FUEL T	1	2	3
OUTBD	252	320	TK SURF	+ 60	+ 61	+ 60
TOPPING FWD	260		TK HTR	+ 61	+ 62	+ 59
AFT	260		ISOL VLV	+ 60	+ 63	+ 58
L	155	50	TEST LN	+ 59	+ 59	+ 58
R	155	50	FEED LN	+ 61	+ 60	+ 63
EVAP FDLN T	A	B	PUMP IN	+ 62	+ 59	+ 64
FWD	70	70	DRN LN	+ 61	+ 60	+ 61
MID 1	70	70	OUT	+100	+102	+101
MID 2	70	70	BYP LN	+100	+101	+102
AFT	70	70				

Figure 2-33.- Display S88.

2011 / / 079 SM SYS SUMM 2 XX 2 237/14:35:12  
 000/01:35:10

CRYO TK	1	2	3	4
H2 PRESS	225	225	225	225
O2 PRESS	950	950	950	950
HTR T1	+ 75	+ 78	+ 10	+ 76
T2	+ 75	+ 77	+ 9	+ 75

APU	1	2	3	HYD	1	2	3
TEMP EGT	950	850	80	PRESS	301	55	62
B/U EGT	850	750	70	RSVR T	80	95	70
OIL IN	220	215	85	QTY	80	78	50
OUT	260	255	80				
SPEED X	82	84	0	W/B			
FUEL QTY	73	75	99	H2O QTY	68	70	99
PMP LK P	0	0	0	BYP VLV	W/B	W/B	BYP
OIL OUT P	80	80	15				
				THERM CNTL	1	2	
AV BAY				H2O PUMP P	70	15	
TEMP	90	90	90	FREON FLOW	1500	0	
FAN ΔP	0.1	0.1	0.2	EVAP OUT T	37	78	

2-59

Figure 2-34.- SM SYS SUMM 2 display.

3-ECLSS

/ / 078 SM SYS SUMM 1				5 237/14:35:02		
				BFS 000/01:30:00		
EMERGENCY				DC VOLTS		
SMOKE	1/A	2/B		1/A	2/B	3/C
AV BAY	1	0.0	0.0	FC	29.7	29.9 38.0†
	2	0.0	0.0	MAIN	29.7	29.8 0.0†
	3	0.0	0.0	CNTL AB	29.8	29.8 29.7
dP/dT	+ .0			BC	29.8	29.7 29.8
				CA	29.8	29.7 29.8
				ESS	29.6	29.8 29.6
CABIN				AC		
PRESS	14.5			VOLT φA	115	114 0†
PPO2	3.7	3.7		φB	115	114 0†
FAN ΔP	0.31			φC	115	114 0†
HX OUT T	65			AMP φA	4.1	5.6 0.0
O2 FLOW	0.0	0.0		φB	4.7	4.1 0.0
N2 FLOW	1.1	0.0		φC	3.9	4.2 0.0
IMU FAN	A*	B	C	FUEL CELL		
TOTAL AMPS	415			AMPS	205	210 0†
KW	12			REAC VLV	OP	OP CL†
				STACK T	+191	+186 +284†
				PUMP		ΔP†

Figure 2-35.- BFS display.



TABLE 2-III.- ATCS CONTROLS

PANEL	TYPE	NOMENCLATURE/ POSITION	FUNCTION	REMARKS
L1	3-pos toggle (spring-loaded)	BYPASS VALVE MAN SEL RAD FLOW/BYPASS	RAD FLOW-Bypass valve is posi- tioned for radi- ator flow. BYPASS-Freon flow bypasses the radiator.	2 switches
L1	2-pos lever lock	NH <sub>3</sub> Boiler A/B PRI/GPC-SEC/ON	PRI/GPC-BFS will turn the ammonia boiler on or off during ascent and entry. SEC/ON-Ammonia boiler is powered and will operate.	2 switches
L1	2-pos toggle	HI LOAD EVAP ENABLE-OFF	ENABLE-Hi Load evap can operate. OFF-Hi load evap operation is inhibited.	
L1	3-pos toggle	FLASH EVAP CONTROLLER SEC GPC-OFF-ON	GPC-BFS turns the controller ON/OFF during ascent and entry. OFF-Evap controller is not powered. ON-controller is powered.	
L1	3-pos toggle	FLASH EVAP PRI A - PRI B GPC-OFF-ON	GPC-BFS turns the controller ON/OFF during ascent and entry. OFF-EVAP controller is not powered. ON-Controller is powered.	2 switches
L1	2-pos toggle	FLASH EVAP CONTROLLER SEC A SPLY-B SPLY	Selects the water supply feedline for the second- ary controller.	

TABLE 2-III.- ATCS CONTROLS

PANEL	TYPE	NOMENCLATURE/ POSITION	FUNCTION	REMARKS
L1	3-pos toggle	TOPPING EVAPORATOR HEATER L-NOZZLE-R A AUTO-B AUTO	Selects and turns on one of two redundant duct nozzle heaters.	2 switches
L1	2-pos toggle	AV BAY 1/2/3 FANS A-B ON-OFF	Circulates the air in the avionics bays.	6 switches
L1	3-pos toggle (spring-loaded) center)	FLOW PROP VLV LOOP 1/2 INTCHGR/ PAYLOAD HX	Selects one of two positions for the Freon flow proportioning valve.	2 switches
L1	talkback	FLOW PROP VLV LOOP 1/2 ICH - PL	ICH-2348 lb/hr flow through the H <sub>2</sub> O/Freon interchanger. PL-1423 lb/hr flow through the H <sub>2</sub> O/Freon interchanger.	2 switches
L1	3-pos toggle	FREON PUMP LOOP 1/2 A-OFF-B	A-Turns Freon Pump A on in loop 1/2. B-Turns Freon Pump B on in loop 1/2.	2 switches
L1	2-pos toggle	RAD CONTROLLER OUT TEMP HI-NORM	Hi-Radiator controls to 56° out temp. NORM-Radiator controls to 38° F out temp.	2 switches
L1	3-pos toggle	RAD CONTROLLER LOOP 1/2 AUTO A - OFF- AUTO B	AUTO A-Powers the A Controller in Freon Loop 1/2. OFF-Controllers are not powered. AUTO B-Powers the B controller in Loop 1/2.	2 switches

TABLE 2-III.- ATCS CONTROLS

PANEL	TYPE	NOMENCLATURE/ POSITION	FUNCTION	REMARKS
L1	2-pos toggle	BYPASS VALVE MODE 1 - 2 AUTO - MAN	AUTO-Radiator con- troller controls radiator bypass valve. MAN-Bypass valve is controlled by the MAN SEL switch.	2 switches
L1	rotary switch	TOPPING EVAP- ORATOR HEATER DUCT OFF-A-A/B-B-C	Selects and turns on the duct heater for the topping evapora- tor.	
L1	rotary switch	HI LOAD DUCT HTR OFF-A-A/B-B-C	Selects and turns on duct heater for hi-load evaporator.	
L2	3-pos toggle	FLASH EVAP FEEDLINE HTR A SUPPLY - B SUPPLY 1 - OFF - 2	Selects and turns on the Flash evaporator feed- line heater.	2 switches
L4	circuit breaker	AC1 FREON LOOP 1 PUMP A	AC1 3-phase power to Freon Loop 1 Pump A switch on Panel L1.	3 cb's
L4	circuit breaker	AC2 FREON LOOP 1 PUMP B	AC2 3-phase power to Freon Loop 1, Pump B switch on Panel L1.	3 cb's
L4	circuit breaker	AC3 FREON LOOP 2 PUMP A	AC3 3-phase power to Freon Loop 2, Pump A switch on Panel L1.	3 cb's
L4	circuit breaker	AC1 FREON LOOP 2 PUMP B	AC1 3-phase power to Freon Loop 2 Pump B Switch on Panel L1.	3 cb's
L4	circuit breaker	AC2 FREON FLOW PROP 1	AC2 $\phi$ A power to Freon Flow Pro- portioning Valve 1 switch on Panel L1.	1 cb

TABLE 2-III.- ATCS CONTROLS

PANEL	TYPE	NOMENCLATURE/ POSITION	FUNCTION	REMARKS
L4	circuit breaker	AC2 FREON SIG CONDR	AC2 $\phi$ B power to the Freon signal conditioner.	1 cb
L4	circuit breaker	AC3 FREON FLOW PROP 2	AC3 $\phi$ A power to Freon Flow Proportioning Valve 2 switch on Panel L1.	1 cb
L4	circuit breaker	AC3 FREON SIG CONDR	AC3 $\phi$ B power to the Freon signal conditioner.	1 cb
L4	circuit breaker	AC1 RAD CNTLR 1B	AC1 $\phi$ A power to Radiator Controller 1B.	1 cb
L4	circuit breaker	AC1 RAD CNTLR 2B	AC1 $\phi$ B power to Radiator Controller 2B.	1 cb
L4	circuit breaker	AC2 RAD CNTLR 1A	AC2 $\phi$ B power to Radiator Controller 1A.	1 cb
L4	circuit breaker	AC3 RAD CNTLR 2A	AC3 $\phi$ B power to Radiator Controller 2A.	1 cb
01	2-pos toggle	FREON EVAP OUT FLOW-TEMP	Selects loop 1 or 2 data for display on Freon meters.	
014	circuit breaker	MN A FREON RAD CNTLR 1 - 2	Provides Main A power to the radiator controllers.	2 cb's
015	circuit breaker	MN B FREON RAD CNTLR 1 - 2	Provides the Main B power to the radiator controllers.	2 cb's
017	circuit breaker	SIGNAL CONDITIONER FREON A/B AC2/AC3	Provides selectable AC2/AC3 power to the Freon loop signal conditioners.	2 cb's

### 2.3.4 ATCS Systems Performance, Limitations, and Capabilities

#### Freon-21 Loop:

Freon-21 boiling point at 14.7 psi . . . . .	48° F
Freon-21 freezing point . . . . .	-211° F
Total flow (2 loops) . . . . .	2350 to 2750 lb/hr
Net positive suction head . . . . .	75 psia
Accumulator operating pressure . . . . .	230 psig
Accumulator proof pressure . . . . .	345 psig
Accumulator burst pressure . . . . .	460 psig
Accumulator volume . . . . .	1658.8 in <sup>3</sup>

#### Radiator:

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

#### Ammonia Boiler:

Heat rejection ability . . . . .	113,200 Btu/hr
----------------------------------	----------------

#### Flash Evaporator:

Heat rejection (on-orbit) . . . . .	Topping only . . . . .	30,000 Btu/hr
	HI LOAD . . . . .	95,500 Btu/hr

## 2.4 SUPPLY AND WASTE H<sub>2</sub>O MANAGEMENT SYSTEM

### 2.4.1 Interfaces

The Supply Water and Waste Management System provides water for the evaporator, crew consumption, and hygiene. It stores water generated by the fuel cells. It stores waste water from the humidity separator and waste water from the crew.

The EPS provides power for heater and valve operation and control. H<sub>2</sub>O telemetry is transmitted to the ground, and status of the equipment is presented to the crew on the CRT. Water tank N<sub>2</sub> pressurization is provided by the N<sub>2</sub> pressurization system.

### 2.4.2 Supply and Waste Water Management System Description

For STS-1 operations, we will use six supply tanks and one waste tank. There is an interface between these two systems which we will describe later in this discussion. Four of the supply tanks are located under the middeck floor. Two tanks are located on the middeck floor.

The Supply Water System receives water from the fuel cells (see fig. 2-36). H<sub>2</sub>O received from the fuel cells is hydrogen enriched. The excess hydrogen is removed at the hydrogen separator. Excess hydrogen is vented

2-66

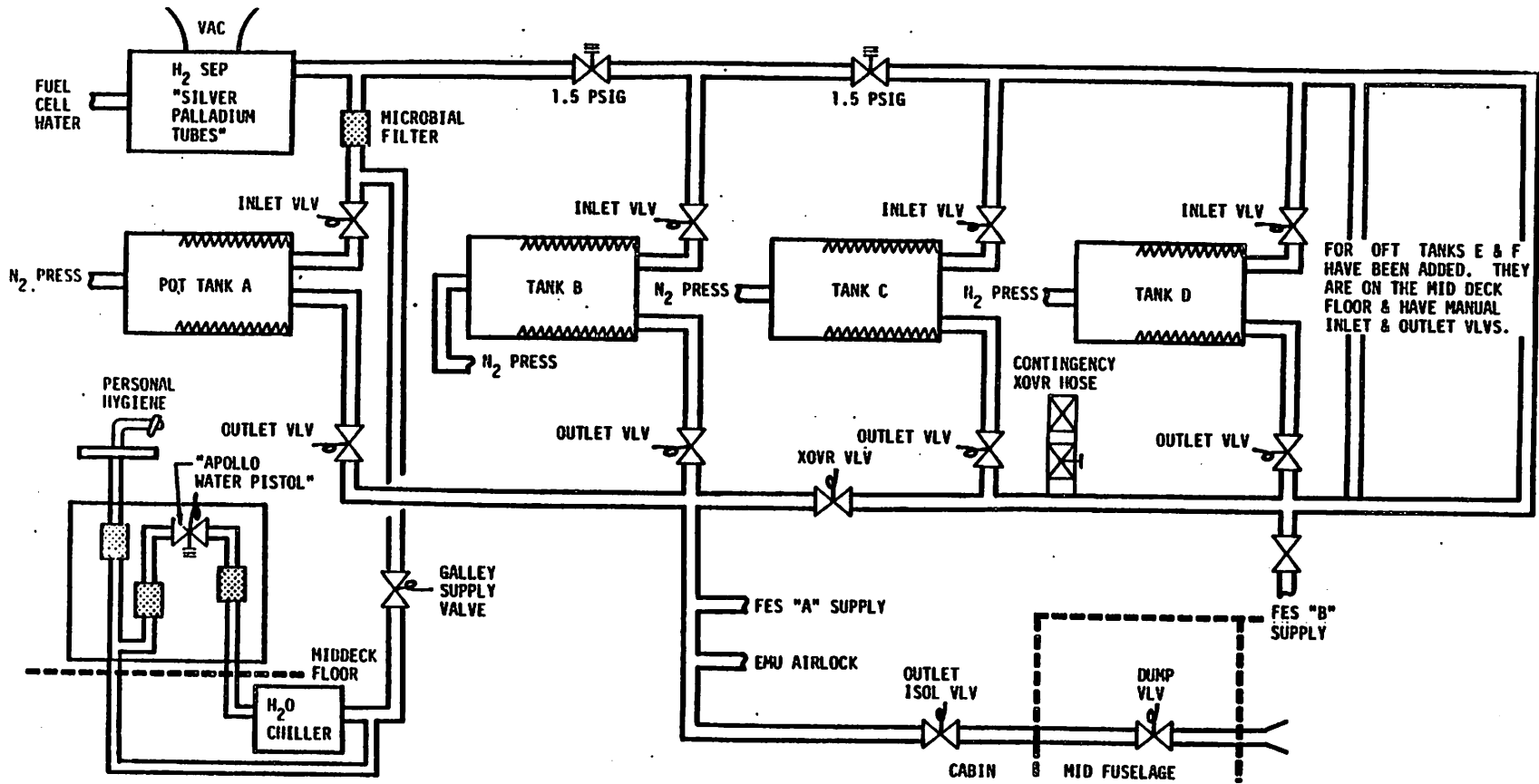


Figure 2-36. - Supply H<sub>2</sub>O Storage.

overboard. Water passing through the H<sub>2</sub> separator can be stored in all six tanks. The water stored in tank A is used for crew consumption, as well as for evaporative cooling. The water entering tank A passes through a microbic filter. This filter adds about 1/2 PPM iodine to the water. Water to tanks B, C, D, E, and F go through a 1.5 psig check valve. Water to tank B branches off at this point. Water to tanks C, D, E, and F passes through another 1.5 psid check valve to the inlet of these tanks. Just prior to the inlet valve of tank A, plumbing leads to the galley. Galley equipment will be discussed in another manual. Each of the six supply storage tanks has an inlet and outlet valve. By manipulating these valves, we can selectively fill or dump these tanks. The tank outlets are manifolded together. The flash evaporator and EMU/airlock feedlines interface with this manifold. Water can be dumped overboard from this manifold via the outlet isolation and dump valve. There is a crossover valve on this manifold located between tanks B and C. It serves to isolate tanks A and B outlets from tanks C, D, E, and F. There is a contingency crosstie valve on the outlet manifold. It permits joining of the supply and waste systems for emergency dumping of H<sub>2</sub>O or flash evaporator use of waste water. The water tanks are pressurized by nitrogen to 16.0 psig (see fig. 2-37). The N<sub>2</sub> pressurization supply is the same supply used for the pressurization system. The tank A isolation and tank A vent valves are ganged together. When the isolation valve is closed, the vent valve is open to cabin atmosphere. The tank A isolation valve is closed for launch. This lowers tank A pressure so the fuel cell water head pressure is lower. This helps prevent flooding of the fuel cells during ascent. Water pressure is maintained in tanks B, C, D, E, and F to feed the flash evaporators.

There is one waste water tank for OFT (see fig. 2-38, waste H<sub>2</sub>O storage).

Waste water is received from the Waste Management System and the humidity separator. The contingency crosstie interfaces with the supply water overboard dump line through a flexible hose. The dump isolation and dump valve permit normal overboard waste H<sub>2</sub>O dumps. Waste water is dumped through the tank inlet valve and then overboard through the dump valves. There are H<sub>2</sub>O line heaters on the supply and waste overboard dump lines. Except for the dump nozzle heaters, these are thermostatically controlled.

#### 2.4.3 Supply Water and WMS Controls and Displays

Panel ML86B on the middeck contains the circuit breakers for the Water and Waste Management System. Panels R12 in the aft station, Panel ML31C and Panel MD24K on the middeck contain the H<sub>2</sub>O control switches. Panel R12 (see fig. 2-39) has supply tank A, B, and C controls.

There are six inlet and outlet switches on panel R12 which open and close the tank valves. The tank A outlet valve is never opened in flight in order to maintain the purity of tank A for crew consumption. Tank A is dumped through its inlet valve into and through tank B, and then to the flash evaporators or overboard. In the lower right-hand corner is the B supply isolation valve. It controls H<sub>2</sub>O to flash evaporator feedline B. Feedline A does not have an isolation valve. The galley supply valve controls water to the galley and water pistol. It is normally open on-orbit

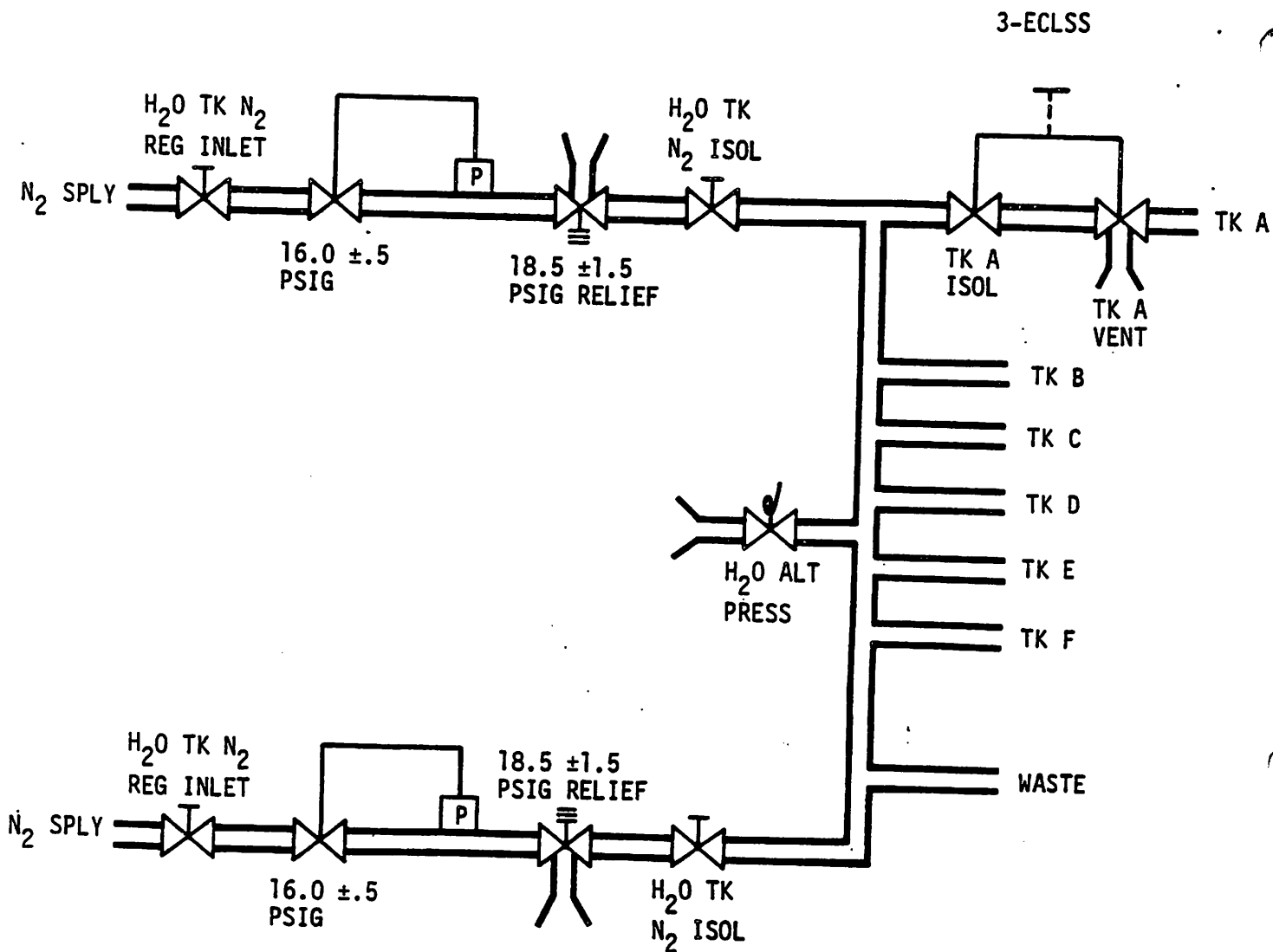


Figure 2-37.- N<sub>2</sub> pressure.



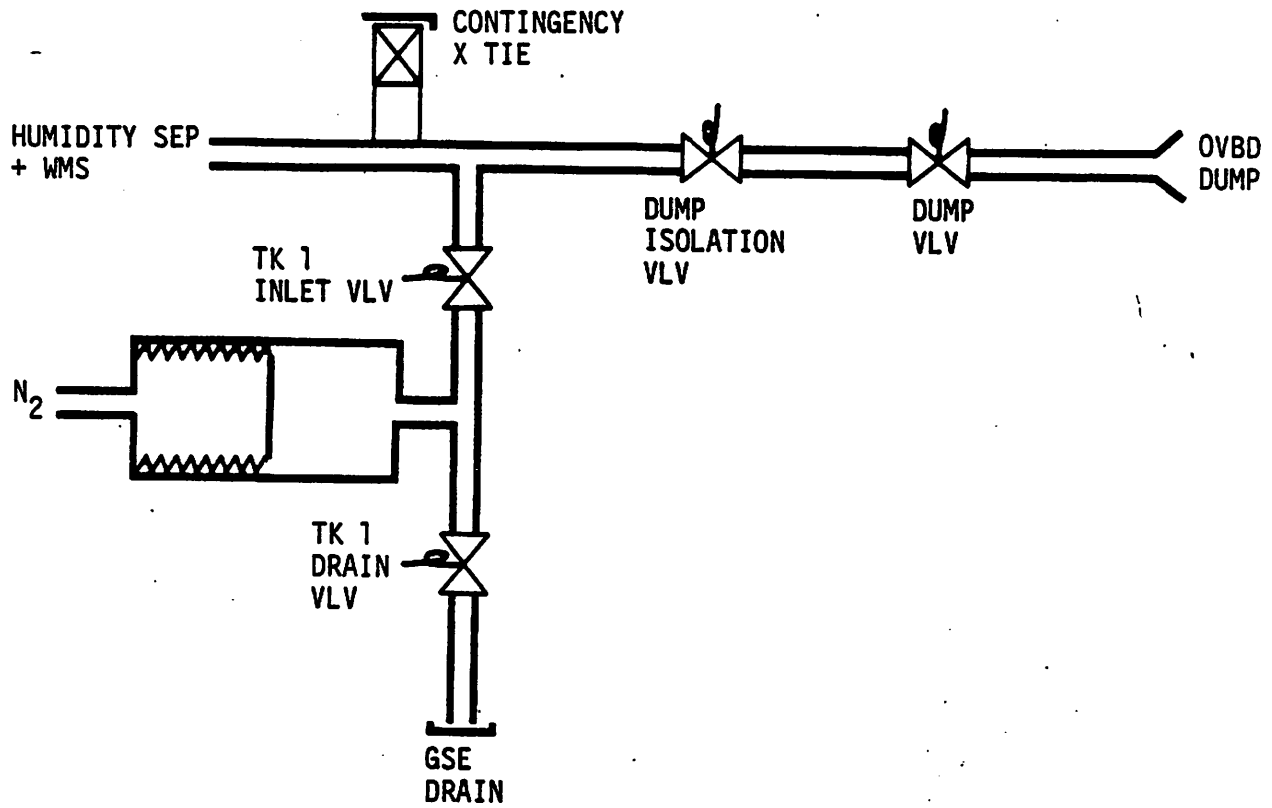


Figure 2.38.- Waste water storage.

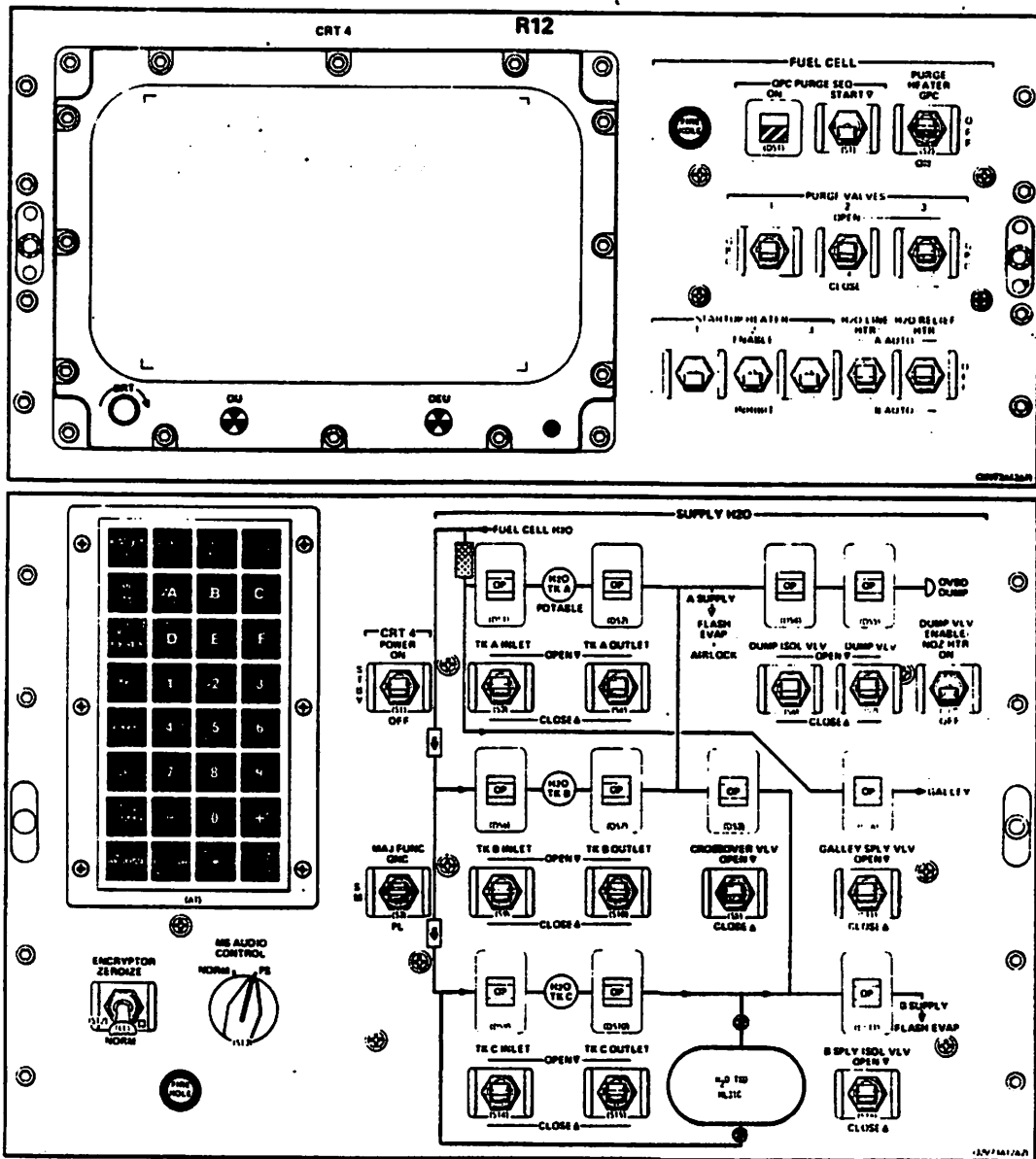


Figure 2-39.- Panel R12.

and closed for ascent and entry. The DUMP VLV ENABLE/NOZ HTR switch turns on the nozzle heater and enables the dump valve. The dump isolation valve and dump valve permit overboard dumping of supply water. The crossover valve in the center of the panel serves to isolate tanks A and B from tanks C, D, E, and F. Panel ML31C on the middeck contains the controls for the waste H<sub>2</sub>O storage and supply H<sub>2</sub>O tank D (see fig. 2-40). Tanks E and F are located on the middeck and have manual valves. Tank 1 drain valve is opened only on the ground for tank draining. In-flight, overboard dumping is done through the inlet valve. The dump valve enable/Noz Htr, dump valve and dump isolation valve operate exactly as the supply valves operate. The VAC VENT NOZ HTR turns the vacuum vent nozzle heater on or off.

The Vac Vent/Noz Htr provides a means of venting the waste collection system overboard. This is a 1.93 in. line. There are manual shutoff valves in the line. The H<sub>2</sub> separator and the N<sub>2</sub>/Emergency O<sub>2</sub> overboard relief interfaces with this line. The airlock, through a manual valve, also interfaces with this overboard vent.

Water management data is available to the crew on CRT display S66 (fig. 2-41). There are no class 2 SM alarms directly associated with the H<sub>2</sub>O management system. There are the following class 3 SM alerts:

CRT	MAJOR FIELD	MINOR FIELD CLASS	CONDITIONS
S66	H <sub>2</sub> O	3	Tk A-B-C-D-E F Qty <75% B >90 C >99 D >99 E >99 F >99
		3	Potable H <sub>2</sub> O Dumpline Temp <60°F or >120°F
		3	Potable H <sub>2</sub> O Dump Nozzle Temp <35°F
		3	Waste H <sub>2</sub> O Liquid Press >22 psig or <13 psig
		3	Waste H <sub>2</sub> O Tank Qty ≥90%
		3	Potable H <sub>2</sub> O Storage Inlet Press <28 >40
		3	Waste H <sub>2</sub> O Dump Nozzle Temp <35°F
		3	Vacuum Vent Temp >200°F
		3	Waste H <sub>2</sub> O Dump Line Temp ≤35°F

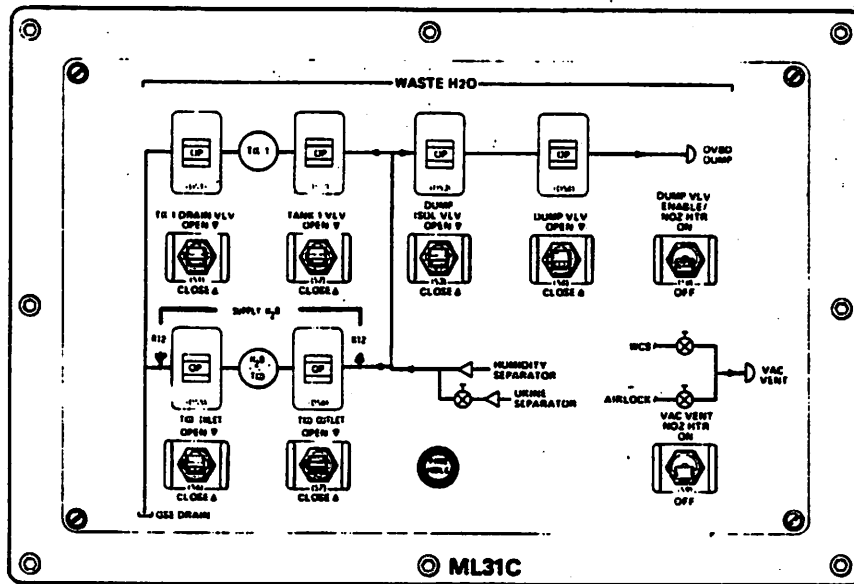


Figure 2-40.- Panel ML31C, waste H<sub>2</sub>O.

2011/ /066 ENVIRONMENT 2 237/14:35:02  
000/01:30:00

CABIN

dP/dT +.0	CABIN P	14.5	AV BAY	1	2	3
PPO2 A 3.2	AIRLK P	14.5	TEMP	90	90	90
B 3.2	FAN ΔP	0.25	FAN P	0.12	0.12	0.15
C 3.2	HX OUT T	65				
	CABIN T	75				

H2O

	1	2	SUPPLY			
O2 FLOW	0.0	0.0	QTY A	100	PRESS	30
REG P	100	0	B	50	DMP LN T	75
N2 FLOW	1.1	0.0	C	98	NOZ T A	60
REG P	200	0	D	98	B	60
O2/N2 CNTL VLV	N2	N2	E	98		
H2O TK N2 P	16	16	F	98		
N2 QTY	70	70				
EMER O2 QTY	55		WASTE			
REG P	300		QTY 1	80	PRESS	17
					DMP LN T	60
	A	B	C	ΔP	NOZ T A	60
IMU FAN *				3.0	B	60
HUMID SEP *					VAC VT NOZ T	100

2-73

Figure 2-41.- Display S66..

3-ECLSS

TABLE 2-IV.- H<sub>2</sub>O MANAGEMENT

PANEL	TYPE	NOMENCLATURE/ POSITION	FUNCTION	REMARKS
L1	2-pos toggle	H <sub>2</sub> O ALT PRESS OPEN-CLOSE	Opens a valve to permit cabin air to pressurize the supply and waste H <sub>2</sub> O tanks.	
ML31C	3-pos toggle (spring-loaded)	WASTE H <sub>2</sub> O TK 1 DRAIN VLV OPEN-CLOSE	Opens/closes waste water Tank 1 Outlet valve.	
ML31C	3-pos toggle (spring-loaded)	WASTE H <sub>2</sub> O TANK 1 VALVE OPEN-CLOSE	Opens/closes Tank 1 Inlet Valve.	
ML31C	talkback	WASTE H <sub>2</sub> O TANK 1 VALVE OPEN-CLOSE	Indicates the Position of the Tank 1 Drain Valve.	
ML31C	talkback	WASTE H <sub>2</sub> O TANK 1 VALVE OPEN-CLOSE	Indicates the position of the Tank 1 Valve.	
ML31C	3-pos toggle	SUPPLY H <sub>2</sub> O TK D INLET OPEN-CLOSE	Opens/closes the Tank D inlet valve.	
ML31C	talkback	SUPPLY H <sub>2</sub> O TK D INLET OPEN-CLOSE	Indicates the position of the Tank D Inlet Valve.	
ML31C	3-pos toggle (spring-loaded)	SUPPLY H <sub>2</sub> O TK D OUTLET OPEN-CLOSE	Opens/closes the Tank D outlet valve.	
ML31C	talkback	SUPPLY H <sub>2</sub> O TK D OUTLET OPEN-CLOSE	Indicates the position of the Tank D Outlet Valve.	
ML31C	3-pos toggle (spring-loaded)	WASTE H <sub>2</sub> O DUMP ISOL VLV OPEN-CLOSE	Opens/closes the waste dump isolation valve.	
ML31C	talkback	WASTE H <sub>2</sub> O DUMP ISOL VLV OPEN-CLOSE	Indicates the position of the dump isolation valve.	

TABLE 2-IV.- H<sub>2</sub>O MANAGEMENT

PANEL	TYPE	NOMENCLATURE/ POSITION	FUNCTION	REMARKS
ML31C	3-pos toggle (spring-loaded)	WASTE H <sub>2</sub> O DUMP VLV OPEN-CLOSE	Opens/closes the waste overboard dump valve.	
ML31C	talkback	WASTE H <sub>2</sub> O DUMP VLV OPEN-CLOSE	Indicates the position of the waste overboard dump VLV.	
ML31C	2-pos toggle	WASTE H <sub>2</sub> O ENABLE/NOZ HTR ON-OFF	Turns ON-OFF the dump nozzle heater and provides power to the waste H <sub>2</sub> O dump valve.	
ML31C	2-pos toggle	WASTE H <sub>2</sub> O NOZ HTR/VAC VENT ON-OFF	Turns ON-OFF the vacuum vent nozzle heater.	
ML86B	circuit breaker	MN A SUPPLY H <sub>2</sub> O TK A INLET	Main A power to Tank A inlet switch on Panel R12.	1 cb
ML86B	circuit breaker	MN A SUPPLY H <sub>2</sub> O TK B OUTLET	Main A Power to Tank B outlet switch on Panel R12.	1 cb
ML86B	circuit breaker	MN A H <sub>2</sub> O LINE HTR A	Main A power to H <sub>2</sub> O dump and vacuum vent line heaters.	1 cb
ML86B	circuit breaker	MN B SUPPLY H <sub>2</sub> O TK B INLET	Main B power to H <sub>2</sub> O Tank B Inlet switch on Panel R12.	1 cb
ML86B	circuit breaker	MN B SUPPLY H <sub>2</sub> O TK C OUTLET	Main B power to H <sub>2</sub> O Tank C Outlet switch on Panel R12.	1 cb
ML86B	circuit breaker	MN B SUPPLY H <sub>2</sub> O DUMP ISOL	Main B power to the dump ISOL switch on Panel R12.	1 cb
ML86B	circuit breaker	MN B SUPPLY H <sub>2</sub> O B SPLY ISOL VLV	Main B power to the B SPLY Isolation switch on Panel R12.	1 cb

TABLE 2-IV.- H<sub>2</sub>O MANAGEMENT

PANEL	TYPE	NOMENCLATURE/ POSITION	FUNCTION	REMARKS
ML86B	circuit breaker	MN B H <sub>2</sub> O LINE HTR B	Main B power to H <sub>2</sub> O dump and vacuum vent line HTRS.	1 cb
ML86B	circuit breaker	MN C SUPPLY H <sub>2</sub> O TK A OUTLET	Main C power to H <sub>2</sub> O TK A OUTLET switch on Panel R12.	1 cb
ML86B	circuit breaker	MN C SUPPLY H <sub>2</sub> O TK C INLET	Main C power to H <sub>2</sub> O TK C INLET switch on Panel R12.	1 cb
ML86B	circuit breaker	MN C SUPPLY H <sub>2</sub> O DUMP	Main C power to Dump Valve Nozzle Heater switch on Panel R12.	1 cb
ML86B	circuit breaker	MN C SUPPLY H <sub>2</sub> O XOUR VLV	Main C power to Crossover Valve switch on Panel R12.	1 cb
ML86B	circuit breaker	MN C SUPPLY H <sub>2</sub> O GALLEY SUPPLY	Main C power to Galley Supply switch on Panel R12.	1 cb
ML86B	circuit breaker	MN A WASTE H <sub>2</sub> O TK 1 VLV	Main A power to Tank 1 valve on Panel ML31C.	1 cb
ML86BB	circuit breaker	MN A SUPPLY H <sub>2</sub> O TK D OUTLET	Main A power to Tank D Outlet switch on Panel ML31C.	1 cb
ML86B	circuit breaker	MN A WASTE H <sub>2</sub> O DUMP ISOL	Main A power to Dump Isolation switch on Panel ML31C.	1 cb
ML86B	circuit breaker	MN B WASTE H <sub>2</sub> O TK 1 DRAIN	Main B power to Tank 1 Drain switch on Panel ML31C.	1 cb
ML86B	circuit breaker	MN B SUPPLY H <sub>2</sub> O TK D INLET	Main B power to Tank D Inlet switch on Panel ML31C.	1 cb



TABLE 2-IV.- H<sub>2</sub>O MANAGEMENT

PANEL	TYPE	NOMENCLATURE/ POSITION	FUNCTION	REMARKS
ML86B	circuit breaker	MN B WASTE H <sub>2</sub> O VAC VENT	Main B power to Vacuum Vent Nozzle Heater switch on Panel ML31C.	1 cb
ML86B	circuit breaker	MN C WASTE H <sub>2</sub> O DUMP VLV NOZ HTR	Main C power to Dump Valve Enable/ Nozzle Heater switch on Panel ML31C.	
016	circuit breaker	MN C H <sub>2</sub> O ALT PRESS	Provides Main C power to the H <sub>2</sub> O Alternate Pressure switch on Panel L1.	1 cb
R12	3-pos toggle (spring- loaded)	SUPPLY H <sub>2</sub> O TK A INLET OPEN-CLOSE	Opens/closes the supply H <sub>2</sub> O Tank A inlet valve.	
R12	talkback	SUPPLY H <sub>2</sub> O TK A INLET OPEN-CLOSE	Indicates the OPEN- CLOSE position of the Tank A inlet valve.	
R12	3-pos toggle (spring- back)	SUPPLY H <sub>2</sub> O TK A OUTLET OPEN-CLOSE	Opens/closes the Tank A outlet valve.	
R12	talkback	SUPPLY H <sub>2</sub> O TK A OUTLET OPEN-CLOSE	Indicates the posi- tion of the Supply H <sub>2</sub> O Tank A outlet valve.	
R12	3-pos toggle	SUPPLY H <sub>2</sub> O TK B INLET OPEN-CLOSE	Opens/closes the Tank B Inlet Valve.	
R12	talkback	SUPPLY H <sub>2</sub> O TK B INLET OPEN-CLOSE	Indicates the OPEN- CLOSE position of the Tank B Inlet Valve.	
R12	3-pos toggle (spring- loaded)	SUPPLY H <sub>2</sub> O TK B OUTLET OPEN-CLOSE	Opens/closes the Tank B outlet valve.	

TABLE 2-IV.- H<sub>2</sub>O MANAGEMENT

PANEL	TYPE	NOMENCLATURE/ POSITION	FUNCTION	REMARKS
R12	talkback	SUPPLY H <sub>2</sub> O TK B OUTLET OPEN-CLOSE	Indicates the OPEN-CLOSE position of the Tank B outlet valve.	
R12	3-pos toggle (spring-loaded)	SUPPLY H <sub>2</sub> O TK C INLET OPEN-CLOSE	Opens/closes the Tank C inlet valve.	
R12	talkback	SUPPLY H <sub>2</sub> O TK C INLET OPEN-CLOSE	Indicates the OPEN-CLOSE position of the Tank C inlet valve.	
R12	3-pos toggle (spring-	SUPPLY H <sub>2</sub> O TK C OUTLET OPEN-CLOSE	Opens/closes the Tank C outlet valve.	
R12	talkback	SUPPLY H <sub>2</sub> O TK C OUTLET OPEN-CLOSE	Indicates the OPEN-CLOSE position of the Tank C outlet valve.	
R12	3-pos toggle (spring-loaded)	SUPPLY H <sub>2</sub> O CROSSOVER VLV OPEN-CLOSE	Opens/closes the crossover VLV permitting isolation or crossfeeding of the A/B Flash Evap Feedlines.	
R12	3-pos toggle (spring-loaded)	SUPPLY H <sub>2</sub> O DUMP ISOL VLV OPEN-CLOSE	Opens/closes the overboard dump isolation valve.	
R12	talkback	SUPPLY H <sub>2</sub> O DUMP ISOL VLV OPEN-CLOSE	Indicates the OPEN-CLOSE position of the dump isolation valve.	
R12	3-pos toggle (spring-loaded)	SUPPLY H <sub>2</sub> O DUMP VLV OPEN-CLOSE	Open/closes the overboard dump valve.	
R12	talkback	SUPPLY H <sub>2</sub> O DUMP VLV OPEN-VALVE	Indicates the OPEN-CLOSE position of the overboard dump valve.	

TABLE 2-IV.- H<sub>2</sub>O MANAGEMENT

PANEL	TYPE	NOMENCLATURE/ POSITION	FUNCTION	REMARKS
R12	2-pos toggle	SUPPLY H <sub>2</sub> O DUMP VLV ENABLE/NOZ HTR ON-OFF	Turns ON-OFF the dump valve Nozzle Heater and provides power to the dump valve switch.	
R12	3-pos toggle (spring-loaded)	SUPPLY H <sub>2</sub> O GALLEY SPLY VLV OPEN-CLOSE	Opens/closes the potable water for crew consumption and hygenic use.	
R12	talkback	SUPPLY H <sub>2</sub> O GALLEY SPLY VLV OPEN-CLOSE	Indicates the OPEN-CLOSE position of the Galley supply valve.	
R12	3-pos toggle (spring-loaded)	SUPPLY H <sub>2</sub> O B SPLY ISOL VLV OPEN-CLOSE	Opens/closes the B Supply Isolation Valve which provides water to the Flash Evaporator Feedline B.	
R12	talkback	SUPPLY H <sub>2</sub> O B SPLY ISOL VLV OPEN-CLOSE	Indicates the OPEN-CLOSE position of the B Supply Isolation valve.	

#### 2.4.4 Water and WMS Systems Performance, Limitations, and Capabilities

Fuel cell - ECLSS interface . . . . .	100 - 220° F
Max flow rate . . . . .	10.7 lb/hr
Max back pressure . . . . .	40 psia
Min back pressure . . . . .	10 psia
Storage volume . . . . .	168.3 lb/tank
Proof pressure . . . . .	37.5 psid
Burst pressure . . . . .	50 psid
Operating temperature range . . . . .	60 - 120° F
G limit . . . . .	5.0 G
Operating pressure . . . . .	15 psig
Supply temp from tank . . . . .	75° F
Tank flow rate . . . . .	0 - 150 lb/hr
Water dump flow capacity . . . . .	2.5 lb/min

APPENDIX A  
ACRONYMNS AND ABBREVIATIONS

ACCUM	accumulator
ALT	alternate
ARS	Atmosphere Revitalization System
ATCS	Active Thermal Control System
ATM	atmosphere
AV	avionics
BFS	Backup Flight System
CAB	cabin
CNTL	controller
C/P	cold plate
CRT	cathode ray tube
C&W	caution and warning
dc	direct current
DFI	Developmental Flight Instrumentation
DMP	dump
DP/DT	delta pressure/delta temperature
ECLSS	Environmental Control and Life Support System
EMER	emergency
EPS	Electrical Power System
EVAP	evaporator
FCL	Freon coolant loop
FE 21	Freon 21
FES	Flash Evaporator System
FREQ	frequency
GPC	General Purpose Computer
GSE	Ground Support Equipment
H <sub>2</sub> O	water
HYD	hydraulics
HX	heat exchanger
Hz	Hertz
ICH	interchanger
IMU	Inertial Measurement Unit
INTCHGR	interchanger
ISOL	isolation
lb	pound
LiOH	lithium hydroxide
MDM	multiplexer/demultiplexer
NEG	negative
NH <sub>3</sub>	ammonia
N <sub>2</sub>	nitrogen

NOZ nozzle  
O<sub>2</sub> oxygen  
OFI Operational Flight Instrumentation  
PNL panel  
PL payload  
POT potable  
PPCO<sub>2</sub> partial pressure carbon dioxide  
PPO<sub>2</sub> partial pressure oxygen  
PRI primary  
PROP proportioning  
psi pounds per square inch  
psia pounds per square inch absolute  
psid pounds per square inch differential  
psig pounds per square inch gauge  
PW pulse width  
QTY quantity  
RAD radiator  
REG regulator  
REST restrictor  
rpm revolutions per minute  
SEC secondary  
SEP separator  
SW software  
SYS system  
TEMP temperature  
TK tank  
TM telemetry