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MSFC SORTIE LAB ENVIRONMENTAL CONTROL SYSTEM (ECS) PHASE B DESIGN STUDY RESULTS

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Astronautics Laboratory

March, 1974

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16. ABSTRACT

Phase B effort of the Sortie Lab program has been concluded. Included herein are the results of that effort which pertains to the definitions of the environmental control system (ECS). Numerous design studies were performed in Phase B to investigate system feasibility, complexity, weight, and cost. The results and methods employed for these design studies are included.

The study has resulted in an autonomous Sortie Lab ECS, utilizing a deployed space radiator. Total system weight was projected to be 1814.4 kg (4000 lbs) including the radiator and fluids. ECS power requirements were estimated at 950 watts.

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TECHNICAL MEMORANDUM X-64832

MSFC SORTIE LAB ENVIRONMENTAL CONTROL SYSTEM (ECS) PHASE B DESIGN STUDY RESULTS

SECTION I. INTRODUCTION

The Sortie Lab (now named Spacelab) is a manned experiment module that will fly as a payload for the Space Shuttle. It remains attached to the Shuttle payload bay at all times during flight. The experimenters receive habitation support for food, waste management and sleeping accommodations in the Shuttle orbiter. Nominal mission duration is 7 days.

MSFC has conducted an in-house Phase B design study of the Sortie Lab to provide system definition prior to initiation of detailed design and fabrication, either in Europe or within the United States. The purpose of the report is to document the Environmental Control System (ECS) portion of the Phase B study. The study assumed that the Sortie Lab was autonomous from the Shuttle in regard to heat rejection and atmosphere revitalization. The projected Sortie Lab crew size is either a maximum of 4 men in the Lab at intervals or 3 men continuously.

The report confines itself primarily to the pressurized module. The ECS for the unpressurized pallet for experiment mounting should consist largely of heaters, insulation, and cold plates, which are very dependent upon the final experiment configurations and requirements.

SECTION II. ENVIRONMENTAL CONTROL SYSTEM (ECS)

The Sortie Lab ECS definition must consider a variety of design options to satisfy the experiment requirements, interface with other Sortie Lab/Shuttle subsystems, maintain a flexible design concept, and provide a low cost program approach. Previous sortie mission studies, such as the RAM Phase B and Sortie Lab Phase A, have provided good background data for satisfying the ECS design goals. A factor which has influenced all of these studies for the past two years is the lack of firm Shuttle interface design data. For this reason, the best design approach for the payload ECS has been to remain as independent of the Shuttle design as possible. This approach provides an advantage to both programs by minimizing sensitivity of (a) Sortie Lab program to Shuttle design changes and (b) impacting Shuttle designs with changing or variable experiment requirements. The ECS trade studies which have been conducted concerning Shuttle resource utilization are discussed in Section VI.

The basic ECS functions required in the lab are given below. A summary of the design requirements for ECS definition are given in Tables 1, 2 and 3. A discussion of how these various design requirements are derived is given in the respective functional design sections which follow.

Crew comfort requirements for the Sortie Lab were not based on average mission metabolic rate, 126 W (430 Btu/Hr), but on a daily expected range of crew activity, 117 to 176 W (400 to 600 Btu/Hr). The comfort envelope for this range of activity levels is given in Figure 1. The crew comfort zone was defined employing minimal restraints on the crew activities by using variable cabin air temperatures and various levels of clothing for the expected metabolic ranges. Maintaining environments in the comfort envelope will allow transient periods of work at much higher rates without discomfort. The range of metabolic levels was chosen based on a minimum level of 117 W (400 Btu/Hr) for an active (awake) crewman and an average maximum level of 176 W (600 Btu/Hr) for mission work which will require four or more hours. The comfort zone is based on the fact that some parameters can be controlled without compromising crew activity. Parameters such as metabolism and ventilation levels are controlled only over a range of values (not selective control in this range). The cabin mean radiant wall temperature can also be included in this category. Other parameters such as crew clothing level and cabin air temperature are assumed controlled by the crew to maintain confort.

TABLE 1. BASELINE ECS DESIGN CRITERIA FOR SORTIE LAB

Mission Length (days)	
(a) Nominal	7
(b) Extended	Up to 30
Payload Crew for Sizing Consumables (7-day mission)	
(a) Maximum (3 crewmen in lab continuous, two shift operation)	42 Man-Days
(b) Nominal (4 crewmen, one shift operation or 2 crewmen, two shift operation)	28 Man-Days
(c) Minimum (2 crew, one shift operation or 1 crewman, two shift operation)	14 Man-Days
Payload Crew Distribution (number of crewmen in the lab at the same time)	
(a) Design point (nominal)	2
(b) Maximum	4
(c) Minimum	0
Pressurized Volumes, m^3 (ft^3)	
(a) Standard module (maximum)	100.1 (3535)
(b) Scientific airlock	2.4 (85)
Repressurization Requirements	
(a) Standard module	Once/Mission
(b) Scientific airlock	1/Day
Atmosphere Leakage, kg/day (lb/day)	
Ambient pressure, 10.1 N/cm^2 (14.7 psia)	1.36 (3)

Cabin Atmosphere

(a)	Total pressure, N/cm^2 (psia)	10.13 ± 0.14 (14.7 ± 0.2)
(b)	Oxygen partial pressure, N/cm^2 (psia)	2.14 ± 0.07 (3.1 ± 0.1)
(c)	Diluent	N_2
(d)	Carbon Dioxide partial pressure	Less than 7.6 mm Hg
(e)	H_2O partial pressure	
	- Range	6-11 mm Hg
	- Nominal	8-9 mm Hg

Metabolic Heat Generation, W/man (BTU/hr-man)		Sensible	Latent	Total
(a)	Maximum design	115 (392)	61 (208)	176 (600)
(b)	Nominal design	102 (350)	61 (208)	163 (558)
(c)	Minimum design	88 (300)	29 (100)	117 (400)

O_2 Consumption, kg/man-day (lb/man-day)

(a)	Nominal design	0.84 (1.84)
(b)	Range	0.77 to 1.0 (1.69 to 2.2)

CO_2 Production, kg/man-day (lb/man-day)

(a)	Nominal design	1.00 (2.20)
(b)	Range	0.87 to 1.22 (1.92 to 2.68)

Water Requirements

(a)	Ingested water, kg/man-day (lb/man-day)	Provided by Shuttle
(b)	Experiments, kg/man-day (lb/day)	TBD

Crew Waste Management

(a)	Urine	Provided by Shuttle
(b)	Feces	Provided by Shuttle
(c)	Trash	Provided by Shuttle

On-Orbit Total Heat Rejection for Radiator Design, kW (BTU/hr)

(a) Maximum	8.55 (29,200)
(b) Nominal	3.99 (13,640)
(c) Minimum	2.00 (6,820)

On-Orbit Cabin Air Thermal Loads, kW (BTU/hr)

(a) Maximum	2.93 (10,000)
(b) Nominal	1.76 (6,000)
(c) Minimum	0.73 (2,500)

Crew Comfort Requirements

(a) Designed for standing man	
- Body surface area, convection, m^2 (ft^2)	1.81 (19.5)
- Body suface area, radiation, m^2 (ft^2)	1.44 (15.5)
(b) Ventilation level over body, m/min (ft/min)	6.1 to 15.2 (20 to 50)
(c) Available clothing variation (clo)	0.35 to 1.0
(d) Metabolic activity variation, Watts (BTU/hr)	117 to 176 (400 to 600)

Cabin Wall Temperature, °C (°F)

(a)[1] Mean radiant	15.6 to 26.7 (60 to 80)
(b) Limit maximum surface temperature that crew might contact	40.6 (105)

Cabin Air Temperature, °C (°F)

(a) Selective range	18.3 to 29.4 (65 to 85)
(b) Nominal set point (design goal)	23.2 ± 1.1 (74 ± 2)

---

[1] In calculating man's radiant heat exchange with his environment, the mean radiant wall temperature "seen" by the man must be used rather than the average wall temperature. Mean radiant temperature is calculated as the summation of the temperature of area surrounding the man multiplied by their subtended solid angle from the man divided by the total solid angle.

TABLE 2. TYPICAL ON-ORBIT THERMAL LOADS FOR SORTIE LAB[2]

Heat Source	Magnitude	
	Watts	BTU/hr
Experiments	293 → 5856	1000 → 20,000
Subsystems	1757 → 2342	6000 → 8000
Fuel Cell Waste Heat	849 → 4392	2900 → 15,000
Crew Metabolism	0 → 703	0 → 2400
Heat Leak	± 146.4	± 500
TOTAL	2928 → 13,469	10,000 → 46,000

TABLE 3. ORBITAL ENVIRONMENT DESIGN CRITERIA

Orbital Heat Flux Source	Maximum (+ 3 σ Deviation)	Nominal	Minimum (- 3 σ Deviation)
Solar Constant, W/m^2 ($BTU/hr\text{-}ft^2$)	1393 (442)	1352 (429)	1311 (416)
ALBEDO (%)	48	30	12
Earth IR, W/m^2 ($BTU/hr\text{-}ft^2$)	299 (95)	236 (75)	173 (55)

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2. Sources:
   (a) Sortie Lab Conceptual Design Study, PD-DO-72-2, March 1, 1972
   (b) Research and Applications Module (RAM) Phase B Study, Contract NAS8-27539, May 1972
   (c) GSFC Space Shuttle Sortie Workshop, August 1972
   (d) Sortie Lab Phase B Study, Task 4.1, October 1972

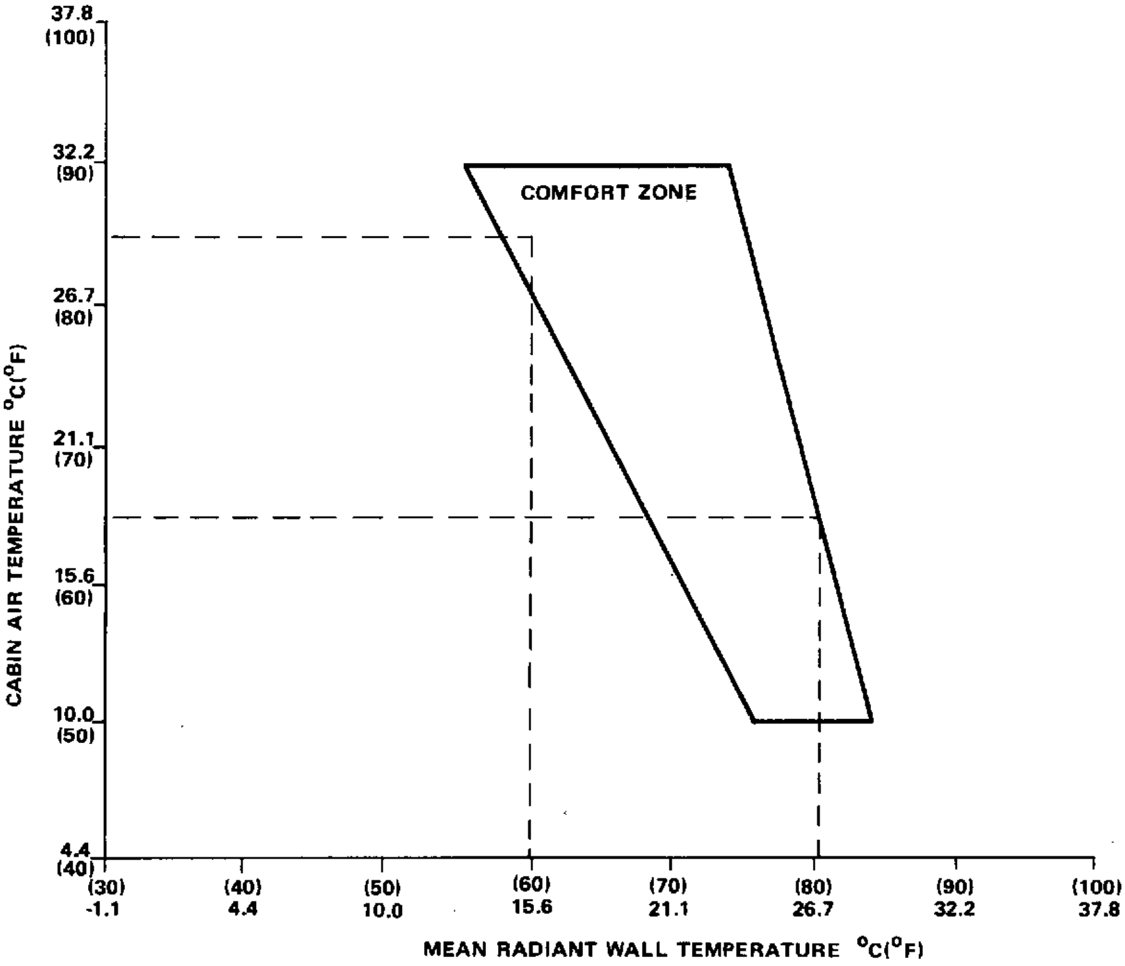


Figure 1. Crew comfort envelope.

The Shuttle will provide the following facilities for the Sortie Lab experimenters:

- Food Management
- Personal Hygiene (crew water and waste management)
- Sleeping Areas
- Launch and Reentry Provisions

In the following sections, a baseline ECS design is described and the associated studies to arrive at this design are reviewed.

MAJOR FUNCTIONS FOR SORTIE LAB ENVIRONMENTAL CONTROL SYSTEM

FLUID SUPPLY AND CONTROL	ATMOSPHERE CONDITIONING	THERMAL CONTROL
• O_2/N_2 Storage and Supply • Cabin Pressure Control • Airlock and Module Depressurization and Repressurization Control • Experiment Requirements • Water Management • Cryogens	• Circulation • Temperature Control • Humidity Control • CO_2 Control • Contaminant Control • Particulate Control	• Crew Comfort • Structural Heat Leak • Subsystem Conditioning • Experiment Conditioning • Heat Rejection

SECTION III. ENVIRONMENTAL CONTROL SYSTEM DESCRIPTION

The baseline ECS design that has evolved during the MSFC Phase B study is primarily independent of Shuttle orbiter functions, except in the habitability areas mentioned. It should be noted, however, that there is considerable commonality in the design approaches. Both systems operate at 10.1 N/cm^2 (14.7 psia) ambient pressure, shirt sleeve crew environments, water coolant circuit in the pressurized areas, and a freon-21 coolant circuit in the unpressurized areas. The basic method of heat rejection on-orbit is via space radiators. A block diagram is given in Figure 2.

The ECS is designed to support a crew which is equivalent to 21 man-days for missions of 7 days. The ECS will perform the following functions:

1. Maintain cabin atmosphere temperature, pressure, humidity, and composition within specified limits.

2. Provide cooling for experiment and subsystem equipment.

3. Collect and store water generated by fuel cells and condensate removed from the cabin atmosphere.

4. Supply water, as required, for experiment use or heat rejection purposes.

5. Reject waste heat to space through radiators or sublimator during flight and to GSE during preflight operations.

The basic capabilities of the system, as baselined, are summarized as follows:

- **Provides for up to 7 kW air cooling in cabin**
- **Experiment cooling available = 4 to 5 kW. (All air cooled if required).**
- **Heat rejection via radiators = 8.5 kW (orbital average)**
- **Total heat rejection using radiators plus sublimator = 10 to 11 kW (orbital average)**
- Normal cabin temperature = 23.9 ± 1.1°C (74 ± 2°F)

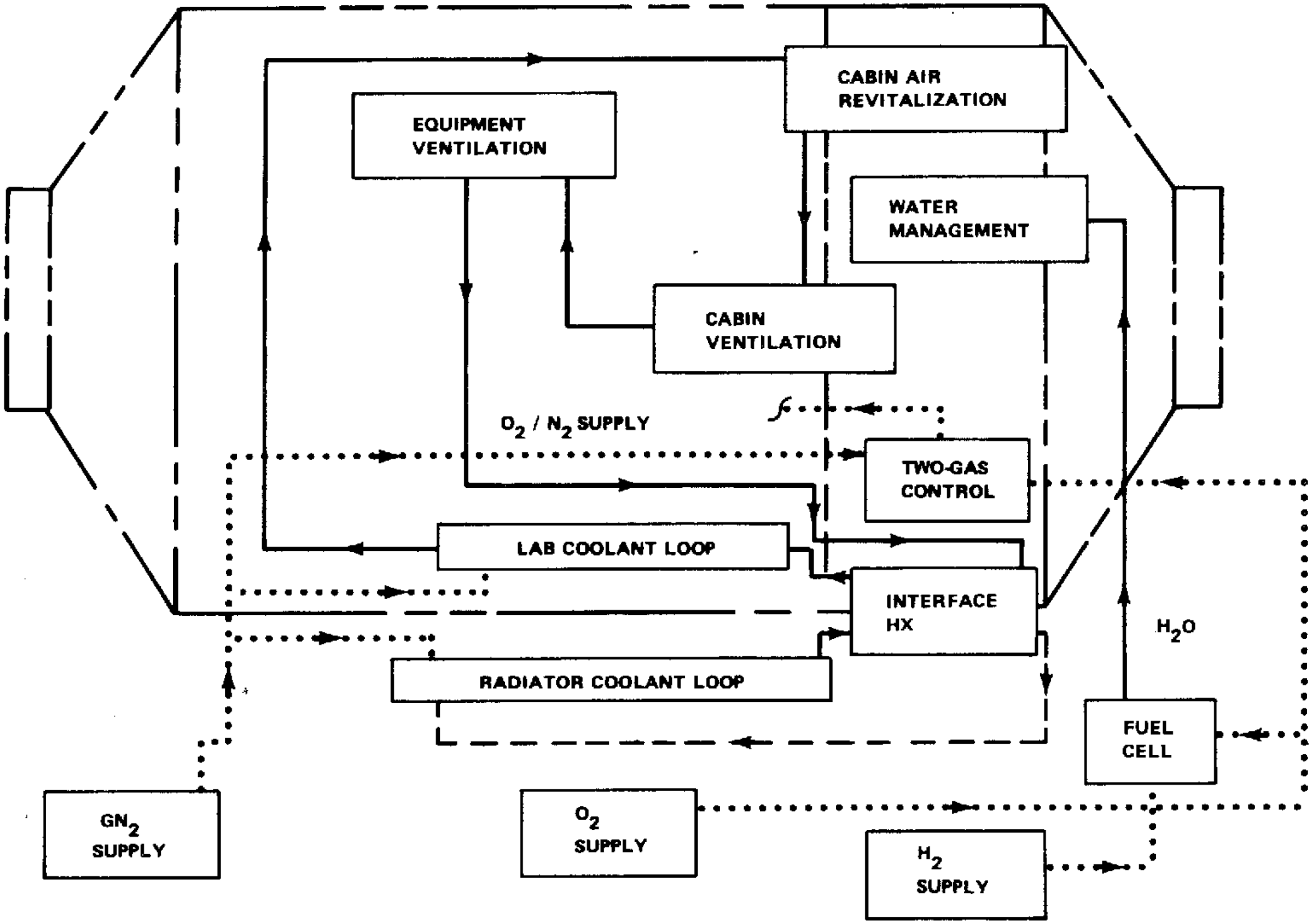


Figure 2. ECS block diagram.

- Normal CO_2 levels $\leqq$ 3mm Hg

- Normal dew point temperature = 7.2 ± 2.8°C (45 ± 5°F)

- Cabin air flitration for 100 μ airborne particles

- Eliminates all overboard dumping of water (fuel cell generated plus condensate) for all payload sensitive missions.

Mechanical and electromechanical schematics are given in Figures 3 and 4. Figure 5 is an illustration of the internal cabin configuration, with internal and external layouts given in Figures 6 through 7. A functional description of the ECS block diagram (Fig. 2) is as follows:

The radiator coolant loop rejects to space all heat generated within the lab cabin or by components located external to the lab cabin via the space radiator. A thermal capacitor is provided in the radiator coolant loop as a supplementary heat sink for transient conditions when the radiator is unable to reject the prevailing system thermal load. The lab coolant loop removes all heat generated within the lab cabin and rejects it to the radiator coolant loop via an interface heat exchanger. A sublimator is provided in the lab coolant loop as supplementary heat rejection for operating conditions when the lab/radiator interface heat exchanger is unable to remove the entire cabin heat load. The lab coolant loop receives heat inputs from three sources: the cabin air revitalization system, the cabin ventilation system, and the equipment ventilation system. The cabin air revitalization system removes CO_2 and moisture produced by crew activity plus some sensible loads. The cabin ventilation system filters the cabin air, removes cabin air thermal loads, and supplies conditioned air to the cabin via an air handling system. The cabin ventilation system is the controlling agent of the cabin drybulb temperature. The equipment ventilation system provides air circulation for the enclosed equipment racks and removes heat produced by subsystems and experiments. The two gas control system maintains the Sortie Lab total pressure and partial oxygen pressure by adding O_2 or N_2 as required. The N_2 supply for the two-gas controller is contained in high pressure bottles and the O_2 supply is stored under super critical conditions. The super critical O_2 supply and an H_2 super critical supply is used to store reactants for the O_2/H_2 fuel cell. Product water from the fuel cell is stored by the water management system for delivery to the sublimator upon demand. A summary of the ECS weight/power allocations are given in Tables 4 and 5, respectively.

A detailed discussion of a contaminant removal system design is given in Section V. It should be emphasized here, that to date, the Sortie Lab ECS design has not decided upon an optimum design solution for contaminant control. A major concern is how to address the problem associated with treatment of toxic gases emitted by commercial equipment.

FOLDOUT FRAME 1

FOLDOUT FRAME 2

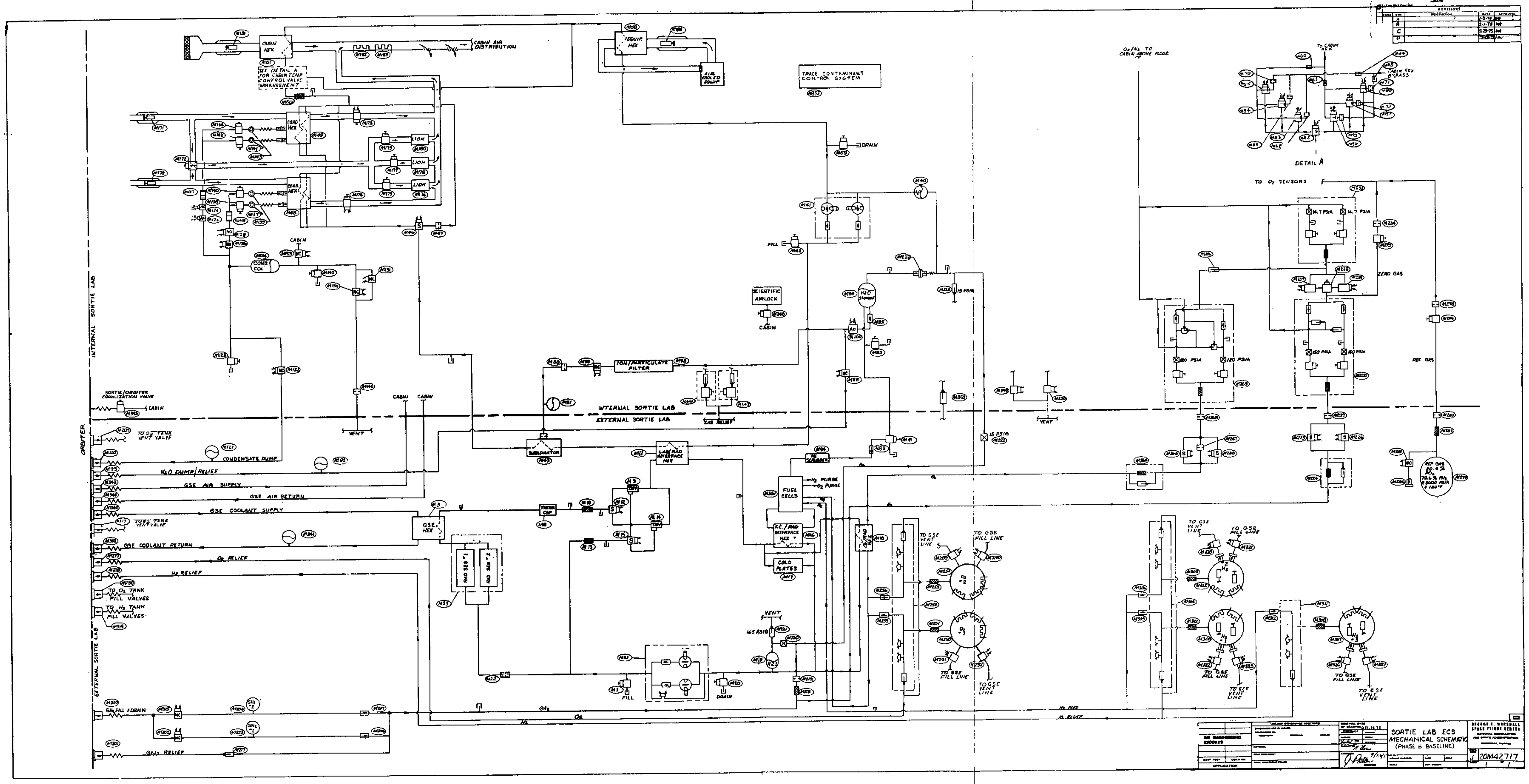


Figure 3. Sortie Lab ECS mechanical schematic.

FOLDOUT FRAME 1

FOLDOUT FRAME 2

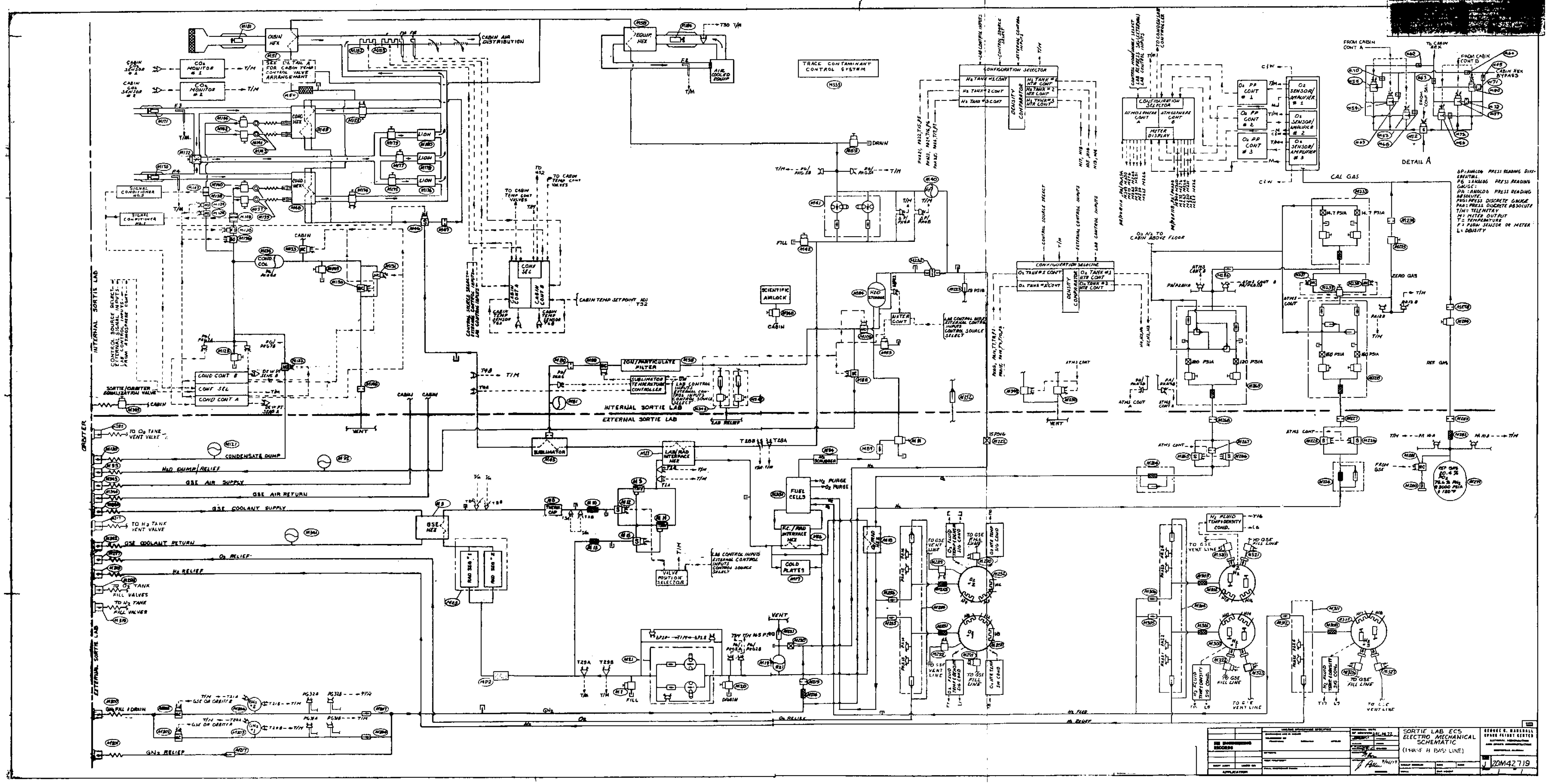


Figure 4. Sortie Lab ECS electro-mechanical schematic.

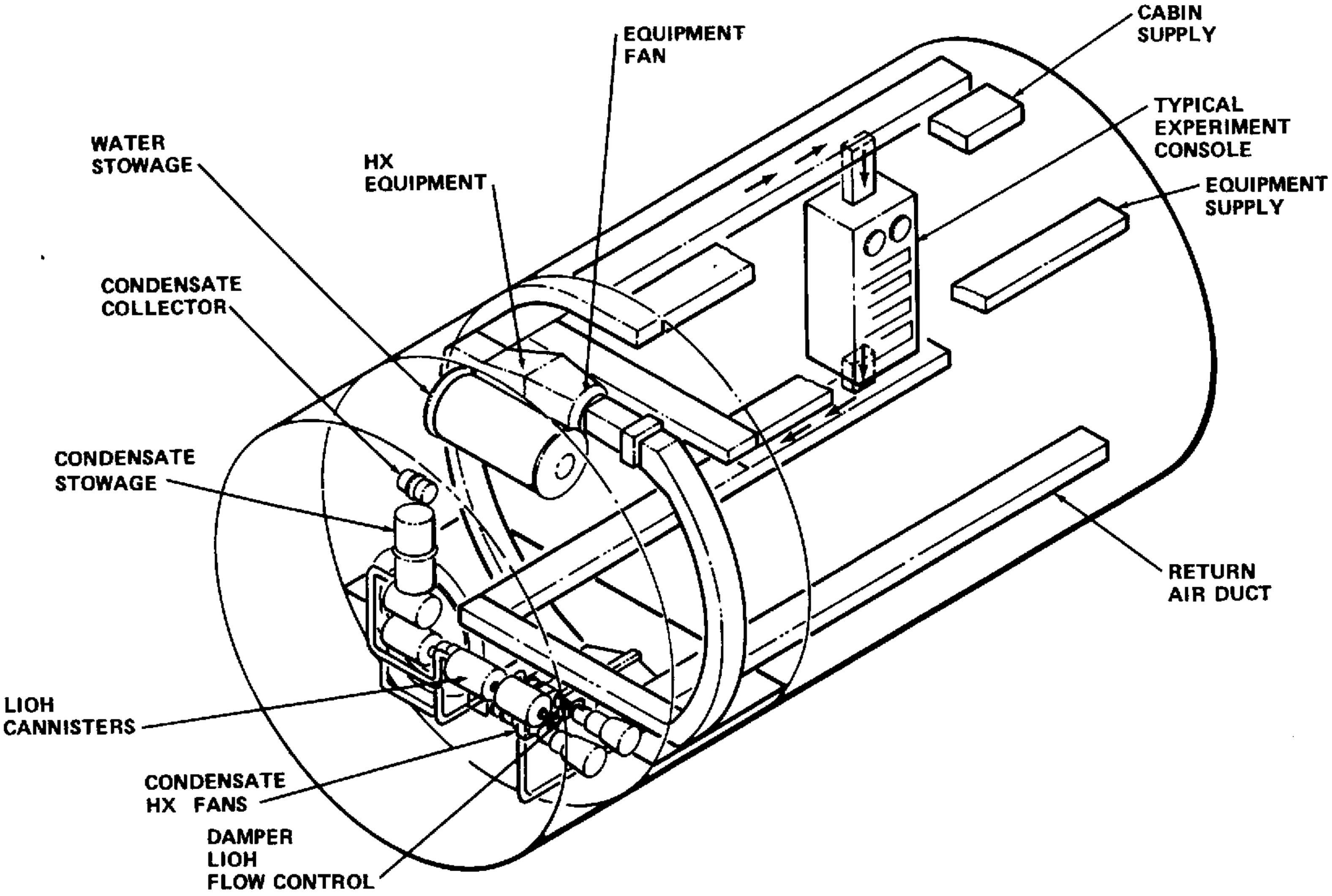


Figure 5. Internal cabin configuration.

FOLDOUT FRAME 1

FOLDOUT FRAME 2

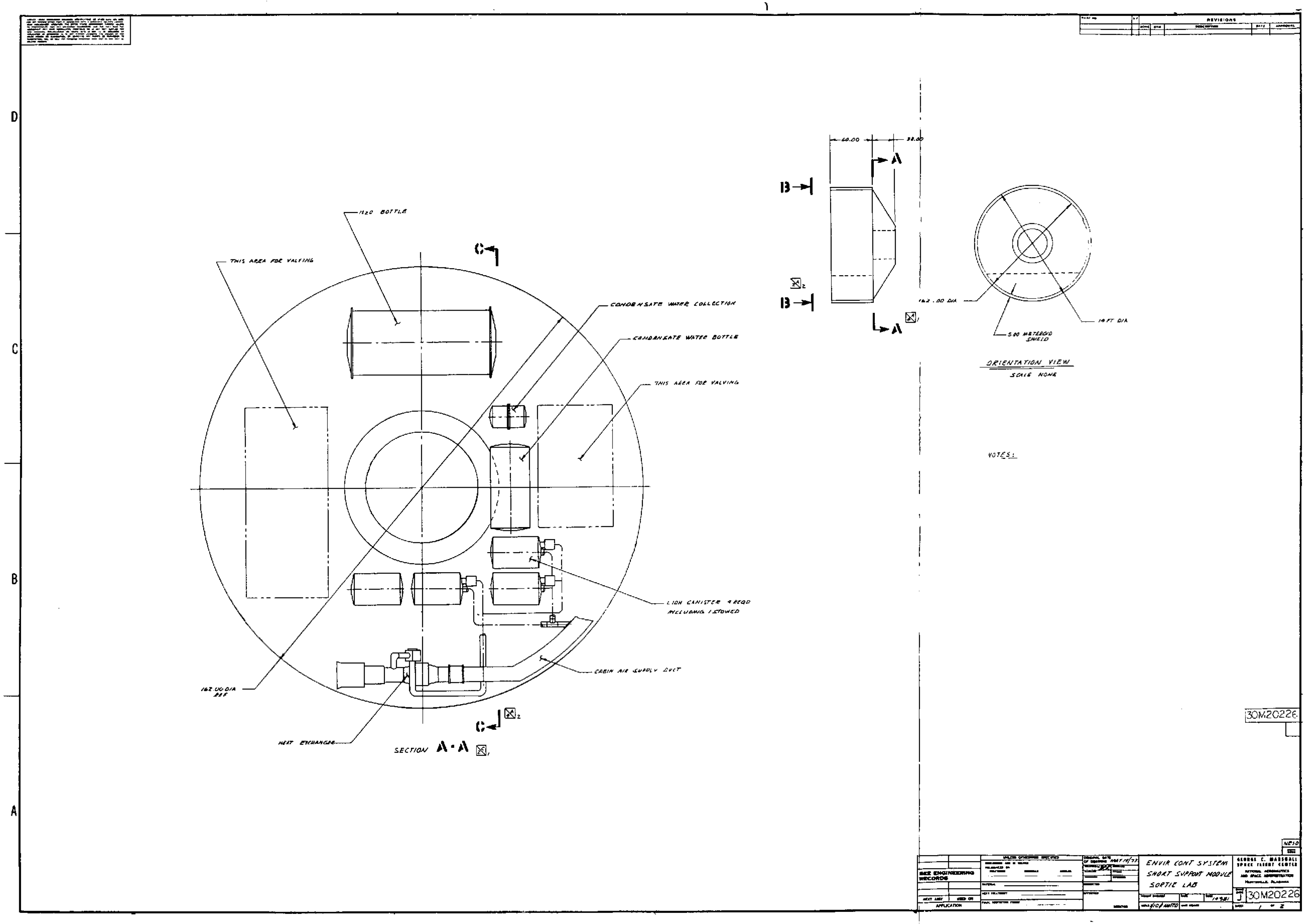


Figure 6. ECS short support module (Sheet 1).

FOLDOUT FRAME 1

FOLDOUT FRAME 2

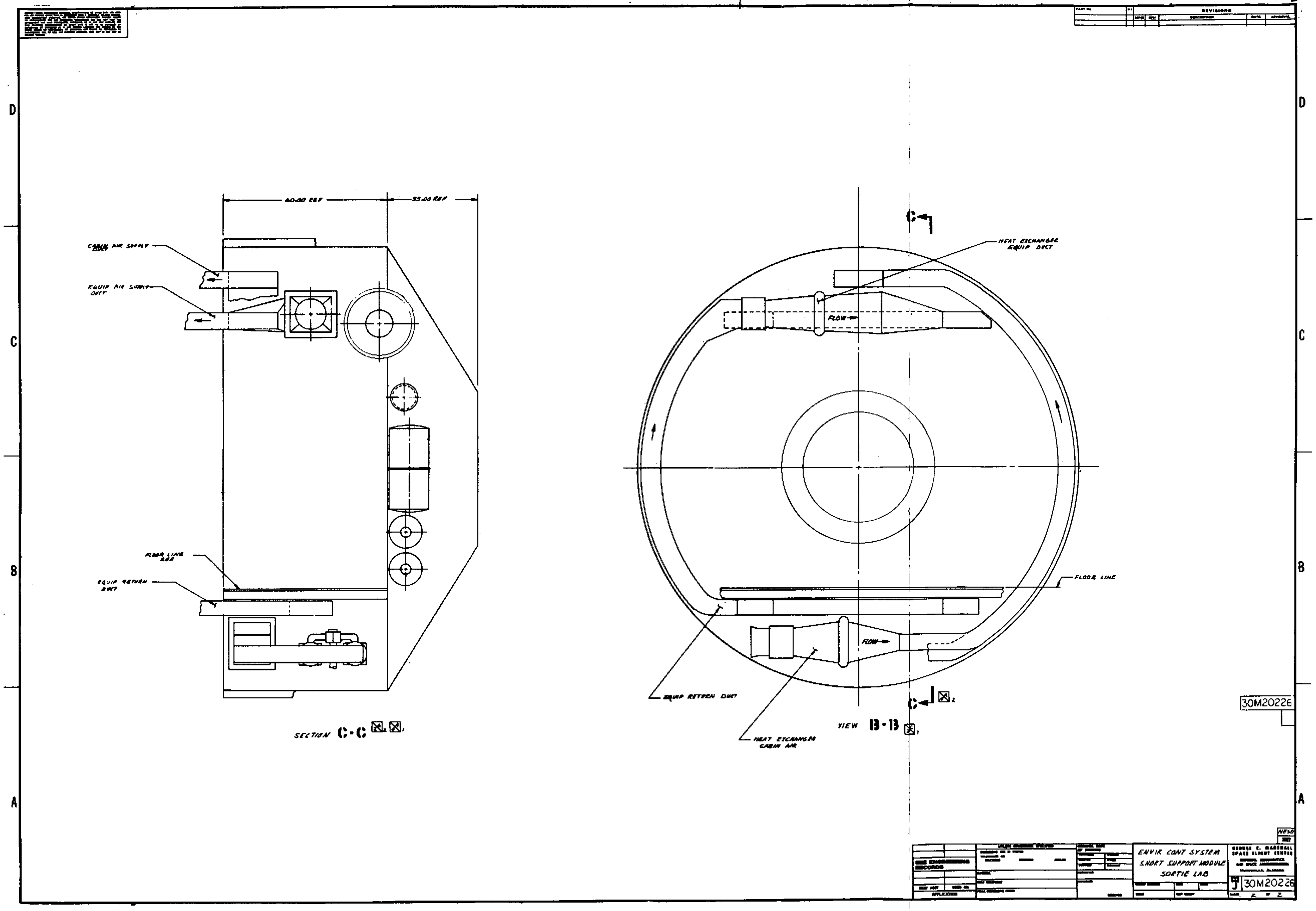


Figure 6. ECS short support module (Sheet 2).

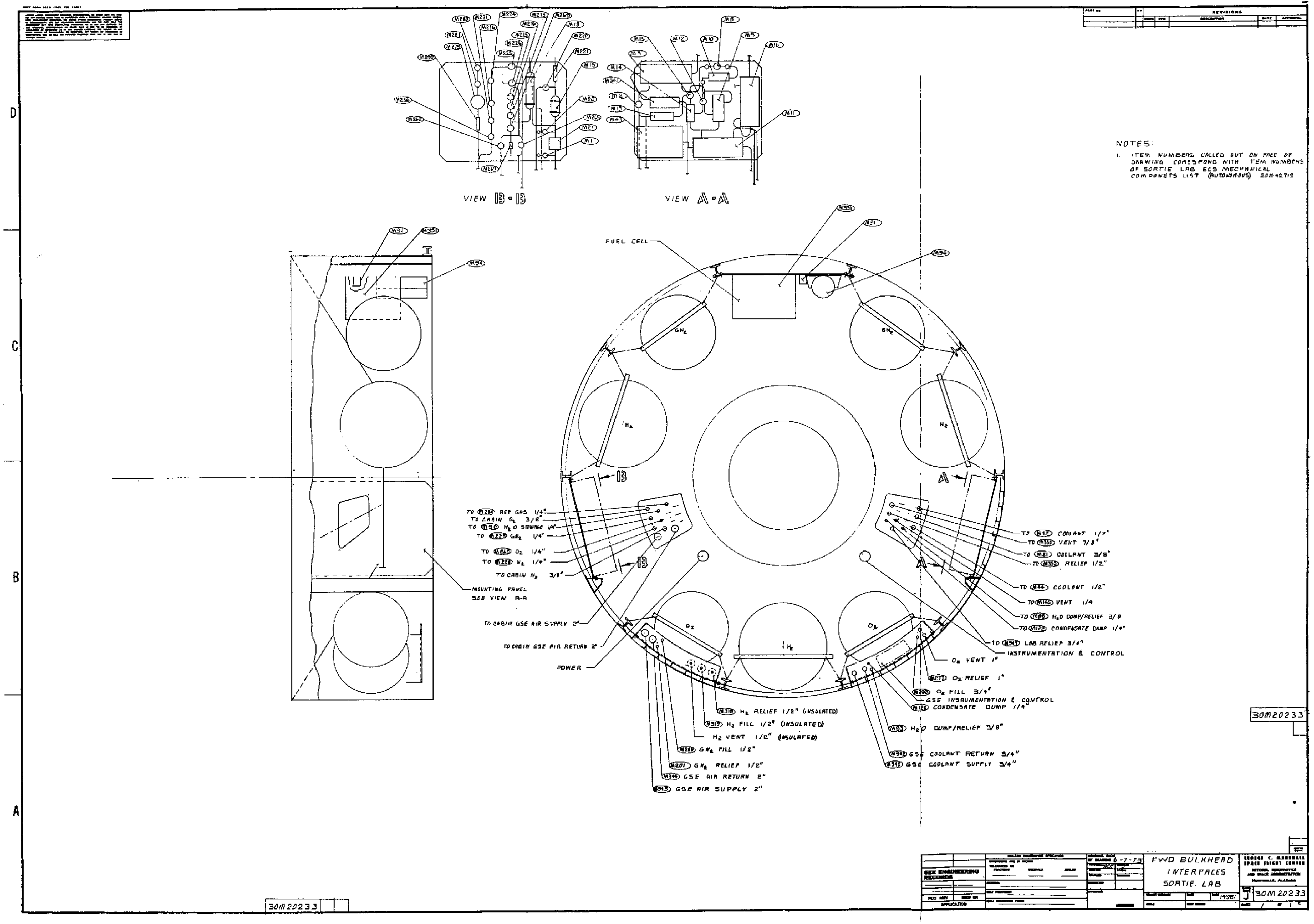


Figure 7. Forward bulkhead interfaces.

TABLE 4. ECS WEIGHT SUMMARY

Subsystem	Launch Weight									
	Components		Ducting and Tubing		Dry (Subtotal)		Fluids		Wet (Subtotal)	
	kg	lb	kg	lb	kg	lb	kg	lb	kg	lb
Freon Coolant Loop	553.4	1,220	11.3	25	564.7	1,245	94.3	208	659	1,453
Lab Coolant Loop	103.9	229	5.4	12	109.3	241	34.0	75	143.3	316
Water Mgmt	121.6	268	2.3	5	123.8	273	40.8	90	164.7	363
Air Conditioning	64.4	142	115.2	254	179.6	396	119.3	263	298.9	659
Condensate Collect	20.9	46	1.4	3	22.2	49	1.8	4	24.1	53
Nitrogen	88.4	195	3.2	7	91.6	202	29.9	66	121.5	268
Oxygen	11.3	25	1.8	4	13.2	29	18.6	41	31.7	70
Miscellaneous	129.7	286	4.1	9	133.8	295	3.2	7	137	302
Sidewall Insulation					249.5	550			249.5	550
Total	1,093.6	2,411	144.7	319	1,487.8	3,280	342	754	1,829.8	4,034

TABLE 5. ECS POWER ALLOCATION

Fluid Prime Mover Machinery*	
CO_2/Humidity Fans (2)	88 Watts
Cabin Ventilation Fan	125
Experiment Equipment Cooling Fan	265
Cabin Water Coolant Pump**	110
Freon 21 Coolant Pump***	200
	788 Watts
Electromechanical Valves (Estimated Average for 24 Hr/Day at 28 VDC)	
Cabin Temperature Control	50 Watts
Condensate Collection System	50
Atmosphere Controller (2-Gas System)	30
PPO_2 Controller	30
	160 Watts
Total Continuous Input Power	0.948 KW

* Input power to motor only (inverters excluded).
** Skylab ATM ECS canister pump.
*** Space Shuttle Freon 21 pump spec. value.

The baseline ECS accommodations for experiments are discussed more in Section IV. Throughout the design of the ECS, maximum use of Skylab hardware has been made to minimize cost and development time. The baseline designs are summarized as follows:

A. Radiator Design

A deployed radiator, approximately 69.7 m^2 (750 ft^2), is the required method of heat rejection for the non-deployed Sortie Lab concept. (The radiator thermal coating is a white paint.) The coolant in this circuit is freon-21 which is also the selected coolant for the Shuttle orbiter program. This loop provides a closely controlled inlet temperature, 3.3 ± 1.7°C (38 ± 3°F), at the heat exchanger which interfaces with the cabin water coolant loop. Temperature control is maintained by a temperature mixing valve which allows bypass of warm fluid around a cold radiator for low thermal loads. Other major items that are conditioned by the radiator loop are pallet cold plates, O_2 heat exchangers, and fuel cell coolant. The pump package maintains the system flow at 907.2 kg/hr (2000 lb/hr). The thermal capacitor, which contains a phase change material, $T_{melt} = 4.4°C$ (40°F), is used to absorb heat during transient periods when the space radiator performance is inadequate. The ground cooling heat exchanger is used for cooling of the freon loop (radiator bypassed) during ground operations. This allows prelaunch cooling of the thermal capacitor and thermal conditioning of the lab, if required. In addition to the thermal capacitor, a water sublimator has been baselined as a supplemental heat rejection method for radiator loads higher than average orbital thermal loads of 8.5 kw (29,200 BTU/hr). The space processing payloads normally require heat rejection in excess of the space radiator capacity. Rather than over size a radiator for this payload, the use of the fuel cell generated water for thermal control was selected. The total heat rejection capability of the radiator plus sublimator is 10 to 11 kw (depending on the total amount of water available for thermal control). This particular payload is not sensitive to external contamination.

B. Structural Heat Leak

The total structural heat leak (gain or loss) to the pressurized module has been minimized to free the thermal design from any orbital attitude constraints. In the preliminary design a total allowable heat leak of 146 w (500 BTU/hr) was assumed through Sortie Lab elements such as the tunnel, sidewalls, bulkheads, scientific airlock, and windows. High performance insulation was used extensively to maintain these structural heat leak designs.

C. Cabin Air Temperature Control

The cabin thermal control system removes heat from the interior of the lab and rejects the heat to the radiator loop through the liquid-to-liquid (freon/water) interface heat exchanger. The cabin coolant is water and is circulated through the system at 227 kg/hr (500 lb/hr). The water flows from the pump through the interface heat exchanger, sublimator, condensing heat exchanger, cabin heat exchanger, equipment heat exchanger, and back to the pump. The water is cooled in the interface heat exchanger and/or sublimator to 4.4 to 7.2°C (40 to 45°F). Two condensing exchangers are connected in parallel and remove moisture from the cabin atmosphere as required to maintain the desired cabin humidity. One condensing heat exchanger is required for a crew of two. Both units are required for a crew of three to four. A fan in each condensing heat exchanger circuit provides 1.27 m^3/min, (45 ft^3/min.) air flow across the heat exchanger. For a nominal two-man crew, only one fan is operating. For a four-man crew, both fans are operating. This design concept has operating flexibility to accommodate variable crew sizes and provides the low humidity levels required for optimum cabin air temperature control. Condensate from the heat exchangers will be stored for the duration of the 7-day mission. The maximum quantity of condensate to be stored is 56 kg (124 pounds).

The cabin heat exchanger is located in the cabin ventilation ducting and maintains the air temperature control for crew comfort. A total air flow of 15.3 m^3/min (540 ft^3/min) across the heat exchanger is provided by the cabin heat exchanger fan. A modulating flow control valve controls coolant flow through the cabin heat exchanger as required to maintain cabin air temperature at the set-point. The maximum heat removal capability of the cabin air circuit for crew comfort is ~3 kW (10,000 BTU/hr) at an ambient temperature of 23.3 ± 1.1°C (74 ± 2°F). This includes the heat removal capacity of the condensing heat exchangers. The allowed split in subsystem and experiment thermal loads for this circuit are still to be determined.

Until better information is obtained, the following design approach has been taken for thermal air conditioning of additional laboratory equipment. An air distribution and thermal conditioning circuit specifically for equipment racks (separate from the crew comfort circuit) will be designed for handling up to ~4 kW (14,000 BTU/hr) air cooling loads. The heat exchanger selected for this circuit is the same type as the cabin heat exchanger. The maximum air flow across the heat exchanger is 19.8 m^3/min (700 ft^3/min). The air and water coolant temperatures in this circuit are a function of cabin and rack thermal loads The maximum return air temperature from the racks is

40.6°C (105°F). An illustration of the air distribution designs for both the cabin and equipment circuits is given in Figure 5. The cabin circuit uses the floor as a return duct, whereas, the equipment circuit has return ducts. No attempt has been made to completely isolate the two compartments, however, the baseline design does tend to isolate contaminants that might occur due to off-gassing from electronic equipment (particularly odors).

D. CO_2 Removal

The CO_2 removal system consists of three lithium hydroxide (LiOH) canisters connected in parallel and integrated with the humidity control system (Figure 8).

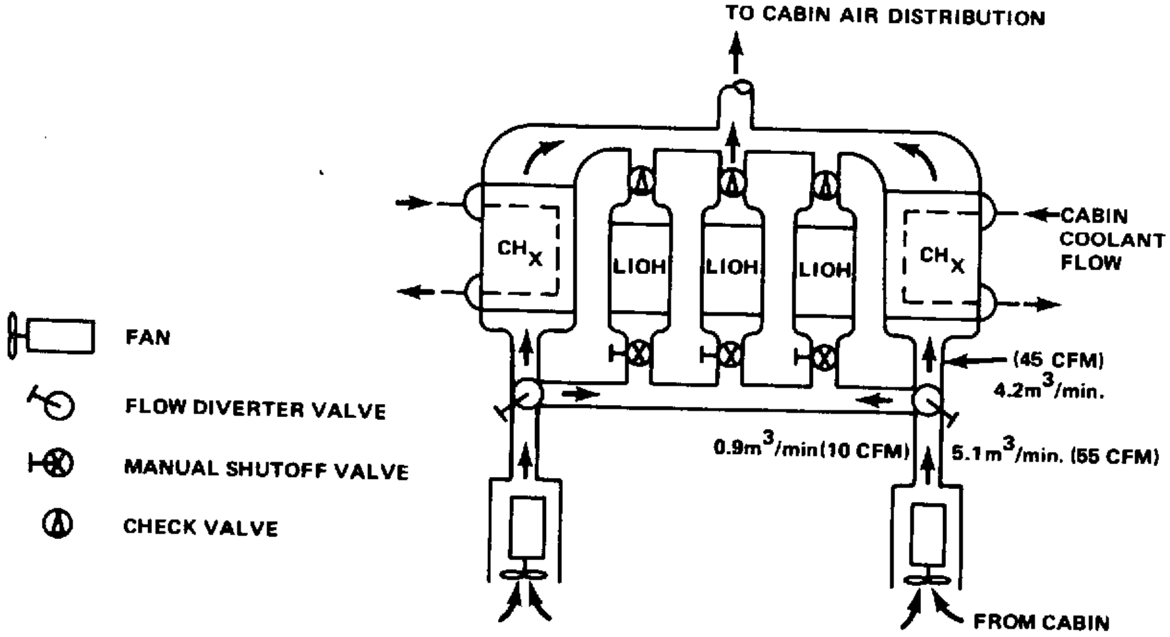


Figure 8. Design concept for CO_2 removal/humidity control.

For a nominal two-man crew, only one fan is operating. This fan provides air flow through both the condensing heat exchanger 1.27 m^3/min (45 ft^3/min) and the LiOH canister 0.28 m^3/min (10 ft^3/min). For a four-man crew, both fans are operating. Each condensing heat exchanger has 1.27 m^3/min (45 ft^3/min) air flow and the total air flow through the LiOH canister is 0.57 m^3/min (20 ft^3/min). As each LiOH canister is expended, the crew diverts the air flow to a fresh canister.

E. Atmosphere Supply and Control

The atmosphere supply and control design maintains the pressurized lab at 10.14 N/cm^2 (14.7 psia), supplies gaseous oxygen and nitrogen for repressurization of the scientific airlock, supplies oxygen for metabolic consumption. The design also includes vent and relief components which permit the lab to be vented to the outside environment and prevent the lab structure from being exposed to excessive internal or external pressure differentials. A separate nitrogen gas supply is used for pressurization of the accumulators in the coolant circuits and the water storage tanks. The 7 day mission atmosphere consumables carried by the lab ECS are 24.5 kg (54 pounds) of oxygen and 23.1 kg (51 pounds) of nitrogen. The breakdown of of these consumables is discussed in Section V. The ECS oxygen requirements are integrated with the fuel cell cryogenic tankage and constitute a 5 to 10 percent increase above the oxygen reactant required for power generation.

The oxygen gas for ECS is supplied from the fuel cell cryogenic tankage at 621 N/cm^2 (900 psia) and -184°C (-297°F). Through an interface with the radiator loop the oxygen is heated to a minimum of -40°C (-40°F) and the pressure is then reduced to 83 N/cm^2 (120 psia) by a pressure regulator. Gaseous nitrogen is stored in a high pressure bottle, 2068 N/cm^2 (3000 psia). Nitrogen gas pressure is reduced to 621 N/cm^2 (900 psia) prior to entering the cabin and is further reduced to 110 N/cm^2 (160 psia) by a pressure regulator. Redundant pressure regulators are provided in both the oxygen and nitrogen supply lines. The shutoff valve immediately upstream of the appropriate regulator is closed when a regulator failure is detected.

The major portion of the two gas control system consists of the pressure sensors, controllers, the mechanical components used to control the flow, and pressure of the oxygen and nitrogen. Normally, the system supplies nitrogen to the cabin atmosphere as required to maintain the total pressure in the lab at the desired leval. When the oxygen partial pressure sensing system determines that the oxygen partial pressure is below the desired value, the supply of nitrogen is stopped and oxygen is supplied to the cabin as required to maintain the total pressure in the cabin at the desired level. When the oxygen partial pressure reaches the desired value, the oxygen is shut off and nitrogen is again supplied to the cabin. A source of reference gas with associated control components is provided for inflight calibration of the oxygen partial pressure sensors.

F. Trace Gas Contaminant Control

A study of the potential trace gases in Sortie Lab and appropriate control methods was begun during phase B studies but has not developed to the point where trace gas removal systems can be incorporated into a phase B schematic. Additional studies and testing to determine the magnitude of the trace contaminant problem will be required before this can be done.

Current information indicates that the generation of trace contaminants can be a problem for Sortie Lab (depending on assumed generation rates and mission duration). Also, the Sortie Lab contaminants could in turn contaminate the Shuttle orbiter cabin if the two atmospheres are exchanged. This is due to the different design philosophies of integrating equipment into the respective cabin design. In Shuttle, the Skylab type materials control program is applied to all equipment located in the crew compartment. The Shuttle avionic bays are located outside of the Shuttle cabin area and are designed to incorporate all equipment not compatible with the Skylab type materials control. The bays are designed to leak overboard at a controlled rate and are maintained at a constant pressure differential, 0.28 N/cm^2 (0.4 psid) below the cabin pressure to preclude avionics generated trace contaminants from migrating into the Shuttle cabin. Sortie Lab currently has no such provision for controlled overboard leakage of equipment racks and as a consequence heating expansion and cooling contraction of air circulating inside the racks will cause pumping of air between equipment racks and Sortie Lab cabin through any available leak point. This could allow any contaminants generated internal to the racks to contaminate the Sortie Lab cabin. Reliable pressure sealing of the racks to prevent air exchanges and the required materials control necessary to eliminate a contaminant source within the rack is probably unacceptable to many experiments payloads. This makes some form of contaminant control necessary for Sortie Lab.

Preliminary analyses of Sortie Lab contaminant control concepts show a catalytic oxidizer system could control 64 out of 74 contaminants within safe levels with water adsorption and/or chemical adsorption to control the remaining 10 contaminants. Water adsorption will occur within the condensing heat exchangers during normal condensate removal operations. Chemical adsorption could be conducted with lithium hydroxide and copper sulfate layers incorporated into the Sortie Lab particulate filters. The reality of these proposed control methods can be verified only by additional studies and testing.

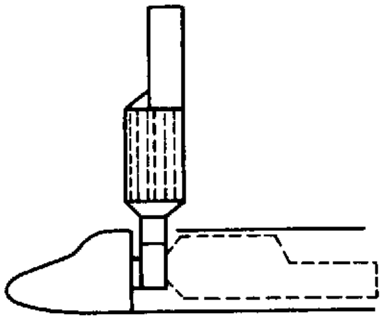
SECTION IV. THERMAL CONTROL DESIGNS

A. Radiator Designs

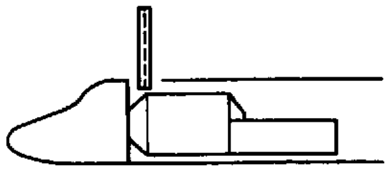
The primary method of on-orbit heat rejection for the Sortie Lab is with a thermal control coolant flowing through a space radiator. The radiator design is based on the estimated thermal loads, required coolant temperatures, and available surface area. The preliminary design values for maximum, nominal, minimum thermal loads were based on the defined experiment requirements (study task 4.1.3)[3] and previous sortie studies (see Table 2). Although higher average orbital thermal loads could be conceived it was decided to determine the radiator requirements for dissipating a maximum of 8.5 kilowatts (29,200 BTU/hr), nominal of 4 kilowatts (13,640 BTU/hr), and a minimum of 2 kilowatts (6820 BTU/hr).

Three Sortie Lab operational concepts were investigated in the design of a radiator heat rejection system:

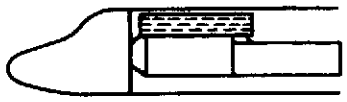
DEPLOYED PAYLOAD



**NON-DEPLOYED PAYLOAD/
DEPLOYED RADIATOR**



**NON-DEPLOYED PAYLOAD/
RADIATOR**



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[3] Experiment Payload Definition Study for Marshall Space Flight Center's Phase B Sortie Lab. PD-MP, June 1972.

TABLE 6. CONSTANT DESIGN PARAMETERS UTILIZED FOR SIZING RADIATOR SURFACE AREA REQUIREMENTS

Parameter	Constant Parameter Assumptions for Study
Mission	Circular earth orbit, 444.5 km (240 nautical miles)
Radiator Coating	White paint, $\alpha s/\epsilon = 0.25/0.92$
Heat Sources	3σ hot orbital heat fluxes plus internal heat generation input to radiator coolant
Shuttle Orientation	Y-POP, Z-LV
Beta Angle (β)	0 deg, 90 deg
Radiator Coolant	Freon-21
Required Outlet Coolant Temperature	4.4°C (40°F)

To compare the three conceptual radiator designs, some constant design assumptions were utilized in the orbital heating analysis (Table 6). The radiator flow distribution is illustrated in Figure 9 for the three concepts being compared. The designs are based on minimum pressure losses and maximum heat transfer. The deployed module has a circumferential radiator integral with a meteoroid shield located along the length of the module. The deployed radiator has two panels. Each panel is a 120 deg arc segment described with a 2.1-m (7-ft) radius. The non-deployed radiator has basically the same geometry as the deployed radiator but remains attached to the non-deployed lab.

Utilizing maximum orbital heating conditions and requiring a maximum (average orbital) radiator outlet coolant temperature of 4.4°C (40°F), the required radiator size for each concept was estimated (Figure 10). To reject a maximum of 8.5 kilowatts heat load through the radiator, the deployed payload radiator length must be 5.6 m (18.5 ft) and the deployed radiator length must be 6.9 m (22.5 ft). The undeployed radiator concept cannot provide adequate coolant temperatures for cabin thermal conditioning under the maximum design loads due to severe orbital heating environments. For example, a radiator length of 7.6 m (25 ft) cannot provide a 4.4°C (40°F) outlet coolant

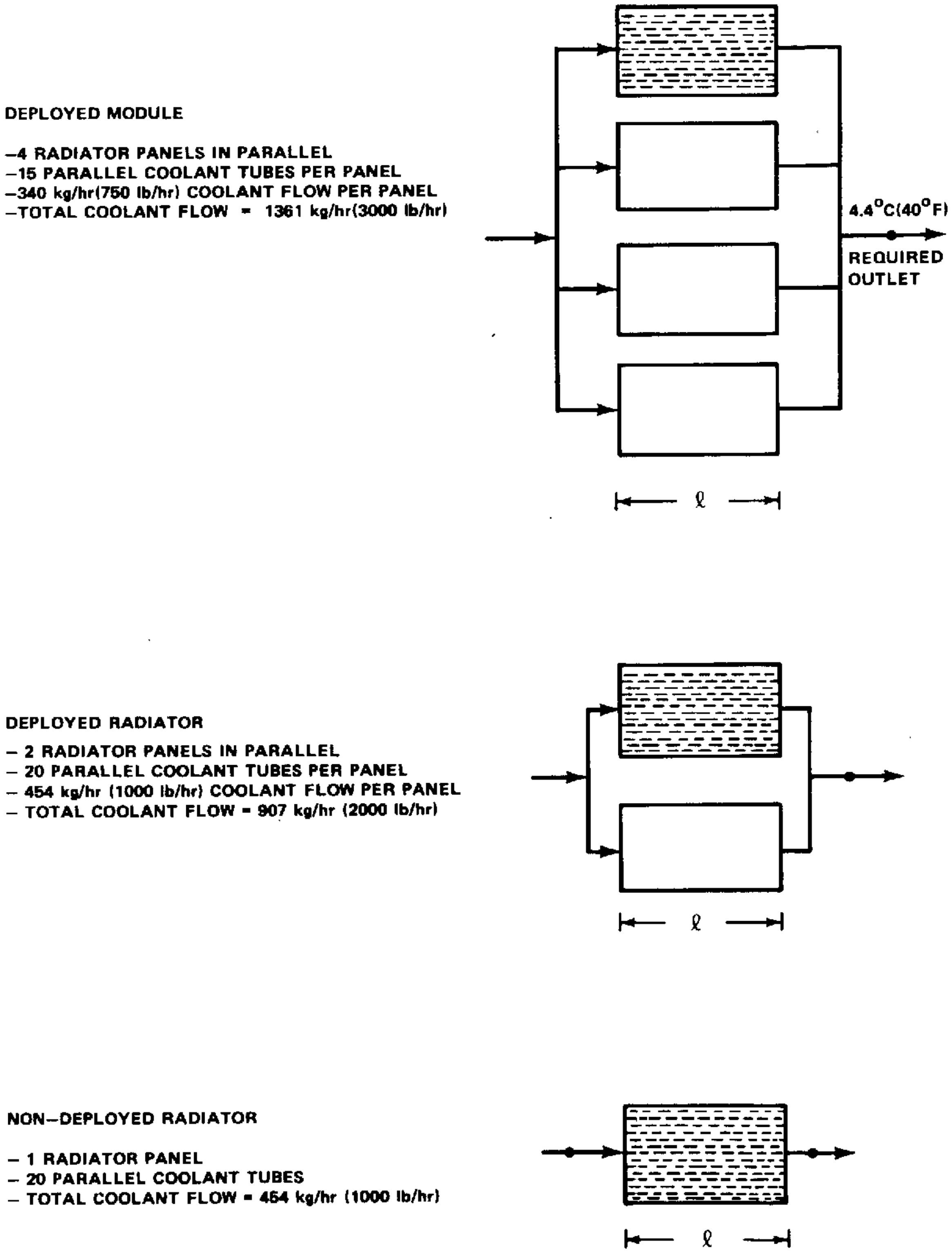

Figure 9. Radiator coolant flow distribution.

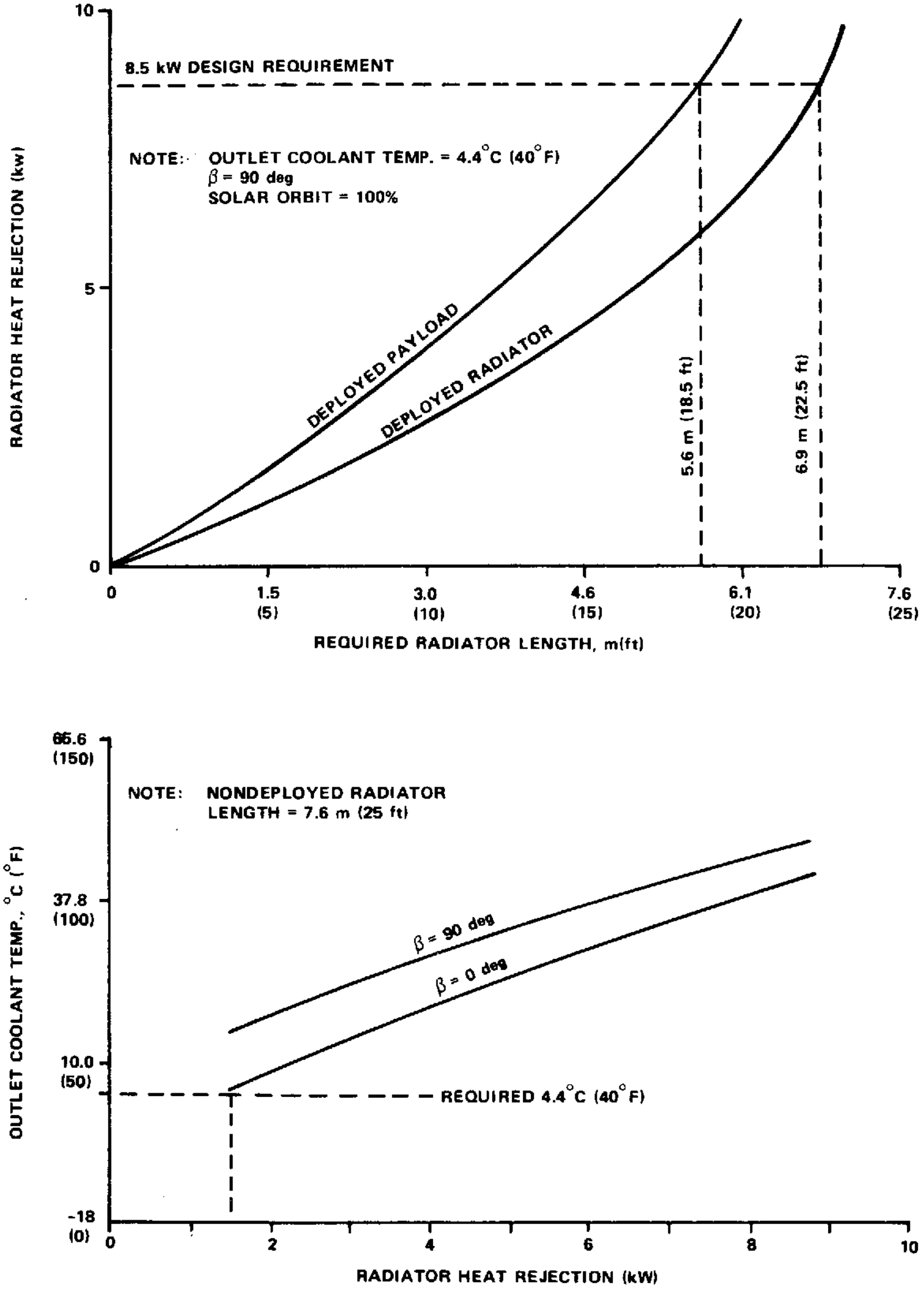

Figure 10. Radiator size versus heat rejection required.

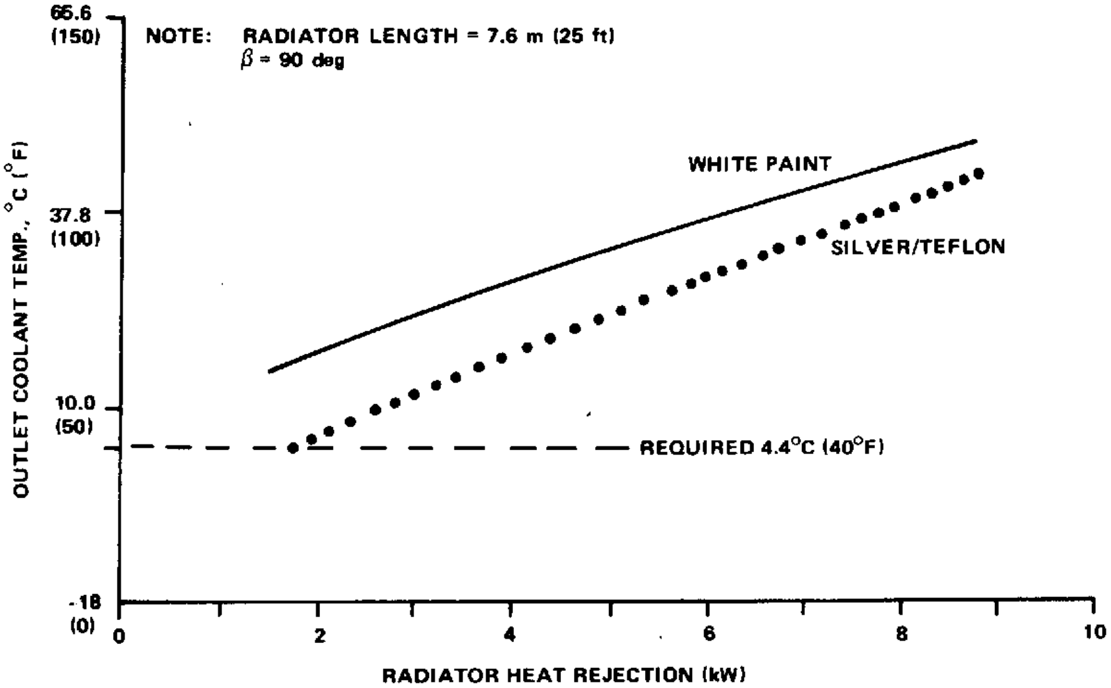

Figure 11. Non-deployed radiator performance utilizing an advanced thermal coating.

for high inclination orbits (β = 90 deg) and can provide a heat rejection of only 1.5 kW for low inclination orbits (β = 0 deg). For a Z-POP shuttle attitude (solar interial), little difference exists in the radiator lengths required for concepts 1 and 2 but the non-deployed concept could not reject the 1.5 kW mentioned above for even the low inclination orbits.

To further improve the potential of non-deployed radiator design, an advanced thermal coating was investigated. A new material, silver coated teflon, with an $\alpha_s/\epsilon = 0.08/0.80$, was compared to the white paint (Figure 11). The new optics produced little improvement for the earth-oriented missions. The non-deployed radiator concept proved to be unacceptable from a thermal control standpoint because insufficient surface area is available for heat rejection.

As a result of these studies the deployed radiator concept was selected as a design reference model for Sortie Lab heat rejection studies because it satisfies mission requirements, minimizes deployment interfaces with the Shuttle and offers design flexibility for changing requirements.

Several trade studies on the deployed radiator concept were made to further optimize its design.

The impact on radiator size of moving the Sortie Lab to various locations in the Shuttle bay was investigated (Figure 12). The initial design reference model assumed the radiator is deployed from the forward bulkhead of the Sortie Lab and that the lab is located next to the Shuttle cockpit area. Translation of the lab to the rear of the payload of the payload bay area is required to satisfy most of the Sortie Lab/Shuttle C.G. constraints. For this case the deployed radiator view to space decreases and a corresponding increase in radiator size is required to reject the 8.5 kw thermal load. If the deployed radiator is translated 12.2 m (40 ft) aft, the radiator length must be increased 0.46 m (1.5 ft).

An assessment was made of potential Shuttle thermal coating variations. The basic thermal coating planned for the external skin surfaces of the orbiter will have an $\alpha_s/\epsilon = 1.0$. This design minimizes refurbishment requirements after each flight. Since the specific α_s and ϵ values are being investigated by Johnson Space Center (JSC), two coatings were assumed to assess potential impacts on the deployed radiator design (Figure 13). The $\alpha_s/\epsilon = 0.35/0.35$ is a coating which will reflect solar and planetary heat fluxes more than a coating of $\alpha_s/\epsilon = 0.90/0.90$. For both cases that were analyzed, the shuttle radiators and Sortie Lab thermal coatings were held constant at $\alpha_s/\epsilon = 0.25/0.92$. Results of the cases that were investigated show that Shuttle coating variations have little effect on Sortie Lab deployed radiator temperatures.

Another study was conducted to estimate the reduction in deployed radiator length by having a combination of fixed radiator and deployed radiator for the lab (Figure 14). For the one orbital case that was examined, the results indicate that for a 4.6-m (15-ft) long non-deployed radiator, a 5.8-m (19-ft) long deployed radiator is required to obtain the 4.4°C (40°F) outlet coolant. For a 7.6-m (25-ft) long non-deployed radiator, the deployed radiator is 5.3-m (17.5-ft) long. Since no weight savings is envisioned for this configuration and more complexity is involved the combination configuration was discarded.

The option of having variable size deployable radiator has both advantages and disadvantages over a fixed deployable radiator configuration and should be examined further. For the present, a fixed size radiator, roughly 7.3 to 7.9 m (24 to 26 ft) in length, is assumed flown on every Sortie Lab

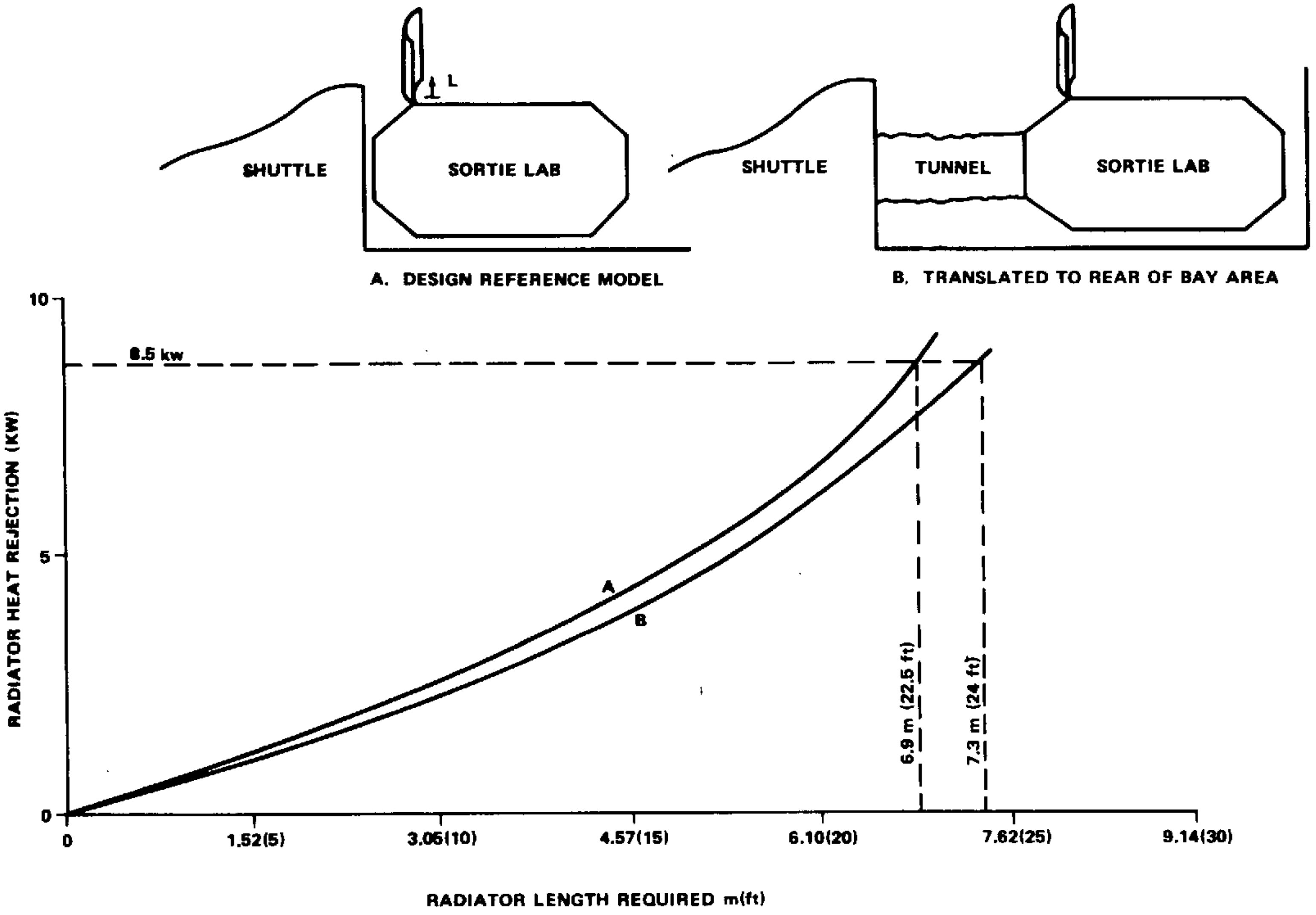

Figure 12. Deployed radiator requirements versus module location in bay area.

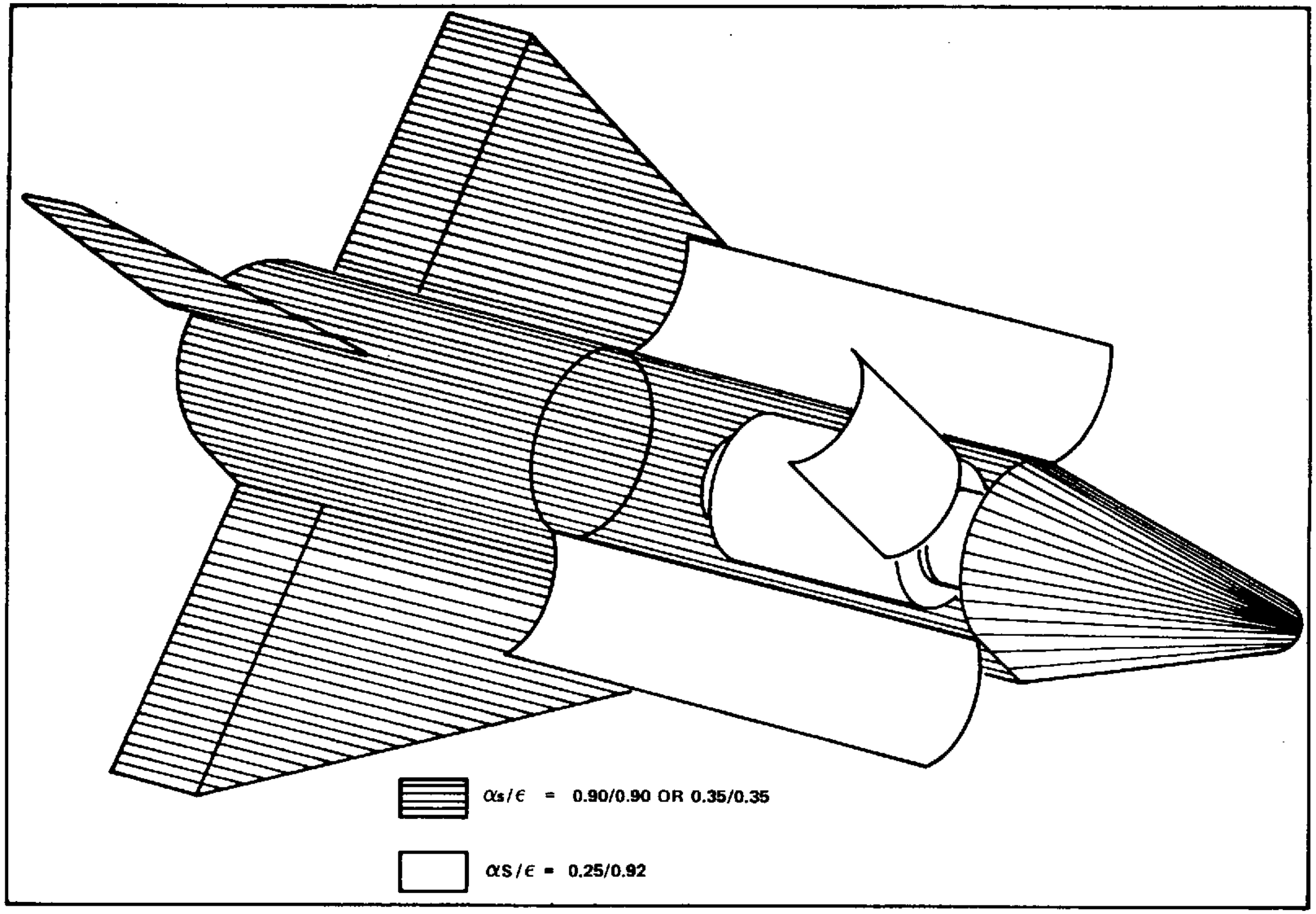

Figure 13. Thermal coatings for Shuttle/Sortie Lab trade studies.

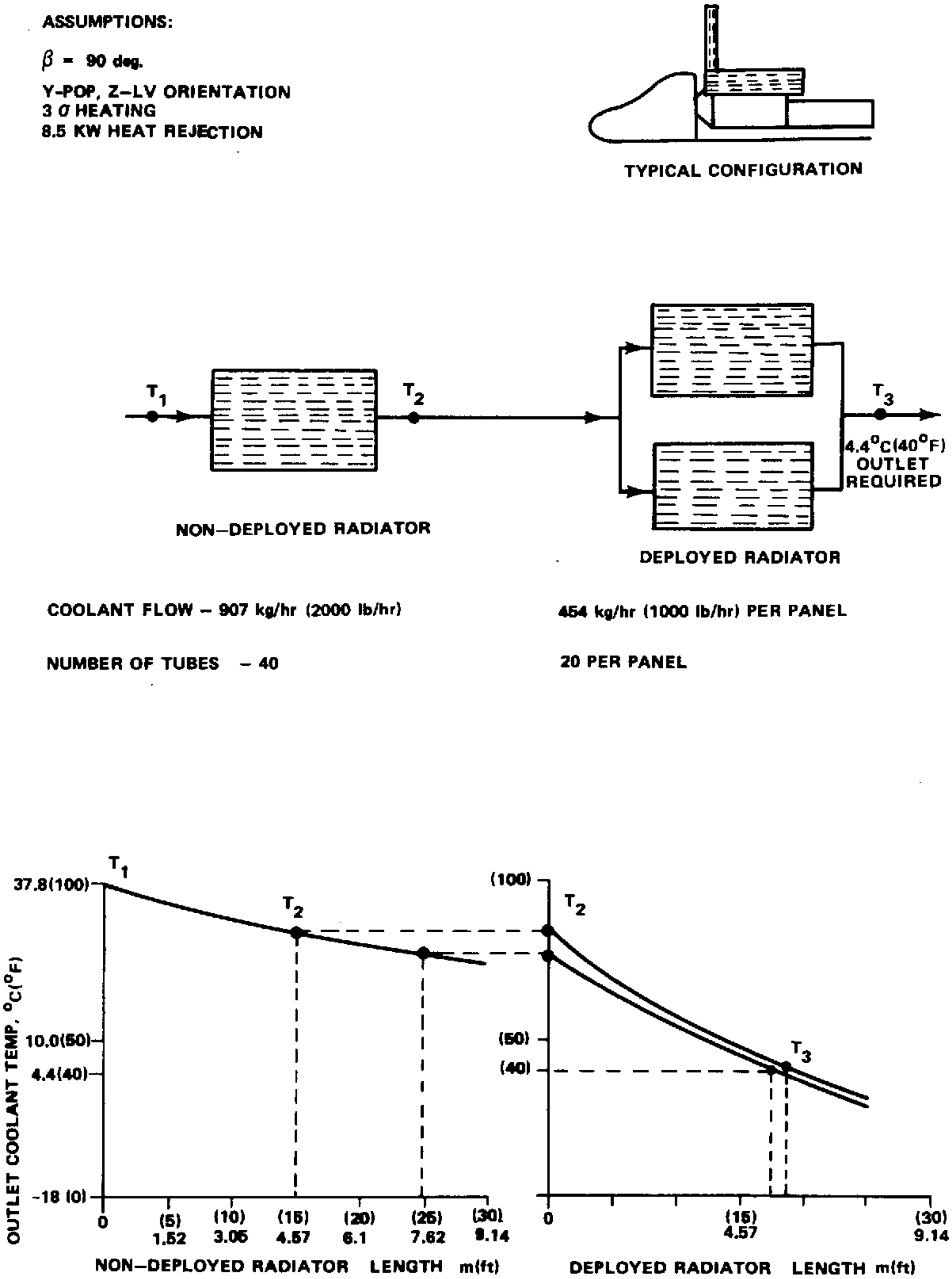

Figure 14. Combination of fixed radiator and deployed radiator surface area requirements.

pressurized module mission. The structural configuration is illustrated in Figure 15. A typical interaction of the fixed configuration radiator (prior to deployment) with a variable size pressure module is illustrated in Figure 16 and shows that the mounting attachments of the radiator with the pressurized module need to be assessed. The identified payloads are taken from the 4.1.3 study task.[4]

Three experiment disciplines were selected from the 4.1.3[4] payloads to evaluate the transient heat rejection capabilities of the deployable radiator concept. The payload disciplines investigated were Communication Navigation (C/N), Materials Science (MS-1, MS-2, MS-3, MS-4) and Earth Observations (EO-2). The thermal loads associated with each discipline were derived from the experiment operation timelines documented in Task 4.1.2.4.1[5] and are depicted in Figures 17 through 19 for a typical 20 hour mission segment. In addition to the experiment power requirements, the radiator thermal loads include a constant 2 kW subsystem power, crew metabolic loads, and fuel cell waste heat created by power generation. The data used for determining fuel cell waste heat is given in Figure 20.

The present baseline requirements are for the radiator to reject a maximum of 8.5 kW (29,200 BTU/Hr) and satisfy the cabin condition requirements for crew comfort and equipment conditioning. A maximum radiator outlet temperature of 4.4°C (40°F) is required for cabin thermal conditioning. For those periods of time when this temperature is exceeded a supplemental heat rejection system is required or the radiator size is increased. If the average is greater than 4.4°C (40°F), then an expendable heat sink (such as a water sublimator) is required or the radiator size increased. The radiator performance for each experiment discipline investigated is discussed separately. All studies consider "worst heating" orbital environments (3σ hot). For the cases examined, no radiator bypass was simulated although this is the primary means of maintaining a 4.4°C (40°F) coolant temperature. Therefore, when thermal loads are lower than 8.5 kW the radiator outlet temperature is shown to be less than 4.4°C (40°F). If radiator bypass were simulated for the transient thermal loads, the radiator structure would be colder and have more thermal capacity to maintain a 4.4°C (40°F) outlet temperature during high thermal load periods. Hence, these analyses are conservative in their design results.

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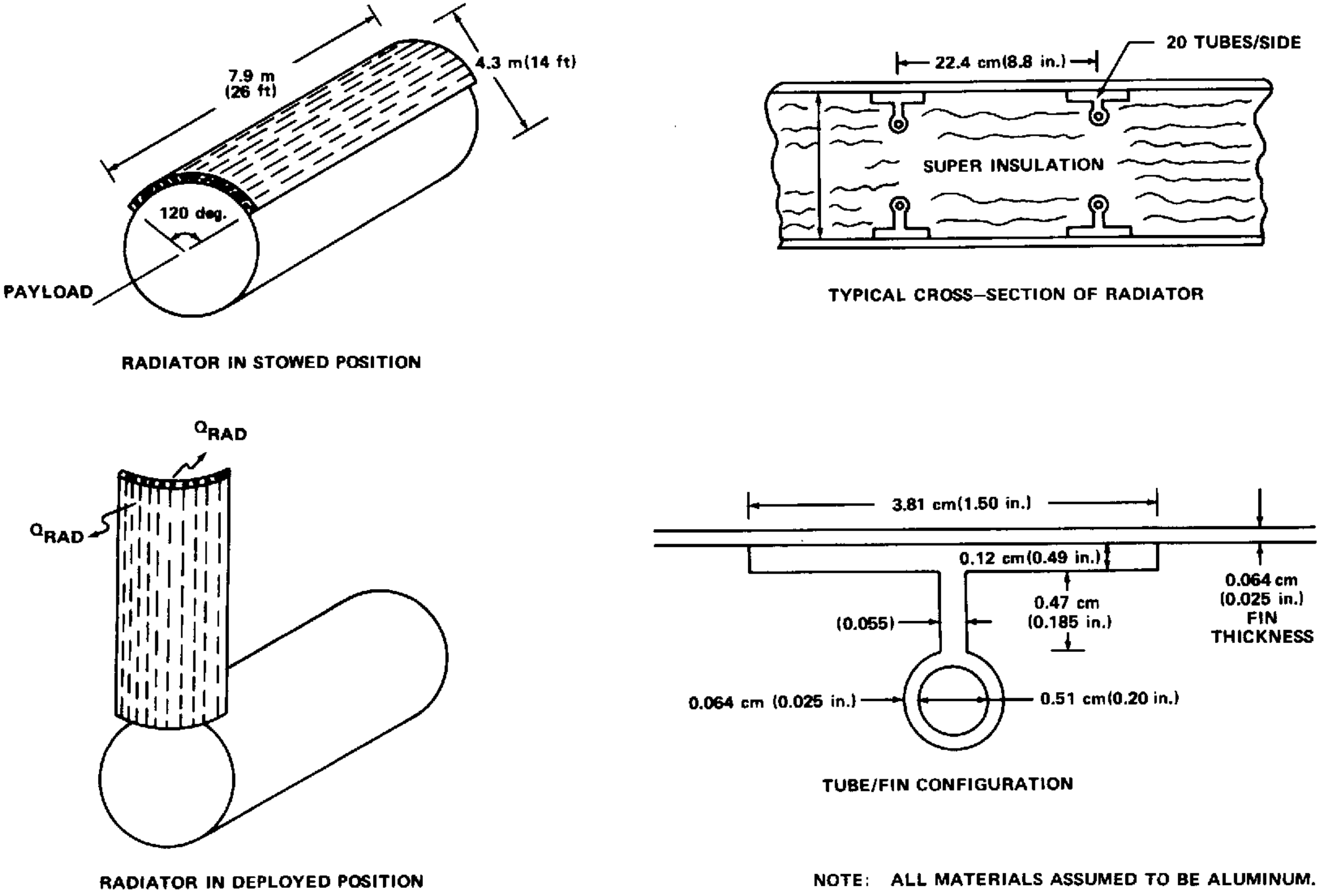
[4] Experiments Payload Definition Study for Marshall Space Flight Center's Phase B Sortie Lab. PD-MP, June 1972.

[5] Experiments Operations Timeline. S& E-AERO-MX-30-72, September 14, 1972.



RADIATOR IN STOWED POSITION

TYPICAL CROSS–SECTION OF RADIATOR

RADIATOR IN DEPLOYED POSITION

TUBE/FIN CONFIGURATION

NOTE: ALL MATERIALS ASSUMED TO BE ALUMINUM.

Figure 15. Structural configuration of deployable radiator.

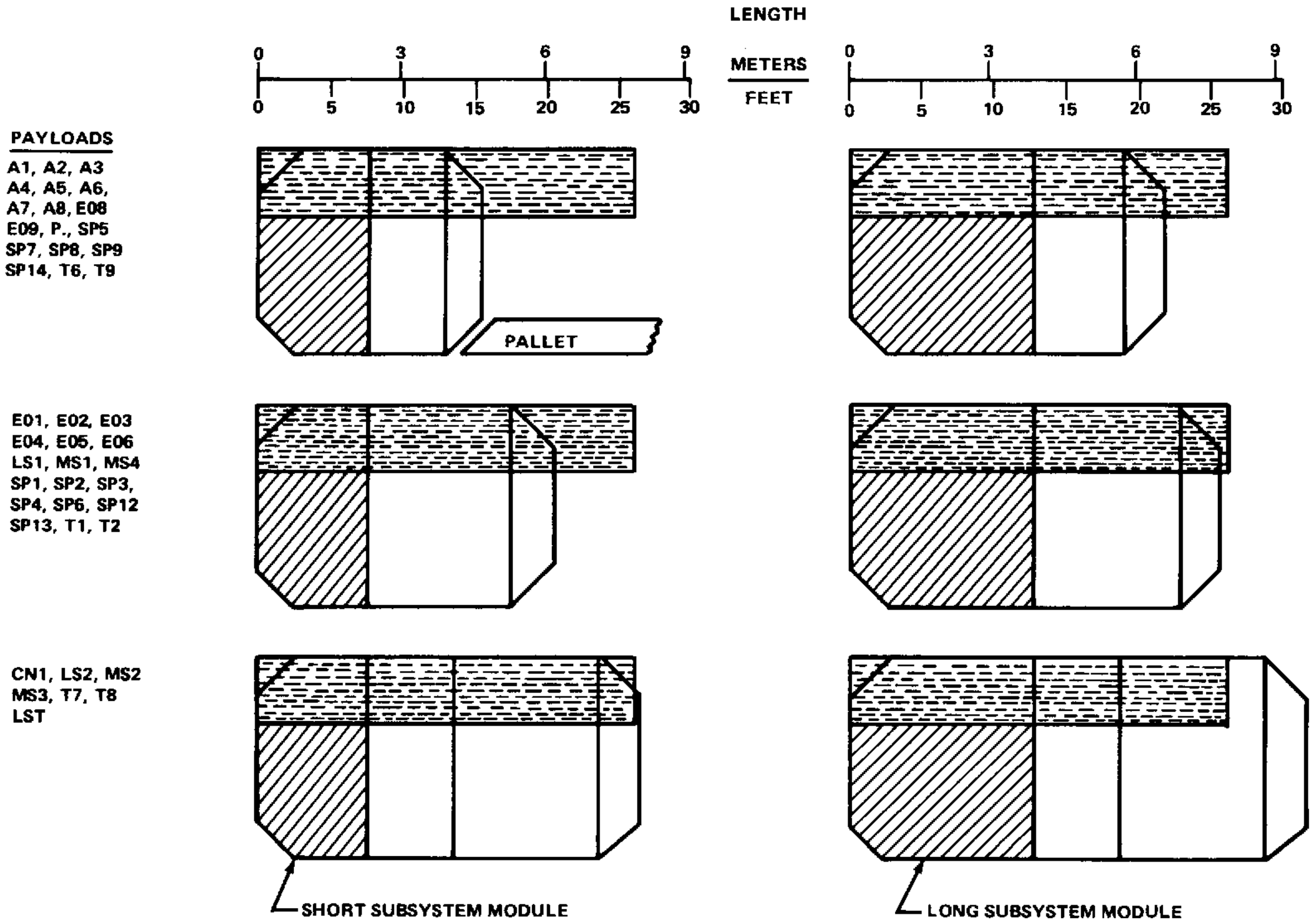


Figure 16. Modular Sortie Lab concept with deployable radiator attached to the subsystems module and pallet attached to experiment module.

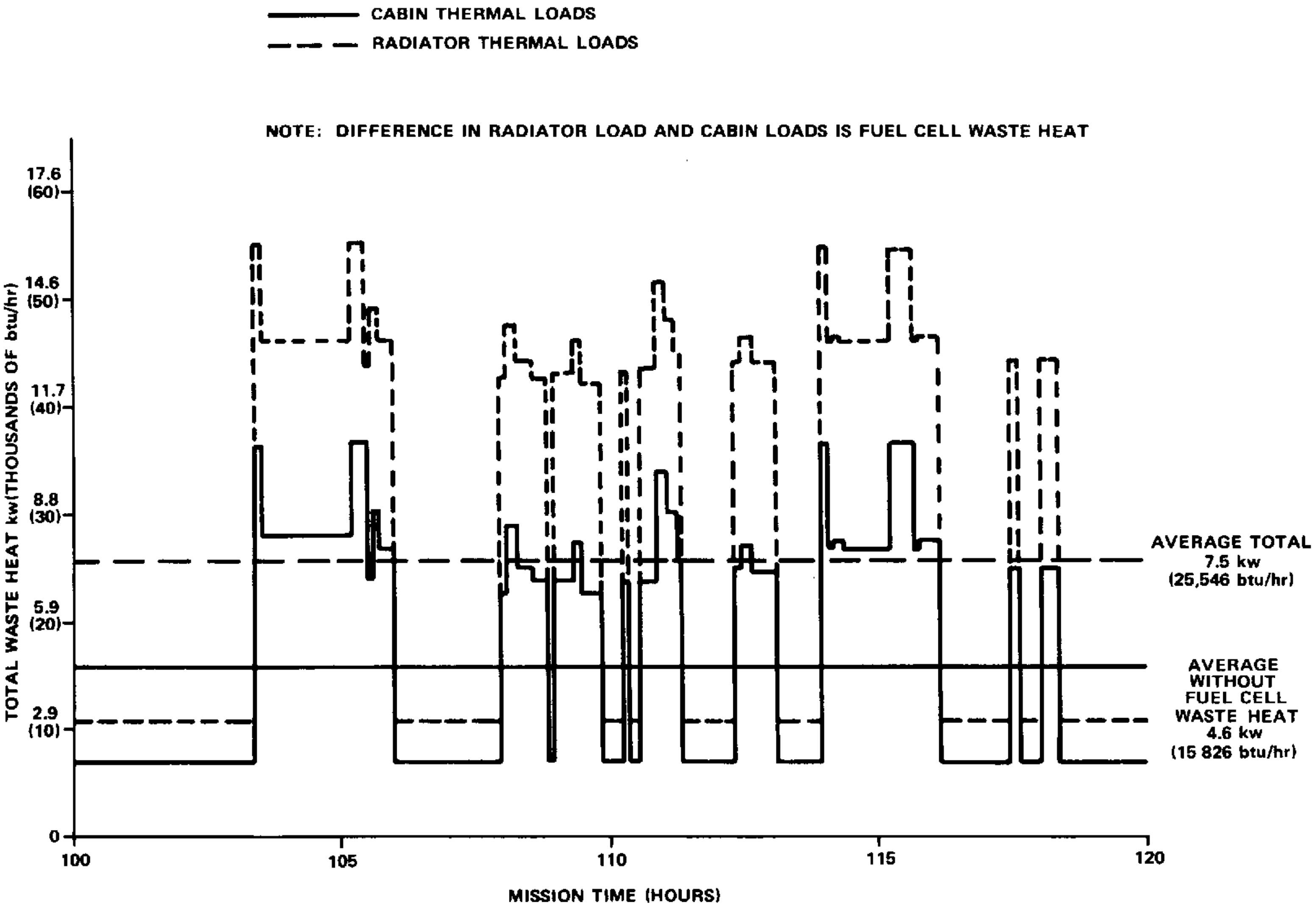


Figure 17. Communication/navigation thermal loads for designing heat rejection systems.

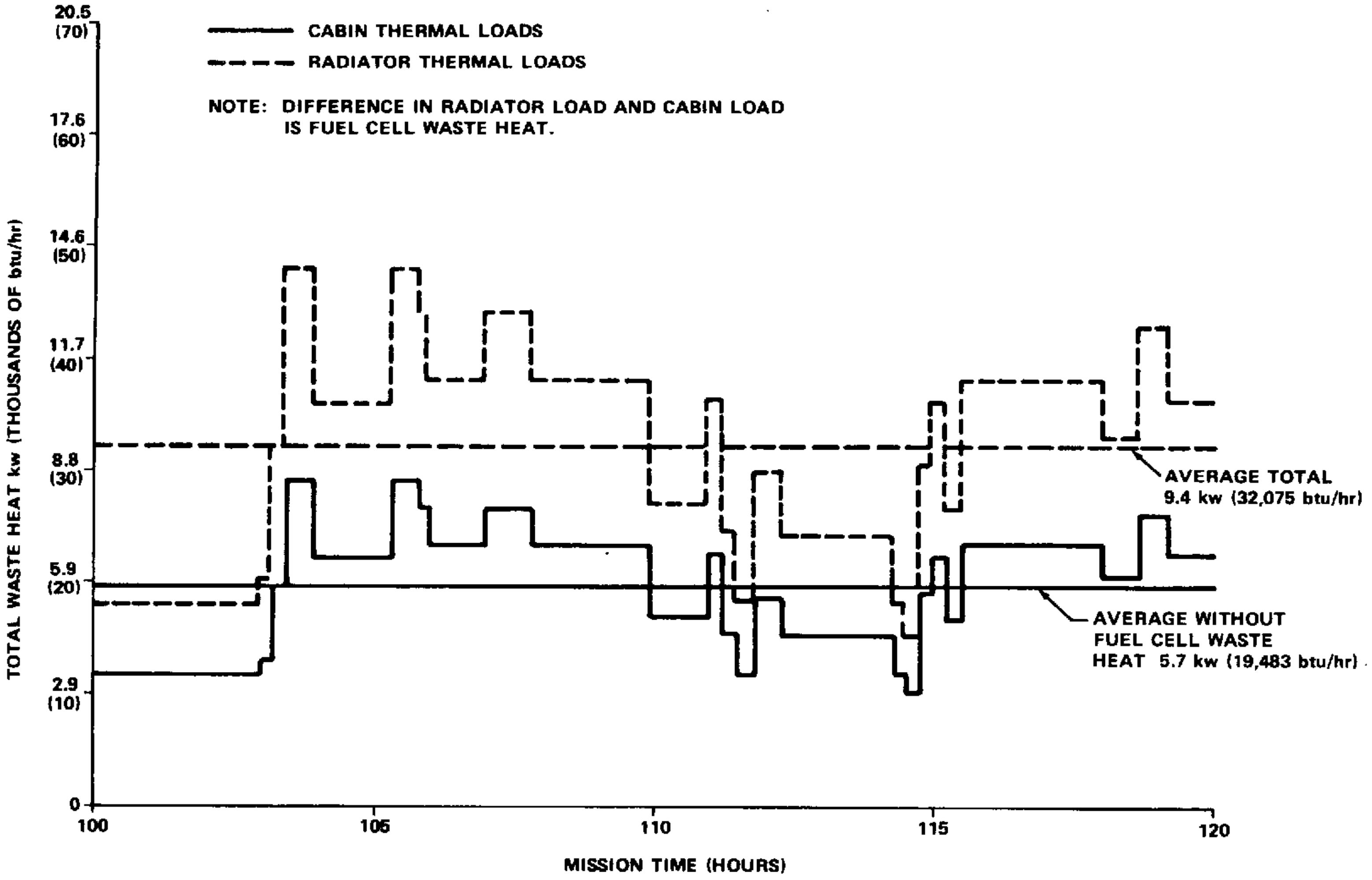


Figure 18. Materials science thermal loads for designing heat rejection systems.

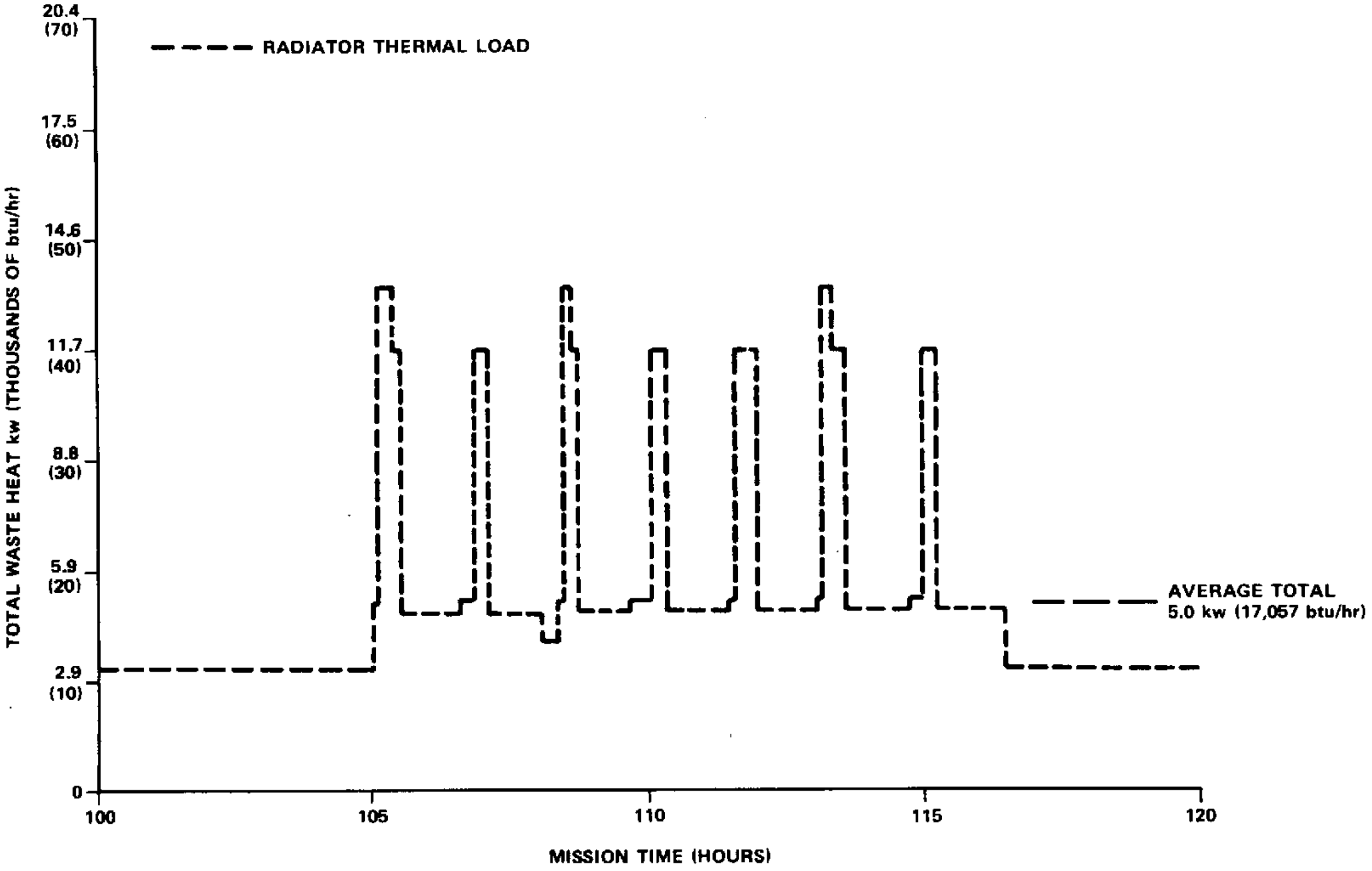


Figure 19. Earth observation thermal loads for designing heat rejection systems.

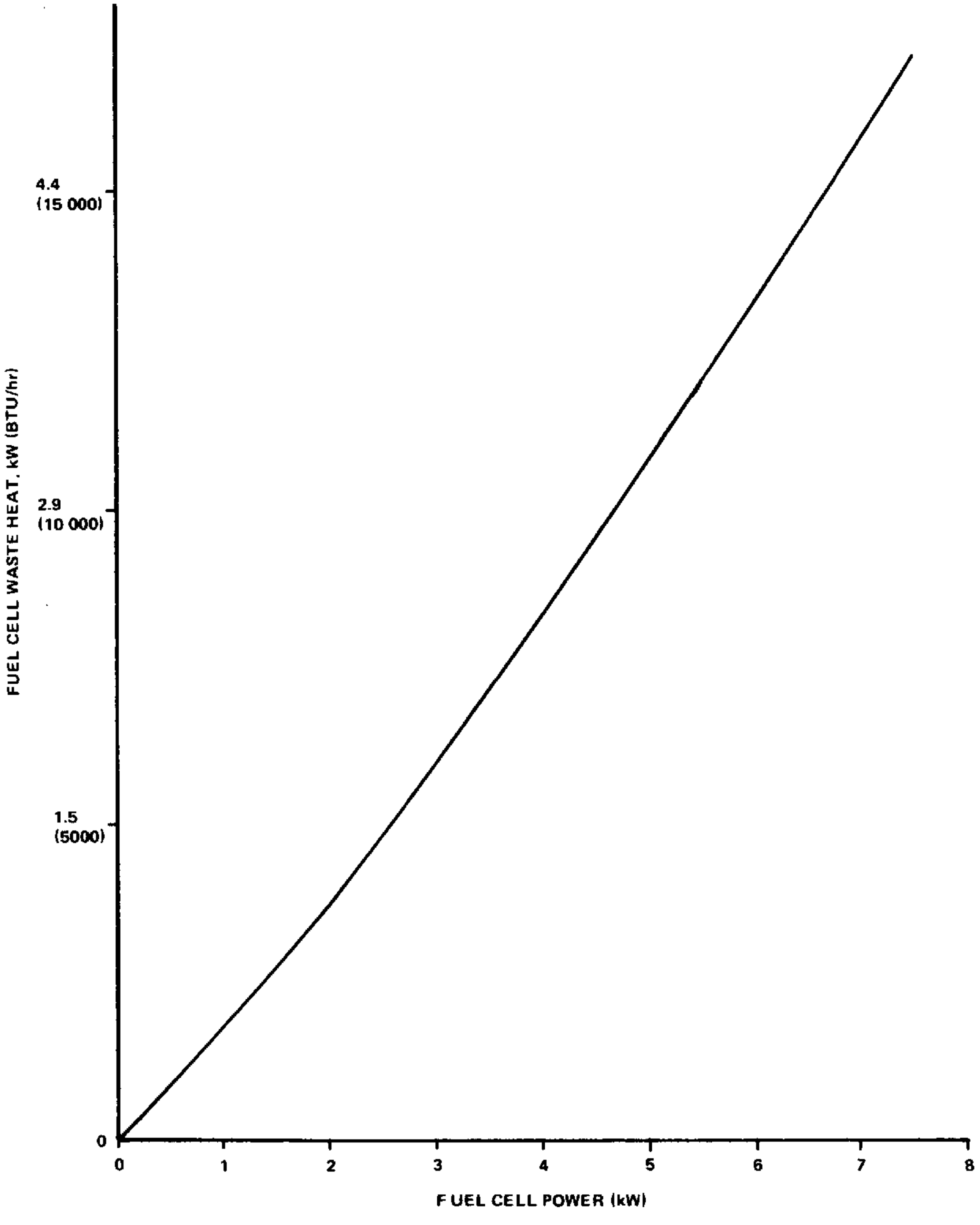


Figure 20. Representative waste heat from Shuttle type fuel cells.

1. Communication/Navigation Payload. This experiment discipline is associated with a high and low β angles. Therefore, the heat load profile shown in Figure 17 was imposed on the radiator for both maximum shadow ($\beta = 0$ deg) and 100 percent sun ($\beta = 90$ deg) conditions. To establish initial steadystate conditions of the radiator, a 5-hour constant heat load 7.5 kW (25,546 BTU/Hr), is imposed prior to the experiment timelining. The results for $\beta = 0$ deg and $\beta = 90$ deg, with a Shuttle attitude of Y-POP, +Z-LV, are given in Figures 21 and 22.

The average heat load conditions are probably more representative of radiator performance than the highly transient loads because the thermal loads do not consider thermal lags or dampening characteristics of the heat dissipating circuits. The baseline radiator design satisfies the heat rejection requirements for the majority of the mission. A thermal capacitor could be designed to eliminate those periods of time when the radiator outlet temperature exceeds 4.4°C (40°F). It should be noted for the $\beta = 90$ deg orbit, that the radiator orbital environment is essentially constant and the transient equipment heat loads size the thermal capacitor. For the $\beta = 0$ deg orbit, the variation in orbital environments is evident during the 95 to 100 hour mission. This variation coupled with transient equipment heat loads will have to be considered in the final definition of a thermal capacitor size.

2. Material Science Payload. The materials science payload had the highest average radiator load examined, 9.4 kW (32,075 BTU/Hr). The timeline analysis of Task 4.1.2.4.1[6] assumed all material science experiments (MS-1, MS-2, MS-3, MS-4) were performed in one 7-day mission. Only a $\beta = 0$ deg case was considered. The predicted radiator performance is given in Figure 23. The results are similar to the communication/navigation payload. The radiator supplemental heat removal could be either a thermal capacitor or an expendable heat sink such as water sublimation. The results show that for low beta angle missions the radiator actually has more capacity than the 8.5 kW (29,200 BTU/hr) design requirements. Hence, with the use of supplemental heat rejection the total rejection of the lab could be increased up to 10-11 kW maximum for the material science mission. This assumes fuel cell generated water is available for use in a water sublimator design.

3. Earth Observation Payload. The earth observation payload (EO-2) had the lowest average radiator load investigated 5 kW (17,057 BTY/hr). All earth observation payloads were for β angles less than 100 percent sun. Little difference in orbital heating is expected for $\beta = \pm 52$ deg for the Y-POP, Z-LV orientation. Therefore, $\beta = 0$ deg was used to evaluate radiator per-

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[6] Experiment Operations Timeline. S& E-AERO-MX-30-72, September 14, 1972.

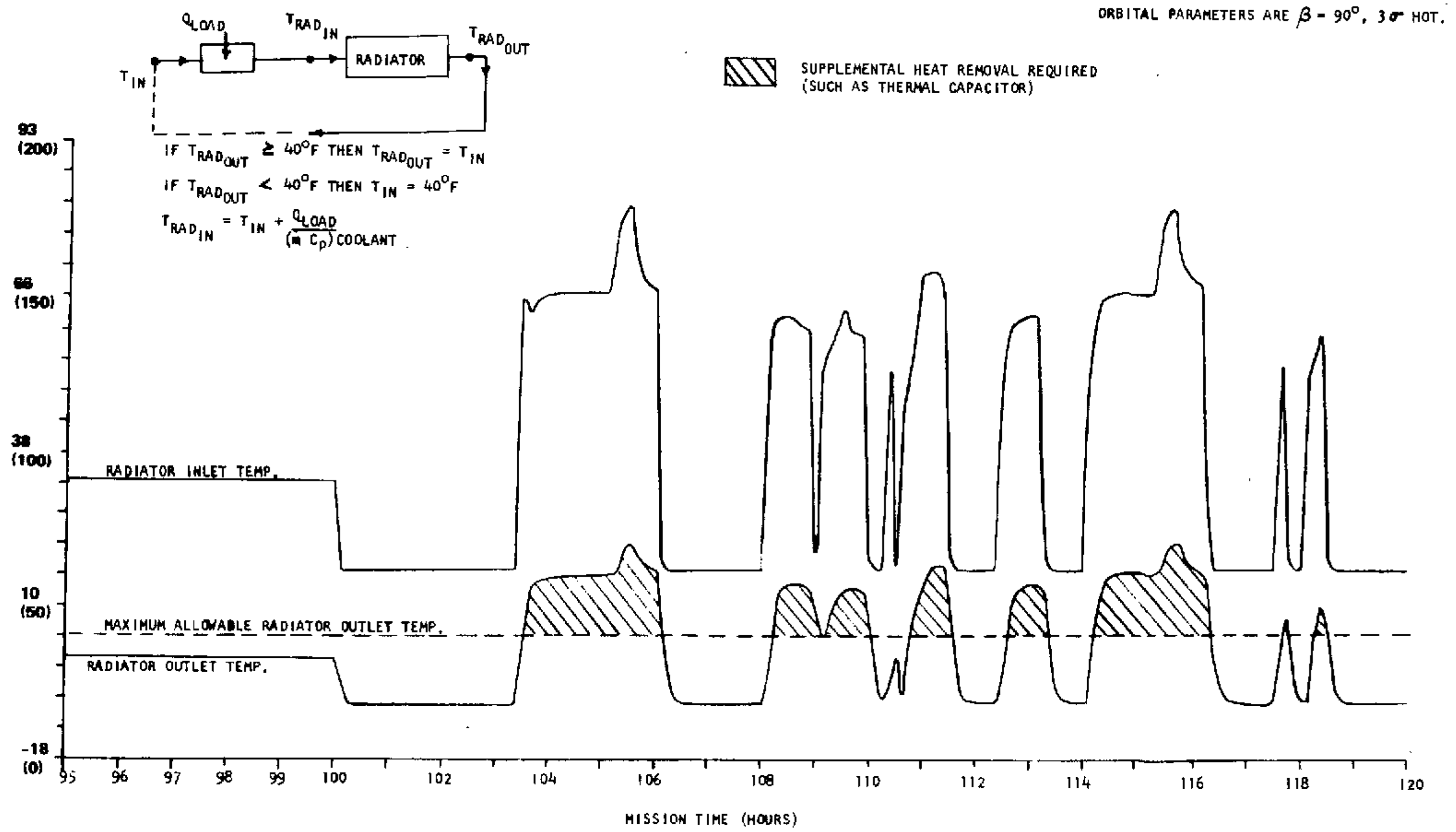


Figure 21. Predicted radiator performance for communication/navigation payload.

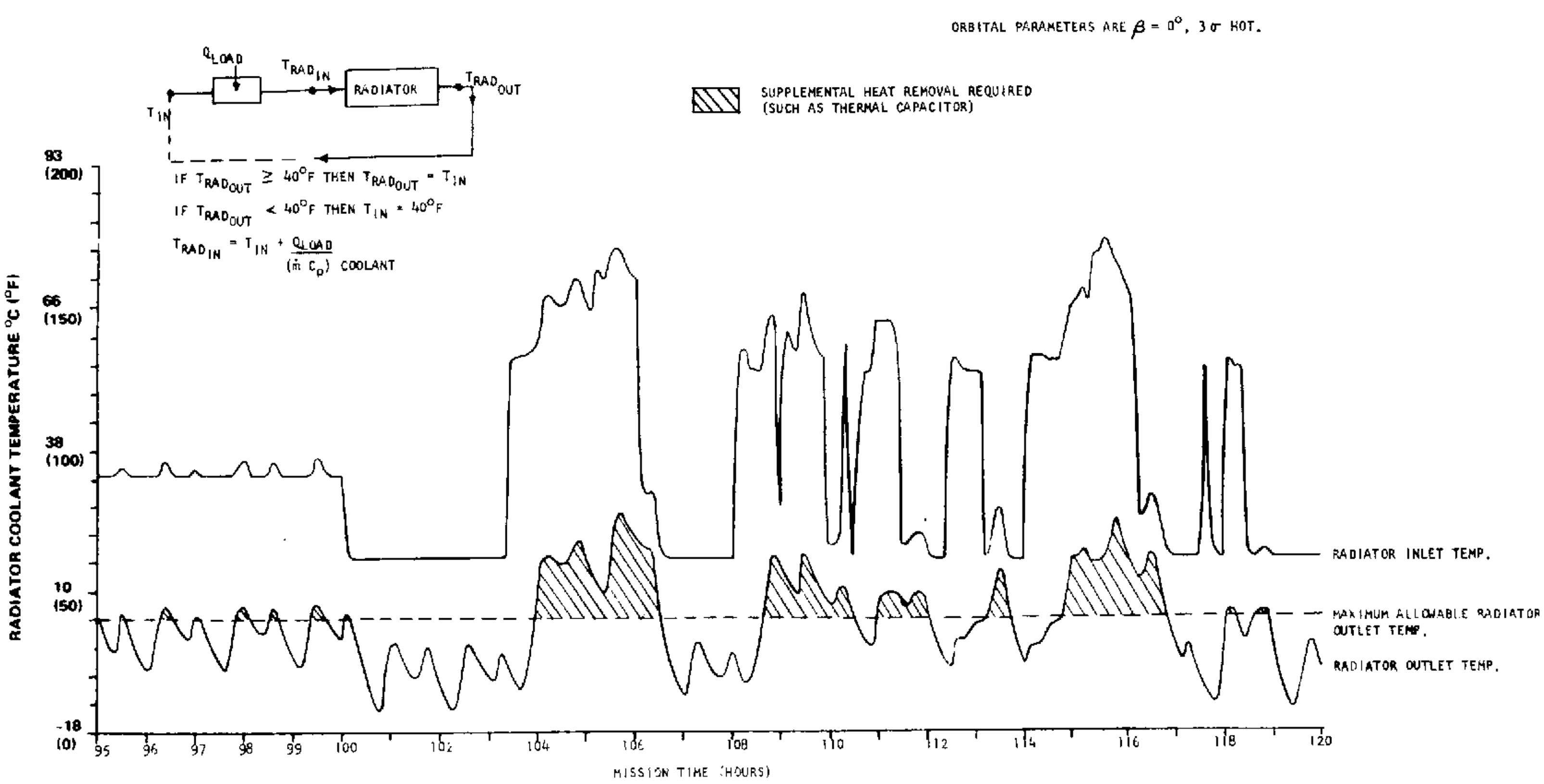


Figure 22. Predicted radiator performance for communication/navigation payload.

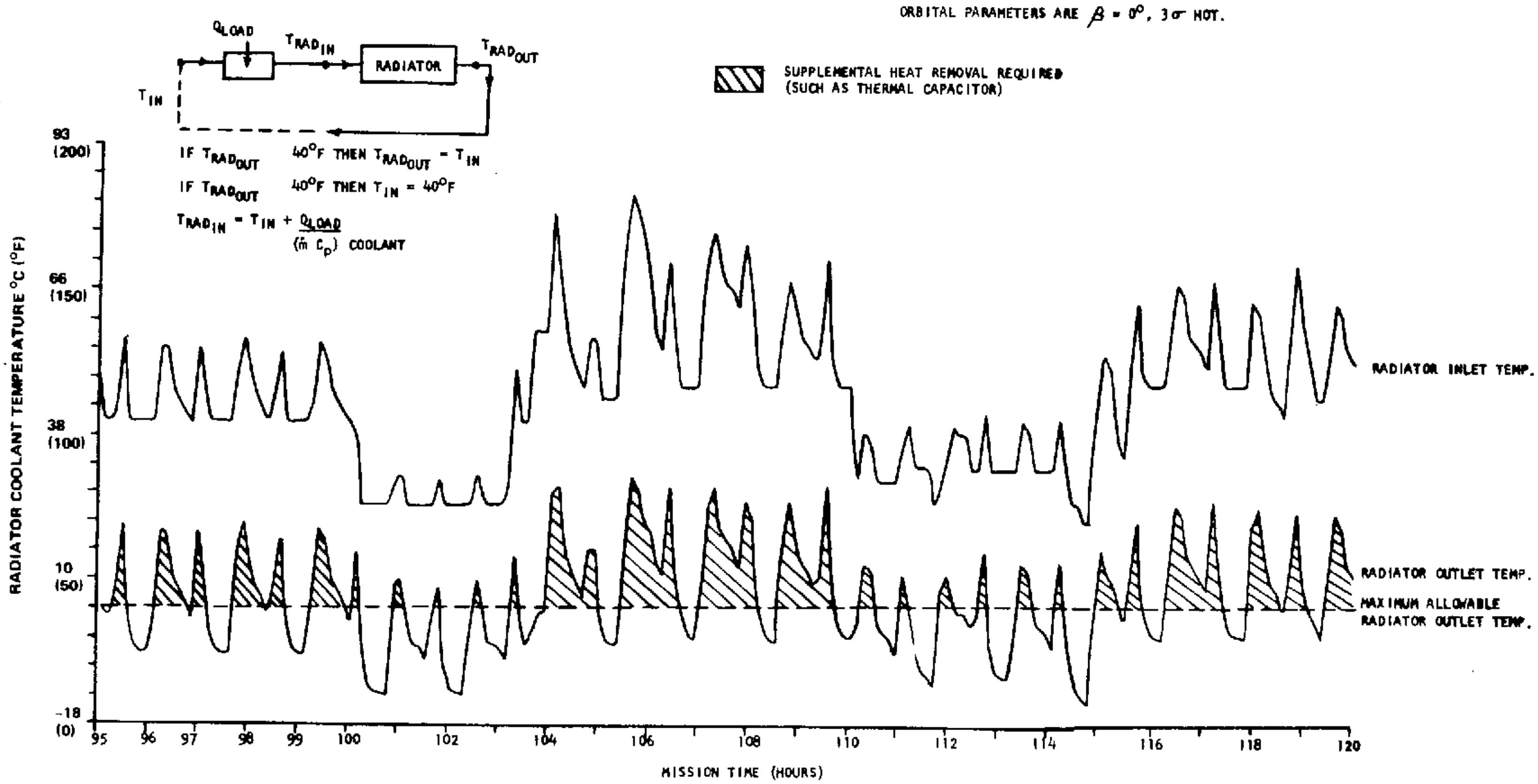


Figure 23. Predicted radiator performance for materials science payloads.

formance. The average orbital radiator outlet temperature is lower than 4.4°C (40°F) throughout the mission (Figure 24). This indicates the radiator could probably satisfy the thermal control requirement without any supplemental heat removal even though small peaks are shown above 4.4°C (40°F).

In summary, the three experiment payloads selected from the 4.1.3 study represented the highest thermal loads for a radiator design. A major assumption in these analyses is the 2 kW continuous subsystem power requirements. Since these analyses were made, a review of subsystem power allocations indicate 3-4 kW is required. The elimination of fuel cell waste heat (for shuttle provided power) combined with this subsystem power increases makes the radiator results still valid. Based on the above analyses, the deployed radiator is capable of rejecting an average thermal load of 8.5 kW without the use of expendable heat sinks (such as water sublimator) but could require a thermal capacitor for peak loads (> 8.5 kW) that occur longer than 30 minutes per orbit. Studies on optimum designs for a thermal capacitor and valve for radiator by-pass are required. Other trade studies that should be performed on the deployed radiator that can impact the weight, length and cost are: (a) use of a silver/coated teflon thermal coating, (b) design for nominal heating environments rather than 3σ, (c) single panel deployed radiator rather than a double-sided configuration, and (d) coolant flow distribution variations.

4. Radiator By-Pass Valve. A vernatherm (wax controlled) type of valve has been designated to be the radiator by-pass valve for the baseline configuration. However, one of the problems experienced during the Skylab mission was that a similar type of valve malfunctioned. This type of valve is highly sensitive to particulate contamination. Therefore, a further study is recommended to examine possible use of a bank of solenoid valves controlling the coolant flow in a step-wise modulation. This concept would be similar to the one that was baselined for the cabin air temperature control. (Section IV-D)

5. Radiator/Cabin Interface Heat Exchanger. The liquid/liquid heat exchanger that interfaces the radiator freon loop with the cabin water loop was investigated to determine its physical size. The parameters that influence the heat exchanger design are coolant flow rates, required inlet/outlet coolant temperatures, and thermal load. The heat exchanger effectiveness was calculated assuming a cross flow, plate-fin, compact heat exchanger design. To reject large thermal loads (7 to 8.5 kW), with a 3°C (5°F) temperature differences between the inlet freon temperature and the outlet water temperature,

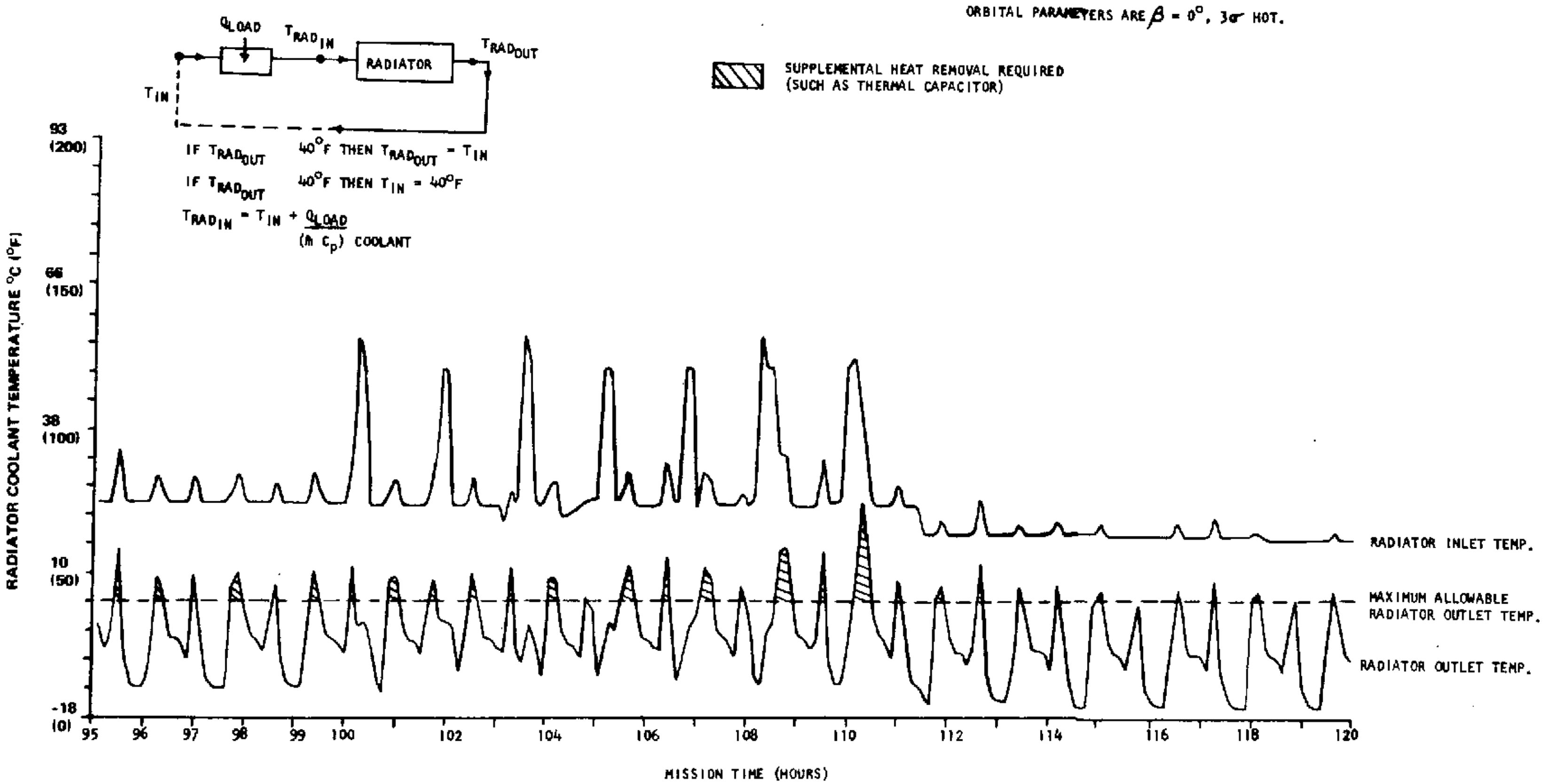


Figure 24. Predicted radiator performance for earth observation payloads.

will require a large, heavy interface heat exchanger unless the radiator coolant flow is increased (Figure 25). Also, the heat exchanger material (aluminum versus stainless steel) will affect the total weight of this unit. Preliminary radiator studies indicate increasing the total radiator coolant flow to 1361 kg/hr (3000 lb/hr) results in a net weight savings, 68 kg /150 lbs), for thermal control. Therefore, future studies should consider a higher flow rate than 907 kg/hr (2000 lb/hr) in the external (freon) coolant.

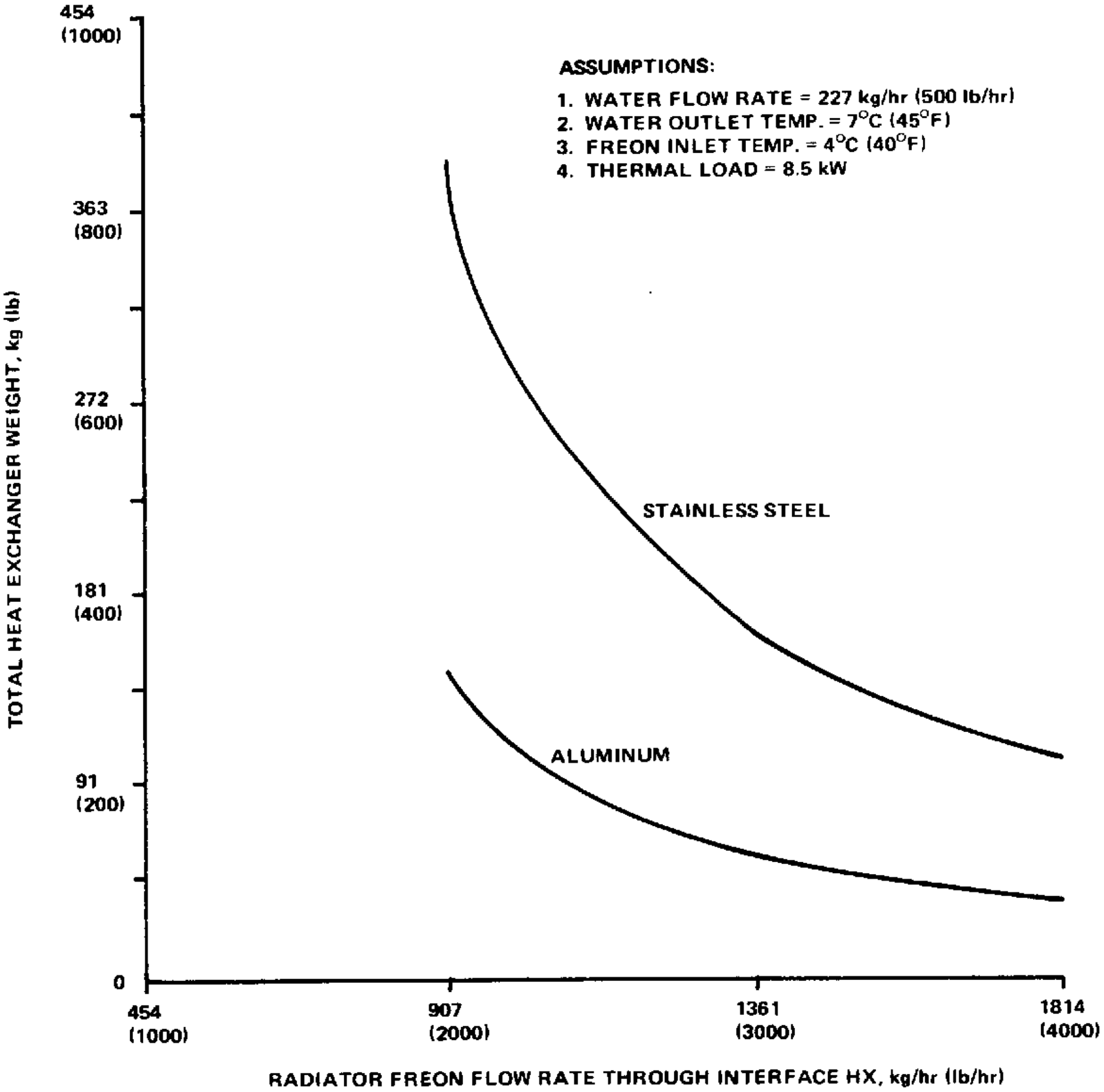


Figure 25. Radiator/cabin interface heat exchanger design.

B. Supplemental Heat Rejection

Supplemental heat rejection beyond what the radiator can provide has been identified in the form of a water sublimator and a thermal capacitor. The following is a rationale for their use in the Sortie Lab:

1. Water Sublimator. The sublimator selected for Sortie Lab was the Saturn Instrument Unit (IU) sublimator. The sublimator would be used on-orbit only and would utilize water from the fuel cells to reject heat loads above the capability of the space radiator (8.5 kW). The sublimator is located in the water loop because the water loop would be closest to the original design conditions of the sublimator which sublimed water and cooled a working fluid of methanol-water. The Sortie Lab sublimator will sublime water and cool water in the cabin loop. In addition, by placing the sublimator in the water loop, the water can be cooled directly to the most desirable temperature, 4°C (40°F). A comparison of the Sortie Lab and IU applications is shown in Table 7 and the IU sublimator configuration is shown in Figure 26.

2. Thermal Capacitor. The thermal capacitor is located downstream of the deployable radiator. Its purpose is to damp out orbital transients and to remove short duration temperature excursions from the outlet temperature of the radiator.

The tentative design is once again taken from an existing design, in this case the Skylab capacitor, in regard to flow design (Figure 27). The proposed capacitor is a larger capacitor than the Skylab design, however. The baseline system consists of 45 kg (100 lb) of Tetradecane wax. Total capacity of the capacitor is 2.9 kW (10,000 BTU).

The heat stored by the capacitor will be rejected during the cold portion of the orbit. The capacitor also offers a heat storage capacity for periods when the radiator is undeployed and the cargo bay doors closed.

C. Structural Heat Leak Studies

In order to initiate the Sortie Lab investigations, a total allowable external heat leak or gain of 146 W (500 BTU/hr) was assumed. Minimizing the external heat leak tends to free the vehicle from orbital and attitude constraints. Based on this assumption, various elements of the Sortie Lab have been analyzed and these elements are: Lab sidewall including stiffeners, flexible tunnel, and scientific airlock. The lab end bulkheads have been

TABLE 7. INSTRUMENT UNIT SUBLIMATOR OPERATING CONDITIONS

	Saturn	Sortie Lab	
Coolant Loop Fluid	60% Methanol 40% Water	Water	Freon 21
Coolant Flow Rate	3538 kg/hr (7800 lb/hr)	227 kg/hr (500 lb/hr)	907 kg/hr (2000 lb/hr)
Coolant Temp In	18°C (64°F)	37°C (98°F)	37°C (98°F)
Coolant Temp Out	15°C (59°F)	4°C (40°F)	4°C (40°F)
Heat Load	8.8 kW (30000 BTU/hr)	8.8 kW (30000 BTU/hr)	8.8 kW (30000 BTU/hr)
Evaporant	Water	Water	Water

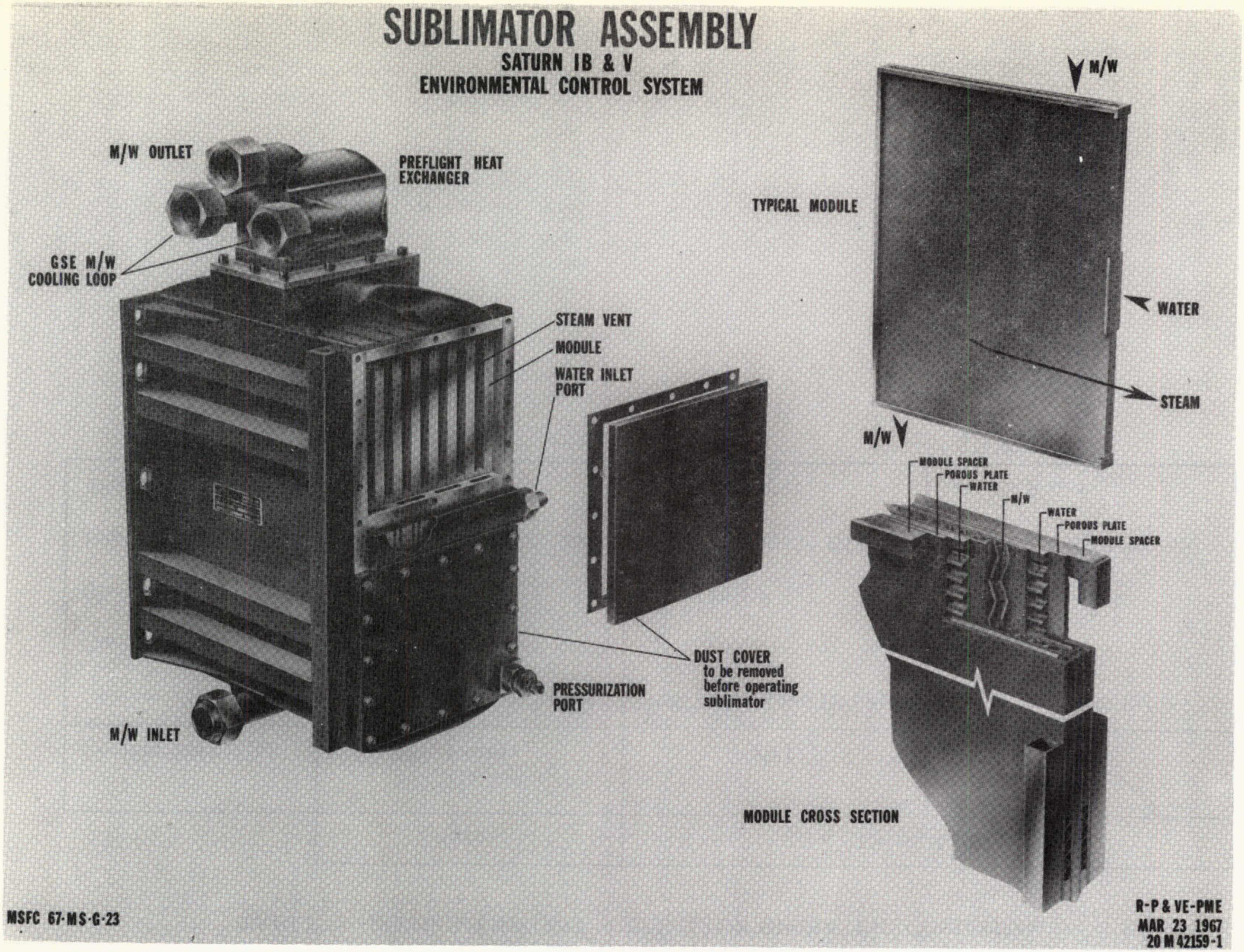


Figure 26. Sublimator assembly.

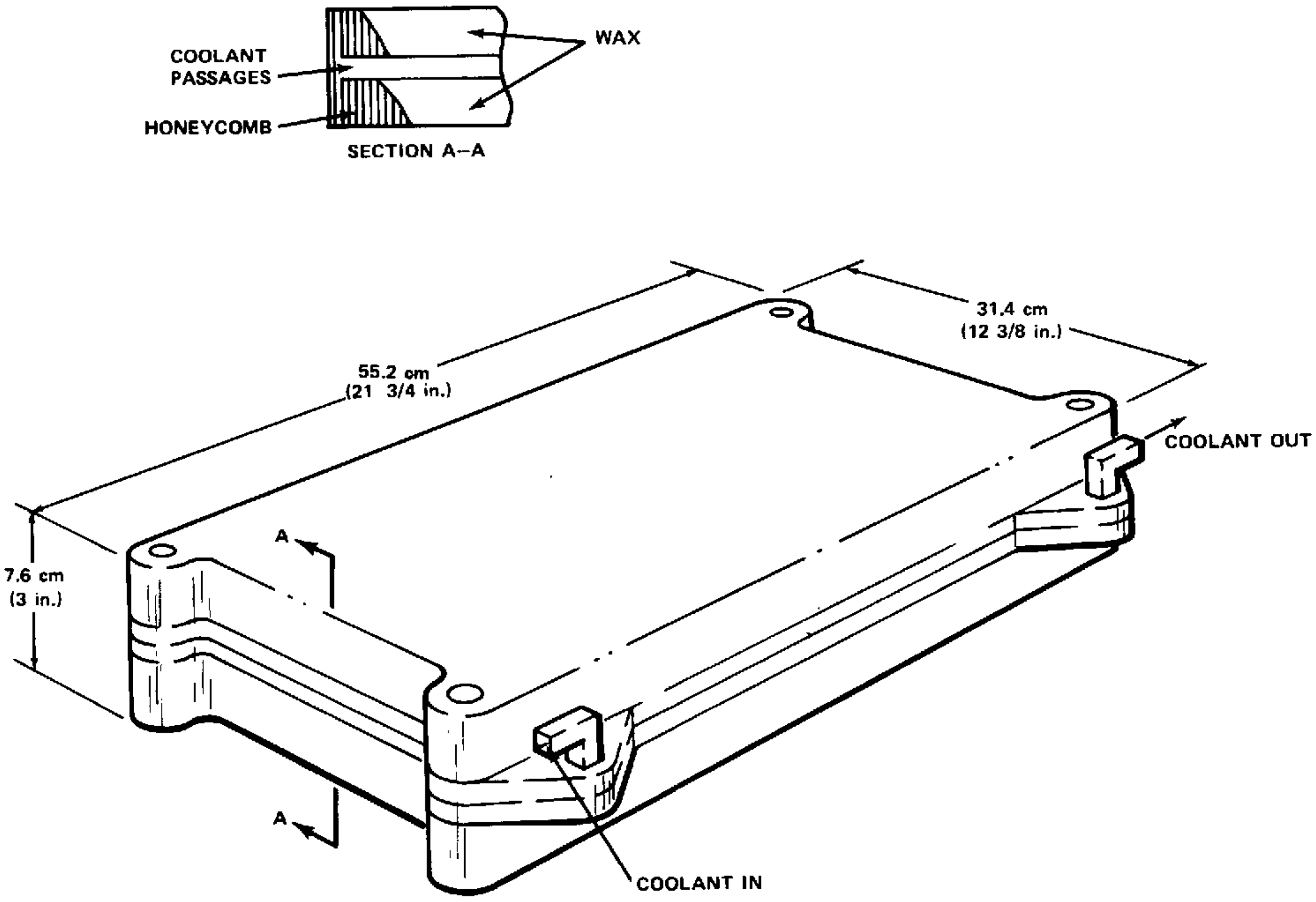


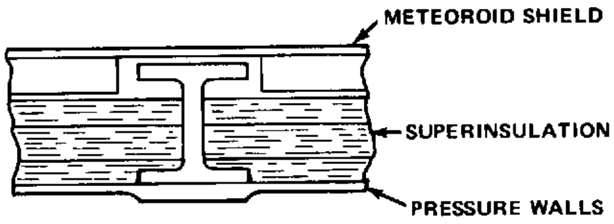
Figure 27. Skylab thermal capacitor module.

assumed to be insulated with the same thickness of high performance insulation as the sidewall, but concepts of laying up the insulation over the curved end bulkheads have not been analyzed. Insulation penetrations, which act as heat shorts, have not been investigated. Typical insulation penetrations are Lab/Orbiter mounting structure, radiator mounting structure, viewports or windows. The discussions of the analyses are presented below.

1. Sidewall. Experimental data was obtained for "as installed" thermal conductivity (k) of high performance insulation from the ATM and other programs. A k of 3.5×10^{-4} W/m-°C (2×10^{-4} BTU/hr-ft-°F) was selected for sizing the insulation thickness. In order to maintain a reserve for heat leak through as yet undefined penetrations, a sidewall heat leak of 51 W (175 BTU/hr) was budgeted. This required $2\frac{1}{4}$ in. of high performance insulation. This first insulation concept selected was double aluminized mylar/dacron net which proved to be too heavy, $\rho = 72$ kg/m^3 (4.5 Lb/Ft^3), and was discarded in favor of crinkled aluminized mylar, $\rho = 14$ kg/m^3 (1.5 Lb/Ft^3).

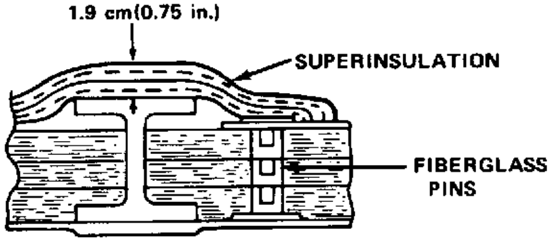
External stiffening rings are required for structural reasons on the lab sidewall. The originally proposed insulation concept is shown on Figure 28. The stiffening ring represents a direct heat short in this case. Therefore, an insulation blanket was proposed to cover the stiffening as shown on Figure 28. The blanket consists of 1.9 cm (0.75 in.) of high performance insulation. Fiberglass pins were added to the insulation as attach points, 16 deg apart circumferentially and 61 cm (2 ft) apart longitudinally. The results of the analysis are shown in Figure 28. Note that the internal wall temperatures adjacent to the stiffeners, for the original design, fall below freezing, thus allowing frost formation and condensation of moisture from cabin atmosphere to form on the wall. Therefore, the original concept is considered unacceptable and the second concept recommended. Note that the total heat leak is estimated to be no more than 5.9 W (20 BTU/hr). Temperature differences between the wall and cabin gas are predicted to be less than 0.6°C (1°F) for the second case.

2. Flexible Tunnel Heat Leak. A flexible tunnel has been proposed to connect the orbiter and the Sortie Lab. Flexibility is needed if the Lab is ever deployed out of the payload bay. In the event of non-deployment, a rigid tunnel will suffice. Goodyear Aerospace Company has designed a flexible tunnel under MSFC contract. The proposed tunnel design was analyzed to evaluate the heat leak effects and potential problems with condensation or ice formation on the internal tunnel walls. Also, the heat leak studies would help size the heater power required to maintain acceptable internal wall temperatures.



DESIGN A

		β= 0 deg. Y–POP, ZLV	β = 90 deg. Y–POP, ZLV	β = 90 deg. Z–POP, ZLV
TOTAL HEAT GAIN	w	-116	-72	-25
	btu/hr	-397	-245	-86
INTERNAL WALL TEMP	°C	-9	3	16
	°F	16	37	60



DESIGN B

		β = 0 deg. Y–POP, ZLV	β = 90 deg. Y–POP, ZLV	β = 90 deg. Z–POP, ZLV
TOTAL HEAT GAIN	w	-6	-4	-1
	btu/hr	-20	-12	-4
INTERNAL WALL TEMP	°C	23	23	23
	°F	74	74	74

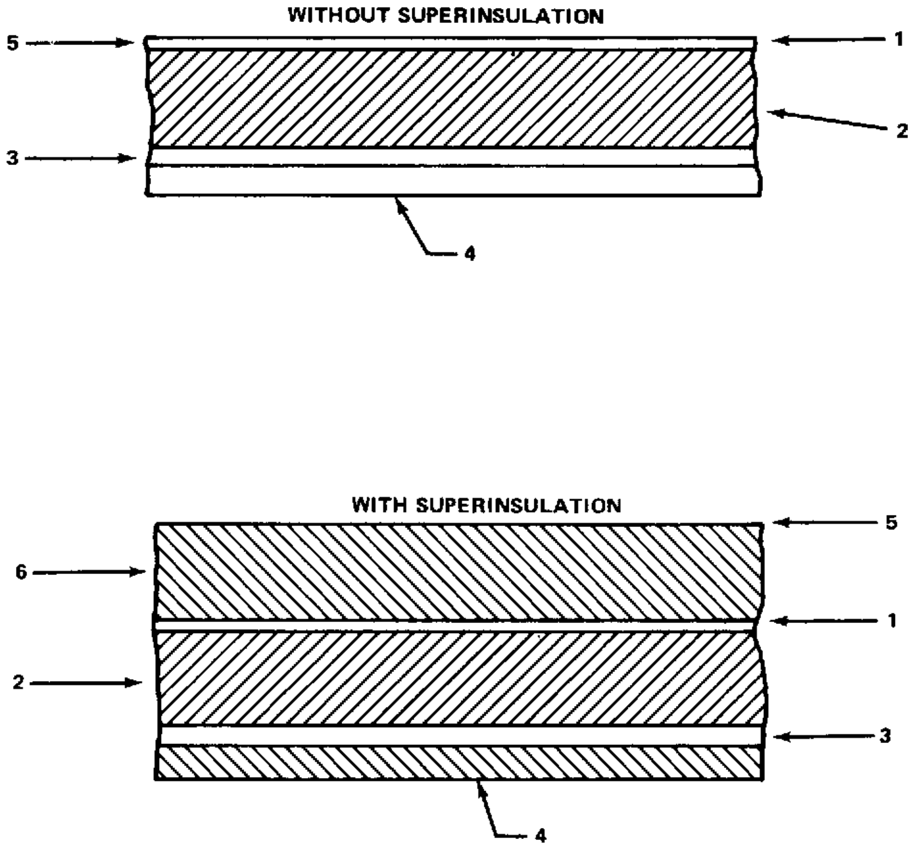
Figure 28. Structural heat leak for module stiffening rings.

The tunnel has been analyzed for various thermal control schemes. The initial part of the study consisted of evaluation of the Goodyear proposed concept with additional thicknesses of foam insulation with and without ventilation of air through the tunnel. The basic concept is shown in Figure 29. Finally the tunnel was analyzed with various thicknesses of superinsulation, $k_{eff} = 8.6 \times 10^{-6}$ W/cm-°C (5×10^{-4} BTU/hr-ft^2-°F), applied on top of the basic tunnel material. The study was done on the basis of a 3m (10 ft) tunnel segment, thus for a 6 m (20 ft) tunnel, for example, the heat leak would be doubled.

Figure 30 shows the conditions for the present design (1 cm of foam) and additional foam thicknesses with no air movement through the tunnel. For Y-POP vehicle orientations the internal wall temperatures are so low that freezing of cabin water vapor will occur. With these low wall temperatures the heat leak for the 3 m (10 ft) segment is 73 to 88 W (250 to 300 BTU/hr). The design goal for the total Sortie Lab heat leak is 293 W (1000 BTU/hr). Conditions for the same tunnel wall design with air movement in the tunnel, ~ 6 m/min (~ 20 ft/min), are shown on Figure 31. In this case ice does not form on the wall but condensation is likely to occur, for Y-POP. However, heat leak is very high for this case and for the current 1-cm design, the heat leak for a single 10-ft segment would be greater than the design goal for the entire Sortie Lab. For these reasons, additional thermal protection in the form of a superinsulation blanket on top of the basic tunnel wall is required. As shown on Figure 32, it was found that a 1.27 cm (0.50 in) insulation blanket would prevent ice or condensation formation, with air ventilation through the tunnel. The heat leak for 1.27 cm (0.50 in) of insulation is rather high, close to 59 W (200 BTU/hr), 2.54 cm (1.00 in) of superinsulation would cut this to 29 W (100 BTU/hr) which is considered acceptable for a 3-m (10-ft) segment. Based on these considerations, 2.54 cm (1.00 in) of superinsulation is recommended for the Sortie Lab tunnel. The insulation material should be the same as whatever is finally used on the Sortie Lab.

The case of superinsulated tunnel with stagnant internal air is not presented herein. For a mission in which the tunnel saw deep space continuously, the tunnel interior would eventually become very cold. It is anticipated that wall heaters would be applied to keep the wall from falling below the condensation temperatures. This condition is still being investigated and results will be documented as soon as available.

3. Scientific Airlock. A scientific airlock is a potential element of the Sortie Lab experiment module. Since the airlock may be pointed at deep space as well as the sun, temperature variations can be extreme. The airlock has been analyzed to determine heat loss/gain and expected temperatures.



TUNNEL WALL CONSTRUCTION

ITEM	MATERIAL	K $\left(\frac{w}{cm\ ^{o}k}\right)$	K $\left(\frac{btu}{hr\text{-}ft\text{-}^{o}r}\right)$
1. OUTER COVER	NYLON CLOTH	1.4×10^{-4}	0.008
2. FOAM BUMPER	POLYURETHANE (OPEN CELL)	0.86×10^{-4}	0.005
3. STRUCTURAL LAYER	FIBER–B CLOTH	16.7×10^{-4}	0.096
4. PRESSURE BLADDER	EPT FORM (CLOSED CELL)	27.6×10^{-4}	0.16
5. S-13G WHITE PAINT			
6. SUPERINSULATION	ALUMINIZED MYLAR	0.86×10^{-5}	0.0005

Figure 29. Sortie Lab flexible tunnel design concepts.

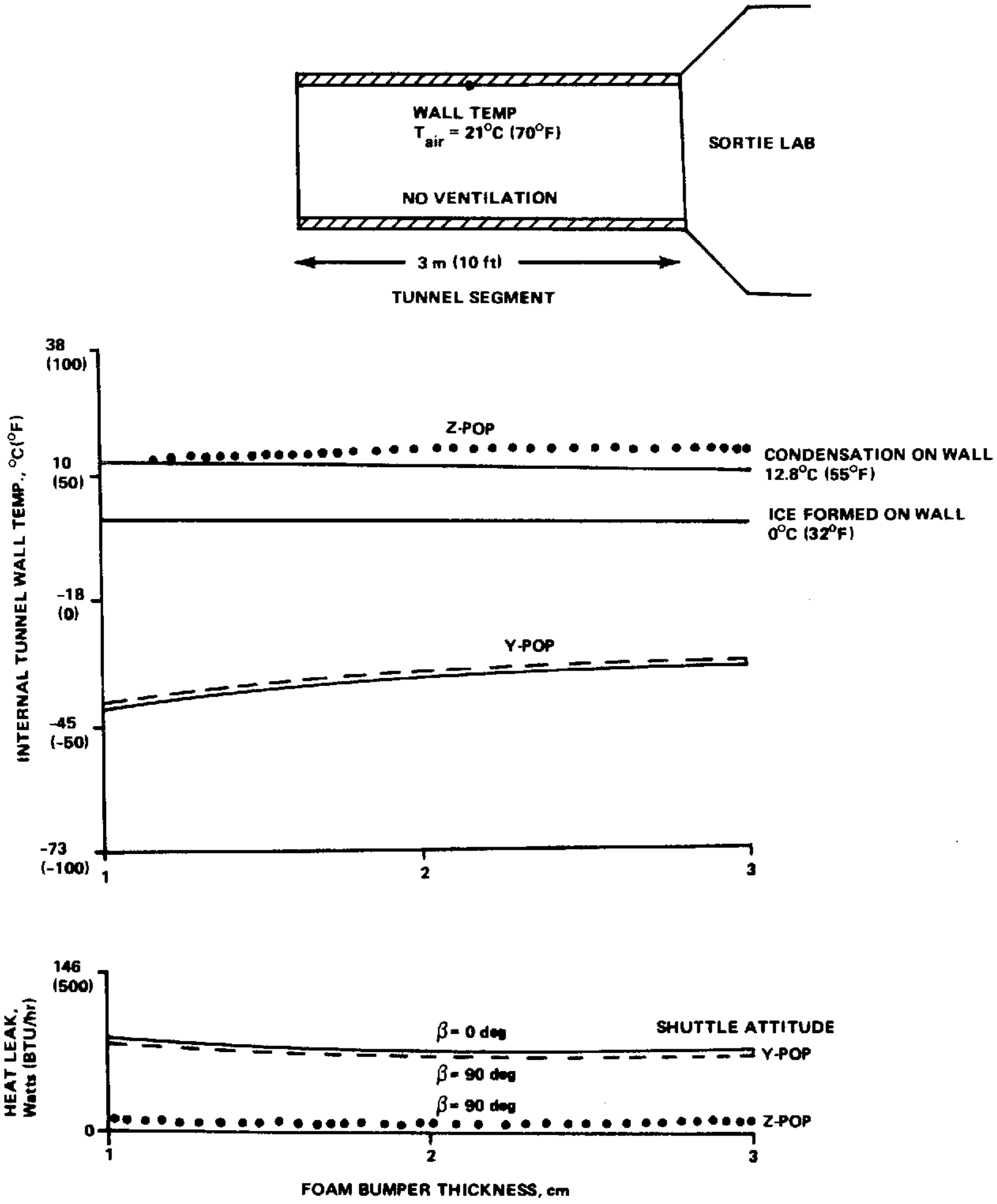


Figure 30. Flexible tunnel temperatures and heat leak with no ventilation in tunnel and no superinsulation.

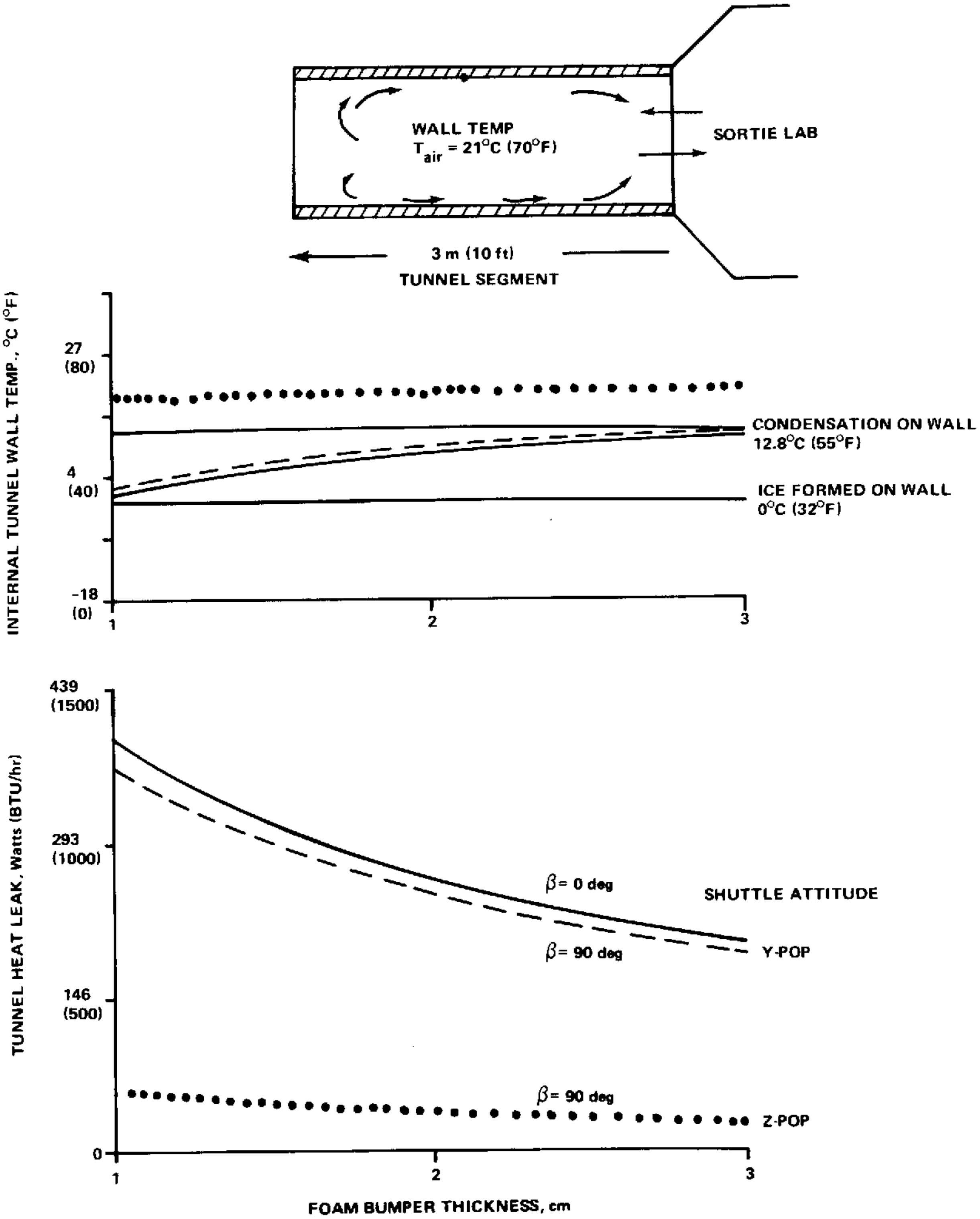


Figure 31. Flexible tunnel temperatures and heat leak with ventilation in tunnel and no superinsulation.

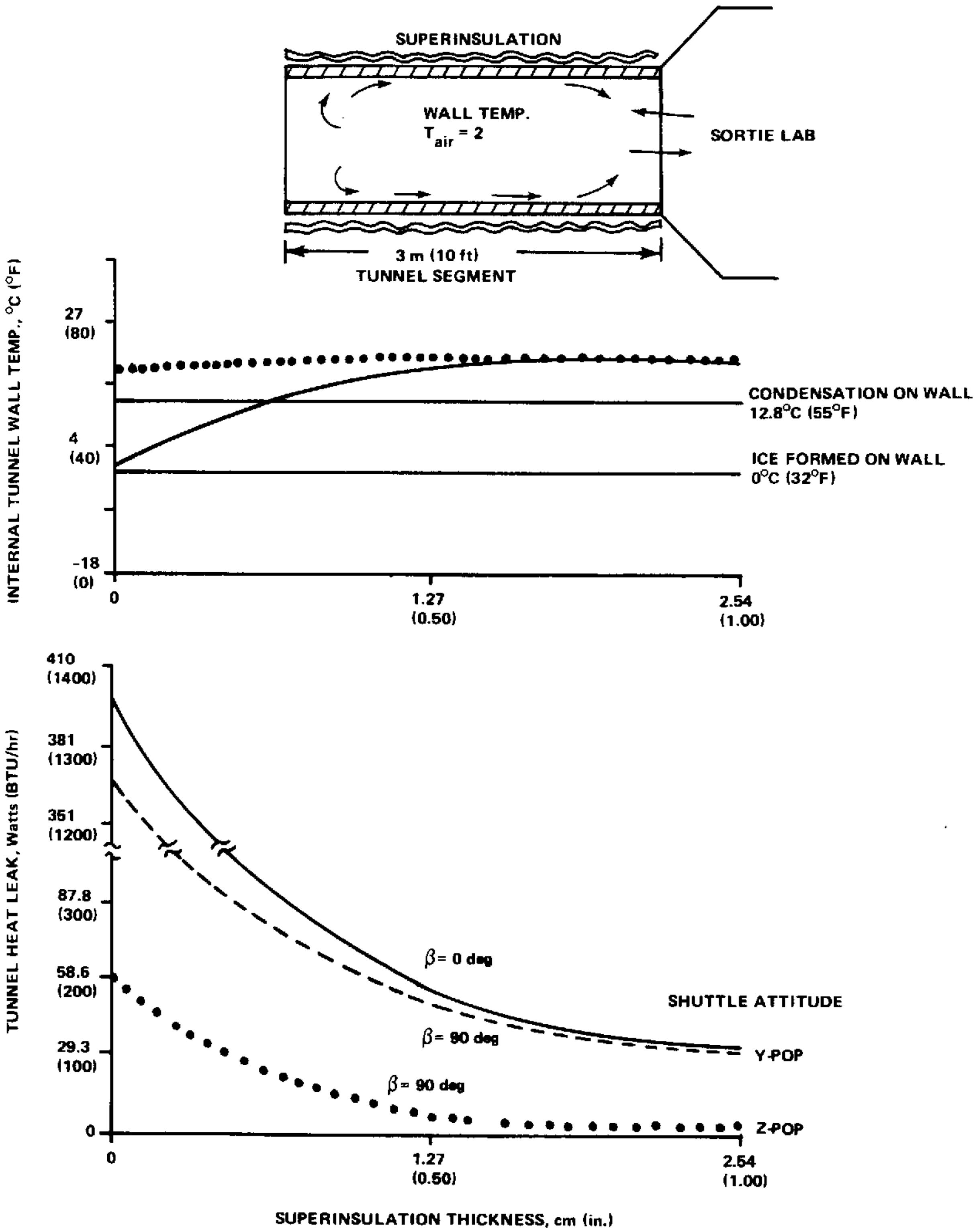


Figure 32. Flexible tunnel temperatures and heat leak with ventilation in tunnel and with superinsulation (foam bumper thickness = 1 cm).

Foam insulation was investigated as a means of controlling temperature and heat leak. In addition coatings (white or black paints) and several airlock orientations relative to the sun (Figure 33) were studied. In all cases, for foam thickness of up to 6.35 cm (2.50 in) the heat loss/gain was found to range from 117 W (400 BTU/hr) to values in excess of 293 W (1000 BTU/hr). An insulation blanket of 2.54 cm (1.00 in) of high performance insulation was recommended for the airlock.

Quite a bit of additional effort is required on the thermal definition of the Scientific Airlock. The proposed high performance insulation must be exposed to a hard vacuum in order to be effective. The insulation must be mounted so that it is not damaged by the installation and removal of experiment equipment. Therefore, a mounting arrangement and a method of venting the insulation to space must be obtained.

Experiments mounted in the airlock and viewing deep space will become very cold. If exposed to the cabin atmosphere immediately after completion of the experiment, frost or condensate can form on the experiment equipment. Therefore, some sort of conditioning system must be developed for airlock experiments.

D. Air Temperature Control/Distribution

1. Air Conditioning Concept Selection. Ten potential air conditioning concepts have been identified for the Sortie Lab. The air conditioning system has the task of removing 2.9 kW (10,000 BTU/hr) of sensible heat from the cabin and 4 kW (14000 BTU/hr) from air cooled thermal racks for electronic equipment. All of the concepts can be made to work by adjusting air or water flow or both. Desired temperatures were 24°C (76°F) maximum for the cabin and 41°C (105°F) for electronics equipment. The results of the comparative study are shown on Table 8. A critique of each concept is given on Table 9. Each concept is shown schematically in Figure 34. Concept 1 (Phase B Baseline) satisfies the maximum temperature requirements with fairly low flow requirements, however, this system brings in cold air 15°C (59°F) into the cabin creating a possible drafty condition. Concept 6 exceeds the cabin specification by 0.6°C (1°F) but requires less air flow than concept 1 and provides air to the cabin at 20°C (68°F) which should minimize draft problems. This concept is considered viable for these reasons and because the one degree above the cabin limit occurs only during maximum power conditions. Concept 7 also meets requirements, in addition, it produces low temperatures in thermal racks which may simplify equipment layouts etc. This concept does require somewhat higher water flow, which could impact the interface heat

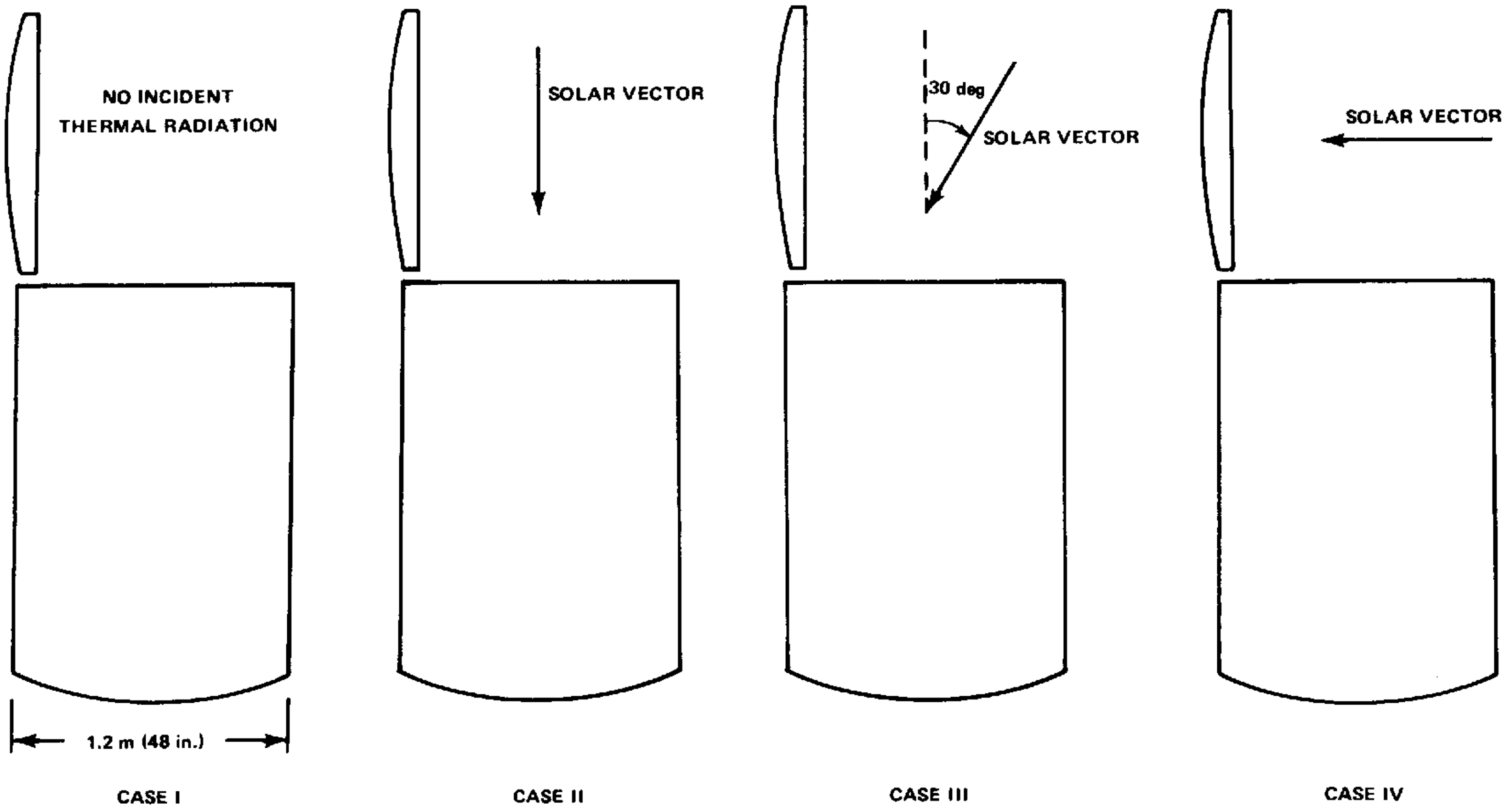


Figure 33. Description of cases considered for scientific airlock heat leak.

TABLE 8. COMPARISON OF T_{CABIN} (T_C) AND $T_{THERMAL\ RACK}$ (T_{TR}) FOR SORTIE LAB AIR CONDITIONING/VENTILATION CONCEPTS

FOLDOUT FRAME 1

FOLDOUT FRAME 2

$\frac{M\,H_2O}{W\,H_{XA}/W\,H_{XB}}$		Concept Number																			
		1				2				3				4				5			
		T_C		T_{TR}		T_C		T_{TR}		T_C		T_{TR}		T_C		T_{TR}		T_C		T_{TR}	
$\frac{kg/hr}{m^3/min/m^3/min}$	$\frac{lbm/hr}{(ft^3/min)/(ft^3/min)}$	°C	°F	°C	°F	°C	°F	°C	°F	°C	°F	°C	°F	°C	°F	°C	°F	°C	°F	°C	°F
$\frac{226.8}{15.3/15.3}$	$\frac{500}{540/540}$									28.9	84.1	35.2	95.3	35.2	95.3	32.7	90.8	37.4	99.4	32.4	90.4
$\frac{226.8}{15.3/19.8}$	$\frac{500}{540/700}$	19.9	67.8	38.9	102.1	35.4	95.8	30.9	87.7												
$\frac{226.8}{15.3/38.1}$	$\frac{500}{540/1346}$	19.9	67.8	33.7	92.7																
$\frac{226.8}{19.8/15.3}$	$\frac{500}{700/540}$																				
$\frac{226.8}{19.8/19.8}$	$\frac{500}{700/700}$									29.2	84.5	33.9	93.1	33.9	93.1	32.4	90.3	35.1	95.1	31.3	88.3
$\frac{226.8}{38.1/15.3}$	$\frac{500}{1346/540}$																				
$\frac{226.8}{38.1/19.8}$	$\frac{500}{1346/700}$																				
$\frac{226.8}{38.1/38.1}$	$\frac{500}{1346/1346}$									29.2	84.6	31.6	88.8	31.6	88.9	30.8	87.5	31.4	88.5	29.7	85.5
$\frac{317.5}{15.3/15.3}$	$\frac{700}{540/540}$									22.8	73.2	29.1	84.4	29.1	84.4	26.6	79.8				
$\frac{317.5}{19.8/19.8}$	$\frac{700}{700/700}$					25.2	77.4	22.7	72.8					24.3	75.7	22.3	72.2	23.2	73.8	22.2	71.9
$\frac{340.2}{15.3/15.3}$	$\frac{750}{540/540}$																				
$\frac{340.2}{15.3/19.8}$	$\frac{750}{540/700}$																				

$\frac{M\,H_2O}{W\,H_{XA}/W\,H_{XB}}$		Concept Number																			
		6				7				8				9				10			
		T_C		T_{TR}		T_C		T_{TR}		T_C		T_{TR}		T_C		T_{TR}		T_C		T_{TR}	
$\frac{kg/hr}{m^3/min/m^3/min}$	$\frac{lbm/hr}{(ft^3/min)/(ft^3/min)}$	°C	°F	°C	°F	°C	°F	°C	°F	°C	°F	°C	°F	°C	°F	°C	°F	°C	°F	°C	°F
$\frac{226.8}{15.3/15.3}$	$\frac{500}{540/540}$	25.0	77.0	37.4	99.4	30.6	87.0	36.8	98.2					26.0	78.8	38.6	101.5				
$\frac{226.8}{15.3/19.8}$	$\frac{500}{540/700}$									25.8	78.4	45.9	114.7	27.1	80.7	39.7	98.1				
$\frac{226.8}{15.3/38.1}$	$\frac{500}{540/1346}$																				
$\frac{226.8}{19.8/15.3}$	$\frac{500}{700/540}$													25.7	78.2	38.3	100.9				
$\frac{226.8}{19.8/19.8}$	$\frac{500}{700/700}$	25.4	77.8	35.1	95.1									26.8	80.3	36.5	97.7	34.3	93.7	30.4	86.8
$\frac{226.8}{38.1/15.3}$	$\frac{500}{1346/540}$													24.3	75.8	36.9	98.5				
$\frac{226.8}{38.1/19.8}$	$\frac{500}{1346/700}$													25.6	78.1	35.3	95.5				
$\frac{226.8}{38.1/38.1}$	$\frac{500}{1346/1346}$	26.7	80.1	31.4	88.5																
$\frac{317.5}{15.3/15.3}$	$\frac{700}{540/540}$																				
$\frac{317.5}{19.8/19.8}$	$\frac{700}{700/700}$	16.4	61.5	26.0	78.8													25.4	77.7	21.6	70.8
$\frac{340.2}{15.3/15.3}$	$\frac{750}{540/540}$					22.1	71.8	28.2	82.8												
$\frac{340.2}{15.3/19.8}$	$\frac{750}{540/700}$									19.9	67.8	33.2	91.7								

$M\,H_2O$ = Water Loop Flow Rate

$W\,H_{XA}$ = Cabin Air Flow

$W\,H_{XB}$ = Equipment Rack Air Flow

TABLE 9. ADVANTAGES AND DISADVANTAGES OF SORTIE LAB AIR CONDITIONING/VENTILATION CONCEPTS

Concept Number	Description	Advantages	Disadvantages
1	Series water flow with cabin Hx first. Separate gas loops for cabin and T. R.	1. Performance acceptable at 227 kg/hr (500 lbm/hr) water flow rate. 2. Separate temperature controls for cabin and T. R.	1. Considerable ducting 2. Cold air on cabin occupant.
2	Series water flow with T. R. Hx first. Separate gas loops for cabin and T.R.	1. More comfortable air on cabin occupants 21.4°C (70.5°F). 2. Separate temperature controls.	1. Must go to 318 kg/hr (700 lbm/hr) water flow rate. 2. Considerable ducting.
3	Series water flow. Gas from both Hx's distributed to cabin then circulated to thermal racks.	1. Less ducting than Cases 1 and 2.	1. Must go to 318 kg/hr (700 lbm/hr) water flow rate.
4	Series water flow. Gas from both Hx's distributed to T.R. then circulated to cabin.	1. Less ducting than Gases 1 and 2. 2. Comfortable air temperature into cabin 22.3°C (72.2°F).	1. Must go to 318 kg/hr (700 lbm/hr) water flow rate.
5	Series water flow. Series gas flow through Hx's distributed to T. R. and then circulated to cabin.	1. Less ducting than Cases 1 through 4. 2. Comfortable air temperature entering cabin 22.1°C (71.9°F).	1. Must go to 318 kg/hr (700 lbm/hr) water flow rate.
6	Series water flow. Series gas flow through Hx's distributed to cabin and then circulated to T. R.	1. Marginally acceptable at 227 kg/hr (5000 lbm/hr) water flow rate. 2. Less ducting than Cases 1 through 4. 3. Small total air flow rate required 15.3 m^3/min (540 ft^3/min). 4. Comfortable air temperature entering cabin 20.0°C (68°F).	
7	Parallel water flow. Gas from both Hx's distributed to cabin then circulated to thermal racks. (Same as Case 3 except parallel water flow).	1. Less ducting than Cases 1 and 2.	1. Water flow rate must be greater than 227 kg/hr (500 lbm/hr).
8	Parallel water flow. Separate gas loops for cabin and T.R. (Same as Case 1 except parallel water flow).	1. Easier control of cabin and T.R. temperatures.	1. Water flow rate must be greater than 227 kg/hr (500 lbm/hr).
9	Series water flow. Gas flow from both Hx's into cabin with a fraction of this total flow circulated through the thermal racks.	1. Less ducting than Cases 1 and 2. 2. Acceptable performance at 227 kg/hr (500 lbm/hr) water flow rate. 3. Comfortable air temperature into cabin.	
10	Series water flow. Gas flow from both Hx's into T. R. with a fraction of this total flow circulated to the cabin.	1. Less ducting than Cases 1 and 2. 2. Comfortable air temperature into cabin.	1. Must go to water flow rate greater than 227 kg/hr (500 lbm/hr).

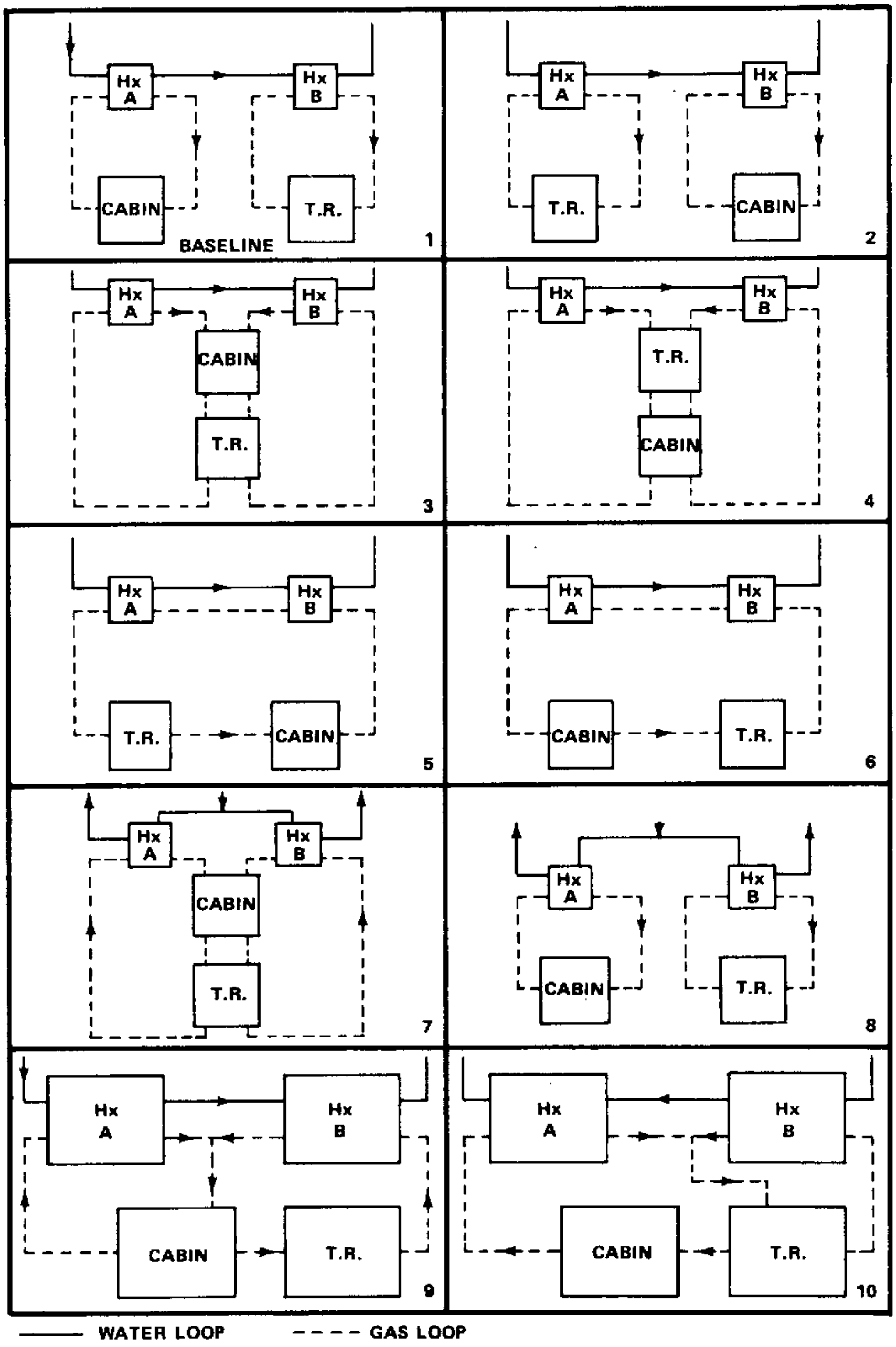


Figure 34. Air conditioning/ventilation concepts considered for Sortie Lab.

exchanger/radiator system. These systems are considered the most viable of the 10. The detailed schematics of these candidates are shown on Figures 35, 36, and 37.

A further evaluation was conducted of the 10 candidate concepts from a mechanical standpoint. Weight and component availability were prime considerations. The results of the mechanical evaluation are discussed below. However, in summary, the conclusions are essentially the same as the thermal evaluation, above.

The design characteristics of 10 system configurations have been evaluated. Concepts 2, 5, and 10 did not meet the Sortie Lab cabin temperature requirements for the coolant and air flow rates used. In concepts 4, 5, and 10, air from the heat exchangers is ducted through the thermal racks into the cabin. This ducting arrangement is not considered satisfactory because of the following reasons:

- Variations in experiment heat loads will result in cabin temperature transients that are not moderated by the cabin heat exchangers.
- Airflow into the cabin is determined by the equipment arrangement and distribution in the cabin.
- Violates good air conditioning practice which is to keep heat from being dissipated into the conditioned space. This is accomplished by directing supply air toward the heat source or locating a return air duct near the heat source.

Concepts 2, 4, 5, and 10 will not be considered further in this study due to the reasons listed above.

In order to reduce the number of ducting configurations that would satisfy the system schematics mentioned above and to simplify the comparison of the systems, the following general guidelines and assumptions were used to establish the system configurations to be evaluated:

- All systems will provide underfloor cooling (requires sealed floor to assure circulation in underfloor area).
- Fan and muffler weights are assumed equal for all concepts.
- Weights of coolant lines and valves are assumed equal for all concepts.

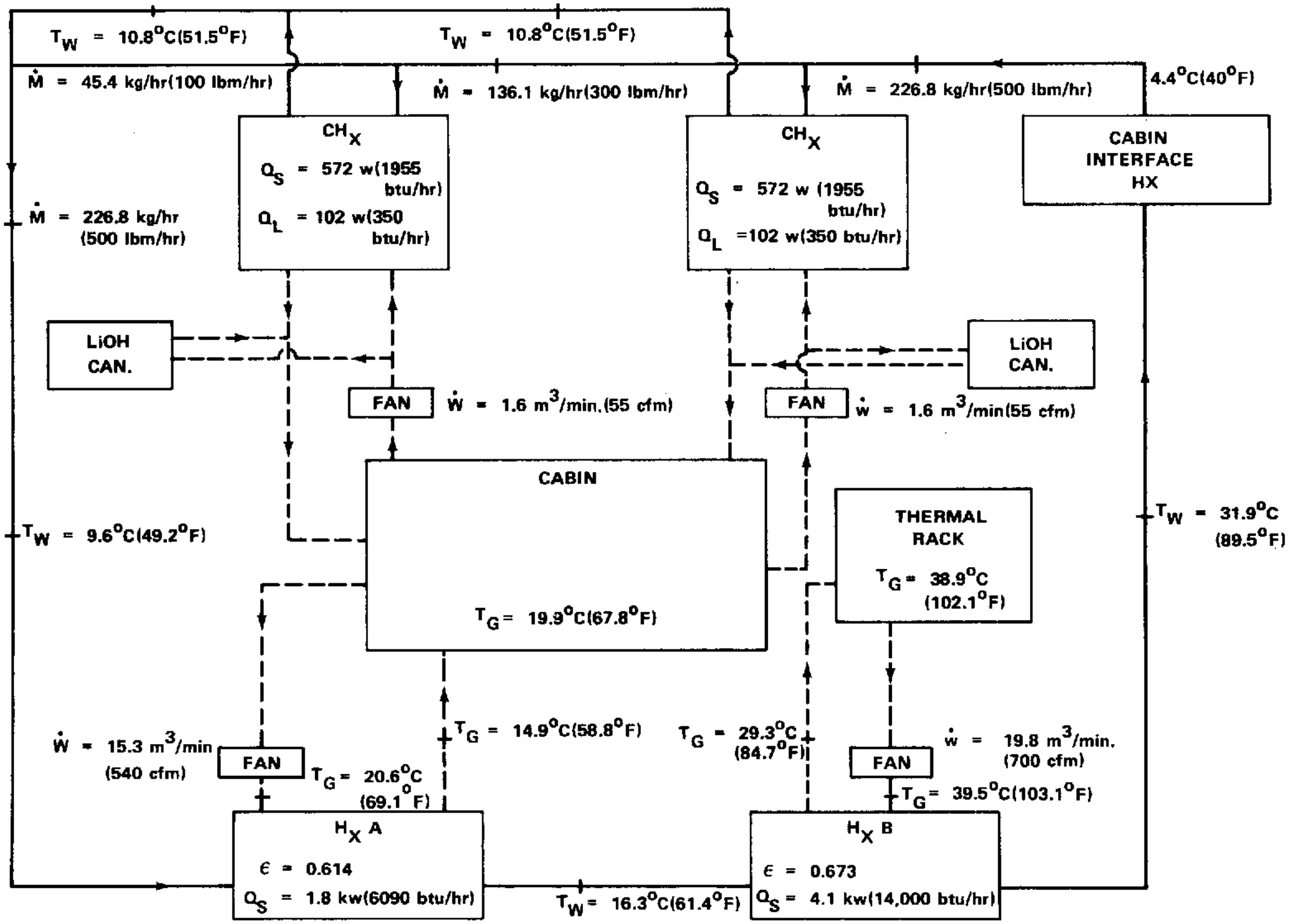


Figure 35. Baseline concept: $\dot{M}_W = 226.8$ kg/hr (500 lbm/hr), $\dot{W}_A = 15.3$ m^3/min (540 cfm), $\dot{W}_B = 19.8$ m^3/min (700 cfm).

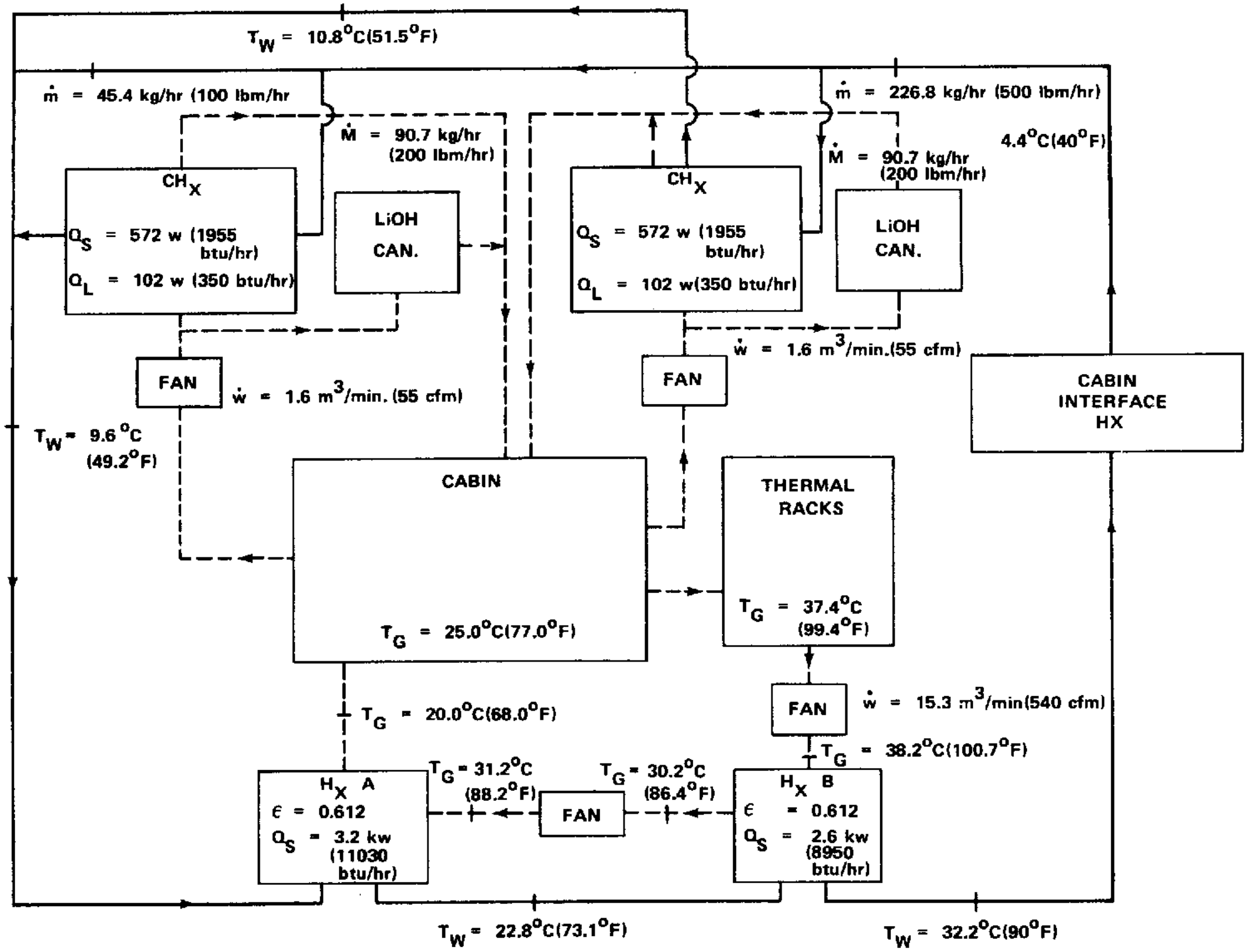


Figure 36. Concept number 6. M_W = 226.8 kg/hr (500 lbm/hr), W_A = 15.3 m^3/min (540 cfm), W_B = 15.3 m^3/min (540 cfm).

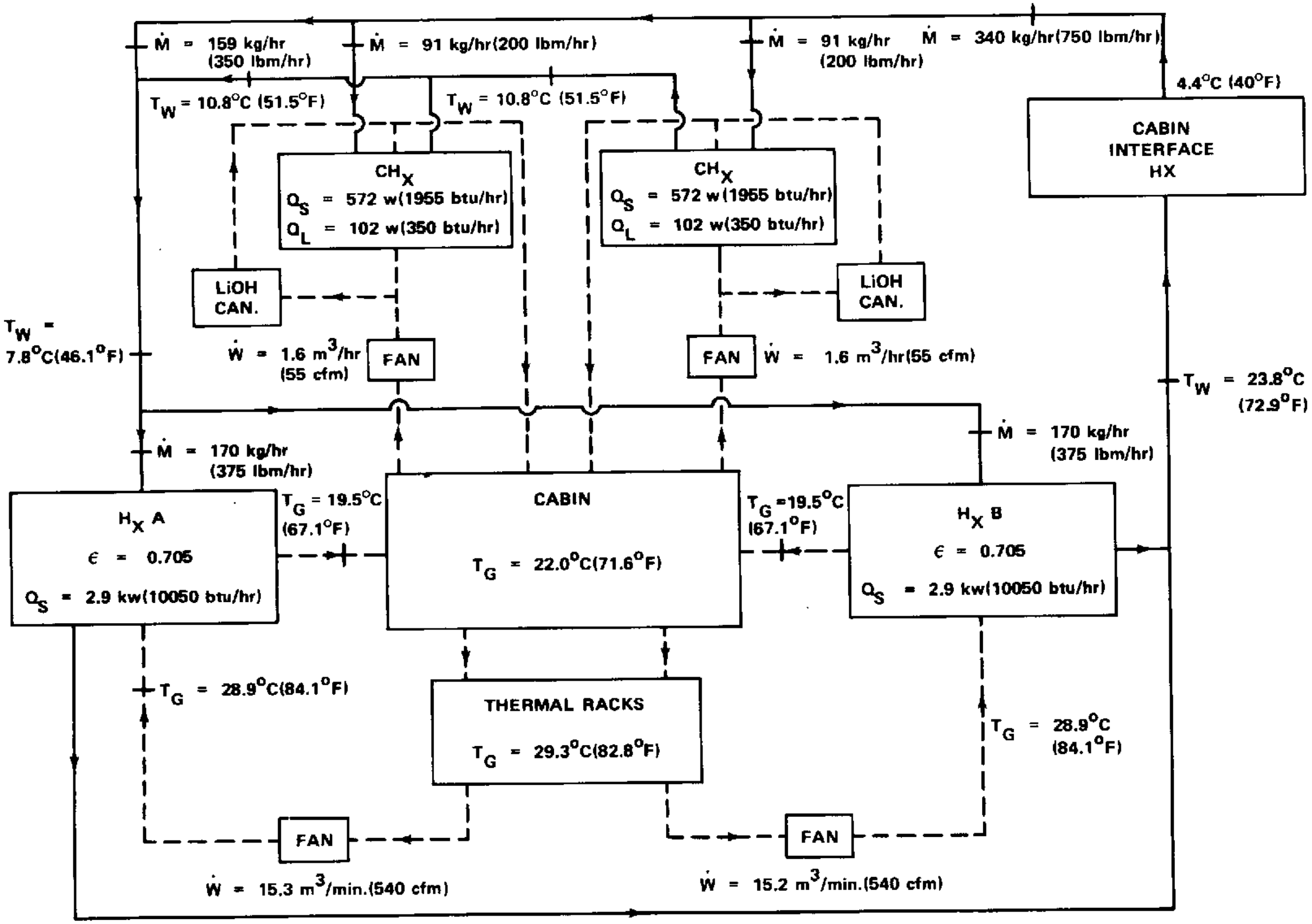


Figure 37. Concept number 7: $\dot{M}_W = 340$ kg/hr (750 lbm/hr), $\dot{W}_A = 15.3$ m³/min (540 cfm), $\dot{W}_B = 15.3$ m³/min (540 cfm).

- Weight of filters is assumed equal in all concepts.
- Ducting sizes were not reduced along the run to maintain a constant velocity or reduce weight.

The ventilation system concepts to be compared are shown schematically in Figures 38 through 43. The ducting arrangements for these concepts are shown in Figures 44 through 47.

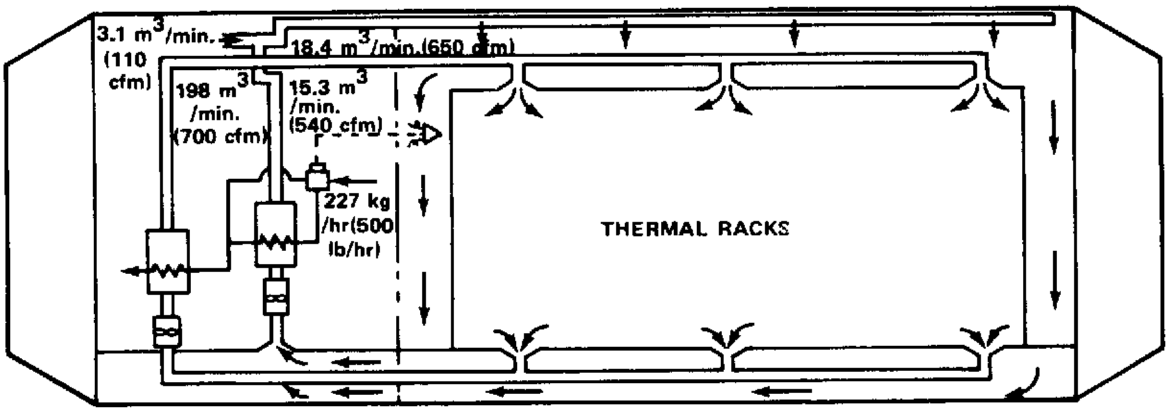


Figure 38. Ventilation system schematic for concept number 1.

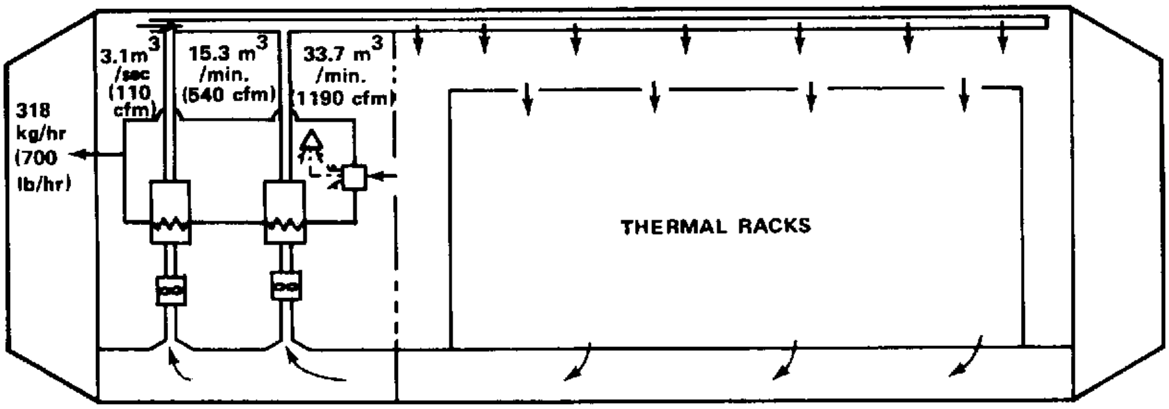


Figure 39. Ventilation system schematic for concept number 3.

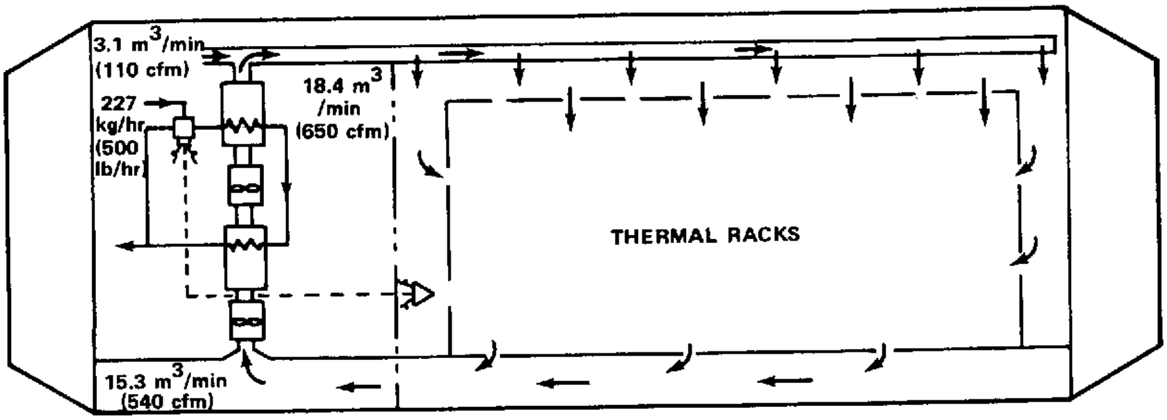


Figure 40. Ventilation system schematic for concept number 6.

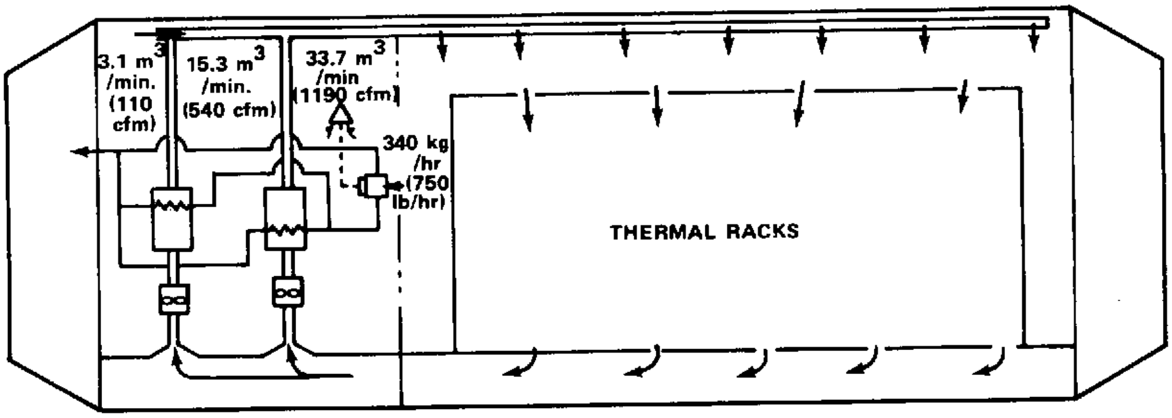


Figure 41. Ventilation system schematic for concept number 7.

a. Evaluation

(1). Method. The system characteristics used to compare the six ventilation system concepts are shown below. The systems are compared for each characteristic and assigned a numerical rating of from 1 to 5 with the highest number indicating the best system. Also shown is a weighting factor which indicates the relative importance of each characteristic. The most important characteristic has the highest weighting factor.

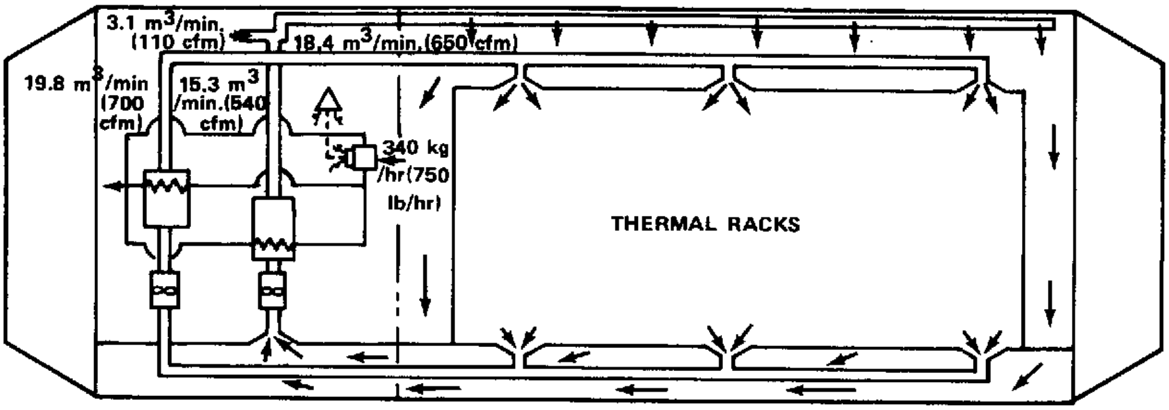


Figure 42. Ventilation system schematic for concept number 8.

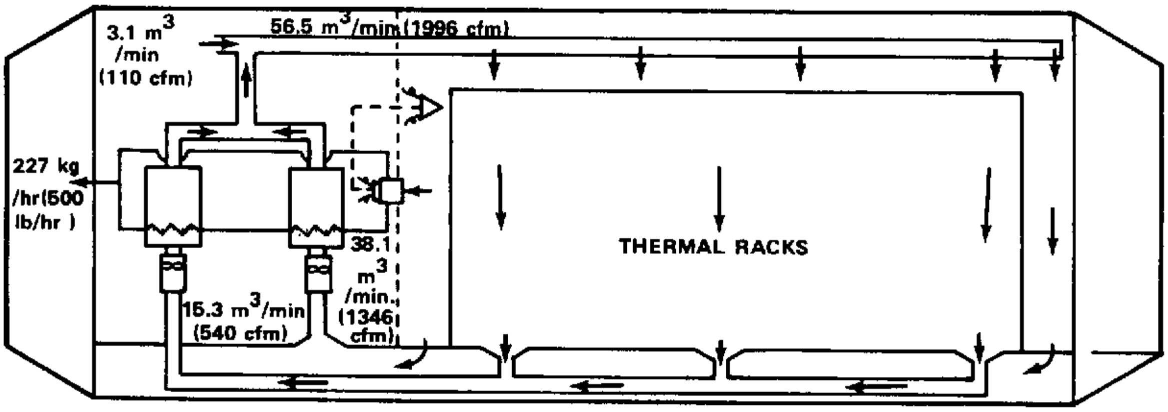


Figure 43. Ventilation system schematic for concept number 9.

Characteristic	Weighting Factor
System Weight	1
Cabin Circulation	2
System Power Required	1
Crew Comfort	2
Experiment Equipment Considerations	2
System Cost	3

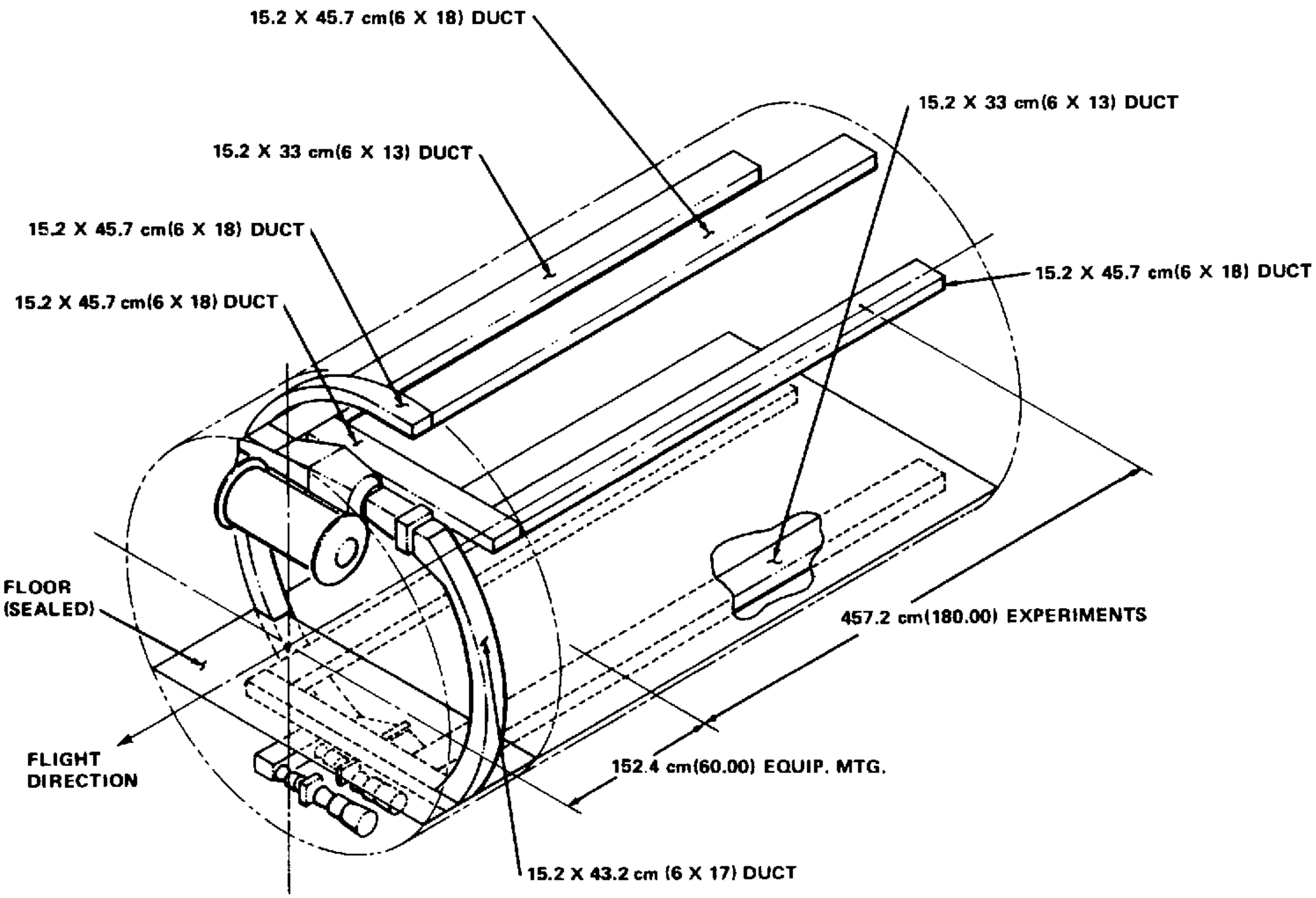


Figure 44. Ducting arrangement for concepts number 1 and 8.

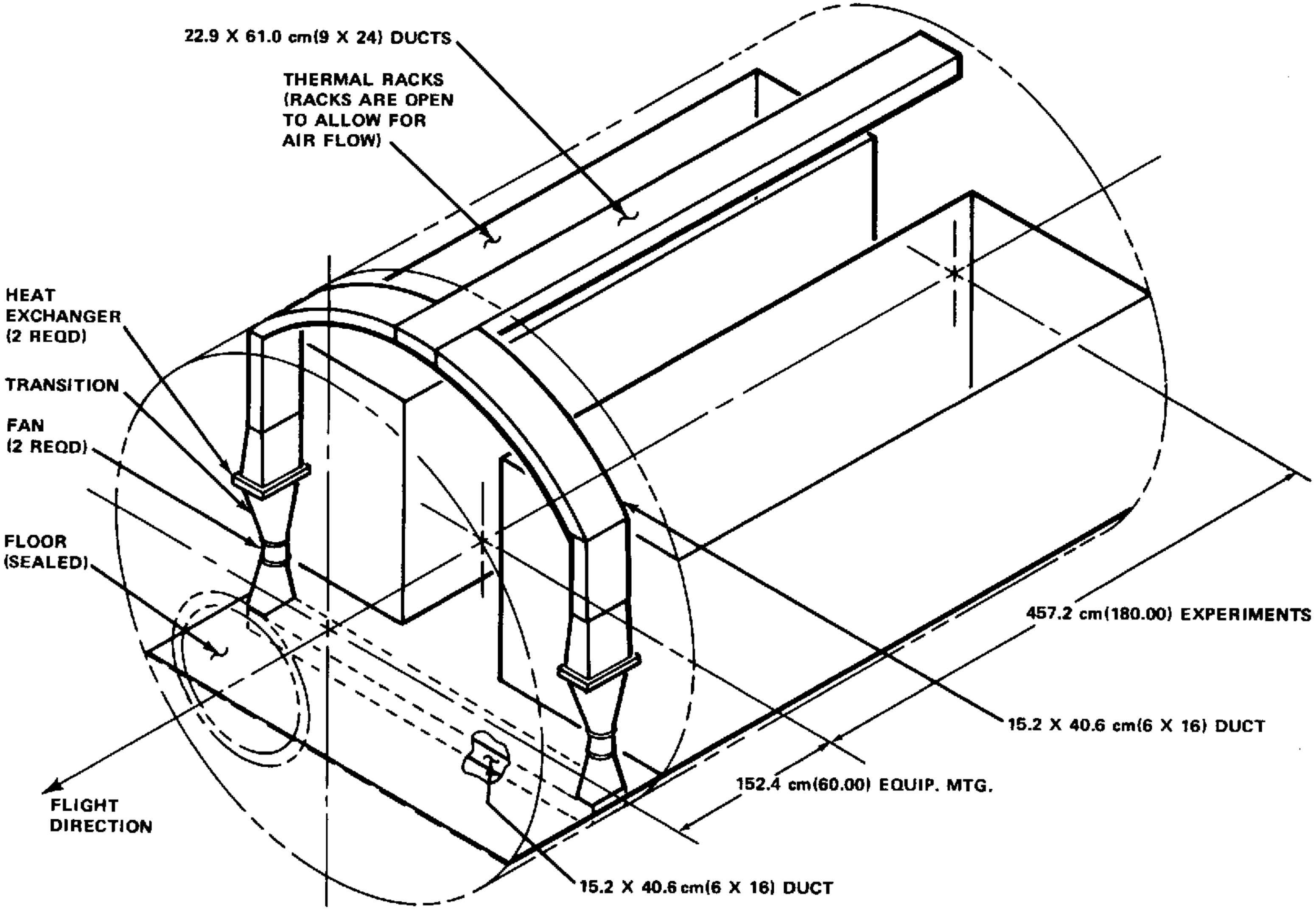


Figure 45. Ducting arrangement for concepts number 3 and 7.

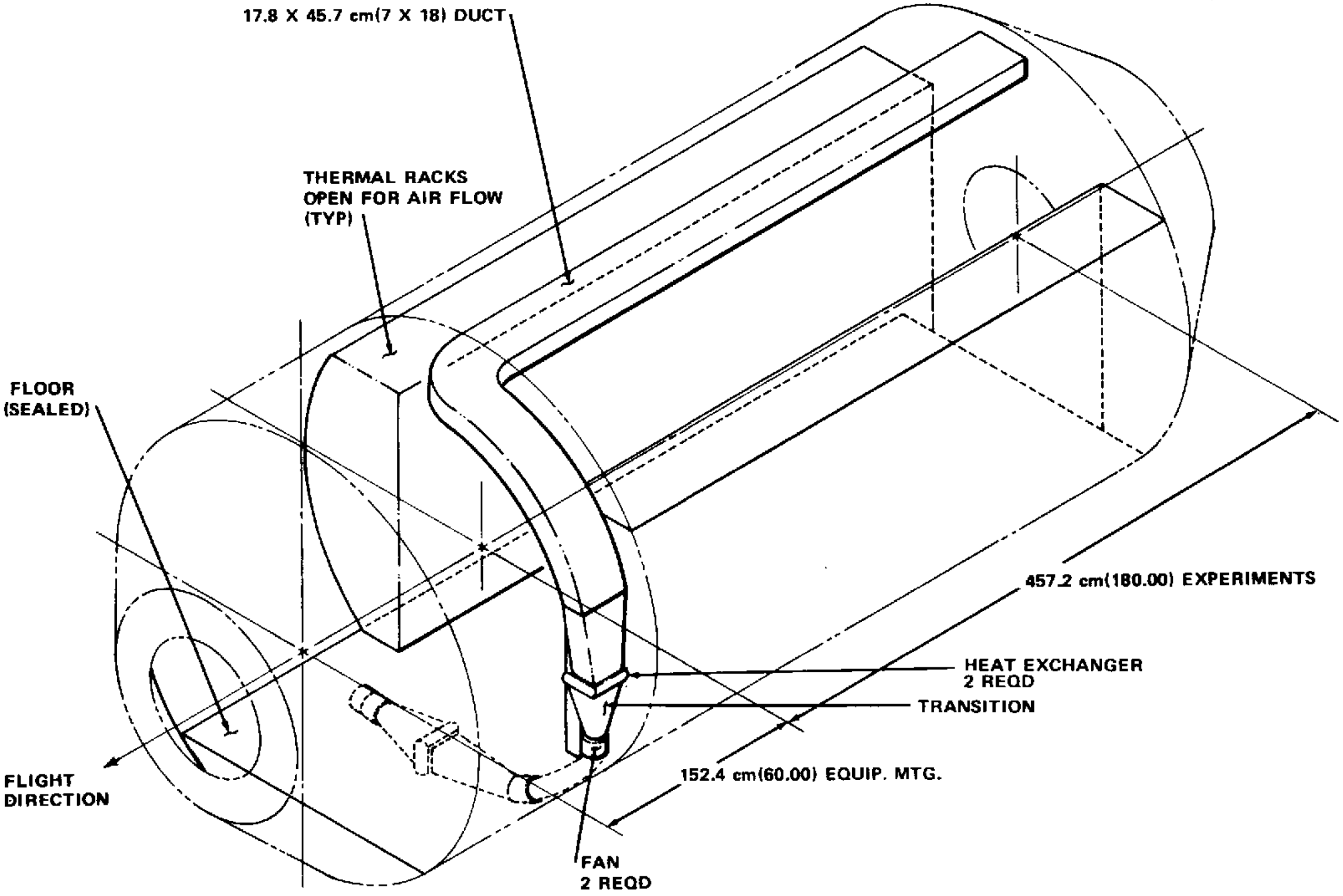


Figure 46. Ducting arrangement for concept number 6.

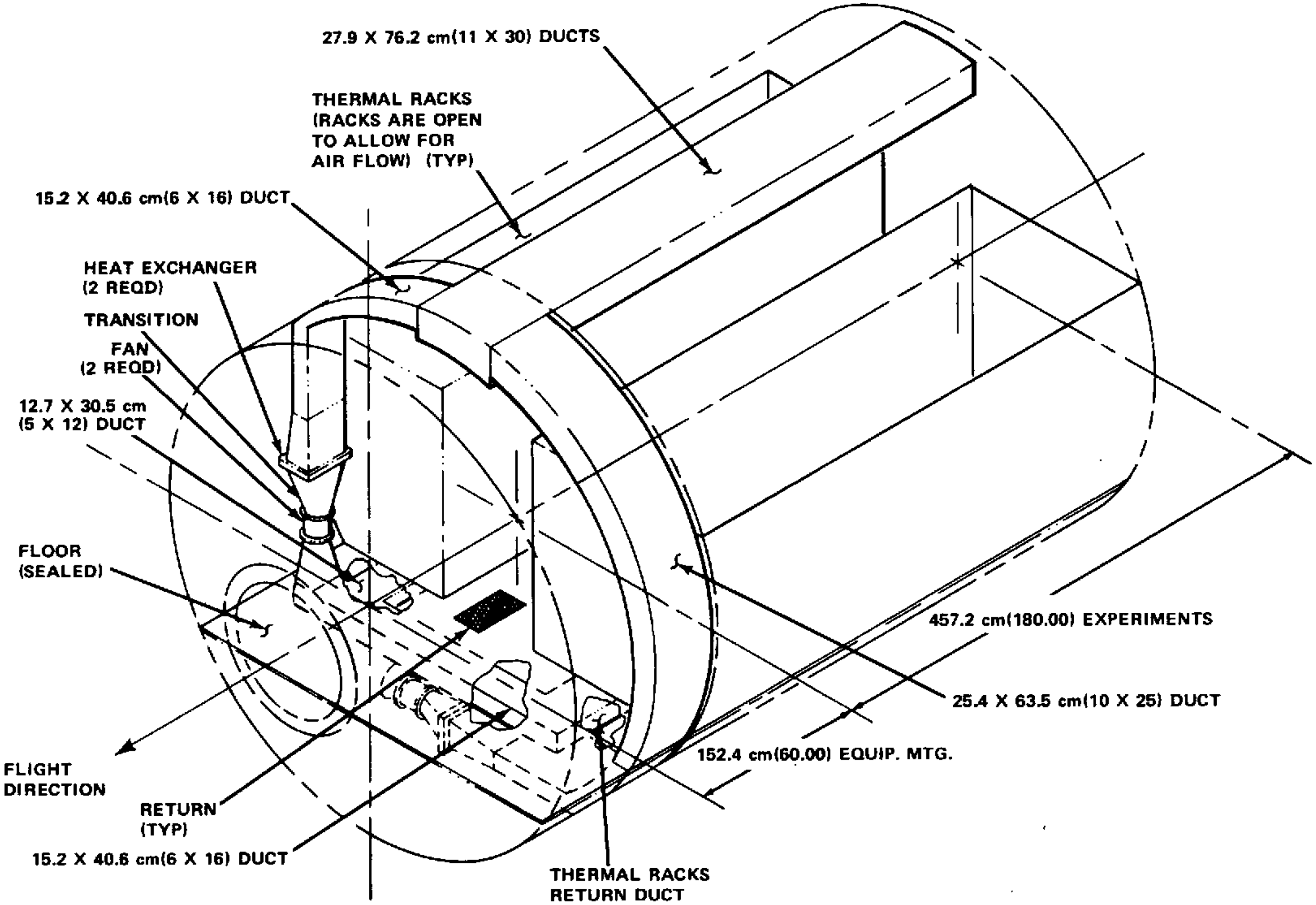


Figure 47. Ducting arrangement for concept number 9.

The ventilation system concept comparison is shown in Table 10. Each characteristic is assigned a numerical relative rating for each system concept. The relative rating is multiplied by the weighting factor to yield a weighted rating. Statements concerning the characteristics are included for each system concept to indicate the basis for assigning the numerical rating. The ratings for each concept are added together to provide an overall numerical rating (relative and weighted) for each concept. The highest numerical rating indicates the most desirable system concept.

(2). Results. The relative and weighted ratings of the concepts are summarized in Table 11. The maximum relative rating possible is 30 and the maximum weighted rating possible is 55. The ranking of the concepts is also shown.

Concept 6 is substantially ahead of the other concepts with 9, 7, 3, and 1 showing little differences. Concept 8 is well below the other concepts.

b. Conclusions. Concept 6 is the most desirable alternate concept compared to baselined concept 1, and concepts 3, 7, and 9. The latter concepts are acceptable. However, before a final decision is made, a more detailed experimental study of concept 6 should be made to insure that adequate circulation can be provided without excessive additional fan power.

c. Future Work. An experiment equipment installation should be defined for a payload with nominal heat loads and a payload with maximum heat loads. Concepts 1, 3, 6, 7, and 9 should be compared for these two payload arrangements. This comparison should be concerned with cabin circulation, crew comfort, and experiment equipment considerations. If a problem is identified for a system, the various methods and equipment that can be used to alleviate the problem should be investigated and evaluated. These could include adding or relocating air supply and return registers, adding ducting and providing additional fixed or movable fans.

2. Cabin Temperature Control Valve Selection. The two primary methods considered for controlling Sortie Lab cabin temperature are to control coolant flow or air flow through the cabin heat exchanger. Four valve arrangements were evaluated for controlling coolant flow while one valve arrangement was evaluated for controlling air flow. More coolant flow control valve arrangements were evaluated because there are more valve designs available that are suitable for controlling coolant flow. The valve arrangements evaluated are shown schematically in Figures 48 through 51.

TABLE 10. AIR DISTRIBUTION SYSTEM COMPARISON

System Characteristic	Air Distribution System Concepts											
	Concept 1		Concept 3		Concept 6		Concept 7		Concept 8		Concept 9	
	Relative Rating	Weighted Rating	Relative Rating	Weighted Rating	Relative Rating	Weighted Rating	Relative Rating	Weighted Rating	Relative Rating	Weighted Rating	Relative Rating	Weighted Rating
Cost	Candidate fans and coolant pump exist. Maximum ducting.		Candidate fans exist.		Candidate Coolant pump and fans exist. Minimum ducting.		Candidate fans exist.		Candidate fans exist. Maximum ducting.		Candidate coolant pump exists. New fan development required.	
	4	12	3	9	5	15	3	9	2	8	3	9
Weight	86 kg (190 lb) ducting		32 kg (70 lb) ducting		20 kg (45 lb) ducting		32 kg (70 lb) ducting		86 kg (190 lb) ducting		64 kg (140 lb) ducting	
	1	1	4	4	5	5	4	4	1	1	2	2
Power Required	Moderate air flow. Maximum ducting length. Minimum coolant flow.		Moderate air flow. Small ducting length. Large coolant flow.		Lowest air flow. Maximum ducting length. Minimum coolant flow.		Moderate air flow. Small ducting length. Maximum coolant flow.		Moderate air flow. Maximum ducting length. Maximum coolant flow.		Maximum air flow. Large ducting length. Minimum coolant flow.	
	3	3	4	4	5	5	4	4	2	2	2	2
Cabin Circulation	Not affected by experiment equip location. Lowest cabin air flow.		Affected by experiment equip location. Good cabin air flow.		Max effect from experiment equip location. Low cabin air flow.		Affected by experiment equip location. Good cabin air flow.		Not affected by experiment equip location. Lowest cabin air flow.		Small effect from experiment equip location. Good cabin air flow.	
	4	8	3	6	2	4	3	6	4	8	5	10
Crew Comfort	Low noise. Low inlet air temp.		Low noise. Good inlet air temp.		Lowest noise. Good inlet air temp.		Low noise. Good inlet air temp.		Low noise. Low inlet air temp.		Maximum noise. Good inlet air temp.	
	3	6	5	10	5	10	5	10	3	6	4	8
Experiment Equipment Considerations	Sealed thermal racks required. Best control of air flow distribution.		Sealed thermal racks not required. Difficult to provide proper air flow distribution.		Sealed thermal racks not required. Difficult to provide proper air flow distribution.		Sealed thermal racks not required. Difficult to provide proper air flow distribution.		Sealed thermal racks required. Best control of air flow distribution.		Sealed thermal racks not required. Fair control of air flow distribution.	
	4	8	3	6	3	6	3	6	4	8	5	10
Total Rating	19	38	22	39	25	45	22	39	16	31	21	41

Weighted Rating = (Relative Rating) x (Weight Factor)

Relative Ratings
1 - Least Favorable
2 - ↓
3 -
4 -
5 - Most Favorable

System Characteristic	Weight Factor (Highest No. = Highest Priority)
Cost	3
Weight	1
Power Required	1
Cabin Circulation	2
Crew Comfort	2
Experiment Equipment Considerations	2

TABLE 11. SYSTEM CONCEPT RATING SUMMARY AND RANKING

Concept No.	Relative Rating	Weighted Rating	Relative Ranking	Weighted Ranking
1	19	38	5	3
3	22	39	2	3
6	25	45	1	1
7	22	39	2	3
8	15	29	6	6
9	21	41	4	2

Redundant temperature control valves can be provided in a coolant flow control system without a large weight penalty and space requirements that would be necessary to provide redundant control valves in an air flow control system. The air flow control valve system reliability can be improved without using redundant valves by making the valve replaceable during flight. The air flow control system provides a faster response to flow control element position changes than the coolant flow control system. The difference in response of the two systems is not important in this application because the cabin volume introduces a relatively large time lag in cabin temperature changes.

The five temperature control systems considered were evaluated for system characteristics of temperature regulation, installation weight, complexity, reliability, and cost. The results of the evaluation are shown in Table 12. The most important characteristic is cost followed by temperature regulation and reliability. Installation weight is least important since control valve weight is a small portion of the total environmental control system weight.

The temperature control valve system selected for the phase B baseline environmental control system is shown in Figure 50. This system uses two-position valves with step control.

The ratings shown are subjective and the system selected was not actually rated the highest due to the possibility of higher rated systems producing unacceptable cabin temperature variations.

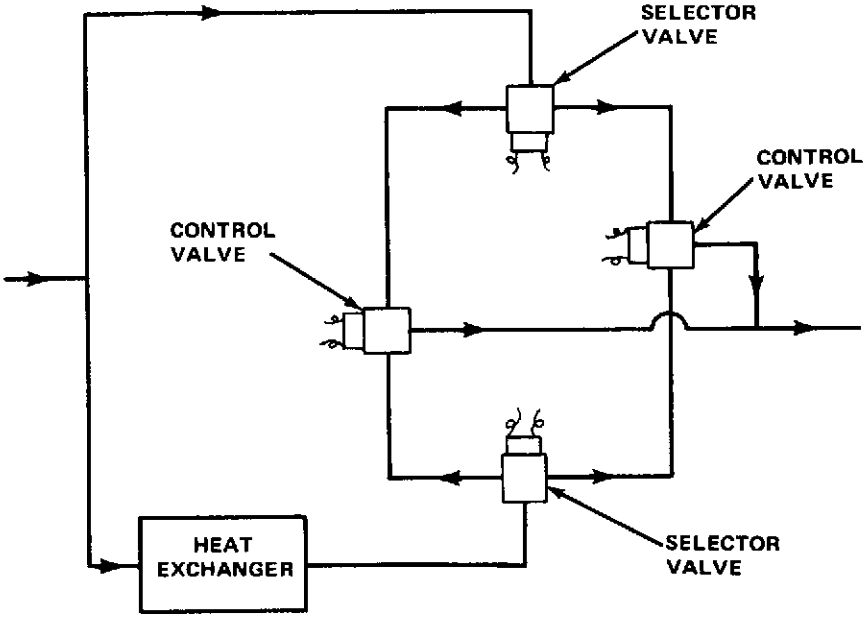


Figure 48. Arrangement for flow control with modulating flow control valve or three-way, two position valve.

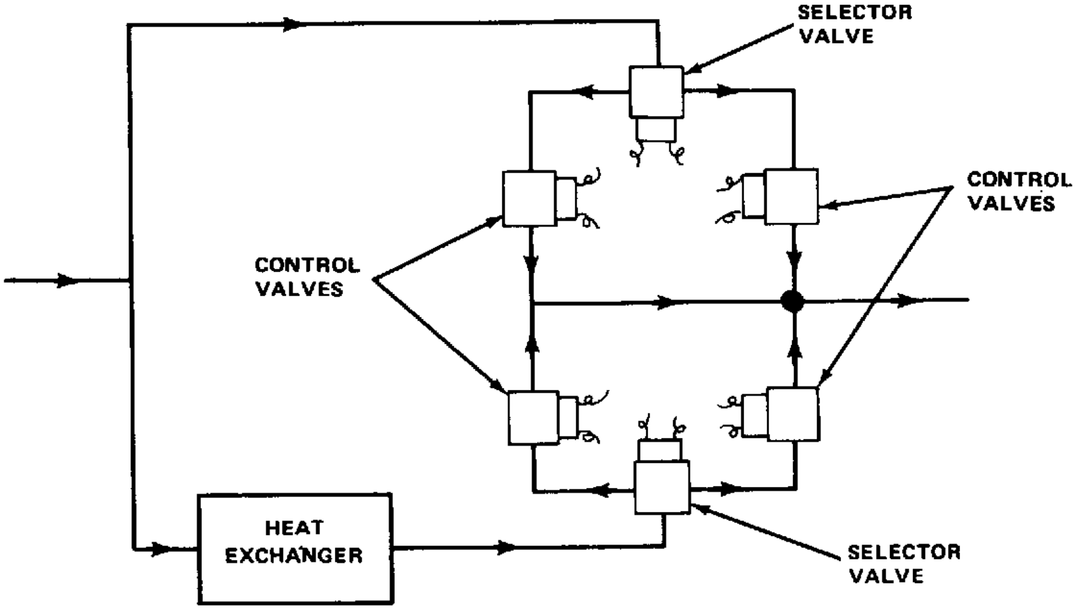


Figure 49. Arrangement for flow control with two-way, two-position valves.

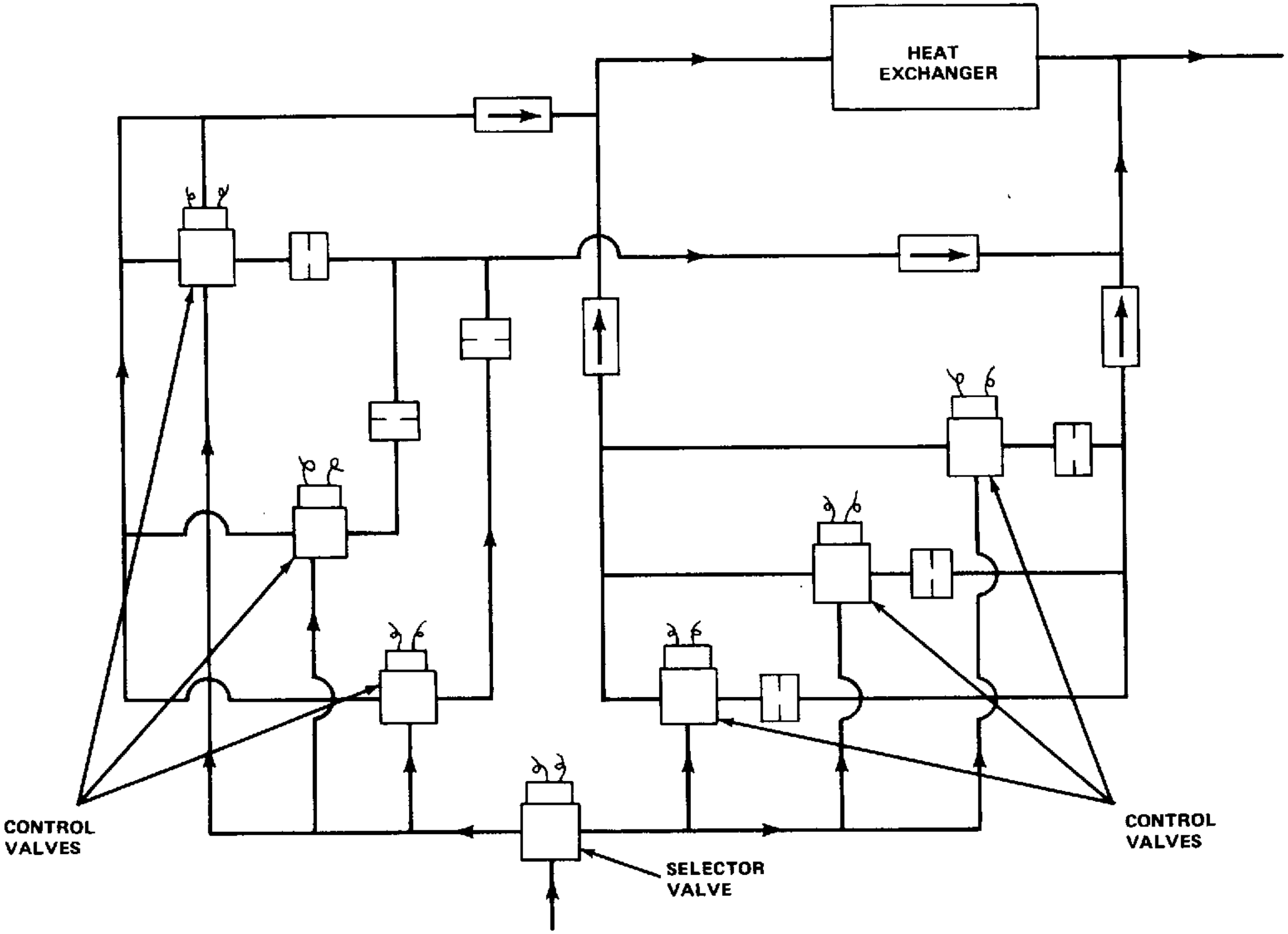


Figure 50. Arrangement for three step flow control with three-way, two-position valves.

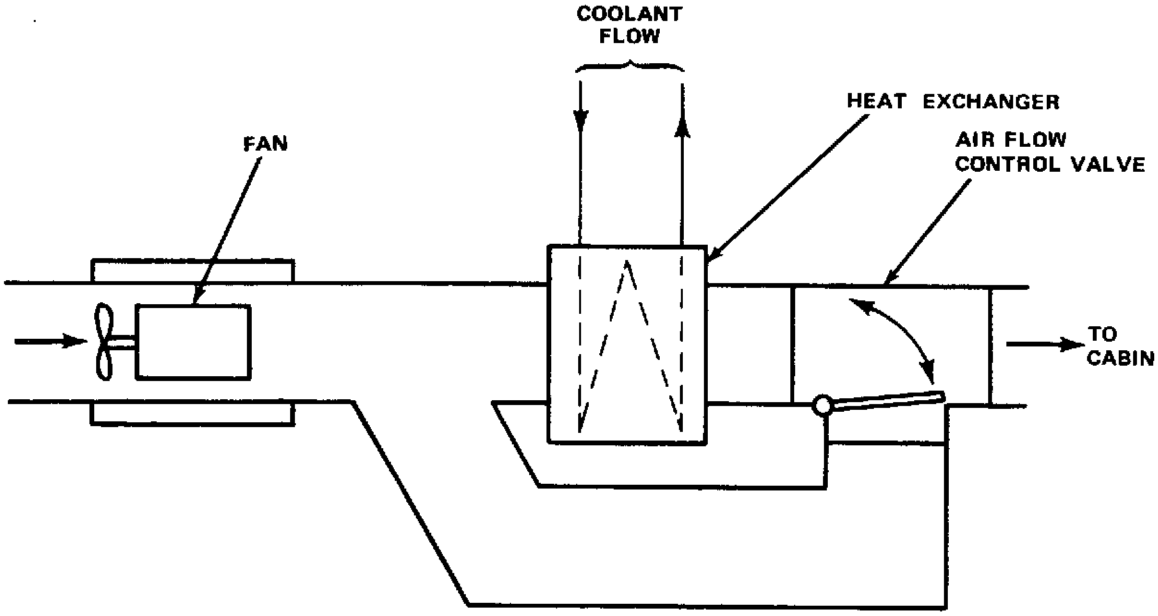


Figure 51. Arrangement for air flow control with modulating air flow control valve.

The selected arrangement gives a semi-modulated flow control, actually of four steps or levels in coolant flow. The associated control electronics consist of basically thermal switches (different settings) and relays for each solenoid valve which makes for simplicity and reduced cost. This system with selection of a long stroke solenoid valve and upstream filtering gives a good compromise between temperature control, cost, and reliability.

The magnitude of temperature variations to be expected from the highest rated temperature control valve arrangements should be estimated by using the performance characteristics of these valve arrangements in the Sortie Lab environmental control system math model. The results of such an analysis may indicate that a different temperature control valve arrangement should be selected for the Sortie Lab.

The Shuttle orbiter cabin temperature control is to be accomplished by using an air flow control system. It should be determined if the components in the orbiter system can be used in the Sortie Lab. If so, the modulating air flow control system could be equal to or better than the baseline system. An additional consideration is the difficulty being experienced with coolant temperature control valves on Skylab — of a total of 10 on board, 4 have

TABLE 12. TEMPERATURE CONTROL SYSTEM COMPARISON

System Characteristics	Temperature Control System									
	2-Way, 2-Position Valves (Figure 49)		3-Way, 2-Position Valve (Figure 48)		2 Pos Valves, Step Control (Figure 50)		Modulating Flow Control (Figure 48)		Modulating Air Flow Control (Figure 51)	
	Relative Rating	Weighted Rating	Relative Rating	Weighted Rating	Relative Rating	Weighted Rating	Relative Rating	Weighted Rating	Relative Rating	Weighted Rating
Temp Regulation	Maximum Temperature Variation		Maximum Temperature Variation		Reduced Temperature Variation		Smallest Temperature Variation		Smallest Temperature Variation	
	1	2	1	2	3	6	5	10	5	10
Installation Weight and Complexity	Low weight. Installation not complex.		Minimum Weight. Least complex installation.		High weight. Most complex installation.		Low weight. Least complex installation.		Highest weight. complex installation.	
	3	3	5	5	2	2	4	4	1	1
Reliability	Reliable. Simple valve construction. Simple controller.		Most reliable. Simple valves. Fewest valves. Simple Controller.		Fair reliability. Simple valves. Max number of valves. Complex controller.		Least reliable. Valve mechanically complex. Most complex controller.		Poor Reliability. Complex valve (motor and gears or linkages). No redundancy. Complex controller.	
	4	8	5	10	3	6	1	2	1	2
Cost	Low cost. Simple valves and controller.		Lowest cost. Fewest valves and simplest controller.		High cost. Most components and complex controller.		Highest cost. Most complex valves and controller.		High cost. One valve required. Complex controller. Complex valve.	
	4	12	5	15	3	9	1	3	3	9
Total Rating	12	25	16	32	11	23	11	19	10	22

Weighted Rating = (Relative Rating) x (Weight Factor)

Relative Ratings

1 - Least Favorable
2 -
3 -
4 -
5 - Most Favorable

System Characteristic	Weight Factor (Highest No. = Highest Priority)
Temperature Regulation	2
Installation Weight and Complexity	1
Reliability	2
Cost	3

developed on-orbit "hang up" problems. These valves are of two types — vernatherm and a complex latching solenoid. Both types are highly sensitive to particulate contamination. The advantage of utilizing an air valve is that a spare can be used as a redundant part. In the event the primary valve would fail, replacement with another valve would require minimum operation time.

Human comfort will become an added parameter to final valve selection, if cost, weight, and reliability studies rule out the modulating air flow valve. A choice between the concepts of figures 48 and 50 may become dependent upon cold air drafts that could be produced by the former system, sending full coolant flow to the heat exchanger. Final determination may depend upon testing with the selected air distribution system.

E. Coolant Fluid Selection

Freon 21 was initially selected for the Sortie Lab heat transport loop in order to maintain commonality with the Shuttle orbiter's thermal control system. An investigation of other candidate fluids was not performed. To substantiate the selection of Freon 21, this study was conducted.

A number of coolant fluids were evaluated for possible use in the heat transport loop of the thermal control system. The Sortie Lab ECS baseline design represents a dual heat transport loop configuration. The coolant media located internal to the lab is water and external is Freon 21.

The candidate fluids with their respective parameters that were investigated are shown in Table 13. These candidate fluids were identified from the Skylab and Apollo programs through a literature survey.

A figure-of-merit parameter was derived to measure performance of the fluid. (First column shown in Table 13 depicts this parameter analysis.) This is a very useful term for fluid evaluation since it takes into account a number of physical and thermal properties of the fluid under study. The figure-of-merit was defined in the following form:

F = Heat transfer effectiveness/pumping power

The larger the figure-of-merit the better the performance of the fluid. Criteria used in evaluation of candidate coolant fluids was as follows:

TABLE 13. SORTIE LAB COOLANT FLUID EVALUATION

Coolant	Figure of Merit	Flash Pt. °C [°F]	Freeze Pt. °C [°F]	Boiling Pt. °C [°F]	Toxicity (Mac)	Odor	Material Compat.
Water*	1.000	N.A.	0 (32)	100 (212)	N.A.	None	Elastomers–no swell corrosive
Methanol/Water* (60/40)	0.234	21 (69)	-73 (-100)	76 (169)	26 mg/m^3	Noxious	Elastomers–no swell corrosive
Methanol/Water* (80/20)	0.154	14 (58)	-103 (-154)	70 (158)	26 mg/m^3	Noxious	Elastomers–no swell corrosive
Glycol/Water* (60/40)	0.114	>116 (>240)	-54 (-65)	110 (230)	114 mg/m^3	Slight	Elastomers–no swell corrosive
Freon E-3	0.013	N. A. Non-flammable	-107 (-160)	153 (307)	Toxic at >260°C (>500°F)	None	Elastomers–slight swell Non-corrosive
Freon 21	0.065	N.A. Non-explosive	-135 (-211)	9 (48)	420 mg/m^3	Very noxious	Elastomers–large swell Non-corrosive
FC-75	0.032	>204 (>400)	-93 (-135)	102 (216)	N.A.	N.A.	Elastomers–no swell
Coolanol-15	0.022	>77 (>170)	-97 (-140)	232 (450)	Toxic at 149°C (300°F)	Slight	Elastomers–moderate swell Non-corrosive
Freon E-2	0.022	N.A. Non-flammable	-123 (-190)	101 (214)	Toxic at >260°C (>500°F)	None	Elastomers–slight swell Non-corrosive
FC-77	0.022	>204 (>400)	-101 (-150)	97 (207)	N.A.	N.A.	Elastomers–no swell
Freon E-1	0.035	N.A. Non-flammable	-154 (-246)	39 (102)	Toxic at >260°C (>500°F)	None	Elastomers–slight swell Non-corrosive
Oronite Flo-Cool 100	0.020	116 (240)	-73 (-100)	149 (300)	N.A.	N.A.	Elastomers–moderate swell

*Corrosive when without corrosion inhibitors.

Fluid Properties

Low freezing point
Low viscosity over wide temperature range
Minimum toxicity
High flash point

Thermal Requirements

$Q = 29,200$ Btu/hr = 8.5 kW
$\Delta T = 58°F = 14.4°C$

Tabulated values shown in Table 14 describe coolant fluid specific heat, thermal conductivity, density, viscosity, and the required mass flow rate that would meet the thermal requirements specified above.

Screening of the coolant fluid parameter shown in Table 13 led to the selection of four candidate coolant fluids for further analysis. They are Freon 21, Freon E-1, Freon E-2, and Freon E-3. Of these four, Freon E-3 exhibits the lower figure-of-merit and is the most viscous. Fluid viscosity versus fluid temperature relationship for the three coolants — Freon 21, Freon E-1, and Freon E-3, is shown in Figure 52. A viscosity curve for Freon E-2 is not shown, but it is higher than that of Freon E-1. Therefore, properties of Freon E-1 and Freon 21 were traded off.

Inspection of Figure 52 shows that Freon 21 has the lowest viscosity across the investigated temperature range of -73°C to 60°C (-100°F to +140°F). Freon E-1 is more viscous than Freon 21, but not much greater.

There is one significant disadvantage of using Freon 21 as a coolant medium. It is incompatible with commonly used elastomeric materials. Freons have been noted to be troublesome in their attack of certain rubbers and other nonmetallic seal materials. For most industrially important Freons, specific rubber types and compounds are known which are satisfactory for most purposes, but Freon 21 ranks as a troublesome exception. Development costs for a satisfactory rubber material can be high when using Freon 21. The Freon E series liquids are much more compatible to elastomeric materials. Secondly, the vapor pressure of Freon 21 is much higher than that of Freon E-1. For example, at 51.7°C (125°F) Freon 21 has a vapor pressure of 41.4 N/cm^2 (60 lb/in^2), whereas, for Freon E-1, it is 15.2 N/cm^2 (22 lb/in^2).

TABLE 14. CANDIDATE COOLANT FLUID PHYSICAL PROPERTIES

Fluid	C_P		$\dot{m}$		k		ρ		$\mu \times 10^4$		$\nu \times 10^5$	
	$\frac{W\text{-}hr}{kg\text{-}^\circ C}$	$\frac{BTU}{lb\ ^\circ F}$	$\frac{lb}{hr}$	$\frac{lb}{hr}$	$\frac{W}{m\text{-}^\circ C}$	$\frac{BTU}{hr\ ^\circ F\ ft}$	$\frac{kg}{m^3}$	$\frac{lb}{ft^3}$	$\frac{N\text{-}sec}{m^2}$	$\frac{lb}{ft\ sec}$	$\frac{m^2}{sec}$	$\frac{ft^2}{sec}$
Water	1.16	1.00	227	500	0.579	0.335	998.18	62.32	13.01	6.74	0.10	1.08
Glycol/Water 60/40	0.86	0.74	306	675	0.380	0.22	1070.89	66.86	59.97	40.3	0.56	6.03
Coolanol-15 (MCS-198)	0.50	0.43	528	1163	0.114	0.066	900.15	56.2	21.28	14.3	0.24	2.54
Oronite Flo-cool 100	0.55	0.46	493	1087	0.099	0.057	895.35	55.90			0.28	3.01
Freon 21	0.297	0.256	886	1953	0.121	0.07	1387.07	86.60	3.60	2.42	0.03	0.28
Freon E-1	0.28	0.24	945	2083	0.069	0.040	1561.65	97.5	5.58	3.75	0.04	0.38
Freon E-2	0.28	0.24	945	2083	0.069	0.040	1681.78	105.0	12.40	8.33	0.07	0.79
Freon E-3	0.28	0.24	945	2083	0.069	0.040	1742.64	108.8	27.38	18.4	0.16	1.69
FC-75	0.28	0.24	945	2083	0.140	0.081	1789.09	111.7	17.41	11.7	0.10	1.05
FC-77	0.28	0.25	945	2083	0.069	0.040	1801.91	112.5			0.08	0.90
Methanol-Water 60/40	0.93	0.80	284	625	0.329	0.190	895.35	55.9	15.33	10.3	0.17	1.83
Methanol-Water 80/20	0.80	0.69	329	725	0.268	0.155	850.50	53.1	12.60	8.47	0.15	1.59

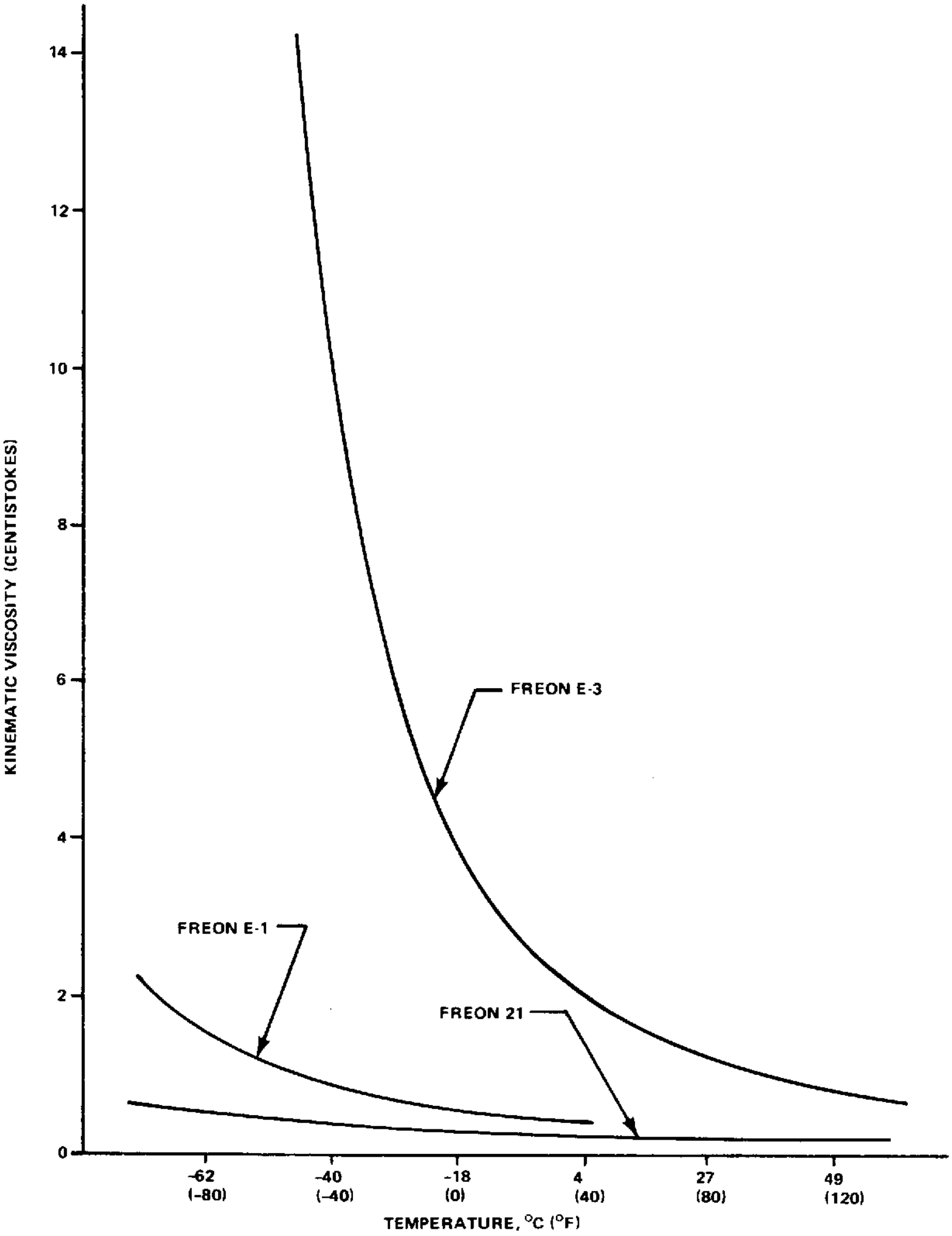


Figure 52. Viscosity of freon compounds.

Freon 21 was selected for the design baseline due to its commonality with the shuttle orbiter. However, based on this study Freon E-1 is a recommended candidate replacement for Freon 21.

F. Dual Heat Transport Loop Design Versus Single Loop Design

The purpose of this study was to determine system weight and power savings relating to the selection of a single heat transport coolant loop in lieu of the Sortie Lab's baseline ECS design — representing a dual heat transport coolant loop configuration.

For the single coolant loop design concept, two major components can be deleted. They are the interface heat exchanger (water/Freon) and a pump package with an associated accumulator. The assumed dry weight for the interface heat exchanger used in this study was 46 kg (105 lb), but more recent estimates indicate this component would weigh several hundred pounds and would be a very difficult design problem in terms of achieving a reasonable weight and volume. The size of the heat exchanger is a function of the ΔT and fluid flow rates. The ΔT is the difference between the outlet temperature of the water side and the inlet temperature of the Freon 21 side. For given fluid flow rates, the smaller the ΔT the larger the heat exchanger. This heat exchanger is not an existing item and the development costs may be high.

Table 15 describes advantages and disadvantages in trading off the two coolant loop design concepts. Experience with the Skylab ECS showed that there were on-orbit problems that required system servicing and that access to hardware was limited. With a single loop design, all critical hardware (except the radiator) could be located within the cabin. These are some of the reasons why a single coolant loop design concept was traded against the baseline.

Schematic identifying the single coolant loop design concept is shown in Figure 53.

For the single coolant loop design concept, five different coolant mediums were selected for analysis. They were: Freon 21, glycol water (60/40), Freon E-1, Freon E-3, and FC-75. Parameters evaluated were total system flow losses and the system weight change relative to the "baseline" dual coolant loop design concept.

TABLE 15. SINGLE LOOP VERSUS DUAL LOOP

Single Loop

Advantages

- Freon/water interface heat exchanger not required.
- Water pump and accumulator not required.
- Less system weight and volume.
- Less complex coolant interface with orbiter (if interconnect with orbiter is required).
- Less GSE required — reduced prelaunch servicing and leak checking (one coolant loop — not two).
- All functional hardware accessible for on orbit trouble shooting.
- Reduced coolant related corrosion problems.
- Commercial leak detection devices available.
- Less complex qual test rig.
- Less logistic problems and paperwork to maintain.
- Experiment integration flexibility.

Disadvantages

- Use of Freon coolant in cabin. More toxic and flammable than water.
- Byproducts of Freon oxidation are toxic.

Dual Loop

Advantages

- Limited heat rejection still available in the event of loss of Freon loop and radiator.

Disadvantages

- Freon/water interface heat exchanger design requirements unreasonable, creating large bulky hardware.

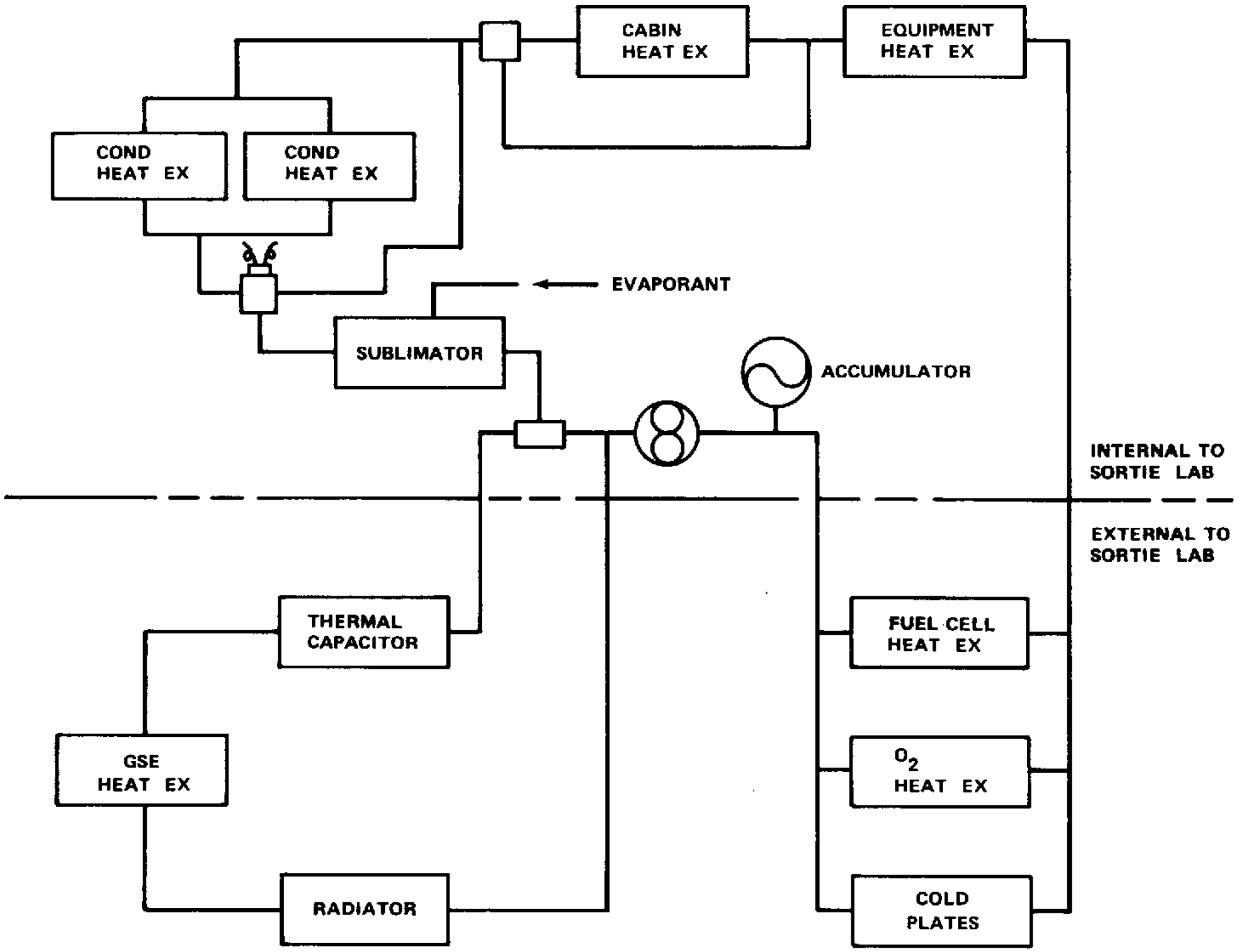


Figure 53. Sortie Lab thermal control single coolant loop concept.

Assumptions made for this study were that a heat exchanger and radiator efficiencies are constant, heat rejection capability of the fluid analyzed is 8.5 kW, and the Sortie Lab mission length is 7 days (used for consumable weight calculation purposes).

System weight change was determined by the summation of the following elements: (1) change in coolant density, (2) change in consumable weight (O_2 and H_2) required for pump power, (3) change in weight of associated valves due to line size changes, and (4) change in weight of deleting the interface heat exchanger (water/Freon 21) and the water pump package used in the dual coolant loop design. Components used in the single coolant loop design for system flow loss calculations were the same type as for the dual coolant loop design.

Table 16 shows a summary of the study results. The weight savings for the single loop coolant system are presented in column 1 along with the flow loss in column 2, and power requirements in column 3. The tubing sizes for the dual coolant loop design baseline model are 1.27-cm (0.50-in.) diameter for the water line and 1.91-cm (0.75-in.) diameter for the Freon 21 line.

Figures 54 and 55 show generated curves depicting weight and ΔP changes versus line size for the Freon 21 and Freon E-1 coolant fluids used in the single coolant loop design concept. (For the interpretation of system weight change, a (-) sign indicates weight savings whereas (+) sign indicates additional weight as compared to the dual loop concept). Weight and ΔP curves were also generated for glycol water (60/40), Freon E-3, FC-75, but are not shown since coolant fluids Freon 21 and Freon E-1 are the prime candidates for the single coolant loop design.

Referring back to table 16, the selection of Freon 21 for the single loop design indicates a total system weight savings of 49.3 kg (108.6 pounds) with a system pressure drop of 25 N/cm^2 (36 lbf/in^2) when traded against the "baseline" dual coolant loop design. Selection of Freon E-1 for the single loop shows a total system weight savings of 37 kg (81.5 pounds) with a system pressure drop of 27 N/cm^2 (38.5 lbf/in^2). Obviously, Freon 21 exhibits better performance than Freon E-1, and glycol water (60/40) would be the best. However, glycol water has a major disadvantage, that is it has a higher freezing point -54°C (-65°F) compared to the Freon coolants -135°C (-211°F) for Freon 21 and -154°C (-245°F) for Freon E-1, and it is more toxic. Therefore, again this leads to a trade-off between Freon 21 and Freon E-1 coolants for the single coolant loop design concept.

TABLE 16. DUAL LOOP VERSUS SINGLE LOOP STUDY RESULTS

Sys. Para. Coolant	Sys. Wgt. kg (lb.)	Sys. Flow Loss N/cm^2 (lbf/in^2)	Pump Power In (Watts)
Dual Loop Baseline (Water and Freon 21)	--	22.5 (32.7)*	114
Single Loop			
Freon 21	-49.3 (-108.6)	24.8 (36.0)	176
Glycol Water (60/40)	-83.1 (-183.3)	9.8 (14.2)	31
Freon E-1	-37.0 (-81.5)	26.5 (38.5)	178
Freon E-3	-22.1 (-48.7)	35.5 (51.5)	214
FC-75	-19.0 (-41.8)	31.0 (45.0)	182

*ΔP = 10.7 N/cm^2 (15.5 lbf/in^2) for water loop and ΔP = 11.9 N/cm^2 (17.2 lbf/in^2) for Freon 21 loop.

Assumptions:
Line size = 1.91 cm (0.75 inch)
A new pump design for each specific application
Pump/motor efficiency = 25 percent
Shuttle design interface HX for dual loop [79.4 kg (175 lb.) wet wgt.]

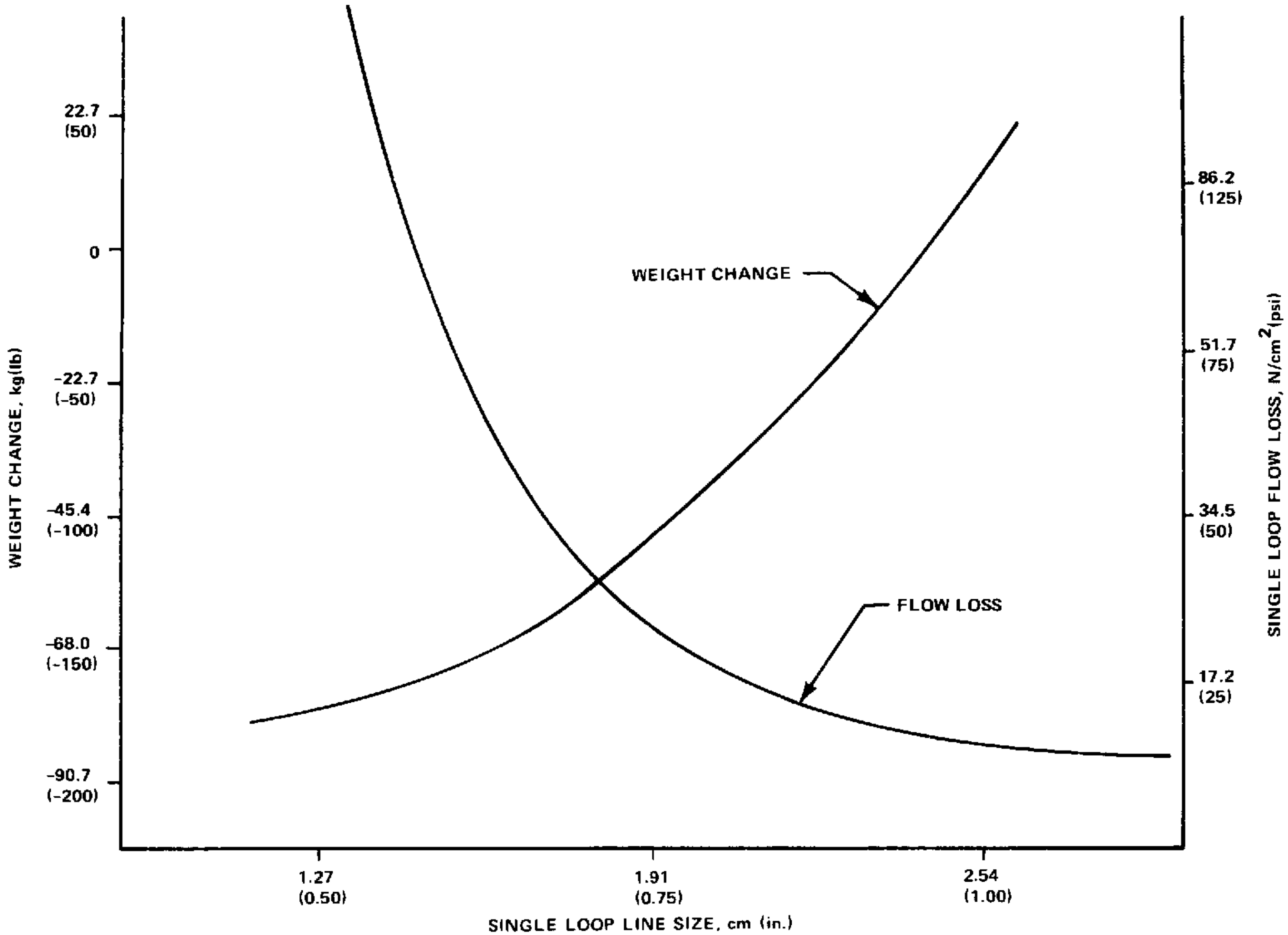


Figure 54. Flow loss for single coolant loop using Freon 21 and weight change from Phase B baseline coolant system.

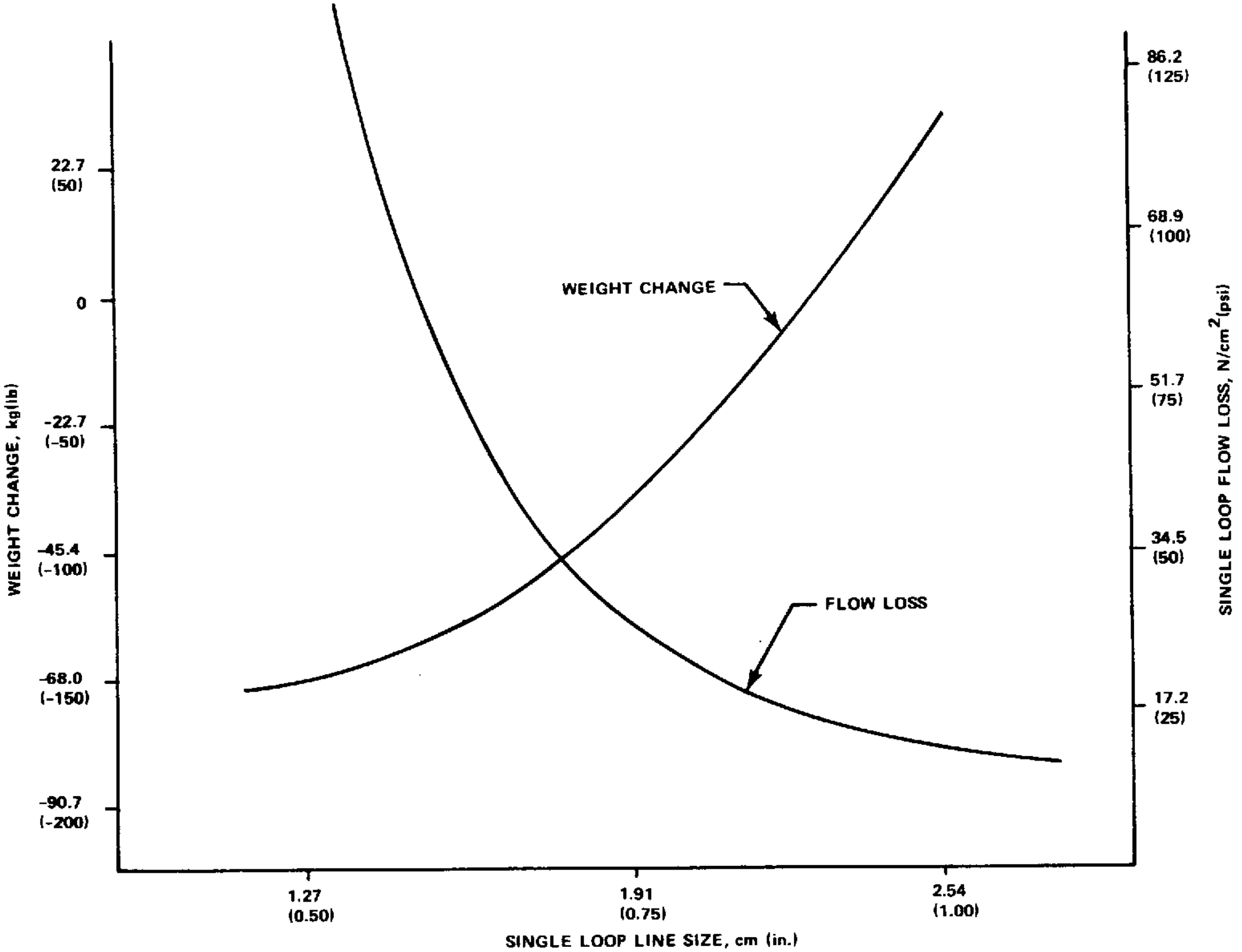


Figure 55. Flow loss for single coolant loop using Freon E-1 and weight change from Phase B baseline coolant system.

Freon E-1 was selected as the single loop coolant fluid even though Freon 21 has the best thermal performance properties. Freon E-1 is less toxic and more compatible with elastomeric materials and has a lower vapor pressure than Freon 21. This lower vapor pressure, with its resulting lower allowable system operating pressure, will permit use of more existing hardware for the cabin secion of the coolant loop. Operational concerns with Freon 21, not now readily visible, could develop into serious problems.

Thus, Freon E-1 is the recommended coolant for the single coolant loop design configuration. The reason for not selecting a single coolant loop design as the baseline in lieu of the dual coolant loop design is the fear of using Freon inside the cabin. Toxicity characteristics of the Freon coolants need a more thorough investigation.

SECTION V. LIFE SUPPORT

The baseline life support systems for Sortie Lab were derived from the requirements for crew size, mission length, and experiment support (see Table 1).

A. Atmosphere Supply and Control

The atmosphere supply and control design maintains the pressurized lab at 10.1 N/cm^2 (14.7 PSIA), supplies gaseous oxygen and nitrogen for repressurization of the scientific airlock, supplies oxygen for metabolic consumption. The design also includes vent and relief components which permit the lab to be vented to the outside environment and prevent the lab structure from being exposed to excessive internal or external pressure differentials. In the early studies, consideration was given to having the capability for one repressurization of the lab during a mission, but this requirement was never imposed on the lab design. A 318 kg (700 lb) weight penalty was associated with satisfying this requirement.

The total oxygen and nitrogen consumables required for the nominal 7-day experiment mission and the LST service mission are given in Table 17. The LST requirements are larger than the nominal experiment mission and would be supplied as an add-on weight to the baseline ECS and chargeable to experiment weight. The LST servicing mission has been eliminated as a future design requirement for Sortie Lab. The lab consumable interfaces with the Shuttle orbiter must be clearly understood. For example, in the experiment missions if the baseline Sortie Lab is entirely dependent on the Shuttle for O_2/N_2 supply the total amount required for payload support is a maximum of 42.2 kg (93 lbs) of oxygen and 23 kg (51 lbs) of nitrogen. However, if the Sortie Lab has its own 2-gas control system the total lab oxygen/nitrogen storage requirements are 24.5/23.1 kg (54/51 lbs), respectively. The delta oxygen weight of 17.7 kg (39 lbs) is the metabolic oxygen makeup required when the crew is in the Shuttle for half of the 42 man-day mission. The other 21 man-day is supplied by the Sortie Lab system. The autonomous lab concept sizes the tankage requirements considering these guidelines.

The vent valve size required to repressurize the lab (assuming cabin depressurization on-orbit) during reentry was estimated for various maximum allowable negative pressures on the module structure (Figure 56). The maximum ambient pressure build-up in the Shuttle payload bay area was assumed to be 0.014 N/cm^2/sec (0.02 PSI/sec). The final vent valve size is based on the allowable structural design and maximum repressurization rates of the Shuttle payload bay area.

TABLE 17. OXYGEN/NITROGEN CONSUMABLES REQUIRED FOR SIZING SORTIE LAB TANKAGE

Consumable Requirement	Experiment Missions				LST Service Mission			
	O_2, kg	lbs	N_2, kg	lbs	O_2, kg	lbs	N_2, kg	lbs
Metabolic*								
- Maximum (42 man-days)	17.7	39	-	-	4.1	9	-	-
- Nominal (28 man-days)	11.8	26	-	-	-	-	-	-
- Minimum (14 man-days)	5.9	13	-	-	-	-	-	-
Cabin Leakage								
- Sortie Lab	2.3	5	7.3	16	2.3	5	7.3	16
- LST	-	-	-	-	2.7	6	8.6	19
Cabin Repressurization								
- Sortie Lab	-	-	-	-	28.1	62	92.5	204
- LST	-	-	-	-	19.1	42	62.6	138
Airlock Repressurization								
- Sortie Lab	4.5	10	15.9	35	-	-	-	-
- LST	-	-	-	-	-	-	-	-
Total								
- Maximum	24.5	54	23.1	51	56.2	124	171.0	377
- Nominal	18.6	41	-	-	-	-	-	-
- Minimum	12.7	28	-	-	-	-	-	-

*Emergency O_2 provisions are to be determined. Oxygen requirement for LST Service Mission is for 10 man-days. Shuttle provides half of the metabolic oxygen.

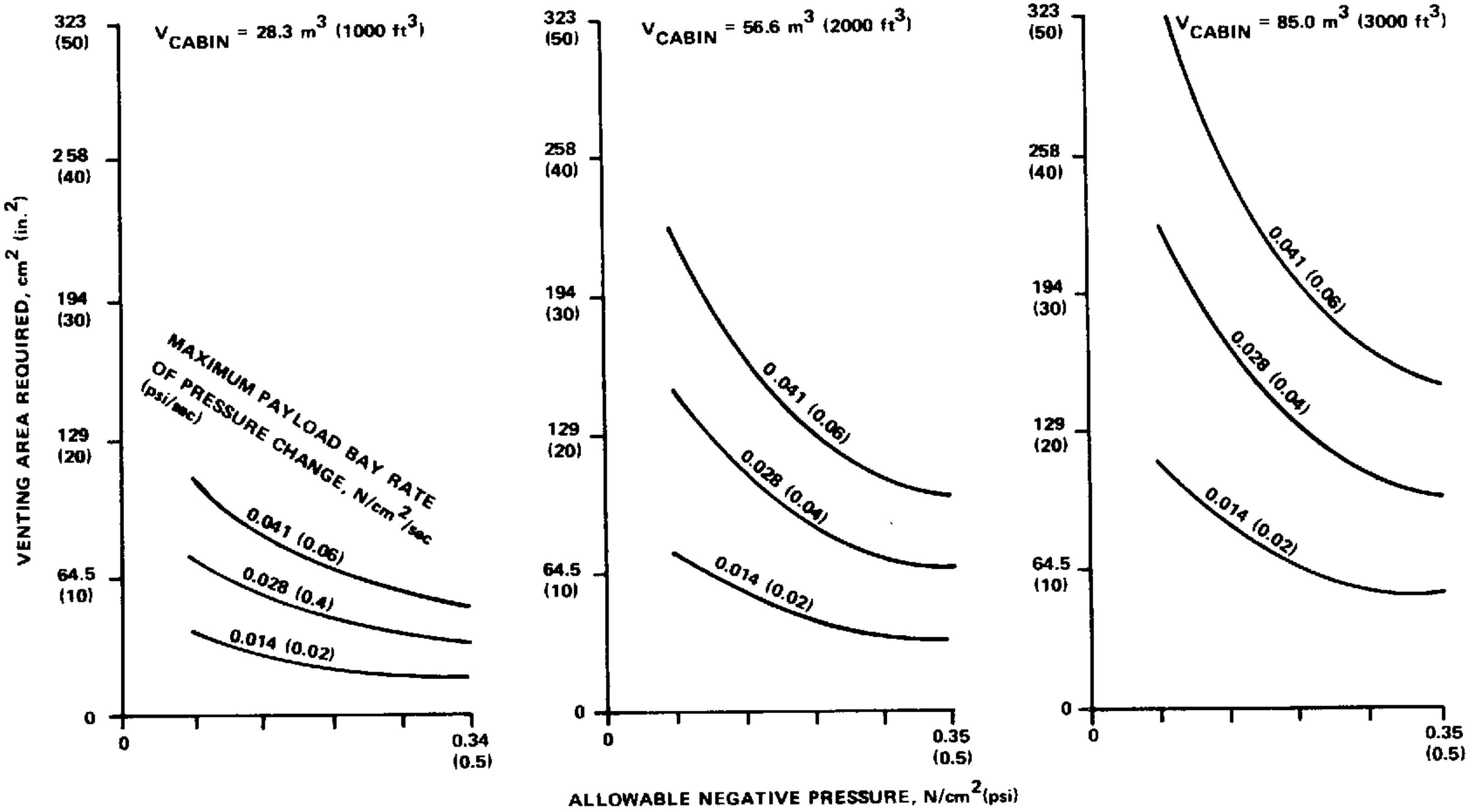


Figure 56. Vent valve size requirements for repressurization of Sortie Lab during reentry.

As a safety measure to prevent overpressurization of the lab, cabin pressure relief valves set to open at 11 N/cm^2 (16 psia) have been provided.

1. Two-Gas Control Systems. Two different two-gas control systems have been investigated. The first system was a regulated pressure system used on Skylab. The second system was a pulse feed system used on the NASA ninety day manned test.

a. Regulated pressure system (baseline configuration). This system operates to control the cabin total pressure with an absolute pressure (psia) regulator. All gasses entering the cabin, both oxygen and nitrogen, must enter through this regulator. The cabin gas composition (hence partial pressures of O_2 and N_2) is controlled by switching the regulator inlet to flow the gas source that is below its partial pressure requirements in the cabin. In Skylab the decision to select between gas sources is made by the partial pressure oxygen (PPO_2) sensor and the PPO_2 controller. Hence, the PPO_2 control system controls the oxygen partial pressure by feeding O_2 to the inlet of the total pressure regulator on a O_2 demand basis and the total pressure regulates the cabin total pressure using whichever gas (O_2 or N_2) is present at the regulator inlet to satisfy the total pressure demand. The regulated system is represented by Figure 57 "Regulated 2-Gas System."

b. Pulse feed system. The pulse feed system as shown in Figure 58: "Pulsed 2-Gas System," has been shown by both analysis and tests to be inherently more precise and flexible than the regulated system. However, these inherent advantages are offset by large unknown areas in regard to costs and design. The system feeds O_2 and N_2 to the cabin by precision timed pulses of gas from a regulated source through an orifice operating under choked flow conditions. The pulse frequency is proportional to the error existing between the required partial pressure set at the input of an integrating amplifier and the prevailing partial pressure existing in the cabin. An increased error results in reduced rise time for the integrated output of the integrating amplifier to produce an output pulse at the level detector. After sixteen pulses a gas pulse is admitted to the cabin. The O_2 and N_2 controllers are electronically independent for the configuration of Figure 58.

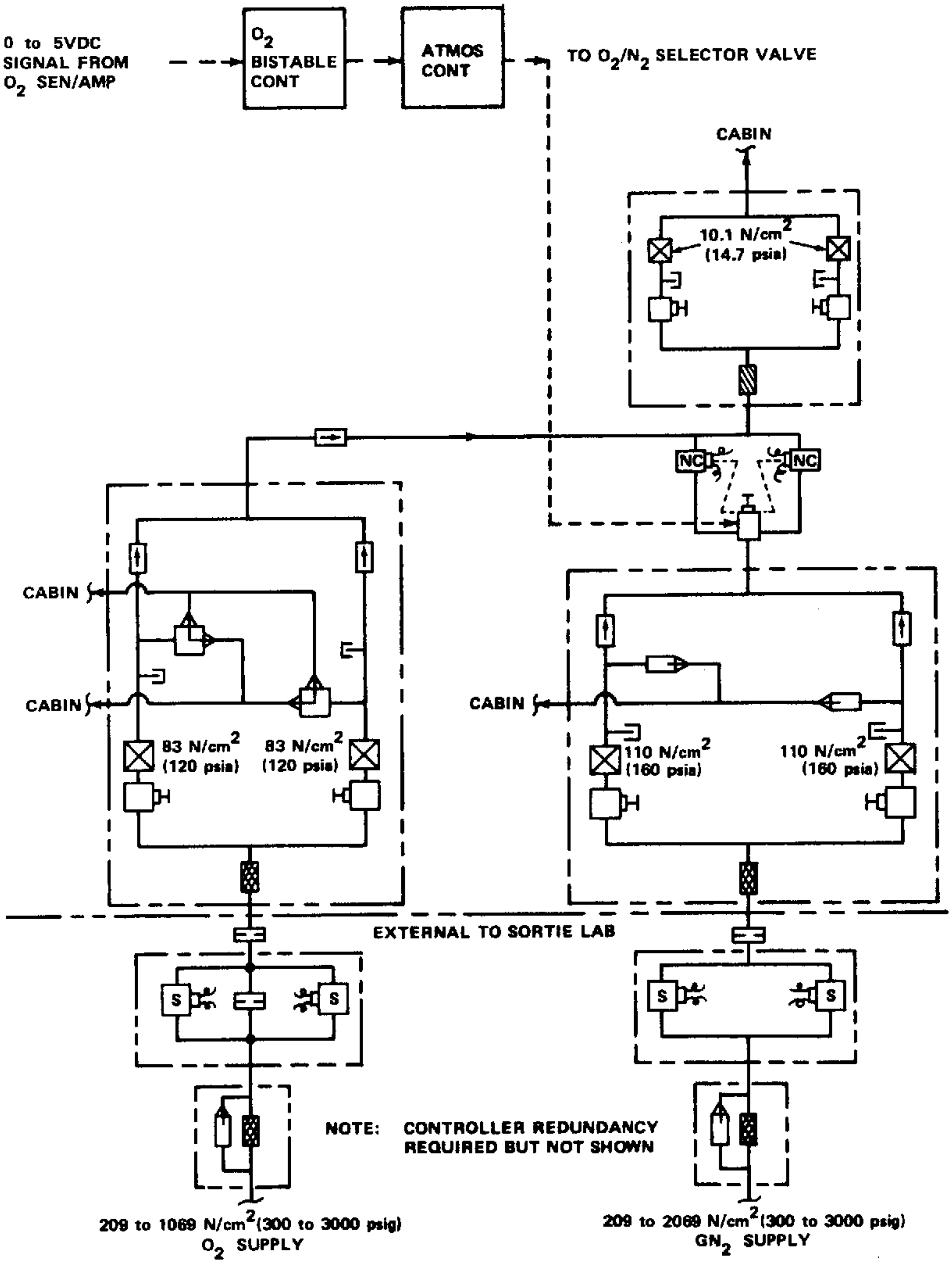
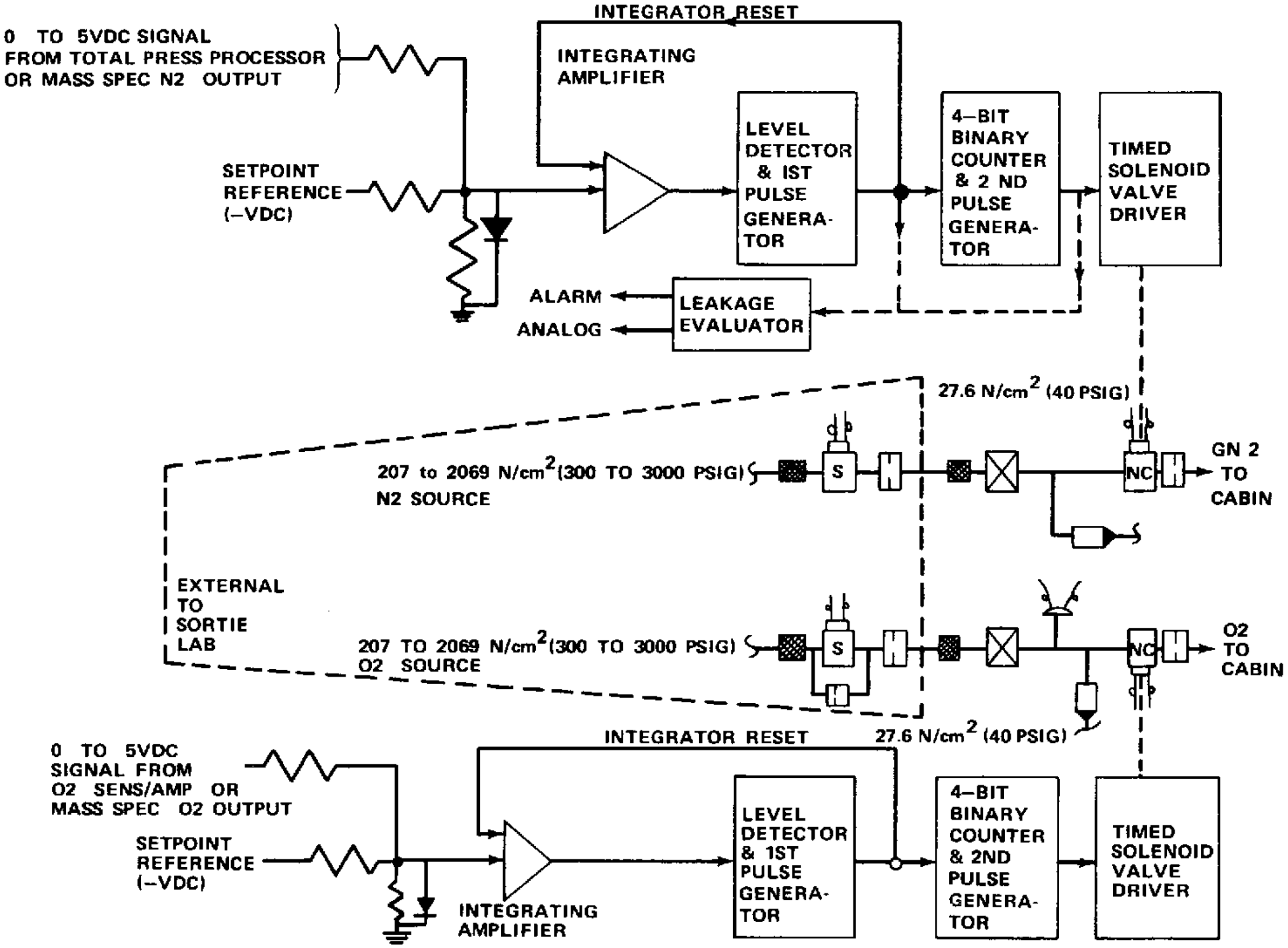


Figure 57. Regulated 2-gas system.



NOTE: NO REDUNDANCY SHOWN, REDUNDANCY REQUIRED FOR DESIGN

Figure 58. Pulsed 2-gas system.

2. Gas Control Selection for Sortie Lab. The pulse system was a candidate for the Skylab two-gas control along with the regulated system. When the Skylab two-gas system was selected more test data and confidence existed for the regulated system than for the pulse system. Therefore, the regulated system was chosen for Skylab. As a result of increased data and flight application in Skylab, the regulated system has continued to be in favor for Shuttle two-gas control and consequently for Sortie Lab two-gas control. The reason for having identical two-gas systems for Shuttle and lab is cost effectiveness and commonality. It was decided to use the regulated two-gas system in Sortie Lab and Shuttle in the same configuration as it is used in Skylab and is currently shown that way on all Phase B study Sortie Lab schematics.

3. Modification of Regulated System. When independent regulated pressure systems are located in separate volumes (i.e., Shuttle cabin and Sortie Lab) the interaction of the two systems needs to be evaluated. The primary concern would be the inability of one system to automatically maintain required O_2 partial pressure control. This problem may occur if the total pressure regulator of one system dominates the other in control of gas supply to the cabin. The other total pressure regulator could flow less oxygen through it than the consumption rate occurring in the cabin and the O_2 partial pressure would decay. A modification of the regulated system to eliminate this condition is shown in Figure 59. This arrangement allows the addition of oxygen around the total pressure regulator without the danger of cabin overpressurization. The O_2 control valves selected are normally closed and the normal failure mode for these valves is in the closed position. Continuation of a more in-depth study of this system is required. A comparison of this system in regards to performance and hardware development against the other two gas regulation systems is shown in Table 18. The modified system would be required for both the Shuttle and Sortie Lab to maintain proper O_2 supply and O_2 partial pressure levels for either closed or open hatches between the cabins. The potential regulator interaction existing in the unmodified pressure regulated systems can be illustrated by an assumed design situation (Figure 60). The Shuttle and Spacelab total pressure regulator design characteristics (gas flow versus pressure) and the consumable usage rates will influence the oxygen control levels. With no crewmen in the lab and the Shuttle airlock hatch closed, the lab regulator supplies O_2/N_2 only to makeup gas leakage overboard. After the hatches are opened and crewmen are in the lab and Shuttle simultaneously, the total pressure in each area is equal with hatches open (assume 14.7 psia). The Shuttle

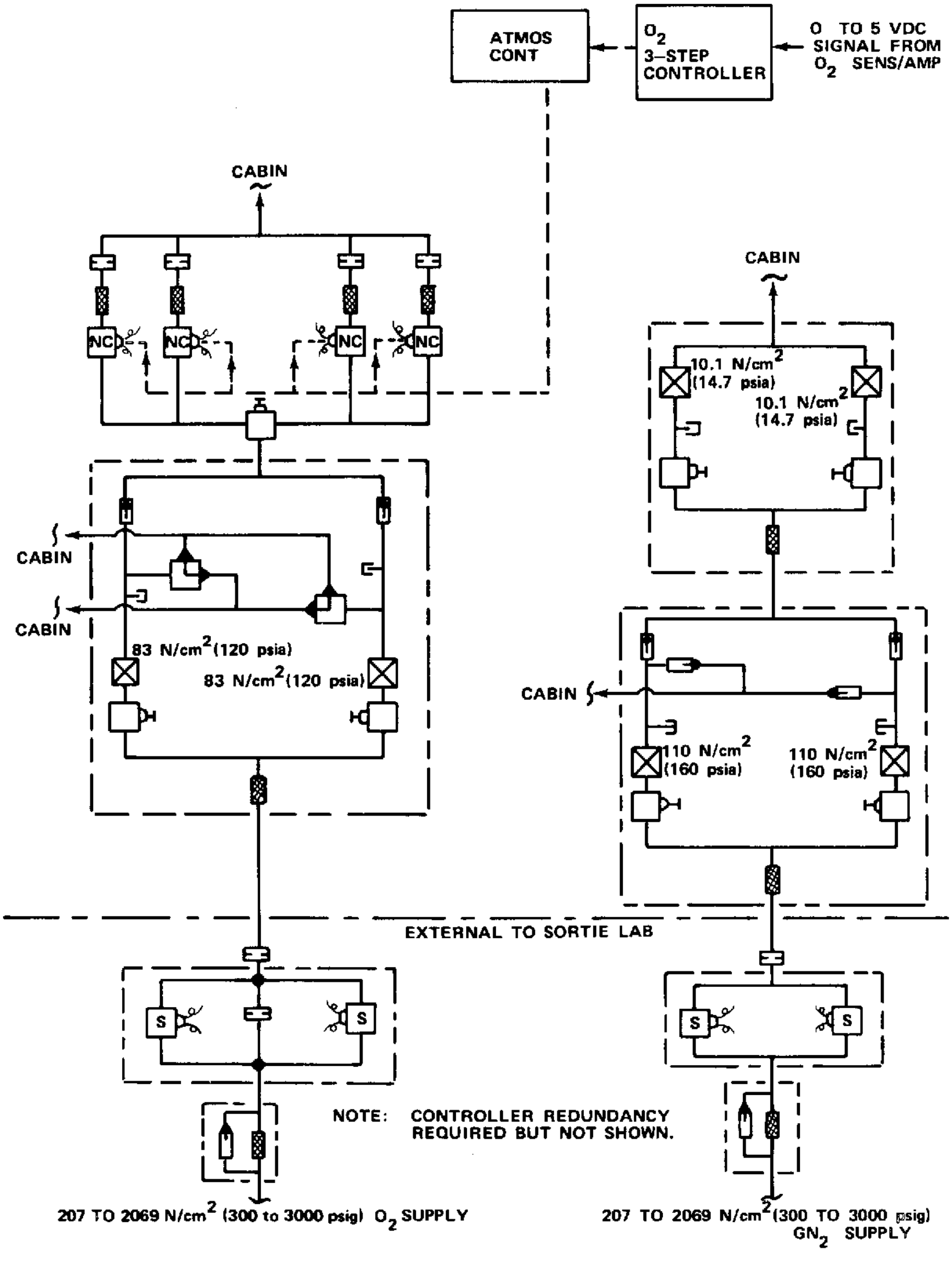


Figure 59. Modified regulated 2-gas system.

TABLE 18. SORTIE LAB 2 - GAS TRADE SUMMARY

Parameter	Baseline Design	Modified Regulated	Pulsed
Total & $PP0_2$ Press 10.1 ± 0.14 N/cm^2 (14.7 ± 0.2 psi) total, 2.1 ± 0.07 N/cm^2 (3.1 ± 0.1 psi) $PP0_2$	10.1 ± 0.1 N/cm^2 (14.7 ± 0.15 psi) total, 2.5 ± 0.2 N/cm^2 (3.6 ± 0.3 psi) $PP0_2$. Lockup problems exists on 0_2 feed	10.1 ± 0.1 N/cm^2 (14.7 ± 0.15 psi) total, 2.1 ± 0.14 N/cm^2 (3.1 ± 0.2 psi) $PP0_2$ No lockup on 0_2 feed	10.1 ± 0.14 N/cm^2 (14.7 ± 0.2 psi) total, 2.2 ± 0.03 N/cm^2 (3.19 ± 0.05 psi) $PP0_2$ No lockup on 0_2 feed
$PP0_2$ Controller	Impacts $PP0_2$ level and tolerance requirements	New design	Shuttle design in design accept test
Total Press Controller	N/A - regulated	N/A - regulated	Shuttle design in design accept test
$PP0_2$ Sensor	Fuel Cell-Type or eq	Fuel Cell-Type or eq	Fuel Cell-Type or eq
Total Press Sensor	N/A - regulated	N/A - regulated	Strain gas - TBD
Atmosphere Controller	New design	New design	New design
Leakage Analysis detection/quanity	Poor	Poor	Good in analysis, no existing design ± 2.7 kg/day (± 6.0 lb/day) 95% confidence level
Hardware design	Designed & qualified	Uses flight qualified Components	TBD

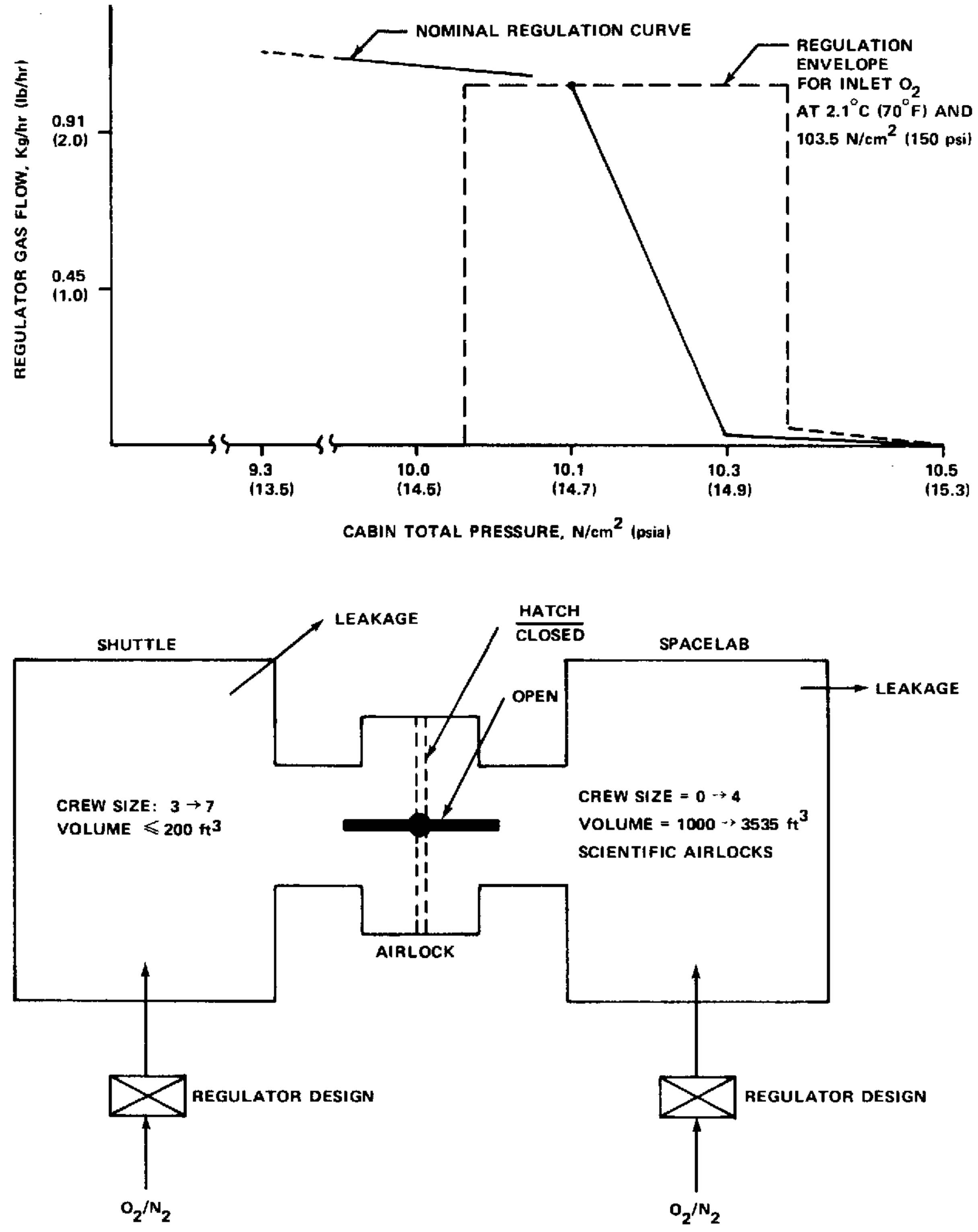


Figure 60. Factors affecting cabin pressure regulation.

and lab regulators may both be flowing oxygen but the quantity through one may be low enough to cause a depletion of oxygen in the cabin because total pressure may be such that oxygen is being consumed faster than it can be delivered into the cabin. This could be the case assuming that the regulators in both cabins operate on the nominal regulation slope shown in Figure 60. It may also be true for the case if the two cabin regulators would not maintain identical slopes and operate outside the nominal regulation slope, but still be contained within the regulation envelope. The expected control levels under varied regulator characteristics, crew timelines and leakage rates need to be evaluated more fully. This evaluation should investigate both open and closed hatch conditions for on-orbit operations.

B. CO_2 Removal/Humidity Control

The Sortie Lab design requirements for CO_2 removal and humidity control are reviewed next. The crew loads and control levels specified are for sizing the Sortie Lab systems and not the Shuttle orbiter. This is important because the crew only spends half their time in the Sortie Lab during the mission.

1. CO_2 Removal. The CO_2 generated by the crew will be removed by passing cabin air through a non-regenerative lithium hydroxide (LiOH) canister design. The basic system reaction is

$$2\,LiOH + CO_2 \longrightarrow Li_2CO_3 + H_2O_{(g)} + \text{Heat}$$

where

LiOH	-	lithium hyroxide
CO_2	-	carbon dioxide
Li_2CO_3	-	lithium carbonate
$H_2O_{(g)}$	-	water vapor (latent load increase 407 BTU/Lb-CO_2 absorbed)
Heat	-	922×10^3 J/lb (875 BTU per lbm) CO_2 absorbed

Compared to other CO_2 removal concepts, the LiOH processing technique is optimum from every standpoint (weight, volume, power, cost, simple operation, and maintenance). The amount of LiOH required to remove the 21 man-day CO_2 load is 23.3 kg (51.4 pounds) (Table 19). This assumes a maximum LiOH canister utilization efficiency of 90 percent.

Design concepts available from past, present and future manned spacecraft programs were reviewed and evaluated for Sortie Lab application. The programs utilizing LiOH canisters for CO_2 removal had a wide range of canister capacities which results in a variable number of canisters required for each concept. The LiOH design being developed under the Space Station Prototype (SSP) program was selected for utilization in the design reference model because it has optimum operating features. Each canister charge will contain 7.9 kg (17.4 pounds) of LiOH. A maximum of 3 canisters is required to satisfy any 7-day Sortie Lab mission. The required air flow through the canister to maintain acceptable CO_2 levels is 0.3 to 0.6 m^3/min (10 to 20 ft^3/min) (Figure 61). Flow pressure drop through the canister for this flow range is less than 2.54 cm (1.0 inch) of H_2O. Commonality with the Shuttle design is a desired feature but requires more maintenance time on-orbit by the crew to change canisters unless the canister capacity is increased.

A study was made to assess the impact on the baseline design to reduce the nominal CO_2 level to 0.23 mm Hg to accommodate life science payloads. A total flow of 5.9 m^3/min (210 CFM) through LiOH canisters will maintain the desired CO_2 level. To achieve this flow, three fans in parallel, 2.0 m^3/min (70 CFM each) flow through the previously baselined three LiOH canisters. It should be noted here that no increase in the number of LiOH canisters is required, only an increase in the flow through the canisters. The basic penalty for this design concept in comparison to the baseline concept is the additional cost, weight and power of three additional fans. These were estimated to be an additional 135 watts, 15 kg (33 pounds) and $9000. The real unknown in this study is the actual LiOH canister performance characteristics (ΔP versus flow, utilization efficiency). For example, if the actual LiOH canister ΔP is 5.08 cm (2.0 inches) of H_2O at 1.0 m^3/min (35 CFM) (rather than the 2.54 cm (1.0 inch) of H_2O at 2 m^3/min (70 CFM) the delta increase in weight and power

TABLE 19. DESIGN CONSIDERATIONS AND CONCEPTS FOR SORTIE LAB CO_2 REMOVAL WITH LiOH

Design Consideration	Maximum		Nominal		Minimum	
	kg	lbs	kg	lbs	kg	lbs
CO_2 Produced, Crew Only	21.0	46.3	14.0	30.8	7.0	15.4
LiOH Required (lbs)	23.3	51.4	15.5	34.2	7.7	16.9

LiOH Design Concepts	Canister Capacity (Man-Days)	Canister Req'd
Gemini	28.0	1
Apollo	1.5	14
Shuttle	4.0	6
SSP	7.0	3

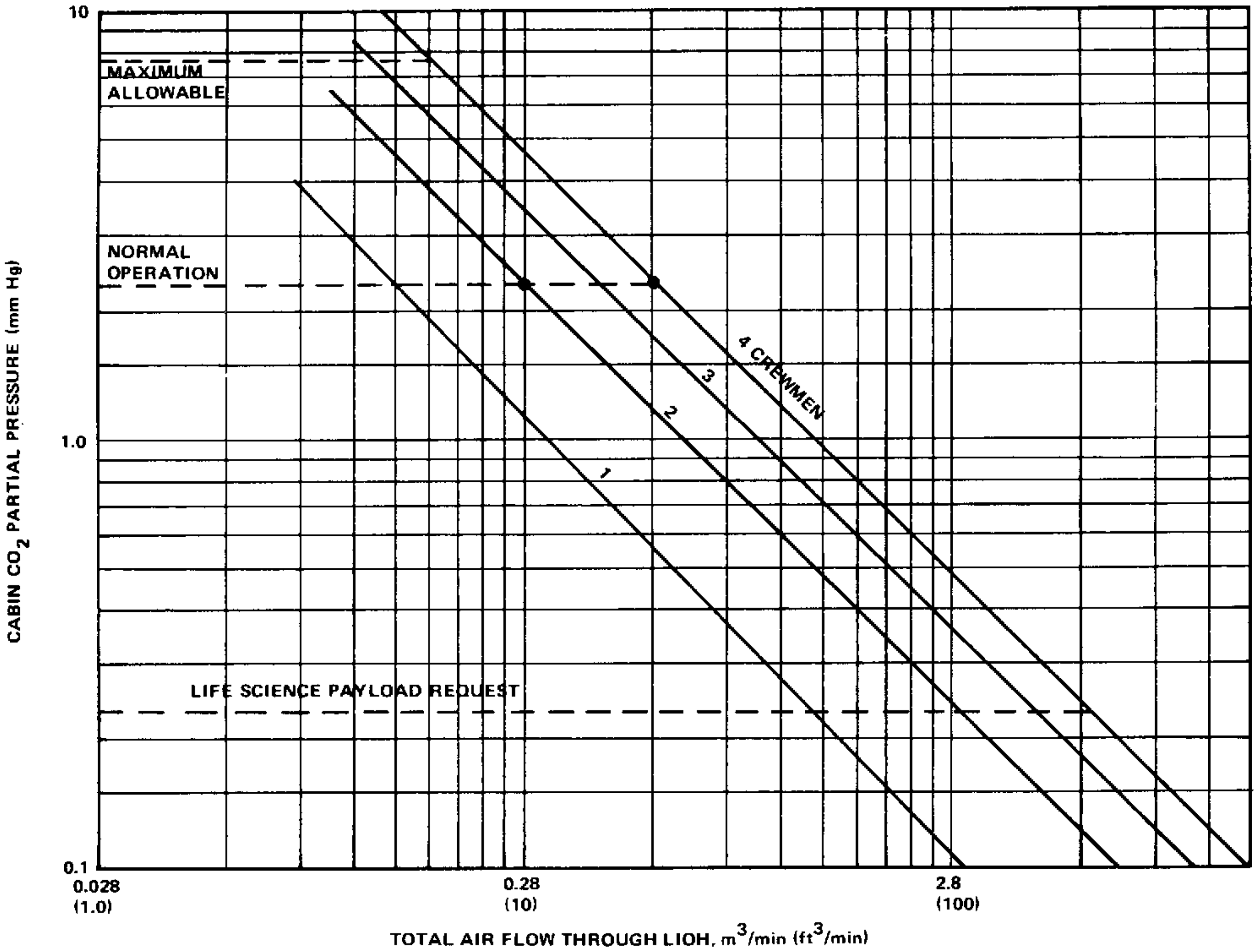


Figure 61. Sortie Lab CO_2 levels as a function of crew size and processing rate through the LiOH canisters.

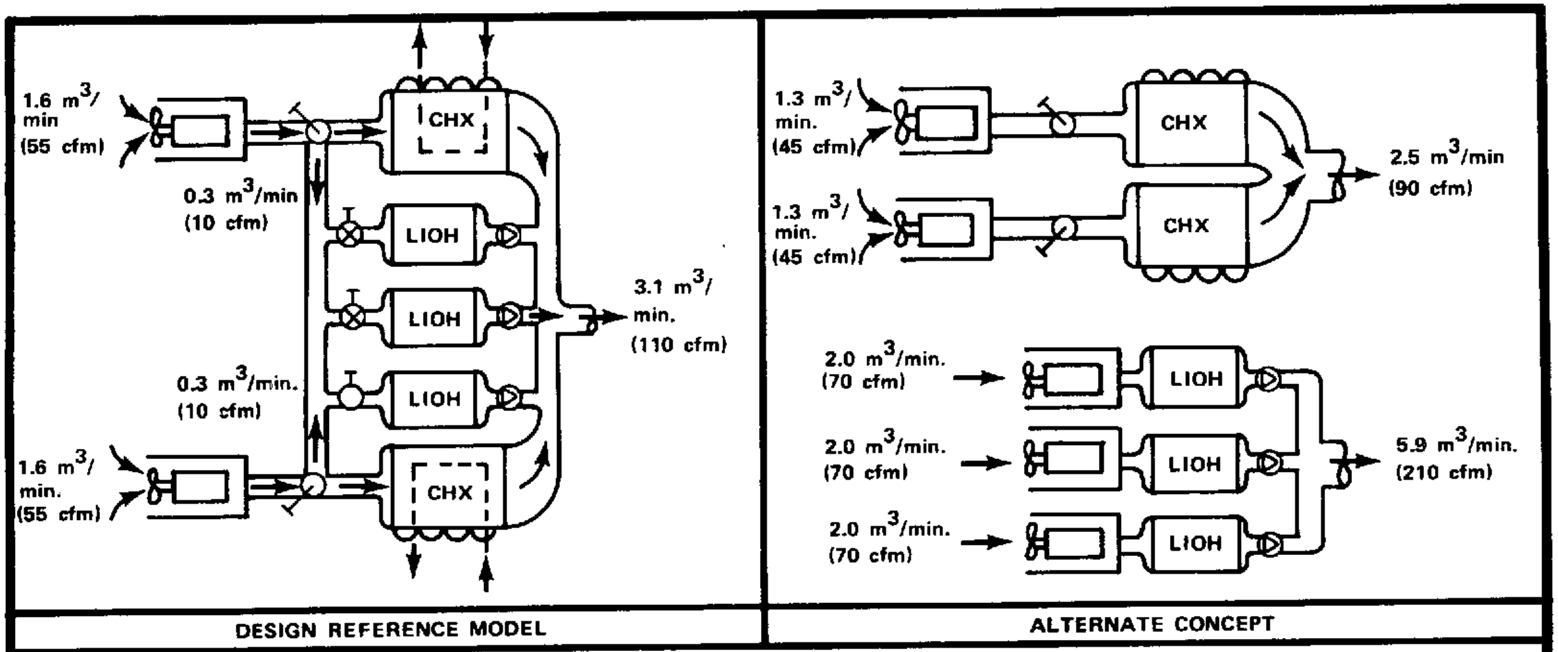
above the baseline design is 74 kg (164 pounds) and 270 watts, respectively. A comparison of the design baseline and the alternate concept is given in Figure 62.

2. Humidity Control. The baseline humidity control method is with a condensing heat exchanger. Again this processing technique is optimum, based on program requirements and past manned spacecraft experience. The cabin humidity (or water vapor partial pressure) will be maintained between 6 and 11 mm Hg. This corresponds to a dew point temperature range of 4 to 13° C (39 to 55° F). Low cabin dew points are required for optimum cabin cooling concepts. The optimum dew point temperature desired for normal operation of the lab is -7 ± 3° C (45 ± 5° F). The rationale for this requirement is reviewed under the cabin air conditioning discussion. The design loads for sizing the condensing heat exchanger are given in Table 20 and consider the latent loads generated by the reaction of CO_2 and LiOH. The maximum loads occur when four crewmen are in the lab.

The Skylab hardware was selected primarily because more design data and experience is available than from the other two concepts. However, it should be pointed out that the capability of a condensing heat exchanger to handle both latent loads and large sensible loads make it a viable candidate for controling both humidity and cabin air temperature for crew comfort. Therefore, trade studies should continue in this area.

The schematic shown in Figure 62 represents the selected design concept for integrating CO_2 removal and humidity control of the Sortie Lab. The operating characteristics are a function of the number of crewmen working on the Sortie Lab. For a nominal two-man crew, only one fan is operating. This fan provides air flow through both the CHx, 1.3 m^3/min (45 CFM) and the LiOH canister 0.3 m^3/min (10 CFM). A fan developed as a backup design for the Skylab program was selected to provide the required air flow and satisfy the system pressure drops. For a four-man crew, both fans are operating. Each CHx has 1.3 m^3/min (45 CFM) air flow and the total flow through the LiOH canister is 20 CFM.

This design concept has operating flexibility to accommodate variable crew sizes and to provide limited humidity control in the system for a fan failure with a four-man crew. For one fan operating with a four-man crew, the cabin dew point would rise to 16° C (60°F) before one CHx could remove the maximum



DESIGN REFERENCE MODEL

ALTERNATE CONCEPT

NOMINAL	MAXIMUM		NOMINAL	MAXIMUM
1 – 2	3 – 4	NUMBER OF CREWMEN	1 – 2	3 – 4
0.3 m^3/min.(10 cfm)	0.6 m^3/min.(20 cfm)	TOTAL FLOW THROUGH LIOH CANISTERS	4.0 m^3/min.(140 cfm)	5.9 m^3/min. (210 cfm)
45 WATTS	90 WATTS	TOTAL FAN POWER (LIOH + HUMIDITY)	135 WATTS	225 WATTS
LESS THAN 3 mm HG		CABIN CO_2 LEVEL	LESS THAN .23 mm HG	
100 kg(220 lbs) MAXIMUM		TOTAL WEIGHT OF CO_2/HUMIDITY CONTROL	115 kg(253 lbs) MAXIMUM	

Figure 62. Comparison of CO_2 removal/humidity control systems.

TABLE 20. DESIGN CONSIDERATIONS AND CONCEPTS FOR CONDENSING HEAT EXCHANGER

Design Consideration	Maximum		Nominal		Minimum	
Latent Load	Watts	BTU/hr	Watts	BTU/hr	Watts	BTU/hr
- Crewmen	244	832	122	416	29	100
- $LiOH/CO_2$ Reaction	44	150	22	75	11	37.5
- Experiments	0	0	0	0	0	0
Total	288	982	144	491	40	137.5

CHX Designs	Heat Removal Capacity						Number Req'd for Sortie Lab
	Latent		Sensible		Total		
	Watts	BTU/hr	Watts	BTU/hr	Watts	BTU/hr	
Skylab	182	620	439	1500	621	2120	2
*Shuttle	498	1701	2454	8380	2952	10,081	1
*SSP	293	1000	2226	7600	2518	8600	1

*Estimated from best available data.

latent loads. The only problem with this condition is the potential for condensation to occur on the cabin sensible heat exchangers and degrade their performance. An alternative is to provide a spare fan for on-orbit maintenance if required. Condensate from the CHx will be stored for the duration of the 7-day mission as a baseline design. The maximum quantity of condensate to be stored is 56 kg (124 pounds).

The crew timeline from the communication/navigation payload was utilized to generate typical cabin CO_2 and humidity levels for the design reference model (Figure 63). The CO_2 levels vary as the crew move between the Shuttle and the Sortie Lab. When no crewmen are in the lab, the CO_2 level begins to decrease. CO_2 levels are always maintained below 3 mm Hg maximum and the average level over the mission is 1 to 2 mm Hg.

The water coolant supply temperature to the condensing heat exchanger is 4.4°C (40°F). For this condition the cabin dew point temperature is controlled at the desired level of $7 \pm 3°C$ ($45 \pm 5°F$).

In summary, the selected design concept satisfies the design requirements. The total power and weight required for the CO_2 removal and humidity control function is 160 watts and 100 kg (220 pounds), respectively. The 160 watts includes the fan power and associated electro-mechanical valves for condensate collection.

C. Condensation, Collection, and Stowage

Four methods of collecting and stowing the condensate from the Skylab wick-type condensing heat exchanger were studied. The wick-type air/water separator was considered almost exclusively as a candidate because of previous experience and designed qualified hardware as opposed to other alternative units that exist only as analytical models.

1. Mechanical Pumping Methods. Of the four proposed collection and stowage methods, two are very similar and operate on available space vacuum to transport and store condensate. The other two methods used mechanical pumping systems to achieve the same functions. One pumping method used a motor driven pump. The pump requires a recirculating relief valve to control the pump rise at 3.4 N/cm^2 (5.0 psia) to pull a 3.4 N/cm^2 (5.0 psi) vacuum on the water side of the condensing heat exchanger air/water separator plates. Pressure control is required to prevent excessive pump suction from pulling cabin air into the condensate system through the heat exchanger air/water

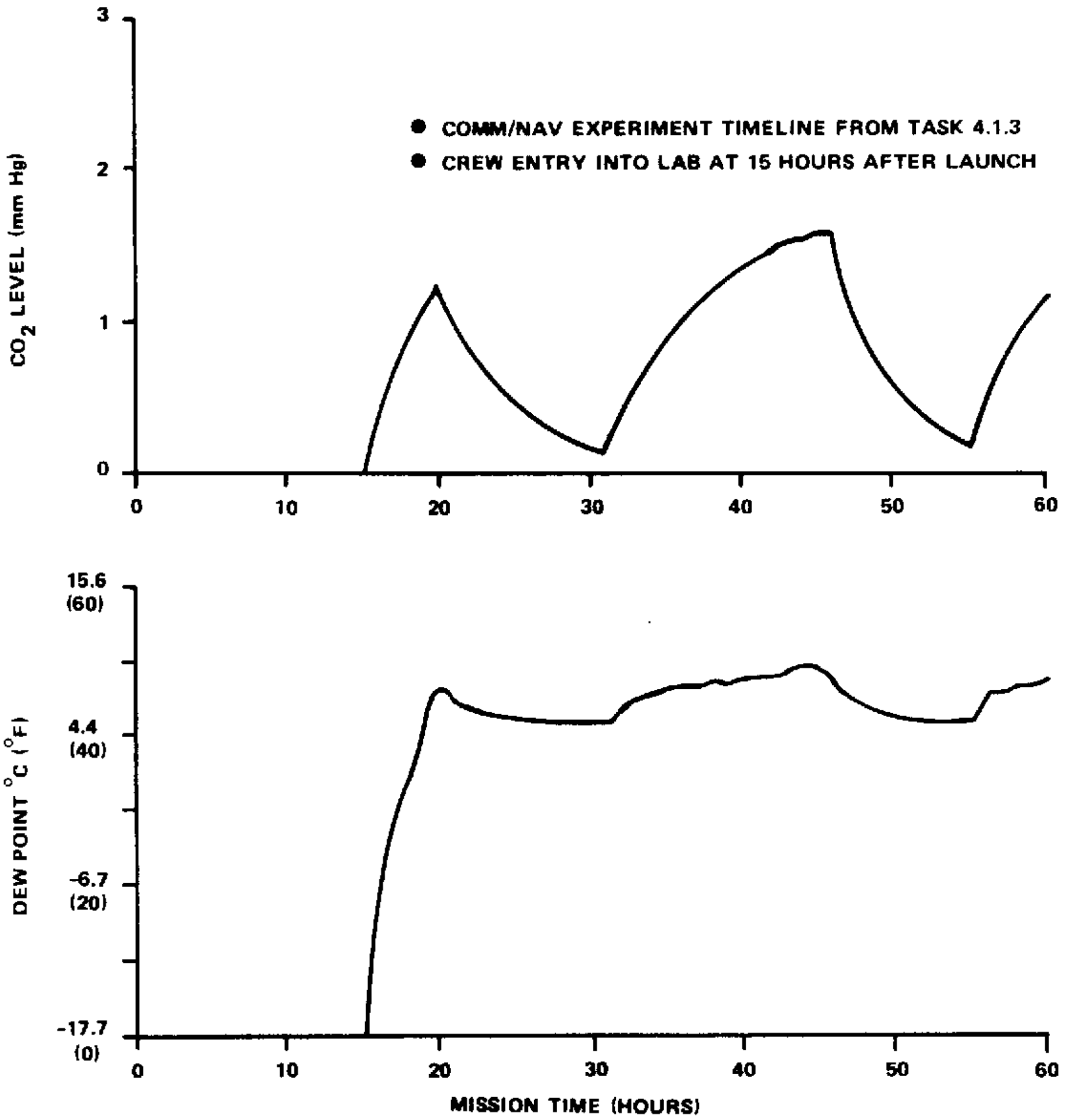


Figure 63. Typical CO_2 and dew point temperature profiles for design reference model.

separator plates. This concept was abandoned for lack of a known qualified pump with associated hardware and unnecessary continuous power consumption. A second pumping system that has qualified designed hardware used a cyclic pumping accumulator as the pumping item. The accumulator was driven by O_2 gas pressure taken from the O_2 stowage bottles with the gas dumped to the cabin after use. A spring pressure exerted against the accumulator bladder during the suction cycle regulated the vacuum applied to the air/water separator plates. This system was discarded due to potential high cost and system mechanical complexity. Also, the gas discharge to the cabin could become undesirable.

2. Space Vacuum Pumping Methods. Two space vacuum pumping methods are shown in Figure 64 and Figure 65, with Figure 65 being the preferred system for Phase B studies. In Figure 64, a small tank is evacuated to 3.4 N/cm^2 (5.0 psid) below cabin pressure to apply the required suction to the air/water separator plates. When the small collection tank becomes partly filled, its contents are transferred to the larger stowage tank which is maintained at 4.8 N/cm^2 (7.0 psi) vacuum below cabin. The vacuum controller monitors the rate of change of the 3.4 N/cm^2 (5.0 psi) vacuum in the collection tank to determine the rate of inflow into the tank. When the rate of pressure change exceeds a preset rate, an air inleak into the condensate system is indicated. Hence, the small collection tank serves as part of an air breakthrough detection system. The complexity of this system was eliminated in Phase B studies by installation of a potentiometric bubble detection system taken from previous programs. This permitted considerable hardware and controller simplification with a corresponding decrease in cost and complexity, and an increase in reliability. In this latter concept only a single tank is required for both condensate collection and stowage. The tank is controlled at 3.4 N/cm^2 (5.0 psi) below cabin pressure.

D. Contaminant Control

Preliminary design of a contaminant control system for Sortie Lab has been undertaken and is nearing completion. This design effort was precipitated due to results of preliminary investigations which indicated that for currently expected contaminants and generation rates, maximum allowable concentrations (MAC's) of a significant number of toxic contaminants would be reached, from zero concentration at launch, within a few hours thereby posing a threat to the crew for even a seven-day mission. Five steps were involved in this design and are described as follows:

1. Define contaminants that can be expected.

2. Determine initial concentrations and subsequent generation rates.

3. Obtain MAC's for each contaminant and class of contaminant (fluorocarbon, hydrocarbon, etc.).

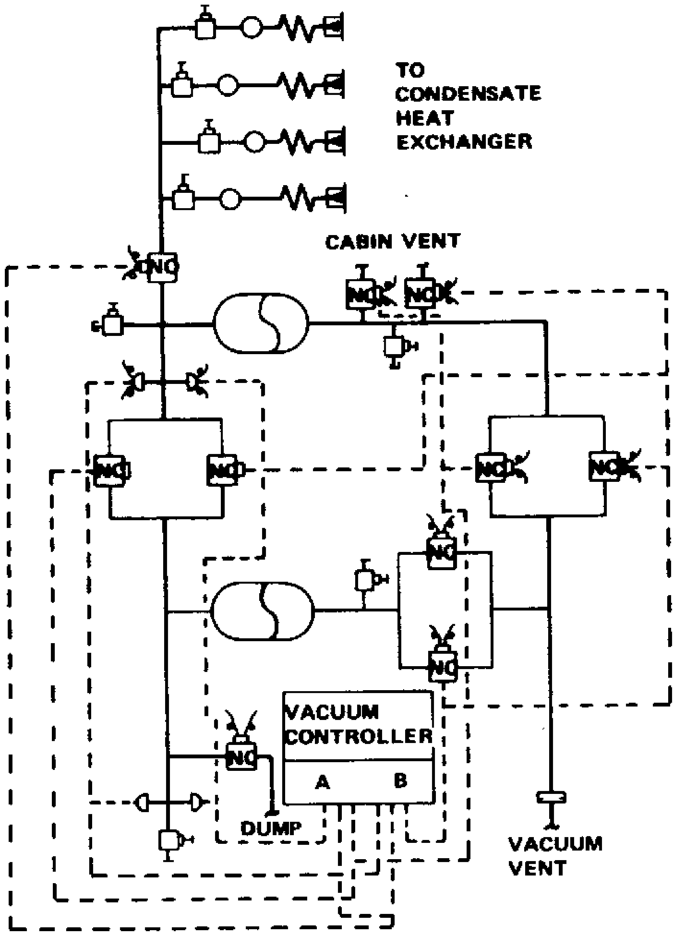


Figure 64. Two-step vacuum-type condensate collection.

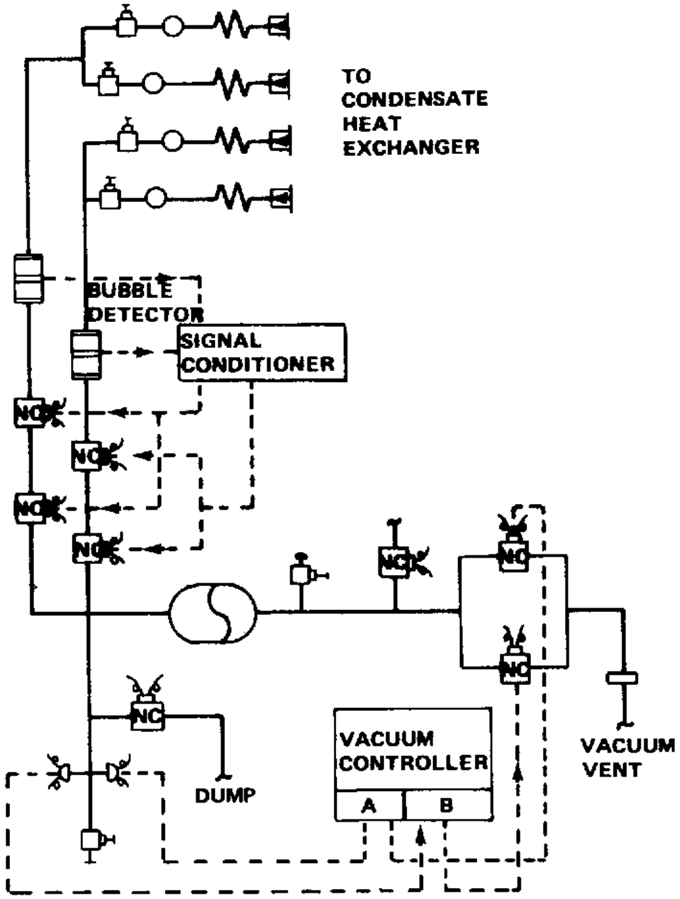


Figure 65. Direct vacuum-type condensate collection.

4. Determine physical removal mechanisms for each contaminant (water solubility, charcoal adsorbtion, etc.).

5. Size equipment and integrate the equipment into the overall ECS design.

Each of these steps are discussed briefly in the following paragraphs.

1. Contaminants List. The contaminant list chosen for this study was that supplied to Hamilton Standard by Johnson Space Center (JSC) for design of the Space Station Prototype (SSP) Life Support System (Table 21). This list was chosen for two basic reasons. First, of eight reference lists examined, the SSP list was the most comprehensive (150 contaminants) of any studied, and secondly, it was felt that a comprehensive list such as this would be required in that commercial, off-the-shelf experiment and experiment support equipment would be used extensively in Sortie Lab.

2. Initial Concentrations and Generation Rates. Two cases have been assumed for the initial concentration of the contaminants: no contaminants and all contaminants at MAC levels. These assumptions yield the extremes with respect to equipment size and provide a measure of the sensitivity of equipment size to initial concentrations. Very rough calculations have indicated that the zero initial concentrations reduce required removal capacity by 44 percent relative to initial concentrations at MAC levels. For the above stated reason this preliminary design has been made, based upon zero initial contaminant concentration at the beginning of the mission.

The generation rates given in the SSP data include biological and nonbiological components. The overall quality of the nonbiological rates are indicated by the fact that about 30 percent are given as 2.5 g/day and 70 percent are given as 0.25 g/day. Only two contaminants, methane and acetone, have nonzero, nonbiological generation rates differing from these two values. The nonbiological rates for methane and acetone are 29.5 g/day and 10.2 g/day, respectively. Only four of the contaminants have significant biological generation rates relative to the corresponding nonbiological rates. These contaminants are ammonia, pyuvic acid, phenol, and methane.

TABLE 21. CONTAMINANTS OF CONCERN FOR THE SORTIE LAB

DATA CODE

A	Non-biological generation rate code.
	1 0.25 g/day
	2 2.5 g/day
	3 10.2 g/day
	4 0.0 g/day
	5 29.5 g/day
B	Days to reach MAC (no control).
C	Total generation rate (g/day).
D	Maximum Allowable Concentration (MAC).
E	Required removal efficiency - flow rate product (cfm).

CONTAMINANT	A	B	C	D	E
Acetone	3	1.75	10.2	240	1.04
Acetaldehyde	2	1.08	2.5	36	1.36
Acetic Acid	1	0.75	0.25	2.5	2.45
Acetylene	2	5.38	2.50	180	0.27
Acetonitrile	1	2.08	0.25	7	0.88

TABLE 21. (Continued)

CONTAMINANT	A	B	C	D	E
Acrolein	1	0.75	0.25	0.25	24.5
Allyl Alcohol	1	0.15	0.25	0.50	12.5
Ammonia	2	0.05	5.50	3.5	38.6
Amyl Acetate					
Amyl Alcohol					
Benzene	2	0.24	2.50	8	7.70
N-Butane	2	5.38	2.50	180	0.34
Iso-Butane					
Butene-1	2	5.38	2.50	180	0.34
Cis-Butene-2					
Trans-Butene-2	2	5.38	2.50	180	0.34
1,3 Butadiene	2	6.57	2.50	220	0.28
Iso-Butylene					
N-Butyl-Alcohol	2	0.90	2.51	30	2.05
Iso-Butyl-Alcohol					
Sec-Butyl-Alcohol					
Tert-Butly-Alcohol					
Butyl Accetate					
Butraldehydes					
Butyric Acid	1	4.18	0.25	14	0.44
Carbon Disulfide	1	1.79	0.25	6	1.02

TABLE 21. (Continued)

CONTAMINANT	A	B	C	D	E
Carbon Monoxide	2	0.87	2.60	29	2.19
Carbon Tetrachloride	1	1.94	0.25	6.5	0.94
Carbonyl Sulfide					
Chlorine	1	0.34	0.25	1.5	4.08
Chloroacetone					
Chlorobenzene					
Chlorofluoromethane					
Chloroform	2	0.72	2.50	24	2.55
Chloropropane					
Caprylic Acid					
Cumene					
Cyclohexane	2	2.99	2.50	100	0.613
Cyclohexene					
Cyclohexanol	1	5.97	0.25	20	0.31
Cyclopentane					
Cyclopropane					
Cyanamide					
Decalin	1	1.49	0.25	5.0	1.23
1,1 Dimethyl Cyclohexane					
Trans 1,2 Dimethyl Cyclohexane					

TABLE 21. (Continued)

CONTAMINANT	A	B	C	D	E
2,2 Dimethyl Butane					
Dimethyl Sulfide	1	4.48	0.25	15	0.41
1,1 Dichloro Ethane	2	1.19	2.50	40	1.53
1,1 Dichloro Ethane					
Di-Iso-Butyl Ketane					
1,4 Dioxane	2	1.07	2.50	36	1.70
Dimethyl Furan	1	0.89	0.25	3	2.04
Dimethyl Hydrazine	1	0.03	0.25	0.1	61.5
Ethane	2	5.38	2.50	180	0.34
Ethyl Alcohol	2	5.61	2.53	190	0.33
Ethyl Acetate	2	4.17	2.50	140	0.44
Ethyl Acetylene					
Ethyl Benezene					
Ethylene Dichloride					
Ethyl Ether	2	3.57	2.50	120	0.51
Ethyl Butyl Ether					
Ethyl Formate	2	0.90	2.50	30	2.04
Ethylene	2	5.37	2.50	180	0.34
Ethylene Glycol					

TABLE 21. (Continued)

CONTAMINANT	A	B	C	D	E
Trans 1, Methyl 3 Ethyl Cyclohexane					
Ethyl Sulfide					
Ethyl Mercaptan	1	0.75	0.25	2.5	2.45
Freon 11					
Freon 12					
Freon 21					
Freon 22					
Freon 23	1	3.58	0.25	12	0.51
Freon 113					
Freon 114					
Freon 114 (unsym)					
Freon 125					
Formaldehyde	1	0.18	0.25	0.6	10.2
Furan					
Furfural	1	5.96	0.25	2	3.06
Hydrogen	2	6.42	2.65	215	0.30
Hydrogen Chloride	1	0.04	0.25	0.15	41.0
Hydrogen Fluoride	1	0.02	0.25	0.08	76.7
Hydrogen Sulfide					
Heptane					

TABLE 21. (Continued)

CONTAMINANT	A	B	C	D	E
Hexene-1					
N-Hexene	2	5.38	2.50	180	0.34
Hexamethylcyclo-Trisilohexane					
Indole					
Isoprene					
Methylene Chloride	2	0.63	2.50	21	2.92
Methy Acetate	2	1.83	2.50	61	1.01
Methy Butyrate					
Methy Chloride	1	6.28	0.25	21	0.29
2-Methy-1 Butene					
Methyl Chloroform	2	5.68	2.50	190	0.32
Methyl Furan	1	0.89	0.25	3	2.04
Methyl Ethyl Ketone	2	1.76	2.50	59	1.04
Methyl Isobutyl Ketone					
Methyl Isopropl Ketone	2	2.09	2.50	70	0.09
Methyl Cyclo Hexane					
Methyl Acetylene					
Methyl Alcohol	2	0.77	2.53	26	2.38
3-Methyl Pentane					
Methyl Methacrylate					

TABLE 21. (Continued)

CONTAMINANT	A	B	C	D	E
Methane	5	4.22	31.3	1720	0.44
Mesitylene	1	0.75	0.25	2.5	2.45
Mono Methyl Hydrazine	1	0.01	0.25	0.035	175
Methyl Mercaptan	1	0.60	0.25	2	3.06
Napthalene	1	1.50	0.25	5.0	1.23
Nitric Oxide					
Nitrogen Tetroxide	1	0.54	0.25	1.8	3.4
Nitrogen Dioxide	1	0.27	0.25	0.9	6.82
Nitrous Oxide					
Octane					
Propylene	2	5.37	2.50	295	0.34
Iso-Petane					
N-Pentane					
Pentene-1					
Pentene-2					
Propane	2	5.36	2.50	180	0.34
N-Propyl Acetate					
N-Propyl Alcohol	2	2.24	2.50	75	0.82
Iso-Propyl Alcohol	2	2.93	2.50	98	0.63
N-Propyl Benzene					

TABLE 21. (Continued)

CONTAMINANT	A	B	C	D	E
Iso-Propyl Chloride					
Iso-Propyl Ether					
Proprionaldehyde					
Propionic Acid	1	4.48	0.25	15	0.41
Propyl Mercaptan					
Propylene Aldehyde	1	2.98	0.25	10	0.61
Pyruvic Acid	4	0.12	1.13	0.9	30.8
Phenol	1	1.08	1.38	1.9	17.8
Skatol					
Sulfur Dioxide	1	0.24	0.25	0.8	7.65
Styrene					
Tetrachloroethylene					
Tetrafluoroethylene					
Tetrahydrofurane					
Toluene	2	2.24	2.50	75	0.82
Trichloroethylene					
1,2,4 Tri Methyl Benzene					
1,1,3 Tri Methyl Cyclohexane					
Valeraldehyde					
Valeric Acid					

TABLE 21. (Concluded)

CONTAMINANT	A	B	C	D	E
Vinyl Chloride	2	3.88	2.50	130	0.05
Vinyl Methyl Ether					
Vinyldene Chloride	1	5.96	0.25	20	0.31
O-xylene	2	1.31	2.50	44	1.40
m-xylene	2	1.31	2.50	44	1.40
p-xylene	2	1.31	2.50	44	1.40

3. Maximum Allowable Concentrations. MAC's are established by members of the medical profession who are familiar with toxicology. However, it is felt that the SSP MAC's should be conservative for Sortie Lab since the values were established for continuous exposure on missions of much longer duration.

4. Physical Removal Processes. The physical removal processes which will be utilized in the Sortie Lab contaminant removal system are adsorption, absorption and, as a recommendation, catalytic oxidation for control of carbon monoxide (CO), hydrogen (H_2), and methane (CH_4). No absorption or adsorption process has been discovered with a capacity great enough to remove these three contaminants from the Sortie Lab atmosphere. The SSP catalytic oxidizer (CO_x) design has been chosen for the Sortie Lab contaminant control system. Table 22 contains basic design parameters of this system. The difference between these parameters and those adjusted for Sortie Lab contaminant loads amounts to a six-percent reduction in bed size. It was felt that this small difference did not warrant new design effort.

It is necessary to abbreviate the contaminant list as much as possible to reduce the number of specific control problems encountered. For the seven days mission length being used as a baseline for Sortie Lab, it happens that some 76 of the contaminants do not reach MAC levels in times short enough to be of concern. Thus, the first shortening of the contaminant list will involve the deletion of these 76 contaminants from subsequent detail treatment. Rather, these 76 will receive a bulk treatment, in that beds will be sized to accommodate the total generation rate of these 76 contaminants which is 27.13 g/day.

The remaining 74 contaminants of concern are listed in Table 21 which includes the non-biological generation rates (in code), total generation rates, MAC's, times to MAC (with no control), and the required processing rates. The 76 contaminants of less concern are listed for reference purposes, but no data are given for these substances.

The next abbreviation of the contaminant list is a callout of the contaminants requiring processing rates greater than the 0.06 m^3/min (2.22 cfm) required for CO. These 24 contaminants are listed in Table 23 in order of increasing flow rate requirements which are seen to range from the lower cutoff value of 0.06 m^3/min (2.22 cfm) for CO up to 5.0 m^3/min (175 cfm) for Monomethyl Hydrazine. The total generation rate for these high flow contaminants is 24.6 g/day. The significance of this table is that a trade-off of CO_x flow versus the use of charcoal need only involve this flow range and these particular contaminants.

TABLE 22. BASIC DESIGN PARAMETERS FOR THE CATALYTIC OXIDIZER FOR THE SPACE STATION PHOTOTYPE FOR A FLOW RATE OF 10 CFM

Catalyst		Units	0.5% Pd on Al_2O_3	20% Pd on Al_2O_3
Contact Time		sec	1.252	1.950
Required Catalyst Volume		m^3	0.006*	0.009*
		ft^3	0.210*	0.325*
Catalyst Mesh Size			6 to 10	6 to 10
Contaminant Removal Rate (g day^{-1}/g-mole day^{-1})			205/ 8.60	205/ 8.60
Bed Frontal (Flow) Area		m^2	0.033	0.033
		ft^2	0.35	0.35
Operating Temperature		°C	304	304
		°F	580	580
Axial Flow Bed Dimensions	Length	cm	24.1	24.1
		in.	9.5	9.5
	Diameter	cm	20.3	20.3
		in.	8.0	8.0
Pressure Drop (H_2O)		cm	17.0	17.0
		in	6.7	9.7

*Average of "starred" values used for bed size dimensions.

TABLE 23. ABBREVIATED SORTIE LAB CONTAMINANT LIST: CONTAMINANTS REQUIRING FLOWS GREATER THAN THAT FOR CO

Contaminant	(n$\dot{Q}$) Required		SSP Generation Rate (g/day)	MAC (mg/m^3)	Days to Reach MAC	Contaminant Short Code Number
	m^3/min	cfm				
Carbon Monoxide	0.063	2.22	2.60	29.0	0.87	1
Methyl Alcohol	0.067	2.38	2.53	26.0	0.77	2
Acetic Acid	0.069	2.45	0.25	2.5	0.75	3
Ethyl Mercaptan	0.069	2.45	0.25	2.5	0.75	4
Mesitylene	0.069	2.45	0.25	2.5	0.75	5
Chloroform	0.072	2.55	2.50	24.0	0.72	6
Methylene Chloride	0.083	2.92	2.50	21.0	0.63	7
Fufural	0.087	3.06	0.25	2.0	0.60	8
Methyl Mercaptan	0.087	3.06	0.25	2.0	0.60	9
Nitrogen Tetroxide	0.096	3.40	0.25	1.8	0.54	10
Chlorine	0.116	4.10	0.25	1.5	0.34	11
Nitrogen Dioxide	0.178	6.82	0.25	0.9	0.27	12
Benzene	0.218	7.70	2.50	8.0	0.24	13
Sulfur Dioxide	0.218	7.70	0.25	0.80	0.24	14
Formaldehyde	0.289	10.2	0.25	0.60	0.18	15
Allyl Alcohol	0.345	12.3	0.25	0.50	0.15	16
Phenol	0.504	17.8	1.38	1.90	0.11	17
Acrolein	0.694	24.5	0.25	0.25	0.075	18
Pyruvic Acid	0.872	30.8	1.13	0.90	0.060	19
Ammonia	1.093	38.6	5.50	3.50	0.047	20
Hydrogen Chloride	1.161	41.0	0.25	0.15	0.045	21
Dimethyl Hydrazine	1.741	61.5	0.25	0.10	0.030	22
Hydrogen Fluoride	2.172	76.7	0.25	0.08	0.024	23
Monomethyl Hydrazine	4.955	175.0	0.25	0.035	0.010	24

The total contamination generation rates and the number of contaminants in each flow rate/time to MAC range are summarized in Table 24 for reference purposes.

TABLE 24. SUMMARY OF GENERATION RATES AND FLOW RANGES.

Required Processing Flow Range		Days to MAC (No Control)	Number of Contaminants	Total Generation Rate (g/day)
m^3/min	cfm			
<0.007	<0.255	>7	76	27.1
0.007 to 0.063	0.225 to 2.22	0.87 to 7	50	126.4
>0.063	>2.22	<0.87	24	24.6
		Totals	150	178.1

5. Integrated Removal Mechanisms. In addition to the CO_x, there will be at least three other removal methods required for the Sortie Lab. Two of these three methods are inherent in the design of the Environmental Control System (ECS) for the Lab. These two methods are the absorption of contaminants onto the wetted surface of the Condensing Heat Exchanger (CHx) and the removal of certain contaminants in the LiOH beds intended for CO_2 control. The third method of control will be a $CuSO_4$ (Copper Sulfate) coated silica gel bed for ammonia control. The baseline lab ECS system employs two Skylab type CHx's at 1.3 m^3/min (45 cfm) each and two LiOH beds at 0.3 m^3/min (10 cfm) each. It is understood that normal operations will involve using only one of the paired devices for both the CHx's and the LiOH beds. Thus, for water absorption and LiOH adsorbtion the available processing flows are 1.3 m^3/min and 0.3 m^3/min (45 cfm and 10 cfm), respectively. However, these values are not necessarily indicative of the efficiency-flow rate products (nQ) available for any given contaminant.

Generally, the removal of water soluble contaminants in the CHx will be at efficiencies significantly less than 100 percent. The actual efficiency will be estimated for particular contaminants of concern. A guess at this time is that the removal efficiency of a contaminant adsorbed by LiOH will approach 100 percent in the LiOH beds. However, this is just an estimate and will require verification. Typically, beds as such will have near 100 percent efficiency. Since the ammonia removal system will be designed to remove the expected loads it will have a design point nQ of 1.1 m^3/min (38.6 cfm) as shown in Table 23. The nQ of this method for other contaminants may be different.

It should be noted that the pre- and post-sorbent beds in the COx flow stream will provide some measure of control. These beds serve to prevent poisoning of the COx and to scrub the gas exiting the COx of any undesirable products of oxidation. The pre-sorbent beds (in the order of LiOH then $CuSO_4$ silica gel) will be included in the accounting of overall removal capacity. However, the down stream bed (LiOH) will not be included and will be viewed as an independent capacity for whatever is generated in the COx. As a consequence of this 0.3 m^3/min (10 cfm) flow, the nQ of the primary ammonia control bed can be reduced to 0.8 m^3/min (28.6 cfm).

These various removal mechanisms are summarized in Table 25. It is seen that all of the methods discussed are available to the 10 cfm level, three are available to the 0.6 m^3/min (20 cfm) level, and two available at about the 40 cfm level. As noted in the title of Table 25, these methods are regarded as the minimum requirement for toxic gas control for the Sortie Lab.

The procedure for evaluating the situation for the 10 gases requiring more that 0.3 m^3/min (10 cfm) is to compare each control process with this list of 10 substances. The comparisons are given in the following sections of the report.

a. Water soluable gas control. Table 26 summarizes analytical data generated in an attempt to determine water absorption characteristics of the remaining ten high flow rate contaminants. Attention is directed to the column entitled "water condensation rate required for control (#M/HR)."

Assuming that all of the condensate is metabolic in origin would indicate that a reasonable expectation for the condensation rate for the Sortie Lab would lie in the range of 0.2 to 0.7 kg/hr (0.50 to 1.50 lbm/hr). Therefore, it is felt that only pyruvic acid, phenol, and possibly allyl alcohol will be controlled by the condensing heat exchanger (one Skylab type unit was considered operative here).

b. Basic gas control. Even though the sorbent bed containing $CuSO_4$ coated silica gel is intended primarily for ammonia control some of the remaining high flow contaminants can at least be partially controlled in this bed. Gases which should be chemisorbed by this bed in addition to NH_3 include formaldehyde, phenol, monomethyl hydrazine, and dimethyl hydrazine.

From Table 23 it is seen that formaldehyde and phenol rank below NH_3 in process flow requirements. However, it is seen that the processing rate for ammonia falls short of the 1.7 m^3/min (61.5 cfm) required for dimethyl hydrazine and far short of the 5.0 m^3/min (175 cfm) for monomethyl hydrazine.

TABLE 25. MINIMUM CONTAMINANT REMOVAL SCHEMES FOR THE SORTIE LAB

Target Contaminant Gases	Removal Mechanism	Maximum $n\dot{Q}$ Available		Typical Gas Controlled By Mechanism
		m^3/min	cfm	
Acidic	LiOH Adsorbtion	0.57	20	SO_3
Basic	$CuSO_4$/Silica Gel	1.08	38	NH_3
Oxidizable	Catalytic Oxidizer	0.28	10	CO
Soluble	Skylab Condensing Heat Exchanger	1.27	45	Pyruvic Acid

TABLE 26. SUMMARY OF ANALYSIS OF CONTAMINANT REMOVAL BY THE CONDENSING HEAT EXCHANGER (FLOWS GREATER THAN 10 CFM)

Contaminants	Short Code Number	β Absorption* Parameter (Dimensionless)	Estimated Removal Rate: Grams Removed per Pound of Water Condensed × 10^6 (10^{-6} g/lbm)	Water Condensation Rate Required for Control		Temperatures for Data Given	
				kg/hr	lbm/hr	°C	°F
Formaldehyde	15	0.02	1	68.9	152	20	68
Allyl Alcohol^{o}	16	0.08	9,400	0.50	1.11	25	77
Phenol^{+o}	17	0.21	252,000	0.10	0.23	16	61
Acrolein^{+}	18	0.03	200	19.5	43	25	77
Pyruvic Acid^{+o}	19	5.4	< 0.725**	0.045	0.10	20	68
Ammonia	20	0.03	176	590	1,300	20	68
Hydrogen Chloride^{+}	21	9.0×10^{-5}	2	3130	6,900	0	32
Dimethyl Hydrazine	22	0.009	366	12.7	28	25	77
Hydrogen Fluoride^{+}	23	0.005	60	78.5	173	20	68
Monomethyl Hydrazine^{+}	24	0.04	353	13.6	30	25	77

*Based on water condensation rate of 0.34 kg/hr (0.75 lbm/hr).

**Pyruvic acid removal rate is in units of g/day assuming use of one Skylab condensing heat exchanger.

+Identified as soluble under SSP conditions by H-S.

oCan be removed by condensing heat exchanger.

It would be possible to simply consider a larger bed size and flow rate. However, at 5.0 m^3/min (175 cfm) for the 2.54 or 5.08 cm (one or two inches) of bed required, the pressure loss would be on the order of 10.2 cm (4 in.) of water, which implies a 100-W fan.

c. Acid gas control. At this point in the definition of the trace contaminant control system there are only three of the high flow gases which have not had a potential removal mechanism identified. These gases are acrolein, hydrogen chloride, and hydrogen fluoride which require 0.7, 1.2, and 2.2 m^3/min (24.5, 41.0, and 76.7 cfm), respectively. Fortunately, all of these gases are essentially acidic in nature and will probably be removed by LiOH. However, the 0.57 m^3/min (20 cfm) through the presorbent bed in the COx stream and the CO_2 control bed is insufficient to provide complete conceptual removal.

6. Summary. In summary, the minimum contaminant removal schemes described above and in Table 25 do not provide sufficient capacity to remove all contaminants described in the Space Station Prototype list. Six of the contaminants listed received only partial removal with the design suggested. If this design recommendation is compromised, the list will increase significantly. There is, at present, no way to know what the contaminant spectrum in Sortie Lab could be and what generation rates could be expected. The use of off-the-shelf equipment, with its necessarily loose materials control program, puts the entire analysis outlined above in the not very educated guess category. No definite statement can be made regarding the completeness, correctness, or reality of the SSP contaminants list when applied to this program.

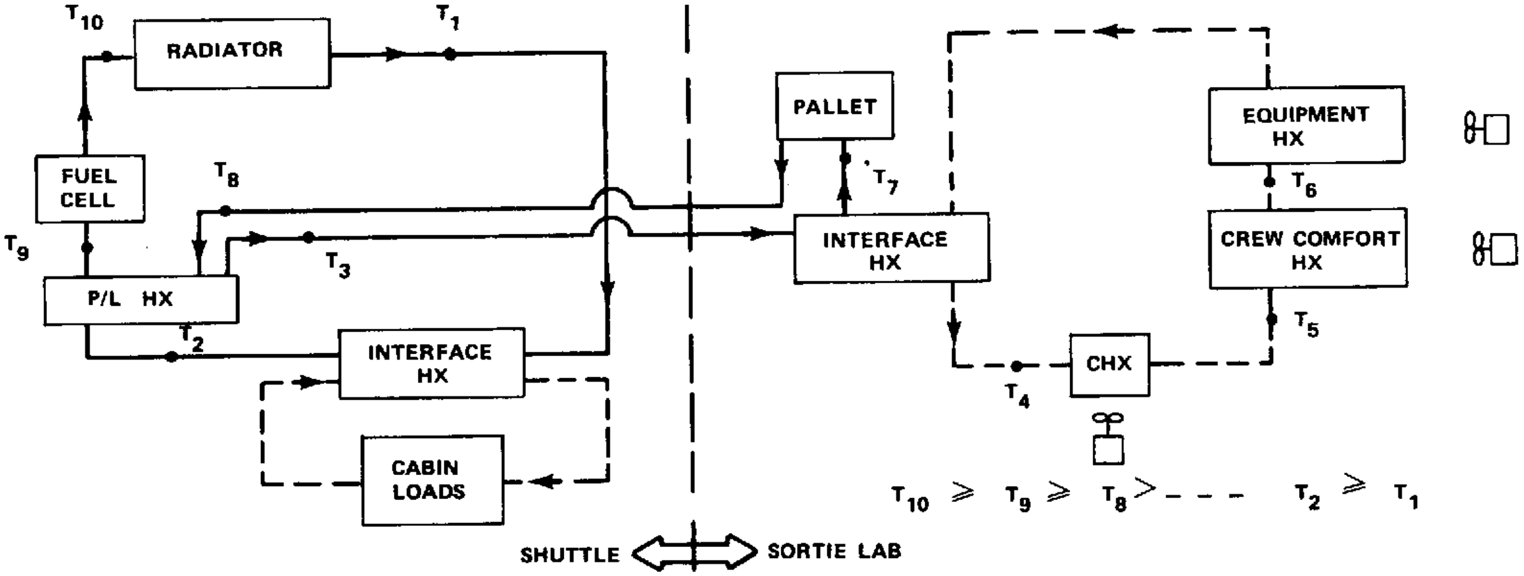
Immediate, comprehensive effort is required to establish, experimentally, a complete and realistic contaminant list which could be utilized as a design tool for this and future programs.

SECTION VI. SHUTTLE ECS RESOURCE UTILIZATION

The Shuttle ECS provisions for payloads was investigated in the Sortie Lab studies. The potential fluid interfaces between the two spacecraft include (a) high pressure gas line ($0_2/N_2$) for represurization, (b) air ducts for atmosphere revitalization and (c) coolant lines for thermal control. The overall goal of these studies is to maintain a simple interface with the Shuttle to minimize integration costs while providing a useful resource for the Sortie Lab.

A. Heat Rejection

The primary thermal control interface between the Shuttle and the Sortie Lab is through a payload heat exchanger located in the orbiter radiator circuit. The objective of the Sortie Lab using any available heat rejection capability for the orbiter is to reduce the Sortie Lab program cost by eliminating (or possibly simplifying) the payload radiator design and development. The baseline Shuttle design presented several interfaces that were incompatible with payload requirements. These were total heat rejection available, payload coolant temperatures available, required payload coolants and associated flow rates. The baseline location of the Shuttle/payload heat exchanger is given in Figure 66. The payload heat exchanger is in series with the Shuttle cabin interface heat exchanger. Therefore, the Shuttle cabin thermal loads dictate coolant supply temperature (T_2) to the payload heat exchanger. The expected temperature variations are $T_2 = 32 \pm 16.7°C$ ($90 \pm 30°F$). This coolant supply temperature was unacceptable to provide adequate temperature control in the lab. Also, the total heat rejection available was 1 kW (nominally) for a Shuttle electrical power generation greater than 8 kW_e and 3.3 kW for a Shuttle electrical power generation less than 8 kW_e. Even with an acceptable coolant supply temperature the total heat rejection available is not enough and would require the Sortie Lab to have a radiator. A proposal was submitted to the Shuttle program manager (Level II change board) to assess and recommend the changes and/or operational constraints necessary for the orbiter heat rejection system to satisfy all or a portion of the Sortie Lab heat rejection requirements using the following guidelines:



SHUTTLE ALLOCATIONS

- FLUID SUPPLY TEMP (T_2) TO PAYLOAD INTERFACE HEAT EXCHANGER IS VARIABLE 90 ± 30°F. BASED ON SHUTTLE CABIN LOADS.

- PAYLOAD HX HEAT REMOVAL CAPACITY
  - POWERED UP SHUTTLE (> 8 KW_E)

    1.0 KW NOMINAL
    1.5 KW PEAK
  - POWERED DOWN SHUTTLE (8 $KW_E \leq$)

    3.3 KW NOMINAL
    6.2 KW PEAK

Figure 66. Shuttle/payload thermal control interface.

1. Sortie Lab Heat Rejection Requirements (kW)

Mission Phase	Average	Peak
Pre-Operational (Pre-Launch, Boost, On-Orbit, Doors Closed)	1.0	1.5
Operational (On-Orbit, Doors Open)	8.5	8.5
Post-Operational (On-Orbit, Door Closed, Reentry)	1.0	1.5

2. Provide a 4.4°C (40°F) fluid supply temperature to the payload heat exchanger for all mission support phases. Payload coolant temperature available = 4.4 to 7.2°C (40 to 45°F).

3. The preferred coolant on the payload side of the interface is Freon-21 (water may be traded against this baseline). Coolant flow rate requirements on payload side of interface shall be determined by design of Shuttle payload heat exchanger. Freon flow of 910 to 1365 kg/hr (2000 to 3000 lb/hr) is desired.

4. The use of an expendable heat sink (such as water, ammonia, Freon) to reject the payload waste heat should be avoided because of potential experiment contamination.

5. It should be generally assumed that the Sortie Lab is not deployed from the payload bay, but maintains a fixed location in the bay. As a delta evaluation, the impact of providing thermal control for an attached but deployed lab should be assessed.

The level II board accepted the request for study. The impact on orbiter design and the required payload interfaces are still under study. Typical data needed by the Sortie Lab for designing to the Shuttle/payload heat exchanger is illustrated in Figure 67. These data would be required for each potential payload coolant interfacing with the Shuttle heat exchanger.

B. Life Support

There are many interfaces issues between the Shuttle orbiter cabin and the Sortie Lab associated with a decision for atmosphere exchange. These issues are discussed after a summary of the proposed Shuttle baseline design is reviewed. The Shuttle is proposing to provide 1.4 m^3/min (48 ft^3/min) of revitalized air to the pressurized Sortie Lab module (Figure 68). The exact mechanical interfaces are under study (for example, a drag-in supply duct

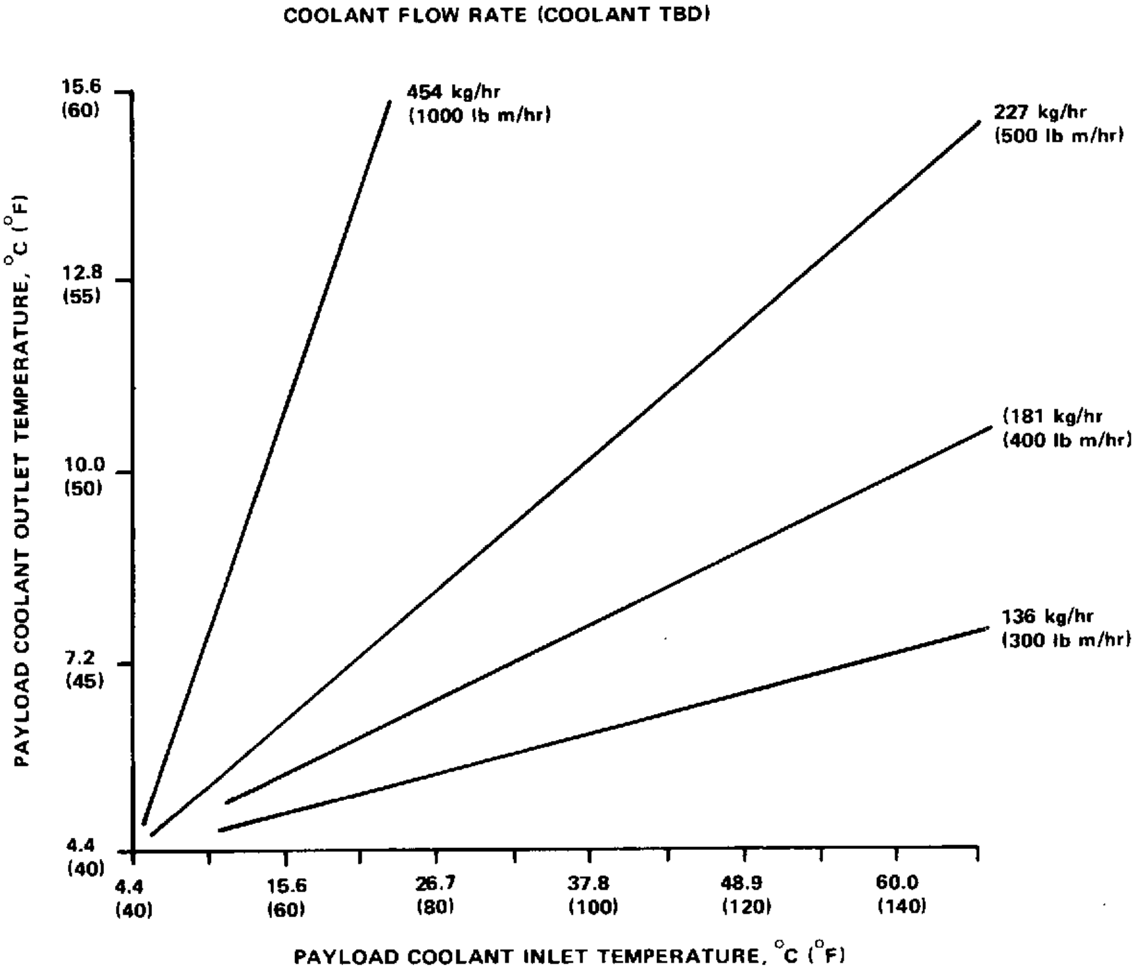


Figure 67. Shuttle/payload heat exchanger performance data.

with open hatches between the cabins versus supply and return ducts with hatches open or closed). The anticipated lab environment for this processing concept is given in Table 27. The Sortie Lab would have humidity levels higher than desired for optimum lab air temperature control. To avoid condensation on Sortie Lab air heat exchangers, the maximum allowable liquid coolant temperatures would be 18.3°C (65°F) for four crewmen in the lab, 13.3°C (56°F) for two crewmen in the lab. Unless the Sortie Lab reduced its thermal design capabilities, these high dew point temperatures are considered unacceptable.

A comparison of weight/power requirements for a Shuttle dependent versus a Sortie Lab provided life support system was made (see Tables 28 and

PROPOSED SUPPORT FUNCTIONS

- ATMOSPHERE TOTAL PRESSURE CONTROL
- OXYGEN PARTIAL PRESSURE CONTROL
- CO_2 REMOVAL
- HUMIDITY CONTROL

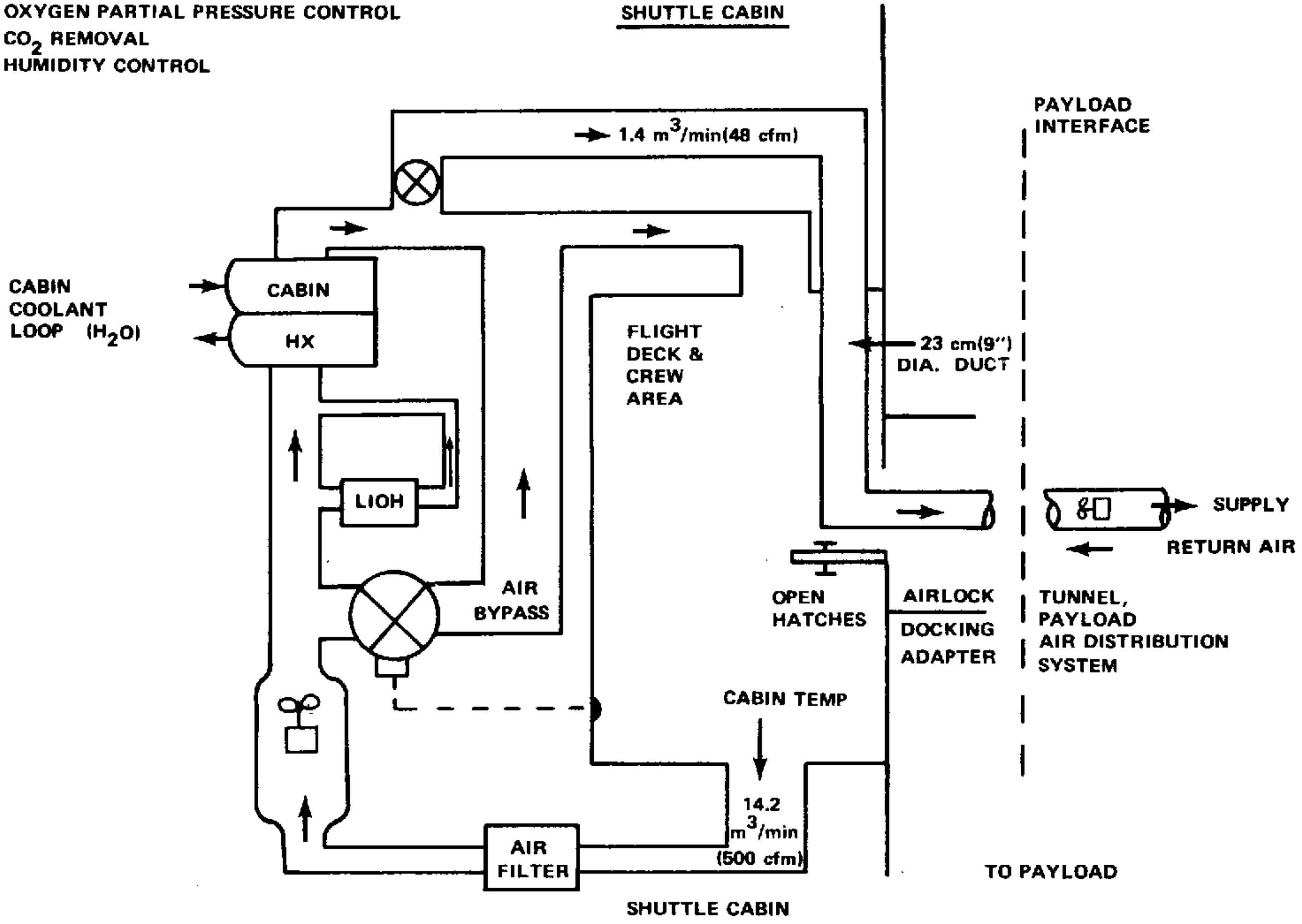


Figure 68. JSC concept for payload ECS support.

TABLE 27. SHUTTLE/PAYLOAD ATMOSPHERE EXCHANGED INTERFACES

		Shuttle Provided Capabilities to Payload		
Parameter	Sortie Lab Reqmt's	Supplied to Payload	Payload Operating Conditions	
			2 Crewmen	4 Crewmen
Total Pressure	10.1 ± 0.14 N/cm^2 (14.7 ± .2 PSIA)	10.1 ± 0.14 N/cm^2 (14.7 ± .2 PSIA)	10.1 × 0.14 N/cm^2 (14.7 ± .2 PSIA)	10.1 ± 0.14 N/cm^2 (14.7 ± .2 PSIA)
Oxygen Partial Pressure	2.1 ± 0.07 N/cm^2 (3.1 ± .1 PSIA)	2.1 ± 0.07 N/cm^2 (3.1 ± .1 PSIA)	2.1 ± 0.07 N/cm^2 (3.1 ± .1 PSIA)	2.1 ± 0.07 N/cm^2 (3.1 ± .1 PSIA)
CO$_2$ Partial	- Normal Operation At 3 MM HG or less - Maximum Level 7.6 MM HG	1 - 2 MM HG	1.5 - 2.5 MM HG	2 - 3 MM HG
Dew Point Temperature	- Normal Operation of 7.2 ± 2.8° C (45 ± 5° F)	- Normal 10.0 ± 2.8° C (50 ± 5° F)	11.1 - 12.8° C 52 - 55° F)	15.6 - 17.8° C (60 - 64° F)
Trace Contaminants	TBD	TBD	—	—
Particulate Filteration	- Nominal Class 100,000	TBD	—	—

TABLE 28. SPACELAB EC/LS WEIGHT/POWER REQUIREMENTS (6 CREWMENT/7 DAYS)

Concept/Function	Shuttle Provided/ Payload Chargeable			Spacelab Provided			Total Payload Req'mt		
	kg	lbs	Power(W)	kg	lbs	Power(W)	kg	lbs	Power(W)
Dependent Atmosphere Revitalization									
. Atmosphere 2-Gas Control and Supply							83.5	184	—
- Metabolic O_2	11.8	26	—			—			
- Leakage Make-up (O_2/N_2)	9.5	21	—			—			
- Airlock Useage (O_2/N_2)	20.4	45	—			—			
- *Tankage (Gaseous N_2)		—		41.7	92	—			
. CO_2 Removal							25.4	56	—
- LiOH Canisters	25.4	56	—						
. Humidity Control							51.3	113	45
- Condensing HX				17.7	39				
- Condensate Collection				28.6	63				
- Fan				5.0	11	45			
. Air Exchange							55.3	122+	90
- Ducting		TBD	—	45.4	100	—			
- Valves		TBD	—		TBD	—			
- Fans		—	—	10.0	22	90			
Total	67.1 kg+	148+	—	148.3+	327+	135	215.5	475+	135

*Assumes No O_2 Tankage Required. Fuel Cell O_2 Utilized.

29). Assuming the lab provided its own humidity control, the maximum weight savings envisioned for the Shuttle dependent concept is 24 kg (53 lbs). Approximately 15 watts more is required for the dependent concept than the independent. If the Shuttle humidity control levels were acceptable, the total weight/power savings to lab is 75.3 kg (166 lb)/30 watts.

Several major issues associated with a decision for Shuttle, orbiter/Sortie Lab atmosphere exchange need resolving. These are

- Cabin contamination control
- Open and/or closed hatches between cabins
- Operational aspects of EVA and rescue
- Tunnel design between cabins
- Spacelab design requirements
- Assessment of C.G./weight constraints
- Pre-flight testing required for interface verification
- Cost

1. Cabin Contamination Control. The Sortie Lab materials control program is not envisioned to be as vigorous as the Shuttle orbiter. If contamination does occur in the lab, transfer of the contamination to the orbiter (a safe refuge area) will occur with atmospheric exchange. In the Shuttle program, a Skylab type materials control program is applied to all equipment located in the crew compartment. Basically this is a fixed, unchanging amount of cabin equipment that has to be evaluated only once. Special air cooled compartments or bays are located outside of the Shuttle cabin area and are designed to incorporate all equipment not compatible with the cabin materials control program. The majority of equipment in these compartments is avionics (off-the-shelf) operating at high ambient air temperatures 37.8 - 54.4°C (100 - 130°F). Access to the equipment during a mission is not required. The compartments are designed to leak overboard at a controlled rate and are maintained at a constant pressure differential 0.28 N/cm^2 (0.4 psid) below the cabin pressure to preclude avionics generated trace contaminants from migrating into the Shuttle cabin. Sortie Lab currently has no such provisions but does envision a systematic approach to contaminant control.

The first step is to develop a laboratory equipment specification document that experimenters can use for screening off-the-shelf equipment with potential contamination problems. This is required because a variety of laboratory equipment will be associated with each payload discipline and a considerable amount of this could be commercial equipment. Since a contamination evaluation test is not envisioned for each Sortie Lab payload, some means of screening equipment is required. The second step is to provide an optimum equipment cooling

TABLE 29. SPACELAB EC/LS WEIGHT/POWER REQUIREMENTS (6 CREWMEN/7 DAYS)

Concept/Function	Shuttle Provided/ Payload Chargeable			Spacelab Provided			Total Payload Req'mt		
	kg	lbs	Power(W)	kg	lbs	Power(W)	kg	lbs	Power (W)
Independent Atmosphere Revitalization									
• Atmosphere 2-Gas Control and Supply	0.0	0.0	0.0				157.8	348	30
- Metabolic O_2	Assumes 4 Crewmen Spend 12 hrs/day in Spacelab.			11.8	26	—			
- Leakage Make-up (O_2/N_2)				9.5	21	—			
- Airlock Useage (O_2/N_2)				20.4	45	—			
- Tankage (Gaseous O_2/N_2)				83.5	184	—			
- Regulation/Controls				32.7	72	30			
• CO_2 Removal							30.4	67	45
- LiOH Canisters				25.4	56	—			
- Fan				5.0	11	45			
• Humidity Control							51.3	113	45
- Condensing HX				17.7	39	—			
- Condensate Collection				28.6	63	—			
- Fan				5.0	11	45			
TOTAL	0.0	0.0	0.0	239.5	528	120	239.4	528	120

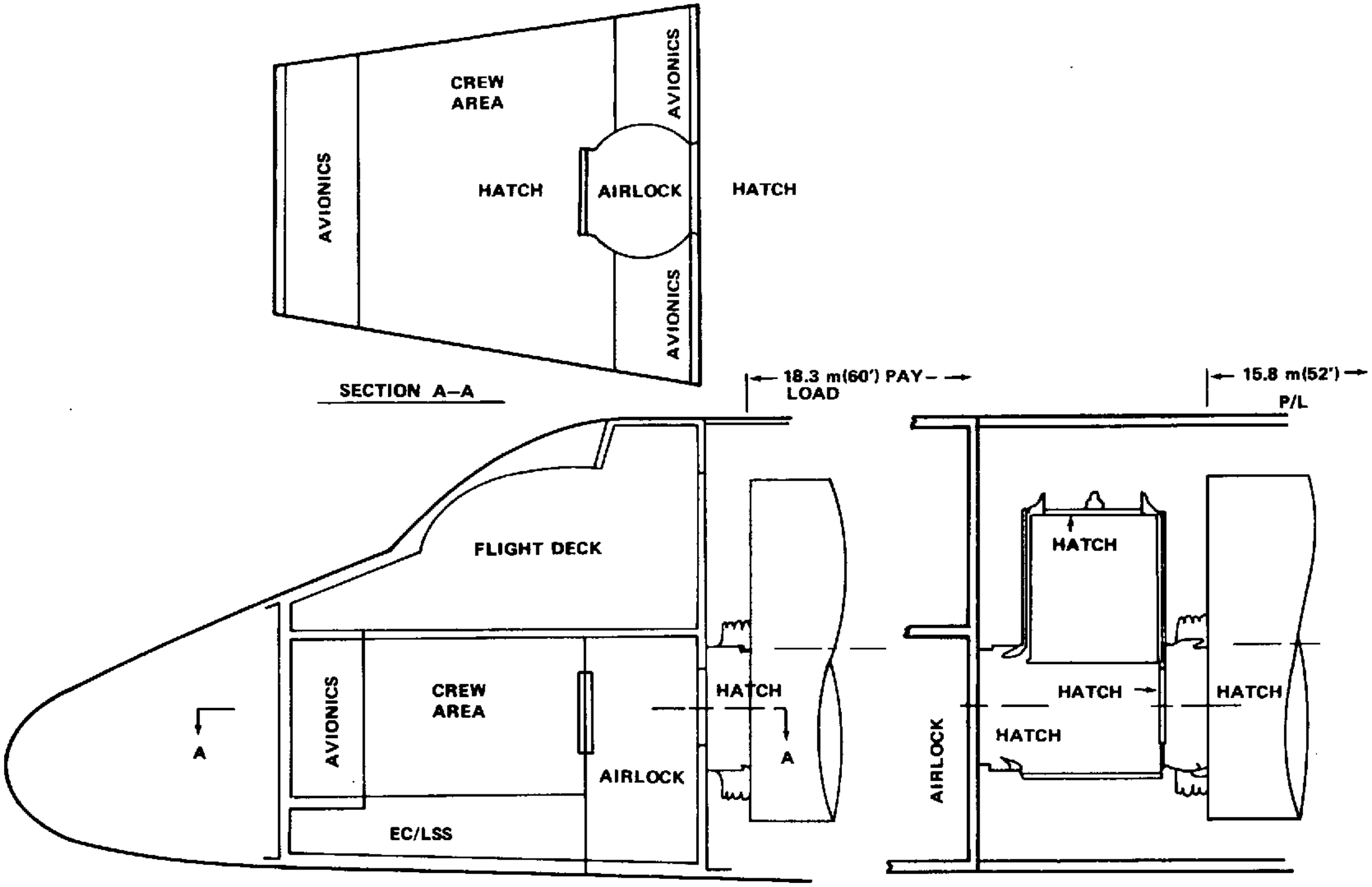
design (air conditioning primarily) by providing low temperature air, 15.6-37.8° C (60-100° F) to minimize outgassing. The lab design should provide reasonable access to equipment and maintain flexibility for integration options. The last step is to provide a contamination control and monitoring system based on contaminants most likely to occur in cabin. If any problem still occurs on-orbit, the crew can use the orbiter as a safe retreat for mission termination.

2. Open and/or Closed Hatches Between Cabins. There will be three to four hatches between the orbiter cabin and the Sortie Lab cabin depending on the requirement to carrying a docking module (Figure 69). The safety implications of operating on-orbit with a closed hatch between the cabins has not been thoroughly evaluated. The interaction of two, independent 2-gas control systems was discussed in Section V,A, for the open hatch operation with present designs. Modification of the Sortie Lab baseline design is proposed to eliminate this problem. The possible diffusion of contaminants has not been evaluated for open hatch operation. For either open or closed hatches, supply and return ducts are required for atmosphere exchange. With open hatch operation, the tunnel and airlock would serve as a return duct. If a crewman has to install a drag-in duct on-orbit, the operational aspects of this open hatch operation would also have to be evaluated.

3. Operational Aspects of EVA and Rescue. The method of providing operational EVA from the Shuttle during a Sortie Lab mission is still unresolved. If the docking adapter is used, the impact of the vacuum conditions on atmosphere exchange designs must be evaluated. Ducting routing is required for minimum interference with EVA, and the possibility of crewmen being in the lab during EVA should be assessed. Similarly, a rescue mode of Shuttle crewmen during Sortie Lab missions must be established and its impact on atmosphere exchange designs evaluated.

4. Tunnel Design Between Cabins. In satisfying the Shuttle/payload center of gravity constraints, a tunnel 3.0 to 12.2 m (10 to 40 feet) between the two cabins is required for crew access to Sortie Lab. The final tunnel design will be impacted by any atmosphere exchange required between the two cabins. For example, the air duct diameters required for air flow will affect clearance space in the tunnel, if located inside the tunnel. The attachment of ducting and fans could influence whether the tunnel is flexible or rigid. Also, the tunnel conditioning requirements for crew usage, EVA or rescue are still under study.

5. Sortie Lab Design Requirements. It should be noted that the proposed Shuttle air flow and associated humidity levels in the lab are not compatible with the desired normal levels. If these high levels are imposed on the cabin thermal



- SHUTTLE/PAYLOAD INTERFACES WITHOUT DOCKING ADAPTER
- WITH DOCKING ADAPTER

Figure 69. Shuttle/Sortie Lab configurations affecting ECS interfaces.

designs, less than optimum air temperature control is available in the lab. The impact of changing or unforeseen experiment requirements on the ECS is possible. Impacting the Shuttle designs could be more expensive than the same requirement imposed on a Sortie Lab.

6. Assessment of Center of Gravity/Weight Constraints. As noted earlier, no overall weight savings is envisioned for Sortie Lab life support provided by Shuttle. The location of consumables in the forward end of the Shuttle could impact the C.G. considerations (especially for 30-day missions). The C.G. advantages of reducing payload chargeable weights in the Shuttle cockpit should be evaluated.

7. Pre-Flight Testing Required for Interface Verification. The requirements for pre-flight testing to verify interfaces between the two cabins for each mission need to be defined. This could affect ground-turn-around time of the Shuttle for Sortie Lab missions.

8. Cost. Cost is a consideration for all of the above issues. It is difficult to assess total cost for a dependent versus an independent life support system for Sortie Lab without resolution of these issues.

SECTION VII. ECS ACCOMMODATIONS FOR EXPERIMENTS

Although some discussion of experiment accommodations was discussed in Section II, Environmental Control Systems, specific accommodations are reviewed in this section.

A. Thermal Control

The ECS is designed for maximum flexibility of experiment equipment with available thermal control. The rationale of the study has been to have all equipment accommodated by the electrical power subsystem also accommodated with heat rejection capability. The resources planned for the following capability and characteristics for experiments:

Thermal Control Resource Available	Allowable Experiment Thermal Loads	
	Module	Pallet
Maximum Heat Rejection (Average per Orbit)	4 to 5 kW	1 kW
Air Cooling		
- Cabin Circuit 21.1 ± 5.6° C (70 ± 10°F)	1 kW	N/A
- Racks 23.9 to 40.6°C (75 to 105°F)	3 to 4 kW	
Cold Plates 7.2 to 30° C (45 to 86° F)	4 to 5 kW	1 kW

The cabin thermal design is oriented toward primarily air cooling of equipment rather than cold plates. If requirements are identified, cold plates can be integrated into the cabin but the total heat rejection available to experiments (air cooled plus cold plates) is 4 to 5 kW. The latest experiment resource allocation studies indicate experiment power will be reduced to 3.4 kW_e average and the subsystem power is 3.6 average. Therefore, the total heat rejection capability of the cabin is still adequate (7 kW) but the split in available resources for subsystems and experiments is about equal. Further work is needed to define the freon flow arrangement to the pallet and tradeoff a pallet interface heat exchanger between an independent pallet loop and the cabin water loop. In this regard, it appears that a single fluid loop between the cabin and radiator would greatly enhance system simplicity and flexibility. It is anticipated that much of the equipment on the pallet can be passively thermally controlled. Passive thermal control consists of insulation, proper optical coatings, and heaters. Once again, final design must await more detailed experiment definition.

Experimenters (lab or pallet) must provide their own cooling system for components that require temperatures below that provided by the radiator (40°F). The thermal control system for the pallet is thought to be somewhat analagoric to that used on the Apollo Telescope Mount (ATM) rack of the Skylab program. The components mounted on the rack are thermally controlled largely by means of insulation and heaters. The layout of the ATM rack components is shown on Figure 70. The components are identified on Table 30. The insulation layout, heat locations and radiation windows which provide controlled heat shorts in the multilayer insulation are shown on Figure 71.

The ATM layout will be nothing like the pallet layout of components nor will the type of components be the same, however, the thermal control design approach may be quite similar.

B. Weight Chargeable Consumables

The Shuttle orbiter has ECS provisions for 28-mandays with nothing charged to payloads and the Sortie Lab has 21-mandays for consumables (O_2, N_2, LiOH). Any provisions above these are charged to experiment weights.

C. Contamination

Several accommodations are planned for various modes of contamination that affect experiment operation. Some experiment disciplines may require high cleanliness levels in the pressurized module, some no overboard dumping of waste products such as fuel cell water or condensate, and some may require wide view angles for sensors mounted on the pallet.

1. Cabin Cleanliness Level. The design requirement to maintain a 100,000 class* cabin cleanliness level imposes a considerable penalty on ventilation system design as indicated in Table 31. The baseline design utilizes filtration in the cabin ventilation system to maintain a maximum particle size of ≈ 75 micron which does not satisfy the 100,000 class requirements. Tighter

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*Maximum of 100,000 airborne particles/$ft^3 \geq$ 0.5 micron and 700 particles/$ft^3 \geq$ 5 microns. Air change rate of 1 every 3 minutes.

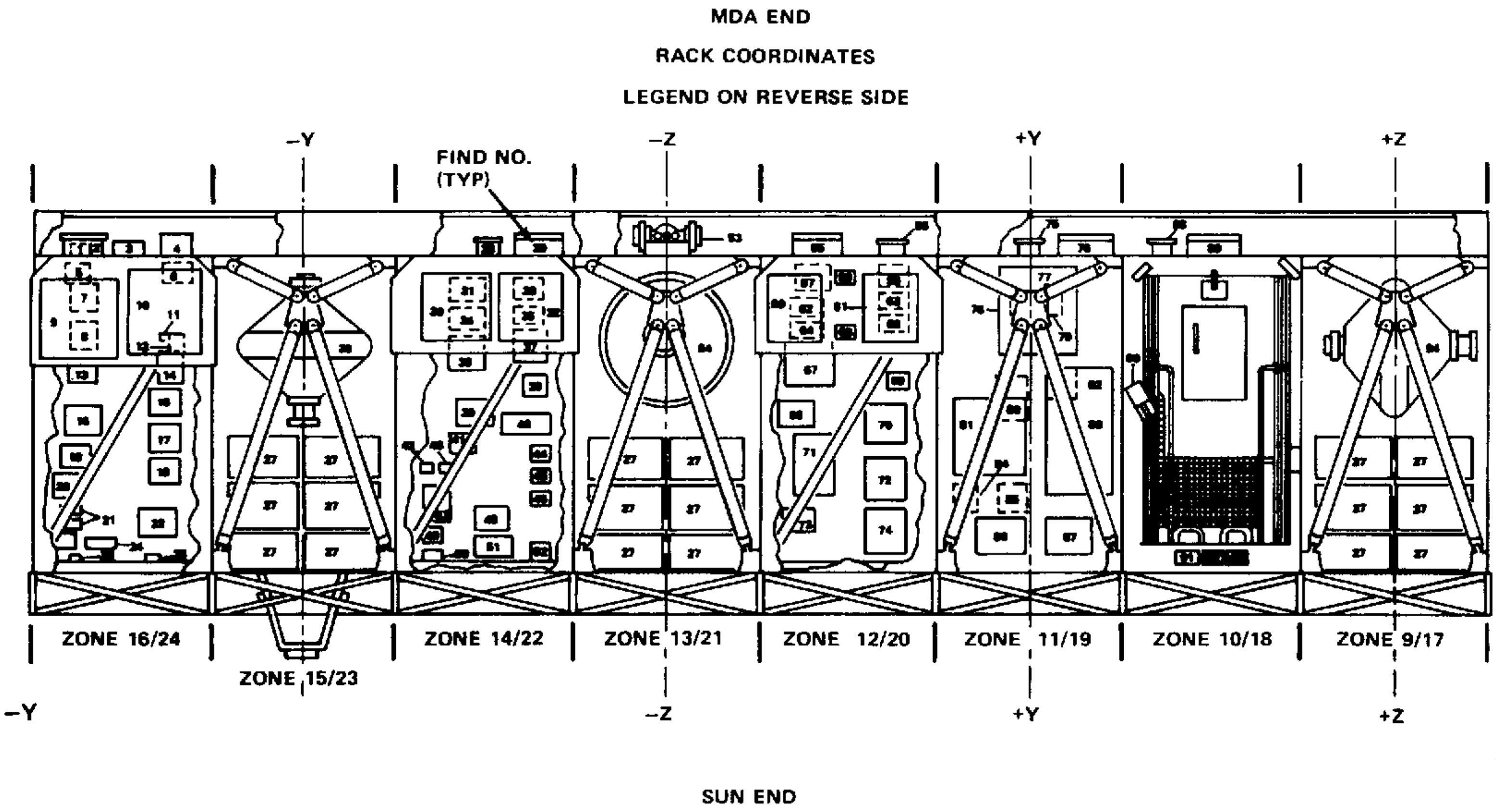


Figure 70. ATM rack exterior flat layout.

TABLE 30. RACK COMPONENT LAYOUT LEGEND

Find No.	Description
1	Command Receiver (Redundant)
2	Remote Analog Submultiplexer (#2)
3	Directional Coupler (COMM)
4	Command Decoder (Redundant)
5	Remote Analog Submultiplexer (#1)
6	Watt Hour Assembly
7	Signal Conditioning Rack (#2)
8	Signal Conditioning Rack (#3)
9	CMG Inverter Assy (#2)
10	Power Transfer Distributor
11	J-Box Assembly
12	Command Decoder
13	Signal Conditioning Rack (#1)
14	Remote Digital Multiplexer
15	Multiplexer Assembly (A2)
16	Multiplexer Assembly (A1)
17	PCM/DDAS Assembly (Primary)
18	Remote Digital Multiplexer
19	PCM/DDAS Assembly (Redundant)
20	Remote Digital Multiplexer
21	Two Channel RF Multicouplers
22	Measuring Distributor (#2)
23	Command Receiver
24	Directional Coupler (COMM)
25	Coaxial Switch (Flight)
26	Control Moment Gyro (#1)
27	Charger/Battery/Regulator Module
28	ATM Rate Gyro Z-2 (Redundant)
29	Control Distributor (#1)
30	CMG Inverter Assy (#1)
31	Signal Conditioning Rack (#5)
32	CMG Inverter Assy (#3)
33	Remote Analog Submultiplexer (#3)
34	Signal Conditioning Rack (#4)
35	Remote Analog Submultiplexer (#4)
36	Multiplexer Assembly (BO)
37	Switch Selector MOD II (#4)
38	Remote Digital Multiplexer
39	Multiplexer Assembly (A3)
40	Amplifier and Switch Assembly

TABLE 30. (Continued)

Find No.	Description
41	Signal Conditioning Rack (#6)
42	Master Measuring Voltage Supply
43	Master Measuring Voltage Supply (Redundant)
44	NRL "A" Power Supply
45	NRL "B" Power Supply
46	HAO Power Supply
47	ASAP Memory Assembly
48	Data Storage Interface Unit
49	Tape Recorder (Primary)
50	Tape Recorder (Redundant)
51	Redundant Converter DC to DC
52	Fine Sun Sensor Signal Conditioner
53	Star Tracker Opto-Mech Assy
54	Control Moment Gyro (#3)
55	Main Electronics Assembly (S-054)
56	Five (5) Micron Filter
57	Signal Conditioning Rack (#8)
58	Memory Load Unit
59	Switch Selector MOD II (#1)
60	Digital Computer
61	Digital Computer (Redundant)
62	Signal Conditioning Rack (#9)
63	Switch Selector MOD II (#3)
64	Signal Conditioning Rack (#7)
65	Memory Load Unit Tape Recorder
66	Switch Selector MOD II (#2)
67	Control Distributor (#3)
68	Remote Analog Submultiplexer (#6)
69	Transient Filter (NRL-A) Transient Filter (NRL-B)
70	Control Distributor (#5)
71	Star Tracker Electronic Assy
72	Control Distributor (#2)
73	Remote Analog Submultiplexer (#5)
74	Measuring Distributor (#1)
75	ATM Rate Gyro Z-3
76	Control Distributor (#6)
77	C and D Logic Distributor
78	ATM Rate Gyro Y-2
79	ATM Rate Gyro Y-1

TABLE 30. (Concluded)

Find No.	Description
80	ATM Rate Gyro Y-3
81	Workshop Computer Interface Unit
82	ATM Rate Gyro X-3
83	EXP Pointing Electronic Assembly
84	ATM Rate Gyro X-1
85	ATM Rate Gyro X-2
86	Main Power Distributor
87	Auxiliary Power Distributor
88	ATM Rate Gyro Z-1
89	Measuring Distributor (#3)
90	EVA Roll Control Panel
91	Telemetry Transmitter (#2)
92	VSWR Measuring Assembly
93	Telemetry Transmitter (#1)
94	Control Moment Gyro (#2)

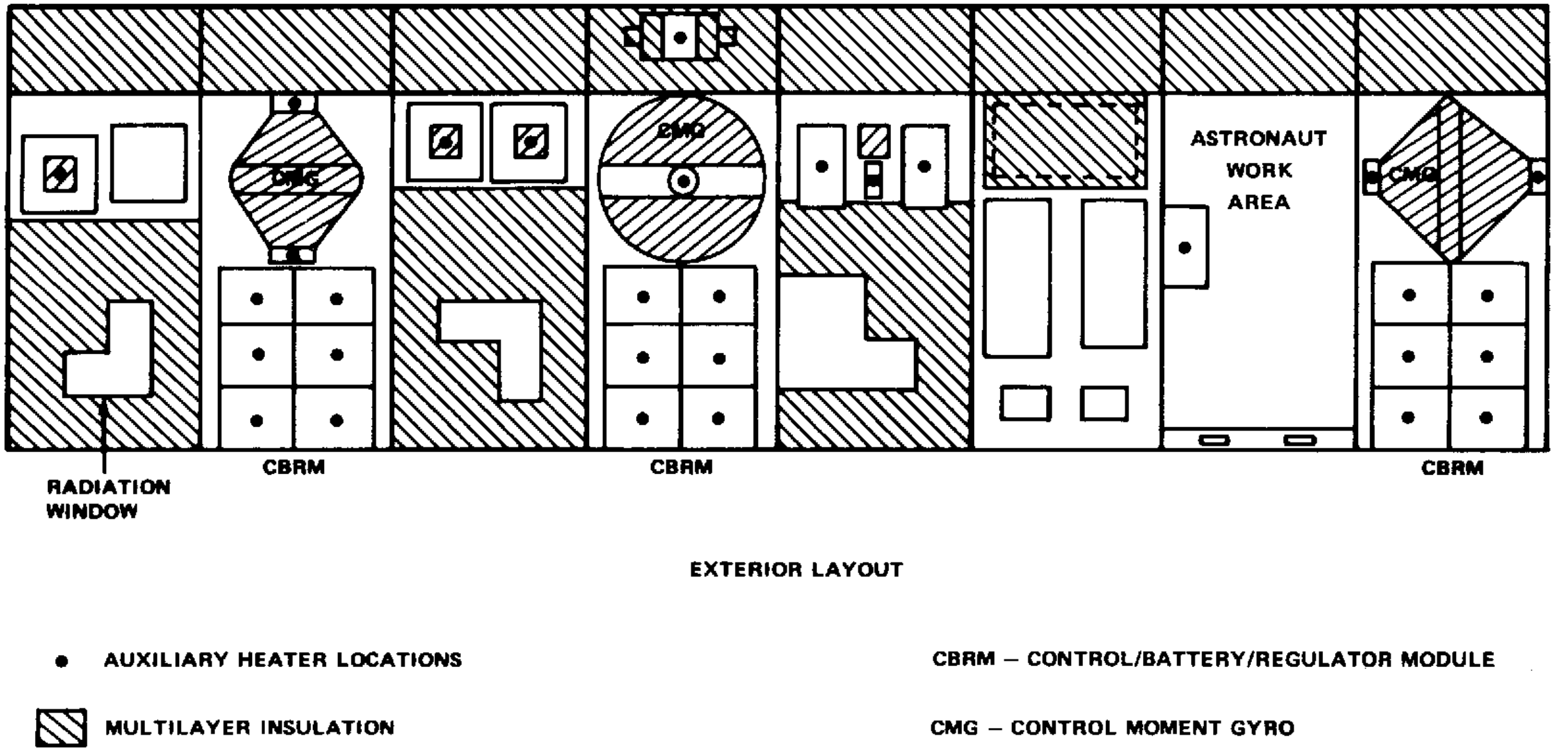


Figure 71. Rack multilayer insulation and auxiliary heater locations.

TABLE 31. DESIGN IMPACT MEETING 100,000 CLASS CLEANLINESS LEVEL

	ECS DRM*	100,000 Class Design
Total Air Flow, m^3/min (CFM)	16.9 to 18.4 (595 to 650)	20.4 (720)
Vent. Fan Flow, m^3/min (CFM)**	15.3 (540)	18.8 (665)
Sys. Resistance, Δ P, cm (inch) of H_2O	1.842 (0.725)	3.683 (1.45)
Fan Input Power (Watts)	120	310 (min)
Fan Noise (overall sound power, dB)****	89.5	96.0
Air Change Rate***	Once per 3.3 min to 3.7 min	Once per 3 min
Filter Area, m^2 (ft^2)	0.2 (2)	0.4 (4); 0.3 m (1 ft) deep
Particle Retention (μm)	74	0.3; (99.7% EFF.)
Special Reqts.	—	HEPA Filter must be installed with a good sealing design. This implies that supply and return ducts are required, ventilation system design flexibility is restricted.

* Considered cabin air loop only. Experiment air cooling loop is isolated and independent of cabin loop.

** Study performed on the vent. fan. Additional 1.6 to 3.1 m^3/min (55 to 110 CFM) that compromises the total air flow comes from the air processing system.

*** Based on an assumed effective volume = 61.5 m^3 (2,170 ft^3)

**** Estimated sound power level. Fan should be within ± 4 dB of this value.

filtration is utilized for air flow through the condensate collection/CO_2 removal system where gas flow rates are much lower with a resulting low penalty. The primary adverse effects of tight filtration in the cabin ventilation system are increased power, increased fan noise levels with larger noise suppression devices and possibility of increased filter maintenance. Table 32 and Figure 72 list potential candidate filters and identify the baseline filter.

Skylab data and experiment success raise the question of need for maintaining the pressurized cabin area at a 100,000 class level. Payload criteria needs to be reexamined and this requirement deleted if possible. The cleanliness level should be specified by airborne, particulate filtration level and surface cleanliness of components prior to module installation. For local areas of high cleanliness, (if identified) workbench areas could be provided as ancillary experiment support equipment.

A review of Skylab filtration capability and the resulting contamination levels was made. Table 33 shows a summary of the various filters used in the Skylab ventilation system (Figure 73). Additional contamination control was achieved by stringent material control and cleaning all hardware prior to assembly by wiping surfaces until visibly clean (No particles exceeding 50 microns).

The cleanliness levels being maintained appear adequate and do not present a significant volume/power penalty or house keeping chore. The crew has reported that surfaces other than filters remain very clean. Objects dropped in the cabin atmosphere are carried by air flow back up to filters where they collect and can be removed. Cabin airborne contamination levels were measured by experiment T-003. Preliminary data are presented in Table 34.

One fault, however, in the Skylab system was inadequate filtration of cabin gas flow across the cabin heat exchangers requiring heat exchanger cleaning as a regular house cleaning chore.

2. Trace Contaminants. All payloads with pressurized modules will be affected by trace contaminants impacting crew safety. The accommodations for controlling trace contaminants from experiment equipment has been discussed under Sections IV and V. Design constraints on experiment payloads are to be determined.

3. Radiator Blockage. Preliminary assessment of the blockage of a deployed radiator on the viewing of pallet-mounted sensors has been completed. The investigation identified the view factors of various pallet floor segments to

TABLE 32. AIR FILTERS CONSIDERED FOR SORTIE LAB APPLICATION

I HEPA Filters (Cambridge Filter Co.)
Efficiency: 99.7% at 0.3μ smoke particles (DOP)
$\Delta P = 1.5$ cm (0.6 in) H_2O at 17.0 m^3/min (600 CFM)
0.6 m × 0.6 m × 0.3 m (2 ft × 2 ft × 1 ft)

II High Performance Disposable Filters (Farr Co.)
HP-100, Efficiency = 75% at $0-5\mu$, 98% at $5-10\mu$
dust (Gravimetric Test Method)
$\Delta P = 0.64$ cm (0.25 in.) H_2O at 17.0 m^3/min (600 CFM)
0.5 m × 0.5 m × 0.2 m (20 in. × 20 in. × 8 in.)

III High Efficiency Disposible Filter (Farr Co.)
J - 12 (Model 3030)
Efficiency = 98% at $5-10\mu$ dust,
36% for NBS atmospheric
$\Delta P = 0.25$ cm (0.10 in.) H_2O at 16.3 m^3/min (575 CFM)
0.3 m × 0.6 m × 0.05 m (12 in. × 24 in. × 1 7/8 in.)

IV Square Mesh Screen (Michigan Wire Cloth)
For $\Delta P = 0.25$ cm (0.1 in.) H_2O at 15.3 m^3/min (540 CFM,)

Mesh	150	200	250	325	400
Micron Retention	104	74	61	44	38
Area Req'd $m^2(in.)^2$	0.057 88.8	0.068 105.3	0.073 118.4	0.108 167.2	0.097 149.6
		Baseline			

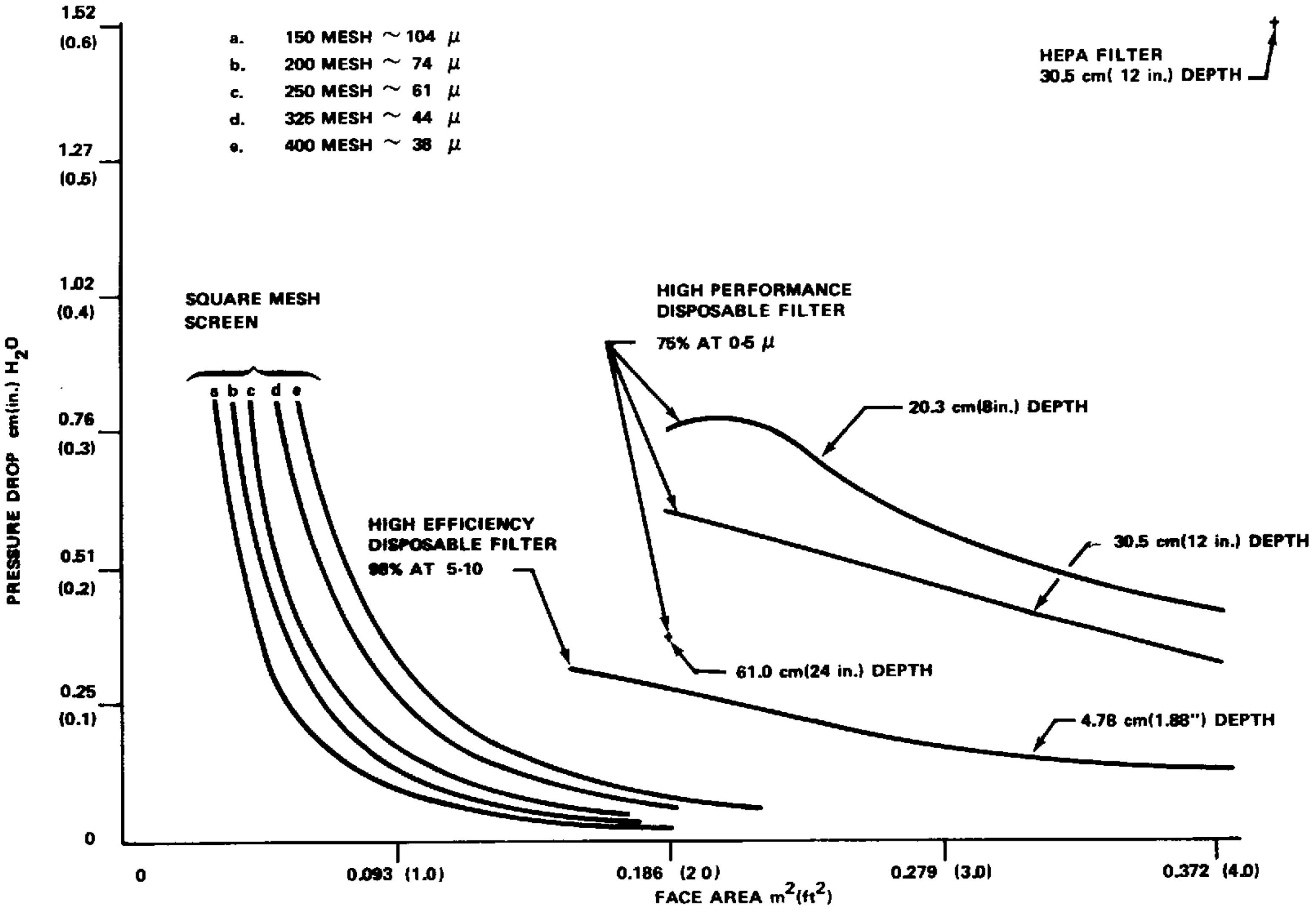


Figure 72. Air filter performance characteristics at a flow rate of 17.0 m^3/min (600 cfm).

TABLE 33. SKYLAB FILTER DESIGN

Item	Location	Filter Design	Air Flow Rate
1. ECS Mixing Chamber Assembly	Workshop	60 × 60 mesh wire cloth filter backed up by a 4 × 4 mesh screen. Filters particles of 231 micron size and greater. Surface area ≈ 0.42 m^2 (654 sq. in.)	56.6 to 68.0 m^3/min ≈ (2000 to 2400 cfm)
2. WMS Fan Odor Filter Assembly	Workshop	Assembly contains 4 types of filters Inlet debris screens, 10 mesh and 40 mesh respectively; upstream filters (inboard and outboard), 60 mesh; downstream filters (inboard and outboard), 11 micron nominal and 25 micron absolute particle retention; and an outlet screen of 6 mesh. Respective surface areas for the above filter are: 10 mesh = 0.10 m^2 (155 sq in.) and 40 mesh ≤ 0.11 m^2 (≤ 170 sq in.); inboard = 0.13 m^2 (200 sq in.) and outboard = 0.19 m^2 (300 sq in.); inboard = 0.14 m^2 (214 sq in.) and outboard = 1.13 m^2 (1750 sq in.); and screen = 0.02 m^2 (39 sq in.).	3.4 m^3/min (120 cfm)
3. Diffuser Screen	Under Workshop floor	6 × 6 wire cloth mesh. Surface area ≈ 0.27 m^2 (424 sq in.)	19.8 to 22.7 m^3/min ≈ (700 to 800 cfm)
4. Portable Fan Assembly Screen	Workshop	6 × 6 mesh. Surface area < 0.013 m^2 (20 sq in.)	4.2 m^3/min ≈ (150 cfm)
5. MDA Cabin Fan Assembly Screen	MDA	6 × 6 mesh. Surface area < 0.013 m^2 (20 sq in.)	4.2 m^3/min ≈ (150 cfm)
6. Cabin Heat Exchanger Fans	Airlock	6 × 6 mesh. Surface area ≈ 0.013 m^2 (20 sq in.) (STS) and < 0.09 m^2 (140 sq in.) (OWS ECS Bay)	4.8 m^3/min ≈ (170 cfm)
7. Mole Sieve Debris Trap	Airlock	Filters 40 micron particles. Surface area ≈ 0.02 m^2 (32 sq in.)	0.93 m^3/min ≈ (33 cfm)

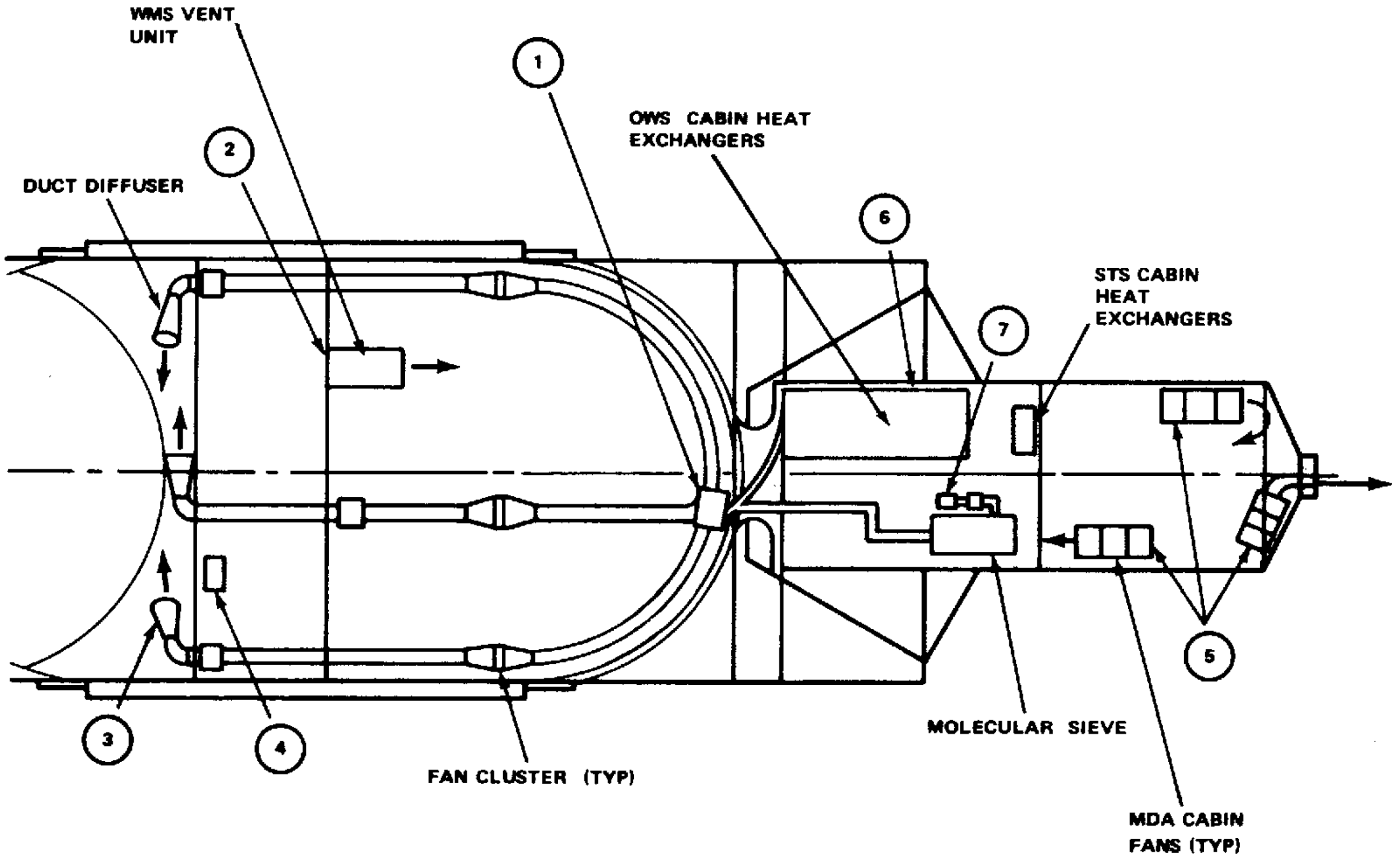


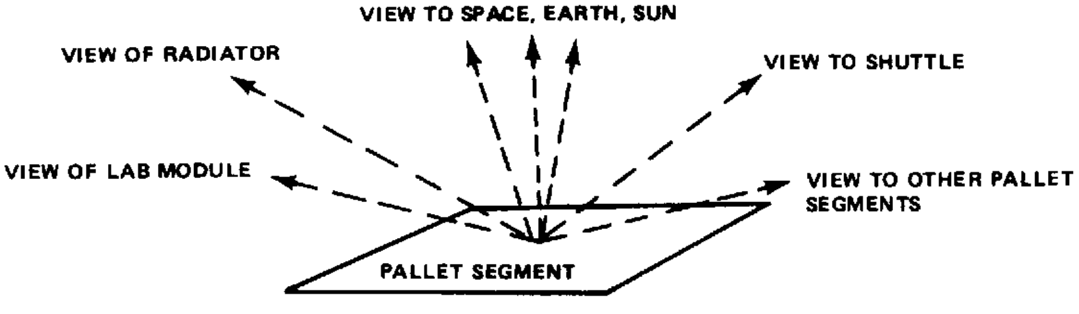
Figure 73. Skylab screen and filter locations.

TABLE 34. SKYLAB EXPERIMENT T-003 AEROSOL SAMPLING DATA

	Particles Per Cubic Foot		
Particle Size / Skylab Mission Day	1 to 3μ	3 to 9μ	9 to 100μ
4 to 9			
Max	16,250	850	500
Min	1,000	0	0
Ave	7,250	350	250
10 to 15			
Max	14,050	1,600	450
Min	1,500	50	100
Ave	5,550	450	200
15 to 20			
Max	12,300	800	350
Min	500	0	0
Ave	4,750	200	100
20 to 25			
Max	6,200	1,250	450
Min	1,500	0	0
Ave	3,500	300	100
25 to 28			
Max	4,650	550	350
Min	2,000	0	0
Ave	3,450	200	100

Data not shown here, but during filter cleaning contamination levels were up by a factor of 3 to 4.

the radiator and the percentage of blockage the radiator contributed to a sensor view angle. An example of what a typical pallet segment "sees" is given below.

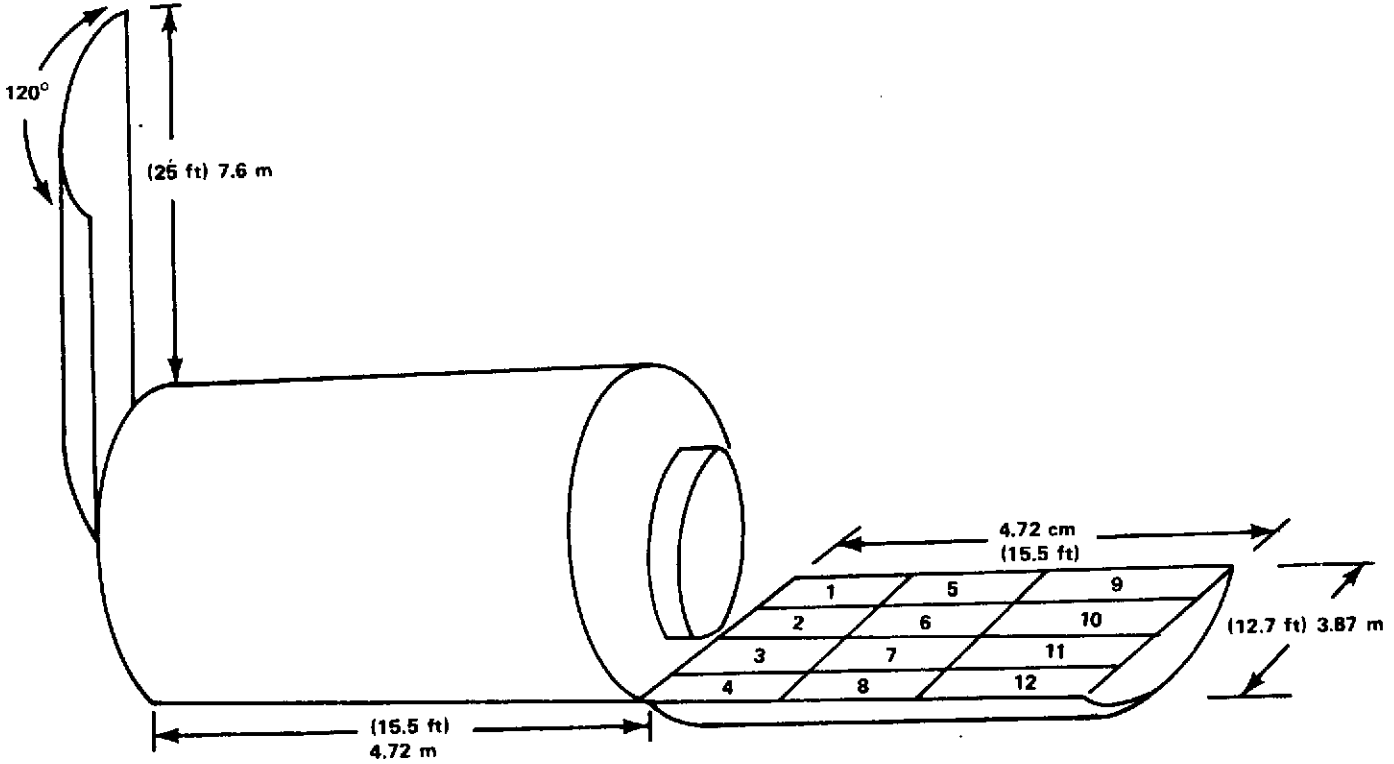


PALLET SEGMENT VIEW FACTORS = 1.0

A view factor (F) of a pallet segment to space equals 0.65 means that other bodies (such as Shuttle, lab, etc.) obstruct 35 percent of the 180 deg view angle to space. Stated in another way, the pallet "sees" or has a view to structural elements because of its location in the Shuttle payload bay area. If the "view angle" requirement is reduced from ± 90 deg to the normal (180 deg viewing) to ± 45 deg, the view to structural elements is reduced. The 180 deg viewing presents "worst case" blockage effects. An illustration of the analytical model utilized in this study is depicted in Figure 74. The configuration consists of a non-deployed lab/pallet in the Shuttle payload bay area with a deployed radiator, 7.6 m (25 feet) in length.

The results of the study are presented in Figure 74 and show that the total radiator blockage to any one segment on the pallet is less than 1 percent. The view to other structural elements such as the pressurized lab, Shuttle, and other pallet elements is much larger (15 percent to 50 percent blockage). If the view factors of the pallet are averaged over the entire floor, the average view factor of the pallet floor to the radiator is 0.0335 (3.35 percent of the total view angle) and to space is 0.591 (59.1 percent of the total view angle). Therefore, it is concluded that for sensors mounted on the plane of the pallet floor, little blockage of the view angle is expected from the deployed radiator. It should be noted that efforts are continuing to simplify the deployed radiator interfaces with the experiment integration requirements. Additional trade studies to be performed in this area of experiment integration are listed below:

a. Radiator length requirements. The present radiator design is based on a white paint coating, 3σ environmental heat fluxes, and a maximum heat rejection of 8.5 kW. The impact of designing the radiator for a silver/teflon coating, nominal heat fluxes, and a maximum heat rejection of 8.5, 6 and 3 kW will be investigated.



PALLET SEGMENT	VIEW-FACTOR TO RADIATOR	VIEW-FACTOR TO SPACE
1	0	0.502
2	0	0.604
3	0	0.604
4	0	0.502
5	0.0035	0.652
6	0.0003	0.772
7	0.0003	0.772
8	0.0035	0.652
9	0.0091	0.676
10	0.0072	0.841
11	0.0072	0.841
12	0.0091	0.676

Figure 74. Geometric view-factor of selected pallet floor segments to a deployed radiator and to space.

b. Shuttle heat rejection support. The present radiator design is autonomous from the Shuttle. The impact of utilizing Shuttle provided heat rejection (3, 6, 8.5 kW) will be investigated. The major trades goals will be elimination for a deployed radiator requirement, reduction in ECS weight allocations, and simple Shuttle/Lab interfaces.

c. Experiment sensor viewing requirements. Attention will be directed to experiment sensors having an interface with a deployed radiator concept. Parameters investigated will be experiment sensor location, view requirements, Shuttle attitudes and orbital inclination to solar vector (β angle). This study will include equipment used on the pallet and the scientific airlock.

4. Water Storage. The water management system provides for the collection, storage and supply of the fuel cell generated water.

Two Skylab bottles of 552.9 kg (1219 lbs) water capacity to store fuel cell water were originally planned for Sortie Lab to avoid contaminating the Lab's external environment. However, review of water generation rates of various experiment disciplines showed the experiments disciplines, with the exception of space processing, did not require more than one storage bottle, (Figure 75). Since this payload does not require an uncontaminated external environment, any water generated from that program that is beyond the capability of one water bottle can be utilized in the sublimator. As a result of this review, the baseline design now has only one Skylab water bottle for the storage of fuel cell water. The storage tank will contain a predetermined volume of water loaded during prelaunch operations to assure supply to the sublimator and/or experiments above that available from fuel cell operation.

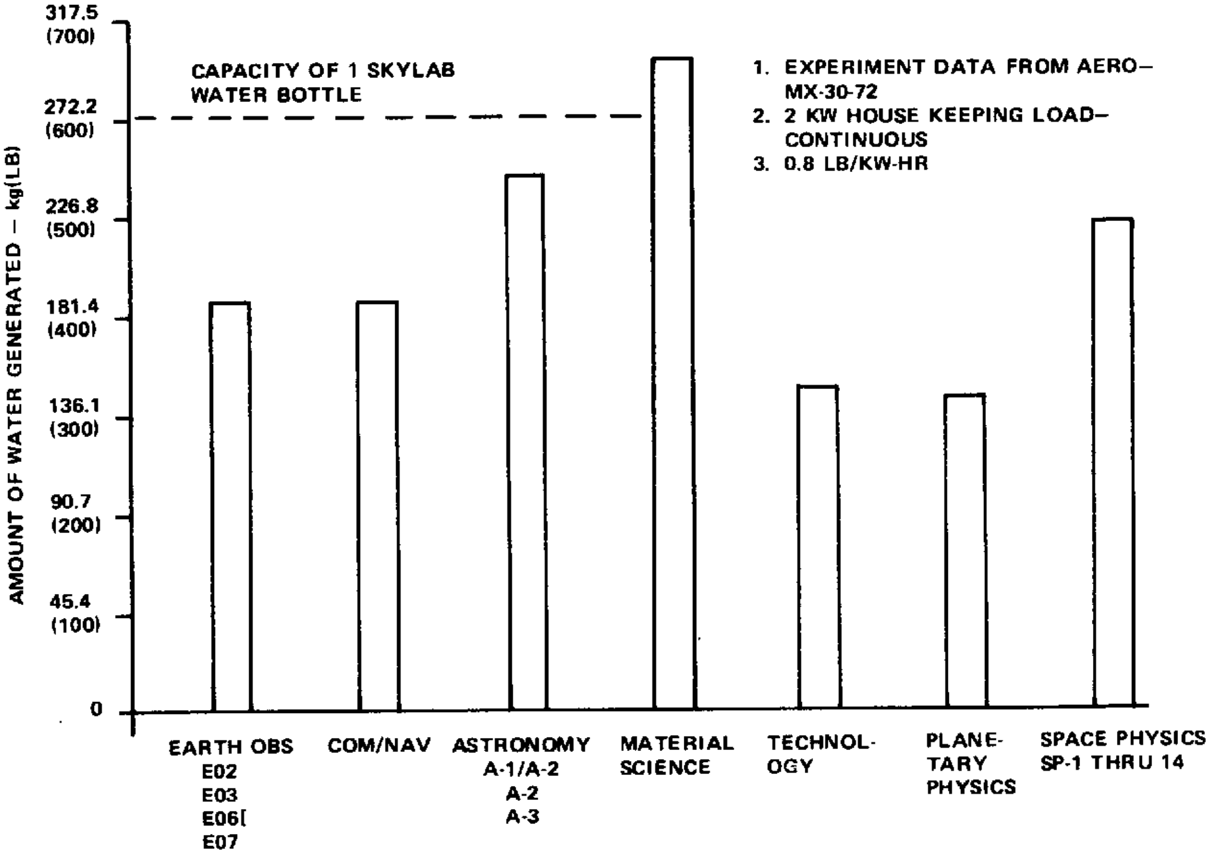


Figure 75. Estimated amount of fuel cell generated water for 7-day Sortie Lab missions.

APPENDIX

SORTIE LAB ECS DESIGN DESCRIPTION FOR REDUNDANCY, CONTROL LOGIC, INSTRUMENTATION, AND SHUTTLE MECHANICAL INTERFACE

SECTION I. REDUNDANCY RATIONALE FOR SORTIE LAB ECS (PHASE B BASELINE)

A. Basic Redundancy Guidelines

1. All systems are designed for fail safe in crew safety and structural protection. (High pressure GN_2 tanks achieve this status by adequate safety factor — no flack shield provided.)

2. A component is designated Criticality I if a failure could jeopardize safety of the crew or the vehicle. A component is designated as Criticality II if it can cause loss of mission. A component is designated as Criticality III if its loss would cause a reduction in a system capacity, control band tolerance, or degradation of some ECS function that could be marginally tolerated by the crew and equipment.

3. A minimum of two Criticality II components must fail prior to jeopardizing crew safety, forcing the crew to leave the lab area, or causing permanent unrepairable loss of a critical ECS subsystem.

4. A single Criticality III component failure will be permitted (if crew safety is not jeopardized, the crew is not forced from the lab area, or if unacceptable damage and/or unacceptable reduction in a subsystem performance capacity is not suffered).

5. Redundant coolant loops will not be utilized. Excessive weight, cost, and control complexity penalties would result if redundant fluid systems were used. Gas supply systems will be orificed or designed to limit gas flow rates into the Sortie Lab for structural protection should line failures internal to the lab occur. Fluid supply systems with a source consisting of two or more storage containers shall be protected from a total system loss resulting from loss of a single storage vessel.

B. Critical Subsystems Designation

1. The O_2/N_2 atmosphere and H_2 supply and control subsystems are judged to be designated under the category of Criticality I. Component and control redundancy has been incorporated for these subsystems.

2. The following subsystems are judged to be of Criticality II and have component and control redundancy or spares for the most probable failure mode of several components: Radiator coolant loop, Lab coolant loop, cabin atmosphere revitalization system (i.e., humidity and CO_2 removel), cabin ventilation system, and equipment ventilation system.

3. The following subsystems are judged to be of Criticality III and have no component or control redundancy for any component: Water stowage/supply and control system, and the sublimator water supply and control system.

C. Criteria Leading To a Subsystem Component Being Designated as Criticality I.

The PPO_2 sensor/amplifier-controller, the atmosphere controller, the O_2 feed system, the N_2 feed system, and lab vent system are all redundant because loss of control will adversely affect crew safety.

The O_2, H_2, and N_2 tanks are Criticality I failure items. There is a very remote possibility of tank rupture. However, each high pressure and cryogenic tank has a pressure relief valve. The cryogenic storage tanks have a pressure relief valve with a backup burst disk in the tank for the relief of any excessive tank pressure. The heater controller for each cryogenic tank may be turned "Off" from one of two sources (directed by caution/warning signal). Each heater winding has over temperature cutout switches in the power line, and each heater resistance element is temperature limited (i.e., its resistance increases with rising element temperatures and the elements draw less current to produce less heat input to the tank as the tank heats up).

D. Criteria Leading To a Subsystem Component Being Designated as Criticality II

1. All fluid pumping components are designated to be criticality II failure items. All fluid pumps can accumulate wear and fail during a mission. Therefore, all liquid pumping components (Freon and water coolant pumps) are parallel-redundant with the redundant pump placed parallel to the primary pump in the applicable loop to allow changeover from primary to secondary w/o fluid spillage. All fans are replaceable-redundant in flight by spares carried onboard. Fans are replaceable-redundant because of weight, and space, penalties that would exist if each fan had a redundant fan installed parallel to the primary fan.

2. Electric solenoid valves which must cycle more than one complete cycle (e.g. open to close to open is one complete cycle) during a mission will be redundant for the most undesirable failure mode which could result in a system criticality II failure. An example is the solenoid valves that control the vacuum condensate collection system. Electrically operated valves which will not normally cycle during midflight operations or that cycle only in terminal mission activities are minor failures and will have no redundancy. An example is the water tank dump valve.

3. Temperature mixing valves (TMV) and flow controlling solenoid valves (FCSV) are redundant within their respective applications because they can accumulate wear and fail during a mission to produce a criticality II loss. The flowpath selector valves (FPSV) which direct the coolant flow to the applicable TMV or FCSV are not redundant because the FPSV will cycle only once during a flight and only then if a control valve fails.

4. The condensate collection system is redundant in controls and components because loss of condensate control is a criticality II failure. This will allow uncontrolled increases in lab moisture (humidity) content which could cause moisture damage to equipment within the lab and/or possible crew evacuation.

5. The cabin temperature control system and components are redundant or spares provided because loss of the temperature control system is a critical II loss of lab thermal control.

E. Criteria Leading to Subsystem Components Being Designated as Criticality III

1. The sublimator controller and related water supply components are not redundant because the sublimator is a supplementary heat sink only and does not constitute a criticality II failure.

2. The water controller and related water stowage/supply components are not redundant because they will function only during terminal mission activities if operated at all. The only failure possible within the subsystem is internal leakage damage to the bellows of the water stowage tanks when water usage exceeds water production from the fuel cells. This water flow balance is contrary to the mission normal (where water production exceeds water consumption) and is not a criticality II failure which will allow most mission objectives to be met.

3. The flow directing valves to each LiOH canister are manual and need not be redundant.

F. Contingency Operation

1. Cabin Atmosphere Revitalization — Operation of various combinations of one fan/one condensing HX or one to three LiOH canisters with subsequent off design moisture and CO_2 control conditions is possible. Also support might be furnished from the orbiter.

2. Radiator Coolant Loop — With this loop shut down, run Sortie fuel cell at low capacity (less than 2 Kw) pick up additional power from the orbiter. Operate Sortie sublimator for heat rejection.

3. Equipment/Cabin Ventilation Subsystem — With either one of the main two air circulating systems in a nonoperative condition, certain low level Sortie activity might be continued. Also support might be furnished from the orbiter.

4. Water Management System — If water stowage is impossible, then water may be dumped overboard continuously.

SECTION II. COMPONENT JUSTIFICATION/LOCATION AND CONTROL LOGIC FOR SORTIE LAB ECS (PHASE B BASELINE)

A. Component Rationale/Location for 20M42717 Rev D

1. General Statements

a. Redundancy: The Lab ECS is baselined to fail safe. Upon this assumption the following guidelines were used to justify redundant components.

(1) Liquid circulating pumps will be redundant in each coolant loop.

(2) Air circulation fans are not redundant but will be accessible for replacement inflight.

(3) Electrically operated valves which will cycle more than one complete cycle (e.g. open to close to open) during the mission and which could be a single point failure for a subsystem will be redundant for the most undesirable failure mode. Electrically operated valves which will not normally cycle during normal midflight operations or which cycle only in terminal mission activities will have no redundancy (e.g. all solenoid valves handling condensate water are redundant since they cycle multiple times during flight, the sublimator water solenoid valve is not redundant since the sublimator is a contingency and supplementary heat rejection sink).

b. In so far as possible the system component and control configuration (Fig. A-1) will require minimum housekeeping in-flight and minimize turn around time on the ground for reuse. Fluid sample and pressure access points will be placed at critical locations in fluid systems to facilitate refurbishment and checkout activities.

c. The normal (unenergized) positions of electrically operated valves will be selected to minimize the time duration the valve requires power unless dictated otherwise by paragraph A. 1. a above.

d. Pumps — All liquid pumps are placed downstream of all thermally conditioned equipment and immediately upstream of heat rejection components so that pump heat will have minimum effect on the coolant supply to thermally conditioned equipment.

FOLDOUT FRAME 1

FOLDOUT FRAME 2

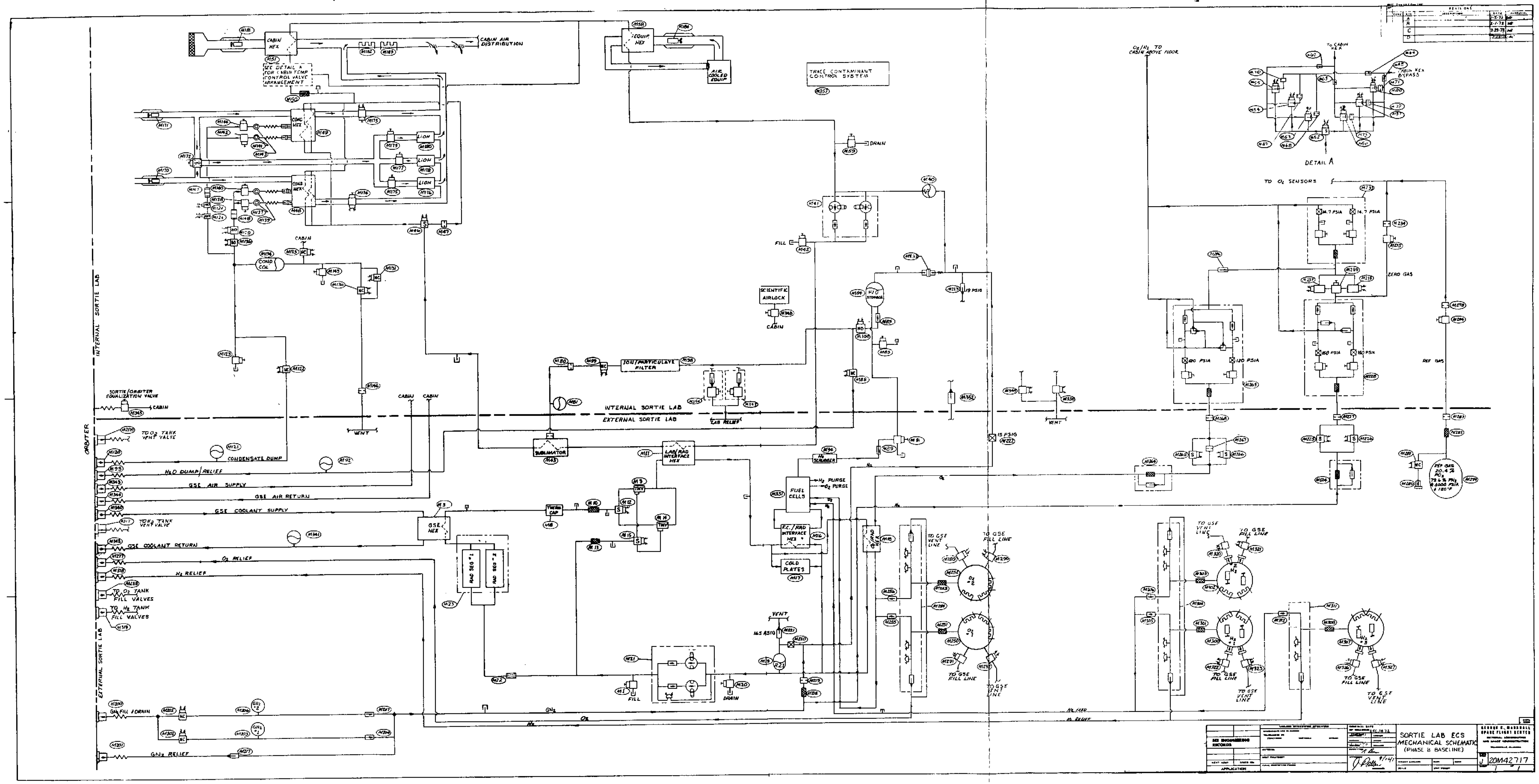


Figure A-1. Sortie Lab ECS mechanical schematic.

e. Pump check valves and fill/drain valves — Pump check valves prevent back flow through an inactive pump and permit the placement of system fill and drain valves at pump inlet and outlet for flow passage filling and draining. Also purging and flushing of the entire coolant system (with exception of the pumps) is possible with the fill and drain valves in this location without the penalty of adding other components.

f. Coolant accumulators — Coolant accumulators are placed at respective pump suction and pressurized by regulated GN_2 to provide proper NPSH to pump suction over entire coolant temperature and viscosity range. The accumulator also accommodates thermal volume changes and replaces system leakage.

g. All air moving fans shall be accessible for inflight replacement.

h. No liquids, high pressure gases, or explosive gas mixtures shall be dumped or vented into the Shuttle cargo bay. All these fluids shall be routed through the Orbiter for external dumping via Q.D. lines interfacing to the Orbiter. Self sealing Q.D. connections shall be used to facilitate removal of Sortie lab from Orbiter without spillage of fluids.

2. Thermal Control Subsystems

a. Radiator Loop

(1). All radiator loop components are located external to Sortie Lab to minimize possibility of refrigerant leakage internal to the lab (free refrigerant when exposed to a catalist or flame generates phosgene gas, an accumulative poison), and to keep cold radiator fluid lines external to the lab to eliminate condensation problems on refrigerant lines and heat exchanger M11 (these items will always be below the cabin dewpoint).

(2). The schematic is shown for a deployed radiator system. The radiators are placed back-to-back and thermally isolated from each other.

(3). Refrigerant drier M22 is located upstream of the radiator inlet to minimize system ΔP. The GSE H_x M3 is located downstream of the radiators to permit prelaunch freezing of the thermal capacitor without cold coolant being passed through the radiator, which could produce undesirable condensation on the radiator surfaces. During mission refurbishment, when the lab is removed from the orbiter, the servicer loop of the GSE Hx is prevented from fluid spillage by selfsealing quick disconnects M340 and M342. The small accumulator M341, between the QD and Hex, accommodates normal thermal expansion of the servicer loop fluid after disconnection to prevent a high pressure buildup on the servicer side from destroying M3 (and possibly the radiator loop through leakage) as M3 warms up to the environment temperature. The accumulator contains a known volume air pocket confined within a pliable container to insure that the air will not be absorbed into the circulating servicer coolant during periods of high fluid pressure and cold temperatures, or an upside down position of M341 occurring during vehicle stacking procedures, launch, reentry, and landing. The quick disconnects are provided to (a) condition the lab independently of the orbiter during refurbishment and (b) facilitate removal of lab from the orbiter.

(4). The thermal capacitor M8 is located downstream of the GSE Hex/radiator heat rejection components and upstream of TMV valves M9 and M14 to permit preflight freezing of the capacitor by M3 and refreezing of M8 by radiators M5 and M6 after any orbital hot periods. Capacitor M8 will be frozen during prelaunch by controlling the refrigerant outlet temperature from M3 with a sensor located in the refrigerant fluid immediately upstream of M8 or by a sensor located in the GSE servicer loop return leg.

(5). The radiator temperature control components (filters M10 and M13, selector valves M12 and M15, and temperature mixing valves M9 and M14) are placed upstream of all heat sources and receive refrigerant within the proper temperature tolerances. Filter M10 and M13 protect TMV M9 and M14 from damage by any particles. Selector valves M12 and M15 select between M9 and M14 in case of TMV failures during flight. TMV M9 and M14 coupled with thermal capacitor M8 shall maintain outlet temperatures from 1.7 to 5.8°C (35°F to 42.5°F) with radiator outlet temperatures from -73 to 5.8°C (-100 to + 35°F) and TMV hot port inlet temperatures from 10 to 43°C (50 to 110°F). The narrow 4.2°C (7.5°F) allowable temperature variation on the outlet of TMV M9 and M14 is required to prevent freezing of the Sortie water coolant within Lab/rad Hx M11 in case Sortie water coolant pumps M41 are stopped and to insure the Sortie water coolant leaving M11 is always adequately cooled to maintain Sortie lab humidity control. TMV valves M9 and M14 are redundant per the redundancy statement of para. A.1.a.(3).

(6). Lab/Rad Hx M11 is the first heat source in the radiator loop because (a) M11 requires the coldest fluid source on the cold side with the closest temperature tolerance to insure the lab coolant leaving M11 is maintained within the proper temperature band, 2.8 to 6.9°C, 18.3°C peak

(37 to 44.5°F nominal, 65 F peak) and (b) because Fuel Cell/Radiator hx M16, the next largest heat source in the radiator loop, will operate satisfactorily over a wider temperature coolant return supplied to the fuel cell, from -28.9 to 48.9°C (from -20 to + 120°F). Hx M11 receives full coolant flow to maximize Hx effectiveness and to minimize the hx hot to cold side ΔT to insure proper dewpoint control of the Sortie lab air. A coolant bypass around M11 is not provided because (a) refrigerant system ΔP must be minimized and (b) the lab coolant entering M11 is expected to always be warmer than the hottest radiator outlet temperatures.

(7). The fuel cell/rad hx M16, O_2/Rad hx M18, and the pallet cold plates M17 are supplied by parallel circuits to minimize total system ΔP. The components are located downstream of the Lab/rad Hx M11 because they have less stringent refrigerant inlet temperatures then M11. O_2/rad Hx M18 is a heat sink to the radiator loop and is better placed in the warmer portion of the radiator loop. The parallel flow arrangement of these components is subject to more information becoming available on their required refrigerant flowrates. The flow arrangement of these components will be rearranged if required to meet refrigerant flow requirements. A potential candidate for receiving full refrigerant flow is fuel cell/radiator Hx M16 to remove the high waste heat rejection rate of the candidate fuel cells. The pallet cold plates M17 are cooled by the refrigerant loop instead of the Lab water loop to avoid freezing problems in the coldplates and minimize the heat load presented to Lab/rad Hx M11.

(8). The freon pump M21 is pressurized to the correct inlet pressure through freon accumulator M19, up to 114 N/cm^2 (165 psig) max, by regulator M220 in the GN_2 system. The accumulator is relieved by GN_2 relief valve M221 for pressures above 114 N/cm^2 (165 psig) which may be produced by cyclic freon thermal expansion (occurring each orbit), which compress the GN_2 in accumulator M19, or any leakage through the regulator seat causing pressure buildup in the accumulator.

b. Lab Water Coolant Loop

(1). The Sortie/radiator Hx M11 is the primary heat rejection component for the Sortie water coolant loop and is consequently located in the hottest portion of the loop to maximize utilization of heat rejection via the Sortie radiator loop during warm radiator conditions. This is done to minimize use of the supplementary heat sink (i.e. the sublimator). M11 is located external to the Sortie Lab.

(2). The sublimator M43 is located downstream of M11 and will be activated only when M11 is unable to maintain a coolant temperature at T4 that is less than the setpoint of the sublimator temperature controller. The sublimator is located external to the vehicle to eliminate a large area penetration of the Lab wall that would be required for the steam vent of an internally mounted sublimator.

(3). Condensing heat exchangers M48 and M49 are the first heat load on the lab coolant and are placed first to receive the coldest fluid for maximum condensing capacity. The condensing Hex will remove the latent heat load of the crew plus the water by-product of the LiOH CO_2 removal system. Units M48 and M49 each have two internal parallel coolant loops. M48 and M49 are connected for parallel water coolant flow. Only one condensing hex need be operative for a crew latent load of two men or less. Both units are operated for a crew in excess of two men.

(4). Selector valve M46 and flow control orifice M47 are used to bypass coolant around M48 and M49 when the condensing heat exchanger function is not needed or when the cabin dewpoint temperature drops excessively low. Orifice M47 insures the total system flow will not be affected when valve M46 bypasses the condensing heat exchangers.

(5). The combined coolant flow of M48 and M49 is 226 kg/hr (500 lb/hr), 113 kg/hr for each unit.

(6). Filter M50 removes migrating particles from the coolant to minimize the probability of particulate damage to solenoid valves M52, M53, M54, M55, M56, M57, and M60.

(7). Cabin Hx M51 is placed downstream of the condensing Hx because it does not require the coldest available fluid to satisfy cabin temperature requirements. Excess coolant not needed for cabin temperature control is bypassed around M51 by redundant valve clusters: M53, M54, M55, (primary) or M56, M57, M60 (secondary). Selector valve M52 is positioned by the cabin temperature controller to direct flow to the selected valve cluster block flow to the other valve cluster. Redundancy is applied to valve cluster M53, M54, and M55, and M56, M57, and M60 per the redundancy statement of para A. 1. a. (3). Failure positions of either valve cluster will be to full flow through M51. The valves of either cluster will provide four levels of coolant supply to M51 at 0. 0, 33 percent, 66 percent, and 100 percent of the total coolant flow. The percentage of coolant flow each solenoid valve sends to bypass or to M51 is controlled by orifices M68, M69, M70 in one valve cluster and M71, M72, M73 in the other valve cluster. Check valves M62, M64 or M63, M65, as applicable, prevent flow from the operating valve cluster from short circuiting through the nonoperating valve cluster if one of three control valves in the nonoperating cluster has failed in the energized position. Short circuiting of coolant flow through the failed valve could cause a reduction in the capacity of M51 during peak loads and an inability to stop all flow to M51 during very low loads.

(8). The thermal racks provide air cooling of electronic equipment and are the largest heat source in the lab. The thermal rack air temperature is always higher than the cabin air temperature. Therefore, the thermal rack equipment heat exchanger M58 is located downstream in the lab coolant loop from the cabin hx M51 because M51 requires colder fluid then M58 to maintain the cabin air temperature.

(9). The water coolant pump package M41 is pressurized on the inlet through water accumulator M40 by regulator M222 in the GN_2 system to 10.3 N/cm^2 (15 psig) and relieved by relief valve M223 at 13.1 N/cm^2 (19 psig) to the cabin.

3. Water Management System

(1). H_2O stowage tank M84 will store by-product water received from the fuel cell M351 via the hydrogen scrubber M94. Scrubber M94 is provisionally included in the fuel cell water discharge pending a decision on the type of fuel cell used. A gas scrubber for fuel product water is not an expected requirement, if the water is removed from the oxygen side of the fuel cell. By cell design, water taken from the oxygen side will contain a minimum of dissolved oxygen when it leaves the cell. However, water taken from the hydrogen side can, by cell design, contain considerable quantities of hydrogen gas dissolved in the water under saturated conditions. If the hydrogen gas is not removed from the product water the gas may precipitate out into tank M84, and reduce its effective water capacity.

(2). Handvalve M91 located downstream of the hydrogen scrubber allows preflight operation of the fuel cell without cell product water entering water stowage tank M84. Placement of the valve downstream of scrubber M94 allows for preflight performance verification of M94.

(3). Checkvalve M89 is provided to protect the fuel cell and hydrogen scrubber from damage or contamination resulting from backflow into these units occurring during GSE activities or Sortie Lab flight operations.

C3

(4). Tank access valve M83 is provided to fill tank M84 with a measured quantity of water during prelaunch for sublimator use. The same valves may be used to drain M84 after shuttle landing.

(5). Tank M84 and water pump accumulator M40 are all pressurized by GN_2 regulator M222 and relieved by relief valve M223 at 13.1 N/cm^2 (19 psig) to the Sortie cabin. The relief pressure of 13.1 N/cm^2 (19 psig) is established by the design inlet pressure of pump M41. The 10.3 N/cm^2 (15 psig) regulator setting insures adequate pressure for the NPSH requirements of pump M41 and water supply for sublimator usage during periods when water consumption exceeds fuel cell water production. The normal operating pressure of tanks M84, M86 and pump accumulator M40 will be 13.1 N/cm^2 (19 psig) above cabin since water inflow from the fuel cell will pressurize the GN_2 ullage of M84 causing relief valve M223 to relieve excess GN_2 to the cabin. M223 is relieved internal to the cabin instead of externally to prevent a 10.3 N/cm^2 (15 psi) change occurring at the outlet of M223 during ascent into orbit. The GN_2 supply to regulator M222 is flow limited for regulator failures by orifice M219 to prevent excessive cabin pressures.

(6). Valve M100 and QD M232 are provided to protect the bellows internal to tank M84 from seeing potentially destructive pressure differentials greater than 4.8 N/cm^2 (7 psid) when M84 is empty of water during flight or ground operations. QD M232 will be decoupled on the ground during GSE checkouts of sortie lab to isolate the bellows of tank M84 from the pressure differential exerted by regulator M222 during checkout of GN_2 systems. Valve M100 will be energized closed during flight by the water controller to protect the bellows of tanks M84, M86 from excessive ΔP when excessive use of water by the sublimator and/or water dumping activities causes the bellows of the tank to bottom out.

(7). Valve M88 is used to dump tank M84 prior to reentry or when the tank becomes over filled. When water stowage tank M84 is being dumped via valve M88, the water controller will close M88 at the end of the water dump. This will prevent the bellows of tank M84 from seeing a potentially destructive pressure differentials when the ΔP across the water tank bellows exceeds a preset differential.

(8). Accumulator M92 is provisionally included in the H_2O/dump relief line to prevent excessive water pressures from occurring between components M88 and M93 or any water flow control component located internal to the orbiter. The most probably time of high water pressures will be during reentry after tank M84 has been dumped. The accumulator contains a pliable bag with a known quantity of air sealed within the bag. The bag air volume is 1/15 or less than the volume of the accumulator at atmospheric pressure. This insures the bag will not be subjected to excessive internal pressures when the accumulator is exposed to vacuum.

(9). Handvalve M82 is used to fill tank M84 during prelaunch with a known quantity of water or drain the tank after landing.

(10). An ion/particulate filter M98 reduces any water contamination level to acceptable limits so that it can be used as sublimator evaporant. Particulate and salt accumulations in sublimator M43 will significantly reduce performance.

(11). Sublimator water evaporant inlet pressure must be maintained within nominal limits 0.7 to 4.8 N/cm^2 (1 to 7 psia) to prevent breakthrough. This range is relatively large and heat rejection rate is not significantly affected over that range, therefore, an expensive water regulator is not required. Inlet pressure is controlled by a combination of an accumulator M81, a line orifice M80, an orifice internal to the sublimator, solenoid valve M99 and control feedback from a pressure switch. Orifice M80 just downstream of the valve M99 limits the water flowrate to sublimator water accumulator M81 when the valve opens to prevent rapid cycling of the pressure switch and valve. The orifice at the sublimator inlet controls water flowrate into the sublimator. The sublimator water accumulator in conjunction with the pressure switch maintains the water pressure on the sublimator inlet orifice to a 1.7 N/cm^2 (2.5 psi) tolerance band. The sublimator inlet orifice limits water flowrate to the sublimator during sublimator fill and breakthrough accidents. The sublimator water accumulator M81 has a flexible plastic bag with a known quantity of air sealed within the bag. The volume of air in the bag at atmospheric pressure is 1/15 or less than the volume of the accumulator. During ascent into orbit the bag will expand to fill the entire volume of M81 with a final internal bag pressure of 0.7 N/cm^2 (1.0 psia) or less. During operation of the sublimator, water enters M81 at pressures above 0.7 n/cm^2 (1.0 psia) causing collapse of the bag to an equalization pressure, thus the volume of air in the bag changes with the water pressure, entering the accumulator.

4. Ventilation Subsystem

a. Cabin Ventilation

(1). The cabin atmosphere is recirculated at a total maximum flowrate of 18.4 m^3/min (650 cfm). Of this, 15.3 m^3/min (540 cfm) is contributed by cabin fan M181, and an additional 1.6 to 3.1 m^3/min (55 to 110 cfm) is contributed by the Atmosphere Revitalization System (Section II, A, 6). The atmosphere revitalization air is dumped downstream of fan M181 and hex M151 because (a) allowing the air to enter upstream of M181 would result in a 1.6 to 3.1 m^3/min (55 to 110 cfm) reduction in overall system air flow (all air must pass through M181) and (b) entering the air upstream of M51 would produce a higher system ΔP and reduced overall system flow (due to a higher flow in M51 and a reduced thermal capacity of M51, the air exiting the atmosphere revitalization is close to dewpoint temperature).

(2). The cabin air is filtered to remove all particles above 100 microns by filters placed upstream of fan M181. The cabin air filtration is placed in the air return area instead of the air distribution system because the air return system has the potential to supply the large filtration areas required to maintain 100K cleanliness without an excessive ΔP penalty on the air circulation system.

(3). Electrical strip heaters M182, M183 are placed downstream in the full air flow since their ΔP in the system is minimal.

(4). Air distribution registers will be sized and placed within the lab as required to meet ventilation requirements.

b. Cabin Atmosphere Revitalization (Condensate Collection and CO_2 Removal)

(1). The atmosphere revitalization system is composed of 4 subsystems: The air handling system (M170 through M174), CO_2 removal system (M175 through M180), condensate collection system (M120 through M146), and GSE air supply connections M343, M344.

(2). Fans M170, M171 are placed at the system inlet to reduce the total number of components required for air flow control. If the fans were placed at the system outlet each fan would require a valve at its discharge (for a total of two valves) to prevent backflow through either fan when it was not operating. With both fans at the system inlet, only one additional valve (M172) is required to prevent unwanted backflow through a non-operating fan.

(3). Valves M173, M174 are electrically operated and may be positioned manually if needed. The valves will open when their respective fan is "ON" (e.g. M174 will open when M170 is "ON") and close when their respective fan is "OFF" to prevent air backflow with resultant condensation from occurring in an isolated condensing hex.

(4). Damper M172 diverts the proper amounts of air to the CO_2 system for different crew metabolic rates. The location of M172 is dictated by the location of fans M170, M171. The flow capacity for each fan M170 and M171 is 1.6 m^3/min (55 cfm). One fan is required for CO_2 and latent loads of two men or less, both fans and condensing hexs are required for loads of three men or greater. With one fan operating and damper M172 positioned to block flow to the inactive system, 0.3 m^3/min (10 cfm) will flow to the CO_2 removal system and 1.3 m^3/min (45 cfm) to the applicable condensing hex. With both fans running and M172 in midposition, the CO_2 system will flow a total of 0.6 m^3/min (20 cfm) and each condensing hex 1.3 m^3/min (45 cfm).

(5). Three LiOH canisters M176, M178, M180 are required to remove a total CO_2 metabolic load of 21 man days. The CO_2 canisters are used one at a time and are selected by manual valves M175, M177, M179. If CO_2 loads in excess of 21 man days are required, one of the three CO_2 canisters must be replaced inflight. Manual valves M175, M177, M179 are placed upstream of the LiOH canisters to prevent unused canisters from seeing the full head pressure of fans M170, M171 which would increase the external air leakage rate of an improperly sealed canisters.

(6). Condensing heat exchangers M48 and M49 are identical and are required to remove latent metabolic load from the Sortie lab. The units are internally redundant for condensate removal. Each unit has two air/water separation modules and condensate water from each module exits through separate QD connections on the sides of the unit.

(7). Condensate water passes through visual sight glasses M137, M139, M141, M143 and through manual isolation valves M138, M140, M142, M144. The hand valves and sight glasses on each condensate outlet are required to locate and isolate a failed air/water separator module during flight before the failure fills tank M134 with air. The condensate system is considered lost if the tanks are allowed to fill with air because inflight dumping of the tanks would contaminate experiments external to the lab. The condensate control system (Section II, B, 6) is designed to recognize air breakthrough in the condensate collection components and stop all water and air flow into the condensate tank until corrective action is taken. The isolation valves will be closed when a condensing hex is to be inactivated or when air breakthrough occurs in a air/water separation module. The module in which air breakthrough has occurred is found by inspecting the sight glasses for the presence of air and closing the applicable hand valve to block subsequent passage of air. The hand-valves and sight glasses are also used for prelaunch and inflight priming of the air/water separators.

(8). Valves M124, M125, M128, M136 are energized closed to block flow from hex M48, M49 to the condensate collection tanks during (a) vehicle ascent or descent, (b) condensate dumping operations and (c) during air breakthrough failures occurring during flight.

(9). Air bubble detectors M147, M148 detect air inleakage resulting from failures in condensing hx M48, M49 and upstream components. When air inleakage into the condensate system is detected, valves M124, M125, or M128, M136, as applicable, will be energized by the condensate controller to prevent the condensate collection tank M134 from filling with air until the leak source is isolated or repaired.

(10). Redundant valves M130, M131 are energized by the condensate controller, as required to maintain tank M134 at a controlled vacuum between 2.1 to 3.4 N/cm^2 (3.0 to 5.0 psi) below cabin pressure. The constant vacuum maintained in M134 provides the ΔP required to pull condensate water through the air/water separators. Bleed orifice M146 limits the tank evacuation air flow rate when valves M130, M131 are open to prevent overshooting the desired pressure. Valve M133 is opened by the condensate controller to pressurize tank M134 to cabin pressure during condensate dumping.

(11). Valves M123 and M145 are used to (a) drain or position the bladder of M134 during GSE operations, (b) verify the functions of the condensate controller and associated control instrumentation, and (c) prime the air/water separators prior to launch.

(12). Condensate stowage tank M134 is sized to hold all condensate water generated over a seven day mission. Tank M134 has a capacity of 66.7 kg (147 lb) of water minimum. The maximum anticipated water generation rate for a 7 day sortie mission is approximately 56.7 kg (125 pounds).

(13). Valve M122 provides capability for inflight dumping of M134 to (a) reduce reentry weight or (b) empty tank M134 after a gross air breakthrough has occurred in the condensate system.

(14). Accumulator M121 is provisionally included in the condensate dump line to prevent excessive water pressures from occurring between components M122 and M120 or any condensate flow control component located internal to the orbiter. The most probably time of high water pressures will be during reentry after tank M134 has been dumped. The accumulator construction and properties are identical to that of M92 described in Section II,A,3(7).

(15). GSE air supply and return for the Sortie lab is supplied by QD M343, M344. The quantity of air supplied is only that required to maintain humidity and acceptable air quality within the Sortie lab during refurbishment. This GSE air supply will not be used for thermal control. Thermal control during refurbishment will be supplied by the flight systems after the Sortie Lab is installed in the Shuttle or by a drag-on system furnished by GSE.

c. Equipment Ventilation

(1). The electronic equipment located in the thermal racks dissipates the largest heat load in lab. The thermal racks air tempearture is always higher than the cabin air temperature. The thermal racks compartments is sealed as tight as possible to minimize heat leakage paths to the cabin.

(2). The thermal rack atmosphere is recirculated at a nominal flow rate of 19.8 m^3/min (700 cfm) by equipment fan M184. Fan M184 is located upstream of the equipment heat exchanger M58 to minimize noise generation between the two items. The equipment fan M184 operates continuously.

(3). The equipment heat exchanger M58 dissipates the equipment heat load to the water coolant loop. The air outlet temperature from heat exchanger M58 is dependent upon the temperature of the coolant supply to M58 and the prevailing power loads in the thermal racks.

(4). The equipment air is filtered to remove all particles over 100 microns. The filter size and location have not been determined.

(5). Equipment air distribution registers will be sized and located to meet the electronic equipment ventilation requirements.

d. Two Gas Control

(1). The two gas control system is supplied with 2069 N/cm^2 (3000 psia) nitrogen regulated to 103 N/cm^2 (150 psia), and 621 N/cm^2 (900 psia) oxygen regulated to 83 N/cm^2 (120 psia). The 150 psia nitrogen and 120 psia oxygen are regulated to the required cabin pressure of 10.1 N/cm^2 (14.7 psia). The cabin gas composition is nominally 21 percent O_2 (PPO_2 of 3.1 psi) and 79 percent N_2 (PPN_2 of 11.6 psi). The two gas control system supplies the correct amount of oxygen and nitrogen to the cabin to replace metabolic and overboard leakage losses.

(2). Filter assembly M264 provides a clean high pressure O_2 to the downstream solenoid valves and orifices. The filter is provided with an internal relief valve to bypass the filter should it become clogged.

(3). Redundant latching solenoid valves M265 and M266, mounted parallel for redundancy, to open, control the O_2 supply to the inlet of the 83 N/cm^2 (120 psia) regulator. The solenoid valves are operated by the lab atmosphere controller. Both valves are open during normal operation. Both valves are closed during lab venting.

(4). Controlled flow assembly M267 is located in a flow path parallel to solenoid valves M265 and M266. The controlled flow assembly M267 allows high pressure O_2 to flow slowly to the downstream side of the solenoid valves. When the solenoid valves are both closed, the O_2 pressure will equalize on both sides of the valves preventing a potential explosive hazard from occurring when the solenoid valves are opened.

(5). Orifice M268 limits the O_2 flowrate to the lab is a downstream component fails or a line ruptures.

(6). The 83 N/cm^2 (120 psia) O_2 regulator M269 reduces the 621 N/cm^2 (900 psia) inlet pressure to an outlet pressure of 83 N/cm^2 (120 psia) for pressurization of the 10.1 N/cm^2 (14.7 psia) two gas control system regulator. The 83 N/cm^2 (120 psia) O_2 regulator M269 contains one inlet filter and two parallel circuits containing redundant manual shutoff valves, regulators, relief valves and check valves. The regulator lockup pressure is 100 N/cm^2 (145 psia) maximum. The internal relief valves are set to relieve at 103 to 117 N/cm^2 (150 to 170 psig) and vent into the cabin area. The manual shutoff valves and check valves isolate each of the redundant circuits.

(7). Check valve M286 operates in series (redundant to check back flow) with checkvalves located at the outlet of each regulator unit in M269. The check valves allow 83 N/cm^2 (120 psia) O_2 to flow to the inlet of the 10.1 N/cm^2 (14.7 psia) cabin pressure regulator M233. The check valves stop any additional O_2 flow to cabin pressure regulator M233 when the cabin partial O_2 pressure is satisfied and the atmosphere controller switches from the 83 N/cm^2 (120 psia) O_2 source to the 103 N/cm^2 (150 psia) GN_2 source. The higher GN_2 pressure, 103 N/cm^2 (150 psia) prevents any additional O_2 flow to the cabin pressure regulator by maintaining a constant back pressure against check valve M286 and the applicable checkvalve located internal to M269.

(8). Filter assembly M224 provides clean high pressure N_2 to the downstream solenoid valves. The filter is provided with an internal relief valve to bypass the filter should it become clogged.

(9). Redundant latching solenoid valves M225 and M226, mounted parallel for redundancy to open, control the N_2 supply to the inlet of the 150 psia regulator. The solenoid valves are operated by the lab atmosphere controller. Both valves are open during normal operation. Both valves are closed during lab venting.

(10). Orifice M227 limits the N_2 flowrate to the lab if a downstream component fails or a line ruptures.

(11). The 103 N/cm^2 (150 psia) N_2 regulator M228 reduces the 2069 to 207 N/cm^2 (3000 to 300 psia) inlet pressure to an outlet pressure of 103 N/cm^2 (150 psia) for pressurization of the 10.1 N/cm^2 (14.7 psia) cabin pressure regulator M233. The 103 N/cm^2 (150 psia) N_2 regulator M228 contains one inlet filter and two parallel circuits containing redundant manual shutoff valves, regulators, relief valves and check valves. The regulator lockup pressure is 124 N/cm^2 (180 psig) maximum. The internal relief valves are set to relieve at 124 to 145 N/cm^2 (180 to 210 psig) and vent into the cabin area. The manual shutoff valves and check valves isolate each of the redundant circuits.

(12). The 3-way manual valve M239 controls the flow path of the N_2 to the cabin pressure regulator M233. The 3-way valve provides the means to select either of two paths through redundant solenoid valves M237 or M238, or to shut off the N_2 flow through both paths. When the flow path through the valve is manually selected, the appropriate electrical circuit is selected by selector switches internal to M239 to operate the corresponding solenoid valve.

The electrical circuits are open when the 3-way valve is in the off position. Oxygen partial pressure sensors located in the cabin area determine when the oxygen partial pressure (PPO_2) is higher or lower than the acceptable limits. If the PPO_2 is too low, an electrical signal is sent to the 3-way valve M239 which closes the selected solenoid valve (M237 or M238) stopping the 103 N/cm^2 (150 psia) N_2 flow. This allows the 83 N/cm^2 (120 psia) O_2 to flow through the psia regulator to the cabin area increasing the cabin PPO_2. When the cabin PPO_2 reaches the correct level, the atmosphere controller sends an electrical signal to the 3-way valve M239 which opens the selected solenoid valve (M237 or M238) allowing the 103 N/cm^2 (150 psia) N_2 to flow through the 14.7 psia regulator. The 103 N/cm^2 (150 psia) N_2 on the downstream side of check valves M286 and M287 closes the check valves stopping the 83 N/cm^2 (120 psia) O_2 flow. The correct oxygen partial pressure range is maintained by the continued cycling of the N_2 solenoid valves (M237 or M238).

(13). The 10.1 N/cm^2 (14.7 psia) nominal two gas regulator M233 reduces the 83 N/cm^2 (120 psia) O_2 or 103 N/cm^2 (150 psia) N_2 to 10.1 N/cm^2 (14.7 psia) for pressurization of the cabin. Regulator M233 contains a common inlet filter and two parallel circuits containing redundant manual shutoff valves and regulators. The manual shutoff valves isolate the redundant circuits.

(14). The O_2 partial pressure sensors may require calibration during flight. The sensors are calibrated at two points, 0 percent O_2 and 20.4 percent O_2. Calibration at 0 percent O_2 is accomplished by supplying the sensors with 100 percent N_2. The N_2 is supplied from N_2 regulator M228 and flows through orifice M234 and hand valve M235. Orifice M234 limits the flowrate to the sensors and is placed downstream of hand valve M235 to slowly meter the N_2 gas to the sensors. Calibration at 20.4 percent O_2 is accomplished by supplying the sensors with a reference gas having a composition of 20.4 percent O_2 and 79.6 percent N_2. The reference gas is stored at 2069 N/cm^2 (3000 psia) in reference gas bottle M279. Bottle M279 is filled and drained through the normally closed solenoid valve M281 and QD M280. Filter M282 provides clean reference gas for the downstream orifices and hand valve. Orifice M283 limits the reference gas flowrate should a line rupture occur. Opening hand valve M284 allows the reference gas to flow through orifice M278 which slowly meters the reference gas to the sensors.

(15). Solenoid vent valves M349 and M350 are provided to vent the lab to the outside environment. The vent valves are mounted in parallel for redundancy to vent.

(16). Relief valves M346 and M347 prevent the internal pressure of the lab from exceeding the external pressure by TBD psia. The relief valves are mounted in parallel for redundancy to vent. A shutoff valve is incorporated in the discharge line of the relief valve to seal the compartment from the outside environment or to isolate a leaking or failed relief valve.

(17). Relief valve M352 is provided to prevent the external pressure outside the lab from exceeding the internal pressure by TBD psia. No redundancy is provided because failure of this valve to operate would be a second order failure. A first failure must occur which requires the lab to be vented down during flight before use of M352 is required.

5. GN$_2$ Supply Subsystem

(1). The GN$_2$ supply system serves two functions: (a) supplies N$_2$ to the Sortie Lab to replace overboard leakage and (b) supplies pressure to water stowage tanks M84, radiator loop coolant accumulator M19, and water coolant accumulator M40. Two N$_2$ tanks are required to meet these requirements.

(2). The two GN$_2$ tanks M203, M206 are mounted in parallel and are connected to a common fill line and common distribution line. Each tank has an individual fill and drain solenoid valve M202, M205, and an individual outlet check valve M204, M207. The GN$_2$ tanks are initially pressurized to 2069 N/cm^2 (3000 psig).

(3). The GN$_2$ tanks are filled and drained through QD M200. The tanks can be filled individually or as a group by opening the appropriate solenoid valves. Pressurization of one tank will not pressurize the remaining tank since each is isolated by a solenoid valve at the inlet and a check valve at the outlet.

(4). If the GN$_2$ distribution system becomes overpressurized by excess filling or overheating, the excess pressure is relieved by relief valve M217 through QD M201. Relief valve M217 is set to relieve at 2413 N/cm^2 (3500 psig).

(5). Filter M218 protects orifice M219 and regulators M220 and M222 from degradation by particulate contamination.

(6). Orifice M219 limits the GN$_2$ flow to an acceptable flowrate should either the line rupture or the regulators fail.

(7). QD 232 is provided to disconnect tank M84, from regulator M222 when this tank is empty of water. This is done to preclude damage to the storage tank bellows by overpressurization during GSE checkout operations of the GN_2 system.

6. Hydrogen Supply Subsystem (Fuel Cell)

(1). The hydrogen is stored in three tanks M300, M302, M307. Three hydrogen tanks are required to meet the maximum power demand of the sortie lab. Each tank contains a quantity probe, a bulk fluid temperature sensor, two destratification fans and two electrical heaters for expulsion of the supercritical fluid. The tank internal volume is 0.7 m^3 (6.83 cu ft) and the normal operating pressure is 168.9 ± 10.3 N/cm^2 (245 ± 15 psia). The usable fluid in each tank is 12.77 kg (28.15 lb). The tanks are filled and drained through individual QD fittings on the tanks.

(2). Filters M301, M303, M308, M310 and M315 are located on the outlet lines of the tanks (one filter per tank). The filters provide clean hydrogen to assure proper operation of the check valves and relief valves.

(3). Valve modules M304, M311 contain a pressure transducer, pressure switch and relief valve for each H_2 tank (M304 is a dual unit). The pressure transducer provides a continuous pressure readout for each tank. The pressure switch and tank density outputs are used by the hydrogen controller to selectively operate the hydrogen tank heaters to equalize tank usage and maintain the required operating pressure. The pressure switch closes when the pressure decays to a minimum of 159 N/cm^2 (230 psia) and opens when the pressure increases to a maximum of 179.3 N/cm^2 (260 psia). The relief valve relieves excess pressures that may be caused by overfilling, over heating, or nonusage of the hydrogen through QD M318. The relief valve is set to relieve at 196.5 N/cm^2 (285 psia).

(4). Check valves M305, M306, M312 (one check valve per tank) are located downstream of the valve modules. The check valves isolate each tank from the other tanks. The check valves prevent the external leakage or rupture of one tank from affecting the normal operation of the other tanks. The check valves also enable the pressure switches to sense when their respective tank pressure is below the pressure switch setpoint, since they isolate their tank from the system pressure when their respective tank ceases to contribute to the system flow.

(5). The three H_2 tank outlet lines are manifolded to one H_2 distribution line downstream of the check valves. The one H_2 distribution line services the fuel cells.

(6). Hydrogen tank fill valves M321, M322, M326 are used for chilldown and fill of the hydrogen tanks at prelaunch and valves M320, M323, and M327 are used to vent the tanks during the tank chilldown and fill activities. The tanks are filled simultaneously from a common H_2 supply from the GSE. The fill valve of each tank is closed by a GSE signal source when the quantity probe in the respective tank indicates that the applicable tank has filled to the required level. The hydrogen tank vent valves are closed by a GSE signal source at the completion of tank filling. After all valves are closed, the cryogenic hydrogen control system (Section II, B, 8) is enabled to supply power to the tank heaters for bringing each tank up to the supercritical state.

7. Oxygen Supply Subsystem (Fuel Cell and Metabolic)

(1). The oxgyen is stored in two tanks, M250 and M252. Two tanks are required to meet the maximum power demands, metabolic usage, and overboard leakage. Each tank contains a quantity probe, a bulk fluid temperature sensor, a heater temperature sensor, and three electrical heaters for expulsion of the supercritical fluid. The tank internal volume is 0.13 m^3 (4.75 cu ft) and the normal operating pressure is 620.6 ± 24 N/cm^2 (900 ± 35 psia). The usable fluid in each tank is 146.72 kg (323.45 lb). The tanks are filled and drained through fittings on each tank.

(2). Filters M251, M253 are located on the outlet lines of the tanks (one filter per tank). The filters provide clean oxygen to assure proper operation of the check valves and relief valves.

(3). Dual valve module M254 contains a pressure transducer, pressure switch, and relief valve for each O_2 tank. The pressure transducer provides a continuous pressure readout for each tank. The pressure switch and quantity probe control the three heaters in the O_2 tanks to maintain the required operating pressure. Manual heater operation is also provided. The relief valve relieves excess pressure caused by overfilling, overheating, or nonusage of oxygen through QD M277. The relief valve is set to relieve at 696 N/cm^2 (1010 psia).

(4). Check valves M255 and M256 (one check valve per tank) are located downstream of the valve modules. The check valves isolate each tank from the other tanks. The check valves prevent the external leakage or rupture of one tank for affecting the normal operation of the other tank. The check valves also enable the pressure switches to sense when their respective tank pressure is below the pressure switch setpoint since they isolate their tank from the system pressure when their respective tank ceases to contribute to the system flow.

(5). The two O_2 tank outlet lines are manifolded together downstream of the check valves. A portion of the O_2 goes to the fuel cells. The remainder of the O_2 passes through the O_2/radiator heat exchanger M18 before supplying the sortie lab with its O_2 requirements. Heat exchanger M18 warms the cold oxygen gas to preclude damage to the downstream valves and regulators.

(6). Oxygen tank fill valves M290 and M291 are used for chilldown and fill of the oxygen tanks at prelaunch and valves M289, M292 are used to vent the tanks during the tank chilldown and fill activities. The tanks are filled simultaneously from a common O_2 supply line from the GSE. The fill valve of each tank is closed by a GSE signal source when the quantity probe in the respective tank indicates that the applicable tank has filled to the required level. The oxygen tank vent valves are closed by a GSE signal source at the completion of tank filling. After all valves are closed, the cryogenic oxygen control system (Section II, B, 8) is enabled to supply power to the tank heaters for bringing each tank up to the supercritical state.

B. Control Logic and Control Instrumentation for 20M42719, Rev C

1. General Statements

a. All critical I & II controllers (Figure A-2) and their applicable instrumentation are redundant to eliminate those single point failures in ECS control systems which would cause rapid loss of Sortie Lab use. Critical I & II controllers are partial pressure oxygen controllers, atmosphere controller, cabin temperature controller, and condensate controller. All remaining controllers are designated as critical II controllers.

b. Critical III controllers are water controller, sublimator controller, radiator valve controller, and hydrogen tank controller. Loss or malfunction of a critical III controller will produce reduction in capacity or loss of a critical III subsystem. Loss of the water controller will cause loss of water supply to the sublimator and/or internal damage to water tank M84.

FOLDOUT FRAME 1

FOLDOUT FRAME 2

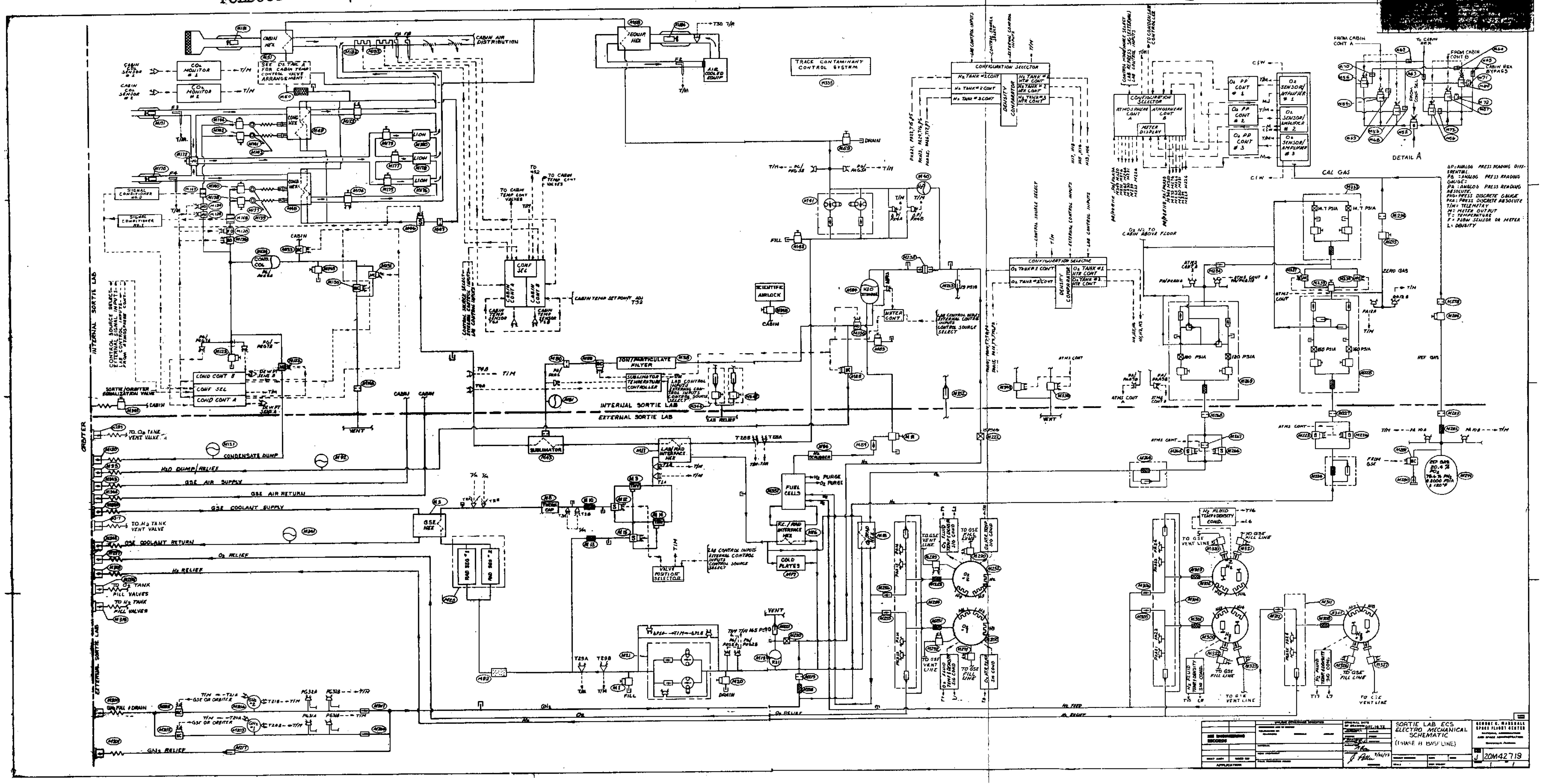


Figure A-2. Sortie Lab ECS electro-mechanical schematic.

Loss of the sublimator controller is a loss of supplementary heat rejection capacity with consequent higher resultant temperatures in the water coolant loop of Section II, A, 2, b. Loss of a hydrogen tank controller could reduce the peak power capacity of the fuel cell and/or the total KWH available during the mission. Loss of an oxygen tank controller could have an impact on the fuel cell comparable to that of the hydrogen controller mentioned above. Also the O_2 supply system could be unable to meet the total mission metabolic requirements. Loss of the radiator valve controller is a second order failure which is applicable only after a failure M9, M14 has occurred. Therefore this controller does not need to be redundant.

c. The water controller is not redundant since it normally performs only three or four discrete operations during a mission. The probability of a failure occurring during either of these operations is very low. The allowable time interval between most possible failure events and the required corrective action could be too short for human response to change over to a redundant controller before internal damage occurred within tank M84.

d. The sublimator temperature controller is not redundant. The sublimator is a supplementary heat rejection sink that is nor normally used inflight. The controller was judged unnecessary for redundancy because the sublimator controller described herein is basically simple in design, is not normally expected to operate for most missions, and because the inherent operating characteristics of the sublimator limit the exiting coolant to temperatures above 0°C (32°F).

e. The hydrogen and oxygen tank controllers are not redundant for each tank because the loss of a single tank controller would only degrade a mission and not cancel it (Section II, B, 1, b).

f. All controllers will have a two position manual "Control Source Select" switch located on the controller (or on a remote panel internal to the Sortie Lab cabin). The switch will select from one of two sources for external commands to the controller; "Sortie Lab," or "External Source" and will remain in the position placed. "Sortie Lab" inputs will all originate from manual control switches located internal to the Sortie Lab. "External Source" will accept commands from any source outside of the lab. The external source may be either orbiter or on the ground. The normal switch position will be in "External Source." Unless otherwise specified in the following description, all manual switches used for "Sortie Lab" inputs shall be the momentary contact type which will return to the center or open position after a man's hand has been removed from the switch operator. All "Control Source Select" switches remain in the position placed and do not return to a center position.

g. All controllers except the water controller and the sublimator controller contain a configuration selector module within the controller assembly. On critical I & II controllers, the configuration selector turns "ON" the desired controller and its applicable control instrumentation, and turns "OFF" the redundant controller and all its activities. The configuration selector for critical III controllers (O_2 and H_2 cryogenic tanks can turn "ON" and "OFF" the control outputs) but not instrumentation outputs of a subcontroller within the controller assembly (e.g. the "O_2 Tank No. 1 Heater Controller" is a subcontroller within the "O_2 Controller" assembly and only the power output to the O_2 tank heaters may be inhibited by the configuration selector). The configuration selector of all controllers contains the "Control Source Select" switch of Section II, B, 1, b and all manual switches for the "Sortie Lab" inputs. All "External Source" inputs enter through the configuration selector and the readings of all control instrumentation exist from the configuration selector. In order to maintain measurement redundancy the configuration selector shall not turn "OFF" or inhibit passage out of the controller of any measurements during any controller operating or nonoperating modes.

h. The controllers as described in the preceding remarks and in the following paragraphs are not to be interpreted as a requirement for all of the controller sections to be incorporated into one assembly containing all control functions. For example a controller might be dispersed with manual switches and visual readouts best located on a control panel, all power handling sections located external to the lab, and solid state logic, etc., placed in some third location.

i. Drawing 20M42719, "Sortie Lab ECS Electro Mechanical Schematic," Rev C (Fig. A-2) shows only that instrumentation which is used by the controllers for sensing inputs, fluid quantity determinations, and failure mode isolation. No other measurements are shown. Measurements used as control inputs to critical I & II controllers (Section II, B, 1, a) are redundant with each redundant controller having its own measurement source. Measurements used for fluid quantity determinations are redundant in the GN_2 supply system but singular in the O_2 and H_2 supply systems because existing hardware is being used in the latter two systems. Nonredundant controlling measurements are used with critical III controllers (Section II, B, 1, b) since critical III controllers have no redundancy.

j. In the following description of control logic and instrumentation, measurement ranges and measurement discrete values (i.e. a binary "ON"-"OFF"output) are specified only as required to complete the logic description. All other measurement ranges and values are TBD or specified in other publications.

k. Measurement notations used in this description and on revision C of drawing 20M42719 are as follows. Measurements are separately numbered in consecutive numerical order within categories for temperature (T), pressure (P), flow (F), and density (ρ). Pressures are either differential ("Δ P"in psid), absolute reference ("PA"in psia), or gage reference ("PG" in psig). A measurement discrete is noted by the letter "K" included in the measurement number. Redundant measurements having the same range and discrete settings have suffix letters "A" and "B" at the end of the measurement number. Example: PG/PKG2A and PG/PKG2B are redundant measurements (suffix letters "A" and "B") at the inlet of radiator coolant pump M21. Each measurement has a gage referenced analog output (PG-), a gage referenced discrete output (-/PKG-), and is measurement number two (-2-) within the pressure measurement category.

l. All controllers shall have an input for GSE checkout purposes, so that when activated by GSE power, will inhibit all controller outputs to all valves, etc., and transfer these controller outputs to a GSE checkout connector(s) that will facilitate GSE checkout and failure analysis of controller outputs to other components. GSE checkout equipment shall be capable of stimulating the controller inputs over the full span of the input and verifying controller outputs.

2. Water Control

a. The water controller (a) monitors excessive pressure differentials across the bellows of water tank M84 and (b) controls dumping of the water stowage tank.

b. The controller monitors the bellows pressure differentials of tank M84 by measurement P/PK3. The PD discrete of each transducer has two actuation points. An "ON" discrete shall be generated on rising pressure when the pressure on the water side exceeds the pressure on the GN_2 side by $2.1 {}^{+0.0}_{-0.34}$ N/cm^2 ($3.0 {}^{+0.0}_{-0.5}$ psid). The discrete shall go "OFF" at falling pressures at $1.0 {}^{+0.34}_{-0.0}$ N/cm^2 ($1.5 {}^{+0.5}_{-0.0}$ psid). When this discrete goes "ON" the water controller shall automatically initiate a water dump from tank M86 by opening dump valve M88. Dumping shall continue until the discrete goes "OFF".

c. The second discrete shall come "ON" with rising pressure when the pressure on the GN_2 side exceeds the pressure on the water side by 2.4

$^{+0.0}_{-0.34}$ N/cm^2 ($3.5^{+0.0}_{-0.5}$ psid). The discrete shall go "OFF" on falling pressures at $1.4^{+0.34}_{-0.0}$ N/cm^2 ($2.0^{+0.5}_{-0.0}$ psid). When this discrete goes "ON" during flight the water controller shall automatically stop all water flow out of M84 by closing valve M100 until the discrete goes "OFF."

d. The controller shall send an inhibit signal to the sublimator controller (Section II, B, 3) when the discrete of step c above is "ON."

e. The controller shall have the following two "Sortie Lab" external control inputs: (a) a power switch to turn the controller automatic control functions "ON" and "OFF" (this switch shall not inhibit any of the measurement outputs, Section II, B, 1, g,) and (b) a water dump switch with positions to "START" or "STOP" the water dump sequence. The "External Source" shall have the same inputs.

f. When the controller is commanded to dump the water tanks by an input from the "Control Source Select" switch, valve M88 will be energized open until the pressure discrete of step c above occurs. When the pressure discrete occurs, the controller shall (a) close valve M88 (to stop the water dump), (b) close valve M100 and (c) send an inhibit signal to the sublimator controller (Section II, B, 1, f). The controller will remain in the dump mode and cycle valves M88, M100 and the inhibit signal as dictated by the pressure discrete signal until a command to "STOP" the water dump is received.

g. Measurement Δ P/PK3 input to the controller and the outputs of these measurements to T/M are not to be interrupted by the "Control Source Select" switch or the controller being turned "OFF" in order to preserve measurement information (Section II, B, 1, g).

3. Sublimator Control

a. The sublimator controller, when active, insures that the temperature of the coolant water supplied to condensing heat exchangers M48, M49 remains at or below 7.2°C (45°F) to maintain cabin dewpoint and sensible temperature requirements. The controller also maintains the pressure of the sublimator water evaporant supply to within acceptable limits during sublimator operation.

b. The controller has two measurement inputs; T4A and PA/PKA6. T4A and T4B shall have a minimum range from -1.1 to 48.9°C (30 to 120°F). The controller shall monitor the value of T4 and, when activated for sublimator operation, shall turn on the sublimator by opening water supply valve M99. The controller monitors the sublimator water supply pressure with PA/PKA6. PA6 has an analog output from 0 to 6.9 N/cm^2 (0.0 to 10.0 psia) and discrete PKA6 closes on falling pressures at $1.4^{+0.34}_{-0.0}$ N/cm^2 ($2.0^{+0.5}_{-0.0}$ psia) and opens on rising pressure at $3.4^{+0.0}_{-0.34}$ N/cm^2 ($5.0^{+0.0}_{-0.5}$ psia). When T4A rises above 7.2°C (45°F) the controller will open M99. The controller will hold M99 open until PKA6 opens at 3.4 N/cm^2 (5.0 psia) or T4A drops below 7.2°C (45°F). The controller will continue to cycle M99 as dictated by PKA6 and maintain the sublimator water supply pressure as long as T4A remains above 7.2°C (45°F). Then T4A drops below 7.2°C (45°F) the controller will close M99 and allow the sublimator water pressure to decay to 0.0 N/cm^2 (0.0 psia) as the sublimator dries out.

c. The controller shall have a "Control Source Select" switch to select between a manual command originating within the lab or external to the lab. Only one manual command switch exists; a power switch to turn the controller automatic control functions "ON" or "OFF". An "Insufficient Water" inhibit signal to the sublimator controller from the water controller prevents the sublimator controller from opening M99 when tank M84 has been depleted or drained. The inhibit signal bypasses the "Control Source Select" switch and cannot be defeated. If M99 was allowed to open with insufficient water in tank M84, then Filter M89 and fuel cell M35 would be subjected to damage induced by vacuum drying and the entire water system could then be evacuated up to valves M100, M88, and M83. An "Insufficient Coolant Flow" inhibit prevents the controller from opening valve M99 when coolant pump M41 is inoperative or is turned "OFF". The source of the coolant flow inhibit signal shall be the closure of pressure switch PK4A or PK4B, the pump ΔP switch. PK4A and PK4B shall close on falling pressures below TBD psid for both switches. The controller shall be inhibited from opening M99 when the pump ΔP is below acceptable limits. This inhibit shall not be defeatable. However, provision should be made for inflight selection between PK4A and PK4B to eliminate this single point measurement failure. Failure to inhibit opening of M99 when the water coolant loop is not circulating will allow the sublimator to freeze stagnated coolant water within M143, producing possible rupture of internal coolant water passages within M143 and loss of the water coolant loop by external leakage of coolant water. Measurements T4A, PA/PKA6 inputs to the controller and the outputs of these measurements to T/M are not to be interrupted by the "Control Source Select" switch or the controller being turned "OFF" in order to preserve measurement information (Section II, B, 1, g).

4. Cabin Temperature Control

a. The cabin temperature controller maintains the temperature of the cabin air to the setpoint of the cabin air temperature. The system has both heating and cooling capabilities with full redundancy in all functions.

b. The controller system has three subsystems: primary ("A") controller (which controls valve cluster M53, M54, M55, and heater M162 with cabin temperature sensor input T6A and flow switch F1A input), secondary ("B") controller (which controls valve cluster M56, M57, M60 and heater M183 with cabin temperature sensor input T6B and flow switch F1B input), and the configuration selector which selects between primary or secondary controllers valve M52. Controllers "A" and "B" have identical operating characteristics.

c. The configuration selector has the following control inputs to the "Control Source Select" switch from "Sortie Lab" and External Source": (a) a controller selector switch(s) with positions "Cabin Controller A ON," "Cabin Controller B ON," and "Controller OFF," and (b) a heater control switch with positions "Heater Auto," "Heater OFF." Measurements T6A, T6B, F1A, F1B inputs to the controller and the outputs of these measurements to T/M are not to be interrupted by the "Control Source Select" switch on the controller being turned "OFF" in order to preserve measurement redundancy (Section II, B, 1, g).

d. When a controller is turned "OFF", all power shall be removed from the coils of the applicable valve cluster. The preferred failure position for internal mechanical failures of a valve in either valve cluster shall be in flow to M51.

e. Heaters M182, M183 are interlocked "OFF" at their respective controllers by flow switches F1A, F1B as applicable until (a) the duct system flowrate is greater than 1.4 m^3/min (50 scfm) and (b) either the cabin temperature drops 1.7°C (3°F) below the setpoint for the cabin temperature (to maintain crew comfort) or less than 4.4°C (40°F) (to prevent freezing of the water systems). The 1.4 m^3/min (50 scfm) duct flowrate will allow air temperature differentials across the heaters up to but not beyond 3.9°C (39°F) when M182, M183 are sized to 500 watts. Each heater element M182, M183 shall have an over-temperature thermostat in the heater element for safety purposes.

f. When a controller is commanded "ON" the configuration selector shall supply a positioning pulse to selector valve M52, to direct the system flow to the active valve cluster and block flow to the inactive valve cluster.

g. The controllers will have an adjustable cabin setpoint indicated by T32. Each controller shall operate its cluster of three valves through all four levels of coolant flow to M51 (Section II, A, 2, b) within a temperature band of ±1.1°C (±2.0°F) about the central (cabin) setpoint. The three valve setpoints shall be at -1.0, 0.0, and +1.0 about the cabin setpoint. Each valve setpoint shall have a deadband from ±0.17 to 0.39°C (±0.3 to ±0.7°F) wide to minimize shortcycling of the flow control valves.

5. Condensation Collection Control

a. The condensate controller performs the following operations: (a) monitors for air breakthrough in the air/water separators of M48 and M49 and prevents tank M134 from filling with air, (b) maintains controlled vacuums in tank M134 to produce proper condensate flow into the tanks, (c) prevents the cabin dewpoint from dropping below acceptable levels, and (d) provides for inflight dumping of the condensate water.

b. The controller system has three subsystems: primary ("A") controller (which controls valves M46, M136, M131, M133, M124, M122, M129, and M125, with pressure input PG/PKG7A, flow sensors F5 and F6, and dew point sensor A), secondary ("B") controller (which controls valves M46, M136, M133, M130, M128, M125, M124, and M122, with pressure input PG/PKG7B, flow sensors F5, F6, and dew point sensor B), and the configuration selector which selects between primary or secondary controllers. Controllers "A" and "B" have identical operating characteristics.

c. The configuration selector has the following control inputs to the "Control Source Select" switch from "Sortie Lab" and "External Source:" (a) a controller selector switch(s) with positions "Condensate Controller A ON," "Condensate Controller B ON," and "Controller OFF," (b) a "Condensate Dump" switch with positions "Dump" and "OFF" (c) a two position toggle switch (this switch shall be present only in the Sortie Lab and shall remain in the position placed) labeled "Flow Sensors" with positions of "ON" and "OFF," and (d) a "Launch" switch with positions of "Hold" and "Normal." A pressure inhibit signal originating from the operational atmosphere controller shall enter the condensate controller. This inhibit signal shall not be capable of being defeated by any source (Section II, B, 8, r). Measurements PG/PKG7A and B, flow sensors F5, F6, sensor A and dewpoint sensor B inputs to the controller and the outputs of these measurements to T/M are not to be interrupted by the "Control Source Select" switch or the controller being turned "OFF" in order to preserve measurement redundancy (Section II, B, 1, g).

d. When both controllers are turned "OFF" all solenoid valves shall return to their normal positions except valves M136, M124, M125, M128 which shall be energized closed as long as power is supplied to the controller.

e. Dew Point Sensor A or B, as applicable, shall be used as the criteria to activate condensing heat exchangers M48, M49 when the cabin dew point is above TBD °F and deactivate the condensing heat exchangers when the cabin dew point is below TBD °F. The condensing heat exchangers are activated when the operational controller pulses latching valves M124, M125, M128, and M136. The condensing heat exchangers are deactivated by restoring the valves to their former positions. The pulses for positioning M46 shall be five seconds or longer in duration.

f. Measurements PG7A and PG7B shall have an analog output of 0.0 to -10.3 N/cm^2 (0.0 to -15 psig) referenced to the prevailing cabin pressure.

g. Discretes PKG7A and PKG7B shall open on increasing vacuum at $-3.4^{+0.14}_{-0.0}$ N/cm^2 ($-5.0^{+0.2}_{-0}$ psig) and close on decreasing vacuum at $-2.1^{+0.0}_{-0.14}$ N/cm^2 ($-3.0^{+0}_{-0.2}$ psig). A second discrete shall close on decreasing vaccuum at $-0.7^{+0.34}_{-0.0}$ N/cm^2 ($-1.0^{+0.5}_{-0.0}$ psig) and open increasing vacuum at $-0.7^{+0.0}_{-0.34}$ N/cm^2 ($-1.0^{+0.0}_{-0.5}$ psig).

h. When PKG7 rises above -2.1 N/cm^2 (-3.0 psig), the operational controller shall open M130 or M131 as applicable to evacuate tank M134 through bleed orifice M146. When PKG7 drops to -3.4 N/cm^2 (-5.0 psig) the controller shall close the valve to hold tank M134 within a controlled vacuum range from -2.1 to -3.4 N/cm^2 (-3.0 to -5.0 psig). As condensate continues to flow into M134, the air remaining behind the tank bladder will be compressed by bladder travel until the tank vacuum decays from -2.1 to -3.4 N/cm^2 (-5.0 to -3.0 psig), at which time the controller will re-evacuate the remaining air space behind the bladder back down to -3.4 N/cm^2 (-5.0 psig).

i. When tank M134 becomes filled with fluids or if the condensate controller fails to maintain the proper tank vacuum level, then the upper discrete of PKG7 will generate a tank full caution at vacuums less than -0.7 N/cm^2 (-1.0 psig). The discrete will cancel out at vacuums greater than -0.7 N/cm^2 (-1.0 psig) after tank fluids are dumped or the controller failure is corrected.

j. Condensate will normally flow from M48, M49 to tank M134 at a flowrate dependent upon cabin latent loads and condensing temperature. The operational controller shall monitor both flow indicators F5 and F6 for indication of air bubbles in the condensate flow. Any air bubble signal from either F5 or F6 indicates a failure in the applicable condensate loop. The condensate controller will lock up the failed section to additional flow by closing M128, M136 if a air bubble is detected by F5 (M148) or by closing M124, M125 if an air bubble is detected by F6 (M147). This will insure that one condensing Hx will continue to remove cabin latent loads until a failure can be corrected. When an air bubble causes a valve closure, a signal output from the controller will indicate which bubble detector produced the closure.

k. If one of the flow indicators fails or random lockups of one condensing heat exchanger begin to occur, which are not resulting from air leakage, then both flow sensors may be bypassed by leaving the "Flow Sensors Bypass" in the "OFF" position.

l. The condensate may be dumped during orbit by placing the "Condensate Dump" switch in the "dump" position. When this is done the controller will (a) close M136, M125, M124, and M128, (b) after a five second pause open M133 and M122. The condensate will be forced by cabin pressure out of tank M134 until the tank bladder has traveled to the limit. The flow of cabin air out of orifice M146 will ve very slow compared to the capacity of valve M133, and the bladder of tank M134 will see full cabin pressure. The system shall remain in this condition until the low pressure discrete has occurred, -3.4 N/cm^2 (-5.0 psig). After the pressure discrete has occurred then (a) M122 shall be closed, (b) after a five second pause close M133, and open M124, M125, M128, and M136. After the dump cycle is completed and valves M124, M125, M128, M136 are opened, a small amount of condensate will flow into M134 and the pressure at PKG7 will rise rapidly from -3.4 to 2.1 N/cm^2 (-5.0 to -3.0 psig). This will trigger an evacuation of the air pressure behind the bladder of M134 from the prevailing cabin pressure down to -3.4 N/cm^2 (-5.0 psig). The condensate collection system will resume normal collecting activities.

m. During launch, engine burns for orbit changes, retrofire, reentry, and touchdown, the "Launch" switch shall be placed in the "Hold" position. This action will (a) position M46 to bypass and (b) close M136, M124, M125, M128 to prevent the air/water separators from seeing acceleration induced pressures above 4.1 N/cm^2 (6.0 psid) or backflow of condensate into separators. When the "Launch" switch is placed in the "Normal" position the controller shall resume its former operating condition.

n. A pressure inhibit signal, a discrete which comes "ON" at 6.9 N/cm^2 (10.0 psia) and lower, originating from the atmosphere controller, shall be monitored by the condensate controller configuration selector for all operating modes. When the discrete comes "ON" (indicating loss of pressure within the cabin), then (a) valves M136, M124, M125, M128 will be energized closed, and (b) valve M133 shall be energized to equalize the tank to the prevailing cabin pressure and M146 positioned to bypass. The control pressure discretes of PKG7 shall be inhibited during this condition. After the discrete has gone "OFF" then (a) valve M133, M124, M125, M128, M136 shall be de-energized to Hx flow, and (b) the pressure control of PKG7 shall be restored to regulate the pressure of tank M134.

6. Cryogenic Oxygen Control

a. The cryogenic oxygen controller performs the following operations: (a) equalizes the rate of consumption among the two O_2 tanks, (b) maintains the pressure within each tank at the proper value and (c) prevents excessive heater temperatures within each tank.

b. The controller system has six subsystems: two O_2 Tank Controllers (one for each tank) which monitor the conditions within each tank and initiate corrective actions, a density comparator which equalizes the rate of consumption among the two O_2 tanks, two O_2 heater controllers (one for each tank) which supply power to the heaters within each O_2 tank (which pressurize the tank for increasing the O_2 expulsion rates), and a configuration selector to receive external commands into the controller system to modify the operating state of the controller system.

c. The configuration selector has the following control input to the "Control Source Select" switch from "Sortie Lab" and "External Source:" (a) a "O_2 Tank Subcontroller" switch with positions of "ON" and "OFF" for each O_2 tank, (b) a "Density Comparator Bypass" switch with positions of "Bypass" and "Normal." When an "O_2 Tank Subcontroller" switch is in the "OFF" position, the outputs of both the O_2 tank controller and O_2 heater controller shall be turned "OFF" for those two subcontrollers which that switch commands and a "Cancel" signal (defined in Section II, B, 6, f below) shall be presented at the input of the density comparator from the applicable O_2 tank controller. When the switch is "ON" both controllers for that tank shall function normally. Measurement inputs to O_2 Tank No. 1 controller are O_2 fluid temperature T7 -186 to 27°C (-320 to +80°F), O_2 fluid density $\rho 1$, 22.3 to 1113 kg/m^3 (1.39 to 69.5 lb/ft^3), O_2 heater temperature T8 -184 to 316°C (-300 to 600°F), O_2 pressure switch PKA13 — closes on fall at 621 N/cm^2 (900 psia), opens on rise at 641 N/cm^2 (930 psia), and O_2 pressure PA14 34 to 724 N/cm^2 (50 to 1050 psia). The corresponding measurements to tank number 2 controller are T9, ρ2, T10, PKA15, PA16. The outputs of the above measurements (and any other measurements from the controller system) are not to be interrupted by the "Control Source Select" switch or the controller being turned "OFF" in order to preserve measurement information (Section II, B, 1, g).

d. Measurements T8, PKA13 are used as control parameters by O_2 tank number 1 controller (tank number 2 controller operates identically) to generate "ON" or "OFF" signal to the density comparator. An "ON" signal will exist when PKA13 is closed and T8 is below TBD °F. If one or both of these measurement conditions are not met, then an "OFF" signal shall be presented to the density comparator.

e. The density comparator shall take the prevailing "ON" signal received from the applicable O_2 tank controllers and compare the two density signals continuously received from the O_2 tanks. The density comparator shall send an "ON" signal to the O_2 tank heater controller whose respective O_2 tank controller has generated an "ON" signal except the one with the lowest density reading. For example, if O_2 Tank number 1 controller has generated an "ON" signal but Tank number 1 has the lowest density reading of the two O_2 tanks then the density comparator will not issue an "ON" command to the O_2 Tank number 1 heater controller. Otherwise, an "ON" command will be given to the O_2 tank number 1 heater controller. When the control system is operated with the density comparator in the "Normal" mode, O_2 comsunption will be equalized among both O_2 tanks.

f. When an "O_2 Tank Subcontroller" switch command turns "OFF" its respective O_2 tank controller and O_2 heater controller, then the density comparator will receive a "Cancel" signal from the applicable O_2 tank controller and continue to operate with the density and "ON" inputs from the remaining O_2 tank controller.

g. If the "Normal" operational mode of the "Density Comparator" is changed to "Bypass" by the "Density Comparator Bypass" switch, then the output of each "O_2 Tank Controller" will be directly coupled to its applicable "O_2 Heater Controller" and the "O_2 Cryogenic Controller" and the O_2 cryogenic control system will operate without equalization of O_2 consumption among the four tanks.

7. Cryogenic Hydrogen Control

a. The cryogenic hydrogen controller performs the following operations: (a) equalizes the rate of consumption among the three hydrogen tanks, and (b) maintains the pressure within each tank at the proper value.

b. The controller system has eight subsystems: three Tank Controllers (one for each tank) which monitor the conditions of state within each tank and initiate corrective actions, a density comparator which equalizes the rate of consumption among the three H_2 tanks, three O_2 heater controllers (one for each tank) which supply power to the heaters within each H_2 tank (which pressurize the tank for increasing the H_2 expulsion rates), and a configuration selector to receive external commands into the controller system to modify the operating state of the controller system.

c. The configuration selector has the following control inputs to the "Control Source Select" switch from "Sortie Lab" and "External Source:" (a) a "H_2 Tank Subcontroller" switch with positions "ON" and "OFF" for each H_2 tank, (b) a "Density Comparator Bypass" switch with positions of "Bypass" and "Normal," and "H_2 Destratification Fan" switch with positions of "ON" and "OFF" for each H_2 tank. When an "H_2 Tank Subcontroller" switch is in the "OFF" position, the outputs of both the H_2 tank controller and H_2 heater controller shall be turned "OFF" for those two subcontrollers which that switch commands and a "Cancel" signal (Section II, B, 7, f) shall be presented at the input of the density comparator from the applicable H_2 tank controller. When the switch is "ON" both controllers of that tank shall function normally. Measurement inputs to H_2 tank number 1 controller are H_2 fluid temperature T15, -251 to -129°C (-420 to -200°F), H_2 fluid density $\rho 5$ 2.7 to 69 kg/m^3 (0.17 to 4.31 lb/ft^3), H_2 pressure switch PKQ21 — closes on fall at 159 N/cm^2 (230 psia), opens on rise at 179 N/cm^2 (260 psia), and H_2 pressure PA22 0 to 172 N/cm^2 (0 to 250 psia). The corresponding measurements to Tank number 2 controller are T16, $\rho 6$, PKA23, PA24; Tank number 3 controller are T17, $\rho 7$, PKA25, PA26. The outputs of the above measurements (and any other measurements from the controller system) are not to be interrupted by the "Control Source Select" switch or the controller being turned "OFF" in order to preserve measurement information (Section II, B, 1, f).

d. Measurement PKA21 is used as the control parameter by H_2 Tank number 1 controller (tank number 2, and 3, controllers operate identically) to generate an "ON" or "OFF" signal to the density comparator. An "ON" signal will exist when PKA21 is closed, otherwise, an "OFF" signal shall be presented to the density comparator.

e. The function of the density comparator for the H_2 controller system is identical to that of the O_2 density controller described in Section II, B, 6, e. The only difference is the number of hydrogen tanks (three) and oxygen tanks (two) presented to the density comparator.

f. The functions of the "H_2 Tank Subcontroller" switches and their impacts on the H_2 tank controller, H_2 heater controller and density comparator are identical to that of the O_2 system as described in Section II, B, 6, f. The only difference is the number of hydrogen tanks and switches.

g. The function of the "Density Comparator Bypass" switch in the hydrogen controller is identical to the function of the "Density Comparator Bypass" switch in the Oxygen Controller as described in Section II, B, 6, g.

8. Atmosphere Control

a. The atmosphere controller performs the following operations: (a) maintains the lab total pressure within proper limits, (b) maintains the partial O_2 pressure within proper limits, and (c) depressurizes the lab.

b. The controller has ten subsystems: a primary ("A") atmosphere controller, a secondary ("B") atmosphere controller, three O_2 sensor/amplifiers, three O_2 partial pressure controllers, an O_2 partial pressure meter display, and a configuration selector.

c. The configuration selector has the following control inputs to the "Control Source Select" switch from both "Sortie Lab" and "External Source:" (a) an atmosphere controller selector switch (s) with positions "Atmosphere Controller A ON," "Atmosphere Controller B ON" and "Controller OFF," (b) an "ON"-"OFF" power supply switch for each corresponding O_2 Sensor/Amplifier and O_2 Partial Pressure Controller pair, (c) an "O_2 Partial Pressure Control Mode" switch(s) with positions "PP02 number 1," "PP02 number 2," "PP02 number 3," "Manual Addition," and "OFF," (d) an "O_2 Supply" switch with positions "Open" and "Close," and (e) a "GN_2 Supply" switch with positions "OPEN" and "Close."

d. In switch of step c (a) above, the controller selected shall control depress and all automatic atmosphere control functions. If the switch of step c. (a) above is "OFF," no atmosphere control functions can occur from the controller system which change the atmosphere pressure or mixture. When the switch of step c. (a) above is "OFF," the switch(s) of step c. (b) above may be activated to read out partial O_2 pressures from any of the three PP02 Sensor/Amplifier and controller units.

e. In switches of step c. (b) above, the O_2 Sensor/Amplifier and O_2 Partial pressure Controller pairs may be turned "ON" or "OFF" in any quantity at any time along with their T/M, meter and control outputs.

f. In switch of step c. (c) above, three different O_2 partial pressure control modes are present for control of Sortie Lab atmosphere oxygen content: (1) automatic addition with active control by one of the three PPO2 controllers, (2) "Manual Addition" which adds pure O_2 to the cabin continuously via M233 at the maximum flow M233 can deliver at the prevailing cabin total pressure, and (3) "OFF" which inhibits any O_2 from being added to the cabin from any source. Only one control mode can be active at any one time. Only one PPO_2 Controller (as selected by switch of step c. (c) will have active control over the lab partial O_2 pressure even though all three O_2 Sensor/Amplifier and O_2 Partial Pressure Controllers may be turned "ON" by switch of step c. (b) above. When the switch is in the "OFF" position the atmosphere controller shall energize valve M237, M238 as applicable to put continuous GN_2 pressure on M233 to maintain the lab total pressure at 10.1 N/cm^2 (14.7 psia).

g. In switch of step c. (d) above, the "Open" and "Close" command will cycle the O_2 supply valves M265, M266 appropriately. The switch command will pass through the atmosphere controller that has been turned "ON" by switch of step c. (a) above. The controller will in turn generate positioning pulses for M265, M266. Commands from switch of step c(d) cannot change the positions of M265, M266 if neither atmosphere controller (ref switch of step c. (a)) is "ON." M265, M266 can be closed by the atmosphere controller by command from switch of step c. (d) at any time. However, the execution of a command to open M265, M266 will be delayed by the applicable atmosphere controller until the time interval specified in Section II, B, 8, q has elapsed. This constraint is imposed to eliminate explosion and fire hazards that could occur if M265, M266 were opened indiscriminately.

h. In switch of step c. (e) above, the "Open" and "Close" commands will cycle the GN_2 Supply valves M225, M226 appropriately. The switch commands for M225, M226 will be handled in the same manner as described in Section II, B, 8, g, above except the time delay constraint to open is not applicable.

i. The configuration selector has the following control inputs to the "Control Source Select" switch from only "External Source:" a "Depress" switch with positions "Vent" and "Stop."

j. In switch of i above, the operating controller will open valves M349 and M350 when the switch is in the "Vent" position and close M349 and M350 when the switch is in the "Stop" position.

k. When switch of step c.(a) is changed from one atmosphere controller mode to another atmosphere controller mode (e.g. change from "Atmosphere Controller A ON" to "Atmosphere Controller B "ON") switch of step i, will have to be reset (if applicable) for the replacement controller to continue the depress cycle.

l. Measurements PA/PKA 11Z, PA/PKA 11B, PA/PKA 9A, and PA/PKA 9B inputs to the controller and the outputs of these measurements to T/M are not to be interrupted by the "Control Source Select" switch or the controller being turned "OFF" in order to preserve measurement redundancy (Section II, B, 1, g). The only exception to measurement interruption is the PP02 T/M signals which are affected by switch(s) of step c.(b) (paragraphs d and e above).

m. Each O_2 sensor/amplifier has a panel meter output which is hardwired to one of three PP02 panel meters located on the controller.

n. When the controller is turned "OFF" (see switch of step c.(a)) valves will return to their normal positions and the interval timer of Section II, B, 8, q will be reset to zero. If valves M265, M266 are not closed prior to turning the controller "OFF" the lab will tend to go to a pure O_2 gas composition as lab leakage, etc., causes nitrogen to excape the cabin.

(NOTE: The following three paragraphs describe controller functions for different modes of operation: Atmosphere Maintenance, Depress, and PPO_2 Calibration.)

o. In Atmosphere Maintenance, the controller simply maintains the PP02 and lab total pressure. The following description assumes the lab is pressurized and the controller is to be turned "ON" from an "OFF" condition and placed in the Atmosphere Maintenance condition: (a) place switch of step c.(a) in a controller "ON" mode, (b) change the position of M239 from "OFF" to either M237 or M238 flow direction, (c) place switch of step c.(e) in the "Open" position to open valves M225, M226, (d) verify that one of the two toggle valves in M233, M228, M269 is open so gas can flow to the cabin, (e) place switch of step c.(d) in the "Open" position (Note: Under certain conditions valves M265, M266 will not open when this step occurs. Valves M265, M266 cannot open until an interval timer has expired to allow pressure to equalize across valves M265, M266. Bleed orifice M267 is the equalization device. After the 150 psia GN_2 system is turned "ON" via switch of step c.(e), the GN_2 pressure checks and stops the O_2 bleed flowing through M286, M287 to allow the O_2 system to bleed up to 83 N/cm^2 (120 psia) downstream of O_2 regulator M269, then bleed up to 690 N/cm^2 (1000 psia) upstream of M269 to equalize the pressure across M265, M266. The interval timer starts when PKA 11A or PKA 11B reaches 69 n/cm^2 (100 psia) and runs for TBD minutes. When the timer expires, the pressure upstream of M269 will have bled up to an acceptably safe pressure for the atmosphere controller to send an opening pulse to valves M265, M266), (f) turn "ON" two O_2 sensor/amplifier and O_2 partial pressure controllers with switch step c. (c) and place one of the two PPO2 controllers into automatic control of $PP0_2$ with switch of step c. (c) (Section II, B, 1, f). The controller is now in the Atmosphere Maintenance mode. The atmosphere controller will continuously feed makeup GN_2 into the cabin through M233 as the cabin pressure drops with gas usage and leakage. When the controlling $PP0_2$ controller senses a partial 0_2 pressure below the controller deadband, an input will be sent to the atmosphere controller from the $PP0_2$ controller. The atmosphere controller will send a de-energizing signal to M237 or M238 as applicable to remove the GN_2 supply from M233. M233 will then maintain the cabin pressure at 10. 1 N/cm^2 (14. 7 psia) using pure O_2 until the $PP0_2$ concentration rises above the controller deadband and initiates a return to GN_2 supply.

p. In Depress Mode, the controller vents the lab to space via a non-propulsive vent. The following description assumes the atmosphere controller is in the Maintenance mode. To depress the lab, (a) Turn to "OFF" switch of step c. (c), "Close" M225, M226 by switch of step c. (e), and "Close" M265, M266 by switch of step c. (d), (b) place switch of step i in the "Vent" position and wait until the desired evacuation pressure is reached and (c) place switch of step i in the "Stop" position. As the pressure of the lab decays, the controller shall observe PA/PKA9A or PA/PK9B as applicable and generate an inhibit discrete on falling pressures at 7 N/cm^2 (10 psia). The inhibit discrete will be hardwired from the atmosphere controller configuration selector to the condensate controller configuration selector. The inhibit discrete shall be canceled on rising pressures at 9.7 N/cm^2 (14. 0 psia) (Section II, B, 6, c).

q. The PPO_2 system may be calibration checked during flight. The PPO_2 system is calibration checked with the atmosphere controller in the Atmosphere Maintenance mode. To calibrate the O_2 Sensor/Amplifiers, position switch of step c. (c) to the "OFF" position and isolate the PPO_2 sensors from the cabin air composition by closing off cabin air flow to the sensors. Open M235 to zero the sensor with GN_2. Verify the meter display indicates zero. Adjust if required. Close M235 and open M284 to flood the sensor cavity with calibration gas. Verify the proper PPO_2 level is indicated by P9A and/or P9B. Close M284 and open the sensor cavity to the lab air. Wait five minutes and return switch of step c.(c) to its former position.

9. Radiator Valve Control

a. The radiator valve controller provides for inflight switching between TMV M9 and M14.

b. The controller valves M12, M15 with measurement input T1A and has a configuration selector.

c. The configuration selector has the following control inputs to the "Control Source Select" switch from "Sortie Lab" and "External Source:" (a) a controller power switch with position "ON" and "OFF," and (b) a switch with positions "Primary TMV" (M9) and "Secondary TMV" (M14), Measurement T1A, input to the controller and the output of this measurement to T/M is not to be interrupted by the "Control Source Select" switch or the controller being turned "OFF" in order to preserve measurement redundancy (Section II, B, 1, g).

d. When a controller is turned "OFF" all valves shall remain in their positions. All valves are pulse operated latching valves. To position valves M12, and M15 to the desired position the controller shall generate the positioning pulse five or more seconds long to the applicable side of the valve.

e. After completion of controller checkout, valves M12, M15 shall be positioned to flow freon to M9 as the primary mode. The controller shall monitor temperature T1A for indication of failures of M9 to maintain mix temperature drops to or below 32°F the valve controller will automatically change M12, M15 to the M14 position to prevent freezing the Lab coolant and generate a caution signal. Failures of M9 for high mix temperatures will be detected by other systems and M12, M15 repositioned manually by the switch of step 3.(b) above.

10. ECS Control Functions Not Using Controllers

a. This section is limited to miscellaneous control functions for fans, pumps, etc.

b. The following switches shall exist internal to the Lab and at an external source for the freon pump M21: (a) switch(s) with positions "Primary Pump ON," "Secondary Pump ON," "OFF," and (b) a switch with positions "Normal" and "Station Keeping."

c. The following switch(s) shall exist internal to the Lab and at an external source for water coolant pump M41: switch(s) with positions "Primary Pump ON," "Secondary Pump ON," and "OFF."

d. Valve M174 shall be tied to the "ON"-"OFF" switch for fan M170. When the fan is turned "ON" the valve shall open. When the fan is turned "OFF" the valve shall close. A second identical switch shall exist for the combination of fan M171 and valve M173. Switches shall be located internal to the Sortie Lab and at an external source.

e. The following switch shall exist internal to the Lab and at an external source for cabin heat exchanger fan M181: a switch with positions "ON" and "OFF."

f. The following switch shall exist internal to the Lab and at an external source for equipment heat exchanger fan M184: A switch with positions "ON" and "OFF."

11. Sortie Lab ECS Measurement List

The following are "Column Headings" and definitions of heading for the tabulated data presented at the end of this section.

a. "Measurement No." is taken from drawing No. 20M42719, Sortie Lab ECS Electro-Mechanical Schematic.

b. "Measurement Name" is the recommended measurement title.

c. "Range" is expressed as analog (0 - 5.0 VDC) with probable analog range called out (e.g. -32 + 120°F) or as discrete (0 or 28 VDC) with probable discrete value called out (e.g. "ON" > 100°F).

d. "Sample Rate" is expressed as minimum acceptable samples per minute at a normal sampling rate. Special minimum sample rates are marked by an asterisk (*). The times during which special sample rates are required are called out in "Remarks" columns.

e. "Handling" — How data is handled during flight and GSE checkout. "T/M" means telemetered to ground during flight. "R" means recorded by onboard recorders during flight. Both "T/M," "R" will operate at the prevailing sample rate of item d above. "GSE" means the measurement is required for system checkout activities on the ground. If a measurement does not have a "T/M" or "R" designation, then it is inoperative during flight. A "GSE" measurement must be available without delay during countdowns, if it has a redline application.

f. "Vehicle Display" — Data display requirements internal to flight vehicle. "SH/I" means displayed in shuttle on intermittant call-up basis. "SH/C" is continuous display in shuttle. "SL/I" is Space Lab intermittent call-up. "SL/C" is Space Lab continuous display.

g. "Ground Display" — Inflight display requirements on ground consoles. "G/I" is ground intermittent call-up. "G/C" is ground continuous display.

h. "Caution/Warning" — "C" designates a caution situation that may not require an immediate command decision. Many resulting decisions may depend upon the operating status of other ECS systems. "W" designates a warning applicable to structure, crew safety, or mission critical situations requiring a command decision.

i. "Remarks" contains additional information on the applicable measurement. A symbol "PE" in this column means the measurement requires pre-entry checkout before a crew enters the Sortie Lab.

ECS MEASUREMENT LIST

Vehicle Sortie Lab
Parameter Temperature
Original Date May 1973
Revised October 1973

Measurement No.	Measurement Name	Range		Sample Rate	Hand-ling	Vehicle Display	Ground Display	Caution/ Warning	Remarks
		VDC	Temp. (°F)						
T1A	Temp, R21 Inlet to Lab/Rad Interface Hx, Primary	0 to 5	25 to 60	60	T/M GSE	SH/I SL/I	G/I		A possible redline
TK1A	Lab/Rad Hex R21 Low Temp Warning & Hi Temp Caution	0 or 28	<32 >45	60	T/M GSE			W 32°F C 45°F	"C-W" Display on Sh, Sl, GND consoles.
T1B	Temp, R21 Inlet to Lab/Rad Rad Interface Hx, Secondary	0 to 5	25 to 60	60	T/M GSE		G/I		
T2A	Temp, Outlet of Preflight Hx, Primary	0 to 5	-100 to +100	2	T/M		G/I		Control sensor to preflt GSCU
T2B	Temp, Outlet of Preflight Hx, Secondary	0 to 5	-100 to +100	2	T/M		G/I		
T3A	Temp, Thermal Capacitor, Primary	0 to 5	-20 to 60	2	T/M GSE	SH/I SL/I	G/I		Primary Redline
T3B	Temp, Thermal Capacitor, Secondary	0 to 5	-20 to 60	2	T/M		G/I		Backup Redline to T3A
T4A	Temp, Water Coolant Supply, Primary	0 to 5	30 to 70	60	T/M GSE	SH/I SL/I	G/I		Output of Subl Cont
T4B	Temp, Water Coolant Supply, Secondary	0 to 5	30 to 70	60	T/M		G/I		
T5A	Temp, Air Supply to Thermal Racks, Sensible, Primary	0 to 5	40 to 120	2	T/M GSE	SH/I SL/I	G/I		Primary Redline
T5B	Temp, Air Supply to Thermal Racks, Sensible, Secondary	0 to 5	30 to 120	2	T/M		G/I		Backup Redline for T5A
T6A	Temp, Cabin Free Air Sensible, Primary	0 to 5	30 to 100	2	T/M GSE	SH/I SL/I	G/I		Primary Redline PE, Output of Cabin Temp Cont.
TK6A	Temp Caution, Cabin Free Air	0 or 28	on > TBD	2	T/M GSE			C	"C" Display on Sh, GND Consoles

ECS MEASUREMENT LIST

Vehicle Sortie Lab Parameter Temperature Original Date ______ Revised ______

Measurement No.	Measurement Name	Range		Sample Rate	Hand-ling	Vehicle Display	Ground Display	Caution/ Warning	Remarks
		VDC	Temp. (°F)						
T6B	Temp, Cabin Free Air Sensible Secondary	0 to-5	30 to 100	2	T/M GSE		G/I		Backup Redline for T6A, Output of Cabin Temp Cont
T7	Temp, O_2 Tank No. 1 Fluid	0 to 5	-320 to 80	1 10*	T/M GSE	SL/I	G/I		*Sample rate during fill/drain. Output of O_2 cont
T8	Temp, O_2 Tank No. 1 Heater	0 to 5	- 300 to 600	6 60*	T/M GSE	SL/I	G/I		*Sample rate during fill/drain. Output of O_2 Cont
T9	Temp, O_2 Tank No. 2 Fluid	0 to 5	-320 to 80	1 10*	T/M GSE	SL/I	G/I		*Sample rate during fill/drain. Output of O_2 Cont
T10	Temp, O_2 Tank No. 2 Heater	0 to 5	-300 to 600	6 60*	T/M GSE	SL/I	G/I		*Sample rate during fill/drain. Output of O_2 Cont
T11									
T12									
T13									
T14									
T15	Temp, H_2 Tank No. 1 Fluid	0 to 5	-420 to -200	1 10*	T/M GSE	SL/I	G/I		*Sample rate during fill/drain Output of H_2 cont
T16	Temp, H_2 Tank No. 2 Fluid	0 to 5	-420 to -200	1 10*	T/M GSE	SL/I	G/I		*Sample rate during fill/drain. Output of H_2 cont
T17	Temp, H_2 Tank No. 3 Fluid	0 to 5	-420 to -200	1 10*	T/M GSE	SL/I	G/I		*Sample rate during fill/drain. Output of H_2 Cont
T18									
T19									

ECS MEASUREMENT LIST

Vehicle Sortie Lab Parameter Temperature Original Date ______ Revised ______

Measurement No.	Measurement Name	Range		Sample Rate	Hand-ling	Vehicle Display	Ground Display	Caution/ Warning	Remarks
		VDC	Temp. (°F)						
T20A	Temp, GN_2 Bottle No. 1 Skin, Primary	0 to 5	-100 to 150	2	T/M	SL/I	G/I		
T20B	Temp, GN_2 Bottle No. 1 Skin, Secondary	0 to 5	-100 to 150	2	T/M	SL/I	G/I		
T21A	Temp, GN_2 Bottle No. 2 Skin, Primary	0 to 5	-100 to 150	2	T/M	SL/I	G/I		
T21B	Temp, GN_2 Bottle No. 2 Skin. Secondary	0 to 5	-100 to 150	2	T/M	SL/I	G/I		
T26	Temp, Surface of Rad No. 1	0 to 5	-100 to 100	2	T/M		G/I		
T27	Temp, Surface of Rad No. 2	0 to 5	-100 to 100	2	T/M		G/I		
T28A	Temp, Water Inlet to $R21/H_2O$ Hx, Primary	0 to 5	50 to 130	60	T/M GSE	SH/I SL/I	G/I		
T28B	Temp, Water Inlet to $R21/H_2O$ Hx, Secondary	0 to 5	50 to 130	60	T/M		G/I		
T29A	Temp, R21 at Pump Discharge Primary	0 to 5	50 to 150	60	T/M GSE	SH/I SL/I	G/I		Possible Redline
TK29A	High Temp Caution, R21 Pump Discharge, Primary	0 or 28	on > 120	2	T/M GSE			C	"C" Display on SH, SL, GND consoles, for fuel cell temp protection
T29B	Temp, R21 at Pump Discharge Secondary	0 to 5		60	T/M GSE	SH/I SL/I	G/I		
TK29B	High Temp Caution, R21 Pump Discharge, Secondary	0 or 28	on > 120	2	T/M GSE			C	"C" on GND Console.
T30	Temp, Air Return from Thermal Racks	0 to 5	70 to 130	2	T/M GSE	SH/I SL/I	G/I		Possible Redline

ECS MEASUREMENT LIST

Vehicle Sortie Lab Parameter Temperature Original Date ____________ Revised ____________

Measurement No.	Measurement Name	Range		Sample Rate	Hand-ling	Vehicle Display	Ground Display	Caution/ Warning	Remarks
		VDC	Temp. (°F)						
TK30	High Temp Caution, Air Return From Thermal Racks	0 or 28	on > 110	2	T/M GSE			C	"C" Display on SH, SL, GND consoles
T31									
T32	Temp, Setpoint of Cabin Temp Controller	0 to 5	40 to 80	2	T/M GSE		G/I		Output of Cabin Cont. Redline
T33A	Temp, Cabin Free Air Dewpoint, Primary	0 to 5	30 to 100	2	T/M GSE	SL/I	G/I		Possible Redline, PE
T33B	Temp, Cabin Free Air Dewpoint, Secondary	0 to 5	30 to 100	2	T/M GSE		G/I		

ECS MEASUREMENT LIST

Vehicle Sortie Lab Parameter Pressure Original Date ______ Revised ______

Measurement No.	Measurement Name	Range		Sample Rate	Hand-ling	Vehicle Display	Ground Display	Caution/ Warning	Remarks
		VDC	Pressure						
ΔP1A	ΔP, Freon Pump, Primary	0 to 5	0 to 40 psid	2 60*	T/M GSE	SH/I SL/I	G/I		Primary Redline *Rqd during checkout and launch
ΔPK1A	Low ΔP Warning, R21 Pump, Primary	0 or 28	on < TBD psid	2 60*	T/M GSE			W	"W" on SH, SL, GND consoles; *Rqd for checkout and launch
ΔP1B	ΔP, Freon Pump, Secondary	0 to 5	0 to 40 psid	2 60*	T/M GSE		G/I		Backup Redline for ΔP1A; *Rqd for checkout and launch
ΔPK1B	Low ΔP Warning, R21 Pump, Secondary	0 or 28	on < TBD psid	2 60*	T/M GSE			W	"W" on GND console. *Rqd for checkout and launch
PG2A	Pressure, Freon Pump Inlet, Primary	0 to 5	0 to 200 psig	2 60*	T/M GSE	SH/I SL/I	G/I		Primary Redline *Rqd during checkout and launch.
PKG2A	Low Inlet Pressure Caution, Freon Pump, Primary	0 or 28	on < TBD psig	2 60*	T/M GSE			C	"W" on SH, SL, GND consoles; *Rqd for checkout and launch
PG2B	Pressure, Freon Pump Inlet, Secondary	0 to 5	0 to 200 psig	2 60*	T/M GSE		G/I		Backup Redline to PG2A; *Rqd during checkout and launch
PKG2B	Low Inlet Pressure Caution, Freon Pump, Secondary	0 or 28	on < TBD psig	2 60*	T/M GSE			C	"W" on GND console; *Rqd for checkout and launch
ΔP3	ΔP, Bellows ΔP of H_2O Stowage Tank M84	0 to 5	± 7.0 psid	2 60*	T/M GSE	SL/I	G/I		Output of water cont. *Rqd during tank fill and drain on ground ΔP reads + psid when H_2O side press is higher than GN_2 side.
ΔPK3-1	Tank Empty indicator of H_2O Stowage Tank M84	0 or 28	Close on Decr @ $-3.5^{+.5}_{-.0}$ psid Open on rise @ $-2.0^{+0}_{-.5}$ psid	2 60*	T/M GSE			C	"C" displayedon SH, Sl, GND consoles. Control input to water controller. *Rqd during tank fill, drain. Output of water cont.

ECS MEASUREMENT LIST

Vehicle Sortie Lab Parameter Pressure Original Date ______ Revised ______

Measurement No.	Measurement Name	Range		Sample Rate	Hand-ling	Vehicle Display	Ground Display	Caution/ Warning	Remarks
		VDC	Pressure						
ΔPK3-2	Tank Full Indicator of H_2O Stowage tank M84	0 or 28	Close on rise @ 3.0 $^{+0}_{-.5}$ psid, Open on Decr @ 1.5 $^{+.5}_{-0}$	2 60*	T/M GSE			C	"C" displayed on SH, SL, GND consoles. Control input to water controller. *Rqd during tank fill, drain. Output of water cont.
ΔP4A	ΔP, Water Pump, Primary	0 to 5	0 to 50 psid	2 60*	T/M GSE	SH/I SL/I	G/I		Primary Redline *Rqd during checkout and launch.
ΔPK4A	Low ΔP Caution, H_2O Pump, Primary	0 or 28	on < TBD psid	2 60*	T/M GSE			C	"C" on SH, SL, GND consoles; *Rqd during chechout and launch.
ΔP4B	ΔP, Water Pump, Secondary	0 to 5	0 to 50 psid	2 60*	T/M GSE		G/I		Backup Redline for ΔP4A; *Rqd during checkout and launch
ΔPK4B	Low ΔP Caution, H_2O Pump, Secondary	0 or 28	on < TBD psid	2 60*	T/M GSE			C	"C" on GND console, *Rqd checkout and launch.
PG5A	Pressure, Water Pump Inlet, Primary	0 to 5	0 to 25 psig	2 60*	T/M GSE	SH/I SL/I	G/I		*Rqd during checkout and launch.
PKG5A	Low Inlet Press Caution, H_2O Pump Inlet, Primary	0 or 28	on < 13 psig	2 60*	T/M GSE			C	Primary Redline, "C" displayed on SH, SL, GND consoles, *rqd during checkout and launch.
PG5B	Pressure, Water Pump Inlet, Secondary	0 to 5	0 to 15 psig	2 60*	T/M GSE	SH/I SL/I	G/I		*Rqd during checkout and launch.
PKG5B	Low Inlet Press Caution, H_2O Pump Inlet, Secondary	0 or 28	on < 13 psig	2 60*	T/M GSE			C	Backup Redline to PKG5A; "C" displayed on GND console, *Rqd during checkout and launch.
PA6	Pressure, Sublimator Water Evaporant Inlet	0 to 5	0 to 10 psia	60	T/M GSE	SL/I	G/I		Output of Subl. Cont.

ECS MEASUREMENT LIST

Vehicle Sortie Lab Parameter Pressure Original Date ________ Revised ________

Measurement No.	Measurement Name	Range		Sample Rate	Hand-ling	Vehicle Display	Ground Display	Caution/ Warning	Remarks
		VDC	Pressure						
PKA6	Sublimator Evaporant Control Pressures	0 or 28	Close on fall @ 2 $^{+.5}_{-0}$ psia, Open on rise @ 5 $^{+0}_{-.5}$ psia	60	T/M GSE		G/I		Pressure control inputs for subl temp controller switch actions avail as outputs from subl cont.
PG7A	Pressure, Condensate Collection Tank, Primary	0 to 5	0 to -15 psig vacuum	2 60*	T/M GSE	SL/I	G/I		*Required during checkout and manual inflight operation. Outputs of cond cont.
PKG7A-1	Condensate Collection Tank Control Pressures, Primary	0 or 28	Open on fall @ -5.0 $^{+.2}_{-0}$ psig, close on rise @ -3.0 $^{+0}_{-.2}$ psig	2 60*	T/M GSE	SL/I	G/I		
PKG7A-2	Condensate Collection Tank High Pressure Caution, Primary	0 or 28	Open on fall @ -1 $^{+0}_{-.2}$ psig, close on rise @ -1 $^{+.2}_{-0}$ psig	2	T/M GSE	SL/I	G/I		
PG7B	Pressure, Condensate Collection Tank, Secondary	0 to 5	0 to -15 psig vacuum	2 60*	T/M GSE	SL/I	G/I		*Required during checkout and manual inflight operation. Outputs of cond. cont.
PKG7B-1	Condensate Collection Tank Control Pressures, Primary	0 or 28	Open on fall @ -5.0 $^{+.2}_{-0}$ psig, close on rise @ -3.0 $^{+0}_{-.2}$ psig	2 60*	T/M GSE	SL/I	G/I		

ECS MEASUREMENT LIST

Vehicle Sortie Lab Parameter Pressure Original Date __________ Revised __________

Measurement No.	Measurement Name	Range		Sample Rate	Hand-ling	Vehicle Display	Ground Display	Caution/ Warning	Remarks
		VDC	Pressure						
PKG7B-2	Condensate Collection Tank High Pressure Caution, Primary	0 or 28	Open on fall @$-1^{+0}_{-.2}$ psig Close on rise @ $-1^{+.2}_{-0}$ psig	2	T/M GSE	SL/I	G/I		
PA9A	Pressure, Cabin Total, Primary	0 or 28	0 to 17 psia	60	T/M GSE	SH/C SL/C	G/C		Primary Redline PE, output of atmos. cont.
PKA9A-1	Overpress Warning, Cabin Total Press, Primary	0 or 28	on $> 15^{+.1}_{-0}$ psia	60	T/M GSE			W	"W" on SH, SL, GND, output of atmos. cont.
PKA9A-2	Pressure Decay Warning, Cabin Total Press, Primary	0 or 28	Close for pressure decay rate > TBD psi/min	60	T/M GSE			W	
PKA9A-3	Total Cabin Press, Inhibit Signal to Cond. Cont., Primary	0 or 28	Open on rise @ $14^{+0}_{-.2}$ psia, Close on fall @ $10^{+.2}_{-0}$ psia	2	T/M GSE		G/I		Output of atmos. cont., input to cond. cont.
PA9B	Pressure, Cabin Total, Secondary	0 to 5	0 to 17 psia	60	T/M GSE	SH/I SL/I	G/I		Backup Redline for PA9A, output atmos. cont.
PKA9B-1	Overpress Warning, Cabin Total Press, Primary	0 or 28	on $> 15^{+.1}_{-0}$ psia	60	T/M GSE			W	"W" on GND consoles, output of atmos. cont.

ECS MEASUREMENT LIST

Vehicle Sortie Lab Parameter Pressure Original Date ____________ Revised ____________

Measurement No.	Measurement Name	Range		Sample Rate	Hand-ling	Vehicle Display	Ground Display	Caution/ Warning	Remarks
		VDC	Pressure						
PKA9B-2	Pressure Decay Warning, Cabin Total Press, Secondary	0 or 28	Close for pressure decay rate > TBD psi/min	60	T/M GSE			W	
PKA9B-3	Total Cabin Press Inhibit Signal to Cond Cont, Secondary	0 or 28	Open on rise @ $14^{+0}_{-.2}$ psia Close on fall @ $10^{+.2}_{-0}$ psia	2	T/M GSE		G/I		Output of atmos cont. input to cond. cont.
PA10A	Pressure, Reference gas bottle, Primary	0 to 5	0 to 3500 psia	2 60*	T/M GSE	SL/I	G/I		Primary Redline *Rqd checkout and launch.
PA10B	Pressure, Reference Gas Bottle, Secondary	0 to 5	0 to 3500 psia	2 60*	T/M GSE		G/I		Backup Redline for PG10A *Rqd checkout and prelaunch.
PA11A	Pressure Outlet of O_2 Regulator, Primary	0 to 5	0 to 150 psia	2 60*	T/M GSE	SH/I SL/I	G/I		Primary Redline *Rqd checkout, launch.
PKA11A	O_2 Supply Interval Timer Start Press, Primary	0 or 28	Close on rise, open on fall @ 100 ± 5 psia	2 60*	T/M GSE		G/I		*Rqd checkout, launch.
PA11B	Pressure, Outlet of O_2 Regulator, Secondary	0 to 5	0 to 150 psia	2 60*	T/M GSE		G/I		Backup Redline for PA11A; *Rqd checkout, launch.
PKA11B	O_2 Supply Interval Timer Start Press, Secondary	0 or 28	Close on rise, open on fall @ 100 ± 5 psia	2 60*	T/M GSE		G/I		*Rqd checkout, launch.

ECS MEASUREMENT LIST

Vehicle Sortie Lab Parameter Pressure Original Date ____________ Revised ____________

Measurement No.	Measurement Name	Range		Sample Rate	Hand-ling	Vehicle Display	Ground Display	Caution/ Warning	Remarks
		VDC	Pressure						
PA12A	Pressure, Outlet of N_2 Regulator, Primary	0 to 5	0 to 180 psia	2 60*	T/M GSE	SH/I SL/I	G/I		Redline, *Rqd checkout, launch,
PA12B	Pressure, Outlet of N_2 Regulator, Secondary	0 to 5	0 to 180 psia	2 60*	T/M GSE		G/I		Backup Redline for PA12A; *Rqd checkout, launch,
PKA13	Pressure, O_2 Cryo Tank No. 1 Press Sw	0 or 28	Open on rise @ 935 psia max. Close on fall @ 865 psia min	2 60*	T/M GSE		G/I		*Rqd for fill and drain. Output of O_2 Tank cont.
PA14	Pressure, O_2 Cryo Tank No. 1	0 to 5	50 to 1050 psia	2 60*	T/M GSE	SL/I	G/I	W@ > 1000 psia	Output of O_2 Tank Cont. Possible Redline. *Rqd for fill and drain. "W" on SH, SL, Gnd consoles.
PKA15	Pressure, O_2 Cryo Tank No. 2 Press Sw	0 or 28	Open on rise @ 935 psia max. Close on fall @ 865 psia min	2 60*	T/M GSE		G/I		*Rqd for fill and drain Output of O_2 Tank cont.
PA16	Pressure, O_2 Cryo Tank No. 2	0 to 5	50 to 1050 psia	2 60*	T/M GSE	SL/I	G/I	W @ > 1000 psia	Possible Redline. *Rqd for fill, drain, launch, Output of O_2 Tank cont. "W" on SH, SL, GND consoles.
P17, P18, P19, P20	N/A								
PKA21	Pressure, H_2 Cryo Tank No. 1 Press Sw	0 or 28	Open on rise @ 260 psia max. Close on fall @ 230 psia min	2 60*	T/M GSE		G/I		*Rqd for fill, drain, Output of H_2 Tank Cont.

ECS MEASUREMENT LIST

Vehicle Sortie Lab Parameter Pressure Original Date ______ Revised ______

Measurement No.	Measurement Name	Range		Sample Rate	Hand-ling	Vehicle Display	Ground Display	Caution/ Warning	Remarks
		VDC	Pressure						
PA22	Pressure, H_2 Cryo Tank No. 1	0 to 5	0 to 350 psia	2 60*	T/M GSE	SL/I	G/I	W @ > 270 psia	Output of H_2 Tank cont, Possible Redline, *Rqd for fill, drain, launch. "W" on SH, SL, GND consoles.
PKA23	Pressure, H_2 Cryo Tank No. 2 Press Sw	0 or 28	Open on rise @ 260 psia max. Close on fall @ 230 psia min	2 60*	T/M GSE		G/I		*Rqd for fill drain, output of H_2 Tank Cont.
PA24	Pressure, H_2 Cryo Tank No. 2	0 to 5	0 to 350 psia	2 60*	T/M GSE	SL/I	G/I	W @ > 270 psia	Output of H_2 Tank Cont. Possible Redline, *Rqd fill, drain, launch. "W" on SH, SL, GND consoles.
PKA25	Pressure, H_2 Cryo Tank No. 3 Press Sw	0 or 28	Open on rise @ 260 psia max. Close on fall @ 230 psia min	2 60*	T/M GSE		G/I		*Rqd for fill, drain, output of H_2 Tank Cont.
PA26	Pressure, H_2 Cryo Tank No. 3	0 to 5	0 to 350 psia	2 60*	T/M GSE	SL/I	G/I	W @ > 270 psia	Output of H_2 Tank Cont. Possible Redline. *Rqd fill, drain, launch. "W" on SH. SL, GND consoles.
P27, P28, P29, P30	N/A								
PA31A	Pressure, GN_2 Bottle No. 1 Lab Atmosphere, Primary	0 to 5	0 to 3500 psia	2 60*	T/M GSE	SL/I	G/I		Redline. *Rqd fill, drain, launch.
PA31B	Pressure, GN_2 Bottle No. 1 Lab Atmosphere, Secondary	0 to 5	0 to 3500 psia	2 60*	T/M GSE		G/I		Backup Redline for PA31A. *Rqd fill, drain, launch.
PA32A	Pressure, GN_2 Bottle No. 2 Lab Atmosphere, Primary	0 to 5	0 to 3500 psia	2 60*	T/M GSE		G/I		Redline. *Rqd fill, drain, launch.

ECS MEASUREMENT LIST

Vehicle Sortie Lab Parameter Pressure Original Date ______ Revised ______

Measurement No.	Measurement Name	Range		Sample Rate	Hand-ling	Vehicle Display	Ground Display	Caution/ Warning	Remarks
		VDC	Pressure						
PA32B	Pressure, GN_2 Bottle No. 2, Lab Atmosphere, Secondary	0 to 5	0 to 3500 psia	2 60*	T/M GSE		G/I		Backup Redline for PA32A. *Rqd fill, drain, launch
P33, P34, P35, P36, P37	N/A								
ΔP38	ΔP, Bellows ΔP of H_2O Stowage Tank M86	0 to 5	± 7.0 psid	2 60*	T/M GSE	SL/I	G/I		Output of water cont. *Rqd during tank fill and drain on ground. ΔP reads +psid when H_2O side press is higher than GN_2 side.
ΔPK38-1	Tank Empty Indicator of H_2O Stowage Tank M86	0 or 28	Close on decr @ $-3.5^{+.5}_{-0}$ psid Open on rise @ $-2.0^{+0}_{-.5}$ psid	2 60*	T/M GSE			C	"C" displayed on SH, SL, GND consoles. Control input to water controller. *Rqd during tank fill, drain. Output of water cont.
ΔPK38-2	Tank full Indicator of H_2O Stowage Tank M86	0 or 28	Close on rise @ $3.0^{+0}_{-.5}$ psid, Open on decr @ $1.5^{+.5}_{-0}$ psid	2 60*	T/M GSE			C	"C" displayed on SH. SL, GND consoles. Control input to water controller. *Rqd during tank fill, drain. Output of Water Cont.
PA39A	Pressure, Partial CO_2, Primary	0 to 5	0 to TBD mm	60	T/M GSE	SH/C SL/C	G/C		PE
PKA39A	High Partial CO_2 Pressure Warning Primary	0 or 28	on > TBD mm	6	T/M GSE			W	"W" displayed on SH, SL, GND consoles for high CO_2.

ECS MEASUREMENT LIST

Vehicle Sortie Lab Parameter Pressure Original Date ______ Revised ______

Measurement No.	Measurement Name	Range		Sample Rate	Hand-ling	Vehicle Display	Ground Display	Caution/ Warning	Remarks
		VDC	Pressure						
PA39B	Pressure, Partial CO_2, Secondary	0 to 5	0 to TBD mm	60	T/M GSE	SH/I SL/I	G/I		
PKA39B	High Partial CO_2 Pressure Warning, Secondary	0 or 28	on > TBD mm	6	T/M GSE			W	"W" displayed on GND consoles for high CO_2.
PA40-1	Pressure, Partial O_2, Sensor/ amplifier No. 1, T/M	0 to 5	0 to 6.4 psi 02	60	T/M GSE	SH/C	G/C		Derived from T/M output of O_2 sens/ amp no. 1. All outputs dead w/o K92. PE
PA40-2	Pressure, Partial O_2, Sensor/ amplifier No. 1, Meter			N/A	N/A	SL/C Panel Meter			Derived from 0–5 VDC meter output of O_2 sens/amp no. 1.
PKA40-1	Output from PPO2 Cont. No. 1 to Atm Cont.	0 or 28	on < TBD psi O_2	2 60*	T/M GSE		G/I		Derived from 0-5 VDC control output of sens/amp no. 1. *Rqd for checkout.
PKA40-2	No. 1 High PPO2 Warning	0 or 28	on > TBD psi O_2	2 60*	T/M			W	Derived from 0–5 VDC C&W output of sens/amp no. 1. *Rqd for checkout.
PKA40-3	No. 1 Low PPO2 Caution	0 or 28	on < TBD psi O_2	2 60*	T/M			C	"C&W" displayed on SH, SL, GND consoles.
PA41-1	Pressure, Partial O_2, Sensor/ Amplifier No. 2, T/M	0 to 5	0 to 6.4 psi O_2	60	T/M GSE	SH/I	G/I		Derived from T/M output of O_2 sens/ amp no. 2. All outputs dead w/o K94.
PA41-2	Pressure, Partial O_2, Sensor/ Amplifier No. 2, Meter		N/A	N/A	N/A	SL/C Panel Meter			Derived from 0–5 VDC meter output of O_2 Sens/amp No. 2.
PKA41-1	Output from PP O_2 Cont. No. 2 to Atm Cont.	0 or 28	on < TBD psi O_2	2 60*	T/M GSE		G/I		Derived from 0–5 VDC control output or sens/amp no. 2. *Rqd for checkout.
PKA41-2	No. 2 High PP O_2 Warning	0 or 28	on > TBD psi O_2	2 60*	T/M			W	Derived from 0–5 VDC C&W output of no. 2. *Rqd for checkout. "C&W" displayed on SH, SL, GND consoles.

ECS MEASUREMENT LIST

Vehicle Sortie Lab Parameter Pressure Original Date ________ Revised ________

Measurement No.	Measurement Name	Range		Sample Rate	Hand-ling	Vehicle Display	Ground Display	Caution/ Warning	Remarks
		VDC	Pressure						
PKA41-3	No. 2 Low PPO2 Caution	0 or 28	on < TBD psi O_2	2 60*	T/M			C	Derived from 0-5 VDC C&W output of sens/amp no. 2. *Rqd for checkout. "C&W" displayed on SH, SL, GND consoles.
PA42-1	Pressure, Partial O_2, Sensor/ Amplifier No. 3, T/M	0-5	0 to 6.4 psi O_2	60	T/M GSE	SH/I	G/I		Derived from T/M output of O_2 sens/ amp No. 3. All outputs dead W/O K96.
PA42-2	Pressure, Partial O_2, Sensor/ Amplifier No. 3, Meter			N/A	N/A	SL/C			Derived from 0-5 VDC meter output of 02 sens/amp No. 3.
PKA42-1	Output from PPO2 Cont. No. 3 to Atm Cont.	0 or 28	on < TBD psi O_2	2 60*	T/M GSE		G/I		Derived from 0-5 VDC control output of sens/amp No. 3. *Rqd for checkout.
PKA42-2	No. 3 High PPO2 Warning	0 or 28	on > TBD psi O_2	2 60*	T/M			W	Derived from 0-5 VDC C&W output of sens/amp No. 3. *Rqd for checkout. "C&W" dispayed on SH, SL, GND consoles.
PKA42-3	No. 3 Low PPO2 Caution	0 or 28	on < TBD psi O_2	2 60*	T/M			C	

ECS MEASUREMENT LIST

Vehicle Sortie Lab Parameter Flow Original Date ______ Revised ______

Measurement No.	Measurement Name	Range		Sample Rate	Hand-ling	Vehicle Display	Ground Display	Caution/ Warning	Remarks
		VDC	Flow						
F1A	Cabin Fan Flow Switch, Primary	0 or 28	on > TBD CFM	2	T/M GSE	SH/I	G/I	W	Poss Redline. Control input to cabin temp cont "A". "W" on SH, SL, GND consoles PE. Output of cabin temp cont.
F1B	Cabin Fan Flow Switch, Secondary	0 or 28	on > TBD CFM	2	T/M GSE		G/I		Control intput to cabin temp controller "B" Switch output from cabin temp cont.
F2	Equipment Fan Flow Switch	0 or 28	on > TBD CFM	2	T/M GSE			W	Possible Redline. "W" displayed on SH, SL, GND consoles.
F3	CO_2/Humidity Fan M170 Flow Switch	0 or 28	on > TBD CFM	2	T/M GSE		G/I		Possible Redline
F4	CO_2/Humidity Fan M171 Flow Switch	0 or 28	on > TBD CFM	2	T/M GSE		G/I		Possible Redline
F5	Bubble Detector Flow Sensor, M14 M148	0 or 28	on > TBD counts/hr	2	T/M GSE			C	"C" displayed on SL, GND consoles.
F6	Bubble Detector Flow Sensor, M147	0 or 28	on > TBD counts/hr	2	T/M GSE			C	"C" displayed on SL, GND consoles.

ECS MEASUREMENT LIST

Vehicle Sortie Lab   Parameter Quantity   Original Date __________   Revised __________

Measurement No.	Measurement Name	Range		Sample Rate	Hand-ling	Vehicle Display	Ground Display	Caution/ Warning	Remarks
		VDC	% (lb/f^3)						
L1	Quantity, Fluid Density, O_2 Tank No. 1	0 to 5	0 to 100 (1.39 to 69.5)	2 120*	T/M GSE	SL/I	G/I		Possible Redline. *Rqd for fill, drain, output from O_2 tank cont.
L2	Quantity, Fluid Density, O_2 Tank No. 2	0 to 5	0 to 100 (1.39 to 69.5)	2 120*	T/M GSE	SL/I	G/I		Possible Redline. *Rqd fill, drain, output from O_2 tank cont.
L3									
L4									
L5	Quantity, Fluid Density, H_2 Tank No. 1	0 to 5	0 to 100 (0.17 to 4.31)	2 120*	T/M GSE	SL/I	G/I		Possible Redline. *Rqd fill, drain, output of H_2 Tank cont.
L6	Quantity, Fluid Density, H_2 Tank No. 2	0 to 5	0 to 100 (0.17 to 4.31)	2 120*	T/M GSE	SL/I	G/I		Possible Redline. *Rqd fill, drain, output of H_2 Tank cont.
L7	Quantity, Fluid Density, H_2 Tank No. 3	0 to 5	0 to 100 (0.17 to 4.31)	2 120*	T/M GSE	SL/I	G/I-		Possible Redline. *Rqd fill, drain, output of H_2 Tank cont.

ECS MEASUREMENT LIST

Vehicle Sortie Lab Parameter Position Original Date ______ Revised ______

Measurement No.	Measurement Name	Range		Sample Rate	Hand-ling	Vehicle Display	Ground Display	Caution/ Warning	Remarks
		VDC							
G1	Water Controller, Water Dump Function: NORM DUMP, H_2O	0 or 28		2	T/M GSE	SH/I SL/I	G/I		Output of water controller. Occurs with K3 signal input to controller.
G2	Water Controller, Water Dump Function: FORCED DUMP, H_2O	0 or 28		60	T/M GSE			W	"W" displayed on SH, SL, GND consoles. Output of water cont. occurs with ΔPK3-2 event.
G3									
G4	Water Controller, Water Use Function: H_2O IN USE	0 or 28		2	T/M GSE		G/I		Output of water controller.
G5	Water Controller, Water Use Function: H_2O USE INHIBITED	0 or 28		2	T/M GSE			C	"C" displayed on SL, GND consoles. Output of water controller, input to sublimator controller occurs with ΔPK3-1.
G6	Sublimator Controller, Water Feed Function: SUBL H_2O VALVE OPEN	0 or 28		60	T/M R GSE		G/I		"R" is tocount the number of openings of valve M91. Output of sublimator controller.
G7	Sublimator Controller, Water Feed Function: SUBL H_2O VALVE CLOSED	0 or 28		60	T/M GSE		G/I		Output of Sublimator controller.
G8	Cabin Temp Cont, Selector Valve Position: CABIN CONT POS A	0 or 28		2	T/M GSE		G/I		Output of Cabin Temp Cont.
G9	Cabin Temp Cont, Selector Valve Position: CABIN CONT POS B	0 or 28		2	T/M GSE		G/I		Output of Cabin Temp Cont.
G10									
G11									

ECS MEASUREMENT LIST

Vehicle Sortie Lab Parameter Position Original Date ________ Revised ________

Measurement No.	Measurement Name	Range		Sample Rate	Hand-ling	Vehicle Display	Ground Display	Caution/ Warning	Remarks
		VDC							
G12									
G13									
G14	Condensate Cont. Col. Tank Evac. Valves Positions: COND COL EVAC VALVE OPEN	0 or 28		10	T/M R GSE	SL/I	G/I		Output of Cond Cont. occurs with PKG7A or PKG7B. "R" counts valve cycles for quantity est.
G15	Condensate Cont., Col. Tank Evac. Valves Positions: COND COL EVAC VALVE CLOSED	0 or 28		10	T/M GSE		G/I		Output of cond. cont. not present when G14 is occurring.
G16	Condensate Cont., Launch Valve Positoin: COND LAUNCH V CLOSED	0 or 28		10	T/M GSE	SL/I	G/I		Redline
G17	Condensate Cont., Launch Valve Position: COND LAUNCH V OPEN	0 or 28		10	T/M GSE		G/I		Backup Redline for G16.
G18									
G19									
G20	Condensate Cont., Cond Hx Bypass Valve Position: COND HX BYPASS	0 or 28		2	T/M GSE		G/I		Output of cond. cont. Bypass occurs when dewpoint drops below min acceptable level derived from T33A or T33B
G21	Condensate Cont., Cond Hx Bypass Valve Position: COND HX NORM	0 or 28		2	T/M GSE		G/I		Output of cond. cont. Not present when G20 is occurring.
G22	Condensate Cont., Cond. Dump Valves Position: COND DUMP VALVES ON	0 or 28		10	T/M GSE	SH/I SL/I	G/I	C	Output of cond. cont. occurs with K33. "C" on SH, SL, GND consoles. Backup Redline for G23.

ECS MEASUREMENT LIST

Vehicle Sortie Lab Parameter Position Original Date ______ Revised ______

Measurement No.	Measurement Name	Range		Sample Rate	Hand-ling	Vehicle Display	Ground Display	Caution/ Warning	Remarks
		VDC							
G23	Condensate Cont., Cond. Dump Valves Position: COND DUMP VALVES OFF	0 or 28		10	T/M GSE		G/I		Output of cond. cont. Not present when G22 is occurring. Redline.
G24	Atm Cont., Cabin Depress Valves Position: CABIN DEPRESS VALVE OPEN	0 or 28		10	T/M GSE			W	Output of atm. cont. "W" on SH, SL, GND consoles, Backup RL to G32.
G25									
G26									
G27									
G28	Atm Cont., O_2 Supply Valves Position: O_2 SUPPLY VALVE OPEN	0 or 28		2	T/M GSE	SH/I SL/I	G/I		Output of atm cont. Backup redline to G29
G29	Atm Cont., O_2 Supply Valves Position: O_2 SUPPLY VALVE CLOSED	0 or 28		2	T/M GSE				Output of atm cont. Redline.
G30	Atm Cont., N_2 Supply Valves Position: N_2 SUPPLY VALVE OPEN	0 or 28		2	T/M GSE	SH/I SL/I	G/I		Output of atm. cont. Backup Redline to G31
G31	Atm Cont., N_2 Supply Valves Position: N_2 SUPPLY VALVE CLOSED	0 or 28		2	T/M GSE		G/I		Output of atm cont. Redline
G32	Atm Cont., Cabin Depress Valves Position: CABIN DEPRESS VALVE CLOSED	0 or 28		10	T/M GSE		G/I		Output of atm. cont. Redline

ECS MEASUREMENT LIST

Vehicle Sortie Lab Parameter Position Original Date ____ Revised ____

Measurement No.	Measurement Name	Range		Sample Rate	Hand-ling	Vehicle Display	Ground Display	Caution/ Warning	Remarks
		VDC							
G33	Atm Cont., O_2/N_2 Selector Valve Position: SELECTOR VALVE O_2 POS	0 or 28		2	T/M GSE	SH/I SL/I	G/I		Output of Atm Cont.
G34	Atm Cont., O_2/N_2 Selector Valve Position: SELECTOR VALVE, N_2 POS	0 or 28		2	T/M GSE		G/I		Output of Atm. Cont.
G35	Rad Cont, TMV Flow Path Sel Valve Position: PRIMARY TMV (M9)	0 or 28		2	T/M GSE	SL/I	G/I		Output of Rad Cont. Redline
G36	Rad Cont, TMV Flow Path Sel Valve Position: SECONDARY TMV (M14)	0 or 28		2	T/M GSE	SL/I	G/I	C	Output of Rad Cont. Backup Redline to G35. "C" on SH, SL, GND consoles.
G37, G38									
G39									
G40									

ECS MEASUREMENT LIST

Vehicle Sortie Lab Parameter Signal Original Date ________ Revised ________

Measurement No.	Measurement Name	Range		Sample Rate	Hand-ling	Vehicle Display	Ground Display	Caution/ Warning	Remarks
		VDC							
K1	Water Controller, Source Select SW Position: INTERNAL	0 or 28		2	T/M		G/I		Output of water controller.
K2	Water Controller, Source Select SW Position: EXTERNAL	0 or 28		2	T/M GSE	SH/I	G/I		Output of water controller. Redline
K3	Water Controller, Water Dump SW Position: H_2O DUMP ON	0 or 28		2	T/M GSE	SH/I SL/C	G/I		Output of water cont. Backup Redline for K4
K4	Water Controller, Water Dump SW Position: H_2O DUMP OFF	0 or 28		2	T/M GSE		G/I		Output of water controller. Redline
K5	Water Controller, Power SW Position: H_2O CONT ON	0 or 28		2	T/M GSE	SH/I SL/I	G/I		Output of water cont. Backup Redline for K6
K6	Water Controller, Power SW Position: H_2O CONT OFF	0 or 28		2	T/M GSE		G/I		Output of water controller. Redline
K7	Sublimator Controller, Source Sel. SW Position: INTERNAL	0 or 28		2	T/M		G/I		Output of sublimator controller.
K8	Sublimator Controller, Source SW Position: EXTERNAL	0 or 28		2	T/M GSE	SH/I	G/I		Output of sublimator controller. Redline
K9	Sublimator Controller, Power SW Position: SUBL ON	0 or 28		2	T/M GSE	SH/I SL/C	G/I		Output of subl cont. Backup Redline for K10
K10	Sublimator Controller, Power SW Position: SUBL OFF	0 or 28		2	T/M GSE		G/I		Output of sublimator controller. Redline
K11	Cabin Temp Cont, Source Select SW Position: INTERNAL	0 or 28		2	T/M		G/I		Output of cabin temp cont.
K12	Cabin Temp Cont, Source Select SW Position: EXTERNAL	0 or 28		2	T/M GSE	SH/I	G/I		Output of cabin temp cont. Redline

ECS MEASUREMENT LIST

Vehicle Sortie Lab Parameter Signal Original Date ________ Revised ________

Measurement No.	Measurement Name	Range		Sample Rate	Hand-ling	Vehicle Display	Ground Display	Caution/ Warning	Remarks
		VDC							
K13	Cabin Temp Cont, Power SWS Position: CABIN CONT A ON	0 or 28		2	T/M GSE	SL/I	G/I		Output of cabin temp cont. Redline
K14	Cabin Temp Cont, Power SWS Position: CABIN CONT A OFF	0 or 28		2	T/M GSE	SL/I	G/I		Output of cabin temp cont. Backup Redline for K13.
K15	Cabin Temp Cont Power SWS Position: CABIN CONT B ON	0 or 28		2	T/M GSE	SL/I	G/I		Output of cabin temp cont. Alternate redline to K13
K16	Cabin Temp Cont Power SWS Position: CABIN CONT B OFF	0 or 28		2	T/M GSE	SL/I	G/I		Output of cabin temp cont. Backup redline to K15
K17	Cabin Temp Cont. Heater Pwr SW: CABIN HTR AUTO	0 or 28		2	T/M GSE	SL/C	G/I		Output of cabin temp cont. Backup Redline to K18
K18	Cabin Temp Cont Heater Pwr SW: CABIN HTR INHIBIT	0 or 28		2	T/M GSE		G/I		Output of cabin temp cont. Redline
K19	Cabin Temp Cont Heater Element: CABIN HTR ON	0 or 28		2	T/M GSE	SL/C	G/I		Output of cabin temp cont.
K20	Cabin Temp Cont Heater Element: CABIN HTR OFF	0 or 28		2	T/M GSE		G/I		Output of cabin temp cont.
K21									
K22									
K23									
K24									
K25									
K26									

ECS MEASUREMENT LIST

Vehicle Sortie Lab Parameter Signal Original Date ____ Revised ____

Measurement No.	Measurement Name	Range		Sample Rate	Hand-ling	Vehicle Display	Ground Display	Caution/ Warning	Remarks
		VDC							
K27	Condensate Cont Source Sel SW Position: INTERNAL	0 or 28		2	T/M		G/I		Output of condensate cont.
K28	Condensate Cont Source Sel SW Position: EXTERNAL	0 or 28		2	T/M GSE	SH/I	G/I		Output of condensate cont. Redline
K29	Condenstae Cont, Power SWS Position: COND CONT A ON	0 or 28		2	T/M GSE	SL/I	G/I		Output of cond cont. Redline
K30	Condensate Cont, Power SWS Position: COND CONT A OFF	0 or 28		2	T/M GSE	SL/I	G/I		Output of cond cont. Backup Redline to K29
K31	Condensate Cont, Power SWS Position: COND CONT B ON	0 or 28		2	T/M GSE	SL/I	G/I		Output of cond cont. Alternate Redline to K29
K32	Condensate Cont, Power SWS Position: COND CONT B OFF	0 or 28		2	T/M GSE	SL/I	G/I		Output of cond cont. Backup Redline to K31
K33	Condensate Cont, Dump SW Position: COND DUMP INITIATE	0 or 28		2	T/M GSE	SL/C	G/I		Output of cond cont for any dump event.
K34	Condensate Cont, Flow Sensors Status: ON	0 or 28		2	T/M GSE	SL/I	G/I		Output of cond cont.
K35	Condensate Cont, Flow Sensors Status: OFF	0 or 28		2	T/M GSE	SL/I	G/I		Output of cond cont.
K36									
K37									
K38	Condensate Cont, Press Launch SW Position: COND FLOW INHIBIT	0 or 28		2	T/M GSE	SH/I SL/C	G/I		Output of cond cont and a function of cabin dewpoint.
K39	Condensate Cont, Press Launch SW Position: COND FLOW NORM	0 or 28		2	T/M GSE		G/I		Output of cond cont and a function of cabin dewpoint.

ECS MEASUREMENT LIST

Vehicle Sortie Lab Parameter Signal Original Date __________ Revised __________

Measurement No.	Measurement Name	Range		Sample Rate	Hand-ling	Vehicle Display	Ground Display	Caution/ Warning	Remarks
		VDC							
K40	O_2 Cont, Source Select SW Position: INTERNAL	0 or 28		2	T/M		G/I		Output of O_2 cont.
K41	O_2 Cont, Source Select SW Position: EXTERNAL	0 or 28		2	T/M GSE	SH/I	G/I		Output of O_2 cont. Redline
K42	O_2 Cont, Tank No. 1 Subcont SW Position: O_2 TANK NO. 1 ON	0 or 28		2	T/M GSE	SL/I	G/I		Output of O_2 cont.
K43	O_2 Cont, Tank No. 1 Subcont SW Position: O_2 TANK NO. 1 OFF	0 or 28		2	T/M GSE		G/I		Output of O_2 cont.
K44	O_2 Cont, Tank No. 2 Subcont Sw Position: O_2 TANK NO. 2 ON	0 or 28		2	T/M GSE	SL/I	G/I		Output of O_2 cont.
K45	O_2 Cont, Tank No. 2 Subcont SW Position: O_2 TANK NO. 2 OFF	0 or 28		2	T/M GSE		G/I		Output of O_2 Cont.
K46	O_2 Cont, Tank No. 1 Heater Pwr: O_2 TANK NO. 1 HTR ON	0 or 28		6 60*	T/M GSE		G/I		*Rqd during fill/drain. Output of O_2 cont.
K47	O_2 Cont, Tank No. 1 Heater Pwr: O_2 TANK NO. 1 HTR OFF	0 or 28		6 60*	T/M GSE		G/I		*Rqd during fill/drain. Output of O_2 cont.
K48	O_2 Cont, Tank No. 2 Heater Pwr: O_2 TANK NO. 2 HTR ON	0 or 28		6 60*	T/M GSE		G/I		*Rqd during fill/drain. Output of O_2 cont.
K49	O_2 Cont, Tank No. 2 Heater Pwr: O_2 TANK NO. 2 HTR OFF	0 or 28		6 60*	T/M GSE		G/I		*Rqd during fill/drain. Output of O_2 cont.

ECS MEASUREMENT LIST

Vehicle Sortie Lab Parameter Signal Original Date ______ Revised ______

Measurement No.	Measurement Name	Range		Sample Rate	Hand-ling	Vehicle Display	Ground Display	Caution/ Warning	Remarks
		VDC							
K50	O_2 Cont, Density Bypass SW Position: O_2 DENSITY COMP ON	0 or 28		2	T/M GSE	SL/I	G/I		Output of O_2 cont.
K51	O_2 Cont, Density Bypass SW Position: O_2 DENSITY COMP OFF	0 or 28		2	T/M GSE		G/I		Output of O_2 cont.
K52	H_2 Cont, Source Select SW Position: INTERNAL	0 or 28		2	T/M		G/I		Output of H_2 cont.
K53	H_2 cont, Source Select SW Position: EXTERNAL	0 or 28		2	T/M GSE	SH/I	G/I		Output of H_2 cont. Redline
K54	H_2 Cont, Tank No. 2 Subcont SW Position: H_2 TANK NO. 1 ON	0 or 28		2	T/M GSE	SL/I	G/I		Output of H_2 cont.
K55	H_2 Cont, Tank No. 1 Subcont SW Position: H_2 TANK NO. 1 OFF	0 or 28		2	T/M GSE		G/I		Output of H_2 cont.
K56	H_2 Cont, Tank No. 2 Subcont SW Position: H_2 TANK NO. 2 ON	0 or 28		2	T/M GSE	SL/I	G/I		Output of H_2 cont.
K57	H_2 cont, Tank No. 2 Subcont SW Positon: H_2 TANK NO. 2 OFF	0 or 28		2	T/M GSE		G/I		Output of H_2 cont.
K58	H_2 Cont, Tank No. 3 Subcont SW Position: H_2 TANK NO. 3 ON	0 or 28		2	T/M GSE	SL/I	G/I		Output of H_2 cont.
K59	H_2 Cont, Tank No. 3 Subcont SW Position: H_2 TANK NO. 3 OFF	0 or 28		2	T/M GSE		G/I		Output of H_2 cont.

ECS MEASUREMENT LIST

Vehicle Sortie Lab Parameter Signal Original Date ____ Revised ____

Measurement No.	Measurement Name	Range		Sample Rate	Hand-ling	Vehicle Display	Ground Display	Caution/ Warning	Remarks
		VDC							
K60									
K61									
K62									
K63									
K64	H_2 Cont, Density Bypass SW Position: H_2 DENSITY COMP ON	0 or 28		2	T/M GSE	SL/I	G/I		Output of H_2 cont.
K65	H_2 Cont, Density Bypass SW Position: H_2 DENSITY COMP OFF	0 or 28		2	T/M GSE		G/I		Output of H_2 cont.
K66	H_2 Cont, Tank No. 1 Fan Power: H_2 TANK NO. 1 FAN ON	0 or 28		2	T/M GSE	SL/I	G/I		Output of H_2 cont.
K67	H_2 Cont, Tank No. 1 Fan Power: H_2 TANK NO. 1 FAN OFF	0 or 28		2	T/M GSE		G/I		Output of H_2 cont.
K68	H_2 Cont, Tank No. 2 Fan Power: H_2 TANK NO. 2 FAN ON	0 or 28		2	T/M GSE	SL/I	G/I		Output of H_2 cont.
K69	H_2 Cont, Tank No. 2 Fan Power: H_2 TANK NO. 2 FAN OFF	0 or 28		2	T/M GSE		G/I		Output of H_2 cont.
K70	H_2 Cont, Tank No. 3 Fan Power: H_2 TANK NO. 3 FAN ON	0 or 28		2	T/M GSE	SL/I	G/I		Output of H_2 cont.

ECS MEASUREMENT LIST

Vehicle Sortie Lab Parameter Signal Original Date ______ Revised ______

Measurement No.	Measurement Name	Range		Sample Rate	Hand-ling	Vehicle Display	Ground Display	Caution/ Warning	Remarks
		VDC							
K71	H_2 Cont, Tank No. 3, Fan Power: H_2 TANK NO. 3 FAN OFF	0 or 28		2	T/M GSE		G/I		Output of H_2 cont.
K72									
K73									
K74									
K75									
K76	H_2 Cont, Tank No. 1 Heater Pwr: H_2 TANK NO. 1 HTR ON	0 or 28		6 60*	T/M GSE		G/I		*Rqd during fill/drain. Output of H_2 cont.
K77	H_2 Cont Tank No. 1 Heater Pwr: H_2 TANK NO. 1 HTR OFF	0 or 28		6 60*	T/M GSE		G/I		*Rqd during fill/drain. Output of H_2 cont.
K78	H_2 Cont Tank No. 2 Heater Pwr: H_2 TANK NO. 2 HTR ON	0 or 28		6 60*	T/M GSE		G/I		*Rqd during fill/drain. Output of H_2 cont.
K79	H_2 Cont Tank No. 2 Heater Pwr: H_2 TANK NO. 2 HTR OFF	0 or 28		6 60*	T/M GSE		G/I		*Rqd during fill/drain. Output of H_2 cont.
K80	H_2 Cont Tank No. 3 Heater Pwr: H_2 TANK NO. 3 HTR ON	0 or 28		6 60*	T/M GSE		G/I		*Rqd during fill/drain. Output of H_2 cont.
K81	H_2 Cont Tank No. 3 Heater Pwr: H_2 TANK NO. 3 HTR OFF	0 or 28		6 60*	T/M GSE		G/I		*Rqd during fill/drain. Output of H_2 cont.
K82									

ECS MEASUREMENT LIST

Vehicle Sortie Lab Parameter Signal Original Date ______ Revised ______

Measurement No.	Measurement Name	Range		Sample Rate	Hand-ling	Vehicle Display	Ground Display	Caution/ Warning	Remarks
		VDC							
K83									
K84									
K85									
K86	Atm Cont, Source Sel SW Position: INTERNAL	0 or 28		2	T/M		G/I		Output of atm cont.
K87	Atm Cont, Source Sel SW Position: EXTERNAL	0 or 28		2.	T/M GSE	S/I	G/I		Output of atm cont. Redline
K88	Atm Cont, Pwr SWS Position: ATM CONT A ON	0 or 28		2	T/M GSE	SL/I	G/I		Output of atm cont. Redline
K89	Atm Cont, Pwr SWS Position: ATM CONT A OFF	0 or 28		2	T/M GSE	SL/I	G/I		Output of atm cont. Backup redline for K88
K90	Atm Cont, Pwr SWS Position: ATM CONT B ON	0 or 28		2	T/M GSE	SL/I	G/I		Output of atm cont. Alternative redline for K88
K91	Atm Cont, Pwr SWS Position: ATM CONT B OFF	0 or 28		2	T/M GSE	SL/I	G/I		Output of atm cont. Backup redline for K90
K92	Atm Cont, PPO2 SWS Position: PPO2 SENS& CONT NO. 1 OFF	0 or 28		2	T/M GSE	SL/I	G/I		Output of atm cont. Redline
K93	Atm Cont, PPO2 SWS Position: PPO2 SENS & CONT NO. 1 OFF	0 or 28		2	T/M GSE		G/I		Output of atm cont. Backup Redline for K92
K94	Atm Cont, PPO2 SWS Position: PPO2 SENS & CONT NO. 2 ON	0 or 28		2	T/M GSE	SL/I	G/I		Output of atm cont. Redline
K95	Atm Cont, PPO2 SWS Position: PPO2 SENS & CONT NO. 2 OFF	0 or 28		2	T/M GSE		G/I		Output of Atm cont. Backup Redline for K94

ECS MEASUREMENT LIST

Vehicle Sortie Lab Parameter Signal Original Date ____ Revised ____

Measurement No.	Measurement Name	Range		Sample Rate	Hand-ling	Vehicle Display	Ground Display	Caution/ Warning	Remarks
		VDC							
K96	Atm Cont, PPO2 SWS Position: PPO2 SENS & CONT NO. 3 ON	0 or 28		2	T/M GSE	SL/I	G/I		Output of Atm cont. Alternative Redline for K92 and K94
K97	Atm Cont, PPO2 SWS Position: PPO2 SENS / CONT NO. 3 OFF	0 or 28		2	T/M GSE		G/I		Output of atm cont. Backup Redline for K96
K98	Atms Cont, PPO2 Cont Mode SW: PPO2 CONT NO. 1 USE	0 or 28		2	T/M GSE	Visual SW Pos in SL	G/I	C	Output of atm cont. "C" at absence of K92. "C" Redline, on SH, SL, GND console.
K99	Atms Cont, PPO2 Cont Mode SW: PPO2 CONT NO. 2 USE	0 or 28		2	T/M GSE	Visual SW Pos in SL	G/I	C	Output of atm cont. "C" at absence of K94. "C" is Redline, on SH, SL, GND console.
K100	Atms Cont, PPO2 Cont Mode SW: PPO2 CONT NO. 3 USE	0 or 28		2	T/M GSE	Visual SW Pos in SL	G/I	C	Output of atm cont. "C" at absence of K96. "C" is Redline, on SH, SL, GND console.
K101	Atms Cont, PPO2 Cont Mode SW: O_2 MANUAL ADDITION	0 or 28		2	T/M GSE	Visual SW Pos in SL	G/I	C	Output of atm cont. "C" is Redline on SH, SL, GND consoles (no launch in this mode).
K102	Atms Cont, PPO2 Cont mode SW: O_2 FEED OFF	0 or 28		2	T/M GSE	Visual SW Pos in SL	G/I		Output of atm cont. Backup Redline to K98, K99, K100, K101.
K103	Atms Cont, O_2 Supply SW: O_2 SUPPLY ON	0 or 28		2	T/M GSE	SL/I	G/I		Output of atm cont. Backup Redline for K104.
K104	Atms Cont, O_2 Supply SW: O_2 SUPPLY OFF	0 or 28		2	T/M GSE		G/I		Output of atm cont. Backup Redline for G29.
K105	Atms Cont, N_2 Supply SW: N_2 SUPPLY ON	0 or 28		2	T/M GSE	SL/I	G/I		Output of Atm cont. Back up Redline for K106.

ECS MEASUREMENT LIST

Vehicle Sortie Lab Parameter Signal Original Date ____ Revised ____

Measurement No.	Measurement Name	Range		Sample Rate	Hand-ling	Vehicle Display	Ground Display	Caution/ Warning	Remarks
		VDC							
K106	Atms Cont, N_2 Supply SW: N_2 SUPPLY OFF	0 or 28		2	T/M GSE		G/I		Output of atm cont. Backup Redline for G31.
K107	Atms Cont, Depress SW: LAB DEPRESS ON	0 or 28		2	T/M GSE	SH/I	G/I		Output of atm cont. Backup Redline for K108.
K108	Atms Cont, Depress SW: LAB DEPRESS OFF	0 or 28		2	T/M GSE				Output of Atm Cont. Backup Redline for G32.
K109									
K110									
K111									
K112									
K113	Rad Valve Cont Source Select SW Position: INTERNAL	0 or 28		2	T/M		G/I		Output of radiator cont.
K114	Rad Valve Cont Source Select SW Position: EXTERNAL	0 or 28		2	T/M GSE	SH/I	G/I		Output of radiator cont. Redline
K115	Rad Valve Cont Power SWS Position: RAD VALVE CONT ON	0 or 28		2	T/M GSE	SL/I	G/I		Output of rad cont. Redline
K116	Rad Valve Cont Power SWS Position: RAD VALVE CONT OFF	0 or 28		2	T/M GSE	SL/I	G/I		Output of rad cont. Backup Redline for K115
K117	Rad Valve Cont Flow Direction: FLOW TO SECONDARY TMV	0 or 28		2	T/M GSE	SL/I	G/I		Output of rad cont. Backup Redline
K118	Rad Valve Cont Flow Direction: FLOW TO SECONDARY TMV	0 or 28		2	T/M GSE	SL/I	G/I		Output of rad cont. Backup Redline for K117.

ECS MEASUREMENT LIST

Vehicle Sortie Lab Parameter Signal Original Date ______ Revised ______

Measurement No.	Measurement Name	Range		Sample Rate	Hand-ling	Vehicle Display	Ground Display	Caution/ Warning	Remarks
		VDC							
K119	Freon Pump, Source Select SW Position: INTERNAL	0 or 28		2	T/M GSE		G/I		Output from source switch.
K120	Freon Pump, Source Select SW Position: EXTERNAL	0 or 28		2	T/M GSE	SH/I	G/I		Output from source switch. Redline
K121	Pump Power SWS Position: PRIMARY R21 PUMP ON	0 or 28		2	T/M GSE	SH/I SL/I	G/I		Output from pwr relay. Redline
K122	Pump Power SWS Position: PRIMARY R21 PUMP OFF	0 or 28		2	T/M GSE	SH/I SL/I	G/I		Output from pwr relay. Backup Redline to K121.
K123	Pump Power SWS Position: SECONDARY R21 PUMP ON	0 or 28		2	T/M GSE	SH/I SL/I	G/I		Output from power relay. Alternate Redline to K121.
K124	Pump Power SWS Position: SECONDARY R21 PUMP OFF	0 or 28		2	T/M GSE	SH/I SL/I	G/I		Output from power relay. Backup Redline to K123
K125	Water Pump, Source Select SW Position: INTERNAL	0 or 28		2	T/M		G/I		Output from source switch.
K126	Water Pump, Source Select SW Position: EXTERNAL	0 or 28		2	T/M GSE	SH/I	G/I		Output from source switch. Redline
K127	Pump Power SWS Position: PRIMARY H_2O PUMP ON	0 or 28		2	T/M GSE	SH/I SL/I	G/I		Output from power relay. Redline
K128	Pump Power SWS Position: PRIMARY H20 PUMP OFF	0 or 28		2	T/M GSE	SH/I SL/I	G/I		Output from power relay. Backup Redline for K127
K129	Pump Power SWS Position: SECONDARY H20 PUMP ON	0 or 28		2	T/M GSE	SH/I SL/I	G/I		Output from power relay. Alternate Redline to K127
K130	Pump Power SWS Position: SECONDARY H20 PUMP OFF	0 or 28		2	T/M GSE	SH/I SL/I	G/I		Output from power relay. Backup Redline for K129

ECS MEASUREMENT LIST

Vehicle Sortie Lab Parameter Signal Original Date ____ Revised ____

Measurement No.	Measurement Name	Range		Sample Rate	Hand-ling	Vehicle Display	Ground Display	Caution/ Warning	Remarks
		VDC							
M131	Condensate Fans, Source Select SW Position: INTERNAL	0 or 28		2	T/M		G/I		Output from source switch.
M132	Condensate Fans Source Select SW Position: EXTERNAL	0 or 28		2	T/M GSE	SH/I	G/I		Output from source switch. Redline
M133	Condensate Fan Power SWS Position: FAN NO. 1 ON (M170)	0 or 28		2	T/M GSE	SH/I SL/I	G/I		Output from power relay. Backup Redline for M134
M134	Condensate Fan Power SWS Position: FAN NO. 1 OFF (M170)	0 or 28		2	T/M GSE		G/I		Output from power relay. Redline
M135	Condensate Fan Power SWS Position: FAN NO. 2 ON (M171)	0 or 28		2	T/M GSE	SH/I SL/I	G/I		Output from power relay. Backup relay for M135.
M136	Condensate Fan Power SWS Position: FAN NO. 2 OFF (M171)	0 or 28		2	T/M GSE		G/I		Output from power relay. Redline
M137	Cabin Fan Source Select SW Position: INTERNAL	0 or 28		2	T/M		G/I		Output from source switch.
M138	Cabin Fan Source Select SW Position: EXTERNAL	0 or 28		2	T/M GSE	SH/I	G/I		Output from source switch. Redline
M139	Cabin Fan Power SW Position: CABIN FAN ON	0 or 28		2	T/M GSE	SH/I	G/I		Output from Power Relay Redline
M140	Cabin Fan Power SW Position: CABIN FAN OFF	0 or 28		2	T/M GSE		G/I		Output from power relay. Backup Redline for M139
M141	Equipment Fan Source Select SW Position: INTERNAL	0 or 28		2	T/M GSE		G/I		Output from source switch.
M142	Equipment Fan Source Select SW Position: EXTERNAL	0 or 28		2	T/M GSE	SH/I	G/I		Output from source switch. Redline

ECS MEASUREMENT LIST

Vehicle Sortie Lab Parameter Signal Original Date ____________ Revised ____________

Measurement No.	Measurement Name	Range		Sample Rate	Hand-ling	Vehicle Display	Ground Display	Caution/ Warning	Remarks
		VDC							
M143	Equipment Fan Power SW Position: EQUIPMENT FAN ON	0 or 28		2	T/M GSE	SH/I	G/I		Output from power relay. Redline
M144	Equipment Fan Power SW Position: EQUIPMENT FAN OFF	0 or 28		2	T/M GSE		G/I		Output from power relay. Backup Redline for M143
M145									
M146									
M147	Pump Mode SW Position: R21 PUMP NORMAL	0 or 28		2	T/M GSE	SH/I	G/I		Output from Power relay. Backup Redline for M148
M148	Pump Mode SW Position: R21 PUMP STATION KEEPING	0 or 28		2	T/M GSE		G/I		Output from power relay. Redline

SORTIE LAB ECS/ORBITOR MECHANICAL INTERFACE
(PHASE B BASELINE)

Function	Fluid	Line Size	Temp	Press	Flow Rate	Remarks
Condensate Dump	H_2O	1/4"	AMB	+3.0 to +15.0 psid	650 lb/hr	Ground service and/or On-Orbit operation
H_2O Dump	H_2O	3/8"	AMB	35.0 psid max	1500 lb/hr	Same as above
GSE Air Supply & Return (2 Lines)	100 K Class air	2"	65°F to 75°F	15 psid max	100 cfm	Ground service operations only
GSE Coolant Supply & Return (2 Lines)	TBD	3/4"	TBD	TBD	TBD	Ground service operations only
O_2 Relief	O_2	1"	-297°F to 80°F	1010 psig max	2.6 lb/hr	Full flow thru relief valve at 130°F
H_2 Relief	H_2	1/2"	-423°F to 80°F	285 psig max	6 lb/hr	Full flow thru relief valve at 130°F
GN_2 Fill and Drain	N_2	3/8"	AMB	3000 psig	TBD	Ground service operations only
O_2 Cryogenic Bottle Fill and Drain	Cryo-O_2	3/4" Fill 1.0" vent	-297°F to 80°F	0 to 983 psig	TBD	Ground service and prelaunch operations only, 0 psig at fill; 983 psig at drain
H_2 Cryogenic Bottle Fill and Drain	Cryo-H_2	1/2" Fill 1/2" Vent	-423°F to 80°F	0 to 273 psig	TBD	Ground service and prelaunch operations only, 0 psig at fill; 273 psig at drain
GN_2 Relief	N_2	1/4"	AMB	TBD above 3000 psig	TBD	

APPROVAL

MSFC SORTIE LAB ENVIRONMENTAL CONTROL SYSTEM (ECS) PHASE B DESIGN STUDY RESULTS

By A. J. Ignatonis and K. L. Mitchell

The information in this report has been reviewed for security classification. Review of any information concerning Department of Defense or Atomic Energy Commission programs has been made by the MSFC Security Classification Officer. This report, in its entirety, has been determined to be unclassified.

This document has also been reviewed and approved for technical accuracy.

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