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A PRELIMINARY INVESTIGATION OF THE ENVIRONMENTAL CONTROL AND LIFE SUPPORT SUBSYSTEM (EC/LSS) FOR THE SPACE CONSTRUCTION BASE MANUFACTURING MODULES

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TABLE OF CONTENTS

		Page
SUMMARY		1
I.	INTRODUCTION	4
II.	EC/LSS DESCRIPTION	12
III.	EC/LSS GUIDELINES AND REQUIREMENTS	17
IV.	ATMOSPHERIC SUPPLY AND PRESSURIZATION ASSEMBLY (ASPA)	17
V.	CO_2 COLLECTION ASSEMBLY	25
VI.	CONTAMINANT CONTROL ASSEMBLY	30
VII.	HUMIDITY AND TEMPERATURE CONTROL ASSEMBLY	41
VIII.	VENTILATION AND MODULE FAN ASSEMBLIES	41
IX.	WATER MANAGEMENT AND SEPARATOR ASSEMBLY	45
X.	CONDENSATE STORAGE ASSEMBLY	47
XI.	MODULE SENSORS	47
XII.	FIRE AND SMOKE DETECTION ASSEMBLY	47
XIII.	WEIGHT, VOLUME, AND POWER SUMMARY	47
REFERENCES		48

LIST OF ILLUSTRATIONS

Figure	Title	Page
1.	MSFC six-man initial baseline space construction base	2
2.	MSFC space construction base manufacturing modules	3
3.	MOSC four-man baseline inboard profile	5
4.	HM/SM EC/LSS overall schematic	6
5.	Space processing prototype biological facility module	7
6.	Space processing directional solidification facility module . . .	8
7.	Space processing crystal ribbon facility manufacturing module	9
8.	Prototype crystal ribbon facility	10
9.	Biologicals commercial production unit concept	11
10.	Space processing production biological facility module	14
11.	Space processing module (biological EC/LSS)	15
12.	Noise criteria curves	22
13.	Atmospheric Pressure and Composition Control schematic . .	23
14.	RLSE three-man intermittent metabolic profile cabin P_{CO_2} response (closed hatch)	26
15.	Hamilton standard contractor (solid amine) concept.	28
16.	Molesieve diagram	29
17.	Trace contaminant control assembly	31
18.	Orbiter tank envelope and mounting provisions	45

LIST OF TABLES

Table	Title	Page
1.	Biological SPM Expendables	12
2.	Manufacturing Module Requirements	18
3.	Tentative Wash Water Standards	20
4.	Typical Composition of Water to be Reclaimed	21
5.	Atmospheric Pressure and Composition Control Weights, Volume, and Power	24
6.	Maximum Concentration and Production Rate of Trace Contaminants	33
7.	Contaminant Control Weight, Volume, and Power	42
8.	Contaminant Control Assembly Expendables/Spares	43
9.	Biological Facility EC/LSS Weight, Volume, and Power Summarization	44
10.	Water Management Weight Summary	46

LIST OF SYMBOLS

APCC	Atmospheric Pressure and Composition Control
ASPA	Atmospheric Supply and Pressurization Assembly
BFM	Beam Fabrication Module
CH_4	Methane
CO	Carbon Monoxide
CO_2	Carbon Dioxide
$CuSO_4$	Copper Sulphate
DM	Docking Module
EC/LSS	Environmental Control and Life Support Subsystem
GPL	General Purpose Laboratory
H_2	Hydrogen
HCL	Hydrochloric Acid
HDC	Hydrogen Depolarized Cell
HF	Hydrogen Fluoride
Hg	Mercury
HM/SM	Habitability Module/Subsystems Module
H_2O	Water
IOC	Initial Operational Capability
JSC	Johnson Space Center
LEO	Low Earth Orbit

LIST OF SYMBOLS (Concluded)

LiOH	Lithium Hydroxide
LM	Logistics Module
MAC	Maximum Allowable Concentration
MM	Manufacturing Module
MOSC	Manned Orbital Space Concepts
MSFC	Marshall Space Flight Center
N_2	Nitrogen
NASA	National Aeronautics and Space Administration
NC	Noise Curve
O_2	Oxygen
PSM	Power Supply Module
PSP	Public Service Platform
RLSE	Regenerative Life Support Evaluation
SCB	Space Construction Base
SIL	Speech Interference Level
SPM	Space Processing Module
SPS	Solar Power Satellite
SSP	Space Station Prototype
TBD	To Be Determined
TDS	Total Dissolved Solids
TOC	Total Organic Carbon

TECHNICAL MEMORANDUM 78123

A PRELIMINARY INVESTIGATION OF THE ENVIRONMENTAL CONTROL AND LIFE SUPPORT SUBSYSTEM (EC/LSS) FOR THE SPACE CONSTRUCTION BASE MANUFACTURING MODULES

SUMMARY

This report presents the results of a preliminary study definition of the Environmental Control and Life Support Subsystem (EC/LSS) for the Space Construction Base (SCB) manufacturing modules. The leading module contenders identifiable at present are the production biological, prototype biological, crystal ribbon, directional solidification, and beam fabrication. These modules are subsidiaries of the early, low-Earth orbit (LEO) SCB being studied by the Marshall Space Flight Center (MSFC).

The basic six-man SCB will consist of a combined Habitability Module/Subsystems Module (HM/SM), a Logistics Module (LM), a Docking Module (DM), a Power Supply Module (PSM), a General Purpose Laboratory (GPL), and several Manufacturing Modules (MM's). Logistics and crew rotation for the SCB and attached modules will be accomplished every 90 days with the Space Shuttle vehicles. The basic envelopes selected initially for the MSFC study are illustrated in Figures 1 and 2.

A group of assemblies was selected that was suitable for fulfilling the EC/LSS requirements of a typical manufacturing module. The primary assemblies are as follows: humidity and temperature control, ventilation and cabin fan, water management and separator, and condensate storage. The use of existing EC/LSS assemblies (such as Spacelab, Orbiter, and Regenerative Life Support Evaluation (RLSE)) to perform the manufacturing module EC/LSS functions might prove economical.

This report gives brief descriptions of these assemblies including design criteria; schematics; preliminary weights, volume, and power summaries; and other pertinent information. The overall dry weight of the selected EC/LSS (three-man capacity) is 166.40 kg (366.8 lb); it occupies 1.048 m^3 (37.0 ft^3), and requires 803 W (average) of power.

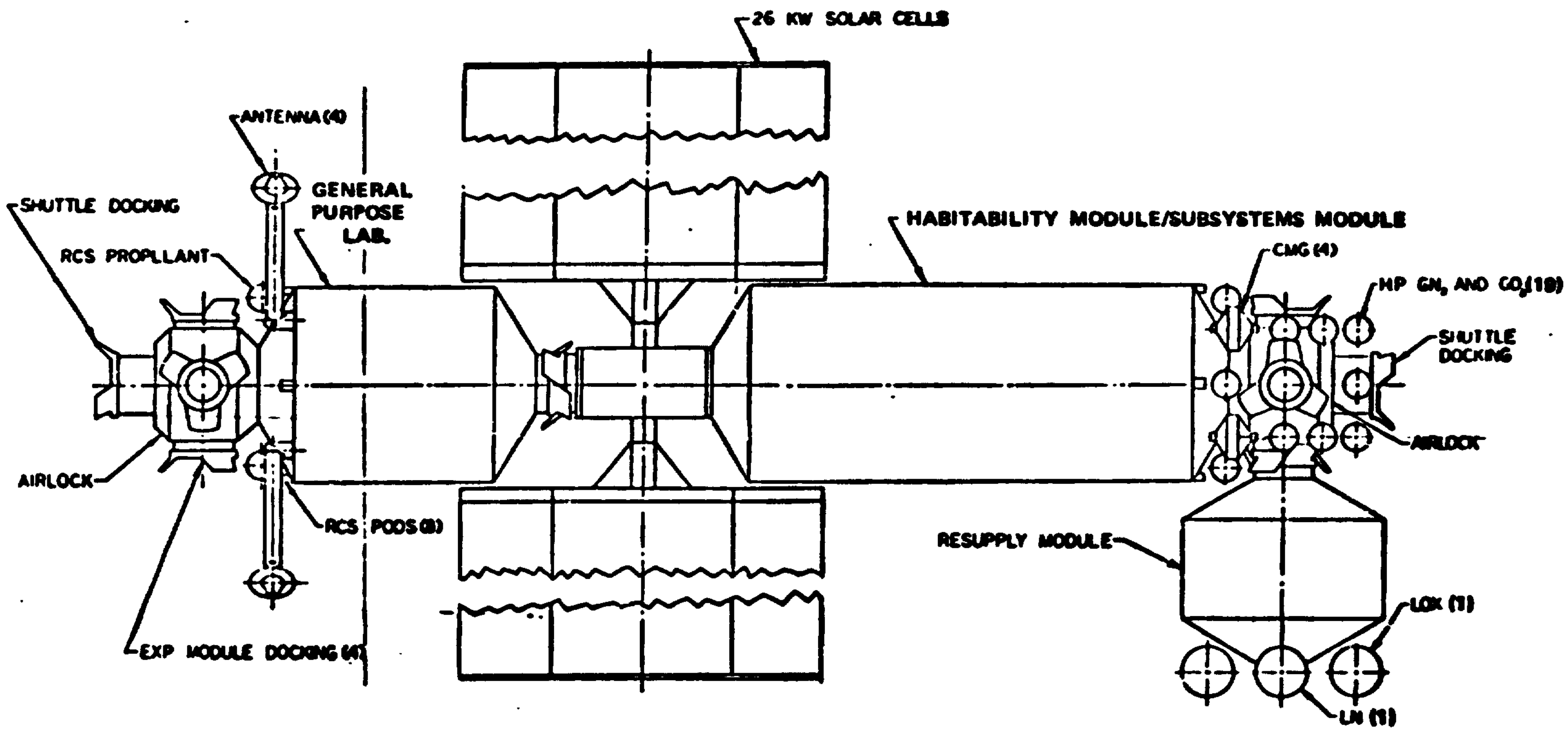

Figure 1. MSFC six-man initial baseline space construction base.

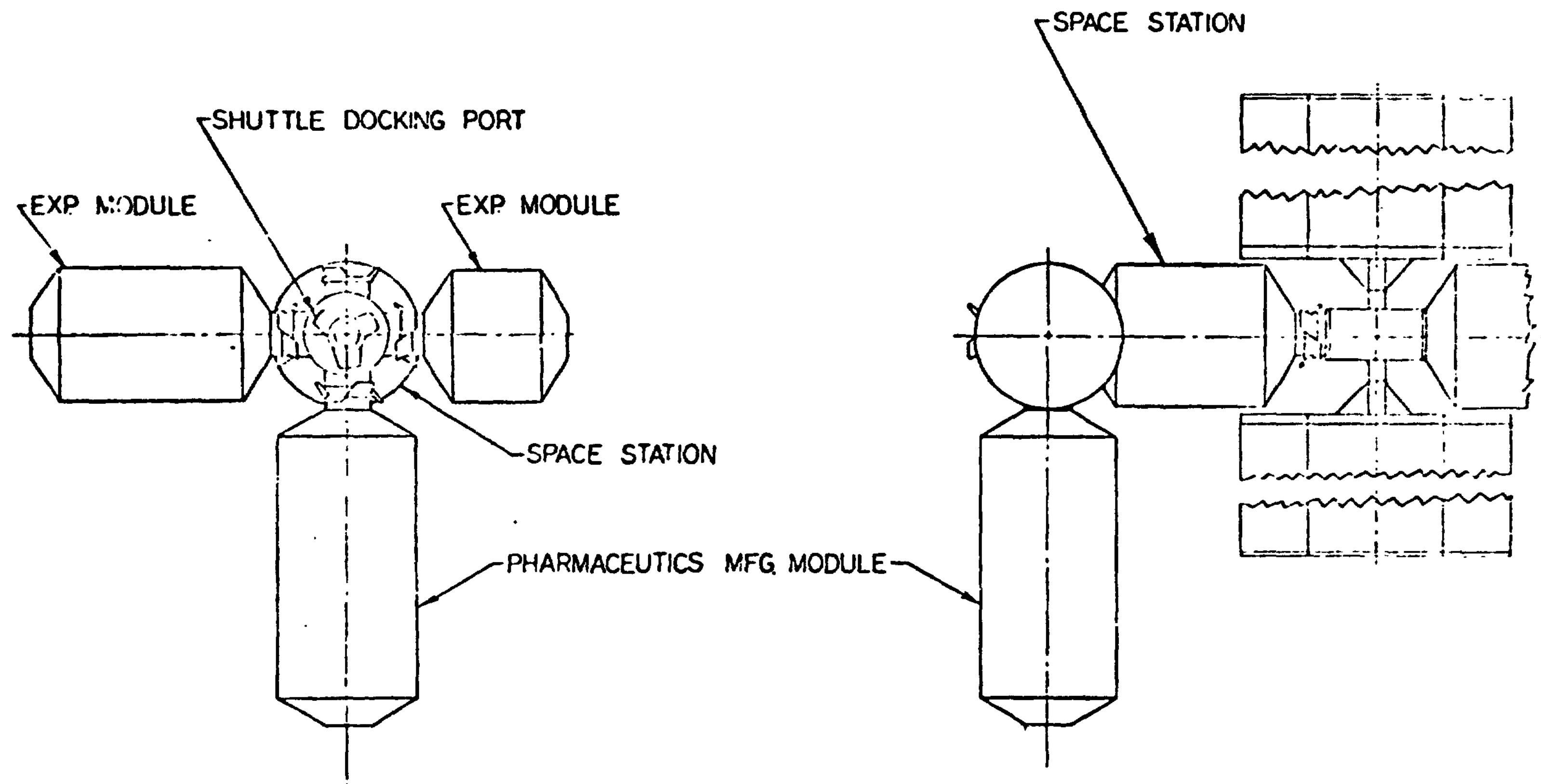

Figure 2. MSFC space construction base manufacturing modules.

I. INTRODUCTION

The National Aeronautics and Space Administration (NASA) is performing preliminary studies at the Johnson Space Center (JSC), Houston, Texas, and MSFC, Huntsville, Alabama, on an early SCB. Present SCB planning has scheduled initial operational capability (IOC) for 1984. The SCB will be modular in design to accommodate anticipated growth in capabilities and crew size during its lifetime. Two previous studies, the "Manned Orbital Space Systems Concept (MOSC) Study" [1] and the "Space Station Prototype (SSP); Environmental/Thermal Control and Life Support System" [2] have been utilized as points of departure. One MOSC configuration is included in Figure 3 for informational purposes.

The reference SCB configuration is depicted in Figure 1. Individual station modules defined for MOSC were analyzed, modified, and adapted to the reference design. Figure 4 portrays a simplified schematic of the HM/SM six-man EC/LSS, which shows the major interfaces among the assemblies. Additional modules (Fig. 2) are being added to the reference design base to perform various functions. Examples are the Space Processing Module (SPM), the Beam Fabrication Module (BFM), and the Public Service Platform (PSP). Biologicals and crystal ribbon manufacture occur in the Satellite Power System (SPS), and extruded beams are fabricated in the BFM for the SPS. The purpose of the PSP is to handle personal communications, ship-to-ship communications, burglar alarm systems, etc. Figures 5, 6, and 7 are representative illustrations of the biological, directional solidification, and crystal ribbon SPM's.

Figures 8 and 9 [3] present schematics of the ribbon growth and biological processes. Ribbon growth is a process in which power is delivered from photovoltaic cells to an RF heating system or solar collectors to melt and possibly shape the ribbon. Biological processes such as tissue culturing by electrophoresis could drastically reduce the cost of drugs.

To standardize the EC/LSS, it was decided to assume a three-man maximum capacity per MM. This would allow the usage of existing EC/LSS assemblies such as Spacelab or Orbiter, which might prove economical.

Atmospheric stores (O_2 and N_2) and drinking water for the MM will be piped in from the aft end of the LM. A crew of two (which is part of the HM/SM crew) will occupy the biological SPM 12 h/day. Table 1 reflects the only SPM consumables [134.7 kg (297 lb)] necessary for leakage and pressurization. Carbon dioxide removal and atmospheric pressure control will be handled

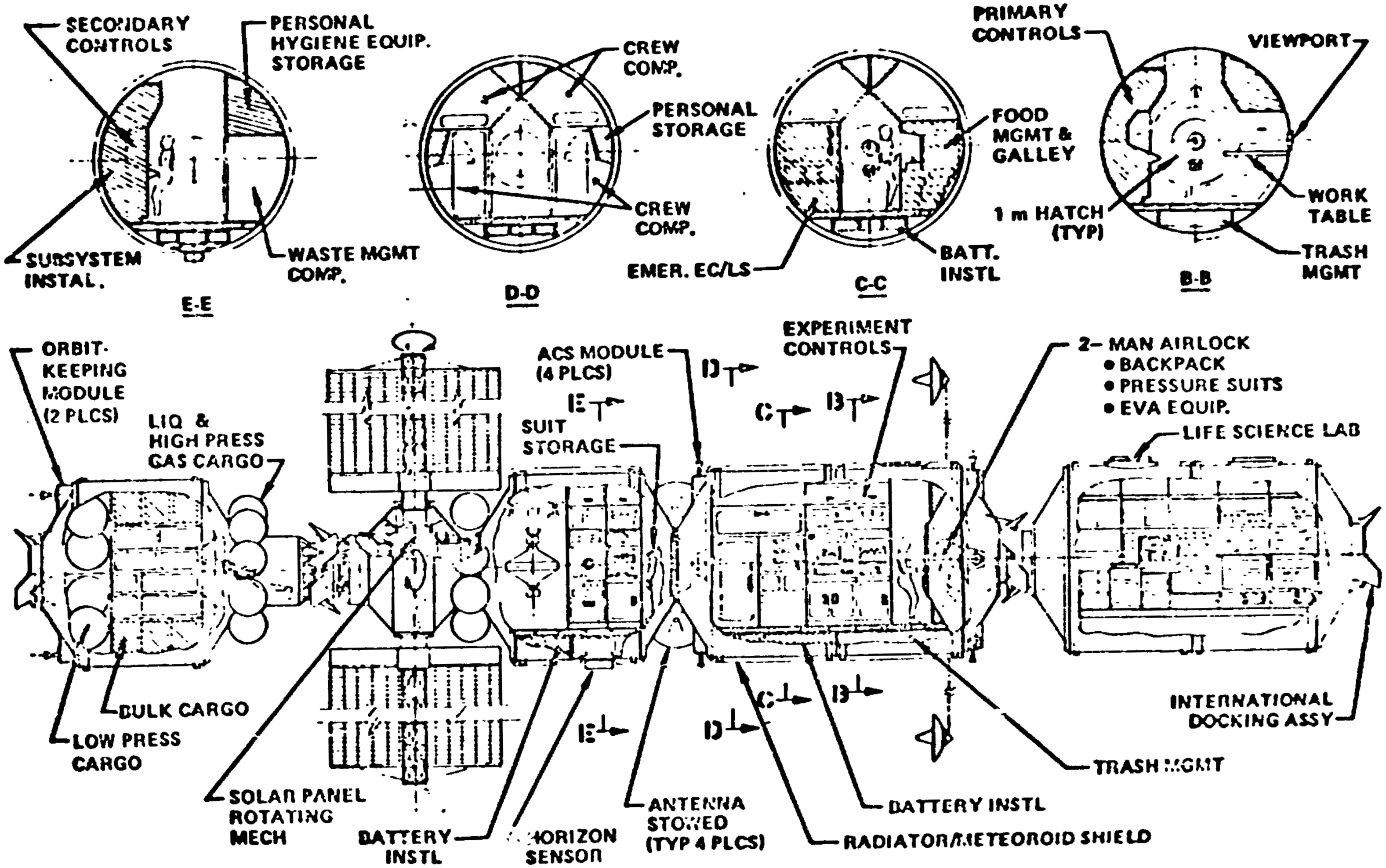

Figure 3. MOSC four-man baseline inboard profile.

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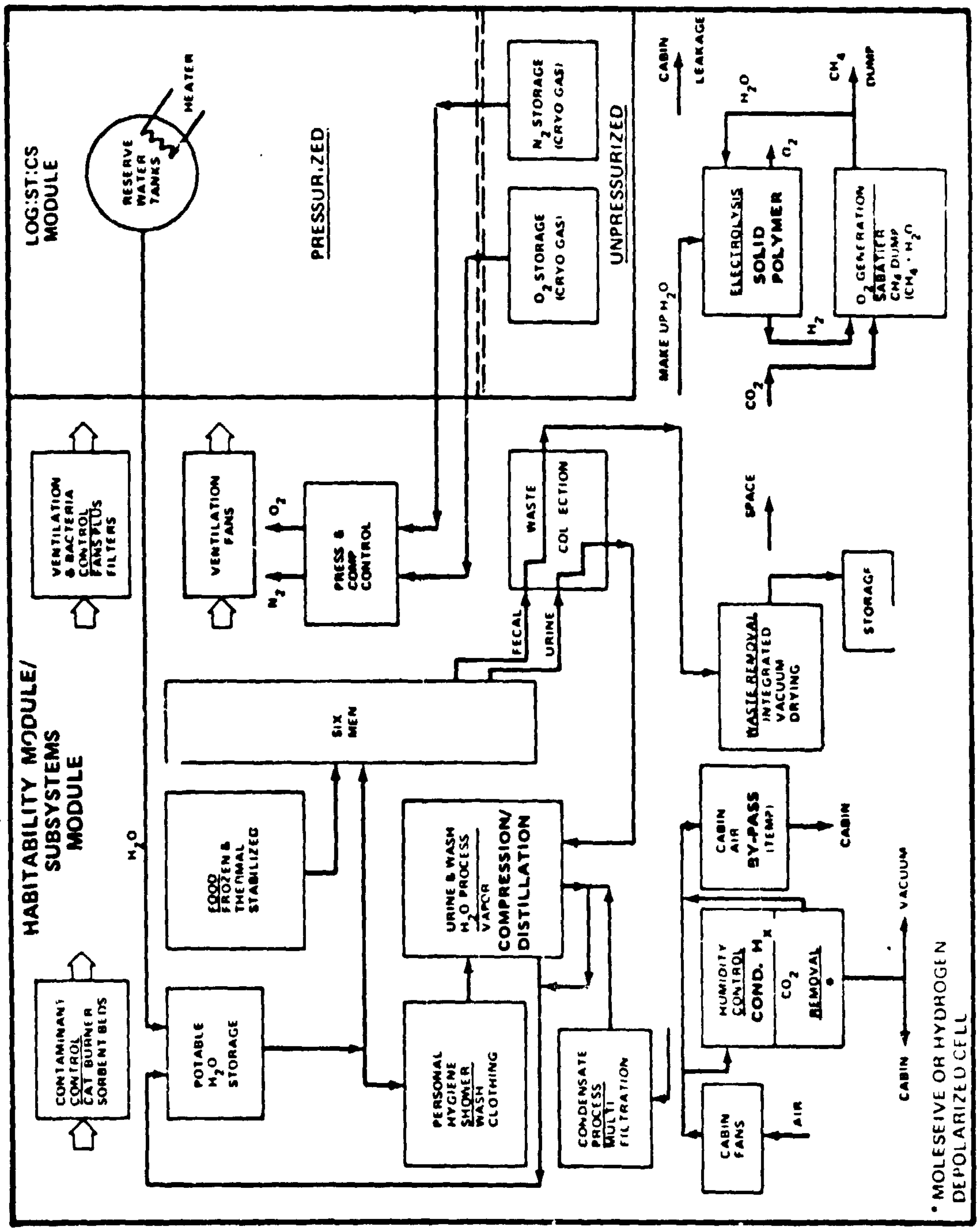
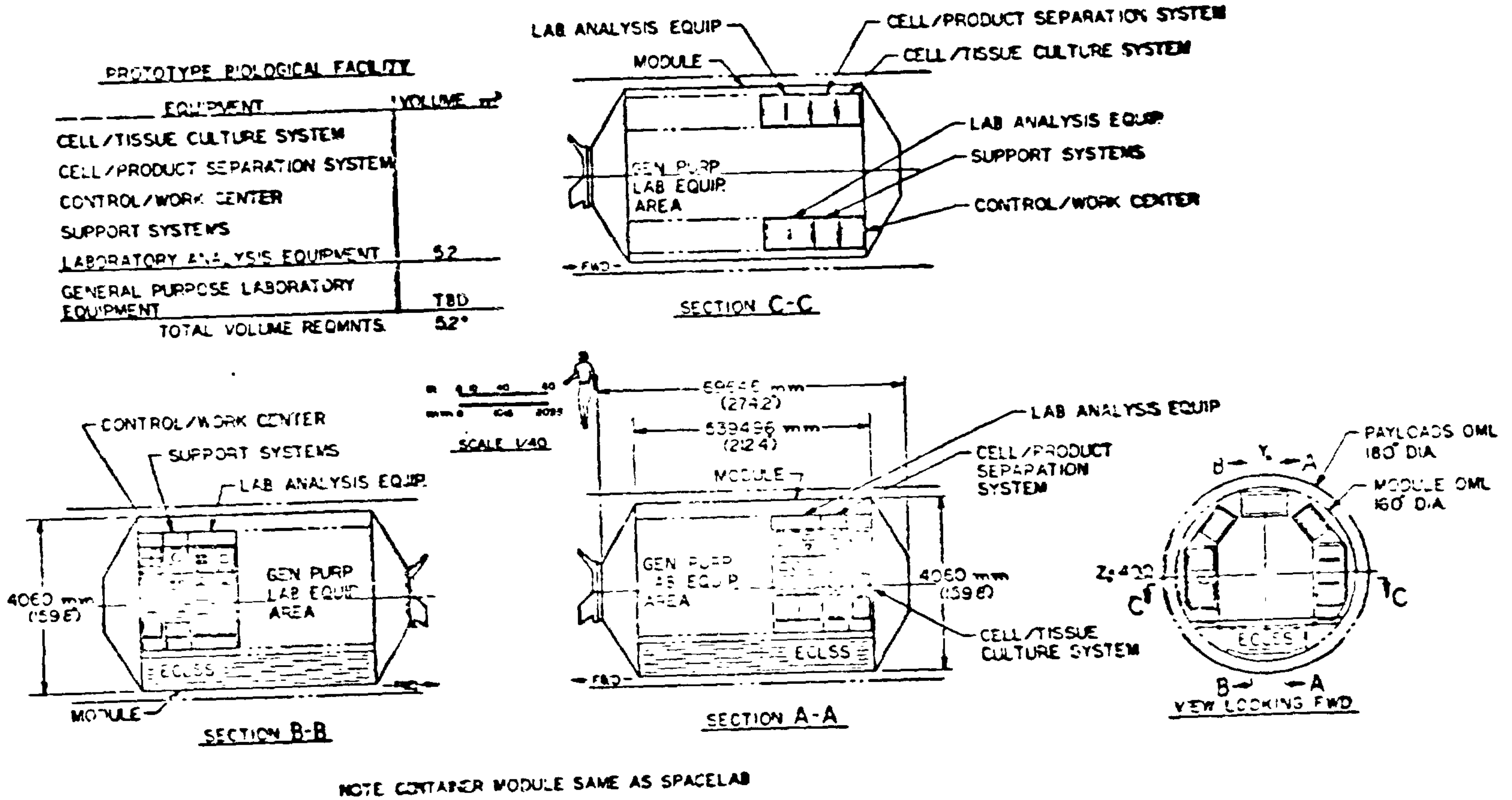


Figure 4. HM/SM EC/LSS overall schematic.



EQUIPMENT	VOLUME m^3
CELL/TISSUE CULTURE SYSTEM	
CELL/PRODUCT SEPARATION SYSTEM	
CONTROL/WORK CENTER	
SUPPORT SYSTEMS	
LABORATORY ANALYSIS EQUIPMENT	5.2
GENERAL PURPOSE LABORATORY EQUIPMENT	TBD
TOTAL VOLUME REQMNTS	5.2*

Figure 5. Space processing prototype biological facility module.

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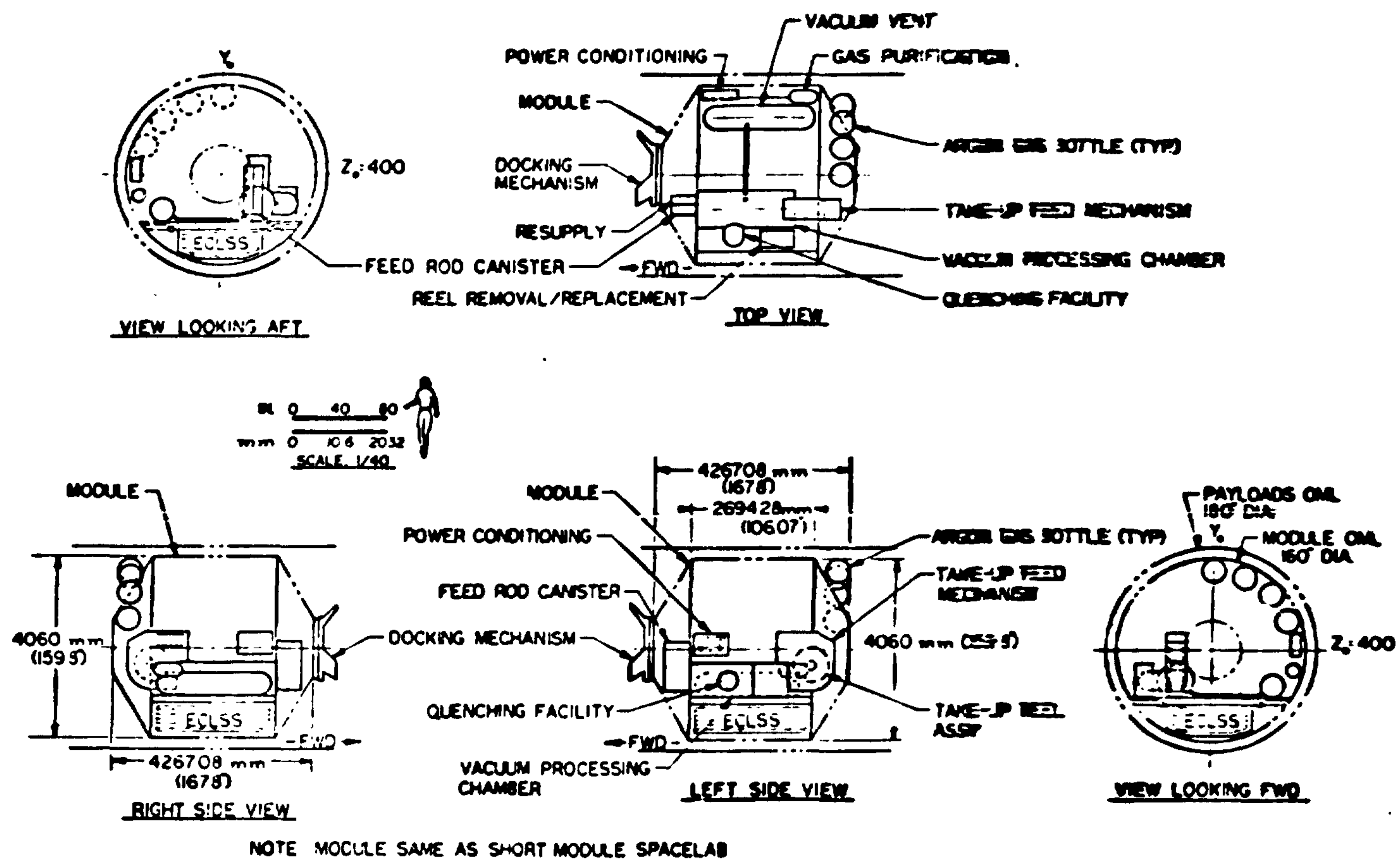

Figure 6. Space processing directional solidification facility module.

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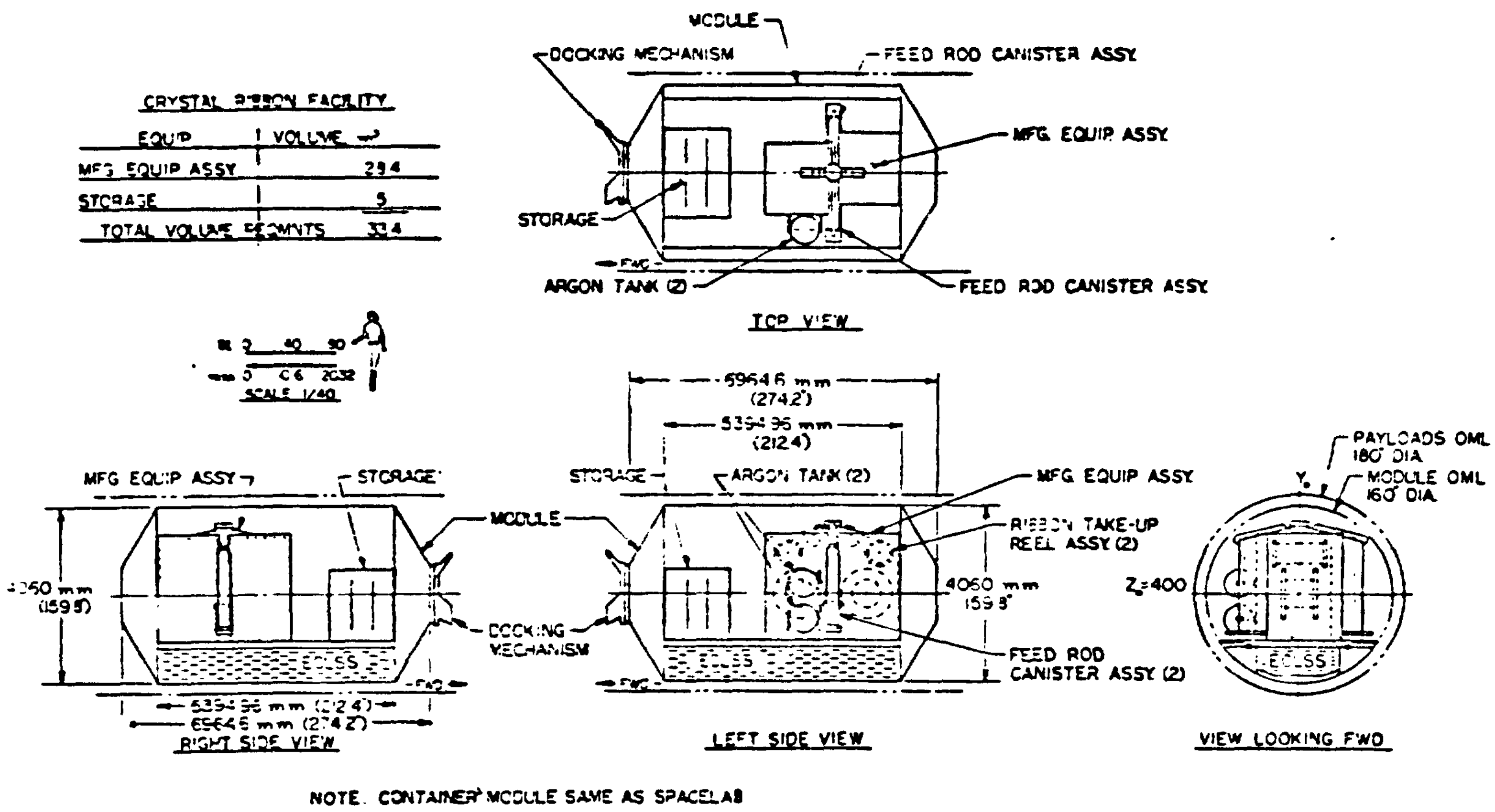
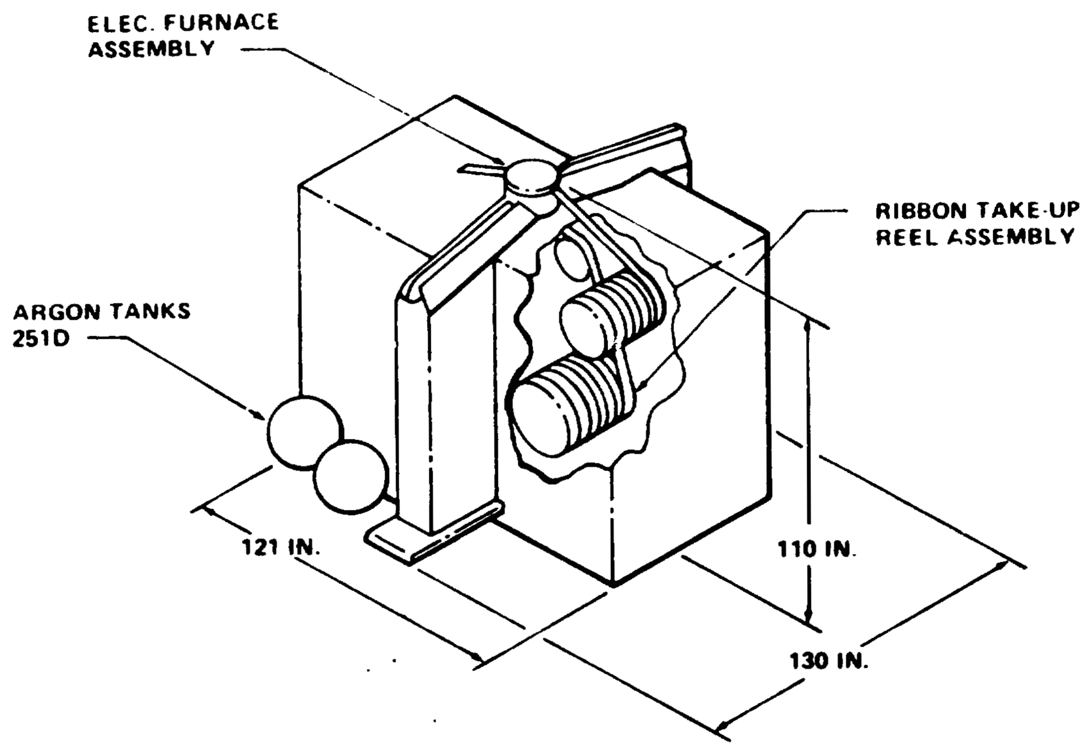


Figure 7. Space processing crystal ribbon facility manufacturing module.



PROPERTIES

- MASS 1476KG
- SIZE $28.4 M^3$
- POWER 6.5KW
- CREWMAN ONE
- RESUPPLY $30 M^3$/90DAYS
- ANNUAL PRODUCTION RATE 60.5 MILLION CHIPS

PROCESS DEFINITION

FEED (1.3 cm/hr.) → MELT (1412°C) → SEED & PULL (190cm/hr.) → SHAPE (880 W/RIBBON) → STORE (25 CM BEND RADIUS)

Figure 8. Prototype crystal ribbon facility.

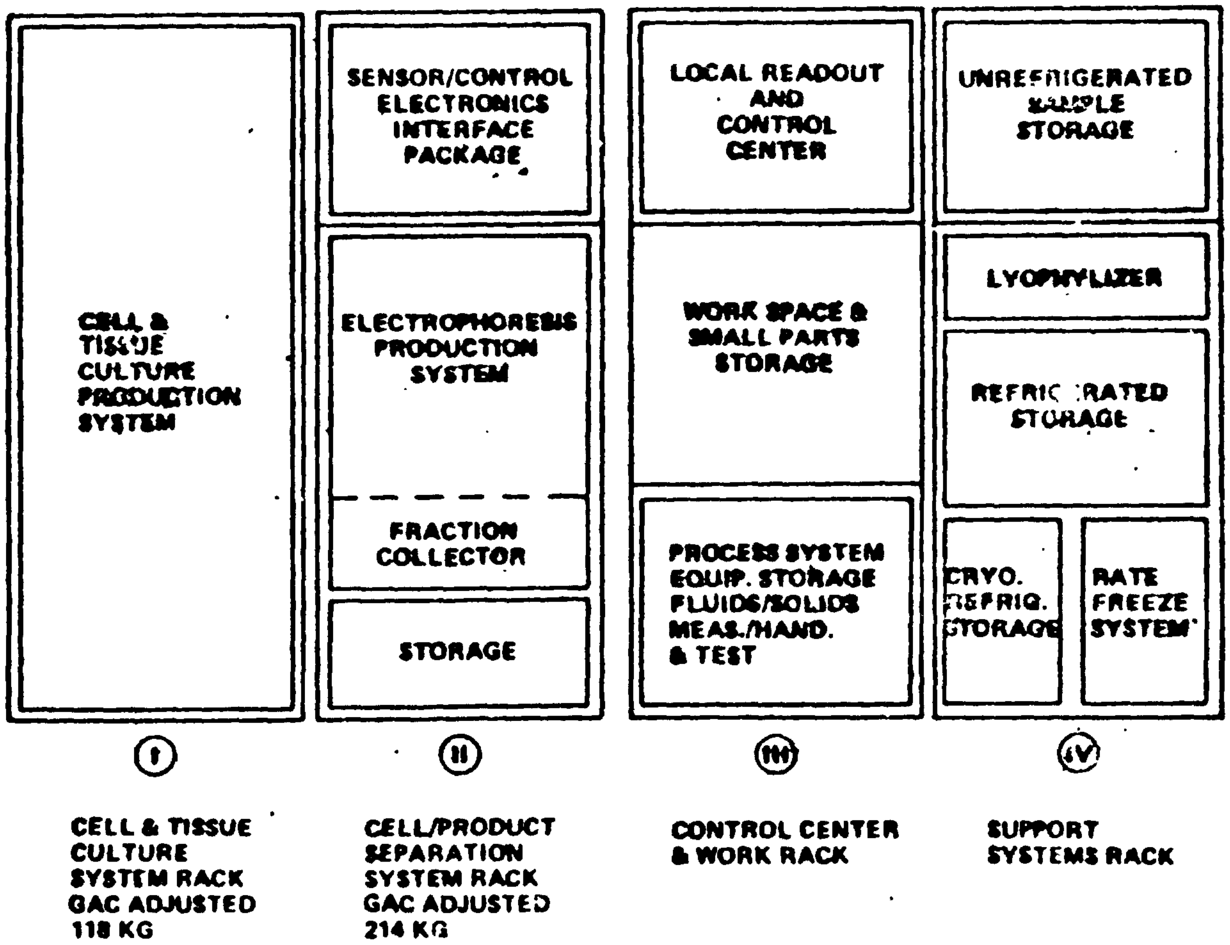


Figure 9. Biologicals commercial production unit concept.

TABLE 1. BIOLOGICAL SPM EXPENDABLES

Requirement	Weight kg (lb)	
	O_2	N_2
Initial Module Pressurization 124.83 m^3 (4411 ft^3)	34.9 (77)	114.3 (252)
Module Leakage[a]	28.6 (63)	93.9 (207)
Module Leakage Reserve (10 percent)	2.7 (6)	9.5 (21)
Overall Requirements	66.2 (146)	217.7 (480)
Less Initial Pressurization Gases	- 34.9 (77)	- 114.3 (252)
Total Cryogen Storage	31.3 (69)	103.4 (228)
Total O_2 and N_2	134.7 (297)	

a. 1.36 kg (3 lb)/module/day

b. Conversion Factor: 2.205 lb/kg and 0.0283 m^3/ft^3

through the HM/SM EC/LSS. Catalytic oxidizers, presorbent, post-sorbent, and other sorbent beds control contaminants; condensing heat exchanger are employed for humidity control. Module temperature control is affected by individual cabin heat exchanger/fan units. A thermal control assembly of some type is needed for the HM/SM and each manufacturing module; however, no attempt was made to include the subsystem in the EC/LSS. The overall weight, power, and volume of the EC/LSS are given in Section XIII.

II. EC/LSS DESCRIPTION

The EC/LSS provides cabin atmosphere control and purification, water management, and thermal control for all the MM's. The MM's presently considered for attachment to the Space Station are space processing and beam fabrication. Additional modules are attached to facilitate the manufacturing such as GPT, construction, control, and pallets. The production biological SPM was selected as a baseline configuration for all the MM's and associated modules; Figure 10 presents an illustration which consists of a pressurized enclosure containing biological racks and equipment, and two docking posts. The module provides utilities and an environment conducive to developmental pilot plant and commercial production activities. It is designed to assure adequate protection for proprietary interests, personnel safety, and quality of space processed products. At launch, it will be equipped with a full complement of space processing equipment and sufficient supplies to support 90 days of operation.

The SPM EC/LSS is based on a three-man crew with provisions for variations in crew size from zero to three men. An economic advantage can be obtained through the use of existing assemblies and components with an IOC of 1984. Existing assemblies and hardware considered for use in this time frame are Spacelab, Orbiter, and RLSE. Spacelab assemblies were utilized as much as possible.

The schematic of the biological SPM EC/LSS is displayed in Figure 11. The EC/LSS provides for SPM ventilation flow, air revitalization, module temperature control, and thermal control activities. (This item is not covered in this report.) The air revitalization encompasses carbon dioxide, trace contaminant, humidity, and odor control.

Air from the module is drawn into a filter/debris trap/unit upstream of redundant cabin fans. Check valves shall be provided to prevent recirculation through the inactive fans. One fan shall be normally operating. A differential pressure sensor shall measure and indicate the fan performance. A temperature sensor shall provide a signal to a cabin temperature controller. The catalytic oxidizer unit uses its own fan to draw a certain portion of the air from the module for contaminant control and discharges it upstream of the bacteria and prime sorbent beds.

The air is then ducted from the cabin fans through the humidity control condensing heat exchanger, which interfaces with the avionics and condensate water loop. The cabin temperature control valve directs a portion of the warm air around the heat exchanger, thereby controlling the temperature of the mixed gas that is returned to the module. The position of the temperature control valve and, subsequently, the amount of air bypassed around the heat exchanger is controlled by a signal received from duct mounted temperature sensors. This signal is sent to the temperature controller which, in turn, provides a positioning signal to the valve actuator. The signal is based upon a desired cabin temperature dialed into a cabin temperature selector, which is mounted in the cabin. Air bypass, rather than coolant bypass, is utilized because greater control over

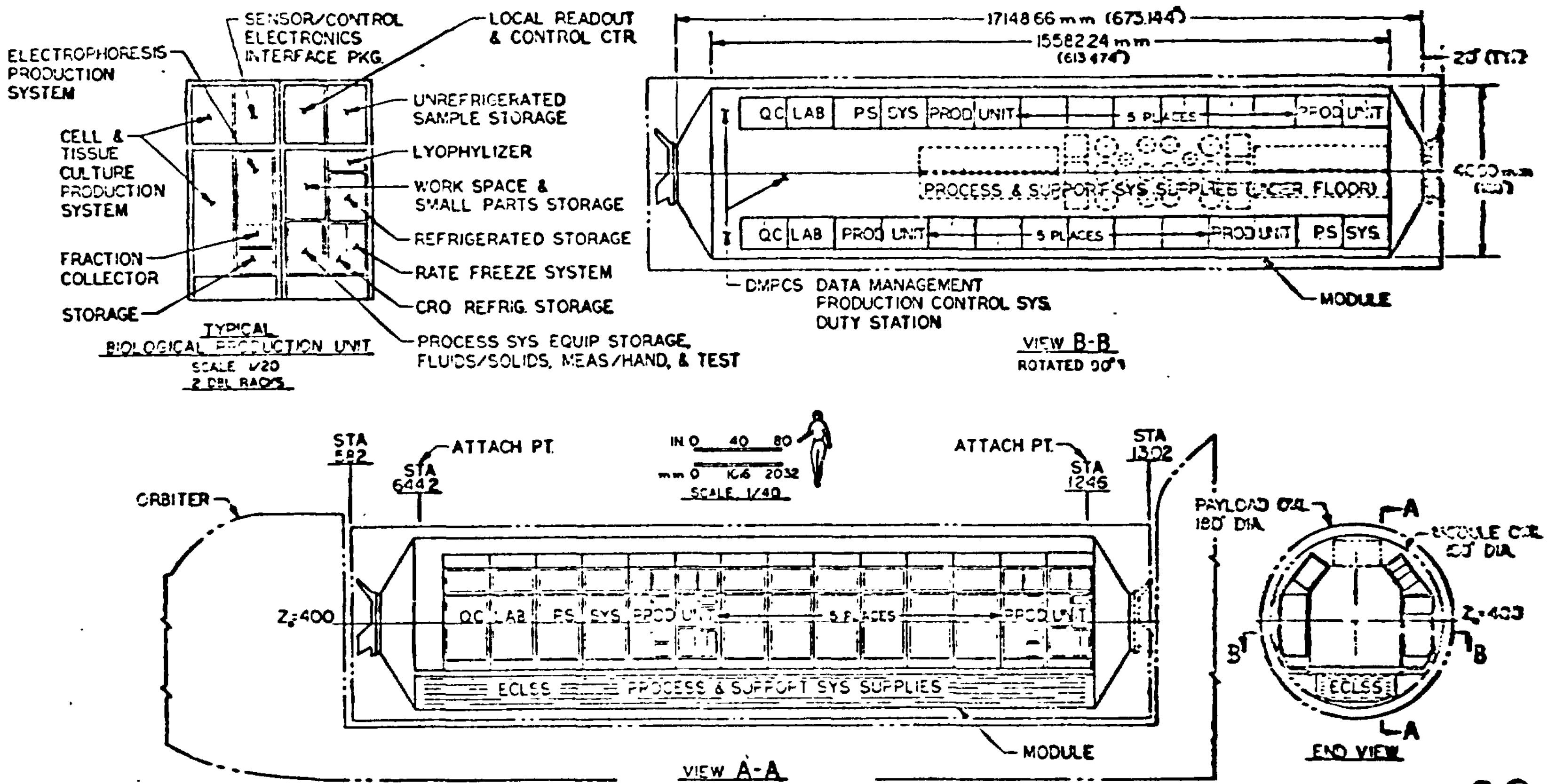


Figure 10. Space processing production biological facility module.

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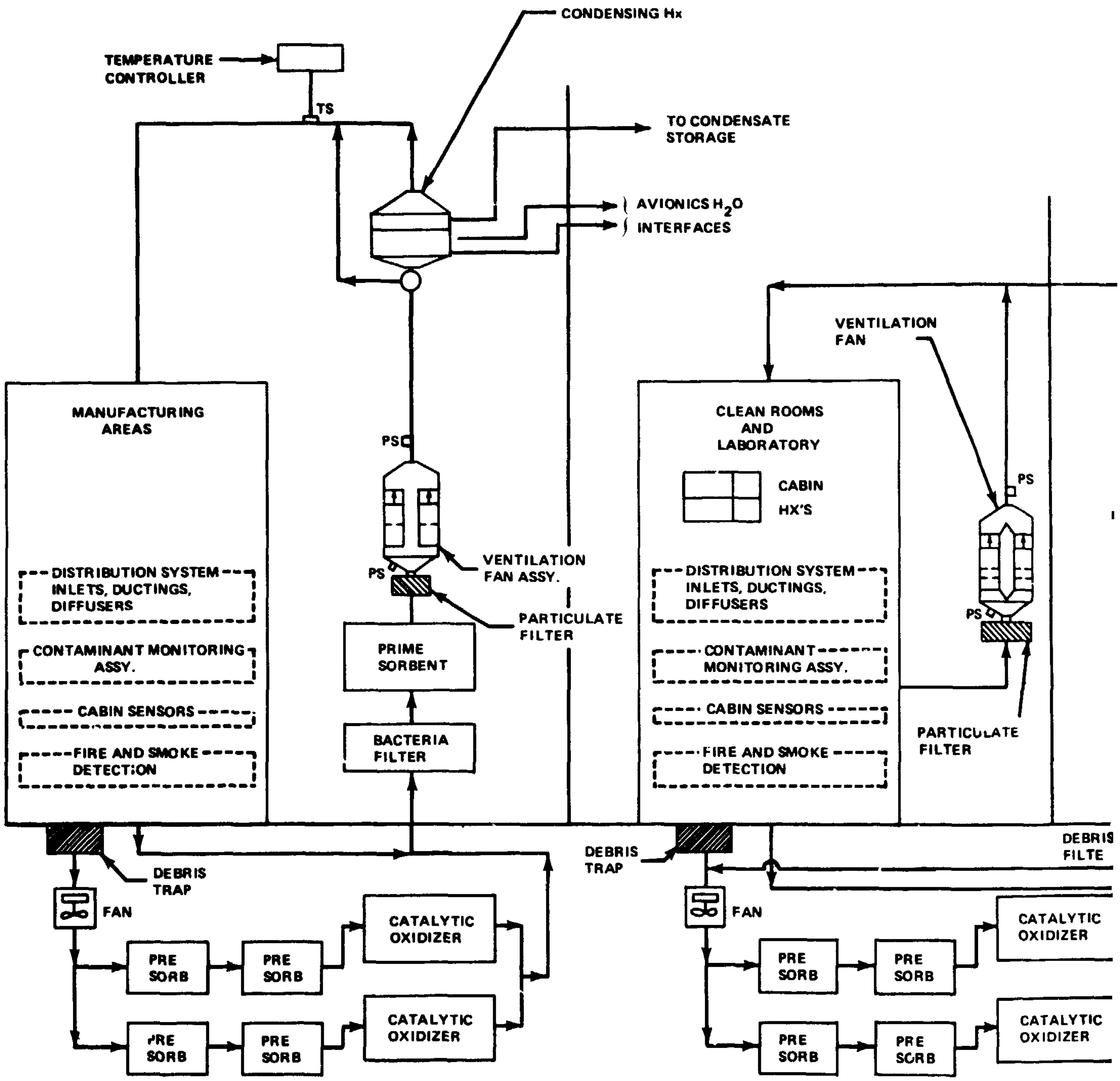
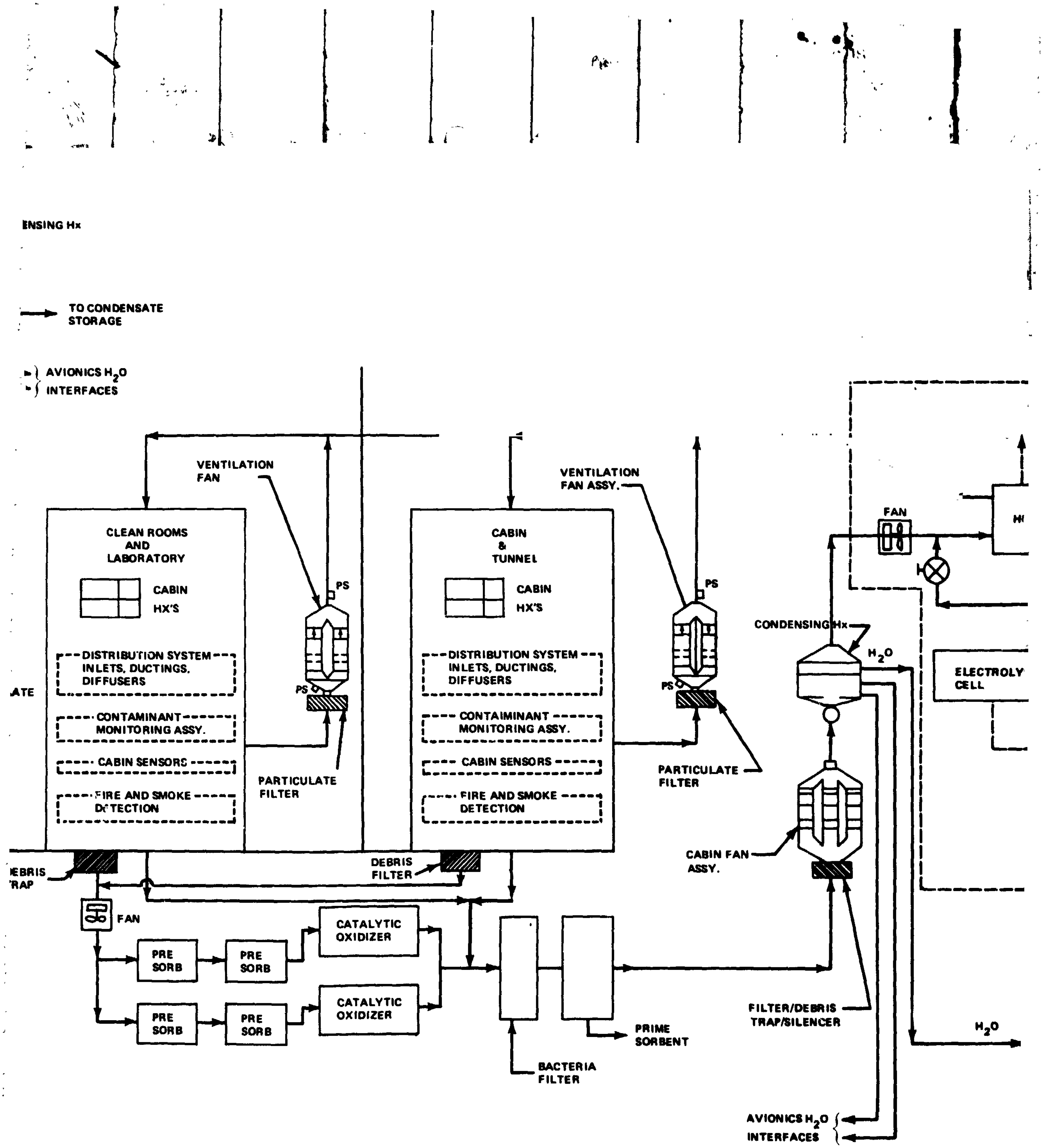


FOLDOUT FRAME 1



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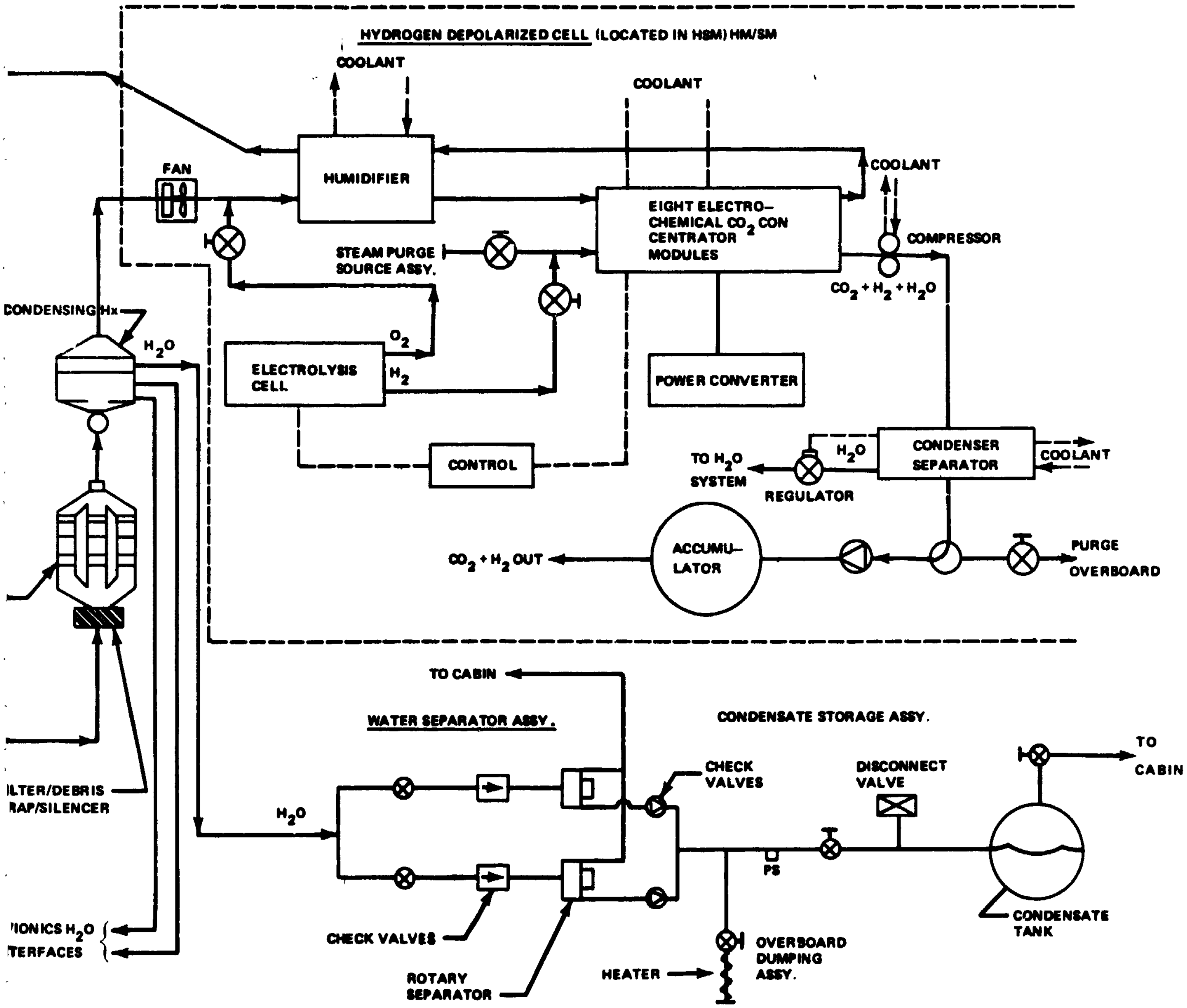


Figure 11. Space processing module (biological EC/LSS).

FOLDOUT FRAME 3

relative humidity can be achieved with varying heat loads. The air that passes through the condensing heat exchanger is cooled below the dewpoint to condense excess moisture and remove excessive cabin heat. The condensed moisture shall then pass through the water separator assembly and be delivered into a condensate storage tank.

The hydrogen depolarized cell (HDC) located in the HM/SM receives air from the humidity control heat exchanger and removes CO_2 by an electrochemical process. Upon leaving the HDC, the processed air is returned to the module compartment. Two ventilation fans are provided in each module compartment as part of the air distribution system to improve module air velocity to satisfy crew comfort requirements. Adjustable air diffusers provide sufficient air velocity for crew comfort only in localized areas.

The EC/LSS for the SPM is composed primarily of Spacelab assemblies with SSP contaminant control derivatives. Since the biological experiments or requirements are unknown at this time, modifications may be required in the EC/LSS. Details are included on all the necessary assemblies in the following sections.

III. EC/LSS GUIDELINES AND REQUIREMENTS

A preliminary listing of the EC/LSS requirements and assumptions necessary to perform a prephase type study for a typical Manufacturing Module is given in Table 2.

IV. ATMOSPHERIC SUPPLY AND PRESSURIZATION ASSEMBLY (ASPA)

To be compatible with the SCB atmosphere, the biological MM atmosphere will be composed of 21 percent O_2 and 79 percent N_2 (by volume) at a total pressure of 101 353 N/m^2 (14.7 psia). The partial pressures for the modules are 21 305 N/m^2 (3.09 psia) for O_2 and 80 048 N/m^2 (11.61 psia) for N_2. Atmospheric stores (O_2 and N_2) will be piped in from the aft end of the LM. Atmospheric leakage is assumed to be the same as Skylab, which amounts to 1.35 kg (2.977 lb)/day/module. This amounts to a leakage rate of approximately 1.36 kg (3 lb)/day, which amounts to 1.043 kg (2.30 lb)/day of O_2 and 0.31 kg (0.70 lb)/day of N_2.

TABLE 2. MANUFACTURING MODULE REQUIREMENTS

	Requirement
A. Crew/Passenger Data [in kg (or lb) / man-day unless otherwise designated]	
Number of Crew (12 h/day)	0-3 Men
O_2 Consumption, kg (lb)	0.839 (1.85)
Range, kg (lb)	0.766-0.998 (1.69-2.20)
CO_2 Produced, kg (lb)	0.989 (2.18)
Range, kg (lb)	0.871-1.215 (1.92-2.68)
B. Manufacturing Module Data	
Station Total Pressure, N/m^2 (psia)	101 353 (14.70)
Atmospheric Mixture, (% volume)	21 O_2 79 N_2
O_2 Partial Pressure, N/m^2 (psia)	21 305 (3.09)
N_2 Partial Pressure, N/m^2 (psia)	80 048 (11.61)
CO_2 Partial Pressure, Nominal Maximum, mm Hg (psia) [4]	3.0 (0.058) or below
CO_2[a] Emergency, Maximum, mm Hg (psia) [4]	15.0 (0.29)
Leakage, kg (lb)/day/module	1.36 (3.0)
Manufacturing Module Free Volume, m^3 (ft^3) (Typical)	124.83 (4411.0)
Operational Temperature, °C (°F)	18 to 26 (65 to 80)
Relative Humidity	6°C (43°F) to 70% Humidity
Resupply Period (days)	90

C. Trace Contaminants [4]

1. Normal atmosphere leakage shall not be considered as a method of controlling the level of airborne trace contaminants.
2. Expected airborne trace contaminants, initial and nominal production rates and their maximum allowable concentrations during nominal operational levels are TBD.

a. Carbon dioxide partial pressure during emergency operations shall be maintained below 2000 N/m^2 (15.0 mm Hg) (allowable exposure time is 2 h) [4]

TABLE 2. (Concluded)

3. The maximum allowable concentration (MAC) of total organics, exclusive of fluorocarbons, is 100 ppm n-pentane equivalents.
4. The MAC of total Fluorocarbons is 100 ppm.
5. The airborne trace contaminants not permitted in the payload atmosphere are: Chlorocarbons
   - Carbon Tetrachloride
   - Chloroform
   - Methyl Chloroform
   - Trichloroethylene

   Miscellaneous
   - Mercury

   The above cleaning agents, solvents, or chemicals should not be used in or around the payload or during manufacture of its components.

6. Airborne Particles Contaminant Control [4]

   The Manufacturing Module life support shall adhere to the Spacelab airborne particle control requirement as follows:

   Airborne particle filtering — 300 μ nominal

D. Potable Water [4]

Reclaimed water used as potable water shall meet the requirements of the water quality specification: NAS-MSC Specification SD-W-0020.

E. Hygiene Water [4]

The hygiene water quality specification will be the same as the wash water specification established by the National Academy of Science and shown in Table 3. Typical composition of hygiene waters to be reclaimed are shown in Table 4.

F. Acoustical Criteria [4]

Continuous noise levels shall not exceed 50 dB in speech interference level (SIL) range (600 to 4800 Hz), 70 dB at frequencies below SIL, nor 60 dB at frequencies above SIL. The noise criteria (NC) curves are shown in Figure 12.

TABLE 3. TENTATIVE WASH WATER STANDARDS [4]

Total Organic Carbon (TOC), mg/1	200
Specific Conductivity, mΩ -cm-1	2000
pH	5 to 7.5
Ammonia, mg/1	5
Turbidity, ppm SiO_2	10
Color, Pt-Co Units	15
Foaming	Nonpersistant more than 15 s
Odor	Nonobjectionable
Total Dissolved Solids (TDS), mg/1	1500
Urea, mg/1	50
Lactic Acid, mg/1	50
NaCl, mg/1	1000
Microorganisms, Number per ml	10

TABLE 4. TYPICAL COMPOSITION OF WATER TO BE RECLAIMED

Materials	Shower kg/kg water × 10^{-6}	(lb/lb water × 10^{-6})	Wash Water kg/kg water × 10^{-6}	(lb/lb water × 10^{-6})
Solubles				
Calcium	0.19	(0.42)	0.127	(0.28)
Chloride	15.12	(33.34)	10.08	(22.22)
Chr mium (hexavalent)	0.023	(0.05)	0.023	(0.05)
Copper	0.454	(1.00)	0.454	(1.00)
Magnesium	0.19	(0.42)	0.127	(0.28)
Manganese	0.023	(0.05)	0.023	(0.05)
Nickel	0.023	(0.05)	0.023	(0.05)
Potassium	5.66	(12.47)	3.77	(8.31)
Silver	0.023	(0.05)	0.023	(0.05)
Sodium	15.12	(33.34)	10.08	(22.22)
Zinc	2.27	(5.00)	2.27	(5.00)
Amino Acids	0.64	(1.41)	0.426	(0.94)
Creatinine	0.376	(0.83)	0.25	(0.55)
Glucose	0.943	(2.08)	0.626	(1.38)
Lactic Acid	4.72	(10.41)	3.15	(6.94)
Urea	6.61	(14.58)	4.41	(9.72)
Uric Acid	0.132	(0.39)	0.086	(0.19)
Detergent	453.51	(1000.00)	453.51	(1000.00)
Germicide	—		—	
Subtotal	506.027	(1115.79)	489.458	(1079.23)
Insolubles				
Sebum	13.293	(29.31)	8.853	(19.52)
Body Hair, Skin, etc.	61.247	(135.05)	40.80	(89.96)
Clothing lint, etc.	—		—	
Food wastes	—		—	
Particulates	—		—	
Subtotal	74.54	(164.36)	49.653	(109.48)
Total Solids	580.567	(1280.15)	539.111	(1188.71)

Note: Conversion factor: 2.205 [illegible] kg.

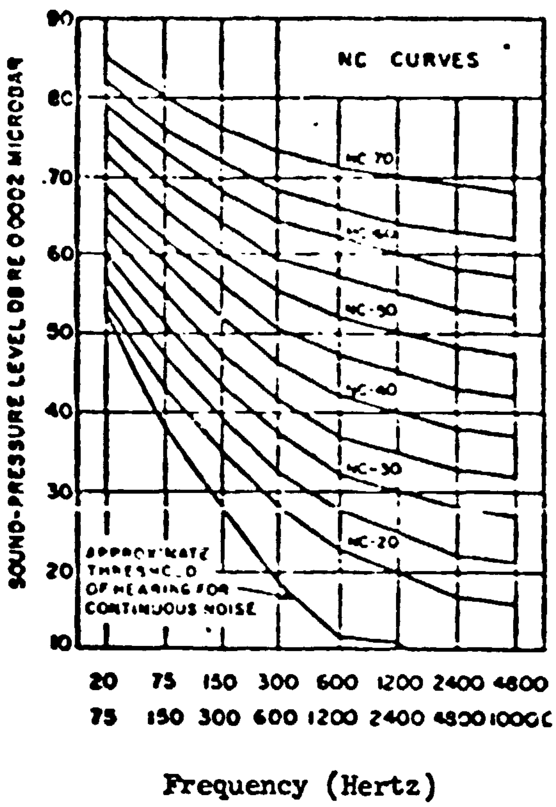
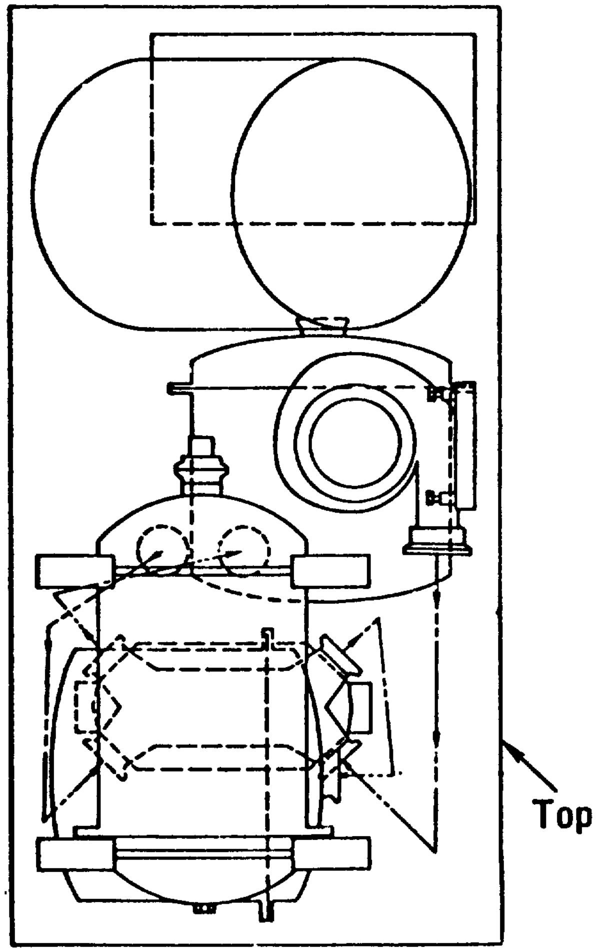


Figure 12. Noise criteria curves.

CO_2 removal and atmospheric pressure control will be handled by the HM/SM and pressure control assembly, respectively. If a separate pressure control assembly is required in the MM, the Spacelab assembly can be modified and added. Figure 13 and Table 5 represent a modified schematic and weights of the Spacelab assembly and are included in this report for information purposes only.

The total amount of O_2 and N_2 requiring storage in the LM cryogenic bottles (AAP type) is 27.21 kg (60 lb) of O_2 and 103.4 kg (228 lb) of N_2 for leakage purposes. The O_2 [27.21 kg (69 lb)] can be stored in the two O_2 bottles provided; however, the 103.4 kg (228 lb) of N_2 will require the addition of another N_2 cryogenic bottle for containment. The initial 21 percent O_2 and 79 percent N_2 pressurization gases [34.9 kg (177 lb) of O_2 and 114.3 kg (252 lb) of N_2] will be loaded into the MM on the ground. Thus, there will be no need to contain the initial atmosphere supply in the supply tanks.

The only weight penalty involving the ASPA is an assumed weight of 24.49 kg (54 lb) for plumbing the various compartments for the SPM.



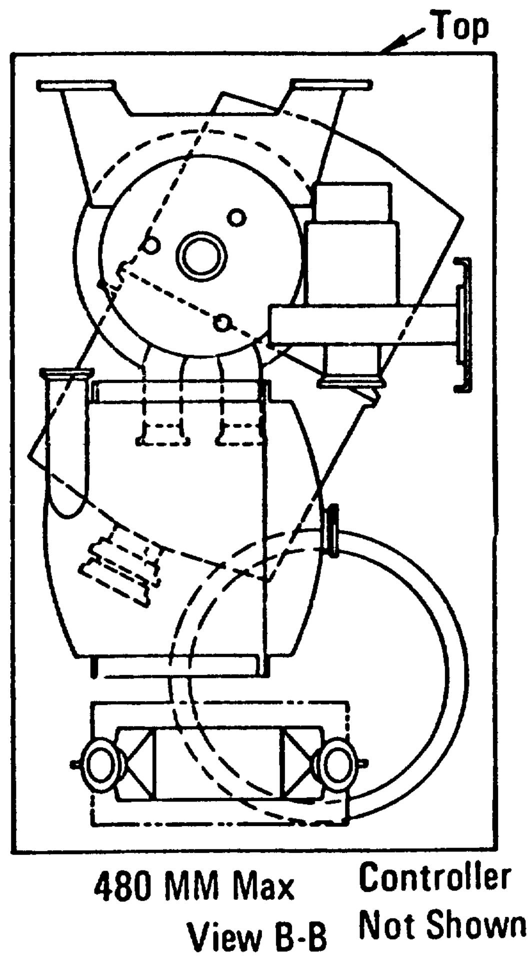


Figure 13. Atmospheric Pressure and Composition Control schematic.

TABLE 5. ATMOSPHERIC PRESSURE AND COMPOSITION CONTROL WEIGHTS, VOLUME, AND POWER

Nomenclature	Quantity	Dimensions m (in.)/m³ (ft³)	Unit Weight kg (lb)	Total Weight kg (lb)	Power (W)
O_2 Supply Unit	(1)			2.934 (6.47)	
Electrical Valve (O_2)	2		0.635 (1.40)		
Valve Position Indicator (O_2)	2				
Pressure Sensor (O_2)	1		0.245 (0.54)		2
Check Valve	2		0.680 (1.50)		
Quick Disconnect	1		0.272 (0.60)		
O_2 Supply Lines	?		1.102 (2.43)		
N_2 Supply Unit	(1)			2.326 (5.13)	
Electrical Valve (N_2)	1		0.635 (1.40)		
Valve Position Indicator (N_2)	1				
Flow Restrictor	1		0.218 (0.48)		
Quick Disconnect	1		0.272 (0.60)		
N_2 Supply Lines	?		1.202 (2.65)		
N_2 High Pressure Regulator Unit	(1)	0.79 × 0.97 × 1.30 (31 × 38 × 51) 0.991 (45)		4.10 (9.04)	
Electrical Valve (N_2)	2		0.635 (1.40)		
Valve Position Indicator (N_2)	2				
Pressure Regulator (N_2)	2		0.726 (1.60)		
Relief Valve (N_2)	2		0.907 (2.00)		
Pressure Sensor (N_2)	1		0.245 (0.54)		1
Check Valve (N_2)	2		0.680 (1.50)		
Manual Shut-Off Valve (N_2)	2		0.907 (2.0)		
Packaging				1.497 (3.3)	
Atmosphere Pressure Control Unit	(1)	1.55 × 0.97 × 1.30 (61 × 38 × 51) 1.955 (69)		5.502 (12.13)	
Solenoid Valve (N_2)	2		0.635 (1.40)		30
Valve Position Indicator (N_2)	2				1
Shut-Off Valve (N_2)	2		0.635 (1.40)		
Flow Indicator (N_2)	1		0.136 (0.30)		6
Check Valve (O_2)	2		0.680 (1.50)		
Flow Indicator (O_2)	1		0.136 (0.30)		6
Module Pressure Regulator	2		1.882 (4.15)		
Module Pressure Sensor	2		0.490 (1.08)		1
Manual Shut-Off	2		0.454 (1.00)		
Manual Oxygen Control Valve	2		0.454 (1.00)		
Packaging				2.500 (5.51)	
Atmosphere Supply Control Assy.	(1)	0.79 × 0.79 × 0.33 (31 × 31 × 13) 0.206 (7.2)		1.800 (3.97)	
Partial Pressure Controller(O_2)	1		1.134 (2.50)		7
Partial Pressure Sensor (O_2)	1		0.490 (1.08)		3
Miscellaneous (Elect. lines, connections, etc.)			0.177 (0.39)		
Packaging				0.700 (1.54)	
Cabin Pressure Relief	(1)	0.63 × 1.30 × 0.84 (25 × 51 × 33) .698 (24.34)		5.08 (11.20)	
Pressure Relief Valve (Pos.)	2		1.860 (4.1)		
Valve Position Indicator (Pos.)	2		0.113 (0.25)		12
Pressure Relief Valve (Neg.)	2		1.860 (4.1)		
Depressurization Valve	1		1.134 (2.5)		
Valve Position Indicator (Depress.)	1		0.113 (0.25)		
Packaging				0.200 (0.44)	
Compartment Supply Unit	(4)	0.63 × 0.38 × 1.30 (25 × 15 × 51) 0.311 (11)		11.193 (24.68)	
Manual Shut Off	4				
Pressure Regulator	4				
Relief Valve	4				
Packaging				?	
Experiment Vent Assy.	(4)	0.63 × 0.38 × 1.30 (25 × 15 × 51) 0.311 (11)		6.357 (14.02)	
Manual Shut-Off Valve	4		1.905 (4.2)		
Restrictor	4		0.870 (1.92)		
Quick Disconnect	4		1.088 (2.40)		
Cabin Bleed Valve Adapter	4		2.494 (5.5)		
Total (Overall)				44.189 (97.43)	69

V. CO_2 COLLECTION ASSEMBLY

The CO_2 collection assembly is employed to remove CO_2 from the MM and deliver high purity CO_2 to either a Sabatier or Bosch reactor (if used) for O_2 generation. To assure continuous, long duration controls of this assembly, redundancy will have to be provided through interconnected dual components, maintainability, repair, replacement, safety equipment, and spares. CO_2 removal and collection for the MM's will be accomplished by piping the air through the HM/SM CO_2 collection assembly, which could be an HDC (six-man capacity), a moleseive, or a Hamilton Standard concentrator.

The CO_2 collection assembly must maintain all MM's at or below 3.0 mm Hg (0.058 psia) even under conditions of maximum CO_2 generation. Because of mixing and variations in crew activity, the average inlet CO_2 partial pressure will be approximately 2 mm Hg (0.039 psia). During emergencies, the CO_2 partial pressure (emergency maximum) must not exceed 15 mm Hg (0.29 psia) (allowable exposure time is 2 h) [3].

Figure 14 is a plot of the RLSE [5] three-man intermittent CO_2 generation and partial pressure responses under closed hatch conditions. The values ranged around 2 mm Hg (0.039 psia) or below for CO_2 partial pressure and approximately 0.136 kg (0.3 lb)/h for CO_2 generation.

Since O_2 generation is a likelihood in the larger SCB crews, the MOSC study [1] recommended usage of either the molecular sieve or the HDC with retrofits for closed oxygen loops. The molecular sieve emerged as the favorite candidate for the McDonnell Douglas Astronautics Company 60 and 90 day manned simulator tests (1971) and Skylab (1974). The HDC is the MOSC favored candidate because of the lower power costs and a well developed SSP. The RLSE program singled out three prime candidates for CO_2 collection, namely the molecular sieve, the Hamilton Standard concentrator (solid amine), and the HDC. RLSE gave preference to the HDC concept.

The baseline Orbiter removes CO_2 from the cabin by filtering the atmosphere through lithium hydroxide (LiOH) filters. Rockwell International has completed a preliminary study [6] to extend the 30 day capability of the Shuttle. The Hamilton Standard solid amine CO_2 removal concept (referred to as HS-C in Reference 6) was designed to adapt to the Orbiter's LiOH CO_2 removal assembly installation.

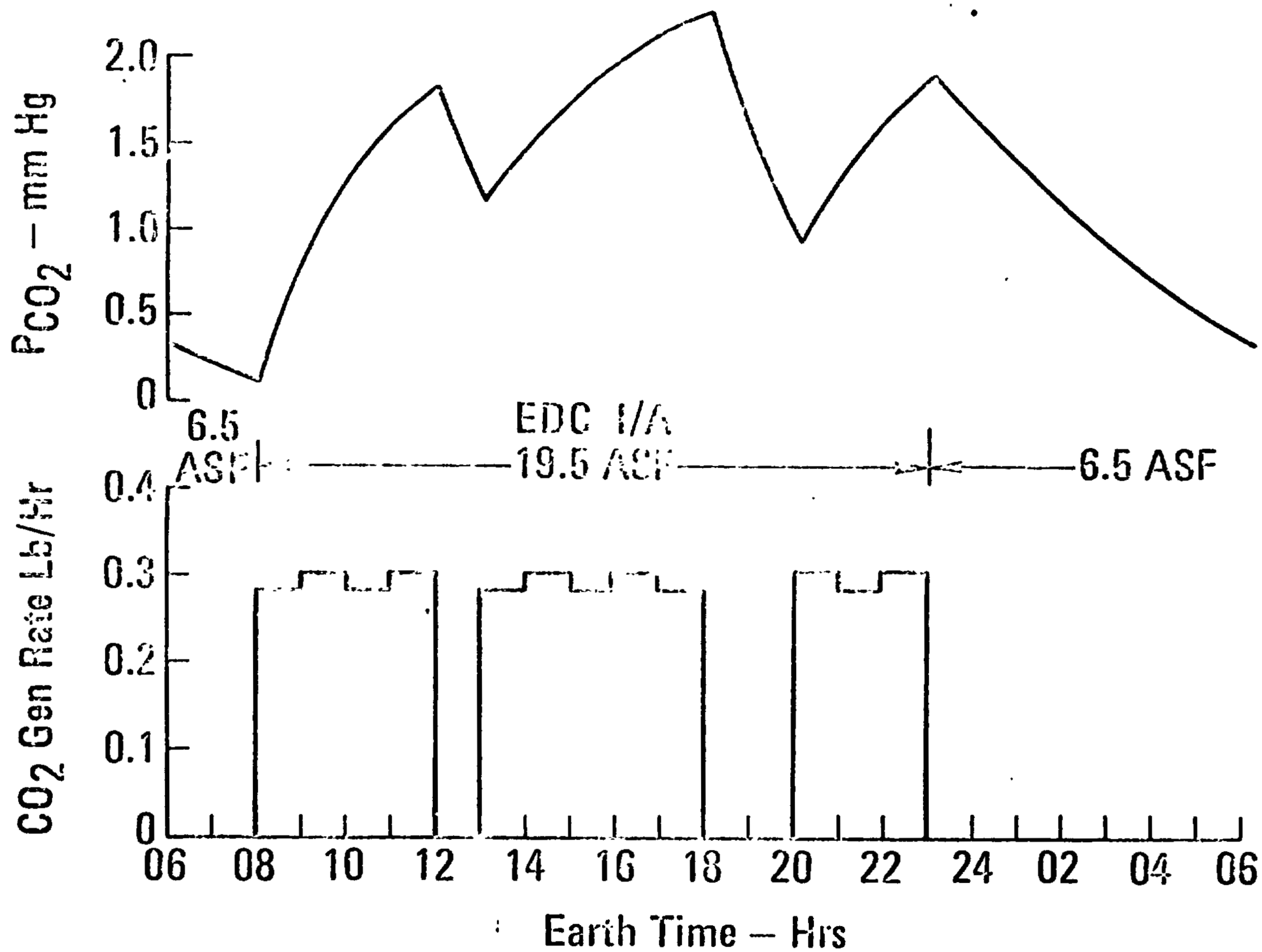


Figure 14. RLSE three-man intermittent metabolic profile cabin P_{CO_2} response (closed hatch).

A schematic showing the Hamilton Standard concentrator plumbing is configured in Figure 15 [7]. Air drawn from the module by a fan enters the amine sorbent bed, where CO_2 and H_2O are removed. The air then returns to the module through a valve. A timer operates motor driven valves, which select the absorbing and desorbing canisters. Cold thermal fluid is directed to the absorbing canisters by a solenoid operated valve. This fluid is heated by a heat exchanger before entering the desorbing canister. CO_2 delivery is difficult because the gas contains considerable water vapor, and a pressure of 40 mm Hg (0.774 psia) is needed for desorption. A condenser-separator and a water-cooled two-stage vacuum pump-compressor are required to deliver CO_2 from 40 mm Hg (0.774 psia) to 275 790 N/m^2 (40 psia). Condensing will occur in the delivery pump. A bypass line to the absorbing bed inlet is used during initial desorption to recycle absorbed and void-volume air, preventing collection of impure CO_2.

The detailed schematic of CO_2 removal by molecular sieve is shown in Figure 16. It consists of two regenerative adiabatic sorbent modules for normal operation and a third module for standby. The condensing heat exchanger is upstream of each molecular sieve module. The moisture from cabin air is removed considerably in the condensing heat exchanger and is stored in the condensate tank for reuse. Each molecular sieve module comprises (1) an adiabatic sorbent canister with bakeout heater and associated temperature sensor and control, (2) a gas selector valve which directs the process air into the bed and back to the cabin or exposes the bed to vacuum for desorption, (3) a switchover valve which positions the gas selector valve in the "absorb" or "desorb" position, and (4) isolation valves to shut off the system in the event of failure. The concept also incorporates three compressors (two are redundant units) to reduce bed pressure to 6894.76 N/m^2 (1.0 psia) before opening the beds to vacuum which reduces the overboard gas loss considerably. Isolation valves are provided to isolate any one of the compressors and in addition a bypass valve permits operation without the compressor. Much of the equipment in this concept is existing designs from the Skylab.

Under NASA sponsored programs, HDC technology has been developed and evaluated for application to a Space Station EC/LSS. Life Systems, Inc., Cleveland, Ohio, successfully developed and tested a four-man capacity HDC with a four-man capacity Bosch CO_2 Reduction Subsystem [8]. Existing HDC and Bosch reduction subsystem prototypes were refurbished and modified to allow for the integrated operation. A one-man [9] and two six-man [10, 11] self-contained HDC's have been developed and experimentally characterized for NASA. Integration of an HDC with Sabatier CO_2 reduction hardware has been investigated previously.

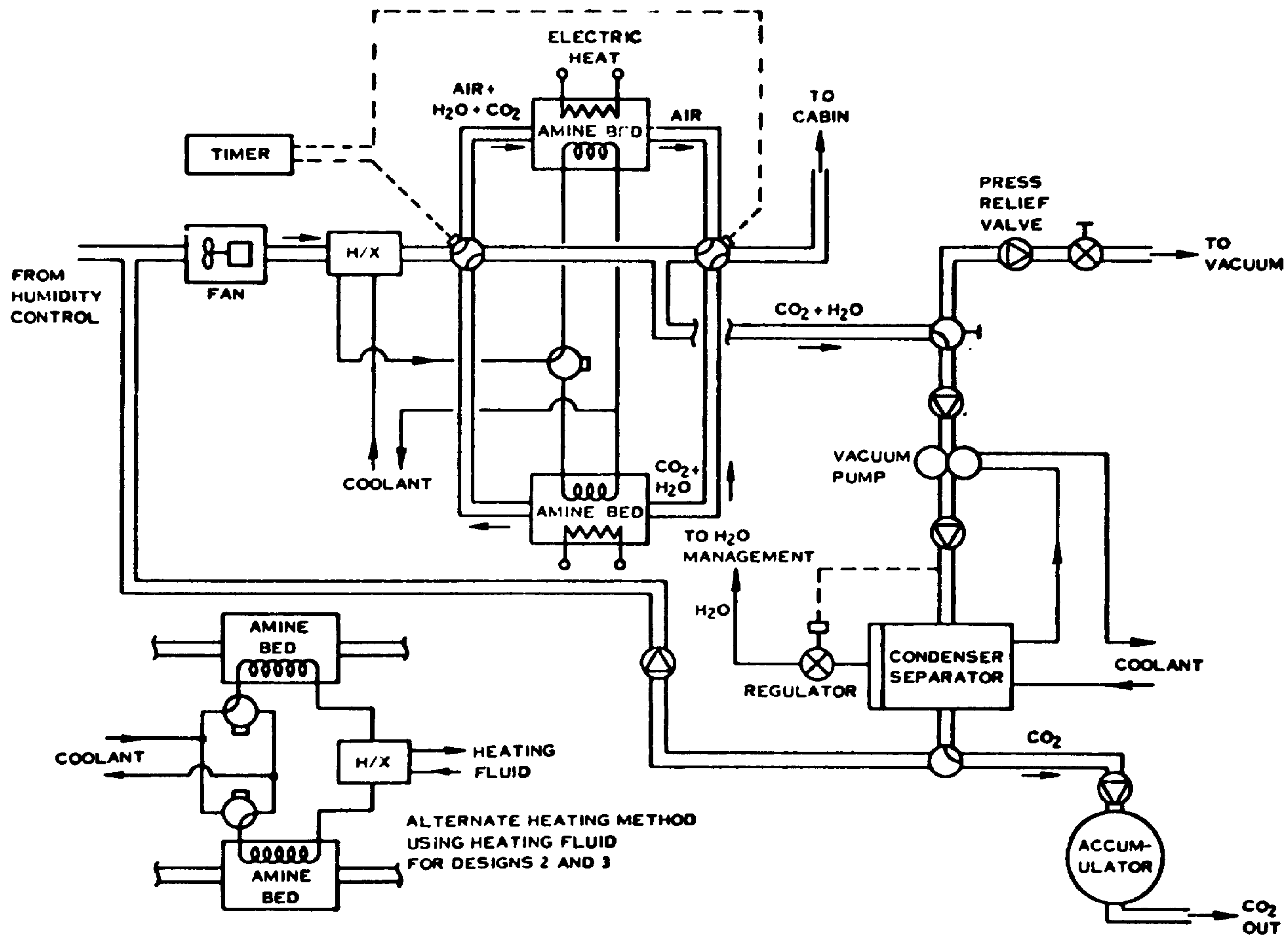


Figure 15. Hamilton standard contractor (solid amine) concept.

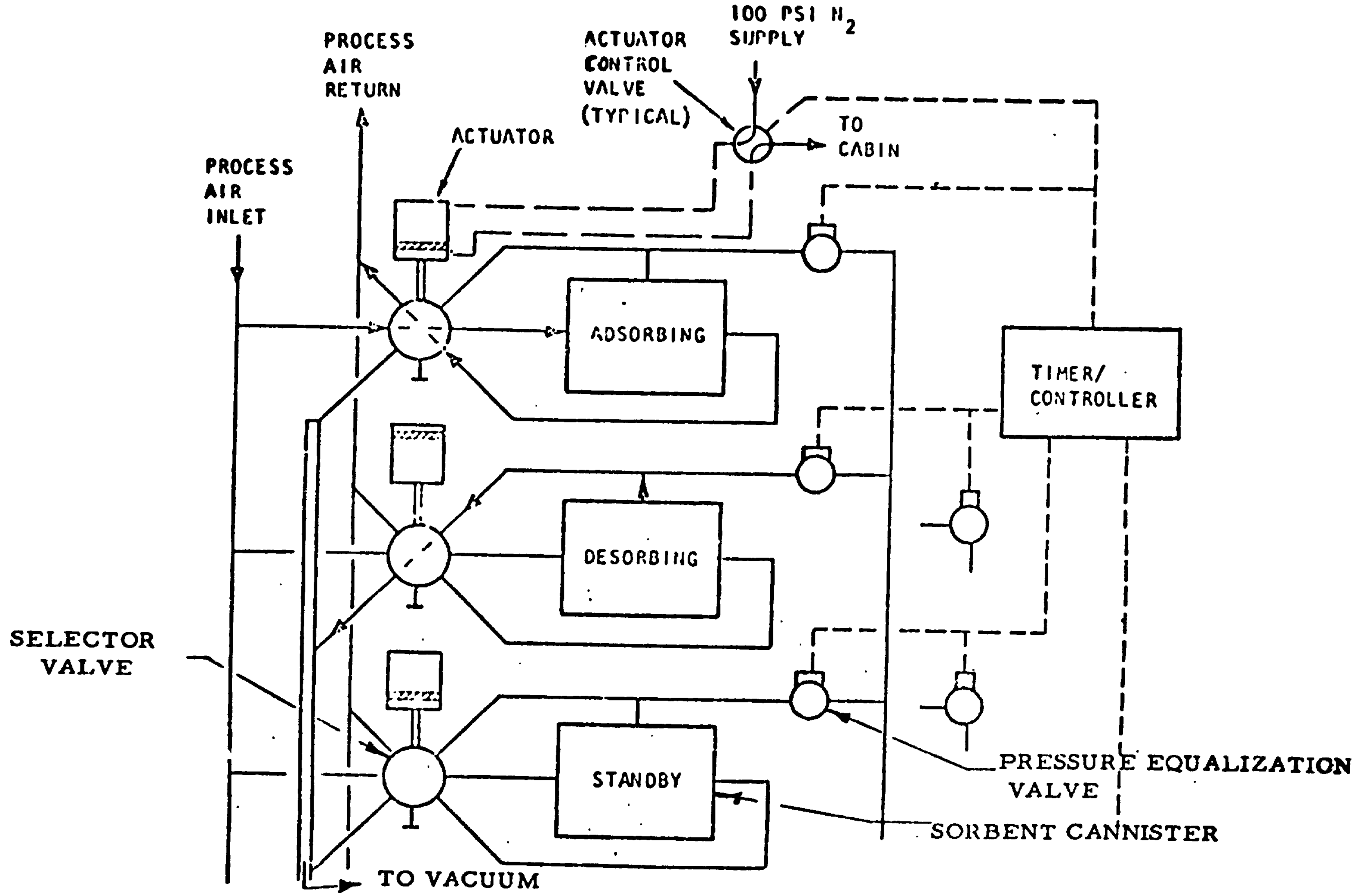


Figure 16. Molesieve diagram.

The four-man HDC is the CO_2 removal assembly utilized by the RLSE program. RLSE is a JSC planned payload scheduled for an early 30 day Spacelab mission and is basically the old SSP activities with Hamilton Standard. Figure 4 (overall EC/LSS schematic) relates the associated plumbing for the HDC concept.

Input power for the HDC is not required because the electrochemical concentration process is superimposed on a fuel cell type reaction between O_2 and H_2, which generates electricity. Inlet air is passed through a humidifier before entering the cell. Within the cell, CO_2 is transferred from the process air to an H_2 atmosphere through an electrolyte maintained in a porous matrix. Outlet process gas returns to the cabin through the other side of the humidifier where water is transferred to the inlet stream through a membrane. H_2 and O_2 are continuously supplied to the concentration cell by the electrolysis cell, and a pump delivers the CO_2 and the excess H_2 to an accumulator through a condenser-separator. Electrical power generated continuously by this system can be conditioned for use or dissipated.

VI. CONTAMINANT CONTROL ASSEMBLY

The contaminant control assembly for the MM removes atmospheric contaminants and maintains contaminant concentrations of less than 0.1 of the industrial threshold limit values. The assembly contains debris and bacterial filters, sorbent beds for ammonia acid and peak contamination production, and a catalytic oxidizer (with a pre- and post-sorbent) for removal of other trace contaminants. The RLSE contaminant control assembly is illustrated in Figure 17 [5].

The Lockheed Missiles and Space Company identified a list of contaminants which was accepted by the JSC under the SSP program [2] as potential trace contaminants. These contaminants are listed in Table 6 together with their maximum allowable concentration and estimates of their generation rates. The SSP contaminant model is based on a crew of six men.

The debris filters prevent particle debris, aerosols, and moisture from entering the MM process air ducting and equipment. They consists of a Teflon coated screen (100 mesh) which lies across the outlet air duct of the MM. The particulate contaminants include wet and dry debris consisting of water droplets and other liquids, fabric particles, nail clippings, skin flakes, hair, etc.

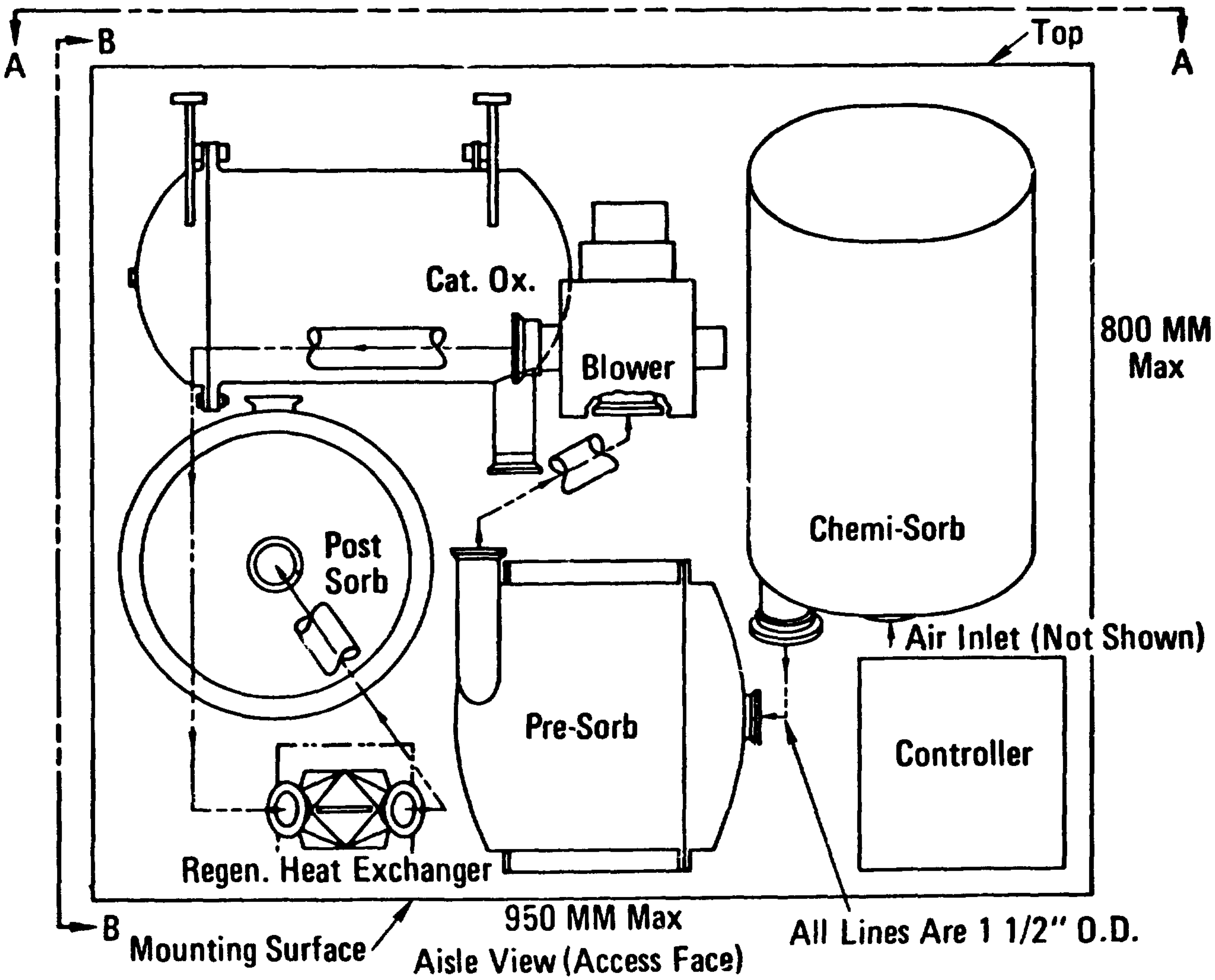


Figure 17. Trace contaminant control assembly [5].

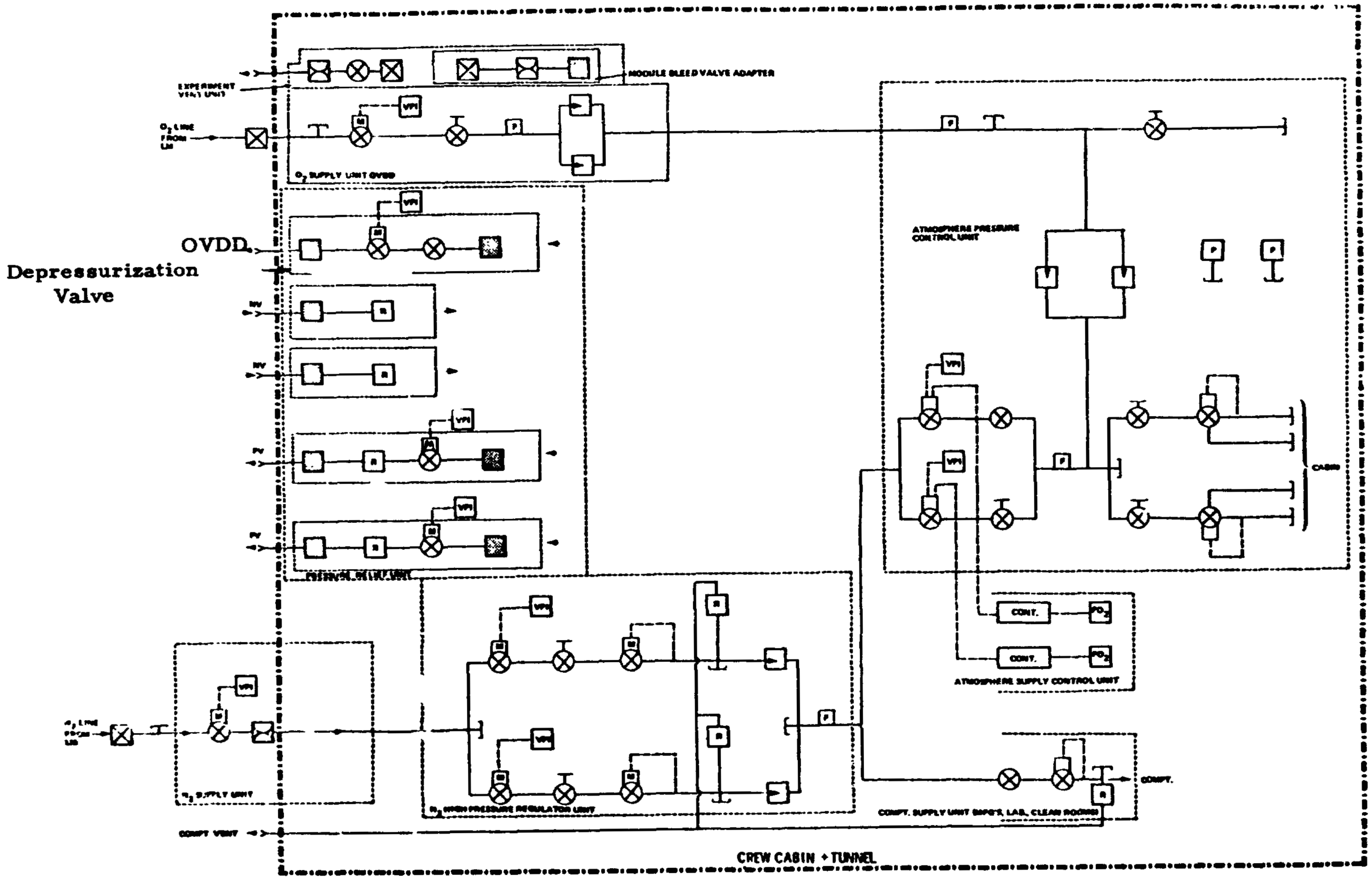


Figure 17. (Concluded).

TABLE 6. MAXIMUM CONCENTRATION AND PRODUCTION RATE OF TRACE CONTAMINANTS [2]

Contaminant	Production Rates			Maximum Allowable Concentration (mg/m^3)
	Non-Biological (gm/day)	Biological (gm/day)	Total (gm/day)	
Acetone	10.20	0.0059	10.20	240
Acetaldehyde	2.50	0.0023	2.50	36
Acetic Acid	0.25		0.25	2.5
Acetylene	2.50		2.50	180
Acetonitrile	0.25		0.25	7
Acrolein	0.25		0.25	0.25
Allyl Alcohol	0.25		0.25	0.5
Ammonia	2.50	12.0	14.50	3.5
Amyl Acetate	0.25		0.25	53
Amyl Alcohol	0.25		0.25	36
Benzene	2.50		2.50	8
n-Butane	2.50		2.50	180
iso-Butane	0.25		0.25	180
Butene-1	2.50		2.50	180
cis-Butene-2	0.25		0.25	180
trans-Butene-2	2.50		2.50	180
1, 3 Butadiene	2.50		2.50	220
iso-Butylene	0.25		0.25	180
n-Butyl Alcohol	2.50	0.036	2.54	30
iso Butyl Alcohol	0.25		0.25	30
sec-Butyl Alcohol	0.25		0.25	30
tert-Butyl Alcohol	0.25		0.25	30

TABLE 6. (Continued)

Contaminant	Production Rates Non-Biological (gm/day)	Biological (gm/day)	Total (gm/day)	Maximum Allowable Concentration (mg/m³)
Butyl Acetate	0.25		0.25	71
Butraldehydes	0.25		0.25	70
Butyric Acid	0.25		0.25	14
Carbon Disulfide	0.25		0.25	6
Carbon Monoxide	2.50	0.4	2.9	29
Carbon Tetrachloride	0.25		0.25	6.5
Carbonyl Sulfide	0.25		0.25	25
Chlorine	0.25		0.25	1.5
Chloroacetone	0.25		0.25	100
Chlorobenzene	0.25		0.25	[illegible]
Chlorofluoromethane	0.25		0.25	24
Chloroform	2.50		2.50	24
Chloropropane	0.25		0.25	84
Caprylic Acid			0.25	155
Cumene	0.25		0.25	25
Cyclohexane	2.50		2.50	100
Cyclohexene	0.25		0.25	100
Cyclohexanol	0.25		0.25	20
Cyclopentane	0.25		0.25	100
Cyclopropane	0.25		0.25	100
Cyanamide	0.25		0.25	45
Decalin	0.25		0.25	5.0
1, 1 Dimethyl cyclohexane	0.25		0.25	120

TABLE 6. (Continued)

Contaminant	Production Rates			Maximum Allowable Concentration (mg/m³)
	Non-Biological (gm/day)	Biological (gm/day)	Total (gm/day)	
trans 1, 2, Dimethyl Cyclohexane	0.25		0.25	120
2, 2 Dimethyl Butane	0.25		0.25	93
Dimethyl Sulfide	0.25		0.25	15
1, 1 Dichloroethane	2.50		2.50	40
Di iso Butyl Ketone	0.25		0.25	29
1, 4 Dioxane	2.50		2.50	36
Dimethyl Furan	0.25		0.25	3.0
Dimethyl Hydrazine	0.25		0.25	0.1
Ethane	2.50		2.50	180
Ethyl Alcohol	2.50	0.12	2.62	190
Ethyl Acetate	2.50		2.50	140
Ethyl Acetylene	0.25		0.25	180
Ethyl Benzene	0.25		0.25	44
Ethylene Dichloride	0.25		0.25	40
Ethyl Ether	2.50		2.50	120
Ethyl Butyl Ether	0.25		0.25	200
Ethyl Formate	2.50		2.50	30
Ethylene	2.50		2.50	180
Ethylene Glycol	0.25		0.25	114
trans 1, Methyl 2 Ethyl Cyclohexane	0.25		0.25	117
Ethyl Sulfide	0.25		0.25	97
Ethyl Mercaptan	0.25		0.25	2.5

TABLE 6. (Continued)

Contaminant	Production Rates			Maximum Allowable Concentration (mg/m^3)
	Non-Biological (gm/day)	Biological (gm/day)	Total (gm/day)	
Freon 11	2.50		2.50	560
Freon 12	2.50		2.50	500
Freon 21	0.25		0.25	420
Freon 22	0.25		0.25	350
Freon 23	0.25		0.25	12
Freon 113	0.25		0.25	700
Freon 114	2.50		2.50	700
Freon 114 unsym	0.25		0.25	700
Freon 125	0.25		0.25	25
Formaldehyde	0.25		0.25	0.6
Furan	0.25		0.25	3
Furfural	0.25		0.25	2
Hydrogen	2.50	0.6	3.10	215
Hydrogen Chloride	0.25		0.25	0.15
Hydrogen Fluoride	0.25		0.25	0.08
Hydrogen Sulfide		0.0007	0.0009	1.5
Heptane	0.25		0.25	200
Hexene-1	0.25		0.25	180
n-Hexane	2.50		2.50	180
Hexamethylcyclotri-sihexane	0.25		0.25	240
Indole	0.25	1.2	1.45	126
Isoprene	0.25		0.25	140
Methylene Chloride	2.50		2.50	21

TABLE 6. (Continued)

Contaminant	Production Rates Non-Biological (gm/day)	Biological (gm/day)	Total (gm/day)	Maximum Allowable Concentration (mg/m^3)
Methyl Acetate	2.50		2.50	61
Methyl Butyrate	0.25		0.25	30
Methyl Chloride	0.25		0.25	21
2-Methyl-1 Butene	0.25		0.25	1430
Methyl Chloroform	2.50		2.50	190
Methyl Furan	0.25		0.25	3
Methyl Ethyl Ketone	2.50		2.50	59
Methyl Isobutyl Ketone	0.25		0.25	41
Methyl Isopropyl Ketone	2.50		2.50	70
Methyl Cyclohexane	0.25		0.25	200
Methyl Acetylene	0.25		0.25	165
Methyl Alcohol	2.50	0.12	2.62	26
3-Methyl Pentane	0.25		0.25	295
Methyl Methacrylate	0.25		0.25	41
Methane	29.5	7.2	36.7	1720
Mesitylene	0.25		0.25	2.5
mono Methyl Hydrazine	0.25		0.25	0.035
Methyl Mercaptan			0.25	2
Naphthalene	0.25		0.25	5.0
Nitric Oxide	0.25		0.25	32
Nitrogen Tetroxide	0.25		0.25	1.8
Nitrogen Dioxide	0.25		0.25	0.9

TABLE 6. (Continued)

Contaminant	Production Rates Non-Biological (gm/day)	Biological (gm/day)	Total (gm/day)	Maximum Allowable Concentration (mg/m³)
Nitrous Oxide	0.25		0.25	47
Octane	0.25		0.25	235
Propylene	2.50		2.50	180
iso-Pentane	2.50		2.50	29
n-Pentane	2.50		2.50	295
Pentene-1	0.25		0.25	180
Pentene-2	0.25		0.25	180
Propane	2.50		2.50	180
n-Propyl Acetate	0.25		0.25	84
n-Propyl Alcohol	2.50		2.50	75
iso-Propyl Alcohol	2.50		2.50	98
n-Propyl Benzene	0.25		0.25	44
iso-Propyl Chloride	0.25		0.25	260
iso-Propyl Ether	0.25		0.25	120
Proprionaldehyde	0.25		0.25	30
Propionic Acid	0.25		0.25	15
Propyl Mercaptan			0.25	82
Propylene Aldehyde	0.25		0.25	10
Pyruvic Acid		4.53	4.53	0.9
Phenol	0.25	4.53	4.78	1.9
Skatol			0.25	141
Sulfur Dioxide	0.25		0.25	0.8
Styrene	0.25		0.25	42
Tetrachloroethylene	0.25		0.25	67

TABLE 6. (Continued)

Contaminant	Production Rates Non-Biological (gm/day)	Biological (gm/day)	Total (gm/day)	Maximum Allowable Concentration (mg/m^3)
Tetrafluoroethylene	0.25		0.25	205
Tetrahydrofurane	0.25		0.25	59
Toluene	2.50		2.50	75
Trichloroethylene	2.50		2.50	52
1, 2, 4 Trimethyl Bezene	0.25		0.25	49
1, 1, 3 Thrimethyl cyclohexane	0.25		0.25	140
Valeraldehyde			0.25	70
Valeric Acid			0.25	110
Vinyl Chloride	2.50		2.50	130
Vinyl Methyl Ether	0.25		0.25	60
Vinyldene Chloride	0.25		0.25	20
O-Xylene	2.50		2.50	44
m-Xylene	2.50		2.50	44
p-Xylene	2.50		2.50	44

Note: The following are pertinent chemical synonyms for Table 6:

2-Buranone = Methyl ethyl ketone

Chlorodifluoromethane = Freon 22

Crotonaldehyde = Propylene aldehyde

Decahydronaphthalene = Decalin

1, 2 Dichloroethane = Ethylene chloride = Ethylene dichloride

Dichlorodifluoromethane = Freon 12

Dichlorofluoromethane = Freon 21

Dichlorotetrafluorethane = Freon 114

p-Dioxane = 1, 4 Dioxane

2-Methyl Butanone-3 = 3-Methyl 2 Butanone = Methyl isopropyl ketone

Methoxy Ethane = Vinyl methyl ether

Propene = Propylene

Propyne = Propone + Methyl acetylene

Pentafluoroethane = Freon 125

Perchloroethylene = Tetrachloroethylene

Trichlorofluoromethane = Freon 11

Trichlorotrifluoroethane = Freon 113

Trifluoromethane = Fluoroform = Freon 23

1, 3, 5 Trimethyl Benzene = Mesitylene

The bacteria filters consist of prefabricated depth filters that consist of continuous sheets of binderless fiber mat folded and separated by a corrugated separator made of a ceramic material. Blockage of the filter is caused primarily by dust build-up, not the bacteria. Effective bacterial removal efficiency is 95 percent with a $0.3\,\mu$ particle size. The filters must be designed to operate in a class 100 000 clean room, which approximates the McDonnell Douglas Astronautics Company 60 and 90 day manned chamber tests.

Trace contaminants, combustible gases, odors, hydrocarbons, etc., are removed by a combination of sorbent beds and a catalytic oxidizer. Sorbent beds are utilized primarily for ammonia, whereas the catalytic oxidizer controls CO, H_2, CH_4, benzene, and other combustible gases.

The catalytic oxidizer has its own blower and operates independently of other elements of the circuit. Module air flows through two prefilter beds (containing LiOH and $CuSO_4$ coated sorbeads), and thence through the catalytic oxidizer, and then through a post-sorbent bed. The oxidizer contains a regenerative heat exchanger, an electric air heater, and a catalyst bed.

LiOH is used as the protective material for the first pre-sorbent and post-sorbent beds. As a pre-sorbent material, LiOH will effectively remove such compounds as SO_2, H_2, S, HCl and HF. As a post-sorbent, it will also remove acid gases such as HCl and HF, which might be created in the oxidization process. The second pre-sorbent bed, containing $CuSO_4$ coated sorbeads is used for ammonia and basic (high pH) compound control.

The prime sorbent bed removes ammonia and handles peak odor productions. A $CuSO_4$ coated silica gel (6-10 mesh size) sorbent type R is used because of its high ammonia capacity. Primary odor control is provided by the catalytic oxidizer.

Tables 7 and 8 depict the unit parts list, component quantities, spares, and expendables, as well as component weights, volumes, and powers. The installation envelope for the assembly is 95.00 × 48.01 × 80.01 cm (37.4 × 18.9 × 31.5 in.) or approximately 0.365 m^3 (13 ft^3). Sparing the catalytic oxidizer and the sorbent canisters is not considered necessary. These components are considered inherently reliable. Should a failure occur, the HM/SM contaminant control assembly is capable of performing the functions.

VII. HUMIDITY AND TEMPERATURE CONTROL ASSEMBLY

Module air cooling and humidity control is provided downstream of the HM/SM HDC (CO_2 removal assembly) by a condensing heat exchanger which interfaces with the water loop. Condensed moisture adheres to the surface of the heat exchanger fins by surface tension. At the outlet of each heat exchanger air passage, a series of holes are provided to draw off a secondary flow consisting of a mixture of air and water. This mixture then passes through the water separator assembly containing redundant motor driven rotary separators.

Module temperature control is achieved by a bypass around the condensing heat exchanger. Air flow is modulated through the heat exchanger according to the control signals of the selected module temperature and the temperature sensors upstream of the cabin fans and downstream of the condensing heat exchanger.

The weight, volume, and power for this assembly are given in Table 9.

VIII. VENTILATION AND MODULE FAN ASSEMBLIES

In the cabin air loop, air is drawn from the module into a filter/debris trap assembly upstream of redundant module fans. Check valves are provided to prevent recirculation through the inactive fans. Normally, one fan shall be operating. A differential pressure sensor measures and indicates fan performance.

TABLE 7. CONTAMINANT CONTROL WEIGHT, VOLUME,[a] AND POWER

Component	Number Required	Weight kg (lb)	Power (W)
Debris Trap	1	0.227 (0.5)	
Pre-Sorb Canister[b]	2	6.984 (15.4)	
Post-Sorb Canister[b]	1	3.492 (7.7)	
Chemi-Sorb Canister[b]	1	4.535 (10.0)	
Fan	1	5.896 (13.0)	83.5
Catalytic Oxidizer	1	4.717 (10.4)	97.5 (Est.)
Regenerative Heat Exchanger	1	1.134 (2.5)	
Controller, Catalytic Oxidizer	1	1.361 (3.0)	
Bacteria Filter[b]	1	3.855 (8.5)	
Valve, Solenoid Shut-Off	4	3.265 (7.2)	
Valve, Manual Shut-Off	7	2.540 (5.6)	
Gas Chromatograph	1	3.401 (7.5)	TBD
Flowmeter[c]	1	0.136 (0.3)	
Temperature Sensor[c]	1	0.091 (0.2)	
Differential Pressure Sensor[c]	1	0.317 (0.7)	
Voltage Sensor[c]	1	0.136 (0.3)	
Total		42.087 (92.8)	183

a. Contaminant Control Assembly Envelope = 95.00 × 48.01 × 80.00 cm (37.40 × 18.90 × 31.50 in.) = 0.365 m^3 (12.88 ft^3)

b. Expendable part of installed unit is replaced on day 90

c. Fault detection instrumentation.

TABLE 8. CONTAMINANT CONTROL ASSEMBLY EXPENDABLES/SPARES

Component	Expendables			Spares		
	Quantity	Weight kg (lb)	Volume cm^3 ($in.^3$)	Quantity	Weight kg (lb)	Volume cm^3 ($in.^3$)
Debris Filter	1	0.227 (0.5)	5096.4 (311)	1	0.227 (0.5)	5096.4 (311)
Fan	0	0	0	1	5.90 (13.0)	6341.8 (387)
Controller	0	0	0	1	0.68 (1.5)	1638.7 (100)
		0.227 (0.5)	5096.4 (311)		6.80 (15.0)	13 076.9 (798)
			0.0051 m^3 (0.18 ft^3)			0.0131 m^3 (0.462 ft^3)

TABLE 9. BIOLOGICAL FACILITY EC/LSS WEIGHT, VOLUME, AND POWER SUMMARIZATION

Assembly	Selected Candidate	Number Required	Dry Weight kg (lb)	Volume m^3 (ft^3)	Average Power (W)
O_2 Piping	1/2 in. Line (Est.)		24.49 (54)	?	—
N_2 Piping	1/2 in. Line (Est.)				
Pressure Control	SSP (Located in HM/SM)		—	—	—
CO_2 Collection	RLSE (Located in HM/SM)		—	—	—
Contaminant Control	RLSE	1	42.09 (92.8)	0.365 (12.9)	183
Contaminant Monitoring	Spacelab	1	1.360 (3)	0.014 (0.5)	80
Humidity and Temperature Control	Spacelab	1	28.57 (63)	0.028 (1.0)	19
Module Fan	Spacelab	1	16.33 (36)	0.142 (5.0) (Est.)	303
Ventilation Fan	Spacelab	2	5.44 (12)	0.006 (0.2)	75
H_2O Tank and Plumbing	Orbiter	1	28.17 (62)	0.439 (15.5)	
Condensate Storage	Spacelab	1	10.43 (23)	0.051 (1.8)	3
Water Separator	Spacelab	1	4.99 (11)	0.003 (0.1)	20
Overboard Dumping	Spacelab	1	3.17 (7)	Neg.	115
Module Sensors	Spacelab	—	1.36 (3)	Neg.	5
Fire/Smoke Detection	Spacelab	TBD	TBD	TBD	TBD
Total			166.40 (366.8)	1.048 (37.0)	803

Two ventilation fans are provided as part of the air distribution system to improve air velocity according to crew comfort requirements.

Weights, volumes, and power values for these assemblies are shown in Table 9.

IX. WATER MANAGEMENT AND SEPARATOR ASSEMBLY

Potable water for the MM's is furnished by the SCB water assembly located onboard the MM. It is piped to the MM and stored in a single Orbiter waste water tank. This tank weighs 15.65 kg (34.5 lb) empty and can contain 74.83 kg (165 lb) of water. However, due to prior use residual and error, the tank has an actual mission usable storage capacity of 68.48 kg (151 lb). An estimated weight (28.12 kg/62 lb) of this tank (Fig. 18) and its associated accessories is given in Table 10.

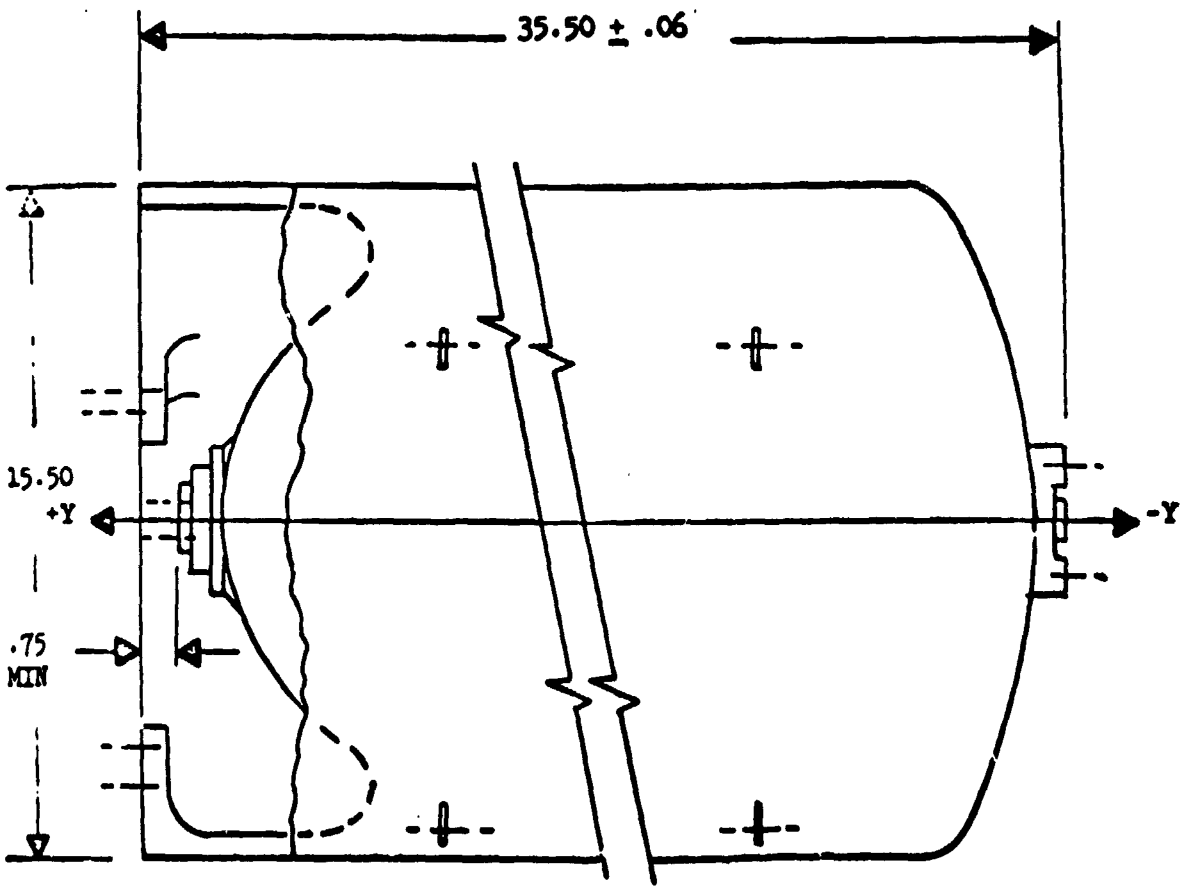


Figure 18. Orbiter tank envelope and mounting provisions (side view).

TABLE 10. WATER MANAGEMENT WEIGHT SUMMARY

Component	Number Required	Weight kg (lb)
H_2O Tank (Orbiter)[a]	1	15.65 (34.5)
H_2O Residuals		6.35 (14.0)
GN_2 Tank, 101.6 mm (4 in.) Diameter	1	0.454 (1.0)
Chiller	1	0.907 (2.0)
Silver Ion Generator	1	0.816 (1.8)
Solenoid Valve	1	0.091 (0.2)
Shut-Off Valves	2	1.088 (2.4)
Flowmeters (H_2O)	2	0.363 (0.8)
Flowmeter Couplers	2	0.082 (0.18)
Check Valve	1	0.150 (0.33)
Cap	1	0.136 (0.30)
Quick Disconnect	1	0.181 (0.40)
Pressure and Quantity Instrumentation		0.771 (1.7)
Water Outlet	1	0.227 (0.5)
Plumbing	?	0.907 (2.0)
Total		28.17 (62.11)

a. Each 393.7 mm (15 1/2 in.) diameter by 901.7 mm (35 1/2 in.) long

Water vapor is condensed from the MM atmosphere by the condensing heat exchanger. The condensate leaving the condensing heat exchanger shall be entrained in the form of water droplets.

The condensed moisture is then passed through the water separator assembly (Skylab extraction) containing redundant motor driven rotary separators. The water is separated from the air by centrifugal effect and delivered into a condensate storage tank. Then the air is returned to the cabin. At the air inlet and water outlet of each separator, check valves shall be provided to prevent water backflow. Speed sensors shall be provided to give indication of separator performance. The weight, volume, and power for the water separator assembly is included in Table 9.

X. CONDENSATE STORAGE ASSEMBLY

Condensate separated in the interfacing water separator assembly will be delivered to the condensate storage tank. The condensate quantity is measured by a quantity sensor. A manually operated shut-off valve is provided to isolate the condensate tank from the water separator and overboard dumping assemblies (Table 9).

XI. MODULE SENSORS

Various sensors are required in the module for measuring temperature, pressure, humidity, etc. The weight and power for these sensors are given in Table 9.

XII. FIRE AND SMOKE DETECTION ASSEMBLY

The fire/smoke detection assembly consists of independently operating ionization sensors. These sensors shall give signals to generate an alarm in response to incipient fire conditions in the module.

XIII. WEIGHT, VOLUME, AND POWER SUMMARY

An overall weight, volume, and power breakdown of the MM EC/LSS constituents is given in Table 9. These values amount to 166.4 kg (377 lb), 1.048 m^3 (37.0 ft^3), and an average power of 803 W.

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APPROVAL

A PRELIMINARY INVESTIGATION OF THE ENVIRONMENTAL CONTROL AND LIFE SUPPORT SUBSYSTEM (EC/LSS) FOR THE SPACE CONSTRUCTION BASE MANUFACTURING MODULES

By Hubert B. Wells

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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