HAMILTON STANDARD

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CONCEPT DEFINITION

FOR AN

EXTENDED DURATION ORBITER

ECLSS

PREPARED BY

HAMILTON STANDARD

UNDER

THE REGENERATIVE LIFE SUPPORT EVALUATION (RLSE) PROGRAM

CONTRACT NAS 9-14782

SEPTEMBER, 1977

HAMILTON STANDARD Division of UNITED TECHNOLOGIES

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INTRODUCTION

Extending the seven-day Shuttle Orbiter baseline mission requires an evaluation of the Environmental Control and Life Support (ECLS) System in order to determine those changes necessary or desirable so that the Orbiter payload capability will not be seriously compromised.

This report defines the ECLSS requirements and subsystem options for extended duration Orbiter missions. Using ground rules agreed to by the NASA and reviewed by prime vehicle contractors, each major ECLS subsystem was examined, and potential methods of extending the mission capability were studied.

The data presented reflects ECLSS actual contractor data as far as it was possible to obtain. The parametric data prepared by Hamilton Standard entitled "Thermal Control and Life Support Subsystems Parametric Data for Space Station" served as the basis for much of the data contained herein.

The mission evaluated most extensively for this effort was a 30-day mission with a crew size of seven men. However, missions up to 90 days duration with crew sizes of three to ten men were also examined.

STUDY METHOD

The methodology used in this study is shown in Figure 1. A set of ground rules were prepared and circulated to NASA/JSC, NASA/MSFC, Rockwell International, Grumman, and McDonnell Douglas. Comments were received, and the ground rules were revised and resubmitted for review. The complete version of the ground rules actually used are noted in the following report section.

Eight Shuttle Orbiter subsystem functions were evaluated. In some cases, where no other practical subsystem options were evident, the subsystem required for the extended Orbiter mission was defined. If a number of viable subsystem concepts for a particular function were available, each was evaluated and the optimum concept selected. In the case of the CO_2 Removal subsystem, the subsystem selection was dependent on many system level factors, and so the CO_2 Removal subsystem was examined on a system basis. These system factors indicated that the CO_2 Removal subsystem selection was dependent on the ECLS system water balance and whether the fuel cells were merely idled or scheduled to produce the water required. Other factors that had to be considered were whether the additional water was stored on board or reclaimed from waste water. The number of hours of extra vehicle activity (EVA) was also an influencing factor.

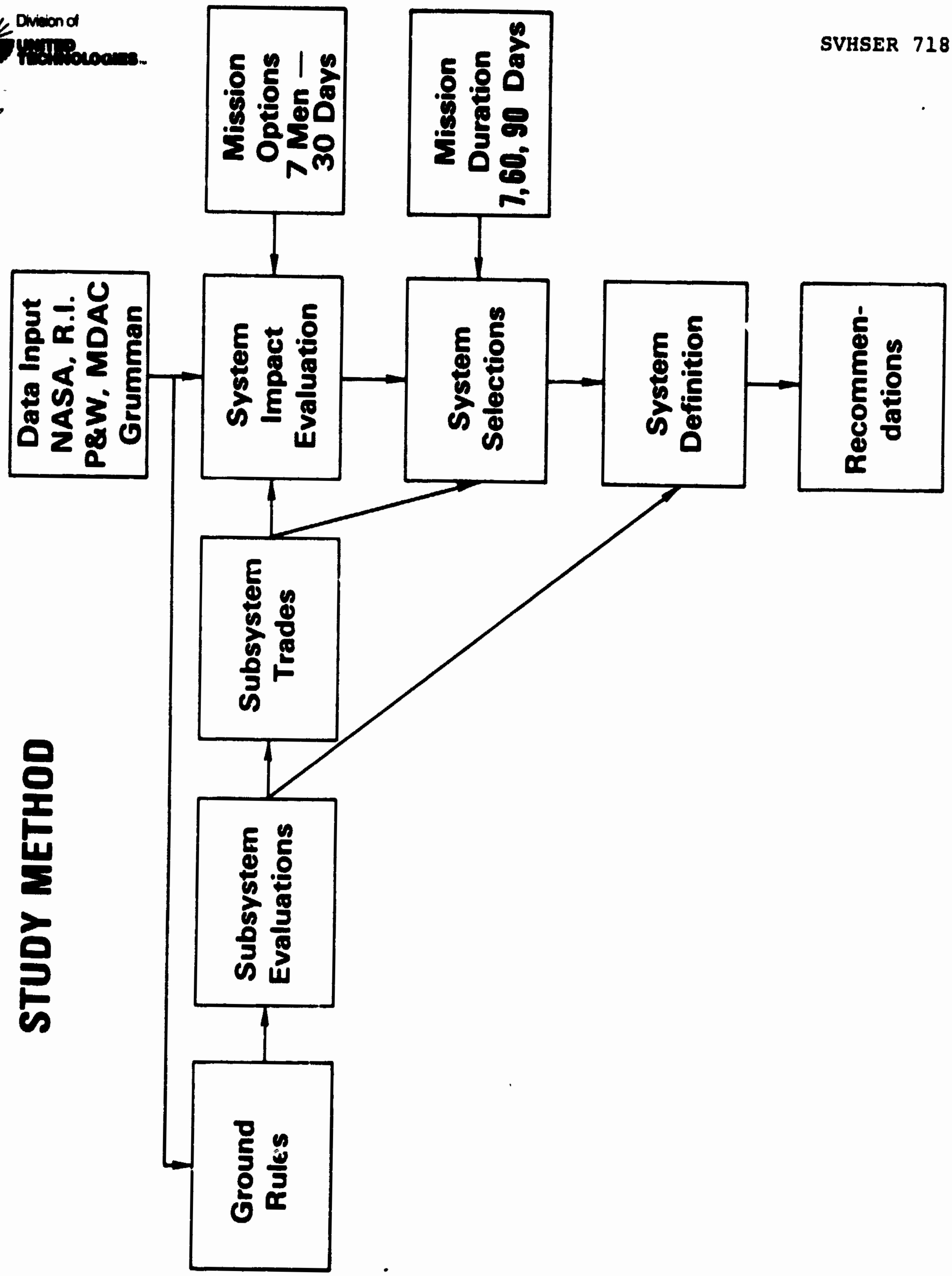

FIGURE 1 - STUDY METHOD

Various missions were defined based on data obtain from other Shuttle, Space Station, and power module studies. The impact of these missions on each system was evaluated, and the significant impacts on payload launch and landing weight, power, volume, heat rejection, and cost were determined relative to the baseline Shuttle seven-day mission. A final CO_2 Removal subsystem selection was postponed at this time pending establishment of acceptable trade criteria.

The trade criteria must establish the relative importance of weight, power, volume, heat rejection, cost, and the impact of significant qualitative considerations. Once the trade criteria is established, an optimum CO_2 subsystem selection considering all of the missions defined can be determined using the data compiled in this study. The complete ECLS system for an extended Orbiter can than be defined.

Table 1 defines the subsystems examined and the level at which they were studied and evaluated.

SUBSYSTEMS EXAMINED

	Subsystem Level	System Level
Trace Contaminant Control	√	—
Oxygen Supply	√	√
Nitrogen Supply	√	—
Waste Management	√	—
CO_2 Removal	√	√
Water Supply	√	√
Water Reclamation	√	√
Temperature and Humidity Control	—	√
Pressure and Composition	—	√

TABLE 1 - SUBSYSTEMS EXAMINED

GROUND RULES

The ground rules used for this study are shown on the following pages.

1. Design critical functions to meet fail safe criteria. Fail safe is defined as suitable backup systems or redundancy to provide 20 hours of ECLSS contingency time. A total of 96 hours vehicle contingency time is required for all subsystems. This criteria will provide a reliability equivalent to the present Shuttle ECLS system seven-day design.

2. For in-flight maintenance it is permissible to replace expendable items, life limited items, and failed items providing the item to be maintained is accessible, results in reduced system penalties, and the down time does not impact system performance significantly.

3. As a goal, all equipment, with the possible exception of expendables, will be installed in the Shuttle Orbiter.

4. It will be considered permissible to discharge overboard carbon dioxide, vapors, and trace contaminants during normal operation. However, the ECLS system shall be capable of operation under a "no dump" situation for a period of 24 hours.

5. Interface will be with the existing Shuttle Orbiter.

6. Baseline crew size design point is seven men. Crew size range is four to ten men. With 10 men or mission durations beyond 30 days, an additional habitability volume of 500 ft^3 minimum will be made available.

7. Baseline nominal mission duration design point is 30 days. Mission duration can then be extended to 60 and 90 days.

8. CO_2 partial pressure will be maintained below 7.6 mmHg. Daily average will be maintained at 5.0 mmHg.

9. Local readouts and warnings will be utilized as it is assumed that Orbiter computer system has no additional capacity.

10. No orientation restrictions will be imposed by the ECLS system other than that required for on-orbit heat rejection.

11. Total cost impact is primary consideration. Reentry penalties will be considered more significant than launch penalties.

12. All subsystems considered shall be capable of certification for actual flight use by early 1983.

13. All ECLS subsystems will be designed for an oxygen/nitrogen mixture of 14.7 psi and have the capability of operation at 8 psi without damage.

14. The ECLS system provides or controls:

    - Oxygen
    - Nitrogen
    - Potable Water
    - Wash Water (Hand Wash, No Shower)
    - Temperature and Humidity Control
    - Carbon Dioxide
    - Trace Contaminants
    - Waste Collection and/or Disposal
    - Heat Rejection

15. The ECLS system shall be capable of operation with water supplied from the fuel cells operating normally or with the water produced by a fuel cell supplied with gas equivalent to an idle fuel cell condition with no useful power output.

16. Payload experiments or missions requiring such things as no vehicle dumps, specific vehicle orientations, etc. will be charged against that particular mission or experiment and will not be considered as a penalty against the Shuttle Orbiter ECLS system.

17. The following data will be used in defining the enhanced Shuttle ECLS system. Metabolic data is based on a 70°F cabin and a level of 10,733 Btu/man-day as currently defined for the Shuttle Orbiter.

	Lbs/Day For No. Men		
	4	7	10
W_{CO_2} = 2.11 lbs/man day	8.4	14.77	21.1
W_{O_2} = 1.76 lb/man day	7.04	12.32	17.6
W_{H_2O} Sweat			
@ 65° 2.72 lb/man day	10.88	19.04	27.2
70° 3.49 lb/man day	13.96	24.43	34.9
75° 4.19 lb/man day	16.76	29.33	41.9
W_{H_2O} Feces = 0.20 lb man day			
Urine			
Water = 3.31 lb/man day	13.24	23.17	33.1
Solids = .13 lb/man day	.52	.91	1.3
Water For Food			
Water in Food = 0.57 lb/man day	2.28	3.99	5.7
For Food Prep. = 1.96 lb/man day	7.84	13.72	19.6
Drink = 3.74 lb/man day	14.96	26.18	37.4
Food Prep. and Drink = 5.70 lb/man day	22.80	39.90	57.0
Solids in Food = 1.30 lb/man day	5.20	9.10	13.0
Solids in Feces = .07 lb/man day	.28	.49	.7
Wash H_2O			
Hand/Body Wash = 2.55 lb/man day	10.2	17.85	25.5

Fuel Cell Power

Total On Orbit = 21 KW
Available for Orbiter = 10-14 KW
Available for Experiments = 8.0 KW Max.
(4.7 KW Avg.)

Conversion to AC Efficiency = 76%

Solar Cell Power - LEO

Total On-Orbit	25 KW
Reg. DC-28 V	560 lbs/KW
Reg. AC-400 Hz 120/208 V	650 lbs/KW

Heat Rejection/Sortie Ops

a) Fuel Cell with 8 Panel Rad ~ 110,000 Btu/hr (21 KW)
b) Solar Cells - 8 Panel Rad ~ 89,000 Btu/hr (25 KW)

Orbiter Leakage

Cabin	6 lb/day
Waste Management	.25 lb/man day
Air Lock	1 lb/day
Tunnel Adapter	1 lb/day

RECOMMENDATIONS

As a result of the study effort described herein, the following recommendations are made and summarized below:

Subsystem	Recommendation
Trace Contaminant Control	Install expendable adsorption canisters periodically in LiOH canisters to provide adequate trace contaminant control up to a period of 90 days.
Oxygen Supply	Utilize existing fuel cell cryogenic oxygen supply up to 60 days. Beyond 60 days, must improve insulation.
Nitrogen Supply	Use existing high pressure nitrogen tanks until nitrogen requirement approaches 600 pounds (over 60 days). At this point, use improved cryogenic oxygen storage tank with improved insulation.

Subsystem	Recommendation
Waste Management	Use existing Shuttle Orbiter subsystem with the addition of a biocide storage tank to replenish the biocide in the waste storage tanks for extended missions. For missions exceeding a total of 210 man-days, an additional commode will be required for each additional 210 man-day period.
CO_2 Removal	Use a regenerable CO_2 Removal subsystem for all missions. (Specific concept to be determined.)
Water Supply	Use all fuel cell water available. For additional water, schedule fuel cell operation to make up water deficiency if possible or supplement with stored water for missions up to 60 days. Beyond this period, incorporate the Thermoelectrically Integrated Memembrane Evaporator Subsystem (TIMES) Water Reclamation Subsystem.

Subsystem	Recommendation
Cabin Temperature and Humidity Control	Use existing Shuttle Orbiter subsystem.
Thermal Control	Use existing Shuttle Orbiter subsystems. Investigate the possibility of using waste water as a heat sink.
Pressure and Composition	Use existing Shuttle Orbiter subsystem.

TRACE CONTAMINANT CONTROL

The Trace Contaminant Control Subsystem removes atmospheric trace gases from the cabin air to maintain their concentrations at acceptably low levels. As mission length increases, the quantity of trace contaminants will gradually accumulate and will reach unacceptable levels if not controlled.

The subsystem defined below which is capable of controlling trace contaminants to an acceptable level consists of a removable sorbent bed and a small fan assembly which can be located in a convenient place in the Orbiter. If the LiOH cartridges are not used because an alternate CO_2 Removal subsystem is on board, then a trace contaminant sorbent bed described below can be resized to fit into the LiOH canister(s).

The analysis for sizing the bed was based upon data contained in Reference 1 which is a computer model of the Shuttle Orbiter/ Spacelab contaminant control subsystem. The computer model is based upon contaminant generation rates from equipment installed in the Spacelab and includes metabolic generation rates. For a 30-day mission a single "add-on" canister containing activated carbon and CO oxidation catalyst (2% platinum on charcoal) is recommended. The bed was designed to be changed out every 15 days.

While the computer program was designed to include contaminant removal by leakage, the condensing heat exchanger (for soluble contaminants), the LiOH canisters, and an add-on charcoal bed, the resultant computer design assumed removal in the condensing heat exchanger and the add-on charcoal bed only.

It was decided to utilize a 15-day changeout bed to reduce maintenance time and number of expendables required. The bed size determined by the computer model was resized by increasing the carbon mass and maintaining the same volumetric flow rate and utilizing the Skylab contaminant bed L/D ratio. In addition, since the bed size model considered only contaminants which will reach their SMAC values in 30 days, it was felt desirable to review the requirements for longer mission periods. For missions exceeding 30 days, five additional contaminants shown in Table 2 require control and additional activated carbon must be provided. From contaminant generation rates and including a coexistence factor to account for coadsorption, the saturated zone addition required was determined to be 0.5 pounds. As a result, bed was resized to control the additional contaminants.

The result is a canister containing 16.7 pounds of material, composed of 16.5 pounds of activated carbon (5.6 pounds of which is H_3PO_4 treated), and 0.2 pounds of CO oxidation catalyst (2% platinum on charcoal). The canister pressure drop will be on the order of 1.0" w.g. with a fan power of 1.3 watts at a flow rate of 4.0 CFM. Bed dimensions are 9.9" O.D. x 12.1" long. This bed, changed out every 15 days, will adequately control all trace contaminants for mission durations of up to 90 days duration.

If a regenerable CO_2 Removal Subsystem is used in place of the present LiOH cartridges, the above chemisorbent bed may be resized to be located in the Shuttle Orbiter LiOH canisters.

In view of the fact that Apollo, Gemini, the 90-day Manned Test, and Naval submarines do not require airborne bacteria control, it is recommended that none be included for extended Shuttle. If it is later found that bacteria filters are required, a filter and fan can be added.

Reference

1. Development of a Computer Program for Spacelab Contaminant Control Analysis, LMSC, January, 1977.

TABLE 2

CONTAMINANTS EXCEEDING SMAC VALUES DURING MISSION

	Compound	SMAC (Mg/M3)	Molecular Weight	Generation Rate Mg/Day	Contaminants Exceeding SMAC Value (Those not exceeding are left blank) Concentrations in Mg/M3 No Leakage Mission Length (Days)				Contaminant Concentrations Including Leakage @ 2.7 Lbs/Day = .025 CFM Mission Length (Days)				Flow Rates Required CFM				A Value
					7	30	60	90	7	30	60	90	7	30	60	90	
1.	Metryl Alcohol	3.9	32.04	2341	128	548	1096	1644	125	487	871	1174	14.84	14.84	14.84	14.84	24.60
2.	Penol	1.9	94.11	48	2.6	11.2	22.5	33.7	2.5	10.0	17.9	24.1	0.313	0.613	0.613	0.613	10.67
3.	Benzene	3.2	78.11	56	3.2	13.1	26.2	39.3	3.1*	11.7	20.8	28.1	--	0.422	0.430	0.430	18.39
4.	Methyl Chloroform	0.5	133.41	890	48.6	208	417	625	47.3	185	332	446	43.65	43.65	43.65	43.65	14.12
5.	Trichloroethylene	0.3	131.39	60	3.3	14.0	28.1	42.1	3.2	12.5	22.3	30.1	4.904	4.90	4.90	4.90	22.76
6.	Methylene Chloride	35.0	84.94	2390	131	560	1119	1679	127	498	890	1119	1.63	1.67	1.67	1.67	26.28
7.	Ammonia	17.0	17.03	3483	190	815	1631	2446	185	725	1297	1746	5.02	5.02	5.02	5.02	71.5
8.	Carbon Monoxide	17.0	28.01	1106	60	259	518	777	58	231	412	555	1.54	1.60	1.60	1.60	102.5
9.	n-Butanol	30.3	74.12	186		43.5	87	131		38.7	69	94		0.08	0.14	0.15	12.16
10.	Cyclohexanol	20.5	100.16	312		73	146	219		65	116	156		0.36	0.37	0.37	8.70
11.	iso-Propanol	[illegible]	60.09	686		161	322	482		143	256	344		0.11	0.17	0.17	15.00
12.	Indene	4 75	116.16	30		7.0	14.0	21.0		6.2	11	15.0		0.09	0.14	0.15	
13.	Toluene	75.3	92.13	2620		613	1227	1840		546	975	1314		0.85	0.85	0.85	10.19
14.	iso-Propyl Acetate	84.0	102.13	444		104	203	312		93	165	223		0.05	0.12	0.13	
15.	Butyl Lactate	3.0	130.0	52		12.2	24.3	36.5		10.9	19.3	26.1		0.42	0.43	0.43	
16.	Carbon Tetrachloride	3.1	153.84	18		4.2	8.4	12.6		3.7	6.7	9.0		0.07	0.13	0.14	20.88
17.	Chloroform	2.4	119.30	21.8		5.1	10.2	15.3		4.5	8.1	10.9		0.18	0.22	0.22	
18.	Freon-11	28.0	137.38	146		34	68	103		30	54	73.5		0.05	0.11	0.13	23.67
19.	Freon-22	350	86.47	2370		555	1110	1664		494	882	1188		0.10	0.16	0.17	23.96
20.	Freon-113	150	187.39	2070		485	969	1454		432	770	1038		0.32	0.34	0.34	13.10
21.	Di-Isobutyl Ketone	29.1	142.23	180		42	84	126		37	67	90		0.08	0.14	0.15	9.65
22.	Methyl Ethyl Ketone	29.5	72.10	216		50.5	101	152		45	80	109		0.13	0.17	0.18	16.24
23.	Methyl Isobutyl Ketone	29.0	100.16	276		64.6	129.2	193.8		57.5	102.7	138		0.20	0.23	0.23	12.41
24.	Acetonitvile	3.0	41.05	42		9.8	19.7	29.5		8.7	15.7	21.1		0.33	0.34	0.34	28.61
25.	Trimethyl Silanol	2.4	90.1	44		10.3	20.6	30.9		9.2	16.4	22.1		0.45	0.45	0.45	
26.	Dichlorodifluoroethylene	27.2	133	96		22.5	44.9	67.[illegible]		20.0*	35.7	48.1		--	0.06	0.08	
27.	Butyraldehyde	150	72.10	312			146	219			116*	156			--	0.03	9.22
28.	Ethyl Benzene	87	106.16	200			94	140			75*	100			--	0.04	9.82
29.	1,2,4-Trimethyl Benzene	44	120.19	210			98.3	147			78.1	105			0.10	0.12	9.20
30.	M-Xylene	44	106.16	189			88.5	133			70.4	95			0.11	0.13	8.49
31.	O-Xylene	44	106.16	189			88.5	133			70.4	95			0.11	0.13	8.49
32.	P-Xylene	44	106.16	189			88.5	133			70.4	95			0.11	0.13	8.49
33.	Methyl Cyclopentane	51.7	84	209			98	147			78	105			0.08	0.10	15.39
34.	Allyl Alcohol	5.0	58.08	9.4				6.6				4.7*				--	24.79
35.	Iso-Butanol	30.3	74.12	42.4				30				21.4*				--	15.32
36.	Ethyl Acetate	140	88.10	278				195				139*				--	15.73
37.	Chloropropylene	49.6	78.5	86				60.4				43*				--	28.16
38.	Cyclohexone	207	84.16	432				303				216				0.03	13.09
39.	Hexamethyl Disiloxane	66	162.4	112				78.7				56.2*				--	
40.	Acrolein	1.2	56.06	2.4				1.69				1.21*				--	27.93

*Below SMAC value using a 30% of actual cabin leakage value.

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OXYGEN SUPPLY

Oxygen in the Extended Duration Orbiter (EDO) is used to power the fuel cells, to supply metabolic oxygen for cabin leakage makeup, and as an emergency backup supply. The quantity of oxygen required for the baseline seven-man, 30-day mission with the fuel cells in the idle mode is shown in Table 3. As noted in the table, a minimum of two Shuttle oxygen cryogenic tanks are required to meet the minimum 30-day oxygen requirement. Fuel cell idle mode is the lowest fuel cell operation level which can be maintained without shutting the cells down. For the three fuel cells on board the Shuttle a total of 1 kw is consumed for this operation resulting in the production of 654 pounds of water over a 30 day period. The oxygen required slightly exceeds the boil-off rate of the cryogenic storage tanks; and boil-off is, therefore, not a penalty factor.

Additional oxygen is required for launch reentry and emergency, adequate fuel cell power generation, EVA purposes, or to operate an Electrochemical Depolarized Concentration (EDC) if used.

The oxygen requirements for a particular mission can be met by:

- Additional Cryogenic Kits or Independent Cryogenic Oxygen Tanks

OXYGEN SUPPLY SUBSYSTEM

7 Men — 30 Days

Requirements:

— Metabolic Oxygen	369.6 lbs.
— Cabin Leakage Makeup	64.2 lbs.
— Minimum Fuel Cell Idle (1 kw Total 3 Cells)	581.9 lbs.
— Launch, Reentry, Abort and Survival	213.3 lbs.
	1229 lbs.

Options:

— (EDC	177.1 lbs.)
— (EVA (6 Hours)	1 lb/Man)
— (Additional Power Generation	0.9 lb/kw)

(781 lbs O_2/Kit 2 Kits (Min.) Required)

TABLE 3 - OXYGEN SUPPLY SUBSYSTEM

- High Pressure Gas Storage Tanks
- Electrolysis of Water

The above subsystems are described in further detail in the following report sections.

CRYOGENIC OXYGEN STORAGE

Cryogenic oxygen is the method used for storing oxygen on board the present Shuttle Orbiter. The present subsystem is capable of supplying oxygen with an acceptable boil-off rate for a period of slightly over 60 days. Each tank stores 781 pounds of oxygen and weighs 1,113 pounds, including mounting structure. The Orbiter oxygen is normally stored on board in a kit which includes 92 pounds of cryogenic hydrogen. Since this subsystem has a light weight and small volume and has been designed and certified for use in the Shuttle, it has a low cost, and as a result, is the optimum method for storing additional quantities of oxygen required for Extended Duration Orbiter missions.

The quantity of oxygen available for various cyrogenic kit installations are shown in the figures noted below. The minimal disposition requirements and quantity left over are also shown.

Mission Length	Primary Power	Number of Kits	Fuel Cell Operation	Figure
7	Fuel Cell	3-4	Normal	-2
30	Solar Cell	3	Idle	-3
30	Solar Cell	4	Idle	-4
60	Solar Cell	4	Idle	-5

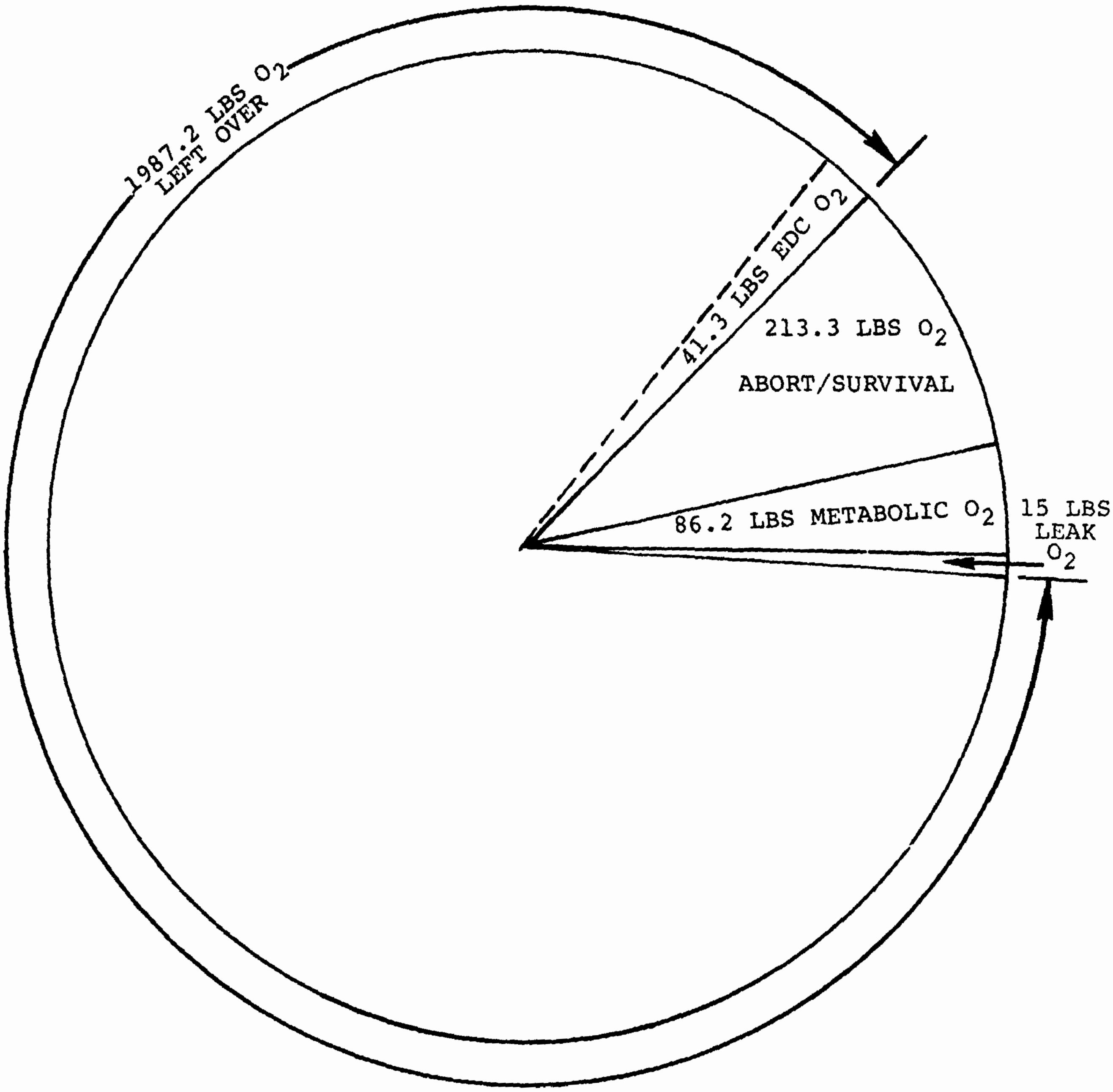

FIGURE 2

CRYOGENIC OXYGEN-3 KITS-7 DAY MISSION WITH 7 MEN

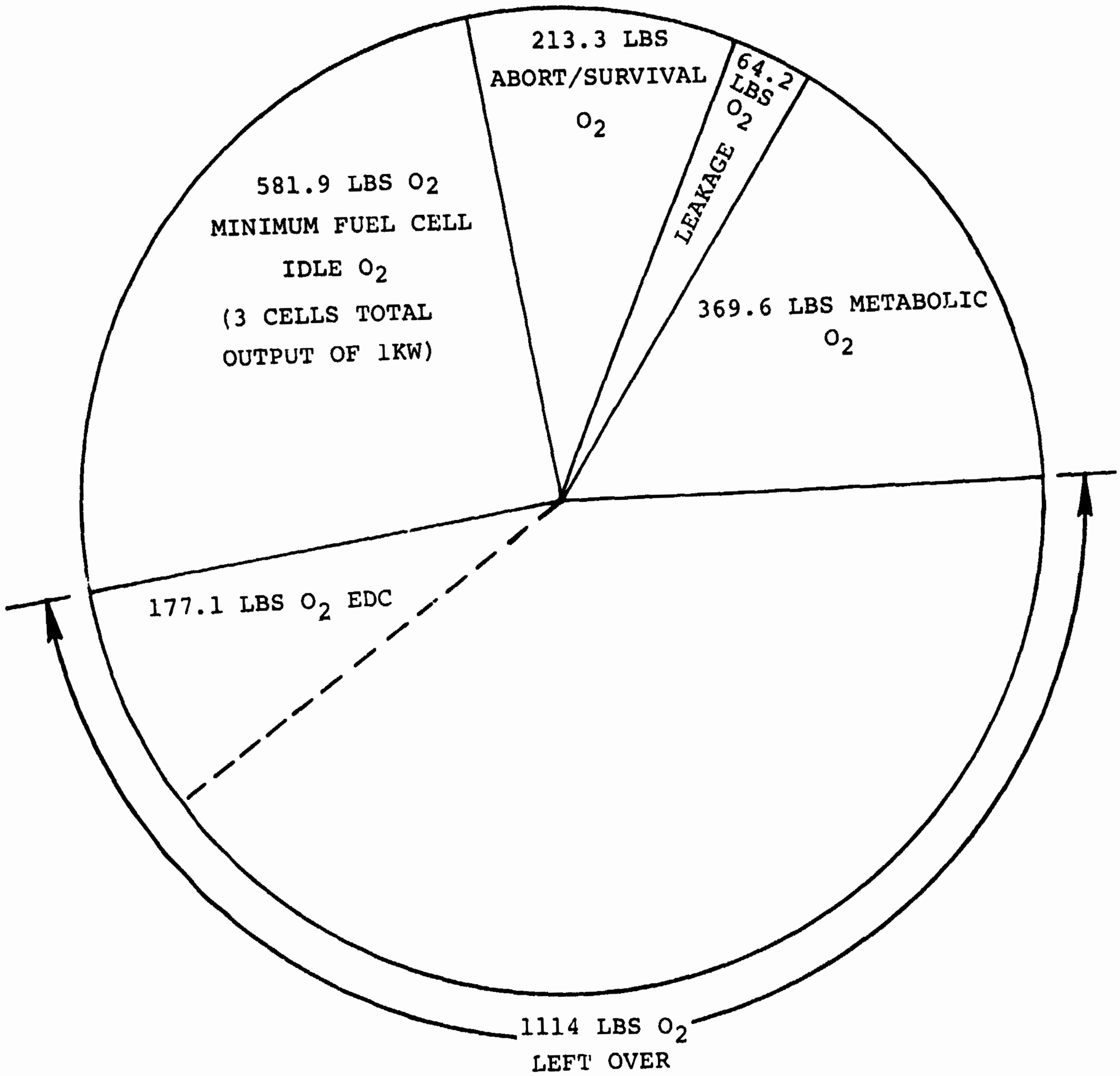

FIGURE 3

CRYOGENIC OXYGEN-3 KITS-30 DAY MISSION, 7 MEN

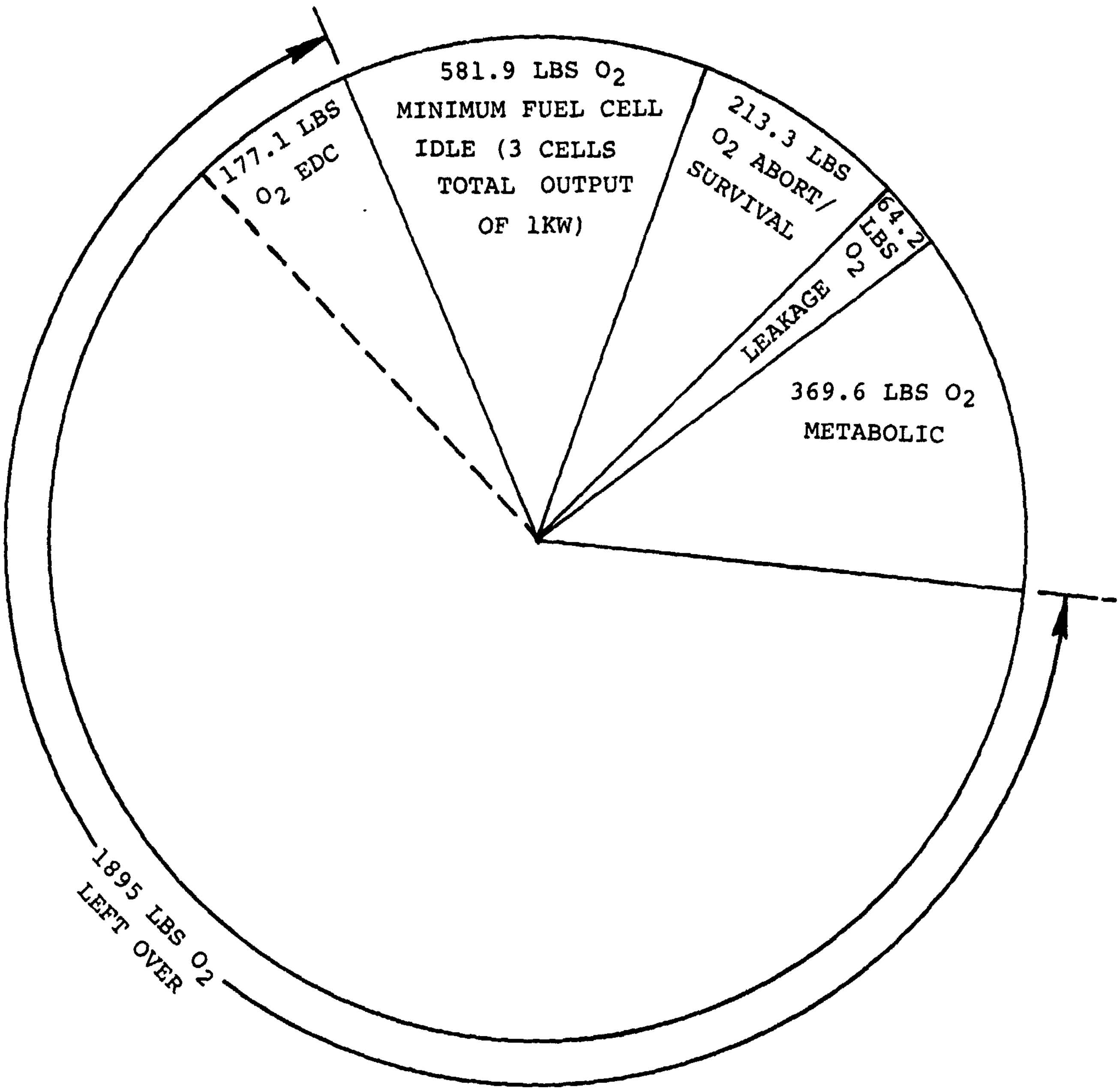

FIGURE 4

CRYOGENIC OXYGEN-4 KITS-30 DAY MISSION WITH 7 MEN

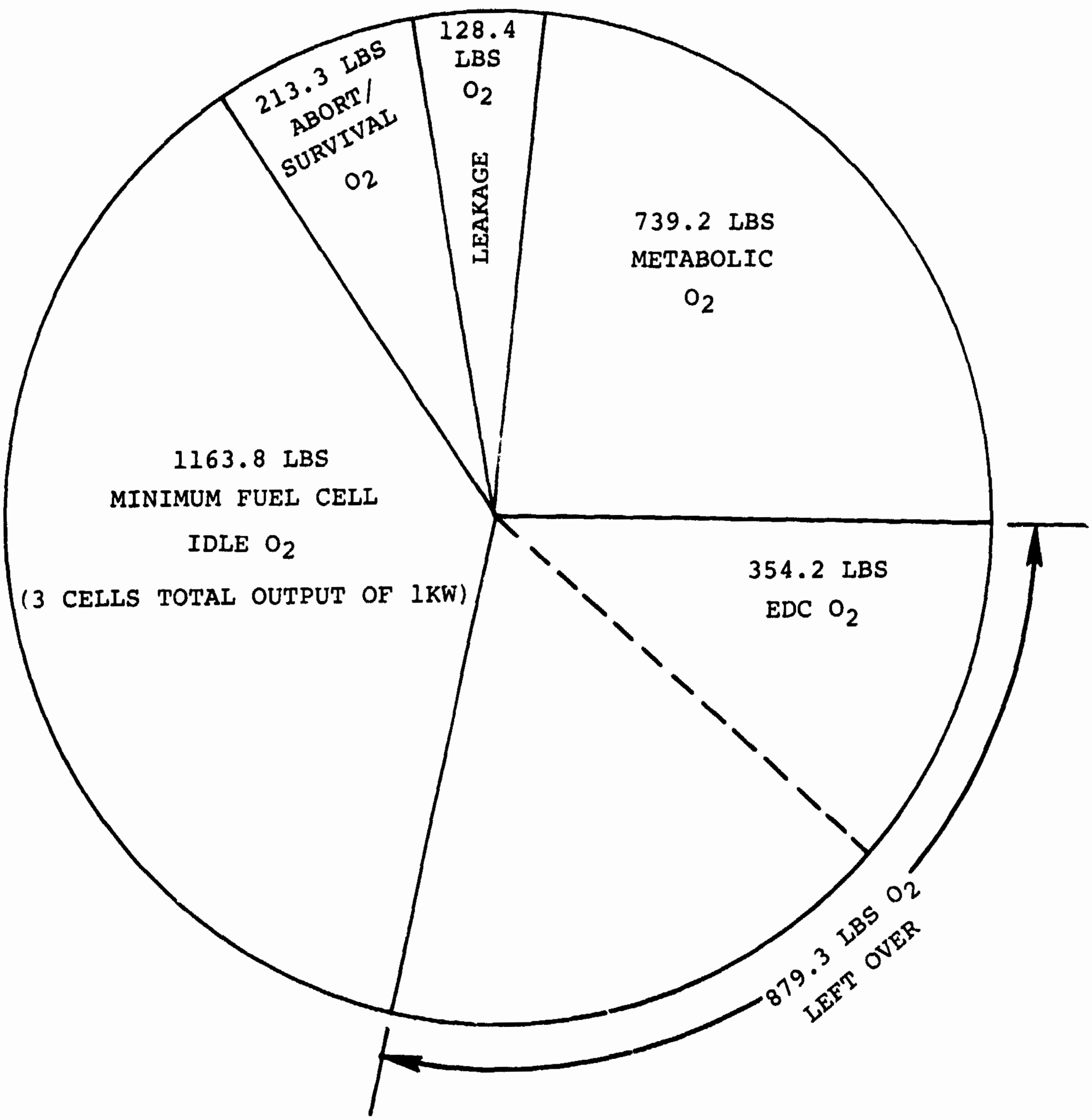

FIGURE 5

CRYOGENIC OXYGEN-4 KITS-60 DAY MISSION WITH 7 MEN

HIGH PRESSURE OXYGEN GAS STORAGE

Currently on board the Shuttle, 65 pounds of oxygen at 3,300 psi is stored for emergency use. Total tank weight, including packaging, is 195 pounds.

As the need for oxygen increases for longer missions, the possibility of adding additional high pressure storage tanks versus a single optimum tank was investigated.

The weight and volume associated with using multiple tanks of the existing Shuttle size versus a single optimum tank is shown in Figures 6 and 7. Figure 8 defines the tank assumptions used.

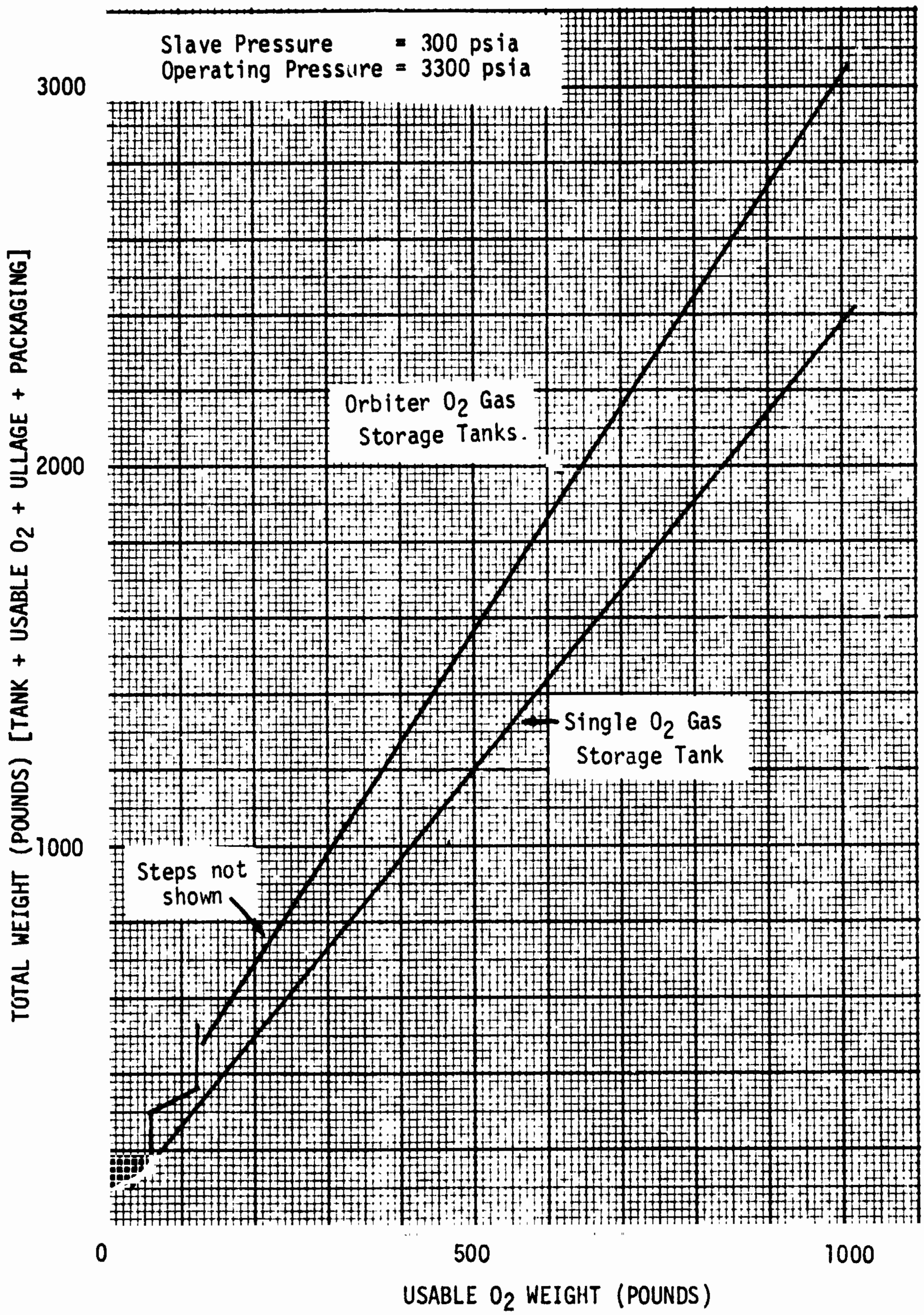

Figure 6 Gaseous O_2 Storage Weight

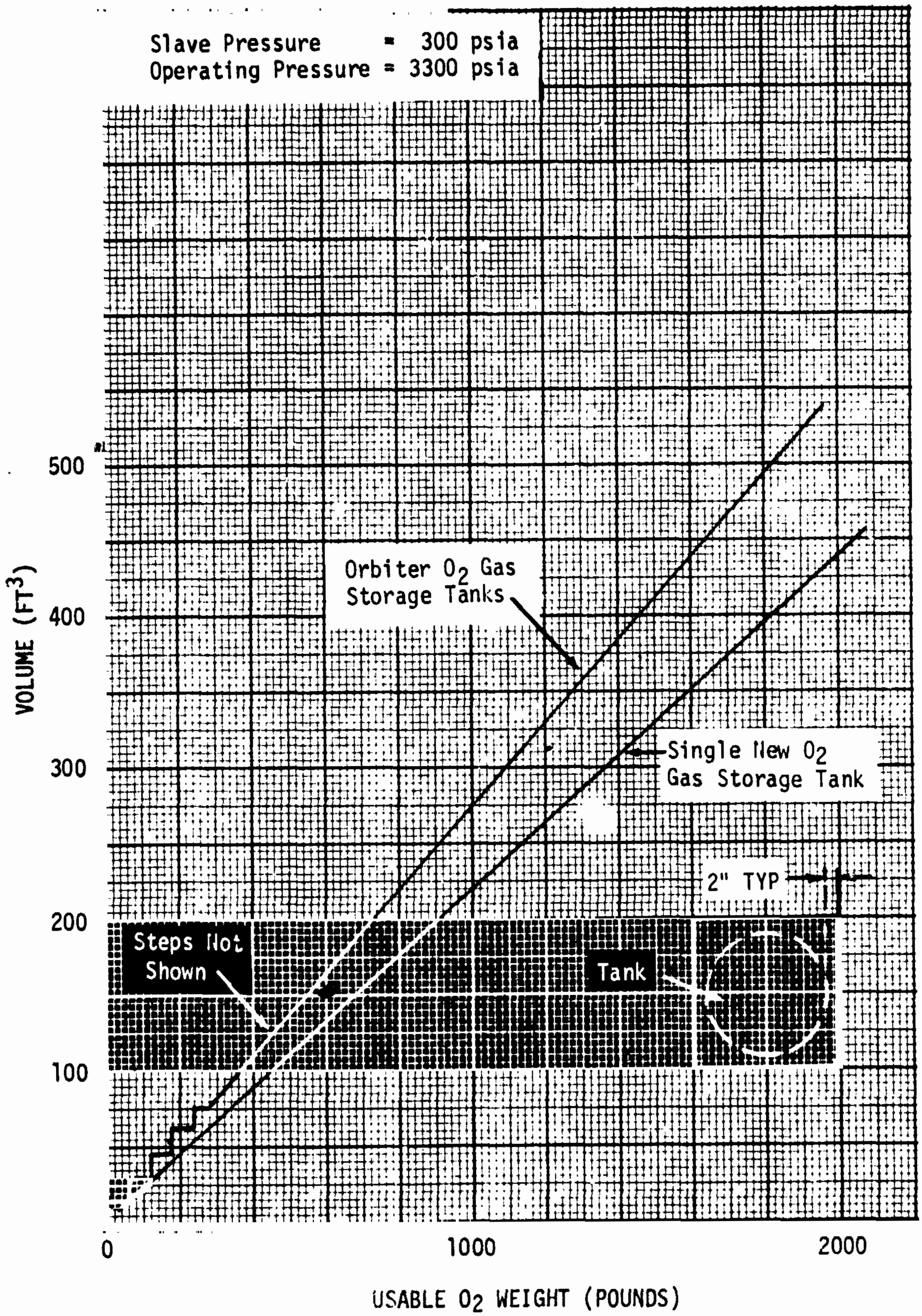

Figure 7 Gaseous O_2 Storage Volume

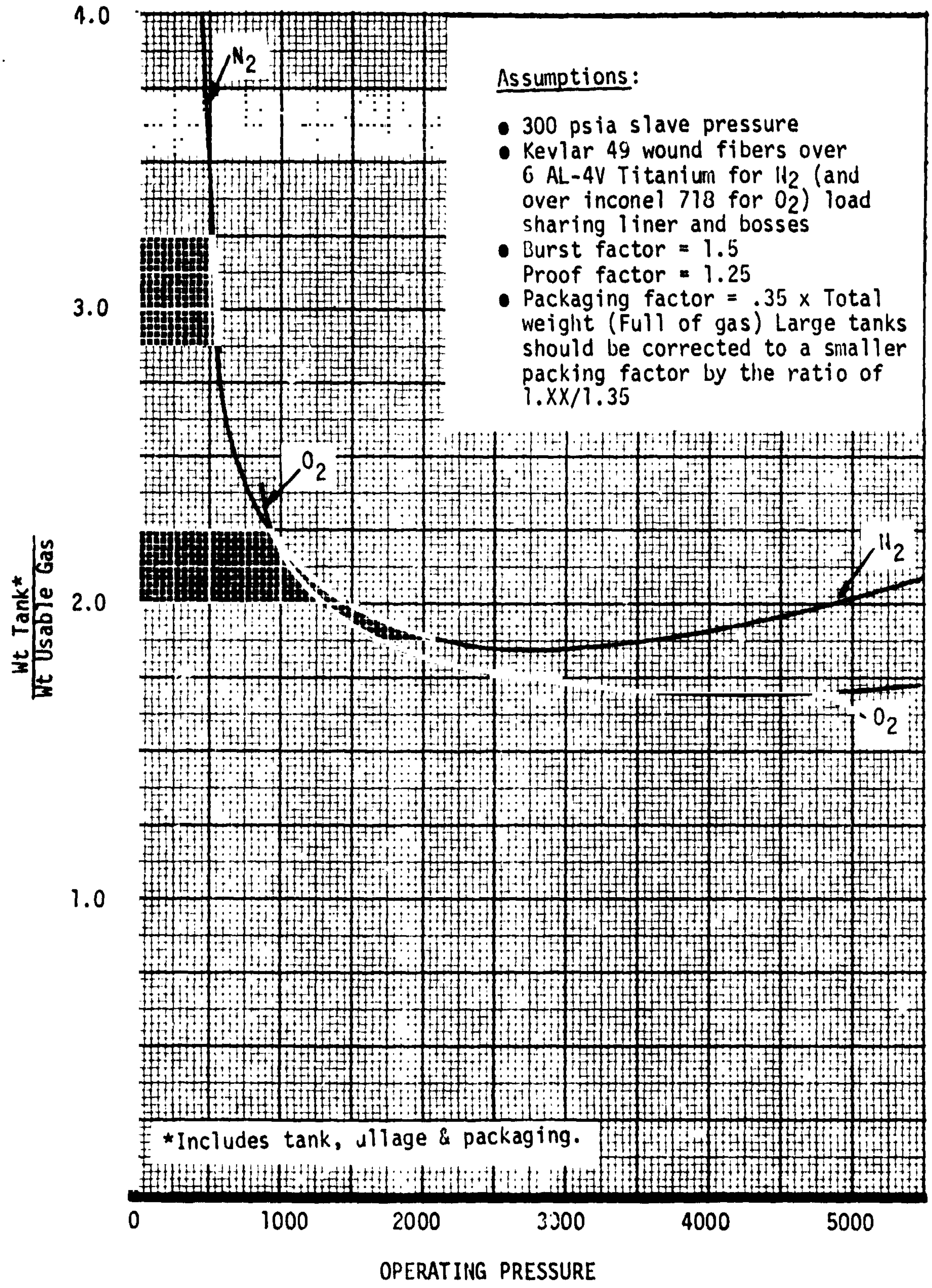

Figure 8 Composite Tank for O_2 & N_2

OXYGEN STORAGE COMPARISON

The total weight of storing gas cryogenically versus that of storing gas at high pressure was compared and plotted on Figure 9. As can be noted, utilization of the existing cryogenic storage tank is much lighter than storing high pressure gas even in a single tank. As a result of this and the fact that the cryogenic tankage already exists for the Shuttle, it is concluded that there is no change to the Orbiter oxygen storage system required for extended missions up to 60 days as long as oxygen is required continuously. Beyond this point the cryogenic tankage insulation must be improved to reduce boil-off as noted previously.

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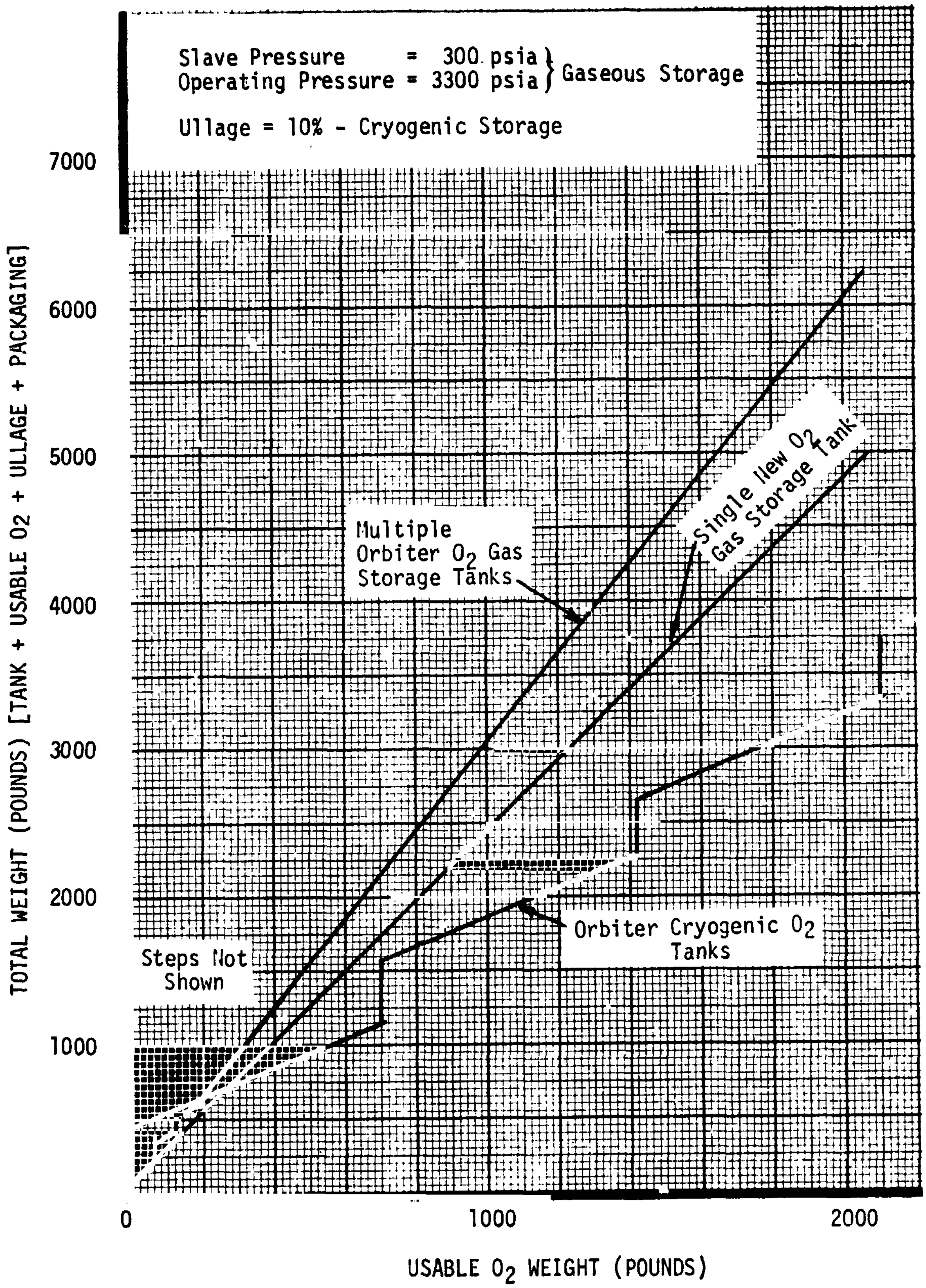

Figure 9 Gaseous O_2 Storage Weight Vs. Cryogenic O_2 Storage

ELECTROLYSIS

Another method of producing oxygen is by electrolysis of water. Two subsystems for generating oxygen using electrolysis of water were considered for use in the Extended Duration Orbiter. These are:

- Water Vapor Electrolysis (WVE)
- Solid Polymer Electrolysis (SPE)

Both of these subsystems are discussed in the following paragraphs.

Water Vapor Electrolysis

The Water Vapor Electrolysis Subsystem (WVE) combines oxygen generation with partial cabin humidity control. The WVE concept is unique in that water is fed as vapor directly from the cabin atmosphere into the WVE module for conversion to hydrogen and oxygen. The subsystem is schematically shown in Figure 10.

Cabin air is drawn into the WVE module and through the module cells by the subsystem fan. Water vapor is absorbed and electrolyzed in the cells, and the product oxygen is returned directly to the air stream through the subsystem fan and back into the cabin. The generated hydrogen is delivered to the CO_2 Reduction Subsystem. The process flow also cools the WVE module with cabin air. A subsystem controller regulates current flow into the WVE module to provide O_2 partial pressure control. The WVE consumes 62.5% of the latent vapor level in a cabin. Water vapor consumption rate and the hydrogen production rate are a function of the oxygen produced.

Prior to shutdown or maintenance of the subsystem, a supply of nitrogen is required to purge hydrogen from the subsystem.

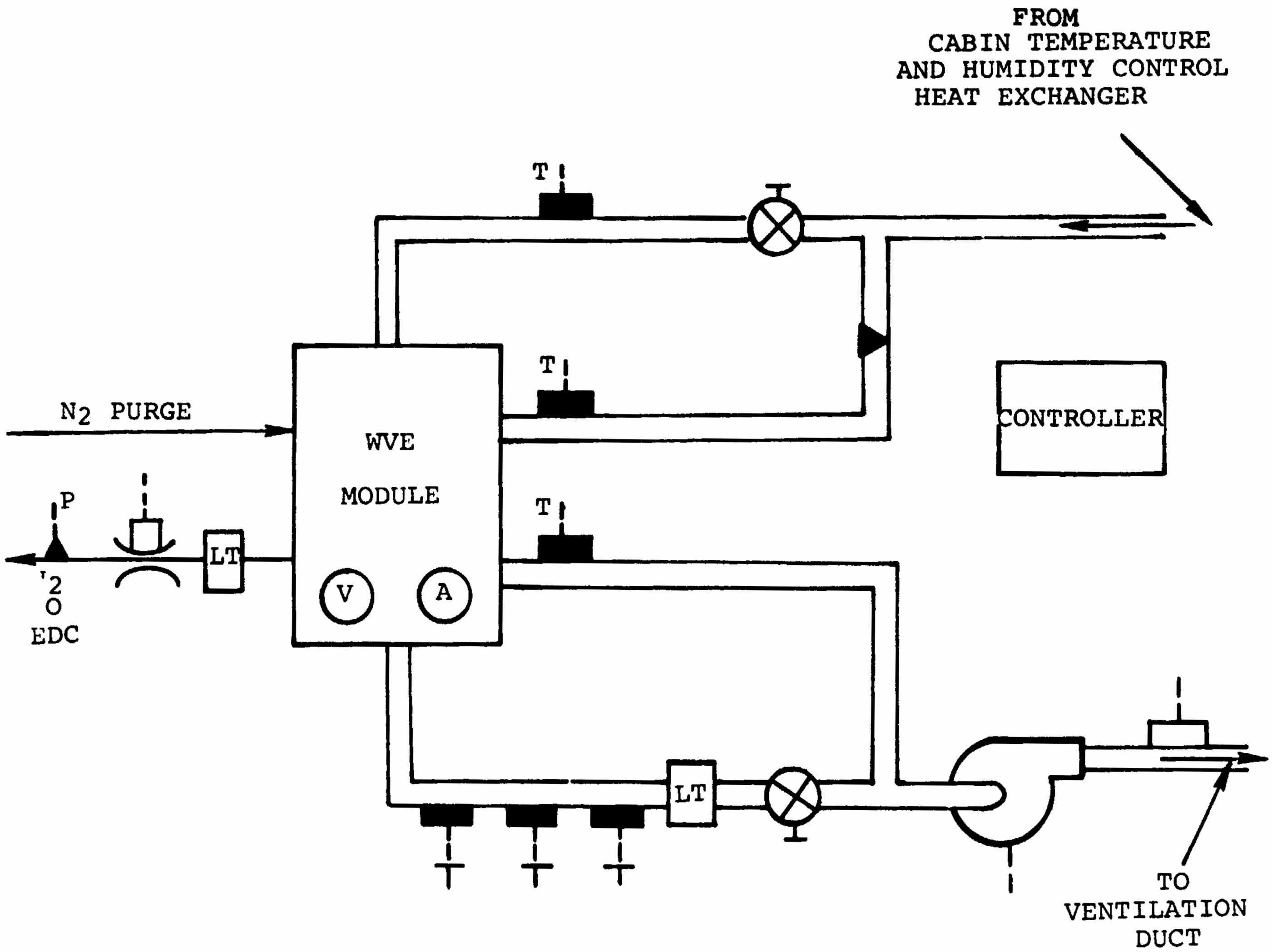

FIGURE 10

WATER VAPOR ELECTROLYSIS (WVE)

All heat generated by the subsystem was assumed to be dissipated as heat to the cabin. This subsystem has no expendable items. Table 4 defines the subsystem characteristics for the extended Orbiter baseline condition.

SUBSYSTEM: O_2 Generation

CONCEPT: WVE

7 MEN - 30 DAYS

SUBSYSTEM:	Weight (Lb)	Volume (Ft^3)	Power (Watts)	Cost ($\$ \times 10^3$)
Installed Unit	200.0	11.6	1,431	350
Flight Expendables	0	0	--	0
Resupply Expendables	--	--	--	0
Nonrecurring Cost	--	--	--	3,500
Totals	200	11.6	1,431	

VEHICLE CONSIDERATIONS:

			Generated	Required
Heat Rejection (Btu/Hr)	1,625			
Number of Interfaces	4	Oxygen (Lb/Day)	12.32	--
Cabin Air Dumped (Lb/Day)	0	Hydrogen (Lb/Day)	1.54	--
Water Loss (Lb/Day)	N/A	Water (Lb/Day)	--	13.86
Water Recovered (Lb/Day)				

COMMENTS:

TABLE 4

Solid Polymer Electrolyte (SPE) Electrolysis

The Solid Polymer Electrolyte Subsystem consists of a water-fed multi-cell electrolysis module and functional components. A schematic of the subsystem is shown on Figure 11.

Process water is pumped into the unit through a deionizer to the electrolysis module cells at a controlled maximum temperature of 150°F. The water temperature is maintained by a temperature regulating valve and a regenerative heat exchanger. Some of the process water is dissociated into hydrogen and oxygen by electrolysis. The excess water absorbs the module waste heat and is discharged with the produced hydrogen. Oxygen is delivered to the cabin directly from the electrolysis cell through redundant pressure regulators. These oxygen backpressure regulators control the oxygen absolute pressure higher than the hydrogen absolute pressure. This assures a positive pressure differential of oxygen greater than the two-phase mixture in the module such that no water is hydraulically transported to the oxygen side of the module and eliminates entrained water in the oxygen discharge. Hydrogen is vented from a phase separator-pump through a differential pressure regulator and is further regulated at an absolute pressure by a hydrogen backpressure regulator where it is discharged to the CO_2 Removal and CO_2 Reduction Subsystems, as required.

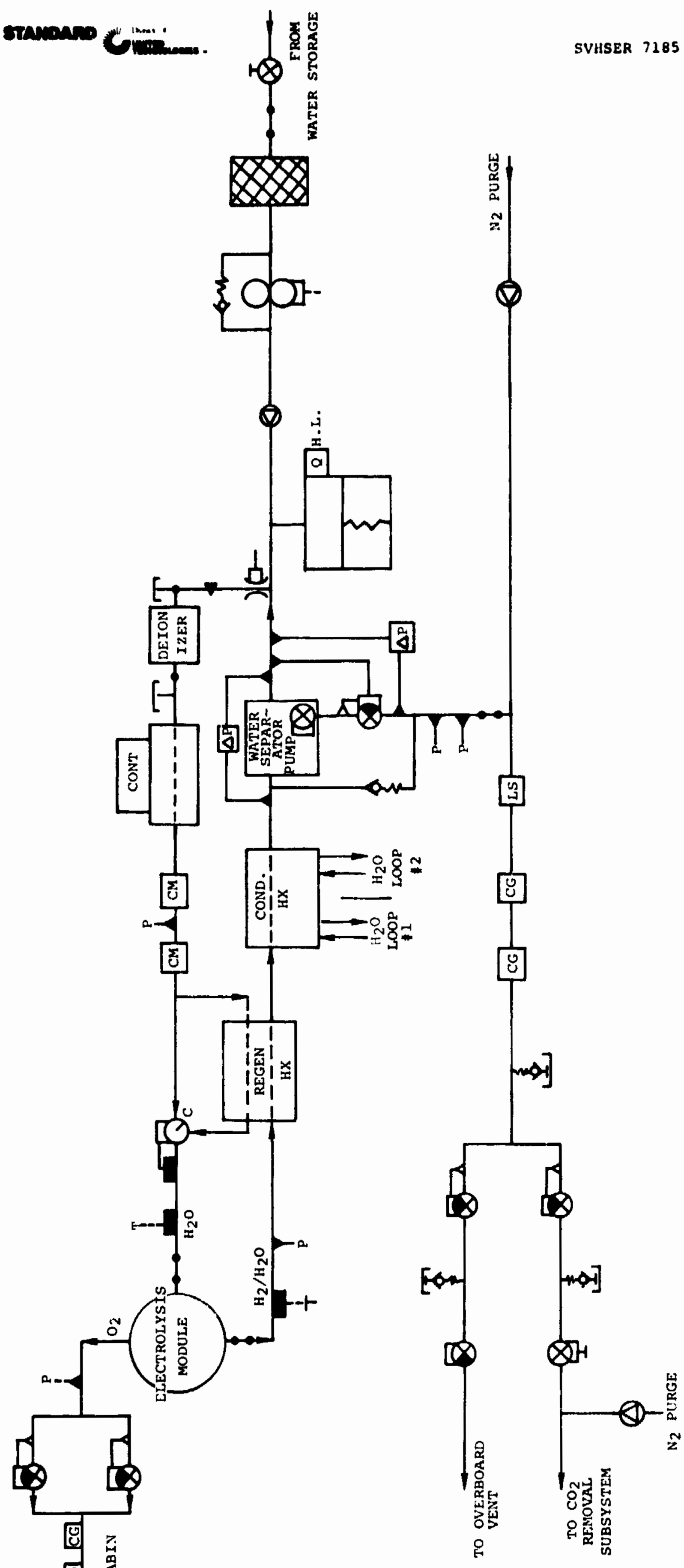

FIGURE 11

SOLID POLYMER ELECTROLYTE (SPE)

Power is delivered to the electrolysis module through a power conditioner in the subsystem controller which acts as a current regulator for maintaining a selected gas (O_2) production rate. The power conditioner which operates at about 92% efficiency rejects waste heat to a cold plate through which process water, being delivered to the hydrogen side of the electrolysis module, is circulated. All power supplied to the controller, phase separator, and makeup pump were assumed to be dissipated as heat to the cabin. Heat rejection by the power conditioner has already been discussed. The heat rejection of a makeup pump has been included; however, it will operate only about 10% of the time.

Prior to shutdown or maintenance of the subsystem, a supply of nitrogen is required to purge hydrogen from the subsystem.

The subsystem requires replacement between missions of a water inlet filter and an deionizer. Table 5 defines the subsystem characteristics for the extended Orbiter base condition.

SUBSYSTEM: Oxygen Generation

CONCEPT: Solid Polymer Electrolyte (SPE)

7 MEN - 30 DAYS

SUBSYSTEM:	Weight (Lb)	Volume (Ft^3)	Power (Watts)	Cost ($\$ \times 10^3$)
Installed Unit	228.7	13.8	1,757	440
Flight Expendables	6.5	0.36	--	0
Resupply Expendables	--	--	--	8
Nonrecurring Cost	--	--	--	5,000
Totals	235.3	14.2	1,757	

VEHICLE CONSIDERATIONS:

Heat Rejection (Btu/Hr)	1,963
Number of Interfaces	5
Cabin Air Dumped (Lb/Day)	0
Water Loss (Lb/Day)	0
Water Recovered (Lb/Day)	N/A

	Generated	Required
Oxygen (Lb/Day)	12.32	--
Hydrogen (Lb/Day)	1.54	--
Water (Lb/Day)	--	13.86

COMMENTS:

TABLE 5

Electrolysis Subsystem Discussion

The characteristics of the above two electrolysis subsystems were summarized as noted in Table 6. An examination of this table shows that the WVE subsystem has the best overall characteristics of the two for use in the Extended Duration Shuttle Orbiter. It imposes the least penalty on the vehicle. As a result, the WVE Subsystem characteristics were used in subsequent ECLS system evaluations involving the use of electrolysis for oxygen and hydrogen generation.

TABLE 6

ELECTROLYSIS SUBSYSTEM DATA COMPARISON SUMMARY
7-MEN - 30-DAYS

	Flight Weight (Lbs)	Volume (Ft^3)	Power (Watts)	Heat Rejection (Btu/Hr)	Vehicle Interfaces (Numbers)	Flight Expendables	Cost ($\$ x 10^6$)
Solid Polymer Electrolyte (SPE)	229	13.8	1,757	1,963	5	None	5.1
Water Vapor Electrolysis (WVE)	200	11.6	1,431	1,625	4	None	3.9

OXYGEN SUPPLY CONCLUSION

A review of the three methods of providing oxygen for the extended Orbiter mission shows that cryogenic storage of oxygen is the optimum method. It has the lowest weight, lowest cost (already developed), and least impact on the vehicle. For mission periods beyond 60 days, the cryogenic tankage insulation must be improved to extend its mission capability.

The use of electrolysis for oxygen generation is not competitive on a subsystem basis due to the high power and heat rejection involved. It appears that as long as a fuel cell is the principal power supply, electrolysis will never trade off. However, if a power module is used, electrolysis might be considered. Tne possibility of integration with other subsystems on a total system basis was examined in the System Section of this report using the Water Vapor Electrolysis Subsystem concept.

NITROGEN SUPPLY

Nitrogen gas is used in the cabin for cabin atmospheric leakage makeup and for miscellaneous uses. For the baseline mission, 315 pounds of nitrogen is required. Nitrogen is currently stored in the Shuttle Orbiter in four high pressure (3,300 psi) tanks, with each containing 63 pounds of gas. As a result, two additional tanks will be required for the 30-day mission.

Nitrogen gas can be stored in high pressure tanks (3,300 psia) or cryogenically. Figures 12 and 13 show the weight and volume respectively of storing gas using the existing shuttle tank and in storing gas in a single new nitrogen tank. Figures 14 and 15 show the weight and volume respectively of storing gas cryogenically using the existing Orbiter cryogenic oxygen tank or a new single cryogenic nitrogen tank. With the present oxygen cryogenic tank the boil-off rate, when charged with nitrogen, is about two times the usage rate so that much more nitrogen must be stored cryogenically. For mission periods approaching 60 days (which will require up to 630 pounds of nitrogen), it appears advisable to stay with the existing high pressure nitrogen tanks. The volume of a single larger tank of this capacity might be impractical to install in the vehicle and would require large nonrecurring costs.

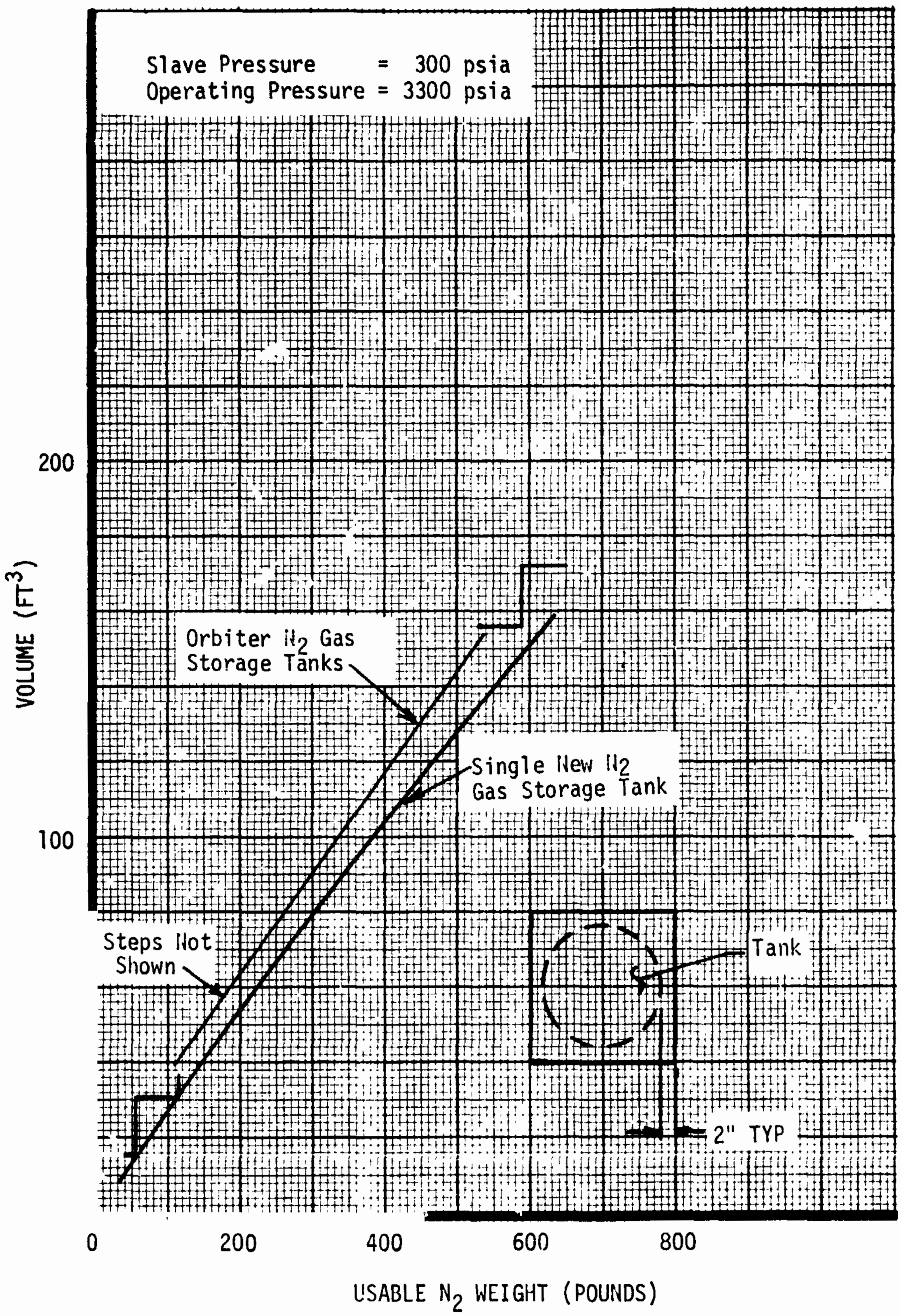

Figure 12 Gaseous N_2 Storage Volume

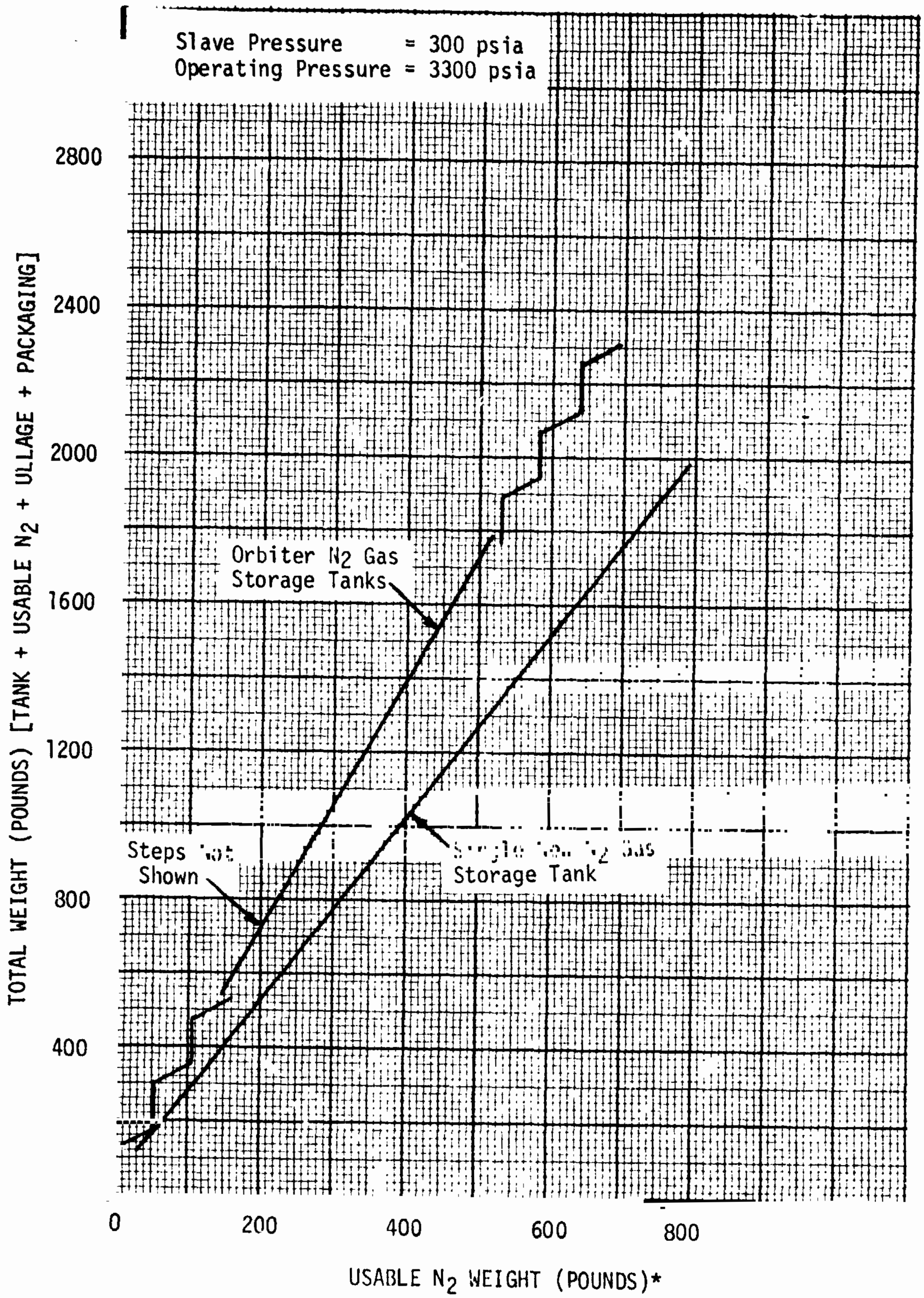

Figure 13 Gaseous N_2 Storage Weight

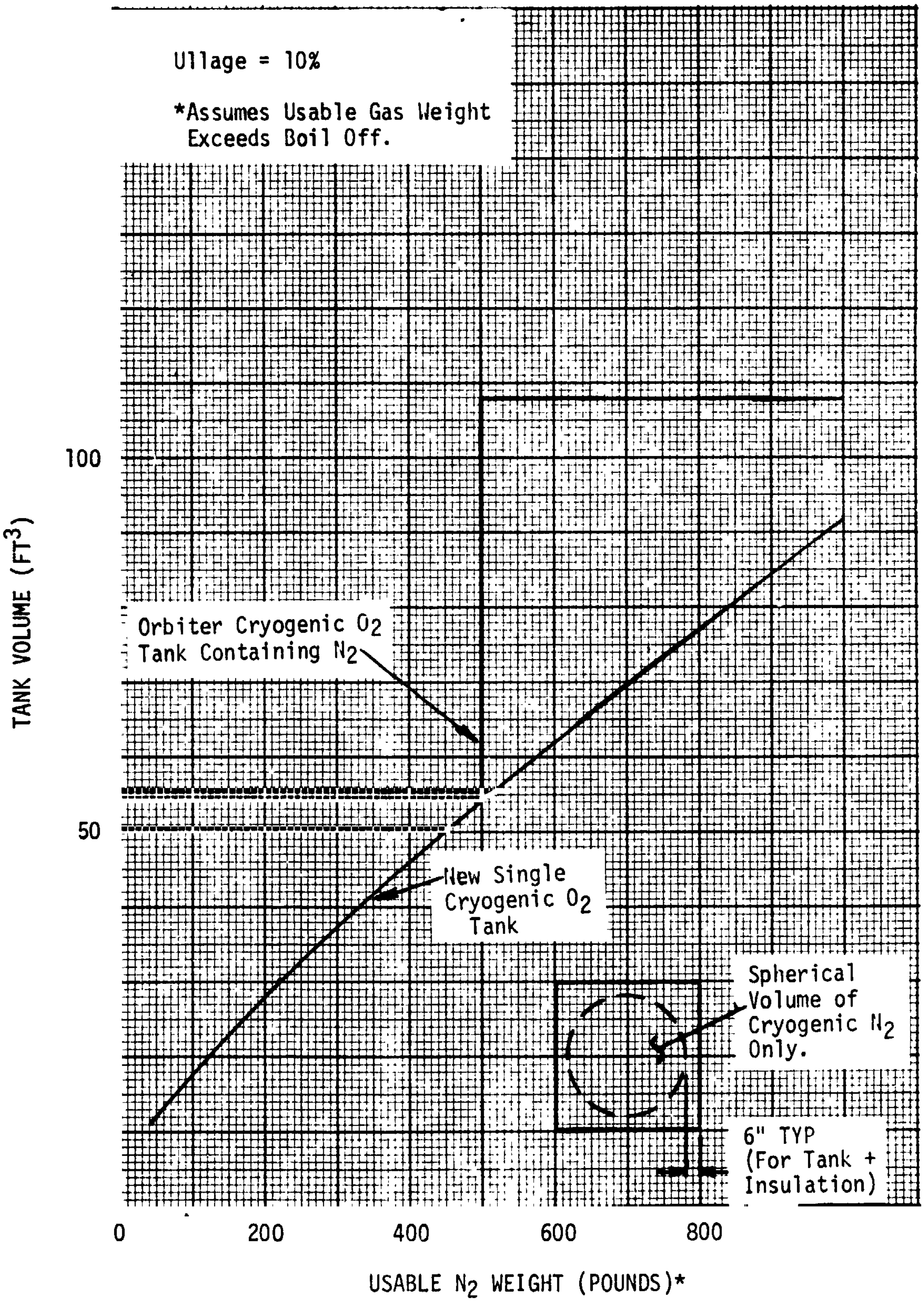

Figure 14 Cryogenic N_2 Storage Volume

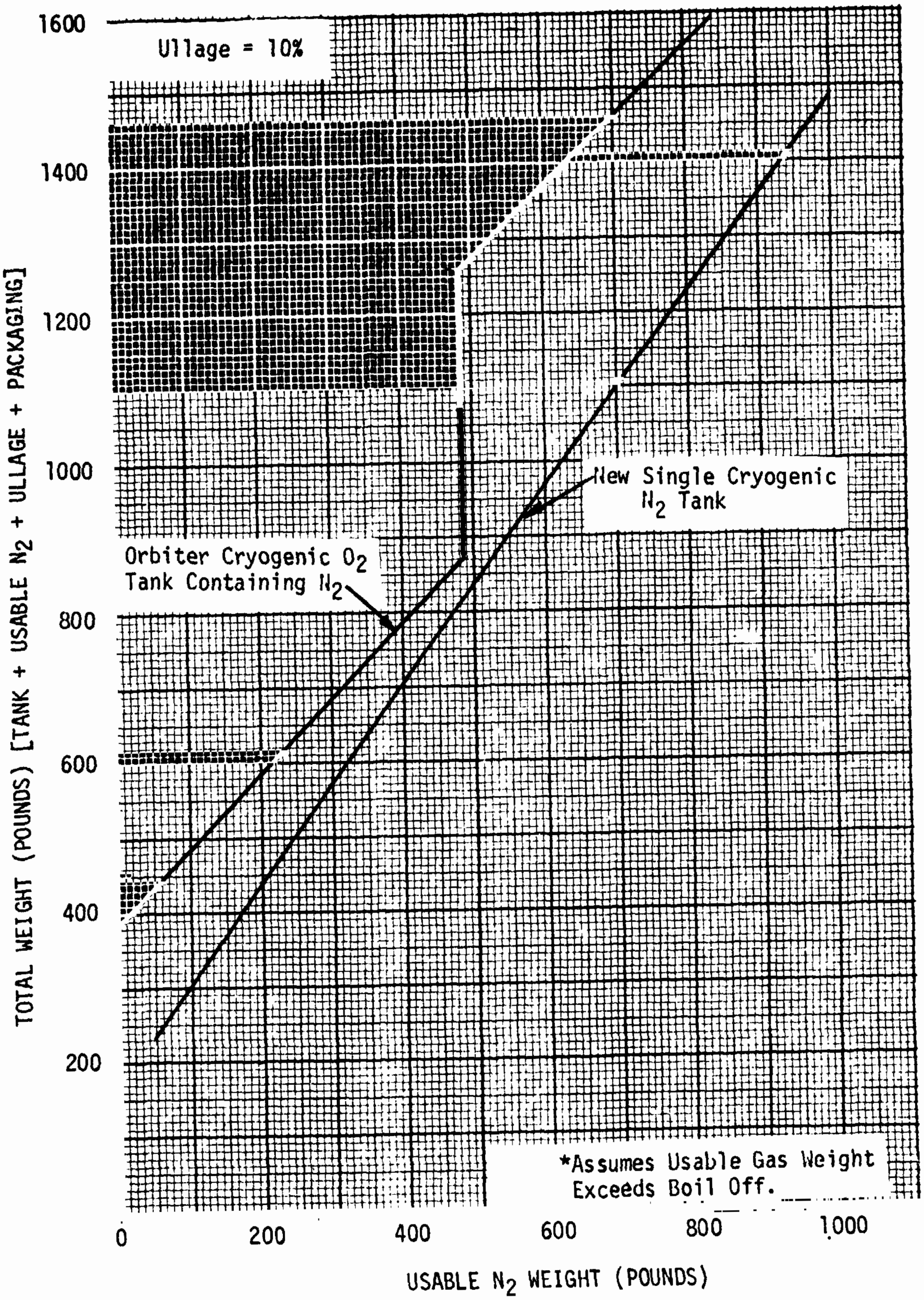

Figure 15 Cryogenic N_2 Storage Weight

Beyond 60 days it would be advisable to use the improved insulated cryogenic oxygen tank to reduce the overall weight and volume penalty, as it is assumed the reduced boil-off rate would be close to the nitrogen requirements. At this mission length, the nitrogen requirements (630 pounds) would approach the capacity of a single oxygen cryogenic tank (781 pounds) and would be much lighter than multiple small high pressure tanks. A new cryogenic tank would be lighter as shown in Figure 14, but again the non-recurring cost would be high and appears unwarranted unless many long duration missions exceeding 60 days are planned.

WASTE MANAGEMENT SUBSYSTEM

The Orbiter Waste Management Subsystem collects and stores condensate, urine, and wash water in two waste water storage tanks which contain a predetermined quantity of biocide. The tanks are sized to hold a total of 320 pounds of waste water. The subsystem also contains a heated overboard dump nozzle to permit dumping of the waste water. The subsystem also collects feces and tissue wipes in a vacuum dry slinger type commode. The commode is sized to hold 210 man-days of feces and wipes.

The Waste Management Subsystem recommended for use in the Extended Duration Shuttle Orbiter is identical to that currently used on board the Shuttle (Flight 6 and subsequent). The only change is the addition of a biocide tank and associated valving so that the biocide in the waste tank can be replenished after the contents are discharged overboard or processed for reclamation. A schematic of the recommended system is shown in Figure 16.

As the present commode is sized for a 210 man-days of operation and each waste water tank holds 160 pounds of waste water, dumping of liquids approximately every four to seven days (depending on the quantity of relative humidity condensate collected) will be required. If a waste water reclamation subsystem is utilized, dumping of waste water will not be required, except in the event of a failure of the waste water reclamation subsystem or to reduce the vehicle landing weight. To extend the mission range beyond 210 man-days, an additional commode must be carried for each 210 man-day increment.

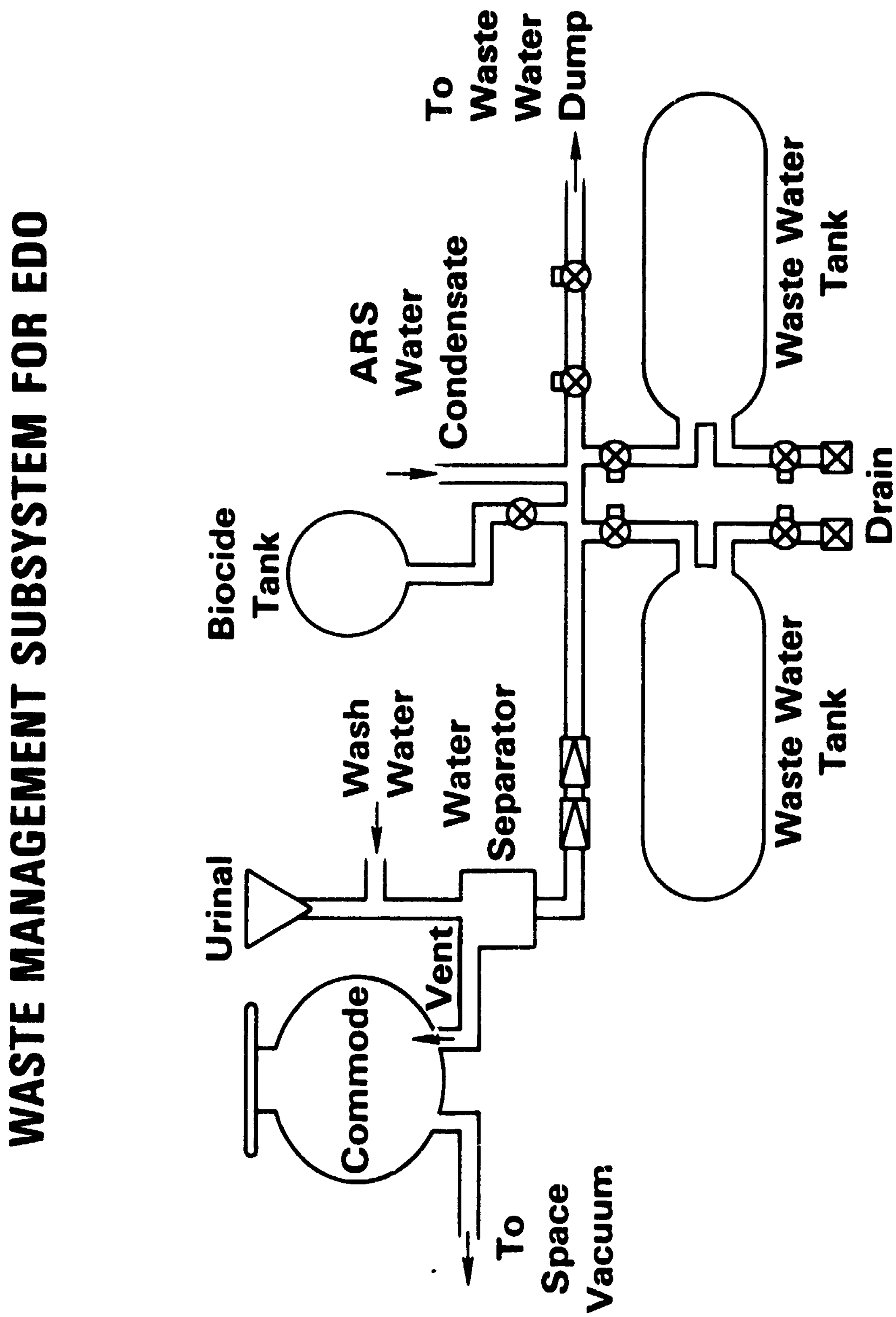

FIGURE 16 - WASTE MANAGEMENT SUBSYSTEM FOR EDO

WATER MANAGEMENT

Water is required on the extended Shuttle Orbiter for four principal purposes: food preparation, drink, washing, launch and for contingency return, and in the flash evaporator for supplemental heat rejection.

In this discussion and according to the ground rules, the use of water for an orbit heat rejection was not considered. As a result, a minimum of 2,063 pounds of water is required to complete the Extended Duration Shuttle Orbiter 30-day mission as shown in Table 7. This water can be provided by fuel cell water, stored water, or reclaimed water. Each of these water sources are discussed in the following paragraphs.

WATER MANAGEMENT SUBSYSTEM

7 Men — 30 Days

Requirements

Food Preparation and Drink	— 1197 lbs
Wash	— 536 lbs
Launch & Contingency Return	— 330 lbs
Minimum	2063 lbs

EVA (14.4 lbs/12 Man Hrs.)

Possible Sources

Fuel Cell "Idle" Water (1 kw)		654 lbs
Stored Water		330+ lbs
Fuel Cell Operate (3 Kits Min.)		As Req'd.
Reclamation		
Condensate (Sweat)	(99% Rec)	0 → 726 lbs
Wash Water	(95% Rec)	0 → 509 lbs
Urine	(95% Rec)	0 → 661 lbs
Other	(99% Rec)	0 → 438 lbs

TABLE 7 - WATER MANAGEMENT SUBSYSTEM

FUEL CELL WATER

Water is a product of the fuel cells as power is generated. During solar cell operation, the fuel cells are never completely shutdown, some water is always available from the fuel cell. The minimum power generation (defined as the "idle" mode) for all three fuel cells is 1 kw. This power is used to keep the cells warm and ready for instant power up condition. For the 30-day mission, 654 pounds of water is produced. Any additional fuel cell operation will directly increase the quantity of water produced.

Figure 17 defines the quantity of oxygen available when the three baseline cryogenic kits are launched full. It shows that there is available 1,114 pounds of oxygen which if used to generate power will produce all the water required for a 30-day mission; 115.9 pounds of oxygen is left over. To produce this water the average fuel cell power output would be 2.6 kw, which may not be useful power. This water can be produced continuously or periodically depending on the power requirement. Operation of the fuel cell to produce the water required at a rate within the existing water storage capacity is defined as "scheduled" fuel cell operation. As the number of cryogenic kits is increased for more fuel cell power generation, the easier the scheduling of the fuel cell operation becomes as more water is available.

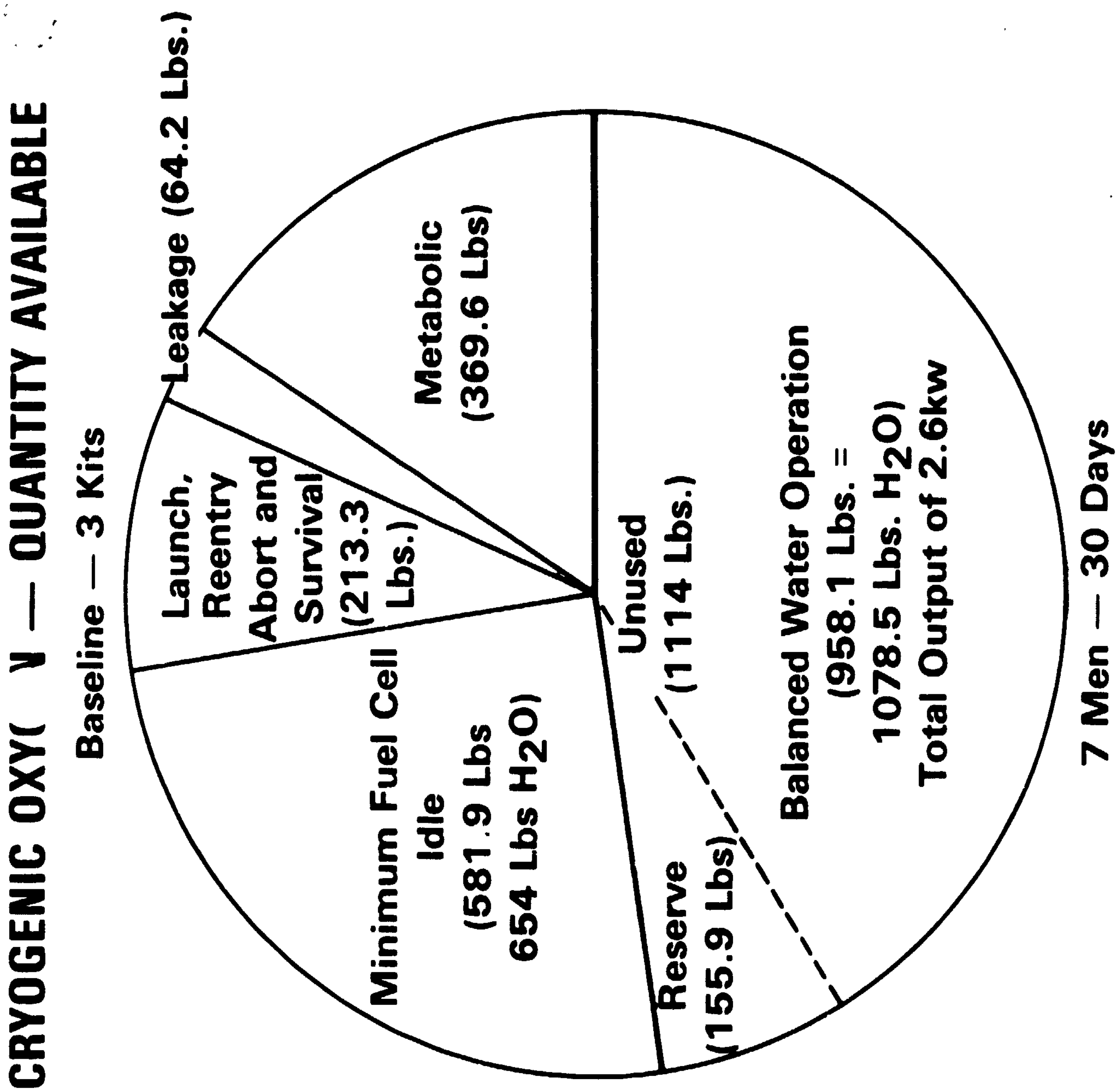

FIGURE 17 - CRYOGENIC OXYGEN - QUALITY AVAILABLE

In summary, all the water requirements (not including on Orbit heat rejection which is not required according to the ground rules) for the extended Orbiter operation can be met with a minimum of three cryogenic kits and with scheduled fuel cell operations. If this cannot be accomplished, then additional water (stored or reclaimed) will be required.

STORED WATER

Water requirements for the Extended Duration Orbiter can be met by carrying the additional water required in tanks. The quantity of water required is dependent on the mission length, crew size, CO_2 removal subsystem, fuel cell operation, whether waste water is reclaimed, etc. As a result, the data presented in this section is discussed in terms of usable water weight.

In order to keep costs to a minimum, only tanks with metal bellows currently available in the Shuttle Orbiter were used for water storage. This results in three candidate designs: the Orbiter potable water tank, the Spacelab water pump package accumulator, and the Orbiter water pump package accumulator. Figures 18 and 19 show the relative weights and volumes of these designs. Figure 18 shows that for usable quantities greater than 11 pounds of water the Orbiter potable water storage tank is the lightest, and Figure 19 shows that its volume is the least of the three for quantities greater than 39 pounds of water. As a result, the 165 pound capacity Orbiter potable water storage tank was used as the standard storage tank.

Figures 20 and 21 show the total wet tank weight and volume of the Orbiter potable water storage tank, including a vehicle packaging factor, which is equal to that of the present Orbiter

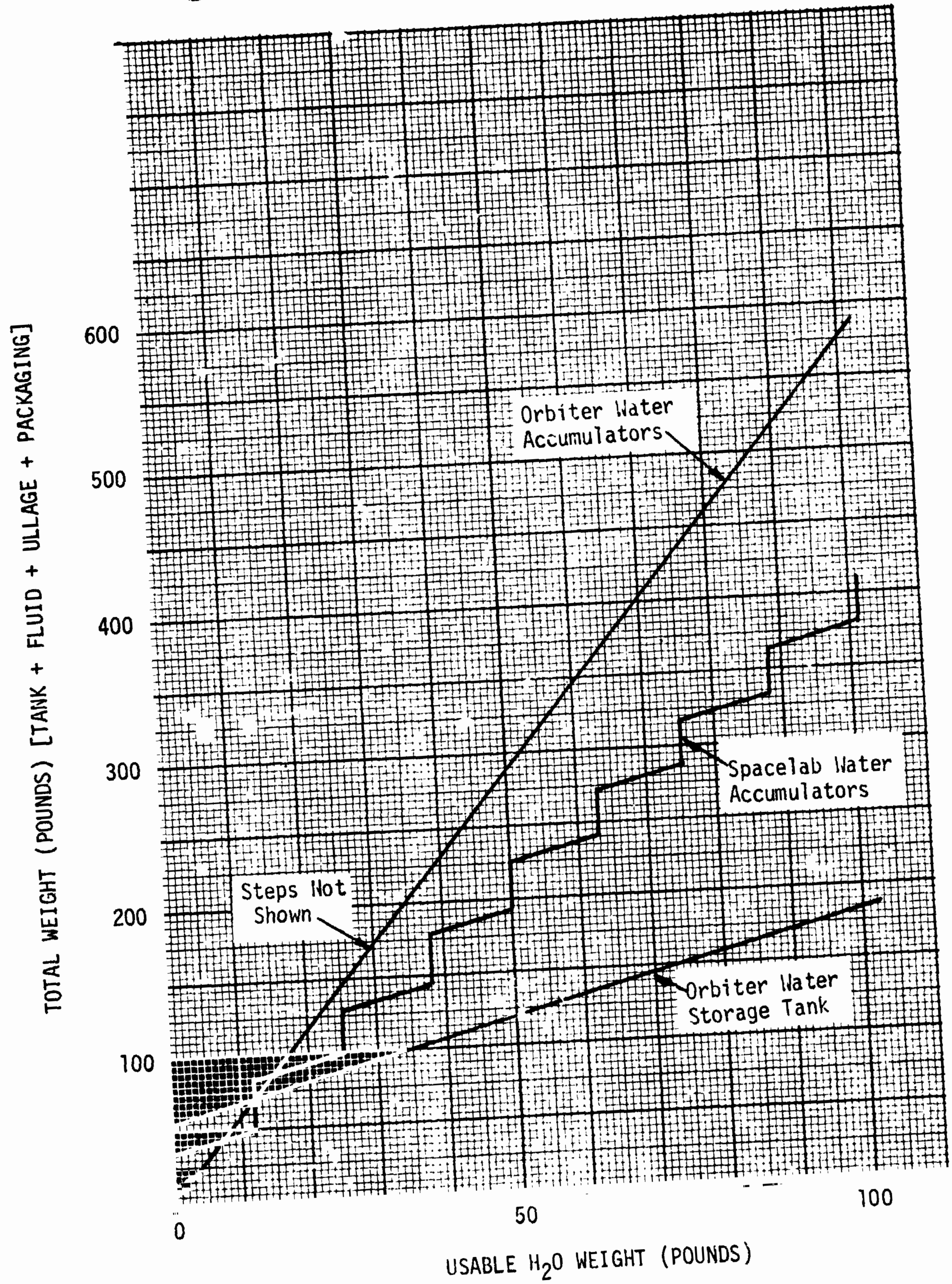

Figure 18 Water Storage Weight (Small Accumulators vs. Shuttle Water Tank)

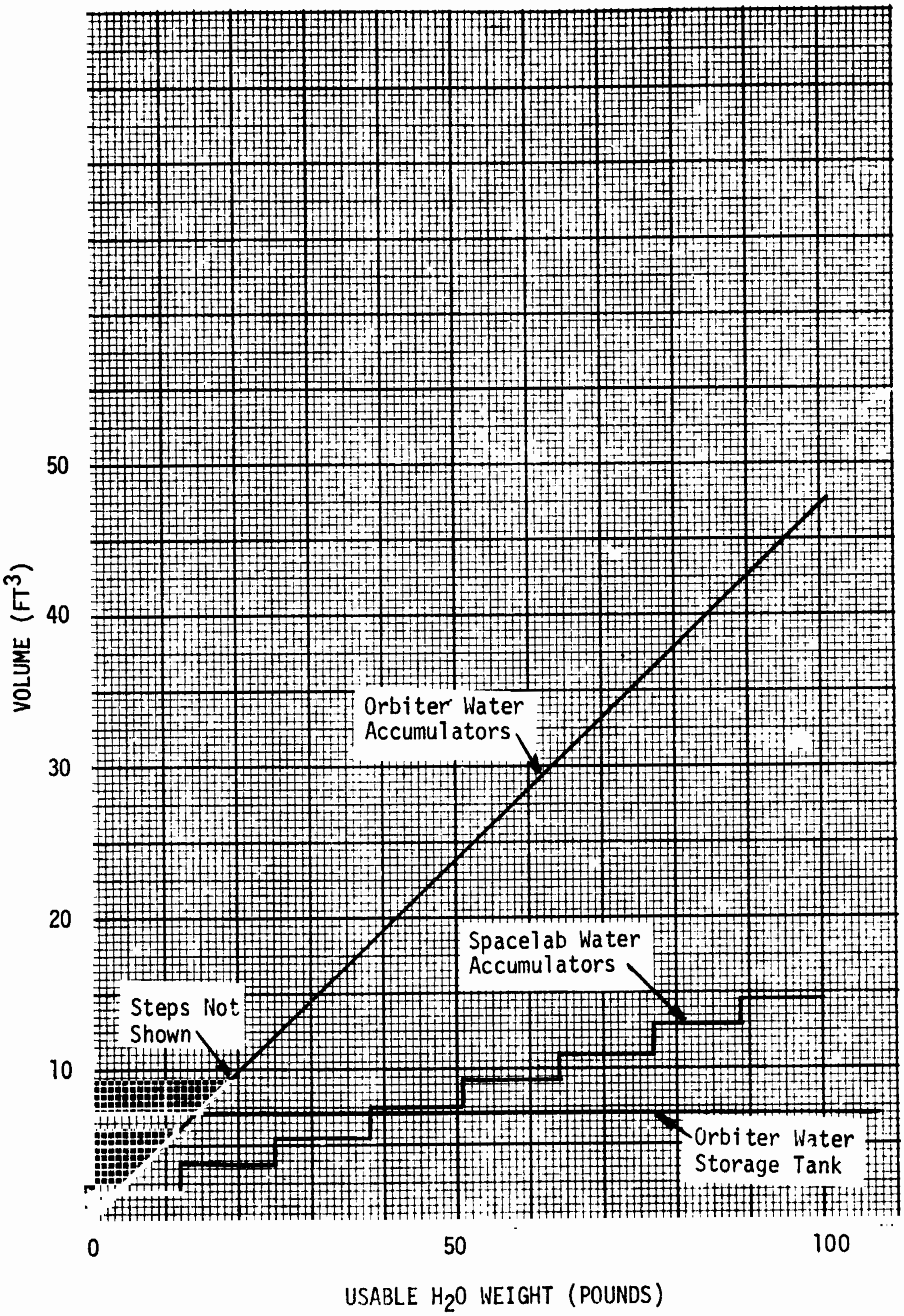

Figure 19 Water Storage Volume (Small Accumulators vs. Shuttle Water Tank)

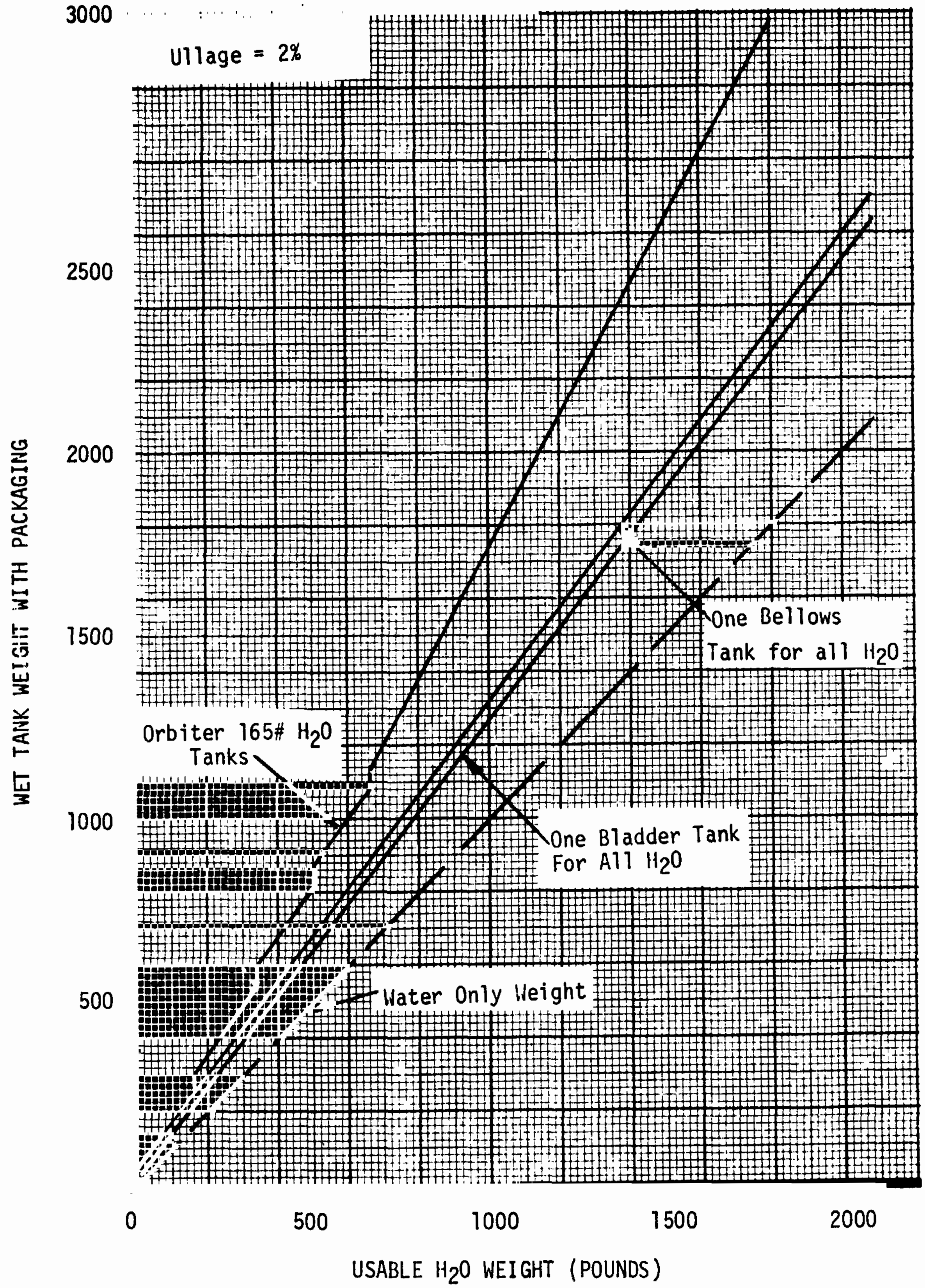

Figure 20 Water Storage Launch Weights

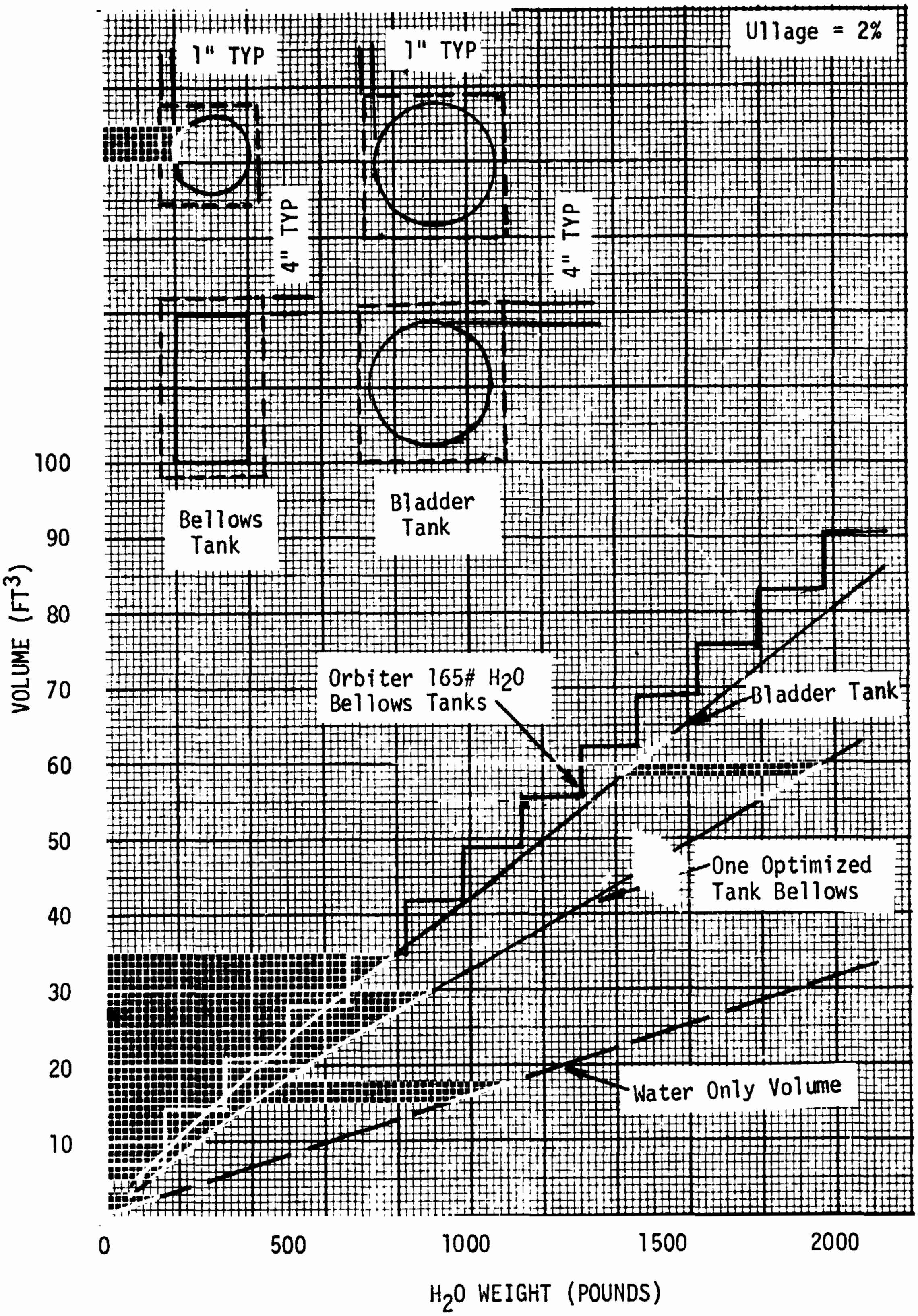

Figure 21 Water Storage Volume

water tank factor. All of the subsequent system trades were based on using this existing 165 pound capacity Orbiter metal bellows water storage tank.

Figure 20 also shows that a special new metal bellows tank designed to hold 400 pounds of usable water would be about 110 pounds lighter than using three of the standard Orbiter tanks. They also show that 1,000 pounds of water in a single large tank would save 350 pounds. Thus, if a significant amount of stored water is required, it may prove to be economically wiser to design, develop, and qualify a new, larger metal bellows tank design than to pay for many smaller Orbiter tanks, which would also weigh more. This assumes that the resultant volume of a single tank would be acceptable. Figure 21 shows the relative volume of each approach.

If a new tank design is considered, the possibility of using a bladder rather than a stainless steel bellows was investigated. To hold 1,000 pounds of usable stored water, a single bladder tank subsystem would weigh about 50 pounds less than the single metal bellows design; but it is considered a less reliable design which would be life limited and have potential gas permeability problems.

POTABLE WATER PROCESSING

Another method of supplying additional water for use in the Extended Duration Orbiter is to reclaim waste water. Three types of waste water are generated during the mission; condensate, urine, and wash water. Condensate can be processed using a relatively simple multifiltration system. A distillation unit is required to reclaim urine. Wash water can be reclaimed using multifiltration, hyperfiltration, reverse osmosis, or distillation. Regardless of the water being processed, the water quality must meet the Shuttle potability requirements. Iodine at a concentration of 5 ppm is added to the water for bacteria control, and the water quality is checked with a Water Quality Monitor Subsystem (WQMS). Since the current WQMS utilizes a relatively large quantity of expendables and power, three possible 30-day operating modes were examined to determine optimum operation. These were: continuous monitoring, 50% monitoring, and 5% monitoring.

For the continuous monitoring use, the unit uses about 170 watts, and the expendable chemicals are at a maximum which results in a total launch weight of about 82 pounds.

For the 50% duty cycle case a Spacelab water pump package accumulator was incorporated which can store 6.5 hours of processed water. The WQMS must go through a warm-up and calibration cycle each time it is turned on before an accurate reading can be attained, and it must perform a flush cycle before it can be shut off again. This takes about four hours per total on-reading-off cycle. Thus, the unit actually operates four out of every 6.5 hours. If the reading is good, the accumulator is then emptied to the potable water storage tank, and a cycle is restarted. This type of intermittent WQM actually operates about 62% of the time, uses an average power of about 105 watts, and weighs (including tankage) about 107.7 pounds. Thus, this intermittent unit is about 25.7 pounds heavier but has an average power savings of 65 watts when compared to a continuous WQMS.

If the Orbiter tank (165 pound capacity) is used as the accumulator, the WQMS need only be operated once every three days or 40 hours in a 30-day mission. This yields a 5.5% duty cycle and an average power of 9.4 watts and weighs 111 pounds (including tankage). The 5.5% duty cycle operation of this subsystem saves on an average basis 160.6 watts and only weighs 2.9 pounds more than the 100% duty cycle WQMS. In addition, it saves 95.6 watts and only weighs 3.3 pounds more than the 62% duty cycle version. As a result, the 5.5% duty cycle was selected for use in all subsequent subsystem trade studies.

Condensate Processing Subsystem

The Potable Water Processing Subsystem for reclaiming condensate water for the Extended Duration Orbiter consists of a multifiltration unit, a Water Quality Monitor Subsystem (WQMS), an iodine dispenser, and a process water storage holding tank.

The subsystem receives water from the Atmospheric Revitalization Subsystem (ARS) water separator, processes it through the multifiltration unit, sterilizes it with 5 ppm of iodine, checks the water quality, and stores water until it can be discharged to the existing Shuttle water supply tanks. If the water quality is not acceptable, the water is returned to the Shuttle Waste Management Subsystem. It has been assumed that the process water quality, which is acceptable for drinking, will be acceptable for use in the Shuttle flash evaporator.

A subsystem was sized to process all the condensate generated during each mission considered. The actual condensate quantity processed is dependent on the CO_2 Removal subsystem and number of EVA's which determines the quantity of condensate (if any) removed in the cabin temperature and humidity control condensing heat exchanger.

A process efficiency of greater than 99% was assumed in sizing the multifiltration units. It contains a carbon bed and an ion exchange bed. The subsystem bed was sized to last for a minimum of 30 days. Expendables will be replaced on the ground during vehicle turnaround. For missions beyond 30 days the bed will be replaced every 30 days using in-line disconnects.

A water storage holding tank as described previously was added to the subsystem to reduce the frequency of water sampling required and thereby reduce the average power and quantity of expendables required by the water quality monitor. This tank will also permit other tests to be conducted on water quality (if desired) prior to discharging the water to the existing Shuttle water storage tank.

The typical condensate processing subsystem will weigh 152 pounds with 111 pounds associated with the water tank, iodine dispenser, WQMS, and associated valving. The multifiltration cartridge assembly, including mounting fittings, weighs 41 pounds, of which 30 pounds is carbon and ion exchange material. The quantity of bed material will vary depending on the amount of water to be processed.

Urine and Waste Water Processing Subsystem

The Potable Water Processing Subsystem for reclaiming urine and waste water for the Extended Duration Orbiter consists of a distillation unit, a multifiltration unit, a Water Quality Monitor Subsystem (WQMS), an iodine dispenser, and a process water storage holding tank as shown in Figure 22.

The subsystem receives water from the existing Shuttle Waste Water tank, processes it through the distillation unit, sterilizes it with 5 ppm of iodine, checks the water quality, and stores water until it can be discharged to the existing Shuttle water supply tanks. If the water quality is not acceptable, the water either is returned to the Shuttle waste storage tank for further processing or dumped to space. It has been assumed that the process water quality, which is acceptable for drinking, will be acceptable for use in the Shuttle flash evaporator.

Each subsystem was sized to process all the urine and wash water generated during the 7-man 30-day design point which is:

Urine - 23.2 lbs/day

Wash water - 17.85 lbs/day

A single water processing subsystem to reclaim urine and wash water rather than two independent systems was selected because the quantity of wash water is relatively low (50% of total).

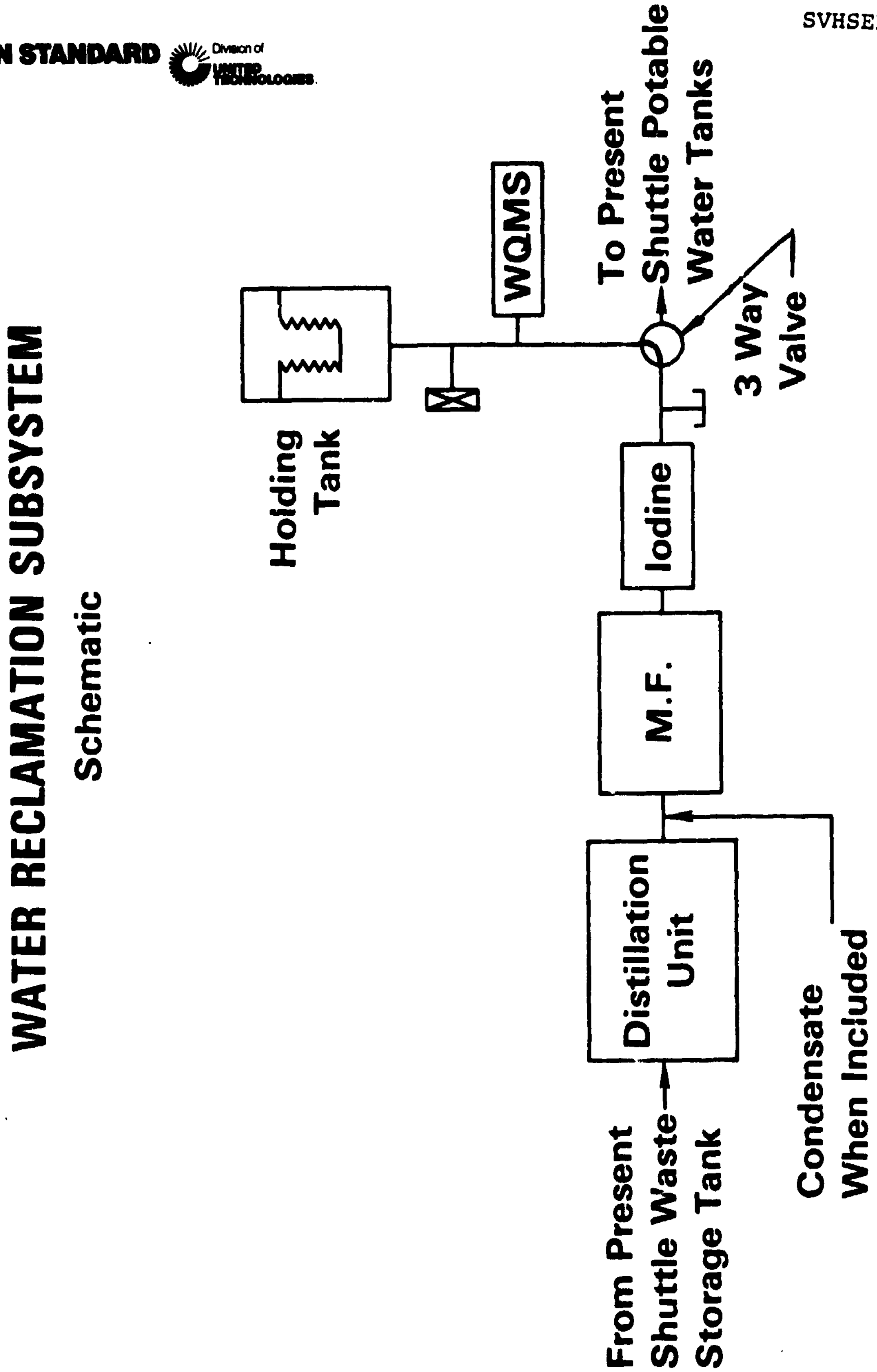

FIGURE 22 - WATER RECLAMATION SUBSYSTEM SCHEMATIC

As a result, the growth impact on the distillation unit is less than that of having two separate subsystems. A comparison of significant factors of two typical separate subsystems versus a large distillation unit shows:

1. A weight savings including expendables of at least 200 pounds.
2. A reduction in volume of at least 50%.
3. A power increase of 120 watts. (This is the only penalty incurred.)
4. A cost reduction of over two million dollars in non-recurring cost, plus two hundred thousand dollars per shipset cost and seventy five thousand dollars in expendables per flight.

A process efficiency of 95% was assumed in sizing the distillation section. For this discussion, condensate was assumed to be processed by a separate filtration unit as discussed previously. If the two systems are integrated, the condensate processing impact on the potable water processing subsystem is estimated to be 20% of an independent equivalent condensate subsystem. The distillation portion of the combined subsystem is not affected by this change as condensate is added downstream of the distillation unit.

All expendables except as noted below were sized to last for a minimum of 30 days. Expendables will be replaced on the ground during vehicle turnaround.

A water storage holding tank, as discussed previously, was added to the subsystem to reduce the frequency of water sampling required and thereby reduce the quantity of expendables required by the water quality monitor. This tank will also permit other tests to be conducted on water quality (if desired) prior to discharging the water to the existing Shuttle water storage tank. In the interest of commonality, a water storage tank identical to the Shuttle water tanks was used. This tank size will permit accumulation of up to four days' worth of processed water which can also serve to supplement the existing Shuttle water storage capacity.

Three subsystems were evaluated. These are:

- Vapor Compression Distillation Subsystem - VCD
- Air Evaporation Subsystem
- Thermoelectrically Integrated Membrane Evaporator Subsystem - TIMES

The above subsystems are described in further details in the following report sections. All the subsystems are designed to fail safe. If the subsystem does fail, waste water can be stored or dumped using the existing Shuttle Waste Management System.

Vapor Compression Distillation (VCD)

Vapor Compression Distillation is a vacuum distillation process for reclaiming waste water which utilizes artificial gravity and intermediate vapor compression which conserves the heat of condensation.

The Vapor Compression Distillation (VCD) Subsystem schematic for use on the extended Shuttle is shown in Figure 23.

Liquid from the Shuttle Waste Collection Subsystem is fed from the Shuttle waste storage tank into the VCD recycle tank. The recycle tank contains a stainless steel bellows and is launched dry. The contents of the recycle tank is pumped, by one of three parallel pumps, located in a common housing, at a controlled flow rate into the evaporation stage of the VCD unit where water is turned to vapor at a low pressure. A purge pump maintains the proper pressure vacuum within the VCD unit. The vapor leaves the evaporator through a rotary lobe compressor and enters the condenser. Condensation takes place on a wall common with the evaporator, which allows the latent heat to be exchanged between the condenser and evaporator. The recycled fluid is removed in an annular sump by a pickup tube and pumped back to the recycle tank, completing the recycle loop. Condensed water is pumped

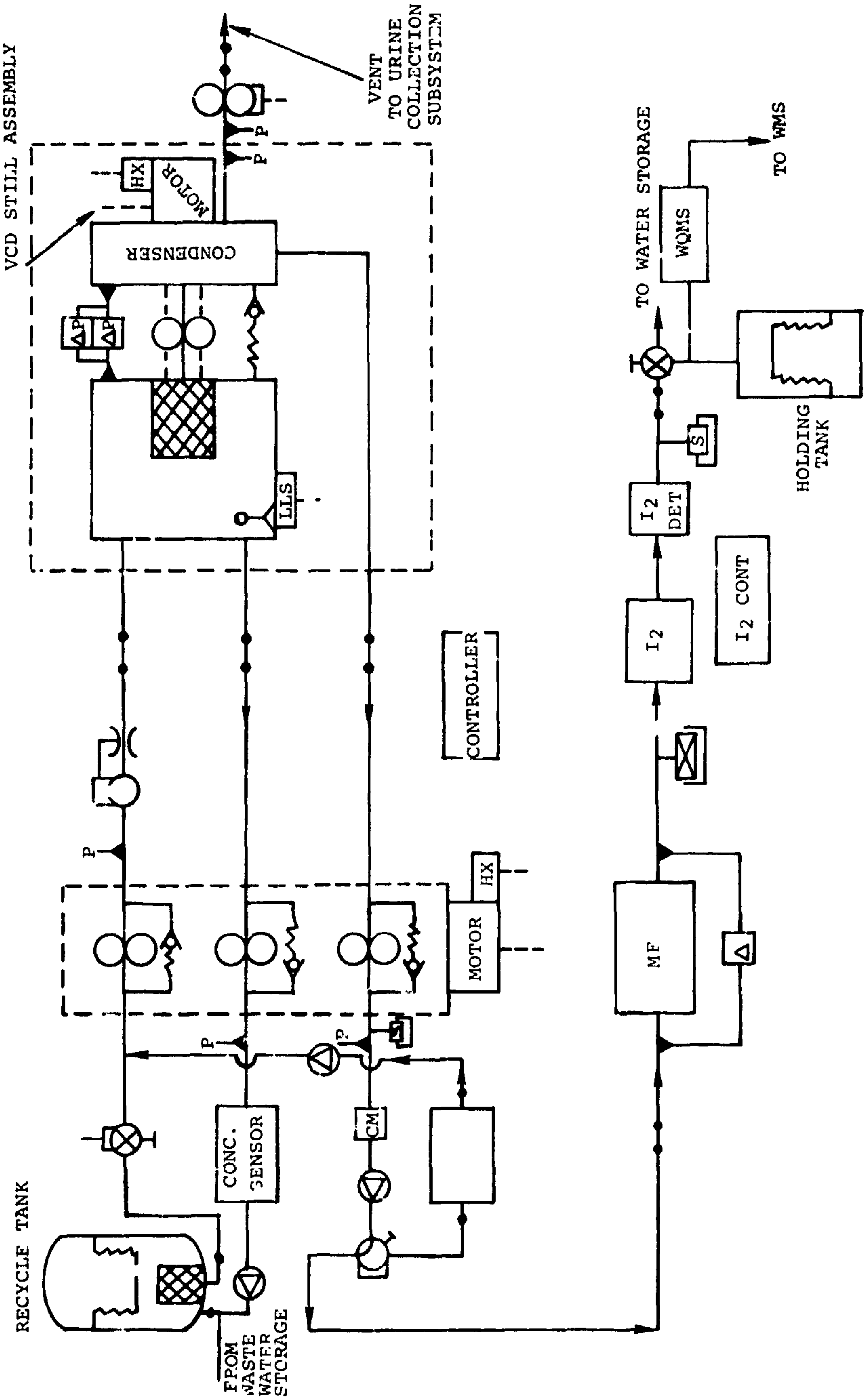

FIGURE 23

VAPOR COMPRESSION DISTILLATION (VCD)

from the still by the condensate pump. It passes through the conductivity meter to determine quality and, if acceptable, is delivered through the multifiltration assembly and an iodine generator for bacteria and odor control, to the potable water holding storage tank. A water quality monitor is used to periodically check the acceptability of the output water. In the event the processed water conductivity exceeds the maximum limit, flow is diverted back to the recycle loop for reprocessing. A bacteria filter is located in the recycle loop as a bacteria check valve barrier. This recycle mode is also used to return processed water to the evaporator for a short period of time for cleaning the evaporator surface prior to initiating system shutdown. After this operation, the still is then run until dry before actual shutdown.

An electronic controller provides the power conditioning, switching sequencing, and control functions for the subsystem.

When the waste water concentration reaches a solid concentration of 50% (95% removal efficiency), the contents of the recycle tank is dumped into the Shuttle commode. All expendable items are designed to last a minimum of 30 days so no in-flight maintenance, other than dumping the recycle tank, is required. Table 8 defines the subsystem characteristics for the extended Orbiter baseline condition.

SUBSYSTEM: Water Management

CONCEPT: VCD

7 MEN - 30 DAYS

SUBSYSTEM:	Weight (Lb)	Volume (Ft^3)	Power (Watts)	Cost ($\$ \times 10^3$)
Installed Unit	359.5	29.5	281	590
Flight Expendables	N/A	N/A	--	5
Resupply Expendables	--	--	--	5
Nonrecurring Cost	--	--	--	6,500
Totals	359.5	29.5	281	

VEHICLE CONSIDERATIONS:

Heat Rejection (Btu/Hr)	960
Number of Interfaces	4
Cabin Air Dumped (Lb/Day)	0
Water Loss (Lb/Day)	0
Water Recovered (Lb/Day) (1)	38.97

	Generated	Required
Oxygen (Lb/Day)	N/A	N/A
Hydrogen (Lb/Day)	N/A	N/A
Water (Lb/Day)	N/A	N/A

COMMENTS:

(1) Assumes 95% of urine/wash recovered.

TABLE 8

Air Evaporation

Air evaporation is an ambient pressure distillation process for reclaiming waste water. It utilizes a carrier gas in a closed cycle to evaporate water from wicks saturated with waste water and carries it to a condenser and a fan/separator for recovery.

The Air Evaporation Subsystem schematic for use on the extended Shuttle is shown in Figure 24.

Liquid from the Shuttle Waste Collection Subsystem is fed directly from the Shuttle waste storage tank at a controlled rate into the wick evaporator. In the evaporator the waste water is evaporated into a closed carrier air loop which becomes nearly saturated with water vapor. The air passes over redundant liquid sensors which check for free liquid carry-over. If carry-over is detected, the flow of waste water metered into the evaporator wicks is reduced. The nearly saturated air stream then enters a condensing heat exchanger where the temperature is reduced, and the condensed water is separated from the carrier air in a combination fan/separator. The fan/separator also provides the driving forces for the recirculation carrier air and the pumping power to move the condensed water through the multifiltration portion of the subsystem.

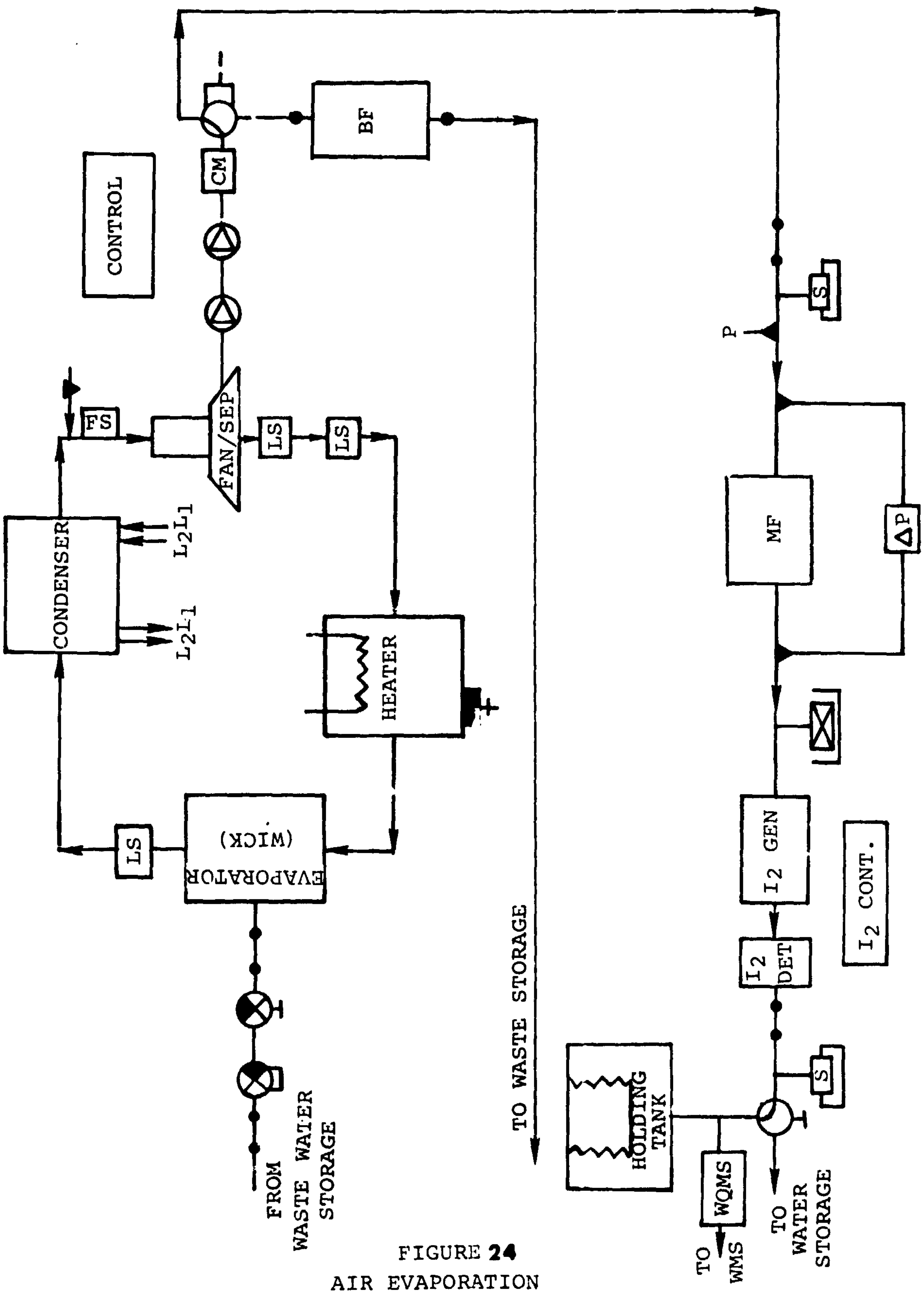

FIGURE 24
AIR EVAPORATION

Carrier air leaving the fan/separator passes through a liquid sensor to an electric heater which heats it before it re-enters the evaporator. The water condensate from the fan/separator is continuously removed and pumped through redundant relief/check valves, which prevent gas entrapment and backflow into the fan/separator, past a conductivity sensor through the multifiltration assembly and an iodine generator for bacteria and odor control to the potable water storage tank. A water quality monitor is used to periodically check the acceptability of the output water. If the conductivity sensor indicates unsatisfactory water, the water flow is automaticallly diverted through a bacteria check valve back to the evaporator.

The air evaporation units were sized for wick replacement intervals of three days in line with previous test units.

Table 9 defines the subsystem characteristics for the extended Orbiter baseline condition.

SUBSYSTEM: Water Management

CONCEPT: Air Evaporation

7 MEN - 30 DAYS

SUBSYSTEM:	Weight (Lb)	Volume (Ft^3)	Power (Watts)	Cost (\$ x 10^3)
Installed Unit	212.5	21.5	896	450
Flight Expendables	16.7	3.0	--	36
Resupply Expendables	--	--	--	40
Nonrecurring Cost	--	--	--	4,800
Totals	229.2	24.5		

VEHICLE CONSIDERATIONS:

Heat Rejection (Btu/Hr)(1)	3,102
Number of Interfaces	7
Cabin Air Dumped (Lb/Day)	0
Water Loss (Lb/Day)	0
Water Recovered (Lb/Day)(2)	3,897

	Generated	Required
Oxygen (Lb/Day)	N/A	N/A
Hydrogen (Lb/Day)	N/A	N/A
Water (Lb/Day)	N/A	N/A

COMMENTS:

(1) Includes 2,500 Btu/Hr to coolant loop.
(2) Assumes 95% of urine/wash recovered.

TABLE 9

Thermoelectrically Integrated Membrane Evaporator

The Thermoelectrically Integrated Membrane Evaporator Subsystem (TIMES) is a passive vaporization-condensation process for reclaiming waste water using Hollow Fiber Membranes for phase separation and a thermoelectric heat pump to achieve latent heat recovery. This subsystem is a refined version of the Vapor Diffusion Reclamation (VDR) system which utilizes an improved membrane and a thermoelectric heat pump to enhance its overall performance and life.

The TIMES schematic for use in the extended Shuttle is shown in Figure 25.

Liquid from the Shuttle Waste Collection Subsystem is fed from the Shuttle waste storage tank in the TIMES recycle tank. The contents of the recycle tank are pumped through a heat exchanger on the hot side of a heat pump, through a hollow fiber membrane module, and back to the recycle tank. Water is produced by permeation through the hollow fiber membrane walls and is condensed in a heat exchanger on the cold side of the heat pump. Condensate is pumped out of the condenser, through a multifiltration assembly and an iodine generator for bacteria and odor control, to the potable water hold storage tank. A water quality monitor is used to periodically check the acceptability of the water.

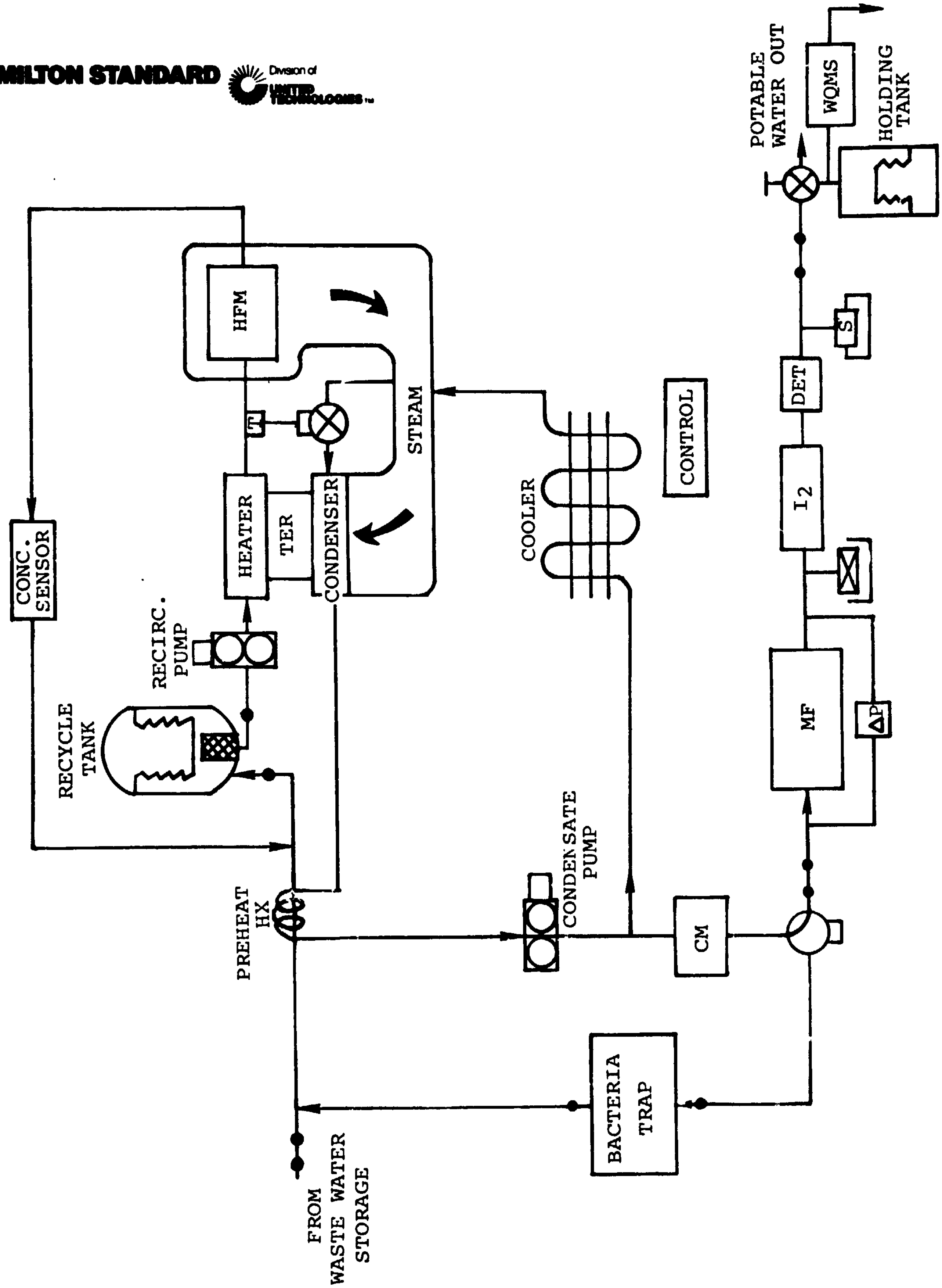

FIGURE [illegible]

TIME SUBSY[illegible]M

When the waste water concentration reaches a solid concentration of 50% (95% removal efficiency minimum), the contents of the recycle tank are dumped to the Shuttle commode. All expendable items are designed to last a minimum of 30 days so no in-flight maintenance, other than dumping the recycle tank, is required. Table 10 defines the subsystem characteristics for the extended Orbiter baseline condition.

SUBSYSTEM: Water Management

CONCEPT: TIMES

7 MEN - 30 DAYS

SUBSYSTEM:	Weight (Lb)	Volume (Ft^3)	Power (Watts)	Cost ($\$ \times 10^3$)
Installed Unit	254.5	20.5	300	495
Flight Expendables	N/A	N/A	--	15
Resupply Expendables	--	--	--	15
Nonrecurring Cost	--	--	--	5,500
Totals	254.5	20.5	300	

VEHICLE CONSIDERATIONS:

			Generated	Required
Heat Rejection (Btu/Hr)	1,021			
Number of Interfaces	3	Oxygen (Lb/Day)	N/A	N/A
Cabin Air Dumped (Lb/Day)	0	Hydrogen (Lb/Day)	N/A	N/A
Water Loss (Lb/Day)	0	Water (Lb/Day)	N/A	N/A
Water Recovered (Lb/Day)(1)	38.97			

COMMENTS:

(1) Assumes 95% of urine/wash recovered.

TABLE 10

Urine and Wash Water Processing Subsystem Discussion

The characteristics of the above urine and wash water reclamation subsystems were summarized as noted in Table 11. An examination of this table shows that the TIMES has the best overall combination of characteristics for use on the Extended Duration Shuttle Orbiter. It has the lowest volume and cost, least number of vehicle interfaces, a reasonably low weight and power, and requires no in-flight maintenance. Its development status is considered as advanced as the other candidate subsystems as it represents a second generation subsystem which makes use of two state-of-the-art technology items (hollow fiber membrane and thermoelectrics) to enhance the performance of the developed vapor diffusion reclamation subsystem. As a result, the TIMES subsystem was selected as the representative waste water reclamation subsystem to be used in subsequent system analyses.

The cost for each subsystem in Table 11 is defined as the sum of the nonrecurring cost for design, development, and certification, plus the cost for one shipset of hardware, plus the spares and expendables required to complete 42 30-day missions. The spares' cost are estimated to be equivalent to the cost of one shipset of hardware based on the data used in the Hamilton Standard report "Thermal Control and Life Support Subsystem Parametric Data for Space Station." This report defined the spares required for every 120 days as equivalent to 10% of the recurring costs. The number of 30-day missions was established by the NASA/JSC.

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WATER RECLAMATION SUBSYSTEM COMPARISON

	Weight Lbs	Volume Ft^3	Power Watts	Heat Rejection Btu/Hr	Vehicle Interfaces	In-Flight Maintenance	Cost Millions $
Vapor Compression Distillation (VDC)	360	29.5	281	960 Air	4	None	7.9
Air Evaporation	229	24.5	896	2500 Liquid 602 Air	7	Yes	7.4
Thermoelectrically Integrated Membrane Evaporator (Times)	254	20.5	300	991 Air	4	None	7.1

Used in System Trade

TABLE 11 - WATER RECLAMATION SUBSYSTEM COMPARISON

WATER MANAGEMENT CONCLUSION

As long as the fuel cells are used as the principal source of power for the Extended Duration Orbiter or fuel cell operation can be scheduled, sufficient water will be generated such that the use of waste water reclamation or large stored quantities of water will not be required.

Additional water, however, will be required when any one of the conditions noted on Table 12 exists. Whether the additional water is provided by a stored water supply or from reclamation of all or part of the waste water available must be determined on a system basis which considers mission profiles, weight, power, volume, heat rejection, and cost penalties.

As a matter of interest, the curves of Figures 26 and 27 show that storage of H_2 and O_2 cryogenically and then combining them in the fuel cell to obtain water is heavier and occupies more volume than storage of liquid water in metal bellows tanks. These figures exclude the equivalent power benefits of the cryogenic storage approach which must be considered when making a final system selection. However, it should be noted that a fuel cell must be operated at a minimum of 2 kw in order to obtain any useful power. Further operation of the fuel cells has a greater heat rejection requirement by the radiators for each unit of useful power due to the inefficiencies of the fuel cells.

ADDITIONAL WATER REQUIRED WHEN

- Have Only 2 Cryo Kits On Board
- Want H_2O Requirements To Be Met Independent of Fuel Cell Operation.
- Fuel Cells Are Shutdown
- Fuel Cells Are Idled at Min. Power (1 kw) for Most of Mission.
- Need Fuel Cell Power in Relatively Long High Power Bursts

TABLE 12 - ADDITIONAL WATER REQUIRED WHEN

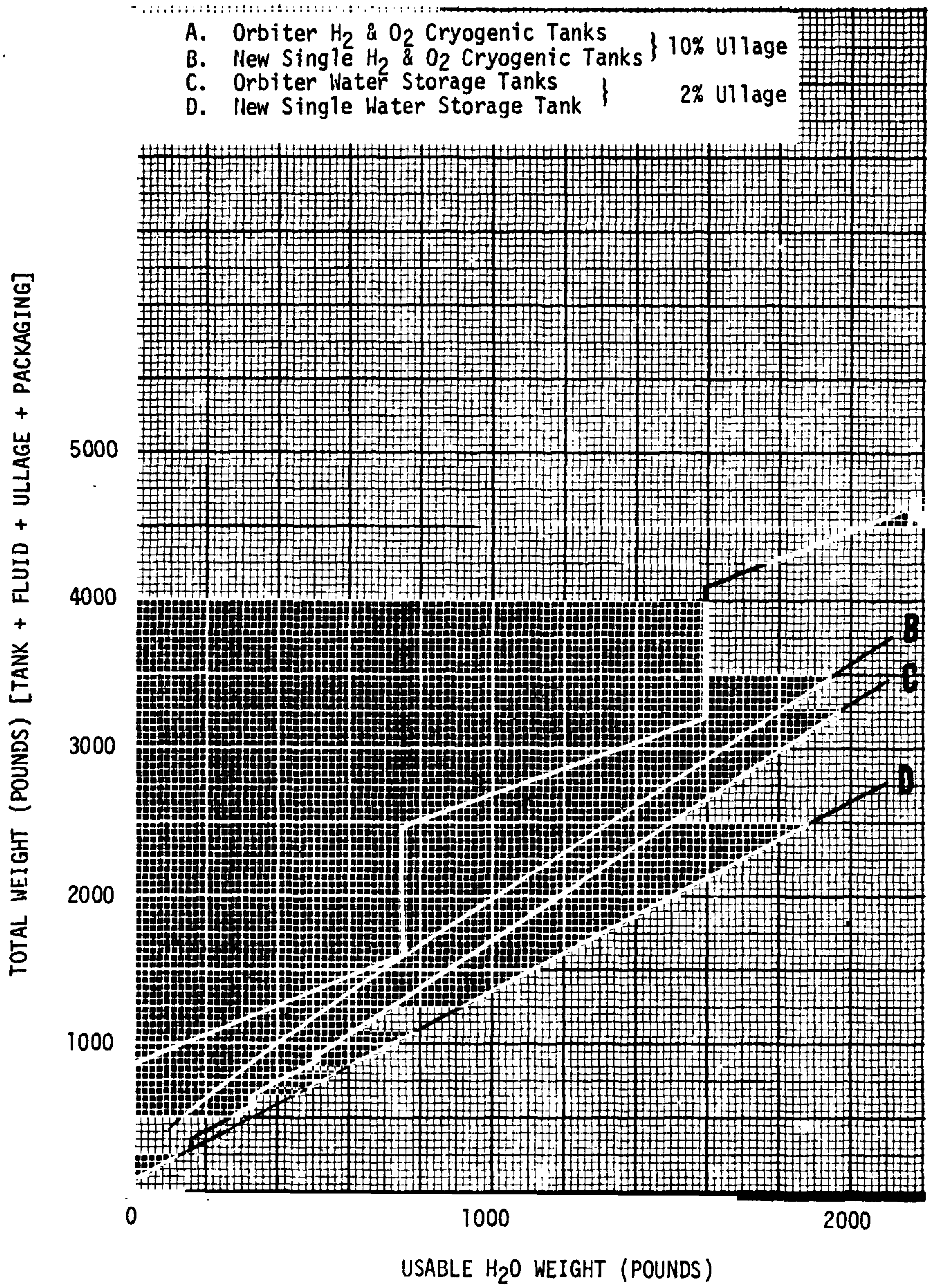


Figure 26 Water Storage: Cryogenic $H_2 + O_2$ vs. Liquid H_2O Weight

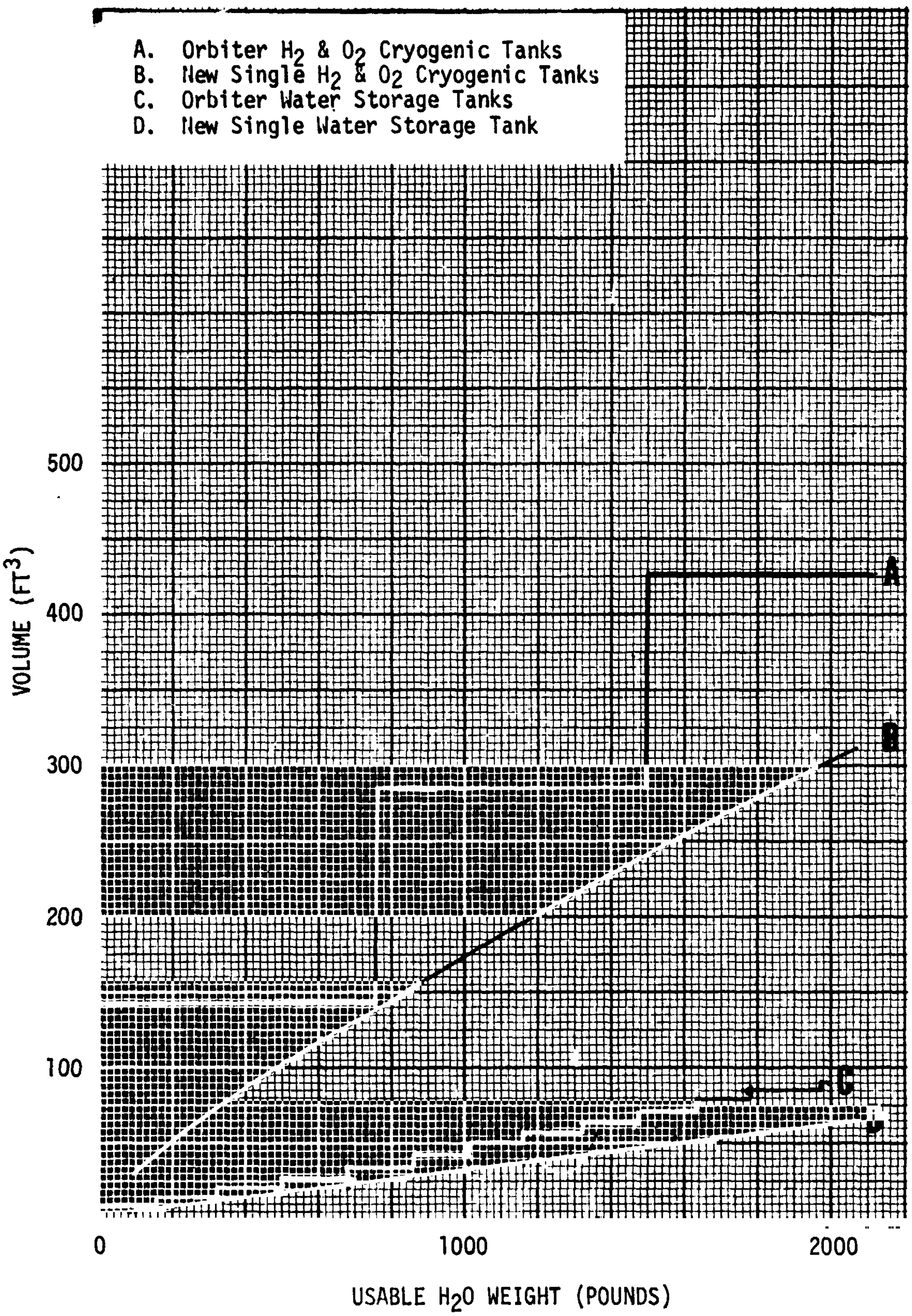


Figure 27 Water Storage: Cryogenic H_2 + O_2 vs. Liquid H_2O Volume

CARBON DIOXIDE REMOVAL

Eight candidate CO_2 Removal concepts were considered and evaluated for the principal purpose of controlling the cabin carbon dioxide (CO_2) to an average partial pressure of 5.00 mmHg. These concepts control the CO_2 partial pressure in a number of different ways and in many cases provide additional functions which affect the ECLS system performance. Table 13 lists the concepts considered, provides a brief description of them, and the functions they perform.

All of these concepts, except for the HS-C RH design, are used with the existing Shuttle Orbiter condensing heat exchanger for Relative Humidity Control. The existing Shuttle LiOH CO_2 central package is used as a fail safe backup to all the CO_2 subsystems listed in Table 13 in the event that a failure occurs. The LiOH package is also used in place of all of the concepts during prelaunch, launch, assent, and descent mission phases.

CO_2 CONTROL CONCEPTS

Concept	Description
Shuttle LiOH	CO_2 absorbed in expendable canisters. Controls CO_2 partial pressure and increases cabin latent and sensible heat loads.
Solid Amine (HS-C) RH	Cyclic — uses two beds — CO_2 and H_2O dumped to space. Provides complete CO_2 partial pressure and cabin humidity control.
Solid Amine (HS-C) — Low Dump	Cyclic — uses two beds — CO_2 and H_2O dumped to space. Provides CO_2 partial pressure control and partial humidity control.
Molecular Sieve — Dump	Cyclic — uses two beds — CO_2 and H_2O dumped to space. Provides CO_2 partial pressure control and partial humidity control.

TABLE 13 - CO_2 CONTROL CONCEPTS

CO_2 CONTROL CONCEPTS (CON'T)

Concept	Description
Molecular Sieve — Water Save	Cyclic — uses four beds — CO_2 dumped to space. Provides CO_2 partial pressure control.
EDC — Dump	Continuous — requires O_2 and H_2 — generates power and water — CO_2 and H_2 dumped to space. Provides CO_2 partial pressure control and increases cabin latent and sensible heat load.
EDC with Sabatier Reactor	Continuous — requires O_2 and H_2 — reduces CO_2. Generates power and water. Provides CO_2 partial pressure control, and increases cabin latent and sensible heat load.
EDC with WVE and Sabatier Reactor	Continuous — reduces CO_2, generates power and own O_2 and H_2 supply. Provides CO_2 partial pressure control and partial humidity control.

TABLE 13 - CONTINUED

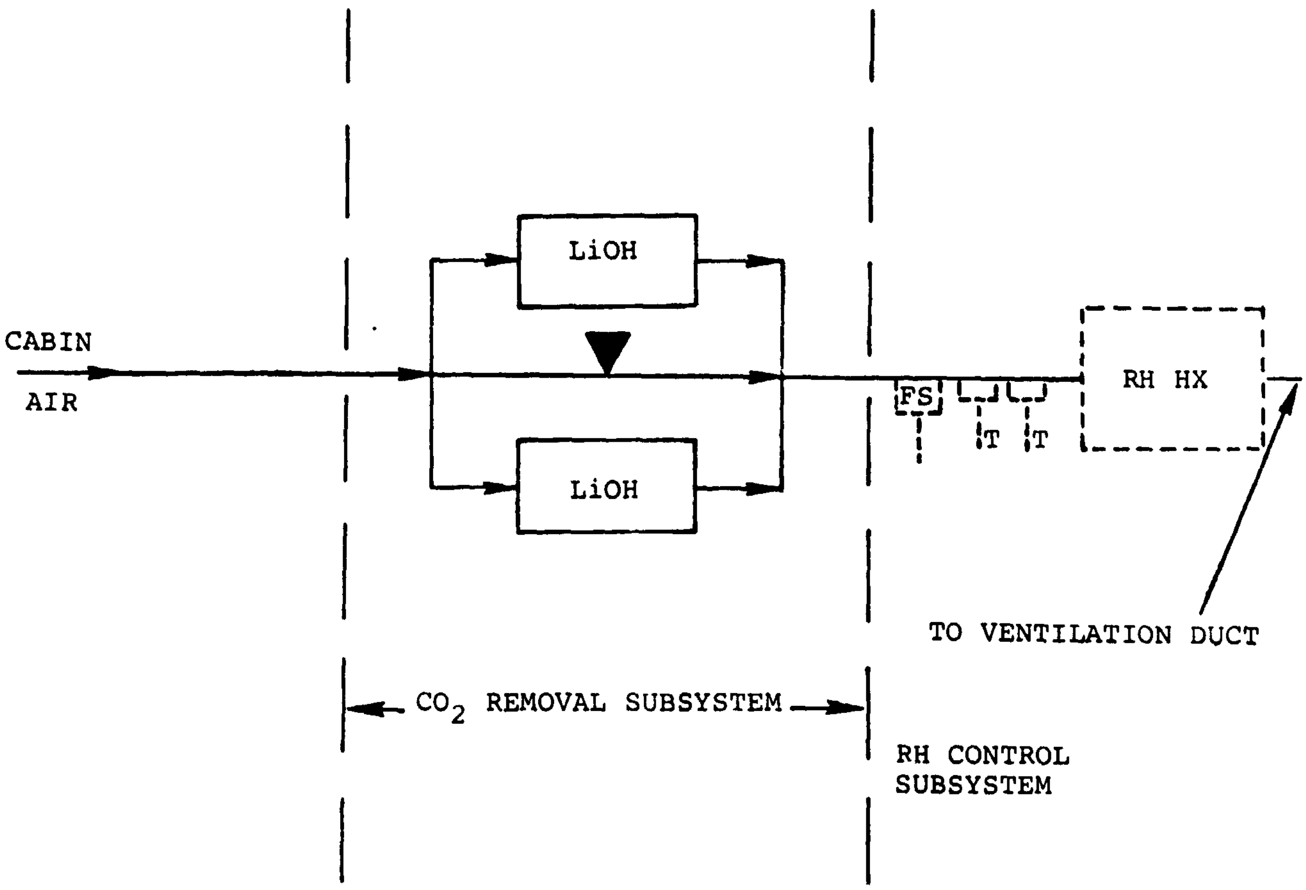
LITHIUM HYDROXIDE

A Lithium Hydroxide Subsystem (LiOH) is currently used in the Orbiter and Spacelab for carbon dioxide removal. Carbon dioxide is removed by absorption in expendable LiOH cartridges. The subsystem schematic is shown in Figure 28.

Process air passes through two parallel canisters. Each Orbiter canister holds one replaceable LiOH (five pounds of LiOH) cartridge which weighs 6.4 pounds. Air flow through the cartridge is supplied by the cabin fans.

The LiOH cartridges are sized for a scheduled replacement interval of 5.5 hours. After the first period of operation one of the cartridges is removed and a new cartridge installed. The next period the remaining previous period cartridge is removed and replaced. This alternating cartridge replacement procedure is followed for each period. With this procedure, 95% LiOH utilization can be achieved and an average cabin PCO_2 level of 5 mmHg maintained. A total of 131 cartridges are required for the seven-man, 30-day mission, plus 18 cartridges for a 96 hour rescue contingency.

Table 14 defines the subsystem characteristics for the Extended Orbiter 30-day mission.



LiOH

FIGURE 28

SUBSYSTEM: CO_2 Removal

CONCEPT: LiOH

7 MEN - 30 DAYS

SUBSYSTEM:	Weight (Lb)	Volume (Ft^3)	Power (Watts)	Cost ($\$ \times 10^3$)
Installed Unit (1)	12.7	0	11	20
Flight Expendables	1,189.0	61.4	--	129
Resupply Expendables	--	--	--	131
Nonrecurring Cost	--	--	--	0
Totals	1,201.7	61.4	11	

VEHICLE CONSIDERATIONS:

Heat Rejection (Btu/Hr)	761
Number of Interfaces	2
Cabin Air Dumped (Lb/Day)	0
Water Loss (Lb/Day)	0
Water Recovered (Lb/Day)	N/A

	Generated	Required
Oxygen (Lb/Day)	N/A	N/A
Hydrogen (Lb/Day)	N/A	N/A
Water (Lb/Day)	6.04	N/A

COMMENTS:

(1) Two installed cartridges only, plus 18 cartridges for 96 hour contingency.

TABLE 14

SOLID AMINE - (HS-C)/RELATIVE HUMIDITY CONTROL

The Solid Amine Relative Humidity Control Subsystem contains two beds, each of which aternately absorbs carbon dioxide and water from the process cabin atmosphere and desorbs these gases to space vacuum. Complete cabin carbon dioxide partial pressure control and relative humidity control is provided. As a result, the latent heat load on the Shuttle cabin relative humidity control condensing heat exchanger is eliminated, and the fan separator can be shut down. This subsystem is shown schematically in Figure 29.

Cabin process air enters the subsystem through a debris trap, which protects the downstream items, into and through the absorbing bed canister. The air flow then mixes with humidity control bypass flow, travels through the subsystem fan, and is exhausted to the cabin temperature heat exchanger. While one bed is absorbing, the second bed is desorbed to space vacuum. An ullage compressor is used to conserve the cabin atmosphere remaining in the on-stream bed prior to exposure to space vacuum.

Table 15 defines the subsystem characteristics for the Extended Duration Orbiter 30-day mission.

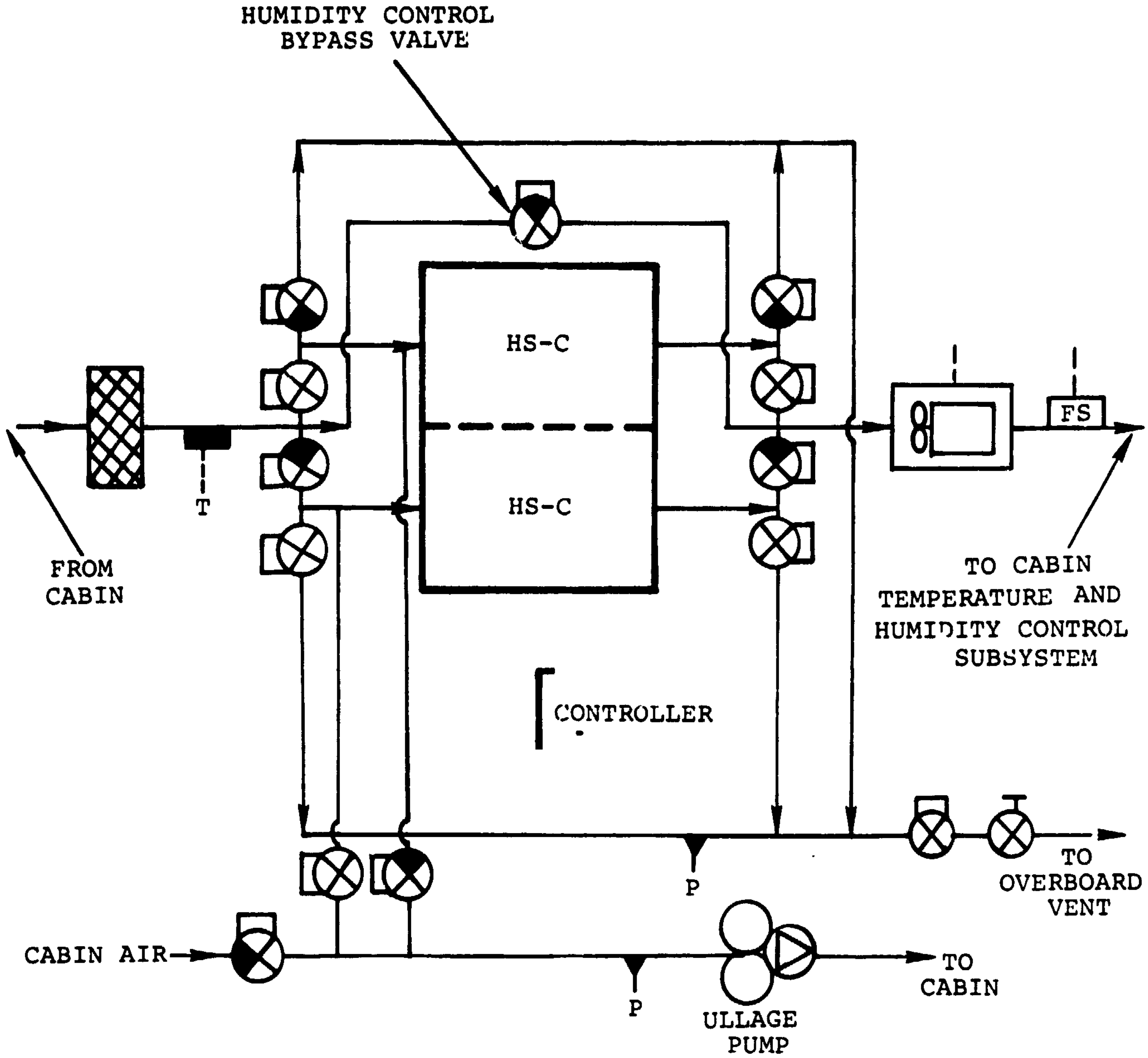


FIGURE 29

HS-C RH CONTROL

SUBSYSTEM: CO_2 Removal

CONCEPT: Solid Amine (HS-C) RH

7 MEN - 30 DAYS

SUBSYSTEM:	Weight (Lb)	Volume (Ft^3)	Power (Watts)	Cost ($\$ \times 10^3$)
Installed Unit (1)	301	16.6	153	255
Flight Expendables	N/A	N/A	--	0
Resupply Expendables	--	--	--	0
Nonrecurring Cost	--	--	--	2,600
Totals	301	16.6	153	

VEHICLE CONSIDERATIONS:

			Generated	Required
Heat Rejection (Btu/Hr)	-496			
Number of Interfaces	4	Oxygen (Lb/Day)	N/A	N/A
Cabin Air Dumped (Lb/Day)	0.2	Hydrogen (Lb/Day)	N/A	N/A
Water Loss (Lb/Day) (2)	14.43	Water (Lb/Day)	N/A	N/A
Water Recovered (Lb/Day)	N/A			

COMMENTS:

(1) Includes four LiOH cartridges for fail safe operation.
(2) Complete Humidity control provided.

TABLE 15

SOLID AMINE - (HS-C)/LOW DUMP

The Solid Amine Reduced Removal Subsystem absorbs carbon dioxide and water in a single bed from the cabin atmosphere and desorbs it to space vacuum. Complete cabin carbon dioxide partial pressure control and partial relative humidity control is provided. As a result, the latent heat load on the Shuttle cabin relative humidity control condensing heat exchanger is less than the HS-C RH Subsystem. This subsystem is shown schematically in Figure 30.

Process inlet air is drawn directly downstream of the relative humidity control subsystem through the absorbing bed canister. The air flow travels through the subsystem fan and is returned to the cabin ventilation system. While one bed is absorbing, the second bed is desorbed to space vacuum. An ullage compressor is used to conserve the cabin atmosphere remaining in the on-stream bed prior to exposure to space vacuum.

Table 16 defines the subsystem characteristics for the Extended Duration Orbiter 30-day mission.

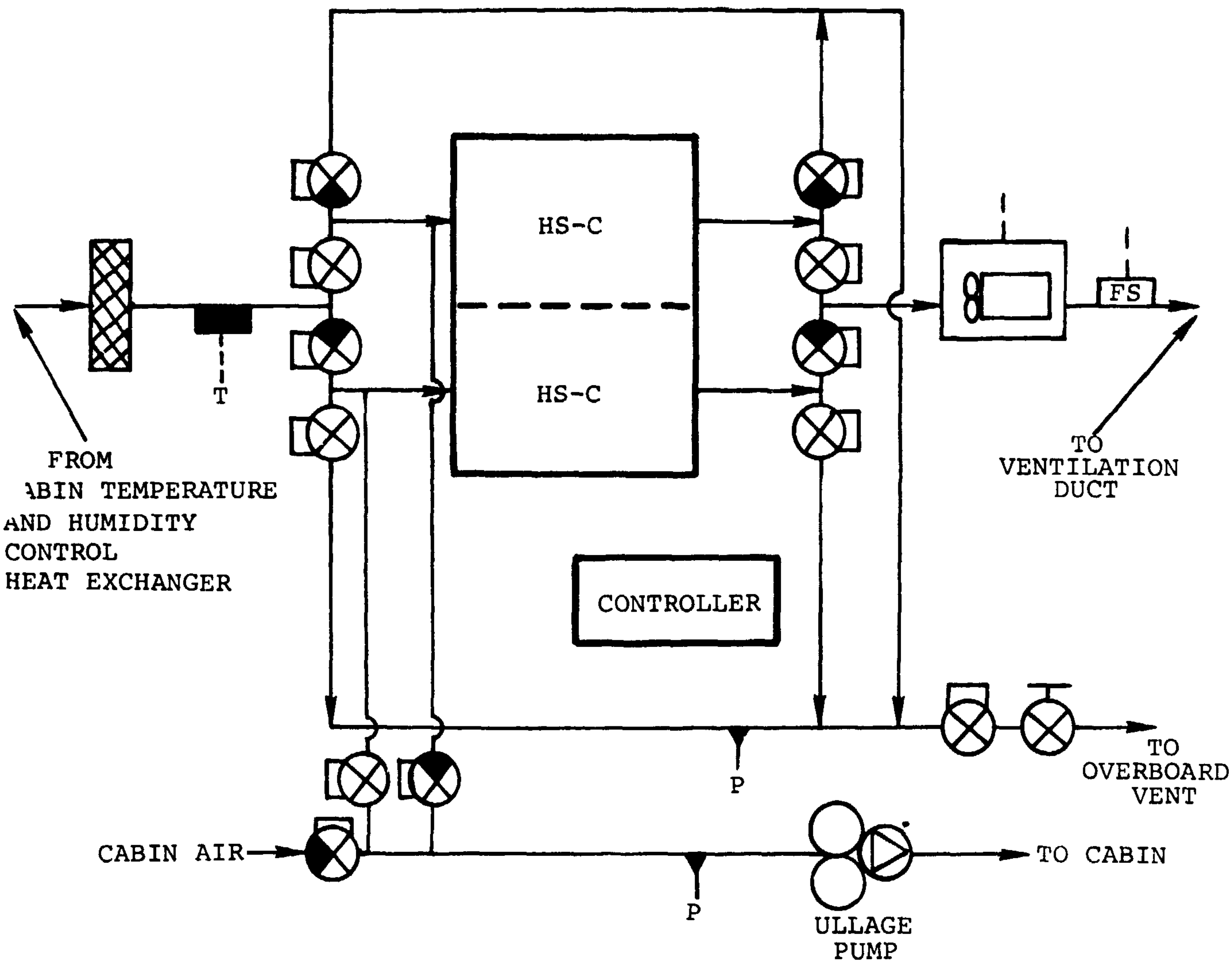


FIGURE 30

HS-C LOW DUMP

SUBSYSTEM: CO_2 Removal

CONCEPT: Solid Amine (HS-C) - Low Dump

7 MEN - 30 DAYS

SUBSYSTEM:	Weight (Lb)	Volume (Ft^3)	Power (Watts)	Cost ($\$ \times 10^3$)
Installed Unit (1)	340	15.2	100	240
Flight Expendables	N/A	N/A	--	0
Resupply Expendables	--	--	--	0
Nonrecurring Cost	--	--	--	2,700
Totals	340	15.2	100	

VEHICLE CONSIDERATIONS:

			Generated	Required
Heat Rejection (Btu/Hr)	-69			
Number of Interfaces	4	Oxygen (Lb/Day)	N/A	N/A
Cabin Air Dumped (Lb/Day)	0.4	Hydrogen (Lb/Day)	N/A	N/A
Water Loss (Lb/Day) (2)	9.83	Water (Lb/Day)	N/A	N/A
Water Recovered (Lb/Day)	N/A			

COMMENTS:

(1) Includes four LiOH cartridges for fail safe operation.
(2) At 50°F cabin dew point.

TABLE 16

MOLECULAR SIEVE DUMP

The Molecular Sieve Dump Subsystem contains two canisters, each of which alternately adsorb water and CO_2 from the process cabin air and desorb these gases to space vacuum. The Molecular Sieve Dump Subsystem is shown schematically in Figure 31.

The subsystem is configured such that water and CO_2 removal are accomplished in a single absorbing canister which is divided into two sections. The front part contains a bed of 10 angstrom molecular sieve for water removal, and the second part contains a bed of 5 angstrom molecular sieve for CO_2 removal. The 10 angstrom material dries the process gas to a low water content to minimize water poisoning of the 5 angstron CO_2 removal bed. Beds are sized to go 30 days without regeneration. After every flight the beds must be reconditioned on the ground utilizing the internal bed heaters and appropriate ground support equipment. For missions up to 60 days, no in-flight regeneration is required. For longer mission times, regeneration must be accomplished in flight.

Process air, from downstream of the Cabin Temperature and Humidity Control Subsystem, flows through the adsorbing molecular sieve bed and the subsystem fan and exits back to the cabin. While one

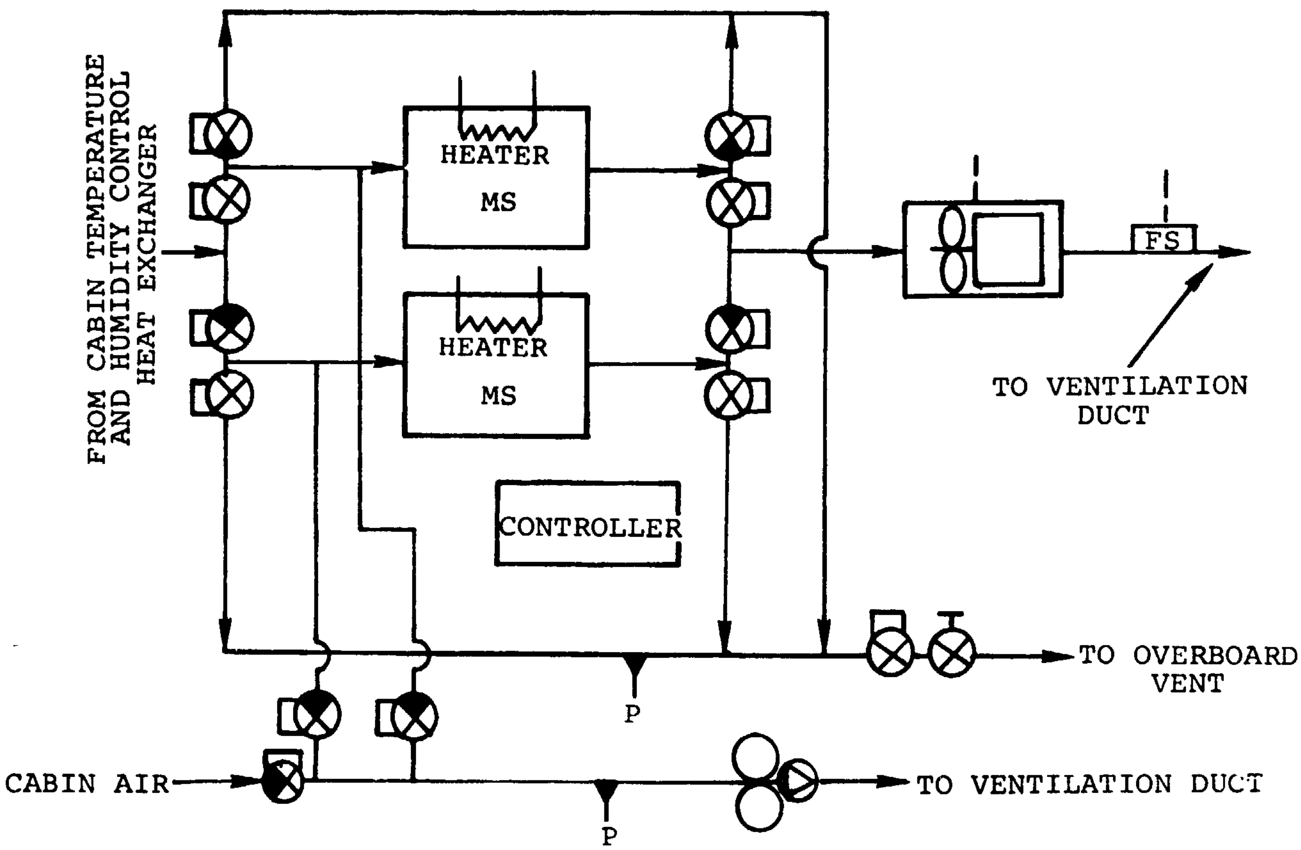


FIGURE 31

MOLECULAR SIEVE - DUMP

bed is adsorbing, the second bed is desorbing to space vacuum. An ullage compressor is used to conserve the cabin atmosphere remaining in the on-stream bed prior to exposure to space vacuum.

Table 17 defines the subsystem characteristics for the Extended Duration Orbiter 30-day mission.

SUBSYSTEM: CO_2 Removal

CONCEPT: Molecular Sieve Dump

7 MEN - 30 DAYS

SUBSYSTEM:	Weight (Lb)	Volume (Ft^3)	Power(1) (Watts)	Cost ($\$ \times 10^3$)
Installed Unit	265.0	16.1	74	275
Flight Expendables	N/A	N/A	--	0
Resupply Expendables	--	--	--	0
Nonrecurring Cost	--	--	--	2,800
Totals	265.0	16.1	74	

VEHICLE CONSIDERATIONS:

Heat Rejection (Btu/Hr)	-271
Number of Interfaces	4
Cabin Air Dumped (Lb/Day)	0.5
Water Loss (Lb/Day) (2)	11.83
Water Recovered (Lb/Day)	N/A

	Generated	Required
Oxygen (Lb/Day)	N/A	N/A
Hydrogen (Lb/Day)	N/A	N/A
Water (Lb/Day)	N/A	N/A

COMMENTS:

(1) Requires bake-out at end of mission using special GSE with GSE cost not included. Peak power of 1834 WDC once every 30 days for bed regeneration.

(2) At 50°F cabin dew point.

TABLE 17

MOLECULAR SIEVE - WATER SAVE

The Molecular Sieve - Water Save Subsystem is a four-bed cyclical adsorption system consisting of two silica gel desiccant beds and two molecular sieve CO_2 removal beds. The Molecular Sieve - CO_2 Concentrator Subsystem is shown in Figure 32.

The desiccant beds contain an integral heat exchanger to permit cooling the beds during the adsorption phase and heating the beds electrically during the desorption phase. During operation of the subsystem, cabin process gas is drawn by a fan through the adsorbing silica gel bed. The silica gel dries the process gas to a low water content to eliminate water poisoning of the molecular sieve beds. Leaving the desiccant bed, gas passes through the adsorbing molecular sieve bed where the CO_2 is removed. On leaving the adsorbing molecular sieve bed, the process gas passes the desorbing silica gel bed which is heated electrically. As it flows through this bed, the dry gas removes the water adsorbed during the previous adsorption phase of the cycle returning it to the cabin.

While one molecular sieve bed is adsorbing CO_2, the second bed is desorbed by exposure to space vacuum. The molecular sieve beds are sized for regeneration every 30 days on the ground utilizing internal bed heaters and appropriate ground equipment. For

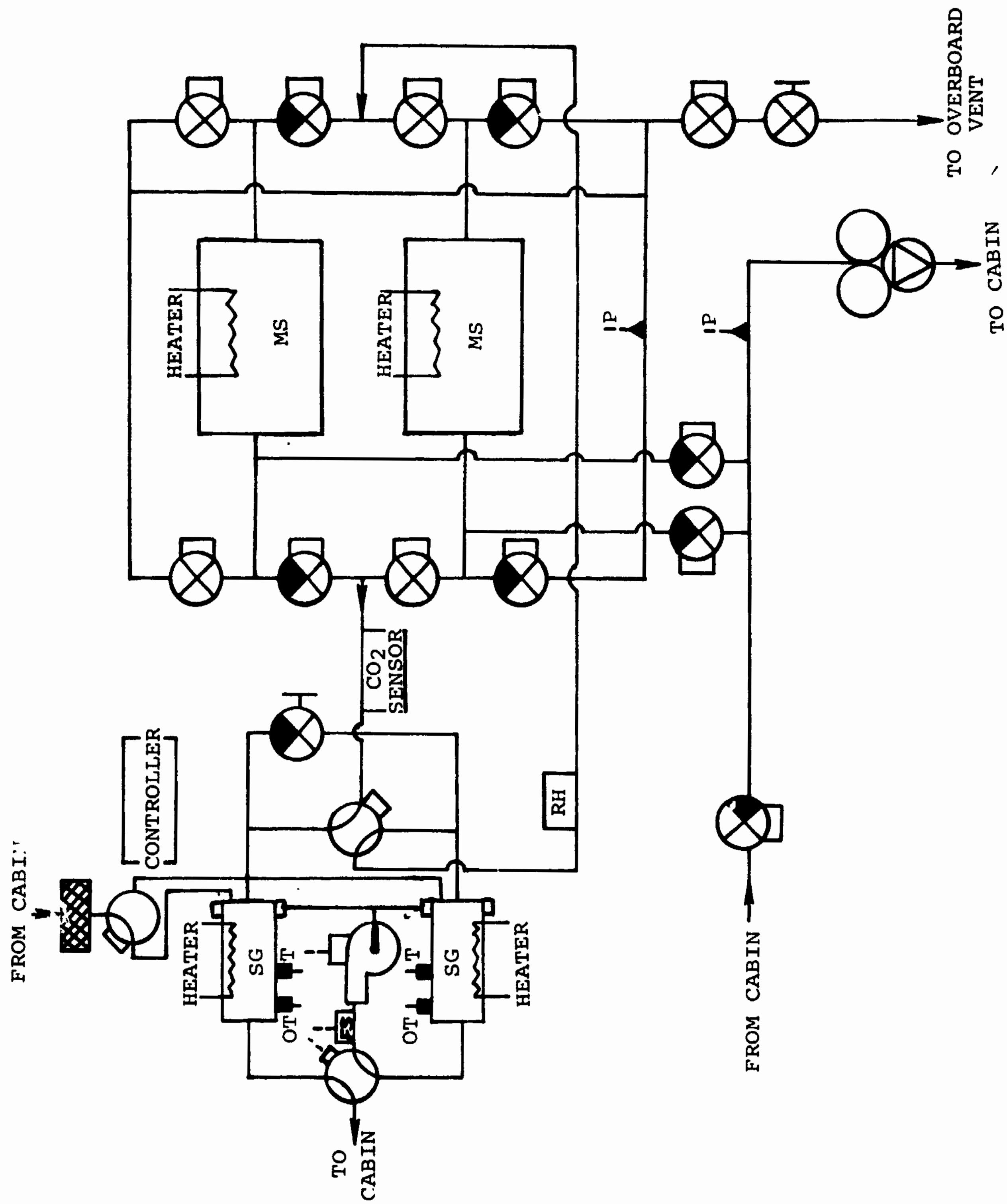


FIGURE 32
MOLECULAR SIEVE - WATER SAVE

missions up to 60 days, no in-flight regeneration is required. For longer missions, regeneration must be accomplished in-flight. An ullage compressor is used to conserve the cabin atmosphere remaining in the on-stream bed prior to exposure to space vacuum.

Table 18 defines the subsystem characteristics for the Extended Duration Orbiter 30-day mission.

SUBSYSTEM: CO_2 Removal

CONCEPT: Molecular Sieve - Water Save

7 MEN - 30 DAYS

SUBSYSTEM:	Weight (Lb)	Volume (Ft^3)	Power (1) (Watts)	Cost ($\$ \times 10^3$)
Installed Unit	270.0	16.0	586	460
Flight Expendables	N/A	N/A	--	0
Resupply Expendables	--	--	--	0
Nonrecurring Cost	--	--	--	3,500
Totals	270.0	16.0	586	

VEHICLE CONSIDERATIONS:

			Generated	Required
Heat Rejection (Btu/Hr)	1,544			
Number of Interfaces	4	Oxygen (Lb/Day)	N/A	N/A
Cabin Air Dumped (Lb/Day)	0.3	Hydrogen (Lb/Day)	N/A	N/A
Water Loss (Lb/Day)	0	Water (Lb/Day)	N/A	N/A
Water Recovered (Lb/Day)	N/A			

COMMENTS:

(1) Requires bake-out at end of mission using special GSE. Cost of GSE not included.

TABLE 18

ELECTROCHEMICAL DEPOLARIZED CONCENTRATOR (EDC) DUMP

The Electrochemical Depolarized Concentrator Dump Subsystem utilizes a fuel cell reaction between hydrogen and oxygen for removal or concentration of carbon dioxide from cabin air. Although designed primarily as a carbon dioxide concentrator to be used in conjunction with a Sabatier reactor and a Water Vapor Electrolysis (WVE) unit, the concentrator can be used to remove carbon dioxide directly by venting carbon dioxide and hydrogen directly overboard through a suitable back pressure valve. Complete cabin carbon dioxide partial pressure control is provided. This subsystem is shown schematically in Figure 33.

Process inlet air is drawn directly downstream of the Cabin Temperature and Relative Humidity Control Subsystem through the EDC module and back to the cabin ventilation system by a circulating fan. The same fan is used to cool the EDC module. Hydrogen from the electrical power supply cryogenic supply or from an independent supply is fed into the unit at a controlled flow rate. A subsystem controller regulates the power flowing into the EDC which controls the CO_2 removal rate.

Water formed in the module is released to the cabin air stream. Electrical energy generated by the fuel cell type reaction is dissipated in an electric heater located in the EDC module system process air stream.

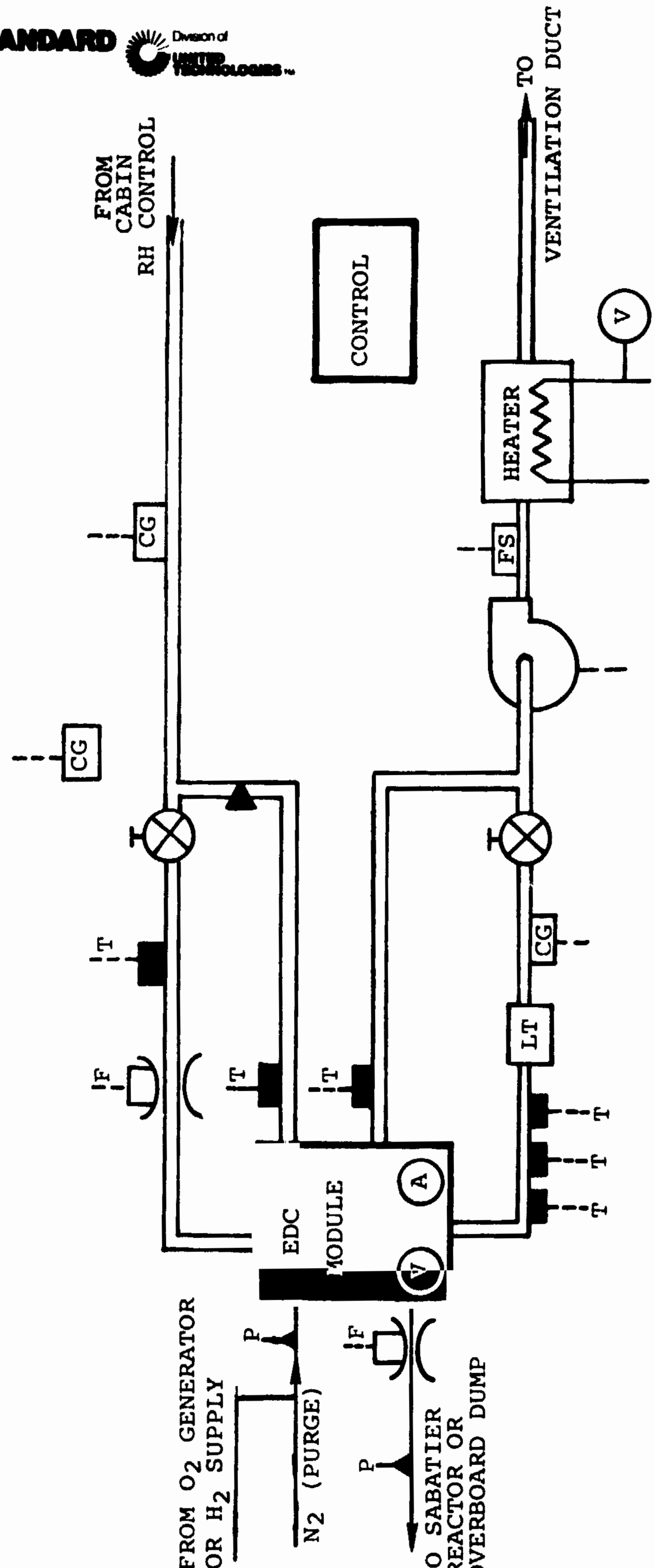


FIGURE 33
ELECTROCHEMICAL DEPOLARIZED CONCENTRATOR (EDC)

A supply of nitrogen gas is required for purging the subsystem at start-up and shutdown.

Table 19 defines the subsystem characteristics for the Extended Duration Orbiter 30-day mission.

SUBSYSTEM: CO_2 Removal

CONCEPT: EDC Dump

7 MEN - 30 DAYS

SUBSYSTEM:	Weight (Lb)	Volume (Ft^3)	Power (Watts)	Cost ($ x 10^3)
Installed Unit	235.0	10.0	347	350
Flight Expendables	N/A	N/A	--	0
Resupply Expendables	--	--	--	0
Nonrecurring Cost	--	--	--	3,500
Totals	235.0	10.0	347	

VEHICLE CONSIDERATIONS:	
Heat Rejection (Btu/Hr)	2,780
Number of Interfaces	5
Cabin Air Dumped (Lb/Day)*	15.63
Water Loss (Lb/Day)	0
Water Recovered (Lb/Day)	N/A

	Generated	Required
Oxygen (Lb/Day)	N/A	5.50
Hydrogen (Lb/Day)	N/A	1.61
Water (Lb/Day)	6.6	N/A

COMMENTS:

*CO_2 and H_2 Dump

TABLE 19

EDC WITH SABATIER REACTOR

The Electrochemical Depolarized Concentrator with Sabatier Reactor Subsystem utilizes an identical EDC unit to that described for the CO_2 dump system, except instead of dumping CO_2 and hydrogen to space vacuum, these gases are delivered to a Sabatier Reactor. Inside the reactor the CO_2 and H2 mixture is passed over a catalyst where the gases are converted to methane and water. The methane and any excess hydrogen is discharged to space vacuum, and the water after condensing and minor clean-up is available for drinking or subsequent electrolysis.

This Sabatier Reactor subsystem is shown schematically in Figure 34. The schematic for the EDC is shown in Figure 33. Table 20 defines the complete subsystem characteristics for the Extended Duration Orbiter 30-day mission.

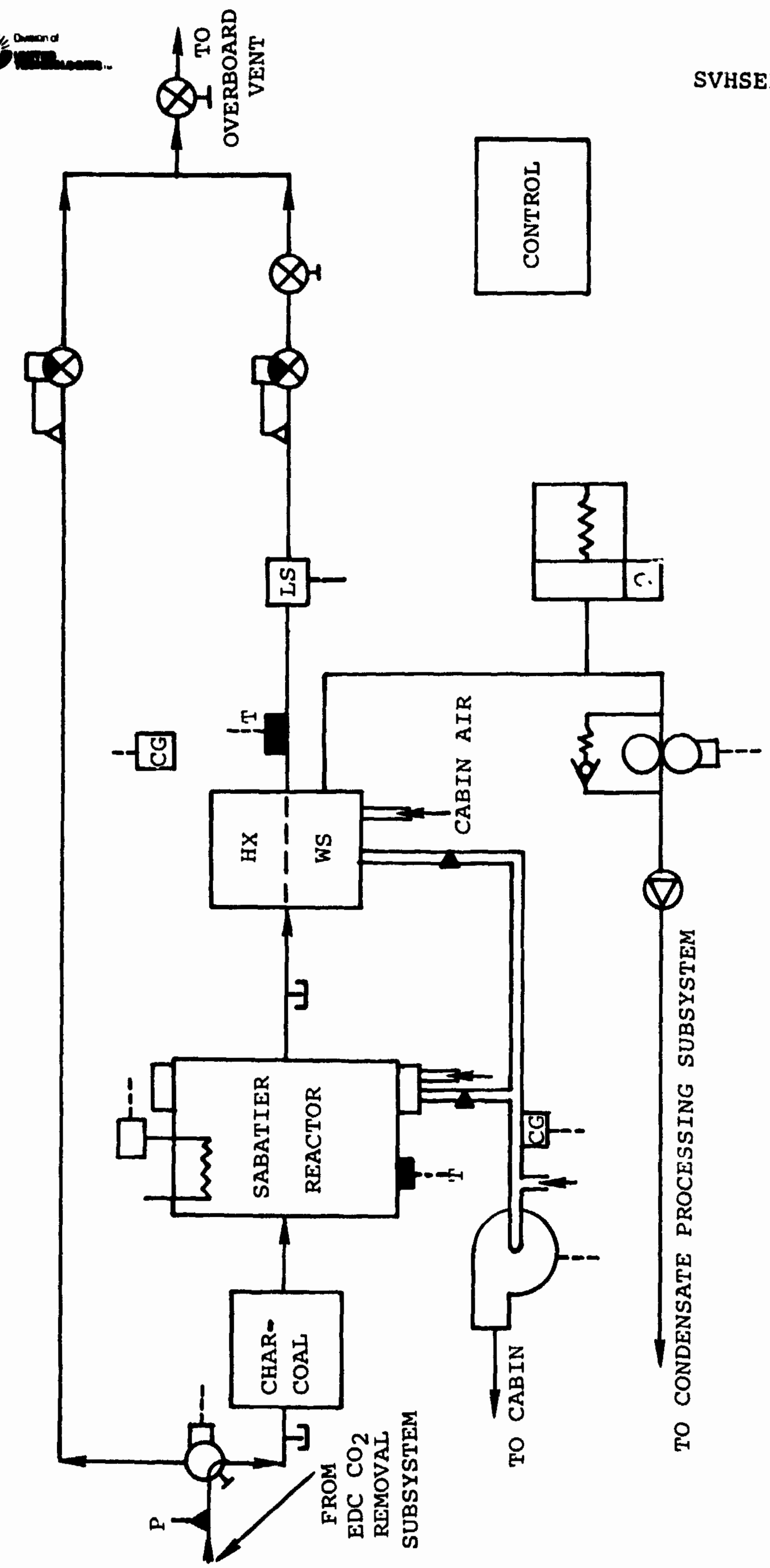


FIGURE 34
SABATIER REACTOR

SUBSYSTEM: CO_2 Removal

CONCEPT: EDC With Sabatier Reactor

7 MEN - 30 DAYS

SUBSYSTEM:	Weight (Lb)	Volume (Ft^3)	Power (Watts)	Cost ($ x 10^3)
Installed Unit	350.6	20.5	389	540
Flight Expendables	N/A	N/A	--	0
Resupply Expendables	--	--	--	0
Nonrecurring Cost	--	--	--	6,300
Totals	350.6	20.5	389	

VEHICLE CONSIDERATIONS:

Heat Rejection (Btu/Hr)	3,393
Number of Interfaces	
Cabin Air Dumped (Lb/Day)*	7.83
Water Loss (Lb/Day)	N/A
Water Recovered (Lb/Day)	N/A

	Generated	Required
Oxygen (Lb/Day)	N/A	5.90
Hydrogen (Lb/Day)	N/A	1.61
Water (Lb/Day)	14.44	N/A

COMMENTS:

*CH_4, CO_2, H_2, and H_2O Dump

TABLE 20

EDC WITH WVE AND SABATIER REACTOR

The Electrochemical Depolarized Concentrator integrated with a Water Vapor Electrolysis unit and used in combination with a Sabatier Reactor is essentially identical to the individual subsystems described earlier. The hydrogen and oxygen generated by the WVE is supplied directly to the EDC so no external hydrogen source or oxygen from the cabin is required. Metabolic oxygen and oxygen leakage makeup is also supplied by the WVE portion of the subsystem. The Sabatier Reactor reduces carbon dioxide to methane and water as discussed previously.

This EDC/WVE portion of the subsystem is shown schematically in Figure 35. The Sabatier Reactor subsystem is shown schematically in Figure 34. Table 21 defines the complete subsystem characteristics for the Extended Duration Orbiter 30-day mission.

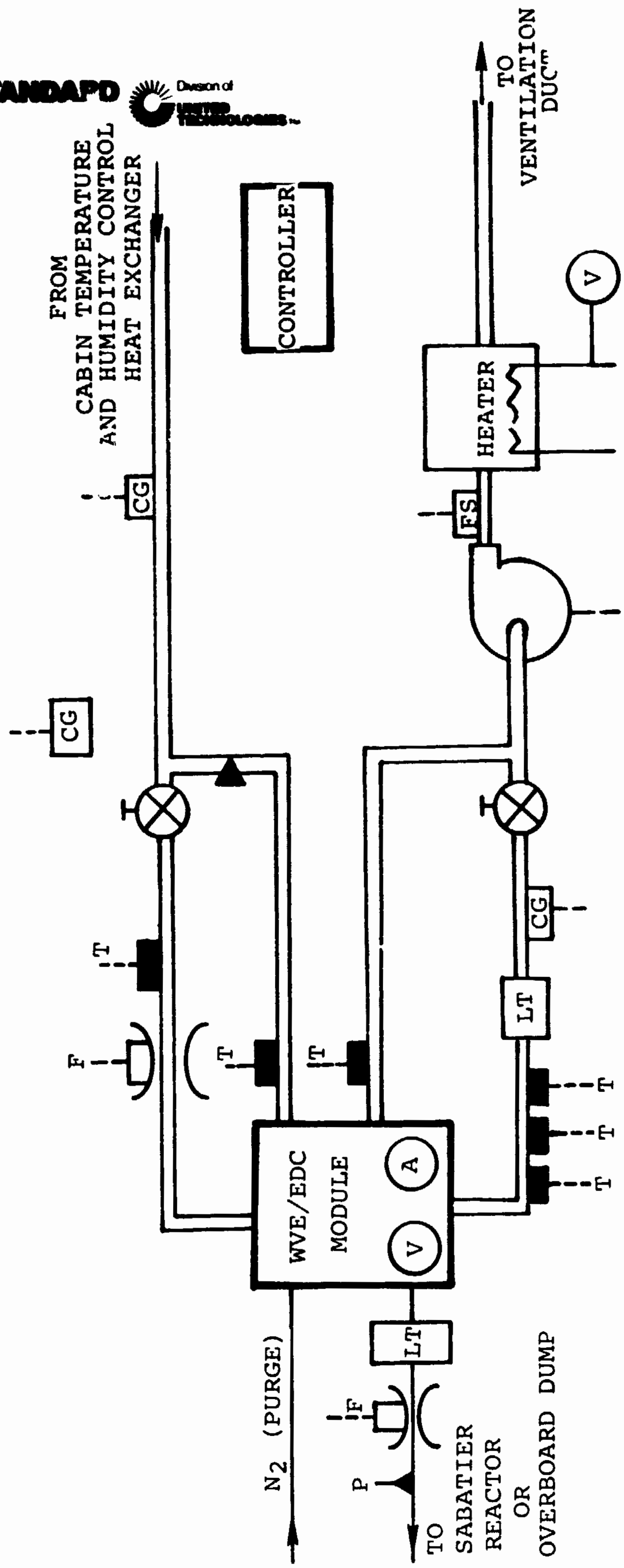


FIGURE 35
ELECTROCHEMICAL DEPOLARIZED CONCENTRATOR
AND WATER VAPOR ELECTROLYSIS (EDC/WVE)

SUBSYSTEM: CO_2 Removal

CONCEPT: FDC/WVE With Sabatier Reactor

7 MEN - 30 DAYS

SUBSYSTEM:	Weight (Lb)	Volume (Ft^3)	Power (Watts)	Cost ($\$ \times 10^3$)
Installed Unit	555.6	26.8	2,389	830
Flight Expendables	N/A	N/A	--	0
Resupply Expendables	--	--	--	0
Nonrecurring Cost	--	--	--	8,700
Totals	555.6	26.8	2,389	

VEHICLE CONSIDERATIONS:

			Generated	Required
Heat Rejection (Btu/Hr)	5,243			
Number of Interfaces		Oxygen (Lb/Day)	18.22	5.904
Cabin Air Dumped (Lb/Day)(1)	7.83	Hydrogen (Lb/Day)	2.27	2.27
Water Loss (Lb/Day)	0	Water (Lb/Day)	14.44	20.50
Water Recovered (Lb/Day)	N/A			

COMMENTS:

(1) CH_4, CO_2, H_2, and H_2O Dump

TABLE 21

CO_2 REMOVAL SUBSYSTEM DISCUSSION

The eight candidate CO_2 Removal Subsystem characteristics are summarized in Figure 36 for the 7-man, 30-day mission. As can be noted, all regenerable concepts are lighter and have less volume than the existing LiOH subsystem for all missions considered. All but two, the EDC with Sabatier and EDC/WVE with Sabatier, have a lower total cost over the projected mission period (42 missions). The cost for each subsystem is defined as the sum of the nonrecurring cost for design, development and certification, plus the cost for one shipset of hardware, plus the expendables and spares required to complete 42 30-day missions. The spares cost is estimated to be equivalent to the cost of one shipset of hardware over the life of the program. The number of missions was established by the NASA/JSC.

Since each carbon dioxide subsystem discussed previously affects the cabin temperature, oxygen supply requirements, water condensate supply, etc. in a different manner, it is necessary to evaluate the candidate on a total ECLS system basis. This was done and is discussed in the "System" section of this report.

CO_2 REMOVAL SUBSYSTEMS
7 Men — 30 Days

	Weight (lbs)	Power (Watts)	Volume (ft^3)	Cost ($\$ \times 10^6$)	New Vehicle Interfaces N_2	E	M	O_2	H_2	GSE	Condensate Left in Cabin lbs/Day	Heat Rejection Btu/Hr	Cabin (°F) ΔD.B.	Cabin (°F) ΔD.P.
LiOH	1189	11	61.4	5.7							30.4	761	0	0
HS-C — R.H.	301	153	16.6	3.2		√	√				0	-496	0	-4°
M.S. — Low Dump	265	74	16.1	3.4		√	√			√	12.63	-271	0	-2°
M.S. — W.S.	270	586	16.0	4.5		√	√			√	24.4	1544	0	0
H.S. — Low Dump	340	100	15.2	3.2		√	√				14.63	-69	0	-2°
EDC	235	347	10	4.2	√	√	√	√	√		31.0	2780	0	+2°
EDC-SAB	351	389	20.5	7.4	√	√	√	√	√		31.0 + H_2O 78	3393	+3°	+2°
EDC/WVE SAB.	555	2389	26.8	10.4	√	√	√				17.1 + H_2O 78	5243	+9.5°	+2°

FIGURE 36 - CO_2 REMOVAL SUBSYSTEMS

TEMPERATURE AND HUMIDITY CONTROL

An analysis of the existing Shuttle Orbiter cabin temperature and humidity control subsystem shows that it is adequate without any changes to handle the system modifications proposed for an extended mission if one of the following CO_2 Removal subsystems are used:

- LiOH: No change.

- EDC: Cabin temperature dew point will rise 2°F.

- Solid Amine (Either Type): Provides increased heat rejection capacity.

- Molecular Sieve (Low Dump): Provides increased heat rejection capacity.

If a Sabatier reactor or an electrolysis unit is used with the EDC subsystem, the cabin temperature will rise as shown in Figure 36 in the CO_2 Removal section.

PRESSURE AND COMPOSITION CONTROL

A review of the existing Shuttle Orbiter pressure and composition control shows that it is completely adequate for long duration missions. No changes appear to be required for other than a subsystem utilizing an electrolysis subsystem.

SYSTEM DISCUSSION

As discussed in the previous report sections, the selection of a Carbon Dioxide Removal Subsystem and the decision to utilize a Waste Water Reclamation Subsystem are ECLS system related discussions.

Figure 37 defines for each of the leading CO_2 removal and water reclamation candidates the possible interactions on a ECLS system basis.

Figure 38 defines the number of mission possibilities that were examined primarily with a 7-man crew for 7, 30, 60, and 90 day missions. A 3-man, one-day mission was also examined. The missions studied are noted in Table 22. The impact on those systems of 10 men will be discussed later.

In order to assist in compiling the data for the 219 mission combinations examined, an Extended Shuttle ECLSS Impact Summary Data Sheet was generated. A copy is shown in Figure 39.

Data from the subsystem data sheets define possible ECLS systems for use in the Extended Duration Orbiter. With this evaluation method, various fuel cell operational modes and the effect of different CO_2 Removal/Reduction Subsystems (with and without water receovery) on the system water balance is immediately apparent.

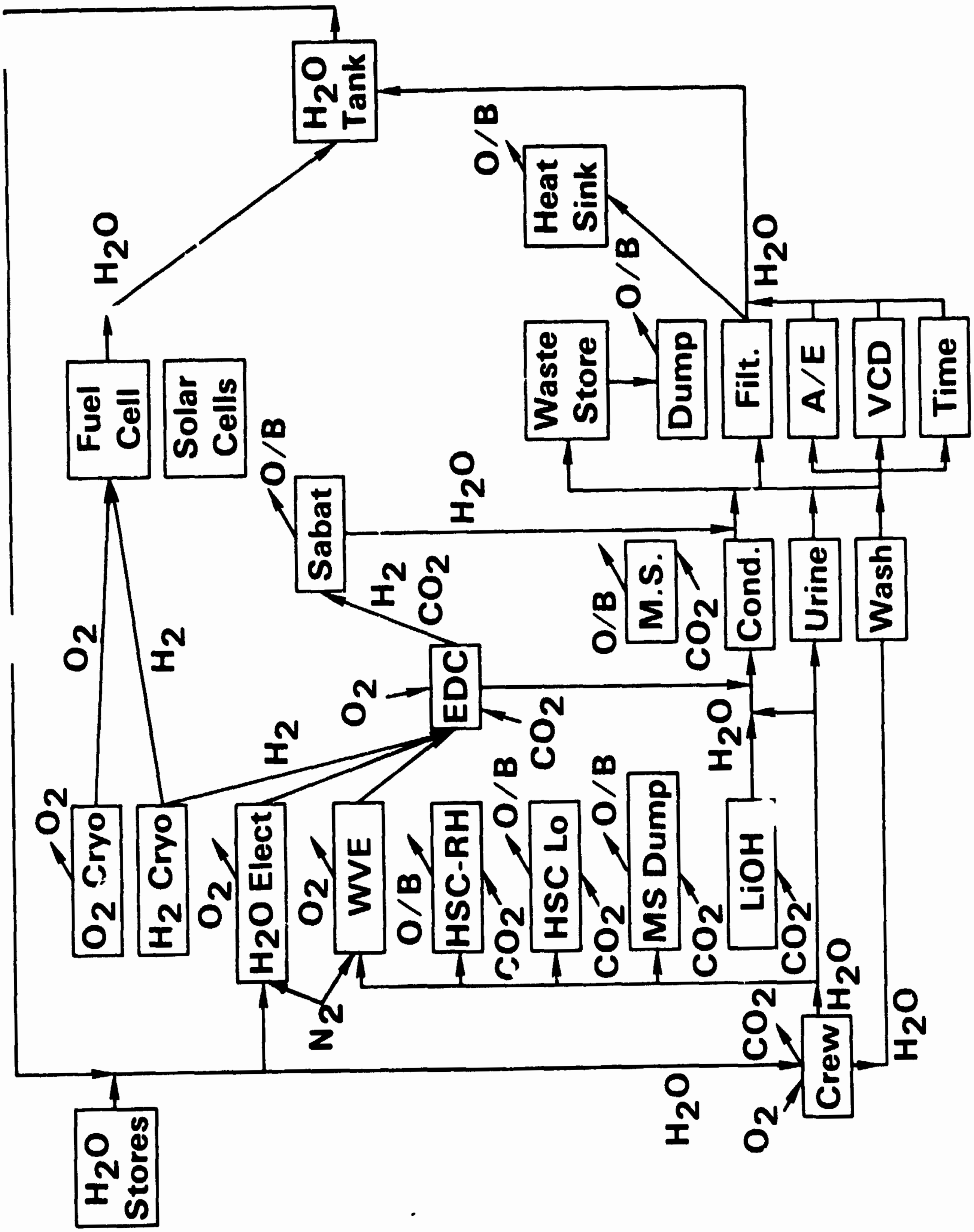


FIGURE 37 - SUBSYSTEM INTERACTIONS

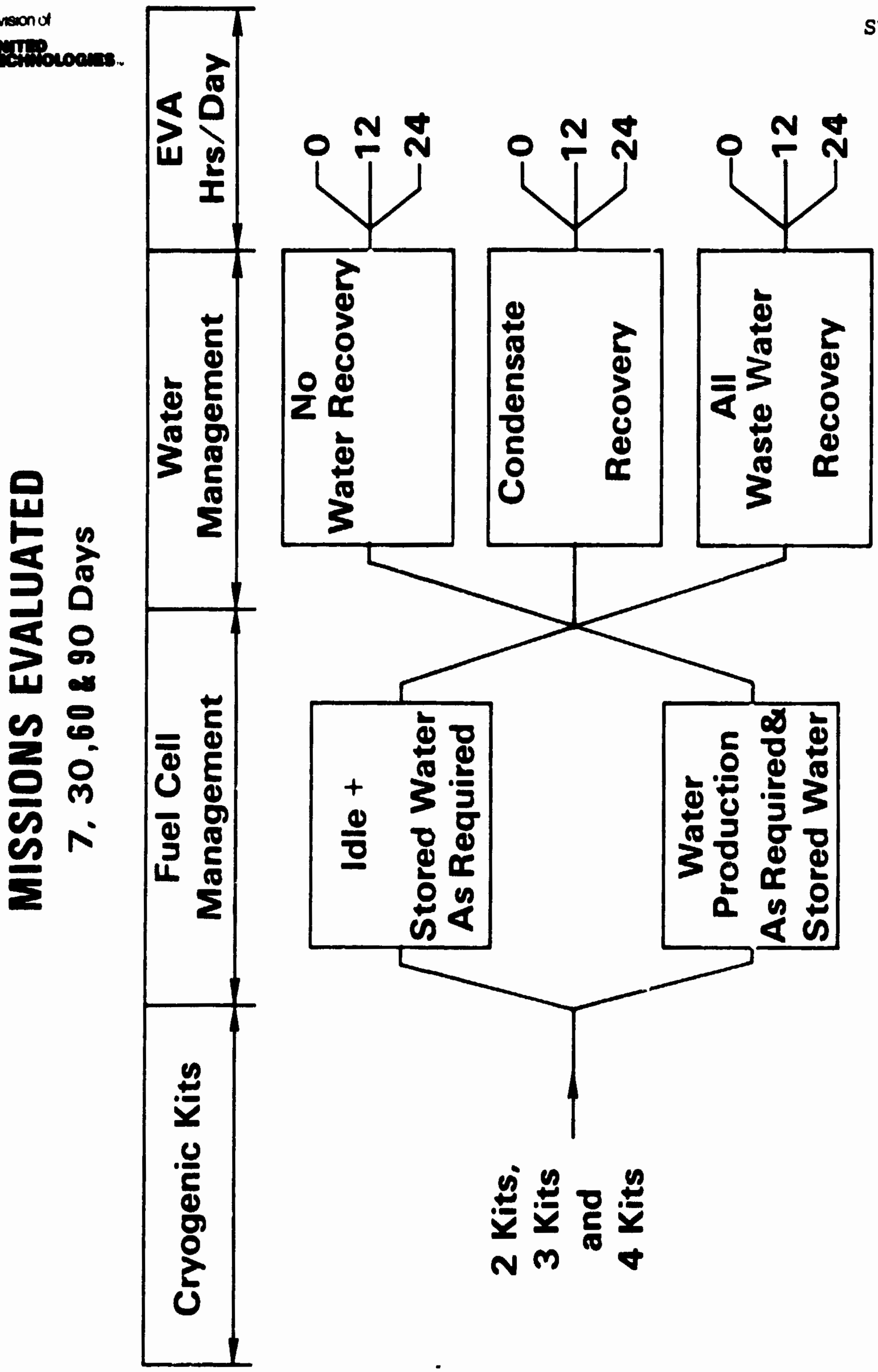


FIGURE 38 - MISSIONS EVALUATED

TABLE 22

ORBITER MISSIONS STUDIED

Subsystems	30 Day Mission - 7 Men Idle Fuel Cell	30 Day Mission - 7 Men Scheduled Fuel Cell	60 Day Mission - 7 Men Idle Fuel Cell	60 Day Mission - 7 Men Scheduled Fuel Cell	7 Day - 7 Men Scheduled Fuel Cell	1 Day - 3 Men Scheduled Fuel Cell	90 Day - 7 Men Idle Fuel Cell
CO_2 Subsystems (8)	0, 12, and 24 Hours EVA	0, 12, and 24 Hours EVA		0, 12, and 24 Hours EVA	0, 12, and 24 Hours EVA	0, EVA (3 Systems)	
CO_2 Subsystems with Condensate Reclamation (8)	0, 12, and 24 Hours EVA		0, 12, and 24 Hours EVA				
CO_2 Subsystems with all Waste Water Reclamation (8)	0, 12, and 24 Hours EVA		0, 12, and 24 Hours EVA				0, 12, and 24 Hours EVA

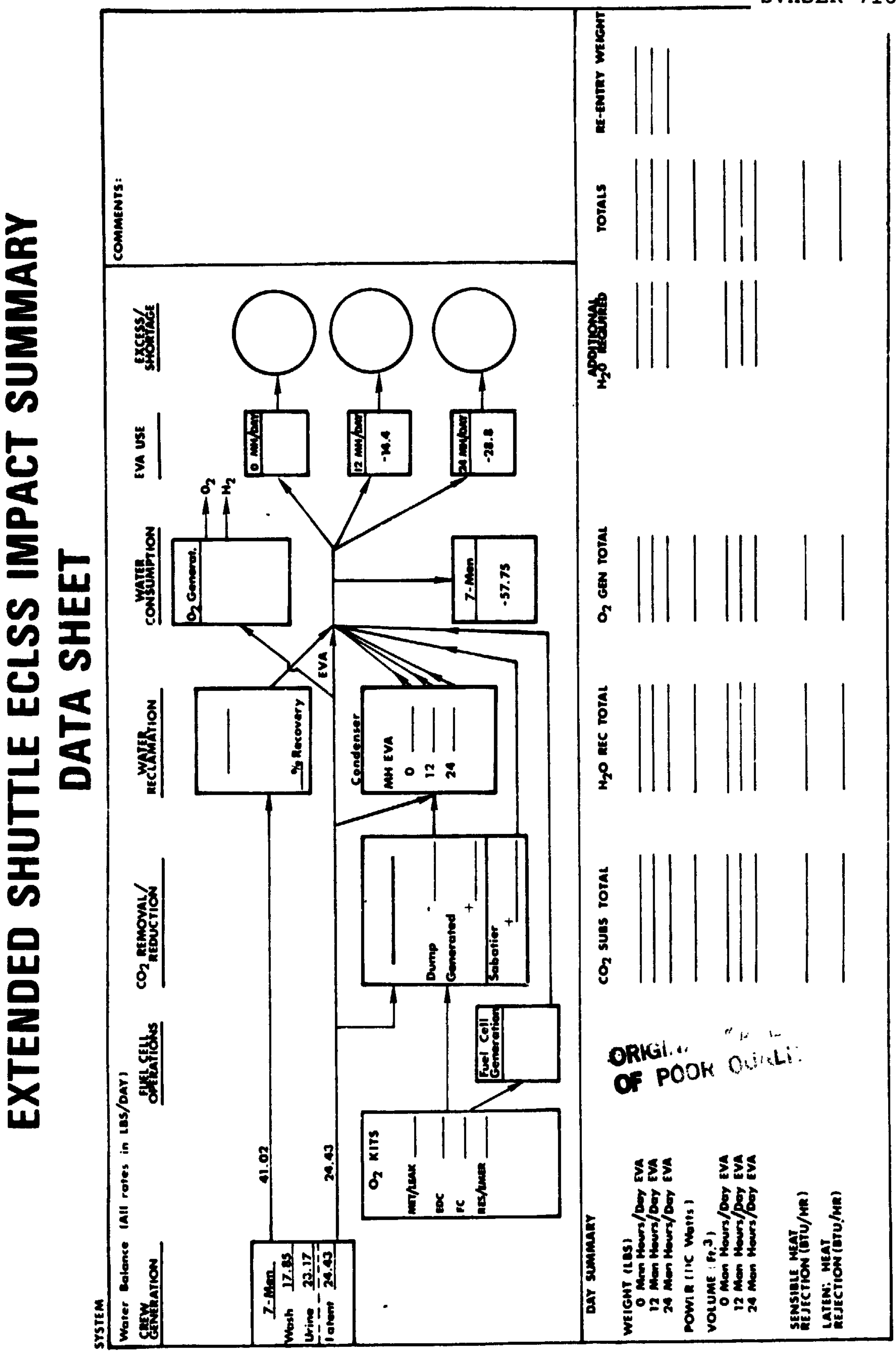


FIGURE 39 - EXTENDED SHUTTLE ECLSS IMPACT SUMMARY DATA SHEET

Cryogenic oxygen storage is shown on the data sheets for illustrative purposes only. Cryogenic oxygen is always required for EDO missions to meet fuel cell idle and ascent/descent requirements as a minimum. Insofar as the cryogenic kit weights are actually part of the electrical power system, kit weights are not included in ECLSS system weights. Fuel cell generated water at the rate of 21.8 lbs/day as the result of cryogenic O_2 usage (at the minimum fuel cell idle condition of 1 kw) has been included in the water balance.

Eight CO_2 Removal Subsystems have been considered for EDO missions which are: LiOH, HS-C Relative Humidity Control, HS-C Low Dump, EDC Dump, EDC/WVE with Sabatier Reactor, EDC with Sabatier Reactor, Molecular Sieve Dump, and Molecular Sieve Water Save. The effect of each candidate CO_2 Removal Subsystem on the overall water balance is indicated under the heading "CO_2 Removal/Reduction," with subsystems either generating water or dumping water. Sabatier Reactor contributions to the water balance are indicated in this block.

Under the heading Water Reclamation," waste water is divided into two categories; one for urine/wash processing, and one for condensate processing due to the differing levels of processing required. For this trade study the TIMES process for urine/wash recovery was selected with multifiltration processing for condensate water. A 95% water recovery efficiency was assumed for urine/wash processing, and a recovery efficiency of essentially 100% was assumed for condensate filtration. Note that these blocks are only filled in if the water recovered is used to augment ECLSS requirements. This factor affects systems in which condensate is produced, but subsequently dumped, such that zeros appear in the condenser block even though condensate is produced.

Factors affecting the amount of condensate produced include the level of EVA and the presence or absence of a WVE electrolysis unit. Each 12 HR/DAY EVA consumes 1.55 pounds of water vapor which reduces condenser load and contamination accordingly. The WVE also reduces latent load at the rate of 20.5 lbs/day corresponding to metabolic and EDC O_2 requirements.

In addition to the 1.55 pounds of water vapor collected in the PLSS per 12 HR/DAY EVA, an additional loaded quantity of 14.4 pounds of liquid water is required for sublimator cooling. This water requirement is the final adjustment to the water balance prior to determination of an excess or shortage of water. Cabin condensate quality is reduced by 1.55 pounds for every 12 hours of EVA.

The system summary on the lower section of the impact summary sheet shows the component subsystem weights, powers, volumes, and heat rejection rates. These are summed horizontally to give the total system weight.

Weight and power adjustments are made to subsystem power requirements to reflect a cabin fan power reduction made possible through removal of the LiOH canisters. From the cabin fan power curve this reduction was estimated to be 11 WDC for all non LiOH subsystems, and thus this power credit was subtracted from the power reported on the applicable subsystem data sheets. In addition, the HS-C relative humidity control CO_2 removal subsystem allows shutdown of the cabin condenser water separator saving an additional 25 WDC of power. This reduction was applied in arriving at the subsystem power for HS-C relative humidity control.

All figures given are relative to the baseline 7-day 4-man Orbiter. First, CO_2 subsystems are given weight credit for LiOH off-loading. This includes the off-loading of 4 men/7 days of LiOH. Also, LiOH contingency off-loading is also subtracted (for non LiOH systems) to reflect a 20-hour LiOH contingency versus the 96-hour contingency required for an all LiOH CO_2 Removal Subsystem.

In the fuel-cell-scheduled system evalutions sufficient cryogenic fuel is aboard to meet all vehicle water demands. An appropriate fuel cell operating schedule at greater than idle is assumed. For these cases (30-days and 60-days), subsystems which utilize cryogenic O_2 are penalized for the O_2 used under the rationale that this would otherwise be available for power production.

This penalty is applied to EDC CO_2 removal and EDC/Sabatier Reactor CO_2 removal. Similarly, the EDC/WVE produces sufficient O_2 to meet metabolic and EDC requirements without draining the cryogenic O_2 stores. The EDC/WVE is actually given a weight credit for O_2 production since cryogenic oxygen is not used for metabolic or leakage makeup. Note again that these penalties and credits have only been applied to the fuel cell scheduled system evaluations, and a comment on such system sheets has been included to flag these cases.

In cases where the water balance indicates a shortage of water, the necessary additional water is assumed to be brought along in multiples of the standard Shuttle/Orbiter water tanks. The total water plus tankage required is listed on the summary sheet under additional water required.

Total launch weight is determined as the sum of the subsystem weights, plus stored water and tankage weights. This launch weight is a delta baseline launch weight, referenced to the 4-man 7-day Orbiter baseline.

Reentry weight is a delta baseline reentry weight for the ECLS equipment referenced to the 4-man 7-day Orbiter baseline mission. In view of the fact that the baseline mission includes LiOH CO_2 removal, non LiOH systems dumping CO_2 to space vacuum result in delta return weights lower then baseline mission weights in many cases due to this CO_2 dumping (versus CO_2) storage for the baseline mission. Any stored water taken up is assumed to be used or dumped prior to return in the reentry weight determinations with empty tanks returning.

Data sheets are supplied in Appendix A for all the missions listed in Table 22. All data compiled is based on a delta impact when compared to the baseline Shuttle Orbiter mission of 4 men for 7 days. This data reference point is illustrated in Figure 40 for the delta launch and delta reentry weight.

The delta mission effect of launch weight, landing weight, volume, power, and heat rejection for typical missions are shown in Tables 23 through 27. Examination of these tables and application of appropriate penalties will determine the optimum CO_2 removal subsystem and also determine when waste water reclamation trades off against carrying stored water. Each system must be further evaluated in regard to such factors as numbers of vehicle interfaces, GSE required, safety, radiator impact, etc. Again, it must be emphasized that these numbers reflect only ECS delta weights.

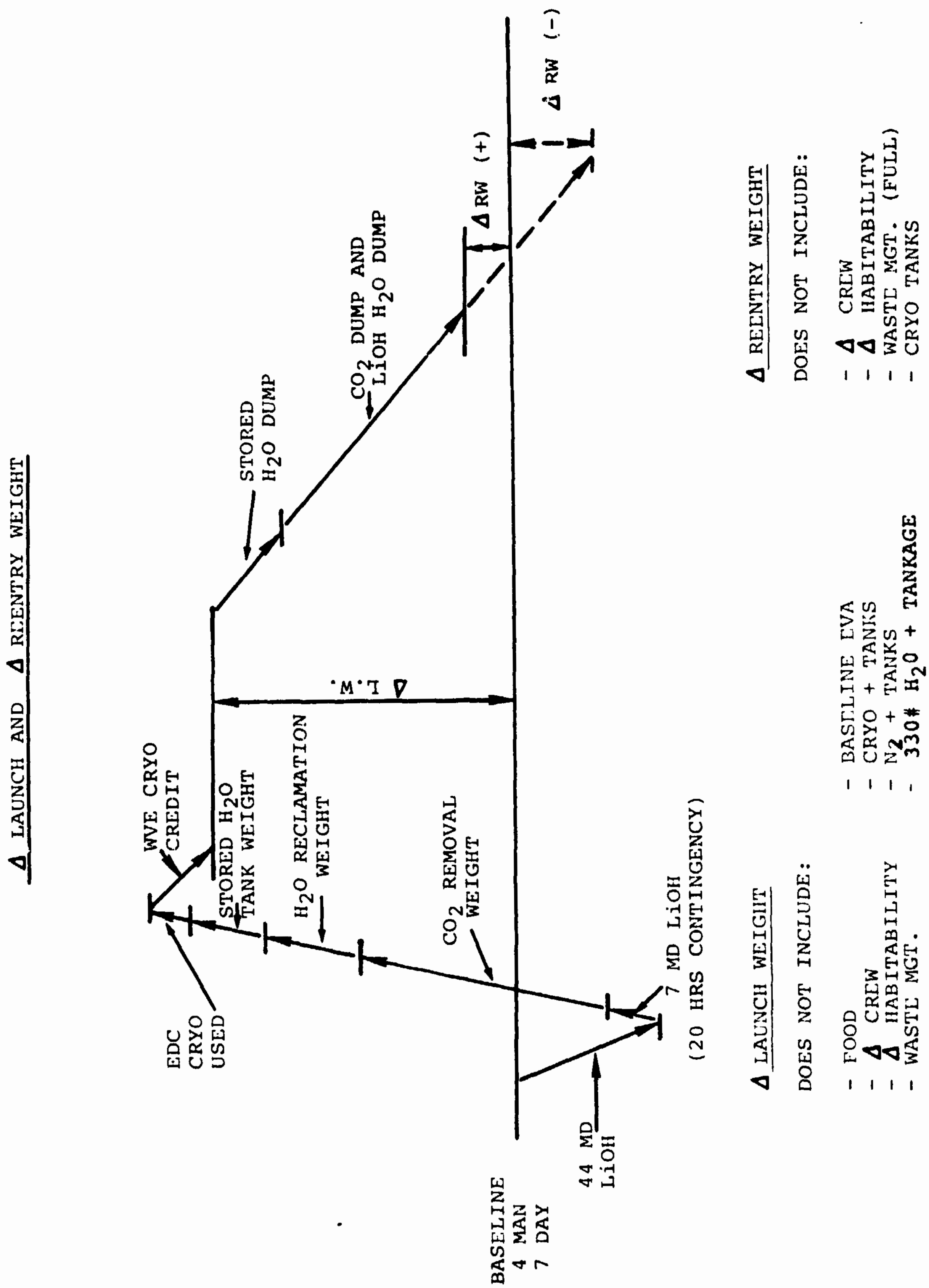


FIGURE 40 - Δ LAUNCH AND Δ REENTRY WEIGHT

TABLE 23

DELTA LAUNCH WEIGHT SUMMARY

		30 Days - 7 Men						60	
		Fuel Cell Idle			Fuel Cell Scheduled			Fuel Cell Id.	
	CO_2 Subsystem	0 MH EVA	12 MH EVA	24 MH EVA	0 MH EVA	12 MH EVA	24 MH EVA	0 MH EVA	12 MH
NO WATER RECLAMATION	LiOH	2791.3	3531.3	4210.3	990.7	990.7	990.7		
	HS-C RH Control	1899.9	2639.9	3319.9	99.9	99.9	99.9		
	HS-C Low Dump	1938.6	2678.6	3363.6	138.6	138.6	138.6		
	EDC	1859.1	2589.1	3279.1	236.2	236.2	236.2		
	EDC/WVE Sab	1809.7	2489.7	3239.7	-167.0	-167.0	-167.0		
	EDC With Sab	1604.7	2284.7	3034.7	351.8	351.8	351.8		
	Mol Sieve Low Dump	1889.1	2629.1	3309.1	89.1	89.1	89.1		
	Mol Sieve Water Save	1894.0	2634.0	3314.0	94.0	94.0	94.0		
CONDENS RECLAMA ONLY	LiOH	1412.9	2201.8	3000.8	Not Applicable			2745.8	432
	HS-C RH Control	1899.9	2639.9	3319.9				3699.9	517
	HS-C Low Dump	1350.8	2149.7	2948.7				2425.5	402
	EDC	451.3	1250.2	2039.2				716.0	230
	EDC/WVE Sab	1466.9	2240.8	3029.8				2416.6	396
	EDC With Sab	326.9	1015.8	1804.6				341.6	171
	Mol Sieve Low Dump	1451.3	2230.2	3039.2				2676.0	423
	Mol Sieve Water Save	861.2	1615.0	2374.1				1490.9	299
ALL WATER RECLAMATION	LiOH	1287.0	1285.9	1284.9	Not Applicable			2380.0	237
	HS-C RH Control	354.4	964.4	1644.4				385.1	160
	HS-C Low Dump	434.3	433.2	1172.2				479.7	47
	EDC	354.8	353.7	352.7				400.2	39
	EDC/WVE Sab	675.4	674.3	1213.3				720.8	71
	EDC With Sab	470.4	469.3	468.3				515.8	51
	Mol Sieve Low Dump	384.8	428.7	1182.7				430.2	51
	Mol Sieve Water Save	389.7	388.6	607.6				435.1	43

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TABLE 23

DELTA LAUNCH WEIGHT SUMMARY SHEET

			60 Days - 7 Men				90 Days- 7 Men	7 Days - 7 Men			1 Day- 3 Men
eduled			Fuel Cell Idle		Fuel Cell Scheduled		Fuel Cell Idle	Fuel Cell Scheduled			Fuel Cell Idle
	A	24 MH EVA	0 MH EVA	12 MH EVA	0 MH EVA	12 MH EVA	0 MH EVA	0 MH EVA	12 MH EVA	24 MH EVA	0 MH EVA
		990.7			2038.9	2038.9		191.4	191.4	191.4	-102.6
		99.9			99.9	99.9		99.9	99.9	99.9	82.6
		138.6			138.6	138.6		138.6	138.6	138.6	
		236.2			413.3	413.3		59.1	59.1	59.1	
		-167.0			-713.7	-713.7		379.8	379.8	379.8	
		351.8			528.9	528.9		174.8	174.8	174.8	
		89.1			89.1	89.1		89.1	89.1	89.1	71.4
		94.0			94.0	94.0		94.0	94.0	94.0	
			2745.8	4323.9							
			3699.9	5179.9							
			2425.5	4023.6							
ble			716.0	2304.1	Not Applicable				Not Applicable		
			2416.6	3964.7							
			341.6	1719.7							
			2676.0	4234.1							
			1490.9	2999.0							
			2380.0	2378.1			3466.1				
			385.1	1605.1			410.2				
			479.7	477.8			517.6				
ble			400.2	399.3	Not Applicable		438.1		Not Applicable		
			720.8	718.9			758.7				
			515.8	513.9			553.7				
			430.2	518.3			468.1				
			435.1	433.2			473.0				

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TABLE

DELTA RE-ENTRY WEIG

30 Days - 7 Men

	CO_2 Subsystem	Fuel Cell Idle 0 MH EVA	Fuel Cell Idle 12 MH EVA	Fuel Cell Idle 24 MH EVA	Fuel Cell Scheduled 0 MH EVA	Fuel Cell Scheduled 12 MH EVA	Fuel Cell Scheduled 24 MH EVA	Fu 0 MH
NO WATER RECLAMATION	LiOH	1836.1	2135.1	2391.1	1113.3	1113.3	1113.3	
	HS-C RH Control	359.5	667.5	91.5	-362.0	-362.0	-362.0	
	HS-C Low Dump	398.2	706.2	954.2	-323.3	-323.3	-323.3	
	EDC/WVE Sab	503.3	751.3	1069.4	-628.9	-628.9	-628.9	
	EDC With Sab	298.3	546.3	864.3	-110.1	-110.1	-110.1	
	Mol Sieve Low Dump	348.7	656.7	904.7	-372.8	-372.8	-372.8	
	Mol Sieve Water Save	353.6	661.6	909.6	-368.0	-368.0	-368.0	
CONDE F RECLA N ONLY	LiOH	1380.5	1690.9	2011.4	Not Applicable			268
	HS-C RH Control	359.5	667.5	915.5				63
	HS-C Low Dump	248.4	568.8	889.3				23
	EDC	-160.0	163.4	473.9				-48
	EDC/WVE Sab	920.2	1694.1	2483.1				45
	EDC With Sab	-135.0	163.0	473.5				-56
	Mol Sieve Low Dump	227.1	589.3	919.8				34
	Mol Sieve Water Save	53.7	329.0	609.6				-10
ALL WATER RECLAMATION	LiOH	1409.3	1408.2	1407.2	Not Applicable			264
	HS-C RH Control	-107.5	161.1	409.1				-51
	HS-C Low Dump	-27.6	-28.7	266.3				-42
	EDC	-107.1	-108.2	-109.2				-50
	EDC/WVE Sab	213.5	212.4	436.1				-18
	EDC With Sab	8.5	7.4	6.4				-38
	Mol Sieve Low Dump	-77.1	-43.1	232.4				-41
	Mol Sieve Water Save	-72.2	-73.3	12.2				-46

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HT SUMMARY SHEET

	60 Days - 7 Men el Cell Idle	60 Days - 7 Men Fuel Cell Scheduled		90 Days- 7 Men Fuel Cell Idle	7 Days - 7 Men Fuel Cell Scheduled			1 Day- 3 Men Fuel Cell Idle
EVA	12 MH EVA	0 MH EVA	12 MH EVA	0 MH EVA	0 MH EVA	12 MH EVA	24 MH EVA	0 MH EVA
		2302.3	2302.3		205.5	205.5	205.5	-119.4
		-805.1	-805.1		-22.3	-22.3	-22.3	57.6
		-766.4	-766.4		16.4	16.4	16.4	
		-1618.7	-1618.7		230.6	230.6	230.6	
		-376.1	-376.1		135.1	135.1	135.1	
		-815.9	-815.9		-33.1	-33.1	-33.1	46.2
		-811.1	-811.1		-28.3	-28.3	-28.3	
0.3	3301.4							
7.9	1253.9							
9.5	880.6							
1.8	149.3	Not Applicable			Not Applicable			
6.8	1047.9							
3.4	33.0							
6.0	971.1							
5.3	445.8							
3.3	2641.4			3870.4				
9.9	17.3			-937.9				
5.3	-427.2			-830.5				
8.8	-505.7	Not Applicable		-910.0	Not Applicable			
4.2	-186.1			-589.4				
9.2	-391.1			-794.4				
8.5	-406.5			-880.0				
9.9	-471.8			-875.1				

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TABLE 25

DELTA VOLUME SUMMARY SHEI

		30 Days - 7 Men						60	
		Fuel Cell Idle			Fuel Cell Scheduled			Fuel Cell Id	
	CO_2 Subsystem	0 MH EVA	12 MH EVA	24 MH EVA	0 MH EVA	12 MH EVA	24 MH EVA	0 MH EVA	12 M
NO WATER RECLAMATION	LiOH	98.4	199.4	133.4	49.4	49.4	49.4		
	HS-C RH Control	51.4	72.4	86.4	2.4	2.4	2.4		
	HS-C Low Dump	50.0	71.0	85.0	1.0	1.0	1.0		
	EDC	45.5	67.5	81.5	-2.5	-2.5	-2.5		
	EDC/WVE Sab	56.3	70.3	91.3	14.3	14.3	14.3		
	EDC With Sab	50.0	64.0	85.0	8.0	8.0	8.0		
	Mol Sieve Low Dump	52.6	73.6	87.6	3.6	3.6	3.6		
	Mol Sieve Water Save	52.5	73.5	87.5	3.5	3.5	3.5		
CONDENSAT RECLAMATI ONLY	LiOH	71.9	92.7	113.4				136.5	17
	HS-C Control	51.4	72.4	86.4				100.4	14
	HS-C Low Dump	44.5	65.3	86.0				73.8	11
	EDC	20.0	41.8	61.5		Not Applicable		28.3	7
	EDC/WVE Sab	57.8	78.6	99.3				87.1	12
	EDC With Sab	23.5	44.3	67.0				24.8	6
	Mol Sieve Low Dump	54.1	74.9	95.6				90.4	13
	Mol Sieve Water Save	40.0	53.8	74.5				90.0	13
ALL WATER RECLAMATION	LiOH	75.9	75.7	75.4				138.3	13
	HS-C RH Control	22.9	43.9	57.9				27.7	6
	HS-C Low Dump	27.5	27.3	48.0				33.6	7
	EDC	24.0	23.8	23.5		Not Applicable		30.1	2
	EDC/WVE Sab	40.8	40.6	54.3				46.9	4
	EDC With Sab	34.5	34.3	34.0				40.6	4
	Mol Sieve Low Dump	30.1	36.9	64.6				36.2	4
	Mol Sieve Water Save	30.0	29.8	43.5				36.1	[illegible]

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TABLE 25

)LUME SUMMARY SHEET

	60 Days - 7 Men Fuel Cell Idle		60 Days - 7 Men Fuel Cell Scheduled		90 Days- 7 Men Fuel Cell Idle	7 Days - 7 Men Fuel Cell Scheduled			1 Day- 3 Men Fuel Cell Idle
A	0 MH EVA	12 MH EVA	0 MH EVA	12 MH EVA	0 MH EVA	0 MH EVA	12 MH EVA	24 MH EVA	0 MH EVA
			105.7	105.7		6.4	6.4	6.4	-5.2
			2.4	2.4		2.4	2.4	2.4	6.3
			1.0	1.0		1.0	1.0	1.0	
			-2.5	-2.5		-2.5	-2.5	-2.5	
			14.3	14.3		14.3	14.3	14.3	
			8.0	8.0		8.0	8.0	8.0	
			3.6	3.6		3.6	3.6	3.6	7.5
			3.5	3.5		3.5	3.5	3.5	
	136.5	178.2	Not Applicable			Not Applicable			
	100.4	142.4							
	73.8	115.5							
	28.3	70.0							
	87.1	128.8							
	24.8	66.5							
	90.4	132.1							
	90.0	131.7							
	138.3	138.0	Not Applicable		199.2	Not Applicable			
	27.7	62.7			31.3				
	33.6	75.0			38.2				
	30.1	29.8			34.7				
	46.9	46.7			51.5				
	40.6	40.3			45.2				
	36.2	42.9			40.8				
	36.1	35.8			40.7				

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TABLE 26

DELTA POWER SUMMARY SHEE

		30 Days - 7 Men						60	
		Fuel Cell Idle			Fuel Cell Scheduled			Fuel Cell Idl	
	CO_2 Subsystem	0 MH EVA	12 MH EVA	24 MH EVA	0 MH EVA	12 MH EVA	24 MH EVA	0 MH EVA	12 MH
NO WATER RECLAMATION	LiOH	0	0	0	0	0	0		
	HS-C RH Control	117	117	117	117	117	117		
	HS-C Low Dump	89	89	89	89	89	89		
	EDC Dump	336	336	336	336	336	336		
	EDC/WVE Sab	2378	2378	2378	2378	2378	2378		
	EDC With Sab	378	378	378	378	378	378		
	Mol Sieve Low Dump	63	63	63	63	63	63		
	Mol Sieve Water Save	575	575	575	575	57[illegible]	575		
ENSATE MATION ONLY	LiOH	24	24	24				24	2
	HS-C RH Control	117	117	117				117	11
	HS-C Low Dump	113	113	113				113	11
	EDC Dump	360	360	360		Not Applicable		360	36
	EDC/WVE Sab	2402	2402	2402				2402	240
	EDC With Sab	402	402	402				402	40
	Mol Sieve Low Dump	87	87	87				87	8
	Mol Sieve Water Save	599	599	599				599	59
ALL WATER RECLAMATION	LiOH	315	315	315				315	31
	HS-C RH Control	417	417	417				417	41
	HS-C Low Dump	404	404	404				404	40
	EDC Dump	651	651	651		Not Applicable		651	65
	EDC/WVE Sab	2693	2693	2693				2693	269
	EDC With Sab	693	693	693				693	69
	Mol Sieve Low Dump	378	378	378				378	37
	Mol Sieve Water Save	890	890	890				890	89

FOLDOUT FRAME

TABLE 26

ELTA POWER SUMMARY SHEET

	60 Days - 7 Men Fuel Cell Idle		60 Days - 7 Men Fuel Cell Scheduled		90 Days- 7 Men Fuel Cell Idle	7 Days - 7 Men Fuel Cell Scheduled			1 Day- 3 Men Fuel Cell Idle
MH EVA	0 MH EVA	12 MH EVA	0 MH EVA	12 MH EVA	0 MH EVA	0 MH EVA	12 MH EVA	24 MH EVA	0 MH EVA
0			0	0		0	0	0	0
117			117	117		117	117	117	117
89			89	89		89	89	89	
336			336	336		336	336	336	
378			2378	2378		2378	2378	2378	
378			378	378		378	378	378	
63			63	63		63	63	63	63
575			575	575		575	575	575	
	24	24							
	117	117							
	113	113							
	360	360	Not Applicable			Not Applicable			
	2402	2402							
	402	402							
	87	87							
	599	599							
	315	315			315				
	417	417			417				
	404	404			404				
	651	651	Not Applicable		651	Not Applicable			
	2693	2693			2693				
	693	693			693				
	378	378			378				
	890	890			890				

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Windsor Locks, Connecticut 06096

TABLE 27

DELTA HEAT REJECTION SUMMARY SH

	CO_2 Subsystem	30 Days - 7 Men, Fuel Cell Idle, 0 MH EVA	30 Days - 7 Men, Fuel Cell Idle, 12 MH EVA	30 Days - 7 Men, Fuel Cell Idle, 24 MH EVA	30 Days - 7 Men, Fuel Cell Scheduled, 0 MH EVA	30 Days - 7 Men, Fuel Cell Scheduled, 12 MH EVA	30 Days - 7 Men, Fuel Cell Scheduled, 24 MH EVA	60 D, Fuel Cell Idle, 0 MH EVA	60 D, Fuel Cell Idle, 12 MH
NO WATER RECLAMATION	LiOH	761	761	761	761	761	761		
	HS-C RH Control	-619	-619	-619	-619	-619	-619		
	HS-C Low Dump	-106	-106	-106	-106	-106	-106		
	EDC	2741	2741	2741	2741	2741	2741		
	EDC/WVE Sab	4462	4462	4462	4462	4462	4462		
	EDC With Sab	3344	3344	3344	3344	3344	3344		
	Mol Sieve Low Dump	-309	-309	-309	-309	-309	-309		
	Mol Sieve Water Save	1507	1507	1507	1507	1507	1507		
[illegible] RECL[illegible]ON	LiOH	842	842	842	Not Applicable			842	842
	HS-C RH Control	-619	-619	-619				-619	-619
	HS-C Low Dump	-25	-25	-25				-25	-25
	EDC	2822	2822	2822				2822	2822
	EDC/WVE Sab	4543	4543	4543				4543	4543
	EDC With Sab	3424	3424	3424				3424	3424
	Mol Sieve Low Dump	-228	-228	-228				-228	-228
	Mol Sieve Water Save	1588	1588	1588				1588	1588
ALL WATER RECLAMATION	LiOH	1843	1843	1843	Not Applicable			1843	184[illegible]
	HS-C RH Control	402	402	402				402	40[illegible]
	HS-C Low Dump	966	966	966				966	966
	EDC	3813	3813	3813				3813	381[illegible]
	EDC/WVE Sab	5534	5534	5534				5534	553[illegible]
	EDC With Sab	4416	4416	4416				4416	4416
	Mol Sieve Low Dump	763	763	763				763	76[illegible]
	Mol Sieve Water Save	2579	2579	2579				2579	257[illegible]

FOLDOUT FRA

TABLE 27

HEAT REJECTION SUMMARY SHEET

d	60 Days - 7 Men Fuel Cell Idle		60 Days - 7 Men Fuel Cell Scheduled		90 Days- 7 Men Fuel Cell Idle	7 Days - 7 Men Fuel Cell Scheduled			1 Day- 3 Men Fuel Cell Idle
MH EVA	0 MH EVA	12 MH EVA	0 MH EVA	12 MH EVA	0 MH EVA	0 MH EVA	12 MH EVA	24 MH EVA	0 MH EVA
761			761	761		761	761	761	761
-619			-619	-619		-619	-619	-619	-619
-106			-106	-106		-106	-106	-106	
2741			2741	2741		2741	2741	2741	
4462			4462	4462		4462	4462	4462	
3344			3344	3344		3344	3344	3344	
-309			-309	-309		-309	-309	-309	-309
1507			1507	1507		1507	1507	1507	
	842	842							
	-619	-619							
	-25	-25							
	2822	2822	Not Applicable			Not Applicable			
	4543	4543							
	3424	3424							
	-228	-228							
	1588	1588							
	1843	1843			1843				
	402	402			402				
	966	966			966				
	3813	3813	Not Applicable		3813	Not Applicable			
	5534	5534			5534				
	4416	4416			4416				
	763	763			763				
	2579	2579			2579				

2 FOLDOUT FRAME

IMPACT OF 10 MEN

The impact of a 10-man crew was investigated, and it was concluded that it was very unlikely that a ECLS system would be designed around this size crew for Extended Duration Orbiter missions. Instead, the ability of the 7-man ECLS system to handle a crew size of 10 men was investigated.

For 10-man operation the CO_2 Removal Subsystem must handle an additional CO_2 load of 6.33 lbs/day. If the CO_2 removal rates were to remain constant at a 7-man rate, emergency conditions of 15 mmHg PCO_2 will be reached in approximately 26 hours. This is shown in Figure 41. In actuality, this time will be slightly longer for the HS-C Solid Amine and Molecular Sieve Subsystems due to the increase in sorption capacity with increasing CO_2 partial pressures. EDC CO_2 removal is affected very little by increases in PCO_2 above 5 mmHg; and, therefore, its emergency limitation will be very close to the 26 hours.

For extended operation (longer than 26 hours) at a 10-man rate, process modifications are required to keep the CO_2 partial pressure within limits. For HS-C Solid Amine, CO_2 control to 5 mmHg, and complete relative humidity control may be maintained by changing the bed cycle time from 20/20 to 10/10 (minutes adsorb/ minutes desorb). No detectable changes in cabin PCO_2 or dew point will be noted at the 10-man rate with this change.

Unlike HS-C Solid Amine, the Molecular Sieve CO_2 Removal Subsystem will not maintain CO_2 partial pressures without changing air flow in addition to cycle time. This would require an oversized fan or an additional fan capable of providing the 10-man process air flow. This fan(s) would be required to provide a 43% increase in air flow for the 10-man case. This size fan was not included in this study.

The EDC CO_2 Removal Subsystem will be capable of maintaining CO_2 partial pressures by increasing the current density. The transfer index will decrease, however, but CO_2 partial pressures will be maintained.

CO_2 partial pressures may be maintained at 5 mmHg for the LiOH subsystems by charging out the LiOH cartridges at 3.2 hour intervals versus 5.5 hours for the 7-man case.

It should be noted that it is possible to operate the LiOH system in conjunction with the Regenerative CO_2 Subsystem without requiring any process modifications for a 10-man crew retreation assuming an ample supply of LiOH cartridges are available.

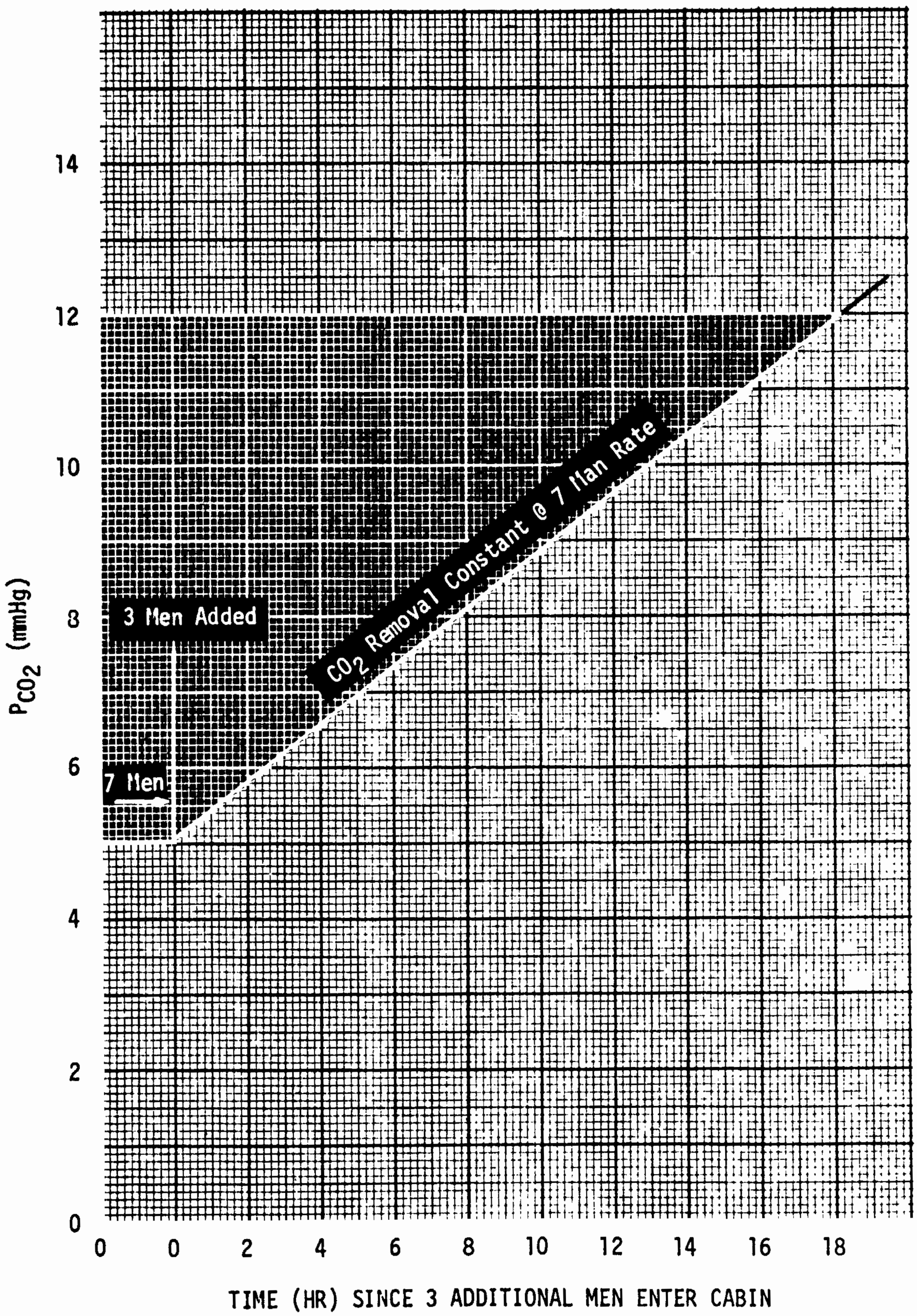


Figure 41 CO_2 Partial Pressure Versus Elapsed Time From Addition of 3 Men to Cabin

VEHICLE CONSIDERATIONS

Three factors that involve the present Shuttle Orbiter to operate on extended duration missions were investigated and are discussed in the following paragraphs. These are:

- Impact on existing Shuttle equipment
- New subsystem locations
- Spares and redundancy requirements

IMPACT ON EXISTING SHUTTLE EQUIPMENT

The present Shuttle Orbiter ECLS system was reviewed as to its capability to accomplish a 30-day mission. These comments are noted in the following paragraphs for each major subsystem.

Freon Cooling Loop

No changes are required as the subsystem is already designed for fail operational/fail safe. Both coolant loops normally operate and non-static devices are all redundant. If there is a failure in both pumps, for example, or a leak in one loop, then a single loop degraded mode of operation is the fail safe condition.

Atmospheric Revitalization Subsystem (ARS)

1) Requires one spare CO_2 PP sensor (located on the cabin fan package). This sensor has three captive fasteners and has no special shimming requirements.
2) The present ARS configuration is fail safe.
3) If the HS-C RH control system is used for CO_2 removal, then the fan separator is not used, and only one fan separator is required for the fail safe requirement.
4) Cabin fans are redundant and, therefore, fail safe.
5) The debris trap for the cabin fan needs to be cleanable in flight or replaceable in flight. The present Orbiter debris trap is cleanable, assuming that a properly design vacuum

cleaner is available. The debris trap is not in flight replaceable at this time. It is recommended that it be redesigned for long term missions.

6) A Regenerable CO_2 Removal system should be incorporated as discussed in this report. If a LiOH CO_2 Removal Subsystem is used, more LiOH cartridges are required for longer duration missions, and space must be alotted for the cartridges required.

Waste Management Subsystem

1) The commode is sized for 210 man days. Additional commodes will be required for 60 and 90 day missions. For fail safe a four day supply of fecal storage bags are required. The used bag volume will fit in a failed commode.

2) Waste storage tanks are defined as static devices and, therefore, are fail operational/fail safe already by definition. Waste water may be dumped overboard at regular intervals so the tank size will not change for long duration missions unless the dump cycle has to change for some reason.

3) A biocide injection device must be added since the baseline method of placing biocide in the waste storage tanks prior to launch does not work for longer missions which will require dumping of waste water during the mission.

4) If a waste water recovery system is used which produces a concentrated waste liquid, provisions for dumping this liquid into the commode is required.

Avionics Cooling

Non-static devices are redundant. If, for example, both fans in one avionics loop fails, there is sufficient overlap with the other two avionics loops to cool critical components. Therefore, the avionics systems are already fail operational/fail safe.

Potable Water Tanks

Tanks may have to increase in number based on system considerations, but since they are static devices, the tanks are already considered fail operational/fail safe. Additional tankage will have to be located below the payload bay. The addition of heaters to these tanks must be considered.

Nitrogen and Oxygen Supply

More tanks will be required for longer missions. Also, each tank should have its own valving rather than the present system which has one valve for two tanks.

Cabin Pressurization

Redundant 14.7 psi and 8.0 psi regulators already exist in the cabin and provide fail operational/fail safe for both O_2 and N_2. The upstream 100 psi O_2 regulators are redundant and if both fail closed, O_2 may be fed through the emergency breathing system or airlock to the cabin. Therefore, this part of the system is actually fail operational/fail safe. The nitrogen 200 psi regulators are redundant, and if both loops fail, then cryogenic or auxiliary oxygen can be used to fail safe.

Wash Water

More soap and more towels will be required. No changes to the waste storage tank will be required as long as water can be dumped overboard.

IMU Cooling

The cooling loop in this system is now supposed to be run open loop. If this is the case, a cleanable or replaceable filter should be provided near the inlet from the cabin.

Water Coolant Loop

Two redundant loops are installed with one operating. The primary loop has redundant non-static devices. If, for example, both primary pumps fail, then the secondary loop can be used to fail safe.

Trace Contaminant Control

The only trace contaminant control system now in the Orbiter is the charcoal in the LiOH cartridges. For longer missions a trace contaminant control system will have to be added as discussed in this study.

Nitrogen Gas Storage

Two additional gaseous storage tanks are required together with appropriate valving.

NEW SUBSYSTEM LOCATIONS

Many changes to the baseline Shuttle Orbiter ECLSS have been discussed as desirable for Extended Duration Orbiter missions. A limited investigation as to where this equipment might be located was conducted as follows:

Trace Contaminant Control

Install charcoal beds in LiOH canister during on-orbit operation if a regenerable CO_2 removal subsystem is selected. Otherwise, install unit in cabin air ventilation duct or on cabin wall.

Waste Management

Add biocide tank adjacent to existing waste water tanks.

CO_2 Removal

Install subsystem under floor next to waste storage tanks in present LiOH storage area. Vacuum duct locations will require additional study.

Waste Water Processing

Install subsystem under cabin floor. This location has not been examined thoroughly and will require additional study.

Nitrogen Gas Tanks

Install tanks under payload floor.

Water Tanks

Two additional potable water tanks, if required, can be installed under the cabin flow. Additional tanks would have to be installed under the payload floor area with appropriate studies conducted to determine the need of providing heat to keep tanks from freezing. Operation of the fuel cells to produce water could trade off better and will require further study.

SPARES AND REDUNDANCY COMMENTS

The baseline Orbiter ECLSS provides, as a minimum, a fail safe backup. This backup provides for the launch/re-entry phases as well as a safe return, should a failure or emergency arise. Many of the new subsystems being considered for the extended missions are not able to function during the launch and recovery phases since they need a vacuum source or cannot operate in a high multidirectional "g" field, thus the backup for these phases will still be required even if spares or redundancy is added to the subsystem.

For this study, redundancy and in-flight spares for new subsystems have been assumed to be zero. This very closely approximates the real 7 to 30 day missions but may be optimistic for the 60 and 90 day trade-offs. However, as the trade-off between subsystems will be made on a certain selected mission length, the redundancy affect will have about the same small percentage affect on each canidate's weight and its volume. Each subsystem penalty will increase only a slight amount when in-flight spares are considered, and thus the relative subsystem-to-subsystem trade affect will be small. In-flight expendables have been included in the various mission length values as they are necessary to complete a given mission.

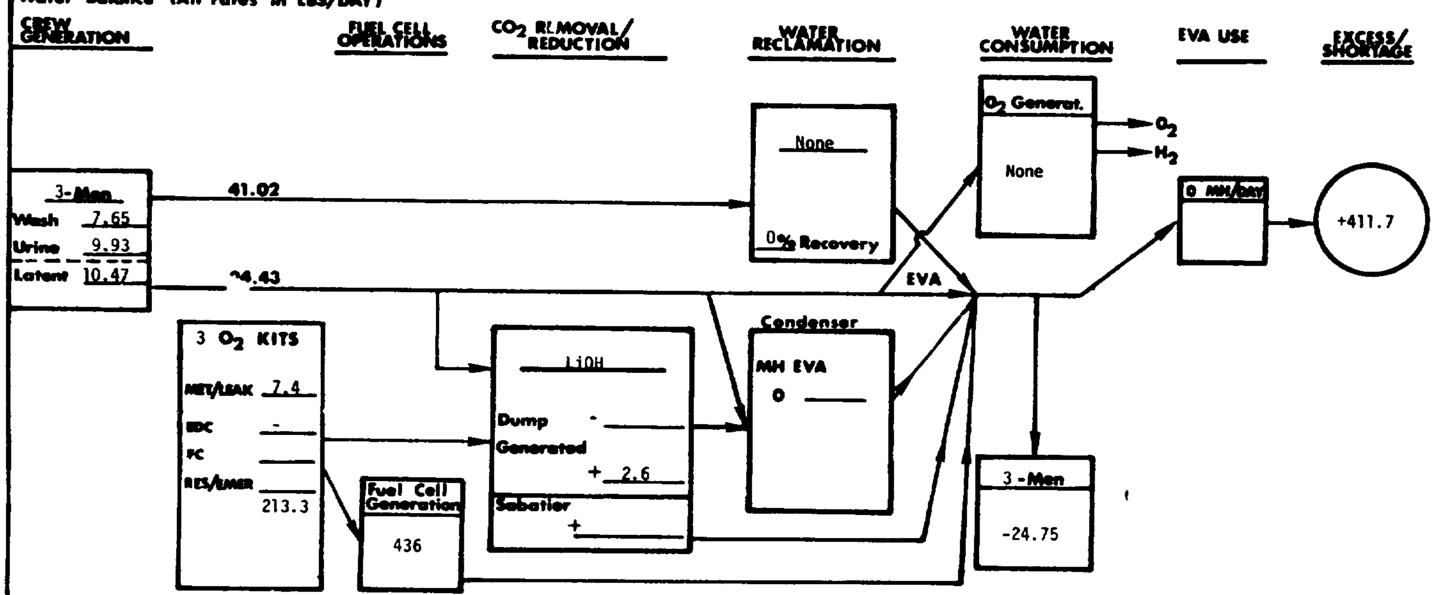
APPENDIX A

EXTENDED SHUTTLE ECLSS IMPACT SUMMARY DATA SHEETS

EXTENDED SHUTTLE ECLSS IMPACT SUMMARY

SYSTEM 1 Day - No Water Reclamation-Fuel Cell Mission - LiOH CO_2 Removal

Water Balance (All rates in LBS/DAY)



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1 DAY SUMMARY

	CO_2 SUBS TOTAL	H_2O REC TOTAL	O_2 GEN TOTAL	ADDITIONAL H_2O REQUIRED	TOTALS	RE-ENTRY WEIGHT
WEIGHT (LBS) 0 Man Hours/Day EVA	-102.6	0	0	0	-102.6	-119.4
POWER (DC Watts)	0	0	0		0	
VOLUME ($Ft.^3$) 0 Man Hours/Day EVA	-5.2	0	0	0	-5.2	
SENSIBLE HEAT REJECTION (BTU/HR)	502	0	0		509	
LATENT HEAT REJECTION (BTU/HR)	252	0	0		252	

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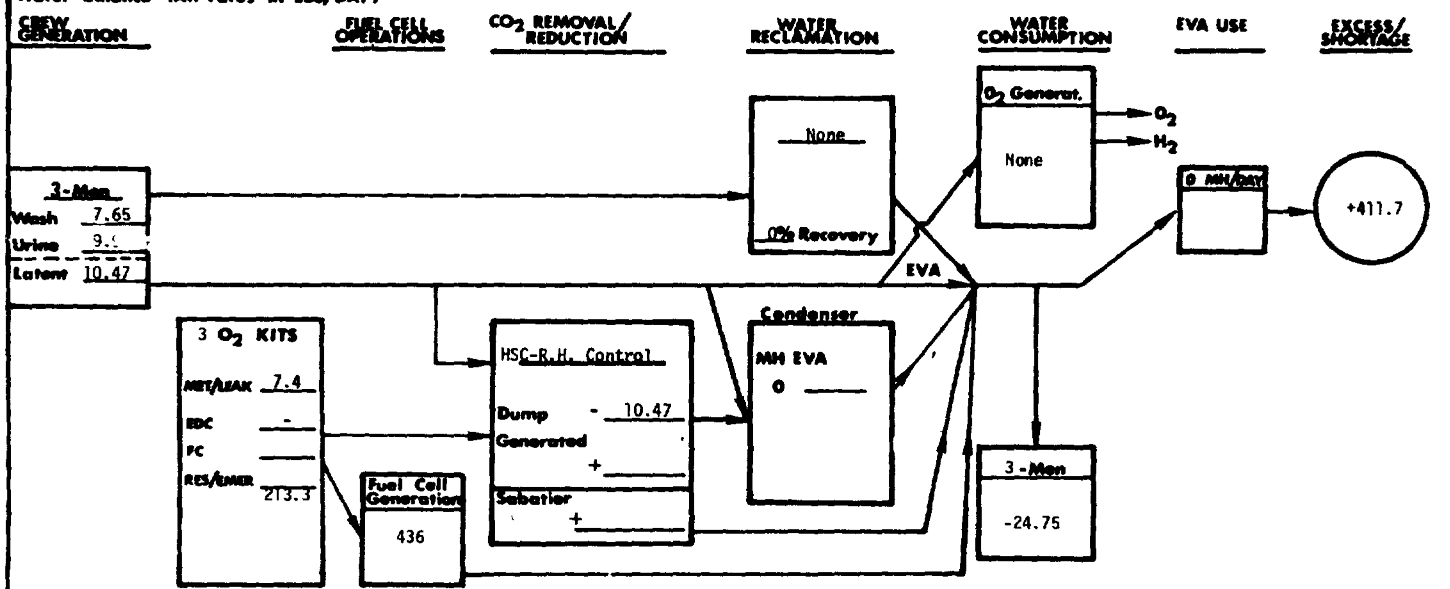
EXTENDED SHUTTLE ECLSS IMPACT SUMMARY

SYSTEM 1 Day - No Water Reclamation - Fuel Cell Mission - HSC R.H. Control CO_2 Removal

Water Balance (All rates in LBS/DAY)



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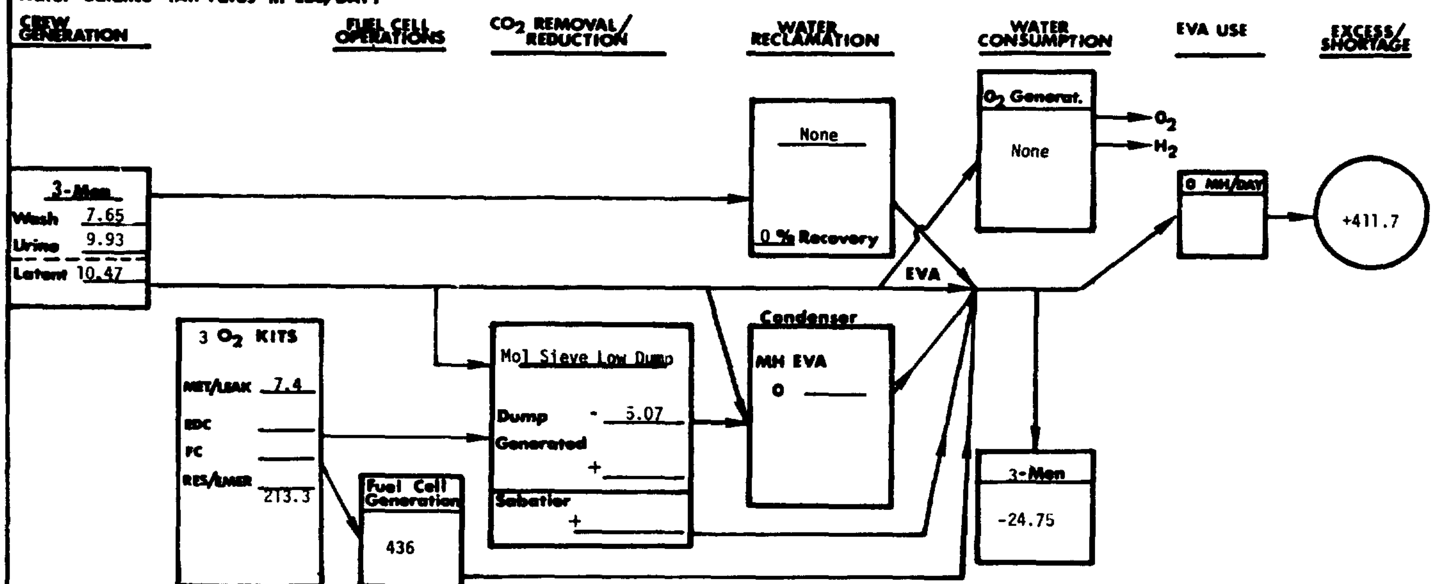
1 DAY SUMMARY

	CO_2 SUBS TOTAL	H_2O REC TOTAL	O_2 GEN TOTAL	ADDITIONAL H_2O REQUIRED	TOTALS	RE-ENTRY WEIGHT
WEIGHT (LBS) 0 Man Hours/Day EVA	+82.8	0	0	0	+82.8	+57.6
POWER (DC Watts)	+117	0	0		+117	
VOLUME (Ft.^{3}) 0 Man Hours/Day EVA	+6.3	0	0	0	+6.3	
SENSIBLE HEAT REJECTION (BTU/HR)	+399	0	0		+399	
LATENT HEAT REJECTION (BTU/HR)	-436	0	0		-436	

EXTENDED SHUTTLE ECLSS IMPACT SUMMARY

SYSTEM 1 Day - No Water Reclamation - Fuel Cell Mission - Mole Sieve Low Dump CO2 Removal

Water Balance (All rates in LBS/DAY)



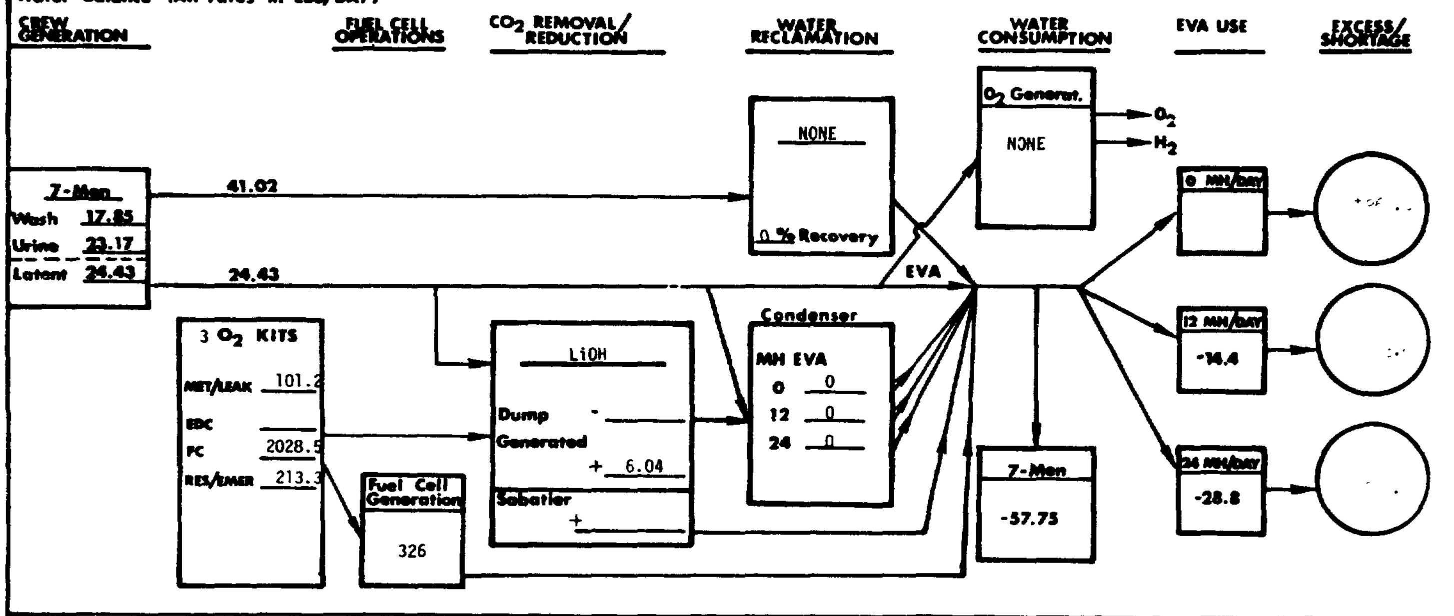
COMMENTS:

1 DAY SUMMARY

	CO_2 SUBS TOTAL	H_2O REC TOTAL	O_2 GEN TOTAL	ADDITIONAL H_2O REQUIRED	TOTALS	RE-ENTRY WEIGHT
WEIGHT (LBS) 0 Man Hours/Day EVA	+71.4	0	0	0	+71.4	+46.2
POWER (DC Watts)	+63	0	0		+63	
VOLUME (Ft.^{3}) 0 Man Hours/Day EVA	+ 7.5	0	0	0	+7.5	
SENSIBLE HEAT REJECTION (BTU/HR)	+215	0	0		+215	
LATENT HEAT REJECTION (BTU/HR)	-	0	0		-211	

EXTENDED SHUTTLE ECLSS IMPACT SUMMARY

SYSTEM 7 Days - No Water Reclamation - LiOH CO_2 Removal - Fuel Cell Power Supply



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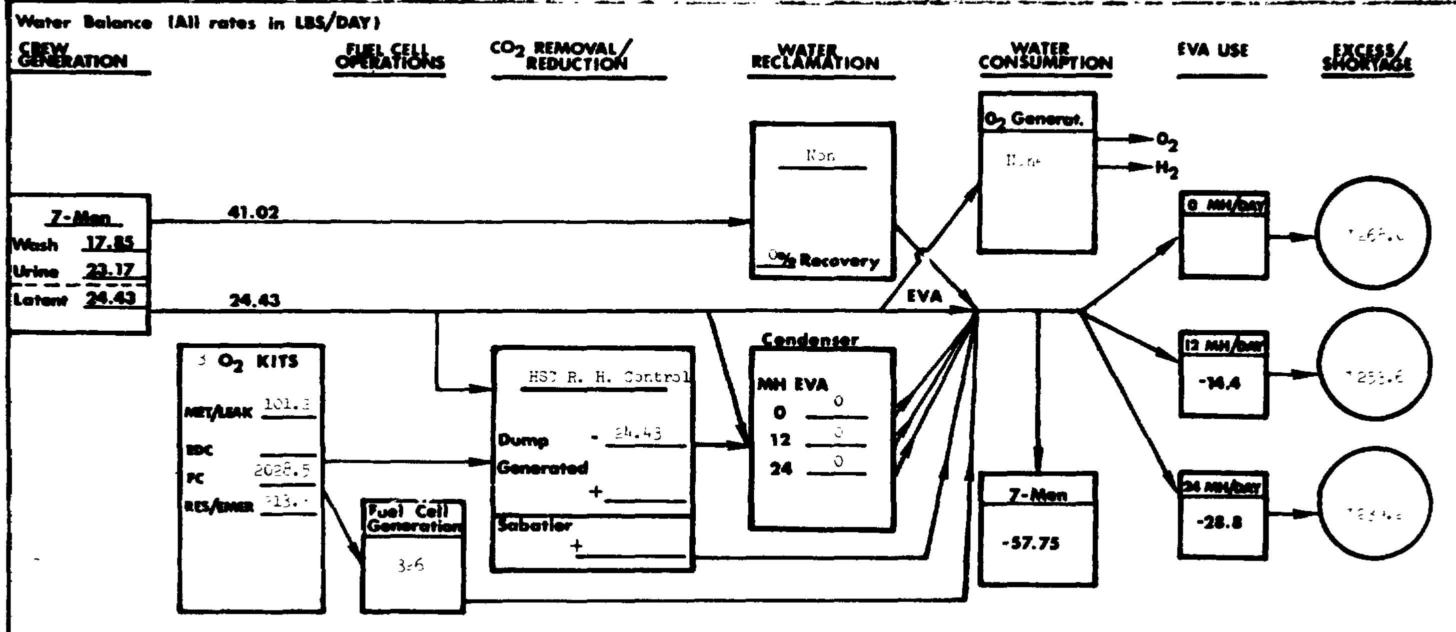
DAY SUMMARY

	CO_2 SUBS TOTAL	H_2O REC TOTAL	O_2 GEN TOTAL	ADDITIONAL H_2O REQUIRED	TOTALS	RE-ENTRY WEIGHT
WEIGHT (LBS)						
0 Man Hours/Day EVA	+191.4	0	0			
12 Man Hours/Day EVA	+191.4	0	0			
24 Man Hours/Day EVA	+191.4	0	0			
POWER (DC Watts)	±0	0	0			
VOLUME (Ft.^{3})						
0 Man Hours/Day EVA	+6.4	0	0			
12 Man Hours/Day EVA	+6.4	0	0			
24 Man Hours/Day EVA	+6.4	0	0			
SENSIBLE HEAT REJECTION (BTU/HR)	509	0	0			
LATENT HEAT REJECTION (BTU/HR)	262	0	0			

EXTENDED SHUTTLE ECLSS IMPACT SUMMARY

SYSTEM 7 Days - No Water Reclamation - HSC R.H. Control-CO2 Removal - Fuel Cell Power Supply



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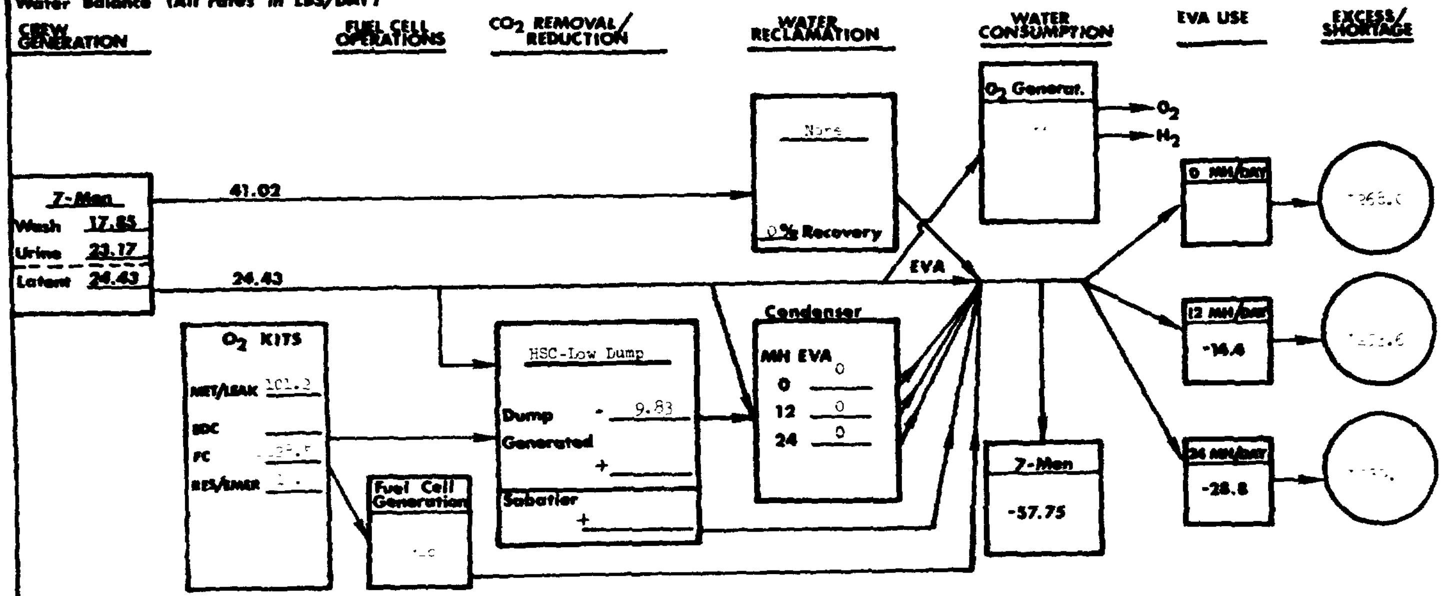
DAY SUMMARY

	CO_2 SUBS TOTAL	H_2O REC TOTAL	O_2 GEN TOTAL	ADDITIONAL H_2O REQUIRED	TOTALS	RE-ENTRY WEIGHT
WEIGHT (LBS)						
0 Man Hours/Day EVA	[illegible]	0	[illegible]	[illegible]	[illegible]	[illegible]
12 Man Hours/Day EVA	[illegible]				[illegible]	[illegible]
24 Man Hours/Day EVA	[illegible]				[illegible]	[illegible]
POWER (DC Watts)	1217				[illegible]	
VOLUME (Ft.^{3})						
0 Man Hours/Day EVA	[illegible]			[illegible]	[illegible]	
12 Man Hours/Day EVA	[illegible]				[illegible]	
24 Man Hours/Day EVA	[illegible]				[illegible]	
SENSIBLE HEAT REJECTION (BTU/HR)	[illegible]				[illegible]	
LATENT HEAT REJECTION (BTU/HR)	[illegible]		[illegible]		[illegible]	

EXTENDED SHUTTLE ECLSS IMPACT SUMMARY

SYSTEM 7 Days - No Water Reclamation - HSC Low Dump-CO_2 Removal - Fuel Cell Power Supply

Water Balance (All rates in LBS/DAY)



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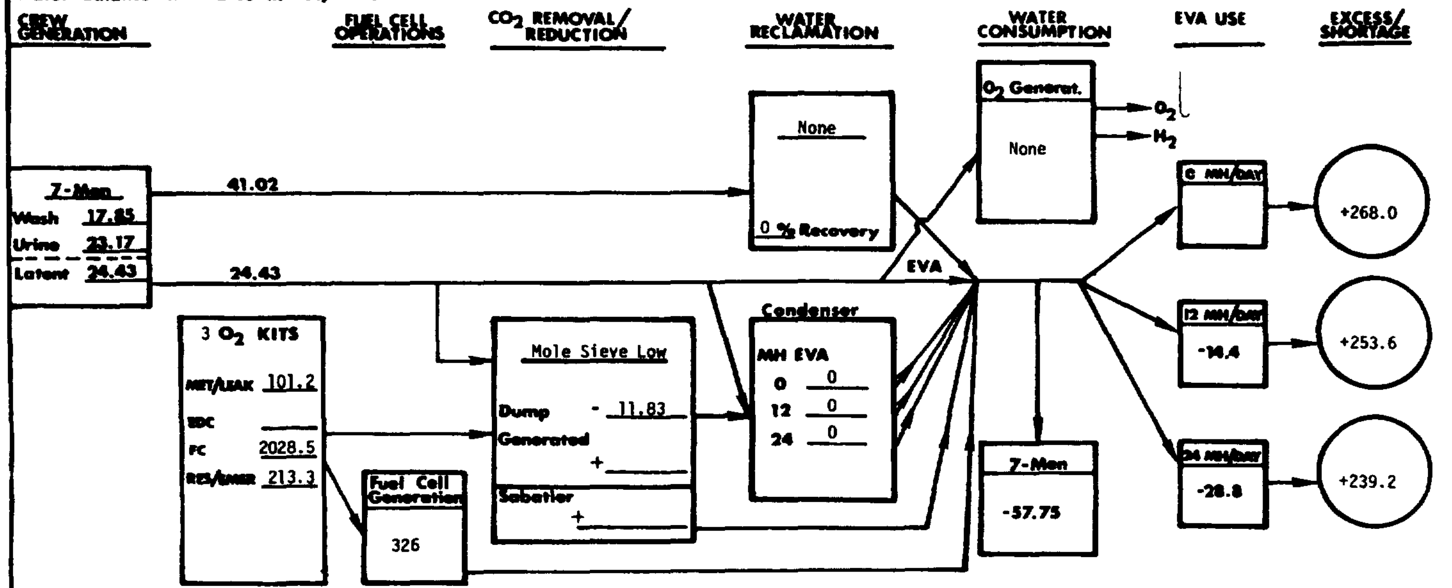
DAY SUMMARY

	CO_2 SUBS TOTAL	H_2O REC TOTAL	O_2 GEN TOTAL	ADDITIONAL H_2O REQUIRED	TOTALS	RE-ENTRY WEIGHT
WEIGHT (LBS)						
0 Man Hours/Day EVA	+138.6	0	0	0	[illegible]	[illegible]
12 Man Hours/Day EVA	+138.6	0	0	[illegible]	[illegible]	[illegible]
24 Man Hours/Day EVA	[illegible]	0	0	[illegible]	[illegible]	[illegible]
POWER (DC Watts)	+89	0	0		[illegible]	
VOLUME (Ft.^{3})						
0 Man Hours/Day EVA	+1.0	0	0	[illegible]	[illegible]	
12 Man Hours/Day EVA	+1.0	[illegible]	[illegible]	[illegible]	[illegible]	
24 Man Hours/Day EVA	+1.0	[illegible]	0	[illegible]	[illegible]	
SENSIBLE HEAT REJECTION (BTU/HR)						
LATENT HEAT REJECTION (BTU/HR)	[illegible]		0		[illegible]	

EXTENDED SHUTTLE ECLSS IMPACT SUMMARY

SYSTEM 7 Days - No Water Reclamation - Mole Sieve Low Dump-CO_2 Removal - Fuel Cell Power Supply

Water Balance (All rates in LBS/DAY)



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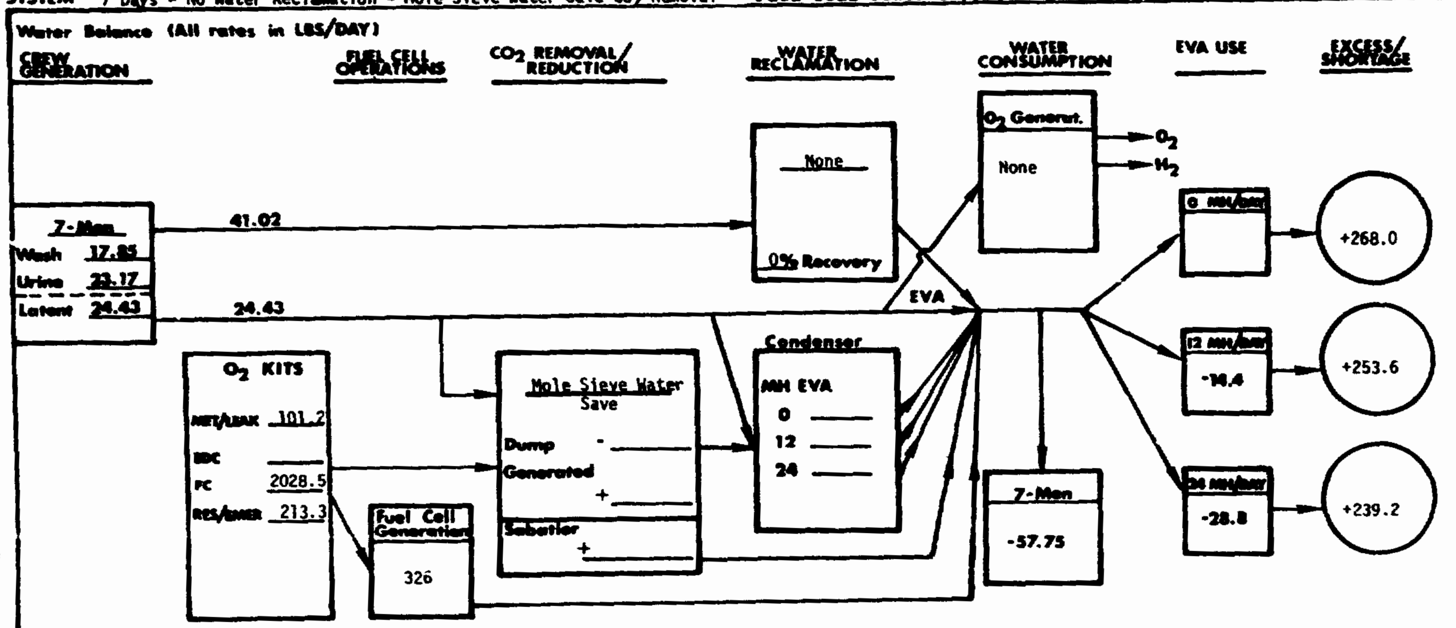
7 DAY SUMMARY

	CO_2 SUBS TOTAL	H_2O REC TOTAL	O_2 GEN TOTAL	ADDITIONAL H_2O REQUIRED	TOTALS	RE-ENTRY WEIGHT
WEIGHT (LBS)						
0 Man Hours/Day EVA	+89.1	0	0	0	+89.1	-33.1
12 Man Hours/Day EVA	+89.1	0	0	0	+89.1	-33.1
24 Man Hours/Day EVA	+89.1	0	0	0	+89.1	-33.1
POWER (DC Watts)	+63	0	0		+63	
VOLUME (Ft.^{3})						
0 Man Hours/Day EVA	+3.6	0	0	0	+3.6	
12 Man Hours/Day EVA	+3.6	0	0	0	+3.6	
24 Man Hours/Day EVA	+3.6	0	0	0	+3.6	
SENSIBLE HEAT REJECTION (BTU/HR)	+215	0	0		+215	
LATENT HEAT REJECTION (BTU/HR)	-524	0	0		-524	

EXTENDED SHUTTLE ECLSS IMPACT SUMMARY

SYSTEM 7 Days - No Water Reclamation - Mole Sieve Water Save-CO_2 Removal - Fuel Cell Power Supply



COMMENTS:

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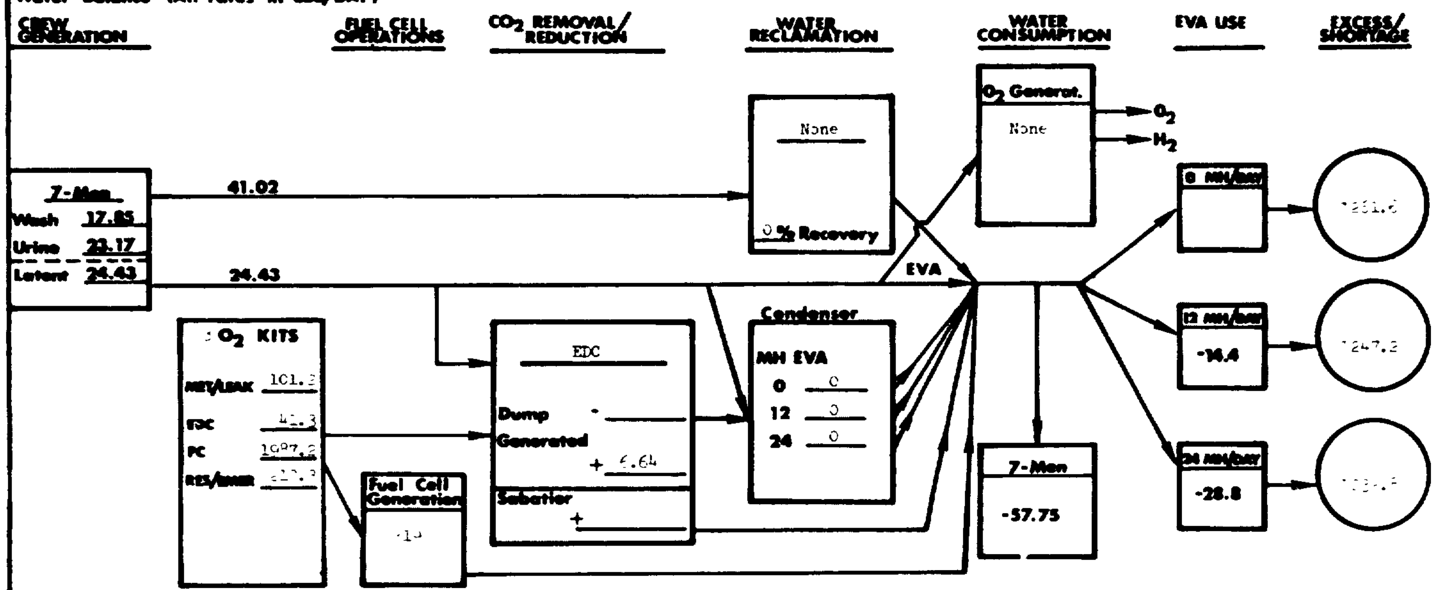
7 DAY SUMMARY

	CO_2 SUBS TOTAL	H_2O REC TOTAL	O_2 GEN TOTAL	ADDITIONAL H_2O REQUIRED	TOTALS	RE-ENTRY WEIGHT
WEIGHT (LBS)						
0 Man Hours/Day EVA	+94.0	0	0	0	+94.0	-28.3
12 Man Hours/Day EVA	+94.0	0	0	0	+94.0	-28.3
24 Man Hours/Day EVA	+94.0	0	0	0	+94.0	-28.3
POWER (DC Watts)	+575	0	0		+575	
VOLUME ($Ft.^3$)						
0 Man Hours/Day EVA	+3.5	0	0	0	+3.5	
12 Man Hours/Day EVA	+3.5	0	0	0	+3.5	
24 Man Hours/Day EVA	+3.5	0	0	0	+3.5	
SENSIBLE HEAT REJECTION (BTU/HR)	+887	0	0		+887	
LATENT HEAT REJECTION (BTU/HR)	+620	0	0		+620	

EXTENDED SHUTTLE ECLSS IMPACT SUMMARY

SYSTEM 7 Days - No Water Reclamation - EDC CO_2 Removal - Fuel Cell Power Supply

Water Balance (All rates in LBS/DAY)



COMMENTS:

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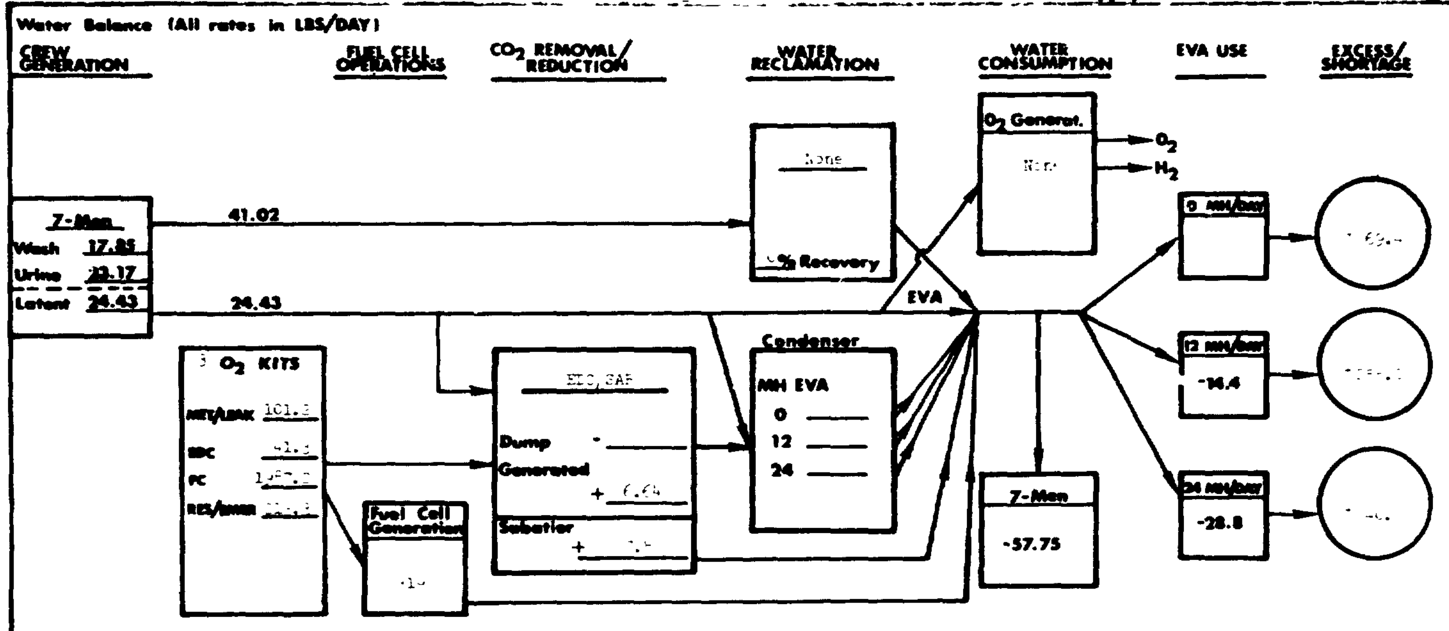
7 DAY SUMMARY

	CO_2 SUBS TOTAL	H_2O REC TOTAL	O_2 GEN TOTAL	ADDITIONAL H_2O REQUIRED	TOTALS	RE-ENTRY WEIGHT
WEIGHT (LBS)						
0 Man Hours/Day EVA	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
12 Man Hours/Day EVA	[illegible]	[illegible]		[illegible]	[illegible]	[illegible]
24 Man Hours/Day EVA	[illegible]	[illegible]		[illegible]	[illegible]	[illegible]
POWER (DC Watts)	[illegible]				[illegible]	
VOLUME ($Ft.^3$)						
0 Man Hours/Day EVA	[illegible]				[illegible]	
12 Man Hours/Day EVA	[illegible]				[illegible]	
24 Man Hours/Day EVA	[illegible]				[illegible]	
SENSIBLE HEAT REJECTION (BTU/HR)	[illegible]					
LATENT HEAT REJECTION (BTU/HR)	[illegible]				[illegible]	

EXTENDED SHUTTLE ECLSS IMPACT SUMMARY

SYSTEM 7 Days - No Water Reclamation - EDC With Sabatier Reactor-CO2 Removal/Reduction - Fuel Cell Power Supply



COMMENTS:

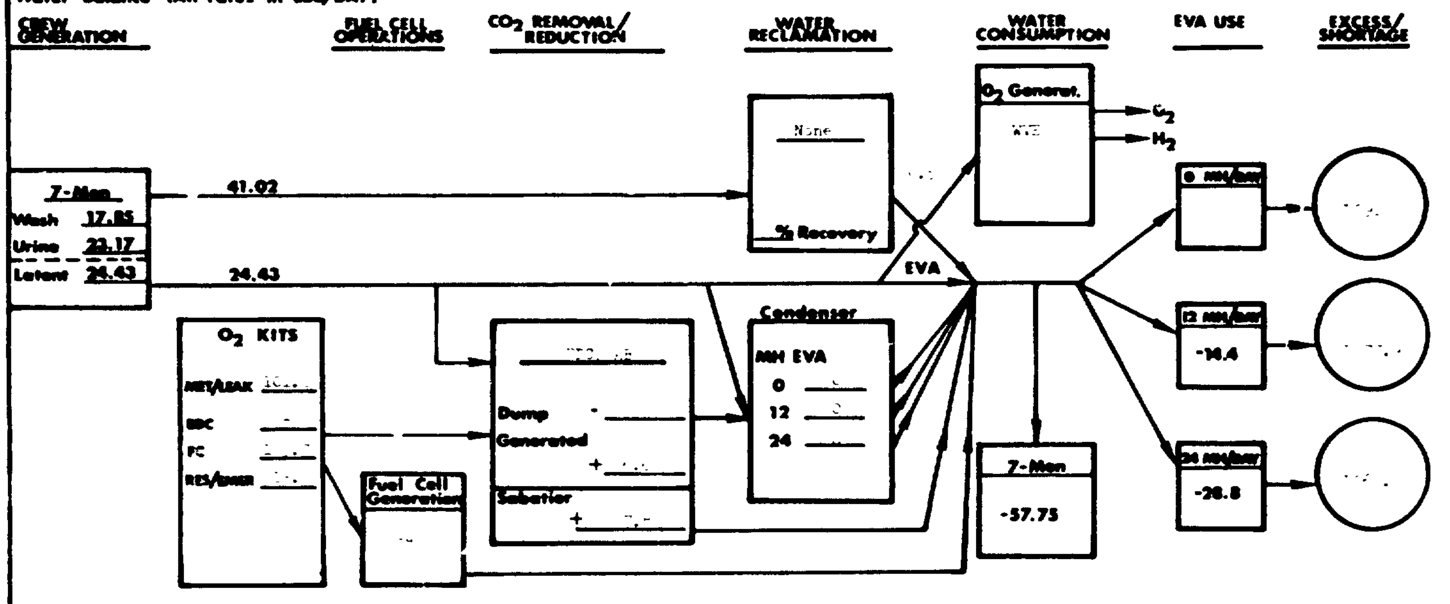
7 DAY SUMMARY

	CO2 SUBS TOTAL	H2O REC TOTAL	O2 GEN TOTAL	ADDITIONAL H2O REQUIRED	TOTALS	RE-ENTRY WEIGHT
WEIGHT (LBS)						
0 Man Hours/Day EVA						
12 Man Hours/Day EVA						
24 Man Hours/Day EVA						
POWER (DC Watts)						
VOLUME (Ft.^{3})						
0 Man Hours/Day EVA						
12 Man Hours/Day EVA						
24 Man Hours/Day EVA						
SENSIBLE HEAT REJECTION (BTU/HR)						
LATENT HEAT REJECTION (BTU/HR)						

EXTENDED SHUTTLE ECLSS IMPACT SUMMARY

SYSTEM 7 Days - No Water Reclamation - EDC/WVE With Sabatier Reactor CO2 Removal/Reduction - Fuel Cell Power Supply

Water Balance (All rates in LBS/DAY)



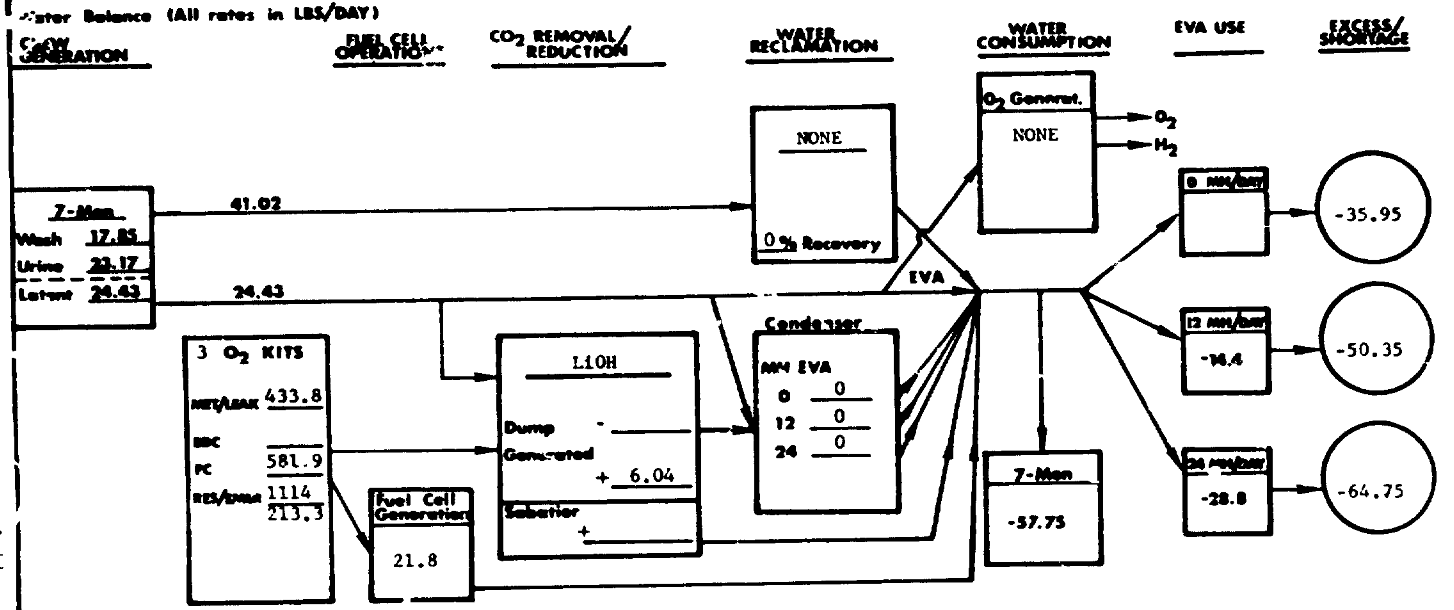
COMMENTS:

7 DAY SUMMARY

	CO_2 SUBS TOTAL	H_2O REC TOTAL	O_2 GEN TOTAL	ADDITIONAL H_2O REQUIRED	TOTALS	RE-ENTRY WEIGHT
WEIGHT (LBS)						
0 Man Hours/Day EVA						
12 Man Hours/Day EVA						
24 Man Hours/Day EVA						
POWER (DC Watts)						
VOLUME ($Ft.^3$)						
0 Man Hours/Day EVA						
12 Man Hours/Day EVA						
24 Man Hours/Day EVA						
SENSIBLE HEAT REJECTION (BTU/HR)						
LATENT HEAT REJECTION (BTU/HR)						

EXTENDED SHUTTLE ECLSS IMPACT SUMMARY

SYSTEM 30 Days - No Water Reclamation - Fuel Cell Idle - LiOH CO_2 Removal



COMMENTS:

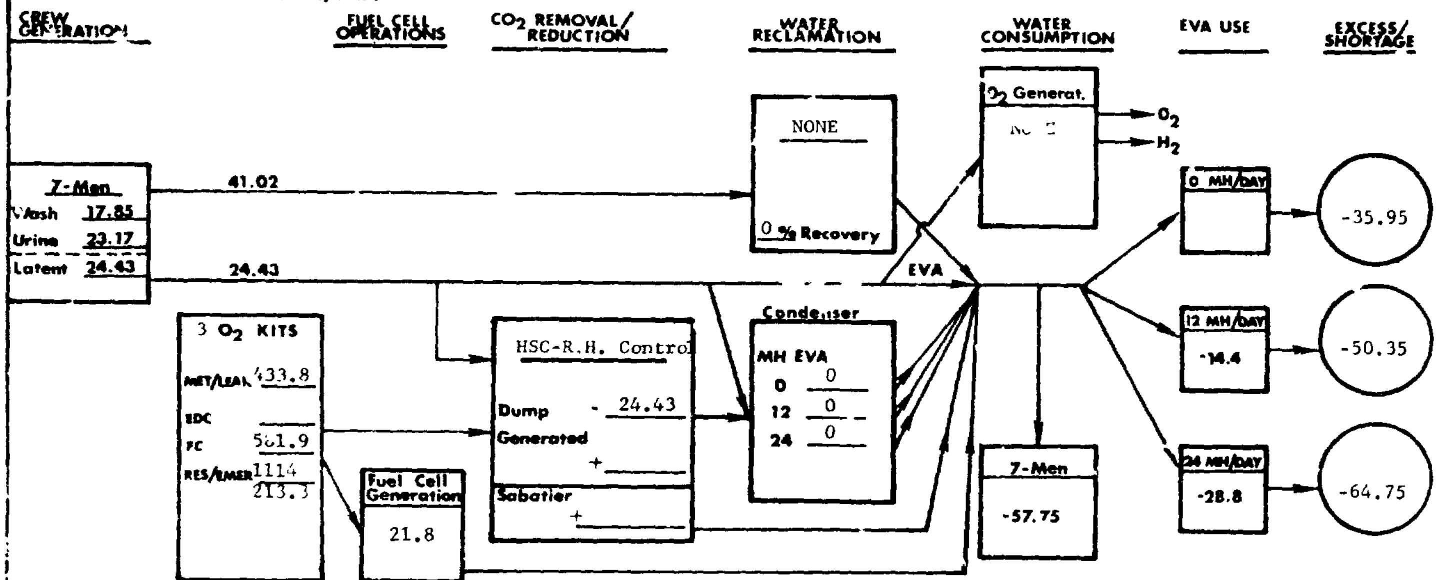
30 DAY SUMMARY

	CO_2 SUBS TOTAL	H_2O REC TOTAL	O_2 GEN TOTAL	ADDITIONAL H_2O REQUIRED	TOTALS	RE-ENTRY WEIGHT
WEIGHT (LBS) 0 Man Hours/Day EVA	+991.3	0	0	+1800	+2791.3	+1836.1
12 Man Hours/Day EVA	+991.3	0	0	+2540	+3531.3	+2135.1
24 Man Hours/Day EVA	+991.3	0	0	+3220	+4210.3	+2391.1
POWER (DC Watts)	±0	0	0		0	
VOLUME (Ft.^{3}) 0 Man Hours/Day EVA	+49.4	0	0	+49	+98.4	
12 Man Hours/Day EVA	+49.4	0	0	+70	+119.4	
24 Man Hours/Day EVA	+49.4	0	0	+84	+113.4	
SENSIBLE HEAT REJECTION (BTU/HR)	+509	0	0		+509	
LATENT HEAT REJECTION (BTU/HR)	+262	0	0		+262	

EXTENDED SHUTTLE ECLSS IMPACT SUMMARY

SYSTEM 30 Days - No Water Reclamation - Fuel Cell Idle - HSC R.H. Control CO_2 Removal

Water Balance (All rates in LBS/DAY)



COMMENTS:

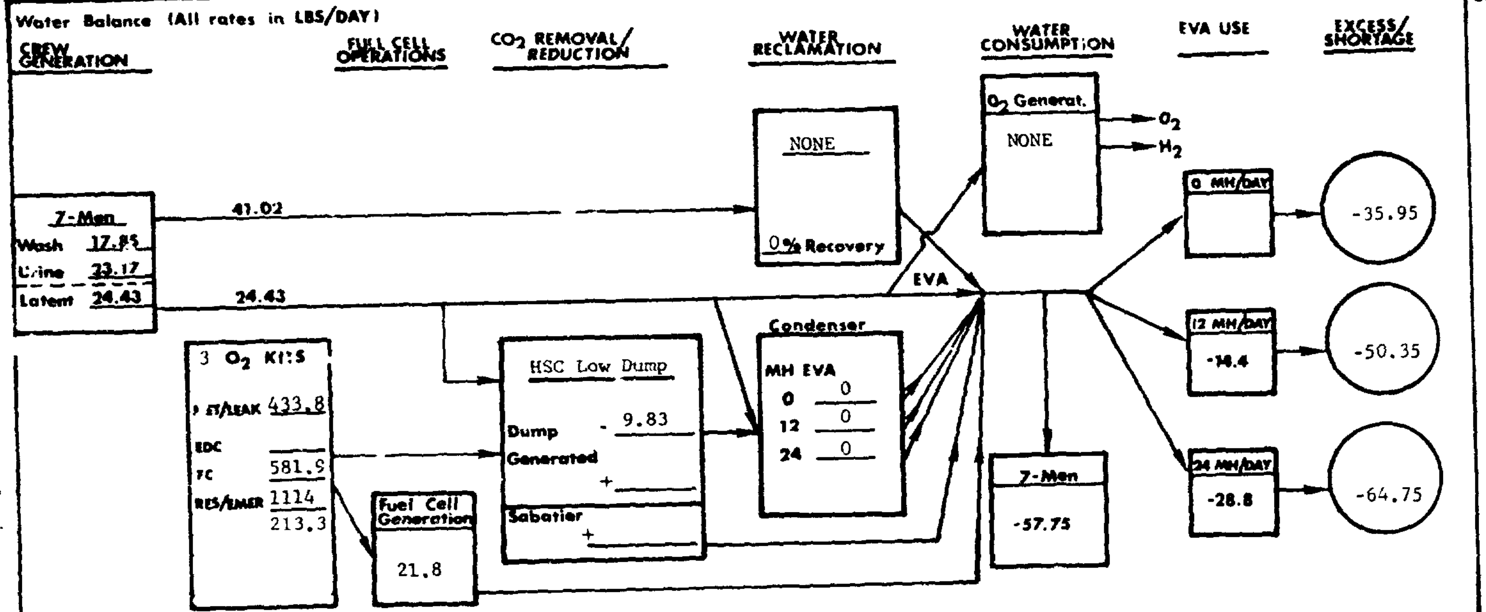
30 DAY SUMMARY

	CO_2 SUBS TOTAL	H_2O REC TOTAL	O_2 GEN TOTAL	ADDITIONAL H_2O REQUIRED	TOTALS	RE-ENTRY WEIGHT
WEIGHT (LBS)						
0 Man Hours/Day EVA	+99.9	0	0	1800	1899.9	359.5
12 Man Hours/Day EVA	+99.9	0	0	2540	2639.9	667.5
24 Man Hours/Day EVA	+99.9	0	0	3220	3319.9	915.5
POWER DC Watts)	+117	0	0		+117	
VOLUME (Ft.^{3})						
0 Man Hours/Day EVA	+2.4	0	0	+49	+51.4	
12 Man Hours/Day EVA	+2.4	0	0	+70	+72.4	
24 Man Hours/Day EVA	+2.4	0	0	+84	+86.4	
SENSIBLE HEAT REJECTION (BTU/HR)	+399	0	0		+399	
LATENT HEAT REJECTION (BTU/HR)	-1018	0	0		-1018	

EXTENDED SHUTTLE ECLSS IMPACT SUMMARY

SYSTEM 30 Days - No Water Reclamation - Fuel Cell Idle - HSC Low Dump CO_2 Removal

Water Balance (All rates in LBS/DAY)



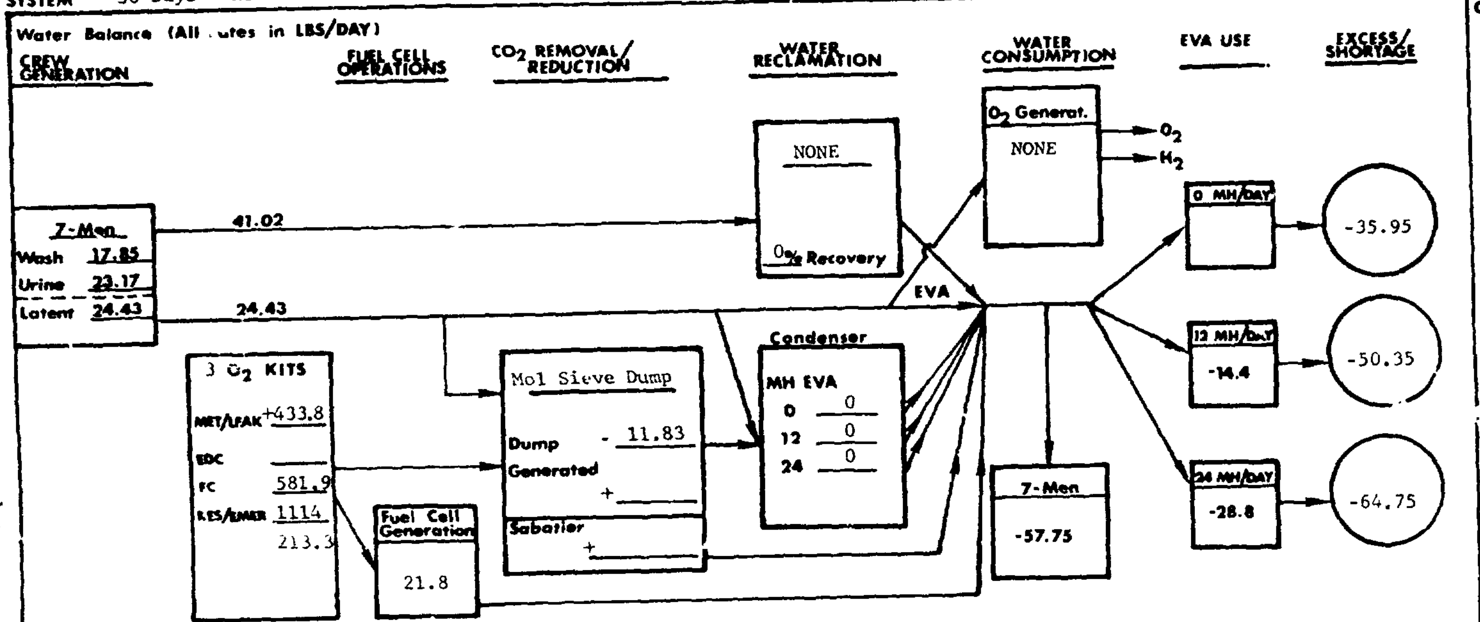
COMMENTS:

30 DAY SUMMARY

	CO_2 SUBS TOTAL	H_2O REC TOTAL	O_2 GEN TOTAL	ADDITIONAL H_2O REQUIRED	TOTALS	RE-ENTRY WEIGHT
WEIGHT (LBS)						
0 Man Hours/Day EVA	+138.6	0	0	1800	+1938.6	+398.2
12 Man Hours/Day EVA	+138.6	0	0	2540	+2678.6	+706.2
24 Man Hours/Day EVA	+138.6	0	0	3220	+3363.6	+954.2
POWER (DC Watts)	+89	0	0		+89	
VOLUME (Ft.^{3})						
0 Man Hours/Day EVA	+1.0	0	0	+49	+50.0	
12 Man Hours/Day EVA	+1.0	0	0	+70	+71.0	
24 Man Hours/Day EVA	+1.0	0	0	+84	+85.0	
SENSIBLE HEAT REJECTION (BTU/HR)	+304	0	0		+304	
LATENT HEAT REJECTION (BTU/HR)	-410	0	0		-410	

EXTENDED SHUTTLE ECLSS IMPACT SUMMARY

SYSTEM 30 Days - No Water Reclamation - Mol Sieve Low Dump CO_2 Removal



COMMENTS:

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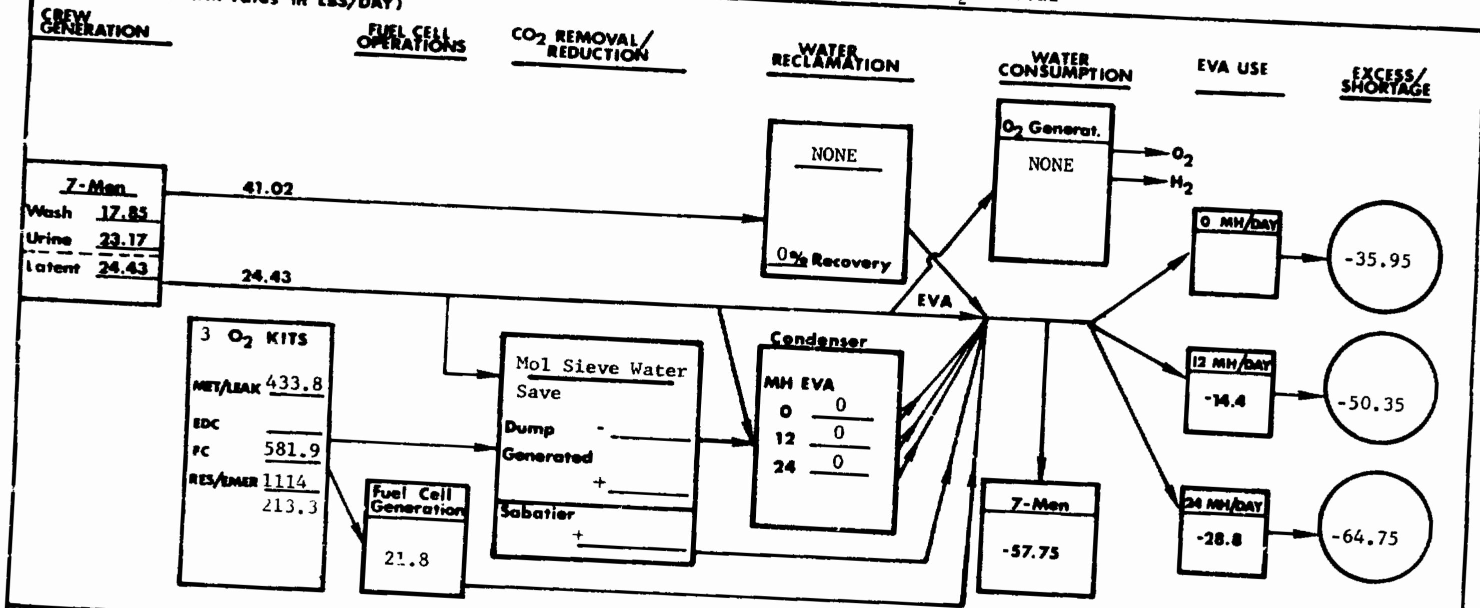
30 DAY SUMMARY	CO_2 SUBS TOTAL	H_2O REC TOTAL	O_2 GEN TOTAL	ADDITIONAL H_2O REQUIRED	TOTALS	RE-ENTRY WEIGHT
WEIGHT (LBS)						
0 Man Hours/Day EVA	+89.1	0	0	1800	+1889.1	+348.7
12 Man Hours/Day EVA	+89.1	0	0	2540	+2629.1	+656.7
24 Man Hours/Day EVA	+89.1	0	0	3200	+3309.1	+904.7
POWER (DC Watts)	+63	0	0			
VOLUME (Ft.^{3})						
0 Man Hours/Day EVA	+3.6	0	0	+49	+52.6	
12 Man Hours/Day EVA	+3.6	0	0	+70	+73.6	
24 Man Hours/Day EVA	+3.6	0	0	+84	+87.6	
SENSIBLE HEAT REJECTION (BTU/HR)	+215	0	0		+215	
LATENT HEAT REJECTION (BTU/HR)	-524	0	0		-524	

EXTENDED SHUTTLE ECLSS IMPACT SUMMARY

SYSTEM 30 Days - No Water Reclamation Fuel Cell Idle - Mol Sieve Water Save CO_2 Removal

Water Balance (All rates in LBS/DAY)



COMMENTS:

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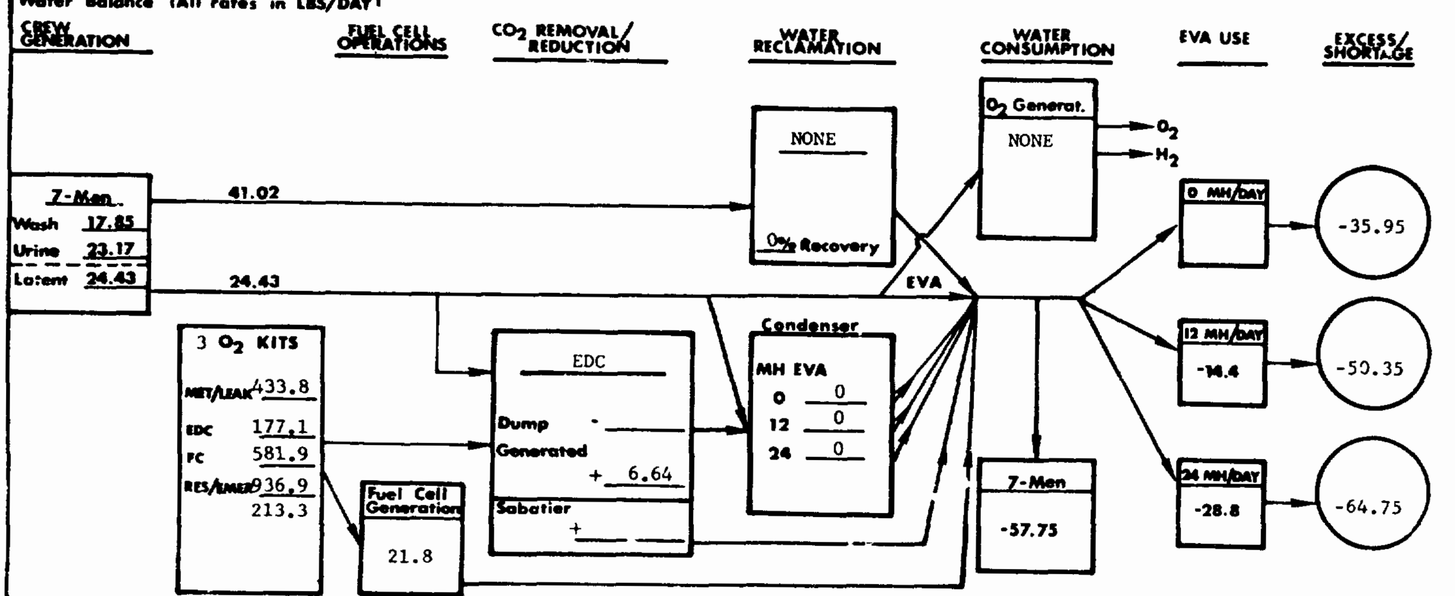
30 DAY SUMMARY

	CO_2 SUBS TOTAL	H_2O REC TOTAL	O_2 GEN TOTAL	ADDITIONAL H_2O REQUIRED	TOTALS	RE-ENTRY WEIGHT
WEIGHT (LBS)						
0 Man Hours/Day EVA	+94.0	0	0	+1800	+1894.0	+353.6
12 Man Hours/Day EVA	+94.0	0	0	+2540	+2634.0	+661.6
24 Man Hours/Day EVA	+94.0	0	0	+3220	+3314.0	+909.6
POWER (DC Watts)	+575	0	0		+575	
VOLUME (Ft.^{3})						
0 Man Hours/Day EVA	+3.5	0	0	+49	+52.5	
12 Man Hours/Day EVA	+3.5	0	0	+70	+73.5	
24 Man Hours/Day EVA	+3.5	0	0	+84	+87.5	
SEN. BLE HEAT REJECTION (BTU/HR)	+887	0	0		+887	
LATENT HEAT REJECTION (BTU/HR)	+620	0	0		+620	

EXTENDED SHUTTLE ECLSS IMPACT SUMMARY

SYSTEM 30 Days - No Water Reclamation - Fuel Cell Idle - EDC CO_2 Removal



COMMENTS:

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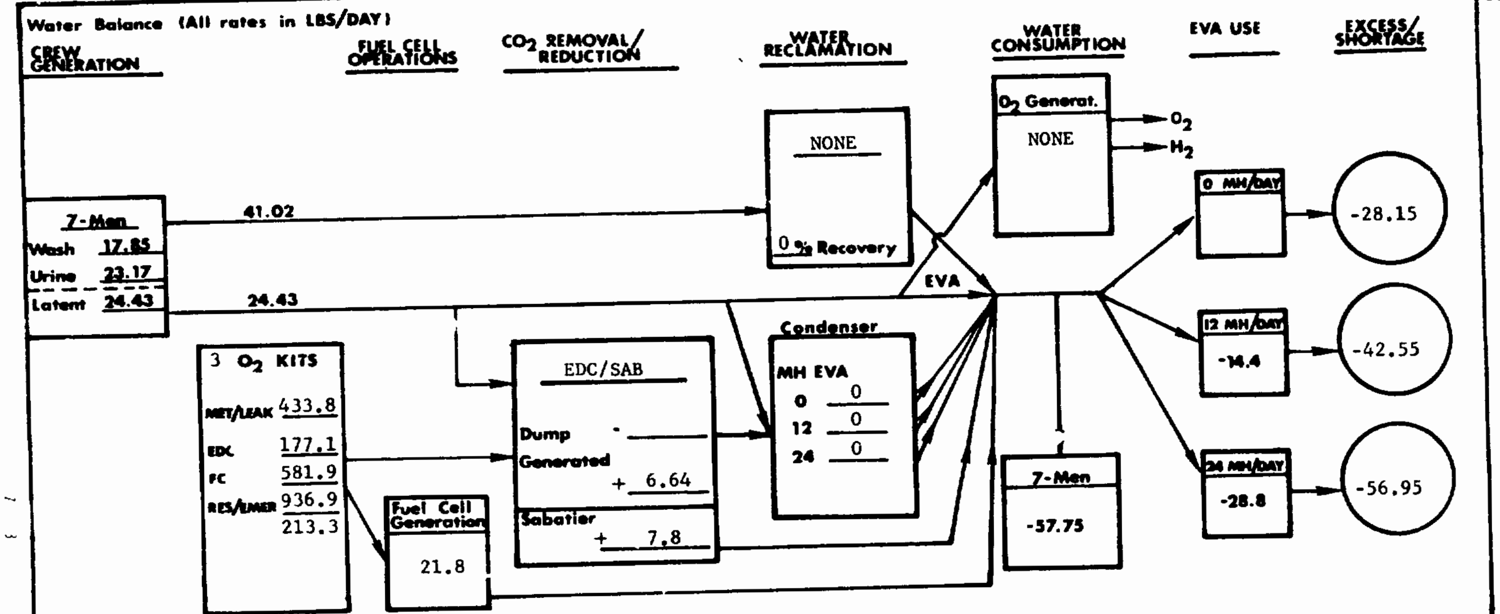
30 DAY SUMMARY

	CO_2 SUBS TOTAL	H_2O REC TOTAL	O_2 GEN TOTAL	ADDITIONAL H_2O REQUIRED	TOTALS	RE-ENTRY WEIGHT
WEIGHT (LBS)						
0 Man Hours/Day EVA	+59.1	0	0	1800	+1859.1	+318.7
12 Man Hours/Day EVA	+59.1	0	0	2540	+2589.1	+616.7
24 Man Hours/Day EVA	+59.1	0	0	3220	+3279.1	+874.7
POWER (DC Watts)	+336	0	0		+336	
VOLUME (Ft.^{3})						
0 Man Hours/Day EVA	+2.5	0	0	49	+45.5	
12 Man Hours/Day EVA	+2.5	0	0	70	+67.5	
24 Man Hours/Day EVA	+2.5	0	0	84	+81.5	
SENSIBLE HEAT REJECTION (BTU/HR)	+2465	0	0		+2465	
LATENT HEAT REJECTION (BTU/HR)	+276	0	0		+276	

EXTENDED SHUTTLE ECLSS IMPACT SUMMARY

SYSTEM 30 Days - No Water Reclamation - Fuel Cell Idle - EDC with Sabatier Reactor CO_2 Removal/Reduction



COMMENTS:

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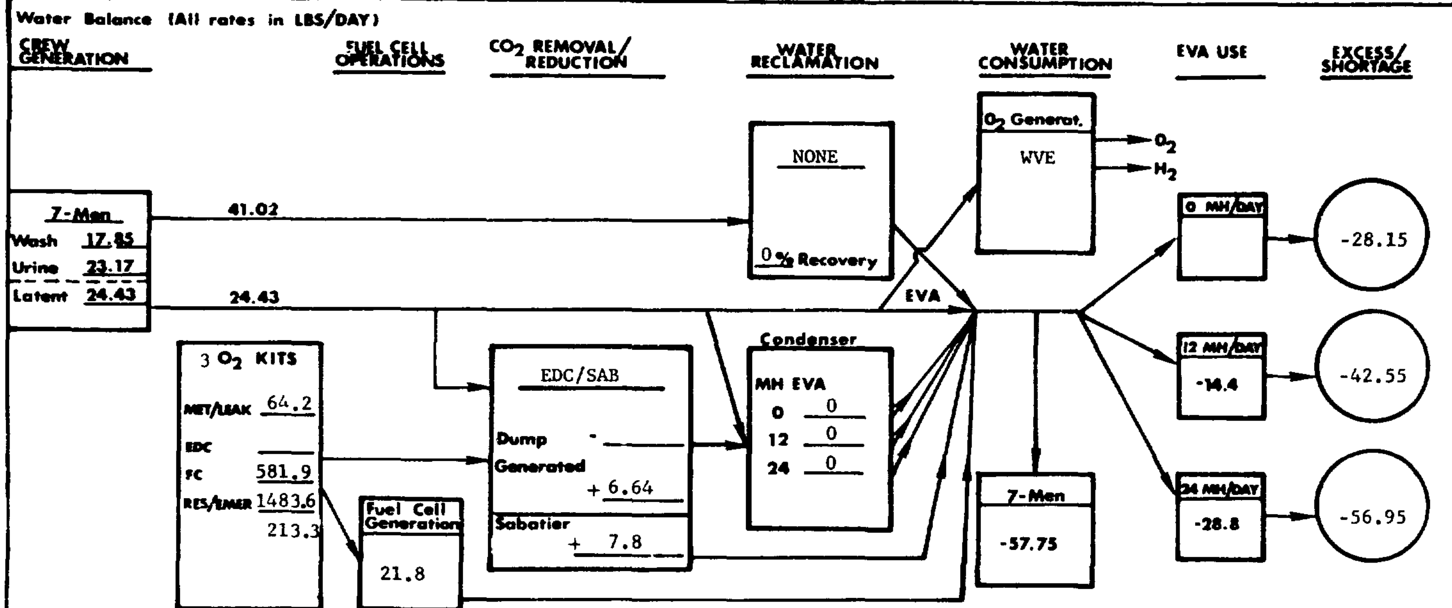
30 DAY SUMMARY	CO_2 SUBS TOTAL	H_2O REC TOTAL	O_2 GEN TOTAL	ADDITIONAL H_2O REQUIRED	TOTALS	RE-ENTRY WEIGHT
WEIGHT (LBS)						
0 Man Hours/Day EVA	+174.8	0	0	+1430	+1604.7	+298.3
12 Man Hours/Day EVA	+174.8	0	0	+2110	+2284.7	+546.3
24 Man Hours/Day EVA	+174.8	0	0	+2860	+3034.7	+864.3
POWER (DC Watts)	+378		0		+378	
VOLUME ($Ft.^3$)						
0 Man Hours/Day EVA	+8.0	0	0	+42	+50	
12 Man Hours/Day EVA	+8.0	0	0	+56	+64	
24 Man Hours/Day EVA	+8.0	0	0	+77	+85	
SENSIBLE HEAT REJECTION (BTU/HR)	+3068	0	0		+3068	
LATENT HEAT REJECTION (BTU/HR)	+276	0	0		+270	

EXTENDED SHUTTLE ECLSS IMPACT SUMMARY

SYSTEM 30 Days - No Water Reclamation - Fuel Cell Idle - EDC/WVE with Sabatier Reactor CO_2 Removal/Reduction



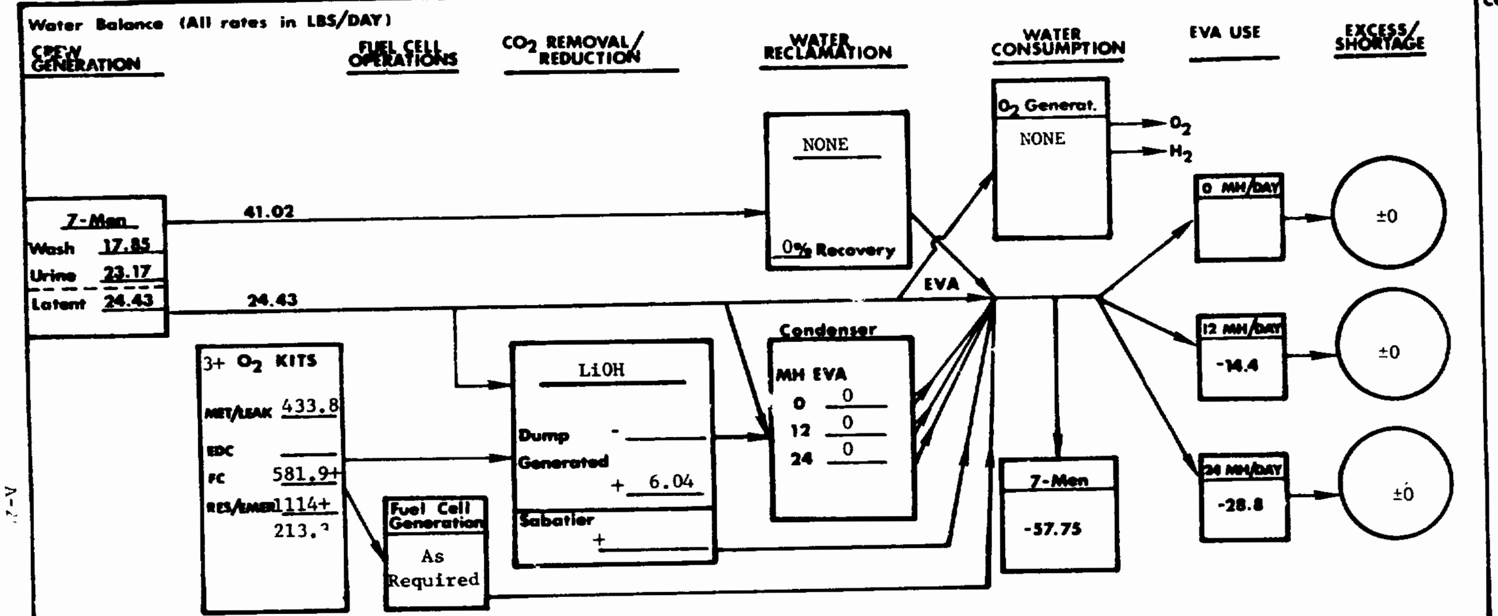
COMMENTS:

30 DAY SUMMARY

	CO_2 SUBS TOTAL	H_2O REC TOTAL	O_2 GEN TOTAL	ADDITIONAL H_2O REQUIRED	TOTALS	RE-ENTRY WEIGHT
WEIGHT (LBS)						
0 Man Hours/Day EVA	+174.8	0	+205	+1430	+1809.7	+503.3
12 Man Hours/Day EVA	+174.8	0	+205	+2110	+2489.7	+751.3
24 Man Hours/Day EVA	+174.8	0	+205	+2860	+3239.7	+1069.4
POWER (DC Watts)	+378	0	+2000		+2378	
VOLUME ($Ft.^3$)						
0 Man Hours/Day EVA	+8.0	0	+6.3	+42	+56.3	
12 Man Hours/Day EVA	+8.0	0	+6.3	+56	+70.3	
24 Man Hours/Day EVA	+8.0	0	+6.3	+77	+91.3	
SENSIBLE HEAT REJECTION (BTU/HR)	+3068	0	+2196		+5264	
LATENT HEAT REJECTION (BTU/HR)	+276	0	-1078		-802	

EXTENDED SHUTTLE ECLSS IMPACT SUMMARY

SYSTEM 30 Days - No Water Reclamation - Fuel Cell Scheduled - LiOH CO_2 Removal



COMMENTS:

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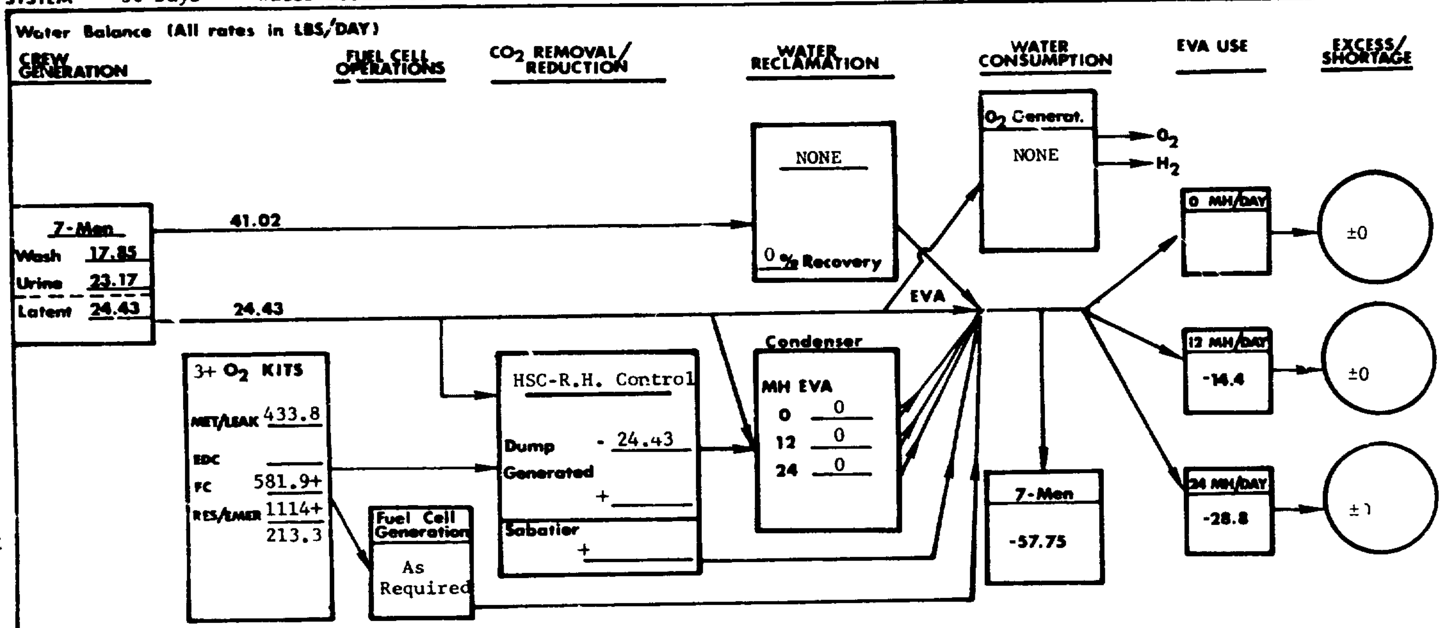
30 DAY SUMMARY	CO_2 SUBS TOTAL	H_2O REC TOTAL	O_2 GEN TOTAL	ADDITIONAL H_2O REQUIRED	TOTALS	RE-ENTRY WEIGHT
WEIGHT (LBS) 0 Man Hours/Day EVA	+990.7	0	0	0	+990.7	+1113.3
12 Man Hours/Day EVA	+990.7	0	0	0	+990.7	+1113.3
24 Man Hours/Day EVA	+990.7	0	0	0	+990.7	+1113.3
POWER (DC Watts)	±0	0	0		±0	
VOLUME (Ft.^{3}) 0 Man Hours/Day EVA	+49.4	0	0	0	+49.4	
12 Man Hours/Day EVA	+49.4	0	0	0	+49.4	
24 Man Hours/Day EVA	+49.4	0	0	0	+49.4	
SENSIBLE HEAT REJECTION (BTU/HR)	+509	0	0		+509	
LATENT HEAT REJECTION (BTU/HR)	+252	0	0		+252	

EXTENDED SHUTTLE ECLSS IMPACT SUMMARY

SYSTEM 30 Days- No Water Reclamation - Fuel Cell Scheduled - HSC R.H. Control-CO_2 Removal



COMMENTS:

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SUMMARY

	CO_2 SUBS TOTAL	H_2O REC TOTAL	O_2 GEN TOTAL	ADDITIONAL H_2O REQUIRED	TOTALS	RE-ENTRY WEIGHT
WEIGHT (LBS)						
0 Man Hours/Day EVA	+99.9	0	0	0	+99.9	-362.0
12 Man Hours/Day EVA	+99.9	0	0	0	+99.9	-362.0
24 Man Hours/Day EVA	+99.9	0	0	0	+99.9	-362.0
POWER (DC Watts)	+117	0	0		+117	
VOLUME (Ft.^{3})						
0 Man Hours/Day EVA	+2.4	0	0	0	+2.4	
12 Man Hours/Day EVA	+2.4	0	0	0	+2.4	
24 Man Hours/Day EVA	+2.4	0	0	0	+2.4	
SENSIBLE HEAT REJECTION (BTU/HR)	+399	0	0		+399	
LATENT HEAT REJECTION (BTU/HR)	-1018	0	0		-1018	

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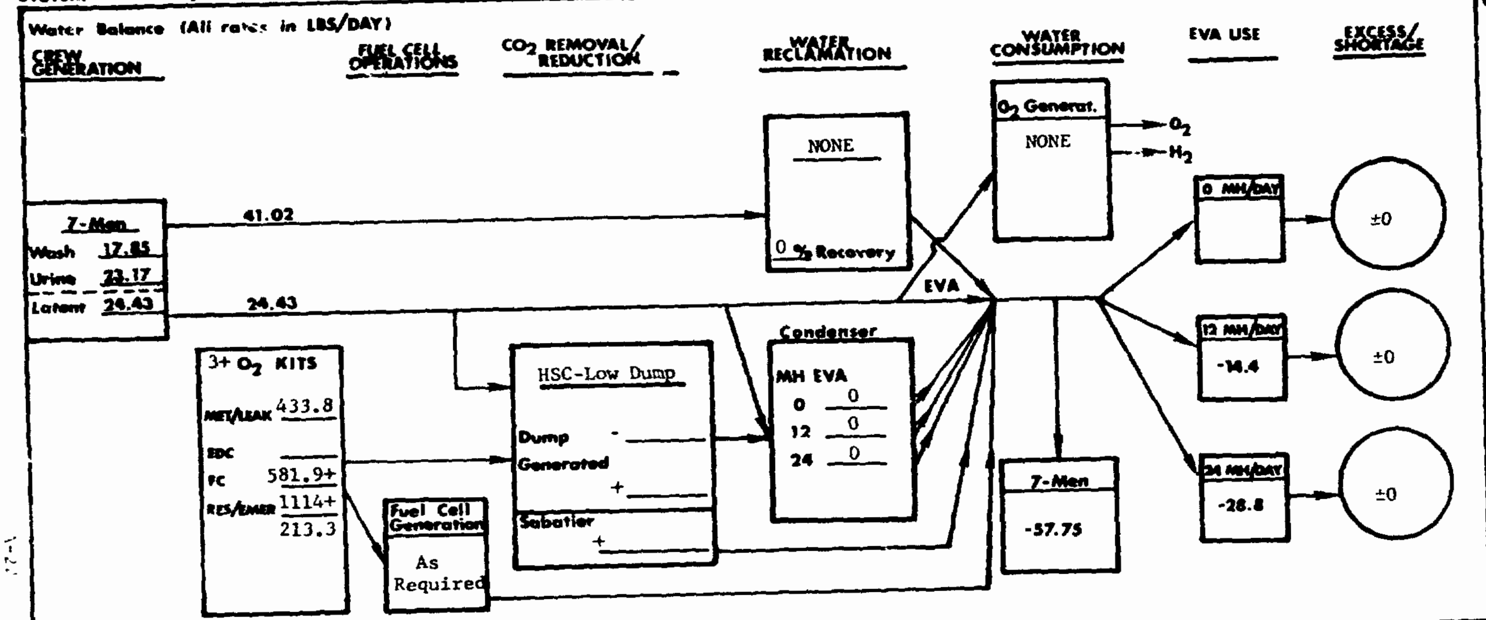
EXTENDED SHUTTLE ECLSS IMPACT SUMMARY

SYSTEM 30 Days - No Water Reclamation - Fuel Cell Scheduled - HSC Low Dump-CO_2 Removal

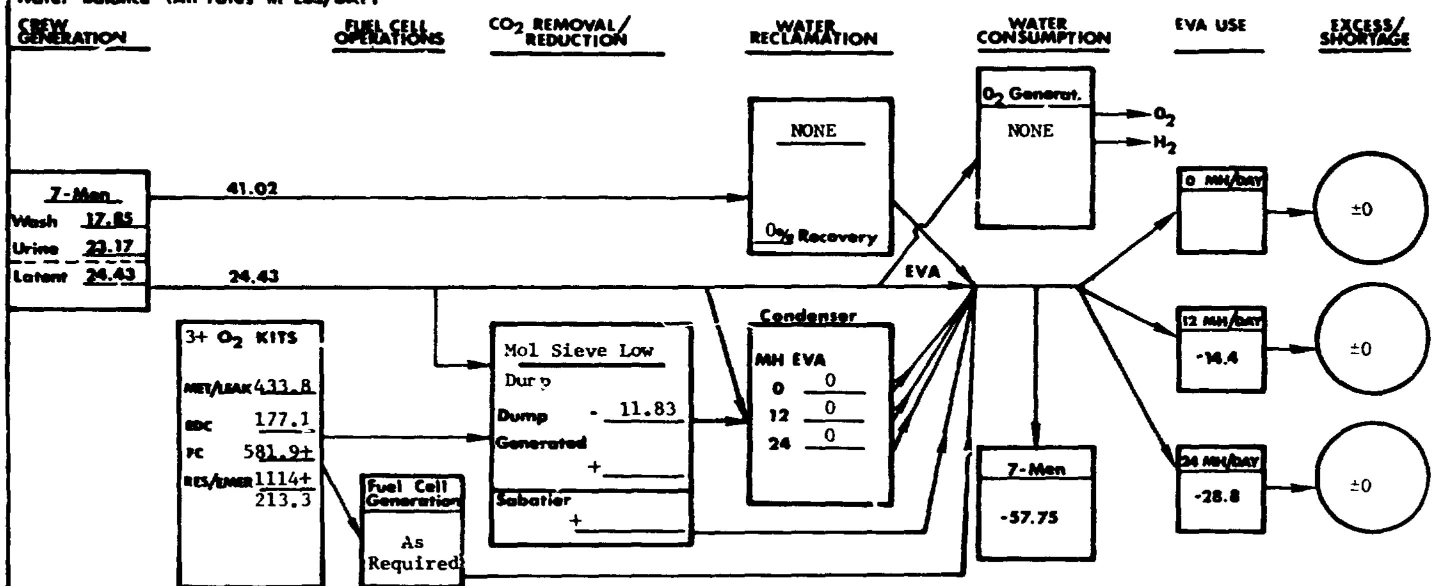


COMMENTS:

30 DAY SUMMARY	CO_2 SUBS TOTAL	H_2O REC TOTAL	O_2 GEN TOTAL	ADDITIONAL H_2O REQUIRED	TOTALS	RE-ENTRY WEIGHT
WEIGHT (LBS)						
0 Man Hours/Day EVA	+138.6	0	0	0	+138.6	-323.3
12 Man Hours/Day EVA	+138.6	0	0	0	+138.6	-323.3
24 Man Hours/Day EVA	+138.6	0	0	0	+138.6	-323.3
POWER (DC Watts)	+89	0	0		+89	
VOLUME (Ft^3)						
0 Man Hours/Day EVA	+1.0	0	0	0	+1.0	
12 Man Hours/Day EVA	+1.0	0	0	0	+1.0	
24 Man Hours/Day EVA	1.0	0	0	0	+1.0	
SENSIBLE HEAT REJECTION (BTU/HR)	+304	0	0		+304	
LATENT HEAT REJECTION (BTU/HR)	-410	0	0		-410	

EXTENDED SHUTTLE ECLSS IMPACT SUMMARY

SYSTEM 30 Days - No Water Reclamation - Fuel Cell Scheduled - Mol Sieve Low Dump



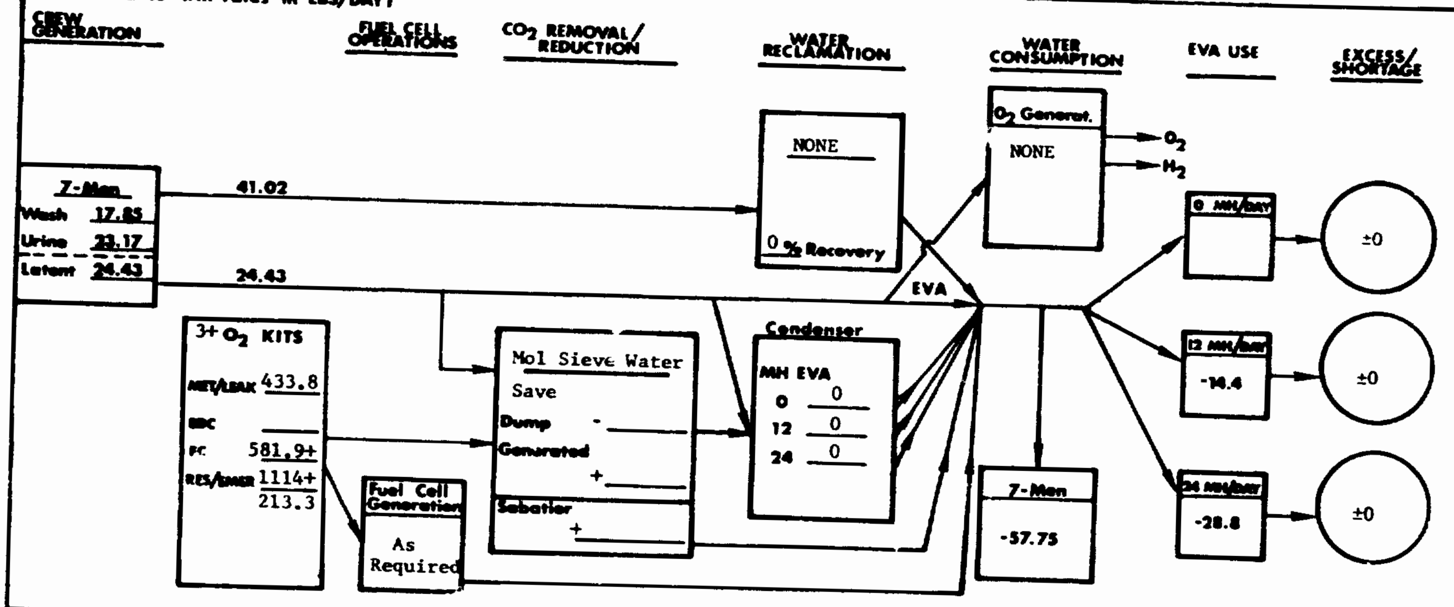
COMMENTS:

30 DAY SUMMARY	CO2 SUBS TOTAL	H2O REC TOTAL	O2 GEN TOTAL	ADDITIONAL H2O REQUIRED	TOTALS	RE-ENTRY WEIGHT
WEIGHT (LBS)						
0 Man Hours/Day EVA	+89.1	0	0	0	+89.1	-372.8
12 Man Hours/Day EVA	+89.1	0	0	0	+89.1	-372.8
24 Man Hours/Day EVA	+89.1	0	0	0	+89.1	-372.8
POWER (DC Watts)	+63	0	0		+63	
VOLUME (Ft.3)						
0 Man Hours/Day EVA	+3.6	0	0	0	+3.6	
12 Man Hours/Day EVA	+3.6	0	0	0	+3.6	
24 Man Hours/Day EVA	+3.6	0	0	0	+3.6	
SENSIBLE HEAT REJECTION (BTU/HR)	+215	0	0		+215	
LATENT HEAT REJECTION (BTU/HR)	-524	0	0		-524	

EXTENDED SHUTTLE ECLSS IMPACT SUMMARY

SYSTEM 30 Days - No Water Reclamation - Fuel Cell Scheduled - Mol Sieve Water Save-CO_2 Removal

Water Balance (All rates in LBS/DAY)



COMMENTS:

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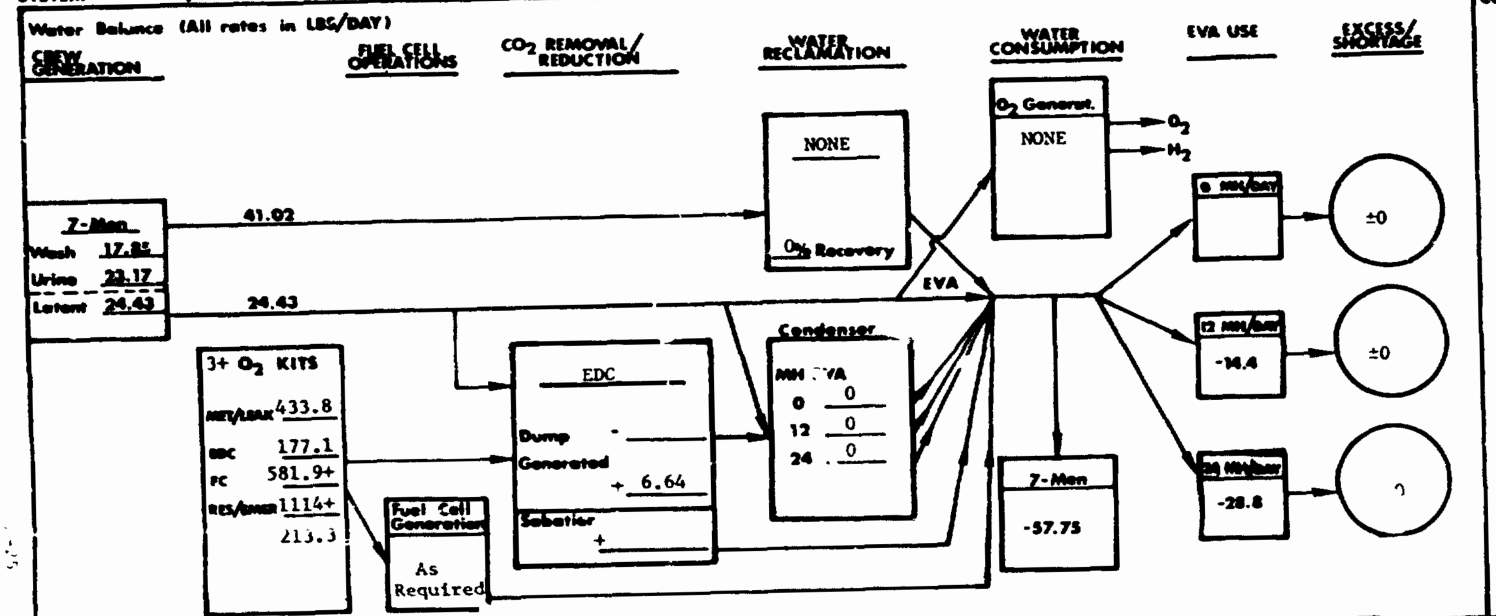
30 DAY SUMMARY

	CO_2 [illegible] TOTAL	H_2O REC TOTAL	O_2 GEN TOTAL	ADDITIONAL H_2O REQUIRED	TOTALS	RE-ENTRY WEIGHT
WEIGHT (LBS)						
0 Man Hours/Day EVA	+94.0	0	0	0	+94.0	-368.0
12 Man Hours/Day EVA	+94.0	0	0	0	+94.0	-368.0
24 Man Hours/Day EVA	+94.0	0	0	0	+94.0	-368.0
POWER (DC Watts)	+575	0	0		+575	
VOLUME (Ft.^{3})						
0 Man Hours/Day EVA	+3.5	0	0	0	+3.5	
12 Man Hours/Day EVA	+3.5	0	0	0	+3.5	
24 Man Hours/Day EVA	+3.5	0	0	0	+3.5	
SENSIBLE HEAT REJECTION (BTU/HR)	+887	0	0		+887	
LATENT HEAT REJECTION (BTU/HR)	[illegible]	0	0		+620	

EXTENDED SHUTTLE ECLSS IMPACT SUMMARY

SYSTEM 30 Days - No Water Reclamation - Fuel Cell Scheduled - EDC CO_2 Removal



COMMENTS:

1. Cryogenic O_2 Usage Penalty Applied.

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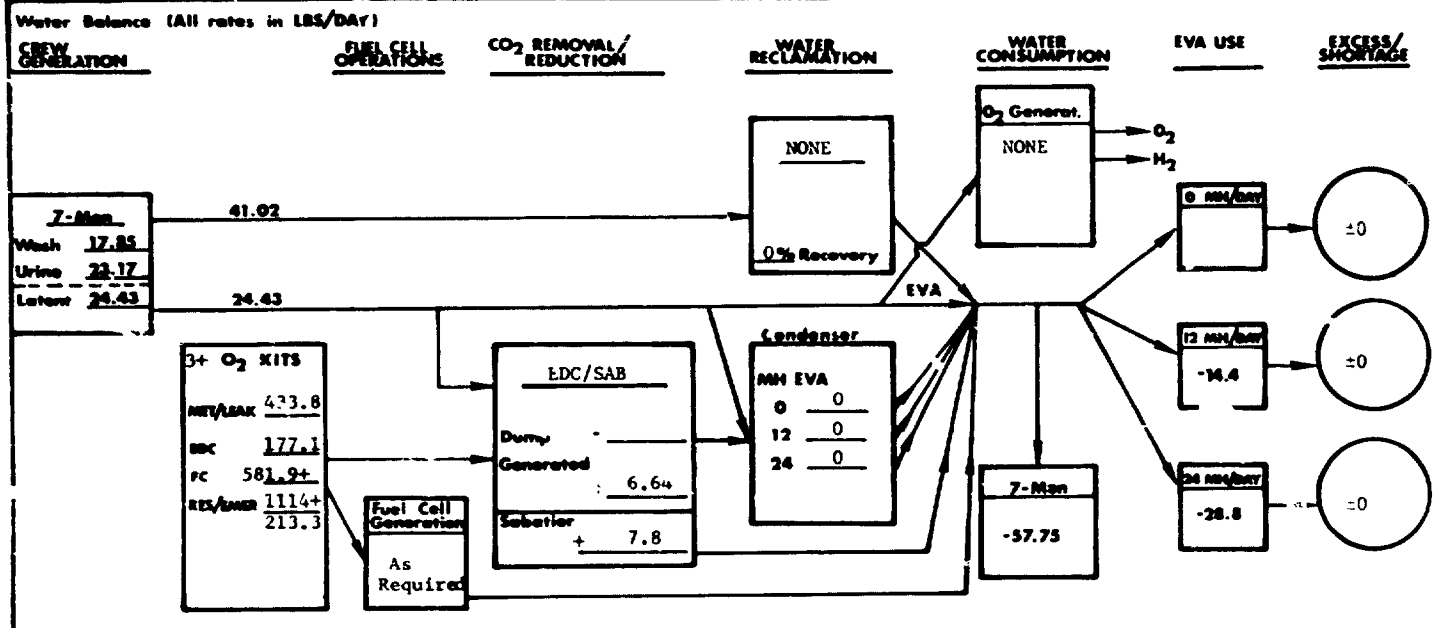
30 DAY SUMMARY	CO_2 SUBS TOTAL	H_2O REC TOTAL	O_2 GEN TOTAL	ADDITIONAL H_2O REQUIRED	TOTALS	RE-ENTRY WEIGHT
WEIGHT (LBS)						
0 Man Hours/Day EVA	+236.2	0	0	0	+236.2	-225.7
12 Man Hours/Day EVA	+236.2	0	0	0	+236.2	-225.7
24 Man Hours/Day EVA	+236.2	0	0	0	+236.2	-225.7
POWER (DC Watts)	+336	0	0		+336	
VOLUME (Ft.^{3})						
0 Man Hours/Day EVA	-2.5	0	0	0	-2.5	
12 Man Hours/Day EVA	-2.5	0	0	0	-2.5	
24 Man Hours/Day EVA	-2.5	0	0	0	-2.5	
SENSIBLE HEAT REJECTION (BTU/HR)	[illegible]	0	0		+2465	
LATENT HEAT REJECTION (BTU/HR)	+276	0	0		+276	

EXTENDED SHUTTLE ECLSS IMPACT SUMMARY

SYSTEM 30 Days - No Water Reclamation - Fuel Cell Scheduled - EDC with Sabatier Reactor-CO_2 Removal/Reduction



COMMENTS:

1. EDC/SAB cryo[illegible] O_2 usage penalt[illegible] [illegible]plied.

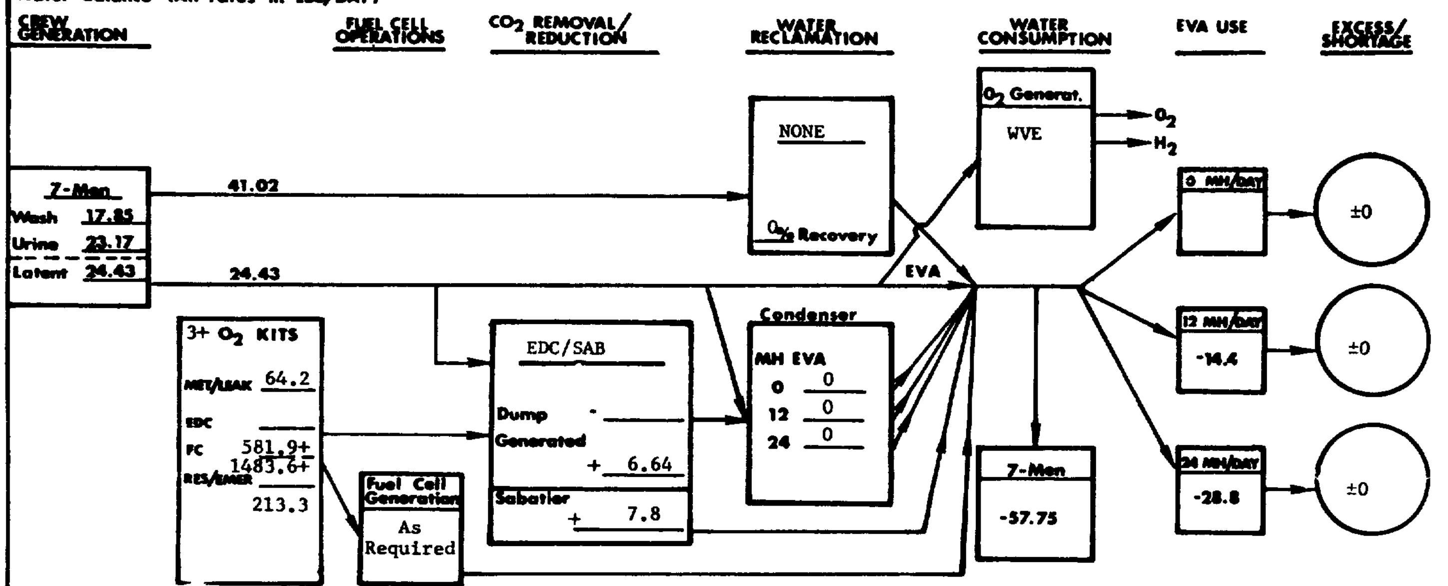
30 DAY SUMMARY

	CO_2 SUBS TOTAL	H_2O REC TOTAL	O_2 GEN TOTAL	ADDITIONAL H_2O REQUIRED	TOTALS	RE-ENTRY WEIGHT
WEIGHT (LBS)						
0 Man Hours/Day EVA	+351.8	0	0	0	+351.8	-110.1
12 Man Hours/Day EVA	+351.8	0	0	0	+351.8	-110.1
24 Man Hours/Day EVA	+351.8	0	0	0	+351.[illegible]	-110.1
POWER (DC Watts)	+378	0	0		+37[illegible]	
VOLUME ($Ft.^3$)						
0 Man Hours/Day EVA	+8.0	0	0	0	+8.0	
12 Man Hours/Day EVA	+8.0	0	0	0	+8.0	
24 Man Hours/Day EVA	+8.0	0	0	0	+8.0	
SENSIBLE HEAT REJECTION (BTU/HR)	+3068	0	0		+3068	
LATENT HEAT REJECTION (BTU/HR)	+276	0	0		+276	

EXTENDED SHUTTLE ECLSS IMPACT SUMMARY

SYSTEM 30 Days - No Water Reclamation - Fuel Cell Scheduled - EDC/WVE with Sabatier Reactor-CO_2 Removal/Reduction

Water Balance (All rates in LBS/DAY)



COMMENTS:

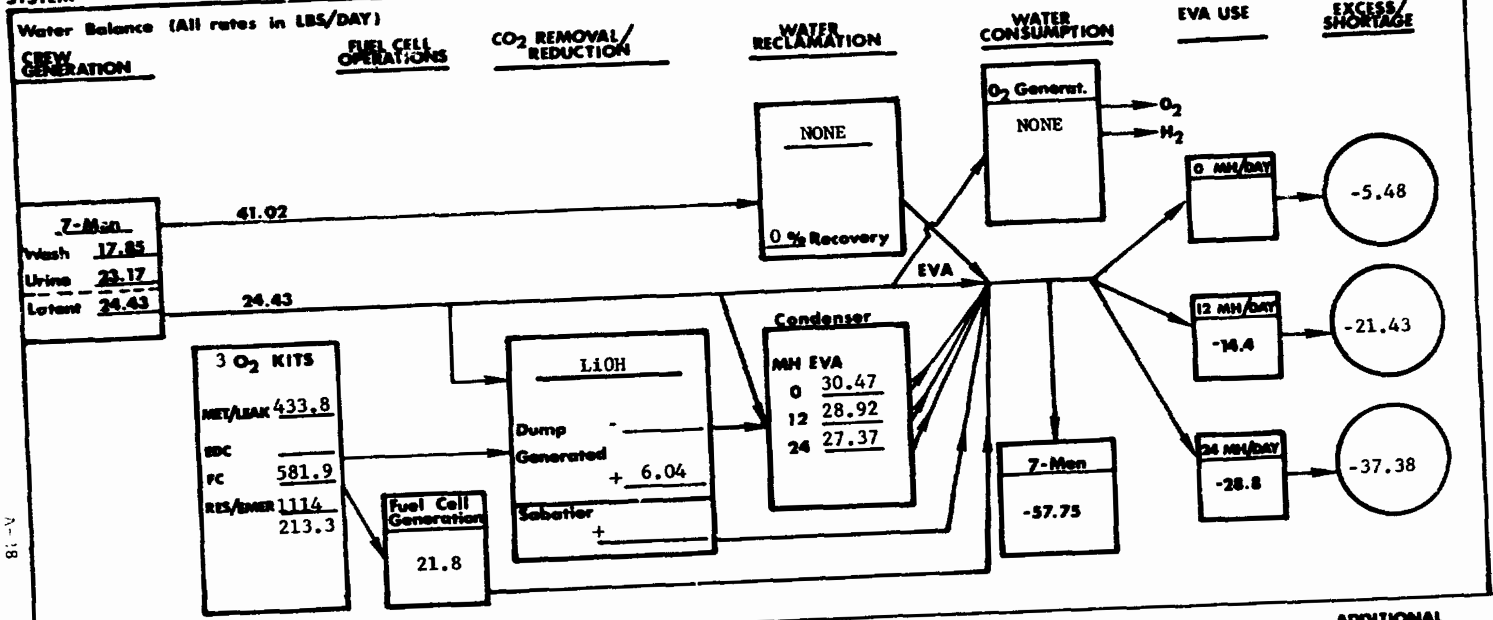
1. EDC/WVE given credit for O_2 generation

30 DAY SUMMARY

	CO_2 SUBS TOTAL	H_2O REC TOTAL	O_2 GEN TOTAL	ADDITIONAL H_2O REQUIRED	TOTALS	RE-ENTRY WEIGHT
WEIGHT (LBS)						
0 Man Hours/Day EVA	+174.7	0	-341.7	0	-167.0	-628.9
12 Man Hours/Day EVA	+174.7	0	-341.7	0	-167.0	-628.9
24 Man Hours/Day EVA	+174.7	0	-341.7	0	-167.0	-628.9
POWER (DC Watts)	+378	0	+2000		+2378	
VOLUME ($Ft.^3$)						
0 Man Hours/Day EVA	+8.0	0	+6.3	0	+14.3	
12 Man Hours/Day EVA	+8.0	0	+6.3	0	+14.3	
24 Man Hours/Day EVA	+8.0	0	+6.3	0	+14.3	
SENSIBLE HEAT REJECTION (BTU/HR)	+3068	0	+2196		+5264	
LATENT HEAT REJECTION (BTU/HR)	+276	0	-1078		-802	

EXTENDED SHUTTLE ECLSS IMPACT SUMMARY

SYSTEM 30 Days - Urine Wash Dump - Condensate Save - Idle Fuel Cells - LiOH CO_2 Removal



COMMENTS:

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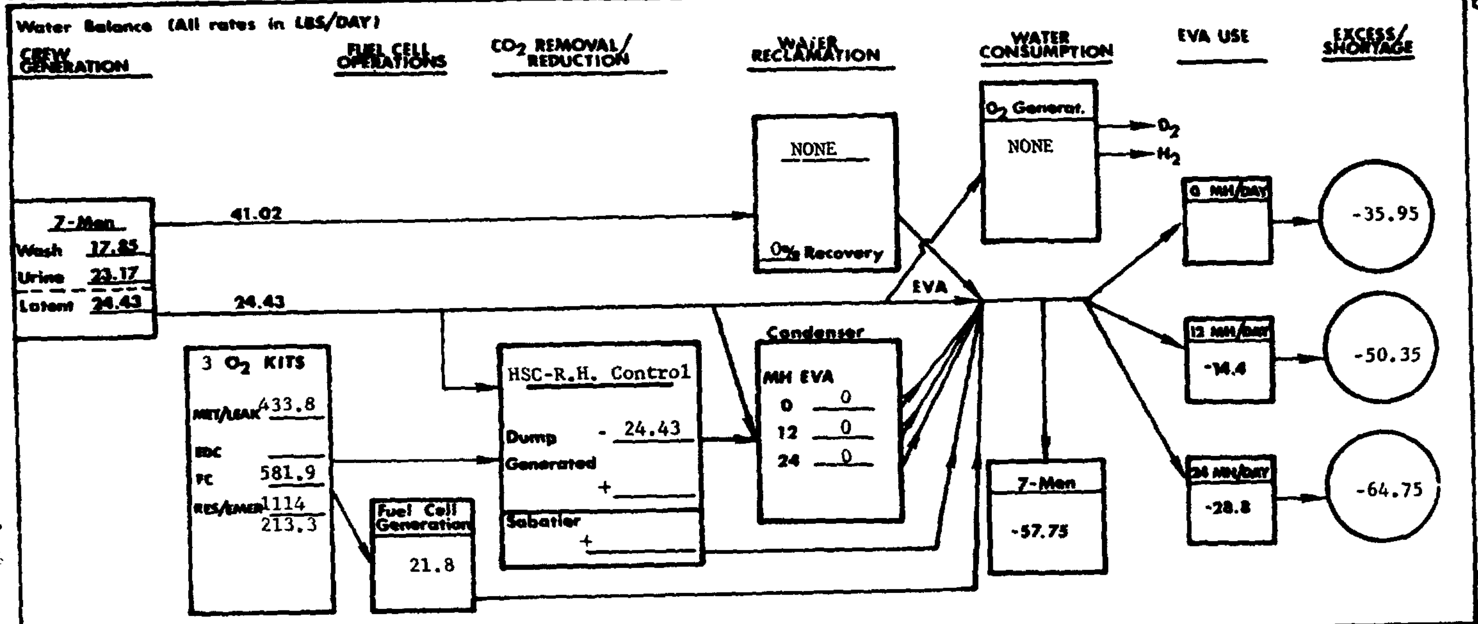
30 DAY SUMMARY	CO_2 SUBS TOTAL	H_2O REC TOTAL	O_2 GEN TOTAL	ADDITIONAL H_2O REQUIRED	TOTALS	RE-ENTRY WEIGHT
WEIGHT (LBS) 0 Man Hours/Day EVA	+990.7	+152.2	0	270	+1412.9	+1380.5
12 Man Hours/Day EVA	+990.7	+151.1	0	1060	+2201.8	+1690.9
24 Man Hours/Day EVA	+990.7	+150.1	0	1860	+3000.8	+2011.4
POWER (DC Watts)	±0	+24	0		+24	
VOLUME (Ft.^{3}) 0 Man Hours/Day EVA	+49.4	+15.5	0	7	+71.9	
12 Man Hours/Day EVA	+49.4	+15.3	0	28	+92.7	
24 Man Hours/Day EVA	+49.4	+15.0	0	49	+113.4	
SENSIBLE HEAT REJECTION (BTU/HR)	+509	+81	0		+590	
LATENT HEAT REJECTION (BTU/HR)	+252	0	0		+252	

EXTENDED SHUTTLE ECLSS IMPACT SUMMARY

SYSTEM 30 Days - Urine Wash Dump - Condensate Save - Idle Fuel Cells - HSC R.H. Control-CO_2 Removal

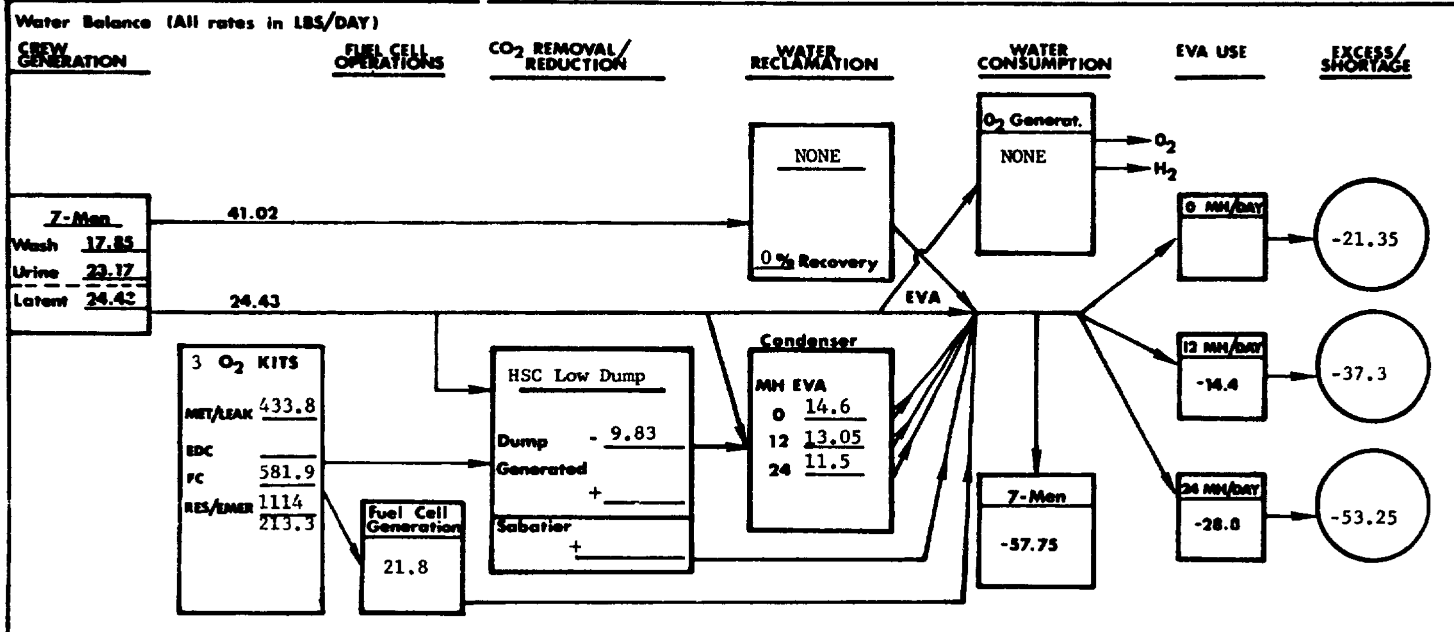


COMMENTS:

30 DAY SUMMARY	CO_2 SUBS TOTAL	H_2O REC TOTAL	O_2 GEN TOTAL	ADDITIONAL H_2O REQUIRED	TOTALS	RE-ENTRY WEIGHT
WEIGHT (LBS)						
0 Man Hours/Day EVA	+99.9	0	0	1800	+1899.9	+359.5
12 Man Hours/Day EVA	+99.9	0	0	2540	+2639.9	+667.5
24 Man Hours/Day EVA	+99.9	0	0	3220	+3319.9	+915.5
POWER (DC Watts)	+117	0	0		+117	
VOLUME ($Ft.^3$)						
0 Man Hours/Day EVA	+2.4	0	0	49	+51.4	
12 Man Hours/Day EVA	+2.4	0	0	70	+72.4	
24 Man Hours/Day EVA	+2.4	0	0	84	+86.4	
SENSIBLE HEAT REJECTION (BTU/HR)	+399	0	0		+399	
LATENT HEAT REJECTION (BTU/HR)	-1018	0	0		-1018	

EXTENDED SHUTTLE ECLSS IMPACT SUMMARY

SYSTEM 30 Days - Urine Wash Dump - Condensate Save - Idle Fuel Cells - HSC Low Dump-CO_2 Removal



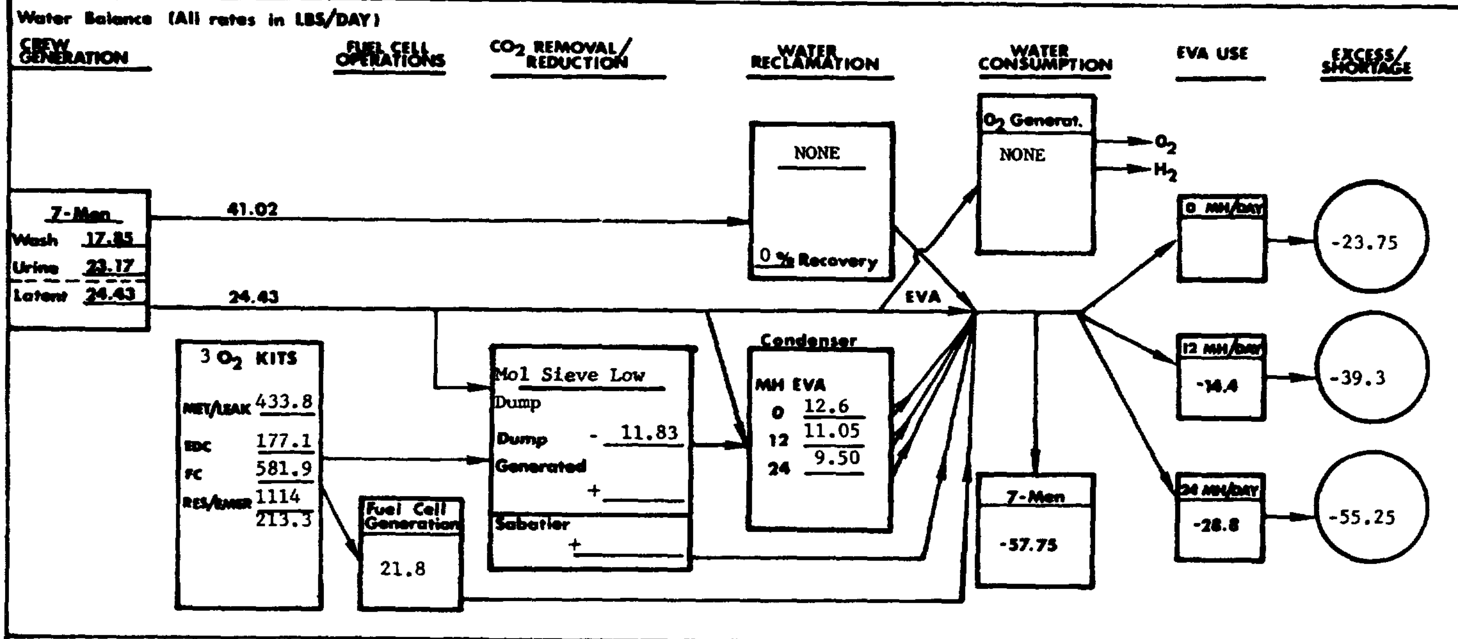
COMMENTS:

30 DAY SUMMARY

	CO_2 SUBS TOTAL	H_2O REC TOTAL	O_2 GEN TOTAL	ADDITIONAL H_2O REQUIRED	TOTALS	RE-ENTRY WEIGHT
WEIGHT (LBS)						
0 Man Hours/Day EVA	+138.6	+152.2	0	1060	+1350.8	+248.4
12 Man Hours/Day EVA	+138.6	+151.1	0	1860	+2149.7	+568.8
24 Man Hours/Day EVA	+138.6	+150.1	0	2660	+2948.7	+889.3
POWER (DC Watts)	+89	+24	0		+113	
VOLUME ($Ft.^3$)						
0 Man Hours/Day EVA	+1.0	+15.5	0	28	+44.5	
12 Man Hours/Day EVA	+1.0	+15.3	0	49	+65.3	
24 Man Hours/Day EVA	+1.0	+15.0	0	70	+86.0	
SENSIBLE HEAT REJECTION (BTU/HR)	+304	+81	0		+385	
LATENT HEAT REJECTION (BTU/HR)	-410	0	0		-410	

EXTENDED SHUTTLE ECLSS IMPACT SUMMARY

SYSTEM 30 Days - Urine Wash Dump - Condensate Save - Idle Fuel Cells - Mol Sieve Low Dump-CO_2 Removal



COMMENTS:

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30 DAY SUMMARY

	CO_2 SUBS TOTAL	H_2O REC TOTAL	O_2 GEN TOTAL	ADDITIONAL H_2O REQUIRED	TOTALS	RE-ENTRY WEIGHT
WEIGHT (LBS)						
0 Man Hours/Day EVA	+89.1	+152.2	0	1210	+1451.3	+227.1
12 Man Hours/Day EVA	+89.1	+151.1	0	1990	+2230.2	+589.3
24 Man Hours/Day EVA	+89.1	+150.1	0	2800	+3039.2	+919.8
POWER (DC Watts)	+63	+24	0		+87	
VOLUME (Ft.^{3})						
0 Man Hours/Day EVA	+3.6	+15.5	0	35	+54.1	
12 Man Hours/Day EVA	+3.6	+15.3	0	56	+74.9	
24 Man Hours/Day EVA	+3.6	+15.0	0	77	+95.6	
SENSIBLE HEAT REJECTION (BTU/HR)	+215	+81	0		+296	
LATENT HEAT REJECTION (BTU/HR)	-524	0	0		-524	

EXTENDED SHUTTLE ECLSS IMPACT SUMMARY

SYSTEM 30 Days - Urine Wash Dump - Condensate Save - Idle Fuel Cells - Mol Sieve Water Save-CO_2 Removal

COMMENTS:

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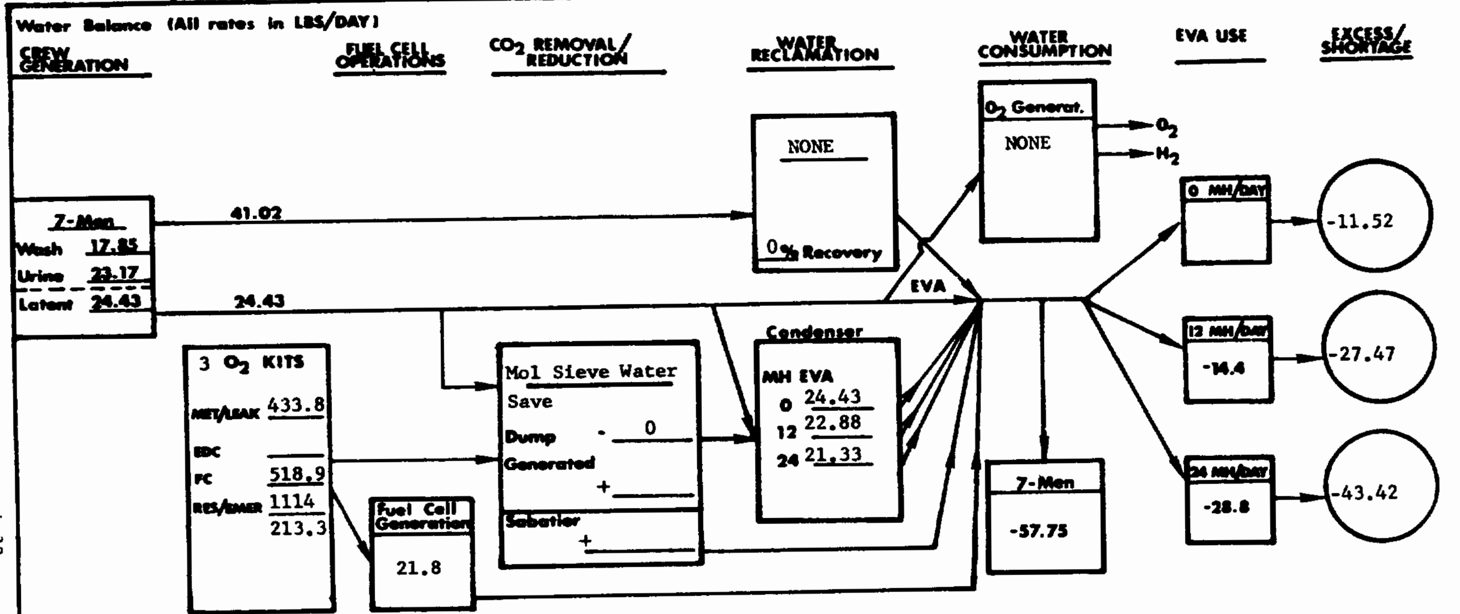
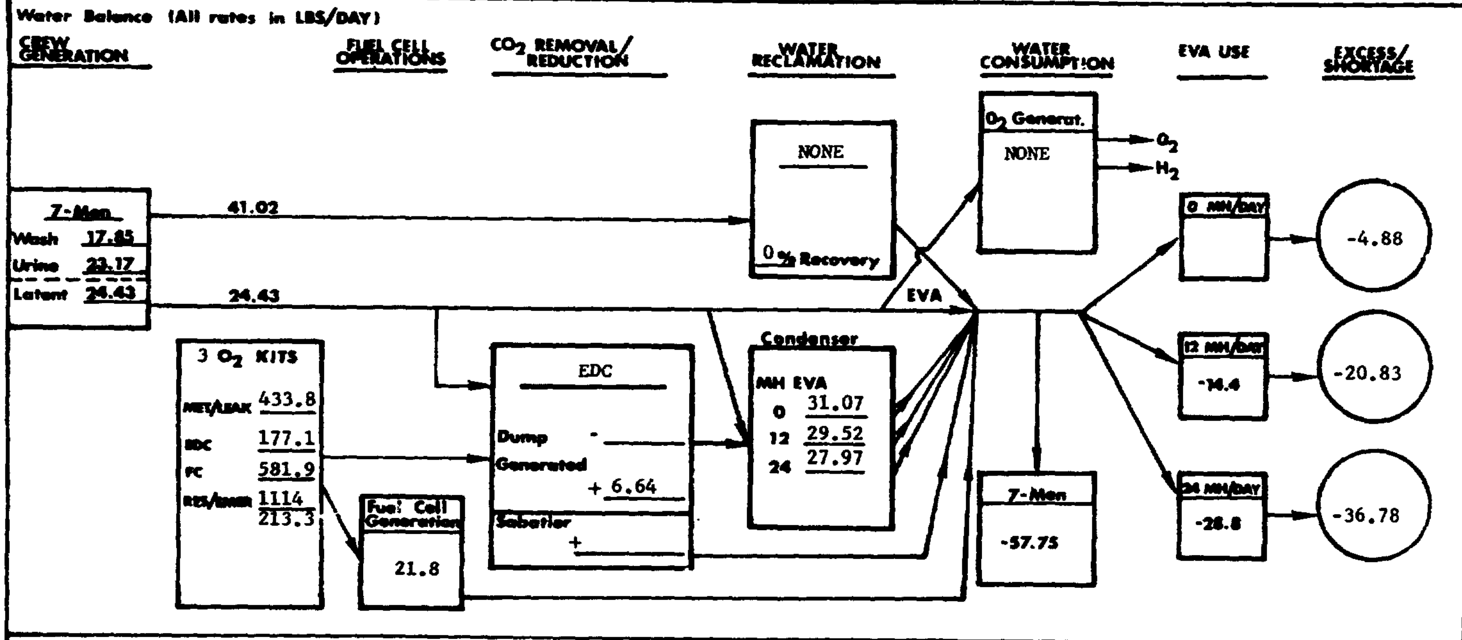


DAY SUMMARY

	CO_2 SUBS TOTAL	H_2O REC TOTAL	O_2 GEN TOTAL	ADDITIONAL H_2O REQUIRED	TOTALS	RE-ENTRY WEIGHT
WEIGHT (LBS) 0 Man Hours/Day EVA	+94.0	+152.2	0	615	+861.2	+53.7
12 Man Hours/Day EVA	+94.0	+151.0	0	1370	+1615.0	+329.0
24 Man Hours/Day EVA	+94.0	+150.1	0	2130	+2374.1	+609.6
POWER (DC Watts)	+575	+24	0		+599	
VOLUME ($Ft.^3$) 0 Man Hours/Day EVA	+3.5	+15.5	0	21	+40.0	
12 Man Hours/Day EVA	+3.5	+15.3	0	35	+53.8	
24 Man Hours/Day EVA	+3.5	+15.0	0	56	+74.5	
SENSIBLE HEAT REJECTION (BTU/HR)	+887	+81	0		+968	
LATENT HEAT REJECTION (BTU/HR)	+620	0	0		+620	

EXTENDED SHUTTLE ECLSS IMPACT SUMMARY

SYSTEM 30 Days - Urine Wash Dump - Condensate Save - Idle Fuel Calls - EDC - CO_2 Removal



COMMENTS:

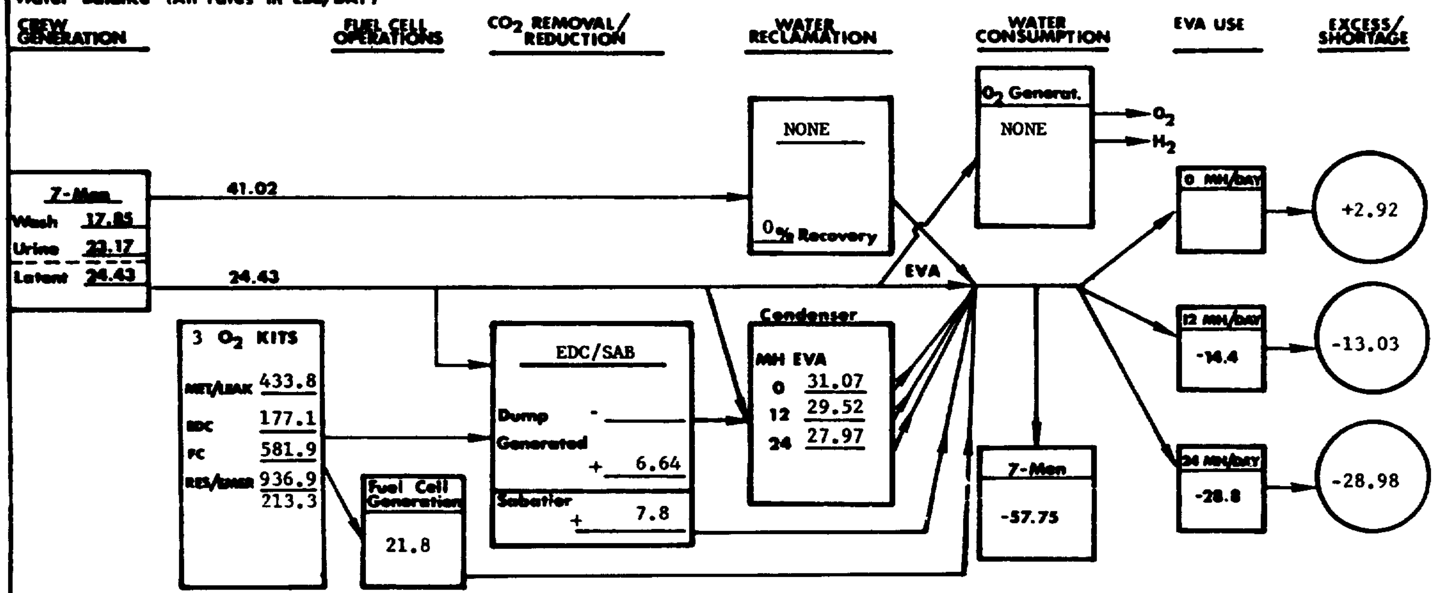
30 DAY SUMMARY

	CO_2 SUBS TOTAL	H_2O REC TOTAL	O_2 GEN TOTAL	ADDITIONAL H_2O REQUIRED	TOTALS	RE-ENTRY WEIGHT
WEIGHT (LBS)						
0 Man Hours/Day EVA	+59.1	+152.2	0	240	+451.3	-160.0
12 Man Hours/Day EVA	+59.1	+152.2	0	1040	+1250.2	+163.4
24 Man Hours/Day EVA	+59.1	+152.4	0	1830	+2039.2	+473.9
POWER (DC Watts)	+336	+24	0		-360	
VOLUME (Ft.^{3})						
0 Man Hours/Day EVA	-2.5	+15.5	0	7	+20.0	
12 Man Hours/Day EVA	-2.5	+15.3	0	28	+41.8	
24 Man Hours/Day EVA	-2.5	+15.0	0	49	+61.5	
SENSIBLE HEAT REJECTION (BTU/HR)	+2465	+81	0		+2546	
LATENT HEAT REJECTION (BTU/HR)	+276	0	0		+276	

EXTENDED SHUTTLE ECLSS IMPACT SUMMARY

SYSTEM 30 Days - Urine Wash Dump - Condensate Save - Idle Fuel Cells - EDC with Sabatier Reactor-CO_2 Removal/Reduction

Water Balance (All rates in LBS/DAY)



COMMENTS:

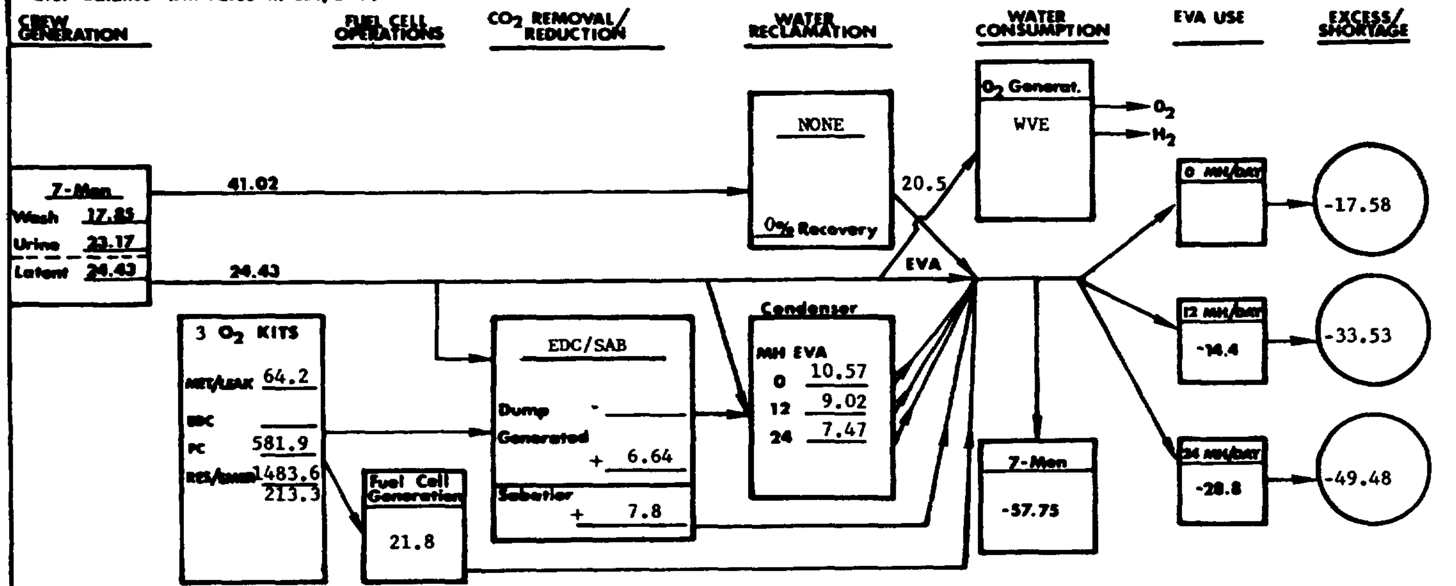
30 DAY SUMMARY

	CO_2 SUBS TOTAL	H_2O REC TOTAL	O_2 GEN TOTAL	ADDITIONAL H_2O REQUIRED	TOTALS	RE-ENTRY WEIGHT
WEIGHT (LBS) 0 Man Hours/Day EVA	+174.7	+152.2	0	0	+326.9	-135.0
12 Man Hours/Day EVA	+174.7	+151.1	0	690	+1015.8	+163.0
24 Man Hours/Day EVA	+174.7	+150.1	0	1480	+1804.6	+473.5
POWER (DC Watts)	+378	+24	0		+402	
VOLUME (Ft.^{3}) 0 Man Hours/Day EVA	+8.0	+15.5	0	0	+23.5	
12 Man Hours/Day EVA	+8.0	+15.3	0	21	+44.3	
24 Man Hours/Day EVA	+8.0	+15.0	0	42	+67.0	
SENSIBLE HEAT REJECTION (BTU/HR)	+3068	+81	0		+3148	
LATENT HEAT REJECTION (BTU/HR)	+276	0	0		+276	

EXTENDED SHUTTLE ECLSS IMPACT SUMMARY

SYSTEM 30 Days - Urine Wash Dump - Condensate Save - Idle Fuel Cells - EDC/WVE with Sabatier Reactor-CO_2 Removal/Reduction

Water Balance (All rates in LBS/DAY)



COMMENTS:

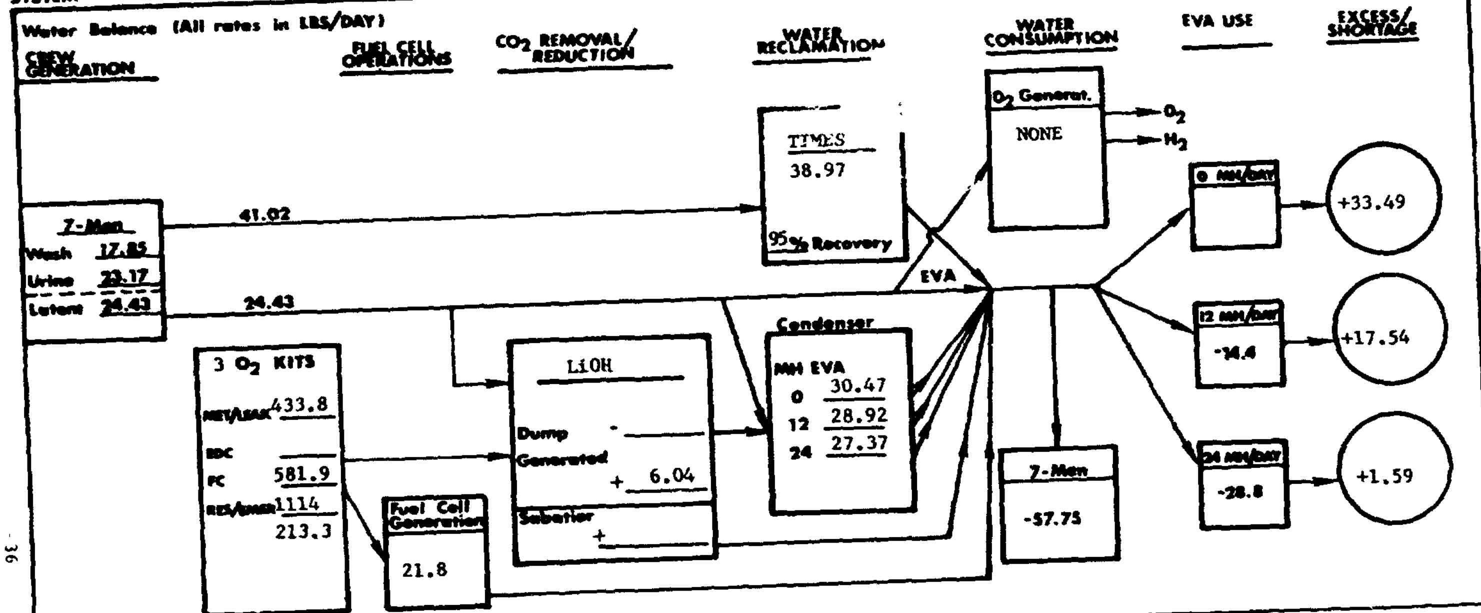
30 DAY SUMMARY

	CO_2 SUBS TOTAL	H_2O REC TOTAL	O_2 GEN TOTAL	ADDITIONAL H_2O REQUIRED	TOTALS	RE-ENTRY WEIGHT
WEIGHT (LBS)						
0 Man Hours/Day EVA	+174.7	+152.2	+205	935	+1466.9	+920.2
12 Man Hours/Day EVA	+174.7	+151.1	+205	1710	+2240.8	+1694.1
24 Man Hours/Day EVA	+174.7	+150.1	+205	2500	+3029.8	+2483.1
POWER (DC Watts)	+378	+24	+2000		+2402	
VOLUME (Ft.^{3})						
0 Man Hours/Day EVA	+8.0	+15.5	+6.3	28	+57.8	
12 Man Hours/Day EVA	+8.0	+15.3	+6.3	49	+78.6	
24 Man Hours/Day EVA	+8.0	+15.0	+6.3	70	+99.3	
SENSIBLE HEAT REJECTION (BTU/HR)	+3068	+81	+2196		+5345	
LATENT HEAT REJECTION (BTU/HR)	+276	0	-1078		-802	

EXTENDED SHUTTLE ECLSS IMPACT SUMMARY

SYSTEM 30 Days - All Water Reclamation - Idle Fuel Cells - LiOH CO_2 Removal

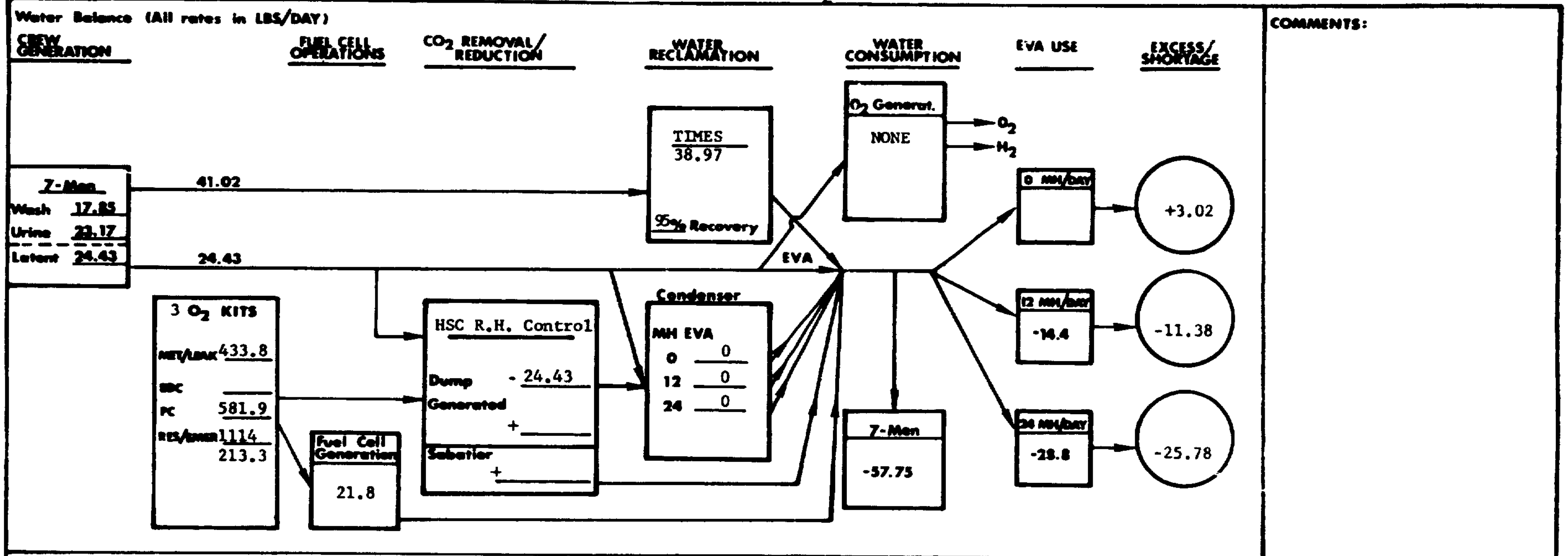
COMMENTS:



30 DAY SUMMARY	CO_2 SUBS TOTAL	H_2O REC TOTAL	O_2 GEN TOTAL	ADDITIONAL H_2O REQUIRED	TOTALS	RE-ENTRY WEIGHT
WEIGHT (LBS)						
0 Man Hours/Day EVA	+991.3	+295.7	0	0	+1287.0	+1409.3
12 Man Hours/Day EVA	+991.3	+294.6	0	0	+1285.9	+1408.2
24 Man Hours/Day EVA	+991.3	+293.6	0	0	+1284.9	+1407.2
POWER (DC Watts)	±0	+315	0		+315	
VOLUME (Ft.^{3})						
0 Man Hours/Day EVA	+49.4	+26.5	0	0	+75.9	
12 Man Hours/Day EVA	+49.4	+26.3	0	0	+75.7	
24 Man Hours/Day EVA	+49.4	+26.0	0	0	+75.4	
SENSIBLE HEAT REJECTION (BTU/HR)	+509	+1072	0		+1581	
LATENT HEAT REJECTION (BTU/HR)	+262	0	0		+262	

EXTENDED SHUTTLE ECLSS IMPACT SUMMARY

SYSTEM 30 Days - All Water Reclamation - Idle Fuel Cells - HSC - R.H. Control-CO_2 Removal



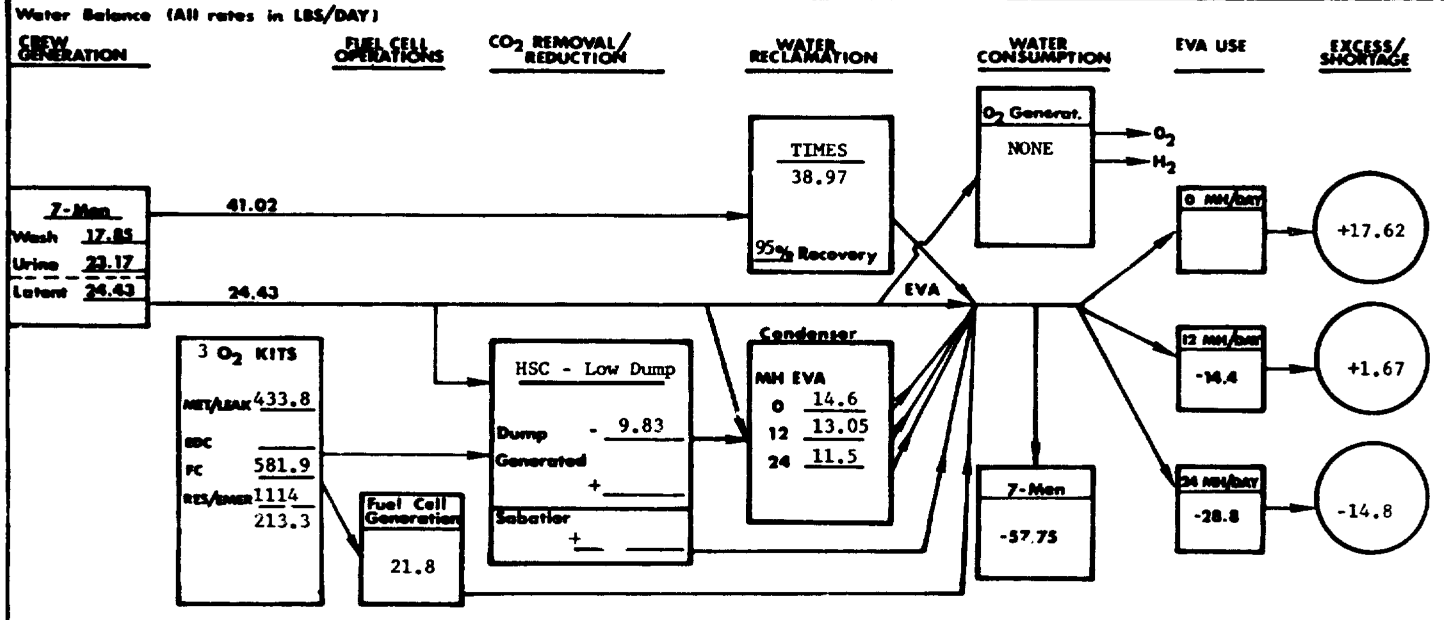
30 DAY SUMMARY

	CO_2 SUBS TOTAL	H_2O REC TOTAL	O_2 GEN TOTAL	ADDITIONAL H_2O REQUIRED	TOTALS	RE-ENTRY WEIGHT
WEIGHT (LBS)						
0 Man Hours/Day EVA	+99.9	+254.5	0	0	+354.4	-107.5
12 Man Hours/Day EVA	+99.9	+254.5	0	610	+964.4	+161.1
24 Man Hours/Day EVA	+99.9	+254.5	0	1290	+1644.4	+409.1
POWER (DC Watts)	+117	+300	0		+417	
VOLUME (Ft.^{3})						
0 Man Hours/Day EVA	+2.4	+20.5	0	0	+22.9	
12 Man Hours/Day EVA	+2.4	+20.5	0	21	+43.9	
24 Man Hours/Day EVA	+2.4	+20.5	0	35	+57.9	
SENSIBLE HEAT REJECTION (BTU/HR)	+399	+1021	0		+1420	
LATENT HEAT REJECTION (BTU/HR)	-1018	0	0		-1018	

EXTENDED SHUTTLE ECLSS IMPACT SUMMARY

SYSTEM 30 Days - All Water Reclamation - Idle Fuel Cells - HSC - Low Dump-CO_2 Removal

COMMENTS:



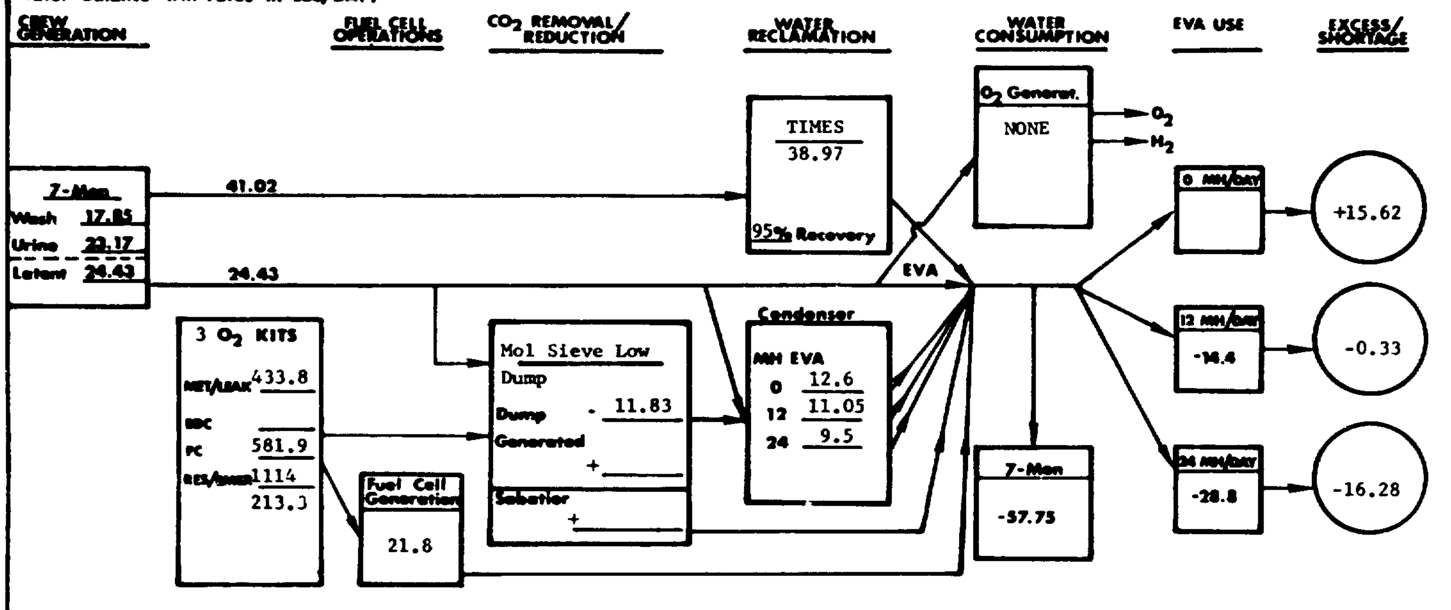
30 DAY SUMMARY

	CO_2 SUBS TOTAL	H_2O REC TOTAL	O_2 GEN TOTAL	ADDITIONAL H_2O REQUIRED	TOTALS	RE-ENTRY WEIGHT
WEIGHT (LBS)						
0 Man Hours/Day EVA	+138.6	+295.7	0	0	+434.3	-27.6
12 Man Hours/Day EVA	+138.6	+294.6	0	0	+433.2	-28.7
24 Man Hours/Day EVA	+138.6	+293.6	0	740	+1172.2	+266.3
POWER (DC Watts)	+89	+315	0		+404	
VOLUME ($Ft.^3$)						
0 Man Hours/Day EVA	+1.0	+26.5	0	0	+27.5	
12 Man Hours/Day EVA	+1.0	+26.3	0	0	+27.3	
24 Man Hours/Day EVA	+1.0	+26.0	0	21	+48.0	
SENSIBLE HEAT REJECTION (BTU/HR)	+304	+1072	0		+1376	
LATENT HEAT REJECTION (BTU/HR)	-410	0	0		-410	

EXTENDED SHUTTLE ECLSS IMPACT SUMMARY

/STEM 30 Days - All Water Reclamation - Idle Fuel Cells - Mol Sieve Low Dump-CO_2 Removal

Water Balance (All rates in LBS/DAY)



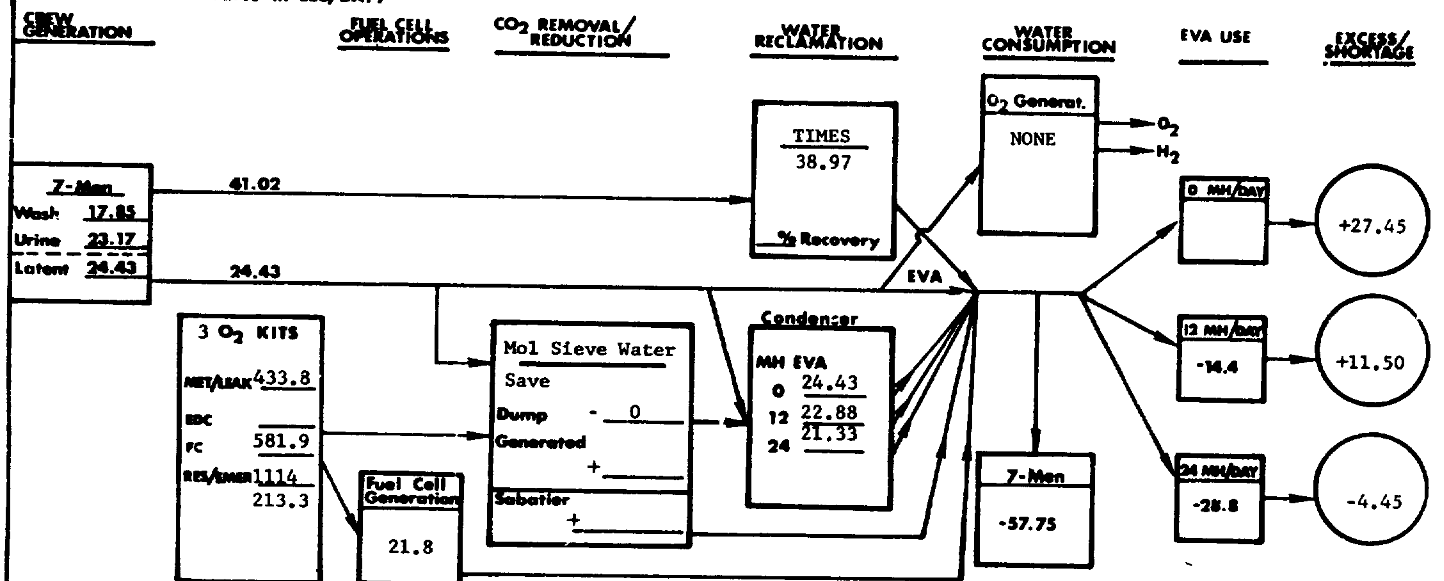
COMMENTS:

30 DAY SUMMARY

	CO_2 SUBS TOTAL	H_2O REC TOTAL	O_2 GEN TOTAL	ADDITIONAL H_2O REQUIRED	TOTALS	RE-ENTRY WEIGHT
WEIGHT (LBS)						
0 Man Hours/Day EVA	89.1	+295.7	0	0	+384.8	-77.1
12 Man Hours/Day EVA	89.1	+294.6	0	45	+428.7	-43.1
24 Man Hours/Day EVA	89.1	+293.6	0	800	+1182.7	+232.4
POWER (DC Watts)	+63	+315	0		+378	
VOLUME (Ft.^{3})						
0 Man Hours/Day EVA	+3.6	+26.5	0	0	÷30.1	
12 Man Hours/Day EVA	+3.6	+26.3	0	7	+36.9	
24 Man Hours/Day EVA	+3.6	+26.0	0	35	+64.6	
SENSIBLE HEAT REJECTION (BTU/HR)	+215	+1072	0		+1287	
LATENT HEAT REJECTION (BTU/HR)	-524	0	0		-524	

EXTENDED SHUTTLE ECLSS IMPACT SUMMARY

SYSTEM 30 Days - All Water Reclamation - Idle Fuel Cells - Mol Sieve Water Save-CO_2 Removal



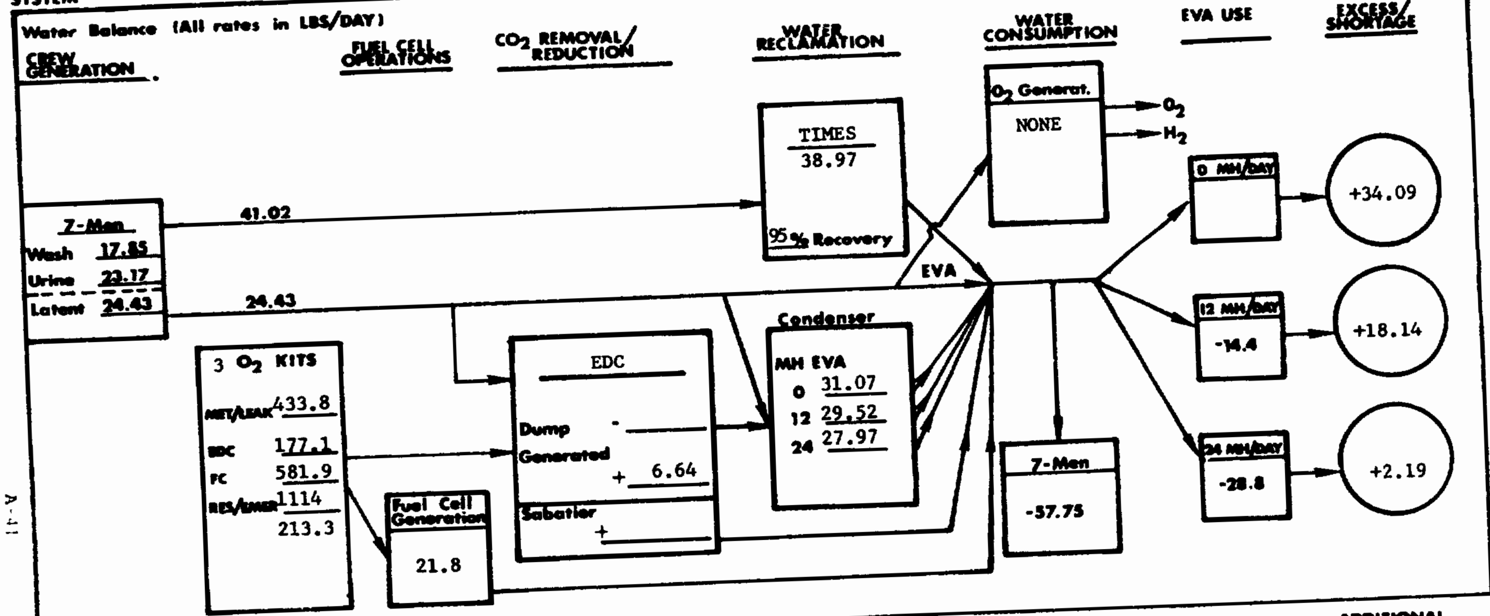
COMMENTS:

30 DAY SUMMARY

	CO_2 SUBS TOTAL	H_2O REC TOTAL	O_2 GEN TOTAL	ADDITIONAL H_2O REQUIRED	TOTALS	RE-ENTRY WEIGHT
WEIGHT (LBS)						
0 Man Hours/Day EVA	+94.0	+295.7	0	0	+389.7	-72.2
12 Man Hours/Day EVA	+94.0	+294.6	0	0	+388.6	-73.3
24 Man Hours/Day EVA	+94.0	+293.6	0	220	+607.6	+12.2
POWER (DC Watts)	+575	+315	0		+890	
VOLUME ($Ft.^3$)						
0 Man Hours/Day EVA	+3.5	+26.5	0	0	+30.0	
12 Man Hours/Day EVA	+3.5	+26.3	0	0	+29.8	
24 Man Hours/Day EVA	+3.5	+26.0	0	14	+43.5	
SENSIBLE HEAT REJECTION (BTU/HR)	+887	+1072	0		+1959	
LATENT HEAT REJECTION (BTU/HR)	+620	0	0		+620	

EXTENDED SHUTTLE ECLSS IMPACT SUMMARY

SYSTEM 30 Days - All Water Reclamation - Idle Fuel Cells - EDC CO_2 Removal

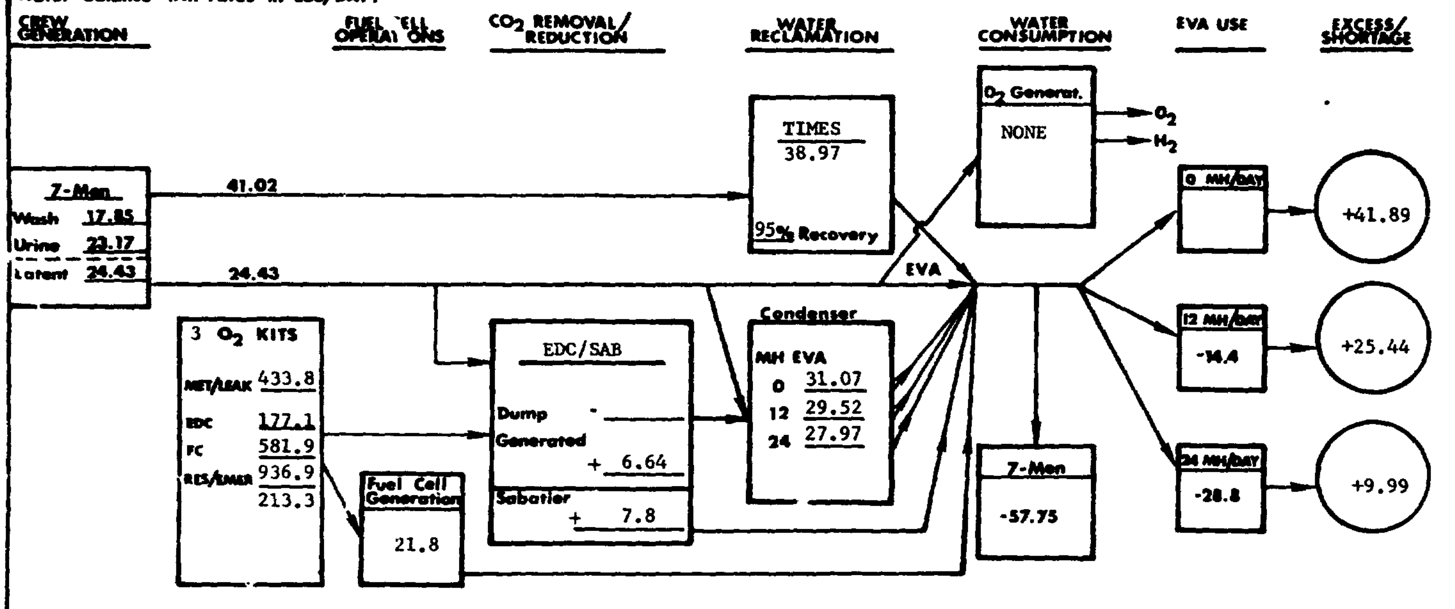


COMMENTS:

30 DAY SUMMARY	CO_2 SUBS TOTAL	H_2O REC TOTAL	O_2 GEN TOTAL	ADDITIONAL H_2O REQUIRED	TOTALS	RE-ENTRY WEIGHT
WEIGHT (LBS)						
0 Man Hours/Day EVA	+59.1	+295.7	0	0	+354.8	-107.1
12 Man Hours/Day EVA	+59.1	+294.6	0	0	+353.7	-108.2
24 Man Hours/Day EVA	+59.1	+293.6	0	0	+352.7	-109.2
POWER (DC Watts)	+336	+315	0		+651	
VOLUME ($Ft.^3$)						
0 Man Hours/Day EVA	-2.5	+26.5	0	0	+24.0	
12 Man Hours/Day EVA	-2.5	+26.3	0	0	+23.8	
24 Man Hours/Day EVA	-2.5	+26.0	0	0	+23.5	
SENSIBLE HEAT REJECTION (BTU/HR)	+2465	+1072	0		+3537	
LATENT HEAT REJECTION (BTU/HR)	+276	0	0		+276	

EXTENDED SHUTTLE ECLSS IMPACT SUMMARY

SYSTEM 30 Days - All Water Reclamation - Idle Fuel Cells - EDC with Sabatier Reactor-CO_2 Removal/Reduction



COMMENTS:

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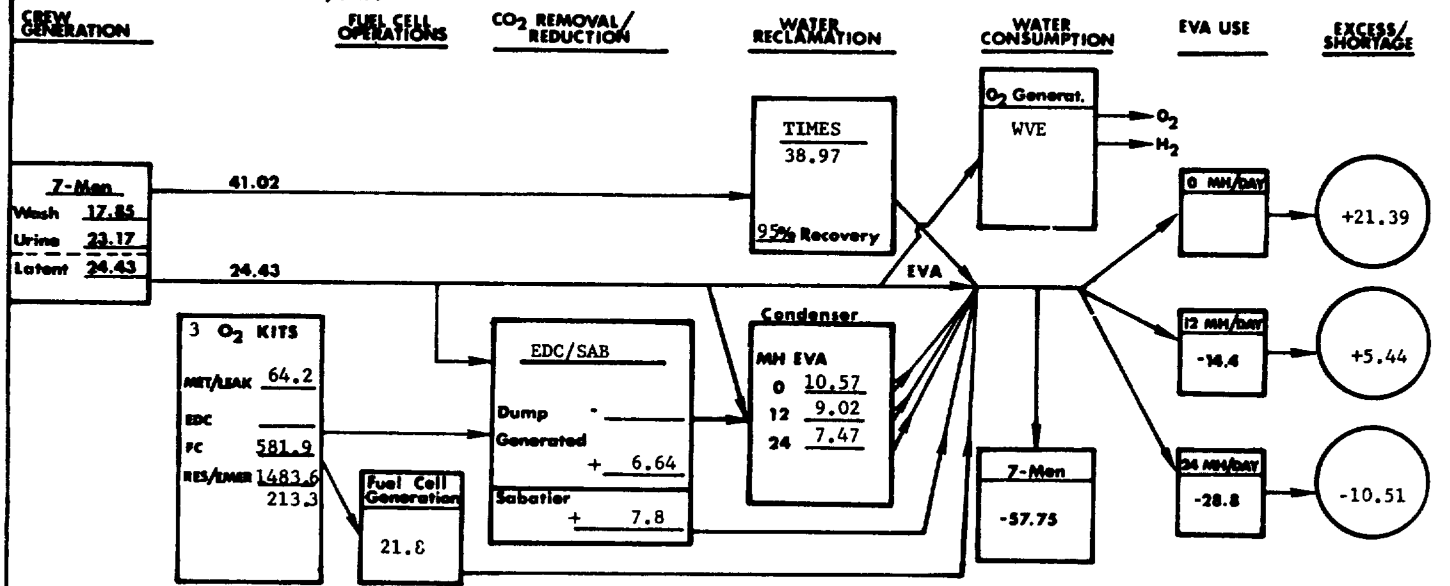
30 DAY SUMMARY

	CO_2 SUBS TOTAL	H_2O REC TOTAL	O_2 GEN TOTAL	ADDITIONAL H_2O REQUIRED	TOTALS	RE-ENTRY WEIGHT
WEIGHT (LBS)						
0 Man Hours/Day EVA	+174.7	+295.7	0	0	+470.4	+8.5
12 Man Hours/Day EVA	+174.7	+294.6	0	0	+469.3	+7.4
24 Man Hours/Day EVA	+174.7	+293.6	0	0	+468.3	+6.4
POWER (DC Watts)	+378	+315	0		+693	
VOLUME (Ft.^{3})						
0 Man Hours/Day EVA	+8.0	+26.5	0	0	+34.5	
12 Man Hours/Day EVA	+8.0	+26.3	0	0	+34.3	
24 Man Hours/Day EVA	+8.0	+26.0	0	0	+34.0	
SENSIBLE HEAT REJECTION (BTU/HR)	+3068	+ [illegible]	0		+4140	
LATENT HEAT REJECTION (BTU/HR)	+276	0	0		+276	

EXTENDED SHUTTLE ECLSS IMPACT SUMMARY

SYSTEM 30 Days - All Water Reclamation - Idle Fuel Cells - EDC/WVE with Sabatier Reactor–CO_2 Removal/Reduction

Water Balance (All rates in LBS/DAY)



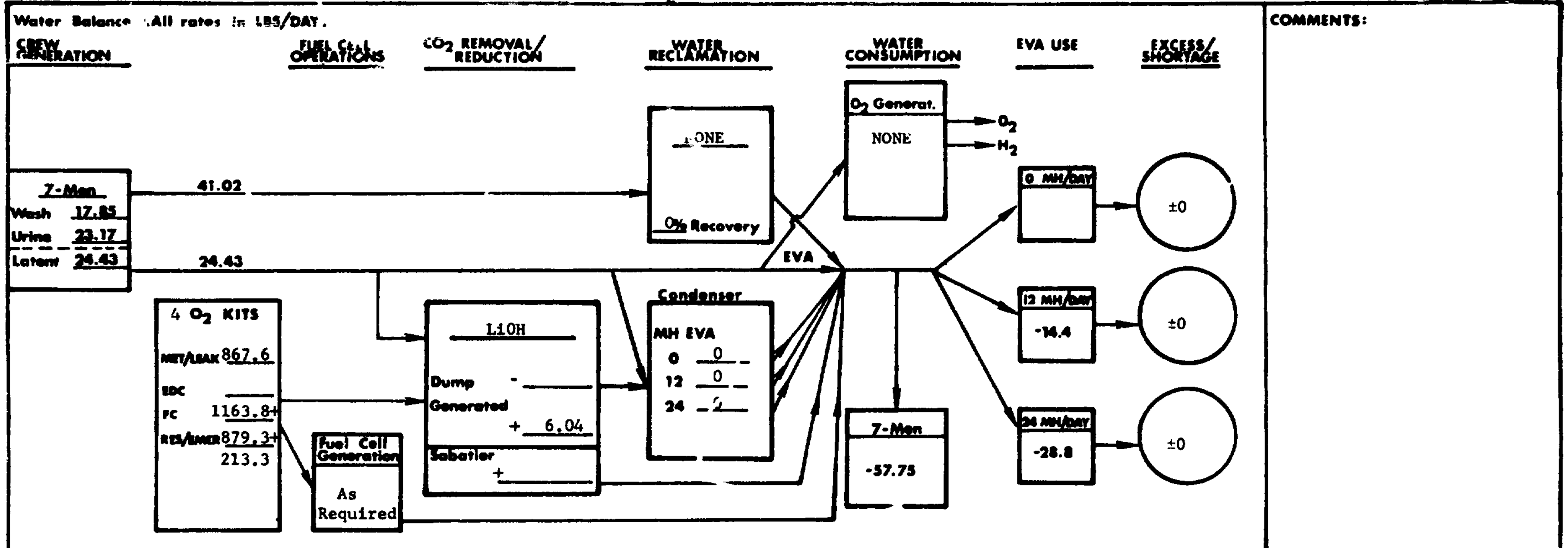
COMMENTS:

30 DAY SUMMARY

	CO_2 SUBS TOTAL	H_2O REC TOTAL	O_2 GEN TOTAL	ADDITIONAL H_2O REQUIRED	TOTALS	RE-ENTRY WEIGHT
WEIGHT (LBS)						
0 Man Hours/Day EVA	+174.7	+295.7	+205	0	+675.4	+213.5
12 Man Hours/Day EVA	+174.7	+294.6	+205	0	+674.3	+212.4
24 Man Hours/Day EVA	+174.7	+293.6	+205	540	+1213.3	+436.1
POWER (DC Watts)	+378	+315	+2000		+2693	
VOLUME (Ft.^{3})						
0 Man Hours/Day EVA	+8.0	+26.5	+6.3	0	+40.8	
12 Man Hours/Day EVA	+8.0	+26.3	+6.3	0	+40.6	
24 Man Hours/Day EVA	+8.0	+26.0	+6.3	14	+54.3	
SENSIBLE HEAT REJECTION (BTU/HR)	+3068	+1072	+2196		+6336	
LATENT HEAT REJECTION (BTU/HR)	+276	0	-1078		-802	

EXTENDED SHUTTLE ECLSS IMPACT SUMMARY

SYSTEM 60 Days - Waste Water Dump - Fuel Cell Scheduled - LiOH CO_2 Removal

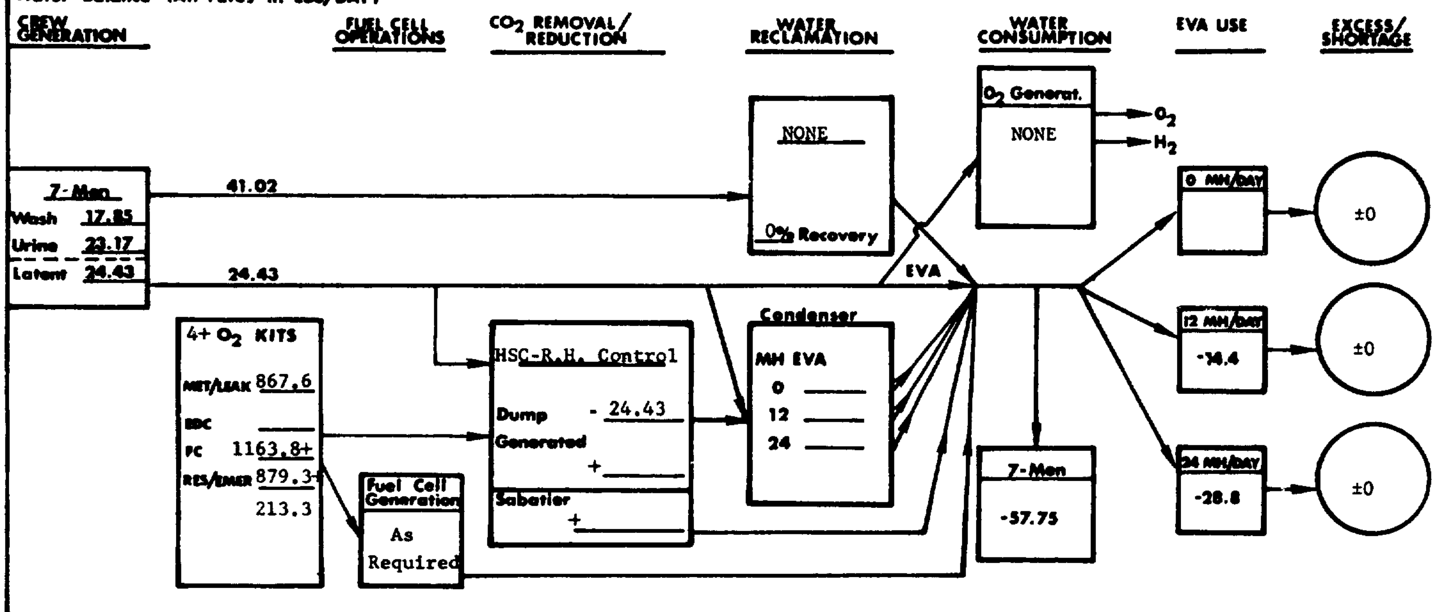


60 DAY SUMMARY

	CO_2 SUBS TOTAL	H_2O REC TOTAL	O_2 GEN TOTAL	ADDITIONAL H_2O REQUIRED	TOTALS	RE-ENTRY WEIGHT
WEIGHT (LBS)						
0 Man Hours/Day EVA	+2038.9	0	0	0	+2038.9	+2302.3
12 Man Hours/Day EVA	+2038.9	0	0	0	+2038.9	+2302.3
24 Man Hours/Day EVA	+2038.9	0	0	0	+2038.9	+2302.3
POWER (DC Watts)	±0	0	0		±0	
VOLUME (Ft.^{3})						
0 Man Hours/Day EVA	+105.7	0	0	0	+105.7	
12 Man Hours/Day EVA	+105.7	0	0	0	+105.7	
24 Man Hours/Day EVA	+105.7	0	0	0	+105.7	
SENSIBLE HEAT REJECTION (BTU/HR)	+509	0	0		+509	
LATENT HEAT REJECTION (BTU/HR)	+252	0	0		+252	

EXTENDED SHUTTLE ECLSS IMPACT SUMMARY

SYSTEM 60 Days - Waste Water Dump - Fuel Cell Scheduled - HSC - R.H. Control CO_2 Removal



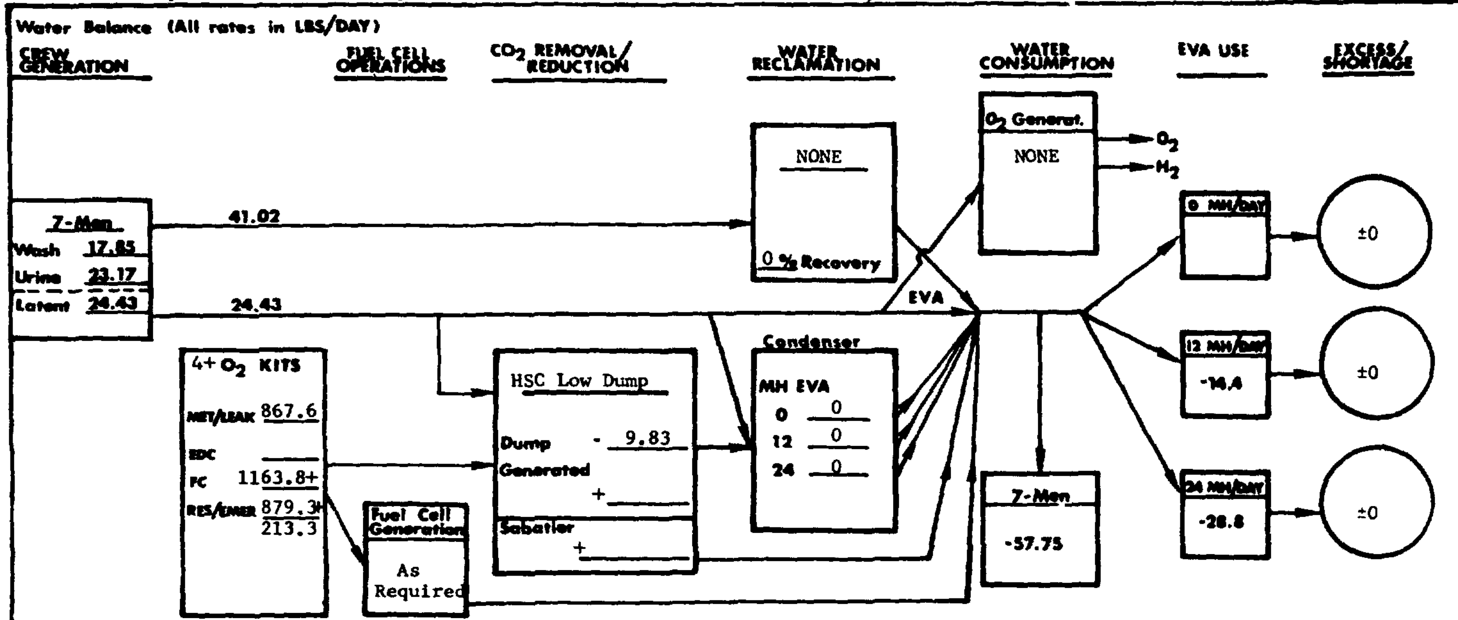
COMMENTS:

60 DAY SUMMARY

	CO_2 SUBS TOTAL	H_2O REC TOTAL	O_2 GEN TOTAL	ADDITIONAL H_2O REQUIRED	TOTALS	RE-ENTRY WEIGHT
WEIGHT (LBS)						
0 Man Hours/Day EVA	+99.9	0	0	0	+99.9	-805.1
12 Man Hours/Day EVA	+99.9	0	0	0	+99.9	-805.1
24 Man Hours/Day EVA	+99.9	0	0	0	+99.9	-805.1
POWER (DC Watts)	+117	0	0		+117	
VOLUME ($Ft.^3$)						
0 Man Hours/Day EVA	+2.4	0	0	0	+2.4	
12 Man Hours/Day EVA	+2.4	0	0	0	+2.4	
24 Man Hours/Day EVA	+2.4	0	0	0	+2.4	
SENSIBLE HEAT REJECTION (BTU/HR)	+399	0	0		+399	
LATENT HEAT REJECTION (BTU/HR)	-1018	0	0		-1018	

EXTENDED SHUTTLE ECLSS IMPACT SUMMARY

SYSTEM 60 Days - Waste Water Dump - Fuel Cell Scheduled - HSC Low Dump CO_2 Removal



COMMENTS:

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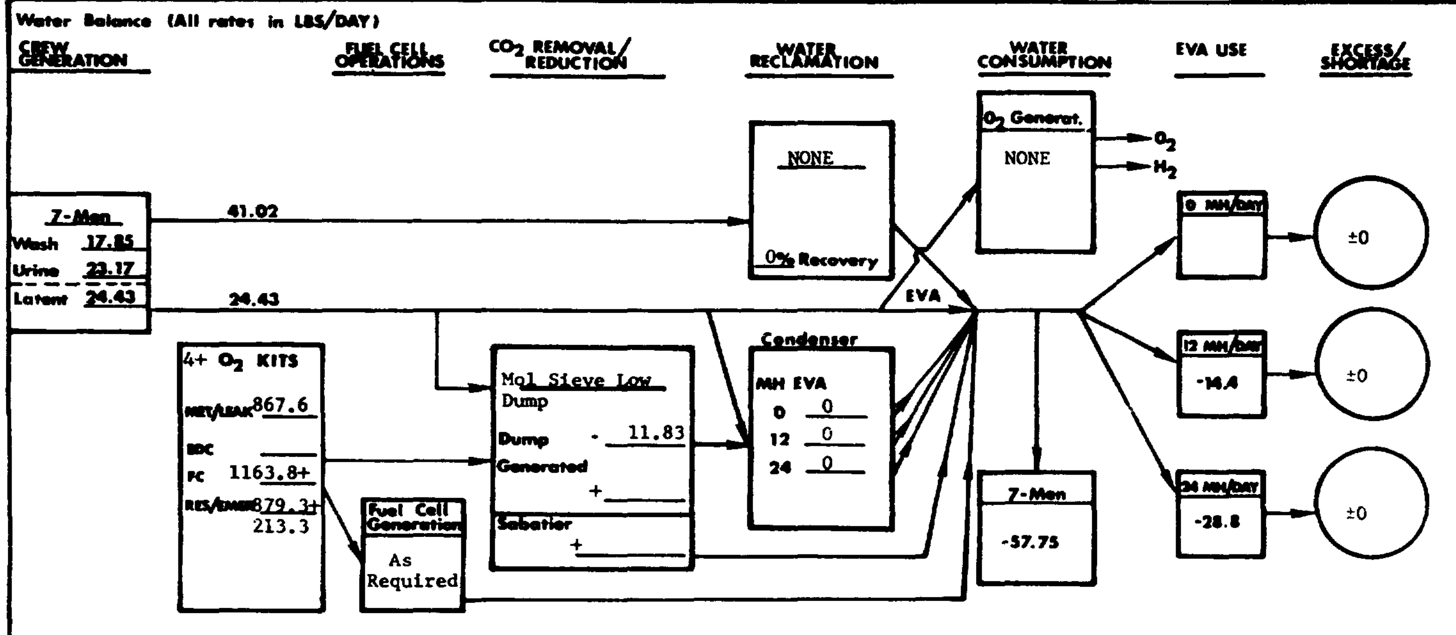
60 DAY SUMMARY

	CO_2 SUBS TOTAL	H_2O REC TOTAL	O_2 GEN TOTAL	ADDITIONAL H_2O REQUIRED	TOTALS	RE-ENTRY WEIGHT
WEIGHT (LBS)						
0 Man Hours/Day EVA	+138.6	0	0	0	+138.6	-766.4
12 Man Hours/Day EVA	+138.6	0	0	0	+138.6	-766.4
24 Man Hours/Day EVA	+138.6	0	0	0	+138.6	-766.4
POWER (DC Watts)	+89	0	0		+89	
VOLUME (Ft.^{3})						
0 Man Hours/Day EVA	+1.0	0	0	0	+1.0	
12 Man Hours/Day EVA	+1.0	0	0	0	+1.0	
24 Man Hours/Day EVA	+1.0	0	0	0	+1.0	
SENSIBLE HEAT REJECTION (BTU/HR)	+304	0	0		+304	
LATENT HEAT REJECTION (BTU/HR)	-410	0	0		-410	

EXTENDED SHUTTLE ECLSS IMPACT SUMMARY

SYSTEM 60 Days - Waste Water Dump - Fuel Cell Scheduled - Mol Sieve Low Dump CO_2 Removal



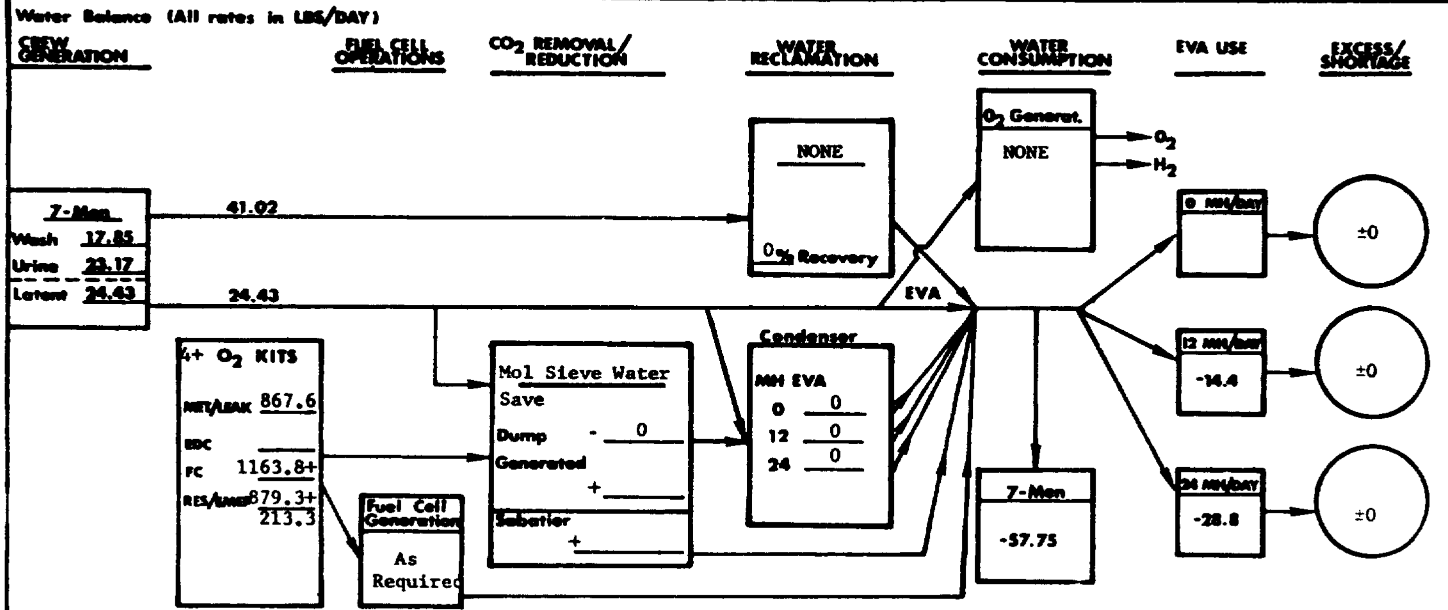
COMMENTS:

60 DAY SUMMARY

	CO_2 SUBS TOTAL	H_2O REC TOTAL	O_2 GEN TOTAL	ADDITIONAL H_2O REQUIRED	TOTALS	RE-ENTRY WEIGHT
WEIGHT (LBS)						
0 Man Hours/Day EVA	+89.1	0	0	0	+89.1	-815.9
12 Man Hours/Day EVA	+89.1	0	0	0	+89.1	-815.9
24 Man Hours/Day EVA	+89.1	0	0	0	+89.1	-815.9
POWER (DC Watts)	+63	0	0		+63	
VOLUME (Ft.^{3})						
0 Man Hours/Day EVA	+3.6	0	0	0	+3.6	
12 Man Hours/Day EVA	+3.6	0	0	0	+3.6	
24 Man Hours/Day EVA	+3.6	0	0	0	+3.6	
SENSIBLE HEAT REJECTION (BTU/HR)	+215	0	0		+215	
LATENT HEAT REJECTION (BTU/HR)	-524	0	0		-524	

EXTENDED SHUTTLE ECLSS IMPACT SUMMARY

SYSTEM 60 Days - Waste Water Dump - Fuel Cell Scheduled - Mol Sieve Water Save CO_2 Removal



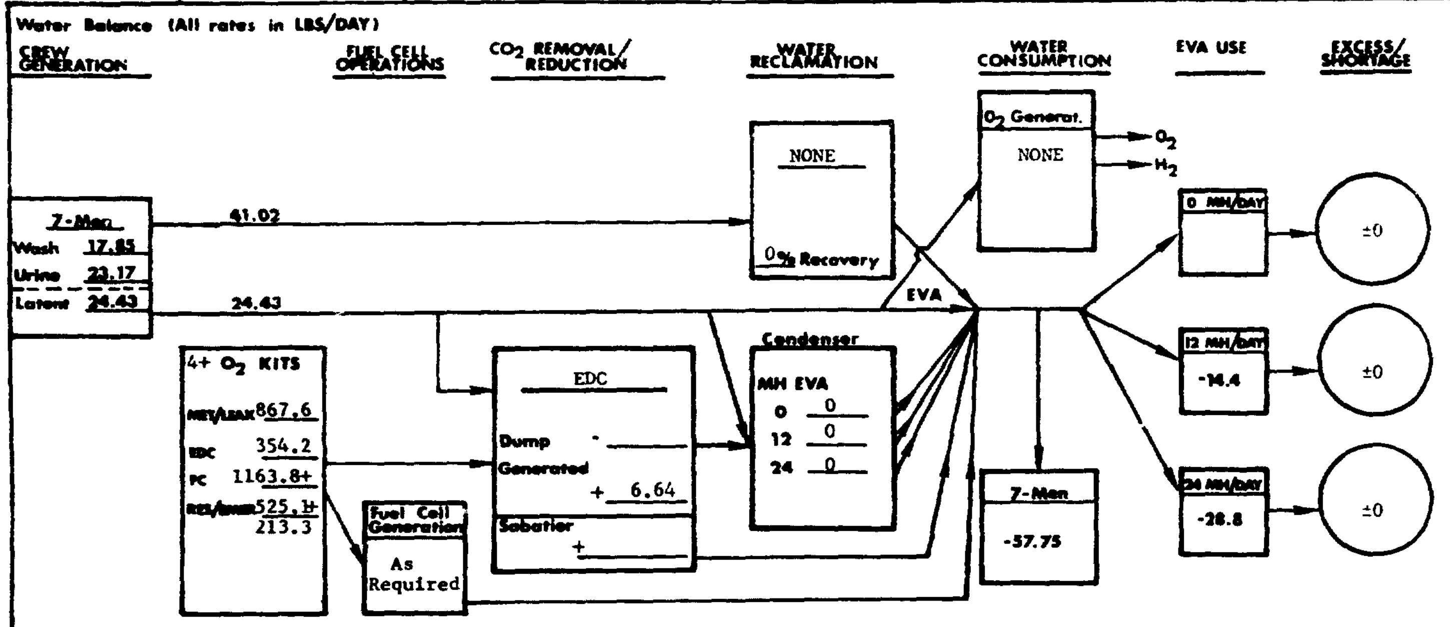
COMMENTS:

60 DAY SUMMARY

	CO_2 SUBS TOTAL	H_2O REC TOTAL	O_2 GEN TOTAL	ADDITIONAL H_2O REQUIRED	TOTALS	RE-ENTRY WEIGHT
WEIGHT (LBS)						
0 Man Hours/Day EVA	+94.0	0	0	0	+94.0	-811.1
12 Man Hours/Day EVA	+94.0	0	0	0	+94.0	-811.1
24 Man Hours/Day EVA	+94.0	0	0	0	+94.0	-811.1
POWER (DC Watts)	+575	0	0		+575	
VOLUME (Ft.^{3})						
0 Man Hours/Day EVA	+3.5	0	0	0	+3.5	
12 Man Hours/Day EVA	+3.5	0	0	0	+3.5	
24 Man Hours/Day EVA	+3.5	0	0	0	+3.5	
SENSIBLE HEAT REJECTION (BTU/HR)	+887	0	0		+887	
LATENT HEAT REJECTION (BTU/HR)	+620	0	0		+620	

EXTENDED SHUTTLE ECLSS IMPACT SUMMARY

SYSTEM 60 Days - Waste Water Dump - Fuel Cell Scheduled - EDC CO_2 Removal



COMMENTS:

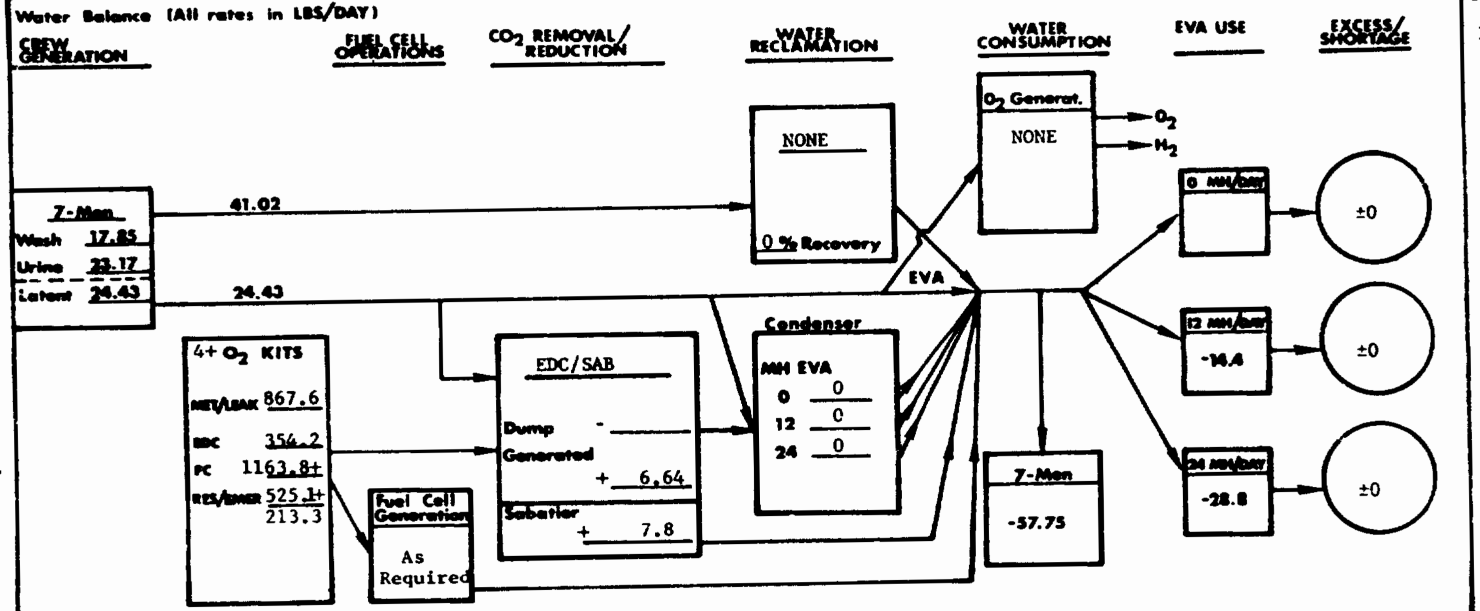
1. Cryogenic O_2 Usage Penalty Applied.

60 DAY SUMMARY	CO_2 SUBS TOTAL	H_2O R.C TOTAL	O_2 GEN TOTAL	ADDITIONAL H_2O REQUIRED	TOTALS	RE-ENTRY WEIGHT
WEIGHT (LBS)						
0 Man Hours/Day EVA	+413.3	0	0	0	+413.3	-491.7
12 Man Hours/Day EVA	+413.3	0	0	0	+413.3	-491.7
24 Man Hours/Day EVA	+413.3	0	0	0	+413.3	-491.7
POWER (DC Watts)	+336	0	0		+336	
VOLUME (Ft.^{3})						
0 Man Hours/Day EVA	-2.5	0	0	0	-2.5	
12 Man Hours/Day EVA	-2.5	0	0	0	-2.5	
24 Man Hours/Day EVA	-2.5	0	0	0	-2.5	
SENSIBLE HEAT REJECTION (BTU/HR)	+2465	0	0		+2465	
LATENT HEAT REJECTION (BTU/HR)	+276	0	0		+276	

EXTENDED SHUTTLE ECLSS IMPACT SUMMARY

SYSTEM 60 Days - Waste Water Dump - Fuel Cell Scheduled - EDC with Sabatier Reactor CO_2 Removal/Reduction

Water Balance (All rates in LBS/DAY)



COMMENTS:

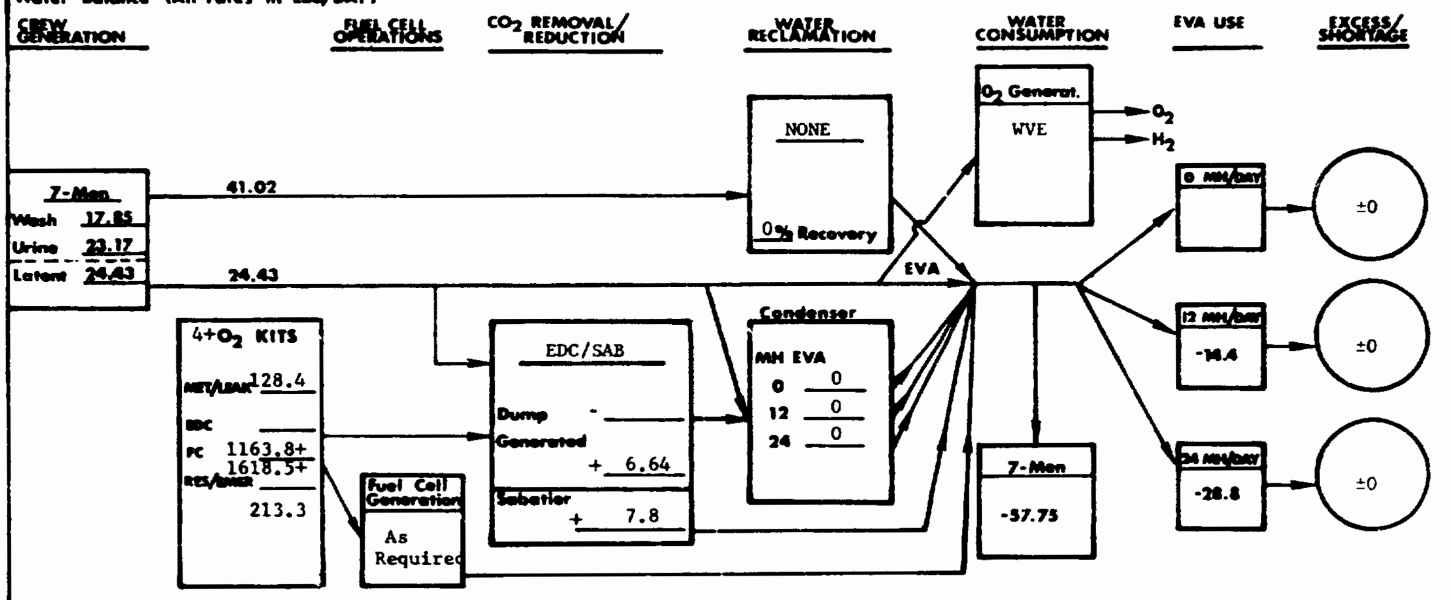
1. EDC/SAB cryogenic O_2 usage penalty applied.

60 DAY SUMMARY	CO_2 SUBS TOTAL	H_2O REC TOTAL	O_2 GEN TOTAL	ADDITIONAL H_2O REQUIRED	TOTALS	RE-ENTRY WEIGHT
WEIGHT (LBS)						
0 Man Hours/Day EVA	+528.9	0	0	0	+528.9	-376.1
12 Man Hours/Day EVA	+528.9	0	0	0	+528.9	-376.1
24 Man Hours/Day EVA	+528.9	0	0	0	+528.9	-376.1
POWER (DC Watts)	+378	0	0		+379	
VOLUME ($Ft.^3$)						
0 Man Hours/Day EVA	+8.0	0	0	0	+8.0	
12 Man Hours/Day EVA	+8.0	0	0	0	+8.0	
24 Man Hours/Day EVA	+8.0	0	0	0	+8.0	
SENSIBLE HEAT REJECTION (BTU/HR)	+3068	0	0		+3068	
LATENT HEAT REJECTION (BTU/HR)	+276	0	0		+276	

EXTENDED SHUTTLE ECLSS IMPACT SUMMARY

SYSTEM 60 Days - Waste Water Dump - Fuel Cell Scheduled - EDC/WVE with Sabatier Reactor CO_2 Removal/Reduction

Water Balance (All rates in LBS/DAY)



COMMENTS:

1. EDC/WVE given credit for O_2 generation.

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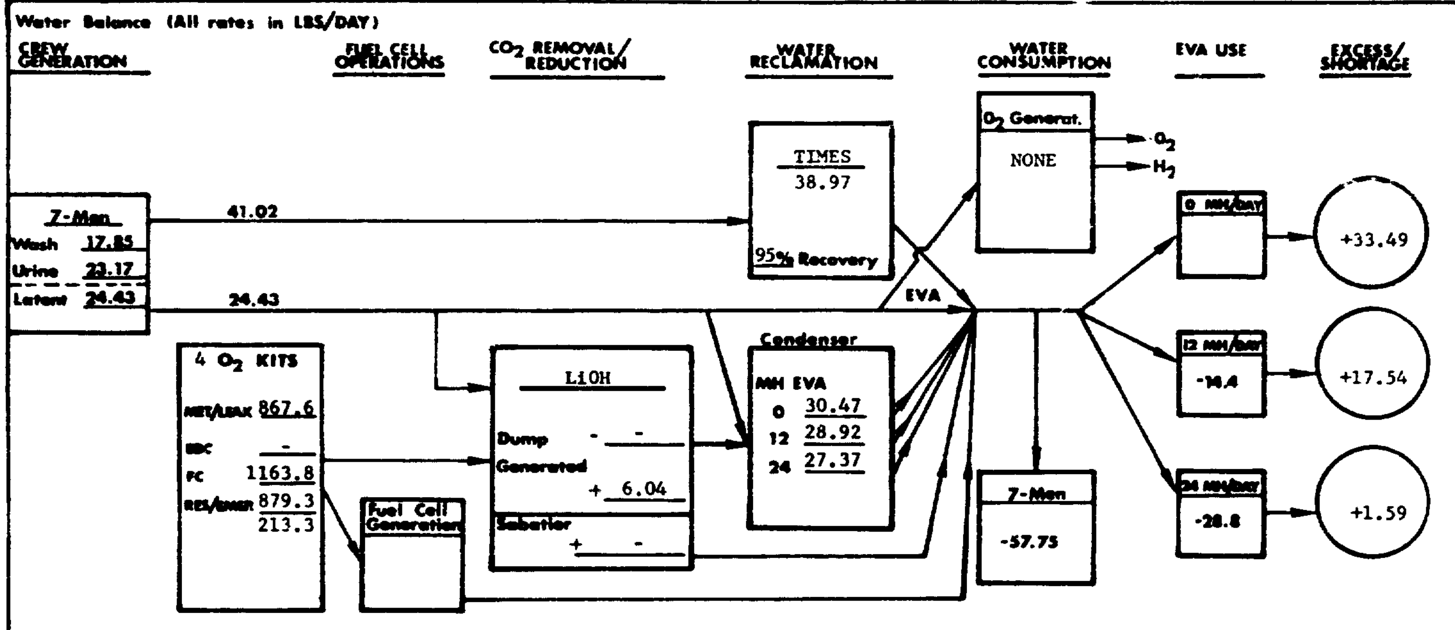
60 DAY SUMMARY

	CO_2 SUBS TOTAL	H_2O REC TOTAL	O_2 GEN TOTAL	ADDITIONAL H_2O REQUIRED	TOTALS	RE-ENTRY WEIGHT
WEIGHT (LBS)						
0 Man Hours/Day EVA	+174.7	0	-888.4	0	-713.7	-1618.7
12 Man Hours/Day EVA	+174.7	0	-888.4	0	-713.7	-1618.7
24 Man Hours/Day EVA	+174.7	0	-888.4	0	-713.7	-1618.7
POWER (DC Watts)	+378	0	+2000		+2378	
VOLUME (Ft.^{3})						
0 Man Hours/Day EVA	+8.0	0	+6.3	0	+14.3	
12 Man Hours/Day EVA	+8.0	0	+6.3	0	+14.3	
24 Man Hours/Day EVA	+8.0	0	+6.3	0	+14.3	
SENSIBLE HEAT REJECTION (BTU/HR)	+3068	0	+2196		+5264	
LATENT HEAT REJECTION (BTU/HR)	+276	0	-1078		-802	

EXTENDED SHUTTLE ECLSS IMPACT SUMMARY

SYSTEM 60 Days - All Water Reclamation - LiOH CO_2 Removal



COMMENTS:

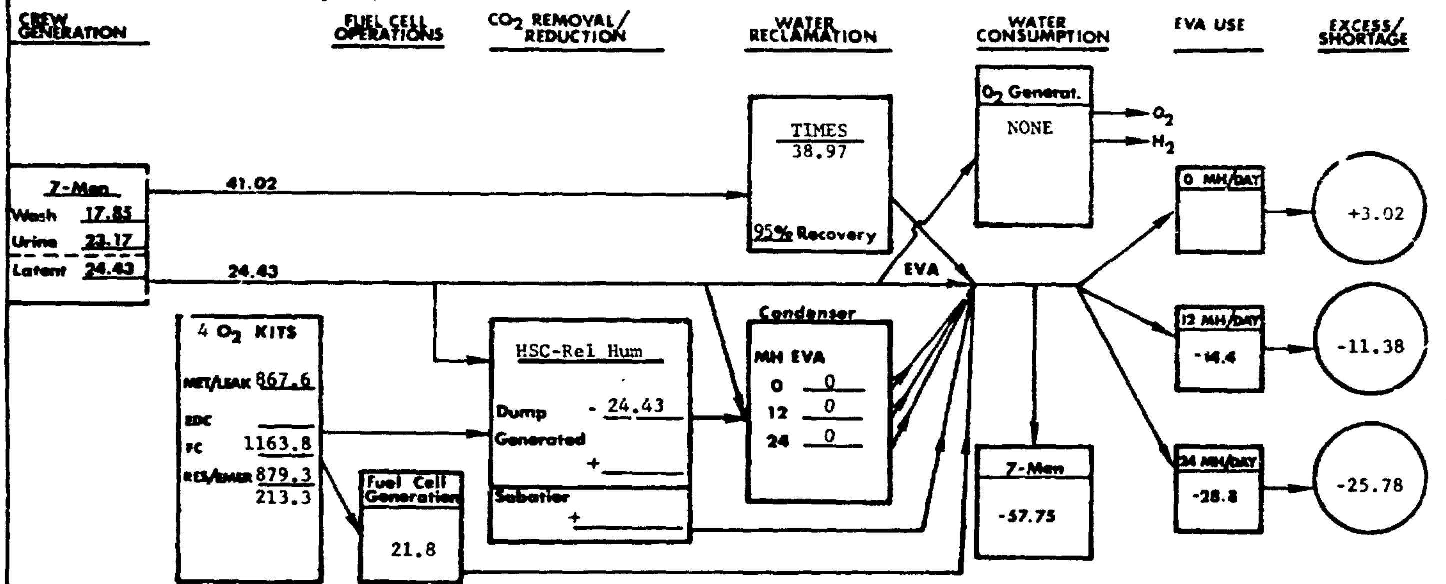
60 DAY SUMMARY

	CO_2 SUBS TOTAL	H_2O REC TOTAL	O_2 GEN TOTAL	ADDITIONAL H_2O REQUIRED	TOTALS	RE-ENTRY WEIGHT
WEIGHT (LBS)						
0 Man Hours/Day EVA	+2038.9	+341.1	0	0	+2380.0	+2643.3
12 Man Hours/Day EVA	+2038.9	+339.2	0	0	+2378.1	+2641.4
24 Man Hours/Day EVA	+2033.9	+337.2	0	0	+2376.1	+2639.4
POWER (DC Watts)	±0	+315	0		+315	
VOLUME (Ft.^{3})						
0 Man Hours/Day EVA	+105.7	+32.6	0	0	+138.3	
12 Man Hours/Day EVA	+105.7	+32.3	0	0	+138.0	
24 Man Hours/Day EVA	+105.7	+32.0	0	0	+137.7	
SENSIBLE HEAT REJECTION (BTU/HR)	+509	+1072	0		+1581	
LATENT HEAT REJECTION (BTU/HR)	+252	0	0		+252	

EXTENDED SHUTTLE ECLSS IMPACT SUMMARY

SYSTEM 60 Days - All Water Reclamation - HSC - R.H. Control CO_2 Removal

Water Balance (All rates in LBS/DAY)



COMMENTS:

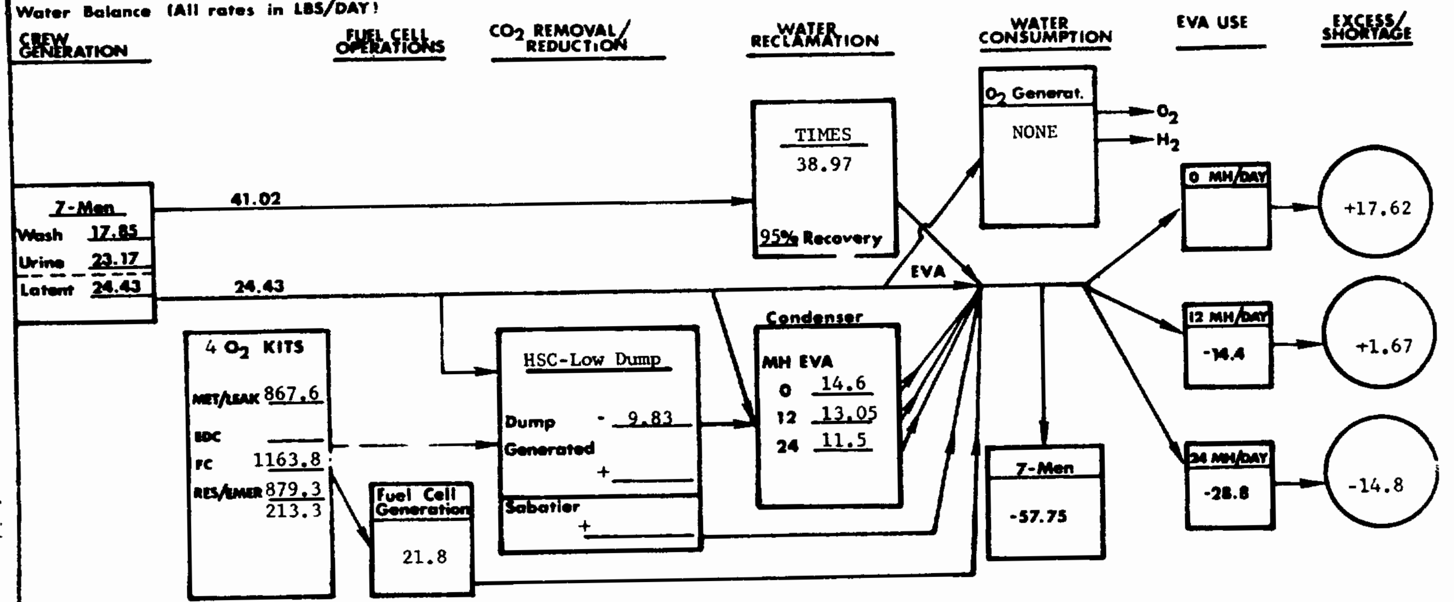
60 DAY SUMMARY

	CO_2 SUBS TOTAL	H_2O REC TOTAL	O_2 GEN TOTAL	ADDITIONAL H_2O REQUIRED	TOTALS	RE-ENTRY WEIGHT
WEIGHT (LBS)						
0 Man Hours/Day EVA	+99.9	+285.2	0	0	+385.1	-519.9
12 Man Hours/Day EVA	+99.9	+285.2	0	1220	+1605.1	+17.3
24 Man Hours/Day EVA	+99.9	+285.2	0	2580	+2965.1	+513.3
POWER (DC Watts)	+117	+300	0		+417	
VOLUME (Ft.^{3})						
0 Man Hours/Day EVA	+2.4	+25.3	0	0	+27.7	
12 Man Hours/Day EVA	+2.4	+25.3	0	35	+62.7	
24 Man Hours/Day EVA	+2.4	+25.3	0	70	+97.7	
SENSIBLE HEAT REJECTION (BTU/HR)	+399	+1021	0		+1420	
LATENT HEAT REJECTION (BTU/HR)	-1018	0	0		-1018	

EXTENDED SHUTTLE ECLSS IMPACT SUMMARY

SYSTEM 60 Days - All Water Reclamation - HSC Low Dump CO_2 Removal

Water Balance (All rates in LBS/DAY)



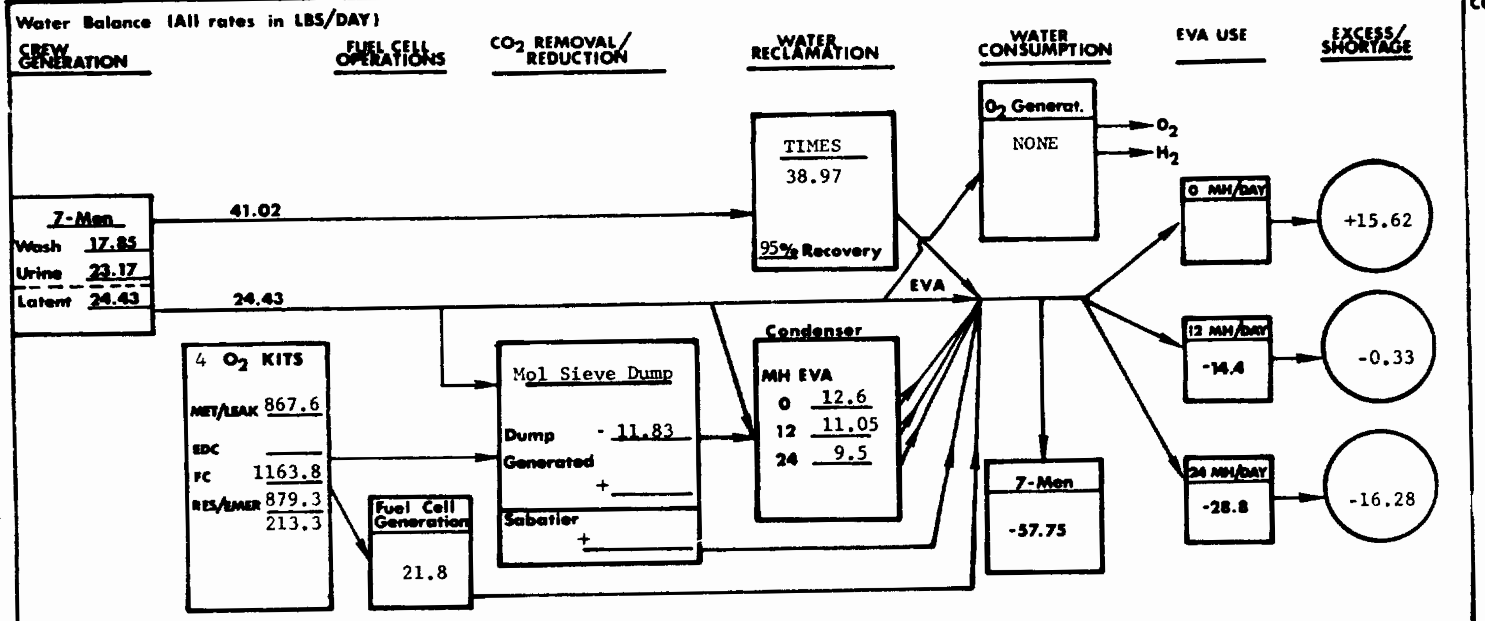
COMMENTS:

60 DAY SUMMARY

	CO_2 SUBS TOTAL	H_2O REC TOTAL	O_2 GEN TOTAL	ADDITIONAL H_2O REQUIRED	TOTALS	RE-ENTRY WEIGHT
WEIGHT (LBS)						
0 Man Hours/Day EVA	+138.6	+341.1	0	0	+479.7	-425.3
12 Man Hours/Day EVA	+138.6	+339.2	0	0	+477.8	-427.2
24 Man Hours/Day EVA	+138.6	+337.2	0	1480	+1955.8	+162.8
POWER (DC Watts)	+89	+315	0		+404	
VOLUME (Ft.^{3})						
0 Man Hours/Day EVA	+1.0	+32.6	0	0	+33.6	
12 Man Hours/Day EVA	+1.0	+32.3	0	0	+33.3	
24 Man Hours/Day EVA	+1.0	+32.0	0	+42	+75.0	
SENSIBLE HEAT REJECTION (BTU/HR)	+304	+1072	0		+1376	
LATENT HEAT REJECTION (BTU/HR)	-410	0	0		-410	

EXTENDED SHUTTLE ECLSS IMPACT SUMMARY

SYSTEM 60 Days - All Water Reclamation - Mol Sieve Low Dump CO_2 Removal



COMMENTS:

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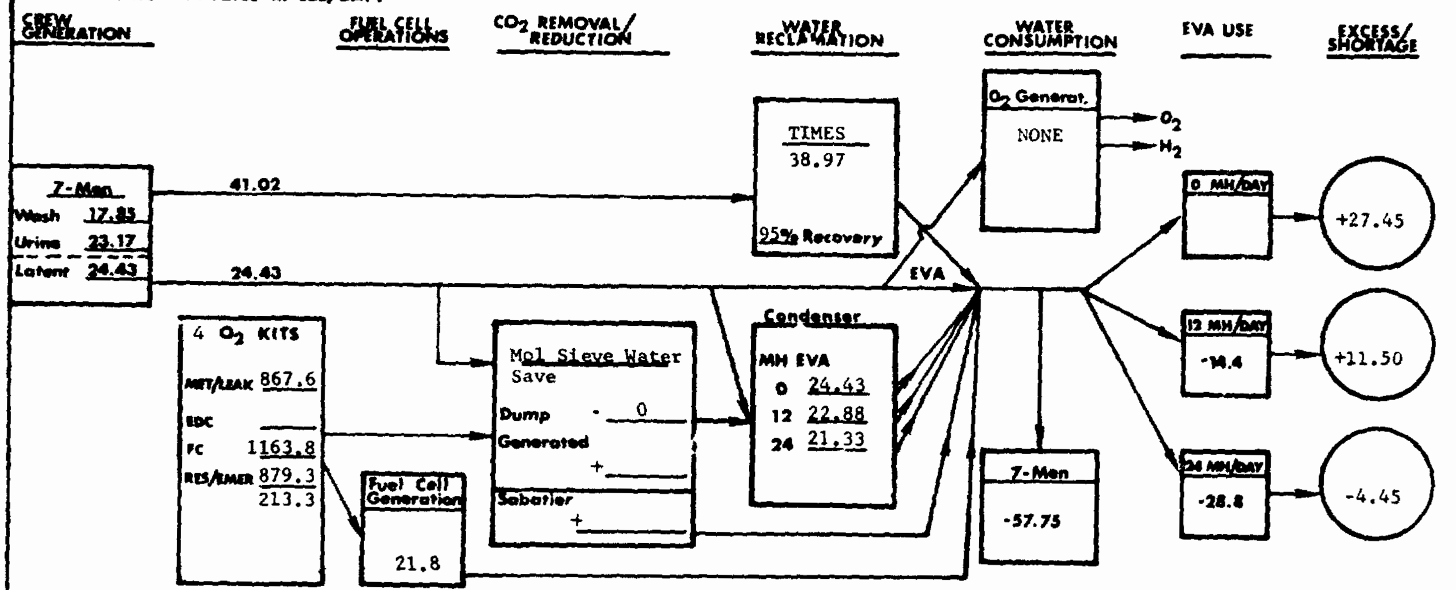
60 DAY SUMMARY	CO_2 SUBS TOTAL	H_2O REC TOTAL	O_2 GEN TOTAL	ADDITIONAL H_2O REQUIRED	TOTALS	RE-ENTRY WEIGHT
WEIGHT (LBS)						
0 Man Hours/Day EVA	+89.1	+341.1	0	0	+430.2	-418.5
12 Man Hours/Day EVA	+89.1	+339.2	0	90	+518.3	-406.5
24 Man Hours/Day EVA	+89.1	+337.2	0	1600	+2028.3	+146.5
POWER (DC Watts)	+63	+315			+378	
VOLUME (Ft^3)						
0 Man Hours/Day EVA	+3.6	+32.6	0	0	+36.2	
12 Man Hours/Day EVA	+3.6	+32.3	0	7	+42.9	
24 Man Hours/Day EVA	+3.6	+32.0	0	42	+77.6	
SENSIBLE HEAT REJECTION (BTU/HR)	+215	+1072	0		+1287	
LATENT HEAT REJECTION (BTU/HR)	-524	0	0		-524	

EXTENDED SHUTTLE ECLSS IMPACT SUMMARY

SYSTEM 60 Days - All Water Reclamation - Mol Sieve Water Save CO_2 Removal

Water Balance (All rates in LBS/DAY)



COMMENTS:

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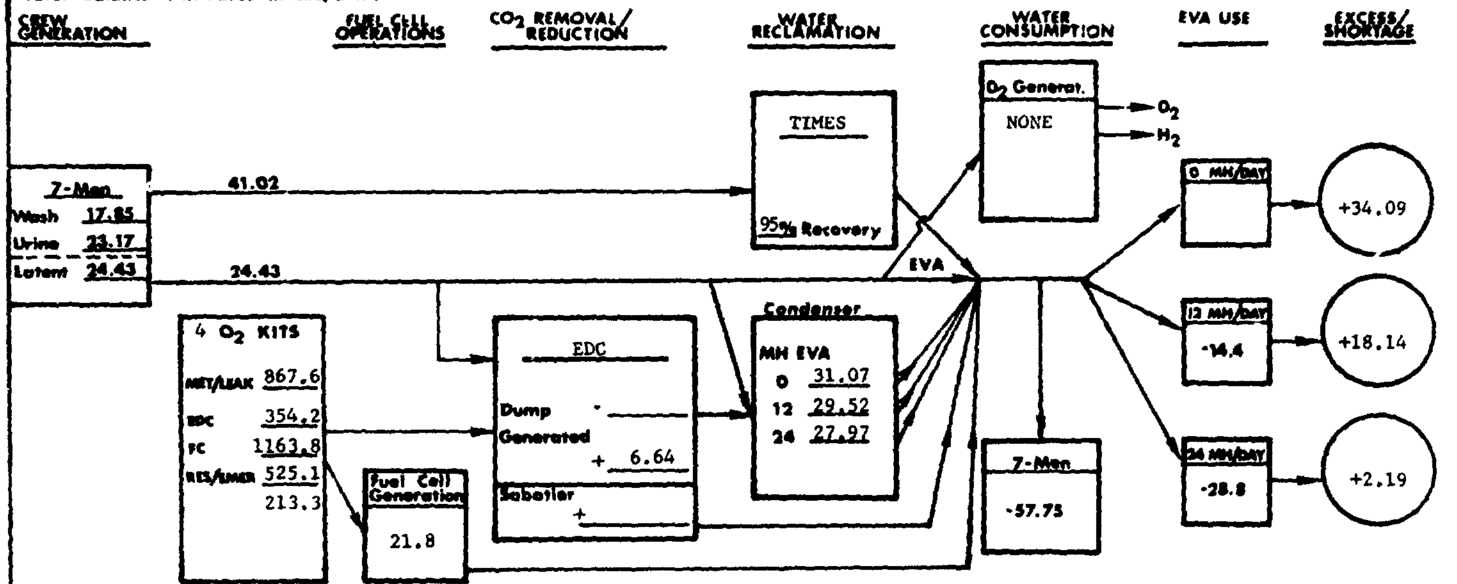
60 DAY SUMMARY

	CO_2 SUBS TOTAL	H_2O REC TOTAL	O_2 GEN TOTAL	ADDITIONAL H_2O REQUIRED	TOTALS	RE-ENTRY WEIGHT
WEIGHT (LBS)						
0 Man Hours/Day EVA	+94.0	341.1	0	0	+435.1	-469.9
12 Man Hours/Day EVA	+94.0	339.2	0	0	+433.2	-471.8
24 Man Hours/Day EVA	+94.0	337.2	0	440	+871.2	-300.8
POWER (DC Watts)	+575	+315	0		+890	
VOLUME ($Ft.^3$)						
0 Man Hours/Day EVA	+3.5	32.6	0	0	+36.1	
12 Man Hours/Day EVA	+3.5	32.3	0	0	+35.8	
24 Man Hours/Day EVA	+3.5	32.0	0	14	+49.5	
SENSIBLE HEAT REJECTION (BTU/HR)	+887	+1072	0		+1959	
LATENT HEAT REJECTION (BTU/HR)	+620	0	0		+620	

EXTENDED SHUTTLE ECLSS IMPACT SUMMARY

SYSTEM 60 Days - All Water Reclamation - EDC CO_2 Removal

Water Balance (All rates in LBS/DAY)

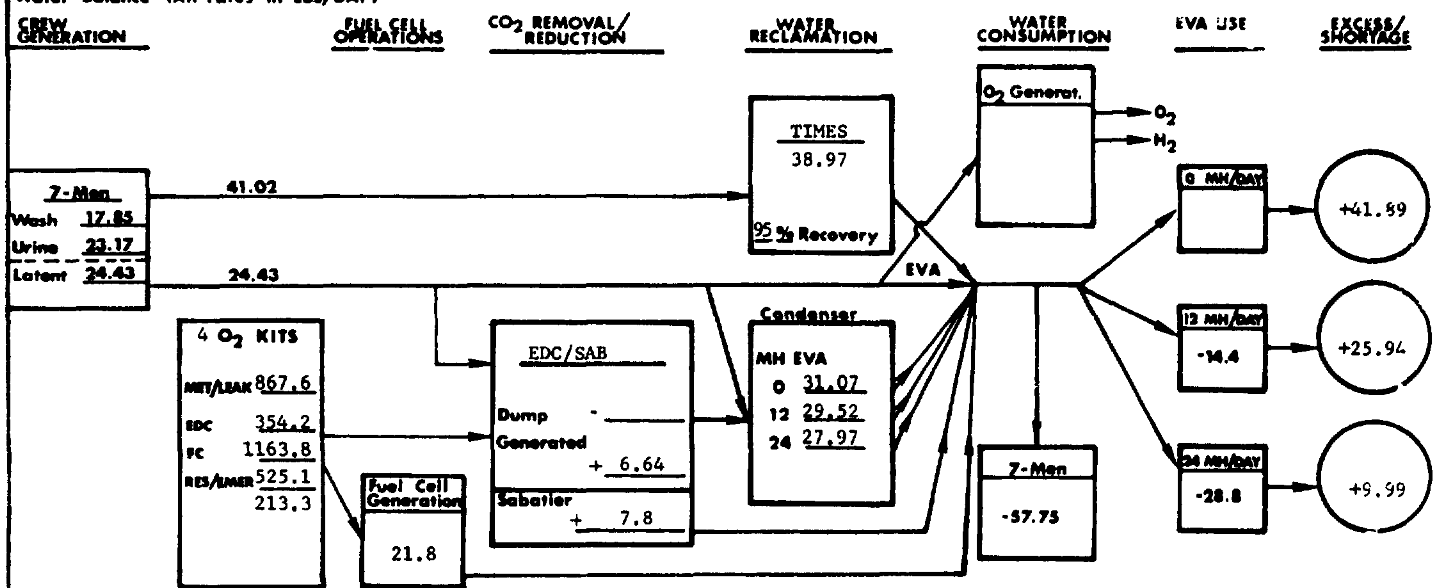


COMMENTS:

60 DAY SUMMARY	CO_2 SUBS TOTAL	H_2O REC TOTAL	O_2 GEN TOTAL	ADDITIONAL H_2O REQUIRED	TOTALS	RE-ENTRY WEIGHT
WEIGHT (LBS)						
0 Man Hours/Day EVA	+59.1	+341.1	0	0	+400.2	-508.8
12 Man Hours/Day EVA	+59.1	+339.2	0	0	+399.3	-505.7
24 Man Hours/Day EVA	+59.1	+337.2	0	0	+398.3	-506.7
POWER (DC Watts)	+336	+315	0		+651	
VOLUME ($Ft.^3$)						
0 Man Hours/Day EVA	-2.5	+32.6	0	0	+30.1	
12 Man Hours/Day EVA	-2.5	+32.3	0	0	+29.8	
24 Man Hours/Day EVA	-2.5	+32.0	0	0	+29.5	
SENSIBLE HEAT REJECTION (BTU/HR)	+2465.4	+1072	0		+3537	
LATENT HEAT REJECTION (BTU/HR)	276	0	0		+276	

EXTENDED SHUTTLE ECLSS IMPACT SUMMARY

SYSTEM 60 Days - All Water Reclamation EDC with Sabatier Reactor CO_2 Removal/Reduction



COMMENTS:

60 DAY SUMMARY

	CO_2 SUBS TOTAL	H_2O REC TOTAL	O_2 GEN TOTAL	ADDITIONAL H_2O REQUIRED	TOTALS	RE-ENTRY WEIGHT
WEIGHT (LBS)						
0 Man Hours/Day EVA	+174.7	+341.1	0	0	+515.8	-389.2
12 Man Hours/Day EVA	+174.7	+339.2	0	0	+513.9	-391.1
24 Man Hours/Day EVA	+174.7	+337.2	0	0	+511.9	+393.1
POWER (DC Watts)	+378	+315	0		+693	
VOLUME (Ft.^{3})						
0 Man Hours/Day EVA	+8.0	+32.6	0	0	+40.6	
12 Man Hours/Day EVA	+8.0	+32.3	0	0	+40.3	
24 Man Hours/Day EVA	+8.0	+32.0	0	0	+40.0	
SENSIBLE HEAT REJECTION (BTU/HR)	+3068	+1072	0		+4140	
LATENT HEAT REJECTION (BTU/HR)	+276	0	0		+276	

EXTENDED SHUTTLE ECLSS IMPACT SUMMARY

SYSTEM 60 Days - All Water Reclamation - EDC/WVE with Sabatier Reactor CO_2 Removal/Reduction

COMMENTS:

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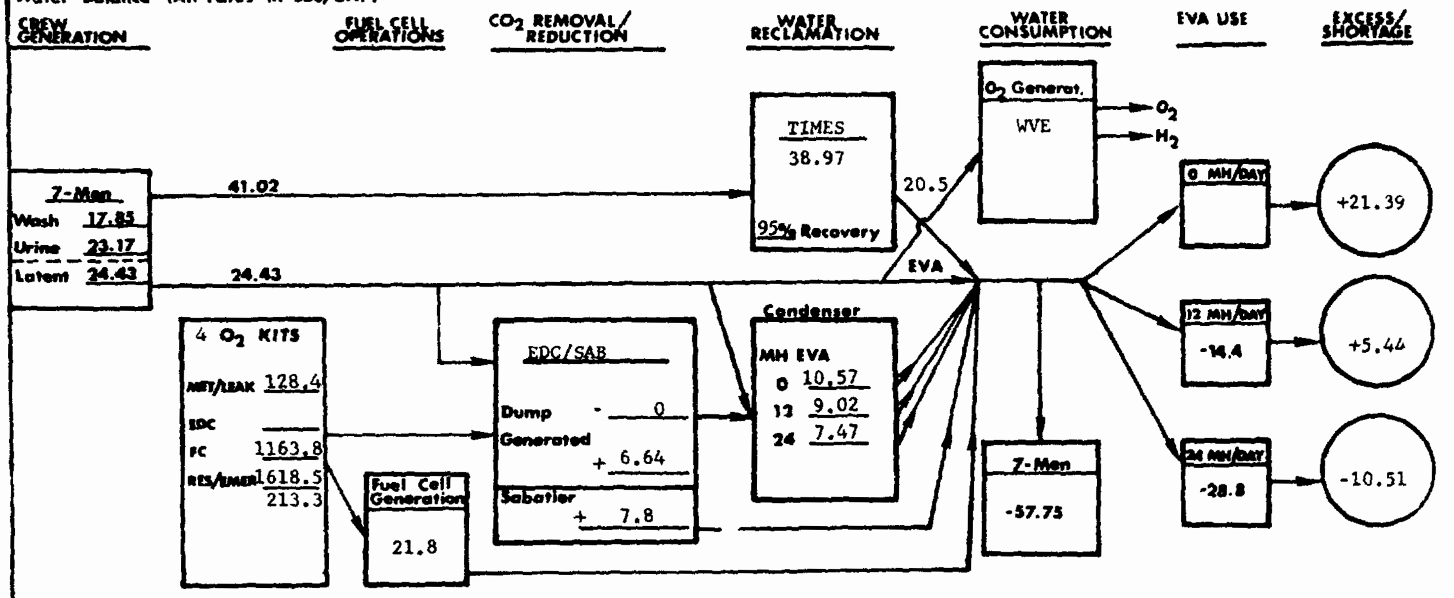
Water Balance (All rates in LBS/DAY)

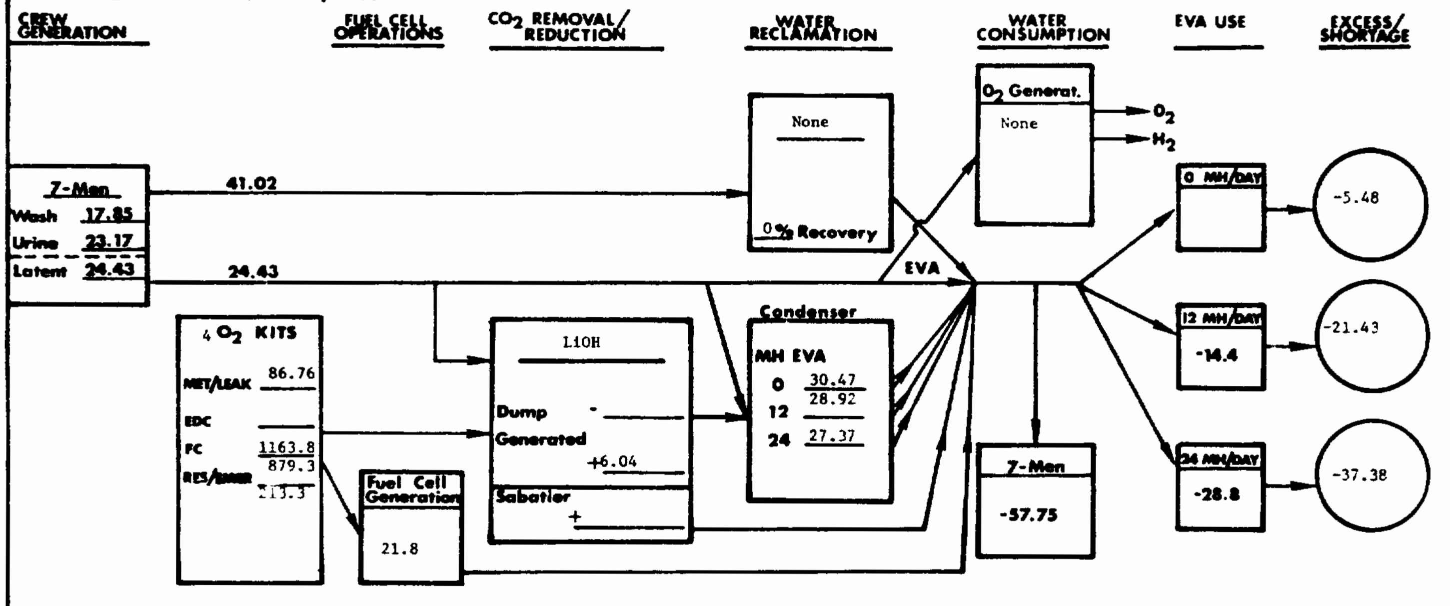


60 DAY SUMMARY

	CO_2 SUBS TOTAL	H_2O REC TOTAL	O_2 GEN TOTAL	ADDITIONAL H_2O REQUIRED	TOTALS	RE-ENTRY WEIGHT
WEIGHT (LBS)						
0 Man Hours/Day EVA	+174.7	+341.1	+205	0	+720.8	-184.2
12 Man Hours/Day EVA	+174.7	+339.2	+205	0	+718.9	-186.1
24 Man Hours/Day EVA	+174.7	+337.2	+205	1080	+1796.9	+261.3
POWER (DC Watts)	+378	+315	+2000		+2693	
VOLUME (Ft.^{3})						
0 Man Hours/Day EVA	+8.0	+32.6	+6.3	0	+46.9	
12 Man Hours/Day EVA	+8.0	+32.3	+6.3	0	+46.7	
24 Man Hours/Day EVA	+8.0	+32.0	+6.3	28	+74.3	
SENSIBLE HEAT REJECTION (BTU/HR)	+3068	+1072	+2196		+6336	
LATENT HEAT REJECTION (BTU/HR)	+276	0	-1078		-802	

EXTENDED SHUTTLE ECLSS IMPACT SUMMARY

SYSTEM 60 DAYS - Urine Wash Dump - Condensate Save - Idle Fuel Cells - LiOH CO_2 Removal



COMMENTS:

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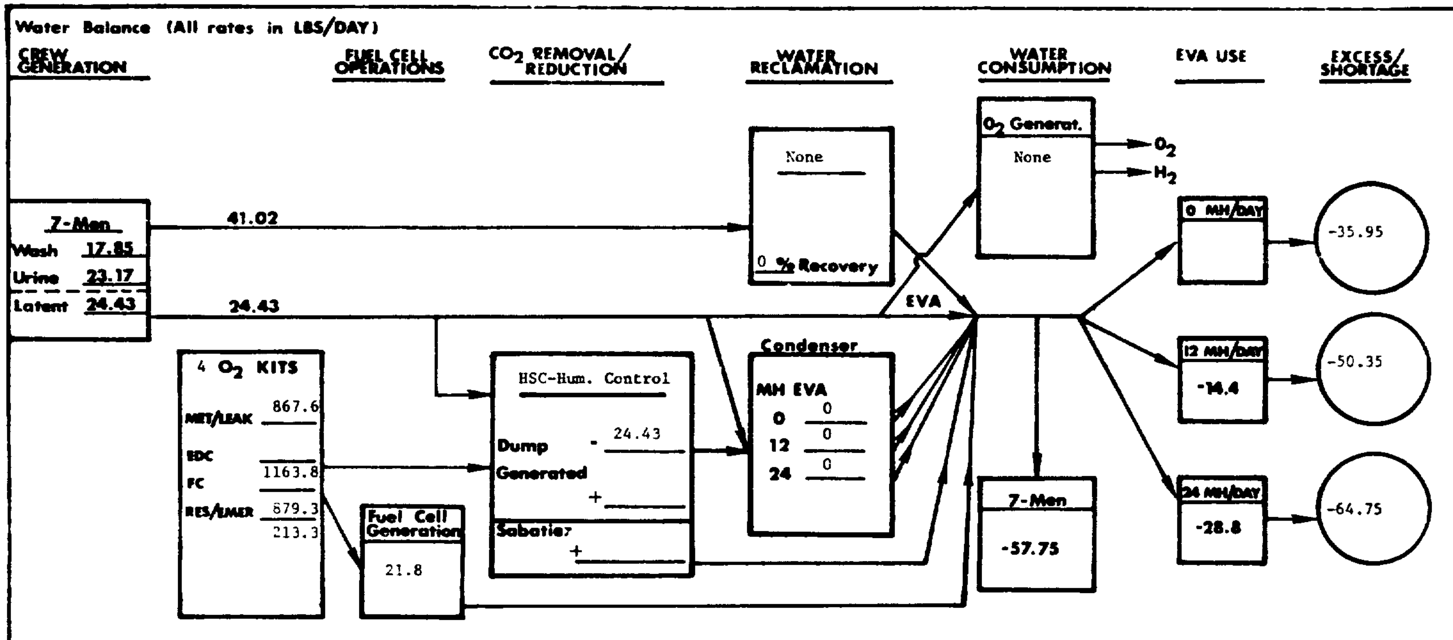
60 DAY SUMMARY

	CO_2 SUBS TOTAL	H_2O REC TOTAL	O_2 GEN TOTAL	ADDITIONAL H_2O REQUIRED	TOTALS	RE-ENTRY WEIGHT
WEIGHT (LBS)						
0 Man Hours/Day EVA	+2038.9	+166.9	0	+540	+2745.8	+2680.3
12 Man Hours/Day EVA	+2038.9	+165.0	0	+2120	+4323.9	+3301.4
24 Man Hours/Day EVA	+2038.9	+163.0	0	+3720	+5921.9	+3942.4
POWER (DC Watts)	+ 0	+24	0		+24	
VOLUME (Ft.^{3})						
0 Man Hours/Day EVA	+105.7	+16.8	0	+14	+136.5	
12 Man Hours/Day EVA	+105.7	+16.5	0	+56	+178.2	
24 Man Hours/Day EVA	+105.7	+16.2	0	+98	+219.9	
SENSIBLE HEAT REJECTION (BTU/HR)	+509	+81	0		+590	
LATENT HEAT REJECTION (BTU/HR)	+252	0	0		+252	

EXTENDED SHUTTLE ECLSS IMPACT SUMMARY

SYSTEM 60 DAYS - Urine Wash Dump - Condensate Save - Idle Fuel Cells - HSC R.H. Control CO_2 Removal



COMMENTS:

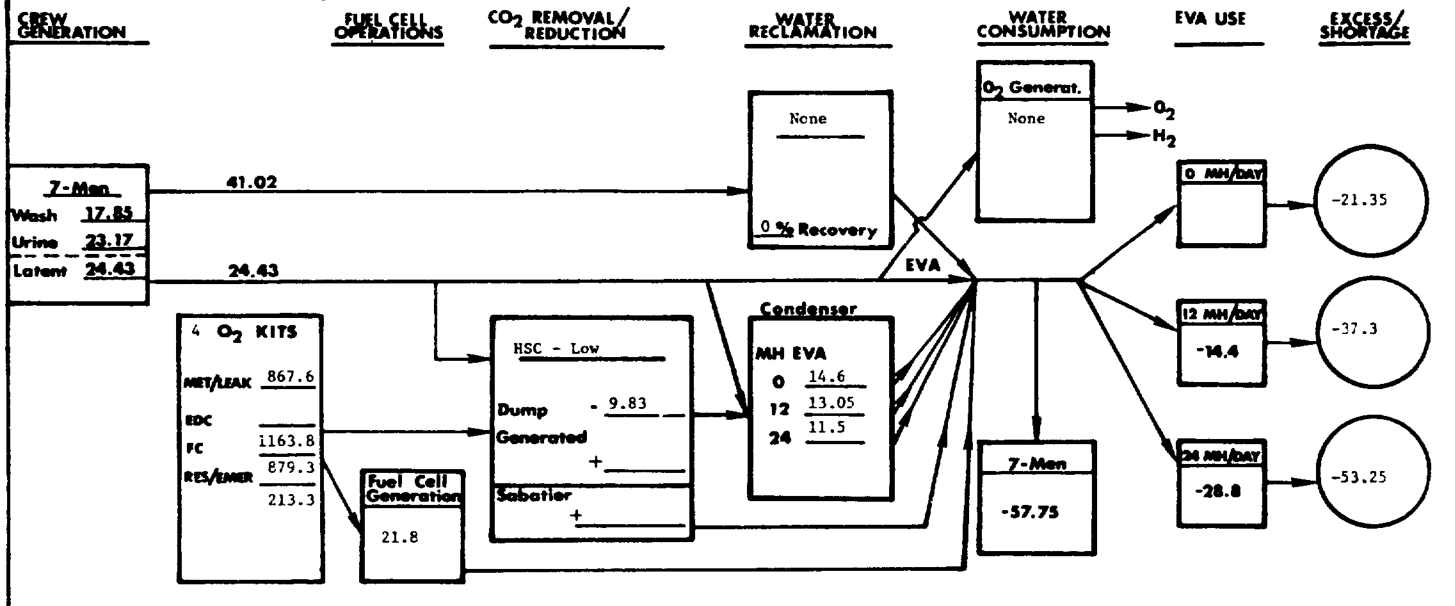
60 DAY SUMMARY

	CO_2 SUBS TOTAL	H_2O REC TOTAL	O_2 GEN TOTAL	ADDITIONAL H_2O REQUIRED	TOTALS	RE-ENTRY WEIGHT
WEIGHT (LBS)						
0 Man Hours/Day EVA	+99.9	0	0	+3600	+3699.9	+637.9
12 Man Hours/Day EVA	+99.9	0	0	+5080	+5179.9	+1253.9
24 Man Hours/Day EVA	+99.9	0	0	+6440	+6539.9	+1749.9
POWER (DC Watts)	+117	0	0		+117	
VOLUME ($Ft.^3$)						
0 Man Hours/Day EVA	+2.4	0	0	+98	+100.4	
12 Man Hours/Day EVA	+2.4	0	0	+140	+142.4	
24 Man Hours/Day EVA	+2.4	0	0	+168	+170.4	
SENSIBLE HEAT REJECTION (BTU/HR)	+399	0	0		+399	
LATENT HEAT REJECTION (BTU/HR)	-1018	0	0		-1018	

EXTENDED SHUTTLE ECLSS IMPACT SUMMARY

SYSTEM 60 DAYS - Urine Wash Dump - Condensate Save - Idle Fuel Cells - HSC Low Dump CO_2 Removal

Water Balance (All rates in LBS/DAY)



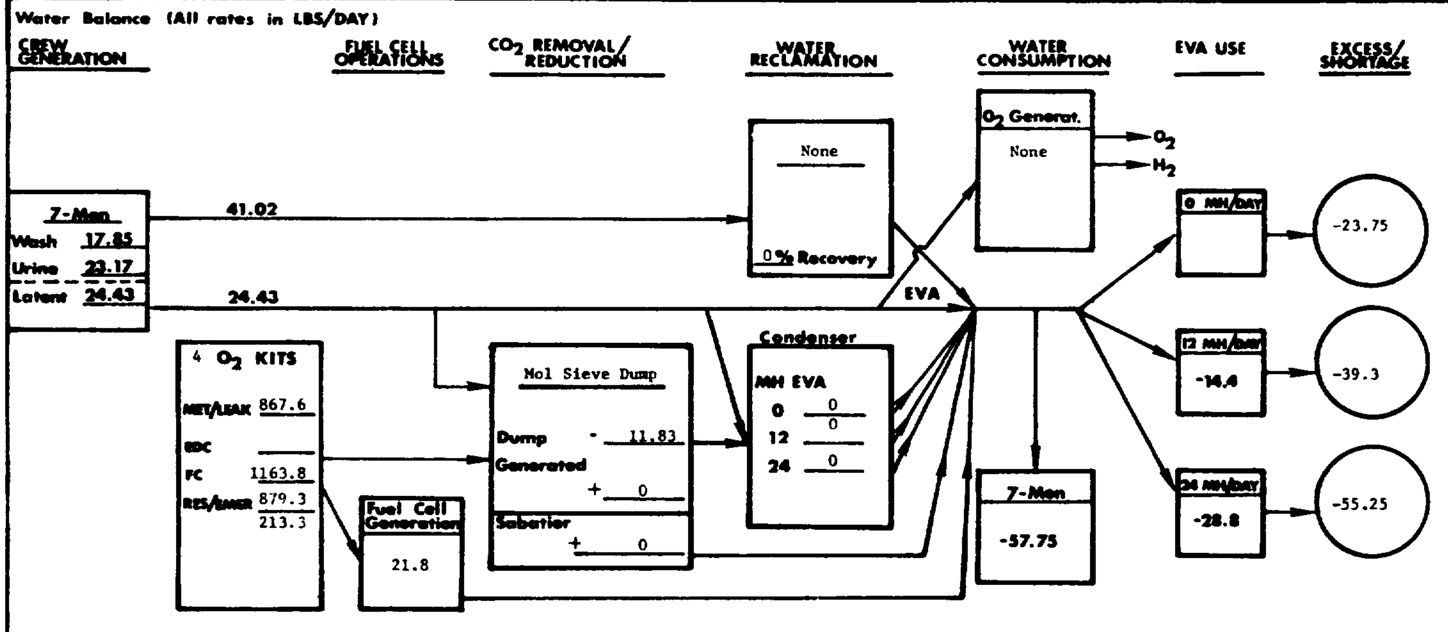
COMMENTS:

60 DAY SUMMARY

	CO_2 SUBS TOTAL	H_2O REC TOTAL	O_2 GEN TOTAL	ADDITIONAL H_2O REQUIRED	TOTALS	RE-ENTRY WEIGHT
WEIGHT (LBS)						
0 Man Hours/Day EVA	+138.6	+166.9	0	2120	+2425.5	+239.5
12 Man Hours/Day EVA	+136.6	+165.0	0	3720	+4023.6	+880.6
24 Man Hours/Day EVA	+138.6	+163.0	0	5320	+5621.6	+1521.6
POWER (DC Watts)	+89	+24	0		+113	
VOLUME (Ft.^{3})	+1.0	+16.8	0	+56	+73.8	
0 Man Hours/Day EVA	+1.0	+16.5	0	+98	+115.5	
12 Man Hours/Day EVA						
24 Man Hours/Day EVA	+1.0	+16.2	0	+140	+157.2	
SENSIBLE HEAT REJECTION (BTU/HR)	+304	+81	0		+385	
LATENT HEAT REJECTION (BTU/HR)	-410	0	0		-410	

EXTENDED SHUTTLE ECLSS IMPACT SUMMARY

SYSTEM 6C DAYS - Urine Wash Dump - Condensate Save - Idle Fuel Cells - Mol Sieve Low Dump CO_2 Removal



COMMENTS:

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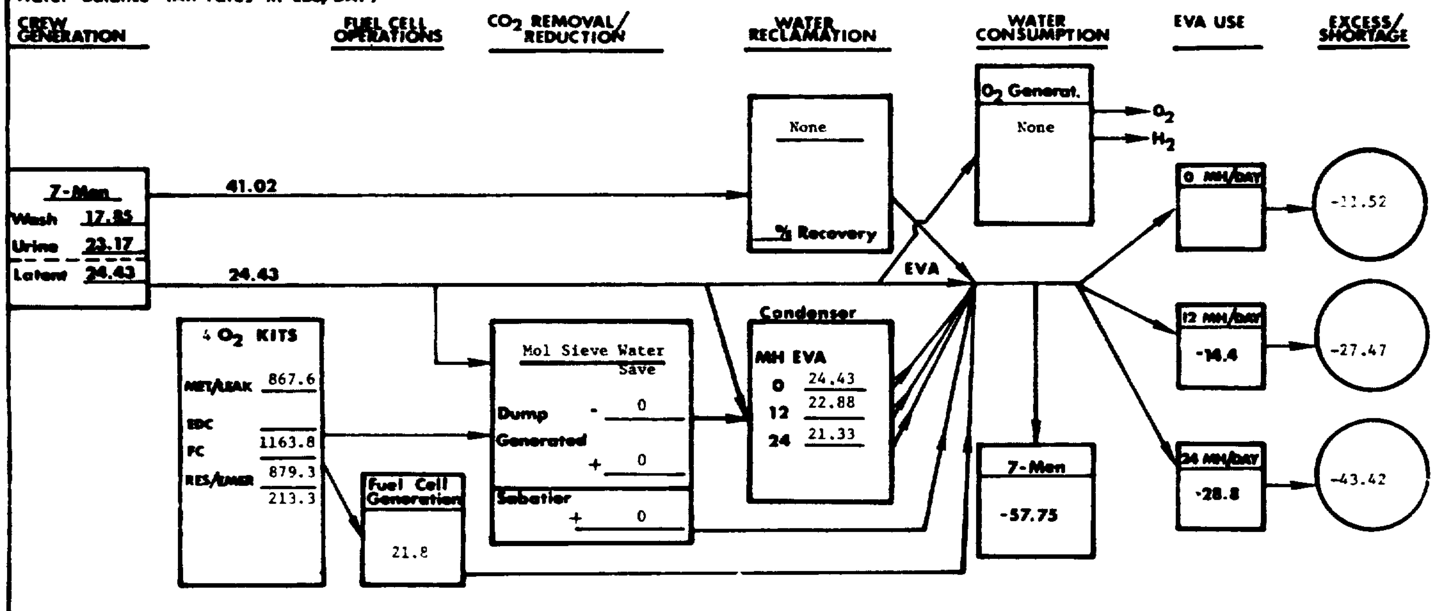
60 DAY SUMMARY

	CO_2 SUBS TOTAL	H_2O REC TOTAL	O_2 GEN TOTAL	ADDITIONAL H_2O REQUIRED	TOTALS	RE-ENTRY WEIGHT
WEIGHT (LBS)						
0 Man Hours/Day EVA	+89.1	+166.9	0	+2420	+2676.0	+346.C
12 Man Hours/Day EVA	+89.1	+165.0	0	+3980	+4234.1	+971.1
24 Man Hours/Day EVA	+89.1	+163.0	0	+5600	+5852.1	+1632.1
POWER (DC Watts)	+63	+24	0		+87	
VOLUME (Ft.^{3})						
0 Man Hours/Day EVA	+3.6	+16.8	0	+70	+90.4	
12 Man Hours/Day EVA	+3.6	+16.5	0	+112	+132.1	
24 Man Hours/Day EVA	+3.6	+16.2	0	+154	+173.8	
SENSIBLE HEAT REJECTION (BTU/HR)	+215	+51	0		+266	
LATENT HEAT REJECTION (BTU/HR)	-524	0	0		-524	

EXTENDED SHUTTLE ECLSS IMPACT SUMMARY

SYSTEM 60 DAYS - Urine Wash Dump - Condensate Save - Idle Fuel Cells - Mol Sieve Water Save CO_2 Removal

Water Balance (All rates in LBS/DAY)



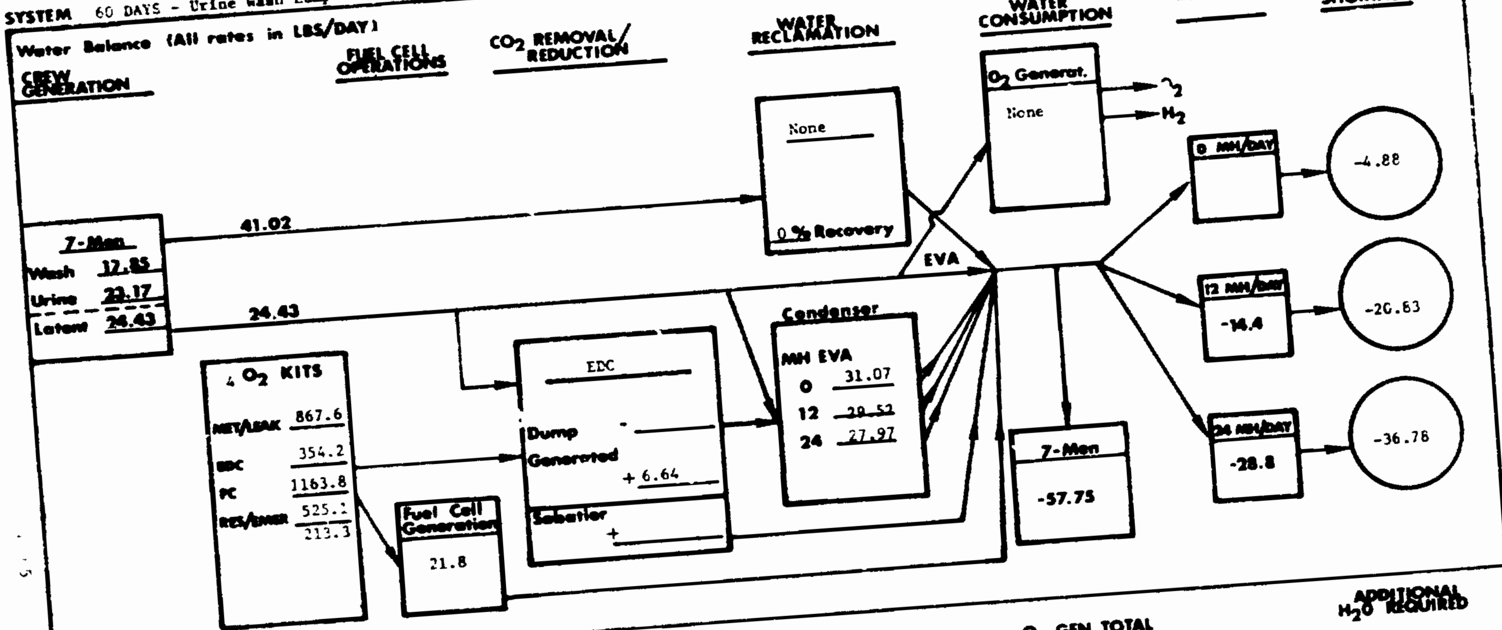
COMMENTS:

60 DAY SUMMARY

	CO_2 SUBS TOTAL	H_2O REC TOTAL	O_2 GEN TOTAL	ADDITIONAL H_2O REQUIRED	TOTALS	RE-ENTRY WEIGHT
WEIGHT (LBS)						
0 Man Hours/Day EVA	+94.0	+166.9	0	1230	+1490.9	-105.3
12 Man Hours/Day EVA	+94.0	+165.0	0	2740	+2999.0	+445.8
24 Man Hours/Day EVA	+94.0	+163.0	0	4260	+4517.0	+1006.8
POWER (DC Watts)	+57[illegible]	+24	0		+[illegible]99	
VOLUME (Ft.^{3})						
0 Man Hours/Day EVA	+3.5	+16.8	0	42	+62.3	
12 Man Hours/Day EVA	+3.5	+16.5	0	70	+90.0	
24 Man Hours/Day EVA	+3.5	+16.2	0	112	+131.7	
SENSIBLE HEAT REJECTION (BTU/HR)	+8[illegible]	+6[illegible]	0		+966	
LATENT HEAT REJECTION (BTU/HR)	+620	0	0		+620	

EXTENDED SHUTTLE ECLSS IMPACT SUMMARY

SYSTEM 60 DAYS - Urine Wash Eump - Condensate Save - Idle Fuel Cells - EDC - CO_2 Removal



COMMENTS:

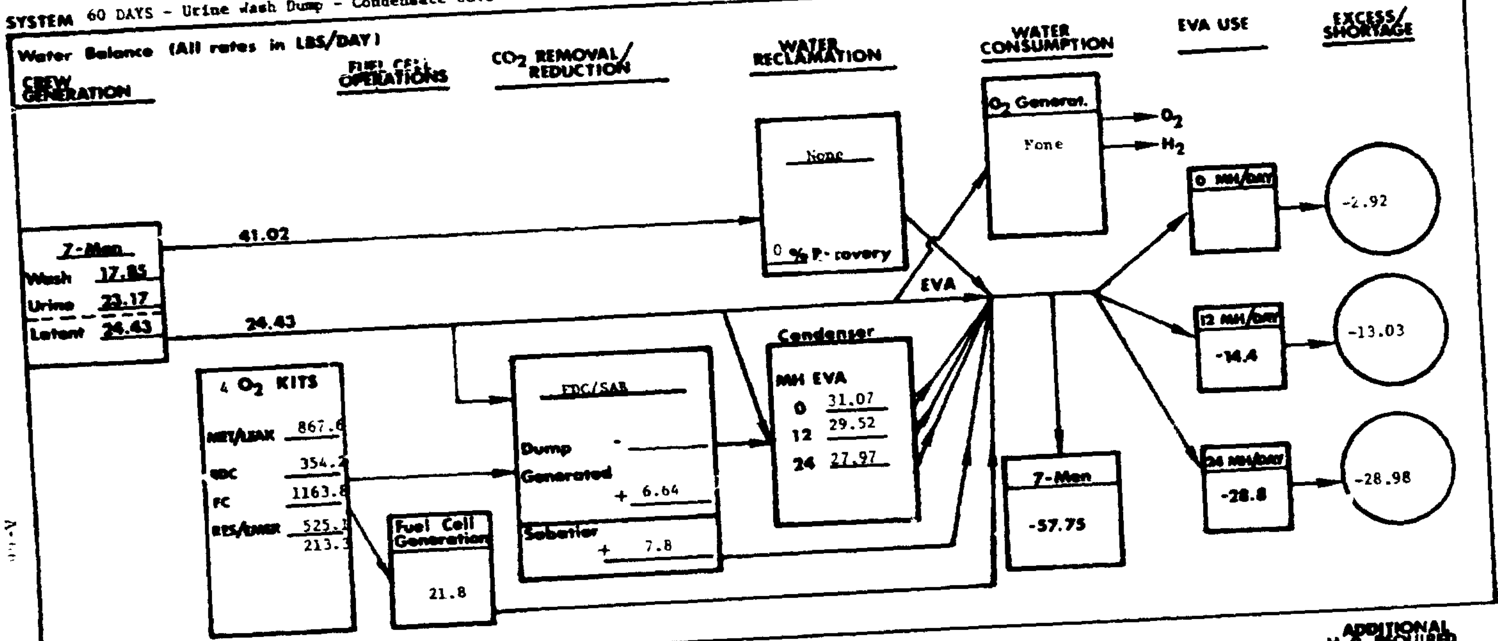
60 DAY SUMMARY

	CO_2 SUBS TOTAL	H_2O REC TOTAL	O_2 GEN TOTAL	ADDITIONAL H_2O REQUIRED	TOTALS	RE-ENTRY WEIGHT
WEIGHT (LBS)						
0 Man Hours/Day EVA	+59.1	+166.9	0	+490	[illegible]	[illegible]
12 Man Hours/Day EVA	+59.1	+165.0	0	+2080	[illegible]	+149.3
24 Man Hours/Day EVA	+59.1	+163.0	0	+3310	[illegible]	+470.5
POWER (DC Watts)	+336	+24	0		[illegible]	
VOLUME (Ft.^{3})						
0 Man Hours/Day EVA	-2.5	+16.8	0	+14	+28.[illegible]	
12 Man Hours/Day EVA	-2.5	+16.5	0	+57	[illegible]	
24 Man Hours/Day EVA	-2.5	+16.2	0	+98	[illegible]	
SENSIBLE HEAT REJECTION (BTU/HR)	+2465	+81	0		+2546	
LATENT HEAT REJECTION (BTU/HR)	+276	0	0		[illegible]	

EXTENDED SHUTTLE ECLSS IMPACT SUMMARY

SYSTEM 60 DAYS - Urine Wash Dump - Condensate Save - Idle Fuel Cells - EDC with Sabatier Reactor CO_2 Removal/Reduction

Water Balance (All rates in LBS/DAY)



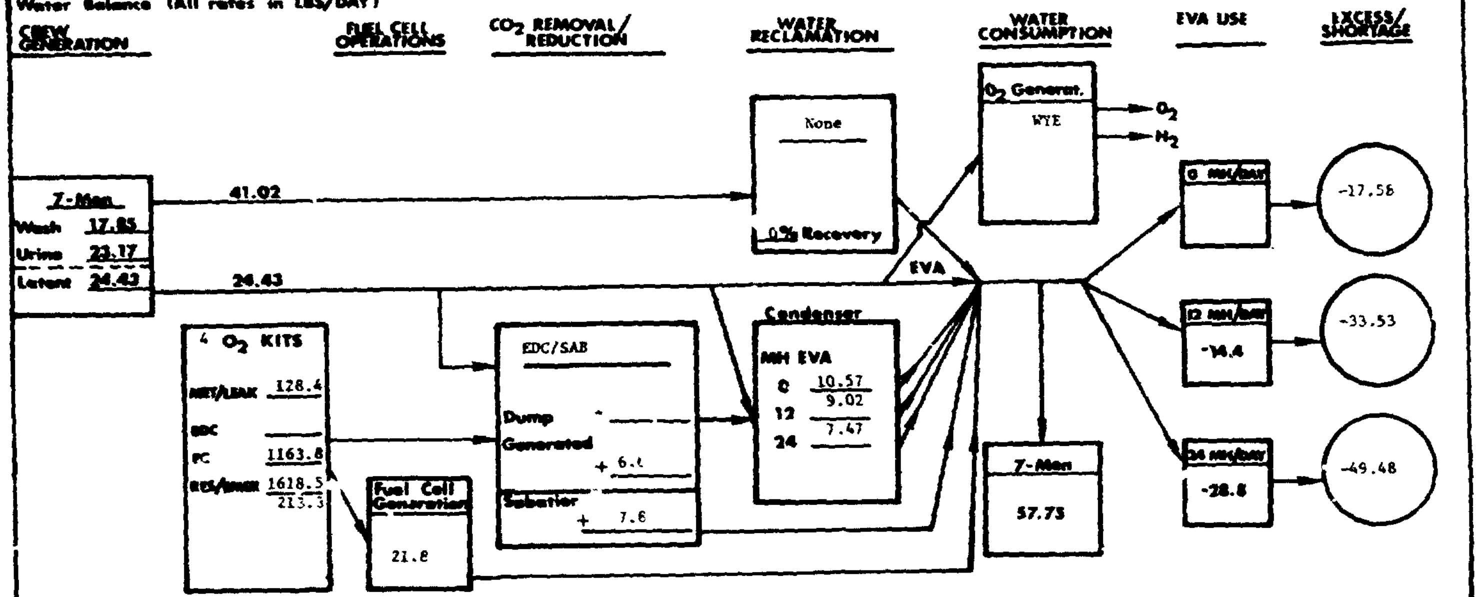
COMMENTS:

60 DAY SUMMARY	CO_2 SUBS TOTAL	H_2O REC TOTAL	O_2 GEN TOTAL	ADDITIONAL H_2O REQUIRED	TOTALS	RE-ENTRY WEIGHT
WEIGHT (LBS)						
0 Man Hours/Day EVA	+174.7	+166.9	0	0	+341.6	-563.4
12 Man Hours/Day EVA	+174.7	+165.0	0	+1380	+1719.7	+33.0
24 Man Hours/Day EVA	+174.7	+163.0	0	+2960	+3297.7	+653.9
POWER (DC Watts)	+378	+24	0		+402	
VOLUME (Ft.^{3})						
0 Man Hours/Day EVA	+8.0	+16.8	0	0	+24.8	
12 Man Hours/Day EVA	+8.0	+16.5	0	+42	+66.5	
24 Man Hours/Day EVA	+8.0	+16.2	0	+84	+108.2	
SENSIBLE HEAT REJECTION (BTU/HR)	+3068	+81	0		+3149	
LATENT HEAT REJECTION (BTU/HR)	+276	0	0		+276	

EXTENDED SHUTTLE ECLSS IMPACT SUMMARY

SYSTEM 60 DAYS - Urine Wash Dump - Condensate Save - Idle Fuel Cells - EDC/WVE with Sabatier Reactor CO_2 Removal/Reduction

Water Balance (All rates in LBS/DAY)



COMMENTS:

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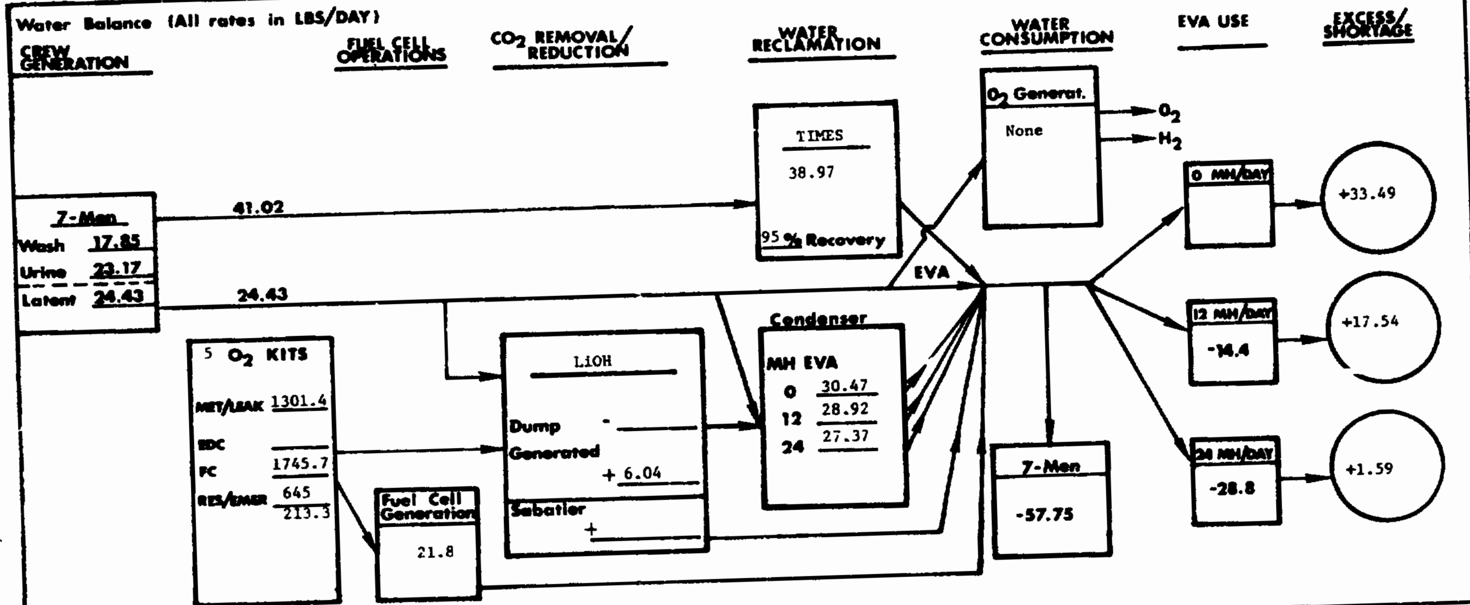
60 DAY SUMMARY

	CO_2 SUBS TOTAL	H_2O REC TOTAL	O_2 GEN TOTAL	ADDITIONAL H_2O REQUIRED	TOTALS	RE-ENTRY WEIGHT
WEIGHT (LBS)						
0 Man Hours/Day EVA	+174.7	+166.9	+205.0	+1870	+2316.6	+456.8
12 Man Hours/Day EVA	+174.7	+165.0	+205.0	+3420	+3964.[illegible]	+1067.9
24 Man Hours/Day EVA	+174.7	+163.0	+209.0	+5300	+5542.7	+1668.9
POWER (DC Watts)	+378	+24	+2000		+2402	
VOLUME (Ft.^{3})						
0 Man Hours/Day EVA	+8.0	+16.8	+6.3	+5[illegible]	+[illegible]	
12 Man Hours/Day EVA	+8.0	+16.5	+6.3	+[illegible]	+129.8	
24 Man Hours/Day EVA	+8.0	+16.2	+6.3	+140	+170.5	
SENSIBLE HEAT REJECTION (BTU/HR)	+3068	+81	+2196		+5345	
LATENT HEAT REJECTION (BTU/HR)	+276	0	-1078		-802	

EXTENDED SHUTTLE ECLSS IMPACT SUMMARY

SYSTEM 90 DAYS - All Water Reclamation - Idle Fuel Cells - LiOH CO_2 Removal

Water Balance (All rates in LBS/DAY)



COMMENTS:

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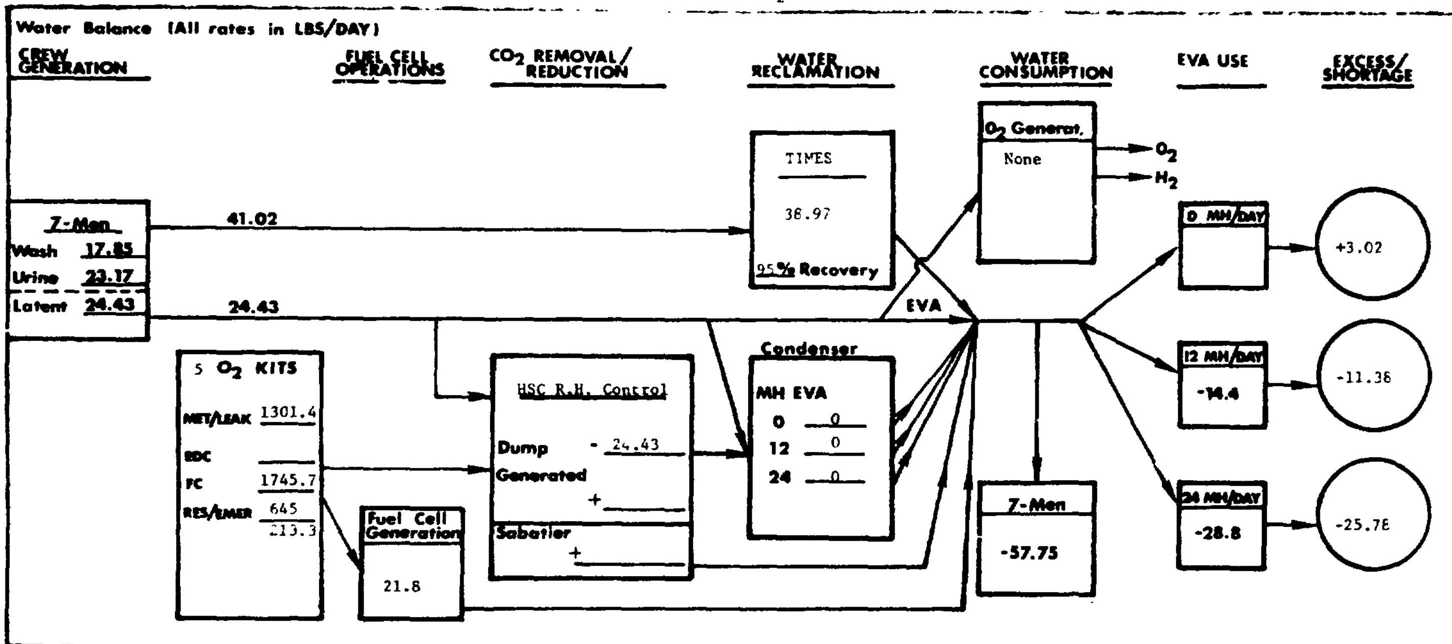
90 DAY SUMMARY	CO_2 SUBS TOTAL	H_2O REC TOTAL	O_2 GEN TOTAL	ADDITIONAL H_2O REQUIRED	TOTALS	RE-ENTRY WEIGHT
WEIGHT (LBS) 0 Man Hours/Day EVA	+3087.1	+379.0	0	0	+3466.1	+3870.4
12 Man Hours/Day EVA	+3087.1	+376.3	0	0	+3463.4	+3867.7
24 Man Hours/Day EVA	+3087.1	+373.5	0	0	+3460.6	+3864.9
POWER (DC Watts)	± 0	+315	0		+31	
VOLUME (Ft.^{3}) 0 Man Hours/Day EVA	+162.0	+37.2	0	0	+199.2	
12 Man Hours/Day EVA	+162.0	+36.8	0	0	+198.8	
24 Man Hours/Day EVA	+162.0	+36.5	0	0	+198.5	
SENSIBLE HEAT REJECTION (BTU/HR)	+509	+1072	0		+1581	
LATENT HEAT REJECTION (BTU/HR)	+262	0	0		+262	

EXTENDED SHUTTLE ECLSS IMPACT SUMMARY

SYSTEM 90 DAYS - All Water Reclamation - Idle Fuel Cells - HSC R. H. Control CO_2 Removal



COMMENTS:

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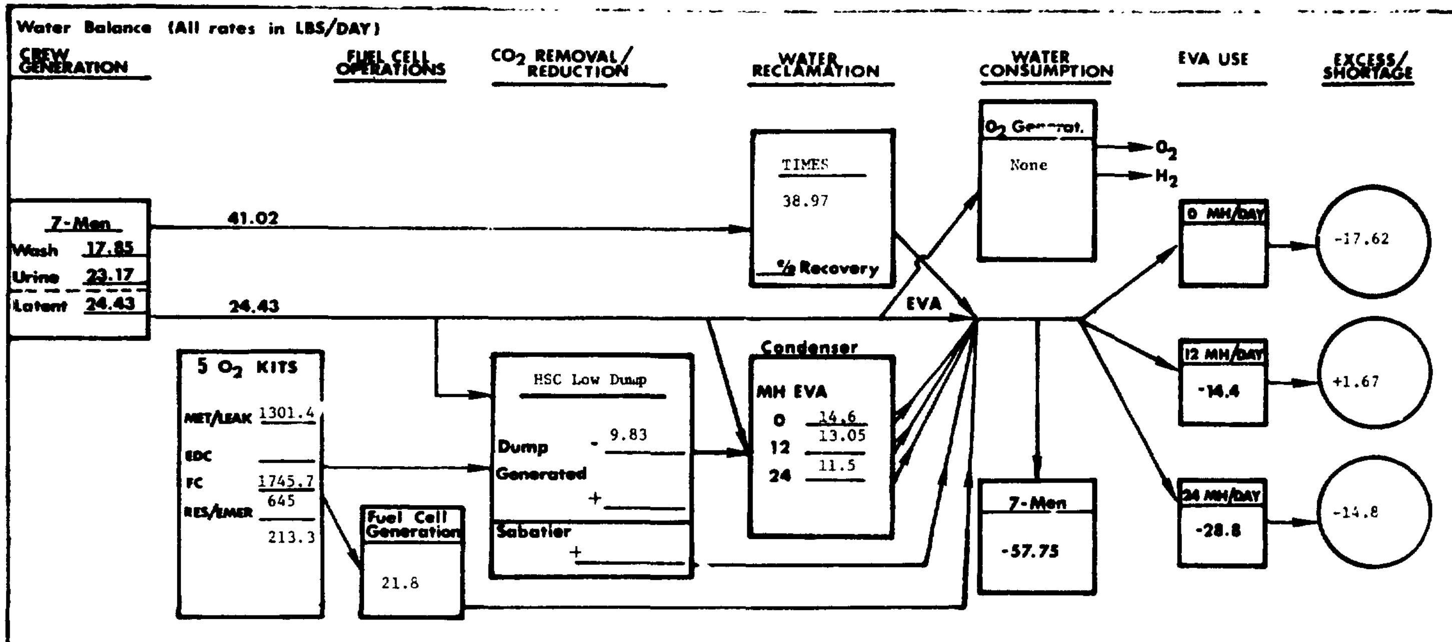
90 DAY SUMMARY

	CO_2 SUBS TOTAL	H_2O REC TOTAL	O_2 GEN TOTAL	ADDITIONAL H_2O REQUIRED	TOTALS	RE-ENTRY WEIGHT
WEIGHT (LBS)						
0 Man Hours/Day EVA	+99.9	+310.3	0	0	+410.2	-937.9
12 Man Hours/Day EVA	+99.9	+310.3	0	+1720	+2130.2	-242.[illegible]
24 Man Hours/Day EVA	+99.9	+310.3	0	+3870	+4280.2	+611.9
POWER (DC Watts)	+117	+291	0		+408	
VOLUME ($Ft.^3$)						
0 Man Hours/Day EVA	+2.4	+28.9	0	0	+31.3	
12 Man Hours/Day EVA	[illegible]	+28.9	0	+49	+94.3	
24 Man Hours/Day EVA	+2.4	+28.9	0	+98	+136.3	
SENSIBLE HEAT REJECTION (BTU/HR)	+399	+1021	0		+1420	
LATENT HEAT REJECTION (BTU/HR)	-1018	0	0		-1018	

EXTENDED SHUTTLE ECLSS IMPACT SUMMARY

SYSTEM 90 DAYS - All Water Reclamation - Idle Fuel Cells - HSC Low Dump CO_2 Removal



COMMENTS:

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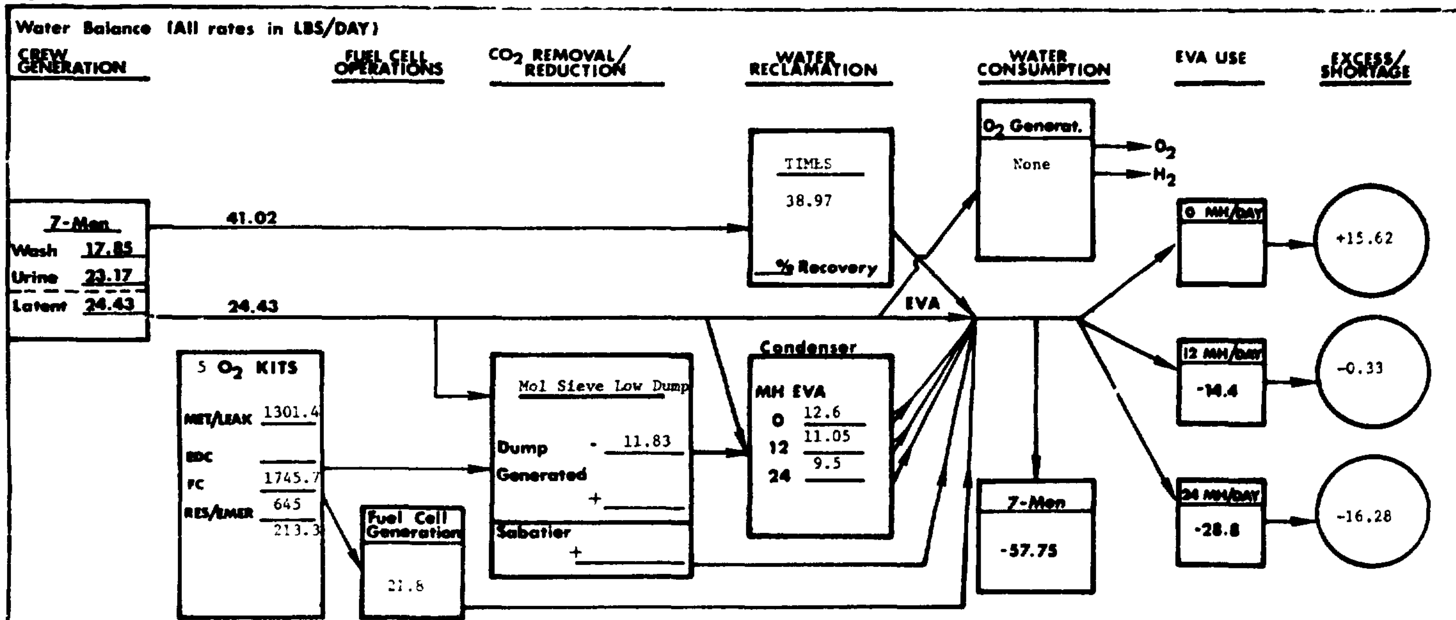
90 DAY SUMMARY

	CO_2 SUBS TOTAL	H_2O REC TOTAL	O_2 GEN TOTAL	ADDITIONAL H_2O REQUIRED	TOTALS	RE-ENTRY WEIGHT
WEIGHT (LBS)						
0 Man Hours/Day EVA	+138.6	+379.0	0	0	+517.6	-830.5
12 Man Hours/Day EVA	+138.6	+376.3	0	0	+514.9	-833.2
24 Man Hours/Day EVA	+138.6	+373.5	0	+2220	+2732.1	+52.0
POWER (DC Watts)	+89	+315	0		+404	
VOLUME (Ft.^{3})						
0 Man Hours/Day EVA	+1.0	+37.2	0	0	+38.2	
12 Man Hours/Day EVA	+1.0	+36.8	0	0	+37.8	
24 Man Hours/Day EVA	+1.0	+36.5	0	+63.0	+100.5	
SENSIBLE HEAT REJECTION (BTU/HR)	+304	+1072	0		[illegible]	
LATENT HEAT REJECTION (BTU/HR)	-410	0	0		[illegible]	

EXTENDED SHUTTLE FCLSS IMPACT SUMMARY

SYSTEM 90 DAYS - All Water Reclamation - Idle Fuel Cells - Mol Sieve Low Dump CO_2 Removal



COMMENTS:

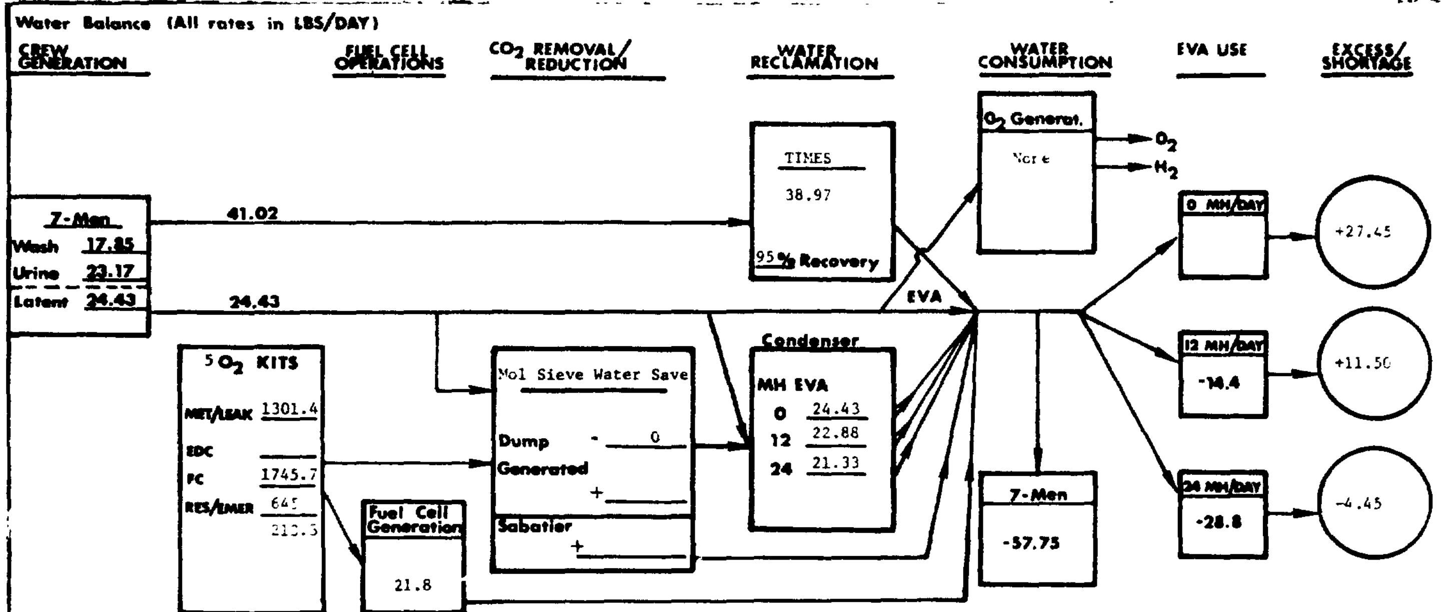
90 DAY SUMMARY

	CO_2 SUBS TOTAL	H_2O REC TOTAL	O_2 GEN TOTAL	ADDITIONAL H_2O REQUIRED	TOTALS	RE-ENTRY WEIGHT
WEIGHT (LBS)						
0 Man Hours/Day EVA	+89.1	+379.0	0	0	+468.1	-860.6
12 Man Hours/Day EVA	+89.1	+376.3	0	+90	+555.4	-822.4
24 Man Hours/Day EVA	+89.1	+373.5	0	+2400	+2862.6	+49.3
POWER (DC Watts)	+63	+315	0		+378	
VOLUME ($Ft.^3$)						
0 Man Hours/Day EVA	+3.6	+37.2	0	0	+40.8	
12 Man Hours/Day EVA	+3.6	+36.8	0	+7	+47.4	
24 Man Hours/Day EVA	+3.6	+36.5	0	+63	+103.1	
SENSIBLE HEAT REJECTION (BTU/HR)	+215	+1072	0		+1287	
LATENT HEAT REJECTION (BTU/HR)	-524	0	0		-524	

EXTENDED SHUTTLE ECLSS IMPACT SUMMARY

SYSTEM 90 DAYS – All Water Reclamation – Idle Fuel Cells – Mol Sieve Water Save CO_2 Removal

COMMENTS:



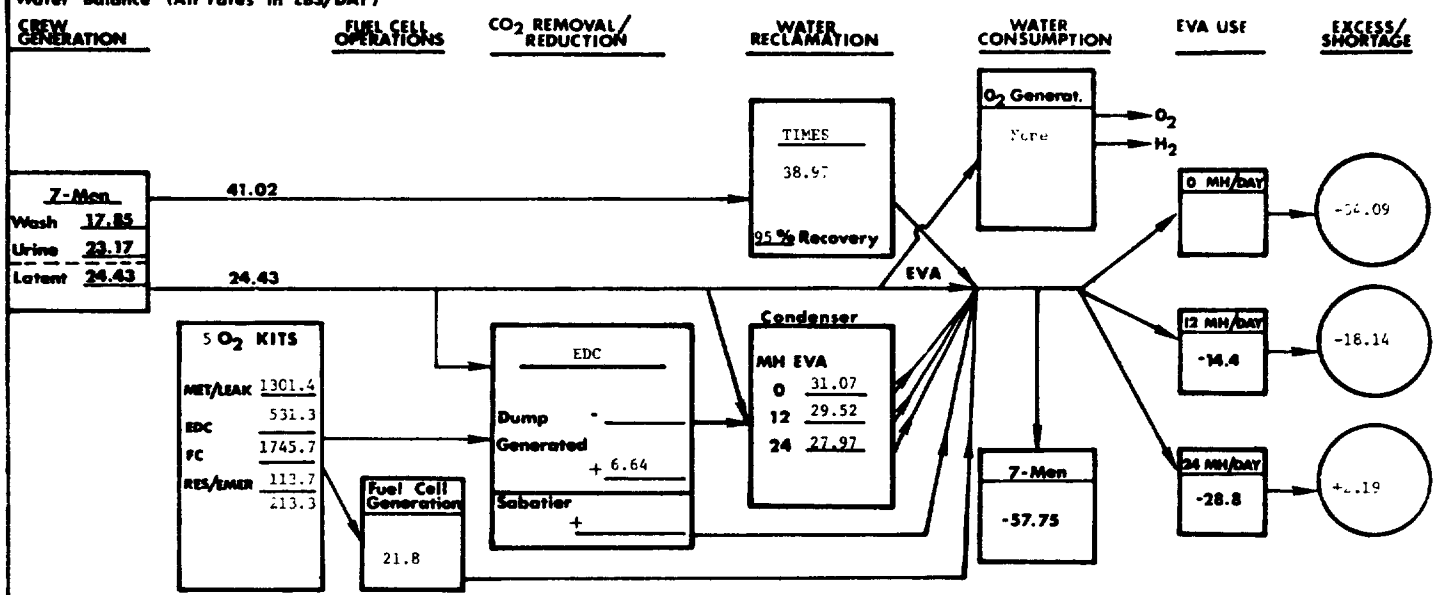
90 DAY SUMMARY

	CO_2 SUBS TOTAL	H_2O REC TOTAL	O_2 GEN TOTAL	ADDITIONAL H_2O REQUIRED	TOTALS	RE-ENTRY WEIGHT
WEIGHT (LBS)						
0 Man Hours/Day EVA	+94.0	+379.0	0	0	+473.0	-875.[illegible]
12 Man Hours/Day EVA	+94.0	+376.3	0	0	+470.3	-877.8
24 Man Hours/Day EVA	+94.0	+373.5	0	+660	+1127.5	-621.1
POWER (DC Watts)	+575	+315	0		+890	
VOLUME ($Ft.^3$)						
0 Man Hours/Day EVA	+3.5	+37.2	0	0	+40.7	
12 Man Hours/Day EVA	+3.5	+36.8	0	0	+40.[illegible]	
24 Man Hours/Day EVA	+3.5	+36.5	0	+21	+61.0	
SENSIBLE HEAT REJECTION (BTU/HR)	+887	+1072	0		[illegible]	
LATENT HEAT REJECTION (BTU/HR)	+6[illegible]	[illegible]	[illegible]		+[illegible]26	

EXTENDED SHUTTLE ECLSS IMPACT SUMMARY

SYSTEM 90 DAYS - All Water Reclamation - Idle Fuel Cells - EDC CO_2 Removal

Water Balance (All rates in LBS/DAY)



COMMENTS:

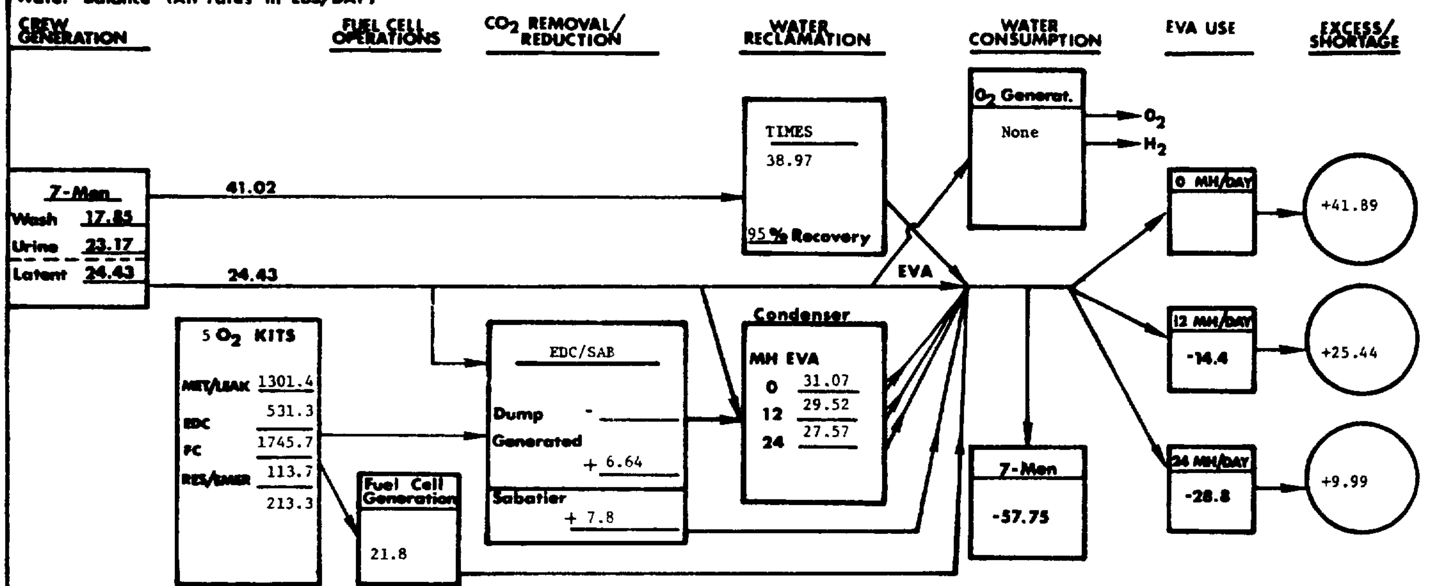
90 DAY SUMMARY

	CO_2 SUBS TOTAL	H_2O REC TOTAL	O_2 GEN TOTAL	ADDITIONAL H_2O REQUIRED	TOTALS	RE-ENTRY WEIGHT
WEIGHT (LBS)						
0 Man Hours/Day EVA	+59.1	+379.0	0	0	[illegible]	-910.0
12 Man Hours/Day EVA	+59.1	+376.3	0	0	[illegible]	[illegible]
24 Man Hours/Day EVA	+59.1	+373.5	0	0	[illegible]	[illegible]
POWER (DC Watts)	+336	+315	0		[illegible]	
VOLUME (Ft.^{3})						
0 Man Hours/Day EVA	[illegible]	+37.2	0		[illegible]	
12 Man Hours/Day EVA	-2.5	[illegible]	0	0	[illegible]	
24 Man Hours/Day EVA	[illegible]	+36.5	0	0	[illegible]	
SENSIBLE HEAT REJECTION (BTU/HR)	+2465	[illegible]	[illegible]		[illegible]	
LATENT HEAT REJECTION (BTU/HR)	[illegible]		[illegible]		[illegible]	

EXTENDED SHUTTLE ECLSS IMPACT SUMMARY

SYSTEM 90 Days - All Water Reclamation - Idle Fuel Cells - EDC with Sabatier Reactor - CO_2 Removal/Reduction

Water Balance (All rates in LBS/DAY)



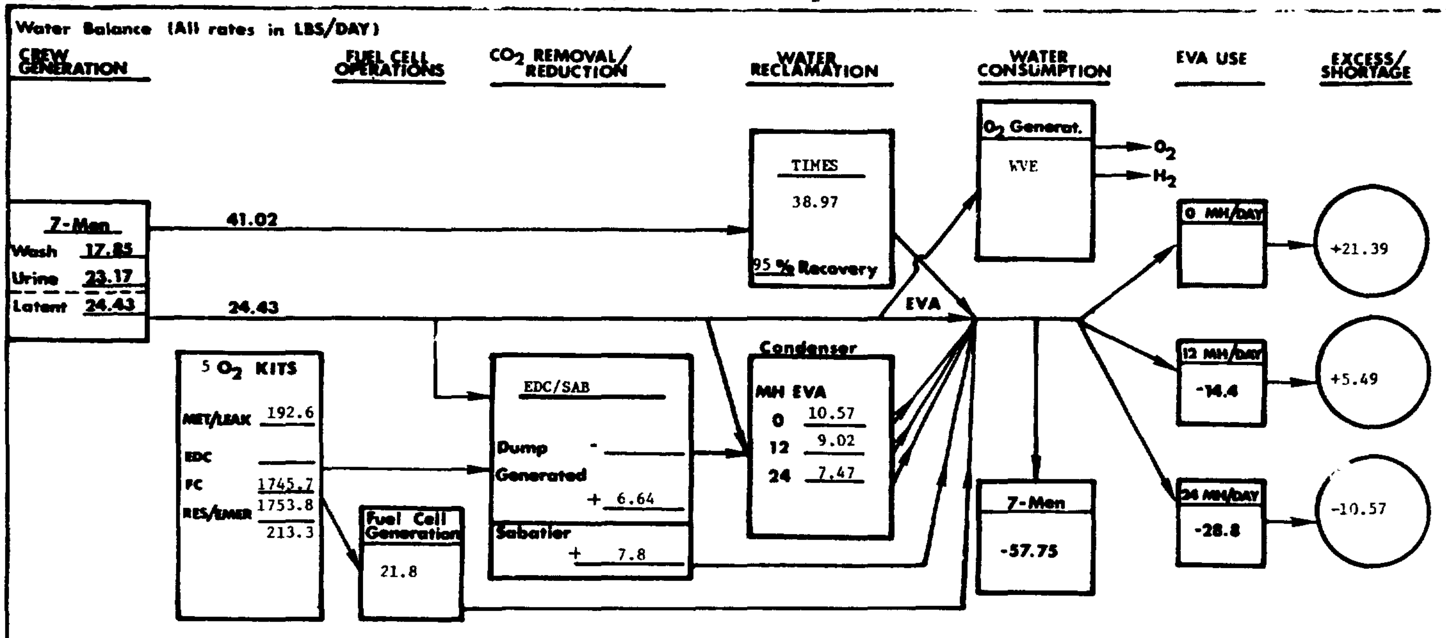
COMMENTS:

90 DAY SUMMARY

	CO_2 SUBS TOTAL	H_2O REC TOTAL	O_2 GEN TOTAL	ADDITIONAL H_2O REQUIRED	TOTALS	RE-ENTRY WEIGHT
WEIGHT (LBS)						
0 Man Hours/Day EVA	+174.7	+379.0	0	0	+553.7	-794.4
12 Man Hours/Day EVA	+174.7	+376.3	0	0	+551.0	-797.1
24 Man Hours/Day EVA	+174.7	+373.5	0	0	+548.2	-799.9
POWER (DC Watts)	+378	+315	0		+693	
VOLUME (Ft.^{3})						
0 Man Hours/Day EVA	+8.0	+37.2	0	0	+45.2	
12 Man Hours/Day EVA	+8.0	+36.8	0	0	+44.8	
24 Man Hours/Day EVA	+8.0	+36.5	0	0	+44.5	
SENSIBLE HEAT REJECTION (BTU/HR)	+3068	+1072	0		+4140	
LATENT HEAT REJECTION (BTU/HR)	+276	0	0		+276	

EXTENDED SHUTTLE ECLSS IMPACT SUMMARY

SYSTEM 90 DAYS - All Water Reclamation - Idle Fuel Cells - EDC/WVE with Sabatier CO_2 Removal/Reduction



COMMENTS:

ORIGINAL PAGE IS OF POOR QUALITY

90 DAY SUMMARY	CO_2 SUBS TOTAL	H_2O REC TOTAL	O_2 GEN TOTAL	ADDITIONAL H_2O REQUIRED	TOTALS	RE-ENTRY WEIGHT
WEIGHT (LBS)						
0 Man Hours/Day EVA	+174.7	+379.0	+205	0	+758.7	-589.4
12 Man Hours/Day EVA	+174.7	+376.3	+205	0	+756.0	-592.1
24 Man Hours/Day EVA	+174.7	+373.5	+205	+1620	+2372.2	+79.2
POWER (DC Watts)	+378	+315	+2000		+2693	
VOLUME (Ft.^{3})						
0 Man Hours/Day EVA	+8.0	+37.2	+6.3	0	+51.5	
12 Man Hours/Day EVA	+8.0	+36.8	+6.3	0	+51.1	
24 Man Hours/Day EVA	+8.0	+36.5	+6.3	+42	+92.8	
SENSIBLE HEAT REJECTION (BTU/HR)	+3068	+1072	+2196		+6336	
LATENT HEAT REJECTION (BTU/HR)	+276	0	-1078		-802	

APPENDIX B

DEFINITION OF SCHEMATIC SYMBOLS

GAS SEPARATOR WITH VENT

HYDROGEN CONTROLLER

URINAL

DISPENSER

COLD PLATE

CAPPED SEPTUM

TEMPERATURE SENSOR

PRESSURE SENSOR

SENSOR

OR

FILTER

WITH MANUAL SCRAPPER

PUMP

ELECTRICAL HEATER

AIR/LIQUID HEAT EXCHANGER

QUICK DISCONNECT WITH CAP

FLOW METER

COMPONENT INSTALLED WITH A PROBE FOR MAINTENANCE

COMPONENT INSTALLED WITH DISCONNECTS FOR MAINTENANCE

SUBSYSTEM FUNCTIONAL BOUNDARY

CONSTANT FLOW VALVE

MANUAL VALVE (SHOWN NORMALLY OPEN)

ELECTRICAL VALVE WITH MANUAL OVERRIDE (SHOWN NORMALLY CLOSED)

3-WAY MANUAL VALVE

4-WAY ELECTRICAL VALVE

3-WAY ELECTRICAL VALVE

3-WAY ELECTRICAL VALVE (WITH MANUAL OVERRIDE)

2-WAY ELECTRICAL VALVE

CHECK VALVE

CHECK VALVE WITH DOWNSTREAM VENT

PRESSURE REGULATOR (SHOWN OPERATING)

PRESSURE RELIEF VALVE OR BACK PRESSURE REGULATOR (SENSING AMBIENT)

WATER SEPARATOR

PSID PRESSURE RELIEF VALVE (SENSING DOWNSTREAM)

OR

MANUAL PRESSURE RELIEF VALVE

TEMPERATURE CONTROL VALVE

FAN (WITH SPEED SENSOR)

BLOWER (WITH SPEED SENSOR)

DEBRIS TRAP

CAPPED LINE

AIR/AIR HEAT EXCHANGER

ACCUMULATOR

OR

BELLOWS TYPE TANK

DIAPHRAGM TYPE TANK

ORIFICE

I_2 DET = IODINE DETECTOR
CO_2 = CO_2 PARTIAL PRESSURE
Q = QUANTITY
LLS = LIQUID LEVEL SENSOR
P = DIFFERENTIAL PRESSURE
RH = RELATIVE HUMIDITY
CG = COMBUSTIBLE GAS
FS = FLOW SWITCH
QHL = HIGH/LOW QUANTITY SWITCH
O_2 = O_2 PARTIAL PRESSURE
DP = DEW POINT SENSOR
I_2 = IODINE GENERATOR
LT = LIQUID TRAP
N_X = SPEED SENSOR
S = SILENCER
W/S = STATIC WATER SEPARATOR
UAC = UREA AMMONIA CONTROL
LS = LIQUID SENSOR
SORB = SORBENT CANISTER
CM = CONDUCTIVITY MONITOR
BF = BACTERIA FILTER
AC = ACTIVATED CHARCOAL
RAU = REMOTE ACQUISITION UNIT
CAT OX = CATALYTIC OXIDIZER
EDC = ELECTROCHEMICAL DEPOLARIZED CONCENTRATOR
HX = HEAT EXCHANGER
pH = pH MONITOR
MF = MULTIFILTER
GS = GAS SEPRATOR
R + RESTRICTOR
C + CARTRIDGE
RH HX = RELATIVE HUMIDITY HEAT EXCHANGER
SW = SWITCH